With the author's kind regards.

MILK AND THE PUBLIC HEALTH

MACMILLAN AND CO., LIMITED
LONDON · BOMBAY · CALCUTTA
MELBOURNE

THE MACMILLAN COMPANY
NEW YORK · BOSTON · CHICAGO
DALLAS · SAN FRANCISCO

THE MACMILLAN CO. OF CANADA, LTD.
TORONTO

MILK

AND THE

PUBLIC HEALTH

BY

WILLIAM G. SAVAGE

B.Sc., M.D. (Lond.), D.P.H.

COUNTY MEDICAL OFFICER OF HEALTH, SOMERSET
LATE MEDICAL OFFICER OF HEALTH AND PUBLIC ANALYST, COLCHESTER
LECTURER ON BACTERIOLOGY, UNIVERSITY COLLEGE, CARDIFF
ASSISTANT IN CHARGE OF THE BACTERIOLOGICAL DEPARTMENT,
UNIVERSITY COLLEGE, LONDON
ETC. ETC.

MACMILLAN AND CO., LIMITED
ST. MARTIN'S STREET, LONDON

1912

PREFACE

THE fundamental importance of milk makes it a subject which should be studied and investigated from every point of view. The present volume is entirely concerned with milk in its relationship to the general health of the community.

A great deal of loose talk is heard at the present time about the dangers of milk—sometimes ill-informed, frequently exaggerated. There can, however, be no question but that this great food, so widely consumed, so readily polluted, is intimately connected with the health of the people, particularly of its younger members, and that the lamentable want of even ordinary care with which it is treated is responsible for an immense deal of sickness, ill-health, and death.

While the danger exists, and should be emphasised by the scientific Public Health investigator, it is for him to neither exaggerate nor underrate it, but first to *measure* and assess the danger, and then to demonstrate how it can be removed or at least diminished. The present volume is an attempt to do this.

Administrative action should be the outcome of the application of accurately determined scientific facts to practical conditions. In Part I. an endeavour has been made to give a summary of our scientific knowledge and of the facts with which the patient labours of many investigators have endowed us as to the bacterial contamination of milk and its relationship to disease. While existing knowledge is extensive there are still large gaps to be filled up.

In Part II., for the benefit of the laboratory worker, the practical bacteriological examination of milk is described. The methods and procedures which may be used have been set out in some detail, as I know of no book in which the bacteriological examination of milk is adequately treated, while it is manifest that the future efficient control of milk must be worked in conjunction with systematic bacteriological examinations.

In Part III. the administrative side of the subject is dealt with, including an account of the powers and procedures which are at present used, either in general or for special purposes, and consideration of the practical, administrative, and legal alterations which are held to be desirable.

All authorities on expert evidence in Courts of Law are emphatic that evidence of fact should be kept distinct from deductions and opinions based upon those facts. In a similar way it is desirable that in text-books as far as possible the scientific facts at our disposal should be presented distinctly, and divorced from the legal and administrative action which has resulted or which should result as the logical outcome from them. In this way clarity of vision is obtained. If fact and deduction were always separated many of the ill-devised and unscientifically-founded public health procedures which are from time to time advocated would be avoided. In pursuance of this object Parts I. and III. have been kept as distinct as the intricacies of the subject would permit, even at the risk of some trifling repetition and some measure of cross reference.

I have to thank a number of friends for valuable reports and scientific papers giving information upon subjects upon which they are recognised authorities. These sources of information are acknowledged in the text. I am indebted to the Dairy Supply Company, Messrs. Lumley and Company, and Messrs. Lawrence and Company for the loan of blocks. Several illustrations have been supplied to me by friends, while in particular Figs. 13 to 17, and 19, 20, and 21 have been obtained through the kindness of Dr. D. S. Davies, Medical Officer of Health, Bristol. All but one of these photographs were taken by Mr. Leat, Inspector of Dairies, Cowsheds, and Milkshops at Bristol, who has been at great trouble to obtain excellent photographs of the conditions illustrated.

No bibliography is appended since one would be of limited utility owing to the enormous number of references which would have to be included. References to papers and reports are given as footnotes and, as far as practicable, and indeed in almost every case, I have directly consulted the original reports and selected the data bearing upon the subject under consideration.

WILLIAM G. SAVAGE.

WESTON-SUPER-MARE.

CONTENTS

PART I

THE BACTERIOLOGY OF MILK: MILK AND HUMAN DISEASE

CHAPTER I

CHAPTER II

CHAPTER III

PART III

PUBLIC HEALTH CONTROL OF THE MILK SUPPLY

CHAPTER XV

CHAPTER XVI

CHAPTER XVII

CHAPTER XXI

APPENDICES

ILLUSTRATIONS

PART I

THE BACTERIOLOGY OF MILK: MILK AND HUMAN DISEASE

CHAPTER I

THE CHEMICAL AND CELLULAR CONTENT OF COW'S MILK

MILK is the secretion of a living animal, and as such is highly complex in nature and liable to variation in its composition, facts which must always be kept in mind in dealing with its chemical, bacteriological, and physiological properties. No artificial mixture of chemical substances, even in the exact proportions in which they occur in milk, will yield milk. It has constituents and properties beyond the merely chemical.

Chemically it is essentially a mixture of proteids, milk sugar and salts dissolved in water, and holding in suspension fat in the form of finely divided globules.

Wynter Blythe[1] gives the average composition of healthy cows' milk as follows:

			Parts per cent by weight.
Milk fat	Butyrin	0·15	3·90
	Caproin	0·14	
	Caprylin	0·02	
	Caprin	0·07	
	Laurin	0·29	
	Myristicin	0·79	
	Palmitin	1·00	
	Stearin	0·07	
	Olein	1·37	
Casein			3·00
Albumen			0·40
Milk sugar			4·75

[1] *Foods: their Composition and Analysis*, 1909, p. 204.

			Parts per cent by weight.
Ash derived from the following salts, of which the percentage composition according to Soldner =	Sodium chloride	10·62	0·75
	Potassium „	9·16	
	Mono-pot. phosphate	12·77	
	Di-pot. „	9·22	
	Pot. citrate	5·47	
	Di-mag. phosphate	3·71	
	Magnesium citrate	4·05	
	Di-calcium citrate	7·42	
	Tri-calcium phosphate	8·90	
	Calcium citrate	23·55	
	Lime combined with proteids	5·13	
Water			87·20

"Besides the above there are the colouring-matter of milk (lactochrome), odorous principles, bitter principles (probably derived from the plants eaten), small quantities of other proteid bodies, kreatinine, urea, alcohol, and fluorides."

In addition milk contains a number of enzymes or ferments, which are of considerable interest. The following may be mentioned:

Galactase.—This is the principal proteolytic ferment found in milk. It converts proteids into proteoses and peptones, and finally into amino-acids. It was first recognised by Babcock and Russell in 1897. According to Jensen it liquefies gelatine. Later investigations have shown that galactase is probably a mixture of enzymes.

Spolverini found trypsin and pepsin in milk, but this observation has not been confirmed.

Lipase.—This fat-splitting ferment has been found by a number of observers. It hydrolyses butyrin into glycerine and butyric acid.

Catalase.—The ferments included under this name have the power of decomposing hydrogen peroxide and are found in milk. *Peroxidases* are also present, shown by their power of effecting the oxidation of certain easily oxidisable substances.

Reductases.—Apparently reducing ferments are present in milk. Formalin-methylene blue solution is reduced by fresh milk, and this is supposed to be due to a reducing ferment.

Little or nothing is known about the physiological importance of these enzymes. Their thermal death points vary with the different ferments, but all those in milk lie between

65° C. and 80° C. They become of practical importance in relation to the pasteurisation of milk and its detection (see Chapter XX.).

Vieth has shown, and this has been abundantly confirmed, that there is a definite ratio existing among the components of the non-fatty solids of normal milk. This ratio is expressed as follows:

Sugar	13
Proteids	9
Ash	2

With milk containing non-fatty solids = 8·9 per cent, this gives

Sugar	4·82
Proteids	3·34
Ash	0·74
	8·90

These percentages agree closely with the figures given above.

Revis[1] has pointed out that results of numerous analyses show that (*a*) When genuine milk is deficient in non-fatty solids, the deficiency is due entirely to an abnormally low percentage of milk sugar, the proteids and ash being present in their normal amounts. (*b*) When a genuine milk shows an unusually high percentage of non-fatty solids, the increase is due almost entirely to an abnormally high percentage of the proteids, the sugar and ash either remaining normal or perhaps slightly increasing also.

The importance of this fact lies in its relationship to the detection of added water in milk. If water is added to milk Vieth's ratio is not, of course, affected, and the sugar should stand at $\frac{13}{24}$ of the solids not fat. If the diminution met with in the non-fatty solids is a natural one, the percentage proportion of milk sugar should be considerably less than $\frac{13}{24}$ of the estimated non-fatty solids. The amount of sugar can be estimated polarimetrically.

While the nature and physical conditions of the proteids, fats, carbohydrates, and salts of milk are of great importance in relation to infant-feeding, these considerations are of no special significance from the point of view of the present work. From

[1] *Journ. Roy. Inst. of Public Health*, 1908, vol. xv. p. 39.

the public health standpoint the broad variations in the chemical content of milk are of much greater importance.

The solids left after milk is evaporated are conveniently divided into the fat and the solids not fat. The percentages of these constituents present in milk have been made the basis of legal enactments (see page 315). Briefly stated, these are to the effect that (*a*) if milk contains less than 3 per cent of milk fat, the presumption is that the milk is not genuine, and that fat has been abstracted or water added; (*b*) if it contains less than 8·5 per cent of milk solids, the presumption is that the milk is not genuine and is adulterated with water.

It is of importance to consider to what extent the fat and solids not fat are affected in milk obtained from cows under different conditions. The following are the most important known or alleged causes of variation.

1. *The Breed of the Cow.*—It is well known that some breeds of cows produce milk of much higher quality, especially as regards its fat content, than others. This is illustrated in the following table from Vieth:

Milk Solids in Milk of Cows of Different Breeds (percentages).

Breed.	Total Solids.			Fat.			Solids not Fat.		
	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.
Dairy shorthorn	18·7	10·2	12·90	10·2	1·3	4·03	10·6	7·6	8·87
Pedigree shorthorn	16·8	10·5	12·86	7·5	1·9	4·03	9·8	7·6	8·83
Jersey	19·9	11·0	14·89	9·8	2·0	5·66	10·4	8·1	9·23
Kerry	18·6	10·6	13·70	10·5	1·8	4·72	10·6	4·9	8·98
Red polled	16·2	9·7	13·22	6·6	2·5	4·34	10·2	7·1	8·88
Sussex	17·4	11·5	14·18	7·6	2·9	4·87	10·3	8·4	9·31
Montgomery	16·1	10·2	12·61	6·5	1·4	3·59	10·0	7·9	9·02
Welsh	17·6	11·9	14·15	8·3	3·0	4·91	9·6	8·9	9·24

Dutch cows, which are fairly numerous in some parts of Essex, give abundant milk, but of low fat content. It may be said that whatever the breed of cow average mixed milk contains milk solids well above the legal standard.

2. *Seasonal Variations.*—Richmond,[1] from his extensive

[1] *Dairy Chemistry*, 1899, p. 127.

experience, finds that winter milk is of very good quality while summer milk is the poorest; the spring and autumn are transition periods. The quality varies in an inverse ratio to the quantity yielded. Richmond gives the following table:

Mean Monthly Averages of Milk.

Month.	Specific Gravity.	Total Solids.	Fat.	Solids not Fat.
		Per cent.	Per cent.	Per cent.
January . . .	1·0322	12·88	4·02	8·86
February . . .	1·0322	12·78	3·93	8·85
March	1·0322	12·71	3·88	8·83
April	1·0322	12·66	3·84	8·82
May	1·0323	12·66	3·82	8·84
June	1·0322	12·59	3·79	8·80
July	1·0317	12·66	3·93	8·73
August . . .	1·0316	12·73	4·02	8·71
September . .	1·0319	12·92	4·12	8·80
October . . .	1·0322	13·13	4·21	8·92
November . .	1·0322	13·19	4·30	8·89
December. . .	1·0322	13·04	4·16	8·88

3. *Morning and Evening Variations.*—In this country cows are milked twice a day, and the afternoon milk is always, or nearly always, richer in fat than the morning milk. As regards solids not fat the difference is comparatively slight. The variations in fat content are sometimes considerable with the same cows. The essential cause is the difference in time between the milkings. When the intervals between successive milkings are approximately equal the morning and afternoon milks are nearly identical in quality, the morning milk being still slightly richer in fat. With the extension of the interval, the percentage of fat in the milk drawn after the longer interval steadily falls.

4. *Influence of Feeding.*—Food exerts a considerable effect upon the quantity and particularly the quality of the milk. The effect is variable, and the individuality of the cow counts for much. The percentage of fat is apparently more readily and markedly affected by the food content than the other constituents of the milk. The beneficial effects of good feeding are not always manifested at once, and in some cases are most

marked in the milk yielded in later years.[1] The quality of the milk may be reduced by feeding with distillery refuse and other improper food. This is sometimes done deliberately, as the quantity of the milk is thereby considerably increased but at the expense of the quality. Excessive quantities of turnips may act somewhat similarly.

5. *Influence of the Individual Cow and the Physiological Condition of the Cow.*—Individual cows vary considerably as regards their milk-producing qualities, the milk of some being much richer in the different solids than others, and this apart from breed, age, or period of lactation. The age of the cow considerably influences the milk. According to Fleischmann[2] the milk-yielding capacity of a cow increases up to her eighth year.

The following table from Speir[3] shows the fat content of a number of cows of different ages:

Ayrshire Milk Record Societies.

Age of Cows.	Number of Cows.	Fat percentage.
2	22	3·8
2½	38	3·89
3	320	3·87
4	189	3·74
5	152	3·65
6	159	3·67
7	127	3·63
8	87	3·64
9	58	3·69
10	46	3·56
11	26	3·62
12	23	3·67

The period of lactation markedly affects the quality and quantity of the milk. With ordinary well-fed cows the percentage of total solids in the milk nearly always rises with the advance of the lactation period. This is especially shown as regards the fat. The actual milking capacity of the cow

[1] For example, see *Bulletin No. 69, Maryland Agric. Exp. Station*, 1900.
[2] *The Book of the Dairy*, 1896.
[3] *Journ. Highland Agric. Society*, 1908.

reaches its highest point within the first two months of calving, and then gradually diminishes until the cow becomes dry.

6. *Influence of the Weather as regards Moisture and Dryness.*—In courts of law when a clever advocate is put to finding scientific justification for milk of such poor quality that it infringes the standard, it is not infrequently pleaded that the cause of the impoverishment is due to the climatic conditions which more or less immediately preceded the collection of the peccant sample. Apparently either very dry weather or very wet weather, whichever happens to best fit in with the legal argument, is credited with the power to produce the poor quality milk.

This may be the case, but the writer is not aware of any reliable evidence in favour of such action, and his own analyses of milk, carried out for over five years, do not bear it out.

With these different factors affecting the quality of milk it is not surprising that occasionally the milk of individual cows, and still more rarely of individual herds, falls below the legal standard. If the cases in which the feeding has been obviously of poor and unfairly poor quality, and the cases in which the interval between the milkings have been excessive be excluded, the percentage of cows yielding milk below the legal standard is small, and of mixed herds very much smaller still.

The question of the justice of the legal chemical milk standards is discussed in Chapter XXI.

Structure of Udder: Cellular Elements

In addition to its chemical constituents milk contains cellular elements and, nearly invariably, bacteria. The nature of the cellular content is of considerable scientific interest and also practical importance.

The udder in the cow consists of four quarters, each with a separate teat. While these quarters are bound together by connective tissue into one whole, they are each complete and self-contained with separate secreting glands, lobules, and milk cistern. In a few cows an additional pair of teats is present on the posterior portion of the gland, and in rare instances these are connected to fully developed secreting glands.

Delépine points out that there is a lymph gland at the posterior end of each half of the udder, close to its attachment to the abdominal wall and to the inner aspect of the thigh. These glands are soft and difficult to recognise by palpation when they are normal, but when diseased they often reach a large size and may then be felt through the skin. When the udder is tuberculous this mammary lymphatic gland is generally considerably enlarged and tuberculous.

The mammary gland in the cow, like the human organ, is composed of a number of lobules united by fibrous tissue.

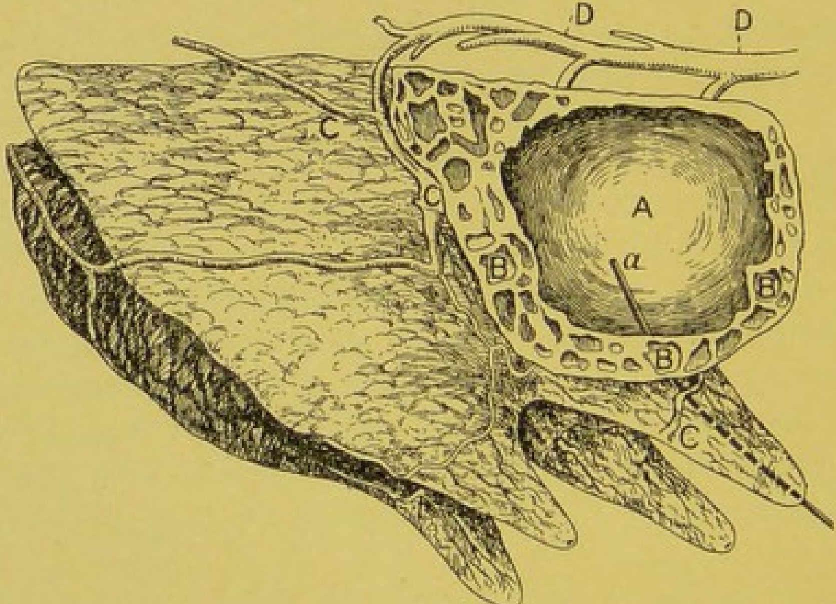


FIG. 1.—Cow's Udder stripped of its Skin to show A, a section of one of the four milk cisterns into which a tube (a) has been passed through the teat; B, smaller milk sinuses around A; C, mammary vein; D, origin of the superficial abdominal vein or "milk vein."

The lobules are composed of acini. The milk is secreted by the cells of the acini and passes into the small lactiferous ducts. These unite to form the galactopherous canals from which the milk passes into the milk cistern or galactopherous sinus. The milk cistern receives the milk of all the acini of one quarter, and the fluid passes from this to the exterior by means of the teat canal. The teat canal gradually narrows to its termination at the end of the teat. The teat walls are thick and contain elastic tissue circularly disposed, which at the orifice acts as a sphincter, preventing the passive escape of the milk.

In the intervals between milking, the milk collects in the milk cistern and in the teat canal, forming in the latter a column of fluid. The existence of this column of fluid in the teat canal has been denied by some observers, but the balance of evidence is in its favour.

In the goat only two mammary glands are present with two teats.

As regards the histological structure of the acini, three layers may be distinguished: (*a*) a layer of epithelial cells forming the glandular cells and lining the lumen of the acinus, (*b*) a thin layer of muscle cells lying upon (*c*) a basement membrane thin and structureless. The actual appearances to be seen in microscopic preparations vary considerably according to the stage of lactation. According to the generally accepted view, the interstitial tissue and the epithelial layers are infiltrated by leucocytes during active secretion, many of which find their way into the lumen of the acini. These, together with the epithelial cells, are found in the milk.

According to Winkler, a further layer of cells is present between the muscle cell layer and the epithelial cells. This he calls the germinal cell layer and considers it as the source from which the epithelial cells of the gland are constantly renewed.

The histological structure throws light upon the cellular content of milk. Cellular elements are always to be found in milk even from the healthiest animals, but marked variations are met with, both as regards their numbers and the varieties present. The cellular elements are usually spoken of as leucocytes, but since it is probable that not all are actual white corpuscles, although many of them are of that nature, it is perhaps better to speak of cellular content rather than of leucocytes.

From his own investigations,[1] the writer classified the cells found in milk into three groups (Fig. 2), although occasionally cells are found which could not be accurately placed in any one of these three groups.

(*a*) *Polymorphonuclear Cells.*—Medium-sized, with a diameter varying from about $7 \cdot 5\mu$ to 10μ. The protoplasm of the cell is only seen with difficulty, but the nucleus stains

[1] *Report of Medical Officer, Local Government Board*, 1906-7, p. 205.

deeply, and from its twisted shape frequently appears like several nuclei.

(*b*) *Large Cells.*—These cells vary greatly in size, but are usually large, their average diameter being from 13μ to 16μ, but they may be as large as 24μ. They have a single nucleus which occupies only a relatively small proportion of the cell. All gradations between these cells and lymphocytes are met with.

(*c*) *Lymphocytes.*—Considerably smaller. They show great variability in size, in some cases being quite small, but for the most part they have a diameter of about $5\text{-}7\mu$. They are circular or nearly so; the nucleus stains deeply and occupies nearly the whole of the cell.

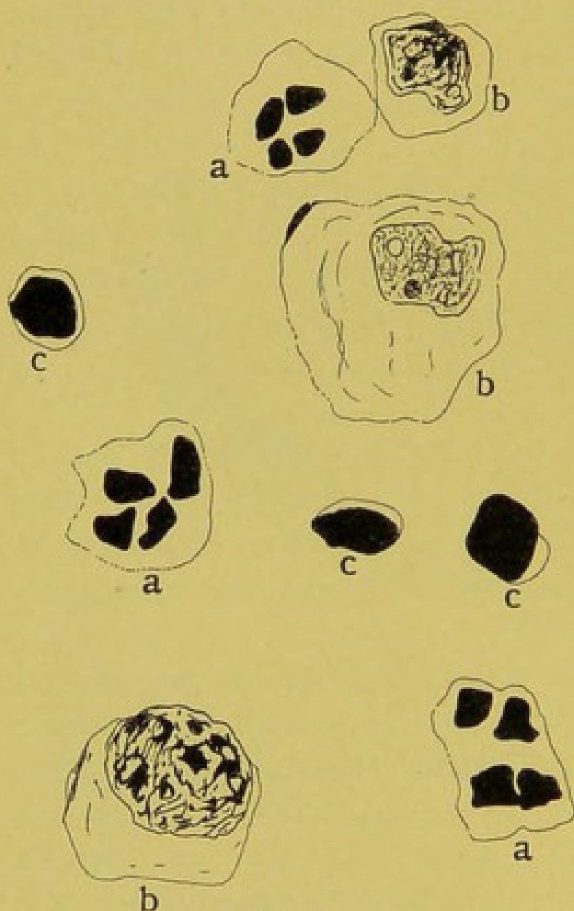


Fig. 2.

The cellular content of milk shows considerable variation, even with apparently perfectly healthy cows. The writer has met with variations ranging from 50 to considerably over 1000 cells per cubic mm. As regards physiological conditions, he found that the age of the cow and the previous number of calves had little or no influence upon the number, while, excluding animals which had only calved within a few days, there was no relationship between the number and the period since calving. In the milk of cows examined within a few days after calving, there is a marked increase in the cellular content, the increase being especially in the lymphocytes.

The milk secreted within a few days after parturition is called colostrum. It is yellow and viscid with a strong odour, and coagulates on boiling. It contains cells laden with fat globules, the so-called colostrum bodies.

The earlier stages of pregnancy do not influence the number of leucocytes, but in the later stages, when the milk is diminishing, a rise in the number of cells almost always takes place, the rise being mainly in the large cells. The milk of cows "drying off" is of high cellular content.

In pathological conditions of the milk-producing apparatus, there is a marked increase in the cellular content of the milk, and numbers as high as 200,000 to 300,000 per cubic millimetre have been recorded by the writer in cases of garget. In inflammatory and other pathological conditions it is particularly the polymorphonuclear elements which are increased. They usually then form 75 to 80 per cent of the whole.

An increase in the cellular or leucocyte content of the milk, as it is usually called, may also be due to some old pathological lesion of the udder or teats, all traces of which had passed away at the time of examination as far as clinical methods are concerned. The following may be quoted as an instance:

Cow No. 46.—Leucocyte count of the four mixed quarters = 1025 per cubic millimetre. No local physical signs on examination, but a very definite history of so-called "milk-fever," involving the R.H.Q. (right-hind quarter) only, at the time of last calving some months previously. At that time this quarter was said to have been painful, and yielded no milk. Examined a few days after the mixed milk sample was taken, the milk from the individual quarters showed the following results:

R.F.Q. =	280	leucocytes.
R.H.Q. =	2250	,,
L.F.Q. =	28	,,
L.H.Q. =	64	,,

Hewlett, Villar, and Revis[1] found that in general, in the case of any particular cow, apart from changes produced by some special causes, the number of cells per c.c. is fairly constant over the lactation period. These investigators have more recently classified the cellular elements found in milk. They distinguish three common varieties, which they speak of as large uni-nucleated cells, multi-nucleated cells, and small uni-nucleated cells, and which closely correspond with the

[1] *Journal of Hygiene*, 1909, vol. ix. p. 271; and 1910, vol. x. p. 56.

above three varieties described by the writer. In addition, they mention as scanty, or often absent, eosinophile cells, vacuolated cells, and cells of indeterminate nature.

Their results are very similar to those previously obtained by the writer, the essential difference being that they do not regard any of the cells as of the nature of leucocytes. They adopt the view of Winkler that the cells found in normal milk are chiefly young epithelial cells and cells of the germinal layer which have been thrust into the lumen of the alveolus and so appear in the milk stream, and that none of them are leucocytes.

Milk Sediments.—In addition to cellular elements, the deposits obtained from ordinary milk, either by centrifugalisation, or on standing, contain a number of other substances. In view of the use which has been made in practical milk examinations of the investigation and measurement of such deposits, their character and sources are worth some consideration.

The amount of sediment obtainable from a given sample will vary with the method of measurement, a larger deposit being obtained with a fast-running centrifuge than by sedimentation in a conical glass.

The terms "dirt" or "filth" are often applied to such sediments, but these are expressions which imply judgment in advance, and are not always applicable, certainly not always to the whole of the deposit.

The sediment is composed in part of leucocytes, in part of inorganic substances, such as sand, but for the most part of dust particles, cotton fibres, manurial matters, particles of straw, hairs, etc., and bacteria. In milk as vended under ordinary present-day conditions, the greater part of it is manurial in origin.

The characters of the cellular elements, and the general prevalence of bacteria, can be readily studied by making microscopic preparations from a little of the deposit.

The relationship of the amount of sediment to the general cleanliness of collection and transmission has been demonstrated by a number of observers.

For example, Houston[1] with London milks recorded the following:

[1] *Report to London County Council*, 1905.

Sediment in Milk (Secondary reading).
(Parts per million by volume.)

	Less than 25 vol.	25 to 50 vol.	50 to 75 vol.	75 to 100 vol.	100 to 150 vol.	Over 150 vol.
Series 1. 20 samples of milk from 20 separate cows . .	100%	...	...	...	...	...
,, 2. 20 samples of milk from purveyors' shops . .	40	25%	15%	5%	5%	10%
,, 3. 20 samples of milk from dairy shops . . .	40	40	10	...	5	5
,, 4. 20 samples of milk from railway stations . .	45	35	15	5	...	...
,, 5. 20 samples of milk from well-known dealers .	60	35	5	...	...	...

It cannot be doubted but that the vast proportion of the matters which make up the sediment of milk gain access at the cowshed.

Orr[1] examined 61 cowshed samples for sediment with corresponding samples at the point where the milk was supplied to the consumer. On considering the cowshed samples and the records of the conditions present on inspection, it was found that the average amount of milk sediment from dirty cows was 52·5 volumes per million, the lowest being 20 volumes and the highest 120 volumes, and the average of milk from clean cows was 31·7 parts, the lowest being 7·5 and the highest 80 volumes per million. The amount of sediment varied with the cleanliness of the cows and the method of filtering.

Comparing the cowshed samples, and the same at the time of retailing, Orr found a decrease in the latter on the whole, and concluded that the sediment gains entrance at the cowshed, and little, if any, in transit.

Delépine[2] estimated the volume of sediment from milk supplied to Manchester over a number of years. Between the years 1896-1900, he calculated the average amount of slime arriving daily in 40,000 gallons of milk to be 106 lb. In 1906 the amount of slime in the same quantity of milk had been reduced to 79 lb. He regards the amount of slime as

[1] *Report on Milk Contamination*, 1908.
[2] *Report of Medical Officer, Local Government Board*, 1908-9, p. 341.

an indication of the care which has been taken in the keeping of the cows and in the collection and distribution of the milk.

He finds that although there is no constant relation between the amount of dirt and the pathogenic properties of the milk when individual cases are considered, there is a distinct average correlation between the amount of dirt and the pathogenicity of the milk. He records from his work that the reduction in the amount of dirt found in the milk supplied to Manchester during the past ten years has been associated with a marked diminution in the number of samples capable of producing disease in inoculated animals.

Delépine, from laboratory observations, says that it appears difficult to obtain milk containing less than 7 grains of sediment per gallon, and he accepts this as the irreducible minimum.

CHAPTER II

THE SOURCES OF BACTERIA IN MILK

MILK as *secreted* is a sterile fluid, but during every stage from the udder to the consumer, contamination is possible, and under much of the present-day conditions is invited. In consequence, milk as vended may, and frequently does, contain very many thousands of bacteria. The sources by which bacteria gain access to milk can be grouped as follows:

1. Intra-mammary.
2. Introduced during the milking operation.
3. From milk utensils.
4. From the use of artificial or special milk apparatus.
5. Contamination in transit.
6. Contamination upon the purveyors' or consumers' premises.

1. *Intra-mammary Contamination.*—The view generally accepted, up to a few years ago, was that the interior of the udder contained no bacteria, and that milk, if not quite sterile when it left the teats, yet contained but a few bacteria derived from the teat ducts themselves. This opinion was largely based upon the fact that with a sterile tube it was sometimes possible to obtain sterile milk from the udder. More recent investigations have, however, shown that this view cannot be accepted.

Two of the earliest investigators to doubt the accuracy of the sterility of the udder were Bolley and Hall,[1] who considered the milk cistern might be a source of much bacterial growth.

Moore and Ward[2] in 1898 examined the udders of six cows slaughtered after reacting to the tuberculin test, and found them non-sterile.

[1] *Centralbl. f. Bakt.*, 1895, Abt. II. i. p. 793.
[2] *Bulletin No. 158, Cornell University Agricultural Experiment Station.*

Ward,[1] in a more recent publication, gives an account of further experiments. The udders of 19 milch cows from five different dairies were examined. All the cows were tuberculous, but in no case was the udder tuberculous or abnormal in appearance. He found that the lactiferous ducts of the 19 udders examined harboured bacteria throughout their whole extent. A number of different kinds of bacteria were isolated, the majority being micrococci. Ward also carefully studied the anatomy of the udder, and concluded that no obstruction capable of excluding bacteria from the milk-cistern exists, except perhaps the sphincter muscle at the lower end of the teat. He further concluded that there was no obstacle to prevent bacteria finding their way through the fine ramifications of the lactiferous ducts to regions remote from the teat.

Uhlmann[2] showed the presence of numerous bacteria in sections of the hardened teats of cows, goats, and sheep.

Henderson[3] examined seven normal udders and found that 76 per cent of the cultures made exhibited growths of bacteria. Staphylococci, streptococci and pseudo-diphtheria bacilli were isolated. All were non-pathogenic. It is interesting to note that two of the normal udders were taken from young heifers and were unexpanded, and all the cultures made from the milk cistern, ducts, and parenchyma, remained sterile.

That milk as delivered from the teats even when obtained with aseptic precautions, and after rejection of the fore milk, contains bacteria, has been demonstrated by numerous investigators. The fore milk contains most of the bacteria, but the middle milk and strippings are also bacterially contaminated. For example, von Freudenreich[4] had 28 cows milked, with careful precautions to avoid outside contamination, into sterile flasks. The mean bacterial content for each cow was 230 per c.c., the number of bacteria varying from 65 to 680.

Lux[5] examined 260 specimens of cows' milk and 95 from goats, the samples being collected direct from individual cows but without special antiseptic precautions. He found, on an average, 1395 bacteria per c.c.

1 *Bulletin No. 178, Cornell University Agric. Experiment Station*, 1900.
2 *Inaugural Dissertation*, 1903.
3 *Journ. Roy. San. Inst.*, 1904, xxv. p. 563.
4 *Centralbl. f. Bakt.*, 1902, Abt. II. viii. p. 674.
5 *Centralbl. f. Bakt.*, 1903, Abt. II. xi. p. 273.

Bergey[1] examined a number of samples of milk collected separately from each of the four quarters of the udder. In these samples the number of bacteria ranged from 0 (32 per cent of the samples) to 93,100 per c.c. Like Henderson he found the prevailing bacteria to be staphylococci, streptococci, and pseudo-diphtheria bacilli. Only about 10 per cent of the samples contained over 5000 bacteria per c.c.

In regard to the sources of these bacteria, their primary origin is certainly from outside the teat. It seems to have been established that after milking a column of milk remains in the teat canal. In this milk column any bacteria introduced through the teat orifice will find a suitable nidus for growth. The bacteria extend up, infect the milk cistern, and ultimately the ramifications of the milk tubes through the udder.

There is obviously, however, a considerable selective action exerted, since the organisms found are almost invariably staphylococci, streptococci, and other forms of micrococci. The evidence of this selective action was clearly shown in certain experiments undertaken by the writer, in which the interior of the teats of goats were inoculated with streptococci of human and bovine origin. As a rule the infecting organisms died out after a period of time, to be measured by weeks, although in one case the infecting streptococcus persisted for the whole duration of the experiment, a period of over seven months. The streptococci of human origin, in general, died out more rapidly.

2. *Introduced during the Milking Operation.*—The bacteria introduced during milking are derived from three sources, (*a*) the coat, udder and teats of the cows; (*b*) dust from the milking shed and the clothes of the milker, and (*c*) derived from the hands of the milker.

(*a*) No person possessed of any bacteriological knowledge, who is acquainted with cows as usually kept, will need convincing that heavy bacterial pollution must result from this source. It is very common, indeed in some districts quite the usual thing, to find the hind-quarters of the cow caked and plastered with partially dried manure. This is, of course, particularly the case in wet weather. The udder and teats of the cows do not show such gross manurial contamination, but are frequently dirty and show evidence of dried manure.

[1] *Bulletin No. 125, Depart. of Agric. Pennsylvania*, 1904.

The udder and teats have only to be washed in clean water, and the water looked at, to demonstrate their filthy condition. Such manurial matter is, of course, loaded with bacteria. As an illustration of the enormous number of bacteria in manure, the following figures obtained by Orr[1] may be quoted:

	Sample.	Number of Organisms per gramme. Agar, 37° C. 48 hours.
Fresh manure which had only lain in the cowshed for one or two hours.	No. I.	725,000.
	,, II.	3,500,000.
	,, III.	8,430,000.
	,, IV.	1,258,000.
Old manure, cut off from the hardened fæces sticking to the udder and side of legs of the cows.	,, V.	66,368,000.
	,, VI.	185,000,000.
	,, VII.	13,050,200,000.
	,, VIII.	8,649,300,000.

It is, of course, chiefly the old dried manure which gets into the milk.

The kinds of organisms present are very numerous. That bacteria of the streptococcus and coli classes are abundant, is shown by the following figures obtained by the writer[2] for quite fresh excreta:

Approximate Number per gramme of Excreta.

Source.	*B. coli.*	Streptococci.	*B. enteriditis sporogenes* spores.
Cow No. 1	0·1 to 1 million	10,000 to 100,000	100 to 1000
,, 2	10,000 to 100,000	0·1 to 1 million	10 to 100
,, 3	1 to 10 millions	over 10 millions	10 to 100
,, 4	1 to 10 millions	0·1 to 1 million	100 to 1000

During milking an appreciable portion of manure drops into the milking-pail. This contamination is greater in winter than in summer when the cows are generally out of the sheds for most of the day and night, and are consequently cleaner. Some experiments of Orr (*loc. cit.*) illustrate this. A number of agar-plates were held under the udder during the process of milking for two minutes each, and after exposure were incubated (4 days at 20° C.). From the respective areas of the plates and the ordinary milk-pail, it would be possible to calculate the number of organisms falling into the milk-

1 *Report on Milk Contamination*, 1908, pp. 19-20.

2 *Bacteriological Examination of Water Supplies*, 1906, p. 35.

pail. All the experiments were carried out in the cowsheds. The following results were obtained:

Series.	Housing of the Cows.	Condition of the Udders and Cows as regards cleaning.	Number of Experiments.	Average Number of Colonies per agar-plate with 2 minutes' exposure.
I.	Summer: All cows out	Untouched	7	440
II.	" "	Udders and flanks brushed and washed	3	170
III.	Winter: Cows indoors	Untouched	3	4752
IV.	" "	Udders and flanks brushed, not washed	3	1752
V.	" "	Udders and flanks brushed, washed, but left moist	6	230
VI.	" "	Udders and flanks brushed, washed, and dried	3	444

The influence of cleaning the udders is also shown by the diminished number of bacteria in the milk. An average of thirteen experiments at the Storrs Station[1] showed the following results:

Bacteria in milk from unwiped udders = 7058 per c.c.
" " wiped " = 716 "

Decrease due to wiping = 6342 "

(*b*) Numerous investigators have shown the presence of bacteria in large numbers in the air of cowsheds. The dusty floors, the usual presence of hay and other feeding-stuffs, combined with the frequent movement, all renders bacterial pollution of the air constant. Orr, for example, exposed plates containing agar in cowsheds for 5 minutes during milking, with the following results, the numbers being calculated as falling on the surface of a twelve-inch pail. At the end of 96 hours at 20° C., the plates were counted and the numbers calculated. The following results were obtained in the five experiments: A = 3456 and 3600; B = 4500; C = 3375 and 4185; D = 1260; E = 2068 and 2700.

[1] *Bulletin No. 42, Storrs Experiment Station.*

The churn which receives the milk is frequently placed in a dusty place, and is very often uncovered.

The clothes of the milker are usually highly dust-laden, and as the wearing of a clean overall is quite exceptional, many bacteria are added to the milk from this source.

(c) The hands of the milker add their quota of bacteria to the milk, for even when washed to start with, they soon become filthy from the dirt upon the cows. Most of this dirt, with included bacteria, is washed into the milk. The influence of the milker in adding bacteria to milk is clearly illustrated by the following experiment recorded by Stocking.[1] The average of 19 tests with two milkers who had had no training in dairy sanitation, and one milker who was a graduate of the Connecticut Agricultural College, showed 17,105 bacteria per c.c. for the untrained men, and 2455 for the trained man. The only difference between the men was the knowledge of what constituted contamination gained by the college graduate, who was a student of bacteriology.

3. *Bacteria introduced from Milk Vessels.*—When improperly cleaned, these are a source of great bacterial contamination to the milk. Orr quotes Harrison as carrying out the following series of experiments. He rinsed out the cans with 100 c.c. sterile water, and then estimated the number of organisms per c.c. of this water.

Series A. Ten samples were examined from cans improperly cleaned, and gave from 215,000 to 806,320 organisms per c.c.

" *B.* Ten samples, from cans cleaned by washing with tepid water and scalding, gave from 13,080 to 93,400 per c.c.

" *C.* Five samples, from cans cleaned by washing with tepid water and then steaming for 5 minutes, gave from 355 to 1792 organisms per c.c.

Even if cans are properly scalded, it is a not uncommon practice to wash them out afterwards with cold water. If the water used for this purpose is not from a pure source this may be a further source of bacterial contamination.

4. *From Artificial or Special Milk Apparatus.*—The commonest apparatus used, not strictly appertaining to milking, is a milk-strainer. It is an almost universal practice of the cow-keeper to strain the milk, usually immediately after

[1] *Bulletin No. 42, Storrs Experiment Station.*

milking. If not kept absolutely clean they may actually add bacteria to the milk (see Chapter XVI.).

Milk-coolers are sometimes a source of bacteria in milk. They may be placed in dusty places, so that the milk passing over them, exposing as it does a large surface to the air, takes up a good many bacteria. Also they may not be kept efficiently clean, traces of milk being left, in which bacteria multiply enormously and are subsequently added to the milk. A third but much less common way by which coolers may contaminate the milk is by being leaky, the water being added in small quantity to the milk.

The following experiments by Orr (*loc. cit.*) illustrate that milk-coolers may act as contaminators of the milk. The mixed milk in each case was sampled before and after passing over the cooler, with the following results:

Experiment.	Condition of Milk.	Agar, 37° C. for 48 hours.	Gelatine, 20° C. for 96 hours.	Relative Number of	
				Liquefiers.	Non-liquefiers.
A	Not cooled	36,000	43,000	1	8·5
	Cooled	53,000	78,000	1	7
B	Not cooled	12,000	14,600	0	12
	Cooled	31,000	129,000	1	5·6
C	Not cooled	20,000	25,500	1	17
	Cooled	32,500	49,000	1	9
D	Not cooled	37,750	76,000	?	?
	Cooled	77,000	162,000	?	?

Orr explains the higher number of organisms at 20° C. compared with at 37° C. as due to the bulk of the added organisms being derived from the air.

In the same way milk-separators usually add bacteria to the milk passing through them. If the separator is not perfectly clean, the increase may be due to added bacteria, but in ordinary cases the increase is more apparent than real.

If milk is separated, and the cream and separated milk remixed, it will usually be found that the germ-content of the reconstructed milk is higher than before separation.

Severin[1] carried out numerous experiments and always

[1] *Centralbl. f. Bakt.*, 1905, Abt. II. xiv. p. 605.

found an increase. In one experiment the apparent increase was about 70 per cent. From his experiments he concluded that bacteria from the air or other source was not responsible, and advanced the view that the increase was due to the breaking down of the groups and clumps of bacteria which occur in milk. Such breaking down would have the effect of considerably increasing the number of colonies and so the apparent germ-content.

Heinemann, Luckhardt, and Hicks[1] also experimented in this direction, and found a considerable increase in the number of bacteria after separation. As an average of 48 examinations of 3 different samples of milk they found the milk before separating to have a germ-content of 738, the separator milk 2130, the cream 132, and the reconstructed milk 1987 bacteria. They concluded that since the conditions under which the separation took place were above reproach, as far as cleanliness and handling were concerned, Severin's view was the correct one, and the increase is due to the disassociation of the aggregates of bacteria.

Artificial milkers are discussed in Chapter XVI. As there explained they are more likely to be a source of bacteria from faulty cleaning than serve to diminish the germ-content of the milk by removing sources of pollution.

5. *Contamination in Transit.*—It is an extremely difficult thing to measure the amount of bacterial contamination of milk which takes place in its transit from cowshed to milk purveyor or consumer. The increase in the number of bacteria added from outside sources is obscured by the increase due to the multiplication of the bacteria already in the milk. It is not possible to give the extent of the contamination in definite terms of bacteria added. In general, it may be said that all the faulty conditions described in Chapter XV. are sources of bacterial contamination of the milk, but the extent of such bacterial additions must vary with the nature of the condition and the opportunities offered for pollution. The addition in transit of bacteria from outside is probably trivial compared with the bacterial additions at the cowshed and in the consumer's house.

6. *Bacteria added on the Purveyor's or Consumer's Premises.*—

[1] *Journ. of Infect. Diseases*, 1910, vol. vii. p. 47.

The masking effect caused by multiplication of the bacteria already present makes calculations as to the extent to which organisms are added on these premises difficult. Orr (*loc. cit.*) has attempted with some success to measure the bacteria added to milk from outside sources while the milk is in the hands of the retailer and the consumer. Samples of milk were collected into sterile bottles from milk in the ordinary milk-containers in the dairies selected, and then kept for a variable number of hours on the counter in locked wire cages by the side of the containers. During the time of exposure, the milk from which the sample had been taken was sold and dealt with by the retailer in the usual way, covered or uncovered. After some time samples were collected from the containers, and these and the control samples were at once transmitted (in ice boxes) for examination. The control samples had been kept at the same temperature as the milk in the container but not exposed to contamination, so that the added organisms could be estimated by comparing the results of the two samples. Eleven such experiments were carried out with the results shown in the following table:

No.	Dairy Control, in Shop same time as Dairy Milk. Bacteria per c.c.	Dairy Milk after remaining for Sale in Shop. Bacteria per c.c.	Covered or not.	Temperature of Air and Milk.		Hours in Shop.	Percentage increase (+) or decrease (−) over Control.
1	130,000	170,000	No	15·5°	8·0°	5¼	+ 30·7
2	4,120,000	4,340,000	,,	8°	18°	16	+ 5·3
3	178,000	133,000	,,	11°	18°	1½	− 25·2
4	96,000	84,000	Yes (nickelled cover)	19°	8°	2¾	− 12·5
5	175,000	168,000	Yes	8°	7°	9	− 4·0
6	147,000	109,000	,,	9°	9°	6¾	− 25·8
7	41,000	51,000	No	5°	5°	17½	+ 24·4
8	125,000	259,000	,,	6°	5°	14½	+ 107·2
9	1,220,000	2,360,000	,,	12·5°	12°	7¼	+ 93·4
10	36,600	64,000	,,	10·5°	12°	2	+ 76·5
11	291,000	310,000	Yes (pasteboard)	11°	7°	3	+ 6·5
Total	6,559,600	8,048,000					

Average increase due to contamination = 22·7 per cent.
Average time in premises = 7·7 hours.

This table shows that the average increase is 22·7 per cent, and Orr counts this as the percentage increase due to contamination in the retailer's premises. As Orr, however, is careful to point out, the number of experiments is small and the results are chiefly of value for comparative purposes.

In a similar way Orr adopted the plan of taking control samples to determine the actual contamination in the consumer's house, the controls being kept at the same temperature and for the same time as the consumer's own milk. The samples were from all classes of houses, "from the small through-house in slum districts to the self-contained house." Twenty-six such control experiments were carried out. In 19 cases the samples from the consumer's own milk showed an increase over the controls varying from 1·1 to 170·9 per cent. In 7 cases there was a decrease varying from 1·4 to 45·6 per cent. The average time in the house was 8 hours. The average increase was 23·5 per cent, which Orr takes as the contamination in the consumer's house.

In these particular experiments the cleanliness of the house did not apparently materially affect the bacterial content of the samples. It should, however, be pointed out that flies were not prevalent to any marked extent during the time these experiments were made.

The important part played by flies in transmitting specific infection is being increasingly recognised. By feeding upon excreta and decomposing matters and then upon milk, sugar, and other foods flies probably frequently act as the actual vehicle of transmission of the specific disease - producing bacteria. The typhoid bacillus has been isolated from flies.

CHAPTER III

THE BACTERIA FOUND IN MILK

In the preceding chapter the very numerous sources whereby bacteria may be introduced into milk have been considered and discussed. The present chapter gives some account of the chief groups of bacteria likely to be present.

In the first place, it must be realised that it is scarcely justifiable to speak of "milk bacteria" in the same way as we speak of manure bacteria, sewage bacteria, etc., thus implying that there are certain bacteria or groups of bacteria which are characteristic of these substances and universally present. The sources of pollution of milk are so many and varied that the bacterial content is very complex, while it is further complicated by the fact that milk is a suitable nutritive medium for most organisms. On the other hand, certain groups of bacteria are especially prevalent in milk, and some measure of selective action is undoubtedly exhibited. Two lines of description may be adopted. On one plan, all the different organisms which have been found in milk may be classified and described as milk bacteria. With present knowledge such a catalogue of bacteria is of practically no value from the public health standpoint. In the first place, many of the descriptions of these bacteria are so scanty as to be practically valueless, while probably the same bacillus is described over and over again under fresh names. Again, such a catalogue of organisms must be very incomplete, the sources of bacteria in milk being so numerous. Even if a fairly complete and accurate register of all the bacteria likely to be found in milk samples was compiled it would not be of much practical service for public health work, since for this what is required is not a knowledge of all the bacteria which may be present in milk, but only the harmful or potentially harmful, and those whose presence may be taken as an index of general or special pollution.

The butter-maker and the pure scientist are in a different position, and have much to gain from a full knowledge of all the kinds of bacteria met with in milk.

It will be sufficient for public health purposes to describe the chief groups of bacteria met with in milk, and to discuss the significance of their presence and the sources of entry.

The following groups are considered:

Group 1. Streptococci and staphylococci.
„ 2. *Bacillus coli* and allied organisms.
„ 3. The lactic acid bacilli.
„ 4. Spore-bearing bacteria in milk.
„ 5. Acid fast bacilli.

The pathogenic bacilli, such as *B. tuberculosis*, are described in subsequent chapters.

It may also be mentioned that a number of interesting chromogenic bacilli are known to occur in milk. Of these may be mentioned *B. prodigiosus*, associated with red milk; *B. cyanogenus*, the cause of blue milk; *B. synxanthus*, the cause of yellow milk.

Special organisms concerned with the production of bitter milk, soapy milk, etc., have been isolated.

Although these bacilli are of considerable interest, they are of little or no importance in relation to public health, and are therefore not discussed in detail.

Group 1.—Streptococci and Staphylococci in Milk

Streptococci.—Streptococci are undoubtedly very prevalent in ordinary samples of market milk. They are not only very numerous in milk as vended, but are often abundant in samples of mixed milk collected immediately after milking at the farm, and examined before any multiplication can have taken place. The writer has found streptococci present in every sample of mixed milk (although many were collected at the farm) which he has examined, when 1 c.c. was sampled, and in over 80 per cent when 0·1 c.c. was examined. Orr gives the following instructive table in which the *percentages* of cowshed, retailers', and consumers' samples, giving positive results in the various dilutions, are shown :

	Cowshed Samples.	Retailers' Samples.	Consumers' Samples.
1 c.c. negative . .	...	...	...
1 „ positive . .	...	...	...
0·1 „ „ . .	17·4	9·2	2·9
0·01 „ „ . .	34·7	26·1	24·6
0·001 „ „ .	31·8	36·9	23·2
0·0001 „ „ . .	14·5	24·6	23·2
0·00001 „ „ . .	1·4	3·0	26·0
0·000001 „ „ . .	...	...	...

The percentages showing a positive result are irregular, but in the highest dilution increase from left to right in the table, being greatest in the consumers' samples column.

Not only are streptococci found in mixed milk, but they are present in milk collected from individual cows, and drawn with great care direct from the teats into sterile bottles, and this even after the fore-milk has been entirely rejected. Out of 88 apparently healthy cows examined by the writer, in which the middle milk (of all four quarters) was examined, in 46, or 52 per cent, streptococci were found when 1 c.c. of the milk was examined. In some cases the streptococci were scantily present but in others very numerous, agar-plates brushed with 0·1 c.c. of milk showing thousands of streptococcus colonies.

The sources whereby streptococci are added to milk are individually no doubt varied, but are mainly four in number.

(*a*) The teat passages and milk cisterns of healthy cows. The streptococci gain entrance by direct infection through the teat mouth, and are transmitted by and multiply in the milk left in the teat canal. The milk cistern becomes infected, and the streptococci establish themselves.

(*b*) Manurial contamination. Streptococci are very numerous in cow manure, varying from 100,000 to 10 millions or more per gramme. In view of the gross manurial pollution of milk this must be regarded as their most abundant source.

(*c*) Stale milk from dirty cans. Streptococci multiply rapidly in milk, and they are often very abundant in the traces of milk left in improperly cleaned milk cans.

(*d*) Cows suffering from mastitis. The relationship of mastitis to streptococci is discussed in Chapter VI. It is sufficient to remark here that in the secretions of cows suffering from mastitis due to streptococci these organisms are present in extremely large numbers. In some instances plates brushed with a single loopful of the fluid will show as many as a thousand streptococcus colonies.

The significance of streptococci in milk has been much debated, and opinion on the subject has passed through two distinct phases. The earlier investigators who found streptococci in milk for the most part inclined to the view that their presence was, if not due to definite pathological lesions of the cow, at least highly unsatisfactory, and fraught with potential harm to the consumers of such streptococcus infected milk, particularly if the consumers were young.

Holst, for example, isolated streptococci from milk supplied by cows suffering from mastitis, and considered them to be the cause of gastro-intestinal catarrh. Beck also believed that the streptococci in milk were closely related to the streptococci found by Escherich in cases of infantile diarrhoea, while Bergey concluded that these organisms were probably not infrequently the cause of serious gastro-intestinal disorders in infants.

As already mentioned, later investigations have shown that streptococci are extremely numerous in milk, are practically present in all samples of mixed milk, and indeed are frequently present in the milk of perfectly healthy cows. Also Kruse, in 1903, and Hölling, in 1904, both working in Bonn, advanced the view that the lactic acid bacilli of the *B. acidi lactici* type were not bacilli, but streptococci. Heinemann, in 1905, independently came to the same conclusion.

These facts and views have caused a modification of the opinion that streptococci in milk are of necessity prejudicial, and the view as to their significance now most commonly held may be said to be one of tolerance qualified by suspicion. Indeed, we can go further and postulate that if any significance is to be attached to the presence of streptococci in milk it must either be because—

(*a*) Their presence is an indication, and their numerical presence an estimate, of undesirable pollution—that is, they act as indicators of pollution, and quite apart from any potential harmfulness of their own; or

(*b*) They are so numerous that their presence can only be explained as derived from a pathological lesion of the cow; or

(*c*) Certain definite varieties are present which are known to be associated with pathological lesions, and to play a disease-producing *rôle* in man.

The possible value of streptococci for these purposes may be briefly considered.

As indicators of manurial pollution they have this in their favour, that, as mentioned above, they are abundant in the materials whose presence we wish to quantitatively measure. The fact that they are found in milk drawn direct from the teats is fatal to their use for this purpose, since to judge the cleanliness of the methods used in milk collection, etc., by a test which is in part independent of such conditions, cannot be considered a satisfactory procedure.

Whether the presence of *enormous* numbers of streptococci in fresh milk can be utilised as a reliable indication that the milk is in part derived from animals suffering from local pathological lesions of the udder or teats is at present undecided. Certain is it that in cow mastitis, some cases of teat ulceration, etc., the lesions show streptococci present in enormous numbers. In one instance the writer found that when the cows of a cow-keeper whose fresh milk contained enormous numbers of streptococci were examined severe teat ulceration, associated with abundant streptococci, was found upon several of the cows.

While streptococci as a class cannot be at once condemned, it is of the utmost importance, in view of the fact that streptococci are amongst the most harmful of bacteria known to man, to study the different varieties present in milk, and to endeavour to separate the pathological and harmful types from the saprophytic and harmless.

Unfortunately the differentiation of streptococci is by no means satisfactory, nor is the basis of classification uniform for different workers. Some investigators rely solely upon the characters most used in earlier bacteriological investigations, such as morphology, pigment-production, characters of the gelatine plate colonies, growth in broth, milk, potato, etc. Other workers place in addition to, or in substitution for, these tests, great reliance upon pathogenicity, agglutination tests, or the haemolytic tests introduced by Schottmüller. A further group of workers base their differentiating characters in large part upon the ability of streptococci to produce acid in certain sugars or alcohols.

It cannot be said that any one series of tests are satisfactory or sufficient, but the writer and others have found from extensive experience with milk streptococci that the sugar-alcohol tests, together with morphology, growth in broth and milk, and pathogenicity, are of most utility.

Houston[1] studied the biological characters of 172 streptococci isolated from various samples of milk. Using the sugar-alcohol tests he found that they differentiated the streptococci into a very large number of groups. He could by these tests, and apart from morphology and growth in broth, divide them into no less than 38 different groups, of which only one group contained more than 12 per cent of the isolated organisms. Houston found that the streptococci of milk differ somewhat from the streptococci of cow-dung and human faeces. This is brought out by the following table, to which is added the results of 71 streptococci isolated by the writer[2] from milk drawn direct from the udder and teats of healthy cows:

	Cow-dung (Houston).	Human Faeces (Houston).	Milk (Houston).	Individual Healthy Cows (Savage).
	Per cent +	Per cent +	Per cent +	Per cent +
Salicin test . . .	93	92·67	60	83
Saccharose test . .	89	86·34	90	94
Lactose test . . .	85	76·34	97	100
Litmus milk test . .	73	61·67	70	80
Neutral red broth test .	All negative	39·34	20	...
Raffinose test . .	74	32	19	59
Mannite test . .	All negative	24·34	20	31
Inulin test . . .	13	4·67	21	27
Coniferin test . .	...	...	...	44

[1] *Report to London County Council*, 1905.

[2] *Report of Medical Officer, Local Government Board*, 1906-7, p. 205.

This table shows that the results obtained with milk samples from individual cows approximate more closely to those obtained with mixed milk samples than to the cow-dung or human faeces results. The chief differences are in regard to the fermentation with salicin and raffinose.

The pathogenicity test for streptococci isolated from milk is probably a test of considerable value if carried out immediately after isolation. The writer tested the pathogenicity of 25 streptococci isolated from the milk cistern and teats of healthy cows. In every case the results were negative. Streptococci isolated from mixed milk also proved negative. On the other hand, streptococci isolated from milk supposed to be causing sore-throat or other human disease have on several occasions been found to be pathogenic to mice.

Heinemann[1] investigated the virulence upon rabbits of a number of streptococci obtained from milk. The initial results were usually only slight local reaction at the seat of inoculation, but by passing the streptococci through a series of rabbits a high degree of virulence was acquired. After five or more passages, subcutaneous injections became fatal in doses of 2 c.c. of 24-hour-old broth cultures. The virulence approximates to, if not equals for this animal, that of typical *Streptococcus pyogenes* from human affections. Heinemann remarks: "The lesions produced by *Streptococcus lacticus* in rabbits are of the same kind and extent as those produced by *Streptococcus pyogenes* from pathological conditions in human beings."

Staphylococci.—This group of organisms is abundantly represented in milk. They are particularly abundant, indeed, in the writer's experience, nearly universally present, in milk samples drawn direct from individual cows and without chance of outside contamination. A number of different varieties may be recognised by appropriate tests. Our present knowledge is sufficient to enable us to say that, in general, their presence is without pathological significance.

Group 2.—Bacillus Coli and allied Organisms

In this group are included a number of lactose fermenting organisms of which *Bacillus coli communis* is the type, but which

[1] *Journ. of Infect. Diseases*, iv. p. 87, 1907.

also contains bacilli differing in more or less important characters from this particular organism.

From the point of view of the application of our knowledge of the bacteriology of milk to practical purposes, *B. coli* and allied forms are of significance only as far as they are themselves organisms of definite pathogenicity, or in so far as they are indicators of undesirable pollution of the milk.

The significance of this group in milk bacteriology and the inter-relationship of the different bacilli may be considered from two points of view: the practical and the strictly scientific.

We may, on the one hand, define the group widely enough to embrace all the varieties which are either themselves harmful or indicators of outside pollution, or we may subdivide up the group, by introducing a large series of tests, into a large, almost an indefinite, number of varieties, and try to ascertain the exact distribution in nature of each variety, and measure its precise significance either as a potentially pathogenic bacillus or as an indicator of some definite kind or kinds of pollution. The latter plan is undoubtedly the more scientific and logical, but the knowledge of this group and the distribution of the different sub-groups is at present scarcely sufficient to make it a procedure of immediate practical value.

MacConkey has given great attention to the further differentiation of the lactose fermenting bacteria of intestinal origin. In his opinion, many of the classical tests for *B. coli* and allied organisms do not permit of adequate differentiation of the lactose fermenting bacilli. He proposes[1] to omit growth in litmus milk, on gelatine slope, the fermentation of glucose, character of the growth on gelatine, production of fluorescence in neutral red, etc., and to lay great stress upon certain fermentation tests. The tests he suggests should be used are the following:

The presence or absence of motility, the fermentation of lactose, saccharose, dulcite, adonite, inosite, inulin, and possibly mannite, the production of indol, and Vosges and Proskauer's reaction.

With these tests, he believes we shall be able to pick out those organisms which are most closely associated with faeces.

[1] *Journ. of Hygiene*, 1909, ix. p. 86.

The comparative value of these tests, with an analysis of the results obtained with them by MacConkey and by Orr, is discussed in Chapter X.

The chief value of the *B. coli* group in milk is that it, as a group, indicates the addition to milk of manurial or other undesirable pollution. The members of this group are, in the first place, extremely abundant in the excreta of both man and animals. They are absent, or almost absent, from the milk of individual cows, or from milk collected under conditions of great care and cleanliness. This fact has been demonstrated by a number of workers.

For example, Harrison[1] examined the milk of 25 cows, the milk being collected direct into sterile vessels, and after the udders and flanks had been wiped with a damp cloth and the first milk rejected. From only two of the cows were gas-producing bacteria isolated.

Von Freudenreich examined 15 samples of milk taken direct from the udder, and found no *B. coli* or other glucose fermenters in any of the samples.

The writer[2] found glucose-fermenting organisms in 4 out of 52 samples of milk from the mixed four quarters of individual cows. In one of these, the examination of the separate quarters a few days previously had shown the presence of *B. coli* in three out of the four quarters. In the collection of the samples strict aseptic precautions were not taken, so probably some of the glucose fermenters were from outside contamination.

MacConkey[3] records that in samples drawn direct from the cow no gas-forming organisms were met with.

The presence of lactose-fermenting organisms of coli type in fresh milk is also largely proportional to the amount of cleanliness exercised in milking. This is illustrated by the following table,[4] in which comparison is instituted between the general cleanliness classification at the cowshed (made before the bacteriological examination was started) and the number of bacteria, and number of *B. coli* and allied organisms. All the milk samples were collected at the farm and examined without delay.

[1] *Centralbl. f. Bakt.*, 1905, Abt. II. xiv. 359.

[2] *Report of Medical Officer, Local Government Board*, 1906-7, p. 205.

[3] *Journ. of Hygiene*, 1906, vi. 385.

[4] Savage, *Report of Medical Officer, Local Government Board*, 1909-10, p. 480.

Classification according to cleanliness.	Number of Bacteria per c.c.					*B. coli* per c.c.: number containing			
	Under 3000.	3000-6000.	6000-12,000.	12,000-24,000.	Over 24,000.	Nil in 5 c.c.	0·1-1.	1-10.	Over 10.
A	5	3	1	3	1	4	6	2	1
B	3	3	4	3	6	2	5	6	6
C	0	0	2	7	9	1	1	8	8
Totals	8	6	7	13	16	7	12	16	15

Classification according to cleanliness.	Number of Bacteria: percentages.					Number of *B. coli*: percentages containing			
	Under 3000.	3000-6000.	6000-12,000.	12,000-24,000.	Over 24,000.	Nil in 5 c.c.	0·1-1.	1-10.	Over 10.
A	38	23	8	23	8	31	46	15	8
B	16	16	21	16	31	10	26	32	32
C	0	0	11	39	50	6	6	44	44
Totals	16	12	14	26	32	14	24	32	30

Group A = Sheds clean and some practical measures of cleanliness in milking practised.
,, B = Sheds more or less clean, but only very slight and inadequate attempts at cleanliness.
,, C = Obvious and marked lack of cleanliness both as regards sheds and cows, and the milking operations.

The coli group may be legitimately used as an index of manurial pollution in milk.

The organisms, which for this purpose may be included within the *B. coli* group, may be defined as those which ferment glucose and lactose, clot milk with acid production, grow as a white or translucent growth upon gelatine without liquefaction, and usually produce indol. Motility may or may not be exhibited.

Such a group will include *B. lactis aerogenes* as well as *B. coli communis*.

Group 3.—The ordinary Lactic Acid Bacilli

The production of lactic acid is the commonest bacterial change which occurs in milk, and is one of great practical importance. Pasteur, in 1857, was the first to describe a definite organism as the cause of the souring. Since that date our knowledge of lactic acid fermentation has steadily increased, and it is now recognised that the production of lactic acid from the sugars in milk is a property possessed by a considerable number of bacteria. Some of the more important organisms which are able to produce lactic acid from milk are *B. acidi lactici* (Hueppe), *B. lactis acidi* (Leichmann), *B. coli*, *B. lactis aerogenes*, *Streptococcus lacticus*, *B. bulgaricus*. Some other less important bacteria have also this property, while there are some lactic acid producing yeasts. The whole subject has been made very complicated by much confusion of nomenclature and bacterial description. Lactic acid producing bacilli have been described as one organism which were really a mixture of bacilli, the same lactic bacillus has been described again and again by different observers as a new bacillus, and frequently under a fresh name, while recently it has been contended that what has hitherto been called a bacillus is in reality a streptococcus.

It would seem, however, that ordinary lactic acid fermentation in milk is mainly, if not entirely, due to two groups of organisms:

(*a*) *B. lactis aerogenes* and its allies.

(*b*) The organisms which are either bacilli or streptococci, and accordingly called *B. acidi lactici* or *Streptococcus lacticus*.

B. lactis aerogenes closely resembles *B. coli* in most of its characters, and has been included here under that group.

Of the *Bacterium acidi lactici* type Conn, Ester, and Stocking[1] give a good description in their report on dairy bacteria, and the following is taken from their description:

Bact. lactis acidi (type).

A bacterium. Size, $0{\cdot}7\mu - 1{\cdot}2\mu \times 0{\cdot}5\mu - 0{\cdot}8\mu$. Sometimes so short as to be described as a streptococcus, and the elements in some cultures are very clearly cocci. No long chains. No motility, no spores. Gram stain is positive.

Gelatine colonies. Small points, rather opaque, not characteristic. Almost wholly under the surface, and typical colonies never grow on the surface. In litmus gelatine they are rather

[1] "Classification of Dairy Bacteria," *Report of the Storrs (Connecticut) Agricultural Experiment Station for 1906.*

dense, strongly acid, and frequently, though not always, surrounded by minute, irregular spines on the edge. The gelatine is not liquefied.

Agar streak. No growth, or one that is scarcely visible.

Lactose, glucose, and saccharose. Acid produced from all three, but no gas.

Bouillon. Frequently no sign of growth, but commonly a slight sediment.

Milk. Acid production and clot in from 6 hours to 2 days. The curd is smooth and hard, without gas bubbles, and never shows any digestion.

Potato. Usually no growth, but sometimes a thin transparent film.

Grows at 20° and 37° C., but better at 20° C. Facultative anaërobe, growing better without oxygen, and hence curdling milk at the bottom first.

"The most characteristic features of this organism are the peculiar litmus gelatine colonies, the absence of surface growth, and the smooth, hard acid curd in milk."

These authors describe several varieties differing in more or less important particulars from this type. The most common variant only differs in the extremely minute colonies on gelatine with absence of the characteristic spines.

The group of organisms described under this type are of immense importance in economic milk problems, but are in themselves of no pathological significance.

According to Kruse, Heinemann, and others, this type of organism should be spoken of as streptococci. Heinemann,[1] after experimentally investigating the matter, concludes, "*Bacillus acidi lactici* is a myth. The ordinary bacteria producing lactic acid fermentation in milk are *B. aerogenes var. lacticus* and *Streptococcus lacticus*." "*Streptococcus lacticus* agrees in morphological, cultural, and coagulative properties with pathogenic, faecal, and sewage streptococci."

On the chemical side it may be mentioned that the lactic acid is not directly produced from lactose. The lactose in milk is first converted by the action of enzymes into glucose and galactose, and the lactic acid is produced from these simpler sugars. As is well known, four isomers of lactic acid exist. Three of them have an identical chemical formula, but differ in their action to polarised light, one, the *d*-acid, rotating it to the right (dextrolactic acid), the

[1] *Journ. of Infectious Diseases*, 1906, p. 173.

second rotating it to the left, *l*-acid (laevolactic acid), while the third is inactive or racemoid lactic acid, *r*-acid. The kinds of acid produced in milk have been investigated by Gadamer and more recently by Heinemann.[1] The latter showed that milk naturally soured at room temperature contains chiefly *d*-acid. Milk soured at 37° C. contains chiefly *r*-acid, with *l*-acid in excess if allowed to stand several days. *Streptococcus pyogenes* and *Streptococcus lacticus* produce the same kind of lactic acid, *i.e.* *d*-acid. *B. lactis aerogenes*, on the other hand, produces *l*-acid. The kind of lactic acid produced in naturally soured milk varies, therefore, according to the kind of lactic acid bacillus mainly present, according to the temperature at which the milk has been kept, and according to the length of time the fermentation has lasted.

It is well known that in the souring of milk under ordinary circumstances a considerable number of other bodies in addition to lactic acid are produced. Amongst these may be mentioned acetic, butyric, and succinic acids, carbonic acid gas, hydrogen, and alcohol. *Streptococcus lacticus* produces almost pure lactic acid (*d*-acid), while *B. lactis aerogenes* forms, in addition, other substances, volatile acids, ethyl alcohol, etc.

The lactic acid bacilli (*B. lactis acidi* type) may be considered from the economic, therapeutic, and public health points of view. From the economic standpoint they are of the utmost importance, since they are active partners in the preparation of butter and cheese, but as this is not germane to the present book, this aspect need not be considered. Equally the therapeutic aspect need not be discussed here, although, as is well known, Metchnikoff and his followers have laid great stress upon the value of soured milk as a therapeutic agency.

Their public health significance is negative rather than positive, since they certainly are not harmful organisms to man. They claim some consideration however, since, in the first place, in enumerating the number of bacteria in milk if low temperature counts are used, they will be enumerated, and so affect the question of a bacterial standard for milk. In the second place, we require to know their relationship to the growth of pathogenic bacteria in milk. As far as our rather incomplete knowledge takes us it would seem that they and their products are directly inimical to the growth of pathogenic bacteria in milk, so that in themselves they are beneficial.

Also by producing *gross* changes in milk which is stale

[1] *Journ. of Biological Chemistry*, 1907, vol. ii. No. 6, p. 603.

(clotting and souring) they render it unsaleable, and as such are a valuable check preventing the sale of very stale milk. But for the presence of this group of organisms it is quite possible that milk laden with other and possible pathogenic bacteria might be kept and sold even in a much staler condition than it is at present. This aspect of the subject is also dealt with under preservatives in milk and in relation to pasteurisation.

Group 4.—The Spore-bearing Bacteria in Milk

Under this group of spore-bearing bacilli found in milk are included a number of different groups which are only associated together here as a matter of convenience. Some of them are strict anaërobes, others strict aërobes.

Very little work appears to have been carried out upon the presence, varieties, and distribution of the anaërobic bacilli in milk. Barthel,[1] in Stockholm, investigated the obligate anaërobes in milk. He found that they were comparatively rare in ordinary milk samples when 15 and 20 c.c. were examined. They were much more numerous in summer than in winter. The organisms isolated were either *B. butrificus* (Bienstock) or a bacillus which Barthel considered to be identical with the bacillus of Schattenfroh and Grassberger. *B. butrificus* was isolated by Bienstock from faeces. Both are spore-bearing varieties.

From the public health point of view the presence and distribution of *B. enteritidis sporogenes* is of chief interest.

B. enteritidis sporogenes.—An anaërobic bacillus isolated by Klein in 1895. It was originally isolated by Klein from the evacuation of patients suffering from an epidemic of diarrhoea in St. Bartholomew's Hospital, London. It has, however, now been established that it is widely distributed and had nothing to do with the outbreak. It is a natural inhabitant of excreta and present in considerable numbers. For example, Houston found the spores 1 to 10 million per gramme of human faeces. The writer has found the spores fairly abundant in animal excreta, that of the horse, cow, pig, and sheep being examined. In the cow, numbers varying from 10 to 1000 spores per

[1] *Centralbl. f. Bakt.*, 1910, Abt. II. xxvi. p. 1.

gramme of moist excreta were recorded. It is also commonly present in dust.

Its essential characters, as described by Klein,[1] are given in the following table:

I. *B. butyricus.*	II. *B. enteritidis sporogenes.*	III. *B. cadaveris sporogenes.*
1. Cylindrical rods, on the average 2·5 to 3·5 μ long, 0·8 to 1·25 μ broad; stains well by Gram's method; some individuals motile.	1. Same as in I.	1. Cylindrical and thread-like; thinner and longer than I. and II.; very motile; stains by Gram's method.
2. Spores oval; stain after the several methods; situated in the middle of the rods more or less.	2. Same as in I.	2. Spores oval, terminal, drumsticks; stain after usual methods.
3. Grows well on the surface of ordinary gelatine as a translucent mass of convoluted threads; does not liquefy the gelatine.	3. Softens rapidly the gelatine; slowly liquefying.	3. Rapidly liquefying; putrid odour; numerous spores formed.
4. In stab in gelatine, forms spherical colonies with numerous horizontal filamentous projections; not liquefying; forms much gas.	4. Much gas; spherical colonies; without filamentous projections; slowly liquefying.	4. Much gas; rapidly liquefying; putrid odour.
5. On the surface of agar, grey, round, flat colonies; margin thin and much crenate; no spores.	5. Same as in I.; few crenations; no spores.	5. On the surface of agar forms thready, branched colonies, with or without finely granular plate; rapidly forming spores.
6. In stab in agar, forms characteristic bundles of threads projecting laterally from the growth in the stab; much gas; no spores.	6. Little tendency for forming lateral branchings; much gas; no spores.	6. Much gas; rapidly forming spores; conspicuous masses of threads growing out of stab.
7. In milk, rapid separation of acid whey and flocculi of casein; smell of butyric acid; no spores; much gas.	7. Same as in I.	7. Milk is slowly decomposed; putrid odour; much gas; rapidly forming spores.
8. Grows well on serum; very slow softening.	8. Grows well; slowly liquefying; some spores formed.	8. Rapidly liquefying; putrid odour; rapidly forming spores.
9. Not pathogenic for rodents.	9. Virulent for rodents.	9. Not pathogenic for rodents.

The virulence of this organism is subject to considerable variation. When fully virulent 1 c.c. of the whey from a

[1] *Report of Medical Officer, Local Government Board,* 1901-2, p. 404.

milk culture 24 to 48 hours old will kill a guinea-pig by subcutaneous injection within about 24 hours. The changes in milk grown anaërobically are the diagnostic characters relied upon for its identification. They are most characteristic after two days' growth. Gas is abundantly formed, the cream being torn so that the surface of the medium is covered by stringy, pinkish-white masses of coagulated casein. Beneath is a colourless, clear, or slightly turbid whey, with some entangled casein. The whey is markedly acid, has a pronounced butyric acid odour, and contains numerous bacilli, but in the non-sporing stage.

B. butyricus closely resembles *B. enteritidis sporogenes.* It shows slight cultured differences, but its essential distinction is its non-pathogenicity to rodents. It is not infrequent in milk.

There is no evidence that either of these organisms are harmful to man, but *B. enteritidis sporogenes* is of importance in that it is a valuable means of measuring the manurial pollution of milk, since the spores of this organism are prevalent in manure and in dust, while they are absent from milk collected under conditions of great cleanliness.

Of the aërobic bacilli included in this group the most commonly met with include *B. subtilis, B. mesentericus vulgatus, B. mycoides, B. lacticola.* There are also a number of other less well-defined organisms which have been isolated, but the differentiation of the included organisms is not very satisfactory.

B. subtilis, and most of the others, are abundant in hay, straw, etc., and obtain access to milk directly or indirectly from such sources. Their presence in milk indicates outside contamination.

They are non-pathogenic, but they decompose and peptonise milk. This whole group—aërobic and anaërobic—are very heat resistant, and constitute most of the bacilli which are left in imperfectly sterilised milk.

Flügge isolated a number of such spore-bearing bacilli, and to one group of peptonising bacilli he ascribed pathogenic effects.

Group 5.—Acid-fast Bacilli

Within the last two decades the number of bacilli known to be resistant to decolorisation by acid after staining has greatly increased, and such acid-fast bacilli, as they are conveniently called, have been shown to be widely distributed in nature. They have been obtained from the human body (mouth, smegma, etc.), and outside the body from manure, milk, butter, various grasses, etc.

Of no particular significance in themselves they owe their importance to the fact that they superficially resemble the tubercle bacillus in being acid-fast, in their morphology and less characteristically in their pathological effects upon rodents. Their possible presence has always to be kept in mind in connection with the diagnosis of tubercle bacilli in milk.

From the point of view of milk and tuberculosis the varieties of greatest interest are the butter bacillus of Rabinowitch and Petri, Moeller's timothy-grass bacilli, I. and II., Johne's bacillus, and the mist bacillus. The smegma bacilli are also important members of this group. Cowie showed that acid-fast bacilli are to be found around the external genitals, etc., of some of the lower animals. It is not clear if these bacilli are identical with the human smegma bacilli.

The Butter Bacillus.—This bacillus serves as a good illustration of the group. It was isolated independently by Rabinowitch and Petri from butter. Morphologically it is shorter and thicker than the tubercle bacillus, but superficially resembles it. Long unbranched thread-like forms are sometimes met with. Culturally it grows rapidly upon agar and glycerine agar, a well-marked thick crinkled growth being present after 3 to 4 days. It grows equally quickly in glycerine broth, a crinkled scum being present after 2 to 3 days' growth, the broth having an unpleasant odour. It will grow in or on these media at room temperatures. Injected intraperitoneally, mixed with butter, into guinea-pigs, it produces lesions which closely resemble those produced by the tubercle bacillus, frequently causing the death of the animal.

The other acid-fast bacilli are very similar. They all agree with the tubercle bacillus in their resistance to decolorisation by acid after staining, while morphologically they are for the most part shorter and thicker. Injected into animals, most of them, like the butter bacillus, exert pathological effects with the production of nodules resembling tubercles. The characteristic which essentially differentiates them from the tubercle bacillus is their comparatively rapid growth on culture media. Their growth in days exceeds that of the tubercle bacillus in the same number of weeks. They will also grow at room temperatures.

As a group, these bacilli have a somewhat lessened resistance to decolorisation by mineral acids as compared with the tubercle bacillus. According to Abbott and Gildersleeve they lose their colour almost instantly if treated by the 25 to 30 per cent nitric acid solution used in the original Koch-Ehrlich process.

CHAPTER IV

THE BEHAVIOUR OF BACTERIA IN MILK

In Chapter II. it has been demonstrated that bacteria are added to milk from very numerous sources, and in Chapter III. the chief kinds so added have been considered. In view of the fact that milk is rarely consumed directly after milking, but only after the lapse of a more or less considerable period, it is of great importance to consider the behaviour in milk of the bacteria which have been added to it.

The subject will be discussed in the following sub-sections:

A. The germicidal property of milk.

B. The general behaviour of bacteria in milk under different conditions both as a whole and for individual groups.

C. The behaviour of pathogenic bacteria in milk.

D. The thermal death-points of pathogenic bacteria in milk.

A. Germicidal Property of Milk

It has been found when samples of freshly drawn milk are examined at very short intervals, that not only may no increase in the number of bacteria result for several hours, but an actual decrease may at first be met with. This has been ascribed to an inherent quality in the milk, and a germicidal property has been evoked to explain it. Fokker in 1890 was the first to draw attention to this property of fresh milk, and since then it has been the subject of a large number of investigations.

The following table, taken from Rosenau and McCoy's valuable paper and report,[1] illustrates this action, and the influence of the temperature of incubation of the milk.

Milk from a Healthy Cow.
(Immediately after milking contained 500 *bacteria per c.c.)*

Time after milking.	Bacteria per c.c. at different temperatures.		
	Room temperature (26°-29° C.).	15° C.	37° C.
2 hours . .	1,300	...	...
4 " . .	700	900	11,300
6 " . .	400	500	38,000
8 " . .	7,800	600	342,000
10 " . .	29,000	1,200	50,000,000
24 " . .	340,000,000	80,000	Sour
48 " . .	Innumerable	1,380,000	...
72 " . .	Sour	89,000,000	...
96 " . .	...	Sour	...

The duration of the period of decrease is longest the colder the milk, and at 37° C. is very short.

The decrease occurs not only with the bacteria usually found in milk, but also with fresh milk inoculated with pure cultures of pathogenic organisms.

While there can be no doubt as to the fact of the decrease of bacteria in quite fresh milk, investigators are not all in agreement as to the explanation.

According to one view the diminution of bacteria is due to a definite germicidal property possessed by the milk analogous to that possessed by fresh blood, although much less powerful. In favour of this view is the fact that the property is destroyed by heating the milk to 75°-80° C., while it is weakened by heating to lower temperature, *e.g.* half-hour at 56° C. Friedel, Kutscher, and Meinicke, and other investigators, have shown that the property is in some respects specific and varies with the organism. Fresh raw milk is, for example, bactericidal to the cholera vibrio, but not, according to these German investigators, to *B. typhosus*, *B. coli*, and

[1] *Bulletin No. 41, Public Health and Marine Hospital Service, U.S.A.*, 1908, p. 449.

the Gaertner and dysentery bacilli. Heinemann and Glenn have shown that some species occurring naturally in milk decrease considerably in numbers during the first 4 or 5 hours, some decrease slightly, some hold their own or even increase. Copeland, in a single experiment, found that the addition of boric acid damaged the inhibitory power, no diminution of the bacteria in fresh milk resulting.

Rosenau and McCoy have shown that the germicidal power of milk is independent of its cellular contents. They found that leucocyte-free milk is quite as active as the leucocyte-rich sediment obtained by centrifugalisation.

On the other hand, numerous investigators have shown that at least part of the decrease is more apparent than real. Stocking, for example, concluded that "the decrease in the number of bacteria during the first few hours is not the result of any germicidal condition or property possessed by the milk, but simply of the natural dropping out of those species which do not find the milk a suitable medium in which to develop."

Other investigators have found that the diminution in the number of bacteria is partially to be accounted for by agglutination of some of the bacteria. The bacteria become agglutinated into clumps, and since a small clump may grow as one colony the apparent number of bacteria is diminished.

From a general consideration of the literature it would seem evident that the decrease is not due to any one cause entirely. Part would appear to be due to agglutination and other causes, but in addition there is evidently some action exerted of a specific nature, and which is rather restraining than definitely germicidal.

B. The General Behaviour of Bacteria in Milk under Different Conditions

Although milk is an excellent nutrient medium for most bacteria it is not equally so for all, and it is easy to demonstrate that there is a struggle for existence between the different bacteria introduced, the survival of one type over another depending upon a number of factors, such as the initial dose, the kinds of other bacteria present, the time interval, and, in particular, the temperature of the milk. It is only in a modified sense possible to speak of "milk bacteria," as if certain bacteria were typical and characteristic of milk, since milk is not kept for very long periods, and any selective action has rarely time to be pronounced. It will, however, be found that certain types of bacteria are especially prevalent in, and indeed characteristic of, stale milk.

The rapid increase in the number of bacteria in stored milk is well known. The multiplication has been shown to depend mainly upon three factors:

(*a*) The temperature at which the milk is kept.
(*b*) The time interval since milking.
(*c*) The kinds of bacteria present.

The influence of the last factor is more variable and more difficult to estimate than that of the first two causes.

The following table from results obtained by Park[1] upon the development of bacteria in a pure and a contaminated sample of milk shows the great influence of both time and temperature. The initial content of sample A was 3000 and of B 30,000 bacteria per c.c.

Temperature Fahrenheit.	After 24 hours' incubation.		After 48 hours' incubation.		After 96 hours' incubation.	
	A.	B.	A.	B.	A.	B.
32°	2,400	30,000	2,100	27,000	1,850	24,000
39°	2,500	38,000	3,600	56,000	218,000	4,300,000
42°	2,600	43,000	3,600	210,000	500,000	5,760,000
46°	3,100	42,000	12,000	360,000	1,480,000	12,200,000
50°	11,600	89,000	540,000	1,940,000	..	..
55°	18,800	187,000	3,400,000	38,000,000	..	..
60°	180,000	900,000	28,000,000	168,000,000	..	..
68°	450,000	4,000,000	25,000,000,000	25,000,000,000	..	..
86°	1,400,000,000	14,000,000,000	..	..	..	..
94°	25,000,000,000	25,000,000,000	..	..	..	..

The same general facts are shown in another way in the following table,[2] showing the development of bacteria in samples incubated at different temperatures. This table is introduced to show the influence of the third factor—the kinds of bacteria present,—since it will be seen that the increase was a very variable one, and only to be explained by the differing initial content and kinds of bacteria present.

1 *Journ. of Hygiene*, 1901, vol. i. p. 398.
2 W. G. Savage, *Appendix B, No. 4 Report of Medical Officer, Local Government Board*, 1909-10, p. 481.

Development of Bacteria in Incubated Milk Samples.
(All samples collected at the cowsheds).

Initial Number of Bacteria.	Number of Bacteria after 24 hours' incubation at 15° C.	Number of Bacteria after 24 hours' incubation at 21° C.	Increase over Initial Number at		Relative Increase at 21° C. over 15° C.
			15° C.	21° C.	
			Fold.	Fold.	Fold.
640	...	1,440,000	...	2250	...
1,150	16,500	680,000	14	590	41
1,550	6,000	55,000	4	35	9
2,150	18,000	577,000	8	270	32
2,330	100,000	...	43	...	...
2,800	65,000	870,000	23	310	13
3,290	37,000	...	11	...	...
3,670	15,000	...	4	...	...
5,750	4,400	75,000	Diminution	13	17
6,400	13,000	440,000	2	70	34
7,530	75,000	1,382,000	10	180	18
8,260	14,000	202,000	1·7	24	14
10,300	...	2,210,000	...	214	...
14,200	125,000	810,000	9	57	6
25,700	...	45,700,000	...	1780	...
31,000	78,000	...	2·5	...	...
35,000	...	3,800,000	...	108	...

In view of the practical importance of keeping milk cool, the effect on the bacterial content of storing milk at 0° C. has been studied by a number of investigators. It is generally assumed that little or no bacterial alteration takes place at the freezing temperature of water, but this cannot be accepted as true without qualification. For fresh samples of milk kept for only 24 to 48 hours at 0° C. it will generally be found that there has been no increase in the number of bacteria but a slight decrease. Park's table, given above, illustrates this decrease, which is no doubt due to the germicidal action of the milk and the suppression of certain types which are in an unsuitable temperamental environment.

When, however, the milk samples are maintained at 0° C. for many days and weeks, it will be found that a great increase in the number of bacteria has taken place. For example, Pennington,[1] working with both pure and ordinary market-milks, found great increase after long periods in samples kept at 29-32° F. For example, one sample, containing only 300 organisms per c.c. to start with, was found to contain

[1] *Journal of Biol. Chem.*, 1908, vol. iv. p. 353.

E

more than a hundred million organisms per c.c. after five to six weeks. She showed that there were present both acid-forming and protein-decomposing bacteria. The casein was digested until rather more than 50 per cent of it was destroyed and changed into soluble compounds (caseoses, amino acids, etc.).

Ravenel, Hastings, and Hammer[1] also investigated this subject. They found that in samples of milk kept at 0° C. there was a slowly developed but marked increase in the bacterial content, resulting in an increase of acidity, an increase in the percentage of soluble nitrogen (so that it eventually amounted to over 70 per cent of the total nitrogen), and a decrease in the total nitrogen-content probably due to a liberation of free nitrogen. The kind of increase they met with is shown in the following table:

Bacterial Content of Specimens kept at 0° C.

Age of Milk in days.	Dairy Milk.	Barn Milk.
0	130,000	3,500
6	72,500	4,050
15	633,500	52,900
20	3,230,000	1,240,000
36	34,950,000	4,800,000
74	91,500,000	36,500,000
106	39,750,000	192,500,000
160	32,650,000	361,000,000

The Barn milk was a very pure milk from the University Herd, and containing only about 3000 bacteria per c.c. The Dairy milk was an average dairy milk. The plating medium was lactose agar, and the plates were incubated at 37° C.

While these results are interesting, the broad practical conclusion remains, that if milk is kept at 0° C. or even at 10° C. (see Conn and Esten below) no material alteration of the germ-content takes place for at least several days.

Of interest and practical importance greater than the total bacterial multiplication in milk, is the relative growth of the different varieties of bacteria under different conditions. In this connection, Conn and Esten[2] have published a valuable report upon "The effect of different temperatures in de-

[1] *Journal of Infect. Diseases*, 1910, vol. vii. p. 38.

[2] *Sixteenth Annual Report, Storrs Agric. Experiment Station*, 1904, p. 27.

termining the species of bacteria which grow in milk." The milk used for the investigation was ordinary market milk, but quite fresh, being only one or two hours old. It usually contained about 20,000 bacteria per c.c. Two series of experiments were carried out, the milk for the first series being kept at 37°, 20°, and 10° C., and for the second at 20°, 10°, and 1° C. The milk samples were bacterially examined at intervals which varied with the temperatures employed. After some preliminary tests, it was found that the best intervals were as follows: Milk kept at 37° C. was plated every 2 hours, that at 20° C. every 6 hours, that at 10° C. every 12 hours, and that kept at 1° C. about every 3 days. The culture medium used for making the plates was litmus lactose whey gelatine. In the study of the plates, the total number of bacteria was determined, and then the total number of different types of colonies that could be differentiated from each other by hand lens and low power of the microscope.

It was found possible to distinguish, without much difficulty, about 15 different groups of bacteria, that is, 15 different types of distinguishing colonies in litmus gelatine. The groups tabulated are differentiated from each other wholly by the character of their colonies upon litmus gelatine. All the groups included several species of bacteria, and sometimes indeed were quite complex, and the weak point of the research is this rather indefinite grouping and differentiation.

From the numerous experiments made, the following were the main conclusions arrived at.

(1) The effect of variations in temperature upon the development of the different species of bacteria in milk is not always the same under apparently identical conditions. In spite of such variations, there appears to be clearly discernible a normal development of bacteria associated with different temperatures.

(2) There is, in all cases, a certain period at the beginning when there is no increase in the total number of bacteria. During this period, some species are multiplying, while others are apparently dying. The length of this period depends upon temperature. At 37° C. it is very short, while at 1° C. it may last from 6 to 8 days, since at this temperature, milk may, in 6 days, actually contain fewer bacteria than when fresh.

(3) After this preliminary period, there always follows

a multiplication of bacteria; but the types that develop differ so markedly, that samples of the same milk kept at different temperatures are, at later periods, very different in their bacterial content, even though they contain the same number of bacteria.

(4) The development of the ordinary lactic species, *Bact. lactis acidi*, in practically all cases checks the growth of other species of bacteria, and finally kills them, since the bacteria regularly decrease in actual numbers after the lactic bacteria have become very abundant.

(5) In practically all samples of milk kept at 20° C., the multiplication of the *Bact. lactis acidi* begins quickly, and progresses with great rapidity. They grow so rapidly that they produce acid enough to curdle the milk in about 40 hours, the growth of other species being held in check. Milk, when curdled at this temperature, shows a smooth acid curd, with no gas bubbles.

(6) Milk kept at 37° C. shows a totally different result. The results are somewhat more variable than at 20° C. Occasionally the *Bact. lactis acidi* grows vigorously at this temperature, but the common result is a development of the *B. lactis aerogenes* type. It forms a curd full of gas bubbles. If *B. coli communis* is in the milk, this also grows luxuriantly at 37° C.

(7) In milk kept at 10° C., neither of the types of lactic bacteria seems to be favoured. The delay in growth lasts 2 or 3 days, after which all types of bacteria appear to develop somewhat uniformly. Sometimes the lactic bacteria develop abundantly, sometimes only slightly. The neutral bacteria almost always grow rapidly, and the liquefiers in many cases become abundant. In time, the milk is apt to curdle, commonly with an acid reaction, but it never shows the predominance of *Bact. lactis acidi* found at 20° C.

(8) There seems to be no difference between the effect of 10° and 1° upon the bacteria, except upon the rapidity of growth: 1° C. very markedly checks the growth of bacteria; but later they grow in great numbers. As at 10°, the lactic bacteria fail to outgrow the other species, so that all types develop abundantly. A few species appear to be particularly well adapted to this low temperature, and are especially abundant at the end of the experiments.

(9) The curdling point appears to be quite independent

of the number of bacteria present. In one sample at 37° C. the milk curdled with only 8,000,000 per c.c., while in others there have been found 4,000,000,000 per c.c., without any curdling. These differences are due partly to the development of enzymes, and partly to the products of some species neutralising the actions of others. The amount of acid present at the time of ordinary acid curdling does not widely vary.

(10) Milk is not necessarily wholesome because it is sweet, especially if it has been kept at low temperatures. At the temperature of an ice-chest milk may remain sweet for a long time, and yet contain enormous numbers of bacteria, among which are species more likely to be unwholesome than those that develop at 20° C. "From this standpoint the suggestion arises that instances of ice-cream poisoning are perhaps due to the preservation of cream for several days at a low temperature, such treatment keeping the milk sweet, but favouring the development of species of bacteria that are, at higher temperatures, checked by the lactic organisms."

The difficulty of laying down standards of the number of bacteria, or of special kinds, such as *B. coli*, to allow in vended milk, is discussed in Chapter XIV. In this connection the importance of studying the rate of multiplication in milk of organisms, and particularly of standard organisms, is obvious.

Bacillus coli communis and its allies multiply rapidly in milk. The following table illustrates its multiplication in pasteurised milk kept at different temperatures. The milk was heated to 80° C. for 10 minutes, and care was taken to add only a few *B. coli*.

	15° C.	22° C.	37° C.
Onset	23	23	23
After 3 hours . . .	15	65	910
" 6 " . . .	73	116	over 30,000
" 9 " . . .	510	930	innumerable
" 12 " . . .	248	3500	innumerable
" 24 " . . .	3210	168,000	...
Twenty-four hours' increase	140 fold	7300 fold	...

All results are per standard platinum loopful.

The writer has carried out[1] an extensive series of experiments to study the rate of growth of *B. coli* and its allies in ordinary market milk, kept under different conditions of time and temperature. The following table shows the multiplication of *B. coli* in milk collected at the byre and examined at once and under definite conditions.

No. of Sample.	Fresh Byre Milk.			After 24 hours' incubation at 15° C.			After 24 hours' incubation at 20°–21° C.		
	Acidity.	No. of Bacteria per c.c.	No. of *B. coli* per c.c.	Acidity.	No. of Bacteria per c.c.	No. of *B. coli.* per c.c.	Acidity.	No. of Bacteria per c.c.	No. of *B. coli* per c.c.
8	..	25,700	100–1000	..	..	..	..	45,700,000	10,000–100,000
9	..	10,300	0·1–1	..	..	..	..	2,210,000	100–100,000
11	..	35,000	100–1000	..	..	..	..	3,800,000	10,000–100,000
13	..	12,170	1–10	..	..	10,000–100,000	..	..	..
15	..	3,670	Absent in 11 c.c.	..	15,000	0·1–1	..	..	..
16	19·5	2,800	0·1–1	17·5	65,000	100–1000	18·5	870,000	10,000
17	20·5	7,530	10–100	21·5	75,000	10,000–100,000	21·0	1,382,000	100,000–500,000
18	23·5	14,200	100–1000	23·5	125,000	10,000–100,000	24·5	810,000	500,000–1,000,000
19	22·7	1,150	Absent in 11 c.c.	21·5	16,500	0·1–1	22·0	680,000	500–1000
20	19·0	8,260	0·1–1	20·0	14,000	1–10	19·5	202,000	1000–10,000
21	23·5	2,150	0·1–0·2	22·5	18,000	0·1–1	26·0	577,000	0·1–1
22	19·0	5,750	0·1–0·2	18·0	4,400	Absent in 5 c.c.	19·5	75,000	Absent in 1 c.c.
23	22·5	31,700	10–100	21·0	78,000	1000–10,000	..	..	..
24	21·5	3,290	1–10	21·0	37,000	100–1000	..	..	..
25	20·0	6,400	10–100	19·3	13,000	1000–10,000	20·5	440,000	1000–10,000
26	19·5	21,000	100–1000	25·0	..	100,000–1,000,000	..	..	..
27	19·0	11,200	1–10	20·0	..	1000–2000	..	..	..
28	17·0	6,380	1–10	17·5	..	20–100	..	..	..
29	22·0	2,330	0·4	22·3	100,000	10,000–100,000	..	..	..
30	18·5	..	10–100	20·5	..	5000–10,000	23	..	..
31	21·3	..	1–10	21·3	..	5000–10,000	23	..	10,000–100,000
32	20·0	..	1–10	20·8	..	1000–5000	22	..	..
34	17·5	1,550	0·2	17·5	6,000	10–50	17·3	55,000	1000–10,000
35	22·0	640	Absent in 5 c.c.	21·5	..	10–50	22·0	1,440,000	10,000–100,000
37	18·0	1,800	Absent in 5 c.c.	21·5	..	1–10	..	..	..
39	21·8	6,000	Absent in 5 c.c.	20·5	..	100–500	20·5	..	Less than 1
40	19·0	..	10–100	18·0	..	1000–5000	55·2	..	..
41	21·5	..	1–10	24·2	..	100–1000	39·0	..	10,000–100,000
43	16·0	..	100–1000	15·5	..	10,000–100,000	20·4	..	..
44	17·5	..	1–10	18·0	..	1000–10,000	..	..	..
45	17·2	..	10–100	17·5	..	1000–5000	..	..	..
47	22·5	..	0·6	23·0	..	500–1000	..	..	..
48	17·0	..	1000–10,000	19·5	..	Over 100,000	..	..	..
59	17·0	40,900	0·4	18·2	..	100–500	18·5	..	1000–10,000
60	16·5	40,400	Absent in 5 c.c.	19·0	..	0·4	24·0	..	500–1000
61	18·0	36,000	1–10	20·4	..	100–1000	22·0	..	1000–10,000
62	16·5	57,200	0·8	18·5	..	100–500	20·5	..	10,000–100,000
63	19·4	4,700	0·2	19·5	..	50–100	19·5	..	5000–10,000
64	18·7	13,000	0·2	19·0	..	1–10	..	..	..

For convenience of study the results are divided into five groups according to the initial number of *B. coli* and allied organisms and are summarised in the following two tables:

[1] *Report of Medical Officer, Local Government Board*, 1909-10, p. 474.

Fresh Byre Milk incubated for 24 hours at 15° C.

Group.	Number of Samples examined.	Initial coli Content.	Coli Content after 24 hours at 15° C.	Increase.
A	6	Nil in 5 c.c.	Variable. 1–10 (mean) per c.c.	...
B	11	0·1–1 per c.c.	,, 10–100 ,, ,,	100 fold.
C	9	1–10 ,,	Fairly uniform. About 1000 ,,	100–1000 ,,
D	6	10–100 ,,	Very ,, 1000–10,000 ,,	100 ,,
E	5	100–1000 ,,	,, ,, 10,000–100,000 ,,	100 ,,

Fresh Byre Milk incubated for 24 hours at 20°–21° C.

Group.	Number of Samples examined.	Initial coli Content.	Coli Content after 24 hours at 20°–21° C.	Increase.
A	3	Nil in 5 c.c.	Very variable.	...
B	9	0·1–1 per c.c.	Variable. 1000–10,000.	10,000 fold.
C	3	1–10 ,,	,, 10,000–100,000.	10,000 ,,
D	2	10–100 ,,	Variable.	100–10,000 ,,
E	3	100–1000 ,,	Variable 10,000–100,000.	100–1000 ,,

Milk is a complex fluid bacterially, and the presence of other kinds of bacteria might be expected to influence materially the multiplication of *B. coli.* The results on the whole show less variation than might have been anticipated. At 15° C. the increase was usually 100 fold, occasionally 1000 fold, and practically never greater than this. At 20°–21° C. the increase was usually 10,000 fold, but was less when the initial number of *B. coli* was very great.

These experiments show that temperature is a more important factor than initial number in determining the final number of *B. coli,* but that both are very important. From a few experiments made, but not recorded here, it would seem that time is less important than temperature.

From the point of view of standards for vended milk the results of the incubation at 15° C. of samples of milk with initial *B. coli* content of not over 1 per c.c. are of greatest interest. As the tables show, the increase was variable, but was very rarely over 1000 fold, and was usually much less.

Bacillus enteritidis sporogenes is another organism of importance in estimating the purity of milk samples. The writer incubated at 15° C. and at 21° C. 18 samples of milk in which the number of the spores of this organism had been determined, and found no evidence of any multiplication.

The investigations of the writer were more particularly directed to ascertaining the effects of time upon milk kept at a temperature (15° C.) at which it would be likely to be subjected under actual practical conditions. Other workers have shown that if milk be kept at a low temperature, for example 10° C., there will not be any marked increase in the number of bacteria within a reasonable time. For example, Houston kept 15 samples of milk at temperatures varying from 6° to 11° C. for 24 hours, and roughly re-determined the *B. coli* content. In 7 samples he found no change, in 6 an increase, and in 2 a decrease.

Stewart[1] kept 25 samples of byre milk at 10° C. for 10 and 20 hours. The temperature was reduced within one hour of milking. Only comparatively slight increase took place in the number of *B. coli communis* even after 20 hours. The following table also shows the results of keeping 11 samples at 40° F. (4·4° C.) for different periods:

1 *Report on the Bacteriological Examination of Milk Samples*, 1909.

[TABLE

As received.		48 hours at 4·4° C.		72 hours at 4·4° C.		96 hours at 4·4° C.	
Number of Bacteria.	*B. coli communis.*	Number of Bacteria.	*B. coli communis.*	Number of Bacteria.	*B. coli communis.*	Number of Bacteria.	*B. coli communis.*
9,250	Absent in 20 c.c.	9,750	Absent in 20 c.c.	...	...	...	...
7,500	,,	7,500	,,	8,000	Absent in 20 c.c.	...	...
8,750	,,	8,250	,,	9,250	,,	...	...
8,500	,,	...	...	8,750	,,	...	...
10,250	,,	...	...	10,750	,,	...	...
9,750	,,	...	...	10,000	,,	...	...
10,750	,,	...	...	11,000	,,	...	...
10,500	,,	11,000	Absent in 20 c.c.	...	...	11,250	Absent in 20 c.c.
11,000	,,	...	...	11,250	Absent in 20 c.c.	11,250	,,
11,500	,,	...	...	12,250	,,	12,500	,,
11,250	,,	...	...	11,750	,,	11,750	,,

These different investigations show the profound influence of temperature upon the multiplication of bacteria in milk. For milk kept at 0° C. no multiplication of any significance takes place for many days; at 10° C. there is some increase, but within a reasonable period it is negligible; at 15° C. there is a considerable increase, but one which is not inordinate; while at higher temperatures the contained bacteria multiply with very great rapidity.

C. The Behaviour of Pathogenic Bacteria in Milk and Milk Products

As every bacteriologist knows, sterile milk is a suitable culture medium for the majority of pathogenic bacteria. In ordinary market milk, any pathogenic bacteria present have, however, to withstand the possible prejudicial effect of the presence of a large number of other organisms which may be better suited to their environment and whose products may be inimical. The extent to which pathogenic bacteria will live and multiply in milk cannot, therefore, be forecasted with certainty, and a number of investigations have had to be carried out to study the question.

Eyre[1] studied the rate of multiplication of some of the pathogenic bacteria in sterile milk. He was careful not to use sterilised milk, but used milk obtained in a sterile condition by drawing it from the healthy cow under aseptic conditions. He obtained the following results:

	0 hours.	24 hours.	48 hours.	7 days.
Bacillus diphtheriae . .	39	1,170	22,000	19,000,000
Streptococcus of bovine mastitis	44	3,100	14,700	30,000,000
Vibrio cholerae . . .	12	...	400,000	4,000,000
Bacillus typhosus . .	78	6,000	10,300,000	440,000,000
Bacillus enteritidis of Gaertner	56	10,370	72,850,000	99,900,000

This table, as Eyre points out, fails to show the exact course of events, and if the results of the examinations at shorter periods of time are studied, a definite bactericidal influence is shown. This is seen from the following table:

[1] *Journ. of State Medicine*, 1904, xii. p. 728.

	0 hours.	2 hours.	4 hours.	6 hours.	8 hours.	12 hours.	24 hours.
Bacillus typhosus	78	50	42	42	46	460	6000
Bacillus enteritidis of Gaertner	56	33	26	48	94	154	10,370

The growth and viability of *B. typhosus* in milk has been studied by many workers. In sterilised milk it has been found to survive for as long as four months (Hesse, also Bolley and Field). In market milk, kept at 7°–10° C. and inoculated with a massive dose of typhoid bacilli, Pfuhl found them alive when examined 11 and 13 days later. Cautley added typhoid bacilli to milk and recovered them after 7 days; while Bolley and Field recovered them from inoculated milk after a month.

While typhoid bacilli grow well in fresh milk, their growth is usually checked by the increased acid production. According to Bassenge,[1] the bacilli are killed out if the acid production reaches 0·3–0·4 per cent and acts for over 24 hours. Bolley and Field,[2] Heim and other workers have, however, obtained different results, and certainly any degree of naturally-acquired acid production in milk cannot be relied upon to kill any contained typhoid bacilli.

The typhoid bacillus has also been shown by numerous investigators to live many days in butter; for example, for 3 weeks by Heim, 5–10 days by Bolley and Field, 24 days by Pfuhl.

Bruck[3] showed that typhoid bacilli could be isolated from cream up to 10 days, after its separation in a separator from milk artificially infected with typhoid bacilli. It could be isolated from the buttermilk for 10 days, and from butter made from the cream for 27 days.

Reitz made butter, incorporated typhoid bacilli, recovered them in one experiment after 10 days but not after 15 days in another experiment.

Pfuhl mixed typhoid bacilli with cheese and isolated the bacilli after 24 but not after 26 days. Other workers found the bacilli died out much sooner. Probably much depends on the type of cheese used for the experiments.

1 *Deutsche med. Wochenschr.*, 1903, xxix. p. 675.
2 *Centralbl. f. Bakt.*, 1898, vol. xxiii. p. 881.
3 *Deutsche med. Wochenschr.*, 1903, xxix. p. 460.

The diphtheria bacillus grows readily in milk, the milk remaining unchanged in appearance although an acid reaction develops. The table of Eyre's, recorded above, shows how rapidly this organism multiplies in sterile milk.

Schottelius,[1] in his investigations, found that the diphtheria bacillus grew better in raw than in sterilised milk, at both room temperatures and at 37° C., the raw milk being obtained direct from the udder. Feinberg has confirmed this, but Jensen, on the other hand, found their growth was retarded in raw fresh milk.

In butter, according to Montefusco, the diphtheria bacillus is killed after two days. The only observation which the writer has found as to growth in cream or cheese is one of Klein's,[2] who found that diphtheria bacilli inoculated into sterile cream and sterile cheese, kept, part at 37° C. and part at 20° C., were not recovered when examined for after two weeks.

Sp. cholerae grows rapidly in sterile milk without naked eye change, but with the production of a little acid. In ordinary market milk the acid reaction initially present, or which rapidly develops, is prejudicial to its growth, as this organism requires an alkaline medium in which to grow. The results of investigations as to the viability of the cholera vibrio in raw milk, show that it does not survive for long periods. Thus, Cunningham could not find it after 24 hours, Uffelmann found it after 30 but not after 40 hours, Friedrich not after 2 days, Basenau not after 38 hours. On the other hand, Heim found it to live 1 to 6 days. From the results obtained and from the known inhibitory action of acid on its growth, it is clear that the viability depends upon the temperature at which the milk is kept and the rate at which acid develops. Klein[2] found it to live longer in milk at 7°–12° C. than when the milk was kept at 12°–22° C.

In butter, Heim[3] and others have shown that this organism soon dies out, usually not living more than a few days; although, in one experiment, Heim records that they were found alive after 49 days. Heim, Rowland, and other workers have

[1] *Centralbl. f. Bakt.*, 1896, Abt. I. xx. p. 897.
[2] *Report of Medical Officer, Local Government Board*, 1899-1900, p. 577.
[3] *Arbeit a. d. Kaiserl. Gesundheitsamte v. 1889*, v. p. 294.

also failed to find this organism after one or two days in cheese.

Micrococcus melitensis grows rapidly in sterile milk with rapid alkali production, but without producing visible change. It is found in the milk of a large proportion of the goats in Malta, producing no visible alteration in the milk.

Tubercle bacilli will grow in sterilised milk, the milk remaining unchanged. They grow so slowly in milk that investigations as to their rate of growth are of no practical significance, while we have abundant evidence that they retain their virulence and viability all the time milk is likely to be kept unconsumed. Living tubercle bacilli have been found in butter made as long as five months previously from milk containing tubercle bacilli, but they appear to usually die out earlier. They apparently die out more rapidly in salt than in fresh butter.

Teichert[1] investigated a large number of butter samples obtained from thirty-six different dairies. None of the samples more than 18 days old set up tuberculosis in guinea-pigs. Teichert concluded that in the salt butters tubercle bacilli lose their virulence in about three weeks.

Mohler, Washburn, and Rogers[2] carried out an interesting series of experiments. Three samples of butter were made, the first from milk artificially inoculated with tubercle bacilli from a culture, the second and third from the milk of a cow suffering from udder tuberculosis, the milk containing great numbers of very virulent tubercle bacilli. The first two were salted in the usual proportions of 1 oz. of salt to 16 oz. of butter, the third sample was left unsalted. The samples of butter were kept in cold storage, while from time to time guinea-pigs were fed and inoculated. The samples were tested when first made, after storing 10 days, after 60 days, and after 5 months. The results showed that each of these samples harboured virulent tubercle bacilli throughout the entire storage period, and that at any time they were capable of setting up tuberculosis in guinea-pigs when inoculated intra-peritoneally.

Tubercle bacilli may also live for some time in cheese.

[1] *Klin. Jahrb.*, 1904, xii. p. 467.

[2] *Bulletin No. 41, Public Health and Marine Hospital Service, U.S.A.*, 1908, p. 494.

Using milk artificially inoculated with tubercle bacilli and then made into cheese, Galtier found the bacilli alive in cheese 2 months and 10 days old respectively. Harrison made cheese from milk artificially inoculated with tubercle bacilli. In cheese made by the Emmental method, they died between the 34th and the 40th day; in Cheddar cheese, after 62 to 70 days.

D. Thermal Death-points of Pathogenic Bacteria in Milk

In view of the extent to which the sterilisation and particularly the pasteurisation of milk is carried out commercially, it is of fundamental importance that accurate information should be available as to the temperatures at which the pathogenic bacteria possibly to be found in milk are killed. For practical purposes it is necessary to distinguish between laboratory results and those obtained under the modifying influences of practical working conditions.

Thermal death-points cannot be stated as definite temperatures since obviously there are two closely related facts—the temperature of exposure and the period of exposure. In addition, factors not without influence are the vitality of particular strains of bacilli and the physical conditions of exposure. Among bacteria some strains are more resistant to physical conditions than others; this must be taken into account, and any accepted figure must relate to the death-point of the most resistant strains of individual bacilli likely to be present. In experimental work it is common to find that certain bacilli, even from a single culture, are more resistant than the rest and survive the heat or chemical employed.

As regards the physical conditions of exposure, since only a single fluid is under consideration, it might be supposed that these would always be the same, but this is not quite the case. The chemical reaction of milk varies, and this may influence a little, while much more important is the presence or absence of surface scum. If milk is rapidly evaporated a surface pellicle forms consisting of coagulated albumens with entangled fat and bacilli. Such a pellicle is at a lower temperature than the fluid beneath, and bacilli enclosed in it will be protected and subjected to a lower temperature than that registered by the thermometer, and so may escape being killed. The physical condition of the bacilli themselves is also an important factor which must be taken into consideration. If the bacilli are agglutinated into clumps or entangled in masses of manure or débris, those in the centre will be subjected to a lower temperature than that recorded or intended to be applied, and may escape destruction.

These considerations and possible fallacies show that the problem is not as simple as it appears, and that in the determination of thermal death-points it is very important to employ bacteria in their greatest state of resistance, and under conditions which allow all modifying factors to be taken into consideration. Further, in deductions for practical work it is advisable to allow a margin of safety sufficient to exclude errors from these sources, and to make the destruction of pathogenic bacteria certain.

Since the pathogenic bacilli differ in resistance the results obtained must be considered separately for each organism.

B. typhosus.—The results of the numerous experiments which have been carried out by different workers are closely in agreement, and show that typhoid bacilli suspended in milk are, as a rule, killed when the milk is heated to 60° C., provided the heating up takes several minutes, while their destruction is ensured if the milk is maintained at that temperature for at least 5 minutes.

As examples of recent investigations the following may be mentioned. Bassenge[1] found that when milk was heated to 60° C. in from 5 to 10 minutes the bacilli were killed, but not all were killed if the time for heating was only 3 minutes.

Kolle, Kutscher, Meinicke, and Friedel[2] found that *B. typhosus*, *B. paratyphosus*, and *B. enteritidis* had the same resistance to heat, and were all killed when the milk was heated to 59° C. if 10 minutes was taken to heat the milk to that temperature.

Rosenau[3] carried out experiments with nine different

[1] *Deutsche med. Wochenschr.*, 1903, xxix. p. 264.
[2] *Klin. Jahrb.*, 1904, xiii. p. 324.
[3] *Bulletin No. 42, Public Health and Marine Hospital Service, U.S.A.*, 1908.

strains of typhoid bacilli. His results showed that in milk heated to 60° C. and maintained at that point for 2 minutes all the typhoid bacilli were killed. The great majority of these organisms were killed by the time the temperature reached 59° C. A few survived to 60° C.

B. diphtheriae.—Welch and Abbott, also Roux and Yersin, have tested the thermal death-point of this bacillus in broth, sterile salt solutions, etc. Both sets of observers found that 10 minutes' exposure at 58° C. killed the bacilli.

Rosenau (*loc. cit.*) found that diphtheria bacilli succumb at comparatively low temperatures. Frequently they failed to grow after heating to 55° C., but some occasionally survived until the milk reached 60° C. Rosenau only used one strain of diphtheria bacillus, but carried out ten different experiments.

Vibrio cholerae.—Kolle, Kutscher, Meinicke, and Friedel found that this vibrio was not killed in milk until a temperature of 60° C. was reached. In their experiments it took 7 to 8 minutes for the milk to reach this temperature.

Rosenau carried out eighteen experiments. He concluded that the cholera vibrio is similar to the diphtheria bacillus so far as its thermal death-point is concerned. It was almost invariably destroyed when the milk reached 55° C., and only once did it survive to 60° C. under the conditions of the experiments.

B. dysenteriae.—Rosenau found this bacillus somewhat more resistant to heat than the typhoid bacillus. He found that it sometimes withstood heating at 60° C. for 5 minutes. All were killed by exposing to 60° C. for 10 minutes, while the majority were killed by the time the milk reached 60° C.

Micrococcus melitensis.—Dalton and Eyre[1] carried out a series of experiments, and found the thermal death-point to be 57·5° C. with a fixed time exposure of 10 minutes. They used five different strains of micrococcus. They did not, however, test the organism in milk. Rosenau carried out three experiments with this organism in milk. He found that it was not destroyed at 55° C. for a few minutes ($4\frac{1}{2}$), that the great majority die at 58°, and at 60° C. all are destroyed. He concluded that 60° C. for 20 minutes is more

1 *Journ. of Hygiene*, 1904, iv. p. 157.

than sufficient to destroy the infective principle of Malta fever in milk.

B. tuberculosis.—Special difficulties have been met with in determining the thermal death-point of this bacillus in milk, and decidedly discrepant results have been obtained by different workers. Part of the difficulty is due to the fact that the only way to ascertain whether the tubercle bacilli are alive or not after the heating is by animal inoculation, and the lesions produced by the injection of dead tubercle bacilli somewhat closely resemble those resulting from injection of the living bacilli. The discrepant results are also in part to be accounted for by the bacilli not being always in uniform emulsion. In this country experiments have been carried out by Woodhead, by Macfadyen and Hewlett and others.

Woodhead[1] obtained discordant and contradictory results. For example, in some experiments 25 minutes at 60° C. killed the tubercle bacilli, in others 8 hours was required.

Hewlett and Macfadyen[2] found that almost invariably milk, to which powdered dry sputum had been added, was rendered free from living tubercle bacilli by momentary heating to 67°–68° C.

Hewlett[3] carried out a few further experiments with artificially inoculated milk. He found that tuberculous milk heated to 60° C. for 30 minutes failed to produce tuberculosis in guinea-pigs, while also such milk contained no living tubercle bacilli after 20 minutes at 68°–65° C. in an Allenbury pasteuriser.

The Continental findings are discrepant. They are rather numerous and only a few can be mentioned. The earlier results of Yersin, Bitter, Bonhoff, Forster, etc., showed that while 60° C. for one hour was nearly always fatal to the tubercle bacillus, the effect of a much shorter time exposure was very variable. De Man's[4] results are frequently quoted, but he did not work with tubercle bacilli in milk, and his findings obtained by using the cheesy substance scraped from the cut surface of tuberculous udders cannot be applied to tubercle bacilli naturally occurring or even artificially added to milk.

1 *Royal Commission Report*, 1895, p. 145.
2 *Trans. Brit. Inst. of Prev. Med.* vol. i.
3 *Journ. of State Med.*, 1900, viii. p. 754.
4 *Archiv. f. Hyg.*, 1893, xviii. p. 133.

Beck, Galtier, and Rabinowitsch, each independently reporting in 1900, all obtained results showing a high degree of resistance for the tubercle bacillus. Galtier, for example, found that 5 minutes at 70° C. or even 85° C. was not always sufficient to kill tubercle bacilli in milk.

Bang's later work in 1902 avoids some of the earlier errors. He found that while heating to 60° C. for 15 minutes did not prevent peritoneal infection from tubercle bacilli in the milk, such heated milk failed to set up tuberculosis in fed animals. Exposure for 1 to 15 minutes at 65° C. killed the tubercle bacilli, and so did momentary exposure at 70°, 75°, 80°, and 85° C.

On the other hand, investigations made in America show a much lower resistance to heat, and the results of their work, which appears to have been very carefully done, are entitled to careful consideration. The work of Theobald Smith, Russell and Hastings, and of Rosenau, may be especially mentioned.

Smith,[1] using a standard temperature of 60° C., and working with tubercle bacilli suspended in distilled water, normal saline, and broth, found that 15 minutes at that temperature was sufficient to kill the bacilli. With milk his results were less uniform. When the milk was heated in closed receptacles so that a surface scum was not formed, the tubercle bacilli were killed by 15 minutes' exposure to 60° C., and were, therefore, not more resistant in milk than in other fluids. When the milk was exposed to the air so that a pellicle formed on the surface, this protected the bacilli, and Smith found that it might contain living tubercle bacilli even after 60 minutes' exposure to 60° C.

Russell and Hastings,[2] following up this work of Smith's, carried out some experiments under practical conditions with tubercle bacillus infected milk heated in a pasteuriser (Pott's pasteuriser). This was a pasteuriser of intermittent type, *i.e.* one in which a definite quantity of milk is heated for a definite time. The pasteuriser was rotated to effect uniform temperature exposure of the milk. Tubercle bacilli cultures of bovine origin were added to the milk. All the experiments were

1 *Journ. Exper. Medicine*, 1899, vol. iv. p. 219.
2 *University of Wisconsin Agric. Experiment Stn.*, *17th Annual Report*, 1900, p. 147.

carried out at a temperature of 60° C., and only 2 to 5 minutes was taken to heat up the milk to this temperature. The viability of the tubercle bacilli was ascertained by intra-peritoneal injection into guinea-pigs. In their first series they carried out 30 experiments. In all the cases in which the milk was kept at 60° C. for 10, 15, 20, 30, or 45 minutes, no tuberculosis in the guinea-pigs occurred, but when the exposure was for only 5 minutes tuberculosis resulted in all the experiments. They concluded that a temperature of 60° C. for 10 minutes is sufficient to effectively destroy the vitality of tubercle bacilli in milk.

These series of experiments were carried out under conditions in which the formation of a surface scum did not readily occur. Two further series of experiments were made to compare these results with those obtained by heating the milk in an open vessel and without stirring. The results summarised in the following table were obtained:

Time of Exposure (all at 60° C.).	Manner of Heating.			
	Series α.		Series β.	
	Closed Apparatus (Pott pasteuriser).	Open Vessel.	Closed Apparatus.	Open Vessel.
5 minutes	+ +	+ +	+ +	
10 „	− −	+ +	− −	+ +
15 „				+ +
Control (unheated) +				

− = No tuberculosis ; + = tuberculosis. Each symbol represents a separate experiment.

Their results show clearly that when the milk was exposed in a quiescent condition, as in a glass tube or bottle, the tubercle bacilli were more resistant than when the milk was in a closed receiver and agitated. The cause of the difference is probably to be ascribed to the formation of a surface scum.

The authors recommend, "in order to thoroughly pasteurise milk so as to destroy any tubercle bacilli which it may contain, without in any way injuring its creaming properties or consistency, to heat the same in closed pasteurisers for a period of not less than 20 minutes at 140° F. (60° C.)."

In a later report[1] they investigated the action of short exposures at a higher temperature upon tubercle bacilli, this being the actual conditions met with in milk pasteurised in apparatus of the continuous action type.

They carried out a large number of experiments with milk heated to 160° F., 175° F., 185° F., with exposure times varying from 1 to 10 minutes. Exposure for 1 minute or longer at these temperatures invariably resulted in the death of the tubercle bacilli as shown by failure to set up tuberculosis in inoculated animals. These results were obtained under laboratory conditions, the milk being infected with tubercle bacilli cultures of bovine source and exposed to the required temperature in sealed glass tubes placed in a water bath. It took three-quarters of a minute for the milk to reach the temperature of the outside water. The authors consider that their results approximate sufficiently to the conditions that obtain in practice where continuous flow pasteurisers are used, to be available for deductions for practical work.

Rosenau[2] carried out numerous experiments, using five different strains of tubercle bacilli, all of bovine origin. Young cultures of tubercle bacilli in fine emulsion in milk were used. All the tests were made by placing test tubes containing the unwarmed infected milk in a water bath containing water at the desired temperature (60° or 65° C.). The test tubes in which the infected milk was heated were open to the air, and scum formation was disregarded in all instances, the object being to determine the thermal death-point under natural conditions so that the results might be applied with confidence to practical pasteurisation. The guinea-pig test was used to ascertain the viability of the tubercle bacilli.

A large number of very careful experiments arranged in 9 series were carried out. The temperature of exposure was always 60° or 65° C., and the results are briefly summarised in the following table:

1 *Wisconsin Agricultural Experiment Station, 21st Annual Report*, 1904, p. 178.

2 *Bulletin No. 42, Public Health and Marine Hospital Service, U.S.A.*, 1908.

Time of Exposure.	Result.	
	60° C.	65° C.
1 minute	+ + + − − +	−
2 minutes	+ + − +	−
3 "	− − − − +	−
4 "	− − − −	
5 "	+ + + − − − −	− −
7 "	+ − − −	
8 "	−	− −
10 "	− − + − − − − −	− −
12 "	+ −	−
15 "	− − − − − − − − −	− −
18 "	− −	
20 "	− − ? − − − − − −	−
30 "	− − − −	
40 "	− − − −	
50 "	− − − −	

In addition, single experiments at 60° C. with time exposures of 6, 23, 25, 28, 35, 45, and 60 minutes were all negative.

+ = tuberculosis and − = no tuberculosis in the inoculated guinea-pig. Each + or − sign represents a separate experiment.

From these experiments Rosenau concludes that the tubercle bacillus in milk loses its infective properties for guinea-pigs when heated to 60° C. and maintained at that temperature for 20 minutes, or to 65° C. for a much shorter time. He remarks: "It should be remembered that the milk in these tests was very heavily infected with virulent cultures, indicated by the prompt deaths of the control animals. Milk would practically never contain such an enormous amount of infection under natural conditions. It is justifiable to assume that if 60° C. for 20 minutes is sufficient to destroy the infectiveness of such milk when injected into the peritoneal cavity of a guinea-pig, any ordinary market milk after such treatment would be quite safe for human use by the mouth so far as tubercle bacilli are concerned."

If the American results are accepted, it would seem that a temperature of 60° C. maintained for 20 minutes is capable of killing all tubercle bacilli in milk, especially if the conditions preclude the formation of surface scum, while a much shorter exposure is sufficient if 65° C. or 70° C. is employed.

The problem of the thermal death-point of tubercle bacilli in milk has been considered in detail because of its fundamental practical importance. The temperature to employ and the period of exposure at that temperature for commercial pasteurisation are based upon the conditions necessary to kill pathogenic bacteria, and especially the tubercle bacillus, in milk.

CHAPTER V

MILK AND THE ACUTE INFECTIOUS DISEASES

It is unnecessary to-day to insist upon the fact that milk may be a vehicle for the transmission of infectious disease to man. So many practical demonstrations of this fact have unhappily been furnished in our own country of raw milk drinkers that the fact has to be universally admitted. As long ago as 1857 Dr. Taylor of Penrith showed that an outbreak of typhoid fever amongst his patients was due to milk infected from a human case of typhoid fever. It throws a strong light upon the backwardness of epidemiology at this period that an interval of ten years elapsed before any important outbreak of infectious disease was again traced to an infected milk supply, and this second investigation we also owe to Taylor, who showed that an outbreak of scarlet fever was due to milk infected from a case of scarlet fever. Since that date milk has repeatedly been shown to be a vehicle for the spread of infectious disease.

Apart from tuberculosis, which is considered in Chapter VII., the infectious diseases which have been shown to have been spread by milk are the following: diphtheria, typhoid fever, scarlet fever, infective sore-throats, Malta fever, and occasionally gastro-enteritis outbreaks, dysentery, and cholera.

Sources of Infection

To convey infectious disease the milk must have had added to it the specific organism of that disease. While individually very numerous the sources of infection can be grouped under one of the three following heads:

A. Direct human infection.

B. Indirect human infection.

C. Infection of bovine origin whether direct or indirect.

Direct Human Infection. — Milk may become directly infected from a person either suffering from infectious disease, or carrying the infective organisms. Of these ways, the following are the most important:—

(*a*) One of the commonest sources of infection is that amongst the milkers, or others handling the milk, one or more are suffering from the infectious disease in a mild and hitherto unrecognised condition. Occasionally, it has not been officially recognised because of culpable carelessness on the part of the sufferer or his employer.

(*b*) A second common source of infection is from persons who are brought into contact with sufferers from infectious disease being employed handling cows, milk, or milk vessels. In many epidemics the origin of the outbreak is to be traced to infectious disease in the family of the cowman or milk distributor. The sufferers are not properly isolated, and the infective organisms are carried into the milk on the hands or clothing of the members of the family connected with the milk supply.

(*c*) Sometimes no person actively suffering from infectious disease can be found in any way connected with the milk supply, and the source of infection has been found to be a person who, while exhibiting no signs of illness, yet carries the germs of the infectious disease in the throat, nose, or other part of his body. The recognition of such carrier cases is a comparatively recent triumph of preventive medicine, and this source of infection is one of great importance.

Allied to these cases is the small group of outbreaks due to infection from persons who have not handled milk while suffering from infectious disease, but who have returned to work apparently cured although still in an infectious condition.

Indirect Human Infection.—In a considerable number of milk-borne outbreaks, particularly of typhoid fever, the source of infection has been indirect, and usually from infected water. The opportunities for such infection are not uncommon, although less operative to-day now that typhoid fever is a comparatively rare disease.

As detailed in Chapter XV. it is still common for milk vessels to be washed in water which is certainly liable to sewage pollution. Cows frequently have to drink from sewage-polluted sources, and contaminate their udders by standing up in such water.

Infection of Bovine Origin.—The possibility of this source of infection is considered in detail in Chapter VI.

The General Characters of Milk-borne Outbreaks

While variations are not uncommon, certain broad general features are met with, and may be looked for in outbreaks spread by milk. The following are the most important:—

1. *The Incidence is upon those who drink a Particular Supply of Milk.*—The invaded houses have a common milk supply, and usually nothing else in common. Inquiry shows that the households supplied with milk from a particular source are picked out and infected. While many such households escape, it is found that when comparative inquiries are made the consumers of the implicated supply furnish a much higher percentage of cases than either the rest of the community or the consumers of milk from any other source.

The percentage affected of consumers of the implicated milk varies greatly in different epidemics and for epidemics of different diseases. Variations as wide apart as 4 and 100 per cent have been recorded.

The smallest percentage invasion of households is met with in scarlet fever outbreaks. It would probably be higher if all ill-defined cases with symptoms mainly or exclusively those of sore-throat were notified and included.

That only a portion, and that a variable one, of the consumers of the implicated supply become infected is, of course, readily explainable. In many households the milk would be rendered harmless by boiling or cooking before use; in others, the particular milk delivered might be free from the infecting organisms although part of the same general supply; in others, the consumers might be insusceptible from natural or acquired immunity. In many, also, the infected milk might be consumed, but infection not occur owing to the organisms being killed in the body before they had opportunity to infect. In other words, when the difficulties of individual infection and the varying degrees of susceptibility are considered, it is obvious that only a portion, possibly a small proportion, of those taking the incriminated supply will be specifically infected.

A difficulty which has to be taken into account is the very considerable interchange of milk which takes place in large towns and elsewhere. This may make the task of comparison between the incidence of infection and the individual milk supply a difficult one. Cases which appear to be supplied with milk from quite a different source, and so to be etiologically unconnected with the outbreak, may be in fact connected, since the dairyman supplying them may have reinforced his own deficient supply with a churn of the implicated milk. Very careful and detailed inquiry is sometimes required to unravel these byways of infection.

The cases due to secondary infection have to be carefully traced and recorded separately in unravelling the epidemiological features of any outbreak.

2. *The Outbreaks are explosive in Character.*—Their explosive nature is a characteristic feature of both milk and water outbreaks. Sometimes they are extremely explosive, the bulk of the cases starting the disease within one or two days of one another. The epidemiological picture will vary somewhat according as to whether the specific infection is a single one, for example at one milking, or is in operation either continuously or intermittently for a number of days.

In many milk-borne outbreaks there is but little secondary infection, and the decline is usually very sudden on removal of the source of infection. On the other hand, long-continued infection with continuous notification of cases without abrupt decline has been a feature of a good many milk outbreaks.

3. *The Incidence falls upon the Milk-consuming part of the Community.—Social.*—The poorer classes consume but little milk compared with their richer neighbours. Milk-spread outbreaks show a higher incidence upon the classes who habitually consume more milk.

A striking example of the relationship between social position and attack incidence is furnished by Sir William Power in his report upon the milk-borne scarlet fever at Wimbledon[1] in 1887, as shown in the following table:

[1] *Report of Medical Officer, Local Government Board*, 1886, p. 327.

Number of Houses supplied and invaded amongst Customers of the Incriminated Milk.

Rateable Values from £10 to £15.		Rateable Values from £16 to £30.		Rateable Values from £31 to £40.		Rateable Values above £41.	
Houses supplied.	Houses invaded.	Houses supplied.	Houses invaded.	Houses supplied.	Houses invaded.	Houses supplied.	Houses invaded.
44	17	120	73	58	40	55	43
= 38·6 per cent.		= 60·8 per cent.		= 68·9 per cent.		= 78·2 per cent.	

Age.—This is very variable in the different epidemics. Children are naturally greater milk consumers, but this is sometimes counterbalanced by the fact that a considerably greater proportion drink their milk boiled than do adults. The habits as regards milk-boiling vary greatly, and, if the outbreak chiefly affects the socially well-to-do, may quite alter the age incidence and show a higher adult attack rate.

Sex.—The incidence is considerably higher on females than on males, presumably because they are greater milk-drinkers. For example, Davies in the 1897 typhoid epidemic at Clifton found that 67 per cent of the total number attacked were women. In the sore-throat outbreak at Colchester the writer found that, out of 74 cases in which the age and sex was recorded, 13 were adult males, 43 adult females, and 18 children. The small proportion of children was due to the good social position of the affected, and the resulting high percentage of cases in which the milk was boiled.

4. *The Milk Drinkers in particular Houses are attacked.*—In many outbreaks careful individual inquiries will show that those attacked are milk consumers, and those who do not drink milk, or only when cooked, escape. This is valuable corroborative evidence.

A typical example which the writer personally observed in the Colchester outbreak mentioned above is the following:[1] "In one family the lady of the house, who drank a glass of raw milk daily for lunch, was first attacked; subsequently both

[1] *Public Health*, 1905, vol. xviii. p. 14.

the maid-servants, one of them being the nurse, were attacked, both of whom drank raw milk; while the head of the house, who only drank milk in tea, escaped, as did also the two children (eight months and four years), receiving all their milk boiled; and this in spite of the fact that the nurse, whose sore-throat was typical, but not severe, continued to look after them."

A more detailed illustration of the relationship between the incidence of attack and the amount of milk consumed is furnished by Sir William Power in the outbreak of milk-borne scarlet fever at Wimbledon in 1887. He gives the following table:[1]

Amount of particular Milk consumed daily per Household.	Total Houses.	Number invaded.	Invaded per cent of Total.	Total Persons.	Number invaded.	Invaded per cent of Total.
Less than 1 pint .	81	39	48·1	315	68	21·6
1 to 1½ pints .	102	62	61·7	472	162	34·3
2 to 2½ „ .	43	32	76·7	207	87	42·0
3 or more pints .	48	39	81·2	362	169	46·6

Diphtheria Outbreaks spread by Milk

As long ago as 1878 Power adduced evidence that an outbreak of diphtheria in Kilburn and St. John's Wood, London, was spread by milk. Since that date many milk-borne epidemics of this disease have been recorded, although the total is smaller than of milk outbreaks of scarlet fever or typhoid fever.

Trask[2] has summarised 51 such diphtheria outbreaks (including those collected by Busey and Kober and by Hart) spread by milk, while there are, no doubt, a very large number which have never been recorded.

The outbreaks summarised by Trask show a very variable case-mortality, being for some as low as 1·5 per cent and for others as high as 30 per cent, or even higher. The epidemics with a high case-mortality are for the most part not recent, and refer to pre-antitoxin times. The highest case-mortality

[1] *Loc. cit.*

[2] *Bulletin No. 41, Public Health and Marine Hospital Service*, 1908, p. 32.

for a large epidemic appears to be that at Enfield in 1887 recorded by Bruce-Low, in which there were forty-eight deaths with a case-mortality of 22·5 per cent. Excluding all outbreaks in which the deaths are not clearly set out, the case-mortality in the epidemics recorded by Trask, taking them all together, was 16·1 per cent. From these figures it would appear that the case-mortality does not materially differ from that of epidemics spread by means other than milk.

In a number of the outbreaks it has not been possible to find the source of infection of the milk. In the few rare cases recorded in Chapter VI. the cow has been implicated. In the majority of cases in which the source has been ascertained it has been traced to a person handling the milk who has either had a slight attack of diphtheria, is in charge of or brought into close contact with a sufferer from diphtheria, or who is a diphtheria carrier. The outbreaks in which a diphtheria carrier is the source of the infection are sometimes difficult to prove, and probably a number of the earlier recorded epidemics in which the cause could not be traced, and for which bacteriological facilities were not available, were due to infection of the milk from either slight and unrecognised cases, or from true carriers.

Apparently no outbreaks have been traced from infected water or other indirect sources.

The following little outbreak illustrates the importance of bacteriology in tracing milk epidemics. It is recorded by Chase.[1] Two children in a milkman's house developed diphtheria, and were removed to hospital and isolated there. All the members of the household were examined bacteriologically, but no diphtheria bacilli were found. Three weeks later cases of diphtheria began to appear among the customers in Brookline (Massachusetts). In Brookline only seven or eight families used his milk, and cases of diphtheria developed in four of these. Cases were also found in Boston receiving his milk. On re-examination of the inmates of the milkman's house and others handling the milk virulent diphtheria bacilli were found in the throats of three men. Up to this time two of them had been employed in milking the cows.

The following is a good example of a milk-spread diphtheria

[1] *Journ. Mass. Assoc. Board of Health*, 1900, p. 5.

outbreak, while it also illustrates the value of bacteriological examinations of all handling milk. The outbreak was in certain parts of Sydney, Australia, and is reported by W. G. Armstrong.[1] The cause of this outbreak of some 40 cases was a man, A. M., who was taken into the employment of the milkman (S. M.) to milk and to distribute the milk. A few days before starting his work he had suffered slightly from sore throat accompanied by swollen glands in the neck. Starting the day after his employment by S. M. and continuing for twelve days, cases of diphtheria sickened amongst S. M.'s customers, and ceased two days after he was recognised as having diphtheria bacilli in his throat. In all, this man and six other persons residing in the dairy premises were found to be harbouring Klebs-Löffler bacilli in their throats. None of these persons were appreciably indisposed, but a culture of the organisms from A. M.'s throat was proved virulent to guinea-pigs.

Four days before these examinations took place G. P., a milker employed by S. M., left the latter's employment, and went to work as a milker for another milk-vendor (A. B.). He had been specially associated with A. M. while at the former dairy. Four days after starting to work for A. B. a case of diphtheria occurred among A. B.'s customers. In all, 5 cases occurred among the customers within a week. After being in A. B.'s employment for six days G. P. returned to S. M.'s dairy in the same capacity of milker and milk distributor. His return started further diphtheria cases amongst the customers of S. M., 4 persons being affected. Four days after his return to S. M. diphtheria bacilli were found in his throat, and he was excluded from the dairy.

Apparently in neither of the infecting persons could a diagnosis of diphtheria have been made without bacteriological means.

The identification of the diphtheria bacillus in milk is a matter of great difficulty, and this bacillus, so far as the writer has been able to ascertain, has only been isolated from milk on the following occasions:

Bowhill[2] isolated a virulent diphtheria bacillus from milk

1 *Public Health*, 1909, xxii. p. 149.
2 *Veterinary Record*, 1899, xi., April.

from a source suspected to have caused an outbreak of diphtheria at Senghenydd in South Wales. There were about 39 cases, and although the epidemic was undoubtedly spread by milk, there was no evidence as to how the milk became infected.

Eyre[1] isolated diphtheria bacilli from milk causing an extensive outbreak of diphtheria in a school. He obtained the diphtheria bacilli from both the cream and the centrifugalised sediment, being especially numerous in the former. Two distinct types of diphtheria bacilli were present, while their virulence was fully confirmed by guinea-pig inoculations.

Klein[2] isolated a virulent diphtheria bacillus in one out of one hundred samples of London milk submitted to him. No information was available to show the source of the bacillus, and whether its presence was associated with human cases of diphtheria.

Dean and Todd[3] isolated diphtheria bacilli from milk, and from lesions on the udders of cows. The outbreak is fully described on page 112.

Marshall[4] isolated the diphtheria bacillus from a sample of milk supposed to be associated with a little outbreak of diphtheria consisting of 2 cases. The bacillus isolated was fully virulent. It was not found possible to ascertain how the milk became infected.

Typhoid Fever spread by Milk

Examination of public health literature shows that typhoid fever has been spread by milk in a very large number of cases. For example, Trask[5] has compiled a list of 317 outbreaks, of which 179 were collected by himself and 138 previously by Hart and by Busey and Kober. These cases form but a portion of the recorded outbreaks, the writer, for example, being acquainted with reports of many epidemics of typhoid fever spread by milk, scattered in different journals which are not included in Trask's summary. In addition, a large

[1] *British Medical Journal*, 1899, p. 586.
[2] *Journ. of Hygiene*, 1901, i. p. 85.
[3] *Ibid.*, 1902, ii. p. 194.
[4] *Ibid.*, 1907, vii. p. 32.
[5] *Bulletin No. 41, Public Health and Marine Hospital Service, Washington*, 1908, p. 21.

number of milk-borne typhoid fever outbreaks are never reported at all, or only recorded in the annual reports of medical officers of health, and as such not readily accessible.

The importance of milk as a vehicle for the spread of enteric fever has been greatly underestimated. As an illustration of its importance it may be mentioned that Harrington[1] records that out of 18 local epidemics of typhoid fever investigated within two years by the Massachusetts State Board of Health 14 were milk-borne, only 3 being water-borne, and 1 of unknown method of spread.

The first outbreak traced to milk appears to have been at Penrith in the autumn of 1857, and recorded by Taylor. In this outbreak there were cases of typhoid fever in the cottage of the milkman who supplied the infective milk.

It is known that a good many cases of enteric fever are of the ambulatory type, and continue about, and not infrequently at work until a comparatively late stage of the disease, and after they have been infectious for several weeks. We also know that in recovered cases the bacilli may persist for very long periods in the excretions of the patients, and that such persons, although cured and apparently in perfect health, yet are passing typhoid bacilli in their evacuations, and in consequence are dangerous potential sources of infection. There are also a not inconsiderable number of cases of quite unrecognised typhoid fever, with symptoms so mild that the true nature of the condition is not suspected, and these cases also may act as carriers of infection. If these facts are associated with the known carelessness of certain classes in regard to personal cleanliness and the disposal of excreta, and the fact that flies undoubtedly can infect milk with typhoid bacilli from excreta, the frequency of milk-borne typhoid fever outbreaks is readily understood.

The actual ways in which milk may become infected with typhoid bacilli are very numerous, but the methods of spread illustrated below include all the chief channels of infection.

1. *Example of a Case of Typhoid Fever at the Farm not properly isolated.*—At Clydach, Glamorgan, W. Williams[2] recorded an outbreak of 16 cases of enteric fever amongst

[1] *New York Medical Journal*, 1907, lxxxv. p. 696.
[2] *Public Health*, 1902, xiv. p. 650.

the consumers of a particular milk supply. The eldest son of the farmer contracted typhoid fever from an unknown source. He was ill between two and three weeks before the condition was correctly diagnosed. Evidence was not forthcoming as to precisely how the milk became infected, but the milk was brought into the farmhouse before distribution.

2. *Example of Infection of the Milk after leaving the Farm from an unrecognised Case of Typhoid Fever.*—Harrington [1] reported an extensive outbreak in Jamaica Plain, Massachusetts, U.S.A., 410 cases of typhoid fever being notified during a period of about six weeks. Of these cases 348 primary and 23 secondary proved to be in families supplied by two milkmen (purveyors not farmers), F. and Q. The cases were nearly equally divided between the two milkmen. There were only 29 cases in which a history of the use of their milk could not be obtained, and 7 in which there was a possibility that the victims had on some one or another day drunk it. The investigations undertaken showed that the source of contamination of the F. milk was the milkman F. himself. F. died of typhoid fever on April 10, and the autopsy showed that he must have suffered from typhoid fever as early as March 20. On or about that date he consulted his doctor, who concluded that F. was merely tired and overworked. From that time until April 2, although feeling ill, he attended to his daily work, which included the general handling of his milk. On April 2 a diagnosis of typhoid fever was made, and he took to his bed. The first case amongst his customers was notified March 31, 1908, and cases continued to be reported until May 15.

The infection of Q. is not so clear, but both F. and Q. obtained their milk from the same dairy, and it is certain that there was the greatest possibility of an interchange of cans between F. and Q., for it was the custom of each to return the empty cans washed but not sterilised.

3. *Examples of Outbreaks spread by Typhoid Carriers.*—One of the earliest outbreaks spread in this way which has been recorded is that described by Jamieson [2] in Melbourne, and dealing with a little outbreak of 6 cases. The dairy-keeper was in hospital for an ordinary severe attack of

[1] *Public Health*, 1908, xxii. p. 19. [2] *Ibid.*, 1902, xiv. p. 655.

typhoid fever, the onset of his attack being December 1. The cases amongst his customers were all in March, and followed his return to work at the dairy. It is interesting to note that this milkman supplied 154 households, that it was found that in most instances the milk was scalded before delivery, but that 22 householders preferred to obtain the milk fresh. All the cases outside the dairy occurred among persons belonging to these households. The dairyman infected the milk fully three months after the beginning of his illness.

The Brentry outbreak, carefully worked out by Dr. Davies[1] (M.O.H., Bristol), is another illustration of a carrier-spread epidemic. The Brentry Inebriate Reformatory, Bristol, contained 240 inmates and 24 resident officers. Typhoid fever first appeared in 1906. The water supply was good, and there were no drainage defects. No cases of typhoid fever existed in the neighbourhood. In September 1906 a kitchen helper developed typhoid fever, and in November 3 further cases occurred. All 3 cases received an allowance of milk, thus suggesting carriage by milk. Fresh cases occurred in May 1907, continuing through July, August, September, October, and November in small groups and at varying intervals. In November 1906 a milk steriliser had been installed, but the 1907 evidence was still stronger against the milk as the cause. There were evidently present opportunities of contamination *after* sterilisation.

Inquiry in November 1907 showed that an inmate employed as cook and dairymaid (Mrs. H.) had suffered in January 1901 from a severe attack of typhoid fever, from which she had apparently recovered. She was admitted to Brentry, April 1906, and was employed in kitchen work up to October 13, 1906, when she was also entrusted with the dairywork, which she continued to do up to November 1907.

The milk, after sterilisation, was stored in the dairy, whence it was measured out for the various "villages" by means of a hand dipper. All the milk passed through her hands.

Mrs. H. was absolutely excluded on November 13 from all kitchen and dairy work, and the last case occurred on November 25, twelve days after her isolation commenced. The institution remained free from typhoid fever subsequently.

[1] *Royal Society of Medicine Proceedings*, Epidemiological Section, April 1908.

On November 18, 1907, the blood of Mrs. H. gave a positive reaction to Widal's test, but typhoid bacilli were not found in the urine or faeces when examined, November 18 and 29. On December 20 typhoid bacilli were isolated from her excreta.

Between September 1906 and the end of November 1907 28 cases of typhoid fever occurred at Brentry. Of the 11 female inmates attacked 3 were employed in the kitchen, 2 as dining-room maids, and 3 in the tea-house, all having access to milk. The 3 other female inmates attacked were in receipt of a daily extra supply of one pint of milk, as they were nursing. They were the only inmates receiving this additional supply. The baby (hand-fed) of one of these three women was also attacked. Practically all the male cases also had access to milk.

4. *An Example of Infection from contaminated Milk Cans.*—An outbreak[1] of typhoid fever occurred in Somerville and Cambridge, Massachusetts, in the autumn of 1907. There were 61 cases, and most of them obtained milk directly or indirectly from the same dealer. Investigation of the dairies from which the milk supply was derived showed that to one or more of them were sent cans from a place where milk was bottled, and these cans were washed by a man who was nursing a sufferer from enteric fever. He was uncleanly in his habits and very careless in his work, and it is probable that infective material from the person whom he nursed was conveyed by his hands directly into the cans and into the milk.

5. *An Example of Infection from specifically polluted Water used for Dairy Purposes.*—In a considerable number of milk-borne typhoid fever outbreaks the source of infection of the milk has been almost certainly specifically infected water used either for washing the cans or occasionally for direct addition as an adulterant to the milk. Complete proof cannot be furnished owing to the extreme difficulty of isolating the typhoid bacillus from water, but this does not at all invalidate the other accumulated evidence. The following is a good example of this method of infection, while it is given in some detail as illustrating the valuable graphic method of recording

[1] *Public Health*, 1908, xxi. p. 2.

introduced by Davies[1] (M.O.H., Bristol) who investigated and described the outbreak.

The epidemic occurred in Clifton, Bristol, and was extensive, the number of cases being 244. The evidence implicating the milk supplied from a particular farm (Farm X.) is very complete. Three particular supplies (X., Y., Z.) were found to be implicated (see Chart). The milk from Farm X. was met by the purveyor and distributed direct from the churn to the customers without its going to any dairy. Any milk not used on the round was, however, returned to the branch dairy, and sold to casual customers. Before the 26th of September (when the big schools reopened) the supply was sufficient to serve two districts—the low level and the high level—but after this date the supply was confined to the high-level district. On these two rounds 56 houses were supplied and 31 were attacked (55·3 per cent), while 114 cases resulted, or more than 2 cases per house. The inmates of these houses numbered 453, so that 25·1 per cent were attacked.

Milkman Y. started with a pure supply, but before entering the city met the X. cart, and occasionally took a supplementary supply from the churn consigned to Clifton. After receiving this supplementary supply he supplied milk which yielded 8 cases outside Clifton, and within the city supplied 40 houses, of which 18 were attacked (45 per cent); 48 cases resulted from these 40 houses, or more than 1 case per house. The inmates of these houses numbered 308, so that 15·5 per cent were attacked.

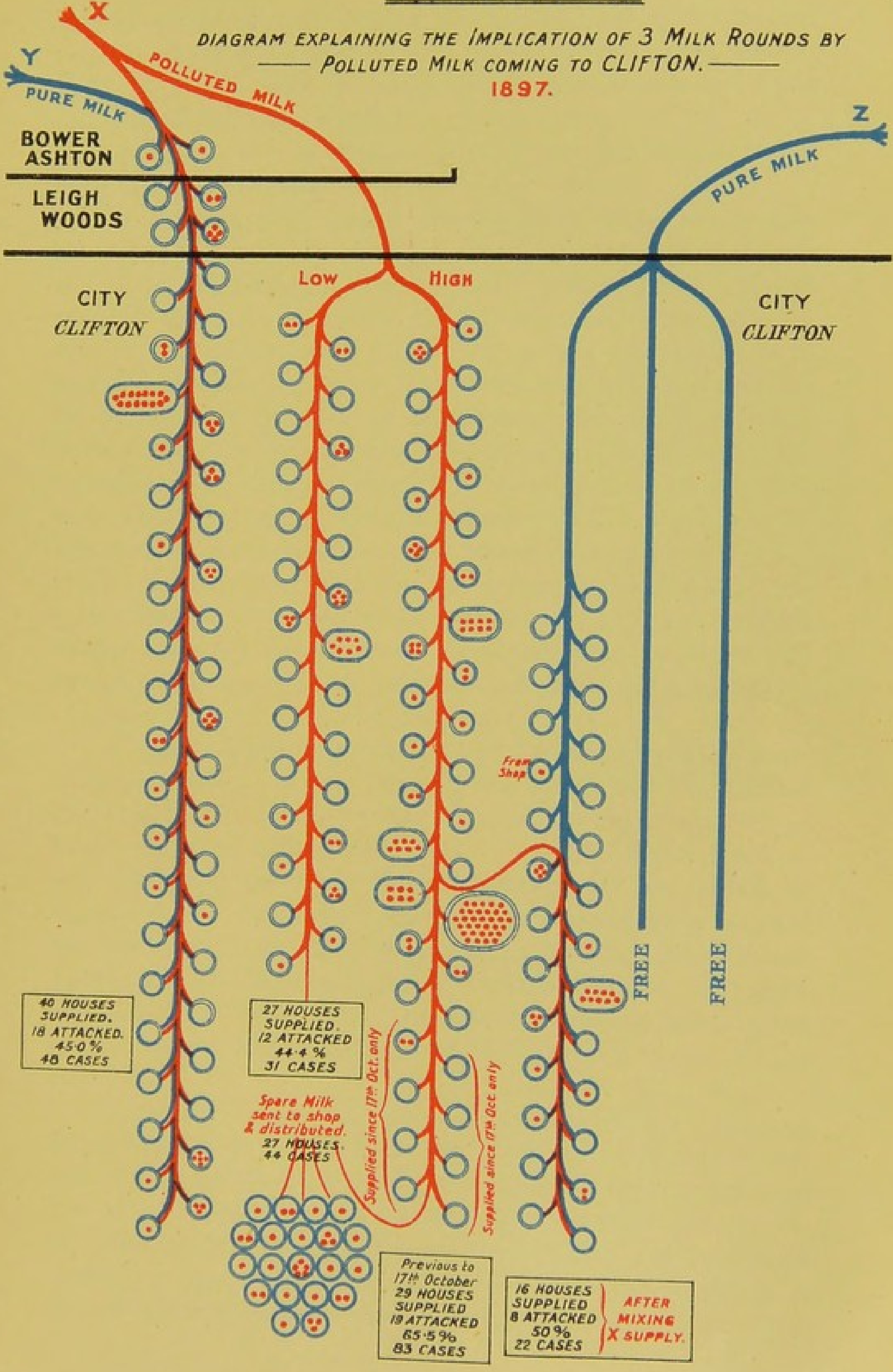
The other implicated supply, Z., was distributed in Clifton on three rounds. Two of these rounds were entirely innocent of cases, and the third round was, with one exception (a servant who lived close to, and admits to frequently obtaining casual supplies from, the branch dairy to which unused X. milk was returned), also free from cases up to a certain point, but beyond this point cases occurred with marked frequency (see Chart). It was found by plotting the routes on a map that at the very corner where this change from freedom to infection occurred, Z.'s round met that of the X. supply, and Z. admitted that he was in the habit, when running short, of obtaining at this point supplementary supplies from X. After this, cases com-

[1] *Trans. of the Epidemiological Society of London*, 1897-98, xvii. 78.

CITY OF BRISTOL.

DIAGRAM EXPLAINING THE IMPLICATION OF 3 MILK ROUNDS BY POLLUTED MILK COMING TO CLIFTON.

1897.



menced at the very next house he supplied, and continued with considerable frequency along his route. After adding the X. milk 16 houses were supplied and 8 were attacked (50 per cent), while 22 cases resulted.

In all, out of 244 cases, 234 (95·9 per cent) were supplied with the infected milk.

Dr. Davies made careful investigations as to the precise source of the infection of the X. milk. It was found that at the X. farm a stream known as the "Ashton Brook" flowed through the farm and close to the farm buildings. By the side of this stream, at a distance of only a few feet from it, was a pump drawing water from a shallow well, and used for all purposes of domestic or dairy use. The analytical data showed that the pump-water was probably supplied from the stream, and, as Davies remarks, "The conditions at the farm were such that, given specific pollution of the brook, similar infection of the pump-water was bound to occur, and the use of this for any dairy purposes was evidently fraught with the gravest danger." Inspection of the course of the Ashton Brook showed that it formed practically the main sewer of the straggling village of Long Ashton, which extends for a distance of a mile or more along the main road.

It was possible to go further and find the probable cause of the outbreak. A farm labourer was found who had suffered from an illness of two weeks' duration in September, whose blood, examined subsequently, gave a positive Widal reaction, and who had, therefore, almost certainly had an attack of typhoid fever. The man worked where he could have polluted the brook, while the dates of the cases forming the outbreak showed that the milk was probably infected between the middle and the end of September. He was the probable cause of the specific brook contamination, and, through this water, of the milk.

It has been suggested that milk-borne outbreaks of typhoid fever might be caused from the cows drinking water contaminated with typhoid bacilli, the bacilli being excreted into the milk. In the light of present-day knowledge this source of infection may be dismissed as non-existent. It is a quite possible source of infection that cows standing to drink in sewage-polluted water may contaminate their udders with typhoid bacilli and so mechanically infect the milk. In one typhoid fever outbreak spread by milk, inquired into by the writer, this source of infection seemed a likely one, as undoubtedly the cows supplying the specifically infected milk had been in the habit of standing in a stream (and drinking its water) polluted with the sewage effluent of a large town containing at the time cases of typhoid fever. Further inquiry, however, detected the presence of an unrecognised case of enteric fever amongst those handling the milk, and this case was probably the source of infection.

The typhoid bacillus is said to have been isolated from milk on a number of occasions, but in nearly all the proofs advanced in favour of the identity of the isolated bacilli with *B. typhosus* would not now (in the light of present knowledge as to pseudo-forms) be deemed sufficient to establish the contention, and must be accepted with reservation.

Shoemaker[1] has reported an interesting means of infection, and claims to have isolated the typhoid bacillus in connection with an outbreak of milk-spread typhoid fever in Philadelphia in 1906. It was spread from a certain dairy, and in regard to this he remarks: "The son was convalescing from typhoid fever and was filling the milk bottles from a tank by siphonage, starting the flow by sucking with the mouth at one end of the tube. A culture made from this end of the tube revealed many typhoid bacilli." He also stated that "a culture made from the milk proved the presence of the typhoid bacillus in it." The facts as to the means of spread are very interesting, but since the report gives not the slightest evidence or information as to the characters of the so-called typhoid bacilli, their presence cannot be accepted as proved.

Scarlet Fever spread by Milk

The number of recorded outbreaks of scarlet fever spread by milk is large, while undoubtedly numerous outbreaks are unrecorded. Trask has collected information in regard to 125 such epidemics, while the writer has notes of a large number recorded in the literature not included in Trask's summary. The sources through which the milk becomes infected with the

[1] *Journ. Amer. Med. Assoc.*, May 1907, p. 1748.

organisms of scarlet fever are varied, but all the means of infection in the recorded outbreaks fall under one or other of the following headings:

1. From a recognised case of scarlet fever insufficiently isolated from direct or indirect contact with the milk.

2. From an unrecognised case of scarlet fever amongst those coming into direct contact with the milk.

3. Through the infection of milk vessels, bottles, etc., with the specific organism of scarlet fever. The place of infection may be anywhere in the course of passage of the milk to the consumer.

4. From specifically infected or infective cows.

In nearly all the outbreaks in which the actual means of infection have been traced the milk has been infected directly from a human source, recognised or unrecognised. The question of bovine scarlet fever will be discussed in Chapter VI. As illustrations of the other ways of spread the following may be given.

1. Mussen[1] reported an outbreak of 59 cases of scarlet fever in Liverpool in 1904. Between January 30 and February 6, 16 cases of scarlet fever were notified in a suburban district which had previously been comparatively free from the disease, and on investigation the only circumstance in common was the milk supply. One of the dairyman's children was found to have been ill, January 16 or 17, was kept in bed for a few days, then allowed to come downstairs about a week previous to the notification of the first case. No medical man was called in. When examined February 6, there was slight oedema of feet and ankles, and copious desquamation from hands and feet, showing clear evidence of recent scarlatina. The child was removed to hospital February 6, and other precautions were taken. A number of persons were attacked after this date, but none after February 10 in houses not previously invaded. In other words, there were no fresh centres of invasion after four days from the child's removal to hospital. The cows were examined by a veterinary surgeon and found to be healthy.

2. Walford,[2] medical officer of health, Cardiff, reported an interesting outbreak of milk-spread scarlet fever in that city

[1] *Public Health*, 1904, xvi. p. 687.
[2] *Annual Report*, Cardiff, 1907.

which illustrates a very common method of infection. The outbreak occurred in May 1907, and consisted of 37 cases. Twenty of the persons attacked were regular customers of a milk-dealer, W. E., who kept no cows but obtained the greater part of his milk-supply from a farmer, E. J., in the surrounding rural district, and who supplied no other dealers or persons but W. E. Out of the 238 houses supplied with the infected milk 18 were infected, or 7·5 per cent as compared with 0·2 per cent amongst the houses in those districts supplied with milk from other sources. The outbreak at once ceased when the supply from the farm was stopped. The twenty cows on the farm were inspected by a veterinary surgeon, who stated that they were all in good health. When the farm was visited it was found that the farmer, E. J., had recently suffered from a slight sore throat, and his niece had in the early part of May also suffered from sore throat, and had been confined to bed for two days. No rash was admitted to have been noticed in either case, and a doctor was not called in. Both the farmer and his niece took an active part in milking and attending to the cows. The daughter of the farmer E. J. was notified as suffering from scarlet fever May 23.

It was subsequently found that shortly before the outbreak several cases of scarlet fever had occurred amongst children living in the village in which the milk purveyors lived, and that these cases were imperfectly isolated. It is probable that the niece derived her infection in this way, subsequently infecting the milk.

3. Robertson[1] recorded an outbreak of over 40 cases of scarlet fever due to the contamination of milk in a milk-shop. The premises were badly constructed in that the shop communicated directly at the rear, by means of a short passage, with a servant's bedroom and the kitchen. Infection was derived from the woman of the house, who was suffering from a sore throat, and who was an unrecognised case of scarlet fever. She infected her two children, a week after the onset of her sore throat, with undoubted scarlet fever. With the removal of the mother to hospital the epidemic suddenly declined. While she was ill and suffering from sore throat she served the customers coming to the shop for milk.

[1] *Public Health*, 1905, xvii. p. 445.

Outbreaks of scarlet fever spread by milk are not infrequently milder in character than those spread by direct contact or other agencies. There would also appear to be less tendency to spread by infection of secondary cases.

The occurrence of cases of an anomalous character has been a feature in several epidemics. Indeed in some epidemics spread by milk a number of the cases have shown so few of the symptoms of scarlet fever that, apart from their obvious relationship to other and undoubted cases, a certain diagnosis of scarlet fever would not be possible. The outbreak of sore throat and scarlet fever spread by milk at Brighton in 1902, reported by Newsholme,[1] may be mentioned as an illustration. In this outbreak there was a considerable number of known cases of sore throat without any scarlatina rash, while there were probably a number unnotified. Dr Newsholme asks the question, "Were all the sore throats as well as the officially notified cases scarlatinal, or were two infections operating? The gradually increasing virulence of the cases, first sore throats, then sore throats mixed with undoubted scarlet fever, then a group composed entirely of cases of severe scarlet fever, supports the first view." "If the same contagium caused the sore throats and the attacks of scarlet fever it is evident that infected milk may carry the scarlatinal contagium in such an attenuated form or in such minute amount that it is not capable of causing all the phenomena of scarlet fever."

The same peculiarity had been previously recorded by Buchanan[2] in an outbreak in Kensington in 1875 in which 12 persons were attacked with scarlet fever and 6 others with sore throat or with sore throat and other symptoms resembling scarlatina. This outbreak was due to infected cream.

Sore Throat and other Septic Conditions spread by Milk

Compared with scarlet fever, enteric fever, and other notifiable diseases the number of sore throat and similar outbreaks spread by milk which have been recorded is very small. This may be due to their actual rarity, but it is highly

[1] *Journ. of Hygiene*, 1902, ii. p. 150.
[2] *Report of the Medical Officer, Local Government Board*, 1876, vii. p. 72.

probable that a large proportion of such outbreaks are unrecognised and unrecorded. It has been pointed out that the part played by milk in the spread of scarlet fever, diphtheria, etc., was for a long time unrecognised or denied. It was not until the notification of these diseases was uniformly enforced that the importance of milk as a vehicle of infection was admitted and proved. If sore throat and similar conditions were notifiable it cannot be doubted, but that the number of known outbreaks of these conditions would be greatly increased. The subject being somewhat obscure and its importance underrated, a summary of all the recorded outbreaks which the writer has been able to trace is given in the addendum at the end of the present chapter. While all or nearly all these outbreaks may reasonably be said to have been spread by milk, in many of them the means by which the milk became infected is not proved. In some the source of infection was apparently from a person brought in contact with the milk while suffering from sore throat. In others the evidence points to the milk having been infected from a cow or cows suffering from sores on the teats, mastitis, or other septic conditions. The possibility of cows so infected specifically infecting the milk is fully discussed in Chapter VI.

ADDENDUM

I. Milk-borne Sore Throat Outbreaks.

(1) Aberdeen [1], 1881.—About 300 cases with three deaths. Symptoms characteristic. Sudden onset, with severe rigor or series of rigors followed by fever. Inflammation of throat and tonsils with swelling of the lymphatic glands in the neck and above the clavicle. Fever usually subsided after two to three days, leaving the patient very weak and prostrate. Outbreak clearly spread by milk. The total number of families supplied with milk from the incriminated supply was 110, and of these at least 90 families were affected. No cases occurred in any families obtaining their milk from other sources. Outbreak ceased when supply of milk stopped. Outbreak ascribed, on what would now be considered as quite insufficient grounds, to the water supply of the dairy. No mention made as to the condition of the cows or of any examination of, or cases of illness amongst, the milkers.

(2) Rugby [2], 1880 (reported by Dr. George Wilson).—Over 100 cases in all. Mostly among the boys at Rugby School. Cases of sore throat, but clinical particulars not given. Outbreak clearly spread by milk. Sudden onset in the three (out of eight) boarding-houses connected with the school supplied from the one milkman; in fifteen out of the thirty-seven families which he also supplied in the town there were one or more cases of the disease. All the cases were supplied with milk from the one milkman. Onset, March 16 and March 17. No cases of suspicious illness on the four farms from which the supply was obtained. Wilson came to the conclusion that the probable cause was a cow suffering from garget on one of the farms.

(3) Dover [3], February 1884 (reported by Dr. M. K. Robinson).—Within four days 188 persons attacked; in all 205 persons affected. Symptoms, those of local inflammation of the throat, enlargement of the lymph glands of the neck, and in some cases vesicular eruptions. Erysipelas was also met with. Four fatal cases. In nineteen out of the forty-two affected streets every house supplied by the implicated milkman was invaded, while in the

remaining twenty-three affected streets, out of eighty-six houses supplied by this milkman fifty-one were invaded by the disease. The number of persons attacked in each house stricken averaged 2·5 per house. The "nursery," or other special milk, supplied by the same milkman was not a cause of infection. The milk was obtained from four farms. On one of the farms it was found that foot-and-mouth disease had broken out on January 14, and that milk from some of the affected cows was delivered to the Dover dairyman and distributed, after mixing with the other milk, to his customers. Strong confirmatory evidence of the relationship of the conditions found on this farm to the outbreak was obtained from the fact that on two separate occasions the farmer sold his milk and cream to another purveyor, amongst whose customers a second simultaneous outbreak occurred. No information given as to illness amongst the milkers.

(4) Craigmore [4], 1890.—The number of cases which came under medical treatment was about 80. In March and April 1890. Symptoms were those of marked inflammatory hyperaemia and swelling of the throat, enlargement of the submaxillary glands and glands of the neck, with high fever and marked constitutional disturbance. Some of the cases were complicated with erysipelas. Three deaths occurred, all children. The evidence showed that the outbreak was spread by the milk from a particular farm. The period of incubation was usually three to four days, but occasionally two days. In some cases the definite onset of the disease after consuming the milk was very striking. For example, a Glasgow family went to Craigmore from Glasgow on March 28, and started using the milk. On April 1 all the members of the family were attacked, including the older children who had returned on March 31 to Glasgow to school, except two members who remained in Glasgow and did not drink the milk. The milk supply was stopped on April 2, and the cases seem to have ceased almost at once. The outbreak commenced about March 17, but the farm was not visited until April 3. The medical officer of health was told there was no illness among the people or the cows. On further questioning, it was elicited that one of the dairymaids had had a sore throat for a few days, but it was so slight that she had been away from work for only half a day (March 17), this being the same day that the outbreak began in at least three families. On April 4, two days after the milk was stopped, erysipelas appeared on the face of the farmer. A veterinary surgeon examined all the cows and gave a certificate that they were in perfect health and condition. It is not clear if he was engaged by the farmer or on behalf of the local authority. The milkmaid was suggested as the cause of the infection of the milk. Apparently no bacteriological investigations were carried out. A cat and a dog belonging to one

of the sufferers, which had been fed a good deal on the implicated milk, became very ill at the same time as their owners, and nearly died from what the veterinary surgeon who attended them called "severe inflammation of the throat."

(5) FINCHLEY [5], November 1894 (reported by Professor H. Kenwood).—Total number of cases not known. The first 24 cases were explosive in onset, all occurring within forty hours. The chief symptom was sore throat, which was not diphtheria, although the throats in many sufferers resembled those found in that disease. The suspected milk supplied 94 per cent of the total number of houses which were infected, but only 17 per cent of the total houses in the district. The disease affected persons in good-class houses with scarcely an exception. On the whole children were not mainly affected. The only source of infection which could be found was that there were on the farm supplying the incriminated milk three cows evidently out of health, and in each case suffering from ulcerations of the teats, while one of the cows had a small chronic abscess in the udder. All the throats of those who milked the cows were examined by Kenwood and found by him to be healthy.

(6) ANGLESEY [6], February 1897 (reported by Dr. C. Grey-Edwards and Mr. W. D. Severn).—Fifteen cases. No deaths. Symptoms were those of follicular tonsillitis. The evidence implicating the milk rests upon the fact that all the cases had a common milk supply derived from the farm upon which the first three cases (two children and a servant) occurred, and that three children between two and three years of age escaped apparently because they received only boiled milk. The cases occurred between February 12 and March 1. The cows were examined some time after the end of February (date not given) by a veterinary surgeon, who failed to detect anything wrong. When the milk of the individual cows was examined, the milk of one contained staphylococci and streptococci. While the outbreak may reasonably be ascribed to the milk, the evidence supplied does not show the cause of infection, whether human or bovine. We are not told if the servant on the farm had anything to do with the cows or milking utensils.

(7) SURBITON [7], 1897 (reported by Dr. Coleman).—Thirty cases at least known, and probably others. Symptoms those of sore throat. Cases supplied from one milkman. One of the milkers found to be suffering from tonsillitis with suppurating whitlows on both hands.

(8) HACKNEY [8], 1900 (reported by Dr. J. King Warry).—The disease was prevalent during nearly the whole of April and the first week in May. Outbreak extensive; 151 known cases in eighty-eight households. The symptoms were those of severe septic

sore throat with ulcerated tonsils, enlarged cervical glands, high temperature, and great prostration. In all cases convalescence was protracted. In one case acute septicaemia supervened, followed by acute septic pneumonia and death. There was a marked tendency for multiple cases to occur in families, and while no age or sex was exempt, a very large number of the sufferers were children. The facts ascertained by Dr. Warry (Medical Officer of Health) proved conclusively that the vehicle of spread was the milk of a certain milk vendor (X.). The returns of cases by medical men showed that 138 cases in seventy-five households were supplied with milk by X., and the remaining 13 cases with milk by seven other dealers; that is, over 85 per cent of the households in which sore throat illness occurred were supplied with milk by X. It was shown that X. supplied a very much smaller proportion of the houses than 85 per cent. House-to-house inquiries also showed that the persons attacked were those who consumed X.'s milk. There is no evidence in the report as to how the milk became infected. The bacteriological examination threw no light upon the origin of the disease. The vendor X. had a few cows of his own, but also received his milk from seven different country dealers. The cows of the dairyman were examined by a veterinary surgeon, who found them to be in good health. There does not appear to have been any investigation or inquiry as regards the outside farms either as to human illness on the farms or as to the condition of the cows.

(9) Brighton [9], November 1901 (reported by Dr. A. Newsholme).—A small outbreak of sore throat involving 18 cases, and followed by a number of cases of scarlet fever. It is not clear how far the sore throat cases were aberrant scarlet fever cases, and Newsholme considered that some of them were of this nature, occurring among girls unprotected by a previous attack of scarlet fever. The symptoms were those of sore throat with greyish exudation on the tonsils, high temperature, and general constitutional disturbance. By careful inquiry the outbreak was traced to a particular milk supply. The cause of infection appears to have been unrecognised cases of infectious sore throat in several families connected with the farmer who supplied the milk. The relationship was not, however, completely established. When the facts were investigated early in December (the cases were mostly in November) no evidence of udder disease was found, and fairly frequent veterinary inspections of the dairy had been made.

(10) Bedford [10], 1902 (reported by Dr. W. G. Nash).—The number of cases was 42, occurring in twenty-two families. In addition there were some milder cases not medically attended. The first case was on June 27. The symptoms were marked swelling and redness of the tonsils, fauces, palate, and uvula, with exudation on the tonsils, marked constitutional disturbance, and

considerable temperature. In every instance the milk was obtained from the same dairy, while no cases of sore throat connected with a different milk supply were observed. In some families the children who drank boiled milk escaped. Nash visited the premises, but could obtain no information as to illness amongst the cows or milkmen. No examination by him or by a veterinary surgeon of the milkers or of the cows appears to have been made, and the source of the infection of the milk was not ascertained. The bacteriological examinations made of the milk after the outbreak were negative.

(11) LINCOLN [11], May 1902 (reported by Dr. L. W. Darra Mair).—An explosive outbreak of 168 cases, sufficiently ill to require medical treatment, all but 5 of which started between May 9 and May 15 inclusive, and all between May 9 and May 19. Of 156 sufferers, the age of whom was recorded, 133 were adults or children over twelve, and only 23 were under twelve. The epidemic came to a sudden termination in spite of the fact that the distribution of the suspected milk was not prohibited. All the cases were characterised by sore throat, well-marked swelling of the tonsils, uvula, and mucous membrane of the pharynx. The cervical glands were enlarged. A rash was present in many cases, but it was unlike the rash of scarlet fever. Mair concluded, after very careful investigation, that the disease was not scarlet fever. There were three deaths. No definite secondary cases at all could be met with. The outbreak was clearly due to a particular milk supply. In the period of five weeks ending May 25, of 199 cases of illness associated with sore throat, 168, or 85 per cent, consumed the suspected milk, while if the cases which started after May 8, when the true epidemic begun, only are considered, the percentage of milk consumers is 87. Also the number of houses habitually supplied with the suspected milk at the commencement of the epidemic was 141; and of these no fewer than 85, or 60 per cent, were invaded. The incidence of disease was exceptionally heavy on households using much milk. The source of infection of the milk could not be traced although the most minute inquiries were made. No sore throat or other illness could be traced amongst those handling the cans or the milk. The cows were examined on May 14 by a veterinary surgeon at the request of the Town Council, and he reported them all healthy, while on May 30 Klein examined the cows and found no symptoms of ill-health in any of them. Klein and Gordon examined swabbings from 17 of the cases of illness. In no instance was the *Streptococcus scarlatinae* found, but in 3 cases a pathogenic yeast was isolated, and it was suggested that this was the cause of the outbreak.

(12) LINCOLN [12], May 1903 (reported by Dr. L. W. Darra Mair).—There were altogether 56 known cases of illness, and the

onset of all was between April 27 and May 7. All the illnesses started with sore throat, and 32 were reported as having a scarlatiniform rash. The 56 sufferers comprised 18 children under twelve and 38 persons over that age. In one house as many as 14 cases occurred. The diagnosis of the illness in this second outbreak again led to differences of opinion, although on this occasion the preponderance of opinion was much more in favour of scarlatina. At least 8 secondary cases were known. The outbreak was in a quite different part of Lincoln to that affected by the 1902 epidemic, and concerned a different milk supply. Twenty-five per cent of the houses supplied with the incriminated milk were invaded. The implicated milkman had five cows. Klein examined the cows on May 6 and found that two of them exhibited a vesicular eruption on the udders and teats somewhat similar to the "Hendon disease." No illness was detected among the milkers or their households. The bacteriological examination of swabs showed neither *Streptococcus scarlatinae* nor the pathogenic yeast found in the first outbreak.

(13) Guildford [13], 1903 (reported by Dr. R. W. C. Pierce). —Extensive outbreak, cases starting early in the last week in September and continuing until the middle of November. The chief symptoms were sore throats of different grades of severity, but for the most part cases of ulcerated sore throat or follicular tonsillitis. In some cases there was marked glandular enlargement, while a number were cases of quinsy. Considerable constitutional disturbance was present, shown by headache, pains in the back and limbs, and fever. In several instances there were joint pains after the acute symptoms had subsided. Five cases developed erysipelas after the sore throat. A few cases were fatal. A considerably larger number of adults were affected than young children. Information was obtained altogether of ninety-eight infected houses, and seventy-six of these were supplied direct by two milkmen obtaining their milk from a common source. The remaining twenty-two households derived their supply from nine other different dealers. With the stoppage of the milk the outbreak ceased. The incriminated farm was visited on November 13 by Pierce and a veterinary inspector. Of the twenty cows on the farm no less than four were affected with mastitis and yielded purulent milk. The farmer suffered from quinsy sore throat about the middle of September, and had pains in his joints subsequently, and was disabled for at least a month. The other members of his family also had sore throats. The first cases, as far as is known, occurred the last week in September, the illness of the farmer therefore probably preceded the outbreak. He occasionally assisted the two men at the milking, and in this way he may have infected the cows and the milk. The bacteriological investigations showed the

presence of streptococci in the milk, and Gordon isolated a streptococcus of the *pyogenes* type virulent to mice. It is probable that the farmer was the original cause of the outbreak, but as infection continued over six weeks, and the farmer could only have infected the milk on one or two occasions at the most, some continuously acting source of infection must have been present. If we assume that this continuous source of infection was the diseased cows, and that they were infected from the farmer, as Pierce suggests, the course of the outbreak is easily explained.

(14) FINCHLEY [14], 1904 (reported by Professor H. Kenwood). —An extensive outbreak, lasting from January 16 to January 30 and involving some 550 persons. The symptoms were those of sore throat with enlargement of the submaxillary glands, and marked malaise. Considerable temperature in most cases, with much prostration. In one or two cases quinsy was present, while septic conditions, such as gland abscesses and cellulitis, were met with as complications. Kenwood came to the conclusion that the outbreak was spread by milk. The cases occurred almost exclusively amongst the customers of a particular milk supply, but exact particulars are not furnished. He also satisfied himself that "the employés of the infected supply had not been spreading the complaint by reason of any one of them suffering from a bad sore throat at the period when the outbreak occurred." The precautions taken for the safe storage and delivery of the milk were quite satisfactory. In regard to the cows, a veterinary examination of every cow was made, and "the veterinary expert reported that all the animals were in a condition of perfect health, with the exception of two cows which had contracted a chill; the chill had affected their udders, causing their milk to become curdled; and that probably these animals had been in this condition for several days prior to his inspection on January 27. Both these cows were at once removed from the herd." Kenwood gives it as his opinion that "the outbreak was in all probability due to the two cows which were suffering from an obscure condition of ill-health towards the middle of January," but he gives no reasons in the report for coming to this decision other than those recorded above. The bacteriological examination of numerous samples of milk were negative. French, one of the medical men in practice at Finchley, gives one very interesting item of information. He found that one of the cases, complicated with severe facial erysipelas, was markedly improved both as regards the erysipelas and the throat symptoms by the use of antistreptococcus serum. He then tried the serum in other cases, and although they were very intractable to the usual remedies, without exception they all improved markedly, the temperature falling to normal within twelve hours. Pus examined from the

suppurating glands of one of his cases showed streptococci on cultivation in pure growth.[1]

(15) BELVIDERE HOSPITAL, GLASGOW [15], 1904 (reported by Dr. A. K. Chalmers).—In May 1904, at Belvidere Hospital, 39 persons were affected; chiefly nurses, cleaners, and wardmaids. The symptoms were those of tonsillitis and were mostly mild. No deaths. The illness was traced to milk, and ceased when the milk was sterilised. The cases extended over a period of about twenty to twenty-five days, half the cases sickening in the week ending May 14. On April 23 a new cow had been added to the herd of seventy-two cows. Towards the end of April the group of cows to which the new cow had first been added began to suffer from a teat eruption, and this spread to the other cows. It spread until 30 per cent of the herd were attacked, the outbreak reaching its height about May 6. The hands of four out of eight milkers were affected with sores. Chalmers regarded the teat condition as the cause of the outbreak.

(16) PAISLEY [16], October 1904 (reported by Dr. A. Robb).—Over 100 cases were known, but there were others which did not come under observation. No deaths. The symptoms were those of acute throat inflammation with constitutional symptoms. Diphtheritic-looking membrane present on the tonsils, sometimes also on uvula and soft palate. Malaise, high temperature, and marked prostration. The only factor connecting the cases was a common milk supply. The burgh veterinary inspector visited the farm late in the epidemic, and reported that many of the cows had evidently recently suffered from cow-pox—the teats showing remains of the eruption—but had now recovered. No information given as to whether there was or had been any illness amongst the milkers. Bacteriological examination of throats showed that the outbreak was not due to the diphtheria bacillus.

(17) COLCHESTER [17], April 1905 (reported by Dr. W. G. Savage).—Outbreak very extensive, probably at least 600 cases, and of these over 170 cases known to be under medical treatment. The symptoms were those of "septic sore throat." The tonsils and other parts of the throat were red and swollen. In some cases diphtheritic-like membrane was present, even extending on to the soft palate. The submaxillary glands were generally enlarged and painful. In no cases were rashes observed. No deaths were recorded. There were few or no secondary cases. Females suffered

[1] French suggests, from these facts, that the cause of the disease was undoubtedly the *Streptococcus mammitis bovi*. My investigations have shown that the ordinary streptococcus of mastitis is *not* the *Streptococcus pyogenes vel erysipelatosus*, and, therefore, the fact that there was evidence in favour of the presence of this latter organism is another link in the chain of evidence demonstrating that when cows' udder abnormalities are infectious to man we have present an organism, such as *Streptococcus pyogenes*, which is of human origin.

about three and a half times as much as males, and adults furnished three times as many cases as children. The incubation period was apparently not longer than two days. The evidence implicating a particular milkman's (M.) milk was complete, being derived from information supplied by medical men and from house-to-house inquiries. The following table shows the relationship of the cases attended by medical men, for which particulars were available, and the milk supply:

Milk Supply.	West side of Town.		Rest of the Town.	
	Households attacked.	Percentage.	Households attacked.	Percentage.
M.'s milk . . .	58	96·6	6	37·5
From other vendors .	2	3·4	10	62·5
	60	...	...	...

The outbreak was nearly confined to the west side, an area not including more than 20 to 25 per cent of the population. The house-to-house inquiries made in four selected areas showed that 50·9 per cent of the houses supplied by M.'s milk were invaded, as compared with 6 per cent for the other milk vendors. The milkman M. obtained his milk from six farms, and from a study of the distribution of the milk to the different milk rounds, and the different incidence of the disease on the different rounds, it was possible to point to farm B as the offending source of supply. All the farms were inspected, but only on farm B were human cases of illness or disease amongst the cows met with. Upon this farm a cow was found, in a shed with the others, suffering from mastitis of one quarter, and which had been noticed to be ill since about April 19. The milk of this cow was being added to the milk up to the time of visit, April 27. The cessation of the outbreak corresponded with the exclusion of the milk of this particular cow. Several cases of illness were found on the farm, but the cases were coincident with cases in the town. The first illness on the farm was that of the farmer himself, who suffered from a severe sore throat, which confined him to bed for three or four days. He never milked the cows, and said he had very little to do with them. The onset of his illness was April 17, a date which coincided with other cases in the town. This with other facts renders it nearly certain that he was infected from the milk and was not the source of infection of the milk. Five or six other cases occurred amongst the farmer's family on the farm, but all began after April 20, and all drank the milk. The outbreak started about April 17 and ceased about April 29, the maximal incidence being on April 21 and April 22. The bacteriological investigations showed that the sore throats were presumably due to streptococci, while no diphtheria bacilli were present. The fluid from the mastitis quarter of the cow showed abundant streptococci.

(18) LEITH [18], June to October 1904 (reported by Dr. W. Robertson).—A long-drawn-out mixed outbreak of diphtheria and septic sore throat. The actual diphtheria notifications in connection with this outbreak were 2 at the end of June, 2 in July, 5 in August, 9 in September, and the last on October 16. The connection of the cases with the incriminated milk supply is not clearly set out in the report, but apparently all the diphtheria cases had a common milk supply. The relationship of the sore throat cases to the milk supply is not established in the report, but apparently there was a close relationship. An examination of the farms failed to find any cases of sore throat or suspected sore throat. Of the 45 cows 5 were found by the veterinary inspector to be suffering from ulcers on their teats. Drying pustules were found on some of the ulcers, and the veterinary surgeon diagnosed the condition as one of cow-pox. A further detailed examination a week later showed 15 cows suffering from ulcerated teats. A dairymaid was affected with pustules on her hands, and the farmer's son was also affected. Although swabs were taken repeatedly from the ulcers and examined, the Klebs-Löffler bacillus was never isolated, although "now and again an organism possessing the microscopical and cultural characteristic of the Klebs-Löffler was detected." They were, however, non-pathogenic to animals.

The above recorded outbreaks are all which the writer has been able to find in the British Isles. Foreign literature has not been searched, but very few such outbreaks appear to have been recorded. The following outbreak at Christiania is of interest.

(19) CHRISTIANIA [19], 1908 (recorded by Dr. Sömme).—An extensive outbreak which began in almost every case with a sore throat. In addition to sore throat with red tonsils and pharynx, the usual symptoms were swelling of the glands of the neck and high temperature. Complications, chiefly of a pyaemic character, were numerous, but gastro-enteritis and diarrhoea were apparently not common. A number of the cases died. Adults were affected about three times as commonly as children. The number of cases of the epidemic notified was 548, but as notification was voluntary, it is probable that the total number was considerably higher. The means of spread of the outbreak was quickly traced to the milk supplied by one dairy, and thence to a cow with a diseased udder. The cow was slaughtered, and a bacteriological examination of the abscess found in the udder led to the isolation of streptococci in every way identical with the streptococci obtained from patients

attacked by the epidemic. The streptococci were long chain forms, pathogenic to mice after intraperitoneal injection.

II. Outbreaks of Diarrhoea or Gastro-Enteritis spread by Milk

Records of such outbreaks are even rarer in the literature than those of sore throat. The following have been recorded :—

(1) Youlgreave [20], (recorded by Dr. Knox, M.O.H., Bakewell, R.D.). On Friday, August 28, 1908, upwards of 30 persons were seized with violent sickness and diarrhoea. There was also much headache and depression, with elevation of temperature (102°–104°). No deaths. On investigation it was ascertained that all the persons attacked had their milk from the same dairy, and that a cow calved on the previous Sunday (August 23) had her milk added to the usual supply on the Wednesday and Thursday, and that all the cases occurred within the next day. The cow had been sold previous to calving, but was not delivered until the Thursday evening. No fresh cases occurred after her removal. The cow was believed to have been healthy by the dairyman. No bacteriological examinations were made.

(2) Aberdeen [21], November 1908 (recorded by Dr. Matthew Hay).—An extensive but circumscribed outbreak. The illness usually began with severe headache, shivering, and backache. More or less severe vomiting or belching, followed with abdominal pain in severe cases. In most cases diarrhoea was present and continued for several days. Usually some fever, and in a few cases cramps in the legs were complained of. All the cases recovered. Inquiry soon showed that it was due to a particular milk supply. For example, Hay found within a short street in which the dairy was situated nearly 70 cases, all of which, except 2, were supplied from the incriminated dairy. In the other houses with a different supply, which constituted more than half the total number, there were only 2 cases and these were of an ill-defined nature. The milk was obtained from 3 farms. On one of these there had been a number of cases of illness. The first persons sickened at the farm on November 5, while, with one exception, all the illnesses of the group investigated in the city commenced on November 6 to November 8. Hay attributed the outbreak to the occurrence of cases of disease at the farm, which infected the milk. No mention is made of the cows, or indeed whether they were examined at all.

Jensen (*Milk Hygiene*) mentions the two following outbreaks :

(3) Stockholm.—In Stockholm the members of 9 families became ill with nausea, vomiting, diarrhoea, fever and weakness, together with cramps in the legs. The disease was traced to the use of milk from a certain herd. The herd comprised 14 cows,

one of which was proved to be affected with mastitis. Two persons working in the stable were sick with the same symptoms.

(4) Lameris and van Harrevelt mention an outbreak of diarrhoea among a number of persons in a hospital. The disease was traced with comparative certainty to the milk of a herd in which several cases of mastitis due to streptococci 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. The milk was used only after being boiled, but the boiling was probably imperfectly done.

REFERENCES TO ADDENDUM

[1] *Brit. Med. Journ.*, 1881, i. p. 657.
[2] *Ibid.*, 1881, ii. p. 415.
[3] *Practitioner*, 1884, xxxii. p. 467.
[4] *Glasgow Med. Journ.*, 1894, xxxiv. p. 241.
[5] *Annual Report Medical Officer of Health, Finchley*, 1894.
[6] *Brit. Med. Journ.* 1897, ii. p. 339.
[7] *Annual Report of Medical Officer of Health, Surbiton*, 1897.
[8] *Ibid.*, *Hackney*, 1900, pp. 60-69.
[9] *Journ. of Hyg.*, 1902, ii. p. 150.
[10] *Lancet*, 1902, ii. p. 1050.
[11] *Report of Medical Officer, Local Government Board*, 1902-3, p. 190.
[12] *Ibid.* p. 213.
[13] *Brit. Med. Journ.*, 1903, ii. p. 1492; *Journ. of State Medicine*, 1904, p. 595.
[14] *Brit. Med. Journ.*, 1904, i. p. 602.
[15] *Public Health*, 1903-4, xvi. p. 769.
[16] *Ibid.*, 1904-5, xvii. p. 773.
[17] *Ibid.*, 1905-6, xviii. p. 1.
[18] *Ibid.*, 1904-5, xvii. p. 246.
[19] *Lancet*, 1908, June 13, p. 1707.
[20] *Public Health*, 1908, xxii. p. 58.
[21] *Public Health*, 1910, xxiii. p. 181.

CHAPTER VI

DISEASES OF THE COW (EXCLUDING TUBERCULOSIS) AFFECTING THE MILK

ALTERATIONS in the health of the cow exert a considerable influence upon the quality of the milk yielded, and sometimes impart to it definite harmful properties. The most important disease of the cow affecting the milk is tuberculosis, and this condition is considered separately and in detail in the next chapter. Excluding this disease the present chapter is concerned with the part which the cow itself plays as a source of disease to man through the milk supply.

The abnormal cow conditions may be divided into three groups:

I. General systemic disease of the cow without local lesions of the milk organs.

II. General systemic disease of the cow with local lesions in or on the udder and teats.

III. Local affections, with little or no general systemic disturbance.

GROUP I

Excluding tuberculosis, the chief general diseases which have to be considered are the following:

Anthrax.—Although this disease readily affects cows, it is generally considered that the danger of anthrax being spread by milk is a remote one. The affected animal usually dies within a few hours of infection, and, during its short illness, the milk secretion is either suppressed or, if present, is abnormal in appearance and rapidly decomposes. This is fortunate, since the anthrax bacillus has been recovered from the milk of infected cows. That the danger from anthrax-infected milk is not altogether problematical is shown by a recent outbreak in Chicago (June-August 1910), when the milk supply of that city was seriously endangered by an outbreak of anthrax. The disease existed for about sixty days, involving twenty farms, and, approximately, 500 cows were exposed to the infection; 87 cows died from the disease. The outbreak was spontaneous, spread rapidly, and required vigorous efforts to prevent its spread. Dairy inspectors from the city were put into the district involved, and by strenuous efforts discovered and quarantined every farm upon which anthrax was found, or was possibly present. All milk on these farms was destroyed, and great care was taken to prevent the sale of milk from infected districts. In consequence of these precautions none of the possibly infected milk reached the Chicago consumer at any time. One of the farmers upon whose place anthrax was discovered subsequently became infected with the disease and died, but apparently not through the milk.

Gaertner Infections.—Although cows are not infrequently infected with one or other member of the Gaertner group of bacilli, and widespread outbreaks of food-poisoning have resulted in consequence of the consumption of the infected meat, the writer has been unable to find any records of outbreaks due to the consumption of the milk of such animals. The probable explanation of this is that, with cows so affected, the milk secretion is either stopped or markedly altered.

Gastro-enteritis.—In cows affected with diarrhoea and other symptoms of gastro-enteritis, the milk is usually abnormal and decomposes rapidly. Such milk is probably liable to produce diarrhoea. The only known instance of which the writer can find record is that recorded by Follenius and Gaffky,[1] in which three persons at Giessen became very ill with malaise, headache, and diarrhoea after the consumption of raw milk from a cow suffering from haemorrhagic enteritis.

Septic Conditions.—In conditions such as puerperal septicaemia, septic metritis, etc., the milk is sometimes markedly altered, and, whether altered or not, no doubt would be prejudicial.

It is also the universal practice to avoid using for human consumption the milk of quite freshly calved cows. The

[1] *Deutsche med. Wochenschr.* xviii. p. 297.

milk just after parturition is called colostrum. It is yellow, somewhat viscid, with strong odour and acid reaction. Such milk if drunk is liable to produce diarrhoea and digestive disturbance.

Malta Fever.—Since cows are susceptible to infection with the *Micrococcus melitensis,* and this organism has been found in their milk, this disease is one which may be spread by cow's milk, but Eyre,[1] in a comprehensive account of the disease, does not mention this as an actual known source of infection.

Group II

Of the second group, which comprises general disease of the cow, with local lesions on the teat and udder, the two commonest conditions are foot-and-mouth disease and cow-pox. Bovine scarlet fever may also be included here, but is more conveniently considered later with Group III.

That foot-and-mouth disease in cows may be transmitted to man through the milk is attested by a number of cases and outbreaks of disease. One of the most interesting is the outbreak recorded by Robinson at Dover in 1884 (see page 91).

Whether cow-pox affects the milk and causes infection in man is doubtful The milk of such cows is usually said to be unfit for food, but there appears to be little or no evidence as to its harmfulness, although the milkers' hands are apt to be infected.

Group III

In this group the essential lesions are in connection with the milk-producing organs. They take the form of inflammation of the udder (garget or mastitis) and the various conditions described under the term "ulcerated teats."

Mastitis in Cows.—A well-recognised and not uncommon condition in cows. Accurate records as to the extent of its prevalence are not available, but the following table for London cowsheds, from Sir Shirley Murphy's annual report for 1908, gives a good idea of its prevalence:

---

[1] Article "Maltafieber," Kolle and Wassermann, 1907.

Summary of the Reports of the Veterinary Inspector for the Year 1908

Details of Examination.	Jan. 11 to March 15.	March 16 to May 26.	May 27 to July 31.	August 1 to October 4.	October 5 to Dec. 5.
Total number of cows examined	3521	3283	3476	3343	3565
Affected with disease or defects of the udder . .	230	223	213	213	258
Affected with tubercular disease of the udder . .	3	3	2	5	3
Suspected cases of tubercular disease	2	1	...	...	...
Subjects of acute mastitis .	23	39	27	29	40
Affected with chronic induration of the udder . .	7	13	12	11	4
Atrophy of one or more quarters	141	117	123	127	142
Injuries, abscesses, simple eruptions, strictures, and obliterations of milk ducts	16	27	22	18	32
Hypertrophied udders without induration	2	2	3	1	1
Giving milk of poor quality (dried-off cows) . . .	36	21	24	22	36

This table shows that, taking the mean of the different inspections, 0·9 per cent of the cows were at the time of inspection suffering from acute mastitis, while 3·7 per cent showed atrophy of one or more quarters. The latter condition is nearly always due to a previous attack of acute mastitis. The results varied somewhat in different years, but not very widely, as shown in the following table compiled from the annual reports:

Percentage

Year.	Affected with Acute Mastitis.	Atrophy of one or more Quarters.
1904	2·2	7·7
1905	0·73	3·9
1906	0·57	3·8
1907	0·27	3·7
1908	0·9	3·7
1909	0·99	3·03

Pathological Investigations upon Mastitis in Cows.—We owe the first definite work upon the bacteriology of this condition to Nocard and Mollereau, who in 1884 isolated a long chain streptococcus from the udder secretion of ten cows suffering from contagious mastitis. Since that date numerous investigations have been carried out by Hess and Borgeaud, Kitt, Guillebeau, Zschokke, Steiger, Gröning, and others. These investigators showed that this disease might be set up by different organisms. Of these, apart from the chronic varieties due to tuberculosis and actinomycosis, the chief were streptococci, staphylococci, and varieties of *Bacillus coli*. In all these investigations there is but little differentiation of the organisms isolated, and the characters given quite fail to separate them from the saprophytic streptococci and staphylococci not only present in manure, sewage, air, etc., but also in the milk drawn direct from the udders of perfectly healthy cows. They are, further, in no way differentiated from the disease-producing streptococci and staphylococci of man, and give no assistance in determining how far the conditions included under the term "mastitis" may be prejudicial to man. The researches of the writer [1] for the Local Government Board seem to be the only pathological investigations which deal with this problem, and as the subject is of considerable practical importance the following brief summary is included as far as it relates to this aspect of the matter.

Out of 36 cases of mastitis in cows investigated, 68 per cent were due to streptococci, 16 per cent to staphylococci, 3 per cent to *Bacillus coli*, 3 per cent (1 case) to *Bacillus tuberculosis*, and in 10 per cent (3 cases) the results were doubtful. If the 3 doubtful cases are excluded, the percentage due to streptococci rises to 75. A large series of tests, including the production of acid in certain sugar-alcohol media, was used to differentiate the streptococci. It was found that 80 per cent of the streptococci isolated could be grouped as forming a common type, called by the writer *Streptococcus mastitidis*. This is a long chain form growing rapidly in broth, forming a coherent deposit, but leaving the upper part clear. It grows upon gelatine without liquefaction, produces acid in milk, clotting

[1] *Report of the Medical Officer, Local Government Board*, 1906-7, 1907-8, 1908-9.

it within three days, gives no neutral red reaction, produces acid in lactose and saccharose media, never in mannite, and not usually in salicin, raffinose, or inulin. It is non-pathogenic to mice. It is of considerable significance that in several other cases quite different streptococci were isolated.

In view of the possible relationship of mastitis in cows to human disease it is a matter of great importance to consider how far the causal organisms of mastitis are present in quarters which clinically appear quite unaffected. To investigate this question, the milk of all four quarters was, as far as possible, examined in every case. Excluding cases in which all four quarters were attacked, in 84 per cent of the cases due to streptococci identical organisms were isolated in one or more of the healthy quarters. In some instances they were present in only one healthy quarter, in others in all of them. It should be noted that not only were these streptococci found in quarters which appeared sound when examined by a veterinary surgeon, but in quarters which frequently showed no evidence of any inflammatory reaction, as demonstrated by the extremely sensitive cytological examination. The milk appeared to be perfectly healthy to the naked eye. Although these streptococci (identical with those in the affected quarters) were present, usually the healthy quarters did not become subsequently involved.

From a public health point of view these results are of considerable significance. In cases of mastitis in cows it is a quite common practice to use the milk from the seemingly unaffected quarters, although the secretion of the diseased quarters is recognised as unfit. The results obtained show that in most cases the farmer is thus adding to the vended milk very large numbers of streptococci indistinguishable from those causing the mastitis.

The primary problem from the human standpoint is whether the streptococci found in cow mastitis are pathogenic to man. To elucidate this further investigation was required. Extended comparison was therefore instituted between the streptococci found in these two conditions. The streptococci found in 16 cases of human sore throat were carefully investigated. Two chief types were found, confirming the results previously found by Andrewes and Horder. The most prevalent type was the variety which they called *Streptococcus anginosus*, while the other was identical with *Streptococcus pyogenes*. Comparing the two types most commonly met with in the bovine and human conditions—the *Streptococcus mastitidis* and *Streptococcus anginosus*—it was found that, morphologically and culturally, they were quite indistinguishable even when the different sugar-alcohol tests were employed. In addition, the commonest cultural deviations from the type were the same in both cases. As regards their pathogenicity towards the lower animals, however, they show distinct differences. *Streptococcus mastitidis* possesses low virulence; occasionally a local abscess is produced, but, as a rule, no pathogenic action is manifested towards mice or guinea-pigs. The *Streptococcus anginosus* type, on the other hand, is possessed of considerable pathogenic action, subcutaneous inoculation into mice frequently causing the death of the animal. The distinction is one of degree rather than kind, and otherwise the close similarity is very interesting. Further comparison is only possible along the lines of their specific properties.

Can the mastitis streptococci, by inoculation upon the human throat, set up inflammatory action? Will the udders of cows when inoculated with streptococci from cases of human disease become infected and mastitis result? Both problems were experimentally investigated. The second question was studied in a series of experiments upon goats. Twenty-two separate experiments were carried out in which the teats were infected with pure cultures of different organisms. The results in the twenty experiments in which pure cultures of recently isolated streptococci were used were as follows: The three streptococci from mastitis cases in cows all set up mastitis in goats. Of two streptococci from sore teats one set up a very severe mastitis, but the other was without effect. A streptococcus very common in, and isolated from, cow dung also produced no visible effect. Thirteen streptococci of human origin, one from a healthy throat, six from cases of sore throat (2 being scarlet fever cases, and 4 ordinary tonsillitis cases), and four isolated from other human diseases, all failed to produce mastitis in the goat. In the remaining two cases, both streptococci not obtained from sore throats, distinct inflammatory reaction and some degree of mastitis resulted.

One of these streptococci was derived from a case of Ludwig's angina, and the other from a case of acute epiphysitis.

The results are distinctive. Comparing the human and the bovine groups, it was found that, although morphologically and culturally they were often indistinguishable, they showed a wide divergence when their action towards animals was considered. The bovine mastitis type was non-virulent towards mice and other rodents, but possessed in marked degree the power to cause udder inflammation in goats. The streptococci from human sources possessed a considerable virulence towards mice, but as regards the strains isolated from sore throats absolutely, and as regards those from other sources in most cases, they were unable to originate mastitis in goats.

These results suggest that an essential difference of functional power separates the types, and that under ordinary conditions the *Streptococcus mastitidis* is not a cause of human disease.

That the *Streptococcus mastitidis* is not a cause of human disease was also demonstrated by direct experiment. In two separate experiments the writer directly infected his own throat with massive doses of this streptococcus, isolated only a day or two previously from cases of cow mastitis. On both occasions no ill-effects were experienced generally or locally, and the streptococcus could only be recovered with extreme difficulty from his throat, and this although the isolation was undertaken only two and three days respectively after the throat inoculation, and although that inoculation was massive in amount.

On pathological grounds it would seem that the great majority of cases of bovine mastitis are due to an organism which is not harmful to man. This is in accord with the fact that while bovine mastitis is common, sore throat and other septic outbreaks from milk are rare.

Epidemics of illness ascribed to this cause have nearly always been of the nature of outbreaks of septic sore throat, although there are one or two in which gastro-enteritis has been the predominant condition. Holst,[1] for example, records four outbreaks of acute gastro-enteritis from the use of raw

[1] Baumgarten's *Jahresbericht*, 1895, p. 52.

milk, and in three of these he considers the cause to have been the milk of cows suffering from mastitis streptococci. In several cases the milk of these diseased cows, after being stopped, was again mixed with the other milk and sold (owing to change in the milkers), and diarrhoea reappeared amongst the consumers on the same day. Holst also swallowed 200 c.c. of a milk culture of the streptococci isolated from one of the mastitis cases which had stood for a few hours at 37° C., and in consequence was ill with body pain and some diarrhoea and vomiting.

At the end of Chapter V. a summary has been given of all the outbreaks which the writer has been able to collect, of sore throat, etc., spread by milk. For many of these a bovine origin has been ascribed. The fact that certain outbreaks do appear to be due to a cow with an infective mastitis is in line with the writer's pathological results. While he found that *Streptococcus mastitidis* was the usual organism of bovine mastitis, it was not the only type of streptococcus associated with this condition. In one case, for example, a streptococcus of extremely high virulence to rodents was found to be the cause of the mastitis, and this organism in many other ways was quite distinctive from the *Streptococcus mastitidis,* and may well have been potentially virulent to man. If we accept the view that the ordinary type of bovine mastitis is due to organisms non-virulent to man, but that in certain uncommon cases this condition is caused by streptococci highly pathogenic to man, it offers a complete explanation of both the bacteriological investigations and the epidemiological facts.

From the practical point of view, it is well to remember that the pathogenic and non-pathogenic types of bovine mastitis are not clinically distinguishable.

Ulcerated Teats.—In addition to the diseases of cows already described, in which the teat eruption is part of a general constitutional disturbance such as cow-pox, not infrequently teat ulcerations and eruptions are met with in cows which seemingly are in perfect health. The cowman speaks of them as "sore teats," usually applies some local treatment, and neither notifies the Medical Officer of Health nor calls in a veterinary surgeon to treat them. When a veterinary surgeon is called in or meets with the condition, he frequently speaks of it as spurious cow-pox, and attaches no significance to its occurrence. In the considerable number of cases which the writer has come across the cowkeeper has always milked the cows as usual and added the milk to the rest for sale.

The relationship of ulcerated teats to human disease is at present undecided. Systematic bacteriological investigations of sore teat conditions do not seem to have been made.

That teat ulcers may be secondarily infected has been demonstrated in the case of diphtheria, and two outbreaks may be briefly mentioned. Dean and Todd[1] in 1902 described a small outbreak in which undoubted diphtheria bacilli were isolated from the teat lesions and from the milk. In this outbreak certain individuals suffered from diphtheria and others from sore throat, probably diphtheritic. They obtained their milk supply from two cows. The cows were affected with papules and ulcers on the udders and teats, which commenced about ten days before the outbreak. One of the cows also showed mastitis in one quarter, the fluid secreted being scanty, ropy, and semi-purulent in appearance. True diphtheria bacilli which were virulent were isolated both from the lesions and from the milk. A healthy cow milked immediately after the diseased cows and by the same milker developed vesicles upon the teats, but neither in the vesicles nor in the ulcerative stage of the disease could diphtheria bacilli be demonstrated. The investigators also showed that in calves infected with the eruptive disease no diphtheria bacilli could be demonstrated, while injecting a calf with 10,000 units of diphtheria antitoxin did not prevent the vesicular eruption. The authors came to the conclusion that the lesions in the cow were not due to the diphtheria bacillus, but that the latter was a superadded infection.

Ashby,[2] in 1906, described an extensive outbreak of diphtheria, affecting seventy-five persons living in forty-three houses. Forty-two of these houses were supplied by two milkmen. Of the cows of one dairyman (Z.) all the teats of two cows were badly ulcerated, and the teats of three other cows were affected

1 *Journal of Hygiene*, 1902, ii. p. 194.
2 *Public Health*, 1906, xix. p. 145.

to a lesser degree. Six of the cows of the other dairyman (Y.) were affected with an ulcerated condition of the teats. From swabs rubbed into the ulcers upon the teats of the two worst of Z.'s cows diphtheria bacilli were isolated. They

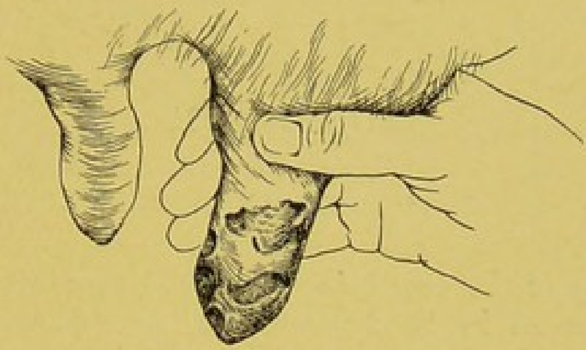


FIG. 3.—Ulcerated Teats.

were fully virulent for guinea-pigs. Cultures from a sample of milk showed only non-pathogenic diphtheria-like bacilli. Ashby adds: "Whether the eruptive disease of the teat was a specific diphtheritic infection of the cow, or whether there was a specific contagious eruptive condition apart from diphtheritic infection, cannot now be told, but certain it is that the diphtheria bacillus was present in the pathological lesions of the cow."

Klein's experimental results in favour of the existence of bovine diphtheria have not been confirmed by either Abbott or Ritter.

Ever since the classical outbreak of scarlet fever at Hendon in 1885 the existence of bovine scarlet fever has been debated. The possibility of such a condition has again become of practical interest since the outbreak of scarlet fever in 1909 in certain parts of London and Surrey was ascribed by Hamer and Jones to a possibly bovine source.

The question of bovine scarlet fever is so technical and involved that if it is to be discussed it can only be profitably done, in some detail. To avoid overburdening the text with what is at most quite a minor portion of the milk problem, it is treated in a separate addendum to this chapter.

ADDENDUM

BOVINE SCARLET FEVER

THE possibility of the cow being an actual source of scarlet fever was first advanced in 1882 by Power[1] as the results of his investigations into the source of an outbreak of scarlet fever in North London. The practical importance of the matter was not, however, fully advanced until after the conclusions of the Hendon outbreak of 1905 had been formulated.

Hendon Outbreak of Scarlet Fever.—This outbreak occurred in N. London in 1885 and affected South Marylebone, St. Pancras, Hampstead, and Hendon. The epidemiological inquiries[2] conducted by Mr. (now Sir William) Power clearly showed that a certain milk supply was at fault, the milk coming from a farm at Hendon with about 90 to 100 cows. Power established that in the four milk districts the disease began at one and the same time, namely, about the end of November or beginning of December. In the district supplied by one of the chief purveyors (Mr. X.) scarlatina continued to attack the consumers day by day, and with increased force up to the date of the inquiry. In the district into which Mr. Y.'s (another purveyor) milk went, after attacking the customers in some numbers for a few days at the end of November and beginning of December, the disease showed no fresh attacks for about ten days (a short but clearly and sharply defined period of intermission); and then about the middle of December attacked the customers again in larger numbers and continued to do so up to the time of the inquiry. A third vendor, Mr. Z., obtained five-sixths of his milk from the Hendon farm, yet there was a total absence of scarlatina from among these customers. Power found that on November 15, three newly-calved cows, purchased from Derbyshire, had been received at the farm. They were quarantined by themselves for some days. Power, after minute inquiry, was able to show that scarlet fever among Mr. X.'s customers appeared soon after the milk of these cows was added to the milk delivered to X., that scarlatina among Y.'s

1 *Report of Medical Officer, Local Government Board*, 1882, p. 63.

2 *Ibid.*, 1885, p. 73.

customers appeared soon after the milk of these same cows was added to the milk delivered to Y., and that the absence of scarlatina among Z.'s customers was correlated to the fact that no milk from these cows was being added to the milk delivered to Z.

As late as December 16, the milk was still capable of causing scarlet fever, as shown by the fact that some given away to poor people in Hendon caused a moderately severe outbreak there.

Dr. Klein visited the farm on December 31, and studied the conditions met with on the cows.[1] It was ascertained that one of the three Derbyshire cows had been the first to suffer from a malady associated with some kind of disease of the udders. From this it spread to many of the other cows. The appearances noted were ulcerations which apparently began as small vesicles and which were covered with a brownish scab. The margins of the ulcers were not raised nor was there any perceptible redness of the skin around. The disease was usually confined to the teats, but in some animals there was also on the lower part of the udder, here and there, an ulcer. The animals were not constitutionally affected, or if so, only very slightly. "As regards the feeding capacity of affected animals, their milking power, and their body temperature, nothing abnormal could be detected." When two of the animals were killed and examined, except some congestion of the lungs and pleural adhesions, very little was found. The kidneys of two of the cows showed glomerulo-nephritis.

Klein carried out certain pathological investigations. Scrapings were made from some of the ulcers on the udder and teats at the stage of their maximum development, and these were inoculated into four calves, the inoculation in each case being into the skin of the groin and the inside of the ear, beneath superficial incisions. In all four cases ulcers with or without vesicles were produced on the area of some of the incisions. The general health of the calves does not appear to have been affected, while the local signs were only at the site of injury, no eruption or ulceration upon teats or udders being recorded.

From the deeper parts of an ulcer upon one of the cows Klein isolated a streptococcus. This grew slowly upon gelatine without liquefaction, grew readily in broth, clotted milk, and microscopically was a streptococcus of variable length. With this streptococcus he inoculated two calves subcutaneously in the groin. One calf was found dead 26 days later with a more or less septicaemic condition, while the other calf was killed after 36 days. Klein traced a similarity between the post-mortem condition of these calves and the post-mortem appearances of the Hendon diseased cows. He also found the condition of the kidneys to coincide with that met with in acute scarlatinal nephritis in man.

[1] *Report of Medical Officer, Local Government Board*, 1885, p. 90.

In a later report Klein[1] recorded further experiments. He injected cultures of the streptococcus which he called *Streptococcus scarlatinae* derived from human scarlatina (either directly or after passage through the calf) into the subcutaneous tissue of the ear of a number of cows. After 4 to 9 days sores and ulcers developed upon the teats. What was taken to be the *Streptococcus scarlatinae* was recovered from the milk of two of the experimental animals. At post-mortem there was found in the affected animals disease of the lungs, pleura, pericardium, lymph glands, spleen, and kidney.

Those who opposed the existence of bovine scarlatina brought forward several very important objections. One of the most important was that 30 cows were purchased at the Derby market, but only 3 went to the Hendon farmer. These other cows showed in many cases sore teats, and spread the disease amongst the herds with which they were mixed. "From the first day to the last, while the milk from these cows was being drunk, no case of scarlatina was heard of among the customers of the dairy."[2] Professor Brown maintained that the Hendon disease was not rare but comparatively common in milch cows.

Power made a special feature of the absence of all possible sources of human scarlet fever. It was subsequently shown that this conclusion could not be maintained, for Axe showed that scarlet fever was present antecedently to and concurrently with the outbreak at Hendon. Cases were present in the Mead, a low-lying street full of laundries and houses tenanted by the poorest inhabitants of the parish. It formed one side of the incriminated farm within which the cows were housed.

The above are the essential pathological and epidemiological data upon which the evidence of the existence of bovine scarlet fever rests. As regards the pathological evidence it cannot now be accepted, in the light of present day bacteriological knowledge, that it is in any way conclusive evidence of bovine scarlet fever. Unless we are prepared to accept the organism described as *Streptococcus scarlatinae* as the organism of scarlet fever all the experiments with such streptococci are not germane to the question of bovine scarlatina. The characters given to this streptococcus are insufficient to differentiate it from the many very numerous types of streptococci now known to be present in both healthy milk and under diseased conditions of udder or teats. With the scanty differentiation tests then available it is not even clear or likely that the same organism was always employed. The experimental work done with the ulcerated teat-scrapings merely

[1] *Report of Medical Officer, Local Government Board*, 1887, p. 203.

[2] *Report on Eruptive Diseases of the Teats and Udders of Cows in relation to Scarlet Fever in Man.* Professor Brown, Agricultural Department, Privy Council Office, 1888.

produced local lesions at the site of inoculation, a not improbable result with such material. The clinical signs of the disease are not in any way sufficient to mark the condition off from similar diseases not very infrequent amongst milch cows. The evidence on which the existence of bovine scarlatina rests is the epidemiological facts elicited by Sir W. Power, and coming from such an acute observer they are entitled to the closest attention. These three cows, and later the others, do seem to have been closely associated with the infectivity of the milk.

Although in other outbreaks subsequent to the Hendon outbreak a bovine origin was suggested, the only one worked out sufficiently in detail to warrant detailed description is the following:

Outbreak of Scarlet Fever in London and Surrey, 1909[1]

An extensive outbreak of scarlet fever in June 1909, which attacked upwards of 400 persons who consumed milk obtained from a particular milk company. The cases attacked were in different parts of London and the county of Surrey. The specific contamination of the milk was very ably traced by Dr. Hamer and Dr. Jones to the milk of one particular farm (called farm X. in the report) in Wiltshire. The facts adduced show clearly that the milk from this farm was the vehicle of infection, but there is room for a difference of opinion as to the precise source and origin of the infection. Hamer and Jones, from their investigations (carried out with the help of Mr. Dunbar, Dr. Mervyn Gordon, and others), came to the conclusion that the source of the outbreak was a morbid condition of one or more particular cows. On the other hand, a human source was possible.

The essential facts bearing upon the precise source of infection are the following: At farm X., which consisted of two farmsteads ($X._1$ and $X._2$), and which was visited six days after the first cases attributed to milk infection, a man (G. L.), his wife, and their three children were all found to be suffering from scarlet fever, although they were at first said to be suffering from German measles. One child had been ill since June 11, and the man had been ill and away from work since the 15th. He acted as carter and auxiliary milker. He was allowed one pint of milk per day from farm X. No human source of infection of this family could be traced.

Dunbar, the veterinary inspector, examined the cows on farm X. on two occasions. He found that most of the milch cows at farmstead $X._2$, and several at farmstead $X._1$, presented scabs and excoriations on the teats and udders; the conditions being similar

[1] *Report to the London County Council*, 1909.

to those first described in 1885 at Hendon. It was further ascertained (but with some obscurity as to precise dates and particulars) that on June 7 the milk of three heifers first came into use. The calf of one of these heifers (the *red* heifer) died four to five days after it was born. All three animals presented distinct evidence of a diseased condition of the teats. The three animals all calved about May 24. The authors of the report are of opinion that the milk of this red heifer was the cause of the outbreak, or as they put it: "The circumstances are highly suggestive of a special pathogenic quality of the red heifer's milk, which may possibly have caused first the death of her calf, and then, on the distribution of the milk in London and Surrey, produced scarlet fever among consumers in those counties. It would appear that June 7, the day on which the red heifer's milk first came into use, was the day on which the milk from the farm first showed evidence of being infective. It is probable that for two or three days the property of infectiousness was confined to the milk of the red heifer; but the roan and white heifers, with which the red heifer had then for some days past been closely associated, must soon have become also involved. The assumption that the infected milk of one or more of these heifers, after being distributed on June 7, 8, 9, and 10, was for one reason or another not distributed on the 11th and 12th, but that it and the milk of other cows which had now become infected was sent to the depot after that date until the time of stopping of the supply from the depot, would afford a satisfactory explanation of the phenomena of the outbreak."

The question of a bovine origin from these cows, or a human origin from the carter, G. L., turns upon several points, of which the most important is the date of origin of the outbreak.

After careful inquiry the writers of the report concluded that the distribution on June 7, 8, 9, and 10, of the milk from farm X. was associated with the development of scarlet fever. Also again on June 13, but not on the 11th and 12th. Since the onset of the infection of the family of G. L. was the 11th to 15th June, they conclude that the milk possessed infective property at least four days before the appearance of symptoms of illness in any member of the milker's family. "It would appear, therefore, that the cases in this milker's family were caused by drinking infected milk from farm X.; in fact, that the milk infected the milker, and not the milker the milk."

The essential fact to justify this conclusion is the date when the milk was first infective. Is the data sufficient to establish the claim that the milk was infective as early as June 7? The chief grounds for fixing this date appear to be contained in the following paragraph: "The information we received in the first instance was to the effect that the earliest cases among this vendor's (*i.e.* vendor A.) customers were not notified until June 18. Further inquiry, however, was made into the matter, and the Medical Officer of Health of the district concerned wrote as follows: 'The doctor who notified nearly all the cases, on the 18th, says that he had several cases of sore throat during the week previous, not followed by rash and not notified. I have also notes of three similar cases where other persons in the house subsequently developed scarlet fever with rash.' The records of milk distributed show that vendor A. received two churns of milk sent from farm X. on June 7; possibly the anomalous character of the early cases among his customers may justify the assumption that the milk possessed on that date a modified infective property as compared with that derived from the same source at a later date." No further evidence is adduced that the sore throat without rash was scarlet fever; we do not know if these cases peeled or not, if they suffered from any scarlet fever complications, or if they had previously suffered from that disease. In view of the great importance of accurately determining the date at which the milk was first infective, it is a singular omission not to furnish more details as to these cases. The fact that the Medical Officer of Health has notes of three similar cases in which other persons in the house developed scarlet fever with rash is, of course, no evidence, since presumably the milk was not stopped, and the latter cases might as reasonably be direct infection from the milk as cases contracted from the sore throat without rash cases. The first *notification* was apparently only made on June 14. The only detailed statement as to cases is in regard to those at Croydon, and in all of these the onset was June 16 or later.

The evidence given in the report as to dates of onset is not sufficient to exclude G. L., the milker and carter, from being the source of the mischief.

In favour of the view that the carter-milker, G. L., was the source of infection, we have the fact that he continued to milk cows up to June 14, when the first case in his family was June 11, and that the 14th of June was the day the milk was the most harmful. The author of the able criticism in the *Journal of Comparative Pathology*[1] supplies another reason for regarding G. L. as the source of the infection. He says: "G. L. had nothing to do with the mixing of the milk, and assuming that he was the sole cause of the epidemic, the only milk infected as it left the farm would be in the churns containing the milk of cows milked by him. As at most he milked only two cows at each farmstead, the chances are greatly in favour of the view that any milk supplied to the milker at farm-

[1] Editorial, *Journ. of Comparative Pathology and Therapeutics*, xxii., 1909, p. 345.

stead $X._2$ would be the milk not contaminated by G. L. The theory that G. L. was the fountainhead of the infection is thus in perfect harmony with the fact that at farmstead $X._1$ the farmer, his wife and her sister, and the foreman milker, and at farmstead $X._2$ the milker, and his family of eight persons, all escaped the disease; whereas the escape of all these persons is very difficult to explain, if it is maintained that the cow diseases discovered at both farmsteads was the source of the infection."

The evidence that this outbreak had a bovine source really rests upon the conclusions of the investigators that no human source could be found, and that the infectivity of the milk was coincident with the use of milk from an animal suffering from sores on teats and udder similar to those found in the Hendon disease. Apart from the fact that such sores and excoriations were found, and that the milk of this herd was causing scarlet fever, there is no evidence, clinical or bacteriological, that they were connected in the relationship of cause and effect, while no evidence was adduced that they might not have been there for a long time previous to the outbreak.

In view of the great difficulty in tracing the sources of isolated cases of scarlet fever, it is of no particular moment that no source of infection for the G. L. family could be found.

The outbreak is an extremely interesting one in view of the possibility of a bovine origin, but the evidence is, in the writer's opinion, insufficient to establish that a bovine origin for the epidemic was the most probable cause.

It would appear that the evidence in favour of the existence of true bovine scarlet fever is insufficient to warrant its acceptance.

The writer[1] has advanced an hypothesis which, in his opinion, offers the best explanation of the outbreaks of scarlet fever and sore throat associated with disease of the cows. This theory is that whenever the cow is a source of scarlet fever or other septic disease it is because it is acting as a carrier of organisms of human origin, often in a purely passive capacity, but sometimes associated with active but *local* disease caused by the human infecting organism. It will be seen that this hypothesis implies the acceptance of two separate conclusions:

(*a*) That the cow may be a source of human disease not because it is constitutionally infective, but because it is acting as a carrier of human pathogenic organisms.

(*b*) That disease of the milk-producing organs of cows is only likely to be harmful to man when the causally associated organisms are of human origin, or when human organisms are superadded as a secondary infection.

[1] *Proceedings of Royal Society of Medicine*, iv., March 1911, Epidemiological Section.

Of course, tuberculosis is not included in this hypothesis. The first conclusion is more capable of proof than the second, and may be accepted without the second being admitted.

Briefly stated, this view regards the bovine udder and teat lesions, as commonly met with, as of purely bovine origin, and, as such, harmless to man. Occasionally, either as an invasion superadded upon the original bovine lesions, or as a primary infection of the milk organs, there is a local infection with organisms of human origin. In such cases the conditions present may be decidedly prejudicial to man. In other words, the cow, in this class of infections, is only potentially pathogenic to man when it acts as a passive carrier of or is actively infected with organisms of *human* origin.

The known facts fit in with this hypothesis:

I. It is clear that the great majority of bovine udder and teat lesions are not harmful to man. As evidence of this we have in the first place the striking disproportion between the prevalence of udder and teat lesions and the recorded outbreaks of human disease ascribed to these conditions. Even allowing for a large number of unrecorded outbreaks and numerous individual cases of illness, the disproportion is very marked. In the second place, the bacteriological investigations recorded above have proved that the commonest type of mastitis is not harmful to man in a healthy condition, and probably not when debilitated. The evidence of the innocuousness of the ordinary type of bovine mastitis is added to by the demonstration of the streptococci causing the condition in abundance in the milk of the clinically unaffected quarters—milk which must, therefore, have been repeatedly added to the vended milk.

II. There is reliable epidemiological evidence connecting at least some sore throat and other human disease outbreaks with affections of the bovine milk organs. The descriptions of these outbreaks in Chapter V. may be referred to for such evidence.

III. There is clear evidence that organisms of undoubtedly human origin *can* in certain cases infect the milk organs of bovines.

The diphtheria instances already recorded offer the most striking evidence of this, because this organism can be readily identified; if the scarlet fever organism could be identified with equal facility, it is probable that similar evidence for that disease would be forthcoming. The outbreak of Dean and Todd is particularly conclusive, since they proved that there was a separate bovine eruption, with the diphtheria bacilli present as a second superadded infection. Klein and Abbott have both demonstrated that diphtheria bacilli, inoculated into calves and cows, could be recovered at the site of inoculation for some time.

Certain of the writer's goat inoculation experiments are very interesting in this connection. The streptococci of human origin, for the most part, died out fairly rapidly when implanted into the teats of goats, but only relatively so; one strain, for example, living for as long as twenty-six days after inoculation. One striking exception was, however, met with. In the case in which the streptococcus isolated from the spleen of a boy who died of acute lymphadenitis was used to infect a goat's teat, it did not set up any inflammation, but survived as a harmless (to the goat) saprophyte for the whole duration of the experiment, extending over seven months. During this period it had not caused any inflammatory changes or alteration in the appearances of the milk, nor had its biological characters become altered except in one particular, and that inconstantly. This streptococcus had originally caused a secondary infection in a boy, with marked elevation of temperature, and, no doubt, largely contributed to his death. We have only to postulate the retention of its virulence for a while, and this goat's milk, if drunk (and it was absolutely normal in appearance), would be a potent disease factor.

It may be suggested that, if we accept this view, the cow would be a much more potent agent for the spread of disease than it now is, seeing the ease with which organisms of human origin can be implanted under present conditions upon cows' teats and udders. This is not likely since, as pointed out, human streptococci for the most part will not grow in or on a bovine habitat. Incidentally it may be mentioned that the opposite is probably also true, since the streptococci of bovine mastitis died out with extreme rapidity in the writer's own throat, although the infection was extremely massive in character.

IV. The above hypothesis offers the best explanation of a number of facts in connection with certain milk-borne sore throat and scarlet fever outbreaks, which otherwise it is extremely difficult to explain. For example, a noticeable feature of some of these outbreaks is the prolonged period during which the milk was serving as a vehicle of infection. If we have a purely human source of infection we should rather expect a very sudden outbreak of short duration, since a human source is not likely to be daily infecting the milk over a long period. In the Guildford outbreak, for instance, the milk was infectious for some seven to eight weeks. While the infection probably started from a human source (the farmer), we cannot, as Pierce points out, account for the prolonged infectivity of the milk, unless we postulate a continuous infection of the cows' milk-producing organs from this human source. The farmer was disabled and unable to milk, etc., for at least a month.

The conflicting views of the Hendon outbreak can be reconciled, and only so, on the above hypothesis. For example:

(*a*) The most telling argument against the bovine scarlatina view, the absence of scarlet fever amongst the rest of the Derby cows, is explainable. On this hypothesis we can accept the view that this outbreak of teat and udder ulceration was very widespread. It was due to a bovine disease of an infectious character to bovines, having nothing to do with scarlatina. Human cases of scarlatina were, therefore, only traceable from such cows when, as in the three sent to Hendon, superadded scarlatinal organisms were present.

(*b*) One of the strongest arguments against a purely human origin was the prolonged infectivity of the milk. The opponents of the bovine origin showed the possibility of human infection. It, however, seems to have been established that none of the milkers or others who came into regular contact with the milk, or the cows, suffered, or had suffered from scarlet fever. The only human infection possible was at the most intermittent, and probably only occurred once or twice. On a well-managed farm, such as this farm was shown to be, to produce prolonged infectivity we must postulate a human factor at work all, or nearly all, the time. There is admittedly not the slightest evidence of prolonged human infection. If, however, we assume that in some now undiscoverable way (possibly in transit to the farm) the already present ulcers and sores of the three cows were infected with the organism of scarlet fever this difficulty vanishes.

(*c*) The most striking fact established by Power in favour of the bovine theory was the definite association of scarlet fever cases with the movements of these three cows. This is obviously explained by the hypothesis of their being locally infective.

(*d*) The opponents of the bovine theory are confirmed in their view by the continued rarity of such conditions. On the hypothesis the rarity of such outbreaks is easily understandable. We have three factors which have to be in operation at once: cows suffering from a bovine disease of the teats and udders, which will allow a secondary infection with the organisms of scarlet fever; the existence of cases of scarlet fever; means of bringing the last condition into intimate relationship with the first.

Klein's results are explainable on the supposition that he was working with the original bovine disease material, and with this he was able to reproduce ulcers and vesicles in inoculated calves.

The suggested hypothesis offers a complete explanation of all the essential facts of the Hendon disease, and reconciles the conflicting views.

Similarly the Glasgow outbreak[1] in 1892, said to be due to the Hendon disease, can best be explained on this hypothesis, particularly as regards the prolonged infectivity of the milk. In this outbreak Klein's results definitely show that an underlying

[1] *Brit. Med. Journ.* 1892, ii., p. 666.

condition of true vaccinia was present in the cows, as well as what he considers to be the virus causing the outbreak.

V. There is also another fact, which may or may not be germane to this subject, but which is very interesting. If the records of milk-borne outbreaks of septic conditions, and especially scarlet fever, are carefully studied, it will be found in a considerable number of them (when the condition has been looked for) that teat ulceration, mastitis, or other local lesions of the milk organs, have been found to be present. This is inclusive of epidemics in which a definite human source of infection has been traced and accepted as a sufficient cause of the outbreak, and where no question of bovine infection has been raised. The writer is of opinion, from his personal experience, that the proportion of cows with ulcerated teats is decidedly higher in the herds of cows from farms implicated in milk epidemics of scarlet fever than for ordinary farms. This higher incidence of lesions may be accidental, but it would seem more probable that a relationship exists, and that the sore teats are not infrequently a nidus for passive infection. That is, given a human milker, actively or passively harbouring scarlet fever organisms, he may, or may not, infect the milk supply, but is more likely to do so if the infection is in the first place conveyed to ulcerated teats, and in this way infects the milk. For one thing, the dose is likely to be larger, and also decidedly less intermittent.

CHAPTER VII

TUBERCULOSIS OF THE COW IN RELATION TO HUMAN DISEASE

By far the most important disease of cows is tuberculosis. This disease as it exists in cows demands very careful consideration on account of its wide prevalence, the frequency with which the bacilli of the disease gain access to milk, and because the disease can be transmitted to man through the cow. The available literature is enormous, and the different aspects of the problem numerous. An attempt has been made to treat the subject with a due regard to the relative importance of the different parts of the question. The administrative control of the disease and the prevention of infection to man is considered in Chapter XVIII.

The Prevalence of Bovine Tuberculosis

The very extensive investigations which have been carried out have shown that tuberculosis of cattle is extremely prevalent in most parts of the civilised world. The prevalence varies greatly from a few small areas of infection up to a condition affecting more than half the number of cows. In a few places, such as the Channel Islands, the disease is unknown in cows, but these cows readily become attacked when they remove to an infected area.

The extent to which tuberculosis is prevalent in cows can only be determined by the use of tuberculin. Writing in 1901, and basing his figures upon the tuberculin test, Dollar [1] remarks that Hunting, who examined 4000 English cattle, found 20 per cent tuberculous, and quotes figures from other countries giving a percentage for Denmark of 31, Sweden

[1] *Trans. British Congress on Tuberculosis*, 1901, vol. iv. p. 44.

42, Norway 8·4, and Belgium 60. In Massachusetts, U.S.A., during 1897, 58·9 per cent of the cases reacted. In Germany the figures varied greatly with the locality. Of 48,172 cows slaughtered in Saxony during 1899, over 35 per cent were tuberculous. The older the animal the higher the percentage. Thus, of 14,684 cows over four years old slaughtered in Berlin, 14,556, or 99 per cent, were tuberculous. The lesions, of course, were in some cases trifling, only the bronchial glands being affected. These last figures were, however, founded upon macroscopic examination in slaughter-houses. With the tuberculin test the proportion would be even higher.

Delépine[1] in 1897-99 tested 128 cows with tuberculin. Of these, 37 (30 per cent) were tuberculous. In the testings carried out at Aberdeen in 1899, out of 137 cows tested, 37 were tuberculous.

The tuberculin test has not been used very extensively in this country, but it is probably safe to assume that 25 to 30 per cent of cows in this country are suffering from tuberculosis.

Apart from local incidence of the disease, one important factor influencing the amount of tuberculosis is the age of the cow. Older cows are much more likely to show evidence of tuberculosis. Bang,[2] for instance, records that during the years 1898-1904 careful examination of 40,624 head of cattle in Denmark, subjected to the tuberculin test for the first time, showed that of calves under six months 12·1 per cent reacted; of yearlings (from six to eighteen months) 27·5 per cent; of two-year-olds (from 1½ to 2½ years) 38·6 per cent; of full-grown animals (from 2½ to 5) 44·9 per cent; and of animals over five years 48 per cent—figures which correspond with the results of tuberculin tests in other countries as well as with the experiences of slaughter-houses.

When the infection was introduced through milk, as when calves were fed upon tuberculous skim milk, Bang noted that while the cows were often very healthy, it was the calves or the young cattle which reacted; sometimes the peculiar fact might be observed that only animals of the same age—for instance, yearlings or two-year-olds—reacted; and when

1 *Report of Medical Officer, Local Government Board*, 1908-9, p. 402.

2 *Transactions Internat. Congress on Tuberculosis*, 1908, vol. iv. part ii. p. 850.

this happened, the heating apparatus of the dairy was found to have been out of order just at the time when milk was supplied to the set of animals that had reacted.

From the practical point of view in relation to human infection, the essential point to consider is the extent to which these tuberculous cows yield tubercle bacilli in the milk. Up to a few years ago it was generally accepted that tubercle bacilli were only found in milk when tuberculosis of the udder was present. This is now known not to be the case, and tubercle bacilli may gain access to the milk from cows which neither clinically nor on post-mortem examination present any signs of udder disease. We owe our knowledge upon this matter largely to Mohler and Schroeder in America, and more recently to the last Royal Commission on Tuberculosis in this country. Some of Mohler's[1] conclusions were as follows :

The tubercle bacillus may be demonstrated in milk from tuberculous cows when the udders show no perceptible evidence of the disease, either macroscopically or microscopically.

The bacilli of tuberculosis may be excreted from such an udder in sufficient numbers to produce infection in experimental animals both by ingestion and inoculation.

The presence of the tubercle bacillus in the milk of tuberculous cows is not constant, but varies from day to day.

Cows secreting virulent milk may be affected with tuberculosis to a degree that can be detected only by the tuberculin test.

The physical examination or general appearance of the cow cannot foretell the infectiveness of the milk.

The milk of all cows which have reacted to the tuberculin test should be considered as suspicious, and should be subjected to sterilisation before using.

Schroeder[2] came to very similar conclusions. He found

. . . among tuberculous dairy cows that retain the appearance of health and are not known to be affected until they are tested with tuberculin, 40 per cent or more actively expel tubercle bacilli from their bodies in a way dangerous to the health of other animals and persons.

The general evidence justifies the conclusion that tuberculous cows do not expel tubercle bacilli until some time after they contract the affection.

Dairy cows that have been affected with tuberculosis three

---

[1] *Bulletin No. 41, Bureau Animal Industry U.S. Dept. Agriculture*, 1903.
[2] *Circular 118, Bureau Animal Industry U.S. Dept. Agriculture*, 1907.

years or more, with possibly rare exceptions, are active agents for the dissemination of tubercle bacilli.

The English Royal Commission on Tuberculosis[1] reports similar results. Their experiments were made with the milk of 6 cows which had contracted tuberculosis in the natural way. Three of the animals showed clinical signs of tuberculosis, but in none of the 6 could tuberculosis of the udder be detected during life.

The faeces of all 6 cows, obtained under conditions precluding contamination from the genito-urinary passages, were used to inoculate guinea-pigs and to feed guinea-pigs and young pigs. The faeces of 5 of these animals were found to contain living and virulent tubercle bacilli. The three which were suffering from severe tuberculosis were eliminating large numbers of tubercle bacilli. This was shown by the occurrence of tuberculosis after the inoculation of very small doses of faecal matter in all but one of the guinea-pigs which survived a sufficient length of time, and by the fact that all the swine fed became tuberculous.

The milk of 5 of the cows was used to inoculate guinea-pigs, some rabbits, and some young pigs. The milk of 2 of these animals (both severely diseased) caused, though not invariably, tuberculosis in guinea-pigs inoculated with relatively small doses. Post-mortem, the udders revealed no signs of tuberculosis. The milk of a third cow caused severe tuberculosis in every guinea-pig inoculated, but the animal was very ill at the time the milk was collected, while post-mortem, four small nodules were present in one quarter of the udder. The milk of the remaining 2 cows did not give rise to tuberculosis in any of the animals inoculated. Both were suffering from tuberculosis of lungs and mediastinal glands.

The Commissioners sum up the matter in regard to tuberculous cows with no udder disease by saying:

> Cows suffering from extensive tuberculosis of the lungs must discharge considerable numbers of bacilli from the air passages in the act of coughing, and some of the bacilli thus expelled may find their way into the milk. But our experiments indicate that the excrement of cows obviously suffering from tuberculosis of the lungs or alimentary canal must be regarded as much more dangerous

[1] *Third Interim Report*, 1909.

than the matter discharged from the mouth or nostrils. We have found that even in the case of cows with slight tuberculous lesions, tubercle bacilli in small numbers are discharged in the faeces; while as regards cows clinically tuberculous, our experiments show that the faeces contain large numbers of living and virulent tubercle bacilli.

The Commissioners also found that the inoculation of large doses of tubercle bacilli, human or bovine, may result in the excretion of tubercle bacilli in the milk of the cow and of the goat without any disease of the udder being produced, and that in the case of the human tubercle bacillus these bacilli may, when large doses are employed, be present in their milk for a long time after inoculation.

The same important fact has also been demonstrated by investigators abroad. For example, Rabinowitch and Kempner examined the milk of 14 cows all reacting to tuberculin, but only one of which exhibited clinical signs of udder disease. Ten out of these 14 cows showed tubercle bacilli in the milk. Also De Jong[1] examined 10 slightly affected tuberculous cows, but clinically healthy, and found 3 which were excreting tubercle bacilli through healthy udders.

These results prove indisputably that tubercle bacilli may and do gain access to milk from cows which clinically show no signs of udder tuberculosis or indeed of any form of tuberculosis. While this fact is of immense importance, it is yet possible to exaggerate its significance. Infection with the tubercle bacillus is largely a question of dosage, and while all tuberculin-reacting cows must now be looked upon as possible sources, and all cows with "open" tuberculosis as actual sources of tubercle bacilli in milk, yet the available evidence shows that *extensive* infection of the milk with the bacilli of tuberculosis is mainly from cows either marked "wasters" or those suffering from tubercular infection of the udder.

On this account chief significance must still be attached to the cows with udder tuberculosis, and information as to the prevalence of this condition is most important. Distinguished veterinary authorities do not altogether agree on this point, but the general consensus of opinion is that about 2 per cent of cows suffer from a tuberculous udder.

[1] *Fortschritte der Medizin*, 1908, vol. xxvi., Sept. 20.

The following figures from the *Transactions of the British Congress on Tuberculosis* (1901), vol. iv., may be quoted in connection with this estimate. Stockman examined 1312 cows and found 28 with lesions of the udder. The cows were slightly selected, so this percentage was probably too high. "However, I do not think it is much below 2 per cent." Sir J. McFadyean concluded that probably 2 or 3 per cent of the cows in the country have tuberculosis of the udder. Nocard remarked, "Tuberculous mammitis is a rare lesion, and not seen in more than 2 per cent of tuberculous cows." Dewar remarked, "Increased experience leads me to believe that the number of tuberculous cows affected with tubercle of the udder is greater than that usually estimated, *i.e.* about 3 per cent. Apart from cows that are only recognised as tuberculous through the action of tuberculin, I think the percentage would be from 5 to 7."

On the other hand, Penberthy[1] thinks this estimate of 2 per cent of tuberculous udders in cows is too high. He mentions that in the county of London there are about 4000 cows kept, and about 12 cases of mammary tuberculosis are discovered annually (0·3 per cent), while 3 per cent of the cases of tuberculosis in cows slaughtered at Islington have tuberculous udders, and taking 25 per cent as representing the proportion of tuberculous to non-tuberculous cows, this works out at 0·75 per cent. He quotes other figures from Glasgow, Sheffield, Leeds, and Liverpool. It is, however, probable that in large towns with rigid inspection cases of udder tuberculosis would be promptly sold out of the town, and this selective action would also in part operate as regards animals sent in for slaughter.

In Chapter XVIII. p. 333, the actual percentage of cows found by the Manchester and Sheffield veterinary inspectors is given for a number of years.

Dr. Hope[2] records that, during the years 1901-9 inclusive, 4919 cows in cowsheds outside the Liverpool city boundaries were examined. Of these, 104 (= 2·1 per cent) cows were suffering from or suspected to be suffering from tuberculosis of the udder. It is not explained, however, what exact proportion of these cows were definitely proved cases of udder tuberculosis.

Sir Shirley Murphy[3] gives the following figures:

	Last 6 months 1908.	1909.
Outside London farms inspected . .	190	439
Number of cows examined . . .	4997	11,004
Number of cows with tuberculous udders	147	219
Percentage of cows found to have clinical symptoms of tubercular disease of the udder	2·9	1·98

[1] *Journ. Royal Institute of Public Health*, 1907, vol. xv. p. 577.
[2] *Annual Report, Liverpool*, 1909, p. 184.
[3] *Annual Reports, London County Council*, 1908 and 1909.

In illustration of the close relationship between the presence of tubercle bacilli in the milk and the presence of a case of udder tuberculosis in the herd, the investigations of Delépine,[1] dealing with the inoculation of milk samples from Manchester and the surrounding districts, may be cited. Out of 1385 farms 294 were found to be supplying tuberculous milk. In consequence of this fact 276 of these farms were inspected, and in 190 of them the veterinary surgeon, *with the help of the bacteriologist*, was able to discover one or more cows with tuberculous udders. After the removal of those cows the milk generally ceased to produce tuberculosis in guinea-pigs when examined on one or more occasions afterwards. In the remaining cases (about 31 per cent) the source of infection could not be found. From the inquiries made at these 86 farms Delépine found that in at least 32 cases cows had been sold between the time of collecting the sample and examining the cows; in others, the farmer had been buying milk from other sources. From his inquiries he believes that in most of these cases the source of the tubercle bacilli was from a cow not on the farm, and gives as his estimate the following:

	Per cent.
Tuberculous udders the cause of infection . . .	78·6
" " probably the cause of infection .	16·0
Nothing definite to connect infection with the state of the cow	5·2

The fact, however, remains, that in 31 per cent of the cases a cow with a tuberculous udder was not found, and its presence could only be deduced with more or less probability in a number of the cases. It is unfortunate that the mixed milk from each of the herds which gave tuberculosis to guinea-pigs, but which contained no cow with a tuberculous udder, was not re-inoculated to see if it could then set up tuberculosis.

While these results emphasise the great significance of the tuberculous udder, the writer reads them as also showing the infectivity of milk without udder lesions, and to a greater extent than Delépine admits, the more especially as the diagnosis of udder tuberculosis was made with the assistance of the bacteriologist.

[1] *Report of Medical Officer, Local Government Board*, 1908-9, p. 341.

The results in other areas with similar legal powers are not nearly so favourable. In particular the Sheffield results may be quoted. In connection with the Sheffield milk clauses, samples have been taken for a number of years from milk reaching the city from outside areas. These are bacteriologically examined, and when tubercle bacilli are found the farms supplying the particular milk samples are visited by a skilled veterinary inspector. When in following up such positive samples no cows can be found exhibiting signs of tuberculosis of the udder, what is called a *control* sample is taken to check the veterinary examination. Such samples are therefore samples of the mixed milk of herds of cows without clinical signs of tuberculosis. The number taken and results of the examinations were as follows:

Year.[1]	Number of Control Samples taken.	Number Tuberculous.	Percentage Tuberculous.
1902	1	...	...
1903	7	...	...
1904	11	3	27·3
1905	17	6	35·3
1906	8	1	12·5
1907	39	8	20·5
1908	62	7	11·2
1909	56	8	14·3
1902–1909	201	33	16·4

In other words, in 16·4 per cent of cases, on an average, tubercle bacilli were found in milk produced by cows passed by a skilled veterinary inspector specially on the look-out for the condition as free from udder tuberculosis. It is not possible to say what proportion of this was due to early and unrecognisable udder tuberculosis.

Dr. Renney[2] writes me that, as regards Sunderland, in quite a large proportion of cases the cows from farms supplying tuberculous milk appear to be in first-class condition, and it was not possible to single out any particular cow which was likely to be affected with the disease.

[1] *Report of Medical Officer of Health, Sheffield*, 1909, pp. 46-47.

[2] Personal communication to the writer.

It is evident from these facts that veterinary inspection of cows, even if repeated frequently and conducted by officers of the highest clinical skill, is, apart from bacteriological examination, a safeguard which is insufficient to prevent tubercle bacilli from gaining access to the milk.

That extremely small quantities of milk from cows suffering from udder tuberculosis may set up tuberculosis in guinea-pigs is shown by the investigations of Ostertag, Ostermann, etc. Ostertag[1] tested the milk of ten cows suffering from udder tuberculosis as regards its capacity to set up tuberculosis when inoculated into the guinea-pig. In every case the undiluted milk set up the disease, while dilutions of the milk as great as 1 : 10 million, 1 : 1000 million, 1 : 10,000 million set up tuberculosis in guinea-pigs in individual cases. Ostermann[2] tested the milk of two tuberculous cows. With the milk of the first cow dilutions of 1 : 1000 and 1 : 5000 set up tuberculosis, but dilutions of 1 : 10,000 and over were ineffective. With the milk of the second cow dilutions of 1 : 5000, 1 : 10,000, and 1 : 50,000 were positive, while 1 : 25,000 was negative. 1 c.c. of the dilution was inoculated in each case. Delépine records that 0·0002 c.c. of milk from a cow with advanced udder tuberculosis set up tuberculosis in a guinea-pig. Greater dilutions were not tried.

These results show the variable number of bacilli in cases of udder tuberculosis, and the very large numbers which may be present.

The detection of bovine tuberculosis may be carried out in three ways: clinical examination, bacteriological diagnosis, and by the use of tuberculin.

Clinical Diagnosis.—This is not the place to discuss the symptoms of tuberculosis in cows, and books on veterinary practice must be consulted. The clinical diagnosis of all but well-marked cases is generally recognised as impracticable. As one veterinary authority[3] has put it: "The clinical diagnosis of tuberculosis even by the most expert clinical examiner, except in advanced cases, is always unreliable, as

[1] *Zeitschrift für Infektionskrankheiten der Haustiere*, 1905.
[2] *Ibid.*, 1908, vol. lx. p. 410.
[3] McEachran, *Trans. British Congress on Tuberculosis*, 1901, vol. iv. p. 111.

tubercle bacilli may exist in such a state as would be impossible of diagnosis by this means."

In view of the stress which has been laid by some writers upon the sufficiency of systematic veterinary inspection to safeguard the purity of milk, it is very important to recognise that the diagnosis of early tuberculosis of the udder is often extremely difficult. For example, Dewar says:[1] "In the udder the progress of the disease is often slow, and there is no doubt but it may exist for weeks in such a condition as to render the milk dangerous before the most expert clinician could detect its presence." Nocard[2] remarks that the diagnosis of tuberculous mammitis is "both urgent and difficult; the clinical symptoms are vague, and generally point to a range of probabilities which are more or less certain. Even if the cow has reacted to tuberculin, it does not necessarily follow that the induration of its udder is tuberculous, for tuberculous cows, as well as healthy ones, are liable to contract mammitis of various natures."

Bacteriological Examination.—The utility of this method will depend upon the nature of the tuberculosis with which the animal is affected. In "closed" tuberculosis, of the glands for example, direct bacteriological examination is of no assistance. For "open" tuberculosis, by which is meant tuberculosis of organs communicating with the exterior, whereby tubercle bacilli are discharged outside the animal body, bacteriological examination of the vaginal secretion, faeces, etc., may be of marked diagnostic value. This method is of fundamental assistance in the diagnosis of udder tuberculosis, and this variety of the disease can be diagnosed with great certainty by bacteriological examination of the milk (drawn off without contamination) and injection into guinea-pigs.

The diagnosis of tuberculosis by the agglutination test has been introduced by Arloing, but the practical difficulties are considerable, and the method has not been adopted as one of wide applicability.

By the Use of Tuberculin.—Tuberculin (Koch's old tuberculin) is prepared by growing tubercle bacilli in glycerine veal

1 *Trans. British Congress on Tuberculosis*, 1901, vol. iv. p. 3.
2 *Ibid.* p. 8.

broth for some months, filtering out the bacilli through porcelain, and evaporating to one-tenth its bulk. It is therefore essentially a concentrated glycerine solution of the extra-cellular toxins of the tubercle bacillus.

The nature of the test rests upon the fact that when tuberculin is injected into a healthy animal no constitutional disturbance takes place, but if the animal is affected with tuberculosis a considerable rise of temperature and other constitutional effects are manifest.

To carry out the test properly requires skill and attention. The temperature of the cow is taken on several occasions beforehand to ascertain the normal temperature of the animal. A variation of 1½ degrees F. may be met with in animals in perfect health. The tuberculin is injected subcutaneously during the evening of the day on which the preliminary temperatures have been taken, and so as to allow an interval of about 10 hours before next morning's milking. The temperature is taken every 2 hours from the 10th to the 18th to 20th hour after the injection. The more numerous the temperature takings the less liability of error. Some practical veterinary surgeons take only 3 or 4 temperature records after injection. The cows should be under as quiet and natural conditions as possible during the test. A rise of 2·0 degrees F. above the normal, if gradual and distributed over a time period of several hours with gradual decline, indicates a positive reaction. A sharp brief rise and fall of the temperature does not constitute a positive reaction. Some authorities regard a rise of 1·5 degrees as constituting a positive reaction, others consider a rise of no more than this as merely suspicious.

The Chicago tuberculin test ordinance requires: "The temperature shall be taken at least 4 times on the day preceding the inoculation, and at least 6 times on the day following the inoculation, at not less than 2 hour intervals. A rise of 2 degrees over the average temperature on the day preceding the inoculation shall be considered a positive test. If a rise of from 1½ degrees to 2 degrees is obtained, the results shall be considered doubtful, and the animal subjected to a later retest."

I am enabled by the kindness of Sir John McFadyean to give the following examples of reactions to tuberculin, all from the one herd:

Animal.	Initial Temperature (F.)	12th hour.	15th hour.	18th hour.
A	101·8	105	105	105
B	101	106	105·5	105
C	102·8	105·5	106·5	106
D	101	105	104·5	104·5
E	101	105	105	105
F	101·2	103·5	104·5	104

Carried out properly the tuberculin test is extremely reliable, the error not being more than about 3 per cent. The test, however, requires to be carried out by a veterinary surgeon,[1] while there are several sources of error.

Sources of Error.—1. Cattle may be tested in an unsuitable condition. The cows, for example, should not be tested directly after such general disturbances as removal to fresh sheds, travelling, exposure to hot sun, or marked changes of food. The test should not be applied within a few days before or after calving, nor while in "heat."

2. Defective tuberculin may be used.

3. Animals suffering from advanced tuberculosis may fail to react. This error is readily obviated by clinical examination.

4. The animal may have been previously treated with tuberculin. This is usually done fraudulently. The first injection must be recent to be a source of error, as after a month from the first injection it is unusual to find the animal not reacting.

5. The animal may be infected with tubercle bacilli, but owing to insufficient time no lesions may have developed. Such an animal will fail to give a reaction, but will subsequently do so.

6. The lesions may be very slight and difficult to find, so that a reacting animal post-mortem may, on insufficient examination, fail to show signs of tuberculosis.

[1] A feature of the Wisconsin, U.S.A., system for the control of bovine tuberculosis is that many of the tuberculin tests are performed by the farmers themselves. The farmers must, however, have undergone training and instruction in the work at the Agricultural College. Also they are not allowed to make the diagnosis, only to carry out the inoculations and record the temperatures on a chart. The actual diagnosis is made by the authorities at the Wisconsin Experiment Station from the records received from the farmers.

This is not really a source of error, it only appears to be one. These instances usually occur among animals for which extensive dissection is impracticable owing to their having to be dressed for sale.

Nocard,[1] a strong supporter of the tuberculin test, makes this very clear. He remarked: "Speaking for myself I have, up to now, personally and publicly performed 500 autopsies of animals which had reacted to tuberculin. In three cases only have I failed to find the lesion sought for; but sometimes it has taken a long time, half-an-hour, three-quarters of an hour, and more, before I could put my hand on some miliary granulations buried in the depth of the lung or scattered in the thickness of a lymphatic gland."

Stated another way, it is sometimes objected to the test that it is too sensitive and detects even the slightest and most latent cases of tuberculosis. From the point of view of clearing a herd of tuberculosis it is very necessary to recognise that these early and latent cases will, almost all eventually and some rapidly, develop into marked cases which will extend the disease and become a source of infection to the milk.

The above sources of error can, for the most part, be guarded against, and rather illustrate the need for care in using the test than any unreliability in the test itself.

During the last few years additional tests have been advocated for the diagnosis of tuberculosis in both man and animals. Those include the ophthalmo-tuberculin test and Von Pirquet's skin reaction test. These tests appear to be of but limited value in the diagnosis of bovine tuberculosis, but extended experience is desirable.

The Methods of Spread of Bovine Tuberculosis

Infection is usually introduced into a herd by the addition of an animal suffering from tuberculosis. The infectivity of the introduced animal will depend upon the extent to which it is excreting tubercle bacilli. From this point of view reacting tubercular cows may be divided into three groups: (*a*) slight cases reacting to tuberculin, but

[1] *Trans. Br. Congress on Tuberculosis*, 1901, vol. iv. p. 10.

with lesions not communicating with the exterior, so that no tubercle bacilli are excreted; (*b*) cows apparently healthy but suffering from "open" tuberculosis and as such excreting tubercle bacilli; (*c*) cows with distinct clinical tuberculosis.

The last group is the source of most massive infection, but the second, being usually unrecognised, may have the greatest range of infectivity. The actual channels of infection are apparently sometimes through the respiratory and sometimes through the digestive tract. The opportunities for infection will vary with the condition of the byre and the degree of association of the cows in it. In well-lit, well-ventilated, and properly constructed byres with well looked after animals the chances of infection are of course reduced. Delépine, for example, records that a larger number of samples of milk containing tubercle bacilli were obtained from farms in an insanitary condition.

In addition to direct infection from cow to cow there is another, much less common, but very dangerous method of spread: this is from the use of skim-milk infected with tubercle bacilli to feed calves. In cases in which the skim-milk is returned from a milk factory or creamery, very wide-spread infection may in this way result.

Russell[1] records a very interesting illustration of this method of spread in Wisconsin State, U.S.A. It was the practice of cowkeepers supplying creameries to take back the skim-milk to feed the calves. This skim-milk is mixed indiscriminately at the creamery, and thus affords a ready means for disseminating any pathogenic bacilli in the milk from one herd to another. By means of the tuberculin reaction Russell studied the distribution of tuberculous cows in the areas of certain creameries. These creameries received their milk from a number of different cowkeepers, and by separating the figures for the different creameries he obtained definite evidence of infection through the skim-milk. This is seen in the following table, which shows that 34·5 and 24·0 per cent of the cows in connection with the Medina and Oak Park creameries were tuberculous, as compared with 8·5 and 10·0 per cent from other creameries. In the case of the two infecting creameries nearly all the animals were raised on the

[1] *Wisconsin University, Agricultural Experiment Station Bull.* 143, 1907.

farm, while the greater part of those reacting in groups A and B had been purchased from outside sources.

Summary of Tuberculin Tests.

Creamery.	Number of Herds tested.	Number of Herds reacting.	Number of Animals tested.	Number of Animals reacting.	Per cent affected.	Results of Slaughter.	
						Number passed.	Number condemned.
Medina	36	33	784	271	34·5	105	123
Oak Park	24	14	429	103	24·0	34	61
Group A	66	42	1249	106	8·5	...	...
„ B	12	8	218	21	10·0	...	...

Group A = a group of 7 creameries immediately adjacent to Medina and Oak Park.

„ *B* = a group of 4 creameries near but not contiguous to Medina and Oak Park.

Of the 184 animals condemned after slaughter as many as 110 showed invasion of lymph glands of body cavity or liver.

The Prevalence of Tubercle Bacilli in Dairy Produce

Milk.—The table on page 332 shows the percentage of tubercle bacilli found in a number of milk samples as supplied to a number of the large cities in England.

The milk supply of the smaller areas appears to be no better, in fact it is probably infected with tubercle bacilli even more extensively. For example, out of 28 samples of milk supplying Wakefield[1] 4 contained tubercle bacilli, a percentage of 14·3. Kanthack and Sladen[2] examined the milk supply of the different colleges in Cambridge. Milk from 16 dairies was examined, 3 specimens being collected from each. Nine of the 16 dairies showed tubercle bacilli in the milk, as demonstrated by guinea-pig inoculations.

Investigations in other countries show an equally high percentage of tubercle bacilli in market milk. In Washington[3]

[1] *Medical Officer*, Sept. 3, 1910.

[2] *Lancet*, 1899, vol. i. p. 74.

[3] *Bulletin No. 41, Public Health and Marine Hospital Service, U.S.A.*, 1908, p. 191.

11 samples of milk from 102 dairies contained tubercle bacilli (10·7 per cent). Hess[1] examined samples of New York raw market milk. Excluding cases in which the guinea-pigs died without results being obtainable, out of 107 samples 17 (16 per cent) set up tuberculosis in the animals.

In Germany very similar results have been obtained. For example, Petri, in 1898, found 14 per cent of Berlin milk containing tubercle bacilli, and Beck in 1900 found 30·3 per cent infected. In Leipzig, Eber, in 1908, found 10·5 per cent positive.

Butter.—The investigations of numerous workers have proved that tubercle bacilli are not infrequently present in butter. The proportion of samples in which they have been found to be present has varied considerably in the different investigations. For some of them, particularly the earlier work, it is not clear that the lesions produced by the acid-fast butter bacillus were in all cases clearly differentiated from those produced by the tubercle bacillus; but with due allowance for this, it is evident that the proportion of butter samples containing virulent tubercle bacilli is a high one.

No English results are available to the writer, but the following are a few examples out of many Continental ones.

A number of examinations of Berlin butter have been made from time to time. Obermüller, in 1897, examined 14 samples and found tubercle bacilli in all of them. Rabinowitsch, in 1897, examined 30 Berlin butters and failed to find tubercle bacilli in any of them. In the same year she examined 50 samples of Philadelphia butter, all also with negative results. In 1899, however, the same investigator, out of 15 Berlin butters, found 2 to contain tubercle bacilli (13·3 per cent). In 1898 Hormann and Morgenroth found 4 out of 13 Berlin butters to contain virulent tubercle bacilli (30·7 per cent).

In other towns similar results have been obtained. Thus Reitz, in 1906, found 8 out of 96 samples of Stuttgart butter to contain tubercle bacilli (8·5 per cent). Roth, in 1894, found tubercle bacilli in 2 out of 20 samples of Zurich butter (10 per cent), and Tobler, in 1901, found tubercle bacilli in 2 out of 12 samples of Zurich butter (16·7 per cent). Eber,

[1] *Trans. 6th International Congress on Tuberculosis*, 1908, iv. pt. ii. p. 523.

in 1908, examined 150 samples of Leipzig butter, and in 18 found tubercle bacilli (12 per cent).

Cheese.—Hormann and Morgenroth found tubercle bacilli in 3 out of 15 samples, Rabinowitsch in 3 out of 5 samples, Harrison in 3 out of 5 samples, and Eber in 2 out of 50 samples.

Bovine Tuberculosis as a Cause of Human Disease

The relationship of human to bovine tuberculosis is a subject which has been much discussed, but which may now be said to rest on a fairly sure basis. The earlier conception assumed a nearly complete unity between the tuberculosis of man and of cattle, based upon the histological identity of the lesions and the close similarity of the bacilli obtained from the two sources. This view was very clearly expressed and emphasised by the Royal Commission on Tuberculosis, who, in their *Report* (1895, Part i.), stated:

> We find the present to be a convenient occasion for stating explicitly that we regard the disease as being the same disease in man and in the food animals, no matter though there are differences in the one and the other in their manifestations of the disease; and that we consider the bacilli of tubercle to form an integral part of the disease in each, and (whatever be its origin) to be transmissible from man to animals, and from animals to animals.

Investigators had pointed out from time to time certain differences of virulence, morphology, etc., while in particular, in 1896, Theobald Smith drew attention to differences of morphology, cultural characters, and virulence between the bacilli derived from human and bovine sources. In particular he showed that human tubercle bacilli inoculated into cattle produced either no tuberculosis or only local non-generalised lesions. The view of the inherent identity of the bacilli from animal sources was, however, generally accepted until 1901, when Koch, at the British Congress on Tuberculosis, lent the weight of his unique authority to the conception that human and bovine tuberculosis are, for practical purposes, distinct diseases, and that the cases in which human infection results from bovine tuberculosis are so rare that special methods against bovine tuberculosis are not required.

The immense practical importance of the subject led to the prompt appointment of another English Royal Commission on Tuberculosis (still sitting, 1911), while fresh investigations to settle the matter were undertaken in many other parts of the world. The general result has been to unmistakably demonstrate that bovine tuberculosis is a source of human tuberculosis. The most conclusive evidence of this fact is set out in the reports giving the very careful and valuable work of the English Royal Commission.[1] Their conclusions and facts, as far as they bear upon this specific matter, and as far as they are yet published, are 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.
>
> 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 milk ought never to be used as food.

In their Final Report (1911) they are even more definite, and state:

> . . . There can be no doubt that a considerable proportion of the tuberculosis affecting children is of bovine origin, more particularly that which affects primarily the abdominal organs and the cervical glands. And further, there can be no doubt that primary abdominal tuberculosis as well as tuberculosis of the cervical glands is commonly due to ingestion of tuberculous infective material.

The important and extended work done by Dr. Nathan Raw deserves mention in this connection.

Raw, in 1903[2] and in subsequent communications, very clearly expressed the view that while human and bovine tuberculosis are separate and distinct diseases, the human body is susceptible to both, and especially to bovine tuberculosis in the early period of life. He based this opinion almost entirely

1 *Royal Commission on Tuberculosis, Second Interim Report*, 1907.

2 *British Medical Journal*, 1903, i. p. 596.

on clinical and pathological evidence. In his opinion, such diseases as Tabes mesenterica, tuberculous glands in the neck, etc., were of essentially bovine origin.

The communicability of the bovine bacillus has been also shown by numerous other investigations. The valuable work of Hamilton and Young in this country may be specially mentioned. Additional evidence is also forthcoming from the numerous recorded cases in which there has been direct evidence of infection of man from bovine sources, generally from accidental inoculation.

From the numerous investigations it has now been established that there are two chief types of tubercle bacilli—a bovine type and a human type—which are differentiated by their cultural characters, and especially by the different pathogenic properties. In brief, the bovine type grows with a scantier growth and with greater difficulty upon artificial culture media, but is much more pathogenic, causing local and generalised tuberculosis when inoculated into bovines, and acute tuberculosis when intravenously injected into rabbits. On the other hand, the human type does not, as a rule, cause tuberculosis in rabbits, and only a localised and retrogressive tuberculosis when inoculated into bovines. These differences are set out in greater detail in Chapter XIII.

How far the two types are simply varieties evolved by environment cannot be said to be yet established, but from the occurrence of intermediate types, gradations being met with between the extremes of the two types, from the fact that the differences are of degree rather than kind, and from the fact that some investigators have been able to considerably modify the human type by passage through animals so that it acquires many of the characters of bovine bacilli, the evidence is in favour of a common origin and an essential unity of the two types.

The Tuberculosis Commissioners sum up the matter as one concerning which there is room for difference of opinion, and add: "We prefer to regard these two types as varieties of the same bacillus, and the lesions which they produce, whether in man or in other mammals, as manifestations of the same disease."

From the available evidence it may be accepted that a certain proportion of the cases of human tuberculosis are due to infection of the human body with tubercle bacilli of bovine origin. The exact proportion is still a matter of dispute and uncertainty. A large number of facts have, however, been ascertained which give some idea of the probable amount of tuberculosis of bovine origin in man.

The English Royal Tuberculosis Commission (1901-11)[1] investigated 108 cases of human tuberculosis other than lupus. The following is a tabular summary of their results:

Nature of Cases.	Number investi-gated.	Tubercle Bacilli isolated.		
		Bovine Viruses.	Human Viruses.	Mixed Viruses (Bovine and Human).
Primary pulmonary tuberculosis	14	0	14	0
Sputum from individual cases of pulmonary tuberculosis .	28	2	26	0
General tuberculosis . .	3	0	3	0
Tuberculous meningitis . .	3	0	3	0
Bronchial gland tuberculosis .	5	0	3	2
Cervical gland tuberculosis .	9	3	6	0
Primary abdominal tuberculosis	29	14	13	2
Joint and bone tuberculosis .	14	0	13	1
Tuberculosis of testicle, of kidney, of suprarenal (1 case of each)	3	0	3	0
	108	19	84	5

In connection with these results the Commissioners remark:

Although the bovine tubercle bacillus may, as it appears, be solely responsible for certain cases of pulmonary tuberculosis (consumption), and though it may be present with the human tubercle bacillus in the bronchial glands, it is evident from the data recorded that the majority of cases in which the bovine tubercle bacillus is the infective agent in the human being are cases of alimentary tuberculosis. Such are cases of cervical gland and primary abdominal tuberculosis. In the latter class of cases at least the tubercle bacillus has unquestionably been swallowed. Received in this way the tubercle bacillus, whether human or bovine, may pass through the pharyngeal or buccal mucous membrane and infect the

[1] *Final Report*, 1911.

cervical glands, or getting into the small intestine it may produce several different lesions, such as ulceration of the gut, tuberculosis of the mesenteric glands attached, and of the peritoneal covering. The percentage of these cases of alimentary tuberculosis due to the bovine tubercle bacillus is very large. Taking both classes of cases (cervical gland and abdominal) together, numbering 38, there are 17 in which the bovine bacillus alone was found, 19 in which the human bacillus alone was found, and 2 in which both were found. Taking the primary abdominal cases alone it is seen that in 16 out of 29 the bovine bacillus was found; in 14 of these it was the sole infective agent present.

The German Tuberculosis Commission[1] examined 56 cases of human tuberculosis, and in 6 of them found the bovine tubercle bacillus as the cause of the tuberculosis. All the findings were in children under seven years of age. The nature of the cases was as follows: 2 cases of tuberculosis of the mesenteric glands, and one each of the following—abdominal tuberculosis with caseating mesenteric glands, calcareous tubercle of mesenteric glands with tubercles in spleen and pleurae, general miliary tuberculosis, including lungs and meninges, acute miliary tuberculosis, involving practically all organs. Out of 10 cases of primary intestinal and mesenteric gland tuberculosis 5 were infected with bovine and 5 with human bacilli, and of 3 cases of cervical gland tuberculosis in children under ten 2 showed bovine and 1 human tubercle bacilli.

Recently Oehlecker has studied the bacilli from 14 consecutive cases of primary cervical adenitis. Two cases were in adults, and in both of these cases human bacilli were isolated. The remaining 12 cases were in children, and from 4 others the bovine tubercle bacillus was obtained.

Lewis[2] studied the types of tubercle bacilli isolated from 15 consecutive cases of tuberculous cervical adenitis. In all cases the material was glands removed by operation. Nine of the cultures were of bovine and 6 of human type. Apart from modifications due to the age of the patients there were no differences in the clinical or pathological picture. The bovine bacilli were from patients $1\frac{1}{2}$ to 18 years old (average

[1] *Tuberkulose Arbeiten a. d. Kais. Ges. Amt.* 1904-1905, Heft i.

[2] *Trans. 6th Internat. Congress on Tuberculosis (Washington)*, vol. iv. pt. 2, p. 692.

age $8\frac{1}{2}$ years), while the human tubercle bacilli were from patients 8 to 32 years old (average age $17\frac{2}{3}$ years).

Fibiger and Jensen[1] tested upon cattle the virulence of bacilli from 29 cases of tuberculosis in man. Eight of these cases contained bacilli able to produce generalised tuberculosis in cattle in the same way as the bacilli most frequently found in spontaneous tuberculosis in cattle. They may therefore be considered as bacilli of bovine type. In 6 of them the patients were children (4 months to 7 years old). In 5 of the children the tuberculosis was undoubtedly primary, and in 1 child it was probably primary in the intestines and mesenteric glands.

"Information in these cases has proved that 3 children had for a long time ($2\frac{1}{2}$ months to 4 years) been fed partly on raw milk, produced, in one case, from a very tuberculous stock and containing a cow with tuberculosis of the udder. In a fourth case, the child had been partly fed, probably for a year, on unboiled milk, only warmed up." In the seventh and eighth cases the patients were male adults. From the autopsy it was quite probable that the seventh was also a case of primary tuberculosis of the intestines.

In the remaining 20 cases of different kinds, 6 patients were children. In all of them the isolated bacilli possessed only a very low degree of virulence for cattle or no virulence at all. Of these 20 cases, primary abdominal tuberculosis was found in 1 child and 3 adults; generalised tuberculosis in 2 children. In one case the bacilli were found only by the inoculation of a guinea-pig with an apparently quite healthy mesenteric gland from a child without any tuberculous lesions. One was a case of tuberculous mammae, and 10 were consumptive adults whose sputum had been used for isolating the cultures.

One of the most recent and important contributions to this aspect of tuberculosis is that of Park and Krumwiede[2] and their assistants. These investigators determined the type of tubercle bacillus present in tuberculous material sent

[1] *Trans. 6th Internat. Congress on Tuberculosis* (*Washington*), vol. iv. pt. 2, p. 672.

[2] "The relative Importance of the Bovine and Human Types of Tubercle Bacilli in the different Forms of Human Tuberculosis," *Studies from the Research Laboratory, Department of Health, New York City*, vol. v., 1910.

to them from different institutions and from a variety of sources, and examined regardless of the type of infection. The tubercle bacilli were all, in the first place, isolated by guinea-pig inoculation. In addition to their own work they also tabulated the results of their own and 17 other groups of investigators into one combined table. Their own results and the combined results are shown in the two following tables:

Tabulation of their own Cases.

Diagnosis of Cases examined.	Adults 16 years and over.		Children 5 to 16 years.		Children under 5 years.			Total Cases.
	Human.	Bovine.	Human.	Bovine.	Human.	Bovine.	Both Types.	
Pulmonary tuberculosis . . .	278	...	8	...	5	...	...	291
Tuberculous adenitis. Inguinal and axillary	1	...	4	...	...	...	...	5
Tuberculous adenitis cervical . .	9	...	19	8	6	12	...	54
Abdominal tuberculosis . . .	1	...	1	1	...	3	...	6
Generalised tuberculosis. Alimentary origin	...	...	...	...	1	1	...	2
Generalised tuberculosis . . .	2	...	1	...	12	4	...	19
Generalised tuberculosis, including meninges	...	...	...	...	18	1	1*	20
Tubercular meningitis . . .	...	...	1	...	14	1	...	16
Tuberculosis of bones and joints .	1	...	10	...	6	...	...	17
Genito-urinary tuberculosis . .	3	1	1	...	...	...	...	5
Tuberculous abscesses . . .	1	...	...	...	...	...	...	1
Totals . . .	296	1	45	9	62	22	1	436

* Double infection. Both types isolated. Child 13 months old. The mesenteric nodes gave human type. Meningeal fluid gave bovine type.

[TABLE

Combined Tabulation, Cases reported including their own series of Cases.

Diagnosis.	Adults 16 years and over.		Children 5 to 16 years.		Children under 5 years.	
	Human.	Bovine.	Human.	Bovine.	Human.	Bovine.
Pulmonary tuberculosis	568	1 (?)	11	...	12	...
Tuberculous adenitis. Axillary or inguinal	2	...	4	...	2	...
Tuberculous adenitis cervical	22	1	33	20	15	20
Abdominal tuberculosis	15	3	7	7	6	13
Generalised tuberculosis. Alimentary origin	6	1	2	3	13	10
Generalised tuberculosis	28	...	4	1	28	5
Generalised tuberculosis; including meninges. Alimentary origin	...	...	1	...	3	8
Generalised tuberculosis, including meninges	4	...	7	...	45	1
Tubercular meningitis	...	...	2	...	14	2
Tuberculosis of bones and joints	18	1	26	...	21	...
Genito-urinary tuberculosis	11	1	1	1	...	...
Tuberculosis of skin	1	...	1	...	1	...
Miscellaneous cases.						
Tuberculosis of tonsils	...	...	...	1	...	...
Tuberculosis of mouth and cervical nodes	...	1	...	...	...	...
Tuberculous sinus or abscesses	2	...	...	...	...	...
Sepsis, latent bacilli	...	...	...	...	1	...
Totals	677	9	99	33	161	59

Mixed or double infections, 4 cases.
Total cases=1042.

This table shows that the bovine type of bacillus was found in only 1·3 per cent of the adults, but in 25·0 per cent of the children 5 to 16 years, and in 26·7 per cent of the children under 5 years of age. When the phthisis cases are excluded, the adult percentage rises to 7·3.

These investigations and figures (and others which limits of space forbid quoting) show that while pulmonary tuberculosis is almost invariably of human origin, a considerable proportion of the cases of other varieties of tuberculosis, especially glandular and intestinal infections in children, are infected with bacilli of bovine type, and derived from bovine sources. It is not possible to determine with any precision the exact proportion of human cases of bovine origin, until the accumulation of further facts and the more precise differentiation of the types of tubercle bacilli. Woodhead quotes Cobbett as calculating from the data of the English Royal Commission, that about 7 per cent of the cases with which we have to deal are infected with bacilli of bovine origin. Woodhead thinks this figure represents an under-statement. Whatever the exact proportion, it cannot be regarded as other than a serious menace to health.

There is also a possibility which, if true, will make the percentage of human tuberculous cases of bovine origin much higher. The differences between the types of bacilli are differences of degree, and it is a possible supposition that bovine bacilli ingested in early life may, under the influence of a human environment, be extensively modified in type, and ultimately approach the human type. The isolated bacilli being then of human type, the infection will be ascribed to a human source while really bovine in origin. There are some facts in support of this hypothesis, but the whole question must await the results of fuller investigations.

In addition to the bacteriological evidence, statistics as to the extensive prevalence of abdominal tuberculosis in children furnish strong evidence that the path of infection is by ingestion in many of these cases. For example, Still, from 269 autopsies on tuberculous children under twelve years, came to the conclusion that in 64 per cent infection was through the lungs, and in 29 per cent through the alimentary canal. In infants under one year, apparently only 13 per cent contracted tuberculosis through the intestine. Shennan, dealing with the autopsies at the Royal Hospital for Sick Children in Edinburgh, put the percentage of cases infected through the alimentary canal at 28·1. Woodhead found that out of 127 cases of tuberculosis in children, in 100 tuberculosis of the mesenteric glands was present, while in 43 there was ulceration of the intestine.

The following tables given by Dr. J. Thomson [1] show that abdominal tuberculosis is a condition which is prevalent to a considerable extent amongst children in Great Britain.

[1] *British Journal of Tuberculosis*, 1907, vol. i. p. 250.

Royal Hospital for Sick Children, Edinburgh.

	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	Average.
Number of in-patients admitted . . .	1154	1219	1361	1398	1533	1597	1504	1596	1844	2114	1532
Percentage of abdominal tuberculosis .	3·63	3·75	2·57	4·36	2·73	3·63	4·98	3·82	3·14	3·20	3·57
Percentage of tuberculous meningitis .	3·29	2·87	2·42	2·21	2·02	1·63	2·12	1·12	1·57	1·27	2·05

Royal Hospital for Sick Children, Glasgow.

	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	Average.
Number of in-patients admitted . . .	691	744	741	714	738	854	996	941	1125	1075	882
Percentage of abdominal tuberculosis .	4·05	4·30	3·91	3·92	5·28	4·58	4·32	5·10	5·24	4·46	4·51
Percentage of tuberculous meningitis .	2·17	2·28	1·21	2·24	2·03	1·63	2·00	2·76	1·60	3·49	2·14

Hospital for Sick Children, Great Ormond Street, London.

	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	Average.
Number of in-patients admitted . . .	1946	2067	1962	1690	2111	2236	2403	2537	2876	3068	2289
Percentage of abdominal tuberculosis .	0·66	1·11	1·32	1·71	1·46	1·61	2·03	2·24	2·60	1·98	1·67
Percentage of tuberculous meningitis .	1·49	0·72	1·52	1·88	1·27	1·11	1·16	1·65	1·53	1·85	1·42

The statistics of other London children's hospitals with regard to abdominal and meningeal tuberculosis seem to resemble those of Great Ormond Street pretty closely.

Dr. Thomson remarks that the smaller proportion of abdominal and of meningeal tuberculosis at Great Ormond Street is probably mainly due to there being a relatively smaller amount of all sorts of tuberculosis in London than in Scotland.

In Germany, primary intestinal tuberculosis appears to be much less common. Thus Koch,[1] writing in 1902, remarks:

In Germany, as far as I have been able to find statements on the subject in literature, and as far as my personal inquiries have reached, all authors have expressed the opinion that primary in-

[1] *British Medical Journal*, Dec. 20, 1902, p. 1885.

testinal tuberculosis is with us a very rare occurrence. The only exception to this is at Kiel, where Heller has found 37·8 per cent of primary intestinal tuberculosis at necropsies of tuberculous children.

The value of such statistics in part depends upon the possibility of infection by ingestion without involvement of the intestine or even the mesenteric glands. There is a considerable body of evidence showing that this may take place.

Behring, in 1903, advanced a theory of phthisis causation to the effect that infection takes place in the early years of life, usually through cows' milk, the bacilli being absorbed through the intestine before the powers of resistance of the intestine are fully developed. The bacilli remain latent until the resistance of the individual is impaired, when the disease then becomes active. This view has not met with wide acceptance, and there are many facts which are against it.

During recent years extended investigation has been carried out to study and determine the paths of infection in tuberculosis. Careful experiments have proved conclusively that ingested tubercle bacilli may pass through the intestinal mucous membrane without causing any lesion. Griffith, for example, working for the Royal Commission on Tuberculosis, found that tubercle bacilli would pass through the intact mucous membrane of the dog's intestine, but not in large numbers or with any certainty. The evidence that they may pass through the mesenteric glands in addition without setting up morbid changes is, however, less firmly attested, and the existing facts cannot be accepted as settling the question.

The matter is too controversial to be dealt with in detail in the space which is available, and involves the discussion of the whole question of the inhalation and ingestion theories of the paths of entry. After a careful review of the subject, Cobbett[1] gives his opinion that—

. . . while I believe that phthisis is commonly caused by the inhalation of tubercle bacilli, I do not deny that many cases of tuberculosis, especially in children, are caused by bacilli which gain entrance through the mucous membrane of the intestine. In such cases, I believe, there are usually lesions in the mesenteric glands, and not rarely in the gut itself. On the question whether tubercle

[1] *Journ. of Pathology and Bacteriology*, 1910, xiv. p. 563.

bacilli ever get through these glands without producing disease in them, and settle down and cause lesions elsewhere, I maintain an open mind. I think it not unlikely that some cases of tuberculosis, possibly of primary bone or joint tuberculosis, have this kind of origin. I am quite prepared to believe that the glands are not a perfectly efficient barrier to the passage of microbes, but I think that the bacilli which get through them are not often numerous enough to set up disease, except perhaps in a *locus minoris resistentiae* in a constitutionally susceptible person.[1]

[1] For a fuller consideration of this very important subject the following may, in particular, be consulted: Cobbett (in paper quoted); Schroeder, *Twenty-fifth Annual Report of the Bureau of Animal Industry* (1908), pp. 138-145; Various papers by Investigators of the Breslau School; *Zeit. f. Hygiene*, 1908, vol. lx.; Sir J. McFadyean, *Journ. Royal Inst. Public Health*, 1910, xviii. p. 705.

CHAPTER VIII

MILK AND CHILD MORTALITY

It is not possible statistically to measure the extent to which dirty and contaminated or chemically unsuitable milk contributes to the morbility and mortality rates of infants and young children, since the different factors which conduce to our high rate of infant mortality are so inter-related. There can, however, be no doubt that of these factors polluted milk is one of great potency.

Apart from the evil effects of milk deficient in its full chemical constituents or administered in incorrect quantities, effects which will not be dealt with here, milk is a cause of child mortality and ill-health in three distinct ways:

(*a*) Milk is a not uncommon vehicle for the transmission of infectious fevers, and in this way shares in the mortality rates caused by these diseases. This relationship has been dealt with in Chapter V.

(*b*) It has been shown that a considerable proportion of cases of tuberculosis in children are of bovine origin, and, for the most part, derived from milk infected with tubercle bacilli. This aspect of the subject has been considered in Chapter VII.

(*c*) There is a large body of unimpeachable evidence showing that the mortality in hand-fed infants is very much higher than that of breast-fed infants, and that a large part of this mortality is due to infected food and particularly milk.

The mortality from bacterially contaminated milk has not yet been dealt with and requires further consideration.

The problem of infant mortality is a serious one, and has been engaging much expert attention during the last few years. While the death-rate has been steadily declining, the infant mortality rate, until within the past few years, has not shared in this decline. In spite of immense sanitary and social improvements, children under twelve months old were, up to a few years ago, dying as extensively as they did seventy to eighty years ago. The infantile mortality rate is still very high in spite of the recent decline. For example, during 1908 one-fifth of the total deaths at all ages in England and Wales occurred in infants in their first year of life.

As is well known, this infant mortality rate varies greatly in different areas, being, for example, very high in mining counties like Durham and Glamorgan, and low in essentially rural counties like Somerset, Wiltshire, and Dorset.

We have to consider sickness as well as deaths. As Newsholme remarks:

> It is fair to assume, in accordance with general experience, that the amount of sickness varies approximately with the number of deaths; and there can be no reasonable doubt that in the counties having a high infant death-rate there is (apart from migration) more sickness and a lower standard of health in youth and in adult life than in counties in which the toll of infant mortality is less.

One of the most important of the factors contributing to infantile mortality is the ravages of epidemic diarrhoea, a disease intimately related to an impure food supply.

Epidemic diarrhoea is an acute infective disease which occurs almost entirely (certainly always in its epidemic form) in the summer, and which mainly affects children under two years of age. Certain epidemiological features are universally recognized, the chief being that it is a disease of the later summer months, that it only occurs to any extent when there is or has been immediately antecedently a high temperature, that it is in the main an urban disease, and that it is more prevalent in dry than in wet seasons. The disease is allied to food-poisoning outbreaks in that it is an infection, often an intoxication, of the gastro-intestinal tract.

The infection is clearly conveyed by food, and is undoubtedly bacterial in nature, although at present no one organism can be accepted as its cause. As regards causation, its relationship to hand-feeding is an outstanding one, as shown by Newsholme, Sandilands, Richards, and very numerous other investigators. This is very clearly brought out in the following tables by Newsholme,[1] the second table giving the results as percentages.

Method of feeding Infants under one year of age in Brighton.

	A. Census of 10,308 houses in house-to-house inspection in the three years 1903-5. Age of infants in months.				B. Infants who died from Epidemic Diarrhoea in the three years 1903-5. Age of infants dying in months.			
	0-3	3-6	6-9	9-12	0-3	3-6	6-9	9-12
I. Suckled only . . .	271	237	186	92	5	3	...	...
Ditto and farinaceous food	14	29	41	69	1	1	...	1
,, ,, cows' milk .	5	6	7	4	1	...	...	...
,, ,, condensed milk	3	6	7	1	1	...	...	...
II. Cows' milk only . .	12	32	28	18	11	22	7	4
Ditto and farinaceous food	4	26	33	33	1	...	4	6
III. Condensed milk only .	6	12	10	11	2	16	12	7
Ditto and farinaceous food	2	6	10	7	...	3	...	1
IV. Farinaceous food, including patent food only mentioned, or "same food as parents"	4	1	2	18	1	1	...	...
V. Unknown	...	...	1	5	2	4	2	2

Percentage of Infants under one year of age fed in different ways.

	A. In 10,308 houses visited house-to-house (1259 infants).	B. Among infants dying from Epidemic Diarrhoea (121 infants).
I. Suckled only	62·3	6·5
Ditto and farinaceous food .	12·1	2·5
,, ,, cows' milk . .	1·8	1·7
,, ,, condensed milk . .	1·4	0·8
II. Cows' milk only . . .	7·2	36·0
Ditto and farinaceous food . .	7·6	9·1
III. Condensed milk only . .	3·1	30·3
Ditto and farinaceous food .	2·0	3·2
IV. Farinaceous foods only mentioned	2·0	1·7
V. Unknown	0·5	8·2
	100	100

[1] *Journ. of Hygiene*, 1906, vi. 139.

While these facts are generally recognised there are several problems in relation to this subject which are still matters of controversy. For instance, there is no unanimous opinion as to whether infection is specific and due to a special organism or whether we have to deal with bacterial poisoning through the toxic products of a large number of bacteria such as *B. coli*, etc. This question is connected with that of the case-to-case infectivity of the disease.

Delépine[1] found that milk samples received by him in hot weather, or after some time in transit, were infectious to guinea-pigs to a much higher degree than milk examined after only a short interval, or for which proper precautions had been taken to keep it cool. From his investigations he concluded that "epidemic diarrhoea of the common type occurring in this country is, apparently in the great majority of instances, the result of infection of food by bacilli belonging to the colon group of bacilli, which are present at all times in faecal matter." He further concluded that the disease is only caused when the infection of the food is massive from the first, or the food is kept for a sufficient length of time and under conditions of temperature favouring the multiplication of these bacilli. In his view the milk was frequently infected at the farm or during transit.

On the other hand, there is a mass of evidence which is overwhelmingly in favour of the view that the place of infection is the home, and indeed any other supposition does not offer an adequate explanation of the facts. For example, the incidence, as Newsholme, Sandilands, the writer, and others, have shown, is proportionately higher on those fed with condensed milk (which is certainly infected in the home) than on those fed with cows' milk.

Thus in an outbreak of epidemic diarrhoea causing over 50 deaths, the figures for the feeding of children under one year of age were as follows:[2]

---

[1] *Journ. of Hygiene*, 1903, iii. 68.
[2] W. G. Savage, *Annual Report*, *Colchester*, 1904.

Method of Feeding.	Healthy Infants.	Infants killed by Diarrhoea.
	Per cent.	Per cent.
Breast-fed, entirely or partially . .	74	10
Cows' milk, entirely or with other food .	12	42
Condensed milk, entirely or with other food	14	48

Again there is a marked difference between the incidence of this disease upon the babies of the rich and those of the poor. The comparative immunity of the rich cannot be adequately ascribed to boiling of the milk, since it is doubtful if heating of the milk is practised much more extensively by the well-to-do. The greater facilities for home infection at the houses of the poor is a far more likely explanation.

Also, as Ballard and many investigators have pointed out, while the incidence of diarrhoea follows the earth temperature it does not correspond with that of the air temperature. As Sandilands[1] clearly points out, commenting upon this, the number of germs in milk is largely a question of temperature, and the higher the temperature of the air the more germs in the milk supply at that given time. Since the diarrhoea does not occur until some time after the onset of the hot weather it results that, during hot weather at the beginning or end of the summer, cows' milk containing enormous numbers of bacteria may be consumed with comparative impunity, and the incidence of diarrhoea is not directly influenced by the number of bacteria occurring in cows' milk.

A further fact is that a small proportion (under 10 per cent) of breast-fed infants get diarrhoea. Here the infection must be other than by cows' milk and must be due to domestic infection.

It is probable that infantile diarrhoea is an infectious disease due to one specific micro-organism, and that it is infectious from case to case. Further, the actual place of infection is usually domestic, and does not originate with manurial pollution at the farm; but this may not be true of all cases.

Most medical officers and others who have had experience

[1] *Journ. of Hygiene*, 1906, vi. 77.

of epidemic diarrhoea from the administrative aspect are satisfied as to its case-to-case infectivity, at least in some cases. Two examples may be mentioned. Epidemic diarrhoea has been a voluntary notifiable disease in Woolwich since 1905. Dr. Sidney Davies, the medical officer of health, remarks in a valuable special report on this disease in 1908: "From the information obtained by the writer and the sanitary inspectors, there can be no doubt that the infection spreads from person to person in a family." By means of spot maps it was shown that there was a very marked grouping of cases.

Sandilands[1] brought forward evidence that certain fatal forms of summer diarrhoea are communicable. He remarks, however—

> . . . nevertheless communicability is by no means a conspicuous feature of epidemic diarrhoea in every case. Thus in 19 out of 35 tenement houses in Kensington where deaths were registered as due to diarrhoea, no other cases occurred. Again in 25 out of 35 fatal cases of diarrhoea, no source of infection was found in the families occupying the houses where these patients died. And lastly, in 22 families containing young children fatal diarrhoea occurred, and yet in these families 44 parents and 58 children were intimately exposed to infection without falling ill. In 5 hospitals there is no evidence of the spread of diarrhoea from patient to patient, and the sum of the evidence suggests that diarrhoea is not more infectious than typhoid fever, and is not conveyed except by the same channels.

In regard to the means by which the bacterial infection is transmitted from case to case the house fly has been suspect for many years, and the evidence implicating flies steadily grows in convincingness. The recent contribution by Niven[2] upon "Summer Diarrhoea and Enteric Fever" may be recommended as a valuable epidemiological study of this relationship.

In considering the relationship of milk and epidemic diarrhoea, while the balance of evidence is decidedly in favour of the view that the specific infection, which is the cause of the disease, is domestic in origin rather than derived from

1 *Trans. Royal Society of Medicine*, 1910, vol. iii. p. 95.

2 *Trans. Royal Society of Medicine, Epidemiological Section*, 1910, vol. iii. p. 131.

the cowshed, it is not possible to exonerate faecal contamination at the farm or in transit from blame. It cannot but be prejudicial to the infant intestine and vital powers to have to deal with milk laden with living intestinal bacteria and toxic products. Their activity may and probably does weaken the resistance of the body against specific infection with the organism of epidemic diarrhoea when that infection takes place. Indeed, there is some evidence that this actually results.

Peters,[1] in a prolonged investigation upon diarrhoea in Mansfield, found no special incidence upon the milk of any one milkman. He found that the rise of diarrhoea incidence to a maximum in the second year with subsequent gradual decline, corresponded exactly with the frequency with which cows' milk appeared in the dietary of children throughout the first few years of life. On the other hand, milk as the cause of diarrhoea could be definitely ruled out for many of the older children.

The possibly prejudicial effect of cows' milk in a general way and apart from containing the specific organism of infantile diarrhoea is also suggested by the investigations of Scholberg and Wallis.[2] These observers studied the chemical and physical changes in milk produced as the result of bacterial contamination. They found that during the summer months, and more especially when the temperature of the air was rising, peptones appeared even in comparatively fresh samples of milk as supplied to the consumer. The quantity of albumoses and peptones present bore a definite relation to the time the sample was kept, and also to the temperature to which the milk was exposed. They furnish evidence that the peptone-like body and the peptones found in milk are toxic to infants, and the authors concluded that milk containing these bodies was unfit for infant feeding. Their bacteriological results pointed to an intimate relationship between the quantitative and qualitative bacterial content and the appearance of peptone-like bodies in milk.

Park and Holt[3] carried out an extended series of observations extending over two years upon the results of feeding

[1] *Journ. of Hygiene*, 1910, x. 602.
[2] *Report of Medical Officer, Local Government Board*, 1909-10, p. 504.
[3] *Archives of Pediatrics*, 1903, p. 881.

infants in tenement houses in New York upon cows' milk. The investigation had three objects:

(1) To make comparison of the results of infant feeding in tenements in winter and summer.

(2) To determine how far such results were affected by the character of the milk used, especially its original bacterial content, its preparation, and whether it was fed after heating or raw.

(3) To see to what extent results were modified by other factors, such as the care the infants received and the surroundings in which they lived.

The observations were extensive, 632 infants being carefully studied. In estimating the results obtained by the different methods of feeding, the factors considered were—the gain or loss in weight and the amount of digestive disturbance, particularly diarrhoea, which occurred.

They divided the cases into four groups. The results obtained were as follows:—

Food and Results—Winter.

	Did well.	Did fairly.	Did badly.	Died.	Totals.
Store milk	47	6	2	0	55
Condensed milk	39	5	2	2	48
Good bottled milk	51	13	1	3	68
Milk from central distributing stations .	35	20	4	0	59
Best bottled milk	5	0	1	0	6
Breast-feeding	7	1	0	1	9
Totals, excluding cases counted twice	156	41	8	6	211

Food and Results—Summer.

	Did well.	Did fairly.	Did badly.	Died.	Totals.
Store milk	21	23	20	15	79
Condensed milk	22	20	14	14	70
Good bottled milk	37	23	29	9	98
Milk from central distributing stations .	84	33	24	4	145
Best bottled milk	9	3	0	0	12
Breast-feeding	17	7	7	0	31
Totals, excluding cases counted twice	184	108	88	41	421

The summer results are of chief interest, and recorded as percentages, give the following table:

Summer Results—Percentages.

	Did well.	Did fairly.	Did badly.	Died.
Store milk	27	29	25	19
Condensed milk	31	29	20	20
Good bottled milk	38	23	30	9
Milk from central distributing stations	58	23	16	3
Best bottled milk	75	25	0	0
Breast-feeding	55	23	23	0
Average percentage	44	26	21	10

The above milks used were briefly the following:

Condensed Milk.—The sweetened variety.

Store Milk.—The poorest grade of milk sold in New York. Bacterial content on average 3 to 20 millions per c.c. in summer, and about 400,000 per c.c. in winter; usually, however, heated in the homes before used for food.

Bottled Milk.—Fairly good. Milk averaged about 500,000 per c.c.

Milk from Central Distributing Stations.—Mostly from the Straus Milk Depôts. Supplied pasteurised. Before pasteurisation averaged about 2 million, and after about 500 bacteria per c.c. Often modified for feeding, and supplied in small bottles, each one containing the quantity for a single feeding.

It is not clear from the Report, but apparently many of the breast-fed infants also received other foods.

As Park and Holt point out, there is a striking contrast between the summer and winter results. They draw attention to the large percentage of good results in the winter by all methods of feeding and the, apparently, so little difference between them. They believe that there are many factors to explain the differences between their summer and winter results, but that heat is the primary factor and bacteria and their products a secondary one, except when the contamination is extreme or pathogenic organisms are present.

The tables quoted are in favour of home infection for much of the diarrhoea, since the store milk was usually heated at home before feeding, and the condensed milk contained only few bacteria.

The authors are emphatic upon the influence of contaminated milk. They state that with the cleanest milk from the best cared for cattle the smallest number of bad results occurred. They also note that the difference between very bad, highly contaminated milk, like that purchased at some of the small stores previous to 1902, and the best bottled milk, was in some cases very striking. Protracted diarrhoea in infants who were taking store milk was often immediately improved, and in several cases promptly cured, by simply substituting clean milk, after an interval of no milk, for the previous food. In some severe cases, however, no improvement followed the purer milk.

The importance of clean milk is also shown by the comparison between the results of feeding with pasteurised and raw milk. These results are summarised in the following table:

Kind of Milk.	Number of Infants.	Remained well for entire summer.	Number having severe or moderate Diarrhoea.	Average number days off milk during summer.	Average weekly gain in weight.	Average number days Diarrhoea.	Deaths.
Pasteurised milk, 1000 to 50,000 bacteria per c.c.	41	31	10	3	4 oz.	3·9	1
Raw milk, 1,200,000 to 20,000,000 bacteria per c.c.	51[1]	17	33	5·5	3·5 oz.	11·5	2

[1] Thirteen of the 51 infants on raw milk were transferred before the end of the trial to pasteurised milk because of serious illness. If these infants had been left on raw milk, it is believed by the writers that the comparative results would have been even more unfavourable to raw milk.

Some further interesting results are recorded by Park and Holt in the following table.

Table showing the results of feeding during July and August 1901, in tenement houses, of 112 bottle-fed infants under one year of age, and of 47 bottle-fed infants between one and two years of age with milk from different sources, and the number of bacteria present in the milk.

Character of Milk.	Infants under One Year.					Infants over One Year.				
	Number of Infants.	Average Weekly Gain.	Diarrhoea.		Deaths.	Number of Infants.	Average Weekly Gain.	Diarrhoea.		Deaths.
			Mild.	Severe.				Mild.	Severe.	
(1) Pure milk boiled and modified at dispensary or stations; given out in small bottles. Milk before boiling averaged 20,000 bacteria per c.c.; after boiling 2 per c.c. .	41	3 oz.	10	8	1[1]	...	...	...	...	...
(2) Pure milk 24 hours old, sent in quart bottles to tenements, heated and modified at home, 20,000 to 200,000 bacteria per c.c. when delivered .	23	4⅛ ,,	8	5	0	24	4½ oz.	8	2	0
(3) Ordinary milk, 36 hours old, from a selected group of farms, kept cool in cans during transport; 1 to 25 million bacteria per c.c., heated and modified at home before using . .	18	4 ,,	6	6	1[2]	12	4 ,,	1	2	0
(4) Cheap milk, 36 to 60 hours old, from various small stores derived from various farms, some fairly clean, some very dirty, 400,000 to 175,000,000 bacteria per c.c. . .	21	¼ ,,	4	13	4[3]	7	⅓ ,,	1	3	0
(5) Condensed milk of different brands, made up with hot water. As given, contained bacteria from 5000 to 200,000 per c.c. .	9	¼ ,,	5	2	3	4	3⅞ ,,	1	3	0
(6) Breast milk	16	2¼ ,,	5	2	0	...	...	...	...	...

[1] This infant died from enteritis and toxemia.

[2] This infant died of pneumonia. There had been no severe intestinal disorder noted.

[3] One of the four had pertussis, the remaining three died from uncomplicated enteritis.

Goler, Health Officer of Rochester, U.S.A., who has done valuable work in improving the milk supply of Rochester, a city of about 185,000 inhabitants, remarks:[1]

The Rochester milk work had its beginning in the summer of 1897, when during July and August we began to establish summer milk stations, where milk put up in nursing bottles could be bought at a nominal price. . . . For the whole period of years from 1888 to 1896 there were 6629 deaths in children under five years of age. For a similar nine-year period, from 1897 to 1905, there were 4403 deaths in children under five years of age, a diminution of over 30 per cent. These deaths represent all the deaths from all causes, and not merely those from intestinal diseases alone.

Taking the deaths in July and August, he finds—

Total deaths under five years, July and August, first period, nine years without municipal milk stations = 2005.

Total deaths under five years, July and August, second period, nine years with municipal milk stations = 1000.

Goler works upon the belief—

. . . that most babies become sick because they are infected by the bacteria and poisons of stable manure contained in dirty milk, and that to keep children well it is necessary to protect them from the dirt in milk just as much as we would protect them from diphtheria or scarlet fever infections.

Goler, in another paper,[2] gives the interesting Chart reproduced on the next page. It does not, of course, prove any relationship between the death-rate and the bacterial count, but the close association is interesting, and at least suggests that they may be related rather than both due to a common cause.

1 *Maryland Medical Journal*, June 1906.
2 *Archives of Pediatrics*, September 1906.

[CHART

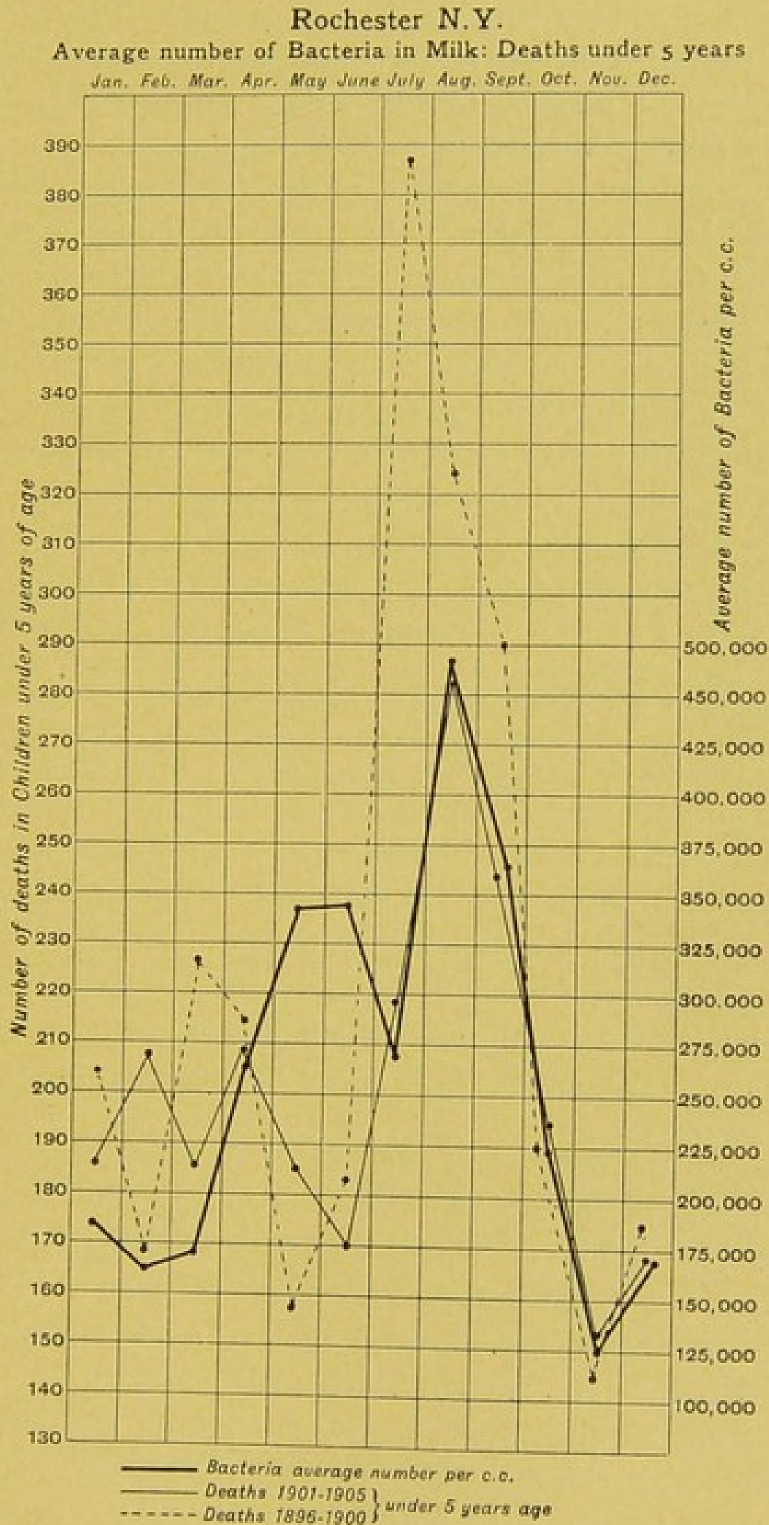


FIG. 4.

Apart from the relationship of milk and infantile diarrhoea there have been several outbreaks of diarrhoea and sickness associated with cows' milk. These outbreaks are closely allied to the epidemics of sore throat and infectious disease considered in Chapter VI., and while they have no special relationship to infant mortality they show that milk may be a cause of human diarrhoea.

The relationship between a pure milk supply and infant mortality is clearly shown by the accumulated evidence obtainable from the different institutions which supply pure milk to infants. Such institutions are the Gout de Lait and Consultation de Nourrissons in France, Milk Depôts in England, and Milk Dispensaries in America.

Dealing with some of the French results Budin[1] remarks:

> From 1892, when I instituted my first consultation, till June 1899, counting only those infants who have been under my care for at least one month, or at most two years, I have had altogether 435 nurslings; 238 were exclusively breast-fed and 197 were on mixed or artificial feeding. Out of these 435, 32 have died, which make a general mortality of 7·3 per cent.

Of the deaths only one was due to diarrhoea, and this child during the day had been having impure milk in a day nursery. Other French figures are quoted by McCleary.[2]

The figures from the various milk depôts established in England show that a much smaller number of the infants fed from them die compared with a proportionate number of infants not so fed, but otherwise similar.

Many of the death-rates given for these infants fed at depôts, compared with outside infants, are not reliable since they are based upon data not readily comparable, and the writer agrees with McCleary (*op. cit.*) that "it is doubtful whether the value of these institutions can be expressed in figures. Clinical testimony is of far greater value than statistics, and this testimony is almost uniformly favourable to the depôts." In particular the part played by the pure milk cannot be altogether disassociated from the other parts of the scheme—the medical advice and the supervision of the homes by a health visitor which usually play a part. Carefully used the figures from milk depôts are, however, of value. The chief particulars of the Woolwich depôt are mentioned on p. 356, and only the following need be mentioned here.

[1] Budin, *The Nursling*, 1907.
[2] *Journ. of Hygiene*, 1904, iv. p. 329.

Davies found that during the three years the depôt had been running 25 children fed on depôt milk had died, the death-rate being 81 per 1000. He compares this with the death-rate of ordinary hand-fed children, which has been estimated at 198 per 1000, excluding the deaths of children in the first week of life, whose inclusion would greatly raise the death-rate. He found that depôt-fed infants only ran one-fourth the risk of getting diarrhoea that other hand-fed children were exposed to. They were, however, much more prone to this disease than breast-fed children.

In dealing with milk depôt children it must be remembered that they are a specially selected class of weaklings, and usually do not remain long enough on the depôt to fully profit by it. As Newman[1] puts it, referring to the Finsbury Milk Depôt:

> Taken as a whole, however, it is abundantly evident that the depôt-fed children suffered much less from epidemic diarrhoea and all other diseases, than other artificially-fed children in the Borough, and even when they were attacked had a much lower mortality. And yet nearly all the depôt children were of the very poorest classes; all of them were artificially fed; all were living at home and subject to precisely the same external conditions of life as other infants in the Borough, and although they formed a selected class of the weakest and most frail, "an unfit residuum" so to speak, of the children born in Finsbury. But they received pure milk and proper supervision and so they survived.

Very valuable results have also been obtained in America by the different Milk Commissions and other agencies which distribute pure milk. Some of the results obtained are tabulated by Kerr.[2] The results cannot be given in the form of reliable death-rates, but the number of deaths when given are clearly few. The results obtained at Newark City (New Jersey) will serve as an example. Dr. Coit, who initiated the Babies' Hospital Milk Dispensary, writes:[3]

> We feed about 500 infants in the tenement houses who are not admitted to our hospitals. They are brought to the annexe of the Babies' Hospital and Consultations, and are then placed upon

[1] *Report on Infant Mortality in Finsbury*, 1906.
[2] *Bulletin No. 50, Public Health and Marine Hospital Service, U.S.A.*, 1910.
[3] Personal communication.

Certified Milk, properly modified, which is delivered by a messenger daily. Among 500 (568 accurately) infants, who received no other attention except this help during the year, the mortality is reduced to 2·7 per cent by this means alone. The mortality in our city among this class is 25 per cent, sometimes 30 per cent. This was accomplished without the work of a visiting nurse to teach infant hygiene in the home, which might leave a doubt in our minds as to the influence of the milk.

PART II

THE BACTERIOLOGICAL EXAMINATION OF MILK

CHAPTER IX

GENERAL PARTICULARS AND PRELIMINARY PROCEDURE

THE bacteriological examination of milk even up to a few years ago could not be said to be very satisfactory, and indeed, apart from tuberculosis, very little was systematically done, while in regard to the procedures that were carried out there was neither uniformity of method nor consensus of opinion as to what was desirable. Even at the present time it is by no means on a uniform or satisfactory basis.

The bacteriological examination of milk may be utilised to give information in the three following directions:

1. To measure the degree of contamination of the milk from faecal and other sources and its general bacterial content.

2. To ascertain the presence or absence of definite disease-producing organisms, *e.g. B. diphtheriae, B. tuberculosis, B. typhosus.*

3. To obtain evidence as to the healthiness of the milk-producing apparatus of the cows which supply the milk.

The procedures to be used will obviously require to be varied according to the purpose and objects of the examination. The different methods are considered in detail in the following chapters.

The chemical examination of milk is fully dealt with in numerous works dealing with that aspect of the subject and is not described in this book. The only chemical procedures dealt with are those, such as the detection of preservatives or the acidity estimation, which are intimately related to the bacterial content, or which have been used as rough indicators of the degree of bacterial contamination.

Collection of Samples.—Care in collection is necessary to obtain samples which are really representative of the milk to be examined. Ordinary samples of mixed milk may be collected at the byres or in course of transit or delivery. The cream and the sediment are the richest in bacteria, so that it is necessary to well mix the milk before a sample is withdrawn. If a sample representing all the mixed milk of the cows at the byre is required, it will be necessary for the collector to remove a definite quantity (*e.g.* half a gallon) from each churn and mix all the fractions in a clean empty churn or other vessel, and take the sample from this.

In the collection of samples from individual cows care must be taken to avoid outside contamination. The cows' udders and teats must be washed carefully, and the milker must wash and disinfect his hands. The milk is milked direct into the bottle, the stopper being held by a second person by its free end to avoid contamination, and inserted immediately after the sample has been collected. The bottle should not have too narrow a mouth. In some cases it may be sufficient to collect a mixed sample from the four quarters, and then care should be taken to as nearly as possible obtain equal quantities of milk from each teat. In other cases it is necessary to collect a separate sample from each quarter. In general the fore milk should be rejected and middle milk sampled. In rare instances it may be necessary to collect fore, middle, and end milk samples from one special quarter or all of them.

In the examination of sterilised milk or ordinary bottled milk an unopened bottle must be selected and used, or two or more bottles may be obtained and a representative sample made up from these.

The milk should be collected in sterile bottles with accurately fitting glass stoppers. For the ordinary examination of mixed milk a sample of about a pint is a convenient amount to obtain, but for most purposes a much smaller quantity is sufficient. The larger amount obviates some of the possible errors in sampling from irregular distribution of the bacteria.

For samples from individual cows 2 oz. of milk is a sufficient quantity. The glass-stoppered bottles are sterilised in their tins, into which they just fit, being prevented from moving by layers of asbestos cardboard (A and B) above and below (Fig. 5).

For larger samples the simple and efficient apparatus (Fig. 6) described by Delépine may be used. It consists of a metal case containing a 7 or 8 oz. bottle and a milk-scoop. All the parts are thoroughly sterilised in the laboratory before being sent out, and the sterilised case is only opened at the time when the sample is taken. The sterilised scoop is used to remove the milk from the cans or other vessels. When obtained direct from a suspected cow, Delépine suggests that the milk may be

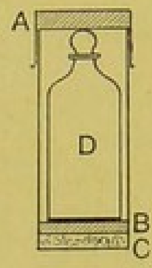


FIG. 5.

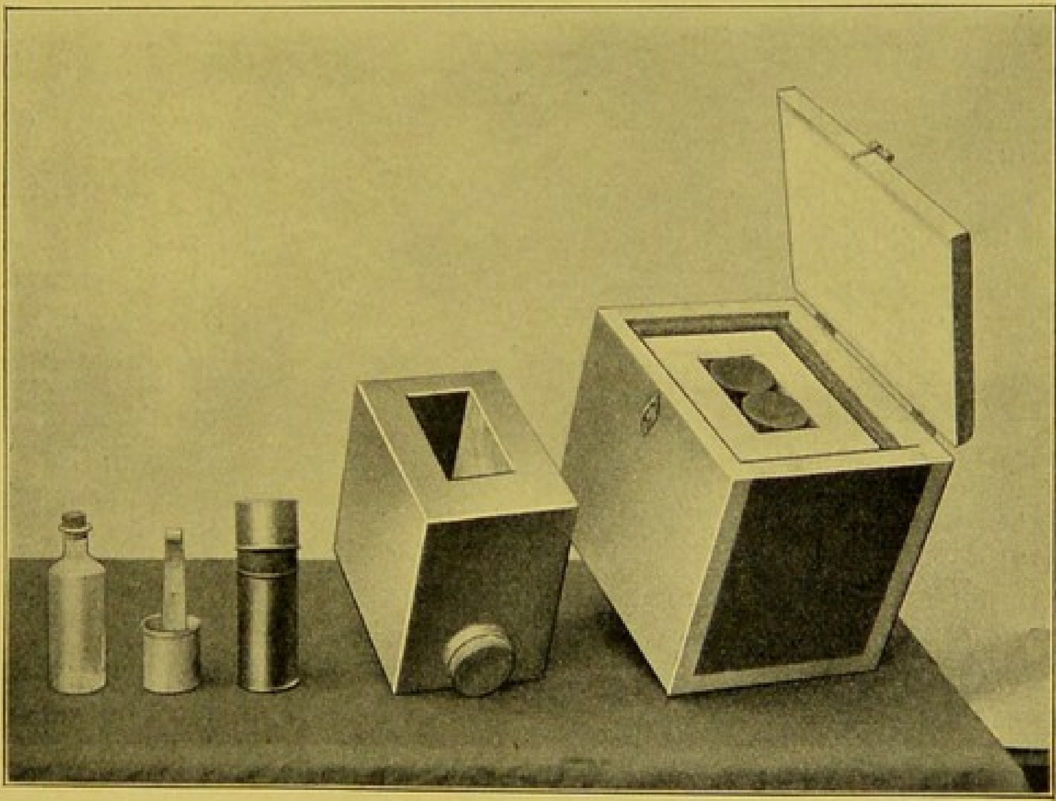


FIG. 6.

milked into the scoop, but it is better to milk direct into the bottles.

If the samples have to be transmitted any distance, or cannot be examined within an hour or two, they must be packed in ice. The ice box figured (Fig. 6), used by Delépine, which is similar to the apparatus the writer uses for bacteriological samples of water, is very convenient. The size the writer uses is made to just hold four 2 oz. bottles and their tins, but larger bottles are more convenient for milk samples.

The growth of bacteria in milk kept at ice temperature, or only slightly above 0° C., has been considered in Chapter IV. While, as explained in that chapter, some bacterial changes take place at these low temperatures, there is no material alteration or error of judgment involved in examining samples kept iced for not more than 12 to 20 hours.

Particulars to record with the Samples.—These must be carefully recorded, and should include:

(*a*) Date and time of sampling.

(*b*) Identification particulars as to farm or person from whom the milk is obtained.

(*c*) If mixed milk or from individual cows.

(*d*) If mixed milk, whether collected from byre, in transit, in shop, etc., or as delivered.

(*e*) If collected at the byre, the number of cows the milk of which it is a sample should be given, and whether the milk has been strained or not, and if so the strainer used.

(*f*) If from individual cows, particulars of the quarter or quarters from which obtained, and if fore, middle, or end milk.

It is useful to take and record the temperature of the milk.

Dilution of the Sample.—In the bacteriological examination of milk the proper dilution of the sample is of the utmost importance if accuracy is to be obtained. It is equally important that the milk should be thoroughly well shaken before dilution, and that the dilutions should be well mixed.

Rosenau and McCoy[1] have shown that the number of bacteria in milk, as determined by plating, is affected by the extent to which the milk sample and dilutions have been shaken. This is also shown by the influence of milk separators on the bacterial count.

Plating whole milk without dilution is always unreliable, even if the milk contains but few bacteria, since the bacteria are not properly separated, while the addition of the milk causes turbidity and so obscures the bacterial colonies.

The following is the most convenient method of dilution. A large number of glass-stoppered bottles of about 120 c.c.

[1] *Journ. Med. Research*, 1908, xviii. p. 165.

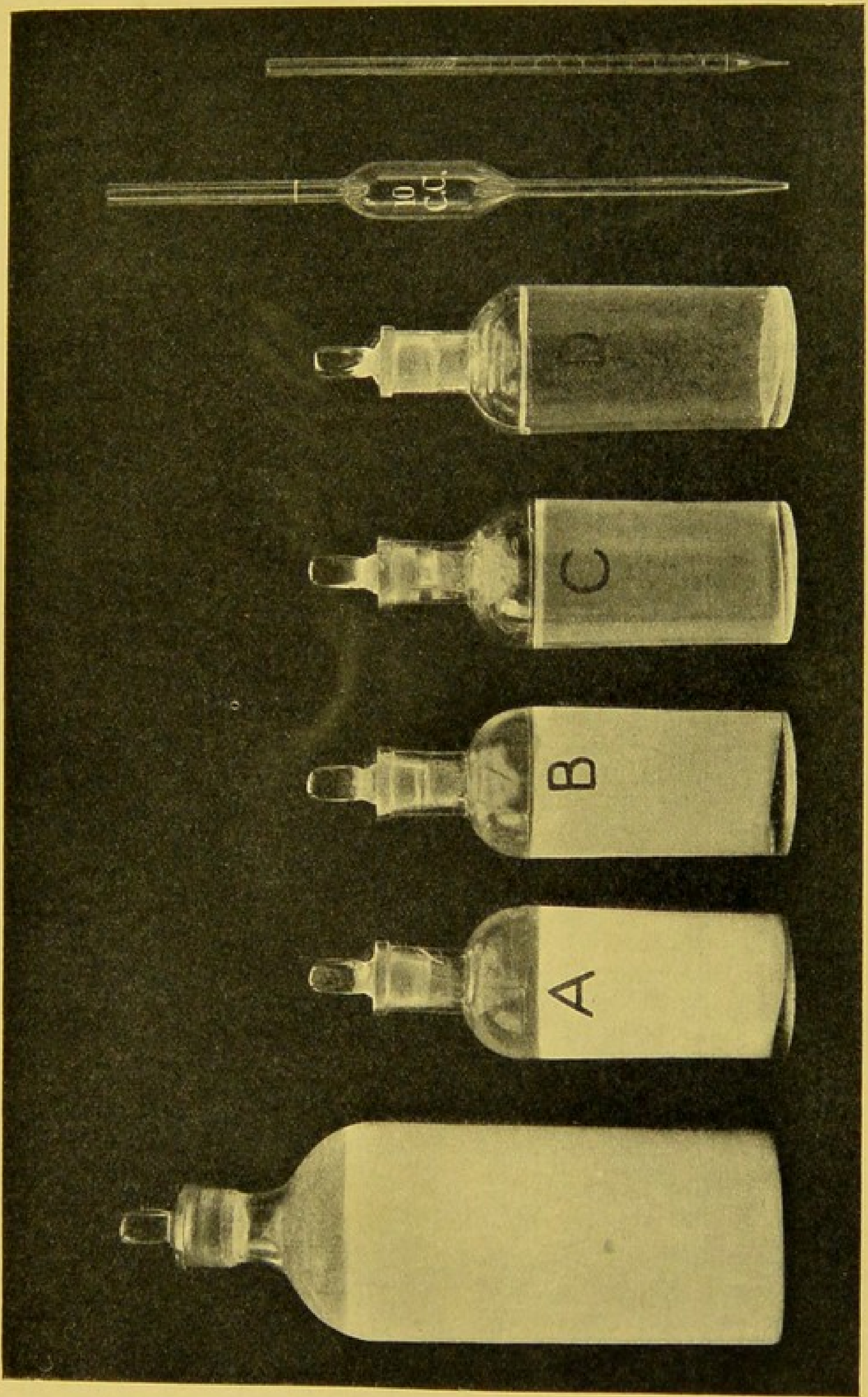


Fig. 7.—Dilution of Milk Samples.

capacity are used, each containing 90 c.c. of sterile tap-water. Sterile one-mark 10 c.c. pipettes are conveniently used to add the milk to the dilution bottles, and these should be made short for convenience of sterilisation. After thorough shaking 10 c.c. of the milk is removed and added to a 90 c.c. dilution bottle (Dilution A). (See Fig. 7.) After well mixing 10 c.c. Dilution A is added to a second 90 c.c. bottle (Dilution B). In the same way Dilution C is made from B and Dilution D from C. Each dilution, of course, represents a tenfold dilution of the one immediately above it in series.

Small 1 c.c. pipettes graduated in tenths of a c.c. are used to add fractions of the different dilutions to the requisite media.

Dilution flasks or bottles containing 99 c.c. or 9 c.c. are often used, and are recommended by the American Committee on Standard Methods of Bacterial Milk Analysis,[1] but the writer is of opinion that the addition of only 1 c.c. of milk for the primary dilutions is unreliable and leads to error. By adding as much as 10 c.c. errors of measurement are reduced to a minimum, while the use of glass-stoppered bottles enables the dilutions to be very thoroughly mixed.

[1] *American Journ. of Public Hygiene*, 1910, xx. p. 315.

CHAPTER X

BACTERIAL ESTIMATIONS TO DETERMINE THE GENERAL CONTAMINATION OF MILK

In this chapter certain bacterial estimations are considered which have for their object the measurement of the degree of bacterial contamination of milk, and more particularly that part of it which is manurial in origin. The significance of such determinations is more fully considered in Chapter XIV.

I. Estimation of the Number of Bacteria

The estimation of the total number of bacteria in milk is impossible with present-day methods, and it becomes necessary to select an arbitrary basis of enumeration. There are no known nutrient media and no known conditions of growth which will allow *all* the bacteria in milk to develop. All that can be said is that some media and some conditions are more favourable to the growth of a larger number of the bacteria in milk than others, and by their employment a higher count is obtained than by the use of less favourable media and conditions. Since all bacterial enumerations are relative, and since not all bacteria in milk are of undesirable significance, there is no particular reason why a medium giving the highest counts should, of necessity, be preferred to one allowing fewer bacteria to develop.

The bacteria which we need to estimate in milk are those whose addition is a measure of its undesirable pollution, and an enumeration of the total number of bacteria in milk (even if it were possible) is of itself a secondary matter. If this point of view is accepted, it is possible to obtain guiding principles as to the best estimation procedure to adopt. The temperature of 37° C. is, in the writer's opinion, preferable to 20°–22° C. for incubation of the milk-plates, since at the higher temperature the usually harmless lactic acid bacilli do not grow, or at least not readily, and it is a disadvantage to enumerate these organisms. On the other hand the manurial bacteria, which serve as the measure of manurial pollution, grow best at 37° C. While, therefore, the count at the higher temperature will be lower, it will yet be more valuable. The higher temperature also enables results to be recorded earlier, thus saving time, and avoiding the locking up of a large number of plates.

It should, however, be mentioned that a number of workers prefer the enumeration at the lower temperature. For example, Heinemann and Glenn[1] have recently compared the value of enumerations at 20° and 37° C. respectively. They found that using both glucose litmus agar and lactose litmus agar the number of colonies after 1 day is higher at 37° C., after 2 days is higher at 20° C., and after 3 days' incubation the number of colonies at 20° is about double that at 37° C. They found many more plates lost by the overgrowth of spreading colonies at 37° than at 20° C. They favoured the incubation at 20° C. for 3 days chiefly because, in their opinion, more groups of bacteria have a chance to develop than at 37° C., and this gives a better insight into the production and handling of milk.

For ordinary enumerations simple nutrient agar, of + 1 reaction, may be used. This medium may be modified for special purposes. For example, lactose litmus agar and glucose litmus agar have been made use of instead of ordinary agar, since they allow the bacilli which ferment these sugars to be differentiated and roughly enumerated. Heinemann and Glenn, comparing these two media, found that there was in some samples a decided relative decrease of acid colonies after 2 and 3 days at both 20° and 37° C. in lactose agar. This phenomenon, they believe, is due to the fact that some milk bacilli of the *B. aerogenes* type form red colonies at first, and then later these colonies assume the blue colour again. This change was not observed in glucose agar, and in consequence

[1] *The Journ. of Infectious Diseases*, 1908, v. p. 412.

these investigators recommend glucose in preference to lactose agar.

The committee of the American Public Health Association on standard milk methods adopted nutrient agar containing 1 per cent agar, and of a reaction of + 1·5. They remark:

> Much work yet remains to be done on media; the above is recommended as giving the highest and most uniform counts as far as our comparative work has extended, and, with but slight variation, is the medium in most common use.

The proper dilution of the sample has already been considered, the other steps are briefly as follows: Tubes of nutrient agar medium are melted, and cooled to a temperature of about 42° C. The diluted milk fractions are then added by sterile pipette. The contents of the inoculated tubes are thoroughly mixed, poured, and solidified in the ordinary way. The plates are inverted and incubated at 37° C. The colonies should be counted after 40 to 48 hours' incubation. Many workers count after 24 hours' incubation, but usually the colony development is then very incomplete, and the number of colonies not easily counted. The counting should be done by the naked eye.

Media, temperature of incubation, period of incubation, must all be accurately recorded, and it is absolutely imperative for comparative work to enumerate under precisely similar conditions.

At least three plates should be poured, and only those plates enumerated which do not contain an excessive number of bacteria. Convenient amounts of the milk to add to the agar tubes are, for fresh byre milk 0·01, 0·02, and 0·004 c.c., and for ordinary vended milk 0·002, 0·001, and 0·0002 c.c. If, however, something is known about the milk, it will usually be possible to obtain a closer and more satisfactory range of dilutions.

Several workers have attempted to estimate the number of bacteria from an examination of the stained centrifugal deposit of a fraction of milk. The estimate is a very rough one, and no numerical figure, with any pretence to accuracy, can be obtained, but it gives a useful idea of the number present. Dealing with samples of doubtful origin, it is a decided advantage to centrifugalise a small definite quantity and at once examine the deposit. This is a useful guide to the best dilutions to add for plating.

II. Estimation of the Number of *B. coli* and Allied Organisms

A great deal of very valuable work has been carried out upon *B. coli* and its allies. We now know that there are a large number of bacteria which can be differentiated from the original *B. coli communis* by cultural tests, but which are nevertheless closely allied and frequently seem to have a very similar origin and distribution in nature. The varieties which are of chief significance in relation to milk contamination all ferment lactose. These lactose fermenters of *B. coli* type are not present in milk as drawn from the teats, and when found in milk are nearly always derived from cow manure, possibly occasionally from human excreta.

To isolate this group of organisms, several procedures may be used, but the following is recommended as, in the writer's experience, the most satisfactory.

Lactose bile-salt broth (conveniently called L.B.B.) in double tubes, is used. To prepare:

Five grammes each of sodium taurocholate and lactose, 20 grammes of peptone, and 1 litre of water are heated together until the solids are dissolved. The mixture is filtered and sufficient strong neutral litmus solution is added to give a distinct colour. The medium is then distributed into fermentation tubes, and sterilised, by steaming for 20 minutes on three successive days.

Definite fractions of the milk are added by pipette to these tubes. The amount to add will depend upon the suspected degree of pollution of the milk. A usual procedure is to add 1·0, 0·1, 0·01 c.c. if the sample is byre milk, and if it is ordinary vended milk to add in addition 0·001, 0·0001, 0·00001, 0·000001, and occasionally even 0·0000001 c.c. The dilutions are obtained in the ordinary way, as described in Chapter IX.

These dilutions are widely spaced, and consequently the number of *B. coli* present can only be enumerated between rather wide limits. The liability to accidental differences from faulty or unequal dilution is not inconsiderable. The writer recommends the following dilutions and procedure for routine work.

Byre milk.—Add 1 c.c. of the milk to each of five L.B.B. tubes, and 0·1 c.c. of the milk to each of two L.B.B. tubes. Incubate all seven tubes at 37° C. for two days, and record as positive all the tubes showing acid and gas. To isolate the lactose fermenting bacilli use one or more of the positive tubes containing the least amount of milk and plate as described below.

Vended milk.—*Winter* (October to April inclusive). Make a series of dilutions of the milk as described in Chapter IX. Inoculate ten L.B.B. tubes, four being with 0·0001 c.c. each, four with 0·001 c.c. each, one with 0·01 c.c., and one with 0·1 c.c. Incubate all ten tubes at 37° for two days and record the positive results. Plate from one or more of the positive tubes containing the least amount of milk.

Summer (May to September inclusive). Dilutions and procedure as for winter samples, but inoculate nine L.B.B. tubes adding the following quantities of milk—0·0001 c.c. to each of four tubes, 0·001 to each of four tubes, 0·01 to one tube.

By this method of examination a much closer estimate of the number of *B. coli* can be obtained than by the ordinary methods and without more expenditure of time and material. The interpretation of the results is dealt with in Chapter XIV.

To isolate these lactose fermenting bacilli solid media must be used, and there are a number of such media which give good results. The most useful of these are fuchsine-agar, nutrose-agar (Drigalski and Conradi's medium) and lactose bile-salt neutral red agar (conveniently called L.B.A). L.B.A. is, on the whole, both the most uniform and convenient to use, while it gives very reliable results.

Preparation of L.B.A.—Sodium taurocholate 5 grammes, Witte's peptone 20 grammes, and distilled water 1 litre, are boiled up together, 20 grammes of agar are added and dissolved in the solution in the autoclave in the ordinary way. The medium is cleared with white of egg and filtered. After filtration, 10 grammes of lactose and 5 c.c. of recently prepared 1 per cent neutral red solution is added. The medium is then tubed and sterilised for 15 minutes on three successive days.

To isolate, add one loopful of the selected lactose bile-salt broth tube to a tube of sterile water. After mixing well, place two loopfuls of the latter upon the surface of the

L.B.A. plate. Distribute with a sterile bent glass rod uniformly over the plate. The L.B.A. plate will be rather wet from condensed water on the surface. To dry, incubate it for 1½ to 2 hours uncovered in the 37° C. incubator. Then cover and invert. Incubate for 24 hours at 37° C.

B. coli and other lactose fermenters grow as red colonies, colour the surrounding medium red, and many of them produce a haze round the colony. Several of the typical red colonies are picked off, subcultivated, and their characters determined as described below.

Another procedure for the isolation of *B. coli* and its allies from milk samples is to directly plate the diluted milk on solid media. Lactose litmus agar, L.B.A., and aesculin agar may be used for this purpose. Aesculin media were introduced by Harrison and Leck.[1] They prepared an aesculin broth and an aesculin agar.

The aesculin agar is made as follows:—

Ten grammes Witte's peptone, 5 grammes sodium taurocholate (commercial), 1 gramme aesculin, 0·5 gramme ferric citrate, 15 grammes agar, tap-water 1 litre. The agar and other ingredients are dissolved in the ordinary way, boiled, filtered, tubed, and sterilised.

Colonies of *B. coli* in this medium are black with a black halo, and can be readily counted against a suitable background. The aesculin (a glucoside) combines with the iron citrate and forms a dark-brown salt, the reaction only taking place in sugar-free media.

The colonies of some other organisms give the reaction, notably *B. lactis aerogenes.* Harrison and Leck say that with care the characters of the colonies of this organism can be distinguished from those of *B. coli,* being larger, moister, and more raised. These investigators recommend that the diluted milk (dilutions 1 : 100 and 1 : 500 being used), and the aesculin agar be mixed together in the Petri dish, allowed to set and incubated at 37° C. The plates are counted after 24 hours, using a white background. To accurately differentiate *B. coli* and *B. aerogenes,* they prefer to leave the plates longer in the incubator. By this method

[1] *Centralbl. f. Bakt.* Abt. II., 1909, xxii. p. 55 ; and *Amer. Journ. of Public Hygiene*, 1908, p. 431.

they believe that an accurate estimation of the number of *B. coli* and *B. lactis aerogenes* in milk can be obtained.

The writer has carried out a large number of milk examinations to determine *B. coli* and allied forms, using at the same time the L.B.B. tubes method and direct plating on aesculin agar or L.B.A. He found the L.B.A. medium quite as useful as aesculin agar, but on the whole with both media, it was difficult to arrive at accurate estimations of the number of these organisms from direct plating on solid media, and this procedure is far inferior to the use of L.B.B. tubes inoculated with definite fractions of the milk.

Identification tests.—The following tests should be carried out for *routine* work:

(*a*) Growth upon gelatine slope, for character of growth and absence of liquefaction.

(*b*) Growth in litmus milk at 37° C. for acid and clot.

(*c*) Growth in lactose peptone litmus solution for lactose fermentation.

(*d*) Growth in peptone water for indol production.

(*e*) Growth in saccharose peptone litmus solution for fermentation of saccharose.

Of these, the saccharose fermentation test is omitted by some workers. The others are the minimum number of tests which should be employed. For research purposes, to accurately study the distribution of the organisms included in one group by the above tests, a greatly extended series of cultural tests will be necessary.

MacConkey has advocated a different series of tests for members of the *B. coli* group. He at first suggested[1] the omission of the fermentation of glucose, growth in milk, character of the growth on gelatine, indol formation and action on neutral red, and the substitution for these tests of the following—fermentation of dulcite, adonite, and inulin, and Voges and Proskauer's reaction. He retained the fermentation of saccharose. In his opinion, "by so doing we should gain a finer differentiation without increase of work, and we should not be classing as *B. coli* organisms which may have little in common with, and have a distribution entirely different from that of the *B. coli communis.*"

[1] *Journal of Hygiene*, 1906, vi. p. 385.

In a later paper[1] further discussing these tests, MacConkey arrived at the opinion that (in view of the better tests for that substance now available) the indol test should be retained. He also modified his opinion as to the value of Voges and Proskauer's reaction. In addition, he introduced three further tests, *i.e.* the fermentation of inulin, inosit, and mannite. MacConkey states:

The method of procedure suggested is that a sloped agar tube should be inoculated from a single colony on a plate, the growth being rubbed all over the surface of the medium and in the water of condensation. After 4 to 6 hours' growth at 37° C. a drop of the condensation water can be examined to ascertain the presence or absence of motility. After 24 hours' incubation at 37° C. a good loopful of the growth is put into tubes of gelatine, lactose, saccharose, dulcit, adonit, and inulin. The agar tube is returned to the incubator, together with the rest of the tubes, and is used later for the indol test. An inosit tube and a glucose tube (for Voges and Proskauer's reaction) may be inoculated at the same time as the others, or these two may be used as confirmatory tests. Voges and Proskauer's reaction may be tested for at the end of 4 days. The other tubes should be kept under observation as long as there is no change in the reaction of the medium.

As regards the value of these additional fermentation tests, it may be said at once that for *research* purposes the greater the number of cultural differentiation tests used the more valuable the information obtained in regard to the distribution of certain strains and their ultimate significance. For *routine* work the increased labour necessitated by the use of a large series of differentiating tests is so considerable that the number of such tests has to be restricted, and only those of proved utility, from the immediate practical point of view, can be adopted.

The practical value of these additional tests turns upon the light they shed as to the origin of the organisms to which they are applied. For example, the dulcite test is fully justified if it can be shown that a dulcite fermenting organism is of greater or lesser significance, and indicates a different distribution than an identical organism which does not ferment that alcohol. Have the workers who advocate the use of these extra tests been able to demonstrate such a proposition?

[1] *Journal of Hygiene*, 1909, ix. p. 86.

It is simple enough to give such organisms different names, and to say one is *B. coli communis*, another *B. coscoroba*, another *B. neapolitanus*, etc., but unless we are able to demonstrate a different distribution and a different significance for such organisms, their use in the practical and routine examination of milk adds nothing of value for administrative purposes, and the use of these names is of doubtful service.

Both MacConkey and Orr have published the results of examinations based upon the use of some or most of these tests.

MacConkey[1] records the examination of 178 samples of human faeces and 131 samples of horse, calf, goat, and pig faeces. He differentiated his isolated organisms by fermentation and other tests into numerous groups. Taking his results, and neglecting the presence or absence of motility as a differentiating test, and grouping together some of the varieties only represented by a very few strains, we obtain the following percentage results:

Strain.*	Origin (percentage).	
	Human Faeces.	Animal Faeces.
A	5·0	5·3
B	23·0	3·1
C	27·0	27·4
D	0	6·9
E	32·2	48·1
F	4·5	0
G	...	...
H	...	...
J	...	...
Strains other than the above . .	8·3	9·2

* For characters of these strains, see table below.

Orr[2] isolated 850 glucose fermenting organisms from milk. He classified them in a very similar manner to MacConkey. Some of them failed to ferment lactose. Excluding these, and dealing only with the bacilli isolated from cowshed, retailer, and consumer milk samples and those obtained from manure, the results in the following table are obtained:

[1] *Journal of Hygiene*, 1909, ix. p. 86.

[2] *Report on an Investigation as to the Contamination of Milk*, 1908.

Strain.	Organisms isolated.				Percentages.			
	Cowshed.	Retailer.	Consumer.	Manure.	Cowshed.	Retailer.	Consumer.	Manure.
A	0	0	0	0	0	0	0	0
B	30	57	30	4	12·1	20·4	16·6	8·3
C	33	29	23	17	13·8	10·4	12·8	34·6
D	0	0	0	0	0	0	0	0
E	45	50	31	9	18·8	17·9	17·2	18·7
F	62	59	48	3	25·9	21·1	26·6	6·2
G	31	27	19	12	12·9	9·6	10·6	27·1
H	12	23	7	1	5·0	8·2	3·9	2·1
J	23	24	16	0	9·6	8·6	8·9	0·0
All others	3	10	6	2	1·2	3·6	3·3	4·0
	239	279	180	48	...	...	...	...

The strains A to J are essentially differentiated by their fermentation characters. They all ferment glucose and lactose, and as regards the others their characters are as follows :—

Strain.	Saccharose.	Dulcite.	Adonit.	Voges and Proskauer.	
A	–	–	+	–	
B	–	–	–	–	*B. Grünthal*, *B. vesiculosus*, etc.
C	–	+	–	–	*B. coli communis*, etc.
D	–	+	+	–	
E	+	+	–	–	*B. neapolitanus.*
F	+	–	+	+	*B. lactis aerogenes.*
G	+	–	–	–	*B. coscoroba.*
H	+	–	–	+	*B. cloacae* (liquefies gelatine).
J	+	+	+	+	*B. oxytocus perniciosus.*

When the results are worked out in percentages, as shown in the above tables, it is possible to compare results.

The essential differences between MacConkey's human and animal excreta figures are the much greater prevalence of strain B in human excreta, and the much more numerous strain E in the animal excreta. Orr's results show the much greater prevalence of *B. lactis aerogenes* in milk as compared with excreta. This is no doubt explained by the fact that *B. lactis aerogenes* often multiplies more rapidly in milk than the other coli group organisms. The writer has found this to be the case in his work. Orr, however, did not find, as might have been anticipated, this strain more numerous in the retailer and consumer samples compared with the cowshed samples. Orr's cowshed, retailer, and consumer results are strikingly alike.

These findings, interesting as they are, fail to demonstrate the value of these additional fermentation tests for routine work. To take but one example, they do not show that the *B. coli communis* type (strain C), which does not ferment saccharose, is any different significance from the *B. neapolitanus* type (strain E), which does ferment saccharose. From these results it is not possible to attach any additional significance to the presence or absence of saccharose fermentation, and the same applies to most of the other sugar-alcohols employed.

The writer has carefully studied the investigations both of MacConkey and Orr, and while their work is of the highest value for scientific purposes, and a basis for future practical work, in his opinion it cannot be said that they have established that any particular variants are of greater significance as an index of excreted pollution than other types. In other words, the practical value of these tests has yet to be demonstrated.

Bergey and Deehan [1] have also studied what they call the colon-aerogenes group of bacteria, using the same differentiating tests as those employed by MacConkey. They isolated and studied bacteria from 50 samples of milk and 8 samples of sewage. As they point out, the 8 differentiating tests employed (fermentation of saccharose, dulcite, adonite, inulin, motility, indol production, Voges and Proskauer's reaction, gelatine liquefaction) represent 256 possible combinations. Of these they found organisms representing only 43 varieties, while those from the milk samples represented only 27 different species, less than half of which had been found by MacConkey. Their results also fail to show any special utility to be obtained from the use of these tests.

In the same way the relative significance of the strains which produce indol, and those which do not, has yet to be

[1] *Journ. of Medical Research*, 1908, xix. p. 175.

accurately determined. The problem is, however, neither so difficult nor so important as the same question applied to water supplies. Lactose fermenters of coli type are absent from pure milk drawn without contamination, and as far as is at present known all such organisms indicate outside pollution of the milk, and in general (directly or indirectly) manurial pollution.

III. Determination of the Number of Streptococci

To estimate the number of streptococci in milk the method recommended as the simplest and most reliable is to add diluted fractions of the milk, 1·0, 0·1, 0·01, 0·001 c.c. etc., to tubes of glucose neutral red broth. Ordinary broth will do, but the neutral red broth is preferable and gives better results. The tubes are incubated for two days at 37° C. and then examined, in hanging-drop preparation, for streptococcus chains. The deposit should be selected for examination, and several hanging-drop preparations made. A positive result should be recorded only when quite definite chains of cocci are detected, or, in doubtful cases, when stained preparations show such definite chains.

To isolate the streptococci, brush diluted loopfuls of the positive tubes over plates containing nutrient agar. Incubate for 24 hours, and if necessary for 2 days, at 37° C. Sub-cultivate the colonies having the characters of streptococcus colonies into broth or upon sloped agar in tubes containing condensation water. In cases in which streptococci are likely to be scanty, part of the centrifugalised deposit may be used to inoculate the agar plates.

The tests recommended to differentiate the streptococcus strains isolated are the following: morphology, growth upon sloped nutrient agar, growth in nutrient broth, growth upon gelatine slope, action upon litmus milk, the production of acid in lactose, saccharose, salicin, mannite, raffinose, and inulin.

These sugar-alcohol media for the differentiation of streptococci were introduced by Gordon, and may conveniently be prepared as follows:

A stock solution is made up containing lemco 10 grammes, peptone 10 grammes, sodium bicarbonate 1 gramme, 10 per cent aqueous litmus-solution 100 c.c., distilled water to 1 litre. This is boiled and filtered in the ordinary way; 1 per cent of the sugar, alcohol, or glucoside is added to portions of this stock solution to make the different media. The tubes are sterilised in current steam for three successive days.

For some purposes it is of great value to ascertain the pathogenicity of isolated strains of streptococci. This is conveniently done by injecting mice subcutaneously or intraperitoneally.

The presence or absence of streptococci in milk may also be studied by a careful examination of the centrifugalised deposit stained by methylene blue. Failure to find streptococcus chains does not mean they are absent, but only suggests they are not present in considerable numbers. The stained deposits from samples of vended milk usually show numerous streptococci, but in those made from fresh byre milk samples they are, as a rule, not to be demonstrated.

IV. Estimation of the Number of *B. enteritidis sporogenes* Spores

The milk itself is directly incubated. The usual quantities of milk to examine are 1, 10, and 20 c.c., the smallest amount being added to a tube of freshly sterilised whole milk, while the other quantities are placed in empty sterile test tubes. The milk tubes are heated in a water-bath to 80° C., and kept at that temperature for ten minutes, then cooled and incubated anaërobically at 37° C. The anaërobic cultivation is most conveniently done by absorbing the oxygen with pyrogallic acid and potash contained in a wide-mouthed bottle in which the tubes are placed.

The amounts given above are too wide apart to yield a satisfactory estimation, and the following method is advocated by the writer:[1] Quite small, narrow (4 by $\frac{1}{4}$ inch), sterile empty test tubes are used in batches of ten for each estimation. 20 c.c. of milk is employed for each test, 2 c.c. being added by sterile pipette to each tube. The ten tubes are heated for 10 minutes at 80° C., rapidly cooled and incubated anaërobically in specimen jars with ground-glass stoppers, just large enough to take the ten tubes, the oxygen being absorbed by the usual potash and pyrogallic acid mixture. The tubes are examined

[1] *Report of Medical Officer, Local Government Board*, 1909-10, p. 477.

after 2 days' incubation at 37° C. for the characteristic changes described on page 42. In the slender test tubes advocated the 2 c.c. of milk rather more than half fills the tube, and the condition of the milk can readily be observed. The tubes being small readily go into a small specimen jar which consequently requires less chemicals to absorb all the oxygen, while space in the incubator is economised. The essential value of the modification is that the test is made much more delicate without additional work.

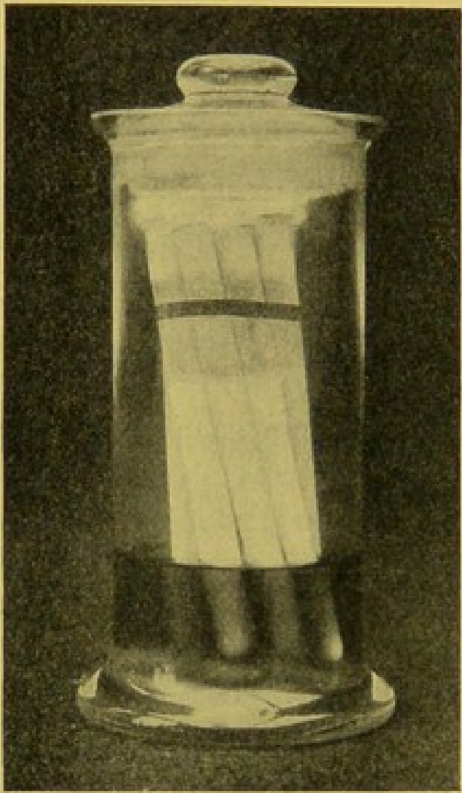


FIG. 8.

Some arbitrary standard is convenient for recording. Each positive result in a tube is counted as 1 *B. enteritidis sporogenes* spore, an assumption which is probably, but certainly not always, true. Thus, if all the ten tubes show a positive "enteritidis change," the result is recorded as 10. All gradations between 0 and 10 may be met with, and a comparative sensitive test is in this way available.

It is not usual to confirm the diagnosis by an animal inoculation test, reliance being placed upon the naked-eye changes in the test tube, the so-called "enteritidis change." From the facts given in Chapter IV. it is evident that other organisms, such as *B. butyricus*, give this appearance in milk. Since, however, these other organisms have, as far as is known, a very similar distribution in nature this fact does not invalidate to any serious extent the value of the test. If pathogenicity is to be tested 1 c.c. of the whey is injected subcutaneously into a guinea-pig.

One great value of this test is that it is a non-multiplying one, so that it is especially useful for vended milk. A drawback to its utility is the fact that the spores are not always uniformly distributed in the milk.

CHAPTER XI

THE CELLULAR AND SEDIMENT EXAMINATION OF MILK

The varieties of cellular elements in milk and the chief factors influencing the numbers present have been considered in Chapter I. The nature and volume of solid deposit obtained by centrifugalisation or sedimentation of milk samples was also described. The present chapter is concerned with three estimations and their utility in practical milk examination. They are the following:

A. The numerical estimation of the cellular content.

B. The examination of the stained centrifugalised deposit.

C. The estimation of the volume or weight of sediment obtained from milk.

A. Estimation of the Cellular Content

Stokes and Wegefarth in 1897 first devised a method for the enumeration of the cells, or, as they are usually called, leucocytes in milk. Their method was based upon the number of leucocytes per microscopic field of a preparation made by centrifugalising 10 c.c. of milk, spreading the sediment on a slide, and staining with methylene blue. Bergey, Stewart, and Slack all used a very similar procedure. This method and modifications of it are extremely inaccurate. Russell and Hoffmann found variations of 112 per cent as compared with 6 per cent using the Doane-Buckley procedure.

Prescott and Breed[1] have recently modified the direct counting procedure as follows. The sample is well shaken to distribute the cream equally through the milk. A measured drop (0·01 c.c.) is then withdrawn by means of a specially

[1] *Journ. of Inf. Diseases*, 1910, vii. p. 632.

constructed capillary pipette with a rubber bulb. The drop is spread evenly over an area of 1 sq. c.m. on an ordinary glass slide. The milk is then dried with gentle heat, the fat dissolved out with xylol or other fat solvent, the smear fixed to the slide by immersion in alcohol for a few minutes, dried, overstained with methylene blue, and decolorized with alcohol. The slide is then ready for examination. Rapid drying is necessary to prevent the segregation of the fat drops which makes the distribution of the cells uneven.

The counting is done with an oil immersion lens. If the diameter of the field is so arranged that it equals 0·16 m.m., then each field covers approximately 0·005 of a sq. c.m. On this basis each cell seen in a field taken at random represents 500,000 cells per c.c. The authors record that the cells are evenly distributed. While an improvement on the original smear method, many errors are obviously possible.

To reliably estimate the cellular content of milk there are only two methods (including later modifications of these methods) with any pretensions to accuracy: the Doane-Buckley method published in 1905, and the method of the writer, which was independently worked out about the same time, but not published until the following year. Both are based upon the same principle, but show essential differences in technique. By using as much as 10 c.c. of milk, the Doane-Buckley counts are in the writer's opinion liable to be much too low.

The German method of Trommsdorf consists in reading off the volume of centrifugalised deposit in a drawn-out graduated tube. The deposit consists of other matters besides leucocytes, and cannot be taken as an estimation of their number. The volume of total deposit does not bear any direct or constant relationship to the leucocyte count.

Savage's Method. — The ordinary Thoma-Zeiss blood-counting chamber is employed. Direct counting of the cells is impossible owing to the opacity caused by the large amount of fat. One c.c. of the milk is accurately transferred to a centrifugal tube (about 15 c.c. capacity) of the pattern shown in Fig. 9, and freshly filtered Toisson's solution[1] is poured in to

[1] This is the well-known indifferent solution used in blood enumerations. It does not injure the cells, but stains them sufficiently to render them clearly visible. Its composition is methyl violet 0·025 grm., sodium chloride 1 grm., sodium sulphate 8 grms., glycerine 30 c.c., distilled water 160 c.c.

almost fill the tube. The two fluids are well mixed and centrifugalised for 10 minutes. The cream is then well broken up by a clean glass rod, to disentangle leucocytes carried to the surface, and the mixture centrifugalised for an additional 5 minutes. All the fluid is then removed down to the 1 c.c. mark, great care being taken not to disturb the deposit. This can be conveniently and readily done by means of a fine glass tube connected to an exhaust pump. Theoretically, all the leucocytes present in the original 1 c.c. of milk are now present in the 1 c.c. of fluid. The leucocytes are thoroughly well mixed (with a wire), and distributed through the 1 c.c. A sufficient quantity is placed on the ruled squares of the Thoma-Zeiss apparatus, and the cover-glass put on. The number of leucocytes is counted in a number of different fields of vision, moving regularly from one field of vision to another. The diameter of the field of vision is ascertained before counting by drawing out the microscope tube until an exact number of sides of the squares spans a diameter of the field of vision.

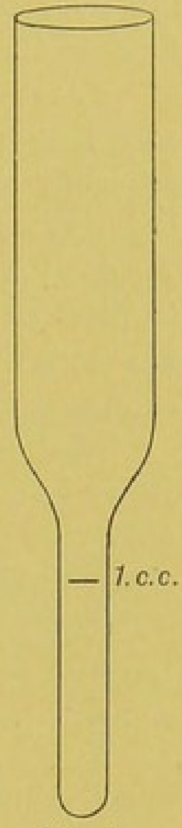


FIG. 9.

The number of leucocytes per cubic m.m. of milk $= \frac{56,000\,y}{11d^2}$, where $y =$ the average number of leucocytes per field of vision, $d =$ the number of squares which just spans the diameter. d is determined once for all by marking the microscope draw tube so that only 20 fields have to be counted, and the figures substituted in the formula.[1]

Doane-Buckley Method.—10 c.c. of milk are centrifugalised for 4 minutes in a graduated centrifuge tube running at about 2000 revolutions per minute. The cream is removed with a

[1] It has been urged as a criticism that this counting procedure makes the method unnecessarily difficult. The counting by field of vision is vastly more accurate than by squares. If the former is done some formula is necessary, but if d is once determined and a line scratched on the microscope tube, the mathematical labour is trivial. In the microscope chiefly used by the writer, d was always 6, and the formula became $\frac{56,000\,y}{11\times 36} = \frac{14,000}{99}y$. For ordinary routine work—number $= 140y$ was then sufficiently accurate, or even more simply, just 7 times the number of leucocytes in the total 20 fields counted.

cotton swab as far as possible. The tube is centrifuged for one minute more and the cream again removed. Without disturbing the sediment, the overlying milk is syphoned off, leaving fluid to the depth of $\frac{1}{8}$ inch above the sediment. Two drops of a saturated alcoholic solution of methylene blue are added, thoroughly mixed with the sediment by shaking, and set aside in boiling water for 2 or 3 minutes to allow the leucocytes to take up the stain. The tube is then filled up to 1 c.c. with water, the contents shaken thoroughly, and a little transferred to a blood-counting chamber. The number of leucocytes in all, or a definite number of the squares, is ascertained, and the number per c.c. of milk deduced.

Modifications of these methods have been introduced. Russell and Hoffmann, using the Doane-Buckley method, found that by heating the milk to 60°–70° C. before centrifugalisation, a very great increase almost always results in the number of cells. They ascribe this to the entangling effect of the fat, an effect which is broken down by heating. They suggest that the milk should be subjected to a preliminary heating. "A momentary exposure at 70° C. or above, or a more prolonged heating for a few minutes at 60° C., will so alter the physical arrangement of the fat globules in milk, that practically all the cellular elements may be recovered."

Hewlett, Villar, and Revis find that the addition of formaldehyde (6 drops of formalin to 60–70 c.c. of milk) has a similar effect. They ascribe this increase to the formalin breaking down aggregations of cells, and causing them to be more evenly distributed.

B. The Examination of the Stained Centrifugalised Deposit

To obtain comparable results the sediment from a definite amount of milk should be examined after centrifugalisation for a definite period. Ten c.c. of milk centrifugalised for 10 minutes is convenient. Part of the deposit is spread thinly but uniformly over a cover-slip, dried in air, fixed in the flame, or preferably by soaking in a mixture of equal parts alcohol and ether for one minute, stained by methylene blue and mounted in balsam.

The preparation may be utilised to gain an idea of the general bacterial content, if streptococci are present, and if so in what numbers and whether intracellular, while, if considered necessary, a differential count may be made of the cellular elements present.

With care a rough but valuable estimate can be obtained from this examination as to the probable number of bacteria in the sample. In Chapter I. a description is given of the different cells found in milk deposits. At least 200 leucocytes should be enumerated.

C. The Estimation of the Volume or Weight of Sediment obtainable from Milk

The amount of sediment in milk has been measured and estimated by a number of observers, each worker using as a rule his own method which, while giving comparable results for his own work, renders comparison with the results of other investigators useless. It may be said that there is no one method which is generally accepted. The following are some of the more important procedures which have been used in this country:

1. *Delépine's Method.*[1]—Delépine estimates the sediment from milk by measuring the diameter of the sediment deposited in tubes of uniform diameter, each containing 40 c.c. of milk, and left for a quarter of an hour in a centrifugal machine running at the rate of about 2500 revolutions per minute. The absolute amount of sediment is not indicated by these measurements, but Delépine estimated the relationship between the diameter and the weight of these sediments. In this way he constructed an approximately reliable scale.

2. *Houston's Method.*[2]—A litre of milk is allowed to stand (with 1 c.c. of formalin added to inhibit bacteria) in a long tube with a narrowed, graduated lower portion provided with a glass tap. The solid matters sink, and after 24 hours the volume of sediment is read off on the scale. This Houston calls the "primary reading." A centrifugal tube with the lower part graduated and of narrow bore is then held under

[1] *Medical Chronicle*, March 1908.

[2] *Report to the London County Council* (No. 933), 1905.

the outlet of the cylindrical sedimentation apparatus, and the stopcock of the latter turned sharply on and off several times until all the deposit has been swept into the centrifugal tube. Distilled water (+ 0·1 per cent No_2CO_3) is added to the centrifugal tube up to the 10 c.c. mark. After centrifugalisa-

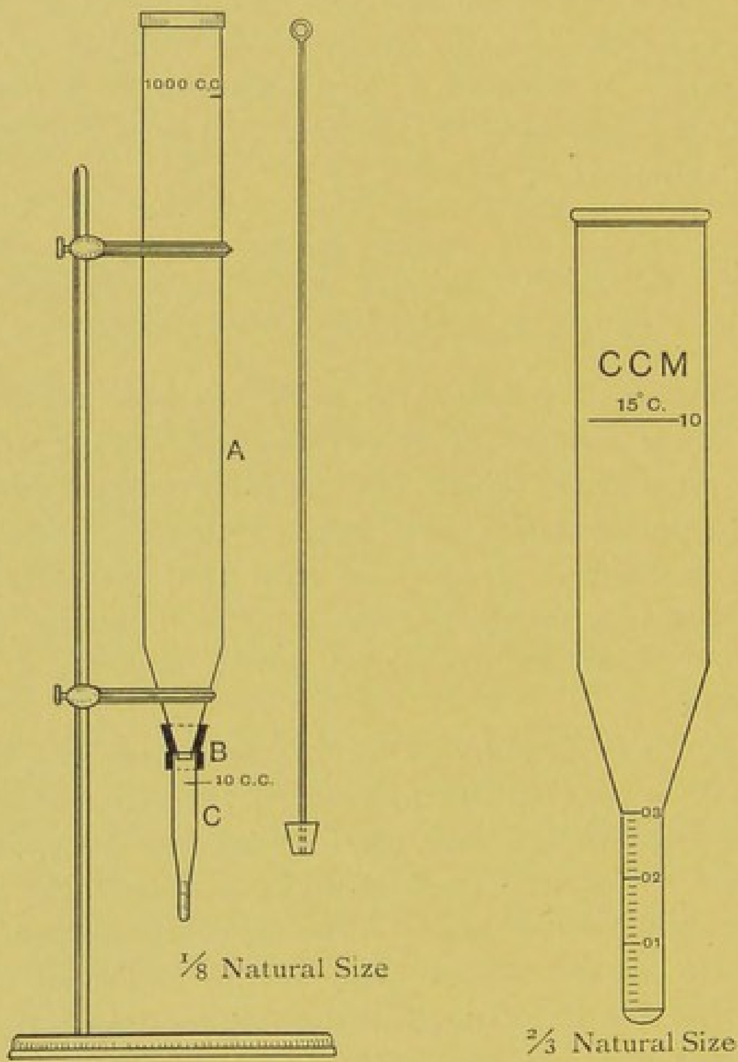


FIG. 10.—A, Glass tube holding a litre of milk; C, Tube for measuring sediment; B, Rubber tubing connecting A and C. At the side is represented a brass rod, with rubber stopper attached, for plugging the lower end of tube A, when C is taken off. Tube C is shown by the side ⅔ natural size. It is graduated in $\frac{1}{10}$ths and $\frac{1}{100}$ths of a c.c.

tion for 2 minutes the volume of sediment is read off on the scale. This Houston calls the "secondary reading."

3. *Orr's Method.*[1]—This method is a modification of that used by Houston. The apparatus used is shown in Fig. 10. The top of the centrifugal tube fits outside the lower part of the large glass cylinder, the two being connected by rubber

[1] *Report on an Investigation as to the Contamination of Milk*, 1908.

tubing. The centrifuge tube is graduated in $\frac{1}{10}$ths and $\frac{1}{100}$ths of a c.c. A litre of milk (after addition of 1 c.c. formalin) is allowed to stand for 12 hours. At the end of that time, a brass rod fitted with a rubber stopper at the lower end is passed through the milk, and fitting into the outlet of the cylinder prevents escape of the fluid when the centrifuge tube is detached. The tube is centrifugalised (1500 to 2000 revolutions per minute) for 3 to 5 minutes, and the milk poured off. Sodium carbonate solution (1 per cent) is then added up to the 10 c.c. mark and the centrifugalising repeated. The deposit is then read off. The primary reading of Houston is omitted.

4. *Revis's Method.*[1]—A tube holding about 70 c.c. is used. This is made of stout glass drawn out at one end and with a small glass cap well ground on. Inside the neck of the tube upon which the cap fits, a glass rod is well ground in, of sufficient length to project beyond the mouth of the tube. The end of the rod is ground flush with the neck, and the cap has such a capacity that when in place $\frac{1}{8}$ inch in depth is left beyond the end of the tube. It is used as follows: 50 c.c. of milk are placed in the tube, the cap being in place and the rod withdrawn. A rubber stopper is put in, and the tube rotated at about 2000 revolutions per minute for 5 minutes. (The cap should be well backed up with a pad of cotton-wool to prevent breakage.) The rod is then carefully inserted in the tube, the cap gently removed with a screwing motion. If stuck, it may be tapped off with a piece of wood and the tube thoroughly washed out. The cap is replaced, and 50 c.c. of distilled water run in, the sediment stirred up with a platinum needle, and the tube, after well shaking, again rotated for 5 minutes. The cap and contents are again removed as before, the tube emptied, the cap replaced, and 1 c.c. of Eau de Javelle run in on to the sediment. This is mixed up with a platinum needle, and the tube again filled up with 50 c.c. distilled water, shaken, and again rotated. The cap is finally removed, dried in the water-oven, and weighed. The cap is then cleaned out, dried, and weighed also. The difference equals the amount of dirt by weight in 50 c.c. of milk after subtracting the weight of a blank Eau de Javelle experiment with distilled water.

[1] *Journ. Royal Institute of Public Health*, 1908, vol. lvi. p. 734.

According to Revis, "this treatment with Eau de Javelle completely dissolves leucocytes, etc., mixed with the dirt, while without any action on the dirt constituents. We therefore get a true estimation of the dirt, and the procedure quite excludes any loss during manipulation. The dirt, after this treatment, may be used for microscopical examination."

5. *Direct Volumetric Measurement of the Centrifugalised Sediment.*—The method of Revis, while accurate, is complicated and tedious, and the results obtained are not worth the trouble involved. Houston's method and Orr's modification both require a litre of milk, an amount not conveniently available for ordinary control routine work. For scientific investigation Orr's procedure is to be recommended. For routine work a rough but sufficiently reliable estimation of the volume of the sediment may be obtained by direct centrifugalisation. Tubes which are of narrow calibre at the lower closed ends (similar to those used by Orr, Fig. 10) are used, preferably with a capacity of 50 c.c. The milk is filled in to a definite volume (50 c.c.), centrifugalised for a definite period at a known rate, and the volume of sediment directly read off in the graduated narrow end. The results are doubled and returned as volume of sediment per 100 c.c. of milk.

It will be convenient to consider in this chapter the value of the cytological and sediment estimations.

Value of the Cytological Estimation.—In Chapter I. the factors which determine and influence the cellular content of the milk of individual cows are considered in some detail. It was there shown that while variations may be met with under different natural conditions, evidence of considerable value is obtainable from this estimation and from a determination of the different kinds of cellular elements present.

The opinion of the writer,[1] expressed in 1910 as a result of his personal experience, is that—

> . . . leucocyte enumerations, as far as individual cows are concerned, are of great value. Rigid standards as to the number of leucocytes to allow in milk cannot be set up, but the count indicates the need for local investigation. With extended experience it may do much more than this. It gives definite information which

[1] Savage, *Journ. Royal Instit. of Public Health*, 1910, xviii. p. 65.

inspection frequently cannot furnish, and the procedure reaches its highest utility when combined with a bacteriological examination of the milk.

It is certainly unjustifiable to lay down rigid standards of the number of leucocytes to permit in milk, as has been done by some American bacteriologists. When present in numbers more than 800 to 1000 per cubic m.m. they indicate the need for careful enquiry as to the local condition of the cow's udder or teats.

Dealing with this estimation in mixed milk samples, it is obvious that it can in no way assist in the determination of the bacterial pollution of milk, but it might be considered that the cellular count is of value as a means of detecting the presence of purulent inflammation of the udder of one or more of the cows composing the herd yielding the mixed milk. The writer has never held this view, since on purely mathematical grounds it seems unlikely that leucocyte enumerations of *mixed milk* samples would be of use to detect purulent inflammation in one or more of the cows. This may be shown most clearly by a concrete instance.

In a herd of 20 cows it is assumed that one animal is affected with mastitis in two quarters, and that the secretion from these quarters is added to the milk with the rest. A reasonable supposition is that as many as 100,000 leucocytes per cubic m.m. are obtained from each affected quarter, and that the yield from each of these quarters is as much as $\frac{1}{10}$ of the normal amount yielded per quarter. It is hardly likely to be more than this, and if more were obtained it would certainly contain less than 100,000 leucocytes per cubic m.m., so that the total number of cellular elements added would be but little altered. The average number of leucocytes per cow may be taken as about 680 (average of a large number of examinations by the writer). The increased number of leucocytes in the added milk due to the addition of the fluid from the diseased quarters can now be readily calculated.

Let x = the average amount of milk yielded per quarter. Then the total number of leucocytes from the 19 cows with healthy quarters $= (19 \times 4)x \times 680 = 51{,}680x$.

The total number of leucocytes from the cow with two diseased quarters $= (2 \times x \times 680) + \left(\frac{2 \times x \times 100{,}000}{10}\right) = 21{,}360x$; $\therefore$ the total number of leucocytes in the whole of the mixed milk $= 51{,}680x + 21{,}360x = 73{,}040x$.

The total amount of milk yielded by all 20 cows $= (19 \times 4)x + 2x + \frac{2x}{10} = 78 \cdot 2x$, or roughly $78x$; $\therefore$ the number of leucocytes per cubic m.m. in the mixed milk $= \frac{73,040x}{78x} = 936$.

If the secretion of the diseased cow had been excluded the number of leucocytes would have been 680, so that the inclusion of the purulent secretion from this animal had only raised the leucocyte count to 936. Such an increase is within the variations met with amongst different mixed milk samples from healthy cows. In other words, the addition of the fluid from these two affected quarters might easily fail to be detected by the leucocyte count.

In only quite small herds is the estimation of the cellular content of the mixed milk likely to give clear evidence of the existence of mastitis in one of the cows yielding the milk.

Value of the Estimation of the Sediment.—Numerous investigators have attempted to judge the cleanliness of milk samples from a determination of the amount of dirt or sediment obtainable from them. The bacteria which gain access to milk are contained in particulate matter, generally in manure, so that there is some justification for estimating the deposit in milk, and taking it as an index of the amount of undesirable bacteria which had gained access to it. The test is also a non-multiplying one, so is as valuable for vended milk as for byre samples. The amount of sediment can also be fairly easily and quickly estimated.

On the other hand, against the use of this test as a measure of the bacterial contamination of milk some weighty objections can be adduced. In the first place, it is well known that only a fractional part of the manurial matter added to milk is recoverable after sedimentation. For example, Thomas[1] states that the Chester city analyst, as the result of many control experiments, in which a known weight of fresh cow dung was added to a known volume of clean new milk, found that only one-eighth part by weight of the cow dung originally present was recoverable in the final results, the rest being represented by water, extractives, and soluble salts which had become incorporated with the liquid part of the milk. The fractional part which can be recovered is a variable and not a definite fraction of the whole.

[1] *The Councils Journal*, June 1908.

A second objection is that the sediment is not all manurial matters, but a considerable part is composed of substances natural to milk, such as cellular elements, and also harmless inorganic bodies like sand, and these are a variable part of the whole.

A further objection is that the amount is directly proportional to the efficiency of straining rather than to the cleanliness precautions adopted. This is the most important of the objections to this estimation, since straining, while it removes the larger dung particles, does not remove the bacteria. This being the case, a milk collected under extremely unsatisfactory conditions as regards cleanliness of sheds, cows, milkers, and milk vessels, but very carefully strained, might show considerably less sediment than a sample of milk collected under far superior conditions as regards general cleanliness but only rapidly strained through coarse muslin.

Straining as a purification process is most irrational. The dung gives up a large part of its bacterial content to the milk, the only part of it which is prejudicial, and the residue is then strained off. Orr[1] made numerous estimations of the amount of sediment, and concluded that "there is no relationship between the amount of sediment and the number of bacteria present." This is what might be anticipated.

There is a further objection to the use of a standard based upon the amount of dirt in milk. If one is set up it is inevitable that the farmer and the milk purveyor will imagine that the dirt itself is at fault and the thing to avoid, and therefore all that is required is to filter off the dirt and deposit by improved filtration processes. Cleanliness will be neglected on the supposition that purification by filtration can come afterwards.

The writer is of opinion that the measurement of the sediment or dirt (as it is often called) in milk is an estimation which it is of no material value to retain. It gives no information which cannot be obtained much better in other ways, while it is open to many and serious sources of error. Take care of the bacteria and the sediment can take care of itself.

[1] *Report on Milk Contamination*, 1908.

CHAPTER XII

CHEMICAL TESTS TO ESTIMATE THE PURITY AND FRESHNESS OF MILK

Acidity Estimations

Statements are conflicting as to the reaction of quite fresh cows' milk. This is partly to be explained by the fact that the reaction largely depends upon phosphates, and these vary in their reaction towards different indicators. Using phenol-phthalein as the indicator, the writer has examined the acidity of a large number of fresh milk samples, both of mixed milk and milk directly obtained from individual cows. In every instance with this indicator the reaction has been acid. Swithenbank and Newman[1] record that 92·3 per cent of a herd of 26 healthy cows gave acid milk, using litmus paper as the indicator. Courant found that fresh milk reacted alkaline to lacmoid and acid to phenol-phthalein.

It may be accepted that fresh cows' milk is, in general, acid to phenol-phthalein and litmus. The acidity is due in small part to carbonic acid, but mainly to mono- and di-basic phosphates. According to Courant, it is in part also due to dicalcium caseinogenate.

Milk when kept becomes more acid, due to the production of lactic acid from the lactose of the milk by the action of bacteria. The lactose is not directly fermented, but has to be first converted into glucose and galactose. In the souring of milk as it takes place under ordinary conditions, the acidity is not entirely due to lactic acid; small quantities of acetic, butyric, and succinic acids are produced. Only when a pure

[1] *Text-book*, 1903, p. 154.

culture of lactic acid bacilli is used in a sterilised milk is lactic acid the only acid produced.

The acidity of milk is generally recorded as so many degrees of acidity. The degree of acidity of a milk sample is the number of c.c. of $\frac{N}{10}$ alkali required to render 100 c.c. of milk neutral to phenol-phthalein. The acidity of fresh milk varies considerably. With over 50 samples of quite fresh milk collected at the byre, the writer found the acidity to vary between 11 and 23·5 degrees of acidity.

Since lactic acid is produced by bacteria, and old stale milk has often a higher acidity than fresh byre milk, the determination of the acidity has been suggested as a quick and easy test by which to judge if milk samples contain an excessive number of bacteria. Thoerner, for example, has suggested as a practical limit for wholesome milk an acidity equal to $\frac{1}{5}$ of the volume of the milk in c.c. of $\frac{N}{10}$ alkali. This is the same as saying 20 degrees of acidity, equal to an acidity of 0·18 per cent of lactic acid. As recorded above, the writer has found this exceeded by perfectly fresh byre milk samples. Newman[1] recommended the determination of acidity as a valuable and reliable test of the staleness or otherwise of a milk. He advocated a standard of not more than 24 to 25 degrees of total acidity. The Committee of the American Association of Medical Milk Commissions dealing with Chemical Standards recommended that the maximum acidity of milk allowed should be 0·18 per cent calculated as lactic acid.

The value of the estimation turns upon whether there is any relationship between the number of bacteria and the degree of acidity. The writer investigated this question carefully,[2] and found no relationship between the acidity and either the number of bacteria or the number of *B. coli*. For example, when the three highest and the three lowest acidity results with fresh byre milk were taken, the results obtained were as follows:

[1] *Public Health*, 1905, xviii. p. 157.

[2] *Report of Medical Officer, Local Government Board*, 1909-10, p. 474.

Byre Milk Samples.

Acidity.	Number of Organisms per c.c.	Number of *B. coli* per c.c.
23·5	14,200	100–1000
22·7	1,150	Absent in 11 c.c.
23·5	2,150	0·1–0·2
17·0	6,380	1–10
16·0	72,800	100–1000
17·0	41,600	1000–10,000

In addition, a large number of fresh milk samples were kept at 15° C. and 20°–21° C. for 24 hours, and the acidity re-determined. The results obtained showed the rather striking fact that in many instances there was no increase at the end of 24 hours in the acidity of samples kept at 15° C., and sometimes none at 20°–21° C. The number of bacteria including the *B. coli* group of organisms increased enormously, so that for these incubated samples, which may be considered to represent ordinary vended samples, there was still less relationship shown between bacterial content and acidity.

The acidity determination cannot be considered of value in relation to bacterial contamination, and it is only retained here since it is still advocated by several authorities.

To estimate the acidity, place 20 to 50 c.c. of milk in a narrow beaker or test tube, add 0·5 c.c. of phenol-phthalein solution (in 50 per cent alcohol), and run in $\frac{N}{10}$ caustic potash to the first appearance of pink. The titration should be done with a control tube or beaker containing milk by the side, and must be carried out in the cold. If the milk is boiled to expel CO_2, very irregular results will be obtained due to decomposition of certain constituents of the milk.

Formalin-Methylene Blue Reduction Time

Shardinger in 1902 found that a mixture of methylene blue and formalin is decolorised by the action of milk. The reaction is due to the presence of a ferment readily destroyed by heat, and this test was proposed by him as a means of distinguishing between raw and heated milk.

Smidt suggested that this estimation might be used to judge the degree of bacterial contamination of milk samples. The test has been investigated, as regards its ability for this purpose, by several workers with somewhat variable results. The writer's own results[1] show that very broadly there is a relationship between reduction time and the freshness of milk. With but one exception, fresh milk samples always took 7 minutes or longer to reduce the blue at 50° C., while milk samples incubated for 24 hours at 15° C. or 20° C., with but few exceptions, always took less than 7 minutes to reduce.

This information, however, is not very valuable, and as more reliable indications can be obtained by other tests, is not worth obtaining as a gauge of present bacterial pollution.

To estimate, place 10 c.c. of each of the milk samples in clean test tubes. To each add 0·5 c.c. of a solution consisting of 5 c.c. saturated alcoholic methylene blue solution, 5 c.c. formaldehyde and distilled water to 200 c.c. The milk and methylene blue solution is well mixed, and the tubes at once placed in the inner receptacle of a double water bath kept accurately at 50° C. The tubes are watched, and the time taken to discharge the blue colour carefully recorded. Difficulty is sometimes experienced owing to the end point not being always sharply defined.

The Detection of Heated Milk

While boiled milk has a definite and peculiar taste, the heating of milk to temperatures somewhat short of boiling does not alter either its appearance or taste. Ordinary pasteurisation cannot therefore be detected by inspection or tasting. There is no legal obligation upon milk sellers to label or otherwise declare if their milk has been pasteurised. It is of value to ascertain if milk has been pasteurised, and if bacteriological standards are made use of in sampling milk, it becomes of great importance to be able to detect whether heat has been applied to the milk.

A number of tests have been introduced to detect cooked

[1] *Loc. cit.*

milk, all of which depend upon ascertaining the presence of certain milk enzymes. There are a number of enzymes in milk (see Chapter I.), but their thermal death points all appear to lie between 65° C. and 80° C. Tests for the presence of peroxidases are used to determine whether the milk has been heated or not. The tests depend upon the fact that these enzymes present in raw milk induce the oxidation of various leuco compounds by hydrogen peroxide. A number of tests may be used for this purpose, of which the following may be specially mentioned.

Guaiacum Test.—Add a few drops of tincture of guaiacum to half a test tubeful of milk. The formation of a green-blue zone where the two liquids join, indicates a positive reaction. The guaiacum tincture should be fairly recently prepared. According to Arnold and Menzel, the tincture is best prepared by dissolving the guaiacum resin in acetone.

Storch's Test.—To about 5 c.c. of milk in a test tube add a drop of weak (0·2 per cent) solution of hydrogen peroxide containing 0·1 per cent sulphuric acid, and 2 drops of a 2 per cent aqueous solution of paraphenylendiamine hydrochloride. Mix. A positive reaction consists in the rapid production of a blue or dark-violet colour. The paraphenylendiamine hydrochloride does not keep well, and should be recently prepared. If the milk is sour it must first be made alkaline with lime water.

Potassium Iodide Starch Test.—To half a test tubeful of milk add a few drops of a 5 per cent watery solution of potassium iodide, a little starch solution, and a few drops of dilute hydrogen peroxide. A positive reaction is shown by the development of a blue colour.

Ortol Test.—To 5 to 10 c.c. of milk add a drop of 0·5 per cent ortol solution and 2 drops of dilute hydrogen peroxide solution (0·2 per cent). A positive reaction is shown by the presence of a mauve-red colour. The ortol solution should be recently prepared.

Kastle and Porch[1] found that a dilute solution of trikresol acts as a sensitising agent in the peroxidase reaction of milk. Phenol, β-naphthol, etc., act similarly. They mixed 5 c.c. of milk with 1 c.c. of 1 per cent solution of trikresol, 0·3 c.c.

[1] *Journ. Biological Chemistry*, 1908, iv. p. 301.

$\frac{M}{10}$ hydrogen peroxide, and from 0·1 to 1 c.c. of the peroxidase reagent (*i.e.* phenol-phthalein, guaiacum, or paraphenylenediamine). They obtained much more reliable results with the addition of the sensitising agent.

Raw milk gives a positive reaction with these tests at once; milk heated to boiling gives no reaction. The exact temperature at which the ferments are destroyed so that no reaction is obtained is usually given at about 80° C., but slightly different results are recorded by different workers. The killing of the enzymes depends not only upon the temperature, but also upon the duration of heating, although the temperature reached is the most important factor.

The following table shows results obtained by the writer as the mean of a number of experiments with different samples of milk, using the above four tests:

Temperature of Heating.	Time of Exposure.	Guaiacum.	Storch.	Iodine.	Ortol.
60° C.	20 minutes	+	+	+	+
60° „	30 „	+	+	+	+
60° „	60 „	+	+	+	+
70° „	5 „	+	+	+	+
70° „	10 „	+	+	+	+
75° „	10 „	+ *a*	+ *a*	+ *a*	+ *a*
75° „	20 „		+ *b*		+ *b*
75° „	30 „	–	–	+ *b*	–
80° „	1 minute	*p*	*p*	+ *b* (3 min.)	*p*
80° „	3 minutes	–	–	–	–
80° „	5 „	–	–	–	–

– = no reaction.
+ = a positive reaction.
+ *a* = positive reaction very slightly delayed.
+ *b* = „ „ after about 30 seconds.
p = a partial and indefinite reaction: no reaction at first, but after standing a few minutes some colour alteration occurs, but not the true tint.

Experiments were also carried out to ascertain what proportion of raw milk must be present, added to the cooked milk, to cause the mixture to give the reactions of raw milk. A quantity of milk was heated to 80° C. for five minutes, and after cooling, definite fractions of raw milk were added to portions of it and well mixed. The following results were obtained:

Mixture.	Guaiacum.	Storch.	Iodine.	Ortol.
Heated milk + 25 per cent raw milk	+	+	+	+
„ + 10 „ „	+ *a*	+ *a*	+	+ *a*
„ + 5 „ „	–	+ *b*	+ *a*	+ *a*

The results obtained show that when pasteurisation is carried out at the lower temperatures, such as 60° and 70° C., this fact cannot be detected by any of the above tests. The last table also shows that, even if the pasteurisation has been carried out at high temperatures (*e.g.* 80° C.), the operation can be effectively disguised, as far as these ferment-tests are concerned, by the addition of 10 per cent of raw milk. This fact is of very great importance in considering the applicability of using bacteriological standards to judge the cleanliness of collection of milk supplies.

The Detection of Preservatives

The detection of preservatives in milk, although a strictly chemical procedure, is one intimately related to the bacteriological examination, since their presence may exert a profound influence upon the bacterial content and totally mask any bacteriological evidences of want of cleanliness in preparation or of staleness of the milk. A bacteriological examination of milk should therefore include an examination for preservatives. The following preservatives may have to be looked for:

Boric Acid and Borates.—Evaporate 15 to 20 c.c. of milk to dryness in a platinum or porcelain dish, first making alkaline with dilute sodium hydrate solution, or preferably baryta water. Ignite and then dissolve the ash in a little hydrochloric acid. Filter and evaporate filtrate to dryness. Moisten the residue with a very little dilute hydrochloric acid solution and dissolve in a little water. Soak a piece of turmeric paper in the solution, then remove and dry in the hot-air oven. A red colour indicates the presence of boric acid. The red changes to a blue-green colour on the addition of dilute alkali solution.

Formaldehyde.—Hehner's test is simple and reliable. To about 10 c.c. of the milk in a test tube add about half its volume of concentrated commercial sulphuric acid, pouring the acid slowly down the side of the tube. A violet zone at the junction of the two liquids shows the presence of formaldehyde.

The Massachusetts[1] test is also reliable. In this test commercial hydrochloric acid (sp. gr. 1·2) containing 0·2 per cent of 10 per cent ferric chloride solution is used. Equal (10 c.c.) quantities of this solution and of the milk are mixed in a porcelain dish and the mixture slowly heated nearly to boiling. The presence of formaldehyde is shown by a violet coloration, the degrèe of colour varying with the amount present. This test is said to be able to detect 1 part of formaldehyde in 250,000 parts of milk.

Another useful test, said to be able to detect 1 in 200,000 parts of formaldehyde, is the gallic acid test. It is carried out by adding 2 c.c. of normal sulphuric acid to 30 c.c. of milk and distilling over 5 c.c.; 0·4 c.c. of a saturated solution of gallic acid in absolute alcohol is added, and 4 c.c. of concentrated sulphuric acid is run into the mixture so as to form a separate layer. The presence of formaldehyde is shown by a green zone, gradually changing to blue, at the junction of the liquids.

Benzoic Acid.—Leach[2] gives the following method:—Shake 5 c.c. of hydrochloric acid with 50 c.c. of the milk in a flask. Then add 150 c.c. of ether, cork the flask and shake well. Break up the emulsion which forms by the aid of a centrifuge, or in the absence of a centrifuge extract the curdled milk by gently shaking with successive portions of ether, avoiding the formation of an emulsion. A volume of ether largely in excess over that of the curdled milk has been found to be less apt to emulsionise (the ether may be readily recovered by distillation). Transfer the ether extract to a separatory funnel, and separate the benzoic acid from the fat by shaking out with dilute ammonia, which takes out the former as ammonium benzoate. Evaporate the ammonia solution in a

[1] *Annual Report, Massachusetts State Board of Health*, 1897, p. 558.
[2] *Food Inspection and Analysis*, 1909.

dish over the water-bath till all free ammonia has disappeared, but before it is completely dry add a few drops of ferric chloride solution. The characteristic flesh-coloured precipitate indicates benzoic acid. Care should be taken not to add the ferric chloride till all the ammonia has been driven off, otherwise a precipitate of ferric hydrate is formed.

Salicylic Acid.—Take 100 c.c. of milk, mix with 100 c.c. of water at 60° C., add 8 drops of acetic acid and 8 drops of mercuric nitrate solution. Shake well. Filter and shake the filtrate with ether in a separation funnel. The ether dissolves out the salicylic acid. Evaporate the ether extract to dryness. The residue is dissolved in a little alcohol and tested with a drop of 1 per cent ferric chloride solution. The characteristic violet colour indicates salicylic acid.

Sodium Carbonate or Bicarbonate.—Occasionally added, since they mask the effects of bacterial action. Their presence in appreciable amount is shown by the effervescence caused by treating the ash from milk with dilute acid.

Hydrogen Peroxide.—Add to 10 c.c. of the milk 4 drops of a 4 per cent alcoholic solution of benzidine and 2 drops of acetic acid. If hydrogen peroxide is present the mixture becomes blue.

The Examination of Cream and Special Forms of Milk

Condensed Milk.—The varieties of condensed milk are considered in Chapter XX., page 391. The analysis of condensed milk is mainly chemical, but a number of investigations have been made of its bacterial content. The chemical analysis is chiefly for three purposes:—(*a*) estimation of the milk-fat, total solids, and ash to determine the chemical quality of the milk used in its preparation; (*b*) estimation of the amount of cane-sugar, or occasionally of the glucose or invert sugar which may rarely take its place; (*c*) examination and estimation of poisonous metals. For directions as to the chemical analysis of condensed milk standard books on chemical analysis must be consulted.

The bacteriological examination of condensed milk should be on the same lines as for ordinary milk, the sample being first thoroughly mixed with a definite quantity of sterile water.

Care must be taken to thoroughly cleanse and sterilize the outside of the tin before opening, while the instrument to open the tin, which most conveniently is an ordinary tin-opener, must be sterilized before use.

The records of bacteriological examinations of milk are not very numerous. The following will give a good idea of the results likely to be obtained.

Sandilands[1] made some experiments upon the rate of multiplication of bacteria in condensed milk, and the liability of condensed milk to decomposition. He used Nestlé's sweetened whole milk in all the experiments. He did not enumerate the number of bacteria in the fresh samples, but only after incubation at 22° and 37° C. respectively. Compared with cow's milk he found the bacterial content of condensed Nestlé's milk very low, and it remained low for a week or more at the ordinary summer temperature of 70° F. (21° C.). The viscidity of the milk and the presence of added sugar are probably the two factors which combine to inhibit bacterial growth.

Newsholme[2] records the results of the bacteriological examination of twelve different samples of condensed milk carried out by Dr. Heggs. The samples were examined when opened, and again after the tins had been opened and exposed to the air, in the laboratory, for some days. The initial number of bacteria present varied from 230 to 70,940 per c.c. on the gelatine-plates grown at 20° C., and from 120 to 44,200 per c.c. on the agar-plates at 37° C. The duration of exposure to the air after opening varied from three to eleven days. In no case was the number of bacteria very large even after eleven days' incubation. These results are in agreement with those of Sandilands, and show the comparative unsuitability of condensed milk as a medium for bacteria compared with ordinary milk.

Klein[3] examined 32 samples of 11 different brands of sweetened condensed milk. All contained bacteria, the number in 0·1 grm. varying from 13 to over 2000 (upon agar at 37° C.). Streptococci were present in 0·1 grm. in

[1] *Journ. of Hygiene*, 1906, vi. p. 77.
[2] *Ibid.* p. 139.
[3] *Public Health*, 1909, xxii. p. 222.

28 cases (= 87 per cent), while *B. enteritidis sporogenes* was present in about half the samples.

Dold and Garratt[1] found that while bacilli were invariably present, the number was, on the whole, much smaller than that usually found in the same quantities of ordinary market milk. *B. coli communis* and *B. enteritidis sporogenes* were found to be absent from 1 c.c. of the condensed milk in all the 19 samples examined. Streptococci were found in 1 c.c. in 8 cases (32 per cent), in 0·1 c.c. in 3 cases. Pathogenic organisms could not be detected in any of the samples, either by microscopic examination or animal inoculation.

Gordon and Elmslie[2] examined samples of 15 different brands of condensed milk, 5 consisting of full cream sweetened milk, 4 of full cream unsweetened milk, and 6 of machine-skimmed sweetened milk. None of the samples were sterile. The 4 unsweetened milk samples contained no organisms that were likely to have existed in the original milk before condensation, streptococci, *B. coli* group organisms, and spore-bearing anaërobes all being absent. Streptococci with characters similar to those found in milk were present in all the 11 sweetened samples. These investigators concluded that while in the process of condensing of unsweetened milk sterility is secured, the organisms found being subsequently introduced from the air, in the condensing of sweetened milk sterility is not attained, some at least of the organisms in the original milk surviving the process of condensation. No organisms of the *B. coli* group were isolated from any of the samples.

Delépine[3] specially investigated the resistance of tubercle bacilli to the processes involved in the preparation of condensed milk. Fresh cows' milk was used mixed with milk rich in tubercle bacilli obtained from a tuberculous cow and with milk artificially infected with bovine tubercle bacilli. The mixture was condensed in a milk factory, the whole of the processes being carried out exactly in accordance with the usual procedure of manufacture. Delépine made inoculation experiments with the milk obtained at various stages of the condensing process and with the finished product. Although

1 *Journ. Royal Inst. Public Health*, 1910, xviii. p. 294.
2 *Report by Dr. Coutts to Local Government Board on Condensed Milk*, 1911.
3 *Ibid.*

the original milk was highly virulent, the milk after condensing had lost its power to infect guinea-pigs on inoculation, all the tubercle bacilli being killed.

Dried Milk.—The nature and preparation of dried milk is described on pages 393-394. To examine bacteriologically, the dried milk would have to be dissolved in sterile water and then examined by methods similar to those employed for milk.

Cream.—The bacteriological examination of cream is of considerable importance, since it is usually richer in bacteria than either whole milk or separated milk. This is shown by direct bacterial examinations, while in guinea-pig inoculation experiments it is not uncommon to find that a considerably higher percentage succumb to acute infections when inoculated with cream than when inoculated with the sediment of whole milk. In examinations for pathogenic bacteria, such as *B. diphtheriae*, *B. tuberculosis*, etc., the cream of the milk samples should never be neglected, while it follows that market-cream itself should be more often examined than is the case.

Anderson[1] gives the following figures as to the number of bacteria in cream. In 26 samples of milk the average number of bacteria in gravity and centrifugally raised cream in the sediment and in the mixed milk was—

Gravity raised	cream layer	68,690,000	bacteria.
	sediment layer	4,840,000	„
Centrifugalised	cream layer	96,840,000	„
	sediment layer	18,840,000	„
Whole milk		14,388,000	„

Cream is bacteriologically examined by methods similar to those used for milk, the cream being diluted with sterile water. For examination for tubercle bacilli the cream itself may be injected direct into guinea-pigs.

A chemical examination of cream for preservatives should always be carried out before the bacteriological examinations are undertaken.

[1] *Bulletin No. 56, Washington Treasury Department*, 1909, p. 739.

CHAPTER XIII

THE DETECTION OF PATHOGENIC BACTERIA IN MILK

I. The Detection and Isolation of Tubercle Bacilli from Milk

Two methods are available—microscopic, and by animal inoculation. Isolation from the milk by direct cultivation is impracticable.

Microscopic Method.—Tubercle bacilli are usually present in only small numbers in market milk, therefore positive findings are only likely when the bacilli are concentrated. To do this centrifugalise the milk and microscopically examine the sediment. The larger the bulk of milk centrifugalised and the more thoroughly it is done (*i.e.* the faster the rotation and the longer the time) the greater the chances of obtaining any tubercle bacilli present, in the sediment. Since many of the bacilli are retained in the cream this should be thoroughly broken up after a first centrifugalisation and the mixture again rotated. If this is not done the cream should be separately examined. For practical routine purposes 50 to 100 c.c. is a convenient amount to centrifugalise in a machine rotating about 3000 times per minute, the centrifugalisation to last at least 30 minutes and preferably longer.

Minute portions of the sediment are spread upon cover-slips, dried, fixed, and stained by the Ziehl - Neelsen method. Delépine recommends placing the films when dry and before staining in a covered capsule containing equal parts of absolute alcohol and ether, in which they are kept for at least two hours, after which the capsule is placed in a dish of water previously brought to a temperature of 80° to 90° C. The mixture of absolute alcohol and ether boils at once, and after

10 to 15 minutes of this treatment the cover-glasses are removed from the hot mixture and washed with absolute alcohol. If treatment with ether is not adopted a better preparation is obtained, if, after pouring off all the supernatant fluid, the tube is filled with distilled water, again rotated for a few minutes, the fluid poured off, and the films made. At least four films should be made and examined.

No reliance can be placed on a negative examination as evidence of freedom of the milk sample from tubercle bacilli, since if the bacilli are present in only small numbers they may be missed. A positive result cannot be accepted as furnishing conclusive evidence of tubercle bacilli, since that organism may be confounded with other acid-fast bacilli, which sometimes occur in milk. Their presence furnishes very strong presumptive proof sufficient for practical but not for research purposes. Delépine states that by adopting the treatment with ether and alcohol described above, no difficulty is caused by acid-fast bacilli.

The procedure the writer prefers for the Ziehl-Neelsen method is as follows:

Spread the sediment uniformly and not too thinly over cover-slips, making at least 4 preparations. Dry and fix in the ordinary way.

Filter a little carbol fuchsine solution into a clean test tube. Heat to boiling, and then pour on sufficient to completely cover the cover-slip, preferably held in Cornet forceps. Leave on for five minutes without further heating.

Wash in water and decolorise thoroughly but carefully in a watch-glass containing 25 per cent sulphuric acid.

Decolorise further for 30 seconds in absolute alcohol.

Wash in water. Counterstain with methylene blue staining for one minute.

Wash in water. Dry and mount in xylol balsam.

The tubercle bacilli are stained red, the tissue elements and other bacteria are blue.

Antiformin has recently been introduced as a means of more reliably detecting the presence of tubercle bacilli in microscopic preparations. This substance is the name given to a mixture of an alkaline hypochlorite and an alkaline hydrate. When sputum, for example, is treated with 15 to 20 per cent antiformin the tenacious lumps are broken down and dissolved. In addition the majority of the other bacilli present are dissolved, while tubercle bacilli resist the solvent action. The use of antiformin has been found valuable in the detection of tubercle bacilli in sputum, and it should be of value in the examination of milk.

Inoculation Methods.—The guinea-pig is extremely sensitive to tuberculosis by inoculation, and is the most suitable animal for the purpose. The method of subcutaneous injection as practised by Delépine[1] gives very reliable results. Two guinea-pigs are each inoculated with the sediment from 40 c.c. of milk, the sediment being mixed with 2 c.c. of the separated milk left in the tube. Guinea-pigs of about 200 grms. weight are used, the injection being made subcutaneously, with aseptic precautions, on the inner side of the leg, at the level of the femoro-tibial articulation. If the inoculated material contains tubercle bacilli, an infection of the glands on the inoculated side takes place. The popliteal, superficial, and deep inguinal, and usually the sublumbar glands on the inoculated side are enlarged (see Fig. 11), and tubercle bacilli can be demonstrated in films made from them. The time at which this can be done varies with the number of tubercle bacilli injected. According to Delépine, with milk containing numerous tubercle bacilli definite evidence of tuberculosis can be seen in animals killed after ten to fifteen days; when not sufficiently numerous to be detected microscopically in the milk—*i.e.* a moderate number of bacilli—at the end of fifteen days, and when very few bacilli are present in the milk, it may be difficult to obtain any clear evidence of infection before the end of the fourth or fifth week. Delépine lays stress upon the importance of keeping the inoculated animals isolated and under favourable hygienic conditions. For ordinary work a good plan is to inoculate two animals, one being killed at the end of three weeks, and the other a week or two later.

While the pathological picture is practically conclusive of tuberculosis, the complete proof should always be obtained by finding tubercle bacilli in the enlarged glands and other tuberculous lesions.

[1] *British Medical Journal*, 1893, vol. ii. p. 664; *Report of Medical Officer, Local Government Board*, 1908-9, p. 341.

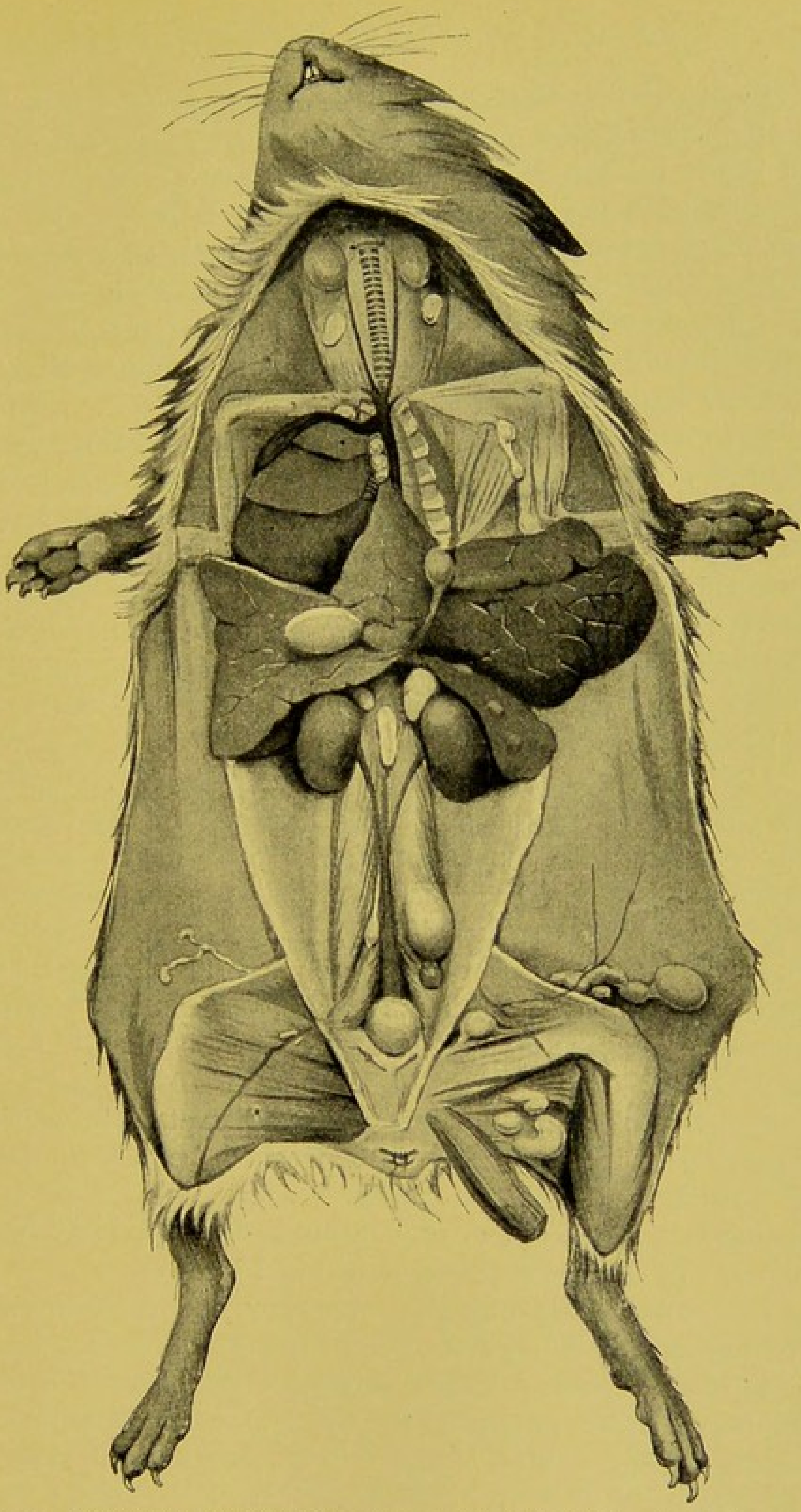


FIG. 11.—Experimental tuberculosis in a guinea-pig (about the third week after inoculation) inoculated subcutaneously in neighbourhood of the left knee-joint. (From Curlis's *Bacteriology.*)

The enlarged popliteal, superficial and deep inguinal, and sub-lumbar glands on the side of inoculation are very obvious ; also the retro-hepatic gland and diseased spleen.

In inoculating market milk it is very important that the injection should take place as soon as possible after collection, and if not possible the sample should be ice-packed. When a considerable interval has elapsed after milking, and the sample is not kept cool all the time, the milk not infrequently contains other bacilli pathogenic to the guinea-pig, and one or both the animals may die from concomitant infection, and before the slower growing tubercle bacillus has had time to cause any visible lesions.

The animal test for tuberculosis takes at least three weeks before any diagnosis can be made. To shorten this period Bloch[1] has suggested that the inguinal glands on the inoculated side should be slightly damaged by squeezing them. When this was done he found that in all positive cases the glands within 9 to 12 days were markedly enlarged and tubercle bacilli present in large numbers both in films and sections. The earlier development of tuberculosis is due to the greater growth in the slightly damaged glands.

Dold[2] extensively tested the question, injecting an emulsion of a pure culture of tubercle bacilli into the inguinal region of guinea-pigs. He found that after 9 to 12 days a striking difference could be noted; whilst the unsqueezed glands did not show any, or but insignificant, enlargement, the squeezed glands were enlarged to tumours of a pea or hazel-nut size. He, therefore, advocates the method as a means of earlier diagnosis. He remarks that the glands can be readily found and squeezed.

Joannovico and Kapsammer[3] also investigated the value of this method, using emulsions containing definite and diminishing quantities of tubercle bacilli. From their work they concluded that Bloch's method enables doubtful cases to be diagnosed by animal experiment within 14 days.

In connection with animal inoculation and tuberculosis it is of importance to note that the injection of dead tubercle bacilli can produce tubercles and other histological lesions, resembling those produced by living tubercle bacilli, and differing chiefly, or even only, in their acuteness. In cases in

[1] *Berlin. klin. Wochenschrift*, 1907, vol. xl. p. 511.

[2] *Journ. Roy. Inst. Public Health*, 1909, vol. xvii. p. 560.

[3] *Berlin. klin. Wochenschrift*, 1907, vol. xliv. p. 1439.

which any doubt exists, it can be cleared up by cultivations from the glands, etc., of the inoculated animal. This difficulty cannot arise in connection with ordinary milk examinations, but has to be remembered and guarded against in experiments directed to determine the thermal death-point of the tubercle bacillus in milk or other substance.

The possible presence of acid-fast bacilli in milk other than the tubercle bacillus, while it diminishes the value of simple microscopic examination, does not to any appreciable extent interfere with the inoculation test. The death of the guinea-pig, with lesions apparently those of tuberculosis, is almost certainly due to tubercle bacilli. As a routine procedure, and certainly in any cases of doubt, cultures should be made on glycerine agar from the enlarged glands. The simulating acid-fast bacilli grow readily and rapidly upon this and other nutrient media, unlike the tubercle bacillus.

The American Committee on standard milk methods[1] give a further test. They remark:

> Tuberculous guinea-pigs may be differentiated from non-tuberculous by giving sufficient crude tuberculin (2 c.c.) subcutaneously to cause the death of the tuberculous animals in 24 hours. Of about 250 guinea-pigs tested in this way no animal that did not have tuberculosis died. Two or three that had slight lesions did not die but became sick. It was noted that all the animals died whose lesions had become caseated.
>
> The reaction seems of distinct service in eliminating infections with acid-fast organisms, and the suggestion is made that with some modification the procedure may have a distinct place as an aid in differentiating true tuberculosis from infections with other acid-fast organisms which produce tubercular-like lesions.

The Differentiation of Human and Bovine Tubercle Bacilli

As pointed out in Chapter VII. two distinct types (apart from the avian type) of tubercle bacilli are met with, according as the bacilli are of bovine or human type, generally corresponding to their being of bovine or human origin respectively. The differences are relative rather than absolute and to some extent intermediate forms are met with. They

[1] *American Journ. of Public Health*, 1910, xx. p. 338.

are, however, in the main distinctive, and afford a convenient, practical means of classification. The essential differences are, that the human type possesses a lower virulence for the bovine animal and a greater degree of cultural luxuriance when grown on artificial media. As Eastwood states :[1]

> These two differences, taken in conjunction, afford strong *prima facie* evidence as to whether or not a particular human bacillus is likely to have been derived from an infected bovine (or other animal capable of harbouring similar bacilli). This evidence is particularly valuable owing to the high degree of stability which the tubercle bacillus usually possesses, as shown by the fact that its individual characteristics are not readily changed by transplantation into the tissues of animals of different species.

Eastwood finds that the parallelism between high virulence and scanty cultural growth is only roughly true. He finds that: "Whereas there is a gradual and unbroken transition between the cultural characters of the strains which grow least well on artificial media, and those which grow most luxuriantly, the transition in the scale of virulence is, on the whole, abrupt." Bearing in mind these reservations, the following tabular summary of the differences may be accepted.

Bovine.	Human.
Morphology.—Cannot be differentiated. In cultures the bovine bacilli are, in general, shorter, thicker, and more regular in their staining.	
Cultural Characteristics.	
Serum.—Grows slowly, and at the end of two to three weeks shows on the surface of the medium a thin greyish uniform growth, not wrinkled and not pigmented.	Grows more rapidly.
Glycerine Agar and Broth.—Grows comparatively feebly and with difficulty. The Royal Tuberculosis Commission divided their cultures into 3 grades according to the rate and luxuriance of their growth.	Grows readily often from the start. Growth tends to become wrinkled.
Pathogenic Properties.	
Calves.—Highly pathogenic. "In calves the subcutaneous injection under the skin of the	Not pathogenic. "In calves, a subcutaneous inoculation of 50 milligrammes of

[1] *Royal Commission on Tuberculosis*, 1907, vol. iv., part ii., Appendix.

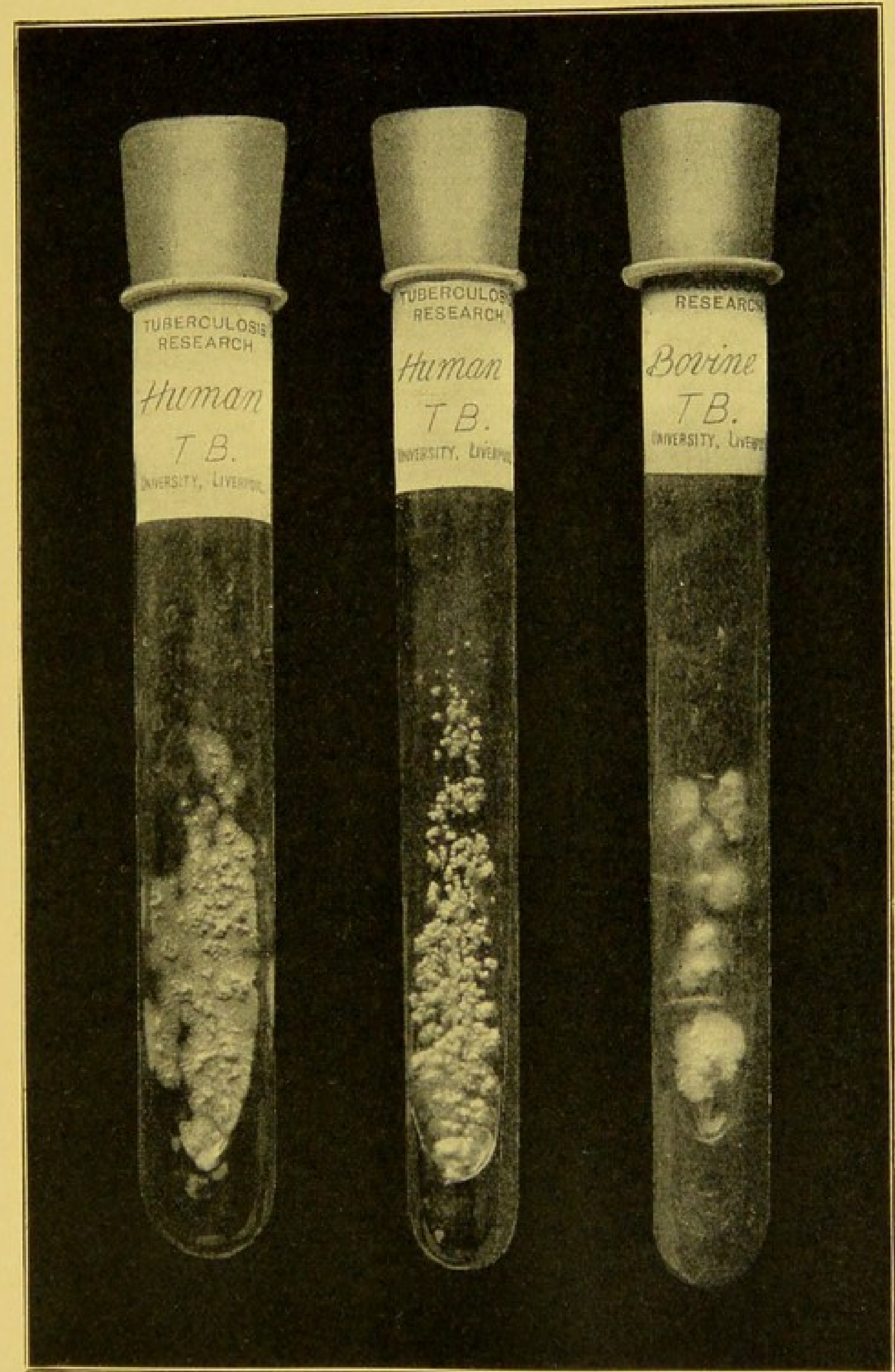


Fig. 12.—Human and Bovine Tubercle Bacilli Cultures upon Glycerine Agar.
(From a photograph supplied by Dr. Nathan Raw.)

neck of 50 milligrammes of a culture of bovine tubercle bacilli not older than three weeks produces generalised tuberculosis, starting from the point of inoculation and ending fatally, usually within eight weeks."[1]	a culture under three weeks old does not produce progressive tuberculosis in the animal, nor does it kill it. In the majority of instances the inoculation results in the formation of a local lesion."[1] This becomes retrogressive and localised.
Rabbits.—Highly pathogenic. Intravenous inoculation of 0·01 to 0·1 mg. or intraperitoneal injection of 0·1 to 1·0 mg. causes acute and rapidly fatal tuberculosis.	Only slightly pathogenic. "Intraperitoneally and subcutaneously injected into rabbits the human tubercle bacillus produces lesions which are scattered, or localised, or retrogressive."[1]
Chimpanzee and Monkey.—Acute tuberculosis produced by very small doses.	Similar to the bovine type.

An additional distinguishing test, introduced by Theobald Smith, is the amount of acid production in glycerine broth. Smith found that after a fairly vigorous growth has been established on glycerine broth the bovine type will convert a bouillon containing 5 per cent glycerine and of a certain degree of acidity to phenol-phthalein (2 per cent $\frac{N}{O}$ acid) into an alkaline medium. At the end of one to two months the solution is alkaline. The acidity of some types reaches 4 per cent of a normal solution; that of other types but 1·5 to 2·0 per cent.[2] The human type does not do this. At the end of one to two months' growth in the bouillon the solution is acid.

The acidity reaction in glycerine broth has not been accepted by all workers as a reliable differentiating character, but Theobald Smith, who first clearly differentiated the two types of tubercle bacilli, finds it of great value and constancy. He remarks: "After a trial of seven years I find the acid or alkali production of different strains, under cultivation from one to fourteen years, constant."

To distinguish the type of tubercle bacillus present in any given material the most convenient and practical tests to employ are the quantity and nature of the growth on glycerine agar and in glycerine broth and the rabbit virulence test. Guinea-pigs are inoculated with the material under investigation, and

[1] *Royal Tuberculosis Commission, Final Report*, 1911, pp. 4-6.

[2] *Sixth International Congress on Tuberculosis*, 1908, iv., part i. p. 651.

the tubercle bacillus is isolated from the lesions in the guinea-pig. The primary isolation may be upon blood serum, or preferably upon Dorset's egg medium. After one or several generations of growth upon the egg medium subcultivations are made upon glycerine agar and in glycerine broth. If no growth takes place upon glycerine agar, as may be the case with the bovine type, further generations are grown upon the egg medium, and growth again tried upon glycerine agar. For the inoculation of rabbits Weber[1] recommends that two should be inoculated, one with 1 c.g. of culture subcutaneously and the other with 1 m.g. intravenously.

The egg medium may be prepared as follows:[2]—Fresh eggs are washed and then partially sterilised by dipping them, held in forceps, in boiling water for about half a minute. They are opened with aseptic precautions, and the contents poured into a sterile flask, to which normal saline is added in the proportion of one part to two parts of egg. The eggs and saline solution are thoroughly mixed in the flask, which should be of large size. The medium is strained through muslin to remove air-bubbles, and poured as quietly as possible into a flask with a side tube near the bottom. The medium is added from this flask to the sterile test-tubes when the latter are in a nearly horizontal position, sufficient being added to make a good slope. Care must be taken to avoid soiling the other parts of the test tube. The tubed medium is inspissated at 80° C. on two successive days.

The Detection of Tubercle Bacilli in Butter.—The inoculation method is the only satisfactory one. The butter is placed in centrifugal tubes which are stood in warm water at 40° C. until the butter is completely melted. The material is centrifugalised while liquid, and the sediment inoculated into guinea-pigs in the ordinary way. It is difficult to keep the butter liquid during the centrifugalisation.

II. Detection and Isolation of Diphtheria Bacilli from Milk

This organism has only been found in milk on a very

[1] Kolle und Wassermann, *Handbuch*, Ergänzungsband 1906, p. 133.

[2] Method communicated to the writer by Dr. F. Griffith, and used in the work of the Royal Commission.

few occasions (see p. 78). Its isolation from milk is a difficult matter. The best method of examination is to take advantage of the rapid growth of this bacillus on blood serum. The milk is centrifugalised, and cultivations are made upon blood-serum tubes from both the cream and the sediment. Dilution is obtained by acting upon the same principle as that used in brushing agar and gelatine plates. A little sediment or cream is taken up by sterile platinum loop, and is rubbed in close vertical lines over the surface of three blood-serum tubes without recharging the loop. A large number of blood-serum tubes should be inoculated from both sediment and cream, incubated at 37° C., and examined after 20 to 24 hours. A careful microscopic examination must be made of all colonies, avoiding those certainly not colonies of the diphtheria bacillus. If bacilli morphologically resembling this organism are found they must be subcultivated and obtained in pure culture. A certain diagnosis of the presence of the diphtheria bacillus from milk cannot be made from the morphological characters alone. The cultural characteristics and, in particular, animal virulence must be ascertained.

The importance of this is exemplified by the fact that several observers have recorded the presence in milk of bacilli which morphologically resemble the diphtheria bacillus, but which from their other characters are certainly not that organism. For example, Eyre,[1] from five milk samples out of a large number, isolated organisms morphologically closely resembling diphtheria bacilli. None of them were capable of initiating lesions in guinea-pigs resembling those produced by *B. diphtheriae*. Their cultural characters also differentiated them from that organism. Bergey[2] isolated a number of organisms from milk, drawn direct from the udder of cows, which morphologically resembled the diphtheria bacillus. They were non-pathogenic. He isolated three groups of organisms, of which the first, in their morphological and biological characters, very closely resembled *B. diphtheriae*. They grew on blood serum in practically the same manner as the diphtheria bacillus.

[1] *Brit. Med. Journ.*, 1900, ii. p. 426.
[2] *Journ. of Medical Research*, 1904, xi. p. 445.

The writer,[1] examining milk samples obtained direct from individual cows, found in a number of them bacilli which morphologically, particularly when stained by methylene blue, closely resembled diphtheria bacilli. They showed beading and granules, and frequently were distinctly clubbed. They were non-pathogenic to mice. They grew upon blood serum as minute white or yellow-white colonies, and differed from *B. diphtheriae* in this and other cultural characters.

III. Isolation of *B. typhosus* from Milk

The detection and isolation of this organism from milk is still a matter of considerable difficulty, but by the use of certain special media its isolation has been greatly facilitated. The milk is thoroughly centrifugalised, the supernatant fluid decanted, and the sediment mixed with a little sterile water. Fractions of the emulsion so made are distributed over the selected media, contained in a series of large Petri-dishes. There are now a number of special media which have been recommended for the purpose, and individual workers often obtain the best results by using those with which they are specially acquainted. Of these media the following may be mentioned: Drigalski-Conradi agar, lactose bile-salt neutral red agar (L.B.A.), fuchsin agar, brilliant green agar, and malachite green agar. As far as the writer has experimentally investigated them he prefers L.B.A., but fuchsin agar is also useful. The composition and preparation of L.B.A. is given on page 181.

After the plates are inoculated they should be thoroughly dried, uncovered, in the blood-heat incubator. They are then covered, inverted, and incubated. After 18 to 24 hours' growth the plates are examined. *B. coli* and other lactose fermenters grow as red colonies, and frequently produce a haze in the surrounding medium. *B. typhosus* and other non-lactose fermenters produce white colonies. The number of white colonies can be considerably reduced by the addition of saccharose, dulcite, and salicin (in 1 per cent solution), as well as lactose, to the medium. By their addition fermenters of these substances, although they may not ferment lactose, are also excluded, since their colonies will now be red.

[1] *Report of the Medical Officer, Local Government Board*, 1906-7, p. 205.

All the white colonies should be investigated. One method is to pick off and subcultivate in broth each white colony, incubating at 37° C. until next day. All the broths are then examined in hanging drop, and those which show actively motile bacilli tested with antityphoid serum. A fairly powerful serum should be used, and a dilution of not less than 1 per cent employed.

A quicker and often preferable method is to directly test each of the white colonies with the antityphoid serum by rubbing up a little of the colony in a drop of 1 per cent serum on a cover-glass. Only those which react are subcultivated. All those which fail to show agglutination are rejected, while those reacting are each subcultivated into litmus milk, glucose litmus broth (in a double tube), and lactose peptone solution (in a double tube). All the organisms giving cultural characters in these media which accord with those of *B. typhosus* are then fully worked out. The tests should include accurate and extended agglutination tests with highly dilute sera.

Some such procedure as the above will rapidly decide whether any typhoid bacilli have been isolated.

The isolation of *Spirillum cholerae* and other pathogenic bacteria may be carried out on the general lines set out in text-books of bacteriology, and these should be consulted. They are not sufficiently frequently met with in milk to warrant a special description in this place.

CHAPTER XIV

INTERPRETATION OF RESULTS AND BACTERIOLOGICAL STANDARDS FOR MILK

MILK is liable to bacterial pollution from numerous sources, but they can all be included into three groups:

A. Bacterial contamination from the cow herself before the milk leaves the teats. This may be with harmful bacteria, such as the tubercle bacillus or some streptococci; or harmless, such as from saprophytic streptococci and staphylococci present in the milk cistern of the udder.

B. Bacterial contamination from specific disease-producing bacilli, such as *B. typhosus* or *B. diphtheriae*, gaining access to the milk from infected sources.

C. General bacterial contamination due to insufficient cleanliness at the time of milking and subsequently up to the time of consumption.

The first two sources are very different from the third, and involve the detection of certain special disease-producing bacilli. For these the actual detection is all that matters, and their quantitative presence is comparatively immaterial. With infection from these two sources there is no question of numerical standards, and difficulties in the interpretation of results do not arise. The third source of pollution is very different, and the quantitative estimation of bacteria, or groups of bacteria, is of essential importance. This necessitates the consideration of the question of standards and the interpretation of results.

To measure the general bacterial contamination of milk the following procedures are available:

Estimation of the total number of bacteria.
" " number of *B. coli* and allied organisms.
" " " streptococci.
" " " *B. enteritidis sporogenes* spores.

Procedures such as the estimation of the degree of acidity and the amount of sediment, which indirectly indicate the bacterial contamination, have been dealt with in Chapters XI. and XII. The advantages and limitations of these four procedures will be briefly considered.

Estimation of the Number of Bacteria

Prejudicial contamination of milk is essentially one with bacteria-holding substances, and milk is dangerous because of the bacteria in it. The estimation of the number of bacteria in milk should serve, therefore, as a reliable index of the degree of pollution to which it has been subjected, and as a measure of the undesirable condition to which it has attained. On the other hand, numerous objections may be raised to this estimation, which must be considered.

(*a*) Actual estimations vary greatly with the details of the laboratory procedure adopted. To estimate the total number of bacteria is, with present methods, an absolute impossibility. The bacterial count which is obtained is merely that number of organisms which will develop upon the particular medium used within the arbitrary time selected and at the particular temperature employed. Variation in any of the factors will cause variation in the resulting bacterial count.

So varied are the kinds of bacteria in milk, and so sensitive are many of them to the action of temperature, chemical reaction, and nutritive material, that the differences met with, due to variations in the methods employed, are not slight and unimportant but very marked. They are very much greater than the differences met with in water enumerations obtained by different methods. Indeed, these laboratory details are so important that very little practical and no scientific utility is attained by comparing the number of bacteria in milk in different places when the exact enumeration procedures are different or not recorded.

To say that milk shall contain not more than so many bacteria per unit of volume is really only possible with an exactly defined procedure, and is meaningless when applied as a statement referable to milk generally and without regard to a rigidly defined laboratory procedure. It may be urged that these objections can all be answered by the provision of a uniformly accepted, easily performed, and exactly defined laboratory procedure. While this would greatly increase the practical utility of bacterial milk counts it is not possible to eliminate all variants and to obtain absolute uniformity of procedure. Chemicals vary, the reactions of media alter with time, etc. These and other slight variants prevent any absolute uniformity.

(*b*) A second objection to this measure of pollution is that it makes no distinction between bacterial pollution before and that after the milk leaves the cow. It has been shown that milk, as delivered from the teats, frequently contains large numbers of staphylococci, and, to a lesser extent, streptococci and other organisms. We have no evidence that such organisms are harmful, or any reasonable grounds for demanding that milk containing them should be rejected. Every precaution in regard to milking may be taken to prevent external contamination, but they will still gain access and be counted as so many bacteria in the milk. The measurement is not purely one of external contamination. It is not the presence of large numbers of bacteria as such which is bad, but numerous bacteria are objected to because their presence shows that the methods of obtaining and handling milk used are such as permit undesirable bacteria-laden matter to gain access, matter which may contain harmful organisms.

(*c*) A third objection only applies to vended milk. While the general bacterial estimation, in spite of the above drawbacks, is capable, under rigidly defined conditions, of being used as a fairly accurate measure of the amount of pollution in samples collected at the farm, it cannot under present conditions serve to gauge the outside pollution of samples of milk collected as vended. An ordinary sample of vended milk obtained under reasonably clean conditions, and with but little outside bacterial pollution, may show, owing to multiplication of the bacteria, a much higher bacterial count than another sample collected under conditions of gross neglect, but examined after only a short period from milking, or perhaps taken at a cooler time of the year.

While this objection applies to some of the other bacterial tests for pollution, it is particularly operative for this estimation, since ordinary milk is so bacterially complex. The experiments recorded in Chapter IV. show that there is no regularity in the multiplication of bacteria in milk, even under known conditions of time and temperature. It is not in any way possible to gauge the amount of external pollution which has been added to milk from the estimation of the number of bacteria in chance samples of vended milk.

Estimation of the Number of *Bacillus coli* and allied Organisms

In seeking for a reliable measure of the degree of manurial pollution of milk, attention is naturally directed to the group containing *B. coli* and allied organisms. The writer, in his book *The Bacteriological Examination of Water-Supplies* (1906), defined the conditions of a perfect bacterial indicator as the following:

1. It should be abundant in the substances for which its presence serves as an indicator.
2. It should be absent, or at least relatively absent, from all other sources.
3. It should be easily isolated and numerically estimated.
4. Its characteristics should be definite and not liable to variation, whereby its distinctive characters might be impaired.

B. coli, as an indicator of the manurial contamination of milk, fulfils these conditions very adequately, as far as samples collected at the cowsheds are concerned.

B. coli is extremely abundant in manure, while it is absent from sources not subject to manurial pollution.

It has been shown in earlier chapters that *B. coli* and other glucose fermenters are not found in milk drawn direct from the teat, and that they are absent in milk samples collected under conditions of great cleanliness.

B. coli and allied organisms can be readily isolated and numerically determined, while their characters can be defined with sufficient accuracy.

As regards the characters considered to be essential to constitute *B. coli*, considerable divergence is noticeable between different workers. The problem is less acute than is the case when determining the significance of these organisms in water, since in the latter allied organisms may be derived from soil or other comparatively harmless sources. In milk, on the other hand, *B. coli* and the closely allied forms all, as far as we know, equally indicate outside manurial pollution. It is also possible that certain varieties of *B. coli*, for example those which ferment or do not ferment dulcite, saccharose, etc., are of greater significance as manurial indicators than other strains, but this has not yet been established.

This estimation, as regards samples taken at the byre, is a very direct and valuable method of measuring the degree and extent of manurial contamination.

The value of the enumeration for chance samples of ordinary vended milk involves matters of great complexity, and it is a problem of great difficulty to correctly gauge the significance of their presence. If it were a practicable and universally adopted procedure to thoroughly cool milk after collection, and then to maintain it until sold at a temperature so low that *B. coli* will not multiply in it, any standards framed for *B. coli* in byre milk would be equally applicable to milk as sold. Under present conditions this is by no means the case, and it becomes a very complicated problem to say what number of *B. coli* may be allowed in vended milk samples as sold under present-day conditions.

The solution of the problem turns upon the rate of multiplication of *B. coli* in milk under varying conditions of temperature and bacterial content. A number of experiments dealing with this matter have been considered in Chapter IV., but certain theoretical considerations bearing upon the question of definite standards may be conveniently discussed here.

The actual number of *B. coli* in milk samples will depend upon five factors:

(*a*) The initial number added at the time of milking.

(*b*) The temperature at which the milk has been kept.

(*c*) The time since milking.

(*d*) The other kinds of bacteria present, and their relative proportion in the sample.

(*e*) The bacteria added to the milk subsequent to the initial pollution at the byre.

It may be said that the various investigations carried out show that temperature is the most important of these five factors, while, at the same time, it is the one most subject to variation and fluctuation. Temperature being a more potent factor than initial numbers, when the former is unknown or variable it is obviously impossible to measure the initial milk pollution by an examination of ordinary milk samples.

It may be argued that the *B. coli* are in themselves harmful, and, if numerous, the milk on that ground is bad, whether the initial pollution was large or not. This view cannot be accepted, the importance of the *B. coli* estimation depending solely upon its value as an indicator of pollution.

The problem may be looked at in another way. Maximum limits may be taken and maximum standards, not to be exceeded, framed. Using algebraic notation, we may state the proposition that a milk with an initial coli content of not greater than x, kept for not more than y hours at a temperature not greater than t, will show a coli content always below z.

Leaving aside bacterial pollution subsequent to that at the byre, if a coli content greater than z is obtained with a vended milk sample, it means that either the initial pollution exceeded x, the temperature was above t, or the period since milking was greater than y hours. An increase beyond the limit for any one of these factors is sufficient to cause z to be exceeded. If x, y, and t are all allowed to be variable, it is obviously hopeless to arrive at reliable deductions from z enumerations. These variations cannot be defined, but we can define their *maxima*.

It is a reasonable proposition that unless milk is kept at a temperature below that at which *B. coli* multiplies, all milk should be sold within 24 hours. Granted this, y may be taken as 24 hours as a maximum time.

The temperature of milk, unless artificial cooling is employed, varies with the air temperature, so that in summer it is higher than in winter, and multiplication of *B. coli* rapidly takes place. 15° C. (59° F.) is a warm temperature for milk, and if milk is initially cooled very ordinary precautions should prevent it being exceeded. To take t as 15° C. is to assume that the milk may be kept at that temperature for the whole period, and is obviously too generous a limit, but may be taken as an extreme maximum.

A reasonable limit for initial pollution is that there should not be more than one *B. coli* or allied organism per c.c., so that x may be taken as one *B. coli* per c.c.

The problem can now be re-stated. To arrive at the maximum pollution allowable in vended milk we have to ascertain what will be the final coli content (z) in a milk sample initially containing not more than one *B. coli* per c.c., kept for 24 hours at a temperature of 15° C. The figure z so obtained can be reasonably accepted as the *maximum* number of *B. coli* to be allowed in vended milk at any time of the year.

Like all biological problems, in contrast to chemical, such determinations can never be precise and unvarying, but within limits they are very valuable. Two important factors leading to variation in actual practice have to be considered.

1. The above considerations take no account of pollution in transit or in the shops of milk purveyors. It may reasonably be contended that no *B. coli* should be admitted to the milk in transit. Even under the present-day unsatisfactory conditions it should be comparatively easy to prevent any considerable *B. coli* addition during transit or while being purveyed. This factor does not seriously affect the above contention.

2. The influence of the number and kinds of the other bacilli present cannot be neglected. They considerably influence the multiplication rate of *B. coli* in milk. The significance of this factor can only be determined by a wide series of experiments.

The writer has carried out a series of such experiments. The chief results and conclusions obtained are recorded in Chapter IV. Applying these results to the practical question of *B. coli* standards for vended milk, and taking the maximum limits laid down above, it would seem that if the initial number of *B. coli* and allied lactose fermenters is not more than one per c.c. the vended milk should not contain, as a rule, more than 100, and certainly not more than 1000 *B. coli* and allied organisms per c.c. This is a maximum allowance, and is based on the supposition that the milk is maintained at 15° C. for at least 24 hours. Obviously in winter such a temperature would not be maintained, often never reached, and a lower standard would still be fair and reasonable. If separate summer and winter standards are set up, the summer limit for vended milk might reasonably be not more than 1000 lactose fermenters of coli type per c.c., and not more than 100 for winter samples, but the more lenient standards set out below might be adopted in the first place. These standards should be made more stringent as the conditions of milk transit, etc., improved.

Estimation of the Number of Streptococci in Milk

Here the enumeration is considered purely as an index of the degree of cleanliness of the milk.

Streptococci are extremely numerous in both fresh and old manure. They are also abundant in stale milk contained in improperly cleaned milk vessels. As indicators of pollution they have this, therefore, in their favour, that they are abundant in the materials the presence of which it is wished to quantitatively measure. On the other hand, as has been shown, streptococci may be present in considerable numbers in milk drawn directly from the teats. To judge the cleanliness of the methods used in milk collection by a test which is in part independent of such cleanliness is not a satisfactory procedure.

In regard to vended milk samples, the difficulties caused by multiplication under varying conditions of time and temperature, considered in reference to the general bacterial and *B. coli* counts, apply also to the streptococcus estimation.

This test cannot be recommended as equal in value to the *B. coli* estimation as a means of measuring the ordinary manurial pollution of milk.

Estimation of the Number of Spores of *B. enteritidis sporogenes*

Certain facts are in favour of this estimation. The spores are present in considerable numbers in cow dung. If the virulence test is not considered essential their presence can be readily determined. In particular, *B. enteritidis sporogenes* is an organism which does not multiply in milk, so that this determination should be especially valuable for vended milk. On the other hand, there is some doubt as to how far this bacillus may gain access to milk from other than manurial sources, and these, although undesirable, may be less prejudicial than direct manurial pollution. The spores, being highly resistant, may live for very long periods.

The ordinary method of examination is not sufficiently sensitive, and a more delicate method of enumeration, such as the one described on p. 189, must be used if this enumeration is to be of value. There is also a possible error due to unequal distribution of the spores and irregularities of sampling. Further experiments as to the value of this test are required.

As regards definite standards, any adopted are equally applicable to byre and vended milk, and for all times of the year.

Examination of Stained Centrifugalised Deposit

This is a procedure which is very readily carried out, while the results are available without delay. It enables unknown milk samples to be divided into those which are recently collected and those which are either stale, or if fresh, then collected under conditions of gross bacterial contamination. With care a rough but useful opinion can be obtained from the stained deposit as to the probable number of bacteria present.

Considering all the different procedures, the writer is of opinion that the most reliable estimate as to the bacteriological condition of a given milk sample, and the cleanliness conditions under which it has been collected, can be arrived at from the enumeration of *B. coli* and allied organisms, number of spores of *B. enteritidis sporogenes*, and examination of the stained centrifugalised deposit.

The other procedures add very little to the information obtained from these three tests.

Bacteriological Milk Standards

It is a matter of much practical importance to consider whether definite bacteriological standards can be set up for milk, if they can be legally applied, and what they should be.

It has been advanced that it is practicable and proper to have a legal limit of the number of bacteria to be allowed in milk, and such legal bacterial standards have been adopted in several American cities. For example, in 1904 the Boston Board of Health adopted the following regulation:

> No person by himself, or by his servant or agent, or as the servant or agent of any other person, firm, or corporation, shall bring into the city of Boston for the purpose of sale, exchange, or delivery, or sell, exchange, or deliver any milk, skimmed milk, or cream which contains more than 500,000 bacteria per cubic centimeter, or which has a temperature higher than 50° F.

There are considerable difficulties in the way of adopting bacterial standards for milk, in part due to the rapid multiplication of bacteria in milk, in part to the great bacterial complexity of even fresh milk. Bacterial standards theoretically may be used either *in themselves* directly to pass or condemn—the condemnation being followed up by punishment, such as exclusion from the area supplied, revocation of licence, or even prosecution—or they can be indirectly used as a means of improving the general supply. With existing knowledge, and with the present condition of the milk trade, the writer believes that the latter procedure is the only one which is feasible. It does not seem practicable, at any rate at present, to set up any bacterial standards either of the number of bacilli or of the number of any special groups of bacteria which can serve as a basis in themselves of direct administrative action.

On the other hand, bacterial standards can and should be set up for guidance in administrative work. If a sample is found to infringe them, attention should be specially directed to the supply, the premises being, if possible, inspected, and those responsible warned. Bacteriological examination of milk should be worked hand in hand with sanitary inspection. In this way general improvement of the conditions of milk supply is likely to be effected. Persistent infringement would furnish reasonable grounds for more decisive measures.

To avoid injustice in framing practical working standards it is necessary not only to have separate standards for byre and for vended milk, but these also must be varied for summer and winter. The following are suggested as useful working standards.

Lactose Fermenters of coli type per c.c.

Source of Sample.	Pass.	Unsatisfactory.	Condemn.
Byre—			
Winter (October to April inclusive) . . .	0·4 or less	0·6	0·8 or more
Summer (May to September inclusive) .	0·6 or less	0·8, 1·0	2 or more
Vended—			
Winter	under 100	100–500	500 or more
Summer . . .	„ 1000	1000–2500	2500 or more

B. enteritidis sporogenes spores.—The standards suggested are—*good*, 0 or 1 (*i.e.* all 10 tubes negative or only 1 positive); *unsatisfactory*, 2, 3, or 4 tubes positive; *bad*, 5 or over positive. Rigid standards for the spores of this organism cannot be set up, while the results are chiefly confirmatory of the lactose fermenters estimation. The one standard is equally applicable to vended and byre milk, and to all times of the year.

To use the above standards the method of examination to determine the number of lactose fermenters must be defined. The following is suggested.

Byre Milk—

Add 1 c.c. of milk to each of 5 L.B.B.[1] tubes.
„ 0·1 „ „ 2 „

Incubate all 7 tubes at 37° C. for two days, and record as positive all the tubes showing acid and gas. If the results obtained pass the standard, the presumptive tests are sufficient. If they transgress, the tubes containing the least milk yielding a positive result can, if considered necessary, be plated, and the *B. coli* or other lactose fermenting organisms isolated.

Vended Milk.—Make dilutions A, B, C, D, as described in Chapter IX. Inoculate 10 L.B.B. tubes from these, *i.e.*:

[1] L.B.B. = Lactose bile-salt broth. For composition see p. 180.

Add 1 c.c. dilution	D	to each of	4	L.B.B. tubes.
"	C	"	4	"
"	B	"	1	"
"	A	"	1	"

Incubate all 10 tubes for two days at 37° C. and record as for byre milk. In summer the L.B.B. tube inoculated from dilution A may usually be safely omitted.

Using this method of examination results much less spaced than with the usual dilutions with 0·1, 0·01, 0·001 c.c., etc., of milk can be obtained, while in actual working the examination is very simple. For byre milk samples, the seven L.B.B. tubes can be at once prepared from the milk with the one pipette, and the results read off after two days' incubation. For vended milk samples, the dilutions would have to be prepared with one 10 c.c. pipette, and then the ten L.B.B. tubes inoculated, and the results read off after two days' incubation.

The interpretation of the results appears perhaps somewhat complicated, but the following explains how they should be interpreted.

Byre samples.—The possible variations are:

0·1 c.c.	2 positive	= 10 or more	per c.c.
	1 "	= 5–10	
	2 negative	= less than 5	
1 c.c. tubes	5 positive	= 1 or more	
	4 "	= 0·8	
	3 "	= 0·6	
	2 "	= 0·4	
	1 "	= 0·2	
	0 "	= absent in 5 c.c.	

Vended milk samples.

D tubes	4 positive	= over 10,000	per c.c.
	3 "	= 7500–10,000	
	2 "	= 5000–7500	
	1 "	= 2500–5000	
	0 "	= less than 2500	
C tubes	4 "	= 1000 or more	
	3 "	= 750–1000	
	2 "	= 500–750	
	1 "	= 250–500	
	0 "	= less than 250	
B tube	1 "	= 100 or more	
	0 "	= less than 100	
A tube	1 "	= 10 or more	
	0 "	= less than 10	

While complicated in interpretation, the results are extremely simple to record in actual work. Two examples may be given :

1. *Byre Milk.*—In a sample, four of the 1 c.c. L.B.B. tubes are positive, while the fifth and the two 0·1 c.c. tubes are negative.

In 5 c.c. of milk = 4 lactose fermenters.
„ 1 „ „ = 0·8 „ „

By using the table given the same result can be read off without any calculation.

Such a finding would be recorded as unsatisfactory in summer, and sufficient to condemn in winter.

2. *Vended Milk.*—In a sample the A and B and three of the C tubes are positive, while the remaining C tube and the four D tubes show no acid or gas.

In 0·004 c.c. of milk = 3 lactose fermenters.
„ 1 „ „ = 750 „ „

The sample contains 750 to 1000 lactose fermenters per c.c.—a result which could be directly read off from the table.

Such a finding would pass the sample in summer, but condemn it in winter.

PART III

PUBLIC HEALTH CONTROL OF THE MILK SUPPLY

CHAPTER XV

EXISTING CONDITIONS OF THE MILK SUPPLY

In this chapter the general sanitary conditions under which milk is produced and sold in this country are detailed. The facts stated are in the main derived from the writer's personal experience in both rural and urban districts, supplemented by information contained in very numerous reports of Local Government Board Medical Inspectors, Medical Officers of Health, and Veterinary Inspectors.

Chapter II. and the present chapter may be considered supplementary to one another, the one dealing with existing conditions as they supply bacteria to milk, the other with the same conditions from the sanitary and practical aspect. Reading the two chapters together, the relationship of the insanitary conditions to the bacteria found in milk will become obvious.

The conditions at the farm naturally first claim attention.

A. Byre Conditions

1. *Structural.*—The structural conditions of cowsheds vary enormously, and all degrees may be met with ranging from the sanitary, efficient, and satisfactory cowsheds erected by many enlightened landowners to wretched hovels lacking every essential of a cowshed.

Figs. 13 and 14 illustrate cowsheds defective in almost every particular, and yet not very uncommon. The worst conditions are met with in the rural districts, and in general it may be said that the construction and cleanliness of urban cowsheds is distinctly superior to what is found in the rural districts. This superiority is readily explained. Urban cowsheds are more supervised than rural, the inspector supervising often has higher sanitary standards, while, in particular, insanitary and unsatisfactory conditions reported to an urban authority are more likely to receive sympathetic consideration, and do in fact receive more attention, than in rural areas where the individuals comprising the controlling authority are intimately interested in the dairy and farming industry.

The most important structural defects met with are those of flooring, drainage, lighting, ventilation, and cubic space.

Flooring defects are very common in cowsheds. Many rural

FIG. 13.—A country Cowshed occupied by four Cows; in the occupation of a Registered Purveyor.

cowsheds have no properly constructed floor at all, the cows standing and lying upon ordinary earth, water-sodden and manure-saturated, with or without the interposition of some straw or other litter. Only less unsatisfactory is the floor composed of cobble stones with ordinary earth acting as the cement. Occasionally clay floors are met with. It is obviously impossible with all such floors to have any proper system of drainage, and usually there is no drainage at all, but sometimes they have a channel or grip dug out along their length to serve for the conveyance of liquid excreta. The more permanent floors are composed of bricks, stone slabs, or cement concrete. As a rule, the bricks used are of the ordinary

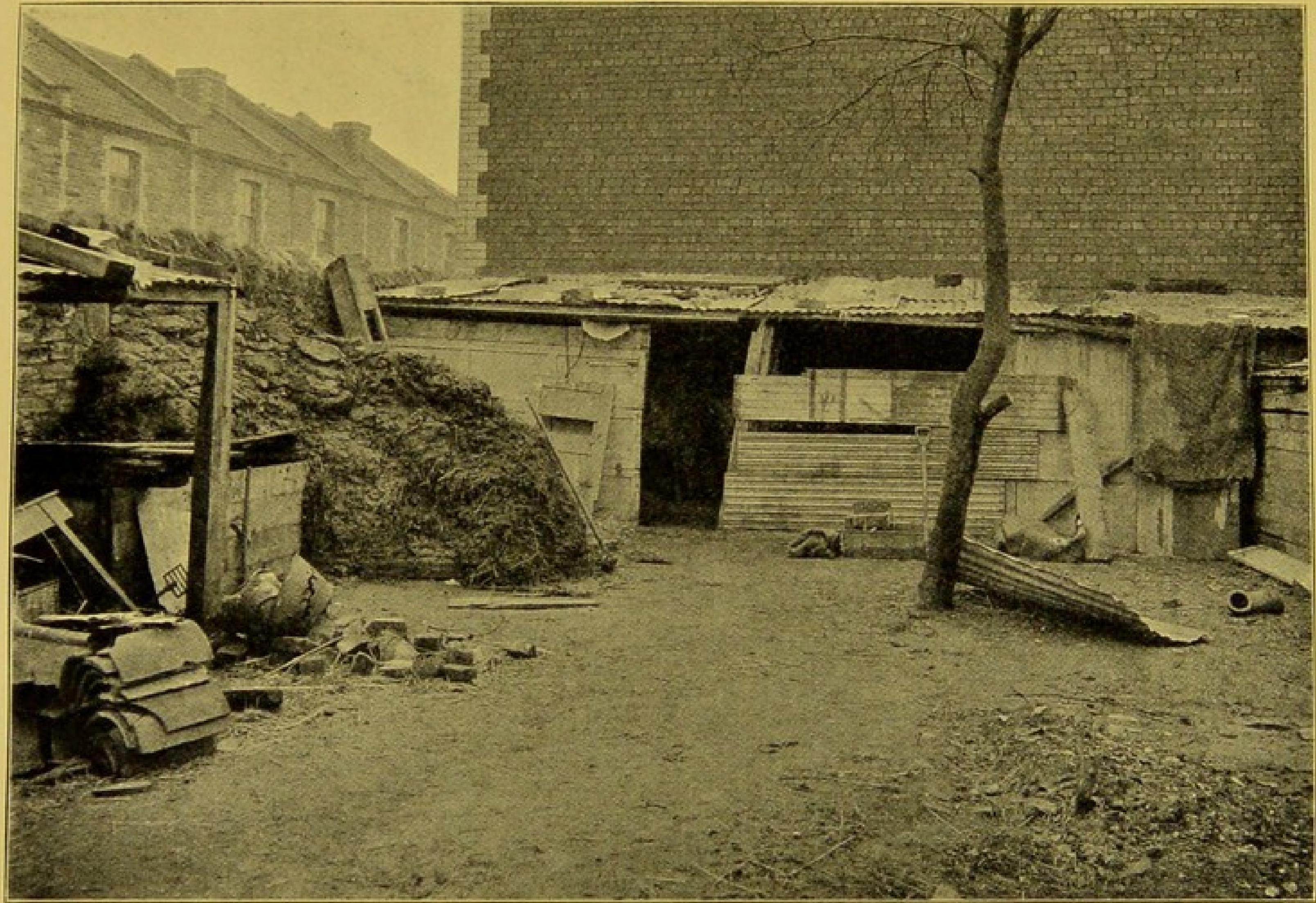


FIG. 14.—Dilapidated Premises used as a Cowshed for three Cows in an Urban District.

absorbent variety, and when seen are frequently worn, irregular, and with gaping joints. The writer has only seen a small number of floors constructed of impervious brick. Stone slab floors are often very badly jointed. In the better constructed sheds the floor is most commonly a cement one, and is usually ribbed to prevent slipping. Even with a cement floor, it is not uncommon to see it made so badly, and with such bad material, that it is all in holes and depressions.

Where drainage is provided, as in most sheds with cement or brick floors, the fluids pass away by a drain into a cesspit, or not infrequently into the stack yard.[1] The cesspit is sometimes uncovered, and usually is too near the sheds.

The lighting and ventilation of most cowsheds leaves much to be desired. In some parts of the country—for example, in many parts of Somerset—the cowsheds are entirely open on one side. The prejudice against the free ventilation of cowsheds is very strong and widespread. Even when air openings are provided they are often blocked up. It is common to find that the doors are the only means of ventilation, while, when openings are provided, they are often too small and so badly placed that they give rise to draughts detrimental to the cows. Lighting defects are also extremely prevalent, ranging from the shed which is quite dark when the doors are shut to the shed which is only dark in places. Lighting and ventilation defects are usually associated together.

Gross overcrowding of cows within the sheds is also common, either habitually or more often only at special times.

The actual structure of the sheds varies greatly, ranging from low sheds with galvanised iron roofs to lofty barns with or without a hay-loft above. Even when the main cowsheds are satisfactory it is very common to find a number of loose boxes adjacent to the sheds and con-

[1] This plan is not always adopted as an economy, but sometimes for manurial purposes. For example, the writer inspected some newly constructed cowsheds, built by an enlightened and progressive landlord. The sheds occupied three sides of a square and were of most satisfactory design and construction, apart from the fact that the liquid excreta and washings were intentionally conducted into the central yard by short pipes. The old litter and the manure from the sheds were dumped into the middle of the yard, and were watered and matured by the liquids. The cows walked through the quagmire to their sheds. The writer was considered a faddist when he compelled alteration.

taining milking cows. That these should be expected to have a proper floor instead of a manure-soaked floor, have sufficient light, and be of sanitary construction generally, strikes the farmer as a most exacting and unreasonable proposition which he resists with all his power.

The one great, almost universal, defect of the environment of the cowsheds is the proximity of the manure heap. With a personal experience of many hundreds of cowsheds, the writer can only recall about half a dozen instances in which this was not stacked quite near the cowshed. Fig. 16 illustrates an extreme but by no means uncommon example of such manurial and litter deposit. As a rule the cows have to wade through a moist, filthy, manure-filled yard to their sheds, and while there they are never free from air impregnated with rotting manure.

2. *The Cows.*—In most parts of Somerset and other of the western counties the cows are out all the summer and nearly all the winter. Sometimes they come into the sheds for milking, but often they are milked in the fields. In some towns the cows are in the sheds all the year round, and practically all the time. All gradations between these two extremes are to be met with.

The state of cleanliness in which the cows are kept varies greatly. In exceptional cases the cows are groomed and kept thoroughly clean, but the general rule is to milk cows with more or less manure-caked hind-quarters with or without dirty udders. Veterinary assistance is only called in when a cow is obtrusively ill, and abnormalities such as sore teats and slight udder inflammation are often treated by the farmer himself.

3. *Milking Vessels.*—Upon some farms the cans are cleaned by steam, but generally hot water heated in a copper is employed. In the writer's experience considerable attention is usually paid to the need of quite clean cans, but many writers have recorded instances of want of cleanliness. Proper places with cement- or stone-flagged floors are often provided for washing the milk vessels.

4. *Water Supply for Cows and Vessels.*—This varies very greatly, both as regards water for the cows to drink and for cleaning milk vessels. The majority of the cowsheds known

FIG. 15.—Immense Wall of Manure just outside Shed and a foul pool of Yard Drainage and Manure Soakage; cows milked in the shed.

to the writer are without water laid on to the sheds for the cows to drink. The cows have to go outside to drink, and frequently their only drinking water is obtainable from ponds, ditches, and streams not uncommonly of very doubtful purity. That a supply of water is also useful to wash down the sheds is a fact very seldom recognised.

Water for washing the milk vessels has to be provided, and frequently is of good quality, but it is far from rare for the only source to be derived from wells of very doubtful purity, and sometimes of certain impurity. In illustration the writer may mention two cases. In one the only water supply available for the cows (a large herd of 50 cows or more) and for washing the milk vessels was a small river which, about 1½ mile higher up, had received the untreated drainage of a large semi-urban district of about 1200 inhabitants. In the other the cows drank from ditches in the fields, and the only water supply for the milk vessels was from a shallow well yielding water of unpleasant odour, which the farmer admitted was so bad that none of the family ever used it for drinking purposes.

Porter[1] states: "Those of us who are in charge of rural districts have to face the fact that a large number of farms rely on wells which, on analysis, would be at once condemned as unfit for drinking purposes, whilst many others would be classed as being of doubtful purity." He notes that there were about 100 dairy farms in his rural district (Reigate Rural), and that 44 relied partially or entirely on well water. He examined bacteriologically samples from 34 of the water supplies. Using very lenient bacteriological standards, 4 only could be considered as pure, 18 were bad bacteriologically, and 12 doubtful.

Richmond,[2] as chemist to the Aylesbury Dairy Company, gave particulars of 278 dairy farms, on which there were altogether 447 water supplies; of these, 146 farms with a total of 210 water supplies were passed, 86 farms with 113 water supplies were condemned and entirely rejected on this account, while 46 farms were found at first to have altogether 75 polluted supplies, which were cut off, and a total of 49

[1] *Public Health*, 1909, xxii. p. 251.
[2] *Ibid.* p. 254.

new good supplies were found on these farms. He remarks: "Excluding the public supplies, and taking only wells, springs, etc., into account, I find that I have been able to pass 187 water supplies, while I have condemned 188. This indicates that 50 per cent of the waters on farms are polluted."

5. *Farm Dairy*.—Nothing is more noticeable, as a rule, than the contrast between the state of the cowshed and the condition of the dairy. The dairy is usually scrupulously clean, and often is an airy and satisfactory place. As a rule the milk to be sold never goes near the dairy.

B. The Milking Process

It may be said as a general broad dictum that, upon the ordinary farm, arrangements for performing the milking process so as to avoid contamination of the milk are rarely adequate, and for the most part their need seems to be scarcely recognised. The milk pail may be clean, but that is usually all that is clean.

The place of milking is usually the dusty byre, although in many parts of the West of England much out-of-door milking is done. The cow's hind-quarters, ungroomed and dung-laden, add their quota of manure to the milk. Fig. 16 is an illustration of dirty cows, and one only too common. The long, untied-up, manure-stained tails of the cows are flicked about and assist in further contaminating the milk. The udder may be superficially clean, but usually shows dried dung adherent to the hairs. Even when apparently clean, an inspection of water used for washing it will demonstrate that its cleanliness is only a matter of degree.

The milker, now generally a man, milks as if milking was a work on a level with manure carting, and requiring as much or as little personal care; indeed, he will go from the one to the other with equal readiness and indifference. His dust-laden dirty clothes are but rarely hidden by an overall, and if one has been provided in a hygienic moment, or as the result of outside pressure, one it remains, and is used over and over again without washing, until its smooth texture is the only thing left in its favour.

Farmers frequently direct (or tell the medical officer that

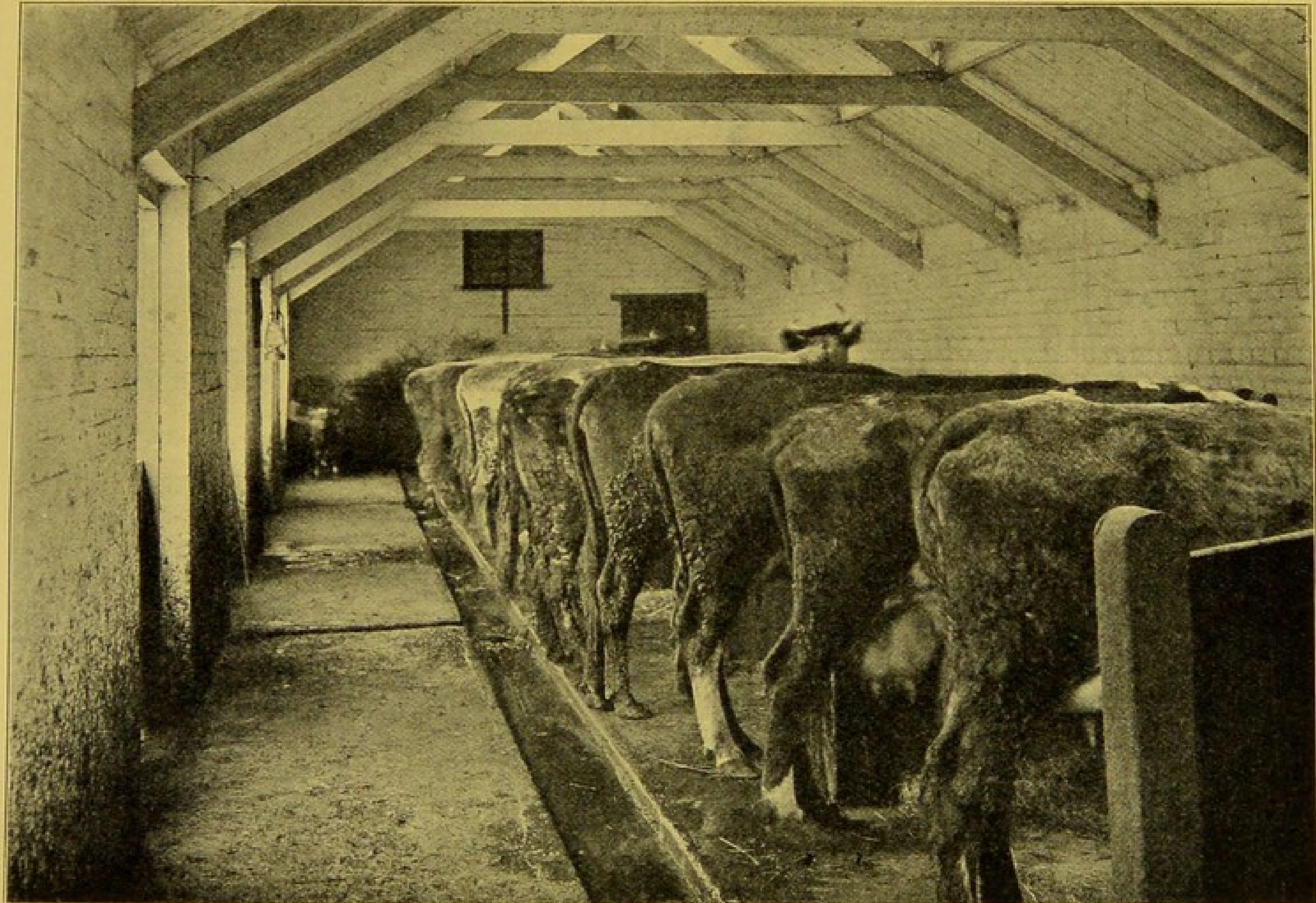


FIG. 16.—Dirty Manure-plastered Cows in a Shed with a good Floor.

they have so directed) their milkmen to wash their hands before milking, but as they rarely see that their orders are followed, and often neglect to provide facilities for washing, such directions do not amount to much. The writer has made it his practice to visit cowsheds, as far as possible, at milking time. He has repeatedly noted that, even when water, towel (sometimes even towels), and soap are provided, they have not been used, while even if the hands have been washed before starting milking, he has never once found them re-washed during milking. Hands soiled with milk and then used to push over the manure-coated flanks of cows and handle a dirty milking-stool fail to show any evidence of washing after two or three cows have been milked.

The objectionable process of wet milking is not uncommon. As witnessed by the writer, the milker gives a few pulls at the teats, and allows a little milk to flow on to his hands. He then makes an emulsion of the milk and the dirt on his hands by rubbing them together, the overflow falling into the pail beneath. He then feels in a position to start milking in real earnest, which he proceeds to do. The writer has seen a man do this coming straight from manure carting. Other observers record that they have seen the wet milkers start by dipping their hands in the milk itself.

The milk pails used to receive the milk are usually pails with quite open tops into which dirt and manure readily fall.

The milk before it is sent away is strained, and whatever else is omitted, straining is not omitted. The strainer is usually a wire one with or without a layer of muslin. Not infrequently, however, strainers of more elaborate kind are adopted. The cowkeeper evidently has a lurking idea that pieces of manure in milk will not increase its saleable properties, so he strains them out. He then feels he has done all that can reasonably be asked of him. The ineffectiveness, etc., of strainers is considered on page 286.

The above is a description of the milk conditions on an average dairy farm. There are model farms where milking is properly conducted, and in a cleanly fashion, but they are very few in number. That the description given is no exaggeration is attested by a multitude of reports by impartial men. An example of conditions found in an urban and in a rural district, as recently described by Local Government Board Inspectors, may be given.

Dr. Sweeting,[1] in a report on the sanitary conditions of the Borough of Leigh (Lancashire), states:

> I visited rather more than one half of the cowsheds. Nearly all that I saw were dark, exceedingly dirty, badly ventilated, badly paved and channelled. In many, cubic space was deficient; but in the majority of instances the cows are grazed out. The udders of most of the cows were very filthy. The practice largely obtains of storing milk in larders and cellars with food and drink. . . . There is an excellent code of Regulations, adopted in 1901, but these are not enforced.

Dr. Wheaton,[2] in a report upon the sanitary circumstances of the Helmsley Rural District (North Riding of Yorkshire), writes:

> The condition of nearly all the cowsheds is extremely unsatisfactory, although a very few satisfactory ones are to be found. Some are mere hovels of rubble, with a little straw thrown over a few beams as a roof, almost wholly without light, ventilation, or drainage, and greatly overcrowded. No attempt is made to keep the cattle clean, or to cleanse the teats or the milkers' hands before milking. The dairies are in nearly all cases mere cupboards, often without light and ventilation, cut off from the living room by a loose partition only, and they are nearly always also used as pantries and larders. Frequently an accumulation of stinking filth, manurial or otherwise, is placed beneath the only opening by which fresh air can enter the so-called dairy. It need hardly be said that under such circumstances no cheese or butter industry could flourish. . . . There are Regulations for Dairies, Cowsheds, and Milkshops, but they are not enforced.

C. The Transit of Milk from the Byre to the Purveyor

Milk after collection at the byre may be distributed in three ways. In rural and small urban districts, the cowsheds are reasonably near the areas to which the milk is supplied, and the farmer either distributes the milk in his own carts, or sells it to a purveyor, who himself at once distributes it. Here there is no delay, and the milk is never cooled. The milk cart is ready, and when milking is completed, the cart is

[1] *Report of the Medical Officer, Local Government Board*, 1907-8, p. 51.
[2] *Ibid.* p. 84.

FIG. 17.—Premises and Cleaning Appliances for Milk Vessels.

loaded up and the distribution at once takes place. The pollution at the byre is the only pollution to which the milk is subjected, and practically no multiplication of bacteria takes place between collection and distribution. The only likelihood of such increase is in cases where all the milk is not sold, and the unsold balance is kept and vended at the next purveying time, whether in the afternoon or the following morning.

Farmers who deal with their milk in this way rarely or never cool it. For example, in the Borough of Colchester, out of 26 farms selling milk, almost all was sold locally, and upon none of them was the milk cooled. In rural areas some distance from a convenient urban population the milk has to be sent considerable distances, and almost always by rail. The milk is either sent off direct by the farmer to the town, or he delivers it at a conveniently situated milk depot or factory. In the former case the farmer should, but does not invariably, cool his milk before sending it away. His only means of cooling may be by standing the churn in cold water, but mostly when he does cool it he runs it through one of the different coolers on the market.

When the milk is sent to a milk factory, the farmer usually delivers it twice a day uncooled and as soon as possible after collection. The milk factory owner cools the milk and often pasteurises it as well in the summer, and sends it away by rail. The churns of the farmer are frequently steamed and washed for him at the factory. Many of the milk factories or depots are in connection with large milk companies in the town, but some are independent local enterprises.

Most of the milk depots seen by the writer have had proper cement floors, have been provided with a good water supply, and have suitable facilities for steaming and cleansing the churns. They are built conveniently situated in relation to a railway station. Fig. 17 illustrates conditions often met with on small milk factories and on the premises of the larger dairymen. Apart from the unsatisfactory jointed floor the arrangements shown are reasonably satisfactory.

The present conditions of railway milk transit in England are decidedly unsatisfactory. The majority of the churns used are of unwieldy size (17 gallons), and being of bad shape and type, permit dust, dirt, and rain to get into the milk. Orr[1] in his investigations paid special attention to the churns used, and found considerable variation, especially in the form of lid employed. He found five patterns of lids (types A to E sketched below) in common use. Out of 45 noted, 8 per cent were type A, rainproof and without ventilating holes; 13·3 per cent type B with ventilating holes; 6·6 per cent type C, *i.e.* funnel-shaped lid, unventilated; 33·3 per cent type D, funnel-shaped with ventilating holes; and 37·7 per cent were type E, simple lids with or without ventilating holes.

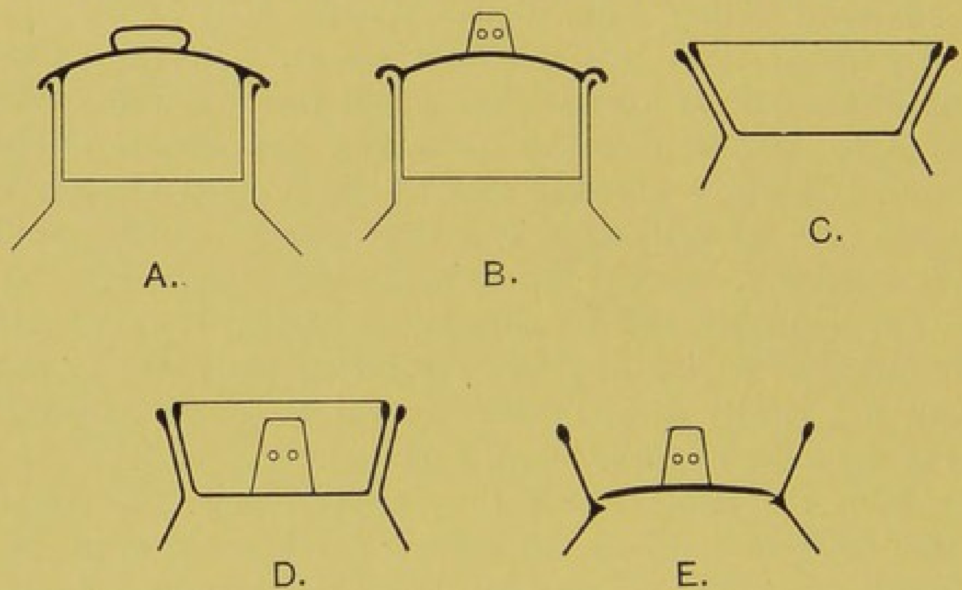


FIG. 18.—Diagram of Type of Milk Churn Lids.

Type A is the only pattern which is more or less satisfactory, while types D and E, which comprise 71 per cent of whole, and are apparently the prevalent types used in England, are extremely objectionable. As Orr, referring more particularly to type E but applying nearly equally to type D, says:

Than this, a lid more calculated to allow contamination of the milk could not possibly be designed. Dust accumulates in the funnel-shaped portion, and either falls past the margin of the lid, which generally fits badly, or is washed off with the milk discharged from the cans. It is quite common for the milk to wash up over the rim lid during handling, and to take up the dust on the top in the process. During wet weather, any dust which escapes being washed in by the milk in this way is carried into the can by the rain.

[1] *Report on Milk Contamination*, 1908.

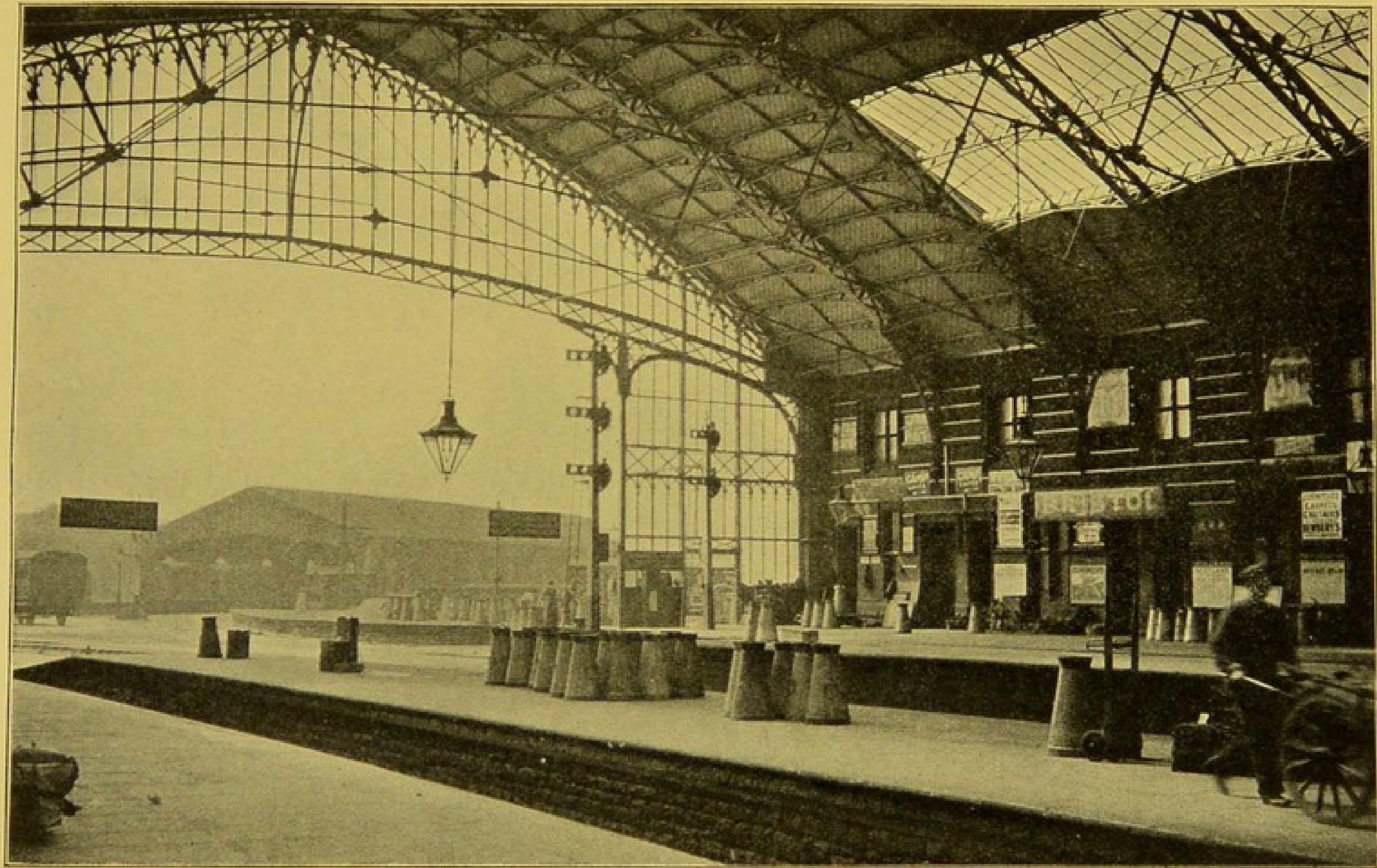


FIG. 19.—Railway Station showing Churns full of Milk deposited on the Platforms, and illustrating the absence of precautions to avoid Dust and Sun.

It may also be stated that the ordinary 17-gallon churns are too heavy when full, and are too deep to allow careful cleaning and hand-brushing.

The churns are as a rule sent unlocked. In this way toll can be, and probably often is, taken of the contents on the way, any deficiencies being made good with water. Gross pollution occasionally results from this habit of leaving the churns unlocked.

The means of transmission are bad. Refrigerator cars appear to be unknown, and while special vans have been provided by a number of railway companies, they are not apparently in regular use. The milk churns are usually carried in badly ventilated luggage vans, often containing other and miscellaneous goods, and occasionally live stock. Cases in which the milk has been sent in fish vans or other objectionable vans have been noted by several writers. Orr, for example, reports as regards milk in Yorkshire :

In only one instance during the present enquiry was milk carried in a van reserved for milk traffic only, and this only for part of the distance to be travelled. Here milk journeyed from Derbyshire to Hull and by the special van as far as Doncaster only. This van and another running from Leeds to Sheffield once daily are the only special vans used for carrying milk in the whole districts dealt with in this report. In all other cases the ordinary luggage vans, which are usually badly ventilated and close in summer, were used for the milk transportation. The vans, as a rule, contained a miscellaneous collection of luggage, parcels, and dead meat. In one case a crate of live pigeons, in another a dog, and in another a quantity of fish accompanied the milk. In this last case the van was very dirty.

An Inspector reported, in one instance, that the van was full of people, some of whom were sitting on the lids of the cans, a practice which is common enough, but which might be a source of dangerous pollution, especially when so many defective lids are used. So many people were in this van that the air, according to the Inspector, was foul. As is well known, luggage vans are usually not over clean, and are apt to be dusty. In dealing with luggage also, clouds of dust are apt to be raised, which settles upon the tops of the churns, to drop into the milk through defective lids, or be washed off by the contents of the cans on pouring out. An Inspector reported that "a porter swept out a van, raising clouds of dust while the churns were in it, and the lids defective." The lids here were of the worst type, and badly fitted.

Apart from the actual conditions of transit serious sanitary objection may be raised to the treatment of the milk before and after transit. Churns of milk are sometimes left for considerable periods on dust-exposed railway platforms standing in the sun (see Fig. 19). It is usually left to the milk vendor to fetch away his milk, and if any arrangements exist for transferring the milk to special cooled sheds they are only employed in a very few places. For example, Walford[1] writes as regards milk for Cardiff: "Most of the milk supplied to the inhabitants of Cardiff is delivered at the G.W.R. station, and remains either on the passenger platform or on a separate part of that platform overnight, the local milk dealer usually fetching it for delivery to his customers in the early morning."

A most objectionable practice, sometimes carried out, is for the milk to be actually distributed into the milkman's vessels at the railway stations. This leads to much contamination. The two following quotations will illustrate the practice.

Orr mentions that in 14 out of 34 deliveries at railway stations the churns were taken straight to the dairy and there transferred, but that in 16 the churns were emptied in bulk at or in the neighbourhood of the station, in places which were often in a dirty or dusty condition. In 4 the milk was transferred by measuring. The last procedure, involving as it does the dipping into the churn of doubtfully clean vessels by probably dirty hands, is a source of much pollution.

Manley[2] remarks:

> The milk supply of this town (West Bromwich), with very few exceptions, arrives by rail per the G.W.R.; there, every morning about 11 o'clock, the cans which contain the milk are opened, and the milk mixed, served, and decanted from can to can by men and boys, who plunge their dusty coat sleeves in the depths of the can, and who usually have a pipe or a cigarette in their mouths; if the serving is not done here it is done in the course of the round.

The conditions under which milk is transported from the cowshed to the purveyor are becoming of increased importance, owing to the long distance which much of the milk which goes to large centres of population has to travel. Swithinbank

[1] *Medical Officer*, January 1, 1910, p. 5.
[2] *Annual Report, West Bromwich*, 1909.

Fig. 20.—General Shop used for selling Milk. One half of the shop is used for the sale of old clothes, etc., the other half for general goods, including lamp oil, raw and cooked meat, and *milk*. (The sale of milk has now been discontinued.)

and Newman [1] give the following table as to the distance which the milk supplied to London has to travel.

Railway.	Maximum Distance in Miles from which Milk is carried.	Time occupied by the Railway Journey in Hours.	Whether Special Vans and Carriages are used for Conveyance of Milk.	Whether Refrigerator Vans are used for the Milk.
Great Eastern . . .	130	4	Yes	No
Great Northern . .	150	$5\frac{1}{2}$	Yes	No
Great Western . . .	300	11	Yes	No
London, Brighton, and S.C.	86	$3\frac{1}{2}$	No	No
London and N.W. . . .	359	$8\frac{3}{4}$	Yes	No
London and S.W. . .	150	5	Yes	No
Midland	423	12	Yes	No

The table is compiled from evidence brought before the Committee on Food Preservatives (1901). It appears that the average distance from which these railway companies bring the milk supply into London is more than 200 miles. During 1899 the Great Western Railway, the largest carriers of milk, conveyed 23,495,925 gallons in 1,642,380 cans.

D. The Purveying of Milk

In London and many of the great towns the distribution of milk is in the hands of large dealers, who receive regular consignments of milk from the farmers, store it in cold storage upon their premises, frequently pasteurise it, and distribute it to their customers as soon as possible. The large milk dealers are usually impressed with the need of cold and of cleanliness in connection with the vending of milk, and from the time the milk reaches them there is but little to complain of. They usually insert clauses in their agreements with the farmers which aim at securing a clean milk free from the risk of conveying infectious disease. While these agreements mark an advance, and are a recognition of the need for special precautions, they are of doubtful efficiency as carried out, and until some more stringent powers are available are largely ineffectual.

Milk is vended either delivered direct to the consumer,

[1] *Bacteriology of Milk*, Text-book, 1903.

sold in special dairies, or sold in small shops, which only sell milk as an incidental part of their business.

Delivery of milk in bottles appears to be rare in this country. The milk is usually taken round in a churn, and the quantity required for each customer withdrawn by a dipper and poured direct into the jug or other vessel of the customer. It is not an ideal method, and a certain amount of contamination of the milk is likely to result.

The dairy shops scattered about the towns are usually scrupulously clean, the milk vessels are equally clean, and the attendant neat and tidy. Indeed, for those who know the average conditions under which milk is produced, and the gross contamination to which the milk sold in such dairies has probably been subjected, there is keen irony in the beautiful surroundings which envisage the milk as soon as it comes within the purview of the consumer, and a whited sepulchre comparison is felt to be not unwarranted.

The small shop which only sells milk as an incidental part of its trade is an absurd anomaly, but such shops are very common (see Figs. 20 and 21). In Colchester,[1] for example, a town of 40,000 inhabitants, there were 37 such milk sellers registered when a special enquiry was made by the writer in 1904. They were for the most part small general provision shops, selling only small quantities of milk, very rarely more than 3 to 4 gallons a day. In only a few were objectionable substances, such as fish or paraffin, also sold, because this had been stopped some years earlier. Not a single one of the counter pans was covered, although most of the shops were very dusty, and many were full of flies.

Newman[2] found in the Borough of Finsbury (London), when special enquiry was made by him in 1903, that there were 261 milk vendors registered: 40 were confectioners or maintained coffee-shops, leaving 221 who sold milk for consumption off the premises. The latter consisted of 39 so-called dairies and 182 general shops. All 221 milk-shops were inspected, and 116 (52 per cent) were found to have one or more sanitary defects. As a rule, the most defective premises were those used for general purposes, and

[1] *Annual Report*, 1904.

[2] *Report on the Milk Supply of Finsbury*, 1903.

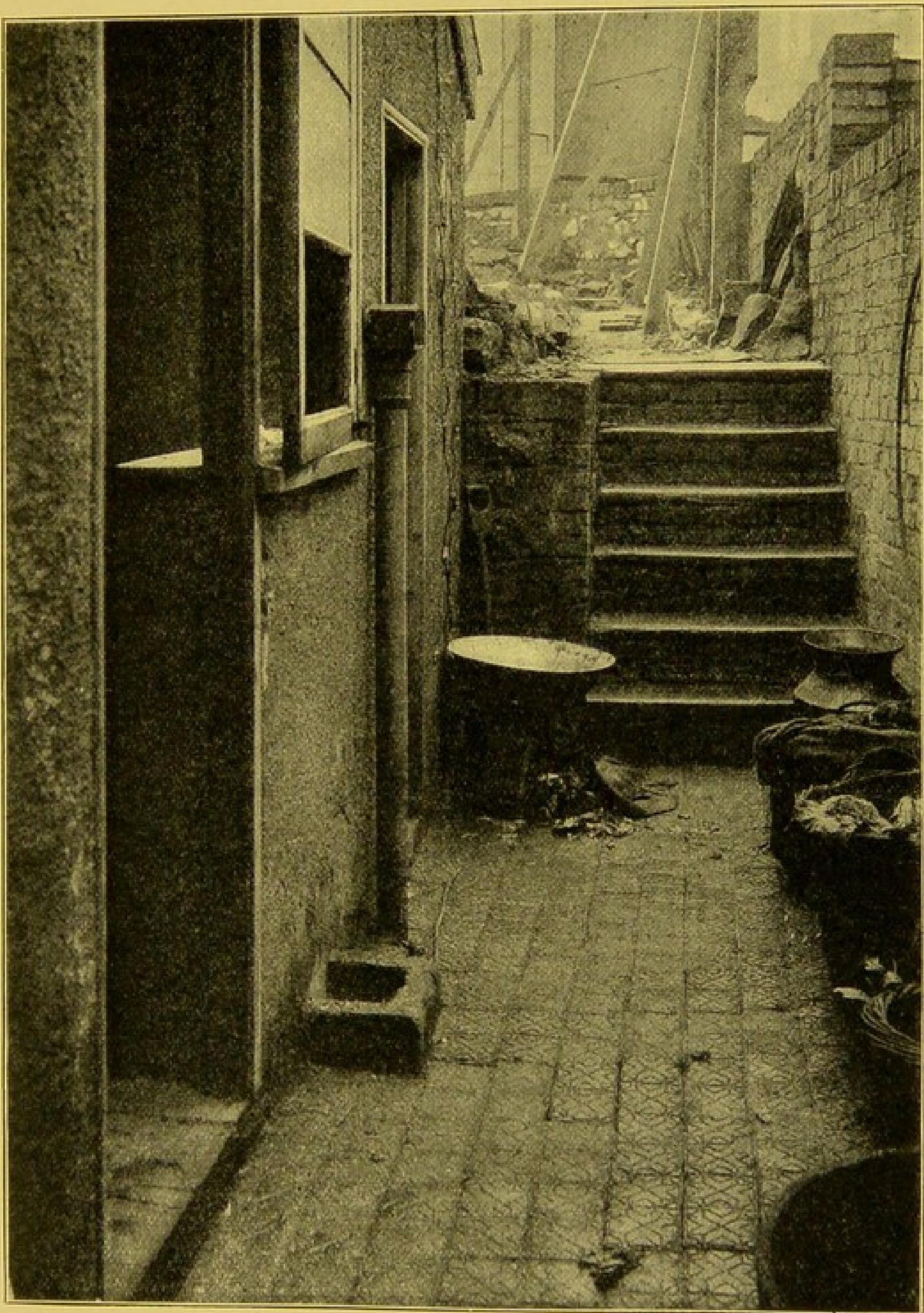


Fig. 21.—Part of the Premises of a General Dealer (Meat and General Shop). He sold about 20 gallons of milk a day, and stored it in the yard shown. The mica flap of the air inlet was broken.

where a few pints or quarts of milk were sold. In some cases, however, sanitary defects were met with at dairies carrying on a large business. Although two years previously instructions had been given that all the counter pans were to be covered in 161 shops (or 73 per cent), no cover at all was being used at the time of the enquiry.

The provision made for storing milk and other foods in the home of the consumer is frequently extremely bad, and causes further pollution of the milk. In the writer's experience it is quite the exception to find proper larder accommodation in the homes of the working classes. By proper larder accommodation is meant some place, room, or even cupboard, in a cool position and with a window opening into the open air. For example, in Colchester the following figures were obtained in house-to-house inspections:

Year.	Houses inspected.	Houses without separate Larder Accommodation.	Percentage of Houses without Larder Accommodation.
1905	501	473	94·5
1906	931	876	94·1
1907	689	626	90·9
1908	548	502	91·6
4 years.	2669	2477	92·8

Thus over 90 per cent of the houses inspected in a provincial town were without any proper provision for storing milk, and food generally, within the home. The usual storage place was a cupboard either in the kitchen by the side of the fireplace or under the stairs. Such cupboards were always unventilated and without openings to the outer air.

Orr records in his report that in 22 out of 75 cases there was no ventilation whatever in the places in which the milk was stored.

CHAPTER XVI

REFORMS IN THE CONDITIONS OF MILK SUPPLY

THE average present-day conditions under which milk is produced and supplied have been described in the previous chapter. As there pointed out, they are in the main highly unsatisfactory and in urgent need of alteration. The present chapter is concerned with the practical reforms, both as regards the structure of premises and the methods of handling the milk, which are essential to the production of a pure milk. The machinery by which these alterations are to be effected is discussed in Chapter XXI., leaving actual practical requirements for the present chapter. The reforms required may conveniently be considered under four separate headings:

A. Reforms at the source of supply.
B. Reforms in the transit of milk.
C. Reforms in the purveying of milk.
D. Reforms in the care of milk by the consumer.

A. THE SOURCE OF SUPPLY

1. *Structural Requirements.* — There are at least four essential requirements for the structure and fittings of a good cowshed:

(*a*) While protecting the cows, the shed must provide a sufficiency of air-space, light, and ventilation.

(*b*) A structure and environment which enables the cows to be kept clean.

(*c*) A pure water supply available for the cows, and so accessible that it can be readily used for washing down the sheds.

(*d*) A construction and arrangement convenient to the farmer, which enables the labour of attending to the cows to be reduced to a minimum.

Provided these requirements are fulfilled, a shed may be of very simple design, although of course some types of sheds are preferable to others.

Considerable latitude may be allowed in the general construction of the sheds, provided the essential matters of ventilation, lighting, and composition of the floor are satisfactory. The actual material used must be largely governed by the local building material available. Sheds of brick or stone are preferable to those of wood. A slate or tile roof is the best. Thatched roofs are unsatisfactory, as they harbour much dirt, but may be rendered fairly satisfactory by covering the under surface with any smooth substance. Corrugated iron roofs are bad, owing to the difficulty of regulating the temperature. In many old cowsheds the ceilings form the floors of hay-lofts, which is a very bad arrangement unless, as is rare, the hay-loft is completely boarded off from the cow-shed with tongued and grooved boards, and separate extraction shafts are provided. It is an advantage to have half-doors, *i.e.* the doors to be in two halves, the top and bottom opening separately.

The internal walls of the cowshed should be impervious, and if they are of ordinary brick they should be cement-covered to half-way up. A cheaper form of impervious lining is to smooth and cover the bricks with some form of petrifying liquid.

Many cowsheds, particularly in Somerset and other parts of the West of England, are completely open along one side, and few cowkeepers who have used such sheds are willing to return to closed ones. With these cowsheds, problems of air-space and ventilation do not exist, and the lighting is usually a simple matter.

The majority of sheds are closed, and for these some standard of air-space is necessary. The model by-laws of the Local Government Board recommend 800 cubic feet per cow. Some writers of repute have advocated 600 cubic feet per cow, but this seriously adds to the difficulty of ventilating without draught. In calculating air-space the model by-laws state: "No space shall be reckoned which is more than 16 feet above the floor; but if the roof or ceiling is inclined, then the mean height of the same above the floor may be taken as the height thereof for the purposes of this regulation." 800 cubic feet will give about 50 square feet of floor-space per cow, and this should be insisted upon.

The lighting of cowsheds should be carefully considered. It is impossible to have clean cows and clean milking in a dark shed. The Model Regulations are vague, and only specify that every dairy "shall be sufficiently lighted with windows, whether in the sides or roof thereof." "Sufficient" should be taken to mean light enough to enable every part of the interior to be easily visible in ordinary daylight and *with the doors shut.* It is probably better to have a definite but reasonable standard of amount, such as 3 square feet of light-space per cow. The cowkeeper often asserts that cows are healthier and give more milk when kept in dark sheds, but the writer has never met with such a one who had made any comparative investigations or who could substantiate that assertion in any way.

Efficient ventilation is essential to a satisfactory cowshed. The Model Regulations are vague, and require "every cow-keeper shall cause every dairy in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air, to keep the air in the dairy in a wholesome condition."

With 800 cubic feet per cow it is quite feasible to ventilate efficiently but without draught. The inlet openings should be about 30 square inches per cow, and outlet openings not less than this. These openings are to be exclusive of the doors. Barwise has suggested the following ventilation standard: "To provide for each cow 36 square inches of permanent openings, to be provided, one half in the front external wall, the other half in the wall above the head of the cow, or in the ceiling at the opposite end of the shed to the inlet opening."

The ventilation provided should be such that the entering air does not impinge directly upon the cows, but is directed upwards. While this can be done in many ways, the writer has a preference for windows falling inwards, with side checks, placed on opposite sides of the cowshed, about $5\frac{1}{2}$ to 6 feet above the ground. Inlet ventilation apertures near the ground are not satisfactory. The outlet ventilators are placed at or near the ridge of the roof. A continuous louvre running almost the whole length of the roof is sometimes put in, or one or more separate louvre openings, or openings with cowls. All these forms may be quite satisfactory.

The cowkeeper not infrequently objects to adequate ventilation, because, on the one hand, he declares that the sheds being colder, the cows produce less milk, while, on the other hand, he believes the animals are likely to be chilled and illness result. Exact experiments do not bear out the former supposition. For example, John Speir[1] concluded from a careful series of experiments that as much milk was produced by the cows in freely ventilated sheds as in those less ventilated and warmer.

These experiments were repeated by Lauder and Fagan[2] in 1909-10. Two equal groups of cows as similar as possible in respect of age, yield, quality of milk, and period of lactation were selected. The one group was kept in one part of the byre which was freely ventilated even in the coldest weather, and the other in the other part of the byre in which the ventilation was greatly restricted, so as to keep the temperature as nearly as possible 10 degrees higher than in the cold end. The average weekly temperature in the cold byre varied from 43° to 55° F., the average temperature being 50·5° F. The results showed that the average yield per cow per day in the cold byre was 27·54 lb., and in the warm byre 27·14 lb.; the average percentages of fat were 3·74 and 3·7 respectively. These results were confirmed at other centres. The authors concluded that byres may be freely ventilated even in very cold weather without impairing either the yield or the quality of the milk.

A herd of cows in Shropshire kept under open-air conditions produced as much milk as a similar herd kept under warm-shed conditions. The experiment was continued for four years.

The other contention is probably the exact opposite to the truth. The cow is an adaptable animal, and if acclimatised

[1] *Trans. of the Highland and Agricultural Society of Scotland*, 1908.
[2] *Journ. of Meat and Milk Hygiene*, 1911, vol. i. p. 142.

to cold in the autumn, it will put on a heavy coat in the winter. Many of the cows in Somerset are out of doors nearly all the year. Such animals are decidedly less likely to suffer from mastitis and other inflammatory conditions than cows living under artificial conditions of warmth, since these are always liable to sudden temperature variations. Of course, if cows are suddenly turned out of cowsheds which have been kept too hot by insufficient ventilation, they may catch cold, but this is obviously a quite different matter.

The composition of the floor is another feature of primary importance. It is essential that it should be of some impervious material, and, on the whole, cement-concrete is the best. It should be ribbed to prevent slipping, and must be of the best quality. It is false economy to construct the floor of asphalt or poor quality concrete, since, owing to the very hard wear to which it is subjected, such floors soon fall into holes and require renewal. Some landowners and cowkeepers have objected to the whole of the floor being cemented, and construct the fore part of clay, as they maintain that the cows' knees are apt to be damaged by the hard concrete. Impervious bricks set in cement also make a good floor.

The floor should slope gently back ($\frac{1}{2}$ inch fall is sufficient) to a grip running the whole length of the cowhouse, the grip having a slight fall to a gully outside the cowshed. The grip or manure trench should be about 12 to 18 inches wide, and is usually about 4 inches deep. Speir,[1] however, dealing with this point, remarks: "The manure channel should be 24 inches wide, 6 inches deep at the side next the cows, and 4 inches at the walk. The floor of the channel should be $\frac{1}{2}$ inch lower at the walk than at the cows' heels. It should also have a fall lengthways of $\frac{1}{2}$ inch for each cow." He remarks that these apparently trifling details are of immense importance as far as the cleanliness of the animals is concerned. If made in this way, the opportunities for a cow fouling herself from her excreta are largely reduced. He adds: "A *sine qua non* of an efficient byre is a manure-channel 24 inches wide, sloped as suggested, and nothing else will give satisfactory results."

The distance from the front of the feeding-trough to the manure grip is another detail of essential importance, and one

[1] *Public Health*, 1900, xii. p. 775.

upon which opinion varies. It should be sufficiently long for the cows to lie down properly, while it should be short enough to allow the faeces and urine to drop direct into the channel. Its appropriate exact length must vary with the size of the cows kept. In general, a length of $6\frac{1}{2}$ to 7 feet may be recommended. Speir in the same paper recommends: "For

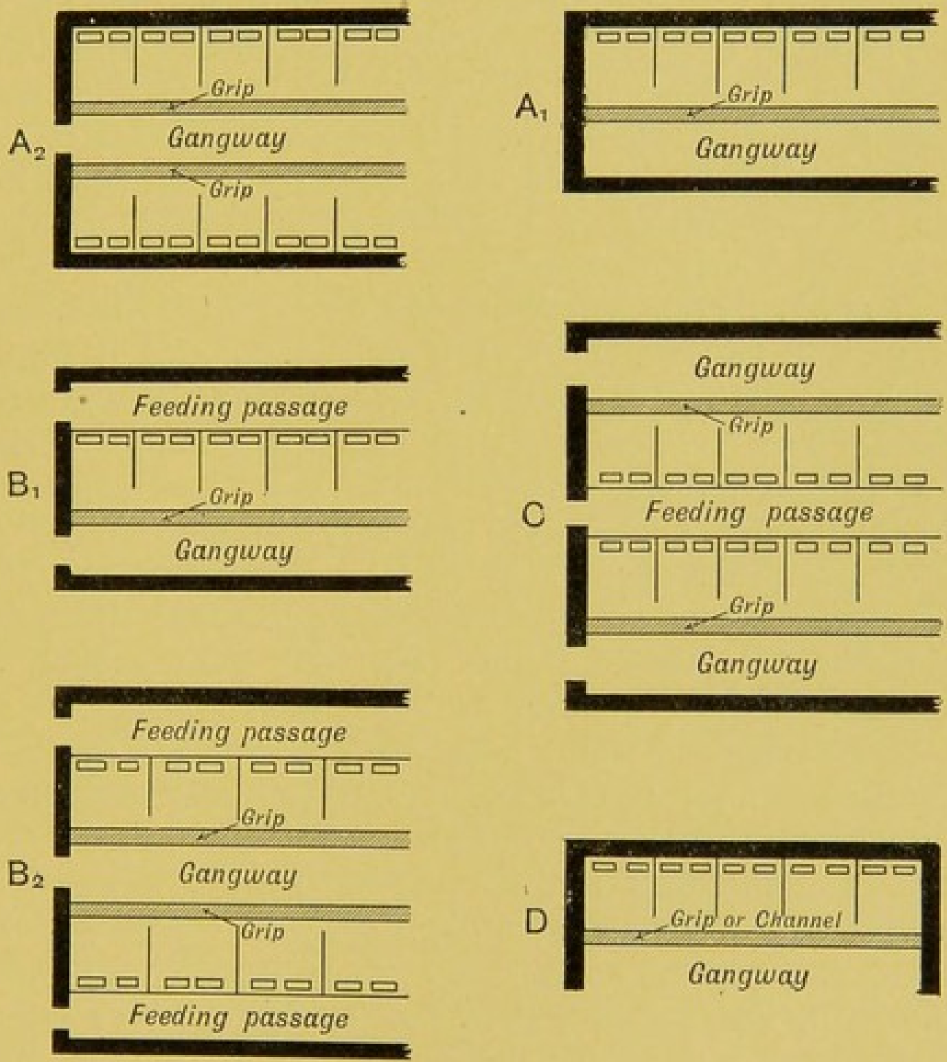


FIG. 22.—Types of Cowsheds as met with in England.

the smallest size of cows, such as Jerseys, Kerrys, and young Ayrshires, the stall should be from 6 ft. 10 in. to 7 ft. long, inclusive of the breadth of the trough. For Ayrshires, a stall 7 ft. to 7 ft. 2 in. is quite sufficient, and for shorthorns 7 ft. 3 in. to 7 ft. 6 in. suits very well." The gangway behind the grip should be at least 4 to 5 ft. wide. If less, the hind wall will be splashed with dung.

The internal arrangement of the cows inside the sheds varies considerably. The chief types are shown in diagram form in Fig. 22. The commonest type in the writer's experience is type A, either in its single form A_1 or the double byre A_2. It is the cheapest form to construct. The mangers are quite close to the wall, and there is not free ventilation round the heads of the cows. From this point of view it is undesirable, and a feeding-passage in front of the cows' heads, as in type B (B_1 and B_2), is a great improvement. Type C, in which the cows face and breathe the air vitiated from each other, is undesirable. Cowsheds open along one side are usually similar to type D when properly constructed, but even for these partly open sheds a feeding-passage in front of the cows is very desirable.

It is usually considered sufficient for the stalls to be about 3½ feet wide for each cow. It is by no means an advantage to allow a wide lateral space for each cow, as the animals are then apt to lie crosswise, and in this way foul one another with their excretions. The drainage should pass along the grip and discharge outside the shed over a trapped gully. It should be conducted to a properly constructed water-tight covered cesspool of not too large dimensions, and situated a reasonable distance from the cowshed. This should be periodically emptied over the land.

The manure and fouled litter should be removed a reasonable distance from the cowshed. Their decay and maturition, however necessary to the farmer, are not beneficial to the cow. The best arrangement, and one which the writer has seen in use in several instances, is to put the manure at once into a little trolley running on rails, and run it into the deposit-pit at a definite distance away from the cowshed. Such a means of deposit is inexpensive to construct, and requires little labour to use. A definite regulation is required, forbidding under penalty the stacking of manure within 40 feet of any cowshed or dairy. Farmers sometimes complain of the plague of flies round the cows in the summer, and try to mitigate it by shutting out the light and much of the ventilation from the hapless animals. Removal of the manure to a reasonable distance is a much more rational procedure.[1]

[1] Newstead (*Fly Report*, 1907, to the City of Liverpool) found no house-fly larvae or pupae in middens containing cow-manure exclusively owing to the

A water supply is required for the cowshed both to supply the cows and for cleaning purposes. In a number of cowsheds the arrangement adopted is to supply the water, by gravity or by pumping, to a covered tank, and from this the water gravitates as required to a long iron gutter running the whole length of the shed in front of the cows. Such gutters should not be less than 9 inches wide. When separate troughs are provided they may be of stone or concrete. A water supply should also be available for washing down the cowshed. Obviously a proper impervious floor is necessary before this can be done.

2. *Clean Milking.*—It cannot be too strongly emphasised that milking is a *process*, and a process which has to be repeated at regular intervals. Being a process, and not a concrete matter which can be settled once for all, it is essential that those who carry it out should understand clearly the nature of the ritual required, and appreciate adequately the results to be attained from such a ritual. In other words, clean milking can only be attained by those who understand both what cleanliness means and how to ensure it. Clean milking is essentially a result of education. While, on the one hand, it is true to say that clean milk can only be obtained by a milker who has been educated to the appreciation of cleanliness in milking, it is equally true to state that clean milk is impossible unless certain simple environmental conditions connected with milking are fulfilled. These conditions are clean cows, clean milkers, clean vessels, and clean sheds. The attainment of these conditions will now be considered.

Clean Cows.—The cow is naturally an animal which produces with ready facility manure and milk. The object of clean milking is to keep the two apart. To keep cows clean they require to be groomed. The farmer, confronted with his manure-caked herd of cows, almost invariably rejects such a proposal as impossible, and, if not impossible, certainly as wholly impracticable. He has said the same in the past of many other things, and this will, it is to be hoped, follow the

---

excessive amount of moisture, but such larvae were present when horse-manure was mixed with it. He also notes that the admixture of straw with cow-manure would produce similar results.

same road. It is merely a matter of habit—the horse is groomed, the cow is not. It is not necessary to remove every particle of manure from the hind-quarters, but they must be reasonably clean. There are two reasons why, at the present time, keeping the cows clean is somewhat onerous. One is that the sheds are kept and left in such a dirty condition, and are so badly constructed, especially as to a suitable floor, that the cows readily become dirty. The other reason is the generally filthy approaches to the cowshed. If cows have to wade daily through manure and other filth they will naturally be difficult to keep clean. With clean sheds and clean approaches grooming the cows is not a lengthy process. The brushing and cleaning must be completed at least half an hour before milking commences.

Orr[1] states: "It has been found by experiment that one man in winter can keep twenty cows in a clean condition by devoting a single hour a day to the work; of course, this is only after they have been thoroughly freed from the manure on their haunches, the removal of which may take some days at first." Two minutes per day per cow has been given as a sufficient time, but probably a little longer than this would be required. In some places the cows' hind-quarters are washed down instead of being brushed, and there seems no objection, as veterinary authorities do not find it causes chills.

Even more important than grooming is the regular cleansing of the udders and teats before each milking. Recommendations as to the exact procedure differ slightly, some writers recommending washing, others wiping with a damp cloth. A leaflet[2] of the Board of Agriculture and Fisheries states: "Shortly before milking begins, some one with a clean, rough, dry cloth should be sent to wipe each cow's udder. If any cow's udder is found to be soiled in such a manner that it cannot be cleansed in this way it should be washed. The practice of washing the udder was attended with no ill effects in the Yorkshire experiments. After washing, the udder must be carefully dried, otherwise the cow might get cold in one or more quarters of the udder."

It would certainly seem preferable that the udders and

[1] *Report on Milk Contamination*, 1908.

[2] Leaflet No. 151, 1908.

teats should actually be washed. They should be carefully dried with a clean cloth. Many cowkeepers have declared to the writer that such washing causes chapped and sore teats and is detrimental to the cows, but as none of them had ever practised such cleansing, their opinion was of doubtful value. The writer is not aware of any authoritative veterinary opinion in favour of such a supposition. He has had goats' teats and udders repeatedly washed, and at all times of the year, without any such conditions arising. It is, of course, important that the water and cloths used for cleaning the udders should be clean. The one cloth should not be used for all the cows, and several changes of fresh water are required, while it is very important that it should be used for the udders and teats only and not for other parts of the cow. It may be remarked that any one examining the water from the washing of the udders of even a few cows cannot but be satisfied as to the need for cleansing the udder.

It may be objected that the operation of washing takes up too much time. In regard to this Orr remarks: "Practical experience shows otherwise, as two men can wash 10 cows thoroughly in half an hour, and, when pushed for time, one man can do it in the same time, perhaps not so thoroughly, but without apparently influencing the bacterial content of the milk to any extent. The cost of one man for an hour, or two men for half an hour, does not add much to the cost of gallon of milk. If the cost of a man for an hour be taken as 4d. (a fair figure), and the quantity of milk produced by 10 cows is 15 gallons, it will be found the additional cost per gallon of milk is about a farthing."

Clean Milkers.—Each milker should thoroughly wash his or her hands and arms before commencing to milk, and if many cows have to be milked should wash more than once during the milking. Disinfectants and disinfectant soaps are quite unnecessary, but a nail-brush should be provided. It is important, in order to encourage and if possible ensure their use, that the water, basins, and towels should be handy for the milkers. In so many places where the writer has been assured that the milkers always wash their hands before milking, on looking for the means of ablution he has been informed that they wash in the house, frequently a considerable distance away. Such absence of facilities is not conducive to regular washing, particularly at 6 A.M.

The milker should wear a clean linen smock when milking, and to be worn only then. Such a smock or overall not only prevents contamination of the milk from dirty clothes, but if it is to be kept reasonably clean it will mean the milker must take some trouble to keep the cows, stool, and other things with which he comes in contact clean. It is important that the milking-stool should be kept clean, as, if dirty, the milker's hands will soon be dirty. A metal stool is preferable to a wooden one.

Clean Vessels.—All milk vessels should be so constructed that all parts can be thoroughly cleaned. All joints must be

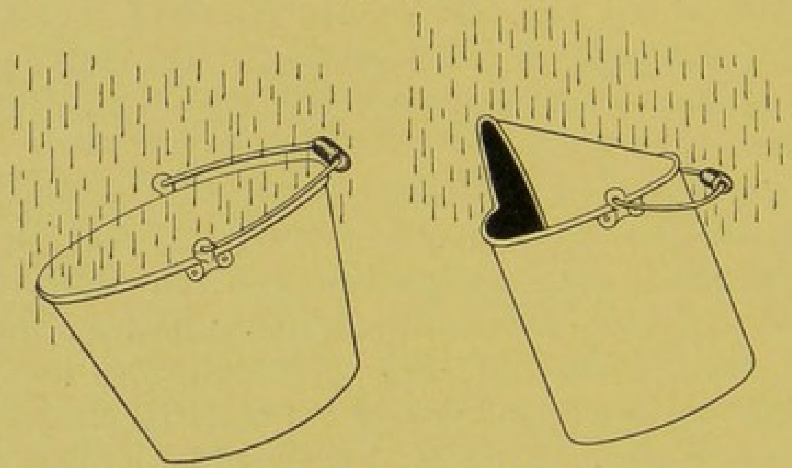


FIG. 23.—Two kinds of Milk Pails.

properly made. As Leaflet No. 151 states: "All should be cleansed immediately after use, and on no account should milk be allowed to dry upon them. The cleansing may be best accomplished by first washing them in cold or slightly warm water, afterwards using hot water and a stiff brush, which is much better than a cloth. The utensils should finally be rinsed in boiling water. If steam is available, and the vessels can be put over a steam jet, so much the better. The hotter the final rinsing or steaming, the greater the likelihood of all forms of germ-life being killed. After cleansing, milk vessels should be left in an airy position, with the mouth or opening turned downwards, but in such a position that the air has unrestricted access. Parts which are not easily accessible should be washed with lime-water occasionally." The ordinary wide-open milk pail is unsatisfactory, and one with a partially covered-in top is preferable, as shown in Fig. 23, to exclude dirt falling in. It must, of course, be readily cleansable.

Milking-Machines.—In view of the contamination of milk which results from the ordinary methods of milking, milking-machines have been welcomed by some writers as a solution of the problem. They have been introduced as a means of milking a number of cows together, or at least more rapidly than by hand, and, apart from their sanitary importance, must

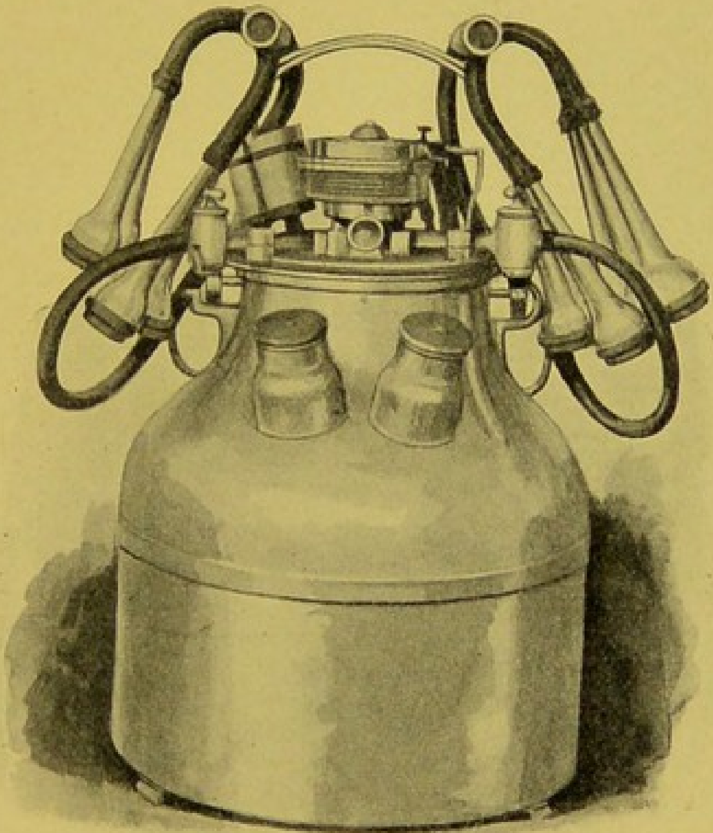


FIG. 24.—The Burrell-Lawrence-Kennedy Cow Milker.

succeed or fail according as they are economically efficient or not. They appear to have been more used in America than in this country. Solely from the point of view as to whether they are likely to give a milk freer from bacteria than one obtained in the ordinary way they cannot be recommended. They are complicated in construction, and have a number of long rubber tubes. They must therefore be extremely difficult to clean and keep clean, and in the hands of any but the most aseptic-minded persons are almost sure to be an added source of bacteria rather than the opposite. Fig. 24 illustrates one type of milking-machine. It is true that milking-machines have been tested by bacteriologists, and reported upon favourably by some although others have reported adversely, but in such hands cleansing would be thorough and very different from the routine cleansing of actual daily use.

The careful report of Woll and Humphrey[1] may be quoted as an example of such an investigation. They tested the

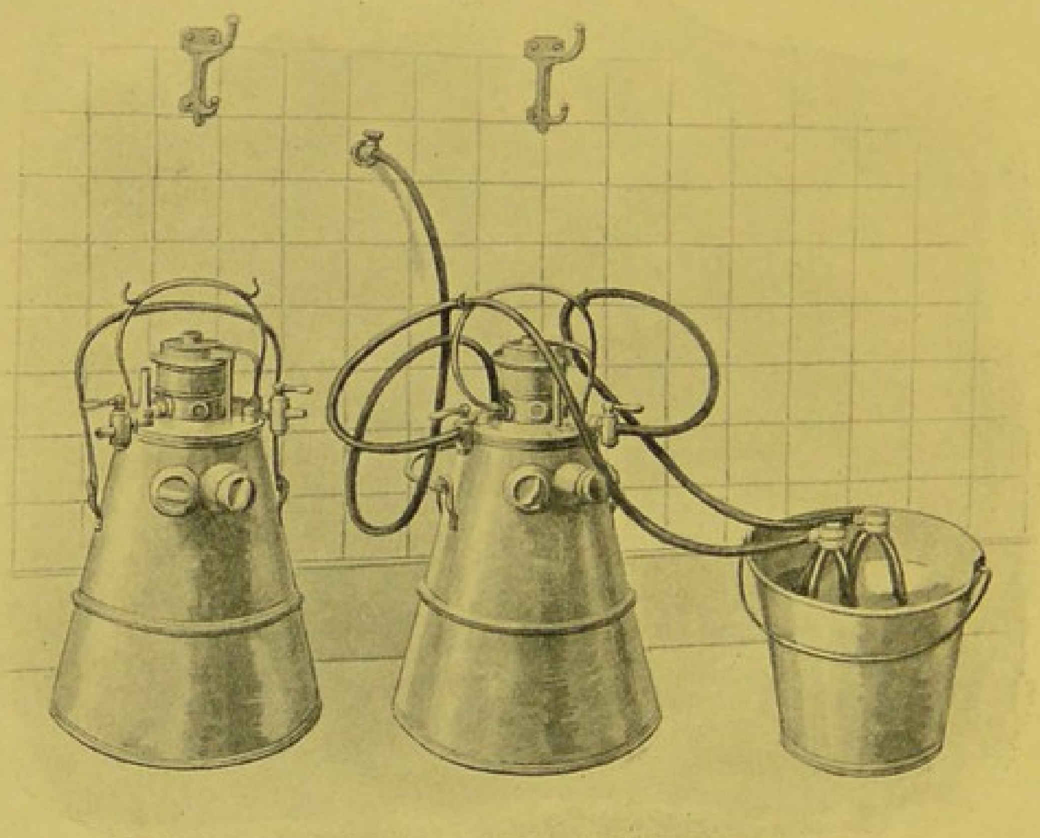


FIG. 25.—Milking Machine. To show method of cleaning the machine and its connections.

Burrell-Lawrence-Kennedy Cow Milker (B. L. K. Milker). Forty separate trials were made, and the 29 cows of the University herd were milked continuously by the machine for an average of 26 weeks. The machine acts by suction, in imitation of the sucking of the calf. The air is partially exhausted by means of a vacuum pump from a tightly covered milk pail, which is connected by rubber tubing with a system of piping extending in front of the cows' stalls. The milk pail is connected with the cow's udder by means of a rubber

[1] *Wisconsin University Agricultural Experiment Station*, 1909, *Research Bulletin No. 3.*

tube and the so-called teat-cups and mouth-pieces which fit over each teat. Through the pull of the partial vacuum in the milk pail the milk is drawn into it. By a mechanical device the suction is intermittent. Several cows can be milked at one time. The investigators found no ill effects upon the cows, while they report favourably on the economy of the machine. Bacteriologically they found that the milking-machine produced milk with a slightly lower bacterial content than that drawn by hand. They conclude that "the success of machine milking will depend largely upon the man operating the machine, and on his attitude towards machine milking." More eloquent, however, than any bacteriological tests conducted under the best possible conditions is the picture given of the machine and the method of cleansing (Fig. 25). Obviously, this is not a machine to entrust into any hands but those of persons trained in a bacteriological laboratory.

3. *Freedom of the Cow and of those who handle Milk from Disease.*—From the particulars given in earlier chapters it is evident that if a milker or other person handling milk is suffering from an infectious disease he may be the cause of a widespread outbreak of disease amongst the consumers of the milk. It is very necessary that all persons handling milk should be free from disease or the suspicion of disease. They should abstain from handling milk until proved free from disease to the satisfaction of the Medical Officer of Health. The expense of any such procedure and stoppage from work should not fall upon the farmer, unless proved to be due to his neglect, but upon the community who profits by the precautions adopted. All persons who have had typhoid fever should be excluded from handling milk unless repeated examinations of their stools show no evidence of typhoid bacilli.

The importance of the cow as a vehicle for the transmission of disease harmful to man to milk has been considered in Chapters VI. and VII. It need only be mentioned here, therefore, that the cows must be healthy and free from disease.

4. *Care of the Milk at the Farm.*—The churns which receive the milk from the milking-pails should not stand, as is customary, in the cowhouse itself, but should be in a separate clean dairy, or if not possible, then in the open air outside.

As a rule the milk is despatched to its destination almost immediately after milking, but if it has to be stored it must be kept in a cool, clean, and well-ventilated dairy.

The straining of the milk, so universally practised by the cow-keeper, should not be necessary, and is ineffective to remove the bacteria. The writer is of opinion that milk is better unstrained, and that as far as possible the use of milk strainers should be discouraged on the following grounds:

(1) They are useless to improve the bacterial quality of the milk.

(2) Unless great care is taken to keep them scrupulously clean they may actually increase the number of bacteria in milk.

(3) They encourage the farmer to think that cleanliness precautions can be neglected or at least relegated to a secondary place, since all additions are removed by the strainer. This view has again and again been presented to the writer by the farmer as an excuse for want of cleanliness in milking.

(4) It is quite possible that if one batch of milk is specifically contaminated (*e.g.* with typhoid bacilli) the strainer may serve to inoculate other batches which otherwise would have remained uncontaminated.

The less milk is brought into contact with strainers and other apparatus the fewer the sources of pollution. The use of a milk strainer should be looked upon as a sign that cleanliness precautions are not properly practised during milking. In view of the prevailing unsatisfactory conditions, there is little likelihood that their use will be discontinued, since without them the neglect of cleanliness is often apparent even to the unsophisticated consumer.

The strainer figured is an illustration of one of the best strainers, although experiments[1] with it showed on the whole no bacterial diminution in milk when filtered through it.

This strainer consists of a conical funnel ending in a short cylinder, just above which is a ledge supporting two gauze metal discs. Between these metal discs, which also act as

[1] Savage, *Report of the Medical Officer, Local Government Board*, 1909-10, p. 474 *et seq.*

strainers, is placed the filtering medium, consisting of a specially prepared cotton-wool. A cup-shaped lid with apertures fits on top of this, the whole being kept in position by means of a curved cross-piece which acts as a spring. A fresh piece of the prepared cotton-wool must be used for each batch of milk filtered.

Cooling.—In every case it is desirable, and in all cases in which the milk has to go by train, or be otherwise kept

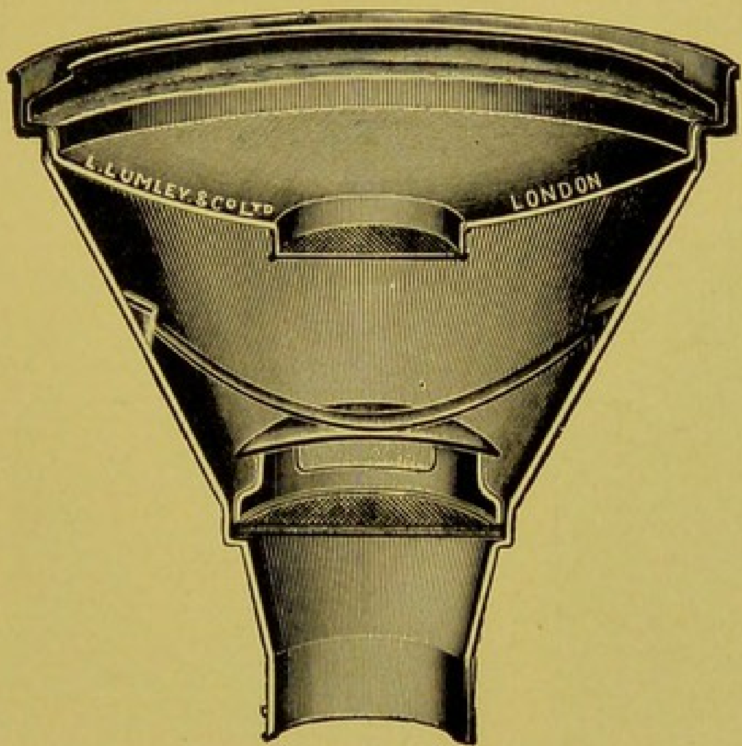


FIG. 26.—"Ulax" Strainer.

before distribution, it should be imperative, that the milk be cooled. Where proper cooling appliances are not installed the milk churn should be stood in cold water changed several times, but this is a very inefficient substitute for a proper cooling apparatus.

To prevent bacterial multiplication in transit the value of thorough initial cooling cannot be exaggerated. Milk in bulk in churns cools very slowly, as the following experiment shows. One gallon of milk was warmed in a steam steriliser to about 33° C., and the contents poured into a cool two-gallon churn. The rate of cooling was as follows :[1]

Time.	Air Temperature.	Milk Temperature.
	° C.	° C.
11 A.M.	16	33
12 noon	16	30
1 P.M.	16·8	27·5
2 "	19	26
3 "	19	24
4 "	19·7	24
5 "	21·0	23

The rate of cooling would be even slower if a larger bulk of milk had been used. Milk (17 gallons) chilled to 4° to 6° C.,

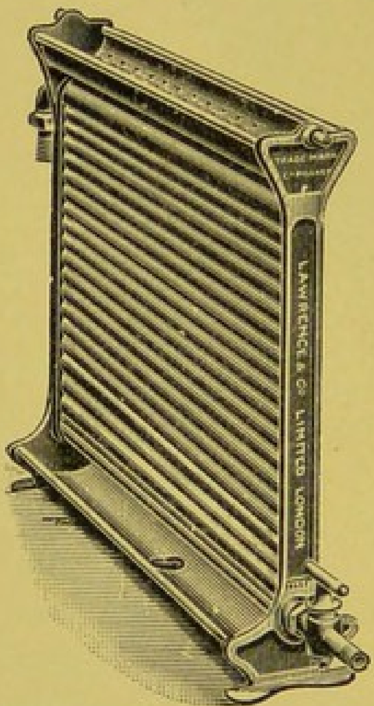


FIG. 27.
Lawrence's Refrigerator.

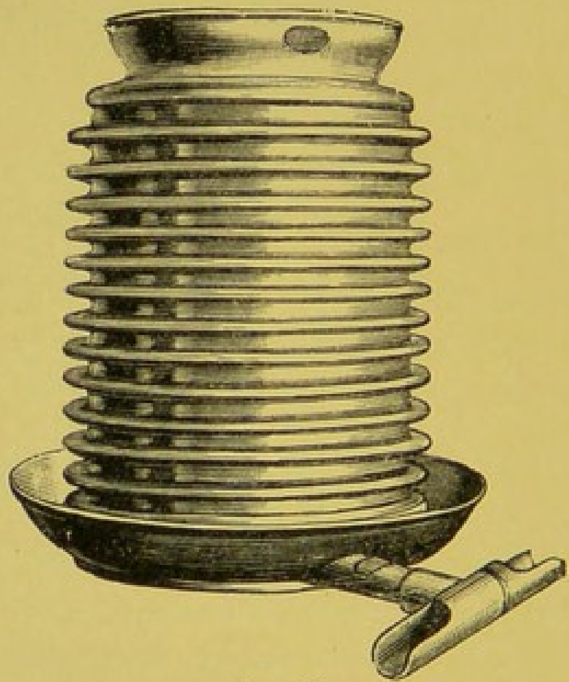


FIG. 28.
Cylindrical Refrigerator.

kept at a room temperature of 19° to 21° C., took over 6 hours to reach a temperature of 13° C.

In another experiment a churn of milk, cooled to 6·4° C., was sent out in a milk cart at 11.40 A.M., covered with an ordinary canvas churn cover to protect it from the direct rays of the sun. It was driven about over parts of London, returning to the depot at 4 P.M., when the mean temperature of the milk was 10·8° C. The initial air temperature was 18·6° C., and the final 21·6° C. (a warm summer day). In

$4\frac{1}{2}$ hours the temperature of the milk only increased by 4·4 degrees, although the air temperature throughout was high.

Good milk-cooling apparatus can now be readily obtained. They are either of the flat or of the cylindrical type. The cylindrical type is not much used except for cream cooling.

The milk passes in a thin stream over a coil of pipes through which a stream of cold water passes from below upwards. In large milk depots the milk coolers are often of double form; the milk passing over the upper part is cooled by water, and then passes over the lower part and is cooled by a saline mixture to a still colder temperature. The milk is damaged if too suddenly chilled to a very low temperature.

The degree of cooling of the milk depends upon—

(*a*) The initial temperature of the milk.

(*b*) The extent of surface exposed to the cold water.

(*c*) The temperature of the cooling water.

(*d*) The slowness of the passage of the milk.

Three points may be mentioned in regard to the use and care of milk coolers:

(1) Since the milk passes over the surface of the cooler, it is important that the cooler be fixed in a clean place and supplied with pure air. (The writer has found a milk cooler in a large milk factory fixed directly above an untrapped drain.)

(2) The water used for cooling should be pure. This is not unimportant, since occasionally leaks occur and the water gains access to the milk.

(3) They must be cleaned thoroughly directly after use, while immediately before use they should be looked to, and if necessary again washed.

It is of importance that water should not be left in the coolers after use. This prolongs their life, while in frosty weather this precaution is essential.

B. The Transit of Milk

In the smaller towns the milk purveyor, who may be the farmer himself, usually has his cart ready waiting to take the milk and distribute it. The milk destined to supply the large towns has usually to be sent by rail. Sometimes it is sent direct by the farmer, otherwise it goes in the first place to a collecting depot. While usually satisfactory, this is not always the case. The chief requirements are light and airy premises, a properly made cement floor sloped to a drain outside and a water supply which is pure and abundant. The floor requires to be very well made and with the best cement concrete, as the heavy churns are very apt to break it up; spilt milk then lodges in the fissures and decomposes.

They should be provided with means for generating steam, and with suitable arrangements for using it, to thoroughly clean the churns and other vessels. A cooling plant is also essential, while, if of any size, they should have a cold storage room attached, large enough to hold a number of churns. The latter is necessary for the milk which arrives late and has to be kept for many hours until the next despatch. Many country depots are also provided with pasteurising plant and cream separators. They are usually situated quite near to railway stations, and must be free from objectionable surroundings.

For the transference of the milk from the farmer to the consumer or large purveyor in the big town, railway transit is essential, and becomes a more and more important part of the milk business as the agricultural land recedes from the towns and the large towns grow larger. To ensure that a clean, fresh milk shall be delivered in a state which has not materially affected its purity or freshness, the transit must be rapid, and the milk must be kept cold. In addition, to ensure its cheapness, the cost of transit must be low. It is also necessary that the transit should be in proper vessels.

Milk Churns.—As pointed out in Chapter XV. the ordinary types of churns in use are very bad. There is no necessity for the churns to be ventilated. The writer has carefully compared the bacterial content, the development of acidity, and the rapidity of souring in milk samples kept under identical conditions, except that one series were in air-tight bottles and the other in vessels with free air access. He found no constant differences.

Doane[1] made determinations of the number of bacteria and the percentage of acid in aerated and unaerated milk.

[1] *Experiment-Station Record*, 1903, vol. xv. No. 3.

At the end of 24 hours there was no noticeable difference in the acid content as shown by eleven trials conducted under ordinary dairy conditions. The aeration also made no appreciable difference to the development of the bacteria.

In America it appears to be the universal procedure to send milk in unventilated churns. Thus Eastwood[1] remarks: "All the American cans I saw were covered with a closely-fitting metal lid, none of the lids were perforated"; and also: "The fact that, in the American trade, milk is hauled in dust-proof receptacles demonstrates the absurdity of the notion that ventilation holes are necessary." In addition to being non-ventilated the churns should be dust-proof and of more hygienic construction.

The points which must be taken into consideration in devising a churn which will satisfy both sanitary considerations and trade requirements are the following:

(1) Trade requirements are in favour of one size only. The general convenience of one standard size outweighs the fact that a churn may sometimes have to travel half full. Proper cleaning brushes in use at the large factories will only fit the one size.

(2) The ordinary 17-gallon churn is convenient to the trade. It holds a lot of milk, while it is rollable and can just be lifted on to a cart. This size of churn is easily cleaned by steam. On sanitary grounds, however, it is too large for thorough cleansing when steam is not available.

(3) The churns are subjected to much rough usage and must be strongly made. It is particularly important that the neck and lid should be very strong, otherwise they get out of shape and the lid will no longer fit properly.

(4) From the sanitary point of view the structure of the lid is all important. The type with everted lid (Fig. 18, type A, p. 260) is often recommended, but as it will not satisfy the exigencies of the trade it is not a good type. The bent-over lid always, sooner or later, gets knocked out of shape, and the top will not fit properly. Churns of this type cannot stand on top of one another. This the trade finds necessary both to economise space in depots and in the carriage of empties.

(5) The churn must be lockable, non-ventilated, water

[1] *Report to the Local Government Board*, 1909, new series, No. 1, p. 76.

must not be able to get in, the milk must not be able to get out.

The churn illustrated (Figs. 29 and 30) is an excellent type, which fulfils all reasonable requirements. The knob in the centre of the lid is a convenience to porters when rolling the milk.

A minor point, but not unimportant, is that the gallon marks inside must not be on a separate brass slip, but the content should be indicated by accurate indentations. If

Fig. 29.—Whole Churn.

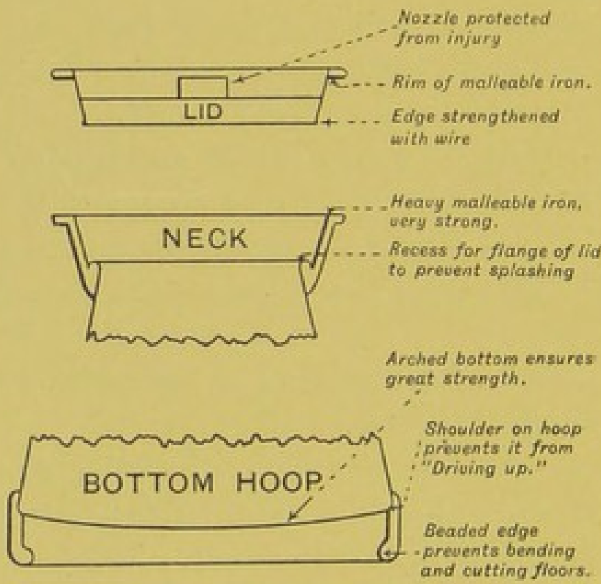


Fig. 30.—Section of Churn.

there is a separate brass slip it works loose, milk gets behind, and the cleaning of the churns is made more difficult.

The fact that the great bulk of the milk sent by train in this country is still sent in unlocked churns is eloquent both of the unprogressiveness and of the sanitary ignorance of most farmers, since it costs no more to send the milk in locked churns. The author of the valuable report upon "The Milk Supply of Large Towns," published in the *British Medical Journal* of 1903, dealt with the question of locked churns and the railway companies. Replies to letters to the principal railway companies of England were in the form of assurances from almost all that they were ready to carry milk in sealed churns at the same rate as in churns with unlocked lids. They required that in the case of "sealed cans" each can must have its tare conspicuously stamped thereon outside. The Board of Agriculture and Fisheries Leaflet, No. 110, "Carriage of Milk by Rail in Locked Cans," makes clear these same facts. Regulations should be enacted prohibiting the transmission of milk other than in locked air-tight churns. All churns should have stamped upon them the name of the cowkeeper. The railway companies reserve to themselves the right of opening locked churns when there is any reasonable doubt as to the accuracy of the consignment. In all such cases it should be obligatory upon the railway company to seal up the can again as soon as possible, and with their own seal, so that the milk-vendor may know that the opening has been by some authorised person.

The need for rapid transit of the milk is generally recognised, and appears to be fairly well met, but there is need for more special transit. For carrying the churns special, well-ventilated trucks are required. They should be limewashed, and kept as cool as possible. Refrigerator vans are, of course, desirable, but it is doubtful how far they are essential, if the other conditions are satisfactorily met. They would add considerably to the cost of transit, and so make the rates higher. To make special cooled vans obligatory would throw additional cost upon the railway companies not only in capital expense, but more particularly for cost of conveyance. If, however, the milk trade were better organised, so that full consignments could be counted upon, this might not be the case.

As Newman[1] points out, viewed from the railway standpoint, the milk traffic is not worth exceptional consideration. From their point of view, to make it worth their while to have special trucks, they must have not only a sufficient number of churns to carry in them, but also a reasonable certainty as to a regular supply of such churns. This is a fact often overlooked, and is one illustration of the fact that the cost of distribution can only be kept down by an organised milk trade.

In connection with railway transit, there is great need for the provision of a proper shed or sheds for the storage of churns on arriving at the urban railway centre. Such sheds should be well ventilated, hygienically satisfactory, kept cool,

[1] *British Medical Journal*, August 27, 1904, p. 420.

and used only for milk. The measuring out of milk on station premises should be prohibited.

C. Purveying of Milk

One of the most difficult matters to adjust in any scheme for a purified milk supply will be regulations in regard to the mixing of milk from different sources. The Medical Officer of Health, faced with a milk-spread outbreak of infectious disease, at once seeks to find the source of the evil and stop further damage. If his sphere of activity is a large city his search is often impeded, sometimes stopped, at the outset. The dairyman purveying the milk cannot tell him the source, since all or much of the milk is mixed. From the public health point of view it is most important to be able to promptly trace back the milk to the cows which yielded it, and the possibly infectious persons who handled it.

On the other hand, the large purveyor says it is impossible to keep all milk consignments separate. The milk as received is removed from the original churn, usually strained, often cooled, sometimes pasteurised, all this being done in bulk with other consignments. He points out that book-keeping would be impossible if every contributor's churns had to be separately entered and the milk kept apart. He goes further, and says that the mixing is essential in order to obtain a uniform chemical standard. It has also been suggested to the writer by a large purveyor that the dilution of any pathogenic properties in one churn by the bulk of harmless milk is a great safeguard to the spread of infection. It may be so, but in view of the rapid multiplication of bacteria in milk is hardly likely. On the other hand, it might, by causing the cases to be distributed over a very wide area, render it more possible to overlook the milk origin of the outbreak. It is certain that a great deal more could be insisted upon, than is now done, in the way of keeping accurate records of the source of all milk, without inflicting any undue hardship upon the milk purveyor.

Improvement of the conditions under which milk is purveyed will necessitate a concentration of the milk trade, and the small purveyor will tend to disappear. The small general shops selling small quantities of milk as a quite subsidiary part of their trading are most unsatisfactory, and, as far as the sale of milk is concerned, they should be eliminated by making the requirements as to the sale of milk on unsuitable premises very stringent. Short of their suppression, the sale of milk should only be permitted upon premises which are clean and in a sanitary condition. It should only be sold from vessels provided with proper muslin or metal covers, and the ordinary dipper should be abolished. Article 13 of the Dairies, Cowsheds, and Milkshops Order, 1885, allows such a regulation as the following to be made under it: "Every retail purveyor of milk shall cause every vessel containing milk to be protected from dust, flies, and other sources of contamination by means of suitable covers."

An important problem for consideration is whether milk should be sold in bottles or cans.

Cans have the following advantages: They are easy to handle; after the initial capital outlay there is no continuous expense to replace broken cans, as they last fairly well; they are easy to clean. They have the following disadvantages: The lids become badly fitting after rough usage and allow dust and dirt to get in; they afford much greater opportunity for home pollution; contamination from dust may occur when the milk is poured into them; they often contain short measure.

The delivery of milk in bottles has two great advantages. If properly filled in a clean place, and properly sealed, they prevent contamination during delivery, while they diminish contamination after delivery. Their disadvantages are, unfortunately, many. The breakage of bottles is considerable, and makes the expense of using them considerable. Being heavy, a smaller quantity of milk can be carried round by one man. Many bottles are lost, the lower class of consumer breaking and retaining them, while they are often returned in such a condition that efficient cleaning is especially difficult. The bottles are difficult to clean, and to clean properly require costly cleaning machinery. Fig. 31 illustrates a good type of steam turbine brush machine for

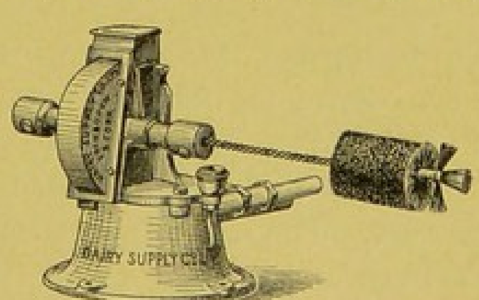


FIG. 31.—Steam Turbine Brush Machine.

cleaning bottles. If not dated, the milk may not be fresh; even if dated, there is no guarantee that the date is correct.

Bottles have usually been advocated on hygienic grounds as preferable to cans for delivery of milk. While they are undoubtedly better for special purposes, such as for milk delivered from a milk depot or for certified milk, it is doubtful whether there is any decided advantage derived from their use for ordinary milk-delivery work. The increased expense is very considerable, and under the conditions which are likely to prevail the benefits are qualified by many drawbacks.

The milk bottles in use are chiefly of two patterns, the

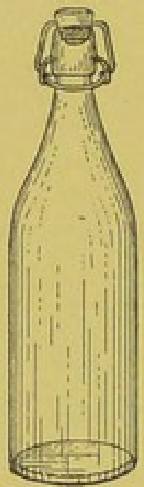


Fig. 32.
Type of bottle commonly used for sterilised milk.

Fig. 33.
Milk bottle for ordinary milk.

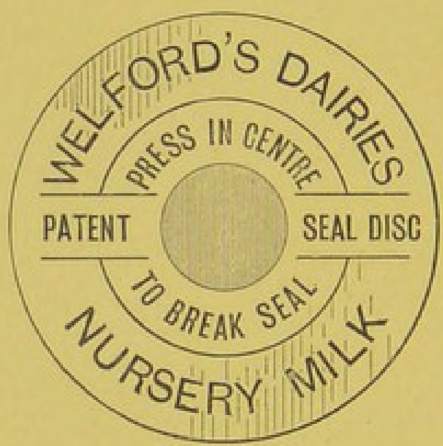


Fig. 34.—Cap.

one being used for "sterilised milk" (Fig. 32), the other for milk bottled for delivery. The bottles for delivery have a wide mouth and no projections (Fig. 33).

One of the chief difficulties is to have a satisfactory stopper or cap. The cap illustrated (Fig. 34), as used by Messrs. Welford and Sons, is a very satisfactory cap. If, after bottling under suitable conditions, the caps are put in at the depot, and the man who delivers the milk has not access to them, it is not possible for milk to be filled on the round into bottles or to be tampered with. The cap must be destroyed to get at the milk.

Bottles of paper or other material, which will allow the bottles to be thrown away after being once used, have been suggested. Their use does not appear to have made any headway, and it is evidently difficult to make a bottle both satisfactory as a milk-container and cheap enough to be thrown away after use.

D. Care of Milk by the Consumer

The consumer urgently requires education. There is often a lamentable lack of care for the storage of milk in the home. This is in part due to the absence of facilities for milk and food storage, as pointed out in Chapter XV., but in addition amongst the poorer classes there is only too frequently very imperfect and hazy notions in regard to the ease with which milk can become polluted.

The provision of proper food storage in a new house should be as rigidly insisted upon as, say, a damp-course. The larder may be quite small, but it must have a window which opens to the outer air, must be protected from flies, and must not be part of a kitchen or other living room.

Provision of storage room and instruction of householders as to the necessity of care in storage, the use of perfectly clean vessels, the necessity of covering milk and keeping it cool, are all essential to prevent contamination of milk after delivery.

CHAPTER XVII

LEGAL POWERS IN ENGLAND APPLICABLE TO MILK

THE legal enactments in force in this country dealing with milk are fairly numerous, although unfortunately many of them are permissive and not compulsory. They are set out in detail or summarised, according to their importance, in the present chapter.

The most important power is that of the Local Government Board to make general or special Orders relating to milk. This power is contained in the Contagious Diseases (Animals) Acts. Section 34 of the Contagious Diseases (Animals) Act, 1878 (41 & 42 Vict. c. 74), is as follows, substituting the Local Government Board for the Privy Council, the Authority in the original section:

The Local Government Board may from time to time make such general or special Orders as they think fit, subject and according to the provisions of this Act, for the following purposes, or any of them:

(i.) For the registration with the local authority of all persons carrying on the trade of cowkeepers, dairymen, or purveyors of milk.

(ii.) For the inspection of cattle in dairies, and for prescribing and regulating the lighting, ventilation, cleansing, drainage, and water supply of dairies and cowsheds in the occupation of persons following the trade of cowkeepers or dairymen.

(iii.) For securing the cleanliness of milk-stores, milk-shops, and of milk-vessels used for containing milk for sale by such persons.

(iv.) For prescribing precautions to be taken for protecting milk against infection or contamination.

(v.) For authorising a local authority to make regulations for the purposes aforesaid, or any of them, subject to such conditions (if any) as the Local Government Board prescribe.

Under the above section, which is not repealed by 57 & 58 Vict. c. 57, the Privy Council issued the Dairies, Cowsheds, and Milkshops Order of 1885.

Leaving out a few legal points irrelevant at the present day, the terms of the Order of 1885, now in force, are as follows:

THE DAIRIES, COWSHEDS, AND MILKSHOPS ORDER OF 1885

Short Title.

1. This Order may be cited as the Dairies, Cowsheds, and Milkshops Order of 1885.

Extent.

2. This Order extends to England and Wales and Scotland only.

Commencement.

3. This Order shall commence and take effect from and immediately after the thirtieth day of June one thousand eight hundred and eighty-five.

Interpretation.

4. In this Order—

The Act of 1878 means the Contagious Diseases (Animals) Act, 1878.

Other terms have the same meaning as in the Act of 1878.

Revocation of former Order.

5. The Dairies, Cowsheds, and Milkshops Order of July 1879 is hereby revoked.

Registration of Dairymen and others.

6.—(1) It shall not be lawful for any person to carry on in the District of any Local Authority the trade of cowkeeper, dairyman, or purveyor of milk unless he is registered as such therein in accordance with this Article.

(2) Every Local Authority shall keep a Register of persons from time to time carrying on in their District the trade of cowkeepers, dairymen, or purveyors of milk, and shall from time to time revise and correct the Register.

(3) The Local Authority shall register every such person, but the fact of such registration shall not be deemed to authorise such

person to occupy as a dairy or cowshed any particular building or in any way preclude any proceedings being taken against such person for non-compliance with or infringement of any of the provisions of this Order or any regulation made thereunder.

(4) The Local Authority shall from time to time give public notice by advertisement in a newspaper circulating in their District, and, if they think fit, by placards, hand-bills, or otherwise, of registration being required, and of the mode of registration.

(5) A person who carries on the trade of cowkeeper or dairyman for the purpose only of making and selling butter or cheese or both, and who does not carry on the trade of purveyor of milk, shall not, for the purposes of registration, be deemed to be a person carrying on the trade of cowkeeper or dairyman, and need not be registered.

(6) A person who sells milk of his own cows in small quantities to his workmen or neighbours, for their accommodation, shall not, for the purposes of registration, be deemed, by reason only of such selling, to be a person carrying on the trade of cowkeeper, dairyman, or purveyor of milk, and need not, by reason thereof, be registered.

Construction and Water Supply of New Dairies and Cowsheds.

7.—(1) It shall not be lawful for any person following the trade of cowkeeper or dairyman to begin to occupy as a dairy or cowshed any building not so occupied at the commencement of this Order, unless and until he first makes provision, to the reasonable satisfaction of the Local Authority, for the lighting and the ventilation, including air-space, and the cleansing, drainage, and water supply of the same, while occupied as a dairy or cowshed.

(2) It shall not be lawful for any such person to begin so to occupy any such building without first giving one month's notice in writing to the Local Authority of his intention so to do.

Sanitary State of all Dairies and Cowsheds.

8. It shall not be lawful for any person following the trade of cowkeeper or dairyman to occupy as a dairy or cowshed any building, whether so occupied at the commencement of this Order or not, if and as long as the lighting, and the ventilation including air-space, and the cleansing, drainage, and water supply thereof, are not such as are necessary or proper—

(*a*) For the health and good condition of the cattle therein; and

(*b*) For the cleanliness of milk-vessels used therein for containing milk for sale; and

(*c*) For the protection of the milk therein against infection or contamination.

Contamination of Milk.

9. It shall not be lawful for any person following the trade of cowkeeper or dairyman or purveyor of milk, or being the occupier of a milk-store or milk-shop—

(*a*) To allow any person suffering from a dangerous infectious disorder, or having recently been in contact with a person so suffering, to milk cows or to handle vessels used for containing milk for sale or in any way to take part or assist in the conduct of the trade or business of the cow-keeper or dairyman, purveyor of milk, or occupier of a milk-store or milk-shop, so far as regards the production, distribution, or storage of milk; or

(*b*) If himself so suffering or having recently been in contact as aforesaid, to milk cows, or handle vessels used for containing milk for sale, or in any way to take part in the conduct of his trade or business, as far as regards the production, distribution, or storage of milk—

until in each case all danger therefrom of the communication of infection to the milk or of its contamination has ceased.

10. It shall not be lawful for any person following the trade of cowkeeper or dairyman or purveyor of milk, or being the occupier of a milk-store or milk-shop, after the receipt of notice of not less than one month from the Local Authority calling attention to the provisions of this Article, to permit any water-closet, earth-closet, privy, cesspool, or urinal to be within, communicate directly with, or ventilate into any dairy or any room used as a milk-store or milk-shop.

11. It shall not be lawful for any person following the trade of cowkeeper or dairyman or purveyor of milk, or being the occupier of a milk-store or milk-shop, to use a milk-store or milk-shop in his occupation, or permit the same to be used, as a sleeping apartment, or for any purpose incompatible with the proper preservation of the cleanliness of the milk-store or milk-shop, and of the milk-vessels and milk therein, or in any manner likely to cause contamination of the milk therein.

12. It shall not be lawful for any person following the trade of cowkeeper or dairyman or purveyor of milk to keep any swine in any cowshed or other building used by him for keeping cows, or in any milk-store or other place used by him for keeping milk for sale.

Regulations of Local Authority.

13. A Local Authority may from time to time make regulations for the following purposes, or any of them:

(*a*) For the inspection of cattle in dairies.

(*b*) For prescribing and regulating the lighting, ventilation, cleansing, drainage, and water supply of dairies and cow-sheds in the occupation of persons following the trade of cowkeepers or dairymen.

(*c*) For securing the cleanliness of milk-stores, milk-shops, and of milk-vessels used for containing milk for sale by such persons.

(*d*) For prescribing precautions to be taken by purveyors of milk and persons selling milk by retail against infection or contamination.

Provisions as to Regulations of Local Authority.

14. The following provisions shall apply to Regulations made by a Local Authority under this Order:

(1) Every Regulation shall be published by advertisement in a newspaper circulating in the District of the Local Authority.

(2) The Local Authority shall send to the Privy Council a copy of every Regulation made by them not less than one month before the date named in such Regulation for the same to come into force.

(3) If at any time the Privy Council are satisfied on inquiry, with respect to any Regulation, that the same is of too restrictive a character, or otherwise objectionable, and direct the revocation thereof, the same shall not come into operation, or shall thereupon cease to operate, as the case may be.

Existence of Disease among Cattle.

15. If at any time disease exists among the cattle in a dairy or cowshed, or other building or place, the milk of a diseased cow therein—

(*a*) Shall not be mixed with other milk; and

(*b*) Shall not be sold or used for human food; and

(*c*) Shall not be sold or used for food of swine or other animals, unless and until it has been boiled.

Acts of Local Authorities.

16.—(1) All Orders and Regulations made by a Local Authority under the Dairies, Cowsheds, and Milkshops Order of July 1879, or any Order revoked thereby, and in force at the making of this Order shall, as far as the same are not varied by or inconsistent with this Order, remain in force until altered or revoked by the Local Authority.

(2) Forms of Registers and other forms which have been before

the making of this Order prepared for use by a Local Authority under the Dairies, Cowsheds, and Milkshops Order of July 1879, or any Order revoked thereby, may be used, as far as they are suitable, for the purposes of this Order.

Scotland.

17. Nothing in this Order shall be deemed to interfere with the operation of the Cattle Sheds in Burghs (Scotland) Act, 1866.

This Order was amended in 1886 by the substitution of the Local Government Board for the Privy Council, and by the provision of a penalty. The penalty clause is Article 3, which enacts: "If any person is guilty of an offence against the Order of 1885, he shall for every such offence be liable to a penalty of Five Pounds, and in the case of a continuing offence to a further penalty of Forty Shillings for each day after written notice of the offence from the Local Authority. Provided, nevertheless, that the justices or court before whom any complaint may be made, or any proceedings may be taken in respect of any such offence, may, if they think fit, adjudge the payment as a penalty of any sum less than the full amount of the penalty imposed by this Order."

A further Order was issued in 1899, which amended Article 15 of the 1885 Order in an important direction as follows: "Article 15 of the Order shall be altered so that, for the purposes of the provisions of paragraphs (*a*) and (*b*) thereof, the expressions in the said Article which refer to disease shall include, in the case of a cow, such disease of the udder as shall be certified by a veterinary surgeon to be tubercular; and the Order and the Amending Order shall apply and be construed with the modifications necessary to give effect to this Article."

Under Article 13 of the 1885 Order a Local Authority has power to make regulations for certain specific purposes. The Local Government Board have issued Model Regulations, and as these have been widely followed they are given *in extenso*:

MODEL REGULATIONS: DAIRIES, COWSHEDS, AND MILKSHOPS[1]

REGULATIONS made by the[2]
with respect to DAIRIES, COWSHEDS, and MILKSHOPS in the[3]

INTERPRETATION

1. Throughout these regulations the expression "the Council" means the[2]
the expression "the District" means the[3]
the expression "Cowshed" includes any dairy in which milking cows may be kept, and the expression "Cowkeeper" means any person following the trade of a cowkeeper or dairyman who is, or is required to be, registered under the Dairies, Cowsheds, and Milkshops Order of 1885.

FOR THE INSPECTION OF CATTLE IN DAIRIES

2. Every occupier of a dairy wherein any cattle may be kept, and which the Medical Officer of Health, or the Inspector of Nuisances, or any other officer of the Council specially authorised by them in that behalf, may visit for the purpose of inspecting cattle, and every person for the time being having the care or control of any such dairy, or of any cattle therein, shall afford such Medical Officer of Health, Inspector of Nuisances, or officer, all reasonable assistance that may, for the purpose of the inspection, be required by him.

FOR PRESCRIBING AND REGULATING THE LIGHTING, VENTILATION, CLEANSING, DRAINAGE, AND WATER SUPPLY OF COWSHEDS AND DAIRIES IN THE OCCUPATION OF PERSONS FOLLOWING THE TRADE OF COWKEEPERS OR DAIRYMEN.

PART I.

The regulations in this Part shall apply to cowsheds, the cows from which are habitually grazed on grass land during the greater

---

[1] An additional regulation, not included in the model, but one which has been adopted in many places with advantage, is to the effect that "Every purveyor of milk or person selling milk by retail shall cause every vessel containing milk for sale to be kept properly covered, or to be otherwise sufficiently protected from contamination by dust or flies."

[2] "Mayor, aldermen, and burgesses of the borough of , acting by the Council" *or* "Urban (*or* Rural) District Council of ," *as the case may be.*

[3] "Borough" *or* "Urban (*or* Rural) District of ," *as the case may be.*

part of the year, and when not so grazed, are habitually turned out during a portion of each day.

Lighting.

3. Every cowkeeper shall provide that every cowshed in his occupation shall be sufficiently lighted with windows, whether in the sides or roof thereof.

Ventilation.

4. Every cowkeeper shall cause every cowshed in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air to keep the air in the cowshed in a wholesome condition.

Cleansing.

5.—(1) Every cowkeeper shall cause every part of the interior of every cowshed in his occupation to be thoroughly cleansed from time to time as often as may be necessary to secure that such cowshed shall be at all times reasonably clean and sweet.

(2) Such persons shall cause the ceiling or interior of the roof, and the walls of every cowshed in his occupation, to be properly limewashed *twice* at least in every year, that is to say, once during the month of May and once during the month of October, and at such other times as may be necessary.

Provided that this requirement shall not apply to any part of such ceiling, roof, or walls that may be properly painted, or varnished, or constructed of or covered with any material such as to render the limewashing unsuitable or inexpedient, and that may be otherwise properly cleansed.

(3) He shall cause the floor of every such cowshed to be thoroughly swept, and all dung and other offensive matter to be removed from such cowshed as often as may be necessary, and not less than *once* in every day.

Drainage.

6.—(1) Every cowkeeper shall cause the drainage of every cowshed in his occupation to be so arranged that all liquid matter which may fall or be cast upon the floor may be conveyed by a suitable open channel to a drain inlet situate in the open air at a proper distance from any door or window of such cowshed, or to some other suitable place of disposal which is so situate.

(2) He shall not cause or suffer any inlet to any drain of such cowshed to be within such cowshed.

Water Supply.

7.—(1) Every cowkeeper shall keep in, or in connection with, every cowshed in his occupation a supply of water suitable and sufficient for all such purposes as may from time to time be reasonably necessary.

(2) He shall cause any receptacle which may be provided for such water to be emptied and thoroughly cleansed from time to time as often as may be necessary to prevent the pollution of any water that may be stored therein, and where such receptacle is used for the storage only of water he shall cause it to be properly covered and ventilated, and so placed as to be at all times readily accessible.

PART II.

The regulations in Part I., and also the following regulation, shall apply to all cowsheds other than those the cows from which are habitually grazed on grass land during the greater part of the year, and, when not so grazed, are habitually turned out during a portion of each day.

8. A cowkeeper shall not cause or allow any cowshed in his occupation to be occupied by a larger number of cows than will leave not less than *eight hundred feet* of air-space for each cow.

Provided as follows:

(*a*) In calculating the air-space for the purposes of this regulation, no space shall be reckoned which is more than *sixteen feet* above the floor; but if the roof or ceiling is inclined, then the mean height of the same above the floor may be taken as the height thereof for the purposes of this regulation.

(*b*) This regulation shall not apply to any cowshed constructed and used before the date of these regulations coming into effect, until two years after that date.

PART III.

9. In this part, the expression "Dairy" means a dairy in which cattle are not kept.

Lighting.

10. Every cowkeeper shall provide that every dairy in his occupation shall be sufficiently lighted with windows, whether in the sides or roof thereof.

Ventilation.

11. Every cowkeeper shall cause every dairy in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air to keep the air in the dairy in a wholesome condition.

Cleansing.

12.—(1) Every cowkeeper shall cause every part of the interior of every dairy in his occupation to be thoroughly cleansed from time to time as often as may be necessary to secure that such dairy shall be at all times reasonably clean and sweet.

(2) He shall cause the floor of every such dairy to be thoroughly cleansed with water at least *once* in every day.

Drainage.

13.—(1) Every cowkeeper shall cause the drainage of every dairy in his occupation to be so arranged that all liquid matter which may fall or be cast upon the floor may be conveyed by a suitable open channel to the outside of such dairy, and may there be received in a suitable gulley communicating with a proper and sufficient drain.

(2) He shall not cause or suffer any inlet to any drain of such dairy to be within such dairy.

Water Supply.

14.—(1) Every cowkeeper shall cause every dairy in his occupation to be provided with an adequate supply of good and wholesome water for the cleansing of such dairy and of any vessels that may be used therein for containing milk, and for all other reasonable and necessary purposes in connection with the use thereof.

(2) He shall cause every cistern or other receptacle in which any such water may be stored to be properly covered and ventilated, and so placed as to be at all times readily accessible.

(3) He shall cause every such cistern or receptacle to be emptied and thoroughly cleansed from time to time as often as may be necessary to prevent the pollution of any water that may be stored therein.

For securing the Cleanliness of Milk-Stores, Milk-Shops, and of Milk-Vessels used for containing Milk for Sale by Persons following the Trade of Cowkeepers or Dairymen.

Cleanliness of Milk-Stores and Milk-Shops.

15. Every cowkeeper who is the occupier of a milk-store or milk-shop shall cause every part of the interior of such milk-store or milk-shop to be thoroughly cleansed from time to time as often as may be necessary to maintain such milk-store or milk-shop in a thorough state of cleanliness.

Cleanliness of Milk-Vessels.

16.—(1) Every cowkeeper shall from time to time, as often as may be necessary, cause every milk-vessel that may be used by him for containing milk for sale to be thoroughly cleansed with steam or clean boiling water, and shall otherwise take all proper precautions for the maintenance of such milk-vessel in a constant state of cleanliness.

(2) He shall, on every occasion when any such vessel shall have been used to contain milk, or shall have been returned to him after having been out of his possession, cause such vessel to be forthwith so cleansed.

For prescribing Precautions to be taken by Purveyors of Milk and Persons selling Milk by Retail against Infection or Contamination.

17.—(1) Every purveyor of milk or person selling milk by retail shall take all reasonable and proper precautions in, and in connection with, the storage and distribution of the milk, and otherwise, to prevent the exposure of the milk to any infection or contamination.

(2) He shall not deposit or keep any milk intended for sale—

(*a*) In any room or place where it would be liable to become infected or contaminated by impure air, or by any offensive, noxious, or deleterious gas or substance, or by any noxious or injurious emanation, exhalation, or effluvium; or

(*b*) In any room used as a kitchen or as a living room; or

(*c*) In any room or building, or part of a building communicating directly by door, window, or otherwise with any room used as a sleeping room, or in which there may be any person suffering from any infectious or contagious disease, or which may have been used by any person suffering from any such disease and may not have been properly disinfected; or

(*d*) In any room or building, or part of a building in which there may be any direct inlet to any drain.

(3) He shall not keep milk for sale, or cause or suffer any such milk to be placed, in any vessel, receptacle, or utensil which is not thoroughly clean.

(4) He shall cause every vessel, receptacle, or utensil used by him for containing milk for sale to be thoroughly cleansed with steam or clean boiling water after it shall have been used, and to be maintained in a constant state of cleanliness.

(5) He shall not cause or suffer any cow belonging to him or under his care or control to be milked for the purpose of obtaining milk for sale—

(*a*) Unless, at the time of milking, the udder and teats of such cow are thoroughly clean; and (*b*) Unless the hands of the person milking such cow, also, are thoroughly clean and free from all infection and contamination.

PENALTIES

18. Every person who shall offend against any of the foregoing regulations shall be liable for every such offence to a penalty of *five pounds*, and in the case of a continuing offence to a further penalty of *forty shillings* for each day after written notice of the offence from the Council.

Provided, nevertheless, that the justices, or court before whom any complaint may be made or any proceedings may be taken in respect of any such offence may, if they think fit, adjudge the payment as a penalty of any sum less than the full amount of the penalty imposed by this regulation.

COMMENCEMENT OF THE REGULATIONS [1]

19. These regulations shall come into force on and after the day of 19 .

REVOCATION OF REGULATIONS [2]

20. From and after the date on which these regulations shall come into force, all regulations heretofore made under, or having effect in pursuance of the Dairies, Cowsheds, and Milkshops Order of 1885, shall, so far as the same are now in force in the district, be revoked.

Certain sections in the Public Health Act, 1875, apply to milk in common with other foods, and have occasionally been useful in relation to milk. These powers are comprised within the following four sections:

Section 116.—*Unsound Meat, etc.*—Any medical officer of health or inspector of nuisances may at all reasonable times inspect and examine any animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk exposed for sale, or deposited in any place for the purpose of sale, or of preparation for sale, and intended for the food of man, the proof that the same was not exposed or deposited for any such purpose, or was not intended for the food of man, resting with the party charged; and if any such

---

[1] The date to be inserted in this clause should be one which will admit of compliance with the requirements of Article 14 (2) of the Dairies, Cowsheds, and Milkshops Order of 1885.

[2] If this clause is not included in the series submitted to the Local Government Board for approval, it should be stated whether or not there are any regulations in force upon the subject.

animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk appears to such medical officer or inspector to be diseased, or unsound, or unwholesome, or unfit for the food of man, he may seize and carry away the same himself or by an assistant, in order to have the same dealt with by a justice.

Section 117 deals with the condemnation of the same by the justice, on order for destruction; and provides for penalties.

Section 118 provides for penalties for hindering the officer from inspecting the meat, milk, etc.

Section 119 provides for a search warrant being granted by a justice, on complaint made on oath by an officer of the local authority that he has reason to believe that there is kept or concealed any animal, carcase, milk, etc., which is intended for sale for the food of man, and is diseased, unsound, or unwholesome.

The powers and scope of Section 116 are extended by Section 28 of the Public Health Acts Amendment Act, 1890:

Section 28.—(1) Sections 116 to 119 of the Public Health Act, 1875, (relating to unsound meat) shall extend and apply to all articles intended for the food of man, sold or exposed for sale, or deposited in any place for the purpose of sale, or of preparation for sale, within the district of any local authority.

(2) A justice may condemn any such article, and order it to be destroyed or disposed of, as mentioned in Section 117 of the Public Health Act, 1875, if satisfied on complaint being made to him that such article is diseased, unsound, unwholesome, or unfit for the food of man, although the same has not been seized, as mentioned in Section 116 of the said Act.

This section has to be adopted like the rest of the Act.

These sections are of but little use in connection with milk, since milk must be in an excessively bad condition to be visibly unsound, or unwholesome, or unfit for the food of man. A few convictions, however, have been obtained under it, or under the analogous clauses of the Public Health Act, 1891 (London). One such case may be mentioned as an example. At Marylebone Police Court, on February 21, 1909, Alfred Massingham, dairyman, was fined £10 for having in his possession, or deposited on his premises, for the purposes of sale, four quarts of milk which was unwholesome and unfit for food. A sanitary inspector who visited the defendant's premises, saw there a pail containing dirty milk, seized it, and sent samples to a bacteriologist, who reported that the milk contained a large number of pus cells, vegetable tissue cells, faecal matter, thorns, and hair, and a quantity of organisms. The milk was exceedingly filthy and totally unfit for human consumption. The defendant had said he would have strained the milk before selling it, but the bacteriologist said that straining would not remove the bacteria. The effect on infants and invalids of using such milk would be to cause diarrhoea.

The nuisance sections (Sections 91 to 94) of the Public Health Act, 1875, are sometimes of value in dealing with cowsheds. Cowsheds and dairies can sometimes be dealt with as "premises in such a state as to be a nuisance or injurious to health," while two of the other sub-clauses, "any animal so kept as to be a nuisance or injurious to health," "any accumulation or deposit which is a nuisance or injurious to health," may occasionally be successfully invoked. The use of this Act has the important advantage that, by its use (Section 94), the landlord may be made responsible for the main structural alterations.

The Infectious Diseases Prevention Act, 1890, Section 4, gives additional powers in relation to milk. It must be remembered that this Act is an adoptive Act. Section 4 reads as follows:

In case the medical officer of health is in possession of evidence that any person in the district is suffering from infectious disease, attributable to milk supplied within the district from any dairy situate within or without the district, or that the consumption of milk from such dairy is likely to cause infectious disease to any person residing in the district, such medical officer shall, if authorised in that behalf by an order of a justice having jurisdiction in the place where such dairy is situate, have power to inspect such dairy, and if accompanied by a veterinary inspector or some other properly qualified veterinary surgeon to inspect the animals therein, and if on such inspection the medical officer of health shall be of opinion that infectious disease is caused from consumption of the milk supplied therefrom, he shall report thereon to the local authority, and his report shall be accompanied by any report furnished to him by the said veterinary inspector or veterinary surgeon, and the local authority may thereupon give notice to the dairyman to appear before them within such time, not less than twenty-four hours, as may be specified in the notice, to show cause why an order should not be made requiring him not to supply any milk therefrom within the district until such order has been withdrawn by the local authority, and if, in the opinion of the local authority, he fails to show such cause, then the local authority may make such order as aforesaid; and the local authority shall forthwith give notice of the facts to the sanitary authority and county council (if any) of the district or county in which such dairy is situate, and also to the Local Government Board. An order made by a local authority, in pursuance of this section, shall be forthwith withdrawn on the local authority, or the medical officer of health on its behalf, being satisfied that the milk supply has been changed, or that the cause of the infection has been removed. Any person refusing to permit the medical officer of health, on the production of such order as aforesaid, to inspect any dairy, or if so accompanied as aforesaid, to inspect the animals kept there, or after any such order not to supply milk as aforesaid has been given, supplying any milk within the district in contravention of such order, or selling it for consumption therein, shall be deemed guilty of an offence against this Act. Provided always, that proceedings in respect of such offence shall be taken before the justices of the peace having jurisdiction in the place where the said dairy is situate. Provided also, that no dairyman shall be liable to an action for breach of contract, if the breach be due to an order from the local authority under this Act.

"Dairy" shall include any farm, farmhouse, cowshed, milk-store, milk-shop, or other place from which milk is supplied, or in which milk is kept for purposes of sale; "dairyman" shall include any cowkeeper, purveyor of milk, or occupier of a dairy.

Certain sections of another adoptive Act, The Public Health Acts Amendment Act, 1907, also deal with milk. These sections are as follows:

Section 52.—(1) If any person knows that he is suffering from an infectious disease, he shall not engage in any occupation or carry on any trade or business unless he can do so without risk of spreading the infectious disease.

(2) If any person acts in contravention of this section, he shall be liable in respect of each offence to a penalty not exceeding forty shillings.

Section 53.—(1) If the medical officer certifies to the local authority that any person in the district is suffering from infectious disease, which the medical officer has reason to suspect is attributable to milk supplied within the district, the local authority may require the dairyman supplying the milk to furnish to the medical officer within a reasonable time fixed by them a complete list of all the farms, dairies, or places from which his supply of milk is derived, or has been derived during the last six weeks, and if the supply, or any part of it, is obtained through any other dairyman, may make a similar requisition upon that dairyman.

(2) The local authority shall pay to the dairyman for every list furnished by him, under this section, the sum of sixpence, and, if the list contains not less than twenty-five names, a further sum of sixpence for every twenty-five names contained in the list.

(3) Every dairyman shall comply with the requisition of the local authority under this section, and if he fails to do so, shall be liable in respect of each offence to a penalty not exceeding five pounds, and a daily penalty not exceeding forty shillings.

Section 54.—(1) Every dairyman supplying milk within the district of the local authority from premises whether within or beyond the district aforesaid, shall notify to the medical officer all cases of infectious disease among persons engaged in or in connection with his dairy as soon as he becomes aware, or has reason to suspect, that such infectious disease exists.

(2) Any dairyman who shall fail to comply with this section shall, for every such offence, be liable to a penalty not exceeding forty shillings.

These sections will not be operative in the district of any local authority until they have been applied to such district by an Order of the Local Government Board. The expression "infectious disease" means any infectious disease to which the Infectious Disease (Notification) Act, 1889, for the time being applies within the district of the local authority.

The purity of milk, from the chemical point of view, is protected by the various Sale of Food and Drugs Acts.

THE SALE OF FOOD AND DRUGS ACT, 1875

The sections which include milk within their scope are the following:

Section 3. Forbids under a penalty that any person shall mix, colour, stain, or powder any article of food with any ingredient or material so as to render the article injurious to health, with intent that the same may be sold in that state. A penalty also attaches to the sale of such doctored food.

Section 5. Provides that no person shall be liable to conviction under the above section if he can present proof of absence of knowledge of the mixing, colouring, etc.

Section 6. "No person shall sell to the prejudice of the purchaser any article of food or any drug which is not of the nature, substance, and quality of the article demanded by such purchaser under a penalty not exceeding £20." No offence is deemed to be committed under this section under certain contingencies which hardly affect milk.

Section 8. "Provided that no person shall be guilty of any such offence as aforesaid in respect of the sale of an article of food or a drug mixed with any matter or ingredient not injurious to health, and not intended fraudulently to increase its bulk, weight, or measure, or conceal its inferior quality, if at the time of delivering such article or drug he shall supply to the person receiving the same a notice by a label distinctly and legibly written or printed on or with the article or drug to the effect that the same is mixed."

Section 9. "No person shall, with the intent that the same may be sold in its altered state without notice, abstract from an article of food any part of it so as to affect injuriously its quality, substance, or nature, and no person shall sell any article so altered without making disclosure of the alteration, under a penalty in each case not exceeding £20."

THE SALE OF FOOD AND DRUGS ACT AMENDMENT ACT, 1879

Section 3. Provides that any medical officer of health, inspector of nuisances, inspector of weights and measures, any market inspector or police constable, may procure at the place of delivery a sample of milk in course of delivery to submit to analysis.

Section 4. Enacts a penalty of £10 for refusal to allow such milk to be taken.

THE SALE OF FOOD AND DRUGS ACT, 1899

Section 1. Makes it an offence to import into the United Kingdom "condensed, separated, or skimmed milk, except in tins or other receptacles which bear a label whereon the words 'Machine-skimmed Milk' or 'Skimmed Milk,' as the case may require, are printed in large and legible type."

Section 2. Provides for the sampling of any article of food by an officer of the Local Government Board or Board of Agriculture for the purpose of analysis.

Section 3. Makes it the duty of every local authority entrusted with the execution of the laws relating to the sale of food and drugs to put in force these powers so as to provide proper securities for the sale of food and drugs in a pure and genuine condition. The Local Government Board or Board of Agriculture can act in default.

Section 4. Gives the Board of Agriculture power to make regulations for determining what deficiency in any of the normal constituents of genuine milk, cream, butter, or cheese, or what addition of extraneous matter or proportion of water, in any sample of milk (including condensed milk), cream, butter, or cheese shall, for the purposes of the Sale of Food and Drugs Acts, raise a presumption, until the contrary is proved, that the milk, cream, butter, or cheese is not genuine or is injurious to health.

Section 9. Requires that any milk vendor who sells milk or cream from a vehicle or from a can or other receptacle must have his name and address conspicuously inscribed on the vehicle or receptacle.

Section 10. When milk is sampled in course of delivery a portion must be sent to the consignor if his name and address appear on the case or package.

Section 11. "Every tin or other receptacle containing condensed, separated, or skimmed milk must bear a label clearly visible to the purchaser on which the words 'Machine-skimmed Milk,' or 'Skimmed Milk,' as the case may require, are printed in large and legible type." A penalty is imposed for contravention.

Section 17. Extends the penalty for contravention of the Sale of Food and Drugs Acts for second and subsequent offences.

Under Section 4 of this Act the Board of Agriculture made in 1901 certain regulations, known as the Sale of Milk Regulations, 1901. They include the following:

Where a sample of milk (not being milk sold as skimmed, or separated, or condensed milk) contains less than 3 per cent of milk-fat, it shall be presumed, for the purposes of the Sale of Food and Drugs Acts, 1875 to 1899, until the contrary is proved, that the milk is not genuine, by reason of the abstraction therefrom of milk-fat, or the addition thereto of water.

Where a sample of milk (not being milk sold as skimmed, or separated, or condensed milk) contains less than 8·5 per cent of milk solids other than milk-fat, it shall be presumed, for the purposes of the Sale of Food and Drugs Acts, 1875 to 1899, until the contrary is proved, that the milk is not genuine, by reason of the abstraction therefrom of milk solids other than milk-fat, or the addition thereto of water.

Where sample of skimmed or separated milk (not being condensed milk) contains less than 9 per cent of milk-solids it shall be presumed, for the purposes of the Sale of Food and Drugs Acts, 1875 to 1899, until the contrary is proved, that the milk is not genuine by reason of the abstraction therefrom of milk-solids other than milk-fat, or the addition thereto of water.

These sections almost entirely refer to milk as a chemical food, or as a food to which chemicals may be added. It has been suggested that they may be legally interpreted to deal with tubercle bacilli in milk, but they were clearly not framed to include this definition, and it seems scarcely justifiable to extend their original meaning to make them apply.

The following recent Act gives powers for dealing with imported milk :

THE PUBLIC HEALTH (REGULATIONS AS TO FOOD) ACT, 1907

1.—(1) The power of making regulations under the Public Health Act, 1896, and the enactments mentioned in that Act, shall include the power of making regulations authorising measures to be taken for the prevention of danger arising to public health from the importation, preparation, storage, and distribution of articles of food or drink (other than drugs or water) intended for sale for human consumption, and, without prejudice to the generality of the powers so conferred, the regulations may—

(*a*) Provide for the examination and taking of samples of any such articles ;

(*b*) Apply, as respects any matters to be dealt with by the regulations, any provision in any Act of Parliament dealing with the like matters, with the necessary modifications and adaptations ;

(*c*) Provide for the recovery of any charges authorised to be made by the regulations for the purposes of the regulations or any services performed thereunder.

(2) For the purposes of regulations made under this Act, articles commonly used for the food or drink of man shall be deemed to be intended for sale for human consumption unless the contrary is proved.

(3) In the application of this Act to Scotland, Part IV. of the Public Health (Scotland) Act, 1897, shall be substituted for the Public Health Act, 1896.

The legal enactments dealing with milk show the influence of the progressive growth of epidemiological knowledge. The earliest legislation classified milk with bread and meat, apparently recognising no special dangers as appertaining to milk, dealing with it as a food which, like other foods, might be, on inspection, unsound or unwholesome. The Sale of Food and Drugs Act, 1875, passed about the same time, also recognised the necessity of protecting food from chemical sophistication, but here again milk was not specifically differentiated from other foods. The Amending Act of 1879 specifically mentions milk, while in the 1899 Act the peculiar needs of milk as regards standards of chemical composition are clearly outlined and given definite expression in the Milk Regulations of 1901.

The fact that milk is a special food, with peculiar liabilities to contamination, and needing special regulations for its protection and preservation in a state of purity, is legislatively conceded by the issue of the Dairies, Cowsheds, and Milkshops Order of 1885. Article 9 of this Order clearly admits the conception that milk may be a vehicle for spreading infectious diseases, a view which receives further legislative endorsement by the Order of 1899, by Section 4 of the Prevention Act, 1890, and by the sections quoted above from the Public Health Acts Amendment Act, 1907.

It will be seen that, broadly speaking, the laws affecting milk are framed with three objects:

(1) To regulate the quality of milk as a food and its chemical content.

(2) To preserve the purity of milk as a food.

(3) To prevent milk acting as a vehicle for the spread of disease, particularly infectious disease.

The introduction of the Milk and Dairies Bill, 1909, of Mr. John Burns is an admission that the present laws are inadequate to effect these three objects.

The relationship between milk and infectious disease is one of growing *legal* importance. From this point of view the case of Frost *v.* The Aylesbury Dairy Company is one of great significance; the facts are therefore briefly appended.

Frost v. *The Aylesbury Dairy Company.*—This case was ultimately decided by the Court of Appeal. The Aylesbury Dairy Company supplied the plaintiff, Mr. Ralph Frost, with milk during the summer of 1903. According to the plaintiff the milk in question was infected with the germs of typhoid fever, with the result that the plaintiff's wife contracted typhoid fever and died from it. It was ascertained that a son of the woman who kept the utensils clean at the farm from which the milk came had a severe attack of typhoid fever and died. Twenty-three cases of this disease occurred in Ealing, where the milk from this farm was supplied. The scientific evidence was not completely conclusive that the infection was due to the milk, but the legal finding was that it did so, and judgment was based upon that assumption. The jury in the first trial found a verdict for the plaintiff for £106. The Court of Appeal dismissed the application for judgment or a new trial. It was not found that there had been any negligence. The decision turned entirely on the question as to whether or not the Company had warranted the milk as being fit for food. C. E. Allan[1] (barrister-at-law), discussing the case, remarks: "There was no express warranty, but the Court held that there was an implied one. When a person warrants an article to be fit for any particular purpose he thereby renders himself liable for all damages that may be caused if the article turns out to be unfit for that purpose." In this case the Company, by their writings supplied to the plaintiff, gave full particulars dealing with the precautions taken by them and as to their knowledge and skill. The Master of the Rolls said: "The buyer could not escape being permeated with the sense that he was secured against the possibility of danger if he bought the defendants' milk." This was the implied warranty, and showed that the buyer relied on the sellers' skill or judgment. The Master of the Rolls then dealt with the contention "that the buyer could not rely upon the sellers' skill or judgment in a case where no skill or judgment could have found out the defect. That was a contention that a person could not become liable for an undiscoverable latent defect." That was decided by the Court of Appeal in *Randall* v. *Newson*, where it was held that on the sale of an article for a specific purpose there was a warranty by the vendor that it was reasonably fit for the purpose, and that there was no exception as to latent undiscoverable defects.

This case is one of the first, if not the first, in which a person or company has been found liable for damages for communicating a disease to another through food. One result will be that the giving of such implied warranties will be largely avoided in the future.

Since this case there have been others dealing with the liability of milk-sellers in relation to infectious disease. The following is of interest: In the Civil Court of the Liverpool

[1] *Public Health*, 1905, xvii. p. 415.

Assizes, held November 1909, the proprietor of the Woodlands School, near Conway, obtained, under the Sale of Goods Act, 1893, £500 in damages against a dairyman for supplying milk which, it was alleged, had caused an outbreak of typhoid fever in the school. The evidence adduced as to the cause of the school outbreak was conflicting, but the facts in favour of milk causation were very cogent, and after a four days' hearing the jury awarded the above damages. An important practical point raised by the jury was whether, assuming the farmer to have taken all possible precautions, would this fact affect the question of liability, a question which Mr. Justice Bray answered emphatically in the negative.

The question of the prohibition of preservatives in milk is one of great importance. The necessary legal powers are contained in Sections 3 and 6 of the Sale of Food and Drugs Act, 1875, and a very large number of successful prosecutions have been instituted under one or other of these sections. The likelihood of a successful prosecution has been increased by the issue by the Local Government Board of a Circular to Local Authorities, dated July 1906, upon preservatives in milk. The circular states:

In some districts action under the Sale of Food and Drugs Acts has been frequently and successfully taken in order to bring about the disuse of preservatives in milk. Proceedings instituted against vendors of milk containing preservatives have usually been taken under Section 6 of the Sale of Food and Drugs Act, 1875. Conviction has followed, it being held that when the purchaser who asks for milk is supplied with milk plus a preservative he does not receive an article of the nature, substance, and quality demanded, and is prejudiced thereby.

The Board are of opinion that action under the Sale of Food and Drugs Acts in regard to preservatives in milk is desirable, and that this subject deserves attention from all authorities in England and Wales charged with the execution of these Acts.

The Board would suggest that the Council should notify to milk traders, by circular or otherwise, that action will be taken under the Sale of Food and Drugs Acts in instances where preservatives are reported in milk. Subject to this being done, and to exceptional cases . . . . the Board consider that when the presence of any added preservative is reported in a sample of milk taken in accordance with the provisions of the Sale of Food and Drugs Acts, the case should in ordinary circumstances be regarded as one for the institution of proceedings under those Acts.

The circular also deals with cases in which the presence of preservatives is declared with the object of escaping liability under Section 6 of the Act:

Where preservatives are reported in milk thus sold, the question will arise whether, in view of the nature and quantity of the preservatives added, it can be considered that the article has been rendered injurious to health, or that the purchaser has been prejudiced to an extent which would justify the institution of proceedings under Section 3 or Section 6 of Sale of Food and Drugs Act, 1875, notwithstanding the declaration made at the time of purchase.

This question is not without difficulty in view of the general objection to the employment of any preservatives in milk.

As regards formalin and boron preservatives, however, the Board are advised that the presence in milk of formalin to an amount which is ascertained by examination *within three days of collecting the sample* to exceed 1 part in 40,000 (1 part in 100,000 of formic aldehyde) raises a strong presumption that the article has been rendered injurious to health, and that the purchaser has been prejudiced in the above sense; and also that similar presumption is raised when boron preservatives are present in milk to an amount exceeding 57 parts of boric acid per 100,000, or 40 grains of boric acid per gallon.

It appears desirable that the addition of preservatives to skim milk, separated milk, and condensed milk, should be watched and controlled on similar lines.

CHAPTER XVIII

THE PREVENTION OF HUMAN TUBERCULOSIS OF BOVINE ORIGIN

In Chapter VII. facts and conclusions were set out which make it evident that a considerable amount of human tuberculosis is of bovine origin. While man is the main source of human infection, the proportion due to infection from material of bovine origin is sufficiently large to make it very important that proper steps should be taken to prevent this source of human disease. It must be conceded that, while infected meat cannot be altogether excluded as a source of human tuberculosis, in nearly all the cases of human infection from bovine sources the vehicle is milk or milk products.

The problem of the prevention of human tuberculosis of bovine origin involves two quite separate considerations:

I. The control and elimination of bovine tuberculosis.

II. The prevention of human infection from material containing bovine tubercle bacilli.

I. The Control of Bovine Tuberculosis

The control of bovine tuberculosis is urgently required in the interest of agriculture, and quite apart from its relationship to human disease. The loss to the agricultural community from this disease is enormous. Since the danger of human disease from tuberculous cows can never be removed unless bovine tuberculosis is scientifically attacked some consideration of methods of control for this disease is necessary. The eradication of this disease amongst cows and oxen is admittedly an extremely difficult task, owing to the insidious nature of the disease and its extremely wide prevalence. The suggestion that all the cattle in the country should be tested with tuberculin, and all found tuberculous killed and compensation paid, is wholly impracticable since the amount of compensation required would be enormous, while no surety that the disease was extirpated could be arrived at, unless the animals surviving were all re-tested with tuberculin, and all imported animals regularly tested and re-tested. Apart from this the killing of about 25 per cent of all the milch cows in the country would cause a milk famine. All responsible veterinary authorities are united in advocating that measures for dealing with this disease must be on selective and preventive lines, operating somewhat slowly.

Of the methods for the eradication of this disease that of Bang of Denmark has been the most widely practised.

Bang's Method.—The principle of the method is the separation of the healthy from the diseased animals, and the rearing of a healthy non-infected stock. The procedure adopted is very clearly described in the Report[1] of the Birmingham Committee which visited Denmark in 1908 to study this method. The following description is largely taken from this report.

Tuberculin is used as the diagnostic agent, and is recognised as reliable for this purpose if the uncertain reactors are separated from the healthy stock until a subsequent test shows them to be tuberculous or decidedly free, and this second test is not deferred too long. All cows suffering from udder tuberculosis and "wasters" are slaughtered. The herd is then divided into a "free portion" and an "infected portion." Bang recommends the removal of one of these to another farm, or failing this, to another shed as far apart from the original premises as possible. Where neither of these is available, he, as a last resource, advises the separation of the diseased from the healthy by a brick or a wooden partition in the cowshed, unprovided with doorway or other opening, and the restriction of each group to a separate end of the shed. At first separation by partition in this way was deemed sufficient, but the risks of communication from time to time during the year are so great that wherever buildings some distance apart are procurable their use is advised. Similarly in summer, separate fields are prescribed, but on

[1] *Special Report to Birmingham Health Committee*, 1908.

small farms their provision may not be possible. In such cases the diseased are restricted to one end of the field, and the healthy to the other. The only safe way, however, is the complete separation of diseased from healthy, both in the house and at grass. The premises must be systematically and thoroughly disinfected.

The next step is the rearing up of herds free from tuberculosis. Bang has shown that the calves of tuberculous mothers (except in very rare cases) are born free from tuberculosis, and will remain so if protected from infection. The calves are removed at birth from their infected mothers to a place free from infection, and care is taken that no infection subsequently gains access to them. The calves are fed on milk heated to 80° C. (sufficient to kill tubercle bacilli). In practice it is desirable to avoid rearing the calves of cows with very advanced tuberculosis, as it is in these that the few cases of intra-uterine infection are found. To guard against mistakes and accidents the calves, like the other stock, are tested with tuberculin. Subsequently the whole stock is submitted to testing with tuberculin every half-year, any reactors being at once removed. In Denmark the veterinary services and tuberculin are supplied gratuitously, the chief expense being the cost of the separate accommodation required.

Bang[1] lays great stress upon the killing of cows suffering from tuberculosis of the udder. He says that Danish farmers readily co-operate, and that more than 2500 samples of milk from cows suspected to be suffering from udder tuberculosis are sent in yearly to his laboratory to be examined. Tubercle bacilli are found in about 30 per cent of the cases. About 700 such cows are killed every year, and the compensation paid for them generally amounts to 50,000 kr. yearly (about £2600). The Danish law requires that cows suffering from tuberculosis of the udder shall be killed under proper supervision. "The owner shall be entitled to a compensation for the animal amounting to one-third of the market value of the carcase, calculated at the current price." Further compensation is also paid, equal to half its value, for such parts of the animals as are declared unfit for food. See Appendix, p. 431.

[1] *Sixth International Congress on Tuberculosis*, 1908, vol. iv. part ii. p. 850.

Bang's method has certain marked advantages. It is efficient and by its means a tuberculosis-free herd can be reared. The initial expenses are not great, and the current expenses caused by the separation of the herds are so spread as not to be a financial burden. It does not cause any disturbance of the milk trade or of agricultural interests. In other words it is conservative, efficient, and cheap when properly and completely carried out. The essential difficulty and disadvantage of the method is that to properly and completely carry it out requires extra labour and great vigilance, such as many farmers are either unable or unwilling to practise. Any relaxation of precautions may undo the work of years and re-introduce the disease amongst the healthy stock. Such re-infections are very disheartening, and their occurrence being attributed to the method and not to the true cause—the lack of persistent care on the part of the farmer—tends to bring the method into disrepute in the neighbourhood in which the farm is situated. Pearson remarks[1] concerning the use of this method in Pennsylvania, U.S.A.:

> It is important to note that the Bang system has never been widely used outside of Denmark, and its use is diminishing rather than growing in that country. That is not because it is not effective—it is effective—but because it involves extra labour, watchfulness, care, and expense for such a long time that only a few herd owners have the courage and perseverance to carry it out. It is unfortunate that this is so, for this system furnishes a method to gradually eradicate tuberculosis at a minimum of loss. It is conservative to the last degree. Those who have carried it out correctly have had good results. But we have to take the facts as they are, and to recognise that the Bang system in its entirety is not likely to be used extensively in this country.

Bang finds that excellent results have been obtained on the small farms in Denmark although it would seem especially difficult for them. Bang (*loc. cit.*) describes a Danish association which is worthy of imitation in this country. Its members are small farmers and the object of the association is for "promoting the breeding and maintenance of healthy, non-tuberculous stocks of cattle and pigs." Only such farmers

[1] Quoted by Dr. Eastwood, *Report on American Methods of Milk Control*, p. 9.

are allowed to join as have had their stock subjected to the tuberculin test, and, in case of its proving only partially healthy, have suitably isolated the healthy animals from the diseased ones. No increase of the herd by animals of other stock (except calves under one month) is allowed, unless they come from a healthy stock and have been found healthy on being tested with tuberculin. The object of the association is, besides setting a good example, to facilitate the purchase of healthy animals, as members who want to buy or sell may apply for advice to one among them who keeps a list of the farms where healthy animals are for sale. To some of the members is delegated the duty of superintending the heating of milk at the dairies. Members pay a subscription of 2 kr. (about 2s.) yearly.

Writing in 1908 Bang recorded that the association had prospered greatly since its inception in December 1905 and had 125 members possessing stock amounting to 2740 cows and young cattle.

Through the kindness of Dr. Robertson, medical officer of health, Birmingham, I am enabled to give the following particulars of the working of Bang's system among the cows supplying milk to Birmingham. The Birmingham scheme was initiated in 1908. It only applies to cowsheds situate within ten miles of the city, and from which milk is sent to Birmingham. The Corporation of Birmingham supplies free of cost the tuberculin and veterinary assistance necessary for the testing of the cows twice annually. The farmer undertakes to separate the diseased from the healthy cows, and to gradually get rid of the diseased animals. Wasters and cows with tuberculosis of the udder have to be dried off and sold for slaughter. Tuberculosis-free animals are to be marked. The farmer has to carry out the necessary disinfection after the removal of an infected cow from the shed. Quarterly certificates of freedom from tuberculosis are given by the city of Birmingham and a public list is kept of farms upon which all the cows are free from tuberculosis.

The following facts give particulars of the scheme at Birmingham. At the beginning of 1910, in 13 herds numbering 550 cows, Bang's method was being applied, while 4 herds with 151 cows came into the scheme during 1910.

Two of these 17 herds withdrew during the year. Of the 15 herds left on the list at the end of 1910, 12 were free from tuberculosis and 3 were in process of being freed. Of the 12 only 4 were tubercle-free when first tested. In one of the 3 herds not free the procedure had been in operation between two and three years, the percentage of infected cows being reduced from 57·7 to 17·8. In the other 2 herds the procedure had only been started during the year. During 1910 1111 cows were tested, and of these 219 (19·7 per cent) reacted positively to tuberculin. Dr. Robertson remarks: "There is therefore now in Birmingham a recognised supply of tubercle-free milk, the product of tubercle-free cows; and the demand for such milk appears to be spreading, particularly in the better-class districts."

Ostertag's Method.—This procedure, originated by Professor Ostertag of Berlin, is based upon the elimination of all cases of "open tuberculosis" from dairy herds. The cases of open tuberculosis, *i.e.* those in which tubercle bacilli are eliminated externally, are obviously the only ones which are infective, and if these can be separated fresh cases cannot arise amongst the other animals. Tuberculin is useless to differentiate "open" from other tuberculous cases, and the diagnosis is made by continued veterinary inspection and bacteriological examination. The herd is annually examined by a veterinary inspector followed by bacteriological examination of the mixed milk. If tubercle bacilli are found in the milk or suspicious animals detected clinically, specific veterinary and bacteriological examination is again made of these animals. It is an optional system. The animals with open tuberculosis must be at once isolated and slaughtered for sale, while the premises are thoroughly disinfected. The Birmingham Committee also investigated this method and remark:

> It is obvious that much real good can be effected on Ostertag's lines. Its being a voluntary measure is no doubt against it, and while it remains voluntary the extent of its adoption will probably not be great. At the same time it is a distinct step forward, and on the farms where it is in operation it may confidently be expected to somewhat reduce the prevalence of the disease. It will also probably help to educate public opinion up to the point at which a compulsory measure will be possible.

From the facts given in Chapter VII. it is clear that since it is impossible to recognise when a tuberculous cow not excreting tubercle bacilli may become a case of open tuberculosis, this method cannot eradicate bovine tuberculosis. By removing and eliminating the most infectious animals it can mitigate the extent of bovine tuberculosis, but it is not more than a palliative. As regards the diminution of the risk of tubercle bacilli in milk, it is probably more efficacious.

Vaccination against Tuberculosis.—Numerous investigators have shown that the resistance of cattle to infection by the tubercle bacillus may be increased by vaccination with living tubercle bacilli of virulence too low to cause infection. Theoretically the vaccination of young stock offers therefore a method for combating bovine tuberculosis.

In 1902 Von Behring introduced bovo-vaccine for this purpose. This substance is a culture of human tubercle bacilli of diminished virulence. It is sold as a dried and powdered substance. The most reliable results are claimed when the animals are vaccinated quite young (*i.e.* one to three months old), two injections being made three months apart, the first being with a weaker vaccine than the second.

Further investigation by Eber and others has shown that the immunity is unfortunately not lasting, disappearing within one to two years after vaccination. The general results seem to show that the degree of immunity produced is not sufficient to protect against infection for any length of time, and is not worth the trouble and expense involved in obtaining it.

L. Pearson (Philadelphia) has extensively practised the vaccination of cattle. He remarks that the degree of immunity is proportional, in large measure, to the extent of vaccination, *i.e.* to the number of times vaccinated, the dosage, and the period of time recovered. The duration of resistance is from one to three years. The vaccine may be administered subcutaneously or intravenously. Judgment on its practical value must be suspended pending further results.

Heymans, at the Washington Tuberculosis Congress (1908), reported that in Belgium about 40,000 animals had been vaccinated by his method. In this method Heymans introduces a capsule containing tubercle bacilli under the skin.

The bacilli are retained in the sac, but their toxins pass through the dialysable substance of the sac and immunise the animal. The technique is said to be quite simple and the results so far satisfactory.

These vaccination methods are extremely interesting, but it appears that no results are yet available, proving that they are of permanent value in eradicating bovine tuberculosis.

Niven,[1] from a consideration of the whole subject, concludes that "no proposal which has not for its declared aim the extirpation of bovine tuberculosis contains that element of ultimate profit which justifies large present sacrifices." He summarises the proposals he puts forward to control bovine tuberculosis as follows:

1. The country to lend money at a low rate of interest to landowners, on sufficient security, to enable them to carry out necessary works of construction or reconstruction.

2. The country as a whole to provide the veterinary staff required and the tuberculin, as well as to make good losses involved in the first instance in eliminating tuberculosis from herds.

3. The maintenance of non-tuberculous herds to be compulsory, and the cost of any renewal of stock to fall upon the farmer.

4. In return for their contribution to the agricultural interest, consuming communities should have rights of control over the production of milk which they consume.

5. Milk dealers in entering into contracts should be obliged to satisfy themselves that their milk is produced under reasonably healthy conditions.

The control of bovine tuberculosis has been taken up with vigour and enthusiasm in many of the States comprised in the United States of America. For a critical consideration of the different methods practised, the enactments framed, and the results obtained, the very valuable Report to the Local Government Board by Dr. Eastwood should be consulted. Eastwood's main conclusions upon this subject are as follows:

1. It is imperative, in the interests of agriculture, that dairy cows with advanced or generalised tuberculosis, or with tuberculosis of the udder, should be destroyed.

[1] *British Medical Journal*, Sept. 11, 1909, p. 699.

2. In order to discover these dangerous animals, an efficient service of inspectors is required. The public must be prepared to meet all the cost of adequately inspecting the condition of dairy cattle.

3. It is essential in the interest of agriculture that compensation should not be paid out of the public funds for slaughtered cattle showing advanced or generalised tuberculosis, or tuberculosis of the udder.

4. The testing of entire herds with tuberculin should be encouraged, and for this purpose the assistance of public money is requisite and desirable.

5. If tuberculin is to be of value in the suppression of disease it must be employed as a necessary guarantee of health, not merely as an aid to diagnosis in cases where disease is suspected.

6. Public money spent on re-testing, with a view to establishing thoroughly the soundness of herds giving on the first test either no reactions, or only a small percentage of reactions, would be money well spent.

7. Reacting animals possessing a market value might under special circumstances be taken over by the community at a price exceeding their market value, but, with this limited exception, compensation out of the public funds does not appear to be justifiable. The special circumstances contemplated are when there are only a few reacting animals, and it is advantageous to secure a number of foci of healthy animals.

8. Local authorities, by establishing and maintaining clean herds for the supply of public institutions, would provide a valuable means of educating the farmer.

9. The difficulty at present seems to lie not so much in the lack of public support of a financial nature as in the lack of evidence that the agricultural interest is prepared to turn to good advantage such effective public support as might be offered.

II. The Prevention of Human Infection from Material containing Bovine Tubercle Bacilli

The facts detailed in the earlier part of this Chapter show that the eradication of bovine tuberculosis will be at the best a long and tedious business, even if the problem is tackled with enthusiasm and a long purse. It has been shown that at least 10 per cent of samples of market milk contain tubercle bacilli. What steps should be taken now to deal with this bulk of infectious milk and prevent human disease, pending a successful attack upon bovine tuberculosis? The necessity for some definite action has been realised by a number of the large cities, and special powers have been obtained to deal with this matter and prevent tubercle-infected milk from reaching their inhabitants. These important powers require consideration as well as the results achieved by them.

Local Acts and Powers in England for preventing Milk-spread Human Tuberculosis.—In 1899 Manchester obtained by a private Act—The Manchester Corporation (General Powers) Act, 1899—special powers to deal with suspected tuberculous milk consumed within the city. Certain further sections were added in 1904. These Manchester Milk Clauses are printed in full in the Appendix (pp. 418-421). They have been adopted with slight modifications in a number of other towns, of which may be especially mentioned Liverpool, Birmingham, Sheffield, Leeds, and Sunderland. Through the kindness of Dr. Newsholme (Medical Officer, Local Government Board), the writer is enabled to state that up to the end of 1910 the Local Authorities who have obtained the Model Clauses as to tuberculous milk in Local Acts number 102, consisting of the London County Council, 67 boroughs, and 24 urban districts. It would, however, appear that in the majority of these areas these powers are in the main unenforced. London obtained similar powers by an Act of 1907 (London County Council (General Powers) Act, 1907, Part IV.) which became operative July 1, 1908. In 1904 the London County Council had obtained powers to remove cows suffering from udder tuberculosis, to slaughter them, and to pay compensation, but the powers only applied to cows within the London administrative county. In addition to clauses similar to those of Manchester, their extended powers require that the London County Medical Officer shall in all cases where reasonably practicable, without involving delay in the exercise of the powers, give to the Medical Officer of the

County in which the dairy is situate, previous notice in writing of his intention to enter such dairy for the purpose of inspecting the cows kept therein.

These special powers have been in force in Manchester since 1900 and in other cities for considerable periods, so that it is possible to obtain an estimate as to how far they have succeeded in attaining the objects for which they were framed.

These Milk Clauses require notification by dairymen of all cases of udder tuberculosis among cows in cowsheds sending milk into the city, and prohibit the sale of milk from such cows within the city. They give powers for collecting milk samples and additional powers of inspection for cowsheds within the city. Their essential and characteristic feature is, however, the power of inspection which they give of cowsheds and cows supplying milk into the city, although themselves outside, whenever the city authorities suspect milk from such farms to be tuberculous. The inspection can be followed up by prohibiting the infected milk from being supplied within the city as long as it is dangerous.

The effectiveness of these powers may be considered from several points of view.

(*a*) *Their Influence upon the Prevalence of Tubercle Bacilli in the Milk supplied to the City enforcing them.*—The following table shows some of the results obtained.

[TABLE

Tubercle Bacilli in Mixed Milk Samples (percentages).

	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.
[1] Manchester	8·7	8·57	10·42	6·7	6·15	6·2	5·74	8·28	5·14	...
[2] Liverpool—Country samples	6·1	7·3	5·1	9·2	3·8	6·8	4·7	3·3	1·8	4·1
[2] Liverpool—Town samples	0·6	0·4	0·8	1·5	0·4	1·4	1·5	2·0	0	1·4
[3] Sheffield—Country samples	...	17·8	16·7	6·7	14·7	9·6	9·7	9·9	10·9	10·4
[4] Birmingham—Country samples			prior	to 1908	= 14	per cent		11·3	7·5	7·3
[5] Leeds—Country samples	...	...	...	...	...	...	...	25·3	16·4	...
[6] Sunderland	...	...	...	...	...	...	2·5	7·0	7·4	3·6
[7] London (L.C.C.)	...	...	...	...	...	...	...	11·6	10·4	...

[1] Supplied to me by Dr. Niven, Medical Officer of Health.
[2] *Medical Officer of Health Annual Report*, 1910.
[3] *Medical Officer of Health Annual Report*, 1910.
[4] Supplied to me by Dr. Robertson, Medical Officer of Health.
[5] *Medical Officer of Health Annual Reports*, 1908, 1909.
[6] Supplied to me by Dr. Renney, Medical Officer of Health.
[7] *Medical Officer of Health Annual Reports*, 1908, 1909.

The Manchester figures are the most important, as they deal with a very large number of samples, extending over a number of years.

The table shows that there has been some diminution in the percentage of tuberculous samples, but that, apart from the first few years of working, it has been neither continuous nor very marked. During the first few years some of the worst offenders would doubtless be weeded out and warned off from supplying the particular city. The amount of tuberculous milk for Manchester drops to about 6 per cent, and to about 9 per cent for Sheffield, and there it remains. No regular, consistent diminution in the infective quality of the milk is observable. If the Manchester figures are carried back to 1897, and only the samples bringing milk into Manchester (country samples) are considered, the beneficial results of the first few years working are more clearly brought out. Thus Delépine[1] gives the percentage of tubercle-infected mixed-milk samples arriving in Manchester as 13·3 for 1897, 20·0 for 1898, and 11·1 for 1900. Delépine also records that "the lesions observed in inoculated animals have of recent years become generally slight when compared with those produced ten years ago."

(*b*) *Their Influence upon the Prevalence of Udder Tuberculosis.*—The following tables supply some data.

Year.	Manchester.[2]		Sheffield.[3]	
	Percentage of Farmers sending Tuberculous Milk.	Percentage of outside Cows found with Udder Tuberculosis.	Percentage of Country Cows with Udder Tuberculosis.	Percentage of City Cows with Udder Tuberculosis.
1901	9·9	1·4	...	0·47
1902	10·4	2·5	2·7	0·31
1903	13·6	1·1	0·96	0·45
1904	9·1	0·6	0·59	0·45
1905	8·3	0·9	3·9	0·26
1906	7·7	1·05	3·6	0·14
1907	6·76	1·1	1·9	0·8
1908	9·34	0·9	2·4	0·9
1909	5·79	1·03	4·0	1·1
Average	8·6	...	2·3	...

[1] *Report of Medical Officer, Local Government Board*, 1908-9, p. 393.

[2] From information kindly furnished by Dr. Niven.

[3] *Report of Medical Officer of Health* (Dr. Scurfield), *Sheffield*, 1909.

Manchester.

Year.	No. of mixed Milks tested.	No. of Farms represented in the first column.	No. found to cause Tuberculosis.	No. of Cows outside Manchester examined by Veterinary Surgeon.	No. of Cows proved to be suffering from Tuberculosis of Udder.	Disposal of Cows.					No. slaughtered.	Country Cows with Udder Tuberculosis found as result of notification or otherwise.	No. of Cows with Tuberculosis of the Udder found in City Cowsheds.	No. of Cows with Tuberculosis of the Udder from all sources.
						Sold or not traced.	Died.	Slaughtered.						
								Carcase passed.	Portion only passed.	Condemned.				
1901	310	272	27	1013	14	6	...	1	1	6	8	2	3	19
1902	420	345	36	1236	31	15	...	5	...	11	16	1	2	34
1903	432	329	45	2537	28	6	2	6	...	14	20	...	1	29
1904	432	318	29	2615	16	2	...	6	...	8	14	2	1	19
1905	764	565	47	3241	31	8	...	8	3	12	23	2	1	34
1906	677	542	42	2855	30	9	...	8	...	10	21	1	...	31
1907	662	562	38	2547	28	6	1	5	2	14	22	1	1	30
1908	314	289	26	2423	23	1	2	6	3	13	21	2	...	25
1909	623	535	32	3019	31	3	2	...	2	12	18	...	...	31[1]

[1] A number of these cows were found under special circumstances, and their ultimate disposal was not ascertained. Twenty-seven udders found to be tuberculous by bacteriological examination. Four additional udders found by the veterinary surgeon, no further test being necessary.

The actual figures for Manchester are given in the preceding table, which was compiled by Dr. Niven.

These tables show that the percentage of farmers sending tuberculous milk to Manchester varied from 5·79 to 13·6, the average being 8·6. Except for 1908 there has been a steady, though not very marked, decline since 1903. In other words, there has probably been a moderate but steady diminution in the number of farms with cows suffering from open tuberculosis sending milk to Manchester.

As regards udder tuberculosis the table shows no percentage diminution in either Manchester or Sheffield. In Sheffield during 1909 the veterinary inspectors found as many as 42 cows with tuberculosis of the udder out of about 3600 cows stalled in Sheffield city.

Finding these cases of udder tuberculosis cannot be considered as playing any effective part in the diminution of *bovine* tuberculosis. The elimination of a certain number of cases of open tuberculosis in cattle is no doubt some check upon the spread of bovine tuberculosis, but the number of cases eliminated is so small in proportion to the total bulk of infectious matter in the country that the influence exerted must be trifling. During nine years' work at Manchester 232 cows from country areas and 9 from city cowsheds, and during eight years at Sheffield 74 country cows and 134 from city cowsheds, suffering from udder tuberculosis, were found, obviously a nearly negligible factor in the spread of the disease in cattle. In addition any beneficial effects are further reduced by the fact that not all these cows with udder tuberculosis are slaughtered. The following table shows what became of most of the Manchester and Sheffield cows found to be suffering from udder tuberculosis or marked general tuberculosis :

Fate of Cows.	Manchester (1901-1909 inclusive).	Sheffield (1901-1909 inclusive).
Died or slaughtered . .	170	185
Sold or not traced . .	56 (24 per cent)	24 (11·5 per cent)

It is clear that a certain proportion of these cows are not slaughtered, but are lost sight of under the imperfect powers available.

(*c*) *Their Influence upon the Purity of the Milk Supply as a whole.*—Delépine in Manchester has paid careful attention to this indirect but important aspect of the subject. He estimates the amount of dirt in milk by a method which enables comparison between the different years to be instituted. By his scale for the years 1897, 1898, and 1900 over 60 per cent of the milk samples examined gave sediments measuring 9 mm. or more. For 1901 the amount fell so that only 40 per cent of the samples gave sediments 9 mm. or more. The amount remained about the same for the following five years, but in 1906 a further improvement was noted, only about 32 per cent giving sediment of 9 mm. or more. Delépine[1] gives the following table:

Amount of Sediment separated by Centrifugalisation.

(Manchester.—Mixed milk taken at railway stations, or at other places away from the farm.)

Years.	Clean Milk.				Doubtful.		Milk contained marked excess of dirt or abnormal products.				Total.
	Under 7 mm.		7-8 mm.		9-10 mm.		11-12 mm.		13-20 mm.		
	Actual No.	Per cent.	Actual No.	Per cent.	Actual No.	Per cent.	Actual No.	Per cent.	Actual No.	Per cent.	
1896-1900	19	4·2	160	35·2	218	47·9	45	9·9	12	2·6	454
1901-1902	186	21·5	325	37·7	280	32·5	53	6·1	17	1·9	861
1903-1904	164	18·9	295	34·0	326	37·5	57	6·5	15	1·7	867
1905 . .	190	24·8	276	36·1	242	31·6	49	6·4	7	0·9	764
1906 . .	185	26·2	296	42·0	188	26·7	31	4·4	4	0·5	704
											3650

The numbers indicating the amount of sediment show only the relative amount. The absolute amount of sediment is not given in this table.

If the amount of sediment be accepted as a reliable measure of the cleanliness of a milk supply these results show that the operation of the Manchester Milk Clauses has resulted in a considerable improvement in the cleanliness of the milk supplied to the city.

[1] *Report to the Manchester Sanitary Committee*, 1908.

In considering the value of these special powers it must always be remembered that their sole object is the protection of the particular city for which they were obtained. Apart from any educational influence which they may exert, their effect on the amount of bovine tuberculosis in the country as a whole is, for practical purposes, *nil* as long as they are only locally applied. Their *national* as distinct from their *local* value is negligible.

As regards their effectiveness to protect the community obtaining the powers against the dangers of bovine tuberculosis spread by milk, the figures quoted show that, apart from their initial effects, only a moderate measure of success has been attained. The writer, from a careful study of the results obtained, is of opinion that these clauses, confined in their powers as they are by restrictions and limitations, have not effected results commensurate with the cost of working them. Apart from the first few years of operation, when for easily understood reasons their beneficial influence would be at a maximum, they do not seem to have effected a marked reduction in the amount of tuberculous milk imported into the cities carrying them out.

Several considerations, apart from actual results achieved, show that markedly beneficial results of a permanent character are not likely to accrue. Thus a consideration of the powers acquired and the clauses themselves show that they are essentially based upon an assumption which cannot be accepted without large reservations. The assumption is that the presence of tubercle bacilli in milk is due to the herd supplying the milk containing one or more cows affected with clinically recognisable udder tuberculosis, and if these cows are removed the danger ceases. This assumption, in view of the findings of the Royal Commission on Tuberculosis and of other investigators, cannot be accepted as true. In further support of this statement may be instanced the facts quoted on p. 132 as to the considerable number of cases in which tubercle bacilli are found in milk but in which no cases of udder tuberculosis which can be diagnosed are found. Apparently the cowkeeper in such cases may continue to send unchecked his milk into the city.

Again, action along the lines of the Milk Clauses must fail to effectively deal with the whole problem since they attempt to treat a symptom—they do not treat the underlying condition—bovine tuberculosis. Applied to special areas only, as already stated, they exert a practically negligible influence upon the manufacture of bovine tuberculosis (although they may divert its products to unprotected places) but merely deal with the small amount of it which comes under their special cognizance. If the clauses were universally applied they would, no doubt, be made much more effective; but even then the powers given are insufficient.

One of the greatest weaknesses of the clauses is the absence of powers to deal with a cow with udder tuberculosis when found. She is difficult to diagnose and a potent danger to mankind, and yet when the elaborate business of bacteriological examination and veterinary inspection reaches its fruition and a cow with a tuberculous udder is found, all the law mildly enacts is—

(1) The cow owner must not keep or permit such cow to be kept in any field, shed, or other premises along with other cows *in milk*[1] under a penalty.

(2) The milk of such a cow shall not be mixed with other food, and shall not be sold or used for human food, and shall not be sold or used for food of swine, or other animal, unless and until it has been boiled.

In other words, the owner can banish the cow from other cows in milk and stop using her milk, and then he has fulfilled the whole of the law. There is, apparently, nothing to prevent him selling the cow with or without saying anything about the udder condition.

It is well known that the powers granted are less than those originally asked for, and the slaughter of cows suffering from udder tuberculosis was one of the clauses which Parliament failed to endorse.

The clauses say nothing about disinfection of premises. If a cow is found with udder tuberculosis, it is highly probable that it is not the only case of open tuberculosis in the herd, so that disinfection may seem scarcely worth while. As a

[1] The italics are the writer's. Apparently she may be kept with calves, or cows now dry which will soon again be in milk.

means of impressing the farmer with the infectious nature of the condition it would, however, be sometimes very useful.

The Board of Agriculture and Fisheries issued a Tuberculosis Order with an explanatory letter in 1909, to come into force January 1, 1910. This Order was withdrawn owing to the Milk Bill not being placed upon the Statute Book. This Order is not, therefore, and has never been, in force, but it is printed in the Appendix since it indicates the direction of probable future legislation.

To prevent the dangers of tuberculous milk the essential step would appear to be to help and encourage the farmer to eradicate tuberculosis from his herd. The farmer will not, indeed frequently cannot, do this without State aid. Such aid should be in the direction of free tuberculin and free veterinary assistance. The writer is in agreement with Eastwood that such assistance should not take the form of compensation for cattle slaughtered as suffering from udder or advanced tuberculosis. All such animals should certainly be slaughtered. It might be reasonable and probably would be politic, if any general scheme of prevention is inaugurated, to pay compensation for such animals for perhaps the first two or three years; but after that, if any cows with advanced tuberculosis are found in cowsheds the owners should be fined. Any compensation should be paid out of imperial rather than local funds, otherwise the urban districts do not pay their share.

It would be a decided advantage if at least a few farms supplying milk from non-tuberculous cows could be obtained for each large urban area. The consumer should be educated up to the appreciation of the value of such a supply, and be prepared to pay a little more for such milk. This would both encourage the farmer and stimulate others to go and do likewise.

Quite recently a valuable and authoritative report in America has been issued upon the control of bovine tuberculosis. The American Veterinary Medical Association, at its meeting in Chicago in September 1909, appointed what they called the International Commission on the Control of Bovine Tuberculosis. The following is the main report of the Commission[1] which has been officially published by the Canadian and United States Governments.

Based on the information contained in the reports of its committees and on such other information as was brought out in the general discussions of the Commission, the following resolutions were adopted for presentation to the American Veterinary Medical Association :

(1) *Dissemination.*

As a general policy to be observed, all contact between tuberculous and healthy cattle and between healthy cattle and stables, cars, etc., which may contain living tubercle bacilli should be prevented. To accomplish this the following specific recommendations are made :

(1) There should be no sale or exchange of animals affected with tuberculosis except for immediate slaughter or for breeding purposes under official supervision.

(2) That the managements of live stock shows should give preference to cattle known to be free from tuberculosis, either by providing special classes for such cattle or in some other practical way, and should also take every precaution to prevent contact between such animals and those not known to be free from disease.

(3) All live stock shippers should take every precaution to see that cars furnished are thoroughly cleansed and disinfected before use.

(2) *Tuberculin Test.*

(1) That tuberculin, properly used, is an accurate and reliable diagnostic agent for the detection of active tuberculosis.

(2) That tuberculin may not produce a reaction under the following conditions:

(*a*) When the disease is in a period of incubation. (*b*) When the progress of the disease is arrested. (*c*) When the disease is extensively generalised.

The last condition is relatively rare and may usually be detected by physical examination.

(3) On account of the period of incubation and the fact that arrested cases may sooner or later become active, all exposed animals should be retested at intervals of six months to one year.

(4) That the tuberculin test should not be applied to any animal having a temperature higher than normal.

(5) That any animal having given one distinct reaction to tuberculin should thereafter be regarded as tuberculous.

[1] Taken from the full report reprinted in the *Journal of Meat and Milk Hygiene*, 1911, vol. i. p. 248.

(6) That the subcutaneous injection of tuberculin is the only method of using tuberculin for the detection of tuberculosis in cattle which can be recommended at the present time.

(7) That tuberculin has no injurious effect on healthy cattle.

(3) *Evidence from Tuberculin Test.*

That a positive reaction to tuberculin in any properly conducted test, official or otherwise, in any animal in any herd, shall be considered evidence sufficient upon which to declare the herd to be infected.

(4) *Compulsory Notification.*

That this Commission recommends the passage of legislation providing for the compulsory notification by owners and by veterinarians of the existence of tuberculosis in a herd, whether such existence be made known by detection of clinical cases or by the tuberculin test.

(5) *Location through Slaughter.*

This Commission recognises that the discovery of tuberculosis in animals slaughtered for food purposes furnishes one of the best possible means of locating the disease on the farm, and therefore recommends the adoption of some system of marking, for purposes of identification, all cattle three years old and over, shipped for slaughter.

As tuberculosis of hogs is almost invariably due to bovine infection, this recommendation should also be made to apply to hogs of any age shipped for slaughter.

It is further recommended that the discovery of tuberculosis in animals coming under government inspection should be used, whenever identification is possible, as a means of locating infected herds and premises. All such cases should be reported to the proper authorities for control action.

(6) *Disposition of Tuberculous Animals.*

The Commission Plan.—(1) As a general policy, in the eradication of tuberculosis the separation of healthy and diseased animals and the construction of a healthy herd are recommended.

In order to accomplish this, the following recommendations are made:

1. If the herd is found to be extensively infected, as shown by the tuberculin test or clinical examination, even the apparently healthy animals in it should be regarded with suspicion, until they have been separated from the reacting animals for at least three months.

If, after the expiration of this time, they do not react to the tuberculin test, they may be considered healthy and dealt with accordingly.

It is recommended that a herd extensively infected should not be treated by the method of general separation, but that the construction of a new herd from the offspring only is advisable.

2. If the herd is found, by either or both of the above methods, to contain a relatively small proportion of diseased animals, separation of the diseased animals from the healthy animals, and the construction of a sound herd from the healthy animals, and the offspring of both, is advocated.

As a working basis in carrying out these principles, we advise:

(*a*) That herds containing 50 per cent or more of diseased animals be treated as coming under section 1.

(*b*) That herds containing under 15 per cent of diseased animals be treated as coming under section 2.

(*c*) That herds falling between these figures be graded according to the option of the owner.

(*d*) That it shall be the prerogative of the owner to reject either plan, and have his herd dealt with by removal and slaughter of diseased animals, with or without compensation, according to the public policy in operation.

(2) That when by any means the officials properly charged with the control of tuberculosis become aware of its existence in a herd to which a policy of slaughter and compensation cannot reasonably be applied, such herd must be dealt with by the owner, under Government supervision, on the principle of the separation of all sound animals from those affected. Such separation must be effected by treating the whole herd as diseased, and rearing the calves separately, either on pasteurised milk or the milk of healthy cows; or when the number of those affected is so small as to warrant such a course, by the application to the whole herd, from time to time, under official supervision, of the tuberculin test, and the entire segregation of all animals found to react.

In the event of any owner refusing or neglecting to adopt either of the above methods, his entire herd to be closely quarantined and sales therefrom to be entirely prohibited.

(3) That a policy of compensation be recommended as useful and usually necessary as a temporary measure.

(4) That, when slaughter is necessary, in order to avoid economic loss, every effort should be made to utilise as far as possible the meat of such animals as may be found fit for food on being slaughtered under competent inspection.

(5) The details of the Commission Plan are fully set forth in a separate Appendix (not reproduced).

(7) *Prevention.*

(1) That with the object of preventing the spread of infection, persons buying cattle for breeding purposes or milk production should, except when such purchases are made from disease-free herds, which have been tested by a properly qualified person, purchase only subject to the tuberculin test. In order to assist in the proper carrying out of this suggestion, the Commission recommends that official authorities should adopt such regulations as will prevent the entry to their respective territories of cattle for breeding purposes or milk production unless accompanied by satisfactory tuberculin test charts.

(2) That all milk and milk by-products used as food should be properly pasteurised unless derived from cows known to be free from tuberculosis.

(8) *Control of Tuberculin Test.*

That the Commission recommends the passage of legislation which will prevent the sale, distribution or use of tuberculin by any persons other than those acting with the full knowledge, or under the direction, of official authorities.

(9) *Education.*

As a clear knowledge of the cause and character of tuberculosis among animals, the modes of dissemination, and its significance as an economic and as a public health problem, underlie an intelligent adherence to the principles that must be observed in all efforts for eradication, as well as the establishment of proper co-operation in the great work between physicians, veterinarians, live stock owners, legislators, and the public generally, it is recommended that a widespread campaign of education be undertaken. To accomplish this end it is recommended that, first of all, a simple pamphlet on bovine tuberculosis be written, in which the language used shall be of such character that every person of average intelligence shall be able to read it without being mystified by technical terms or phrases. This pamphlet should be published with the endorsement of the American Veterinary Association and the special endorsement and consequent authority of the International Commission on Bovine Tuberculosis Control.

(10) *Publicity.*

In concluding its work the Commission desires to especially appeal to the Press, metropolitan, agricultural, and local, to join in the work of extending as much as possible among the people the conclusions here arrived at. The vital importance of the life of farm animals to the welfare of all classes of society needs no argument in its support. The aim and sole purpose which has actuated this Commission has been to arrive at the soundest conclusions possible in the light of the best knowledge obtainable.

(11) *Legislation.*

It is recommended that legislation regarding the control and eradication of tuberculosis among domestic animals be made uniform; that the laws of the United States and Canada and other American countries for the admission into America of animals from without be made stringent and as much alike as possible; and that the laws governing the interstate and interprovincial movement of cattle and that between different American countries be harmonised.

The laws governing interstate and interprovincial movement of cattle should be of such character that every state and every province will be free in its eradication work from unnecessary difficulties due to the existence of the disease in other states and provinces.

Legislation is especially required to prevent the various frauds which interfere with the satisfactory use of tuberculin sold to be used by veterinarians and others.

(12) *Sanitation.*

In the eradication of tuberculosis it should be kept in mind that, in addition to protecting the animals against exposure to tubercle bacilli, it is desirable to make them as resistant to infection as possible. This can be done by stabling them in clean, disinfected, and properly lighted and ventilated barns, giving them abundant clean water and nutritious food, a sufficient amount of daily exercise in the open air, and attending generally to those conditions which are well known to contribute to the health of animals.

The daily removal of manure from stables, and water-tight floors and good drainage in stables are urgently recommended.

Young stock particularly should be raised as hardy as possible, and should be accustomed to liberal exercise and living in the open.

(13) *Immunisation.*

That as none of the various methods for the immunisation of animals against tuberculosis have passed sufficiently beyond the experimental stage, the Commission is unable to endorse any of those for practical use at the present time.

(14) *Animal Tuberculosis and Public Health.*

While the members recognise that the subject with which this Commission is primarily intended to deal is the control and eradication of tuberculosis among animals as an economic problem, they cannot feel satisfied without declaring their recognition of the fact that tuberculosis among animals is also an important public health problem. Considered as such, the eradication of tuberculosis among animals should have the approval and support of all those persons who are interested in curtailing human suffering and prolonging human life.

(15) *General Statement.*

The members of the Commission wish it to be clearly understood that they recognise the limitations of a report necessarily based on actual and not on theoretical conditions. They fully realise that in the event of the policy of which their recommendations form the framework being anywhere adopted even in its entirety, much greater benefit will be derived, at least for some time, from its educative than from its executive features.

The control, to say nothing of the eradication, of bovine tuberculosis, is impossible of achievement, without the hearty co-operation of the men who are actually engaged in the cattle industry. In order to secure this co-operation, it will doubtless be necessary, in most communities, to carry on an active and prolonged educational campaign.

It is apparent that in the dissemination of practical and reliable information regarding the disease, it will be possible to employ a very large variety of methods. Many of these methods, such as bulletins, lectures, and actual demonstrations of disease, having already been found valuable, will doubtless continue to be largely used.

It must not be forgotten, however, that in this, as in any other educative process, a measure of disciplinary control is essential to success. Needless to say, such control can be secured only by the passage of legislation which, while clear and comprehensive, must, at the same time, be sufficiently conservative to avoid exciting alarm or arousing antagonism on the part of owners especially of valuable herds.

The best law ever framed can be made an utter failure by stupid or injudicious administration, while, on the other hand, the most drastic legislation can be rendered acceptable if enforced with reasonable tact and diplomacy. Provided, therefore, that these qualities, combined with integrity, thoroughness, and determination, are available for administrative purposes, the members of the Commission are convinced that the enforcement of a law based on their recommendations, will prove to be far the most powerful and effective educational agency which could possibly be employed.

In concluding its report, the Commission would suggest that the Association should make such provision as may be necessary to carry on the work either by continuing the Commission as at present constituted or with such changes in the *personnel* as may be considered desirable.

CHAPTER XIX

SPECIAL METHODS TO OBTAIN A PURER MILK SUPPLY

THE inability of the present laws, both theoretically and as practically carried out, to ensure a pure milk supply is clearly recognised by those intimately acquainted with the subject, and through their efforts a number of special powers have been obtained, or special procedures practised by local communities, to obtain a cleaner and a purer milk supply. In America especially, great attention has been paid to this subject, and several methods have been originated which are of great value and worthy of at least careful consideration, if not imitation, in this country. These special methods are conveniently considered together under the following heads:

I. English special milk powers.
II. The "certified milk" movement.
III. English milk depots.
IV. The score-card system.
V. Special American regulations.

I. English Special Milk Powers

These powers are practically confined to milk in its relationship to tuberculosis, and as such have been fully considered in Chapter XVIII.

II. Certified Milk

The honour of originating the Medical Milk Commission movement belongs to Dr. Henry Coit[1] of Newark, New Jersey,

[1] I have to thank Dr. Coit, Dr. O. P. Geier (Secretary of the American Medical Milk Commissions Association), and Mr. L. G. Tedesche (Bacteriologist, Milk Commission, Cincinnati) for sending me their reports and numerous other pamphlets on the subject, from which the account given has been largely compiled.

U.S.A. In 1890 the Medical Society of the State of New Jersey, at his suggestion, appointed a committee of forty physicians to study the relationship between mortalities and milk supplies, and to secure better legislation to improve the milk supply. Failing in this direction, Coit, with other medical men, started in 1893 the first Commission, which was called the "Essex County Milk Commission." The idea grew but slowly at first, for only twelve were organised in other areas during the next fourteen years. In 1907 the movement received a considerable impetus by the formation of an association (The American Association of Medical Milk Commissions) comprising all the Medical Milk Commissions then in existence. Four annual conferences have been held. At the time of the third annual conference in 1909, at Atlantic City, it consisted of 58 component commissions in the United States and Canada.

The Milk Commissions exist to ensure the production of a better quality of milk—*certified milk*. The certified milk movement may be described as a co-operative system between certain members of the medical profession and certain purveyors of milk. The former, in the interests of the community and for the benefit of their patients, are willing to lay down the conditions necessary to be fulfilled to obtain a pure milk, and to take the appropriate means to ensure compliance with such conditions. The latter, in their own interests, are willing to comply with the regulations for the sake of the increased price obtainable for their milk.

Compliance with the requirements of the Commission ensures that a pure milk is obtained, while the use of the word "certified" assures the consumer that it is pure and worth the extra price charged for it by the dairyman, who is put to the increased expense of producing it.

The term "certified" was copyrighted by Francisco, the first dairyman signing a contract to produce milk under the supervision of a Commission with the understanding that any Milk Commission should have the right to its use. It is, of course, very important that the expression "certified milk" should not be degraded by being employed for inferior milk, and the restricted use of the term has been upheld in the law courts. This has also been recognised by several of the States, and

New York has added a clause to her pure food law protecting the term against false use and regulating its employment by Milk Commissions: "All milk sold as certified shall be conspicuously marked with the name of the Commission certifying it." Kentucky also has passed a law regarding certified milk. The first law anywhere that gives legal recognition to the Medical Milk Commission is the one passed in 1909 by the State of New Jersey. As this is of considerable interest and importance it is reprinted in the Appendix, p. 447.

The Commissions are composed (with rare exceptions) of medical men usually appointed by medical societies. They themselves receive no pay, but employ experts who are generally paid. The expenses incurred are paid for by the dairymen, the money being raised in different ways, one of the commonest being by the sale of caps for the bottles.

According to Machell, the additional cost to the consumer in the United States has varied from 3 to 8 cents per quart. The average additional advance has been about 5 cents per quart above the cost of ordinary market milk. Coit,[1] however, remarks: "While no milk fit for ordinary domestic use can be produced with profit to the dairyman for less than 5 or 6 cents at first cost, milk of a suitable grade for hospitals or for infant feeding cannot be sold at a profit for less than 15 cents per quart."

The work carried on by the Commission may be best outlined in Coit's own words:[1]

> The plan provides that the medical commission establish correct clinical standards of purity for the milk; become responsible for periodical expert inspections of the dairy or dairies under its patronage; provide for frequent examinations of the product by a chemist and a bacteriologist, the first to determine its food values, and the latter to serve as a detective control over the methods employed in collecting and handling the milk. The medical commission also directs a frequent scrutiny of the live stock by competent veterinarians, whose duties consist in keeping the herd free from disease and also in the detection and exclusion of bovine tuberculosis. Likewise the commission directs a systematic medical supervision of the health of the dairy employees, and insists upon a continuous knowledge, through reports by a physician, of their health and personal hygiene. By the service of reliable experts in

[1] *Public Health*, 1909, vol. xxiii. p. 93.

these four departments, safeguards are established against the common dangers of impoverished and contaminated milk.

The actual conditions of production required are usually very stringent, and are controlled by frequent bacteriological examination. In many instances a numerical standard of the number of bacteria per cc. is adopted, this in most cases being not more than 10,000 per cc.

As an example of the requirements of a Milk Commission the regulations of the Milk Commission of the Medical Society of the County of New York[1] may be quoted in detail:

The Commission has fixed upon a maximum of 30,000 germs of all kinds per cubic centimetre of milk, which must not be exceeded to obtain the indorsement of the Commission. This standard must be attained solely by measures directed towards scrupulous cleanliness, proper cooling, and prompt delivery.

The milk certified by the Commission must contain not less than 4 per cent of butter fat on the average, and have all other characteristics of pure, wholesome milk.

Milk must not be sold as certified beyond the day on which it reaches New York City. No milk may be shipped as certified which will reach the city more than 36 hours after production.

In order that dealers who incur the expense and take the precautions necessary to furnish a truly clean and wholesome milk may have some suitable means of bringing these facts before the public, the Commission offers them the right to use caps on their milk jars stamped with the words, "Certified by the Milk Commission of the Medical Society of the County of New York." The dealers are given the right to use these certificates when their milk is obtained under the conditions required by the Commission and conforms to its standards. In accordance with a law passed at the last legislature, the word "certified" may be used on the cap only when accompanied by the name of the society which certifies it.

The tin sealed cap, authorised by the Commission, must be used on all the certified milk passing through the hands of dealers selling milk other than the certified. These caps are sent by the makers only to the farm where the milk is bottled. The name of the farm from which the milk comes must appear on either the paper cap or the tin cap.

Each bottle of milk must be dated on the date of bottling or date to be sold.

The Milk Commission looks to the dealer for its fee.

Each dealer is expected to send a bottle of milk each week to the Research Laboratory of the Department of Health, taken at

[1] *Bulletin No. 18, State of New York Department of Agriculture*, 1910.

random from the day's supply, for examination by experts for the Commission. Any dealer shipping to more than one town or city must supply a sample weekly from each town.

The dealers are to furnish deep, covered boxes for the certified milk.

The required conditions are as follows:

1. *The Barnyard.*—The barnyard should be free from manure and well drained, so that it may not harbour stagnant water. The manure which collects each day should not be piled close to the barn, but should be taken several hundred feet away. If these rules are observed, not only will the barnyard be free from objectionable smell, which is an injury to the milk, but the number of flies in summer will be considerably diminished. These flies are an element of danger, for they are fond of both filth and milk, and are liable to get into the milk after having soiled their bodies and legs in recently visited filth, thus carrying it to the milk. Flies also irritate cows, and by making them nervous reduce the amount of their milk.

2. *The Stable.*—In the stable the principles of cleanliness must be strictly observed. The room in which the cows are milked should have no storage loft above it; where this is not feasible the floor of the loft should be tight, to prevent the sifting of dust into the stable beneath. The stables should be well ventilated, lighted and drained, and should have tight floors, preferably of cement, never of dirt. They should be whitewashed inside at least twice a year, unless the walls are painted or of smooth cement finish which can be washed frequently.

The air should always be fresh and without bad odour. A sufficient number of lanterns should be provided to enable the necessary work to be properly done during the dark hours. The manure should be removed twice daily, except when the cows are outside in the fields the entire time between the morning and afternoon milkings. The manure gutter must be kept in a sanitary condition. All sweeping of dry floors must be completed before grooming of cows is begun. All sweeping must be completed before the last washing of udders is begun.

There should be an adequate supply of water, warm and cold, and the necessary wash-basins, soap, and towels.

3. *Water Supply.*—The whole premises used for dairy purposes, as well as the barn, must have a supply of water absolutely free from any danger of pollution with animal matter and sufficiently abundant for all purposes, and easy of access.

4. *The Cows.*—No cows will be allowed in the herd furnishing certified milk except those which have successfully passed a tuberculin test. All must be tested at least once a year by a veterinarian approved by the Milk Commission. All tuberculin

tests must be arranged through the Milk Commission, or with the approval of the Milk Commission, and must be so planned that the representative of the Milk Commission may be present throughout, and be accommodated at or near the farm in the same way as the doctor who makes the test, if the Commission so desires.

No test will be regarded as satisfactory to the Milk Commission unless the temperatures are taken through the eighteenth hour after injection. Should the State Department, in state test, feel unable to instruct its veterinarian to take temperatures through the eighteenth hour, and should he not do so of his own accord, the Commission may require a private test later at the expense of the owner.

The farmer for whom the test is made must make sure that a chart of each test is furnished to the Milk Commission, to keep on file, within a week after the test, whether it be a private or state test. The Milk Commission reserves the right to decide what cows shall be kept in the herd.

Any animal suspected of being in bad health must be promptly removed from the herd and her milk rejected. No cow whose udder is imperfect shall be allowed in the certified herd, nor shall the milk from an udder in any way diseased be put in the certified milk, as long as any disease exists. Do not allow the cows to be excited by hard driving, abuse, loud talking, or any unnecessary disturbance.

Feed.—Do not allow any strongly flavoured food, like garlic, to be eaten by the cows.

When ensilage is fed, it must be given in only one feeding daily, and that after the morning milking, and the full ration shall consist of not more than twenty pounds daily for the average sized cow. When fed in the fall small amounts must be given and the increase to the full ration must be gradual.

Corn-stalks must not be fed until after the corn has blossomed, and the first feedings must be in small amounts and the increase must be gradual. If fed otherwise, ensilage and corn-stalks are liable to cause the milk to affect children seriously.

Cleaning.—Groom the entire body of the cow daily. Before each milking, wash the udder with a cloth used only for the udders and wipe it with a clean dry towel. Never leave the udder wet, and be sure that the water and towel used are clean. The tail should be kept clean by frequent washing. If the hair on the flanks, tail, and udder is clipped close, and the brush on the tail is cut short, it will be much easier to keep the cow clean.

The cows must be kept standing after the cleaning until the milking is finished. This may be done by a chain or rope under the neck.

5. *The Milkers.*—The milker must be personally clean. He

should neither have nor come in contact with any contagious disease while employed in handling the milk. In case of any illness in the person or family of any employee in the dairy, such employee must absent himself from the dairy until a physician certifies that it is safe for him to return.

In order that the Milk Commission may be informed as to the health of the employees at the certified farms, the Commission has had postal cards printed, to be supplied to the farms and to be filled out and returned each week by the owner, manager, or physician of the farm, certifying that none are handling the milk who are in contact with any contagious disease.

Before milking, the hands should be washed in warm water with soap and nail brush and well dried with a clean towel. On no account should the hands be wet during milking.

The milkers should have light-coloured, washable suits, including caps, and not less than two clean suits weekly. The garments should be kept in a clean place protected from dust, when not in use.

Iron milking stools are recommended and they should be kept clean.

Milkers should do their work quietly and at the same hour morning and evening. Jerking the teat increases materially the bacterial contamination of the milk and should be forbidden.

6. *Helpers other than Milkers.*—All persons engaged in the stable and dairy should be reliable and intelligent. Children under twelve should not be allowed in the stable or dairy during milking, since in their ignorance they may do harm, and from their liability to contagious diseases they are more apt than older persons to transmit them through the milk.

7. *Small Animals.*—Cats and dogs must be excluded from the stables during the time of milking, and fowls at all times. No animals allowed in dairy.

8. *The Milk.*—All milk from cows sixty days before and ten days after calving must be rejected.

The first few streams from each teat should be discarded, in order to free the milk ducts from the milk that has remained in them for some time and in which the bacteria are sure to have multiplied greatly. If any part of the milk is bloody or stringy or unnatural in appearance, the whole quantity yielded by that animal must be rejected. If any accident occurs in which a pail becomes dirty or the milk in the pail becomes dirty, do not try to remove the dirt by straining, but put aside the pail and do not use the milk for bottling, and use a clean pail.

Remove the milk of each cow from the stable immediately after it is obtained to a clean room and strain through a sterilised strainer of cheese-cloth and absorbent cotton.

The rapid cooling is a matter of great importance. The milk should be cooled to 45° F. within an hour, and not allowed to rise above that as long as it is in the hands of producer or dealer. In order to assist in the rapid cooling, the bottles should be cold before the milk is put into them.

Aeration of milk beyond that obtained in milking is unnecessary.

9. *Utensils.*—All utensils should be as simple in construction as possible, and so made that they may be thoroughly sterilised before each using.

Coolers, if used, should be sterilised in a closed steriliser, unless a very high temperature can be obtained by the steam sent through them.

Bottling machines should be made entirely of metal, with no rubber about them, and should be sterilised in the closed steriliser before each milking or bottling.

If cans are used, all should have smoothly soldered joints, with no places to collect the dirt.

Pails should have openings not exceeding 8 inches in diameter, and may be either straight pails or the usual shape with the top protected by a hood.

Bottles should be of the kind known as "common sense" and capped with a sterilised, paraffined paper disc and the caps authorised by the Commission.

All dirty utensils, including the bottles, must be thoroughly cleansed and sterilised. This can be done by first thoroughly rinsing in warm water, then washing with a brush and soap or other alkaline cleansing material and hot water and thoroughly rinsing. After this cleansing they should be sterilised by boiling, or in a closed steriliser with steam, and then kept inverted in a place free from dust.

10. *The Dairy.*—The room or rooms where the utensils are washed and sterilised and the milk bottled should be at a distance from the house and the barn, so as to lessen the danger of transmitting through the milk any disease which may occur in the house.

The bottling room, where the milk is exposed, should be so situated that the doors may be entirely closed during the bottling and not opened to admit the milk nor to take out the filled bottles.

The empty shipping cases should not be allowed to enter the bottling room, nor should the washing of any utensils be allowed in the room.

The workers in the dairy should wear white washable suits, including cap, when handling the milk.

Bottles must be capped as soon as possible, after filling, with the sterilised discs.

11. *Examination of the Milk and Dairy Inspection.*—In order that the dealer and the Commission may be kept informed of the character of the milk, specimens taken at random will be examined weekly by experts for the Commission at the Laboratory of the Department of Health, the use of the laboratories having been given for that purpose.

The Commission reserves to itself the right to make inspections of certified farms at any time and to take specimens of the milk for examination, and to impose fines for repeated or deliberate violations of the requirements of the Commission.

The Commission also reserves the right to change its standards in any reasonable manner upon due notice being given to the dealers.

Although the use of certified milk has extended, such milk constitutes only a minute fraction of the total supply, even in any city in which it is obtainable. It cannot be anticipated that milk produced under such rigid control will ever constitute any considerable part of the general milk supply, since it must of necessity be sold at a high price and the poor cannot possibly afford to pay for it. It furnishes a pure milk for those who can afford it, while it is very valuable for special cases, hospitals, and similar institutions. As educational agencies Medical Milk Commissions have been and are of the greatest value. They show that pure milk can be obtained as a commercial article, and, in particular, by showing what milk ought to be, their existence is a valuable stimulus to the production of a purer general supply.

III. English Milk Depots

Milk depots for the supply of pure or purified milk are of comparatively recent origin. The first two institutions of this character appear to have been both established in 1889, one in the St. Gertrude district of Hamburg, and the other by Koplik at the Good Samaritan Hospital, New York. The next to be started was in 1892 by Dr. Variot in connection with the Belleville Dispensary in Paris. The first British Infant Milk Depot was established by the St. Helens Corporation in 1899. Since that date a small number of additional depots have been started in Great Britain. The first depot in London was at Battersea in 1902 under the charge of Dr. McCleary. The movement was given a considerable impetus by the publication by McCleary of his valuable book on Infants' Milk Depots.

The British milk depots are not all conducted in the same way, but the usual plan is for them to be financed and controlled by the Municipality. Special premises are provided where milk of good quality is received and distributed. Before being distributed it is modified chemically and sterilised or partially sterilised. It is distributed in sealed bottles and sold to the poor at prices which do not pay for the cost of provision and preparation. In other words, they are usually rate-subsidised agencies for the provision of purified and modified milk as an aid to the prevention of infantile mortality. Their very existence is a striking condemnation of the conditions under which milk is produced and vended in crowded urban areas.

As an illustration of the nature and methods of working of a milk depot managed on proper lines, and for which the records have been most admirably compiled, the following particulars of the Woolwich Milk Depot may be given.[1] The Depot was opened November 5th, 1906, and closed at the end of July 1910. It was thus in active working for only three years nine months. The reasons for its closure were essentially financial.

Method of Payment.—The milk was not sold by the pint, but payment was made according to the age of the infants, viz. 1s. 6d. per week to children under six months old; 2s. to those six to twelve months; and 2s. 6d. to those over twelve months.

Character of the Milk.—The milk was modified, using various proportions of milk, cream, sugar, and water. Three different qualities were prepared. The milk was bottled and either pasteurised at 170° F. for fifteen minutes or, in hot weather, heated to 212° F. for twenty minutes. The milk was obtained from a single farm upon which satisfactory hygienic conditions prevailed. The cows were frequently examined by veterinary surgeons, and the milk periodically chemically analysed, but apparently no bacteriological examinations were made.

Selection of Babies.—Only admitted if provided with a

[1] Dr. Davies, *Annual Reports, Woolwich*, 1907, 1908, 1909.

doctor's certificate, or after a visit from the woman health visitor and pronounced by her to be a suitable case. Only those children were admitted to the depot whose mothers were unable to suckle them, or who were actually found to be wasting on the mother's milk.

Supervision of the Cases.—Homes all visited by the health visitor, and visits repeated as found necessary. Children were weighed every fortnight as far as possible.

The Woolwich Depot had one peculiarity. It was the only depot which undertook delivery of the milk at the customers' homes. An additional charge of 4d. per week was made for this. It only paid for about half the cost of delivery.

Financial Cost.

(*Total Capital Expenditure*, £662.)

Annual Cost.	1907.	1908.	1909.
Expenditure	£962	£960	£958
Income	530	608	562
Loss on working expenses . .	432	352	396
Loan charges	68	66	64
Approximate total loss for the year .	500	418	460

Children Fed, etc.

	1907.	1908.	1909.
Number of infants supplied . . .	313	368	332
Average number of infants being fed at any one time	...	116	110
Average duration of feeding for each infant at the depot	3 months	5 months	5 months
Total number of infants coming on the depot during the year	313	245	217
Number of children coming on the depot during the year, who were unwell when starting depot milk	176 (56 per cent)	130 (53 per cent)	82 (38 per cent)
Deaths of infants while on depot milk (excluding deaths one week after starting and adding those one week after leaving off the milk)	13	6	6
Death-rate of depot children calculated by Dr. Davies's method (see below) .	...	52 per 1000	52 per 1000

The population of Woolwich estimated to the middle of 1909 was 127,993.

As Sidney Davies (Medical Officer of Health, Woolwich) points out, it is difficult to give a milk depot death-rate. Such rates are often based upon the rate per 1000 infants fed, but are then totally incomparable with normal infantile death-rates. The method which Davies suggests as the fairest is to take the deaths occurring while children are actually being fed at the depot (deducting those dying within a week of coming on, and adding deaths occurring within a week of going off) and estimate the rate on the average numbers being fed at one time. This is the method adopted in calculating the death-rates in the table above. During the three years (1907–1909) 25 depot-fed children died while on the depot, and the death-rate was 81 per 1000.

The Liverpool Milk Depot is the largest in England. It was started in 1901, and since that date to the end of 1909 16,131 have been fed upon humanised milk supplied either at the milk depots (10,171 infants) or through dairies (5960 infants). The average age at the commencement of such feeding was $3\frac{3}{4}$ months. The expenditure for each of the nine years varied from £2000 in the first year to £4077 for 1909, the income from the sale of the milk varying from £518 in the first year of working to £1328 in 1909. The deficit payable out of rates for 1909 was £2749. The milk is supplied from special farms by contract and is modified and sterilised.

Of the 10,171 infants supplied through the depots, and of whom accurate records are kept, there were 941 cases in which the infant died, but of these 75 had been fed on the milk for less than one week, or had been irregularly fed on it; 713 were ill, some of them hopelessly ill, when the milk was first supplied. Each death formed the subject of a careful inquiry, and it was found that out of the total numbers of infants who died only 179 were fairly healthy at the time of admission and had been properly fed since.[1]

At Leicester Dr. Millard has been carrying out an interesting modification in Milk Depots by the use of dried milk. The depot was originally started on orthodox lines by the use of bottled humanised milk, but in 1907 the use of

[1] Dr. Hope, 1909, *Annual Report, City of Liverpool.*

dried milk was started, and at the end of 1909 about four-fifths of all the babies at the depot were being fed on it exclusively. In 1911 the use of humanised milk was finally abandoned. Millard finds that dried milk has the great advantage of being more digestible, and many infants who are unable to keep down fresh milk easily retain dried milk. Owing to its convenience it is very popular with the mothers, and the average number of infants treated has steadily risen from 102 in 1907, 195 in 1908, 216 in 1909, to 274 in 1910.

The practice at the depot is to regulate the richness of the milk as follows: For infants under two months old, half cream milk; for infants between two and six months, three-quarters cream; for infants over six months old, full cream. In each case the milk is slightly sweetened by the addition to the dried milk of 10 per cent of castor sugar. These mixtures are retailed at 8d., 10d., and 1s. per lb., and at this price it costs about the same to feed an infant as if fresh cows' milk were purchased from a dairy. The dried milk is said to keep good for months and does not turn sour. By the use of dried milk the depot can be run at much less expense, the bottles and their cleaning being a very heavy item in the ordinary depot. For the financial year ending March 1910 the receipts were £868, the expenses £979, and the deficiency £111, of which £25 was a contribution towards the salary of the health visitor. For 1910 the excess of expenditure over receipts was only £43.

Milk depots should have a much wider function than merely to distribute pure milk. If used at all they should be one part, but strictly a part only, of the system of municipal surveillance of infant feeding and treatment which is one of the latest and most valuable developments of public work.

Sir G. Newman[1] has laid down four dicta as to the functions and proper management of a milk depot with which most persons who have studied the matter will agree. They are:

1. The supply of milk from these depots should be restricted absolutely to children who cannot be breast fed.

[1] *Proceedings Infantile Mortality Conference*, 1906, p. 90.

2. They are to be used in association with regular medical supervision of the infants.

3. The depots should be worked in conjunction with careful home visitation either by a doctor, lady visitor, or experienced hospital nurse. It is a matter of the greatest importance in respect of the work of a milk depot to take means to increase maternal responsibility.

4. The control of the milk should begin at the farm, instead of having the milk brought into the town in bulk and then sterilised and treated. Whatever modifications milk is to pass through, whatever manipulations it is to receive, it should receive immediately after milking at the farm. Newman, however, admits that this is not always possible.

A fifth but less important point is—

5. The milk should be sold at market prices; only the expenses of the depot itself, that is, the expense of the management and distribution, should fall on the rates. The children who come to the depot and are too poor to pay the necessary market price, which will range from 1s. 6d. to 2s. per week, should be supplied with tickets through the Poor Law under the form of outdoor relief.

The figures and facts collected in regard to infants fed at these depots show that these institutions have played an important part in the reduction of infant mortality in the areas in which they have been operative. It is not possible to determine the relative value which the pure milk itself, and the additional care and advice bestowed upon the infants, have respectively played in the reduction of infant mortality and morbidity. Both no doubt have been valuable factors.

Used in conjunction with other efforts to minimise maternal neglect and ignorance and to foster maternal responsibility, milk depots have their place in the armament of preventive measures, but at their best they can play a small part only in the problem. They are in no way a substitute for a general pure milk supply, and while in some places very valuable, they are more or less temporary expedients not to be recommended for wholesale adoption. If they are merely used to supply sterilised milk at a price below the cost of production, because subsidised out of the rates, to all who are willing to pay for it, and without any supervision, they are most unsatisfactory.

IV. The Score-card System

This system of recording the results of dairy and cow-shed inspections is a system of American origin, which has greatly extended in America of recent years. It was first introduced and used in 1904 by Dr. W. C. Woodward, Health Officer of the District of Columbia. A little later Professor R. A. Pearson, of Cornell University, introduced a somewhat different form of score-card. The Dairy Division of the Bureau of Animal Industry took up its use and extended it. At the third meeting of the Official Dairy Instructors' Association, July 1908, the committee presented the score-card in a new form, embodying, as far as possible, the criticisms submitted by the heads of the various dairy departments. This card, with a few minor changes, was adopted by the association and by the Dairy Division of the Bureau of Animal Industry. This card,[1] which is reproduced on pages 362, 363, may therefore be considered the standard and best type of card so far evolved. Size of card, 8 × 5 inches.

As Lane and Whitaker point out, a valuable feature of the card is the separation of dairy conditions into equipment and methods. The score for equipment indicates the quality and sufficiency of the tools the dairyman has to work with, while the score for methods gives an accurate idea of the way the dairyman uses his equipment, and indicates whether he is practising right methods.

The card is arranged with separate columns, for "Equipment" and "Methods," and allows a total of 40 and 60 points, respectively, for each. This arrangement of points is made for the purpose of emphasising the importance of good methods, and giving unmistakable credit for cleanliness. A person may be handicapped by poor buildings which he has inherited or leased, and which he cannot afford to rebuild; but he can be clean. Painstaking methods, particularly in regard to cleanliness, will give a creditable score in spite of poor equipment.

[1] I am greatly indebted to Mr. G. M. Whitaker, of the U.S. Department of Agriculture, for permission to reproduce this card, for copies of it, and for other information, particularly Circular 139, issued April 1909, by C. B. Lane and G. M. Whitaker, upon "The Score-card System of Dairy Inspection."

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
DAIRY DIVISION.

SANITARY INSPECTION OF DAIRIES.

DAIRY SCORE CARD.

Adopted by the Official Dairy Instructors' Association.

Owner or lessee of farm ....

P.O. address .... State ....

Total number of cows .... Number milking ....

Gallons of milk produced daily ....

Product is retailed by producer in ....

Sold at wholesale to ....

For milk supply of ....

Permit No. .... Date of inspection ...., 191

REMARKS ....

....

....

....

....

....

....

....

....

....

....

....

(Signed) ....
Inspector.

[*Front of Card.*]

DETAILED SCORE.

EQUIPMENT.	SCORE. Perfect.	SCORE. Allowed.
COWS.		
Health	6	....
Apparently in good health 1		
If tested with tuberculin once a year and no tuberculosis is found, or if tested once in six months and all reacting animals removed 5		
(If tested only once a year and reacting animals found and removed, 2.)		
Comfort	2	....
Bedding 1		
Temperature of stable 1		
Food (clean and wholesome)	2	....
Water	2	....
Clean and fresh 1		
Convenient and abundant...... 1		
STABLES.		
Location of stable	2	....
Well drained 1		
Free from contaminating surroundings 1		
Construction of stable	4	....
Tight, sound floor and proper gutter........................ 2		
Smooth, tight walls and ceiling 1		
Proper stall, tie, and manger... 1		
Means of lighting: Four sq. ft. of glass per cow	4	....
(Three sq. ft., 3; 2 sq. ft., 2; 1 sq. ft., 1. Deduct for uneven distribution.)		
Ventilation: Automatic system	3	....
Adjustable windows 1		
Cubic feet of space for cow: 500 to 1000 feet	3	....
(Less than 500 feet, 2; less than 400 feet, 1; less than 300 feet, 0; over 1000 feet, 0.)		
UTENSILS.		
Construction and condition of utensils	1	....
Water for cleaning	1	....
(Clean, convenient, and abundant.)		
Small-top milking pail	3	....
Facilities for hot water or steam	1	....
(Should be in milk house, not in kitchen.)		
Milk cooler	1	....
Clean milking suits	1	....
MILK ROOM.		
Location of milk room	2	....
Free from contaminating surroundings.................... 1		
Convenient..................... 1		
Construction of milk room	2	....
Floors, walls, and ceiling....... 1		
Light, ventilation, screens..... 1		
Total	40	....

METHODS.	SCORE. Perfect.	SCORE. Allowed.
COWS.		
Cleanliness of cows	8	....
STABLES.		
Cleanliness of stables	6	....
Floor 2		
Walls 1		
Ceiling and ledges 1		
Mangers and partitions 1		
Windows...................... 1		
Stable air (dust and odours) at milking time	6	....
Barnyard clean and well drained	2	....
Removal of manure daily to field or proper pit	2	....
(To 50 feet from stable, 1.)		
MILK ROOM.		
Cleanliness of milk room	3	....
UTENSILS AND MILKING.		
Care and cleanliness of utensils	8	....
Thoroughly washed and sterilised in live steam for 30 minutes........................ 5		
(Thoroughly washed and placed over steam jet, 4; thoroughly washed and scalded with boiling water, 3; thoroughly washed, not scalded, 2.)		
Inverted in pure air........... 3		
Cleanliness of milking	9	....
Clean, dry hands 3		
Udders washed and dried..... 6		
(Udders cleaned with moist cloth, 4; cleaned with dry cloth at least 15 minutes before milking, 1.)		
HANDLING THE MILK.		
Cleanliness of attendants in milk room	1	....
Milk removed immediately from stable	2	....
Prompt cooling (cooled immediately after milking each cow)	2	....
Efficient cooling; below 50° F.	5	....
(51° to 55°, 4; 56° to 60°, 2.)		
Storage; below 50° F.	3	....
(51° to 55°, 2; 56° to 60°, 1.)		
Transportation; iced in summer	3	....
(For jacket or wet blanket, allow 2; dry blanket or covered wagon, 1.)		
Total	60	....

Equipment .... + Methods .... = ... **Final Score.**

NOTE 1.—If any filthy condition is found, particularly dirty utensils, the total score shall be limited to 49.

NOTE 2.—If the water is exposed to dangerous contamination, or there is evidence of the presence of a dangerous disease in animals or attendants, the score shall be 0.

[Back of Card.]

The Bureau of Animal Industry, U.S.A. (Dairy Division), gives the following advantages for the score-card system:

1. Provides the health officer with a permanent, accurate, and convenient record of all his dairies.

2. May be used as a basis for issuing permits to sell milk. A number of cities have set standards of 50 to 60 points, which every dairyman must reach before a permit is issued. This forces the poorer dairies to improve or go out of business, as they are given only a limited time to comply with the demands of the board of health.

3. Serves as a check upon the work of the inspectors.

4. Information as to the conditions in the dairies can be tabulated, and by the publication of the scores at intervals every dairyman is given credit for every effort he has made to produce clean milk.

One of the great hindrances to improvement is that milk from good dairies and poor dairies practically all sells for the same price. Publication of scores goes a long way toward correcting this state of affairs. Customers who take an interest in their milk supply are not slow to note the standing of the dairies, and frequently select one that rates well, even though the price of the milk may be a little higher. Naturally this encourages the dairyman who is trying to do things right, and discounts the dirty and slovenly dairyman.

5. Is a valuable means of improving dairy conditions. Where it has been introduced it generally results in marked improvements being effected.

6. Is of great value to the inspector in pointing out conditions and making it impossible for him to overlook any point of importance.

7. Is of value to the milk dealer in assisting him to locate the better dairies, thus making it easier to secure a supply of milk to meet the demand made upon him for a good product.

The score-card system, in its application to this country, must be considered from two points of view—(*a*) As an administrative agency without publication of the scores; (*b*) as an administrative agency with publication of the scores.

(*a*) As a means of administratively recording the condition of cow-sheds and dairies, keeping the inspectors up to their work, and ensuring that essential details are not overlooked, score-cards are most useful. Indeed their chief difference from the forms of recording used in the better-administered districts in this country is in the fact that numerical scores are given for each condition, instead of the results of the inspection being embodied in writing. The numerical score method is advantageous, but from its very facility is liable to error on the part of an incompetent or careless inspector. Also, unless all the inspections are carried out by the one man, scores will not be strictly comparable, as standards of efficiency vary greatly. On the whole, however, the use of score-cards as an administrative method of marking and recording the condition of dairies is to be strongly recommended.

(*b*) The distinctive and essential feature of the American score-card is really its publication (however carried out), and most of the improvements which have been effected by its use appear to be due to the stimulus of publication. The farmer improves his cow-sheds and his methods because low marks are prejudicial to him commercially. Eastwood,[1] who studied the system at work in America, writes, in reference to the system in Ithaca:

> The scores are published periodically in the local paper, are keenly discussed, and stimulate the rivalry of the farmers. The prospect of scoring more marks will induce a farmer to keep his cows clean, clip the hair about the udder, and attend to other details, far more effectively than discussions of bacterial content or the general requirements of a pure milk supply. The special feature of the system is that it stimulates improvement by voluntary enterprise and without resort to coercion. When the inspector knows his business, and gains the confidence of the farmer, he rarely has to resort to the threat that the licence will be withdrawn unless improvements are effected. The farmer endeavours to reform because a bigger score means an increase of his reputation amongst his neighbours, and a possible expansion of his custom.

The publicity of the marks scored is, however, alien to the way public health work is carried out in this country. The whole framework of our administrative work is based upon the fact that the results of inspections, etc., are private between the inspector, his superior officers, and his authority, and only

[1] *Report to the Local Government Board*, 1909, p. 72.

become public, and that to but a limited degree, when coercive measures are demanded and sanctioned by law. If English inspectors were to work on the basis of their findings being public property it would cause much resentment and friction, as well as restriction of sources of information now available.

The principle of the publication of the individual scores has much to commend it, and the result would doubtless be very beneficial in effecting marked improvement in present milk conditions, but it is extremely doubtful whether it will be possible, or even politic, to introduce what amounts to a drastic alteration in the basis upon which public health administrative work is carried out in this country. The publication of scores might also render the local authorities liable to legal actions if they published particulars of score-cards which were inaccurate.

V. Special American, etc., Regulations

American city regulations for the control of milk are, in general, much more drastic and stringent than those in force in this country. The fundamental basis upon which they are worked is the permit system, and while the actual regulations vary considerably, underlying them all, as Eastwood[1] points out—

> There is the general principle that the local authority has the right and the duty of defining the conditions under which milk may be sold without danger to the public health, and of prohibiting the sale, within the area over which it holds authority, of milk not satisfying these requirements. As these requirements include provisions that the milk, from its source to its destination, shall not be exposed to conditions liable to render it unwholesome as food, a powerful control is indirectly exercised upon the producer living outside the district, since he cannot obtain a market within the district for milk not satisfying the local regulations as regards its production and handling.

The actual regulations made may not be, and frequently are not, more stringent than those which may be obtained and enforced in this country under the Dairies, Cow-sheds, and Milk-shops Orders. The difference is the added power given

[1] *Report to Local Government Board*, 1909, p. 28.

to enforce them by the system of permits, which may be withdrawn if the regulations are not properly complied with.

The Chicago regulations, for example, contain the following, in regard to licences for milk-sellers:

Rule 2. *Inspection and Investigation of previous Record.*—No application for licence shall be approved by the Commissioner of Health after May 1, 1908, if the records of the milk division show that the depot, store, or any part of the establishment in which the business is to be conducted is in an insanitary condition. If the applicant's record is not on the file in the office, or if he is newly engaging in the milk business, an inspection of his place shall be made within five days after making the application, to determine the sanitary conditions. No application for licence shall be approved if applicant has a bad record. The applicant, if refused a licence on account of bad sanitary conditions, or for repeated adulterations of milk and cream, may make application to the Commissioner of Health for a hearing. The Commissioner of Health may then recommend the applicant for a licence, if he is satisfied that the regulations of the department will be complied with in the future.

Rule 3. *Revoking of Licence.*—If at any time after the granting of such licence the holder fails to comply with the sanitary regulations of the department, or repeatedly sells or offers for sale, or has in his possession for the purpose of selling, milk and cream below the grade prescribed by the ordinances or rules of the Department of Health, the Chief Food Inspector shall recommend to the Commissioner of Health that his licence be revoked with or without further notice. Said Commissioner of Health may grant the defendant a hearing, if he deems this necessary.

Rule 4. *Re-issuing of Revoked Licence.*—If all the regulations of the department have been complied with the Commissioner of Health may recommend that the licence be re-issued.

Rule 5. *Licence Exhibited.*—Every milk dealer shall post his licence in a conspicuous place on the premises for which it has been issued.

Taking Chicago as an illustration, while the regulations as to the care of the milk in the city are not strikingly different from those in force in this country, considerably greater power than is permitted in England is exercised over the entrance of unclean milk into the city from farms outside the city area. Very similar regulations are in force in other American cities. As Eastwood and others have pointed out, it has not been always possible to compel compliance with all the regulations enacted, and sometimes the actual regulations enforced are considerably less than those which on paper are operative.

It cannot, however, be doubted that the permit principle, with revocation of licence if unsatisfactory, is a powerful lever for bettering the present-day milk conditions. An annual charge should be made for the licences, and this and other fees would be available to balance or at least diminish the cost of milk-inspection and bacteriological examination.

The most extreme example of municipal control over the milk supply with which the writer is acquainted is in connection with the city of Wellington, New Zealand, a city with a population of 76,390. The powers available are contained in the Wellington City Milk-supply Act of 1910. This Act is the outcome of a valuable report in 1909 by Dr. Frengley, the city District Health Officer, and to whom the writer is indebted for copies of the Report and Act. At the time of writing, the powers given in the Act were about to be exercised. The Act gives, among other things, the following powers:

1. Power to the City Council to establish within or adjacent to the city a milk-station for testing, treating, and distributing the milk supply of the city.

2. To buy and sell milk, and to sell cream, and to manufacture and sell butter and other milk products, and ice.

3. Generally to carry on the business of a dealer in milk and butter.

4. Subject to the provisions of this Act relating to milk brought into the city by road, it shall not be lawful, so long as such milk-station is available for testing milk, to receive for storage or for sale, sell, offer, or expose for sale in the city, milk which has not been tested and passed at such milk-station.

Notwithstanding anything hereinbefore contained, milk may, while a milk-station is available as aforesaid, be brought into the city by road and there sold subject to the following conditions:

(*a*) That such milk is delivered to the consumer within four hours from the termination of the time of milking:

Provided that during the period in any year commencing on the fifteenth day of March and ending on the thirtieth day of November, where sufficient and suitable means of storage are available on the milking-premises, the milk collected at the evening milking may be delivered to the consumer within four hours from the time of being removed from such storage, being in no case later than four hours after the time within which the milk collected at the next succeeding morning milking is required to be removed :

(*b*) That any person supplying milk as set forth in subsection (*a*) hereof shall keep an exact record of the milk obtained by him at his dairy, and of the milk sold by him in the city, and shall from time to time furnish to the Council returns in the prescribed manner and form, verified by a statutory declaration, showing how much milk he has from time to time sold :

(*c*) That any person so supplying milk shall from time to time, and not less than once in any week, furnish samples of milk to the milk-station, or to an inspector for testing at the milk-station :

(*d*) That no person shall sell milk in the city pursuant to the provisions of this section unless he is the holder of a licence granted for that purpose under by-laws made by the Council.

5. (1) No milk shall be passed at the milk-station which does not come within the definition of or reach the standard prescribed by the regulations made under the Sale of Food and Drugs Act, 1908.

(2) If any milk tested be found by the responsible officer in charge of the milk-station to be unfit for human consumption it shall be destroyed or disposed of as the Council may think fit, but no such milk shall be sold or used for human consumption.

(3) If, on testing, any milk shall be found not to reach the specified standard, but to be in no other way unfit for human consumption, it shall be separated. The cream shall be the property of the owner of the milk, and the balance of the milk shall be destroyed or disposed of as the Council shall think fit :

Provided that, in the absence of evidence of skimming or watering, any milk in which the percentage of butter-fat is found to be less than three point twenty-five, but not less than three, may be delivered by the responsible officer in charge of the milk-station to the vendor, if accompanied by a written statement giving the actual percentage of butter-fat found.

6. The Council may, subject to the approval of the Minister of Public Health, fix fees and charges for testing the milk, bottling, storage, etc.

Geographical considerations allow the milk-station to be in such a position as to capture all the milk on its way to the city. This would be a difficult matter for many English cities.

Dr. Frengley estimates that the municipal milk-station will safeguard the chemical composition, and freedom from preservatives, ensure clean milk only being sent into the city, prevent initially insufficiently cooled milk being sent into the city, enable outbreaks of milk-borne infectious diseases to be traced, and ensure that only milk certified as to standard and quality shall be distributed to milk-vendors or householders.

CHAPTER XX

ARTIFICIAL METHODS FOR THE PRESERVATION OF MILK

It is a matter of common knowledge that milk will not keep fresh for any length of time. Scientifically this has been shown to be due to the fact that milk (as has been abundantly demonstrated in earlier chapters), as produced at the present day, is heavily contaminated with bacteria, and that such bacteria multiply rapidly in milk. The products of the bacteria spoil the milk. Added to this we have the fact that under modern conditions some delay is inevitable between the collection of the milk and its consumption, and in the case of large cities this interval may have to be many hours.

The utility if not the necessity of using some artificial method for the preservation of milk is therefore widely recognised. All such methods may be included in the following groups:

I. Refrigeration.
II. Sterilisation.
III. Pasteurisation.
IV. Addition of chemical preservatives.
V. Condensation and drying.

Each procedure requires to be considered from the following points of view:

(*a*) Its efficiency to attain the object aimed at.
(*b*) Any prejudicial effect upon the milk as an article of human food.
(*c*) Its influence upon the price at which the milk can be supplied.

I. Refrigeration

The scientific facts which bear upon this question have been discussed in Chapter IV. In that chapter it was shown that at temperatures ranging from freezing to blood-heat the higher the temperature of the milk the more rapid the multiplication of the contained bacteria. It may be concluded from the figures there given that if samples are kept at 0° C. for reasonable periods (*i.e.* not more than forty-eight hours) no increase in the number of bacteria takes place. Even if kept at 10° C. no marked increase takes place within twenty-four hours. Refrigeration can therefore be made efficient.

There is further no evidence that any prejudicial effects upon the digestive properties of the milk result by refrigeration.

Cooling the milk even to 0° C. does not diminish any bacterial harmfulness it may possess; it will not, for example, injure pathogenic bacteria; but it prevents the increase of toxic properties by preventing the multiplication of bacteria already present and the production of their toxic products. It is obvious, therefore, that the place of cooling should be at the farm and not when it reaches the purveyor. The latter may have to cool the milk for his own protection, but he is merely preserving what may already be a damaged product from deteriorating still further.

The cost will depend upon the facilities for obtaining ice, the degree of cooling required, etc. Types of milk coolers are described on pages 288 and 289.

As regards the cooling of milk as a method of artificial preservation, summing up the matter, it may be said that it is efficient and harmless and by far the best available method. The degree of efficiency attained will depend upon the temperature adopted. For practical purposes 10° C. is a convenient temperature and one sufficiently efficient. The extent to which it can be used need only be governed by the question of cost and its influence upon the price of the vended article.

II. Sterilisation

The term "sterilised milk" has two meanings, the scientific and the meaning of the trade. To the bacteriologist sterilised milk means milk which is sterile, that is, free from bacteria or their spores. As used in the milk trade "sterilised milk" means milk which has been heated to a temperature which it is hoped has killed the bacteria present. Like so many trade expressions it does not mean what it says, or if it purports to mean it, it is not true.

Bacteriologically sterile milk can be obtained, indeed it is obtained every day in the bacteriological laboratory, but to obtain it means either heating the milk to a temperature above boiling-point sufficient to kill all spores within the time of exposure, or keeping it at 100° C. for short periods on several successive days. Neither of these procedures is applicable for trade purposes since the appearance and taste of the milk are thereby adversely affected. Indeed, the man who would sterilise milk commercially has a difficult problem to solve, since the heat which is to kill the bacterial life must yet be insufficient to alter materially the taste and appearance of the milk.[1] The latter usually is attained at the expense of the former, and "sterilised milk" which is sterile is a rarity. This fact has been demonstrated by a number of investigators who have studied commercial "sterilised milk." For example, Flügge's[2] work led him to the conclusion that most of the so-called sterilised milk on the market was not sterile. He divided the bacteria isolated by him into three groups; and to one group, which he called the peptonising bacilli, he ascribed prejudicial effects, since they caused diarrhoea when fed in milk to young dogs, and were pathogenic to mice, guinea-pigs, and rabbits when injected subcutaneously or intraperitoneally. His results as to the pathogenic properties of these heat-resisting organisms have not been confirmed by other investigators.

Weber[3] examined 150 samples of sterilised milk from Berlin shops and found only 54 per cent sterile. Although he isolated and described eighteen species of "peptonising" bacilli he could not confirm Flügge's feeding experiments, and only considered this group as possibly harmful by setting up fermentative changes in the milk.

[1] His problem is analogous to that of the manager of a sewage farm who has to treat the sewage on the land to purify it, while at the same time he is supposed to farm the land profitably and take off good crops. Subordination of the sanitary to the commercial usually results in both cases.

[2] *Zeit. f. Hygiene*, 1894, vol. xvii. p. 272.

[3] *Arbeit. a. d. Kaiserl. Gesundheitsamte*, 1900, vol. xvii.

The writer[1] in 1902 examined 33 samples of "sterilised milk" bought in Cardiff dairies and found only 17 (or 51 per cent) sterile.

Robertson and Mair[2] examined milk sterilised in bottles and supplied to infants by the Leith Corporation from the Infant Milk Depot. They examined 90 samples, finding only 14 (or 15 per cent) sterile. They concluded that the reliability and safety of the milk depended largely upon the temperature at which it was kept afterwards.

Lubenau[3] concluded that the *Bacillus peptonificans* was the cause of an epidemic of gastro-enteritis, but the evidence he adduces is most inconclusive. In ordinary milk this group of bacilli are present, but are overgrown by the ordinary lactic acid bacilli.

The bacteria left in boiled milk are of two classes—anaërobic and aërobic spore-bearing bacilli. From the evidence it would appear that no very harmful effects are to be anticipated from these groups of bacilli, if boiled, or commercially sterilised, milk is consumed within a reasonable period of preparation, or if kept cooled meanwhile. Certainly all sterilised milk should have the date on which it is prepared stamped upon it. It must also be put up in bottles with proper stoppers. For practical purposes it is necessary for the stopper to be attached to the bottle, otherwise it is certain to be lost, while a fresh rubber ring should be used each time. Fig. 33, p. 296, illustrates the ordinary type of bottle or stopper used.

Ordinary *domestic boiling* of milk is allied to commercial sterilisation, and may conveniently be studied here. Here the temperature does not reach 100° C., indeed it rarely exceeds 97° C. owing to the milk "boiling" and frothing over when that temperature is reached.

As regards the efficiency of domestic boiling of milk to kill pathogenic bacteria, it would appear, from a consideration of the thermal death-points in Chapter IV., that it may be relied upon to kill pathogenic bacteria, including *B. tuberculosis*, particularly if the heating up be done slowly. It is a pro-

1 *Annual Report 1902, Cardiff and County Public Health Laboratory.*

2 *British Medical Journal*, 1904, vol. i. p. 1122.

3 *Centralbl. f. Bakt.*, Abt. Orig. I. xl. p. 433.

cedure, therefore, which makes the milk bacterially safe to consume.

There is, however, another and a very important side of the problem which is still a very debatable one. This is a chemical and physical matter, and may be put in the form of the question,—Is cooked milk inferior to raw milk as regards digestibility and nutritive properties, and is it liable to cause or lead to human disease because it has been boiled?

The Changes which occur when Milk is heated.—The actual changes which occur are influenced by two factors—the duration of the exposure to heating and the actual temperature attained. When milk is boiled the following are the essential changes which result. A skin forms on the surface when the heating is done in an open vessel, the pellicle consisting mainly of lact-albumen. Its formation commences at a temperature between 60° and 70° C. This surface pellicle does not form if the milk is heated in a closed vessel. Carbonic acid gas is expelled, and the calcium and magnesium salts are precipitated. The precipitation of the calcium salts makes the casein in the milk less easily coagulated by rennet. The lecithin and nuclein are also said to be decomposed. The normal emulsion of the fat globules is disturbed so that the cream does not rise. The lactose is partially burnt (caramelisation), the milk becoming brownish in colour. The milk acquires a peculiar taste, which is marked in boiled milk, especially if carried out in an open vessel, but which is also noticeable in milk heated to 70° C. Boiling also kills the ferments in the milk.

According to Kastle the ferments in milk, or most of them, can withstand a temperature ranging from 60° to 65° C. for some time without material injury. Between 65° and 70° C. most of them are weakened in their activity, and between 70° to 80° C. all of them are destroyed even after relatively short exposure. In addition to these changes the germicidal power of the milk is lost, or almost completely so, by boiling. The essential bacterial change is that almost all the bacteria are destroyed, those left consisting entirely of sporing forms and certain highly resistant varieties.

The effects of these by no means inconsiderable changes produced by heat have been much discussed as regards their influence upon the milk as a food for infants.

The subject has been submitted to direct experiment. A considerable number of animal experiments have been carried out, but since deductions from them to human feeding cannot be accepted as altogether reliable, too much stress cannot be laid upon them. On the whole they show no evident differences as regards digestibility and nutritive value between raw and cooked milk. As illustrating the kind of investigations made the following may be mentioned.

Brüning[1] used litters of newly-born animals, feeding part with raw and part with boiled milk. When the milk of another species was used better results were obtained with boiled than with raw milk, but when the animals were fed on raw milk of their own species they did better than those receiving it cooked. He experimented with pigs, dogs, rabbits, guinea-pigs, and goats.

Lane-Claypole[2] experimented with young rats, starting her experiments with these animals when they were, as nearly as possible, a fortnight old. Her careful investigations showed no diminution in nutritive properties for rats when the milk was boiled, or even when evaporated and dried at 120° C.

Some experiments have also been carried out on comparative lines with children. Koplik, for example, fed infants with raw and cooked milk, estimating the nitrogen in the faeces. He apparently did not also estimate the nitrogen in the urine. On the whole his experiments showed that the percentage amount of nitrogen unabsorbed was practically the same whether the milk was pasteurised or sterilised, but that the percentage unabsorbed was rather less with raw milk. Finkelstein[3] carried out experiments with healthy infants, on sick children, and on small ill-developed children. He found no superiority for either raw or cooked milk, since neither the progress of the healthy children nor the recovery of the sick were apparently influenced by the kind of milk.

From the clinical point of view, results being based upon the general development of the infants and not upon exact chemical data, very diverse opinions have been expressed. On the whole, it would appear, taking all the facts into considera-

[1] *Zeit. für Tiermed.*, 1906, pp. 198, 277.

[2] *Journ. of Hygiene*, 1909, ix. p. 233.

[3] *Therap. Monats.*, October 1907, p. 508.

tion, that there is no satisfactory evidence to show that cooked milk is either less easily digested or less easily absorbed from the intestine than raw milk. The loss of nutritive value by heating is also negligible.

In addition to nutritive and digestive alterations it has frequently been contended that boiling or otherwise cooking milk deprives it of its antiscorbutic properties, and that such milk is a cause of infantile scurvy, rickets, and other conditions of mal-nutrition.

It is difficult to find definite evidence in favour of such an assumption, and the case seems to mainly rest upon rather vague assertions based upon clinical experience which is not submitted in any concrete form. On the other hand, the opponents of any such connection are able to point to an immense number of children systematically fed on sterilised milk without any prejudicial effect being detectable. For instance, at the dispensary of La Goutte de Lait de Belleville a very large number of infants have systematically been fed upon sterilised milk under Variot, and he is entirely in favour of the view that the nutritive and assimilative properties are not appreciably affected, while no cases of rickets or infantile scurvy have been observed.

Since boiled milk is deprived of its ferments it may be prejudicial if used as the sole form of food for infants, but this has yet to be proved, and at the most is only likely to be true of sterilised milk kept for some time. In the absence of proof to the contrary it would seem that there is no detrimental effect likely to be manifested in infants fed on cooked milk either as regards diminution of nutrition or the development of disease, while the safety conferred by such a procedure from the elimination of possibly dangerous bacteria is very great.

III. Pasteurisation

There has been a good deal of discussion as to the efficacy of pasteurisation, much of which has arisen from the lack of definition as to what is meant by the term, processes differing considerably in their practical results all being included as pasteurisation processes.

Pasteurisation dates from some experiments of Pasteur upon the diseases of wine and beer, and the temperature of heating necessary to preserve them from abnormal fermentation. Soxhlet in 1886 advocated the application of the same principles to milk. The term, as practically applied to milk, is taken to mean the heating of milk for a limited period, to a temperature short of the boiling-point. The temperature advocated has never been below 60° C. and has been as high as 90° C., and the time for heating has varied from so short a period as one to two minutes to as long as one hour.

In view of this looseness of meaning it is well to define exactly what is meant when the term "pasteurisation" is used.

The best temperature and exposure time for pasteurisation can only be arrived at when the exact objects of the process are considered. Pasteurisation is, or should be, a makeshift arrangement, to render milk which has been or which may have been bacterially polluted, safe for consumption, while at the same time not depriving it of any of its valuable properties. Put scientifically it means that the temperature of the milk, and the period during which it is maintained at that temperature, must be, on the one hand, sufficient to kill all harmful organisms which may possibly be present, while, on the other hand, the heating must not damage the milk as a food.

Two types of pasteurisers are on the market. In the one—*continuous-flow* (*or flash*) *pasteurisers*—the milk is heated to a certain temperature but only for a moment; while in the other—*retainer pasteurisers*—the milk is heated to a lower temperature, but is kept at that temperature for a definite and much longer period, for example 30 minutes.

Of the two types of pasteurisers the "retainer" type would seem to be the best from the hygienic point of view, while the continuous-flow or flash pasteuriser is the more convenient for trade purposes, since it allows a greater quantity of milk to be treated in a given time than in the other kind.

Ayers and Johnson from their work conclude :

> The "holder" process of pasteurisation is superior to the "flash" process. With the "holder" process a high efficiency may be obtained with a low temperature, while to obtain the same efficiency with the "flash" process a high temperature would be required. A temperature of 62·8° C. (145° F.) for thirty minutes seems best adapted for pasteurisation.

In Fig. 35 is shown an illustration of a good type of pasteuriser of the retainer pattern.

The thermal death-points of the different bacteria likely to be present in milk are considered in Chapter IV. The tubercle bacillus is the most important organism to kill, and

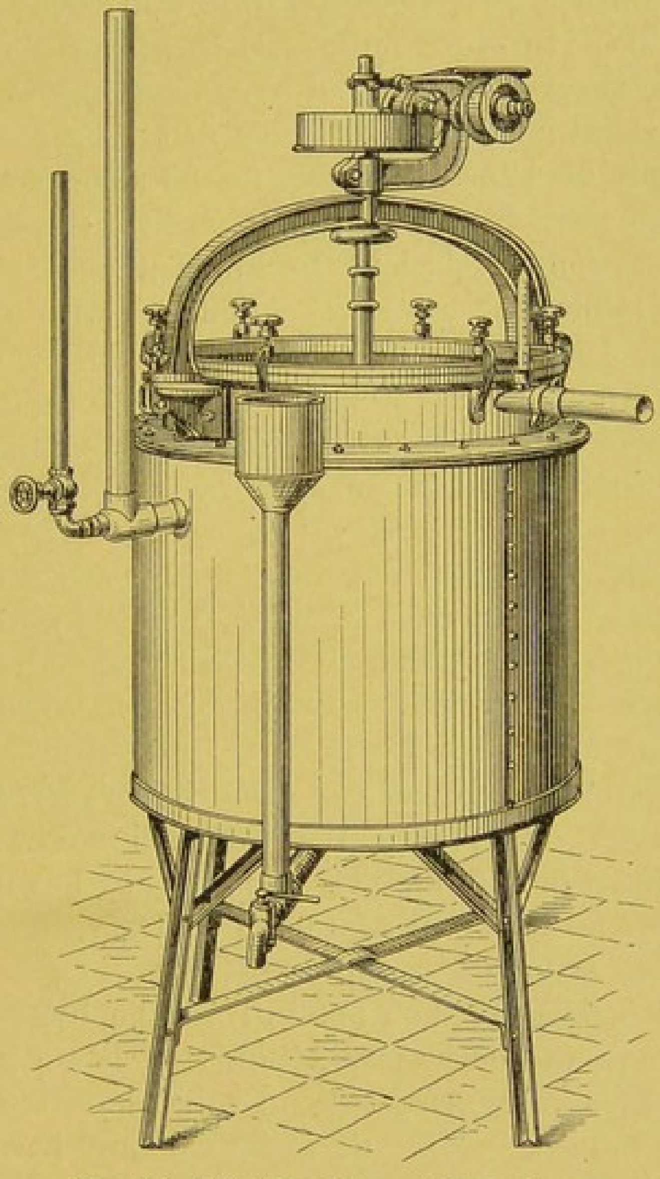


FIG. 35.—"Retainer" type of Pasteuriser.

being more resistant than the others, the temperature and time exposure which will kill this bacillus may be taken as the standards for practical purposes. From the experiments recorded in Chapter IV. it would seem that an exposure to 71° C. (160° F.) for one minute or to 60° C. (140° F.) for 20 minutes is sufficient. Since, however, as pointed out in that chapter, there is not complete agreement as to these thermal death-points it is better to err on the safe side, and for practical working higher temperatures are recommended. Temperatures of 77° C. (for continuous-flow pasteurisers) and 65° C. for 20 minutes are probably safe temperatures.

The Danish law (Appendix III. p. 430) selects 80° C. as the temperature to which milk must be heated. The Chicago regulations enact "milk from cows reacting to tuberculin shall be rejected unless it shall have first been pasteurised at a temperature of 175° F. or over for 30 seconds or longer in a stream not more than a quarter of an inch thick."

Pasteurisation is efficient to kill pathogenic organisms, will vastly reduce the bacterial content, and within limits will increase the keeping qualities of milk. On the other hand, there are a number of weighty objections to its use as a routine procedure which must be considered.

(1) While pasteurisation destroys the majority of the bacteria present we have no certain evidence that it destroys their toxins. The process is but rarely carried out on the farm, so that, in general, the bacteria will have had many hours in which to produce their toxins. Some toxins, such as those of the meat-poisoning bacilli, are very heat-resistant, and although the toxins likely to be present in milk may be killed at the temperature of pasteurisation, we have no certain evidence upon this point. We do not know whether the toxins produced in milk are prejudicial or not, but it is reasonable, in the absence of proof to the contrary, to assume that some of them may be harmful.

(2) Pasteurisation does not kill all the bacteria in milk but only most of them. By killing the lactic acid bacilli, which are themselves harmless and which have a considerable restraining influence upon the growth of any harmful bacilli which may be present, it has been suggested that such milk is likely to develop decidedly toxic properties when kept.

This view arose out of Flügge's work already mentioned (p. 373), work which, however, cannot be altogether accepted at the present day. If all the lactic acid bacilli are destroyed it is probable that the spore-bearing forms will more rapidly develop and produce their products, but it is not clear that such products are toxic.

In this connection Ayers and Johnson[1] have carried out a number of very interesting experiments which deserve close attention. They made careful comparison of the bacterial content of commercially pasteurised and raw market milk, both when fresh and on each successive day as long as the milk was fit for consumption. By commercial pasteurisation they mean milk heated from 60° C. to 65·6° C. in the "holder" process, or up to 71·1° C. in the "flash" process. They tested both types of pasteurisers. They divided the organisms present in the milk samples into three groups—peptonising, lactic acid, and alkali or inert bacteria. Under *peptonising bacteria* were classed all forms which liquefied gelatin. All bacteria that gave red colonies with litmus were classed under the head of *lactic acid bacteria.* In the group called *alkali formers* or *inert bacteria* were classed all those forms which do not noticeably produce acid or liquefy gelatin. The total counts and percentages of the different groups were as far as possible carefully worked out.

The following were the main results obtained by these workers. They found that the relative proportion of the groups of peptonising, lactic acid, and alkali or inert bacteria was approximately the same in efficiently pasteurised milk and in clean raw milk. In both cases the alkali or inert forms constituted the largest group, the lactic acid bacteria next, while the peptonisers were in the minority. When both of these milks—the efficiently pasteurised and clean raw milk—were stored, the group relations changed; but when the changes which took place were compared, it was found that they were the same in each. At the time of souring, the group proportions changed, so that the lactic acid bacteria constituted the largest group, with the alkali or inert forms next in order, while the peptonisers, as initially, were in the smallest proportion. In both of these classes of milks the group of peptonisers sometimes increased slightly in its proportion to the other two groups during the first few days, but then gradually decreased and always formed the smallest group.

Even with inefficiently pasteurised milk and dirty raw milk the peptonisers formed the smallest proportion of the total

[1] *Bulletin No. 126, U.S. Department of Agriculture, Bureau of Animal Industry*, 1910.

bacteria. The number of peptonisers in a good grade of commercially pasteurised milk on the initial count and on succeeding days was found to be approximately the same as in a clean raw milk when kept under similar temperature conditions.

Contrary to the views generally expressed, the authors found that lactic acid bacilli were always present after pasteurisation. They found that commercially pasteurised milk always sours because of the development of certain lactic acid bacilli, which, on account of their high thermal death-point, survive pasteurisation, and perhaps in some cases because of subsequent infection with acid-forming bacteria during cooling and bottling. They found that when milk was heated for 30 minutes at 60° C., on an average about 4·8 per cent of the total acid colonies resisted the heating, when heated to 65·6° C. about 0·74 per cent survived. The authors consider that these heat-resisting lactic acid bacilli play an important rôle in pasteurised milk. They also found that the total bacterial increase in an efficiently pasteurised milk and a clean raw milk was about the same when the samples were kept under similar temperature conditions.

(3) While these experiments fail to support the view that the bacteria surviving pasteurisation are more toxic in kind, and produce harmful products in stored pasteurised milk, they do not refute the possibility that if pathogenic bacteria gain access to a milk *after* pasteurisation, they are likely to more abundantly multiply in such milk than in ordinary raw milk. Since the bacterial content is so much less this is certainly likely to occur. This liability shows the great importance of rapidly cooling pasteurised milk, and the need for preventing any bacterial contamination of milk after pasteurisation. In illustration of this it may be mentioned that a number of food-poisoning outbreaks from ice-cream, brawn, etc., owe some, if not most, of their virulent effects to the fact that the food-poisoning bacilli, added subsequent to the partial cooking, have found themselves in an environment largely freed from competitive bacteria and heated to a temperature just suited to their growth.

(4) A further objection to pasteurisation is that although pasteurised milk will sour it sours much later, and so may be, and in practice probably often is, kept for a number of

days. Old, stale milk may be sold as fresh, owing to the removal of most of the lactic acid bacilli. Such milk will appear normal to sight and taste, but may be bacterially highly dangerous.

(5) If used without statutory control, there can be but little doubt that the extensive use of pasteurisation would lead to neglect of general sanitary precautions even more completely than is the case to-day, under the belief that the pasteurisation would be an efficient substitute for cleanliness.

(6) The pasteurisation may, by altering its chemical and physical composition, damage the milk as a commercial article and diminish its digestive and nutritive properties. The extent to which such changes take place will depend upon the temperature of pasteurisation. At 60° C. the milk appears to be physically or chemically unaffected. At 71° C. the milk is affected, and the cream will not rise properly. The influence of cooking milk upon its utility in infant feeding has been already discussed. Unless the pasteurisation temperature is a high one, there is probably no great objection to the process on this ground.

It is probable that much commercial pasteurisation is inefficiently done. It is a procedure involving an accurate adjustment of time and temperature, and frequently being left to be performed by careless and unskilled persons (the so-called "practical man") it is very unequally and inefficiently done. If pasteurisation is to be allowed at all, it should be controlled both as regards methods and apparatus.

In the writer's opinion, summing up the matter, pasteurisation is an efficient and useful procedure, which may be very valuable pending satisfactory and radical improvement in the milk business as a whole, but it is likely to be more harmful than beneficial unless the practice is rigidly supervised and the conditions under which it may be employed regulated.

IV. Chemical Preservatives

Chemical preservatives are added to milk to retard or prevent bacterial growth, so that the milk will keep in an apparently unaltered condition for a period considerably longer than if they were absent. The substances which have been added almost all exert a direct inhibitory action upon bacteria, but one of them (sodium carbonate), sometimes found in milk, is added not so much to check bacterial growth as to neutralise the acidity resulting from bacterial growth.

The preservatives most frequently added to milk are formaldehyde and boric acid or one of its compounds. Preservatives occasionally added are benzoic acid, salicylic acid, acid potassium fluoride, sodium carbonate, and hydrogen peroxide.

As regards efficiency there is no doubt that by the use of chemical preservatives the development of bacteria can be retarded or even absolutely inhibited. It is merely a question of dosage. As actually used in milk, preservatives are employed not to inhibit all bacterial growth, but to retard it so that the milk will keep good for a further period of 12 to 24 hours. The quantities of preservative necessary to do this have been studied by several workers, chiefly in regard to boric compounds and formalin. Richmond[1] gives the following table:

Table of the Length of Time in Hours that Milk will keep at various Temperatures when Preservatives are added.

Temperature.	Preservative added to Milk.					
	None.	Boric Preservative.		Formaldehyde.		
		Per cent. 0·05	Per cent. 0·10	Per cent. 0·0023	Per cent. 0·0047	Per cent. 0·0093
	Time in Hours.					
F. 60°	50	84	110	60	100	140
70°	34	43	54	40	58	92
80°	22	26	36	29	40	66
90°	15	18	27	18	31	52
100°	9	12	23	11	27	44

It is assumed that milk turns sour when an acidity increase of 25 degrees has taken place (*i.e.* 100 c.c. of milk require 25 c.c. more N/10 soda solution to neutralise to

[1] *Report of Departmental Committee on the Use of Preservatives, etc., in Food*, 1901, p. 409.

phenolphthaline than when quite fresh). When the differences of time are calculated the following table is obtained:

Table of Additional Time which Milk will keep sweet when Preservatives are added.

Temperature.	Preservative added to Milk.				
	Boric Preservative.		Formaldehyde.		
	Per cent. 0·05	Per cent. 0·10	Per cent. 0·0023	Per cent. 0·0047	Per cent. 0·0093
	Time in Hours.				
F. 60°	34	60	10	50	90
70°	9	20	6	24	58
80°	4	14	7	18	44
90°	3	12	3	16	37
100°	3	14	2	18	35

Richmond adds: "It is assumed that to be of any appreciable use, preservatives should increase the "life" of the milk by 12 hours at 80° to 90° (hottest summer temperature), and on this basis 0·09 per cent boric preservative and 0·004 per cent formaldehyde are the minimum amounts necessary in summer."

Rideal,[1] taking 0·25 per cent lactic acid as the maximum acidity allowable, found that 1 : 2000 boric acid and 1 : 50,000 of formaldehyde kept milk sweet for the 23 hours of the experiment at as high a temperature as 24° C. (75·2° F.).

Price[2] found that formaldehyde added to milk in the proportion of 1 : 20,000 prevented the development of the more commonly met with bacteria in milk, and when added in the proportion of 1 : 1560 killed them.

It is not, however, satisfactory to take the amount of lactic acid produced as a reliable index of the bacterial changes taking place. It is quite possible, and does take place to a certain extent, that while the lactic acid bacilli may be inhibited other bacteria may be much less affected. For

[1] *Departmental Committee Report*, 1901, p. 400.
[2] *Centralbl. f. Bakt.* Abt. 2, 1905, xiv. p. 65.

example, Rothschild and Netter[1] concluded from their investigations that the addition of 1 : 10,000 formaldehyde retarded the lactic acid bacilli sufficiently for practical purposes, but that the increase of the other saprophytic bacteria and the pathogenic varieties is not sufficiently checked.

Chako, using the number of bacteria as the test, found that in milk containing 1 : 10,000 formaldehyde a slight diminution resulted during the first twenty-four hours, followed by a slow, then a very rapid increase in the germ-content. In milk containing 1 : 20,000 formaldehyde there was a slow diminution for the first twenty-four hours, followed by a rapid increase. In milk containing 1 : 40,000 formaldehyde the bacteria developed nearly as rapidly as in the control milk free from preservative.

The quantities of these preservatives actually found in milk show wide variations. They have usually been found to be markedly in excess of the amounts which experimental determinations have shown to be required to preserve milk for twelve to twenty-four hours. Thresh and Porter[2] give the following table, compiled from the Report of the Departmental Committee, showing the maximum and minimum quantities of boric acid which have been found by different observers in milk.

Authority.	Amount of Boric Acid in Grains per Pint.	
	Maximum.	Minimum.
Professor A. W. Blyth	80·0	...
Dr. W. Williams	26·2	1·7
Dr. J. R. Kaye	20·0	...
Mr. W. F. Lowe	20·0	6·0
Professor Thorpe	17·5	...
Dr. A. Hill	15·7	0·625
Mr. C. E. Cassal	12·6	2·4
Dr. E. Walford	9·2	0·35
Dr. J. S. Cameron	2·5	...

Thorpe compiled for the Departmental Committee a list

[1] *Revue d'hygiène et de méd. inf. ann. de la polyclinique H. de Rotschild*, 1905, iv. No. 4.

[2] *Preservatives in Food and Food Examination*, 1906, p. 102.

of trade preservatives, with the amounts recommended by the vendors to be added to the different foods. As regards boric compounds, the amounts recommended to be added to milk varied from 1·2 to 14 grains per pint. The number of preparations of formaldehyde sold under trade names was much smaller than for the boric preparations, while the addition recommended for milk varied from 1 : 32,000 to 1 : 82,000.

Whatever may be advanced in favour of the addition of preservatives to other foods, when added in definite and declared amounts, the consensus of opinion is overwhelmingly against their addition to milk. It is easy to understand why many milk vendors favour their employment. Their use converts a perishable article into a comparatively non-perishable one, allows surplus milk to be kept over until next day without loss and be sold as fresh milk, and enables the farmer and purveyor to neglect the necessary laws of cleanliness in production. They are a further source of economy in that they save the cost of cooling the milk. Preservatives are the friend of the filthy dairyman.

The essential objections to the addition of any preservatives to milk are the following:

(1) There is evidence that their consumption may be directly harmful. The preservatives commonly added to milk are admittedly prejudicial to the animal organism in large doses. Boric acid and borax are given definite doses in the British Pharmacopoeia. Obviously, then, the *onus probandi* is upon those who add them to food to prove that they are harmless in small and moderate doses. It cannot be said that their users have proved any such harmlessness; they have only failed to demonstrate deleterious effects in certain groups of experiments.

Very numerous investigations have been undertaken to test their effect upon digestion, their action upon the digestive ferments, and any prejudicial effects upon metabolism and the functions generally of the body. Space will not permit these investigations being discussed in detail, and the reader is referred to the Departmental Committee Report and to the Reports of the investigations themselves.

The generally accepted view is that while these substances may possibly not be injurious in all cases, or even generally, when ingested in small doses by the healthy adult, yet they are actually, or likely to be, hurtful to invalids and young children in the doses in which they have been frequently found in milk, particularly if administered over a long period.

The available data is a mixture of negative evidence of ill-effects and a smaller but still not inconsiderable volume of evidence of harmful results from their ingestion. In such cases positive evidence is of much greater value than negative, and from the whole it is justifiable to conclude that the addition of preservatives to milk, the food of infants and invalids, is totally unjustifiable.

It must always be kept in mind that the amounts found have frequently been far in excess of any possible requirements. The milk may be dosed by the farmer, the middleman, and the actual purveyor. The persons who handle milk are, for the most part, unscientific and incapable of adding precise and accurate quantities of preservatives, and in general add much more than is required.

(2) The action of preservatives upon bacteria is not a simple, general one, but is selective. It is possible to add preservative to milk in quantity sufficient to check lactic acid formation by inhibiting the lactic acid bacteria, while, at the same time, certain other bacteria, some possibly pathogenic, are not inhibited. This aspect of the subject has not been sufficiently investigated, but it is obviously theoretically possible for such milk to be exceedingly dangerous. The lactic acid bacilli are not themselves harmful, but visibly alter the milk. Remove the warning signal of their presence without inhibiting the other bacteria, and it is possible for a milk to be not visibly altered yet very stale, and containing very numerous bacilli and their toxins.

(3) Their addition is totally unnecessary, and is a direct incentive to dirty methods of milking and handling milk. There is abundant evidence that cleanly collected milk, properly cooled, requires no addition of preservative to enable it to keep in good condition all the time necessary for its transmission, sale, and use in the consumer's house. Richmond,[1] for example, remarks: "It has been found by the experience of the Aylesbury Dairy Company that by cooling

[1] *Departmental Committee Report*, 1901, p. 387.

as soon as possible after milking, the milk can, in the hottest weather experienced in England, be brought up by rail from distances from 30 to 300 miles from London, and be delivered to customers in a condition permitting its use within a reasonable time." Upon this point the Departmental Committee remark: "As to the feasibility of conducting the traffic in the largest towns without preservatives we have no doubt whatever."

The addition of preservatives allows milk to be collected under conditions of gross dirt and neglect, and yet to be protected from the natural result of these dirty methods—a rapid bacterial multiplication and a prematurely soured milk. As the Departmental Committee state:

> There is this further objection to the use of preservatives in the milk traffic, that they may be relied upon to protect those engaged therein against the immediate results of neglect of scrupulous cleanliness. Under the influence of these preservatives milk may be exposed without sensible injury to conditions which otherwise would render it unsaleable. It may remain sweet to taste and smell and yet have incorporated disease-germs of various kinds, whereof the activity may be suspended for a time by the action of the preservative, but may be resumed before the milk is digested.

The Departmental Committee made the following recommendations concerning milk and milk products:

> A. That the use of formaldehyde or formalin, or preparations thereof, in foods or drinks be absolutely prohibited.
>
> B. That the use of any preservative or colouring matter whatever in milk offered for sale in the United Kingdom be constituted an offence under the Sale of Food and Drugs Acts.
>
> C. That the only preservative which it shall be lawful to use in cream be boric acid or mixtures of boric acid and borax, and in amount not exceeding 0·25 per cent, expressed as boric acid. The amount of such preservative to be notified by a label upon the vessel.
>
> D. That the only preservative permitted to be used in butter and margarine be boric acid or mixtures of boric acid and borax, to be used in proportions not exceeding 0·5 per cent, expressed as boric acid.

The addition of preservatives to milk has markedly declined (or, at least, the addition of the commoner varieties of preservative) since local authorities have made a firm stand against their addition. The grounds upon which legal action can be taken are given in Chapter XVII. The following table, submitted by Dr. Hill to the Departmental Committee, illustrates the extent to which they were used in Birmingham up to 1899. From the reports of public analysts it would appear that they are much more rarely met with at the present day.

Variation in the Use of Preservatives in Milk in Birmingham.

Year.	Percentage of Samples containing			
	Boric Acid.	Formic Aldehyde.	Both.	Total.
1896 (April to Dec.)	8·3	...	...	...
1897 . . .	5·5	3·3	0	8·8
1898 . . .	3·1	6·7	0·4	10·2
1899 (Jan. to Sept.)	1·2	6·3	0	7·5

This table shows that the percentage prevalence of boric acid has declined and the formic aldehyde percentage increased. Such variations are partly the result of fashion, but are also largely due to the influence of successful prosecutions for the presence of the one preservative.

The Use of Hydrogen Peroxide in the Preservation of Milk.—The bactericidal action of hydrogen peroxide is well known, and its use to preserve milk has been tested by Chick, Rosam, Budde, and others.

Budde has introduced a method of treating milk on a commercial scale under the name of "Buddeised Milk." In this process the milk is heated to 122° F. (50° C.), and pure 3 per cent hydrogen peroxide is added, so that the milk contains 0·03 to 0·035 per cent of hydrogen peroxide. The mixture is well stirred for 15 to 30 minutes. It is then drawn into bottles with tightly-fitting stoppers, the bottles placed in a water-bath at 122° F. for 2 to 3 hours, and then cooled in cold water. The method is a combination of heat and chemical action. Hewlett and others have investigated the method and speak well of its effectiveness.

If hydrogen peroxide is left in appreciable amount in the milk, it imparts an unpleasant bitter taste, although it is probably harmless in the small quantity present. Another objection is that commercial solutions of hydrogen peroxide are not always free from arsenic or other impurities, and these substances may in this way be added to milk.

The process does not appear to be extensively used in this country, and if the contention of Rosenau is well founded that heating to 60° C. for 20 minutes is sufficient to kill all the pathogenic bacteria likely to be present in milk, it is decidedly preferable to heat to 60° C. for 20 minutes than to heat to 50° C. for several hours and also add hydrogen peroxide. A temperature of 60° C. is not more detrimental to the digestibility of milk or the contained ferments than is one of 50° C.

V. Condensation and Drying

Under this head may be mentioned two special methods, designed for the preservation of milk, the resulting substances being known respectively as condensed milk and dried milk.

Condensed Milk.—Condensed milk is prepared by concentrating either whole or separated milk, with or without the addition of sugar. Theoretically, therefore, there are four kinds of condensed milk, but the writer is not aware of any unsweetened separated brands. The four kinds are:

(*a*) Sweetened condensed whole milk.
(*b*) Unsweetened condensed whole milk.
(*c*) Sweetened condensed separated milk.
(*d*) Unsweetened condensed separated milk.

The condensation of the milk is usually carried out by evaporating the milk in vacuum jars under reduced pressure until sufficiently concentrated. In the sweetened varieties cane sugar is added before concentration. The separated milk variety usually contains more sugar (containing often as much as 40 to 45 per cent) than the whole milk. The milk is sold in hermetically sealed tins. In the unsweetened brands these, after filling but before sealing, are heated to a temperature of over 100° C. for some time.

It has been shown in Chapter XII. that while bacteria are present in condensed milk, the number present is relatively and actually low. The method of preparation is sufficient to eliminate most bacteria.

The use of condensed milk in this country would appear to be on the increase. Coutts[1] states that there are (1911) nine or ten factories in England and as many in Ireland engaged in this industry. Accurate figures are not available as to the total or the relative amounts of each, but Coutts thinks that about half are makers of machine-skimmed varieties. The imports of condensed milk into the United Kingdom show a steady increase. In 1895 they were 545,394 cwts., and in 1900 and 1901, 987,003 and 919,319 cwts. respectively. From 1902 to 1909 the importations were as follows:

Year.	Separated or Skimmed Sweetened.	Full Cream Sweetened.	Full Cream or Skimmed slightly Sweetened.	Condensed Milk not Sweetened.	Total.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
1902	307,984	554,389	5754	46,548	914,675
1903	323,877	547,567	3020	41,253	915,717
1904	365,543	497,551	1248	39,794	904,136
1905	374,560	483,960	1170	33,944	893,634
1906	458,675	421,180	3052	25,076	907,983
1907	458,980	428,936	1228	22,627	911,771
1908	475,108	407,690	1019	36,393	920,210
1909	507,304	436,035	370	47,669	991,378

In addition to its use by the ordinary consumer, condensed milk is used to some extent by milk purveyors to add to ordinary milk. In this connection Coutts (*loc. cit.*) remarks:

Considerable amounts of full-cream condensed milk, either unsweetened or only slightly sweetened, are imported in large tins. There is good reason to believe that a considerable amount of such milk is purchased by dairymen, who mix it with water to a suitable consistency, and utilise the product to expand their supply of ordinary milk. . . . The practice of mixing condensed milk with fresh cows' milk is said to be most prevalent in times of special shortage, when there may be a large demand for condensed unsweetened milk for this purpose, even small 1 lb. tins being bought, and occasionally even the fully-sweetened variety utilised. But apart from the difficulties caused by a shortage in the supply of fresh milk, there is reason to believe that some dairymen make a fairly constant practice of adding diluted condensed milk to genuine fresh cows' milk.

[1] *Report to Local Government Board*, New Series, No. 56, 1911.

Condensed milk is undoubtedly used to a large extent for infant feeding. In this connection the present regulations are not precise enough as to the necessity for the unmistakable differentiation of whole condensed and machine-skimmed condensed milk. The extensive use of the latter for infant feeding is partly due to this reason and partly to ignorance on the part of mothers.

Coutts makes a number of valuable recommendations, of which the following may be mentioned:

1. Tins of condensed skimmed milk to be required to bear, in a prominent and unobscured place, in letters of prescribed size, the words, "Skimmed milk—unfit for infants."

2. Prohibition of the use of any preservative, except sugar, in condensed milk.

3. Control over trade statements liable to mislead the purchaser as to the character, food value, or wholesomeness of the product sold.

4. Declaration of the content of milk fat and of added substances foreign to milk.

5. Some arrangement adopted for the systematic marking of tins so as to indicate the manufacturer or person responsible. If possible also the approximate date of canning should be indicated.

Dried Milk.—Dried milk is now manufactured commercially to a considerable extent. It is the powder obtained either by passing milk rapidly between heated surfaces so that it is deprived of its water, or by drying on a cylinder in a partial vacuum. This dry powder, on being again mixed with water, is converted into a fluid which looks like milk, and which, on ordinary chemical analysis, shows the chemical constituents of that substance. It is not, however, correct to speak of such a fluid as milk, since it has been considerably altered. The enzymes have been destroyed, the fat globules have been physically altered, etc. It is a highly nutritive, nearly sterile fluid, which may very possibly be in every way as good a nutritive food as milk, but this has not been proved.

Dried milk is prepared by several processes, and the experiments which have been carried out have shown that in all the methods the temperature is sufficient to kill the non-resistant bacteria, and the resulting powder is almost sterile. Tubercle bacilli appear to be killed. For example, Hoffmann[1] tested whether the Just-Hatmaker method would kill tubercle bacilli. He introduced tubercle bacilli into the liquid milk, and found that none remained alive in the dried milk, as shown by guinea-pig inoculation tests.

Both these methods of preserving milk are special procedures, and, as such, not comparable to the methods of preservation described above. The conversion of the milk into a tinned form, whether as a dry powder or a syrup, costs money, so that economically they are more expensive than milk.

These methods may be useful for special purposes, but cannot be practically applied to the milk supply generally, while, if practicable, their extended use would be undesirable on public health grounds.

Reconstructed Milk.—Dr. Buchanan,[2] in his Report on Foods, etc., to the Local Government Board, draws attention to the existence of a process for reconstructing milk after separation and concentration, which has lately been employed on a commercial scale at an establishment near London.

In this process, which is said to have considerable vogue in New York and other American cities, milk is separated, and the separated milk concentrated in a specially constructed receptacle at 140° F. (60° C.), while a current of filtered air is passed through the liquid. By concentration for $2\frac{1}{2}$ hours to 3 hours the separated milk is reduced to about one-fifth of its original volume. The cream is also exposed, for about an hour, to similar treatment. The concentrated separated milk and the cream are then despatched by road or rail to a town depot, at which they are mixed in any desired proportion with boiled tap water, and distributed in bulk or in bottles.

At the establishment in question, this reconstructed milk was stated always to contain at least 3·25 per cent of milk fat. Analysis of several samples confirmed this statement, and also the claim of the producers that, in consequence of the low temperature of concentration, enzymes are retained which are natural to raw milk but are destroyed in ordinary processes of pasteurising. On the other hand, bacteriological tests failed to confirm the claims of the producers that the milk was exceptionally free from bacteria, and that

---

1 *Archiv f. Hygiene*, 1906, vol. lix. p. 216.

2 *Report of Medical Officer, Local Government Board*, 1909-10, p. 211.

the process could be relied upon to destroy any pathogenic organisms which might have been present in the original milk. Bacterially the reconstructed milk closely resembled an ordinary raw milk of reasonable cleanliness.

Buchanan adds: "It seems desirable that when milk is prepared by this process, the product should be sold as prepared milk."

CHAPTER XXI

MACHINERY AND PROCEDURES TO OBTAIN A PURE MILK SUPPLY

In various chapters, particularly in Chapter XVI., existing defects in the conditions of milk supply have been pointed out, and the requirements of a pure supply indicated. Innumerable scientific papers condemning the existing state of affairs have been written. Health Congress after Health Congress has passed resolutions in favour of a cleaner and purer milk supply, and learned committees have considered the subject and framed admirable rules and regulations as to what is required. The practical results have been meagre. It is safe to say that the milk supply to-day is nearly if not quite as infected with tubercle bacilli as it was ten or twenty years ago. Milk as supplied may be a little less dirty and bacteria laden than it was ten to twenty years ago, but the average improvement has been trifling. Epidemics of infectious disease spread by milk are still regularly and frequently recorded in the scientific press. On the chemical side preservatives have been for the most part eliminated, but milk adulteration and cream abstraction is still very much with us; it is merely changing its character, and instead of being coarse and crude is becoming scientific and a matter of *toning*. Clearly the milk problem is not becoming any less of a problem, and our available legal enactments conspicuously fail to provide the consumer with pure milk. The present chapter is devoted to a broad general consideration of the administrative machinery and procedures required to obtain a pure clean milk supply.

In considering this problem of a pure milk it must be remembered that there are four separate requirements, and pure milk implies the following:

I. The whole milk of the cow without additions or abstractions, and free from physical alteration.

II. Milk derived from healthy cows, and, in particular, from cows free from tuberculosis.

III. Milk uninfected with specific disease-producing organisms such as those of diphtheria, scarlet fever, or typhoid fever.

IV. Clean milk—that is, milk so collected, transmitted, and vended that it is free, or reasonably free, from manurial or other objectionable pollution.

These requirements are quite different and distinct, and the procedures to obtain them are in the main different and distinct although they overlap.

I. To obtain Chemically Pure and Whole Milk

The law to ensure this is considerable (see Chapter XVII.), but an immense amount of discussion has taken place as to the justice of the Board of Agriculture standards. To the writer the following appear to be the salient facts and considerations bearing upon this question:

(*a*) The average quality of unadulterated milk in this country is well above the standards fixed. In other words, the chemical standards for milk are *low*. The average composition of milk as given in Chapter I. is: milk fat, 3·9; solids not fat, 8·9. On this basis the careful manipulator can abstract as much as one-quarter of the cream, or add to the milk about one-quarter of its bulk of skim milk, without infringing the standards. A low standard is clearly prejudicial to the consumer.

The evil effects of a low milk standard are enhanced by the great frequency with which ridiculously inadequate penalties are imposed in conviction cases, particularly where there are no stipendiary magistrates.

A simple mathematical calculation will illustrate the extent to which milk adulteration pays. Dealing with cream abstraction only, or its equivalent, addition of skim milk, and taking the average composition of milk to be only 3·5 per cent milk fat, which is below the usual amount, we will suppose the fraudulent milk purveyor merely tones his milk by reducing the fat to 3·0 per cent by the addition of skim milk. Obviously he can add one gallon of skim milk totally fat free to six gallons of milk with fat content 3·5 to bring its combined fat content down to 3·0 per cent. The average retail price of milk is 4d. per quart, so that on every seven gallons of milk he makes four quarts = 1s. 4d. less the cost of the separated milk.

To make the illustration concrete, it will be supposed that the fraudulent purveyor is trading in a provincial town such as Colchester with a population of 42,000 odd, and that he only supplies $\frac{1}{50}$ of the whole population. A reasonable allowance of milk is 8 oz. per head per day. This with the above population is equal to 16,800 pints per day = 2100 gallons. Supplying $\frac{1}{50}$ of this, the fraudulent dairyman will supply 42 gallons per day. It has been shown above that one-seventh may be separated milk without infringing the standard, so he sells 6 gallons of milk per day of separated milk at the price of milk = 8s. per day. In a year his illegal profit will be 365 × 8s. = £146, less the cost of the separated milk. This at 4d. per gallon would amount to (4 × 365 × 6) £36 : 10s., or at a liberal allowance £46. This gives a clear profit of £100 per annum.

In this particular town the Food and Drugs Acts are well enforced; $2\frac{1}{2}$ samples per 1000 of population (105 samples) are taken, of which 50 are milk samples. It is mathematically likely, therefore, that only one sample per annum would be taken from the fraudulent vendor, as he supplies only $\frac{1}{50}$ of the population. If his milk sophistication is done with care his sample will probably not infringe the standard, or if it is just below he will not be prosecuted, since prosecutions are not instituted when the fat is only just below 3·0 per cent. The present standards allow him to pocket the £100, and if he is a manipulative artist his risk is negligible. If, of course, he deliberately reduces the fat per cent to 2·5 by adding separated milk, his profit is over £200 per annum. On mathematical chances he would not have a sample taken for six months, so he would make a clear £100 before he was detected. Not infrequently some trumped-up story is accepted as mitigation of the offence, sometimes even condones it, and at the worst he usually is fined 10s. to 20s. Perhaps with costs it totals to

£4. Obviously milk adulteration is very profitable, while milk toning, if less lucrative, is safer and as remunerative in the end.

As showing that the present low standard is appreciated by the fraudulent milk seller the Annual Report of the Local Government Board for 1908–1909 may be quoted. 45,093 samples of milk were analysed during the year, and 4738, or 10·5 per cent, was reported as adulterated, or as failing to reach the minimal limits fixed by the Sale of Milk Regulations, 1901. In the four years 1905–1908 the proportion of milk samples reported as adulterated in England and Wales has three times been 10·5 per cent. The Report states that while the systematic milk adulteration practised thirty years ago has practically disappeared, judging by the numbers of samples which are reported as "poor," "very poor," or as just reaching the legal limit of 3 per cent fat, all of which have to be returned as genuine, the practice of robbing good milk of a large proportion of its cream, so that it may just escape condemnation by the public analyst, is on the increase.

A firm of milk and cream contractors lately represented to the Board that a systematic practice is growing up in the South and West of England of "toning" milk before it is despatched to London and other large towns. "Toning" consists of reducing the quality of milk so that it barely complies with the minimum limits prescribed by the Sale of Milk Regulations. The firm states that samples taken in December 1908, without notice, of the milk sent by nine farmers to one of their depots showed that the average fat in the morning and evening milks was 4·08 per cent, and that a large illicit profit can be made without risk when milk is thus systematically impoverished. Commenting on this, the Report observes:

> Some magistrates appear to consider the limit for fat fixed by the regulations as representing milk of average quality, and regard all milk coming within 5 or 10 per cent of that limit as passable. It must, however, be remembered that milk of good average quality contains more nearly $3\frac{1}{2}$ per cent of fat than the 3 per cent which has been fixed for the purpose of the regulations referred to.

The extensive prevalence of milk toning is also shown by the fact that the percentage of fat and solids found in ordinary vended milk closely follows the prevailing standards. In certain places the local authorities, by refusing to prosecute unless infringements are well below the standard, have practically reduced the standards for their districts with disastrous results to the unprotected consumer. Dr. Buchanan[1] gives a striking instance of this. In the borough of Middlesbrough it became the practice of the local authority to disregard the milk standards and not to institute legal proceedings against the vendor in any case where the sample of milk had a fat content of over 2·7 per cent. The proportion of milk samples infringing the legal standard for milk fat increased from 14 per cent in 1905 to 17, 30, and 35 per cent in the three following years. In 1909 the proportion was 32 per cent. "This progressive deterioration could not be attributed to alteration of methods of sampling, and had occurred notwithstanding the considerable energy which had be shown by the sampling officers of the local authority."

(*b*) A low standard, such as the present legal one, is undoubtedly prejudicial to the producer of high-class milk, and is an incentive to dishonest practices. The high-grade milk producer has to compete with milk vendors whose deliberately impoverished milk fetches precisely the same price as the high-class milk. By the use of semi-legalised practices the fraudulent milk vendor, while keeping within the four corners of the law, is in a position, owing to his enhanced profits, to undersell the honest milk producer and purveyor. The term "semi-legalised" is used, for while it is clearly an offence to add or abstract anything from milk, even if thereby the milk is *not* reduced below the legal limits, yet in practice the methods of chemical analysis are the only means of detection available.

(*c*) In a few cases, individually not numerous, and collectively, compared with the total, nearly negligible, the mixed milk of a herd of cows may and does fall below the legal standards as regards its chemical constituents. When such a condition exists it is usually for a temporary period only, and almost invariably is present at but one out of the two daily milking periods.

[1] *Report on Work of Food Inspectors, Annual Report of Medical Officer, Local Government Board*, 1909-10, pp. 210-211.

In another small group of cases the food supplied to the cows is so deliberately poor, the animals being fed on brewers' grain, etc., or given excessive amounts of water to drink, that the milk is below standard. These instances are excluded from consideration, as they are really cases of adulteration of the milk through the cow.

Apart from mixed milk it appears to be not uncommon for individual cows to yield at certain times, and at the morning milking, milk which is deficient in fat even to the extent of infringing the legal fat standard of 3·0 per cent. This deficiency in the milk of individual cows in a herd of any size is nearly always balanced by the rich milk of other cows, the mixed milk being well above the legal standards.

In the few cases of genuine failure of mixed milk to reach the legal standards the law appears to operate unfairly and prejudicially to the milk producer. The milk is adjudged to be adulterated, and unless the contrary is proved, an accusation of fraudulent practice confronts the innocent farmer or purveyor.

On the agricultural and trade side much is made of these few instances and the alleged hardship inflicted upon the milk trade. By bringing forward the same cases again and again they are made to appear much more numerous than is really the case.

The hardship is more apparent than real. The milk purveyor can get a warranty from the milk producer. The farmer knows or should know the legal standards, and it is his business to look after the quality of his milk in the same way as any other trader. He knows the time of year and other conditions when his milk may possibly be below average quality, while facilities are generally available at a low cost[1] (usually sixpence per sample) for him to have his milk analysed, while, if he prefers it, he can install his own milk-testing apparatus. Local authorities are always ready to withdraw a prosecution if the farmer demonstrates to them the naturally inferior quality of his milk.

To avoid any hardship to farmers the so-called "appeal to the cow" has been instituted in a number of places.

[1] Full particulars are given in Leaflet No. 146 of the Board of Agriculture and Fisheries.

When the sample analysed falls below the legal limits the milk producer is notified of the fact, and, with his permission, a mixed milk sample is collected from his herd at the same milking-time as when the deficient sample was obtained. If the mixed milk of the cows sampled at the farm falls below the legal standard, it is presumptive evidence that the deficiency is due to the cows and not to outside human sophistication.

There are a number of possible fallacies and sources of error which make this test less valuable than would at first sight appear. It is, for example, very important that the interval between the collection of the first sample and the taking of the second from the cows should be as short as possible. Otherwise the herd may have altered in composition by removal of some animals (running dry, by sale, etc.) or by the addition of fresh animals. This will be used as an argument that the samples are not comparable. Also, if the interval between the samplings is considerable, it will be urged that the feeding has been altered, the weather has changed, etc., and so, consequently, the samples are not comparable.

Further, there is room for deliberate fraudulent manipulation. One or more of the cows giving the richest milk may be temporarily removed and the fact suppressed, the interval between the previous milking and the milking for the second sample may be intentionally much prolonged; while, in particular, at the second sampling, many of the cows may be intentionally not milked dry, so that the strippings (very rich in fat) are not added. From all these causes a specially impoverished milk may be artificially produced and the cows be saddled with the blame. The writer does not believe that such practices are anything but rarities, but their possibility must be kept in view. It is not usually to the farmer's interest to proclaim his milk of poor quality.

Another source of error is that the sampling must be properly done, and that however carefully done the samples are really not comparable. A farmer does not, in general mix the milk of all his cows before sale. He fills one churn with the milk of four or five cows, then the next churn, and so on. The deficient sample will probably not represent the mixed milk of all his cows, and probably no one is in a position to say exactly which cows' milk it does represent. The inspector can only take precautions to ensure that what he collects as his second sample is the mixed milk of all the cows, as the nearest thing comparable. Food and drug inspectors are not used to taking representative mixed milk samples, and it is very necessary to give them precise directions how to collect them.

The writer has used the "appeal to the cow" test in a considerable number of cases in connection with his work as a Public Analyst. In no instance has he found the mixed milk on second sampling below standard, although in one case the percentage of fat was only 3·1. He invariably arranged for the second sample to be taken within three or four days of the first, and personally gave the directions as to sampling.

The above considerations lead the writer to the view that, if there is to be any alteration of the chemical milk standards, it should be rather in the direction of raising than lowering. The present low standard means a handicap to the high-class milk producer, considerable diminution of the nutritive qualities of the milk as supplied to the consumer, with prejudicial effect to the infant poor, and a heavy illicit profit to the ever-present "milk toner."

There is one alteration of procedure which should be carried out whether standards are altered or not. In all cases in which analysis has shown that the sample is below standard the person from whom the milk has been obtained should be, with as little delay as practicable, notified of the fact (without prejudice), and before any question of prosecution has been entertained. This would enable the milk purveyor to arrange for the mixed milk of the cows at the farm supplying the incriminated sample to be sampled. The local authority should afford facilities for this to be done with their supervision, and should give the services of their inspector for collecting the sample, but the actual cost of the analysis should be met by the milk purveyor, since it is for his protection. If the mixed milk is below the standard the local authority might remit this cost at their discretion.

If the purveyor of the deficient quality milk fails to avail himself of this means of protection from impoverished cows, after being supplied with full information, he should not be permitted to raise this plea in court.

It will be said that such notification of deficiency will be of no use to the large milk purveyor, since he cannot trace the particular herd supplying the defective sample. This is of small moment, since, while it has been pointed out that a few herds do occasionally yield sub-standard milk, it is never to be anticipated that the mixed milk of half a dozen herds will be so deficient.

It has been contended that milk should be sold priced according to quality like other articles. Theoretically this is sound, but in practice the difficulties are so great, owing to the natural variations in the chemical quality of milk, that it is impracticable. If, however, milk standards were raised, there would have to be provision made for allowing the sale of the small amount of genuine milk which was below the raised standard.

An alternative plan is to deliberately define milk as a fluid containing 3·0 per cent fat and 8·5 solids-not-fat to which nothing had been added. This would legalise the reduction of the quality of the milk to the legal standard. In some ways it would be fairer to the community generally and to the milk trade, but it would press unfairly upon the smaller purveyors and farmers. The big milk vendors with skilled staff could reduce to the legal limits to a nicety, while the small man would be unable to hit the happy mean between a profitable abstraction and an excessive but illegal removal.

II. Milk derived from Healthy Cows

This subject is of greatest importance in connection with tuberculosis, and that aspect of the subject is fully discussed in Chapter XVIII. There is considerable need for much greater veterinary supervision in connection with cows, although, as pointed out in Chapter XVIII., veterinary inspection alone will not go far in diminishing the danger from tubercle-infected milk.

III. Protection of Milk from Specific Contamination with the Bacilli of the Acute Infectious Diseases

As pointed out in Chapter XVII. the legal powers available for the protection of the public from this group of infections are contained in Article 9 of the Dairies, Cowsheds, and Milkshops Orders, Section 4 of the Infectious Diseases Prevention Act, and Sections 52, 53, 54 of the Public Health Acts Amendment Act 1907.

Article 9 is very useful, but has several limitations. For example:

(*a*) The term "dangerous infectious disorder" is indefinite. For instance, a person suffering from open phthisis should be included, but such an interpretation is probably not intended in the section.

(*b*) The Article does not say who is to judge when infection is at an end. The certificate of the Medical Officer of Health should be required.

(*c*) It only becomes operative when the infectious disease is known to be present. There is no power given to the Medical Officer of Health or other official to make inquiries or investigations to determine whether any of the persons associated with the dairy are infectious or suffering from infectious disease.

(*d*) The dairyman, under this Article, has not to report the existence of the dangerous infectious disorder. He should be required to notify his suspicions before they become definite knowledge, to the Medical Officer of Health.

Sections 52-54 of the Amendment Act are very useful, but they have to be adopted. Section 52 is vague. The person suffering, apparently, is in the first place to be the judge as to whether he can carry on his business without risk.

The need for further powers is, however, especially felt in regard to the control and prevention of milk-borne epidemics originating outside the area of the local authority in which the epidemic exists. For this purpose Section 4 of the Prevention Act has, in general, to be relied upon. This section, on superficial examination, seems to promise much practical assistance, but in practice it is of extremely limited value. Its defects are the following:

(*a*) The Act containing it has to be adopted, so that it is not in force in many parts of the country.

(*b*) There is considerable initial delay in inspecting the farm or farms supplying the suspected milk. The Medical Officer of Health has first to collect his evidence, then apply to a justice having jurisdiction in the place where the dairy is situated. Dealing with a large town this may mean a journey of anything from 50 to 200 miles. On arriving he has to search out a justice who, not knowing anything about him, may require him to submit his evidence before he will grant the order. The justice has entire discretion to grant or withhold the order to inspect. Knowing this, the Medical Officer of Health has to see that his evidence is considerable, or, in other words, he must delay to get sufficient evidence, a reasonable suspicion may not be enough.

(*c*) He has only power to inspect the animals and the dairy, and the former only if accompanied by a veterinary inspector. There is no authority given him to obtain information from the cowkeeper, or to examine the persons on the farm, although this is the most important thing for him to do. He may presumably ask questions, but it is left to the discretion of the cowkeeper to answer them. Apparently a careful survey of the cows and a contemplation of the manure heap and other features of the cowshed is, in some occult way, to furnish him with the key to the outbreak.

(*d*) Delay is caused while the Medical Officer of Health is reporting to his authority.

(*e*) Further delay follows, since, after receiving the report of the Medical Officer of Health, the local authority have to give the dairyman notice to appear before them, and they must give him at least 24 hours' notice.

(*f*) There is nothing in the section to say that the infected milk shall not be supplied to some other district, and presumably those districts would have to go through the same time-destroying procedures.

Stated in a few words, this section gives inadequate powers, and its operation necessitates delay so long and so unnecessary as to render it of very little practical value, since all the time the peccant milk may be daily infecting large numbers of consumers. It is sometimes used, but only in want of better powers.

In the valuable Milk and Dairies Bill (see Appendix) introduced by Mr. John Burns most of these defects are eliminated in Sect. 2 of the Bill which was to replace the above section.

IV. To obtain Clean Milk (and also to obtain a Pure Milk)

It is now generally admitted that ordinary market milk is heavily and unnecessarily bacterially contaminated, while most of those who have studied the problem are of opinion that to obtain clean milk additional legislation is required. The structural and other alterations of detail required have been considered in Chapter XVI. and the broad administrative procedures only have to be dealt with. There is no unanimity as to the methods required to obtain a clean milk supply, and those which have been advanced may be classified as follows:

(*a*) *Improvement in Existing Administrative Powers.*—One of the alterations most in favour is the transference of the administration of the legal duties and obligations in regard to milk, more particularly those contained in the Dairies, Cowsheds, and Milkshops Orders, from the District Councils to the County Councils. It is pointed out that these legal powers, if only they were properly carried out, would result in a great improvement of the milk supply. An improvement would certainly result, but we should not get clean milk, only a somewhat cleaner milk. Clean milking is a *process*, not a thing which can be obtained by regulations as to structural requirements, supplies of water laid on, and the like. It can only be obtained by education in some form or another. Also these regulations are very deficient as regards the cooling, transit of milk, etc.

While the transference of the duties and powers to the County Councils would no doubt be an improvement and a great advance, it would only go a short way towards the production of clean milk. For a County Council to adequately supervise the dairies and cowsheds, it would be necessary to appoint a large staff of veterinary and sanitary inspectors, while extended bacteriological examinations would have to be undertaken. The expenses would be heavy, and it is hardly to be expected that a County Council, composed of members largely, directly or indirectly, interested in the production of milk, and put into office by an electorate largely influenced by the agricultural interest, would view the work and the expense in the enthusiastic manner necessary for success. This lack of enthusiasm would be accentuated by the fact that the benefits were mainly for urban districts quite unconnected with the county which provided the money. Indeed, it may reasonably be contended that it is not fair to throw this financial burden upon County Councils.

(*b*) *Artificial Purification of Milk.*—Another view is that the provision of clean pure milk is so difficult and impracticable that the best plan is not to strive for it but to take what we now have and by sterilisation and pasteurisation render it bacterially harmless. While a considerable body of argument may be advanced in favour of such a plan as a temporary measure pending the obtaining of pure milk, most authorities are agreed that this solution is no satisfactory solution, and that sterilised milk is not equal to pure new milk. The reasons for this view have been fully considered.

(*c*) *Municipalisation.*—Leslie Mackenzie appears to have been the first (1898) to suggest that some measure of municipalisation may be the solution of the problem, and this view has been advanced by a number of writers. Another writer, for example, says: "The more I study this question the more firmly am I convinced that only by an extension of the principle of direct municipal ownership and supply can we bring about a really adequate reform of the milk supply."

In the writer's opinion there are practically insuperable difficulties in the way of such a proposal, and even if it were practicable it is not desirable. It is not within the range of practical politics. Municipal ownership might possibly be useful in the case of a few individual herds, kept as an object lesson of cleanliness, and also to supply a specially pure milk on the lines of the milk supplied by the American Milk Commissions.

(*d*) *Provision of Clean Milk by a gentle Process of Education of the Milk Producer and Milk Vendor.*—This is a view extensively advocated as *the* solution of the problem, and indeed may be said to be the solution offered by the milk trade itself. This attitude is clearly expressed in the following remarks of Mr. J. Sadler (Secretary of the Cheshire Milk Producers' Association), in a discussion upon the reform of the milk supply:[1]

He was quite prepared to admit that the ideal of what constitutes clean milk production was too low, but it was a process of education, and on the best managed farms the ideal already existed. They might at present be considered isolated farms, but he did not admit that they were few in number, and, in fact, they were growing more numerous every day. In his opinion this was the direction in which they, as representing the public health authorities, should develop. . . . They could not do without the dairy farmer, therefore they should approach him reasonably, encourage him, and carry him with them, and they would not find him half so black as he was painted. The dairy farmer, like every other farmer, moved slowly, like the processes of nature with which he was associated, but he was open to conviction, and once he was persuaded that the way they pointed was the right way—right also in the public interests,—then he would move with them, for if he was slow he was equally sure. They should not aim at displacing the present methods of milk production and distribution, but should aim rather at perfecting them.

This was spoken in 1905. Are the conditions of the milk trade any better to-day? Speaking generally there has been no improvement, or, if any, it has been extremely slight. The structural conditions are probably somewhat improved, but the general manurial pollution of milk appears to have but little diminished. It is rather difficult to see why the farmer should have improved in any of the districts where sanitary pressure is not put upon him. In the great majority of rural districts such sanitary pressure is not employed, and as he gets the same price for dirty as for clean milk, there is no reason why he should feel that the way of cleanliness was the right way.[2]

[1] *Public Health*, 1905, vol. xvii. p. 427.

[2] The idea that the average cowkeeper will of his own accord, and without outside pressure, supply a clean milk instead of a manure-laden one, cannot be seriously entertained by those who have extensively discussed this matter with him. The writer has met with a few cowkeepers who could be moved along the way of sanitary cleanliness as regards their cows by gentle suasion and the light of sweet reason, but very few compared with the number

Education is required, but it is especially education of the consumer. The consumer as an individual is usually totally ignorant of the bacterial content of his milk, and is in consequence completely apathetic about it. The idea that his milk may have been depleted of its cream will sometimes throw the householder into a white heat of indignation against his dairyman, with beneficial results as regards the future fat content of his milk; but the fact that he and his may and do consume countless hordes of bacteria, some of them actively virulent, which certainly ought not to be there, moves him not at all, as he does not know of their presence. Even if the matter is explained, he would probably not be greatly alarmed since he would not comprehend their significance.

As showing the lack of interest by the public, Heinemann[1] mentions that in Boston, a city of 600,000 population, where milk investigation is invited by the authorities, the average number of samples presented for examination daily is less than one. The apathy of the general public is further shown by the failure of milk companies to maintain their financial footing when they have given the public a pure, clean milk, but at the same time have had to charge an increased price for it.

Certain efforts have been made by individuals or companies

---

who regarded real cleanliness precautions as a silly fad. The great majority take refuge in the following argument in turn: First, that they do take all necessary steps, and that practically nothing does get into the milk. Confronted with milkers with filthy hands, and with still filthier cows, they abandon this argument for the next, which is, that if anything does get into the milk the strainer removes it all. Strainer, with much gross manurial filth removed by it from the milk, produced in triumphant confirmation. With the significance of this explained to them they fall back upon their final plea, that perhaps manure does get into the milk, but it does not matter, and they milk like their fathers before them, and what was good enough for their fathers is good enough for them. The latter may be a true statement, but, as the writer explains to them, is not the point, which is whether it is good enough for the milk consumer who may not desire what their and his father had. Their fathers had a heavy incidence of infectious disease, a heavy tuberculosis mortality, and always a high death-rate. These are not good enough to-day. The statement also neglects the important modern effect of urbanisation, and the fact that milk usually has now to travel very many miles to all the large cities. Also the practical abolition of the milkmaid has diminished cleanliness in milking.

[1] *Archives of Pediatrics*, 1908.

in the milk trade to supply a purer milk to the public. Large milk companies such as those of Messrs. Welford and Sons, and The Aylesbury Dairy Company in London, or Mr. Sorensen's dairy near York may be mentioned as taking steps to provide a cleaner and purer milk supply. These Companies do not, however, charge more than the usual market price for their milk. The precautions which they take are partly for their own protection, and partly in order that their milk will thereby command a better sale.

In Appendix VI. particulars are given of the Reports required from the local medical officer and veterinary inspector before a farmer is accepted as a milk contractor to Messrs. Welford's, also the weekly report required from the farmer, and the medical and sanitary rules which he is required to observe. They show a great advance over the ordinary methods.

The writer is of opinion that none of the above suggested procedures is in the least likely to obtain a pure milk supply, and reluctantly he has come to the conclusion that the following is the only plan likely to obtain what is required. This may be called:

(*e*) *Education of the Milk Trade by the Rejection of Dirty Milk.*—If it is important for the community to have clean milk, the milk trade (using the term to cover all who deal commercially with it) must be made to provide it. It is essentially a question of supply and demand. The only way to ensure its provision is for the consumer to refuse to drink dirty milk. The individual consumer does not and cannot know when and to what extent his milk is manured, but he provides a health department to see to that for him. As McCleary[1] has pertinently put it, it is not his business to know. "As a ratepayer he may point out that he regards his public health department as a specialised organisation for the protection of his health, and that if we attach so much importance to a pure milk supply, it is our business to get it for him." At present the health department of cities cannot give the consumer pure milk, however much they may realise that he should have it. That power should be given to them. Translated into legal action, if milk comes into the

[1] *Public Health*, 1905, vol. xvii. p. 421.

district of a local authority for purposes of sale that local authority should be given power to collect samples of such milk from anywhere, and authority to inspect all dairies, cowsheds, and cows, wherever situated, supplying such milk, if there is reasonable grounds for suspecting that adequate precautions are not observed to preserve it as a pure and wholesome article. If the conditions are unsatisfactory, and are not remedied on complaint, the local authority should have power to prohibit the sale of that milk within their district until written permission to resume is given. The milk producer or his agent must be served with notice to be present to enable him to state his side of the case, and the local authority must be prepared to furnish definite conditions which, on being complied with, would entitle the milk producer to again send his milk into the prohibited urban area. The power given to the local authority would simply be to prohibit the sale of the milk within their area. They would have neither power to prosecute nor to order specified works to be carried out.

To carry out such a regulation it is obviously essential that the law should require all milk vendors to send to the local authority in the area in which they distribute milk, a list of the sources of their milk, and to keep it up to date by notifying alterations. This procedure to obtain clean milk was enunciated by the writer[1] in 1906, and added experience has only confirmed his belief in it.

Some of the objections which will, no doubt, be made may be considered.

1. It will be said, as the Central Chamber of Agriculture declared in connection with Clause 2 of the Milk and Dairies Bill of Mr. Burns seeking to do the same thing, but for milk in relation to infectious diseases only, that it is a violation of the whole principle of local government by authorising the officials of one local authority to interfere in the area of another.

It is more than twenty-five years since the Dairies, Cowsheds, and Milkshops Order of 1885 was issued; many rural areas have made no regulations under it, and where they have they are essentially a dead letter. The rural areas will

[1] *Journ. Royal San. Institute*, 1906, xxvii. p. 685.

not put their own house in order; it is, therefore, not unreasonable that the milk-drinking areas should be given power to deal with the matter themselves.

Principles of local government are not fixed and unalterable, but are being yearly extended in all directions, and this principle is one which has received considerable sanction in numerous local enactments, besides being widely practised in America without detriment.

2. It will be said that the burdens thrown upon the urban communities will be heavy and out of proportion to the benefits received. When an urban community wants a clean water supply it has to pay for it; if it wants clean milk it also must be paid for. Also there is no reason why the expenses should be prohibitive. Systematic bacteriological examination of the milk would be necessary, and would greatly reduce working expenses. The chemical purity of the milk supply is maintained by taking a large number actually, but still, compared with the total bulk of milk, a small number proportionally, of samples of milk. The bacterial purity of milk can be maintained by an extension of the same principle of spot samples.

The heavily manured and badly handled milk samples would be ascertained in the first place by bacteriological examination. The responsible persons would then be warned. If the milk still continued impure the source of supply and the methods of transmission would then be personally inquired into by the city milk inspector, who should be a veterinary surgeon if possible.

The conditions and methods which required altering would be pointed out, and if they were not altered, or milk continued to be bacterially bad, the responsible persons would be cited to appear before the urban authority to show cause why their supply should not be stopped from being admitted into the urban area. In default of improvement the milk supply would be excluded, under a heavy penalty, from being sent into that district.

The urban medical officer of health would no doubt send a list, a "black list," of the suspended purveyors or cow-keepers to other local authorities for their information, and would report the non-compliance of the milk producer to the local authority in whose district his premises are situated, calling their attention to the breach of their own regulations.

The carrying out of systematic bacteriological examinations and the provision of inspectors would not be a costly business. This plan would have the great advantage that the cost of working it would fall on those who benefit, and not, as now, on those who are out of pocket by it. The urban authorities which neglected their powers would have the dirty milk; or, much better, it should be made compulsory for all urban authorities to exercise these powers in the same way as a minimum number of food and drug samples are required to be taken.

It may incidentally be remarked that to ensure a reasonably clean milk supply bacteriological examinations are essential and nothing can take their place. Some authorities write as if regular sanitary, and particularly veterinary inspection, is sufficient and efficient to ensure clean milk. However thoroughly this is done, and however vigorously their findings are backed up by the authority appointing them, they cannot ensure a clean milk supply, although, of course, they can do much. This is obvious since clean milking is a process, and while bad buildings and surroundings may render clean milk impossible, their presence cannot ensure it. Detection of dirty procedures is only possible by bacteriological examination. It is also just the improvements in the personal methods of milking which the writer has found so difficult to obtain. Johnstone,[1] inspecting Sherborne Rural District, records the same difficulty. He remarks: "The dairy-farmers were more opposed to reform in the personal methods of their milkers than to any proposition in the way of improved ventilation and drainage in the cowsheds."

On the other hand, bacteriological examination alone is inadequate. Bacteriological standards as fixed methods for judging milk and as a direct basis for administrative action are, in the writer's opinion, unsatisfactory and are not advocated (see Chapter XIV.). Bacteriological methods, combined with inspections and investigations, must go hand in hand, the former serving as a guide and also a check upon the latter.

3. It may be advanced that the procedure suggested would

[1] *Report of Medical Officer, Local Government Board*, 1907-8, p. 96.

be ineffectual and would merely have the effect of disorganising the milk business. The farmer would send his milk to some other centre, and the regular distribution would be upset. Its effectiveness would depend upon whether the urban authorities cared to make it effectual. The black list would keep other districts informed of the bad offenders, and even if a voluntary system only was enforced it is scarcely likely that town B would be satisfied with milk not pure enough for town A. The bad milk producer would have no market, and would have to come back to the urban authority and ask on what conditions his milk could be taken back. He would be given the printed regulations of that authority, setting out what he must do, and when he had made his alterations, structural and educational, he would be allowed to send his milk back. The consumer, as represented by his health authority, would have educated the milk producer and vendor up to his requirements.

4. It will, of course, be said that the scheme advocated will press very hardly upon the agricultural interests, will render milk production unprofitable, and cause farmers to give up cow-keeping, and, in other words, will harass the milk industry out of existence. There is no reason why such a gloomy picture should be realised. In the first place, all regulations and requirements of urban areas should be required to be sanctioned by the Local Government Board, and need not be more stringent than what is admitted by all authorities to-day to be reasonable requirements. The rural authorities should have power to appeal to the Local Government Board against too stringent urban requirements as to occasional lapses from cleanliness, etc.

It is surely also not a difficult administrative feat to so arrange that the first effects of the urban control would be the gradual elimination or levelling up of the worst offenders. It is a steady, continuous improvement which is required, not a sudden rejection of half the supplies in the country.

There is no difficulty in protecting the agricultural industry from unfair stringency of requirement, and with their powerful parliamentary influence this aspect is hardly likely to be neglected. If to require the farmer to keep his cows more nearly like his horses, and to see that his milkmen do not come direct from the muck-fork to the milk-pail without ablution or overall is to harass the farmer, it is surely time he was harassed.

5. It will be advanced that to require milk to be clean will send up the retail price of milk. Even eminent public health authorities, as well as laymen, proclaim the view that whatever is necessary the price of milk must not be raised, otherwise more harm than good will be done.

To the writer this does not appear a sound argument. Crudely stated, it means that a manure-polluted, bacteria-laden, nearly putrefying milk at 4d. a quart is a better food for the poor than a clean pure milk at 4½d. to 5d. a quart. We do not apply the same argument to other foods. Meat is vital food as well as milk, but we do not argue that since rejection of diseased meat or rotten fish may send up the market price of meat or fish, that it is better to let people eat diseased meat or rotten fish rather than risk a rise in price. Unfortunately manured milk does not so readily betray itself.

The logical plan is to carefully measure the danger to the community of dirty and infected milk, to decide what is necessary and what is reasonable on sanitary grounds to require, and then to devise measures to enforce those reasonable requirements, and this whether or no the price of milk is likely to be a little enhanced.

It is probable that effective measures of improvement will increase the cost of milk. The farmer and the milk purveyor are not philanthropists, and have a right to a fair profit, and if it costs more to produce milk in a clean condition, it is surely only reasonable that the price should be raised to give them that fair profit.

The writer's own opinion is that the enforcement of proper procedures in regard to milk will, at first, cause the retail price of milk to go up. This rise will be only temporary, and will fall when it is found that the requirements are not costly in themselves, but essentially matters of education and the elimination of bad habits and practices. After a time it will be found that the cost of production is not appreciably raised, consequently, by the action of ordinary economic forces, the prices will go back to the old level, but the price will be that of a clean instead of a dirty milk. That this is likely to occur is shown by the fact that to-day there are a certain number of cow-keepers and milk producers who produce and vend their milk under admirable conditions, and can make a working profit at current prices. Further, it is obvious that much money could and should be saved by thoroughgoing improvements in distribution and by better co-operation amongst milk producers. The money saved in this way should materially if not entirely counterbalance any increased expense in production.

The writer is well aware that there are other practical difficulties in the way of the proposed plan, of which perhaps the most important are the difficulty of regulating the mixing of milk from different sources, as practised by the large companies, and the control of pasteurisation, but these do not interpose insuperable difficulties, and certainly do not invalidate the general principle.

APPENDIX I

CITY OF MANCHESTER

Tuberculosis and Milk

By the Manchester Corporation (General Powers) Acts, 1899 and 1904, it is enacted as follows:

1899 Act, Section 19.—(1) In this section—

"Dairy" shall include any farm, farm-house, cow-shed, milk store, milk shop, or other place from which milk is supplied, or in which milk is kept for purposes of sale;

"Dairyman" shall include any cow-keeper, purveyor of milk, or occupier of a dairy;

"Medical officer" shall include any person duly authorised to act temporarily as medical officer of health.

(2) Every person who knowingly sells, or suffers to be sold, or used for human consumption within the city the milk of any cow which is suffering from tuberculosis of the udder, shall be liable to a penalty not exceeding ten pounds.

(3) Any person the milk of the cows in whose dairy is sold, or suffered to be sold, or used for human consumption within the city, who, after becoming aware that any cow in his dairy is suffering from tuberculosis of the udder, keeps, or permits to be kept, such cow in any field, shed, or other premises, along with other cows in milk shall be liable to a penalty not exceeding five pounds.

(4) Every dairyman who supplies milk within the city and has in his dairy any cow affected with, or suspected of, or exhibiting signs of tuberculosis of the udder, shall forthwith give written notice of the fact to the medical officer, stating his name and address, and the situation of the dairy or premises where the cow is.

Any dairyman failing to give such notice, as required by this sub-section, shall be liable to a penalty not exceeding forty shillings.

(5) (a) It shall be lawful for the medical officer, or any person provided with and, if required, exhibiting the authority in writing of such medical officer, to take within the city for examination

samples of milk produced, or sold, or intended for sale, within the city.

(B) The like powers in all respects may be exercised outside the city by the medical officer, or such authorised person, if he shall first have obtained from a justice having jurisdiction in the place where the sample is to be taken, an order authorising the taking of samples of milk, which order any such justice is hereby empowered to make.

(6) (A) If milk from a dairy situate within the city is being sold, or suffered to be sold, or used within the city, the medical officer, or any person provided with and, if required, exhibiting the authority in writing of the medical officer, may, if accompanied by a properly qualified veterinary surgeon, at all reasonable hours enter the dairy and inspect the cows kept therein, and if the medical officer, or such person, has reason to suspect that any cow in the dairy is suffering from tuberculosis of the udder, he may require the cow to be milked in his presence, and may take samples of the milk, and the milk from any particular teat shall, if he so requires, be kept separate, and separate samples thereof be furnished.

(B) If the medical officer is of opinion that tuberculosis is caused, or is likely to be caused, to persons residing in the city from consumption of the milk supplied from a dairy situate within the city, or from any cow kept therein, he shall report thereon to the Corporation, and his report shall be accompanied by any report furnished to him by the veterinary surgeon, and the Corporation may thereupon serve on the dairyman notice to appear before them within such time, not less than twenty-four hours, as may be specified in the notice, to show cause why an order should not be made requiring him not to supply any milk from such dairy within the city until the order has been withdrawn by the Corporation.

(C) If the medical officer has reason to believe that milk from any dairy situate outside the city, from which milk is being sold, or suffered to be sold, or used within the city, is likely to cause tuberculosis in persons residing within the city, the powers conferred by this sub-section may, in all respects, be exercised in the case of such dairy, provided that the medical officer, or other authorised person, shall first have obtained from a justice having jurisdiction in the place where the dairy is situate, an order authorising such entry and inspection, which order any such justice is hereby empowered to make.

(D) Every dairyman, and the persons in his employment, shall render such reasonable assistance to the medical officer, or such authorised person or veterinary surgeon as aforesaid, as may be required by such medical officer, person, or veterinary surgeon, for all or any of the purposes of this sub-section, and any person refusing such assistance, or obstructing such medical officer, person, or veterinary surgeon, in carrying out the purposes of this sub-section shall be liable to a penalty not exceeding five pounds.

(E) If, in their opinion, the dairyman fails to show cause why such an order may not be made as aforesaid, the Corporation may make the said order, and shall serve notice of the facts on the county council of any administrative county in which the dairy is situate, and on the Local Government Board, and if the dairy is situate outside the city, on the council of the borough or county district in which it is situate.

(F) The said order shall be forthwith withdrawn on the Corporation, or their medical officer, being satisfied that the milk supply has been changed, or that it is not likely to cause tuberculosis to persons residing in the city.

(G) If any person, after any such order has been made, supplies any milk within the city in contravention of the order, or sells it for consumption therein, he shall be liable to a penalty not exceeding five pounds, and, if the offence continues, to a further penalty not exceeding forty shillings for every day during which the offence continues.

(H) A dairyman shall not be liable to an action for breach of contract, if the breach be due to an order under this sub-section.

(7) The Corporation shall cause to be given public notice of the effect of the provisions of this section by advertisement in local newspapers, and by handbills, and otherwise in such manner as they think sufficient, and this section shall come into operation at such time, not being less than one month after the first publication of such an advertisement as aforesaid, as the Corporation may fix.

(8) Offences under this section may be prosecuted, and penalties may be recovered by the Corporation before a petty sessional court having jurisdiction in the place where the dairy is situate or the offence is committed, and not otherwise.

(9) All expenses incurred by the Corporation in carrying into execution the provisions of this section shall be chargeable on the city fund and city rate, and the Corporation may also charge upon the same rate any expenses incurred by them in the application by a veterinary surgeon of the tuberculin, or other reasonable test, for the purpose of discovering tuberculosis to any cow whose milk is, or was recently, being supplied within the city. Provided that no such test shall be applied except with the previous consent of the owner of such cow.

(10) This section may be carried into execution by a Committee of the Council formed in accordance with, and subject to, the provisions of the Fourth Schedule to the Diseases of Animals Act, 1894, except that the Committee shall consist wholly of members of the Council.

1904 Act, Section 92.—(1) The dairyman may appeal against an order of the Corporation under Section 19 of the Manchester Corporation (General Powers) Act, 1899, or the refusal of the Corporation to withdraw any such order either to a petty sessional court having jurisdiction within the city, or at his option, if the dairy is situate outside the city, to the Board of Agriculture and Fisheries, who shall appoint an officer, to hear such appeal. Such officer shall fix a time and place of hearing within the city, and give notice thereof to the dairyman and the town clerk, not less than forty-eight hours before the hearing. Such officer shall, for the purposes of the appeal, have all the powers of a petty sessional court.

The Board of Agriculture and Fisheries may, at any stage, require payment to them by the dairyman of such sum as they deem right, to secure the payment of any costs incurred by the Board of Agriculture and Fisheries in the matter of the appeal.

The court or the Board of Agriculture and Fisheries, as the case may be, may confirm, vary, or withdraw the order which is the subject of the appeal, and may direct to and by whom the costs of the appeal (including any sum paid or payable to the Board of Agriculture and Fisheries as aforesaid) are to be paid, but, pending the decision of the appeal, the order shall remain in force unless previously withdrawn by the Corporation.

(2) If such an order is made without due cause, or if the Corporation unreasonably refuse to withdraw the order, the dairyman shall, if not himself in default, be entitled to recover from the Corporation full compensation for any damage he has sustained by reason of the making of the order, or of the refusal of the Corporation to withdraw the order.

The court, or the Board of Agriculture and Fisheries, may determine and state whether an order the subject of appeal has been made without due cause, and whether the Corporation have unreasonably refused to withdraw the order, and whether the dairyman has been in default.

Any dispute as to the fact whether the order has been made or maintained without due cause, or as to the fact of default, where any such fact has not been determined by the court, or Board of Agriculture and Fisheries, or as to the fact of damage, or as to the amount of compensation, shall be determined in the manner provided by Section 308 of the Public Health Act, 1875, and that section shall accordingly apply and have effect as if the same were herein re-enacted, and in terms made applicable to any such dispute as aforesaid.

APPENDIX II

TUBERCULOSIS ORDER OF 1909 OF THE BOARD OF AGRICULTURE AND FISHERIES

(*Subsequently withdrawn*)

THE Board of Agriculture and Fisheries, by virtue and in exercise of the powers vested in them under the Diseases of Animals Acts, 1894 to 1903, and of every other power enabling them in this behalf, do order, and it is hereby ordered, as follows:

Interpretation.

1. In this Order—

"The Board" means the Board of Agriculture and Fisheries:

"Local Authority" means a Local Authority for the purposes of the Act of 1894:

"The Act of 1894" means the Diseases of Animals Act, 1894:

"Inspector" includes Veterinary Inspector:

"Bovine animal" means a bull, cow, ox, heifer, or calf:

"Milk" includes cream and separated or skimmed milk.

Other terms have, where the context so permits, the same meaning and scope as in the Act of 1894.

Notice of Disease.

2.—(1) Every person having in his possession or under his charge:

(i.) any cow which is, or appears to be, suffering from tuberculosis of the udder, indurated udder, or other chronic disease of the udder; or

(ii.) any bovine animal which is, or appears to be, emaciated from tuberculosis,

shall without avoidable delay give information of the fact to a constable of the police force for the area wherein the animal is, or to an Inspector of the Local Authority, and the constable or Inspector shall transmit the information to the Local Authority, who, if not themselves the Sanitary Authority, shall inform that Authority.

(2) The person in possession or having charge of the animal shall forthwith take such steps as are necessary to secure compliance with Article 8 (*Precautions to be adopted with respect to Milk, etc.*) and Article 9 (*Detention and Isolation of Suspected Animals*).

Inspection and Examination of Animals.

3.—(1) Where a Local Authority, by reason of information received under the preceding Article or otherwise, have reasonable ground for supposing that on any premises in their district there is a cow which is suffering from chronic disease of the udder or giving tuberculous milk, or a bovine animal which is emaciated from tuberculosis, the Local Authority shall with all practical speed cause such veterinary examination of the bovine animals on such premises to be made by a Veterinary Inspector as in the opinion of the Local Authority is necessary to ascertain whether any cow thereon is suffering from tuberculosis of the udder or giving tuberculous milk, or whether any bovine animal thereon is emaciated from tuberculosis. The Inspector may apply the tuberculin test to a bovine animal with the previous consent in writing of the owner thereof or of his agent, but not otherwise.

(2) For the purpose of such examination, a Veterinary Inspector may at all reasonable hours enter on any part of the premises and examine any bovine animal thereon and require any cow to be milked in his presence and may take samples of the milk, and the milk of any particular teat shall, if he so require, be kept separate, and separate samples thereof shall be furnished.

(3) The Inspector may also take samples of the faeces or urine of any bovine animal on the premises, or of any abnormal discharge from any bovine animal thereon.

(4) The occupier of the premises and the persons in his employment shall render such reasonable assistance to the Inspector as may be required for all or any of the purposes of this Article, and any person refusing such assistance shall be deemed guilty of an offence against the Act of 1894.

(5) The Inspector shall as soon as possible send to the Local Authority a report showing the result of his inspection and examination, and of the examination of any sample taken by him. The Local Authority, if not themselves the Sanitary Authority, shall send a copy of the report to that Authority.

(6) If the report of the Inspector as to any animal does not show that it is suffering from tuberculosis of the udder, or giving tuberculous milk, or emaciated from tuberculosis, the Local Authority shall forthwith give notice in writing to the owner or person in charge thereof that the provisions of this Order relating

to precautions to be adopted with respect to milk, and detention, and isolation of suspected animals, have ceased to apply to the animal.

Slaughter of Diseased Animals.

4.—(1) Where a Local Authority are satisfied by the report of the Inspector that in their District there is a cow which is suffering from tuberculosis of the udder, or giving tuberculous milk, or a bovine animal which is emaciated from tuberculosis, the Local Authority shall with all practicable speed give notice in writing (in the Form set forth in the Schedule hereto or to the like effect) to the owner or person in charge of the animal and also to the Board and cause the animal to be slaughtered; provided that if the owner of the animal, or any person on his behalf, gives notice in writing to the Local Authority, or to their Inspector or other officer directed to carry out such slaughter, that the owner objects to the animal being slaughtered under the provisions of this Order, it shall not be lawful for the Local Authority to cause the animal to be slaughtered without the special authority of the Board first obtained; provided also that this special authority shall not be given in the case of any animal valued under this Order at more than thirty pounds, if and so long as the animal is detained and isolated, and the milk (if any) is dealt with, in accordance with the provisions of this Order.

(2) If the value of an animal proposed to be slaughtered, as agreed or certified under this Order, exceeds thirty pounds, the Local Authority shall not proceed with its slaughter unless so directed by the Board.

Valuation for Compensation.

5.—(1) Before the slaughter of an animal the Local Authority shall either agree in writing with the owner of the animal the value thereof in its condition at the time of valuation, or if they shall fail so to agree shall cause such value to be ascertained by a valuer appointed by them or appointed on the application of the Local Authority by the Board but paid by the Local Authority, and such valuer shall give to the Local Authority and to the owner a certificate in writing of the said value.

(2) In ascertaining the value of an animal, regard shall be had to any Act, Order, or Regulation dealing with the sale or use of milk, milk products, or carcases for human food.

(3) The value shall be ascertained both on the basis of the certificate of examination hereinafter required showing that the animal was suffering from tuberculosis, and also on the basis of its not showing that the animal was suffering from tuberculosis, and the amount to be paid for compensation shall depend on such certificate accordingly.

Post-mortem Examination of Slaughtered Animals.

6.—(1) In the case of every animal slaughtered under this Order, the carcase shall, at the time of slaughter or as soon as practicable thereafter, be examined by a Veterinary Inspector of the Local Authority, or (if so required by the owner or person in charge of the animal before it is slaughtered) by some other veterinary surgeon, who, failing agreement between the Local Authority and such owner or person, shall be nominated by the Board but paid by the Local Authority.

(2) The Veterinary Inspector or other veterinary surgeon shall, at the conclusion of his examination, give to the Local Authority and to the owner of the animal a certificate of the result of the examination in the Form set forth in the Schedule hereto or to the like effect.

Compensation.

7.—(1) If the Local Authority fail to carry out the examination required by the preceding Article, or if the certificate of such examination does not show that the animal was suffering from tuberculosis, the Local Authority shall, by way of compensation, pay to the owner thereof a sum equal to the value of the animal as agreed or certified in manner aforesaid, and a further sum of twenty shillings.

(2) If the certificate of the examination shows that the animal was suffering from tuberculosis (not being advanced tuberculosis), the Local Authority shall, by way of compensation, pay to the owner a sum equal to three-fourths of the value of the animal as agreed or certified in manner aforesaid, after deducting therefrom one-half of their reasonable costs of any valuation of the animal by a valuer appointed by the Board, and of any examination of its carcase by a veterinary surgeon other than the Veterinary Inspector.

(3) If the certificate of the examination shows that the animal was suffering from advanced tuberculosis, the Local Authority shall, by way of compensation, pay to the owner a sum equal to one-fourth of the value of the animal, as agreed or certified in manner aforesaid or the sum of two pounds, whichever sum is the greater, after deducting from this compensation one-half of their costs of valuation and examination as in the preceding case.

(4) For the purposes of this Order an animal slaughtered under this Order shall be deemed to have been suffering from advanced tuberculosis

(*a*) when there is miliary tuberculosis of both lungs;

(*b*) when tuberculous lesions are present on the pleura and peritoneum;

(c) when tuberculous lesions are present in the muscular system, or in the lymphatic glands embedded in or between the muscles; or

(d) when the carcase is emaciated and tuberculous lesions are present.

Precautions to be adopted with respect to Milk, etc.

8.—(1) The milk produced by any cow which is, or appears to be, suffering from chronic disease of the udder or emaciated from tuberculosis, shall not be mixed with other milk until the cow has been examined by a Veterinary Inspector in accordance with the provisions of this Order, and until the owner or person in charge thereof has been notified that this Article has ceased to apply to the cow; and all milk affected by this Article shall forthwith be boiled or otherwise sterilised, and any utensil in which such milk is placed before being so treated shall be thoroughly cleansed with boiling water before any other milk is placed therein.

(2) A Local Authority, or a Veterinary Inspector on their behalf, may by written notice apply the restrictions imposed by this Article to the milk produced by any cow specified in the notice which is suspected of giving tuberculous milk and is being examined under this Order, and such restrictions shall apply accordingly.

Detention and Isolation of Suspected Animals.

9.—(1) Every person having in his possession or under his charge any cow which is, or appears to be, suffering from chronic disease of the udder, or any bovine animal which is, or appears to be, emaciated from tuberculosis, shall keep the animal isolated as far as practicable from other bovine animals, and also keep the animal in his possession or under his charge, until the animal has been examined by a Veterinary Inspector in accordance with the provisions of this Order, and the owner or person in charge thereof has been notified that this Article has ceased to apply to the animal; provided that the animal may at any time be slaughtered by the owner or person in charge.

(2) A Local Authority, or a Veterinary Inspector on their behalf, may by written notice apply this Article to any bovine animal specified in the notice which is being examined under this Order, and such Article shall apply accordingly.

Suspected Animals in Markets, Fairs, and Sales.

10.—(1) A Veterinary Inspector of a Local Authority may by notice served on the owner or person in charge of a bovine animal exposed in a market, fairground, or saleyard, which appears to him to be (i.) suffering from tuberculosis of the udder, indurated udder, or other chronic disease of the udder; or

(ii.) emaciated from tuberculosis,

require the animal to be removed from the market, fairground, or saleyard to the premises from which it was brought thereto, or if the owner or person in charge so desires, to any other suitable premises, to be specified in the notice, and thereupon the animal shall forthwith be moved by the owner or person in charge to those premises for the purpose of examination under the foregoing provisions of this Order.

(2) Where the premises to which the animal is required under this Article to be moved are not in the same district as the market, fairground, or saleyard, the Inspector serving the notice shall forthwith send a copy of the notice to the Local Authority of the district in which the first-mentioned premises are situate.

Cleansing and Disinfection.

11. The occupier of any premises on which there has been a cow suffering from tuberculosis of the udder or giving tuberculous milk, or a bovine animal emaciated from tuberculosis, shall if so required in writing by an Inspector of the Local Authority cleanse and disinfect at his own expense, and to the satisfaction of the Inspector, that part of any shed or other erection in which the animal has recently been placed or kept.

Reports to the Board.

12. Every Local Authority and their Inspectors and officers shall send and give to the Board such reports, returns, and information as to their proceedings under this Order as the Board require.

Extension of certain Sections of Diseases of Animals Act, 1894.

13. Tuberculosis shall be a disease for the purposes of the following sections of the Act of 1894 (namely):

Sections nineteen and twenty (slaughter and compensation);
Section forty-three (powers of police);
Section forty-four (powers of inspectors);

and also for the purposes of all other sections of the said Act containing provisions relative to or consequent on the provisions of those sections and this Order, including such sections as relate to offences or procedure.

Offences.

14. Every person who

(i.) fails to give the notice required by Article 2 of this Order; or (ii.) fails to comply with any provision of this Order, or any direction given by the Board under this Order, relating to precautions to be adopted with respect to milk or relating to detention and isolation of animals; or

(iii.) fails to comply with any notice directing removal of an animal from a market, fairground, or sale-yard; or

(iv.) fails to cleanse or disinfect any erection which under this Order he is required to cleanse or disinfect;

shall, according to and in respect of his own acts and defaults, be deemed guilty of an offence against the Act of 1894.

Extent.

15. This Order extends to England and Wales and Scotland.

Local Authority to Enforce Order.

16. The provisions of this Order, except where it is otherwise provided, shall be executed and enforced by the Local Authority.

Commencement.

17. This Order shall come into operation on the first day of January, nineteen hundred and ten.

Short Title.

18. This Order may be cited as the TUBERCULOSIS ORDER of 1909.

SCHEDULE

FORMS

TUBERCULOSIS ORDER OF 1909

Form of Notice of Intended Slaughter.

(Article 4)

To   of

The Local Authority for the county [borough *or* burgh] of   hereby give notice that they are satisfied that [*insert description of animal*] which is now kept at [*insert description of premises where it is kept, stating parish*] is

*(*a*) suffering from tuberculosis of the udder;
*(*b*) giving tuberculous milk;
*(*c*) is emaciated from tuberculosis,

and that they propose with all convenient speed to slaughter the animal.

* *Strike out part which is inapplicable.*

(Signed)

By direction of the Local Authority.

Dated , 19 .

Note.—If the owner of the animal, or any person on his behalf, gives notice in writing to the Local Authority, or to their Inspector or other officer directed to carry out the slaughter, that the owner objects to the animal being slaughtered, it may not be slaughtered without the special authority of the Board first obtained.

The compensation payable by the Local Authority is regulated by the Order.

Tuberculosis Order of 1909

Form of Certificate of Result of Post-mortem Examination.

(Article 6)

I, *A. B.*, a Veterinary Inspector of the Local Authority for the county [borough *or* burgh] of [*or* a veterinary surgeon acting under the Tuberculosis Order of 1909], do hereby certify that my examination of the carcase of [*here describe animal slaughtered*], which was caused to be slaughtered by the Local Authority for the county [borough *or* burgh] of , on the day of 19 , and which animal belonged to , of , does not show that the animal was affected with tuberculosis [*or* shows that the animal was affected with tuberculosis (not being advanced tuberculosis within the meaning of the Tuberculosis Order of 1909) *or* shows that the animal was suffering from advanced tuberculosis within the meaning of the Tuberculosis Order of 1909].

(Signed) *A. B.*

Dated , 19 .

APPENDIX III

DENMARK

Act of February 5, 1904, containing Measures against Tuberculosis among Cattle and Pigs[1]

A sum of 100,000 kr., granted every year by the Rigsdag (Parliament) on the recommendation of the Committee of Ways and Means, shall be placed at the disposal of the Minister of Agriculture for the support of cattle-farmers who wish to employ tuberculin as a diagnostic remedy in combating tuberculosis among their cattle, the tuberculin test being applied according to detailed regulations issued by the Minister. The support shall be granted to none but such farmers as guarantee their ability to keep the animals, proved by the test to be healthy, safely isolated from the animals affected by tuberculosis, or which have not been subjected to the tuberculin test.

The Minister of Agriculture shall—on the same conditions—be entitled to employ part of the sum to support cattle-breeding associations which wish to subject the animals selected for breeding purposes to the tuberculin test, as well as to support farmers' associations desiring to subject cows belonging to cottagers to the tuberculin test.

Farmers who do not fulfil their obligations with regard to isolation shall return to the State the grants which have been made to them in accordance with the above provisions.

Any veterinary surgeon superintending the application of the tuberculin test on a farm shall satisfy himself, under penalty of a fine, that safe isolation between the animals is established, and if his orders to this effect are not obeyed by the farmer, he shall notify this to the chief veterinary surgeon of the country.

Applications from cattle-farmers, cattle-breeding associations, and farmers' associations desiring to take advantage of the oppor-

[1] As printed in Professor Bang's paper, *Sixth International Congress on Tuberculosis*, vol. iv. part ii. p. 865.

tunity offered to them by this Act of having their cattle subjected to the tuberculin test shall be sent direct to the Minister of Agriculture.

Sec. 2.—Importation of live cattle from abroad shall only take place at such places as are mentioned in the regulations issued by the Minister of Agriculture. Immediately after their arrival the animals shall be quarantined, and shall, in accordance with the regulations of the veterinary police, be subjected to the tuberculin test, according to regulations issued by the Minister of Agriculture, within five days after their arrival at the quarantine stable. After the test the non-reacting animals shall be left at the disposal of the owner, while the reacting animals shall either be returned or taken direct to a public slaughter-house, or to a slaughter-house recognised by the Minister of Agriculture, where same shall be destroyed under control of the veterinary police. The expenses incurred in providing the requisite quarantine stables at the places of import, as well as the expenses of the tuberculin tests, but none of the expenses attendant on the other measures mentioned in this section, shall be borne by the State.

The regulations relating to tuberculin tests, mentioned in Sec. 1, shall also apply to such other diagnostic remedies as may be recommended by veterinary authorities for the combating of tuberculosis among cattle, and are approved by the Minister of Agriculture.

Sec. 3.—Animals imported for killing purposes may be exempted from quarantining and the tuberculin tests ordered in Sec. 2. Such animals shall, after having been branded (see Sec. 4), be taken direct to a public slaughter-house or to a slaughter-house recognised by the Minister of Agriculture.

The Minister of Agriculture shall be entitled to permit cattle imported for killing purposes—after having been marked—being taken direct to a cattle-market, where the animals shall be stabled so as to be, in the opinion of the veterinary police, duly isolated from all other cattle. From this place they shall be taken direct to a public slaughter-house or to a slaughter-house recognised by the Minister of Agriculture. The animals imported for killing purposes mentioned in this section shall be killed within ten days after their arrival in this country.

Sec. 4.—The Minister of Agriculture shall issue regulations for the marking of the imported animals.

Sec. 5.—Cows suffering from tuberculosis of the udder shall be killed, in accordance with the regulations of the State, under control of the veterinary police or in a public slaughter-house. The owner shall be entitled to a compensation for the animal, amounting to one-third of the market value of the carcase, calculated at the current price, according to regulations issued by the Minister of Agriculture. The owner shall further be entitled to a compensation for such parts of the animal as are declared by the veterinary surgeon to be unfit for human consumption, amounting to half of the value of the condemned meat, calculated as above. Such parts of the animal as are declared fit for human consumption shall be left at the disposal of the owner. The compensation as well as the expenses attendant on the killing shall be paid by the State.

Sec. 6.—None but such milk and buttermilk as has been heated to a temperature of at least 64° Réaumur (80° C.) shall be returned from dairies to serve as food for cattle and pigs. Exceptions from this rule may take place when the heating cannot be performed on account of an accident, which fact shall be made known to the person to whom the milk is to be returned. The heating mentioned in this section shall also apply to all cream destined for the making of butter for exportation. The sediment scraped off the sides of the cream-separator during the cleaning of the same shall be burned.

Sec. 7.—None but such milk and buttermilk as has been sufficiently proved in the opinion of the Minister of Agriculture to have been heated to a temperature of at least 64° Réaumur (80° C.) shall be imported from abroad. The Minister of Agriculture shall, however, be entitled to grant exemption from the above prohibition when special circumstances necessitate it.

Sec. 8.—The carrying out of the provisions of this Act shall be enforced by the veterinary police, the custom-house officers, and the butter and margarine inspectors, in accordance with the directions of the Minister of Agriculture.

Sec. 9.—Offenders against the provisions of Secs. 1, 2, 3, 6, and 7 shall be liable to fines of from 10 to 20 kr. for the first offence; in case of repetition, to fines of from 20 to 200 kr. Repeated offences against Sec. 6 shall not be looked upon as such if at least one year has elapsed since the offender was last fined. The fines shall accrue to the exchequer. The proceedings in these cases shall be summary. In the case mentioned in Sec. 7 the prohibited articles shall be confiscated and heated to the temperature defined in the above section. In Copenhagen the proceeds of the sale of such articles shall accrue to the municipal fund; in other places, to the poor fund.

Sec. 10.—This Act, which shall not apply to the Faroë Islands, shall come into force October 1, 1904.

APPENDIX IV

MILK AND DAIRIES BILL

Memorandum

The main objects of this Bill are to provide for—

(1) The more effective registration of dairies and dairymen;

(2) The inspection of dairies and the examination of cows therein;

(3) The prohibition of the supply of milk from a dairy where such a supply has caused or would be likely to cause infectious diseases, including tuberculosis;

(4) The prevention of the sale of tuberculous milk;

(5) The regulation of the importation of milk so as to prevent danger to public health arising therefrom;

(6) The issue of regulations for securing the supply of pure and wholesome milk;

(7) The establishment by local authorities in populous places of milk depots for the sale of milk specially prepared for infants.

The provisions as to registration supersede the provisions as to the registration of dairies contained in the Contagious Diseases (Animals) Acts and the orders made thereunder.

The provisions as to the inspection of dairies and the prohibition of the supply of milk reproduce with amendment section 4 of the Infectious Diseases Prevention Act, 1890, section 71 of the Public Health (London) Act, 1891, and the model milk clauses incorporated in many local Acts.

The clause as to the prevention of the sale of tuberculous milk is also taken from the model milk clauses, but the scope of the enactment is somewhat extended.

The Board of Agriculture and Fisheries will in connection with this Bill issue an order under the Diseases of Animals Act, 1894, dealing with the notification of tuberculosis in cattle and the inspection, examination, detention, isolation, and slaughter of tuberculous cattle, and the giving of compensation in appropriate cases.

Arrangement of Clauses

A Bill to make better Provision with respect to the Sale of Milk and the Regulation of Dairies

Be it enacted by the King's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:—

1.—(1) A person shall not carry on the trade of dairyman in any dairy within the district of a sanitary authority unless he and the dairy are registered with the sanitary authority in accordance with this Act and the orders made thereunder, and if he does so he shall be guilty of an offence and shall be liable on summary conviction to a fine not exceeding *five pounds*:

Provided that—

(*a*) in the case of a farm comprising several cowsheds it shall not be necessary to register each cowshed as a separate dairy:

(*b*) in the case of a purveyor of milk not having a dairy within the meaning of this Act, the place where he keeps the vessels used by him for the purpose of the sale of milk shall be deemed to be a dairy for the purposes of this section.

(2) The sanitary authority may remove any dairy from the register, or may refuse to register any premises as a dairy if—

(*a*) the premises become or are unsuitable to the purposes of the business carried on or proposed to be carried on therein; or

(*b*) the premises are a nuisance or do not comply with the provisions of this Act or the orders made thereunder; but any person who feels himself aggrieved by such removal or refusal may appeal to a court of summary jurisdiction, which may, if it thinks just, make an order requiring the sanitary authority to restore the dairy to, or enter the dairy in, the register.

(3) On the second or subsequent conviction of a dairyman of an offence against this Act or the orders made thereunder the court by which he is convicted may, if it thinks fit, having regard to the nature of the offences of which he has been convicted, in addition to or in substitution for any other penalty, order that the name of the offender be removed from the register of dairymen either absolutely or for such period as may be specified in the order.

2.—(1) If the milk from any dairy is being sold or used for human consumption within the district of any sanitary authority, the medical officer of health for that district shall, whether the dairy is situate within or without the district, have power at all reasonable hours to enter and inspect the dairy, and if accompanied by a veterinary inspector or some other properly qualified veterinary surgeon, to inspect the animals therein:

Provided that if the dairy is not situate within the district of the sanitary authority the medical officer of health shall not be empowered so to enter and inspect the dairy unless he has evidence that infectious disease is caused, or is likely to be caused, by consumption of the milk supplied from the dairy, and shall, before inspecting the dairy, give notice of the intention to do so to the clerk and medical officer of health of the district in which the dairy is situate.

(2) If on any such inspection the medical officer of health or the veterinary inspector or surgeon has reason to suspect that any cow in the dairy is suffering from tuberculosis with emaciation or from tuberculosis of the udder, or is giving tuberculous milk, he may require the cow to be milked in his presence, and may take samples of the milk, and the milk from any particular teat shall, if he so requires, be kept separate and separate samples thereof furnished.

(3) Every dairyman and the persons in his employment shall render such reasonable assistance to the medical officer of health or a veterinary inspector or veterinary surgeon as he may require for all or any of the purposes of this section, and any person refusing such assistance or obstructing such medical officer of

health or veterinary inspector or veterinary surgeon in carrying out the provisions of this section shall on summary conviction be liable to a fine not exceeding *five pounds*.

(4) If on any such inspection the medical officer of health is of opinion that infectious disease is caused or is likely to be caused by consumption of the milk supplied from the dairy, or of the milk of any particular cow kept therein, he shall report thereon to the sanitary authority, and to the Local Government Board, and his report shall be accompanied by any report furnished to him by the veterinary inspector or veterinary surgeon, and the medical officer of health, if he considers the case to be one of urgency on account of the spread or suspected spread of infectious disease, may, pending the decision of the sanitary authority,—

(*a*) agree on behalf of the sanitary authority with the dairyman, that the dairyman shall, on such terms and to such extent and subject to such conditions as may be agreed, stop the supply and use of milk from his dairy or from any particular cow kept therein; or

(*b*) make an interim order prohibiting the supply for human consumption, or the use, or supply for use, in the manufacture of products for human consumption, of milk from the dairy or from any particular cow kept therein, until the expiration of such time not exceeding ten days, as may be specified in the order, either absolutely or unless such conditions as may be prescribed in the order are complied with; or

(*c*) refer the matter to the sanitary authority,

and where the matter is so referred to them the sanitary authority may, pending their final decision, make such interim agreement or order as the medical officer of health might have made.

(5) On the receipt of such a report the sanitary authority may serve on the dairyman notice to appear before them within such time, not less than twenty-four hours, as may be specified in the notice, to show cause why an order should not be made prohibiting him, either absolutely or unless such conditions as may be prescribed in the order are complied with, from supplying for human consumption, or using, or supplying for use, in the manufacture of products for human consumption, any milk from the dairy or from any particular cow kept therein until the order has been withdrawn in accordance with the provisions of this section.

(6) The sanitary authority, if in their opinion the dairyman fails to show such cause, may make such order as aforesaid specifying the ground on which the order is made, and shall forthwith serve a copy of the order on the dairyman, and shall serve notice of the facts on the council of the county in which the dairy is situate, and on the Local Government Board, the Board of Agri-

culture and Fisheries, and, if the dairy is situate within the district of another sanitary authority, also on that authority.

(7) If any dairyman, whilst any interim or other order made under this section of which he has notice is in force, supplies or uses any milk in contravention of the order, he shall, on summary conviction, be liable to a fine not exceeding *five pounds*, but a dairyman shall not be liable to an action for breach of contract if the breach is due to any such order.

(8) An interim or other order made under this section shall be forthwith withdrawn on the sanitary authority or their medical officer of health being satisfied that the milk supply has been changed or that it is not likely to cause infectious disease, and the medical officer of health shall have power to withdraw any interim order made by himself and, if so authorised by the sanitary authority, any other order made under this section.

(9) The dairyman may appeal against an order, other than an interim order, made under this section or a refusal to withdraw any such order—

(*a*) to the Local Government Board, if the order is made on the ground that an infectious disease (other than tuberculosis or any other disease with respect to which the Local Government Board order that the appeal in all cases should be to the Board of Agriculture and Fisheries) was or was likely to be caused by the consumption of milk from the dairy or from any cow kept therein; and

(*b*) in any other case, to the Board of Agriculture and Fisheries;

and on any such appeal the officer appointed by the Board to hear the appeal shall report to the Board, and the Board may confirm, vary, or withdraw the order which is the subject of the appeal, and may direct to and by whom the costs of the appeal are to be paid, and the Board may at any stage of the proceedings require the dairyman to pay such sum as the Board consider proper to secure the payment of the expenses incurred by the Board in the matter of the appeal, and the expenses so incurred by the Board (including the remuneration of the officer appointed to hear the appeal not exceeding three guineas a day) shall be treated as part of the costs of the appeal. Pending the decision of the appeal, the order shall remain in force unless previously withdrawn.

(10) For the purposes of an appeal under this section the Local Government Board and the Board of Agriculture and Fisheries, and any officer appointed by either such Board, shall have the same powers as the Local Government Board and their inspectors have for the purposes of an inquiry under the Public Health Acts.

(11) If any order is made under this section either by the

medical officer of health or by the sanitary authority without due cause, or if the sanitary authority or medical officer of health unreasonably refuse to withdraw any such order, the dairyman shall, if not himself in default, be entitled to recover from the sanitary authority full compensation for any damage which he has sustained by reason of the making of the order, or of the refusal to withdraw the order, and in the case of an appeal the Board to whom the appeal is made may determine and state whether an order the subject of appeal has been made without due cause, and whether the withdrawal of the order has been unreasonably refused, and whether the dairyman has been in default.

(12) Any dispute as to the fact whether the order has been made or maintained without due cause, or as to the fact of default (where any such fact has not been determined on appeal by the Board to whom the appeal is made), or as to the fact of damage, or as to the amount of compensation, shall be determined in the manner provided by section three hundred and eight of the Public Health Act, 1875, and that section shall accordingly apply and have effect as if the same were herein re-enacted and in terms made applicable to any such dispute as aforesaid.

(13) Where a sanitary authority have delegated their powers under this section to a committee anything authorised or required by this section to be done to or by the authority shall be done to or by the committee.

3.—(1) If a person—

(*a*) knowingly sells, or offers or exposes for sale, or suffers to be sold or offered or exposed for sale, for human consumption or for use in the manufacture of products for human consumption; or

(*b*) knowingly uses or suffers to be used in the manufacture of products for human consumption :

tuberculous milk or the milk of any cow which is suffering from tuberculosis of the udder, or which is emaciated from tuberculosis, he shall for each offence be liable on summary conviction to a fine not exceeding *ten pounds*, unless he proves that the milk has been boiled or otherwise sterilised.

(2) Any dairyman after he becomes aware that any cow in his dairy is suffering from tuberculosis with emaciation, or from tuberculosis of the udder, or is giving tuberculous milk, shall, so far as is practicable, not keep that cow or permit it to be kept in any field, shed, or other premises along with other cows in milk, and if he does so shall be liable on summary conviction to a fine not exceeding *five pounds*.

4.—(1) It shall be lawful for an inspector of the Local Government Board, or the medical officer of health of a county or of any sanitary district, or any person provided with and, if required, exhibiting an authority in writing from such an inspector or medical officer of health, to take for examination samples of milk:

Provided that the powers of a medical officer of health and of a person authorised by him under this section shall, except so far as the Local Government Board may by order otherwise direct, be exerciseable only within the county or district for which the medical officer of health acts.

(2) If any person obstructs a medical officer of health or person authorised by him in the execution of his powers under this section, he shall on summary conviction be liable to a fine not exceeding *five pounds.*

5.—The Local Government Board may, by order, require the council of any county, borough, or urban district to appoint, or combine with another such council in appointing, for the purposes of this Act, one or more veterinary inspectors, or to employ for those purposes any inspector or other officer appointed by the council under the Diseases of Animals Act, 1894.

6.—(1) The Local Government Board, after consultation with the Board of Agriculture and Fisheries, may make such general or special orders as they think fit for the purpose of carrying this Act into effect, and, in particular, with respect to all or any of the following matters:

(*a*) The registration with the sanitary authority of dairies and dairymen, including the inspection and taking copies of and making extracts from the registers, and the fees to be charged in respect of any such matters;

(*b*) The inspection and examination of dairies and cows therein;

(*c*) The lighting, ventilation, cleansing, drainage, water supply, floor space, air space, and construction of floors, of dairies;

(*d*) The prevention of impurities in milk intended for human consumption and the cleanliness of vessels used for or containing such milk;

(*e*) The measures to be taken for cooling milk and otherwise for protecting milk against infection or contamination;

(*f*) The prohibition or regulation of the use of preservatives in milk;

(*g*) The manner of conveyance of milk intended for sale for human consumption and the identification of churns and vessels used for the conveyance of such milk;

(*h*) The prohibition or regulation of the mixing of the milk in one such churn or vessel with the milk in another such churn or vessel;

(*i*) The labelling of the receptacles of milk for sale for human consumption where the milk is sold otherwise than in its natural state;

(*j*) The provision of assistance to be given by sanitary authorities to county councils and by county councils to sanitary authorities, in carrying out their duties under this Act;

(*k*) The form of orders to be made by sanitary authorities and medical officers of health under this Act;

(*l*) The qualifications, duties, salaries, and tenure of office of veterinary inspectors;

(*m*) The authorities by whom the orders are to be executed and enforced, and the powers of entry and inspection exerciseable by such authorities and their officers for the purpose.

(2) Orders made under this section may impose on persons contravening the provisions thereof such fines recoverable summarily as may be specified in the order, not exceeding *five pounds* for each offence, and in the case of a continuing offence, a further fine not exceeding *forty shillings* for each day during which the offence continues.

(3) All general orders made under this section shall be laid as soon as may be before Parliament, and the Rules Publication Act, 1893, shall apply to such orders as if they were statutory rules within the meaning of section one of that Act.

(4) If the occupier of a dairy alleges that the whole or part of the expenses of complying with any order under this section ought to be borne by the owner of or other person interested in the dairy, he may by complaint apply to a court of summary jurisdiction, and that court may make such order concerning the expenses or their apportionment as appears to the court to be just and equitable under the circumstances of the case, regard being had to the terms of any contract between the parties.

7. A warranty or invoice shall not be available as a defence to any proceedings under the Sale of Food and Drugs Acts, 1875 to 1907, where the article in respect of which the proceedings are taken is milk.

8. The Local Government Board shall make regulations under the Public Health (Regulations as to Food) Act, 1907, for the prevention of danger arising to public health from the importation of milk intended for sale for human consumption.

9.—(1) The sanitary authority of any district (other than a rural district) with a population of fifty thousand or upwards may, subject to regulations under this section, establish and thereafter maintain depots for the sale of milk specially prepared for consumption by infants under two years of age, and purchase and prepare milk and provide such laboratories, plant, and other things, and exercise and perform such other powers and duties, as may be necessary for the purposes of this section.

This provision shall extend to any district (other than a rural district) with a population of less than fifty thousand but not less than ten thousand, if the sanitary authority of the district make an application for the purpose to the Local Government Board and the Board consent.

(2) The Local Government Board may make regulations for carrying into effect this section, and those regulations may (amongst other things) contain provisions—

(*a*) as to the sources of the milk to be obtained;

(*b*) as to the nature of the milk to be supplied;

(*c*) as to the manner in which, and the conditions under which, the milk is to be purchased, collected, conveyed, delivered, prepared, stored, and sold, including the classes of persons to be supplied, and the prices which may be charged on sale;

(*d*) as to the plant and other things to be provided, and as to the purposes for which, and the manner in which, and the conditions under which, they may be used;

(*e*) as to the statistical and other records to be kept;

(*f*) as to the visitation of the homes of the persons supplied, and as to any other mode of obtaining particulars prescribed by the regulations with regard to those persons;

(*g*) authorising and regulating the acquisition and appropriation of land for the purposes of this section, and the disposal of any land so acquired;

(*h*) in the case of the Common Council and the council of a municipal borough, as to the accounts of receipts and expenditure under this Act to be kept by every such council, and as to the audit of those accounts in the same manner and subject to the same provisions as to any matters incidental to the audit or consequential thereon as the accounts of a county council;

(*i*) authorising and regulating the borrowing of money by a sanitary authority for the purposes of this section;

(*j*) as to the employment of officers;

(*k*) authorising the holding of local inquiries by the Local Government Board for the purposes of this section, and requiring returns and reports to be made to the Board;

(*l*) facilitating the co-operation of any sanitary authority having powers under this section with any other such authority, and the provision of assistance by one such authority to another;

(*m*) applying for the purposes of this section, as respects any matters to be dealt with by regulations, any provisions in any Act of Parliament dealing with the like matters, with the necessary modifications or adaptations.

Regulations so made shall be applicable to all authorities having powers under this section, except so far as may be otherwise provided by the regulations.

(3) Population for the purposes of this section shall be calculated according to the returns of the last published census for the time being.

10.—(1) If on a complaint to the council of a county in which a county district is situate—

(*a*) from any four inhabitant householders of the county district; or

(*b*) from the parish council or parish meeting of any parish within the district; or

(*c*) from the sanitary authority of a district within which milk is supplied from any dairy in the county district;

it appears to the county council, after holding a local inquiry, that the council of the county district have failed to fulfil their duties, whether as sanitary authority or otherwise, under this Act, the county council may pass a resolution to that effect, and thereupon the powers and duties of the council of the county district shall be transferred from that council to the county council, and the county council shall proceed to put in force the powers and duties so transferred.

(2) All expenses incurred by the county council in executing this section in any county district shall be paid in the first instance out of the county fund as expenses for general county purposes, but shall, on demand, be repaid to the county council by the council of the county district.

(3) If the council of a county or county borough fail to fulfil any of their duties under this Act, whether imposed on the council by this Act, or in the case of a county council transferred to the council from the council of a county district under this section, the Local Government Board may, after holding a local inquiry, make such order as they think necessary or proper for the purpose of compelling the council to fulfil their duties, and any such order may be enforced by mandamus.

(4) If on a complaint to the Local Government Board—

(*a*) from any four inhabitant householders of any county district; or (*b*) from the parish council or parish meeting of any parish within a county district; or

(*c*) from the sanitary authority of a district within which milk is supplied from any dairy in a county district; or

(*d*) from the council of the county in which a county district is situated,

it appears to the Local Government Board, after holding a local inquiry, that the council of that county district have failed to fulfil their duties, whether as sanitary authority or otherwise, under this Act, the Board may by order declare the council to be in default, and may either—

(i.) make an order directing the council within a time limited by the order to take such action or do such things as may be specified in the order for the purpose of remedying the default, and any such order may be enforced by mandamus, or

(ii.) make an order empowering the person named therein to perform the duties of the council, and upon such appointment sections two hundred and ninety-nine to three hundred and two of the Public Health Act, 1875, shall apply.

11.—(1) Any notice, order, or other document required or authorised to be served under this Act may be served by delivering the same or a true copy thereof either to or at the usual or last-known residence of the person to whom it is addressed, or where addressed to the owner or occupier of premises, then to some person on the premises, or, if there is no person on the premises who can be served, then by fixing the same or a true copy thereof on some conspicuous part of the premises; it may also be served by sending the same or a true copy thereof by post addressed to a person at such residence or premises as above mentioned.

(2) Any notice required or authorised for the purposes of this Act to be served on a sanitary authority shall be deemed to be duly served if in writing delivered at, or sent by post to, the office of the authority or council, addressed to the authority or council, or their clerk.

(3) Any notice by this Act required to be given to or served on the owner or occupier of any premises may be addressed by the description of the "owner" or "occupier" of the premises (naming them) in respect of which the notice is given or served without further name or description.

12. The expenses of local authorities under this Act shall be defrayed—

(*a*) in the case of a county council, out of the county fund;

(*b*) in the case of the Common Council, out of the general rate;

(*c*) in the case of the council of a metropolitan borough, as part of the expenses incurred by the council in the execution of the Public Health (London) Act, 1891;

(*d*) in the case of the council of a municipal borough or urban or rural district, as part of their general expenses incurred in the execution of the Public Health Acts.

13.—(1) Proceedings against a dairyman for failure to comply with an order made by a sanitary authority or a medical officer of health requiring the dairyman not to supply milk from a dairy or from any cow in a dairy may be taken before a court of summary jurisdiction either in the place where the offence was committed or in the place where the dairy is situated, and shall be taken only by the authority by whom or by whose medical officer of health the order was made or by the sanitary authority of the district in which the dairy is situate.

(2) Where a person is convicted of an offence under this Act, and the offence is a continuing offence, the offender shall be liable, in addition to any fine which may be imposed under this Act in respect of the offence, to a further fine not exceeding *forty shillings* for each day during which the offence continues.

14.—(1) In this Act—

The expression "dairy" includes any farm, farm-house, cow-shed, milk-store, milk-shop, or other place from which milk is supplied, or in which for purposes of sale or manufacture into butter or cheese milk is kept or used;

The expression "dairyman" includes any cow-keeper, purveyor of milk, or occupier of a dairy, but shall not include a person who only sells milk of his own cows in small quantities to his workmen or neighbours for their accommodation;

The expression "medical officer of health" includes any person duly authorised to act temporarily as medical officer of health;

The expression "milk" includes cream;

The expression "infectious disease" means small-pox, cholera, diphtheria, membranous croup, erysipelas, tuberculosis, the disease known as scarlatina or scarlet fever, and the fevers known by any of the following names, typhus, typhoid, enteric, relapsing, continued, and includes any other disease prescribed by an order made by the Local Government Board under this Act;

The expression "Common Council" means the mayor, aldermen, and commons of the City of London in Common Council assembled.

(2) Where milk is sold or exposed or kept for sale it shall be presumed to be sold or exposed or kept for sale for human consumption or for use in the manufacture of products for human consumption, unless the contrary is proved.

15.—(1) The powers and duties of metropolitan borough councils as sanitary authorities with respect to the registration of dairymen shall be exercised and performed subject to any by-laws which may be made for the purpose by the London County Council.

(2) The provisions of this Act with respect to the inspection of dairies and prohibition of the supply of milk, and the enforcement of duties of local authorities, shall apply to London, subject to such modifications as may be made by regulations of the Local Government Board, and such regulations may provide for any of the powers and duties of sanitary authorities and their medical officers of health under those provisions with respect to dairies situate outside London being exercised and performed by the London County Council, and the medical officer of health of the London County Council, or by some person appointed by him for the purpose.

(3) Any provisions of the Public Health Act, 1875, applied by this Act shall, for the purposes for which they are so applied, extend to London.

16.—This Act in its application to Ireland shall be subject to the following modifications:—

(1) The Local Government Board for Ireland shall be substituted for the Local Government Board:

(2) The Department of Agriculture and Technical Instruction for Ireland shall be substituted for the Board of Agriculture and Fisheries:

(3) References to the Public Health (Ireland) Acts, 1878 to 1907, shall be substituted for references to the Public Health Acts; a reference to section two hundred and seventy-four of the Public Health (Ireland) Act, 1878, shall be substituted for the reference to section three hundred and eight of the Public Health Act, 1875, and a reference to section fifteen of the Public Health (Ireland) Act, 1896, shall be substituted for the reference to sections two hundred and ninety-nine to three hundred and two of the Public Health Act, 1875:

(4) The expression "medical officer of health" means as regards any sanitary district for which a medical superintendent officer of health is appointed that officer, and

elsewhere the medical officer of health of the dispensary district:

(5) References to a parish council or to a parish meeting shall not apply:

(6) The expenses of a county council under this Act shall be a county at large charge, without prejudice to any right under this Act to recover such expenses from the council of a county district.

17.—(1) This Act may be cited as the Milk and Dairies Act, 1909, and shall come into operation on the *first day of January nineteen hundred and ten.*

(2) This Act shall not extend to Scotland.

(3) The enactments specified in the Schedule to this Act are hereby repealed to the extent mentioned in the third column of that Schedule, and there shall also be repealed so much of any local Act as deals with any of the matters dealt with by any of the provisions of this Act or of the orders made thereunder.

SCHEDULE

Enactments Repealed

Session and Chapter.	Short Title.	Extent of Repeal.
41 & 42 Vict. c. 74.	The Contagious Diseases (Animals) Act, 1878.	So much of the Act as is unrepealed except so far as it relates to Scotland.
49 & 50 Vict. c. 32.	The Contagious Diseases (Animals) Act, 1886.	So much of the Act as is unrepealed except so far as it relates to Scotland.
53 & 54 Vict. c. 34.	The Infectious Diseases Prevention Act, 1890.	Section four.
54 & 55 Vict. c. 76.	The Public Health (London) Act, 1891.	Section twenty-eight. Section seventy-one.
62 & 63 Vict. c. 14.	The London Government Act, 1899.	In Part I. of the Second Schedule, the last paragraph in both columns.
8 Edw. VII. c. 56.	The Tuberculosis Prevention (Ireland) Act, 1908.	Section nineteen.

APPENDIX V

STATE OF NEW JERSEY

An Act providing for the Incorporation of Medical Milk Commissions and the Certification of Milk Produced under their Supervision.

Be it enacted by the Senate and General Assembly of the State of New Jersey:

1. Any five or more physicians duly authorised to practise medicine under the laws of this State who shall desire to associate themselves together for the purpose of supervising the production of milk intended for sick-room purposes, infant feeding, and for use in hospitals, may make, record, and file a certificate in writing in the manner hereinafter mentioned.

2. Such certificate shall set forth:

(i.) The name of such association which shall be as hereinafter designated.

(ii.) The purposes for which the association shall be formed.

(iii.) The names and the residences of the medical directors who shall manage the affairs of the association for the first year of its existence.

(iv.) The county in this State where such association shall operate.

3. Such certificate shall be proved or acknowledged and recorded as required of deeds of real estate in a book to be kept for the recording of certificates of incorporation in the office of the clerk of the county where the purposes of such association are to be carried out, and after being so recorded, shall be filed in the office of the Secretary of State; said certificate or a copy thereof duly certified by the said clerk or Secretary of State shall be evidence in all courts or places.

4. Upon making such certificate and causing the same to be recorded and filed as aforesaid, the said physicians so associating

themselves together and their successors shall by virtue of this act be a body politic and corporate in fact and in law by the name stated in such certificate, and by that name they and their successors shall have perpetual succession, with power to sue and be sued, plead and be impleaded, answer and be answered unto in all courts and places whatsoever, and to make and use a common seal at pleasure.

5. The name of such association shall be the "The Medical Milk Commission of . . . . (designating name of county) county, of New Jersey," and in case more than one association shall be organised under this act or otherwise, such subsequent association or associations shall use the name designated herein, but shall indicate in such name its proper sequence in organisation or incorporation by adding thereto the words: "Number Two," "Number Three," "Number Four," or as the case may be.

6. Such medical directors shall have the power from time to time to make, alter and amend by-laws not inconsistent with the Constitution and Laws of the United States and of this State, fixing or altering the number of its medical directors and providing for the mode of filling vacancies and removing any member from their number and prescribing qualifications for membership in the association and the appointment of such agents and officers as shall in their judgment tend to promote or advance any purpose or purposes of such commission, and to prescribe their respective duties; and for the regulating of the conditions under which milk shall be produced by any dairyman or dairymen under contract with such commission.

Such Medical Milk Commissions shall have power to certify to any milk produced under their supervision which shall meet the requirements hereinafter mentioned.

7. No medical director of any association organised under this act shall receive, directly or indirectly, from such association or dairyman or dairymen producing milk under agreement with such commission any salary or emolument or any compensation of any kind or character for any services rendered under the provisions of this act, and any medical director who shall receive any salary, emolument, or compensation of any kind or character for such services, shall be liable to a penalty of one hundred dollars ($100.00), to be recovered in an action of debt by the association of which he is a member, and in addition thereto shall be removed from his office as a member of said association and thereafter disqualified from becoming a member of any association incorporated under the provisions of this act.

8. Every such association shall have power to enter into agreement in writing with any dairyman or dairymen for the production

of milk under the supervision of such association for the purposes enumerated in section one hereof, and to prescribe in such agreement the conditions under which such milk shall be produced, which conditions, however, shall not be below the standards of purity and quality for "Certified Milk" as fixed by "The American Association of Medical Milk Commissions," and the standards for milk now fixed or that may hereafter be fixed by the Board of Health of the State of New Jersey. In any contract entered into by any such commission with any dairyman or dairymen, it may be provided that such Medical Milk Commission may designate any analysts, chemists, bacteriologists, veterinarians, medical inspectors or other persons who in its judgment may be necessary for the proper carrying out of the purposes of such commission for employment by such dairyman or dairymen and to prescribe and define their powers and duties, and that such persons so employed by such dairyman or dairymen may be discharged from employment whenever such Medical Milk Commission may request such discharge or removal in writing.

9. All containers of any kind or character used in the carrying or distribution of milk produced by any dairyman or dairymen under contract with any Medical Milk Commission shall have attached thereto or placed thereon a certificate or seal bearing the name of the Medical Milk Commission with which such dairyman or dairymen producing such milk shall be under contract, which certificate shall have printed, stamped, or written thereon the day or date of the production of the milk contained in any such container and the words "Certified Milk" in plain and legible form.

10. The work and methods of any Medical Milk Commission organised under this act, and of the dairies on which milk is produced under contract with any such commission, shall at all times be subject to investigation and scrutiny by the Board of Health of the State of New Jersey. The secretary of said State Board of Health shall be an *ex-officio* member of every milk commission organised under this act.

11. No person, firm, or corporation shall sell or exchange or offer or expose for sale or exchange as and for certified milk any milk which is not produced in conformity with the methods and regulations prescribed by and which does not bear the certification of a Medical Milk Commission, incorporated pursuant to the provisions of this act or organised or incorporated in some other State for the purposes specified in section one hereof, and which is not produced in conformity with the methods and regulations for the production of certified milk from time to time adopted by the American Association of Medical Milk Commissions, and which is below the standards of purity and quality for certified milk as

fixed by the American Association of Medical Milk Commissions; and any such person, firm, or corporation violating any of the provisions of this section shall be guilty of a misdemeanour.

12. All acts and parts of acts inconsistent with this act be and the same are hereby repealed, and this act shall take effect immediately.

Approved April 21, 1909.

APPENDIX VI

THE under-mentioned Reports and Rules illustrate the precautions taken by certain large English milk companies to prevent the milk which they handle from acting as a vehicle for the spread of infectious disease. The forms printed are those in use by Messrs. Welford and Sons, London.

MEDICAL OFFICER'S REPORT

(The report sheet leaves spaces for the answers to the under-mentioned questions.)

I. Do you find the occupants of the farm-house, the persons employed on the farm and their families in good health?

NOTE A.—The skin for evidence of eruptive diseases or desquamation.
NOTE B.—The throat for evidence of diphtheria and allied conditions.
NOTE C.—The state of the bowels for typhoid and diarrhoea.

II. Are any of them suffering from disease of a communicable nature? If so, give name and age, with the nature of such disease, and probable source or cause of same.

III. Do you consider the sanitary conditions of the farm-house and premises with the dwellings and other buildings thereon satisfactory?

IV. Where is the cooling performed, and is the position of the refrigerator satisfactory and the surroundings airy, sweet, and clean?

V. Sources of water-supplies. State depth of wells and nature of ground.

(A) For domestic use.
(B) For cooling.
(C) For washing utensils.
(D) For cattle-drinking.

VI. Is the water-supply satisfactory from a sanitary point of view?

VII. If any danger from contamination, please describe it.

Note.—Any suggestion for remedying the same will be much appreciated.

VIII. What is the general health of the population of the district?

IX. Are there any cases of zymotic disease in your district or neighbourhood?

X. Has there been in the district within the past three months any cases of a contagious or infectious character? If so, to what extent and at what distance from the farm?

If there are any other matters likely to affect the present or future milk-supply from this farm add any remarks or suggestions.

VETERINARY REPORT

I. Number of cows in milk at date of inspection. Of what breed, and number of each breed?

II. Are all the cows on the farm in good health and flesh, and free from evident signs of tuberculosis? And what is their general appearance?

III. Are any of the cows suffering from cough, from disease or affections of the udder, from eruptions or chaps on the teats?

IV. Are the cows carefully tended and their coats and udders kept clean?

V. Are any of the cows milking in less than four quarters? If so, state the number of such cows, and specially ascertain cause, and examine for traces of disease.

VI. Do you consider the cows well fed, and with proper food for producing good, wholesome milk fit for the delicate digestions of infants and invalids?

VII. Where is the milking performed? What are the provisions for washing the cows' udders and milkers' hands? Are they satisfactory, and, so far as you can ascertain, strictly enforced?

VIII. What is the nature of the water used for cattle-drinking, from what source, and do you consider it satisfactory and safe for that purpose?

IX. Are the cowsheds of ample cubic space, well ventilated and drained, and are the cowyards regularly cleansed?

X. How much of the year or day is passed by the cows in the fields and in open or closed sheds respectively?

XI. What is the general health of the cattle in your district?

XII. Are there any known cases of tuberculosis in your district? If so, where, and to what extent?

XIII. Has there been within the last three months any case of pleuro-pneumonia or other infectious cattle disease on the farm or in the neighbourhood? If so, at what date, and what distance from the farm?

If there are any other matters likely to affect the present or future milk-supply from this farm add any remarks or suggestions.

MEDICAL AND SANITARY RULES AND FEVER PRECAUTIONS[1]

To be observed by the Employees of Messrs. WELFORD AND SONS, Limited, engaged at their Farms and Dairies

1. The slightest case of sickness of any kind among your family to be immediately reported to your employers.

2. This is especially necessary in all cases of sore throat, whether severe or slight; and it is most important for you to remember that a slight attack of a contagious disease may be as infectious as a severe one.

3. In the event of the illness proving to be of an infectious or contagious nature, steps will be taken to prevent any risk of your conveying contagion to the milk, and either of the following plans may be adopted to prevent your suffering any loss:—

(*a*) Lodgings may be provided for you elsewhere.

(*b*) You may be suspended from work for a period, during which time your wages will be paid as usual.

(*c*) The rest of your family may be protected from the danger of contagion by removing the sick person to a cottage set apart for the purpose.

(*d*) Or under the direction of the medical officers the sick person may be removed to a hospital.

4. You are specially warned against keeping any dust, ashes, garbage, or refuse of any kind, in any room, cupboard, or cellar, or in any part of your house or lodgings.

5. You are also warned against receiving any lodger or visitor into your houses, unless you are perfectly certain that such lodger or visitor has not recently suffered from, or been in contact with, any contagious disease. This particularly applies to children who may visit your children, and may be recovering from scarlet fever, diphtheria, measles, whooping-cough, or other infectious disease.

6. All carriers to wash their hands and put on clean smocks before starting on their rounds of delivery.

7. Each carrier is held strictly responsible for the cleanliness and good order of cans, churns, and measures used on his particular round.

8. Cases of illness occurring amongst customers are to be immediately reported by the carrier to the secretary or manager, so that the medical officer may be consulted, and his advice taken as to serving that particular house.

9. On no pretence whatever is milk to be served out of a churn while it is being conveyed to its destination, except from the tap.

---

[1] Printed on a card to be hung up in the house.

10. No person allowed to drink out of a can during the delivery of the milk in cans.

11. Any carrier or other employee disregarding the above rules will render himself liable to instant dismissal.

12. All employees should bear in mind that their employers' interest should be their own.

By order,

WELFORD AND SONS, LIMITED.

WEEKLY REPORT FROM THE FARMER

Date..

To

Messrs. WELFORD AND SONS.

DEAR SIRS—Above I beg to hand you milk account for last week, and inform you that at this date there is no case of sickness on my farm or amongst my servants or workmen. The cows used for milking purposes are in a perfectly healthy condition, and to my knowledge there is no case of fever or illness of an infectious nature in the neighbourhood of my farm. I have this day examined my milk cooler, and it is in good and sound order.

Signed..

....

INDEX

THE END

Printed by R. & R. Clark, Limited, *Edinburgh*.

50

1932-11
1933-1|11
1934-11
1935-1|||
1936-||||
1937-1
1946-1||/
1947-1
1950-1|1

b. SFG.

28.x.31
HaG