FOR OFFICIAL USE

REPORTS

ON

PUBLIC HEALTH AND MEDICAL SUBJECTS

No. 63

A

MEMORANDUM

ON

Bovine Tuberculosis in Man

With Special Reference to Infection by Milk

MINISTRY OF HEALTH.

LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.
1931.

Price 6d. Net.

CONTENTS.

4119. Wt. 25724—4879/2204. 1,250. 4/31. Wy. & S., Ltd. Gp. 2.

PREFATORY NOTE BY THE CHIEF MEDICAL OFFICER.

On the 6th February, 1930, Colonel Fremantle, M.P. (St. Albans), asked the Minister of Health " if, with a view to effective co-ordination of effort to prevent the spread of bovine tuberculosis from cattle to man and to promote the consumption of milk, he will issue, for the guidance of the public, a review of the main facts, experience, and conclusions on which action should be based." The Minister acceded to this request and promised, as soon as circumstances allowed, a brief memorandum on the subject, and this has now been prepared in the Medical Department of the Ministry. It is issued to the public as a general outline of the position in this country regarding the incidence of tuberculosis and the proportion due to bovine infection, the incidence of tuberculosis in cattle and the estimated percentage of milk from those animals proving tuberculous, together with a consideration of the available known measures which can successfully be adopted for mitigating or preventing the infection of consumers of such milk with the bovine bacillus. Such a memorandum is not intended, of course, to provide a full statement of all our knowledge of the subject of tuberculosis and milk, which would require a lengthy period of preparation. But it does contain a conspectus of information designed to enable the reader to appreciate the needs of the situation and the difficulties of meeting it, which are by no means free from both practical and scientific involvements.

GEORGE NEWMAN.

Whitehall,

March, 1931.

BOVINE TUBERCULOSIS IN MAN WITH SPECIAL REFERENCE TO INFECTION BY MILK.

Introduction.

The purpose of this memorandum is to set forth as briefly as possible the information at present available on this subject, together with a short review of the measures so far taken, especially in this country, to prevent the spread of tuberculous infection from cattle to man.

It is obviously impossible in a short memorandum to reproduce the evidence supporting the various statements made, but care has been taken to differentiate between contentions which are generally admitted by workers having a special knowledge of the subject and those more doubtful points which are still the subject of controversy.

In order to understand the problems involved and to appreciate the difficulty of obtaining reliable information with regard to the amount of human tuberculosis in this country attributable to infection of bovine origin, it is necessary to have some knowledge of the natural history of the infecting organism and of its behaviour when introduced into the bodies of cattle and of human beings. For the present purpose it may suffice to restate some of the facts which have now been firmly established, largely by the labours of the Royal Commission on Tuberculosis (1904–1911).*

Tuberculosis in animals and in man is the same disease, that is to say the pathological changes found are always of exactly the same nature, though they may vary in degree, and the organisms causing them resemble each other so closely in their morphology, cultural characters and pathological effects that they must be regarded as varieties of the same species rather than as distinct organisms. It is, however, possible by observing the cultural peculiarities and pathogenic properties of the organisms concerned to distinguish at least three definite types or varieties, known as the human, bovine and avian, from the frequency with which they are isolated from cases of the disease in man, cattle and birds, respectively. For the purpose of this memorandum it is important to distinguish between the human and the bovine varieties and this distinction is made possible by two facts, namely: (1) that the human bacillus grows more luxuriantly than the bovine type on certain media, the addition of glycerin to the medium favouring the growth of the former and impeding or leaving unaffected the growth of the latter; and (2) that the bovine strain is much more virulent for certain animals (viz., bovines, pigs, rabbits, etc.), than the human strain. For instance the bovine strain sets up acute and generalised tuberculosis when 0·01 mg. of a culture of the bacilli on a

* See also "Tuberculosis in Man and the Lower Animals," by H. H. Scott, Medical Research Council, Special Report Series No. 149, H.M. Stationery Office, 1930.

solid medium is injected intravenously into rabbits ; this effect is not produced by the same dose of the human bacillus.

In spite of these differences between the human and bovine varieties of the tubercle bacillus, it has been amply demonstrated that man can be infected with the bovine, as well as with the human, type of the tubercle bacillus, and, in fact, many fatal cases of tuberculosis in man are due to infection with the bovine variety of the organism. It is in children especially that the bovine bacillus is found, and there is no doubt that a considerable amount of the tuberculosis of childhood is due to infection with bacilli of this type conveyed in milk from tuberculous cows. The extent of this infection will be discussed later.

I.—The Incidence of Human Tuberculosis in England and Wales.

It is not possible to form an exact estimate of the incidence of human tuberculosis in this country from the figures for notified cases, which, however complete, do not take account of duplications and omissions ; at the same time it is generally admitted that notification of the disease has undergone much improvement in recent years. Many new cases, moreover, come to the knowledge of Medical Officers of Health otherwise than by formal notification, and these additional cases are included in the figures for the years from 1923 onwards, given below, causing an apparent increase in the incidence of the disease. The following table, therefore, gives only an approximate idea of the incidence of tuberculosis in England and Wales.

TABLE I.

England and Wales.

Year.	New Cases of Tuberculosis.		
	Pulmonary.	Non-pulmonary.	Total all forms.
1913	80,788	36,351	117,139
1914	76,109	23,388	99,497
1915	68,309	22,283	90,592
1916	68,109	22,799	90,908
1917	68,801	20,884	89,685
1918	71,631	18,942	90,573
1919	61,154	16,357	77,616
1920	57,844	15,488	73,332
1921	56,334	15,368	71,702
1922	53,422	15,837	69,259
1923	59,172	20,216	79,388
1924	60,747	20,411	81,158
1925	60,770	20,667	81,437
1926	59,520	20,134	79,654
1927	58,109	19,781	77,890
1928	57,682	20,199	77,881
1929	57,274	18,682	75,956

The mortality figures for the disease are set forth in Table II below.

TABLE II.

Year.	Deaths from Tuberculosis of the Respiratory System.			Deaths from other forms of Tuberculosis.		
	Males.	Females.	Total.	Males.	Females.	Total.
1911 ...	21,594	16,828	38,422	7,633	7,065	14,698
1912 ...	21,158	16,111	37,269	6,648	6,134	12,782
1913 ...	20,601	15,602	36,203	7,056	6,217	13,273
1914 ...	21,417	16,421	37,838	6,659	5,801	12,460
1915 ...	23,167	17,636	40,803	7,178	6,314	13,492
1916 ...	22,850	17,919	40,769	6,876	6,213	13,089
1917 ...	23,276	19,059	42,335	7,083	6,516	13,599
1918 ...	24,371	20,967	45,338	6,656	6,079	12,735
1919 ...	19,248	16,736	35,984	5,302	5,026	10,328
1920 ...	17,872	14,919	32,791	5,046	4,708	9,754
1921 ...	18,121	15,384	33,505	4,778	4,395	9,173
1922 ...	18,656	15,263	33,919	4,660	4,198	8,858
1923 ...	17,571	14,526	32,097	4,514	4,177	8,691
1924 ...	17,970	14,720	32,690	4,380	4,033	8,413
1925 ...	17,995	14,387	32,382	4,239	3,766	8,005
1926 ...	16,773	13,335	30,108	3,896	3,521	7,417
1927 ...	17,184	13,882	31,066	3,732	3,375	7,107
1928 ...	16,608	13,191	29,799	3,549	3,275	6,824
1929 ...	17,786	13,639	31,425	3,500	3,065	6,565

The gross death rate in 1929 for all forms of tuberculosis was 959 per million, that for respiratory tuberculosis being 793, and for other forms of the disease 166. Although the figures for 1929 are somewhat higher than those for 1928, as regards respiratory tuberculosis, there has been a general trend downwards during the last twenty years—the deaths from non-pulmonary forms of tuberculosis in 1929 being less than half of those for 1911.

However encouraging these results may be, the loss of life from this disease (not to mention the invalidity) is still a very serious matter, and the concentration of every effort in the campaign against tuberculosis is of the greatest importance.

II.—Proportion of Cases attributable to Infection of Bovine Origin.

The estimation of the proportion of cases due to infection of bovine origin is a difficult matter.

In the opinion of most experienced workers the possibility of the gradual modification of bacilli of the bovine type in the human body until they manifest all the characters typical of the human variety is so remote as to be negligible for all practical purposes.

It may be assumed, therefore, that the discovery of bacilli of the human or bovine type in any case of tuberculosis gives a fairly accurate indication of the origin of the infection. The bacteriological work involved in the isolation of the infecting organism and the determination of its type, is, however, considerable, and although many workers have undertaken this task and the total number of cases which have thus been classified is large, it cannot yet be stated with accuracy what proportion of the deaths in each variety of tuberculous disease is due to the bovine bacillus. The most extensive work in this direction, as regards Great Britain, has been carried out by Dr. A. S. Griffith, who has kindly supplied the following table, which includes his latest results.

TABLE III.

Variety of Tuberculosis.	Number of Cases.	Percentage of cases infected with Bovine type of tubercle bacillus.		
		0–5 yrs.	5–15 yrs.	All ages.
Cervical Gland ...	133	84·0	51·5	48·9
Lupus	168	62·5	53·2	52·4
Scrofulodermia ...	59	50·0	43·2	35·6
Bone and Joint ...	541	29·4	18·6	18·7
Genito-Urinary ...	23	—	—	17·4
Meningitis	33	33·3	35·0	27·3
Pulmonary	795	—	—	2·6
Post-mortem Cases ...	183	29·7	14·3	22·3

In this table all the figures, excluding those for the post-mortem cases, refer to cases in which the organism whose type was determined was found in material obtained from the patient during life. Thus, in the cervical gland cases the bacillus was obtained from glands removed at operation or from pus taken from suppurating glands; and in the meningitis cases the bacillus was found in the cerebro-spinal fluid drawn off by puncture. These figures therefore refer to the incidence of the bovine infection and not to mortality from this cause, and if these cases represent a fair sample of the total cases in the country (as is probably approximately true) then a large proportion, and in some varieties as much as a half, of the tuberculous disease in children under 15 is caused by the bovine type of the bacillus. It will be observed that there is little or no evidence of bovine infection producing pulmonary tuberculosis in children.

III.—Incidence of Tuberculous Disease in Cattle.

1. *Results of Tuberculin Test.*

As many estimates of the prevalence of tuberculous disease in cattle are based upon the results of tuberculin tests, it may be as

well to say a word here with regard to the significance of this reaction in bovine animals. A positive reaction in a bovine may be accepted as evidence that the animal is infected with the bacillus of tuberculosis. The test is a qualitative and not a quantitative one; it thus gives no indication of the degree of infection present, except that heavily infected animals may not react to the test; in such cases clinical manifestations are almost invariably present. So great is the risk of the spread of tuberculosis in a herd from a reactor to the tuberculin test that for practical purposes such reactors are to be regarded as infective. By reason of the susceptibility of bovine animals to tuberculosis an infected animal, if allowed to survive long enough, would almost always go on to a condition of active progressive tuberculosis.

There are two main forms of tuberculin test, viz :—(1) The Subcutaneous Test, i.e., a temperature test following on the hypodermic injection of a measured quantity of tuberculin, and (2) The Intradermal Test, i.e., a clinical estimation of the swelling produced by an injection of tuberculin into the skin.

The Tuberculin Committee of the Medical Research Council found that the subcutaneous test, although satisfactory when carried out with the exactitude of a laboratory experiment, was untrustworthy under ordinary farm conditions, and difficult of interpretation. Accordingly they devised a modification of the intradermal test, known as the Double Intradermal Test, the accuracy and reliability of which under ordinary farm conditions have been amply proved.* This test has recently been made obligatory by the Ministry of Health and by the Department of Health for Scotland in the case of herds licensed for the production of Certified Milk and Grade A (T.T.) Milk.

Until the tuberculin test has been applied on a large scale any estimates of the incidence of tuberculous disease in cattle based upon the results obtained by it must be accepted with caution. In the first place there is reason to believe that the incidence of the disease varies very considerably in different localities; and in the second place the reports available relate principally to milch cows, which are more prone to be tuberculous than young cattle and other bovine animals. In these circumstances it is not surprising to find that the percentage of reactors in different investigations has varied within wide limits; 40 per cent., however, would probably be accepted as an average figure for milch cows.

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* *Vide* "Tuberculin Tests in Cattle with Special Reference to the Intradermal Test." Medical Research Council. Special Report Series No. 94, H.M. Stationery Office, 1925, and "The Intradermal Tuberculin Test in Cattle—Collected Results of Experience." J. B. Buxton and A. S. MacNalty, Medical Research Council. Special Report Series, No. 122. H.M. Stationery Office, 1928.

2. *Abattoir Statistics.*

Another source of information is furnished by the results of slaughterhouse examinations. In 1929, at the Metropolitan Cattle Market, Islington, 51 per cent. of the cows slaughtered were found to be tuberculous. In Edinburgh the corresponding figures for 1926 and 1927 were 46·5 per cent. and 42·99 per cent., respectively, but the majority of the cows were affected with the disease to a minor extent only. Such returns as these depend, of course, upon a variety of factors relating to the reasons for slaughter.

3. *Clinical Cases detected by Routine Veterinary Inspection.*

The routine inspection of cattle, especially if combined with biological tests of the milk, gives very valuable information as to the proportion of cattle infected with tuberculosis, but unfortunately such inspection is at present carried out in a few areas only. The results which are obtained give some idea of the number of so-called "open" cases of tuberculosis in the area, but afford little indication of the total amount of tuberculous disease present. It is, however, the "open" cases which are of chief importance in estimating the danger to man from this infection, but it must be remembered that in many cases the veterinary inspection of a herd is undertaken in consequence of the discovery of tuberculous milk and the animals whose examination is recorded are to this extent selected. Savage has collected figures from various English and Scottish County Authorities, carrying out routine clinical inspections of cattle in which the percentage of tuberculous animals so detected varied from 0·22 to 1·77 of the animals examined, and that of cows with udder tuberculosis from 0·10 to 0·40.

4. *Proportion of Cows suffering from Tuberculosis.*

What then is the prevalence of bovine tuberculosis in this country? In 1921 McFadyean estimated that of breeding animals from 3 years upwards not less than 30 per cent. were tuberculous, and that for the principal milking breeds the figure should probably be nearer 40 per cent. These estimates may be regarded as moderate, and the real proportion is probably considerably higher. Not all of these cows are, of course, yielding tuberculous mil , but since the disease is progressive they might be regarded as ultimate sources of such milk if they survive long enough.

IV.—Tuberculous Milk.

1. *Milk as a Vehicle of Infection with the Bovine Bacillus.*

Reference has already been made to the part played by raw milk in the transmission of tuberculosis to children. The evidence now available makes it practically certain that this is the main vehicle of infection with the bovine bacillus and, as will be shown in the next section, the opportunities for infection from this source are

unfortunately frequent. Bovine infection is commoner in children than in adults, and there is reason to believe that the intestinal defensive mechanism is less developed in childhood, which is also the period when more milk is drunk, than in later life. Although there can be no doubt that the chief portal of entry in alimentary infection is the intestine, there is evidence to indicate that the tonsils not infrequently play this role.

Estimates of the prevalence of tuberculosis in cattle give some indication of the danger of human infection by bovines; but, as has alread been remarked, the chief source of infection is milk containing the tubercle bacillus, so that an estimate of the frequency with which cows yield such milk is of the greatest importance.

2. *Proportion of Cows yielding Tuberculous Milk.*

It has been pointed out above that at any given time cows with tuberculosis are not all yielding tuberculous milk, and in order to estimate the proportion of cows which are doing so it is important to have information with regard to the prevalence of tuberculous disease of the udder. This is extremely difficult to assess as it is often impossible to detect such disease clinically, and in the early stages of the infection the milk may contain tubercle bacilli and yet the udder may be unaltered in appearance. It is generally admitted that primary udder tuberculosis is extremely rare, and in something like 50 per cent. of the cows found to be tuberculous on slaughter the disease is generalised in the body. Tuberculous mastitis is much commoner in older cows than in quite young animals, and it is possible that the disease is encouraged by the artificial stimulation of the mammary gland and the unnatural demands made upon it by milking. Slaughterhouse statistics and the routine inspection of cows by veterinary surgeons, such as is carried out in certain parts of the country, give an incidence of something under 1 per cent. for tuberculous mastitis, but some observers believe that the true figure for the whole country is considerably higher. Savage, however, considers that the older estimates (e.g., McFadyean, 2·0 per cent.; Stockman, about 2·0 per cent.; Dewar, over 1·2 per cent.) are probably too high. The Ministry of Agriculture and Fisheries conclude, from the information at their disposal, that probably from 1 to 1·5 per cent. of cows in herds in which the disease has been discovered under the operations of the Tuberculosis Order and the Milk and Dairies Acts yield tuberculous milk.

Where strict cleanliness is not practised, milk from healthy cows may become infected with tubercle bacilli from the milkers or from contaminated manure, fodder or dust.

3. *Proportion of Milk infected with the Tubercle Bacillus.*

The proportion of tuberculous milk in any area will depend very largely upon the extent to which the milk is mixed or " bulked " before distribution, and it cannot, therefore, be taken as an index

of the proportion of tuberculous cows in the herds supplying the area. Nevertheless, a consideration of the results of the bacteriological examination of mixed milk samples is of some interest as giving an idea of the frequency with which market milk is infected with the tubercle bacillus. Savage has collected records of such examinations from the annual reports of medical officers of health, and these are set out in the table below.

TABLE VI.

Percentage of Milk Samples found to be Tuberculous during the period 1922–27 inclusive.

Town.	No. of milk samples examined.	No. of samples found to be Tuberculous.	Percentage Tuberculous.
Liverpool	4,942	350	7·1
Aberdeen	955	53	5·5
Salford	1,871	139	7·4
Birmingham	3,220	244	7·6
Newcastle-upon-Tyne	1,693	85	5·0

As regards Birmingham and Newcastle-upon-Tyne, where great attention is paid to milk problems, Savage remarks that the samples are truly representative of the raw milk going into the town, so that the difference in the proportion of samples found tuberculous probably represents a different proportion of cows secreting tuberculous milk in the rural areas supplying these two towns. Naturally figures for areas in which pasteurisation is carried out before the milk is distributed will only give a true idea of the incidence of tuberculous infection in the milk if the samples are collected before pasteurisation has been carried out. In Manchester during 1929 a total of 1,133 samples of milk were examined for tubercle bacilli, of which 111 (i.e., 9·8 per cent.) gave positive results. The examination of mixed milk samples from 697 country farms during the same period showed that 88 of these farms (i.e., 12·62 per cent.) were sending tuberculous milk into Manchester. The corresponding figure for London in 1929 was 7·5 per cent.

V.—Methods of Controlling Infection.

Methods of control may be divided into two categories, those designed to check the infection at its source and those applicable to the milk immediately before its distribution.

1. At the Source.

(*a*) *Eradication by Slaughter.*

In the fight against any disease the ideal aimed at is, of course, complete eradication and the quicker this task can be accomplished

the better. Nevertheless, the price of any proposed method for achieving this end is often the governing consideration, and in no case is this more true than in that of bovine tuberculosis. McFadyean has said that there is not the least doubt that the disease could be eradicated within a few years, if that were considered necessary, regardless of cost, by enforcing the general tuberculin testing of all the cattle in the country followed by compulsory slaughter of all reacting animals. Such a scheme has, indeed, been carried out with almost complete success in certain places (e.g., Guernsey and certain States of the U.S.A., where high compensation has been paid), but, owing to the high incidence of the bovine disease in this country, its operation would involve the slaughter of from one-third to one-half or even more of all our milking cattle, and of a considerable proportion of the younger stock. This would not only involve the payment of a huge sum of money as compensation for the slaughter of apparently healthy cattle, but it would also immediately reduce very greatly the supply of milk, and increase its price for many years to come. Owing, moreover, to the occasional ambiguities of the tuberculin test and to the presence of the disease in pigs and other animals constituting subsidiary sources of infection, the operation of such a scheme might not prove so successful as McFadyean believed. It is indeed practically certain that within a short time reinfection would occur.

In view of the difficulties involved in such radical measures, various modified schemes of eradication have been considered, the outcome of which was the Ministry of Agriculture and Fisheries' Tuberculosis Order of 1925. This order aims at the destruction of every cow suffering from tuberculosis of the udder, and of every bovine animal suffering from tuberculous emaciation or suffering from a chronic cough and showing definite clinical signs of tuberculosis. The Order schedules three classes of animals, namely :—

(1) any cow which is, or appears to be, suffering from tuberculosis of the udder, indurated udder or other chronic disease of the udder ;

(2) any bovine animal which is, or appears to be, suffering from tuberculous emaciation ;

(3) any bovine animal which is suffering from a chronic cough and showing definite clinical signs of tuberculosis ;

and makes it compulsory for any person in charge of such animals, or any veterinary surgeon employed to examine such animals, to notify the fact to an Inspector of the Local Authority. The animals so notified are then examined by a veterinary inspector appointed by the Local Authority, and if he considers that they belong to any of the three designated groups they are slaughtered and compensation is paid to the owner at a rate depending upon the condition of the animal. The Order thus aims at the elimination of those animals which are the main source of danger to human

beings and to other animals, rather than at the complete eradication of the disease.

This Order has been criticised upon various grounds. First, it is pointed out that the animals in the scheduled categories are often not notified and destroyed until long after they have become infectious, and that consequently most of the harm of which they are capable has been done before they are destroyed. It is true that the Order has only been in operation a short time, and that notifications may tend to be made at an earlier stage in future, but it seems doubtful to what extent this would occur without the introduction of adjuvant measures such as the compulsory routine veterinary inspection of all cattle.

Secondly, the utility of the procedure laid down by the Order is very much limited by the frequent failure to follow up the report on an animal in one of the scheduled categories by a systematic examination of the other animals in the same herd. The necessity for such action has been pointed out by the Ministry of Agriculture and Fisheries (in a circular letter issued in July, 1925) and its frequent neglect is probably due in large part to the extra expense involved.

Thirdly, it is argued that as the farmer is compensated, however late the stage of the disease when reported, there is no strong inducement for him to report early, with the result that a great many cases, particularly of udder tuberculosis, are not notified until they have been infectious for a long time.

These defects would be overcome to some extent by more systematic routine inspection.

(*b*) *Tuberculosis-free Herds.*

A different method of approach to this problem is presented by the policy of building up and maintaining herds free from tuberculosis. This method was first advocated by Professor Bang of Copenhagen, and has been tried with great success in various countries, especially in Denmark. The principle of the method is to separate infected from healthy stock by means of the tuberculin test, and then to rear a healthy herd from the non-reactors, taking care to prevent the introduction of fresh infection. All cows with tuberculosis of the udder or with signs of wasting disease are slaughtered and the reactors and non-reactors are separated, either by keeping the two classes of animals on separate farms or by removing the healthy stock to premises on the same farm as far away from the original sheds as possible. The next step, the rearing of a tubercle-free herd, is effected by removing the calves of tuberculous mothers at birth to clean premises and by strict vigilance preventing the access of infection to these animals. The efficacy of this measure depends upon the fact, demonstrated by Bang, that the calves of tuberculous cows are only very rarely born infected, but as the majority of the exceptions to this rule are born of mothers in an advanced stage of tuberculosis, the calves of such cows should be

excluded from the tubercle-free herd. Watch is kept for the first signs of infection in the healthy herd by half-yearly or more frequent tuberculin tests. Bang advocates the building up of the tubercle-free herd entirely from the calves of healthy animals if infection has been present for long in the original herd.

This method is comparatively inexpensive, but requires considerable labour and great vigilance for its successful prosecution, as any mistake or oversight may undo in a short time the work of years. The economical disposal of reactors, to avoid the financial loss consequent upon the sale of infected animals *en masse*, is an essential part of the scheme.

A considerable number of tuberculin-tested herds exist in this country, but the common practice of recruiting them from without renders it almost impossible to keep them free from tuberculosis. The only hope of doing this is by building up the herd from within and keeping it self-contained.

A special investigation of this method is being made in a selected area in Scotland by the Medical Research Council in conjunction with the Hannah Institute for Research in Dairying, Auchincruive, Ayr.

(*c*) *Immunisation with BCG.*

The possibility of controlling bovine tuberculosis by the active immunisation of cattle with live vaccines has been the subject of controversy in recent years.

In 1908 Calmette isolated from a cow a tubercle bacillus which was of the bovine type and was virulent for guinea-pigs, rabbits and cattle, but as the result of prolonged cultivation on a special medium (glycerinated bile-potato) this organism lost its original virulence and became innocuous to guinea-pigs and cattle. A vaccine for oral administration made from cultures of the bacillus and called BCG (Bacille Calmette-Guerin) has been used in a large number of experiments since 1915 for the inoculation of cattle, and since 1921 for infants, as a protection against tuberculous infection. The inventors of this vaccine claim that it is incapable of causing progressive disease and that it confers a considerable degree of protection both on calves and on infants, if given very early in their lives. This claim, however, has been severely criticised as regards both the manner in which the experiments were conducted and the nature of the statistics produced in its support, and a number of competent workers in various countries have failed to find evidence of protection of children by the vaccine, whilst some of them are inclined to attribute fatalities to the operation of this substance, which purports to be completely innocuous.

Whatever may be the truth of the matter it can be stated that Calmette and Guerin have not yet finally established their claim to the satisfaction of the majority of experienced workers in this field, and that although the recent work of Buxton and Griffith shows that BCG may confer some protection upon calves, the duration of the

immunity is unknown, in infants the production of even a temporary immunity is doubtful, and it is not certain that the inoculation of this living vaccine is free from risk.

Attempts have also been made to produce active immunity in cattle by means of dead tubercle vaccines, but the data so far published do not permit of any conclusion as to their efficacy.

(*d*) *Routine Clinical Examination of Cattle.*

Routine clinical examinations of dairy cattle as a means of checking the distribution of tuberculous milk are carried out at present, to a varying extent, in eleven English counties, and it is interesting to note that in at least one of these areas the farmers appreciate the value of the free advice thus given to them, and are beginning to depend upon the inspectors for help in keeping their herds free from tuberculosis. The Milk and Dairies (Scotland) Act, 1914, requires the inspection of cattle from time to time and at least once a year, and in a Circular issued by the Department of Health for Scotland on 7th March, 1930, it was suggested that a minimum of three inspections a year should be aimed at.

It has already been remarked that it is impossible to detect by clinical examination all cases of tuberculous disease of the udder, but it is claimed by the advocates of this method that the great majority of cows secreting tuberculous milk can be so detected if the examinations are carried out in a thorough manner by a competent veterinarian.

In estimating the success of the method due regard has not always been paid to essential differences between the various schemes in operation. Thus, in some cases so-called routine inspection merely consists in the examination of a whole herd consequent upon the discovery in it of an animal in an advanced stage of tuberculous disease, whereas in other cases every herd in the area is systematically inspected at stated intervals.

The information at present available, however, justifies the view that routine inspection, particularly if combined with other measures, can be of great value, not only directly by bringing about a reduction in the number of infective cows, but also by its educative influence and by the control of the non-tuberculous diseases incidentally discovered.

The utility of this method of control, in common with most others, is impaired by the constant changes occurring in the cow population. Animals are frequently sold off because they have become "dry" or unprofitable or for other reasons, and these are replaced, perhaps immediately after an inspection, by other animals from outside sources.

(*e*) *Bacteriological and Biological Testing.*

The examination of samples of milk for tubercle bacilli, whether by the microscopic test or by guinea-pig inoculation, is chiefly of value where the sample is taken near the source.

Such examination, especially when combined with clinical examination by a competent veterinarian, is of considerable importance, and when carried out in an intelligent manner often enables a Medical Officer of Health to discover a cow secreting tuberculous milk and to stop the sale of the latter.

It is impracticable in most cases as a routine measure to examine the milk from each individual cow on a farm on the chance of finding one which is secreting infected milk. Such a procedure, is, however, not ordinarily necessary, for if a sample is taken from the mixed milk of several cows and a complete list is made of the cows contributing to the sample, it can then be ascertained whether any such infection is present and should this prove to be the case a more detailed examination can be undertaken to determine its exact source. This method, usually known as "bulk sampling," is, of course applicable at local milk depots and the sample may consist of the mixed milk of from 30–50 cows.

It should be noted that direct microscopical examination of bulk samples cannot be relied upon to detect tuberculous infection of the milk, mainly because tubercle bacilli may be missed, but also because there is a slight risk of other acid-fast organisms being mistaken for tubercle bacilli. The procedure is, however, a most useful test for milk obtained directly from a suspected cow, but only positive results are of any significance. A negative result with this test can never be accepted as proof that the milk is free from tubercle bacilli.

Biological examination (by guinea-pig inoculation) is, therefore usually necessary before the individual cow or cows infected can be identified. This test is extremely sensitive; it suffers however, from several drawbacks, namely the long time required for its completion (at least 4 to 6 weeks), the risk of the guinea-pig dying of intercurrent disease during the test, and the expense incurred. The risk of a test being rendered abortive owing to the premature death of the guinea-pig can be partly overcome by using two animals for the test, but this, of course, increases the expense.

(*f*) *Improved Methods of Cowkeeping and the Education of Cowkeepers.*

Although ordinary sanitary measures have proved insufficient for the control of bovine tuberculosis, yet the value of such measures when used in conjunction with other methods should not be underrated. The disease in cattle is spread by means of the secretions of infected animals, adult animals being usually infected by others with lung tuberculosis and calves by the consumption of milk from tuberculous mothers. Cows with pulmonary tuberculosis swallow a large proportion of the infectious secretions coughed up from their lungs, so that their faeces may become heavily infected and contaminate pasture, litter and stalls, providing additional channels of infection. Thus, the frequent cleansing and disinfection of cowsheds, especially those parts most liable to be contaminated by mucus from

the lungs and by faeces, is a matter of great importance. Not only may such materials infect the food and water of other animals but, if they are allowed to dry, the dust of the sheds will become infected and may be inhaled by animals at a distance or even contaminate their food.

Although great improvements in the stalling, care and milking of cows have been effected by milk-producers in recent years, much remains to be done. Old and grossly insanitary cowsheds are still common, and new sheds are often constructed (or old ones adapted) in a manner displaying ignorance of the principles governing the spread of infection. A common fault is to arrange the stalls in a double row with the cows facing each other, with no adequate partition intervening, thus favouring the spread of infection by coughing.

The education of the cowkeeper in matters of sanitation is still of pressing importance, and is too often lost sight of in an enthusiasm for the more drastic methods of reducing the incidence of the disease.

The question whether the elimination of all sources of infection would result in a loss of immunity among the bovine population which would be followed, upon the reintroduction of the disease sooner or later, by a devastating outbreak must be regarded as being at present of purely academic interest in view of the wide prevalence of bovine tuberculosis in this country. Moreover, it must be remembered that, just as in the case of the human disease, there is no known method of controlling the dosage of infection so as to ensure immunity whilst avoiding serious disease.

(*g*) *Graded Milk.*

A word must be said here about the part played by the grading of milk in the campaign against bovine tuberculosis.

The Milk and Dairies (Amendment) Act, 1922, and the Milk (Special Designations) Order, 1923, made thereunder, provide for the use of four special designations for milk, namely : " Certified," " Grade A (Tuberculin Tested)," " Grade A " and " Pasteurised," and lay down the conditions to be fulfilled by producers and distributors licensed to sell milk under these designations.

Certified milk and Grade A (Tuberculin Tested) milk are produced by herds which are clinically examined and tuberculin-tested every six months. These milks must not be pasteurised or otherwise treated by heat. Grade A milk is produced by herds which are clinically examined every three months. It must not be treated by heat unless it is pasteurised, and then it must be sold as " Grade A milk, Pasteurised."

At the present time there are in England and Wales approximately 400 herds producing Certified or Grade A (Tuberculin Tested) milk, and 600 herds producing Grade A milk. Even when allowance is made for the fact that these herds (especially those of the higher grades) are usually larger than the average herds of the country,

the quantity of milk produced under these designations is only a small fraction of the national supply: The demand is small in most districts. A sufficient supply of each grade is available to meet the requirements of any consumer who wishes to obtain it regularly; and the grading movement has had an important influence in encouraging the tuberculin testing and veterinary examination of cattle in herds whose owners have considered the question of applying for a licence.

Pasteurised milk is not subject to any conditions as to production, but it must be pasteurised, that is to say, retained at a temperature of not less than 145° F., and not more than 150° F. for at least 30 minutes, and then immediately cooled to a temperature not exceeding 55° F. It must not be so heated more than once and must not be otherwise treated by heat.

The number of licensed pasteurising establishments in England and Wales is about 200. It is difficult to say what proportion of the milk consumed in the country is represented by the output of these establishments since they vary very much in size and capacity. The present tendency is for the erection of large establishments, and it is probable that most of the milk now sold in London, and some of the large towns, has been subjected to effective pasteurisation.

2. Before Distribution.

The Operation of the Manchester Clauses and the Milk and Dairies Acts.

It is undeniable that the principal attack upon bovine tuberculosis in common with all other infections, should be directed against its source, but a great deal of the early administrative action had its starting point in the farthest outposts of milk distribution, the large towns, and such action, though admittedly inadequate, was at any rate of great educative value.

In 1899, the Corporation of Manchester obtained a Local Act giving them powers for the control of milk produced outside the City and suspected of being infected with the tubercle bacillus. These Manchester Milk Clauses, which were subsequently incorporated in about 100 Local Acts, constituted an important innovation in health legislation in that they enabled the local authority not only to examine milk inside their own area, but to trace it back to the farm, discover by means of veterinary and bacteriological examinations the infecting animals, and prohibit the sale of milk from these animals in their area.

The objections which were raised to these clauses were firstly that they involved interference by one (or perhaps more than one) urban authority in the district of another authority, and secondly that although the sale of the milk of the cows affected might be prohibited in one or more areas, it was still lawful in other areas, usually including the area in which the milk was produced.

In view of these objections an Act was passed in 1914 repealing

the Local Act clauses and replacing them by a national system in which functions were conferred on every County and County Borough Council as regards the cows in their own areas. The provisions of this Act (which were repealed and re-enacted in the Milk and Dairies (Consolidation) Act, 1915) were postponed on account of the War and did not come into operation until 1925. Under Section 3 (in conjunction with the First Schedule) of the Act of 1915, where the Medical Officer of Health of a County or County Borough is of opinion that tuberculosis is caused or is likely to be caused by the consumption of milk from any cows in his area, he reports the matter to his authority, and they, after giving the dairyman an opportunity of being heard, can make an order prohibiting the use of the milk, or any product manufactured from it, for human consumption.

Section 4 of the Act directs that if the Medical Officer of Health of any local authority suspects that milk sold or exposed or kept for sale within the area of the local authority is, or is likely to be, the cause of tuberculosis, he shall endeavour to ascertain the source or sources of supply and, on ascertaining the facts, shall forthwith give notice of them to the Medical Officer of Health of the County or County Borough in which the cows from which the milk is obtained are kept. On the receipt of the notice the Medical Officer of Health of the County or County Borough must have the cattle inspected and make such other enquiries as are necessary. He may then, if his inquiries justify such a course, proceed as provided by the previous Section with a view to the stopping of the supply of milk.

Due notice of the time of the proposed inspection must be given to the dairyman and to the local authority whose Medical Officer of Health gave the notice, to allow that officer or a Veterinary Inspector or other independent Veterinary Surgeon appointed by the local authority or the dairyman to be present.

The final step of stopping the supply of milk is in fact rarely if ever taken, since when the investigations show that a herd contains a cow giving tuberculous milk, steps are taken for her removal and slaughter under the provisions of the Tuberculosis Order.

Section 8 empowers an inspector of the Local Government Board (now the Ministry of Health), the Medical Officer of Health, or any person authorised in writing by either of these officials or by the local authority, to take samples of milk at any time before it is delivered to the consumer, provided that the samples be taken within the area of the local authority in question.

The procedures laid down by this Act are subject to considerable limitations, especially in urban areas. The increasing practice of bulking milk supplies which is carried out by the large companies makes it often impossible to ascertain the particular farm from which any given sample of milk was derived, and in this case all that the Medical Officer of Health can do is to give a list of farms from which the milk may have come. The examination of the cattle on all these farms may impose a severe burden upon the veterinary staff

of the County or County Borough Council, as in a case which recently came to the notice of the Ministry of Health, in which 85 farms were under suspicion of supplying tuberculous milk in connection with one sample. Difficulties such as this could be avoided by sampling at the local depots the milk from herds of a reasonable size before bulking has taken place (see above under Bacteriological and Biological Testing).

Another limitation to the procedure under the Act is the delay consequent upon the long interval which must elapse between collection of the sample and ascertainment of the results of inoculation experiments. During this interval, the composition of the offending herd may have changed considerably, and there may be no record* available of the cows in the herd at the time the milk was taken because nothing was known then of the origin of the infection, and it may be impossible to trace the cows which have been removed.

Again the system of sampling employed under this Act in some urban areas is haphazard ; nothing may be known at the time as to the origin of the milk in the churn from which the sample is taken. The milk may be derived from a few or from many cows ; it may even be milk from a number of different producers ; it may be raw or it may be pasteurised. Even if the churns be all from the same farm, the milk from the only cow with open tuberculosis may be all in one churn.

Many of these limitations do not apply to rural areas, where bulk sampling can be carried out on the farm or at the collecting depot and the field of enquiry thus reduced.

VI.—Pasteurisation.

Pasteurisation is the method originally suggested by Louis Pasteur for treating milk by heat in such a way as to destroy the pathogenic organisms present without causing those chemical and physical changes in the milk which result from boiling. The Milk (Special Designations) Order, 1923, as already stated, requires that milk sold as " pasteurised " shall have been kept at a temperature of not less than 145° F. and not more than 150° F. for at least half an hour, and then immediately cooled to a temperature of not more than 55° F., the milk being heated once only and not otherwise treated by heat.

The process here defined has been shown to give the maximum degree of safety consistent with the preservation of those qualities which give milk its nutritive and commercial value. Milk treated by this process closely resembles raw milk in taste and appearance, and in particular has a good " cream line " (i.e., the amount of visible cream which rises to the surface on standing). It must not

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* The Ministry of Agriculture and Fisheries' Movement of Animals (Records) Order, 1925, makes it compulsory for all cattle owners to keep complete records of the movements of all animals to and from their premises. This Order is not at present, however, fully enforced.

be supposed, however, that the same result cannot be obtained by the use of other time and temperature factors, and a whole series of effective time-temperature factors have, indeed, been worked out by various investigators. The important point in regard to the prevention of bovine tuberculosis in human beings is the determination of the thermal death-point of the bovine tubercle bacillus. Very numerous experiments have been carried out to determine this point, and these justify the English standard, though many American investigators are satisfied that a temperature of 142° F. for 30 minutes gives an adequate margin of safety. It should be realised, however, that even the English prescribed process, with a minimum temperature 3° higher than the above, does not afford an absolute guarantee that the milk so treated will contain no living tubercle bacilli, though it may be accepted that any such bacilli will be present in such small numbers as to constitute a very slight risk of infection for the consumer.

Unfortunately the limits of temperature within which the bovine tubercle bacillus is killed, whilst the commercial value of the milk is unimpaired, are extremely narrow. According to Hamill* the taste and flavour and cream line of milk are hardly, if at all, altered by pasteurisation at 145° F. for 30 minutes, but above this temperature the cream line is affected, being decreased sometimes by 40 per cent. at a temperature of 148° F.

It is for this reason that very strict scientific control is necessary for efficient pasteurisation, and that where milk is heated for commercial purposes only and not sold as " pasteurised " the temperature employed is often chosen with special regard to the retention of the cream line, and is too low to provide a reasonable certainty of destroying tubercle bacilli. Although the " flash " system of pasteurisation, viz., a very short exposure to a high temperature, is theoretically sufficient to kill the tubercle bacillus, yet it is impossible to ensure that any pasteuriser working on this system will consistently raise the whole of the milk to be treated to the required temperature. The " flash " method has, therefore, been universally condemned by hygienists as unsatisfactory, but it is still employed to some extent because it is comparatively cheap and fulfils the main commercial requirement—the postponement of souring.

Apart from changes in pasteurised milk affecting its commercial value there are other possible changes which might be of considerable importance. With regard to changes in the proteins and salts Hamill, summing up the information available, says : " When milk is pasteurised at 145° F. for thirty minutes no appreciable change takes place in the milk proteins ; if, however, the temperature is raised to 150° F. for thirty minutes a small proportion (about 5 per cent.) of the milk albumin is rendered insoluble. Coagulation by rennin occurs slightly more rapidly in pasteurised than in raw

* Notes on the Pasteurisation of Milk. By J. M. Hamill, O.B.E., M.D., D.Sc. Ministry of Health Reports on Public Health and Medical Subjects No. 17, 1923.

milk. The soluble calcium and magnesium phosphates of the milk do not become insoluble or separate out when milk is pasteurised at a temperature of 145° F. for thirty minutes. This treatment has, furthermore, only a slight effect upon the enzymes which are present in milk."* It has recently been ascertained that a small proportion (about 2 per cent.) of the calcium may become indiffusible.

Of at least equal importance is the question of the effect of pasteurisation upon the vitamins in milk. Present knowledge indicates that of these only vitamin C is injuriously affected by pasteurisation.

It will be seen then that pasteurisation carried out in a suitable apparatus and under strict scientific control is capable of protecting the consumer from the danger of infection with the tubercle bacillus, and that milk so treated appears to retain its valuable food properties practically unimpaired.

VII.—Summary as to Present Position.

The main facts with regard to bovine tuberculosis which have been set forth in this memorandum may be summarised as follows :—

(1) The death rates for non-pulmonary forms of tuberculosis in England and Wales, while still high, are decreasing, the rate for 1929 being less than half that for 1911. Loss of life and invalidity from this disease are, however, still matters for grave concern.

(2) It is not possible at present to say what proportion of the cases of tuberculosis in human subjects are of bovine origin, but it seems probable that more than 1,000 children under 15 years die annually in England and Wales from infection of this origin.

(3) It is practically certain that the great majority of human infections with the bovine tubercle bacillus are conveyed by means of cow's milk, and that infection usually occurs during the early years of life, when milk forms a large part of the diet and when susceptibility to infection is greatest.

(4) The proportion of milch cows in this country infected with tuberculosis is not accurately known, but there is reason to believe that it is not less than 40 per cent. Cows are much more often affected than other bovines, and those suffering from tuberculous mastitis are responsible for most of the infection in human beings. The proportion of cows so affected has been variously estimated at 0·3 per cent. to 6 per cent. These estimates, however, apply to cases of "open" tuberculosis and there are in addition many cows showing no clinical signs of tuberculosis but excreting the bacilli in their milk and faeces. The proportion of cows actually yielding tuberculous milk is probably between 1 per cent. and 2 per cent. Whether the incidence of tuberculosis in bovines is increasing or decreasing is not known.

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* Notes on the Pasteurisation of Milk. By J. M. Hamill, O.B.E., M.D., D.Sc. Ministry of Health Reports on Public Health and Medical Subjects No. 17, 1923.

(5) Complete eradication by means of universal tuberculin testing and the slaughter of all reacting animals is not practicable in this country, not only on account of the expense and the dislocation of the milk supply which would be involved in any attempt at such a measure, but also because it is doubtful whether complete and permanent eradication could be effected by this means. A less drastic procedure, but one also involving the slaughter of infected animals, is represented by the Ministry of Agriculture and Fisheries' Tuberculosis Order of 1925. This Order aims at the destruction of cattle in an advanced and more infectious stage of the disease and cannot be expected, without the introduction of adjuvant measures, seriously to affect the incidence of the disease in cattle or man.

(6) The method of building up tuberculosis-free herds has been discussed, and the financial and other difficulties in the way of its success have been pointed out, but it is to be hoped that a more extensive trial will be given to it in this country.

(7) Calmette and Guerin claim to be able to prevent tuberculosis in young calves and babies by protecting them with their vaccine, known as BCG. This claim has not yet been established for babies, but there is evidence that a certain degree of immunity may be produced in young calves.

(8) The next method of control considered is one which has only been tried to a small extent in England and Wales, but has given such encouraging results in Scotland that its area of operation is being rapidly extended. This method is the routine clinical examination of cattle, which, to be fully effective, should involve the thorough and systematic examination by competent veterinary surgeons of all the milk herds at stated intervals, say twice a year, and the exclusion of those found diseased. There is reason to believe that such a procedure, when employed in combination with other methods of prevention, is productive of beneficial results.

(9) The testing of milk by the microscopic and biological methods can be of great value, especially when applied to samples from herds of moderate size (a complete list of the contributing cows being made at the time of sampling) and combined with competent clinical examination of the cattle.

(10) All measures aimed at the reduction of bovine tuberculosis must lose a great part of their effect so long as milch cows are kept under conditions which favour the spread of tuberculous infection. The education of the cowkeeper in the prevention of bovine infection should therefore occupy a prominent place in any scheme for the eradication of bovine tuberculosis.

(11) Reference has been made to the limited success so far achieved by the scheme for grading milk established by the Milk and Dairies (Amendment) Act, 1922, and the Milk (Special Designations) Order, 1923, made under that Act. The campaign in favour

of clean raw milk, must, however, be regarded as of great potential value, and the official grading of milk would constitute an important element in any comprehensive scheme for the improvement of the milk supply.

(12) The Manchester Clauses and the provisions of the Milk and Dairies (Consolidation) Act, 1915, which superseded them, appear to have had but little effect upon the incidence of bovine tuberculosis or the sale of tuberculous milk, though the educational value of these measures has probably been far from negligible. The factors limiting their utility have been pointed out, and a consideration of these demonstrates the paramount importance of those measures which are applicable to the source of the infection or its near neighbourhood.

(13) This conclusion does not justify the neglect of safeguards for the milk consumer which can be applied to the milk after production and before delivery. The problems and procedures of pasteurisation have been reviewed and it has been shown that, subject to careful operation and scientific control, this process ensures a milk which not only is safe for consumption, but also retains its food value practically unimpaired by the heat to which it is subjected.

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Printed under the authority of His Majesty's Stationery Office,
By Wyman and Sons, Limited, Fetter Lane, London, E.C. 4.