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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN NO. 38.

A. D. MELVIN, CHIEF OF BUREAU.

TUBERCULOSIS

OF THE

FOOD-PRODUCING ANIMALS.

BY

D. E. SALMON, D. V. M.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1906.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., May 31, 1906.

Sir: I have the honor to transmit herewith a paper on Tuberculosis of the Food-Producing Animals, by Dr. D. E. Salmon, late Chief of this Bureau, who was especially engaged by you to prepare the same. I recommend the publication of the paper as Bulletin No. 38 of this Bureau.

Animal tuberculosis, though not nearly so prevalent in the United States as in most European countries, is nevertheless a serious problem and a menace to our live-stock industry, and is also regarded as a distinct source of danger to human health. Its infectious nature and the means for its repression should be fully understood, and earnest and intelligent efforts should be made with a view to its ultimate eradication from this country.

The bulletin treats the subject in a very comprehensive manner and reviews some of the more important experimental work which has served to establish the facts and conclusions presented. The author is a recognized authority on the subject with which he deals, and the bulletin is written in the light of the latest scientific knowledge. The discussion of two phases of the tuberculosis problem which have received particular attention in recent years—the relation between the human and bovine forms of tuberculosis and the protection of cattle against tuberculosis by immunization—should be of especial interest at this time.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

OCT 30 1906
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TUBERCULOSIS OF THE FOOD-PRODUCING ANIMALS.

INTRODUCTION.

There are few if any subjects connected with animal husbandry upon which more has been written and published within recent years than tuberculosis. It has been discussed in the publications of the Bureau of Animal Industry, in the bulletins of many experiment stations, in the reports of live-stock sanitary boards and State veterinarians, and in the columns of the agricultural press. The scientific investigations in relation to it have been extremely numerous and important in their results. Notwithstanding this activity in the discussion and investigation of the disease, however, there is probably no subject upon which there is a greater difference of opinion among the owners of live stock, and none of which the importance is so inadequately appreciated.

It is unfortunate that in the first attempts to control this disease in the United States measures were adopted by some of the State authorities which were so radical and harsh that they aroused the antagonism of the cattle owners, the men who above all others should have been aided and benefited, and that a spirit was developed in the contests that followed which has made it extremely difficult to obtain a dispassionate and impartial consideration of the measures that are required to relieve our farmers from the losses which they are now suffering because of the existence of this disease and to remove the danger of the far greater losses with which they are menaced. A disease so widespread can not be controlled unless those most interested in the live stock of the country give their active support to the undertaking. It is therefore wise to examine the subject in an unbiased manner, to study carefully the nature of the disease, to learn as nearly as possible what the losses are, to what extent these losses are liable to increase, and whether measures of repression are or are not advisable. It is not a question of sentiment, but one of fact, and it should be examined as a business proposition.

The object of this bulletin is to present the facts in as clear and concise a manner as possible, giving the observations and views of the best authorities, and of those who have studied the problem longest and are most competent to express an opinion. These facts should be known and considered, and if it appears that the prosperity of the live-stock industry is threatened, or that serious losses are occurring, appropriate action may be taken to check the losses and to remove their cause.

Although tuberculosis is an extremely insidious disease, which may enter the herd by an unsuspected channel and develop to alarming proportions before its presence is suspected, it is nevertheless a preventable disease and one the control of which may now be undertaken with every prospect of success. But to control or eradicate tuberculosis it is necessary to have a clear comprehension of the peculiarities of the disease, of its cause, of its nature, of its mode of extension, of its detection. It is one of the problems which could not be handled without the aid of science; but now that science has come to the relief of the owner of live stock and has shown him how this plague may be managed successfully, he is in a position to avail himself of this knowledge and to adopt such measures as may be required both to stop the losses which it is now causing and to guard against its reappearance in the future.

It is difficult to imagine anything more discouraging or disastrous to the plans of the young breeder than to discover that in bringing together the foundation elements of his herd he has introduced the infection of this disease, which counteracts his efforts to build up a great herd and gradually exhausts his capital. Nor is the case any the less serious when the infection is introduced into a herd already established and developed by the labor and the study of the best years of the breeder's life. How many breeders have been rendered penniless by the ravages of the tuberculosis bacillus; how many priceless animals have been destroyed by it; how many precious strains of blood has it weakened or annihilated!

And finally there is the influence of the tuberculous herd upon the community. A herd of animals is not bred simply for the entertainment and use of the breeder, but the primary object is to produce and sell dairy products, meat, and breeding animals to other people. Is it right to sell a tuberculous animal to go into another breeder's herd when the disease is likely to be carried by that animal, to spread, and to damage or destroy that herd? Is it right to sell tuberculous cattle or hogs for slaughter when we know that many of these animals are slaughtered in establishments where there is no inspection and that the diseased carcasses may consequently be used for human food? Is it right to sell the milk from tuberculous herds knowing that it may be used for the nourishment of the most delicate children, when such milk frequently if not generally contains the tuberculosis bacillus which finds its way to it both through the udder of the diseased cow and the dust of the stable?

These questions, serious from both a moral and a financial point of view, confront the breeder of the present day. There can be no question that the great body of breeders desire to do what is right, and it would appear, therefore, that when a practicable plan of handling tuberculosis is demonstrated to them they will not hesitate in adopting it, but will rapidly suppress this disease and eradicate it from their herds.

PART I.—MATERIAL FACTS CONCERNING TUBERCULOSIS.

THE PREVALENCE OF TUBERCULOSIS.

EXTENT OF THE DISEASE IN THE UNITED STATES.

Tuberculosis is the most serious disease of animals with which the American farmer is confronted. It is the most prevalent disease of cattle, and is becoming very common with swine. It exists in all parts of the United States, even in the Rocky Mountain region, but is most frequently seen in dairy cattle and in hogs that have been raised in dairy districts. Unfortunately it has also been allowed to propagate itself extensively in some of the most valuable beef breeds, as, for example, the Shorthorn and the Angus, and its frequency in other varieties of cattle appears to be increasing.

MEAT-INSPECTION STATISTICS.

The statistics of tuberculosis in this country are fragmentary, and give but an imperfect idea of the actual condition, though we have sufficient to show that it is not as prevalent as in some of the countries of Europe. In the meat-inspection service of the Bureau of Animal Industry the number and percentage of carcasses condemned during the last five years is shown in the following table.

Number of carcasses of cattle and hogs inspected and the number condemned for tuberculosis during the years 1901–1905.

Year.	Cattle.			Hogs.		
	Number of carcasses inspected.	Number of carcasses condemned.	Per cent of carcasses condemned.	Number of carcasses inspected.	Number of carcasses condemned.	Per cent of carcasses condemned.
1901	5,219,149	6,454	0.10	24,642,753	8,650	0.035
1902	5,559,969	7,944	.14	25,277,107	14,927	.059
1903	6,134,410	8,598	.14	21,793,738	20,299	.092
1904	6,350,011	10,173	.16	24,128,462	34,656	.143
1905	6,096,597	10,956	.18	25,323,984	64,919	.256

This table does not show the total number of animals affected with tuberculosis, for in many cases only a part of the carcass was condemned, and probably in a still larger number of cases the disease had progressed so slightly that the entire carcass was passed as fit for human food. These milder cases of disease are not included, as correct statistics of them are not available.

Tuberculosis in sheep is a rare disease, and in most cases appears to be the result of infection from bovine sources. There were but 27 carcasses of sheep condemned by inspectors of the Bureau of Animal Industry on account of tuberculosis during the fiscal year 1905, out of 7,872,671 animals inspected at the time of slaughter. The nodular disease of the intestines (caused by the parasite *Œsophagostomum columbianum*) and caseous lymphadenitis are far more frequent and are often mistaken for tuberculosis by persons not thoroughly familiar with the distinctive characteristics of these diseases.

CONDITIONS SHOWN BY TESTS OF HERDS.

In 1901 Doctors Russell and Hastings, of the Wisconsin Agricultural Experiment Station, published a review of the tests of cattle with tuberculin which had been made in the United States, and from this review the following summary has been made, which is valuable on account of showing the wide distribution of tuberculosis rather than indicating the proportion of cattle affected in the respective States.[1a]

Results of the tuberculin tests of cattle in various States.

State.	Number tested.	Number tuberculous.	Per cent tuberculous.
Vermont	60,000	2,390	3.9
Massachusetts	24,685	12,443	50.0
Massachusetts, entire herds	4,093	1,080	26.4
Connecticut	6,300	.....	14.2
New York, 1894	947	66	6.9
New York, 1897–98	1,200	163	18.4
Pennsylvania	34,000	4,800	14.1
New Jersey	2,500	.....	21.4
Illinois, 1897–98	929	.....	12.0
Illinois, 1899	3,655	560	15.3
Michigan	.....	.....	13.0
Minnesota	3,430	.....	11.1
Iowa	873	122	13.8
Wisconsin:			
Experiment station tests—			
Suspected herds	323	115	35.6
Nonsuspected herds	935	84	9.0
State veterinarian's tests—			
Suspected herds	588	191	32.5
Tests of local veterinarians under State veterinarian on cattle intended for shipment to States requiring tuberculin certificate	3,421	76	2.2

The State veterinarian of Pennsylvania, Dr. Leonard Pearson, thinks that not over 2 per cent of the cattle of that State are tuberculous; and probably if a general test of all the cattle of the other States mentioned were made we should find a very much smaller proportion tuberculous than is indicated by the above tabular statement. The explanation of the high percentages that have been given is found in the fact that it has been, for the most part, suspected herds which have been tested. Admitting that the greater part of these percentages are too high, they nevertheless reveal a very serious condition.

In a report on Tuberculosis of Cattle, Pearson and Ravenel[2] say that it has been found by testing herds that the percentage of tuber-

[a] The figure references are to bibliography at end of bulletin.

culosis varies from 0 to 100 per cent, and there are instances of many large herds in which nearly all of the animals have been infected. As examples of such herds found in Pennsylvania the following are cited:

Herd.	Number of cattle in herd.	Number of tuberculous cattle.	Per cent of cattle found tuberculous.	Herd.	Number of cattle in herd.	Number of tuberculous cattle.	Per cent of cattle found tuberculous.
1	174	166	95.4	8	61	45	73.8
2	73	59	80.8	9	18	16	88.8
3	22	17	77.3	10	13	10	76.9
4	14	14	100.0	11	15	10	66.6
5	63	37	58.7	12	59	53	89.8
6	67	37	55.2				
7	20	20	100.0	Total	599	484	80.8

These figures of course represent extreme and exceptional conditions. Of all the tuberculous herds tested with tuberculin under the auspices of the State live stock sanitary board, about 13 per cent of the animals have proven to be afflicted with tuberculosis.

Russell[3] says this disease is the most devastating animal plague with which Wisconsin farmers have to contend. Of the 70 herds examined by the State live stock sanitary board for the years 1903 and 1904, 49 were found affected. Very frequently only a small number of reacting animals were found, but the appended list shows some startling cases of widespread infection.

Instances of widespread infection of herds that have been tested in Wisconsin during 1903–4.

Date of examination.	Number of animals in herd.	Number found tuberculous.	Per cent affected.	Date of examination.	Number of animals in herd.	Number found tuberculous.	Per cent affected.
December 16, 1902	16	12	75	January 5, 1905	27	21	77
April 6, 1903	39	27	69	January 25, 1905	38	23	60
May 5, 1903	33	20	60	February 5, 1905	14	12	85
May 11, 1903	36	20	55	February 12, 1905	60	14	23
June 2, 1903	28	16	57	March 20, 1905	20	13	65
June 3, 1903	121	24	20	April 20, 1905	22	20	91
October 22, 1903	56	25	44	April 25, 1905	30	17	57
December 9, 1903	49	24	49	May 3, 1905	31	21	69
March 21, 1904	55	27	49	May 8, 1905	92	31	33
March 31, 1904	26	15	57				
April 17, 1904	30	23	76	Total	853	428	50
October 26, 1904	30	23	76				

If such widespread infection as these examinations indicate were found in all herds the stock interests of the country would be on the verge of bankruptcy, and yet the record above presented does not give by any means all of the cases.

A brief list of infected herds which have been more or less carefully studied is useful in showing the extent to which the disease develops under the best conditions of sanitation, and in indicating the difficulty of building up a herd of good cattle even under skillful supervision unless the healthfulness of the herds from which the purchases are made has been ascertained.

Herd of—	Number in herd.	Number tuberculous.	Per cent tuberculous.
Maine State Agricultural College (1886)[4]	51	51	100.0
Soldiers' Home, Washington, D. C.[5]	63	53	84.1
Government Hospital for the Insane, Washington, D. C.[6]	102	79	77.0
Massachusetts Agricultural College[7]	32	25	78.1
New Jersey Agricultural Experiment Station[8]	42	25	59.5
Kansas Agricultural College[9]	56	15	26.8
Wisconsin Agricultural Experiment Station[10]	30	26	86.6
Connecticut Agricultural College, Storrs Experiment Station[11]	49	19	38.8
Colorado Agricultural College[12]	31	10	32.2
Vermont Agricultural Experiment Station	33	21	63.6
Ohio Agricultural Experiment Station, first test[13]	30	14	46.6
Texas Agricultural Experiment Station	21	10	47.6
Louisiana Agricultural Experiment Station[14]	22	7	31.8
New Hampshire College of Agriculture and the Mechanic Arts[15]	55	10	18.2
New York (Geneva) Agricultural Experiment Station[16]	27	15	55.5
Utah Agricultural Experiment Station[17]	18	13	72.2
New Mexico Agricultural Experiment Station[18]	19	3	15.8
Central Experimental Farm, Ottawa, Canada[19]	38	21	55.3

RELATIONS OF CONTAGION AND ENVIRONMENT TO SPREAD OF THE DISEASE.

While bad sanitary conditions undoubtedly favor the spread of tuberculosis it is not preeminently a disease of poor, neglected, underfed scrub cattle, for the better class of cattle have suffered from it to an even greater degree. It has been constantly imported with pure-bred stock, and has consequently been introduced into the best herds and has extended from these to the dairy herds and common cattle.

The beef cattle coming to our markets are still remarkably free from tuberculosis, but the disease appears to be increasing among this class of animals, as is indicated by the percentage of condemnations in the meat-inspection service. There appears to be no climate and no method of handling cattle which entirely arrests the spread of the disease. This is shown by its existence upon the ranges of our Western States, and to an even greater extent in the herds of Argentina, Australia, and New Zealand. Considering that these cattle live in the open air and in climates that have been considered remarkably favorable for people affected with tuberculosis, we can not but be impressed with the importance of avoiding the use of tubercular breeding stock and thus guarding against the dissemination of this contagion.

There are some portions of the world—as, for example, the northern parts of Norway and Sweden, the steppes of Russia, Iceland, and parts of Africa and South America—where tuberculosis is said to be quite rare. The cattle of the Island of Jersey appear to be free from it. This seems to have been true of the common or native cattle of many countries. In the United States there are numerous sections where the original stock of cattle has been bred without much admixture with the improved breeds and where few outside cattle have been introduced. These sections are generally free from tuberculosis. It has also been observed in Argentina and other countries that this disease is unknown among the native cattle, but that it has been intro-

duced with the improved breeds from Europe, and is now common with both purebreds and grades. It is even held by Professor Bang that tuberculosis was brought to Denmark in the first half of the nineteenth century by cattle from Switzerland, Schleswig, and England, and that this method of distribution may now be seen in Sweden and Norway, particularly through the introduction of English cattle.

These facts confirm the conclusions from scientific observation and experimentation that tuberculosis develops only by infection from some existing case of the disease; and that it will be possible in the future, as it has been in the past, for a section or a State to raise cattle that are free from it.

TUBERCULOSIS IN BRITISH HERDS.

The British herds appear to be justly chargeable with much of the tuberculosis of cattle and swine which now exists in many parts of the world. The unparalleled skill of the British breeders in developing useful and superior breeds of animals, and particularly of beef cattle, long since attracted the attention of the world and led to the diffusion of this improved blood through the herds of many countries. But, unfortunately, the breeders of Great Britain were not as skillful in avoiding tuberculosis as they were in increasing the size, perfecting the form, and hastening the maturity of the animals, and the result has been not only that they unwittingly propagated the disease, but that they distributed it in the most extensive manner.

It would not be correct to assume, however, as some have been inclined to do, that Great Britain is the source from which has been derived the tuberculous infection of all other lands, for the equal or greater prevalence of the disease in some other countries, notably in Germany, France, Holland, and Belgium, indicates an infection not less remote. It is probably true that there were infected localities in all these countries, and that, with the improvement of the means of communication and the development of commerce, the exchange of cattle became more frequent, so that the infection, which had previously been limited to a few small districts, was everywhere distributed. At that time the nature of the disease was not well understood, and for many years its existence in the larger part of the affected animals was not even suspected. It was therefore quite natural, when the advancement of scientific knowledge made it possible to detect tuberculosis readily, and when the disease was found to affect a large proportion of the cattle, to charge imported cattle with its introduction.

Nevertheless there are many cases in which the introduction of tuberculosis may be clearly traced to British cattle, and among these may be cited the herds of Canada, of the United States, of Argentina, of South Africa, of Australia, and of New Zealand. That the herds of England and Scotland are badly infected there is ample proof.

The testing of the Queen's herd at Windsor some years ago, and the unexpected discovery that 36 out of 40, or 90 per cent, were affected and that some of them were in a very advanced stage of disease aroused public interest in the subject and brought out much information. The returns from testing cattle with the tuberculin supplied by the Royal Veterinary College, as stated in March, 1900, showed that among 15,392 animals tested 4,105, or 26 per cent, reacted. Taking the various tests made of which records are at hand there is an aggregate of 20,930 head examined, of which 5,441, or 26 per cent, were pronounced tubercular.

That some of the best purebred herds of Great Britain are badly infected is known by the results of testing with tuberculin cattle from such herds in the quarantine stations on this side of the Atlantic, and also by testing cattle which were desired for shipment to the United States. The following table shows the number of cattle tested by the United States inspector stationed in Great Britain and the number that were rejected:

Year.	Number of cattle tested.	Number rejected.
1901	161	18
1902	1,067	139
1903	631	98
1904	239	37
1905	23	11
Total	2,131	303

Of the purebred cattle which were to be imported into the United States during the years from 1901 to 1905, inclusive, 14.2 per cent reacted; but this is not a true indication of the proportion of animals in these herds affected with tuberculosis, since only those animals were offered which were supposed to be in condition to pass the test successfully. It must also be admitted that the more or less frequent testing of the animals in these herds has reduced the proportion of animals which react. The percentage of tubercular animals in these herds is, therefore, without doubt considerably greater than the percentage of reactions obtained by the inspector.

The proportion of reactions to tuberculin obtained with different breeds of animals is interesting as indicating to some extent the relative infection of the different breeds; although, owing to the comparatively small number of animals covered by the tests, conclusions from these figures should not be too absolute. The following table shows the number of animals of each of the principal breeds tested and the number and percentage which reacted:

Breed.	Number of animals tested.	Number of animals which reacted.	Per cent of animals which reacted.
Ayrshire	52	16	30.7
Aberdeen-Angus	390	108	27.7
Shorthorn	248	60	24.2
Jersey	366	24	6.8
Galloway	114	6	5.2
Hereford	417	17	4.1

CONDITIONS ON THE CONTINENT OF EUROPE.

The frequency of tuberculosis among domesticated animals on the continent of Europe is generally admitted. The statistics which reach us from there are somewhat fragmentary, but sufficient to demonstrate the gravity of the situation.

In France Professor Nocard estimated that in the regions of Brie and Beauce approximately 25 per cent of the cattle were tubercular, while the cattle of Auvergne and Limousin (exporting districts) were free from the disease. In Brittany, Nivernais, Upper Vosges, in the southeast, and in certain valleys of the Pyrenees, the disease affects from 25 to 50 per cent of the cattle.

In Holland the percentage of tuberculous cattle found among those slaughtered in Amsterdam gradually increased from 1.7 per cent in 1888 to 13 per cent in 1898, while the proportion of swine affected increased from 1.47 per cent in 1895 to 3.58 per cent in 1898.

The percentages of tubercular cattle found in the slaughterhouses of Prussia and Saxony are shown by the following table:

Year.	Prussia.	Saxony.
1895	11.4	27.28
1897	15.8	.....
1399	14.4	29.76
1902	16.4	30.98

In some of the cities the percentage has been even greater; for example, Berlin, 1902, 25.35 per cent; Breslau, 1902, 34.67 per cent; Leipsic, 1902, 36.16 per cent; Zwickau, 1902, 36.27 per cent; Zittau, 1902, 41.24 per cent.[20]

In Sweden, according to Regnér,[21] there were tested, during the years 1897–1904, 226,864 head of cattle, of which 69,717, or 30.7 per cent, reacted.

In Norway, Bang[22] states that according to Malm there had been tested, up to the beginning of 1902, 131,995 cattle, of which 8,029, or 6.1 per cent, reacted. In Finland, during the years 1894–1900, 75,447 cattle were tested, the proportion of reactions being 13.7 per cent, and according to the official statistics 21,994 were tested in 1903 and 5.6 per cent reacted.

In Denmark the results of the tuberculin tests and of the efforts to control the disease have been extremely interesting. Bang[22] has recently reported the complete statistics of this work in that country, as follows:

Results of tuberculin tests of cattle in Denmark from 1893 to 1904.

Period.	Farms.		Number of animals tested.	Number of animals reacting.	Per cent of tested animals reacting.
	Total.	First testing.			
April, 1893, to June, 1894	327	327	8,401	3,362	40.0
June, 1894, to October, 1895	1,875	1,645	44,902	17,303	38.5
October, 1895, to May, 1896	930	749	20,791	6,622	31.9
May, 1896, to June, 1897	7,316	3,012	84,897	21,668	25.5
June, 1897, to May, 1898		2,165	65,788	15,642	23.8
May, 1898, to January, 1899	1,454	618	35,533	7,725	21.7
Year 1899	1,293	543	33,568	6,759	20.1
Year 1900	1,101	417	26,078	4,976	18.0
Year 1901	695	259	18,818	2,857	15.2
Year 1902	895	396	23,347	3,531	15.1
Year 1903	646	213	19,364	2,875	14.8
Year 1904	738	277	23,164	3,750	16.2
Total	17,268	10,621	404,651	97,070	24.0

The proportion of tuberculous swine found in the slaughterhouses of some of the German cities is interesting as showing the extent to which the disease may develop among this class of animals. The statistics with reference to these findings are presented below:

City.	Year.	Per cent of tuberculous swine.	City.	Year.	Per cent of tuberculous swine.
Berlin	1895	3.09	Magdeburg	1902	5.19
Do	1899	4.01	Potsdam	1900	7.55
Do	1902	5.40	Zittau	1902	5.35
Danzig	1898	5.66	Zwickau	1896	6.06
Do	1902	5.49	.....do	1899	3.89
Magdeburg	1896	1.91	.....do	1902	3.41
Do	1898	3.55			

It is plain that tuberculosis is far less frequent in the United States, with both cattle and hogs, than it is in Europe; but it also appears from the rate of increase shown by the statistics of various parts of the world, including our own meat-inspection reports, that unless its dissemination is by some means checked it will require but a few years for it to gain the same headway here that it has acquired there.

THE LOSSES FROM TUBERCULOSIS.

It is a difficult matter to estimate with any approach to accuracy the losses from a disease like tuberculosis, concerning which the statistics are incomplete in every respect. There are now, however, approximately 11,000 carcasses of beef and 65,000 carcasses of hogs condemned each year by the Federal meat inspectors on account of tuberculosis. We should not be far wrong in estimating the loss on these carcasses at present prices as $40 each on the beef and $12 each on the pork.

We should therefore have as the net annual loss from the condemnation of carcasses $440,000 for beef and $780,000 for pork, or a total of $1,220,000. This statement, however, does not include the 647 parts of beef carcasses and the 142,105 parts of hog carcasses which it was necessary last year to condemn for the same cause, and the approximate value of which can not be ascertained.

In addition to the carcasses condemned by the Federal inspectors, there are a considerable number condemned by State and municipal inspectors. These are mostly carcasses of dairy cattle killed in the work of suppressing tuberculosis, or of cows no longer profitable in the dairy which are sent for slaughter to the smaller abattoirs. The aggregate number of these has not been ascertained, but in some years it has amounted to several thousand carcasses.

The losses to the dairy industry from tuberculosis have been enormous from decrease in milk and depreciation and death of animals. The dairy herds have been affected to a greater extent than any others, and the infection has as a rule spread through the cows of a herd until 50 to 80 per cent of the animals were affected. In the early stages of the disease the product of the cows is not visibly lessened, but as the tubercular process develops the animals often become feverish, their milk is diminished in quantity, and they lose flesh and are no longer profitable. The losses from shrinkage of the milk and from the destruction of so many cows must be tremendous, but it has never been definitely determined.

An extremely serious phase of this subject is the effect of the disease in destroying valuable families of cattle and blood lines which can never be renewed. In most of the breeds there are certain families or strains of blood which have been developed by long and skillful selection and which represent the one marked success in a breeder's life. The representative animals of such a strain are generally few in number and may all be in one herd. Under such circumstances the introduction of tuberculosis has often meant the annihilation of the strain and the blotting out of the achievements of a lifetime of toil and study. Such losses can scarcely be measured in dollars and cents, but they are no less real and no less serious as an obstacle to the development of the cattle industry.

The losses to the breeders of purebred beef cattle have also been and still are so great as to merit the most serious consideration. When the individual animals of a herd are worth hundreds or even thousands of dollars, the introduction of a fatal infectious disease may soon cause the loss of a fortune, and this is just what has occurred upon many a breeding farm. Such a danger, always present and always menacing an industry, must discourage individual efforts and do much to prevent the attainment of lasting prosperity.

The influence upon our export trade of regulations relative to

tuberculosis will probably become more and more unfavorable. Breeding and dairy cattle for Canada and Argentina must now be tested and found free from the disease before they will be admitted. The tendency everywhere is to make more stringent regulations, and any considerable increase in the prevalence of the disease would have an unfavorable effect upon the sale of live animals, meats, and dairy products, even if burdensome regulations were not imposed. To meet successfully the increasing competition in the markets of the world it is important to have products which it can be shown are produced from healthy animals and which do not carry danger of any kind to the health of the consumer.

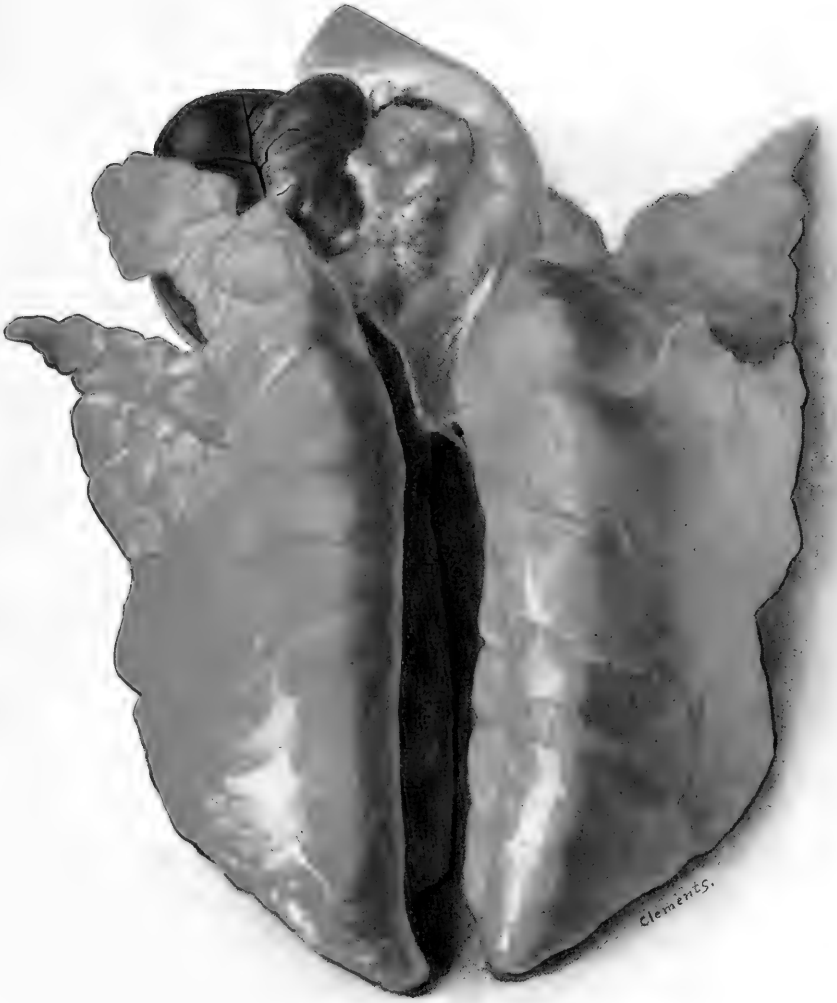
THE NATURE OF TUBERCULOSIS.

EFFECTS UPON THE ORGANS OF THE BODY.

The most striking feature about the disease known as tuberculosis is the formation in different parts of the animal body, but particularly in the lymphatic glands, the lungs and liver, of small masses or nodules, yellowish, grayish, or whitish in color, which are called tubercles. It is from this characteristic that the disease receives its name. Tuberculosis is therefore that diseased condition of the animal body in which tubercles are formed. There are, however, other diseased conditions accompanied by the formation of similar nodules which may also be called tubercles, and therefore it would be necessary in formulating an exact definition of tuberculosis to specify tubercles caused by the *Bacillus tuberculosis*. We might therefore say that tuberculosis is the disease caused by the *Bacillus tuberculosis* and characterized by the formation of tubercles in various parts of the animal body.

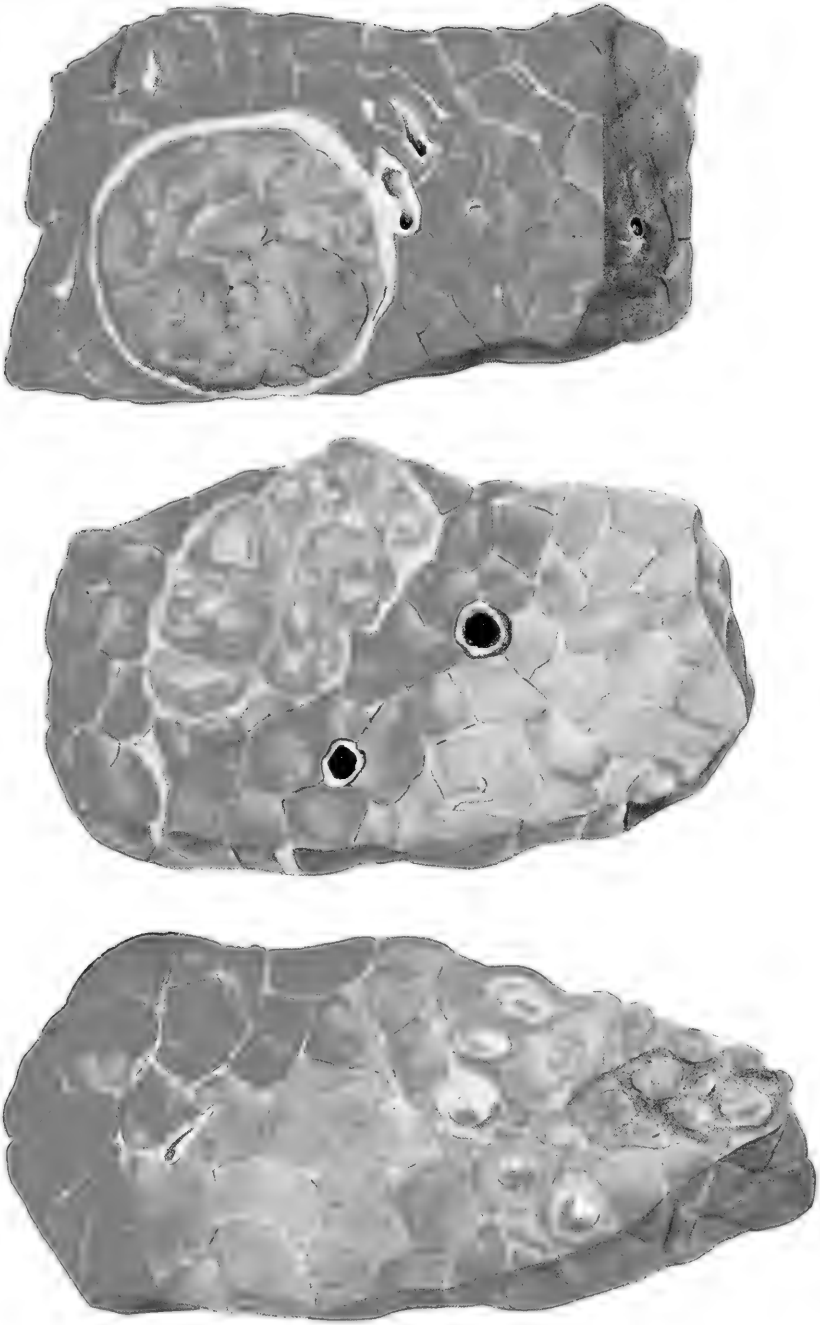
It was formerly believed that the lungs were affected in nearly every case of tuberculosis, but more careful studies have shown that the glands of the neck and chest are even more frequently affected than the lungs. From the very careful autopsies made on the animals of the Soldiers' Home, Washington, D. C., in 1893 by Dr. Theobald Smith,[23] at that time pathologist of the Bureau of Animal Industry, the following interesting information as to the parts affected was obtained:

Total number of animals in the herd	60
Total number of animals infected (88 per cent)	53
Number in which retropharyngeal glands only were affected	5
Number in which the bronchial glands only were affected	5
Number in which the mediastinal glands only were affected	5
Number in which the thoracic glands but not the lungs were diseased	27
Number in which lungs were affected	20
Number with exclusively thoracic lesions	26
Number with exclusively abdominal lesions	1
Total number in which retropharyngeal glands were affected	9
Number in which disease of the thoracic organs was detected	47
Number in which lungs were diseased and glands healthy	1
Number in which digestive tract, including head glands, was affected	26
Number in which intestinal walls were affected	1
Number in which mesenteric glands were affected	16



LUNGS OF A HEALTHY HOG.

TUBERCULOUS LUNGS OF HOG



PORTIONS OF TUBERCULOUS LUNGS FROM CATTLE

TUBERCULOUS SPLEEN OF HOG.

SPLEEN OF HEALTHY HOG.

Number in which portal glands were affected	10
Number in which mesenteric and not portal glands were affected	10
Number in which portal and not mesenteric glands were affected	4
Number in which parenchyma of liver was involved	2
Number in which serous membranes were affected	2
Number in which udder glands were affected	1

From this statement the following table showing the location of the disease has been calculated in percentages:

Organs affected.	Per cent.	Organs affected.	Per cent.
Retropharyngeal glands only	9.4	Total digestive tract, including head glands	49.1
Bronchial glands only	9.4	Intestinal walls	1.9
Mediastinal glands only	9.4	Mesenteric glands	30.2
Thoracic glands but not the lungs	50.9	Portal glands	18.8
Lungs	37.7	Mesenteric and not portal glands	18.8
Lungs but not the thoracic glands	1.9	Portal and not mesenteric glands	7.5
Thoracic organs only	49.1	Parenchyma of liver	3.8
Total thoracic organs	88.7	Serous membranes	3.8
Abdominal organs only	1.9	Glands of udder	1.9
Total retropharyngeal glands	17.0		

This table shows the great frequency with which the tubercular lesions are found in the glands. If we add the cases in which the thoracic glands but not the lungs were affected (50.9 per cent) to those in which the retropharyngeal glands only were affected (9.4 per cent), we find that 60 per cent of the cases had these glands, and not the lungs, affected. It is very seldom that the lungs are affected without the thoracic glands being also diseased.

Doctor Pearson[2] has given the result of 1,200 post-mortem examinations made under his direction for the State live stock sanitary board of Pennsylvania. The following is a tabular statement of these observations, the organs mentioned being arranged in the order of frequency of infection. Practically all of the animals covered by this table were milch cows.

Distribution of lesions in 1,200 cases of tuberculosis.

Organs affected.	Number of cases in which affected.	Per cent of cases in which affected.
Mediastinal lymphatic glands	725	60.42
Right lung	724	60.33
Left lung	685	57.08
Bronchial lymphatic glands	404	33.67
Small intestine	388	32.33
Mesenteric lymphatic glands	278	23.17
Pleura	264	22.00
Liver	247	20.58
Large intestine	189	15.75
Postpharyngeal lymphatic glands	181	15.08
Peritoneum	168	14.00
Lymphatic glands of udder	161	13.42
Diaphragm	136	11.33
Portal lymphatic glands	123	10.25
Lymphatic glands of flank	108	9.00
Udder	104	8.67
Pericardium	98	8.17
Lymphatic glands of shoulder	93	7.75
Stomach	86	7.17
Spleen	68	5.67
Uterus	66	5.50
Kidneys	25	2.08

Of course in a great many of these cases lesions were found in a number of organs, and sometimes they were distributed throughout the abdominal and thoracic cavities. No reference is made to lesions in the brain, skin, muscles, bones, or joints, because these parts were not examined in all cases.

Wherever the disease is located, it is usually made manifest by the formation of a number of tubercles the size of a pin head or smaller. If the tubercles are numerous and situated near to each other, they may become joined together in varying numbers, forming tubercular masses. Both the individual tubercles and the tubercular masses undergo certain changes by which they may become soft, cheesy, or semiliquid, and in other cases they may become gritty or hard through the depositing of lime salts. By such changes a lymphatic gland may be greatly enlarged and filled with tubercular material, which, when cut across, is found to be calcified and hard or broken down and softened until it has acquired a cheesy or pasty consistency.

The tubercles which form in the lungs go through changes similar to those just described as occurring in the glands, but, owing to the different structure of these organs, there are complicating changes in the lungs which give the lesions a somewhat different appearance. The irritation caused by the tubercles usually leads to the development of bronchitis with an abundant catarrhal secretion which fills the smaller air tubes, shuts off the air supply, causes the collapse of the lung tissue thus deprived of air, and leads to the depositing of yellowish cheesy matter in the air tubes and cells of this portion of the lung. This condition is known as tubercular broncho-pneumonia.

In Plate I the lungs of a healthy hog are shown in order to enable the reader to compare these with the illustrations of tuberculous lungs. The color is uniform except for light and shade, the surface is smooth, and the tissue is spongy and elastic. The normal lungs of other kinds of animals have a similar appearance. The tuberculous lungs of a hog are represented in Plate II. Innumerable small tubercles are seen almost covering the surface, and many lobules are collapsed and of a deep red color. Toward the upper portion of the illustration, between the lungs, the enlarged and tuberculous bronchial glands may be distinguished. These lungs were very severely affected, but the tubercles have for the most part remained isolated—that is, they have not united and formed the tubercular masses which are sometimes seen.

Plate III shows different kinds of tubercular lesions observed in the lungs of cattle. In the lower figure there are small tubercular masses distributed throughout a limited portion of one of the lungs. The middle figure shows an aggregation or union of such masses, through which process a mass of considerable size has been formed, and around the border of this may be distinguished a white fibrous wall which when complete enveloped the tubercular material and shut it off from

the tissue of the lungs. The upper figure represents a tubercular mass similar to that just described, but older. The fibrous wall surrounding it is more distinct and thicker, while the contents are more broken down and homogeneous.

When a large number of tubercles develop on the surface of the lungs, an inflammation of the pleura may be caused, with the formation of much new tissue and the adhesion of the lungs to the ribs or the diaphragm. Sometimes the disease has a peculiar tendency to the development of tubercular growth upon the pleura and other serous membranes. The tubercular masses bud and branch, thus forming large wartlike growths; or groups of nodules may even hang from the surface suspended by delicate threads or fibers giving the appearance of a bunch of grapes. These collections of tubercles have often been called grapes, and this form of the disease is known as "pearly disease," on account of the pearly color and glistening appearance of the serous membrane covering the projecting buds and spherical masses. In many cases both the lungs and serous membranes are affected, but often there are extensive growths of this kind upon the surface of the lung, while, singularly enough, the tissue of the lung remains unattacked.

With extensive tubercular disease of the lungs and pleura the bronchial and mediastinal lymphatic glands generally become loaded with tubercular deposit and enormously enlarged. In some instances they constitute masses of tubercular material many pounds in weight.

The organs in the abdominal cavity are also frequently the seat of tubercular disease. In the herd of the Soldiers' Home, above referred to, more than 40 per cent of the animals had abdominal lesions. The mesenteric and portal glands are the organs most commonly affected, but tubercles are often found in other lymphatic glands of this region, and also in the liver, spleen, kidneys, ovaries, uterus, and even in the intestinal walls.

In Plate IV the figure to the right illustrates the appearance of the normal spleen of a hog. Its uniform color and regular outline should be noted. The figure to the left represents the tubercular spleen of a hog. Observe here the yellowish masses of tubercular material which cause elevations of the surface, and the color of which may be plainly distinguished through the membrane which covers the organ.

Plate V was made from a case of tuberculosis of the liver of a cow. A large portion of the lobe of the liver which is shown in the plate has undergone tuberculous changes and been converted into a solid mass of tubercular material. The nodules seen in this illustration are in various stages of the disease, but the majority contain the yellowish, partly cheesy, partly gritty substance which is characteristic of advanced tuberculous degeneration.

Plate VI is an illustration made from a case of severe tuberculous

pericarditis of a cow. The pericardium or sac surrounding the heart is seen greatly thickened by the formation of tubercular material, and the heart itself is compressed and misshapen.

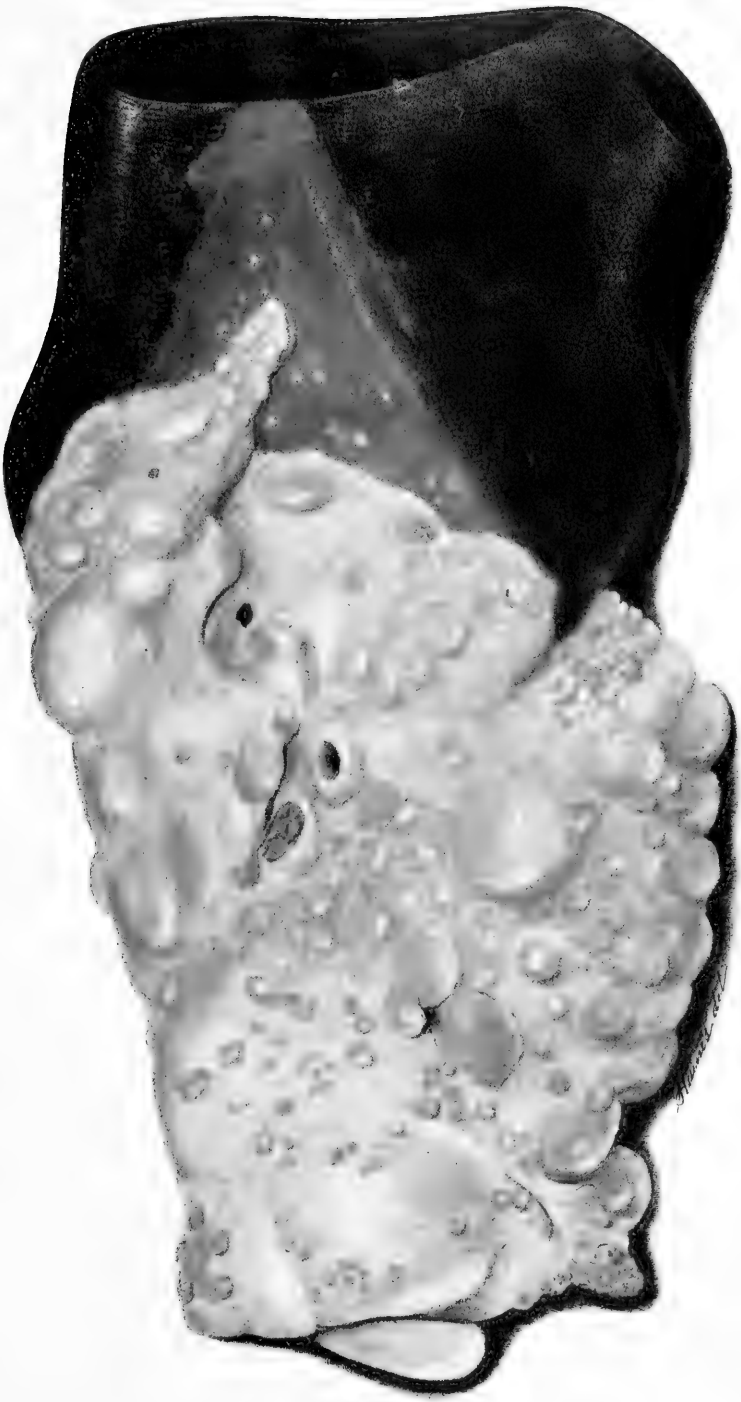
In Plate VII the lower figure represents the tuberculous ovaries of a cow. Many nodules of a size approximating that of a pin head are visible over the surface of the organ, and some are deeply buried in its substance. The upper figure was drawn from a portion of a child's intestine which was thickly covered with small tubercles. The great development of the tubercular process in this case is readily appreciated from the appearance of the plate. This class of cases has been attributed to infection taken into the stomach, and some of these cases are supposed to be due to infected cow's milk.

The udder of cows is sometimes attacked by tuberculosis, in which case one of the quarters is found to be swollen, uniformly firm or hard, and painless. In rare cases one-half of the udder may be affected. Tubercles are formed throughout the affected part of the organ, and there may be tubercles and tuberculous ulcerations upon the surface of the membranes lining the milk tubes. When such a condition is established the milk becomes thin and watery and contains innumerable tubercle bacilli. As the disease progresses larger nodules, such as have been described in other organs, form within the udder and undergo degeneration, softening, and liquefaction. If such a tuberculous mass opens into a milk duct, as is often the case, the liquid or semiliquid contents become mixed with the milk.

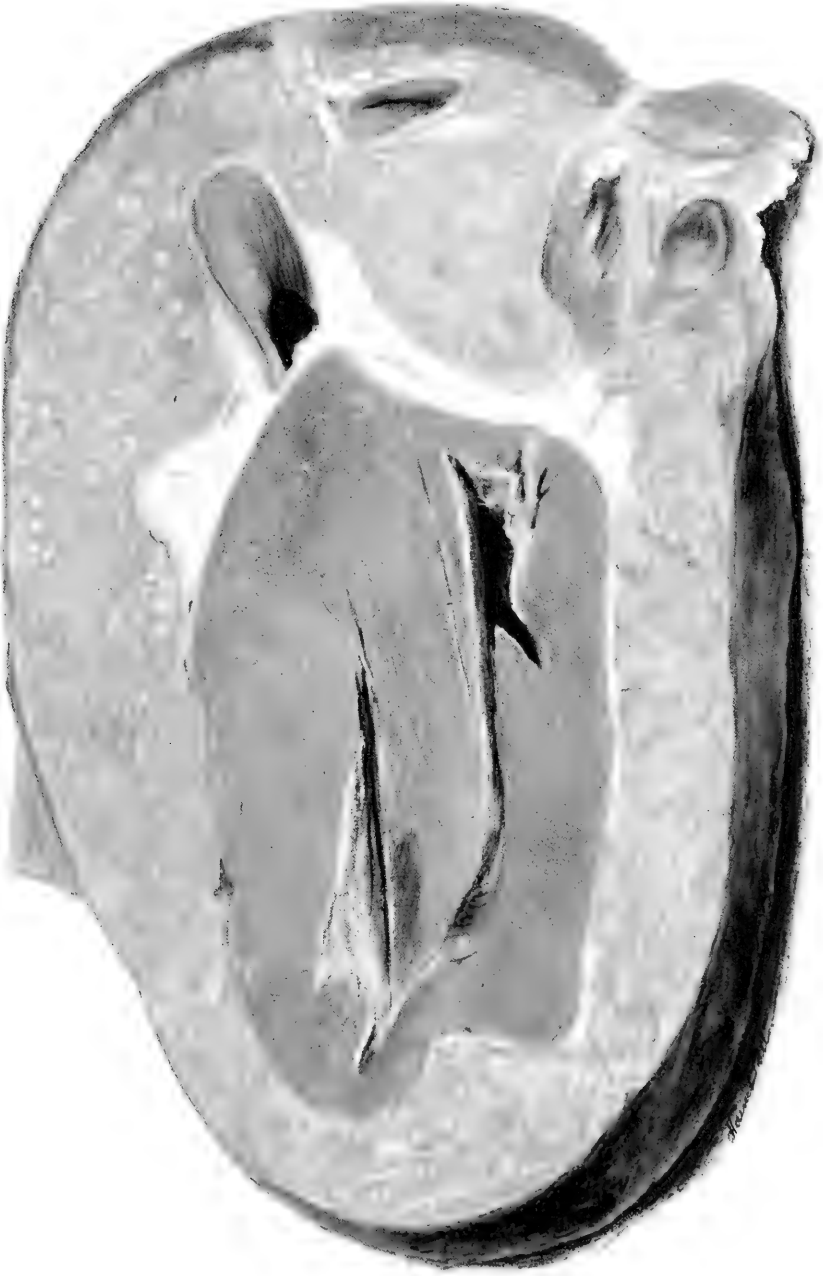
Plate VIII is an illustration of a tuberculous udder which has been cut across to show the distribution of the tuberculous material. This part of the organ is filled and distended with the tuberculous deposits, and the milk cistern showing near the lower portion is ulcerated, lined with tubercles, and covered with cheesy particles. At the upper portion of the illustration may be seen the supramammary lymphatic gland, which is greatly enlarged and studded with small tubercles.

Tubercles are often found in the lymphatic glands in front of the shoulder and in the flank, and in those embedded in various parts of the muscular tissue. As such glands are situated in the portions of the carcass used for food, it is important that they should be examined before the carcass of a tuberculous animal is utilized for this purpose. A tuberculous lymph gland is shown in Plate IX.

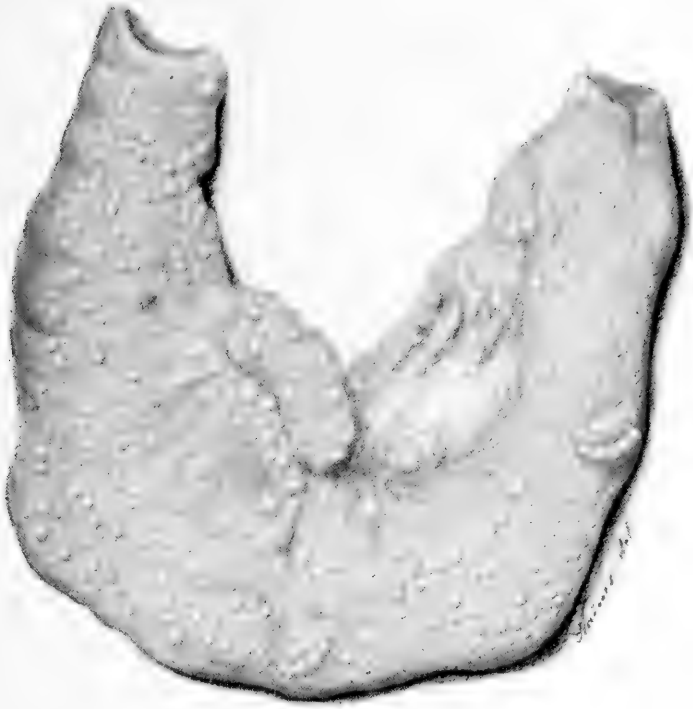
The bones may also be invaded by the tubercular process, especially in swine, and sometimes the whole interior of one or more bones will be filled with tubercular material, either just developed or undergoing degeneration. Often the joints are affected, causing swelling, inflammation, and lameness. The brain and spinal cord are by no means exempt from tuberculous disease, but owing to the difficulty of removing these organs for examination we have fewer statistics relative to them than to most other parts of the body. Semmer found tubercu-



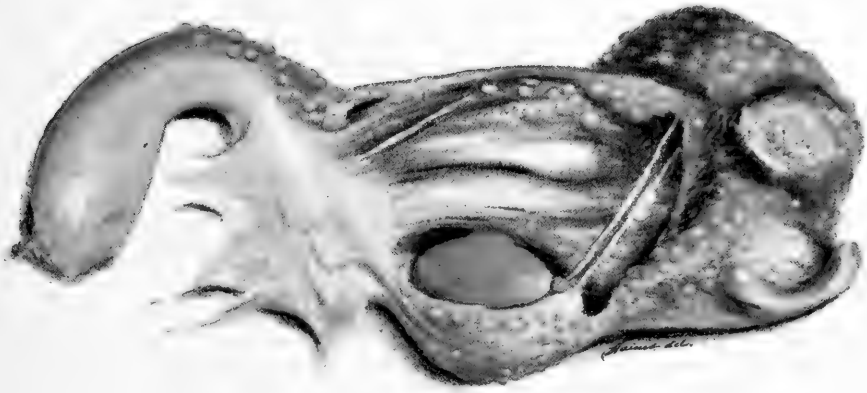
TUBERCULOUS LIVER OF COW.



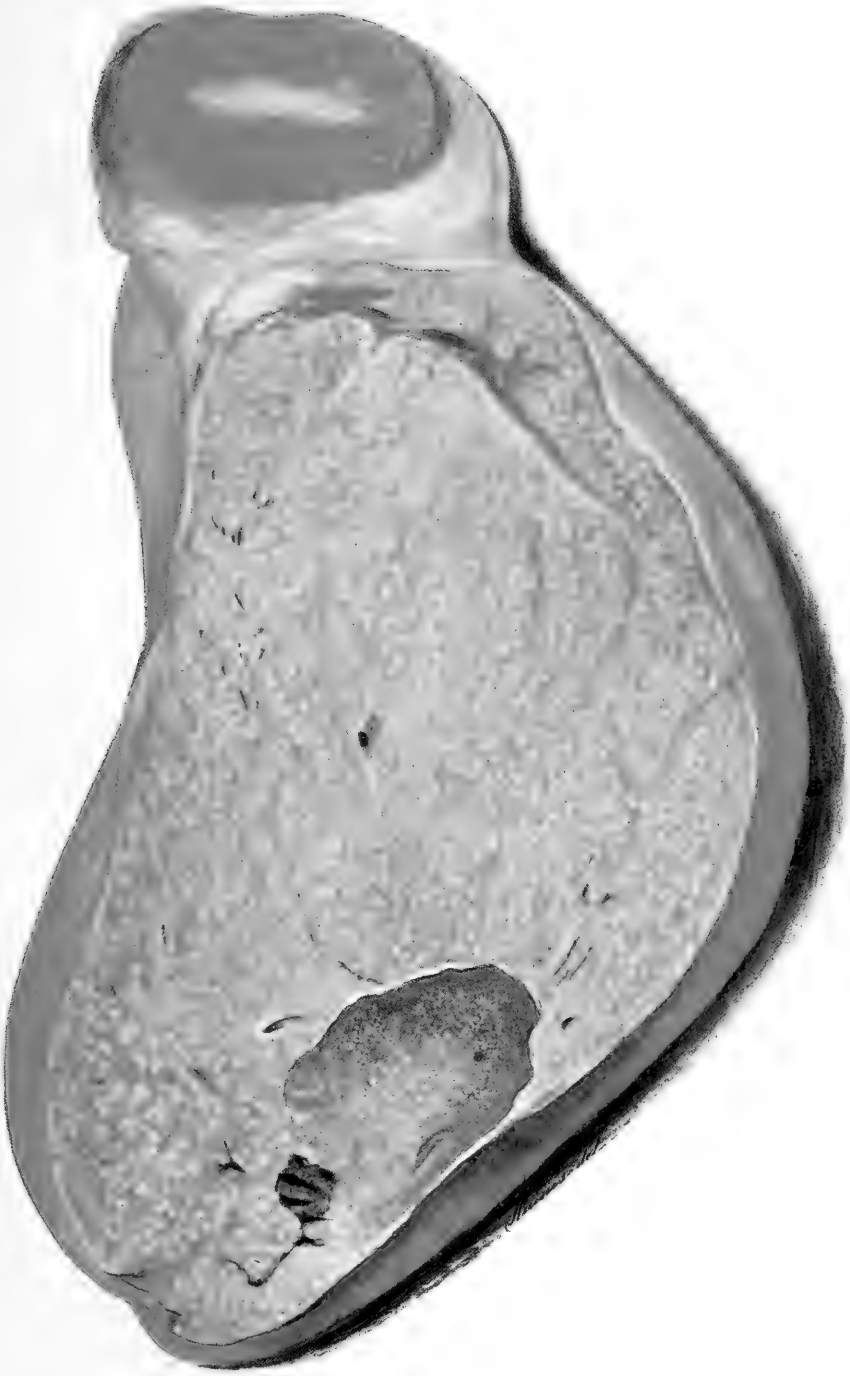
TUBERCULOUS PERICARDITIS OF COW.



TUBERCULOUS INTESTINE OF A CHILD.



TUBERCULOUS OVARY OF COW.



TUBERCULOUS UDDER OF COW.

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TUBERCULOUS LYMPHATIC GLAND OF COW.

losis of the brain in 4 out of 40 cases examined. The tubercles are located on the membranes of the brain and spinal cord, and are also found scattered through the interior tissue of these organs.

It will be seen from what has preceded that tuberculous disease may be found in any part of the animal body, and that while there are certain organs which are affected more frequently than others, none of the living tissues is altogether exempt from its invasion.

The generalized form of tuberculosis is that in which the infection gets into the blood and is distributed through the circulation to many parts of the body. Slaughterhouse statistics of different countries of Europe indicate that about 9 or 10 per cent of the cases of tuberculosis in cattle are in this form. Rieck, quoted by Ostertag, states, as a result of the careful examination of 430 cases of generalized tuberculosis in the abattoirs of Leipzig from 1880 to 1891, that the following percentages indicate the proportion of these cases in which the different organs of the carcasses were affected:

Organs.	Per cent.	Organs.	Per cent.
Lungs	100.0	Muscles and intermuscular lymph glands	49.3
Liver	83.0	Spleen	18.6
Intestinal canal	73.0	Udder	16.7
Serous membranes	57.4	Bones	8.8
Kidneys	52.5		

SYMPTOMS.

In the great majority of cases of tuberculosis in animals the symptoms are slight and not at all clear in their indications. As the functions of the body must be disturbed more or less before any symptoms are apparent, it is plain that in the earliest stages of the disease there are no symptoms, and that when symptoms develop the disease is already considerably advanced. It is only when the affected part is located where it may be easily examined that symptoms are shown by which the infection may be detected at a comparatively early stage. Thus when the udder or the glands of the neck are the seat of tuberculosis the existence of the trouble is more likely to be revealed than when the affected organ is within one of the body cavities.

If the larynx, the air tubes, or the lungs are affected there is a short cough, which is heard particularly in the morning at feeding time or when the animal is let out of the stable in the cold air, or after it has been drinking cold water, and especially after violent exertion. This cough generally becomes more prolonged and convulsive as the disease advances.

In case the uterus or ovaries are effected there may be abortion or sterility with abnormal sexual manifestations. If the intestines are affected there may be irregular attacks of diarrhea. If a joint is diseased it is revealed by lameness.

As the disease progresses the general health of the animal and the

functions of nutrition are affected. Animals which have been in good flesh and laying on fat fail to profit by their food and begin to lose flesh; there is a lusterless, staring, rough coat of hair, the skin becomes tense, the bones prominent, and the eyes sunken in their sockets. The milk secretion diminishes and the milk becomes thin, watery, and blue. In case the serous membranes of the chest become irritated by the tubercular deposits, pressure applied over the ribs may cause the diseased animal to cough, moan, seek to escape, and otherwise manifest evidence of tenderness in this region.

The ear applied to the walls of the chest may sometimes detect abnormal sounds, such as loud crepitation, gurgling, whistling, and creaking, or there may be areas where the respiratory murmur is entirely lost. Percussion sometimes shows abnormal resonance and sometimes areas of dullness corresponding to tubercular deposits or adhesions of the lungs to the chest wall.

In most animals there is high temperature, progressive emaciation, and loss of strength until death results. With some cases the general nutrition of the body remains unaffected and these symptoms of the final stages of the disease are postponed until after the lungs or other vital organs have been almost completely filled with tubercular deposit. But if the disease continues to make progress there must come a time when the nutrition and vigor fail to maintain themselves and rapid prostration follows. There are cases, however, with animals as with men, in which the forces of the body triumph over the disease, and the progress of the tubercular formation is arrested. The tubercular material is then inclosed by fibrous walls which shut it off from the living tissues of the body, caseation and softening or calcification take place, and in the course of time the bacilli may die and disappear. Unfortunately, these cases are the exception and not the rule.

In those cases which progress to a fatal end the attitude and general appearance of cattle are quite characteristic during the final stages. The emaciation is extreme; the outlines of the bones are clearly visible; the skin is tightly drawn over the skeleton; the coat is rough and without luster; the animal remains almost constantly standing; the nose is raised and the head extended on a line with the neck; the elbows are turned out to facilitate the expansion of the chest; the eyes are sunken, and there is a haggard expression to the face in harmony with the general appearance of the body.

The symptoms of tuberculosis in hogs are very obscure and difficult to detect. In the great majority of cases no symptoms are noticed and the disease is only recognized by an examination of the carcass. The parts most frequently affected are the glands of the neck, the bronchial, mediastinal, mesenteric, and portal glands, the liver, lungs, kidneys, and spleen. In numerous cases the glands of the carcass are affected, and tuberculosis of the bones and joints is common.

Although there is a great tendency for tuberculosis to spread to different parts of the body in swine, causing it to become more frequently generalized with these animals than with cattle, the rapidity with which they take on fat apparently enables them to resist the destructive influence of the disease, at least to the age at which they are generally slaughtered. Animals which come to market fat and appear perfectly well just before slaughter may be found quite seriously diseased.

In some cases, however, swine may show enlargement of the glands of the neck and of other parts of the body, diarrhea, emaciation, and tubercular inflammation and swelling of one or more joints. When the nutrition of the body is affected, as shown by loss of flesh, the disease usually runs a rapid course and causes the death of the animal in a few weeks.

EFFECTS UPON A HERD OF CATTLE.

It is no less important to study the effects of tuberculosis upon a herd of cattle than to study its effect upon the individual animal. The experience of those who have had herds free from the disease but who have had the misfortune to introduce it and have seen it develop among their animals must be of the greatest value to others who desire to guard against it. A number of such cases have been carefully studied at the experiment stations and elsewhere and the principal features of the outbreaks ascertained.

AN EXPERIMENT WITH TUBERCULOUS CATTLE.

Phelps[24] relates experiments with four condemned cows which were placed by the Connecticut State cattle commission at the disposal of the Storrs Experiment Station for the purpose of making some observations and experiments on bovine tuberculosis. The herd from which these animals came had been officially tested in March, 1896, and several animals in the herd were condemned and slaughtered, although the four cows mentioned failed to respond and were tagged as free from the disease. In October, 1896, the herd was tested again by the commissioners, and these four cows responded and were then condemned as tuberculous. Shortly afterwards they were brought to the station and were kept in quarantine until they were slaughtered in the fall of 1900.

These particular animals were chosen for the experiment because there was good reason to believe that the disease was present in its earlier stages. While the cows were at the station they were kept isolated from other cattle in a high, light, and airy stable with about 1,500 cubic feet of air space per cow, although later several calves which were used in the experiments with the cows occupied the same stable. Adjoining the stable was a small yard about one-half acre in area in which the animals were allowed to exercise several hours each

day, except in very stormy or extremely cold weather. No special treatment for the disease was attempted, but good care and feed were afforded at all times. During the first year that the animals were under observation all four cows remained in good condition and showed no outward sign of disease. It is evident that these cows were received at the station soon after their infection, when the disease had made but slight progress and before the general health of the animals was noticeably affected. They were kept under excellent sanitary conditions, with outdoor exercise and good food, and were protected from the worst weather. They should, therefore, have done much better than the average farm cow after it is infected with this disease.

The history of these cows at the station is very instructive, and is, in brief, as follows:

Cow No. 1337. This cow produced a vigorous calf April 5, 1897. The calf suckled its dam for six months, and was then placed in the college herd. During 1898 the cow appeared to be in vigorous health and remained in good condition of flesh. She dropped a well-developed calf in September, 1898, which was allowed to suckle its dam for about a year. During 1899 she remained in a vigorous state of health, and produced a healthy calf in December, 1899. Although this calf appeared vigorous and strong at birth, it was soon after attacked by scours and died in a few days. During 1900 the cow remained in good flesh, had a sleek coat, and continued to give a good flow of milk. Early in the year she developed a slight cough, but otherwise appeared in perfect health when killed in November, 1900. Examination of the carcass showed the mediastinal lymphatics to be tuberculous, and a tuberculous nodule was found in the right lung. The other organs were normal.

Cow No. 1341. This cow dropped a dead calf in March, 1897, the carcass of which was carefully examined, but revealed no signs of tuberculosis. She produced a well-developed calf in August, 1898, and seemed to be in a good state of health throughout the following winter. During 1899 she remained in fair flesh and gave a good flow of milk until July. At that time, while being fed green oats and peas, she was attacked by scours and began to run down rapidly. She ceased giving milk for a short time, but when placed on dry feed began to regain flesh and milk flow. She remained in a fair state of health during the fall, but had a tendency to looseness of the bowels. A healthy calf was produced in February, 1900, which was followed by a good flow of milk for several months, but during the spring and summer she lost flesh rapidly until her flanks were hollow and her ribs protruded plainly. The coat became rough, the eyes dull and sunken, the cough increased, and the breathing became more frequent. This cow continued to scour intermittently, and when killed in November, 1900, was generally emaciated, although continuing to give milk up to the time of her slaughter. Two-thirds of the right lung and one-half of the left lung were filled with tuberculous tissues and the mediastinal lymphatics were diseased.

Cow No. 1343. This animal became quite fat during the early part of 1898. She dropped a rather small calf in August, 1898, and was considerably thinner than usual for three months after calving, but soon after that began to gain in flesh. Later in the fall it was noticed that she had a persistent cough. During the spring and summer of 1899 she continued to give a fair flow of milk, but was not as fat as in 1898. Her cough increased during the winter of 1898–99, and in the following spring it was noticed that she coughed badly after eating dry feed or when made to exercise vigorously. However, she produced a vigorous calf in December, 1899, but this was soon after attacked by a mild form of scours, from which it recovered. She gave a fair flow of milk during the early part of the year 1900, although she was losing flesh and had an increasing cough and short, hurried breathing. During the fall of 1900 she lost flesh rapidly, had a rough coat, sunken eyes, and protruding ribs. She lost her appetite, and in October ceased to give milk, and when slaughtered in November was very much emaciated. Up to within a year of the time of slaughtering, this cow had been the fattest and sleekest of the four. The examination of the carcass showed both lungs badly diseased, almost solidified with tuberculous tissue, the chest walls covered with tubercles, and the mediastinal and mesenteric lymphatics badly tuberculous. Tubercles were found on the rumen and the diaphragm.

Cow No. 1344. This cow remained farrow during 1898, but continued to give a good flow of milk. During the fall of 1898 she gained in flesh and appeared to be in

a healthy and vigorous condition. She remained in this condition until some time in the summer of 1899, when she showed lameness in the right stifle joint. She calved in October, 1899, but the calf was weak at birth, and refused to eat. It died about a week after birth. The cow gave a good flow of milk for several months after calving, but was thinner than usual. During the early part of 1900 she lost flesh rapidly, though still giving a good flow of milk. She also developed a severe cough, which was especially noticeable when she was made to exercise vigorously. The lameness in the stifle joint increased in severity and became very troublesome to the cow. She lost flesh during the summer and fall, and, although not as emaciated as Nos. 1341 and 1342, was quite thin, had a rough coat, and appeared to be in a bad physical condition when slaughtered in November, 1900. The examination of the carcass showed the mediastinal lymphatics diseased and an abscess in the left lung.

With three of the four cows in this experiment the disease progressed from the very earliest stage to a point where the animals were worthless within about four years. With the fourth animal it remained nearly stationary and did not apparently affect the general health.

SPREAD OF TUBERCULOSIS BY DISPERSION SALE.

Russell[25] gives the following example of the dissemination of a diseased herd:

In October, 1903, a public sale was held in one of the southern counties of Wisconsin, at which a herd of 46 head of cattle were disposed of in order to divide up the interest of the landlord and the tenant. These 46 head were purchased by twelve persons. The landlord, wishing to retain what he thought were the most valuable animals, had a friend buy in for him 18 head, while the tenant bought 3 for himself.

One of the parties who had purchased 6 of these animals decided in the following February to have his herd tested for tuberculosis. A neighbor, hearing that the test was to be applied, asked to have his family cow tested at the same time. The result of the test was to show positive reactions in the case of this single animal and also in 3 out of the lot of 6 which had been purchased. This revelation led the original owner to investigate the condition of the portion of the herd which he had purchased, and in this case 14 of the original 18 were found to be affected.

The matter at this stage was brought to the attention of the State live stock sanitary board, and after a lapse of some weeks, so as to secure normal results, retests of these herds were made. In addition, all the herds were tested into which any animal had been introduced from the herd dispersed at the sale. The results of these tests are shown in the following table:

Dissemination of tuberculosis into various herds by sale of stock.

Herd.	Number of animals in herd.	Number of animals from original herd.	Number of tuberculin reactions.	Number of reactions in animals purchased.
1	21	5	3	3
2	18	18	14	14
3	38	6	3	3
4	8	3	4	2
5	5	2	2	1
6	3	3	3	3
7	1	1	1	1
8	15	1	1	1
9	32	1	1	1
10	18	3	0	0
11	2	1	1	1
12	2	2	2	2
13	22	9	1	1

It is evident from the above data that the originally affected herd was badly diseased, as 33 out of the total number of 55 disposed of at the sale or before responded to the tuberculin test. And yet none of these animals showed any appearance of the disease, and no one questioned their healthy condition at the time of purchase. The fact that

the owners bought in a large portion of the herd is evidence that they had no idea of the existence of this serious disease.

It was exceedingly fortunate that the first test happened to be made so soon after the sale of this herd, as the disease had apparently just begun to spread in the herds to which the animals from it were taken. It is, nevertheless, a good example of the extent to which the infection may be disseminated by the sale of animals from a single herd which is apparently in healthy condition.

HISTORIES OF AFFECTED HERDS.

The following history of the introduction and development of the disease in the herd of the Connecticut Agricultural College is a striking example of the danger of purchasing cows so long as tuberculosis is prevalent in dairy herds:[26]

Previous to 1896 the herd consisted of grade animals, mostly of Jersey and Guernsey blood, but in that year 15 registered Jerseys, Guernseys, and Ayrshires were purchased. Since then the acquisitions to the herd have been from the natural increase of these animals, and the occasional purchase of grade cows. The herd was examined by the veterinarian and tested with tuberculin in 1896. The registered animals purchased during the year were also tested, and the herd was pronounced free from tuberculosis. The tuberculin test was applied again in 1897, with no reactions.

In October, 1897, several grade cows were purchased, including "Fannie," a grade Guernsey. This cow was bought of a neighboring farmer, who had owned and raised her from a calf. Her owner reports that he had never had tuberculosis in his herd and had never used the tuberculin test. Fannie was a smooth, plump cow, and apparently in perfect health. When purchased she was tested with tuberculin, and, as she did not respond, was given a permanent place in the herd. She remained apparently in good health until about November 1, 1898, when she began to refuse a portion of her allowance of silage, and soon after commenced to scour, but at no time did she cough. From this time on she ran down rapidly, and was killed on November 20, as it was evident that she could live but a day or two longer. A postmortem examination showed a generalized and advanced case of tuberculosis. The herd was tested with tuberculin December 28, 1898, when 12 animals responded; it was again tested May 22, 1899, when 3 more responded; it was tested for the third time December 7, 1899, when 2 more responded; and it was tested for the fourth time April 16, 1900, when 1 additional animal responded. No further reactions occurred in subsequent tests, the last of which recorded was made on February 17, 1902.

Including the original tuberculous animal, there were, consequently, 19 diseased animals found in this heard of 49 animals, the disease having spread to that extent in about two and one-half years, notwithstanding that it was discovered at the end of the first year, and that affected animals were removed as fast as they were revealed by the tuberculin test.

Russell[3] gives the following history of an extensive outbreak of tuberculosis among cattle which recently came to light in the herd of a prominent dairyman supplying milk to the city of Beloit, Wis.:

The owner had a fine dairy farm on the outskirts of the city, and had constructed ample stable room to accommodate his herd. The business had developed until at the time of examination 70 animals were kept, 46 of which were in milk. A veterinary examination of an animal somewhat out of condition revealed the presence of tuberculosis, much to the surprise of the owner, and the tuberculin test was then applied to the whole herd.

Fifty-seven in this herd of 70 reacted to the test. Those that escaped were for the most part young stock. Thirty-three of the best conditioned of the 57 reacting animals were shipped to abattoirs for immediate slaughter, and of this number only 18 passed Federal inspection. Of the 24 killed on the farm not to exceed 7 would have passed for beef had they been sent for slaughter. Thus it appears that 32 of the 57 that reacted were so badly affected as to require total condemnation of the carcasses.

The owner was in California, but it was admitted by the herdsman who had handled the herd in previous years that a considerable number of animals had died or been killed from year to year as long ago as 1897. Frequently animals had been shot to get rid of them as they pined away. No examination was made and the matter was allowed to drift on until the startling revelation was made by the use of the tuberculin test. The slaughter of this herd revealed many cases of advanced tuberculosis, and in some instances even the udders were found diseased. The farm had well-constructed barns and stables, which were kept in a clean and sanitary manner, but no provision was made for ventilation.

Within a week from the time this first-mentioned herd was disposed of, another was examined in the southern part of the State in which even a worse condition was found. In this instance the herd consisted of 72 animals, many of which were fresh in milk, as the product was to supply a Swiss-cheese factory. The condition of the stock revealed by the tuberculin test was shocking. Of the 72 animals tested, 69 reacted. Only 1 mature animal, a yearling bull, and a young calf escaped the disease.

This widespread distribution of the disease was found to be due to the usual cause, neglect and failure to provide proper sanitary surroundings. For several years the owner had been losing animals from time to time, but made no effort to learn the cause of the trouble. This last winter 5 died, the year before 2 others, and during previous years still others. Four years ago he sold to a neighbor 5 head of young stock, which were kept on pasture during the summer. In the fall they weighed less than when bought, and were condemned when shipped to Chicago. Later 7 or 8 others were bought for shipment, 3 of which were condemned when inspected.

The post-mortem findings in this herd revealed many cases of generalized tuberculosis, some of which were in a most aggravated form. In a number of cases the udders showed well-marked physical signs of disease. The development of the disease in young stock in both lung and body cavities, with the infection of the bowel itself, bespoke a double infection, through the milk as well as through the air. The stable in which this entire herd of 70 head was kept, with about a dozen young calves, was located in a stone basement, in which there was absolutely no provision for ventilation. A little light filtered in through five or six tightly closed sash windows of three 8 by 10 inch panes of glass to each window. The interior of the stable was so dark that one could scarcely see to read ordinary newspaper print unless the doors were left open. In addition to these general insanitary surroundings, the manure on the floor of the stable was over a foot thick.

The way these two herds were handled is markedly contrasted with the course of action that was pursued in the following case:

A few weeks ago a member of the farmers' course at the Agricultural College witnessed a demonstration of the tuberculin test, and while he had no reason to suspect the presence of the disease in his own herd, he went home with the thought that it would be prudent for him to apply the test and satisfy himself as to the actual condition of his animals. In his herd of 25 only 1 was found affected, and this was a registered cow that had been bought a few months before for the sum of $150. This animal was the only recent purchase that had been made.

Recently another correspondent wrote that he applied the test to his herd, and found that 3 out of 5 registered Holsteins that he had purchased a short time before at an expense of $1,500 were affected.

THE CAUSE OF TUBERCULOSIS.

THE TUBERCLE BACILLUS.

Tuberculosis is caused by a bacterial organism known as the *Bacillus tuberculosis* microbe, which, so far as is known, does not multiply outside of the animal body except under the artificial conditions supplied in laboratories. As we find the bacillus in the body of an animal it is very exacting in the conditions which it requires for its growth, and for a long time bacteriologists found it difficult to make it develop in their laboratory cultures. Careful study of its peculiarities has, however, resulted in the discovery of methods by which it is now easily isolated from the tissues of the affected animals and grown in pure cultures. The longer it is grown in the laboratory the more readily

it is cultivated, as it adapts itself gradually to the new conditions; but in acquiring this exalted power to live and multiply outside of the animal body it generally loses some of its disease-producing power and becomes less and less virulent until in the course of time it may not be able to cause disease in the most susceptible animals.

The tubercle bacillus produces tuberculosis in all species of domesticated animals and probably in most species of wild animals, though some species of animals are very much more susceptible to its effects than others. It is able to multiply in the bodies of birds whose temperature is considerably higher than that of mammals, and it is likewise able to multiply in the bodies of cold-blooded animals whose temperature is far below that of mammals. It therefore lives, propagates itself, and causes disease under a great variety of conditions—a variety which is truly surprising when we consider the delicacy of the germ and the difficulties which were encountered in cultivating it in the laboratory.

The tubercle bacillus as it is found in widely different species of animals is not always identical in its characteristics, although there are certain general features which it always retains. Its peculiarities in regard to staining are the most striking of these. It does not take up the usual stains which are successful with other bacterial organisms, and consequently must be stained by special methods. Koch first succeeded in coloring it by leaving it for several hours in a solution of methylene blue, to which caustic potash had been added; but this method was soon superseded by a solution of gentian violet in water saturated with anilin oil, which was introduced by Ehrlich. Of late years carbol-fuchsin has been quite generally adopted for this purpose. Another peculiarity of the tubercle bacillus is that having once taken a stain, it fixes it very firmly, and it is, therefore, much more difficult to decolorize than other bacilli. The dilute mineral acids will remove these colors from animal substances and from other bacteria, but not from the tubercle bacilli. Advantage is taken of these peculiarities to make microscopic preparations in which the tubercle bacilli appear brightly stained while everything else is free from color, or to make these preparations so that the tubercle bacilli will appear red and all other micro-organisms will be blue.

The tubercle bacillus obtained from human beings is able to grow between the temperature limits of 30° and 40° C.; that obtained from birds is able to grow between the limits of 25° and 45° C.; while a stock of tubercle bacilli obtained by Friedmann from a tuberculous turtle was able to multiply at the freezing point and its temperature limits were placed by the discoverer at 0° to 43° C. The bacilli from these different sources have different habits of growth in cultures, and some under the microscope appear longer, thinner, and more beaded than others. There is also a great difference in the virulence of the

various stocks for different species of animals. Human bacilli are only with difficulty made to produce disease in fowls or in cold-blooded animals, and the greater number of such stocks have little or no effect upon bovine animals. Various investigators have succeeded, however, in modifying the different stocks of bacilli, and have been able to infect successfully birds and cold-blooded animals with human and bovine bacilli, and have also infected mammals with the tubercle bacilli of birds.

It appears, therefore, that the tuberculosis bacillus is one which is able to adapt itself to a wide range of conditions, and that the bacillus as found in the tuberculous lesions of birds, mammals, and cold-blooded animals is the same organism but modified somewhat by the conditions of environment.

MANNER OF INFECTION AND DEVELOPMENT OF THE DISEASE.

The tubercle bacillus may enter the body through a number of channels and thus cause infection. With cattle it is most frequently drawn into the air tubes in the form of dust floating in the atmosphere of the stable. In many cases, however, it enters into the alimentary canal with food that has been soiled with the saliva or other secretions of diseased animals. It may also gain entrance through a milk duct or through the vaginal opening, or by means of a wound. The bacillus appears to be able to penetrate the mucous membranes, at least in certain places, even when there is no wound or abrasion, and it may pass through the membrane without leaving any tubercular material or other sign to show where it gained entrance. However, in its progress through the tissues it is usually soon arrested either by a lymphatic gland or in some other manner, and then it multiplies and causes the formation of a tubercle. The channel by which the infection occurred may generally be determined with some degree of certainty by the location of the older tubercles. If the bronchial or mediastinal glands show the earliest lesions the infection probably came through the inspired air; but if the retropharyngeal, mesenteric, or portal glands have the oldest lesions the infection was probably through contaminated food.

When the tubercle bacilli have lodged in or invaded any organ their irritating effect upon the tissue surrounding them sets up changes similar to those seen in ordinary inflammation. The fixed connective tissue cells and the cells of the endothelium of the capillaries begin to multiply and produce large numbers of new cells which group themselves side by side in the form of a hollow sphere around the bacilli. These cells are then called epithelioid cells, and for the reason that it is composed of such elements the tubercle at this early stage is known as the epithelioid tubercle.

After the tubercle has made some progress in its development by the process just described and has become barely visible to the naked

eye, small round cells, called by some lymphoid cells, begin to gather around the sphere of epithelioid cells and may become so numerous as to obscure the latter and cause their disappearance. These round cells undoubtedly come from the blood vessels in the vicinity which have been affected by the adjacent tuberculous growth. When these lymphoid cells have increased in number until they predominate in the newly formed tubercle, this is called a lymphoid tubercle.

When the tubercle develops to about the size of a pin head, the lymphoid cells have usually become so numerous that they interfere with the nutrition of the central portion, and, therefore, the cells located at the center begin to die. As the cells die they disintegrate, and there is formed a granular, caseous material from which the bacilli have disappeared. When this process occurs slowly it is accompanied by the formation of giant cells, that is, large cells containing numerous nuclei. These cells are formed either by the fusion of a number of cells together or by an abnormal increase in the protoplasm of a single cell together with the multiplication of its nuclei.

As the tubercles increase in size, either by the addition of more cells or by the fusion of two or more small tubercles, the necrosed and caseated portion at the center becomes larger, and as this process continues tubercular masses of considerable size may be formed, having the same general appearance as the smaller tubercles, but with a relatively larger proportion of caseous material.

When the center has undergone partial caseation, the epithelioid cells surrounding the tubercle may be gradually changed to connective tissue cells, which are deposited in successive layers and thus form a fibrous wall. By the time the former cellular elements of the tubercle have disappeared this fibrous wall or capsule becomes firm and resistant and completely isolates the necrotic focus.

The caseous material within the tubercular mass may soften and form a liquid resembling pus, or there may be a deposition of calcareous salts which at first form as small angular granules and later coalesce into larger nodules until finally the entire caseous material may be calcified. This change is very common with both cattle and hogs.

After an animal has been infected with tubercle bacilli and the first tubercle has commenced to develop in the manner above described, more or less bacilli may be carried from this first point of infection with the streams of lymph or blood and lodge elsewhere to cause the formation of other tubercles. When the bacilli are carried through the lymph channels they usually are deposited before going any great distance, and hence, in this case, the tubercles are limited to one organ or to one part of the body; but if the bacilli penetrate the blood vessels in great numbers, as sometimes occurs, they are carried to all parts of the body and generalized tuberculosis is the result.

The ways in which tubercle bacilli escape from the body are quite as

interesting from a practical point of view as the ways in which they enter it. There are a number of channels through which they may be disseminated, but the most common ones are the air tubes, the digestive tube, and the milk ducts. Tubercles which develop near these channels, or in the mucous membrane lining them, may soften and discharge their contents into the tubes. In the case of the air tubes the material is coughed up, contaminates the saliva, and is partly distributed in the mangers and racks, and over the litter, and partly swallowed to pass away with the excrement. In the case of tubercular ulcers on the internal surface of the intestine, or of cavities in the lung opening into the bronchi, or of similar lesions communicating with the milk ducts, there may be a continuous development of the bacilli and an equally continuous discharge of vast numbers of these germs into the intestine, the bronchi, or the milk ducts, as the case may be. An animal so affected is most dangerous and may soon infect most of the individuals in the herd. The bacilli are less frequently distributed from the genito-urinary organs, although such distribution may occur when the kidneys or uterus are the seat of the disease.

On the other hand, the tubercular lesions may be so situated that they are closed in and have no channels of communication with the exterior, as in those cases where they are confined to a bronchial, mediastinal, or mesenteric lymphatic gland. Under such conditions an affected animal may remain in a herd for a long time without communicating the disease to the other animals of the herd. But probably in the majority of such cases there will sooner or later be an extension of the tubercular formation in the affected animal, when it may suddenly and without warning begin distributing the bacilli and infect the animals which are stabled or pastured with it. This explains why in some instances a tuberculous cow may infect the greater part of a large herd within a few months, while in other instances such a cow may remain in a herd for several years and no other animals become infected. The disease is of the same nature in both cases, but in one case the bacilli are able to escape from the body of the diseased animal, while in the other they are imprisoned and unable to do further harm.

INFECTIVENESS OF MILK OF TUBERCULOUS COWS.

The milk of tuberculous cows is a very common medium for carrying the tubercle bacillus to other animals, for while every cow affected with the disease does not secrete milk contaminated with the bacillus, there are frequently one or more cows in an infected herd whose milk is infected, and this, in turn, infects all milk with which it is mixed. There has been a great difference of opinion as to the proportion of affected cattle which yield milk containing the tubercle bacilli. Some have held that the udder must necessarily be diseased before the bacilli can find their way into the milk ducts, and as only a small proportion of the affected cows have disease of the udder, the danger from this

source was thought to be slight. It seems likely, however, that the udder is affected in a larger number of cases than has usually been admitted. It requires a very long and careful examination to determine positively that the udder is free from the disease. The European statistics have usually given the proportion of udder tuberculosis as from 1½ to 3 per cent of the total number of cases; but Pearson, in the examination of 1,200 tuberculous cows in Pennsylvania, found the udder affected in 8.75 per cent of the animals.

Numerous investigations have also shown that milk may contain tubercle bacilli when there are no appreciable signs of tubercular disease in the udder. A few of the more striking of these may be mentioned. Bang[27] tested the milk of 21 tuberculous cows with normal udders by inoculating 48 rabbits. Two, or 9.5 per cent, of these cows transmitted the disease. Later he injected 40 guinea pigs with milk from 28 cows affected with generalized tuberculosis and showed that virulent milk was being secreted by 4 of these animals, 3 of which on post-mortem examination were found to have lesions in the udder. By intra-abdominal inoculations of 28 guinea pigs with the milk of 14 tuberculous cows he found that 3 of the latter were excreting tubercle bacilli in their milk. The summary of these experiments shows that of 63 cows 9 gave virulent milk, and of this number 3 had tuberculous udders, leaving 9.5 per cent of the cows with normal udders producing infectious milk.[28]

Ravenel [2] experimented with 5 cows which reacted to tuberculin but showed no physical signs of tuberculosis. The udders in every case were free from disease so far as a careful inspection could reveal. The post-mortem examination of these cows confirmed the diagnosis made during life. He inoculated guinea pigs with a single dose, averaging 10 c. c. of milk from these cows. In the first series of experiments 4 out of 31 guinea pigs, or 12.9 per cent, became tuberculous. In the second series of experiments 5 out of 24 guinea pigs contracted tuberculosis, a percentage of 20.8. In the third series, in which the milk of a single cow was employed, 1 guinea pig out of 8 became tuberculous, or 12.5 per cent. In these three series of experiments 10 guinea pigs out of 63, or 15.8 per cent, became infected by a single dose of milk from these cows which apparently had no disease of the udder.

Rabinowitsch[29] and Kempner succeeded in producing tuberculosis in guinea pigs with the milk of 10 out of 15 tuberculous cows, or 66.6 per cent. Two of these cows were later found to have tuberculous udders, 3 showed advanced generalized tuberculosis, while the remaining 5 animals were but slightly affected. The writers conclude that milk from cows with incipient tuberculosis, but without disease of the udder, may contain tubercle bacilli; also that in latent forms of tuberculosis the milk may prove infectious, although the cow may not present any clinical symptoms of tuberculosis; and therefore that milk from all cows reacting to tuberculin should be considered as at least suspicious.

It is believed by Adami[30] that the cells of an actively secreting mammary gland of a cow can take up and discharge the tubercle bacilli without the animal showing any lesion of the lacteal tract. He and Martin examined the milk of 10 cows, and when these were killed the udders were subjected to microscopic examination with negative results. In the milk of 6 (60 per cent) of these cows tubercle bacilli were observed by the aid of the microscope. The milk from the cow showing the greatest number of bacilli was inoculated into 2 guinea pigs, and both died as a result of the infection. Twenty-nine guinea pigs and 26 rabbits were inoculated with varying quantities of milk, and 1 calf was fed for five months, but only 2 guinea pigs died of tuberculosis.

Gehrman and Evans[31] found tubercle bacilli in the milk of 15 out of 41 cows with sound udders, or 36.6 per cent. Guinea pigs inoculated with milk from 10 of these cows died of tuberculosis (24.3 per cent). Their final showing is that 16 of the cows, or 39 per cent, at one time or another, gave milk containing tubercle bacilli.

The milk of 56 reacting cows which showed no signs of disease of the udder was carefully tested in various ways by Mohler and Nörgaard.[32] One or more of the guinea pigs fed with milk from 9 different cows out of this lot succumbed to typical tuberculosis—that is, the milk of 16.07 per cent of the 56 reacting cows was found to be pathogenic to guinea pigs when fed to them.

Of the experimental animals inoculated intra-abdominally in the first series, at least 1 guinea pig died of tuberculosis in each of six different instances, showing that the milk of 10.9 per cent of the 55 reacting cows in this experiment was fatal to guinea pigs. In the second series of intra-abdominal injections, the milk from 7 individual cows out of 45 examined, or 15.5 per cent, was demonstrated to possess virulent tubercle bacilli. By uniting these inoculation results, it is found that 11 out of 55 cows, or 20 per cent, secreted milk which transmitted tuberculosis to one or more experimental animals when injected into the peritoneal cavity.

The combined results of the ingestion and inoculation experiments showed that the milk of 12 out of 56 reacting cows, or 21.4 per cent, at one time or another, during the experiment contained virulent tubercle bacilli.

Specimens of the mammary glands from all the cows yielding this virulent milk were brought to the laboratory and histological examination was made of them without finding any indication of tuberculosis. With one of these cows positive results were obtained in all of the tests—that is, by ingestion, by inoculation, and by microscopic examination of the sediment of the milk and cream—although but 7 of the 10 experimental animals fed and inoculated with the milk of this cow became tubercular. It was evidently a case in which the milk

was seriously contaminated. Special attention was given to the examination of the udder of this cow and numerous serial sections were examined, with entirely negative results.

The results of these careful experiments prove that the milk from a considerable proportion of reacting cows contains the tubercle bacillus and is capable of producing tuberculosis in animals which consume it. The proportion of cows which yield such infected milk is much greater than the proportion which show tuberculosis of the udder. Whether the milk in these cases was actually infected within the udder or whether it became contaminated at the time it was drawn makes little practical difference. Every precaution was taken to prevent such contamination after the milk left the mammary gland, and if the bacilli floating in the air of the infected premises or dropping from the coats of the animals infected the milk in spite of the precautions that were taken, similar infection would certainly occur in ordinary dairy operations. It must be admitted, therefore, that the milk from tuberculous cows is often infected and dangerous when, so far as can be ascertained, the udder is in a normal condition.

The milk from tuberculous herds is a frequent source of tuberculosis in calves and pigs. The calves born in tuberculous herds are fed upon the milk produced by such herds during the early period of their lives, and a considerable proportion of them may be infected in that way. In dairies where butter is made, or from which cream is sold, the skim milk is commonly fed to pigs, and in other cases skim milk is obtained from creameries for feeding to calves and pigs, and the animals are often infected in this way.

Pearson and Ravenel,[2] in treating of the ways in which tuberculosis may be spread, say that the mixed skim milk returned from a creamery to a healthy herd may be contaminated. This danger is so great that in some places (parts of Pennsylvania and New England, France, and Germany) it is the practice to heat skim milk to a temperature that will insure the destruction of the tubercle bacillus. In Denmark and Prussia such heating of skim milk and buttermilk is required by law. Several illustrations of this danger had recently come under the observation of these authors. In one case a large herd was tested with tuberculin and found to be extensively diseased. Two of the cows had tubercular udders. This herd was used for the production of cream that was shipped to market, the skim milk being retained for feeding calves. It was the practice on this farm to remove the calves from their dams when they were three days old and keep them in a separate building distant from the cow stable. The dairy building and separator were located midway between the cow stable and the calf stable. After the cream had been separated the skim milk was carried on for the calves. When the cows were tested the calves were also examined, and it was found that while the prevalence of tuberculosis among the

dairy cows was 75 per cent, all the calves reacted and were condemned. The post-mortem examinations of the calves revealed tuberculosis of the postpharyngeal lymphatic glands or lower digestive tract in all cases, indicating that infection had occurred through the digestive system and that it had been carried to these calves in skim milk.

Only a small proportion of the calves dropped by tuberculous mothers are affected with tuberculosis at the time of birth. In other words, the cases of congenital tuberculosis are very rare. Klepp found at the slaughterhouse in Kiel among 4,068 calves that were slaughtered only 26 affected, or 0.64 per cent, and in a second series of investigations there were found 10 calves affected with congenital tuberculosis among 847, a proportion of 1.18 per cent. Höyberg obtained similar results, having found 6 cases of congenital tuberculosis among 500 calves examined at the time of slaughter. According to the calculations of Klepp only 2.63 per cent of the calves dropped by tuberculous mothers are affected with congenital tuberculosis.[33]

As an example of the proportion of calves found affected, Bang[22] gives the statistics of the small slaughterhouse at Aarhus, Jutland, where very careful examinations are made and where the cattle come from a district in which tuberculosis is very widely distributed. In the year 1903 there were found among 6,765 calves (3,279 quite young calves and 3,484 fat calves) 100, or 1.48 per cent, tuberculous (with 14 new-born calves the existence of congenital tuberculosis was discovered). Among 4,920 grown cattle there were 2,509 tuberculous, or 51 per cent.

It would appear from these figures that possibly not more than 1 per cent of the calves from tuberculous mothers are affected with tuberculosis at the time of birth. In very badly affected herds as high as 2 per cent of the calves may have congenital tuberculosis. Under any circumstances, it is plain that the great majority of calves contract the disease either from contaminated milk or from inhabiting the stables where tuberculous cows are kept.

Bang[22] gives the following table showing the distribution of tuberculosis according to age in 40,624 cattle tested for the first time in Denmark during the years 1898–1904:

Age when tested.	Number tested.	Number which reacted.	Per cent.
Calves up to one-half year	5,559	675	12.1
Cattle from one-half to 1½ years	7,744	2,129	27.5
Cattle from 1½ to 2½ years	5,047	1,949	38.6
Cattle from 2½ to 5 years	10,350	4,644	44.9
Cattle over 5 years	11,924	5,724	48.0
Total	40,624	15,121	37.2

This table shows that, in a country where from 45 to 48 per cent of the adult cattle are tuberculous, 12.1 per cent of the calves are affected by the time they are six months old. If 2 per cent of these calves

have congenital tuberculosis it follows that more than 10 per cent of them contract the disease from the milk which they drink or from the infected stables in which they are kept. During the second half year of the life of the animals an additional 15 per cent become infected. Probably the greater part of the infections during the first year result from contaminated food. These statistics, therefore, show the important rôle played by infected milk as a disseminator of tubercular disease.

Phelps,[24] of the Storrs (Conn.) Experiment Station, reports the results of experiments made there in feeding to calves the milk of tuberculous cows:

During the greater part of the four years that 4 tuberculous cows were at the station the milk of some or all of them was fed to calves. The results of the first two years' feeding show that, while the milk of each of the 4 cows was fed to several calves in periods ranging from three months to one year and four months, in no case was there any indication of disease in the calves during the feeding period. The calves were kept with the cows nearly two years. One of these calves responded to the tuberculin test about five months after the feeding period of sixteen months was ended, and was found upon post-mortem examination to be very slightly diseased.

Two calves, the offspring of tuberculous cows, were selected for a comparison of the infectiousness of pasteurized and raw milk. About half of the milk of 1 cow was heated to about 170° F. and fed to her offspring, and the balance of the milk in its natural state was fed to the offspring of the other tuberculous cow. The calves were isolated from the cows. Neither of the calves responded to a tuberculin test made after a feeding period of about ten months. By a misunderstanding both of the calves were fed the unpasteurized milk of the cow for a period of three weeks (following the tuberculin test), after which they were turned out to pasture for about five months. Three weeks after being returned to the stable with the cows the calf which had been fed the pasteurized milk (except for three weeks) responded to the tuberculin test, while the other calf failed to respond until five months later.

Two other calves were fed the milk of their dams from August and September, 1898, until the next June. At the end of ten months' feeding in one case and nine and one-half in the other neither of the calves responded to the test. One calf was at pasture from June 24 to November 13, while the other remained in the stable with the cows. Both responded to the test on December 2 following, three weeks after one of the calves was returned from the pasture.

Two more calves were fed the milk of the 2 other cows. Both had tuberculous mothers. One was kept in the stable with the cows, and after being fed the milk of cow No. 1344 for a period of ten weeks responded to the tuberculin test. The other was fed the milk of its dam (No. 1343) while isolated in a room in another part of the barn. After a feeding period of nearly three months this calf responded to the tuberculin test.

Three other calves from nontuberculous cows were selected early in May, 1900, and placed in a small pasture near the station barn. Calf L was fed the milk of No. 1337, calf M the milk of No. 1341, and calf N the milk of No. 1343. All practicable precautions were taken to prevent the transmission of the disease in any way except by the milk. The calves were tested May 24–25, about three weeks after the feeding began, and again September 28–29, after having been fed over four and one-half months. None of the calves responded to either test. The calves were not fed milk after the September test but were kept isolated from the cows. Calf M died November 29, and an examination by the station veterinarian revealed a congested condition of the stomach, kidney, and bladder, indicating some form of poisoning. An examination of the lungs also demonstrated the existence of tuberculosis, there being a tuberculous nodule in the right lung, calcified, and the mediastinal lymphatic being tuberculous. The two remaining calves failed to respond to a tuberculin test in February, 1901, and in May were sent to pasture with some other stock.

Thus in the first feeding test 1 calf out of several became tuberculous, and in the four succeeding tests 7 out of 9 eventually became tuberculous. The 2 which did not respond to the test may or may not have been diseased. The uncertainty of depending upon repeated tuberculin tests in such cases is shown by the last-mentioned experiment, in which no tuberculosis would have been found had it not been for the accidental death of one of the calves. Some of these calves may have been infected through cohabitation, but in any case the large proportion of infection shows the danger of having tuberculous cows in a herd.

SPREAD OF TUBERCULOSIS FROM DISEASED TO HEALTHY CATTLE.

The rapid and widespread dissemination of the disease by the sale of breeding stock from tubercular herds has been pointed out by Russell and Hastings.[34]

Where the disease establishes itself in herds that are sold for breeding purposes the danger is much increased, for animals from such sources are much more apt to be widely disseminated, since they generally serve as a foundation for the breeding up of common stock. The State of Wisconsin, as well as other Northwestern States, has suffered in this regard very severely from some of its finest breeding herds. One herd in particular in this State has had anything but an enviable record in this matter, for it has been determined that tuberculosis has broken out in at least 16 herds to which members of this original herd were sold. While it can not be proved that the origin of the disease in each of these 16 cases could be traced to the animals originally purchased, yet it is noteworthy that in a considerable number of cases the first animals to show evident symptoms of the disease were those that were introduced from this badly diseased herd. Not only were a number of fine herds in Wisconsin infected from this source, but the contagion was also spread, in a number of cases, to Minnesota and Iowa.

Schroeder and Cotton[35] have made experiments to test the rapidity with which tuberculosis spreads in a stable from diseased to healthy cattle.

Seven healthy cattle and 3 tubercular cows were confined in a stable containing 10 box stalls, which were separated by solid 2-inch plank partitions 6 feet high. Five of the healthy cattle and the 3 tuberculous cows occupied different stalls each day, in a rotation which exposed each of the healthy cattle equally to the 3 diseased cows. Two of the healthy cattle occupied stalls near the center of the stable and were at no time allowed to enter other stalls or to come into closer contact with any of the other cattle.

Two and one-half months after the beginning of the experiment 1 of the 3 tuberculous cows was removed from the stable, and 2 other and more severely affected cows were introduced. One of these tuberculous cows died after it had been in the stable two months, and was found to be affected with generalized tuberculosis, but without disease of the udder or lymph glands associated with or near the udder. All of the exposed cattle were tested with tuberculin at the beginning of the experiment and found to be free from tuberculosis.

The experiment began January 27, 1903, and the exposed cattle were tested with tuberculin on June 30 following. The two animals which had been confined to their stalls were a yearling bull, which reacted to the last test, and a 6-year-old cow, which did not react. Both animals were found tuberculous when killed and examined August 3, 1903. In the bull the posterior mediastinal glands were slightly enlarged and contained numerous small recent foci of tuberculosis. The anterior mediastinal glands were greatly enlarged and filled with foci of tubercular material, and the bronchial glands contained several small foci of recent tubercular disease. The cow also was diseased, having several of the mediastinal glands greatly enlarged and thickly sprinkled with small tubercular nodules, recent in character, and, in addition, several small recent areas of tubercular disease scattered through the lung.

Two heifers, 1 six months old and 1 eighteen months old, both in good condition, were made to occupy a different stall each day in order that they might be exposed equally to each of the tuberculous cows. When tested with tuberculin on June 30 both reacted. Post-mortem examination of the younger animal showed the left principal lobe of the lung adherent to the chest wall and near the adhesion a tuberculous nodule in the lung tissue about 1 inch in diameter. The anterior and posterior mediastinal glands, the bronchial glands, and the lymph glands about the root of the tongue were greatly enlarged and either entirely tubercular or thickly sprinkled with minute tubercular foci. Several of the mesenteric lymph glands were converted to the extent of half of their substance into tubercular material, and a number of other mesenteric glands were affected, as were also the glands at the brim of the pelvis in the abdominal cavity. The lesions were all of comparatively recent origin. The older heifer had one small focus of tubercular disease in the left principal lobe of the lung, and sprinkled over various portions of the pulmonary pleura of the right principal lobe of the lung were numerous tubercles with corresponding tubercles on the costal pleura. The pulmonary surface of the diaphragm was

sprinkled with numerous small tubercles, and the various lobes of the lung were adherent to each other and to the diaphragm by means of tissue containing many tubercles. The appearances were typical of pearl disease in cattle.

Three other cattle were exposed in the same manner as the 2 just described, but these had previously been given intravenous injections of dead or living tubercle cultures. One of these, a bull calf six months old, had 20 c. c. of dead culture of human origin injected into the right jugular July 12, 1902, and at the beginning of this experiment was in good condition and gave no reaction. When tested June 30, 1903, it reacted, and on post-mortem examination tubercular deposits were found in the anterior and posterior mediastinal glands, while the lymph glands back of the pharynx were five times their usual size and completely tuberculous. There were also a number of recent tubercular foci in the liver. The second animal, a heifer calf about four and one-half months old, had received in the right jugular 20 c. c. of dead bovine tubercle culture July 19, 1902. This animal was also in good condition and failed to react at the beginning of the present experiment. When tested June 30, 1903, she gave a marked reaction. She was slaughtered and examined August 5, 1903, at which time there was found tuberculosis of the mediastinal and bronchial glands and of one mesenteric gland. The third animal of this group was a cow about two years old. This animal had received injections of 10 c. c. each of moderately virulent human tubercle culture into the right jugular vein on July 19, August 6, August 20, September 20, and October 7, 1902. When admitted into this experiment, January 27, 1903, she looked thin and unthrifty, but failed to react. She also failed to react to the test of June 30, 1903. Killed and examined, August 6, 1903, the entire lung was found to be sprinkled with minute white nodules, having an appearance similar to that observed on several occasions after the injection of human tubercle into the veins of cattle. No tuberculous lesions were found in other parts of the body, and the disease in this animal was undoubtly caused by the injections of the cultures of human bacilli.

The rapidity with which tuberculosis spreads in stables occupied by tuberculous cattle is shown with particular emphasis by the two cattle which became tuberculous without actual contact with the tuberculous cows and while standing in stalls which were separated from the other stalls by solid partitions 6 feet high. The distribution of the lesions indicate that the germs of tuberculosis in stable infection are more commonly respired than ingested with food. This experiment clearly shows that cattle can not be protected from tuberculosis when in the stables with tuberculous cattle, even when each animal is carefully restricted to its own individual stall.

THE EFFECT OF INSANITARY CONDITIONS.

The ideal conditions for health and for resistance to the tuberculosis contagion are life in the open air and an abundant supply of nutritious food. The greater the departure made from these ideal conditions, the more is the development of tuberculosis favored. At the same time it should be remembered that this disease will not appear in an animal unless the tubercle bacillus has gained entrance to its tissues, and this bacillus can not originate in a stable, no matter how insanitary its conditions may be. The tubercle bacillus, like other forms of living things, must come from a preexisting germ of the same species; and as it grows only in the body of an animal, it must be transported in some manner from a diseased animal to a healthy one before the latter can contract the disease. These are foundation principles which are thoroughly established and which must be borne in mind in handling animals for the prevention or the suppression of tuberculosis.

Life in the open air is not always sufficient to prevent infection with tuberculosis or to cure animals that are already affected by it, but its influence is favorable and reduces the chances of infection to the smallest proportion, while at the same time it places the diseased animal under the best conditions for its recovery. In most stables the conditions of life are radically different from what they are in the open air. It is only necessary to make the most casual inspection of the ordinary stable to assure oneself that the conditions of life there are unfavorable in the extreme.

Ventilation.—Most stables have no provision for ventilation. Any air which enters them must come through the doors or the walls of the buildings; either there are drafts of air upon the animals, favoring the production of colds and catarrhs, or there is an insufficient supply of oxygen. The circulation of pure air in a stable furnishes an abundant supply of oxygen, which increases the resisting powers of the animal, and it also serves to carry away dust and other impurities which may be floating in the atmosphere of the stable. Where there is no ventilation disease germs carried into a stable are likely to remain there until they infect the animals. Where there is little ventilation stables are almost always damp, and such dampness favors the preservation of the bacilli and tends to the production of catarrh in the air tubes of the animals, which is a condition favorable for the lodgment of these germs. Tuberculosis is most frequent with people, as well as with animals, who are crowded together in small and poorly ventilated quarters. An abundant supply of fresh air in the stable acts favorably in several ways: First, it is a means of supplying the animals with a proper amount of oxygen for carrying on the functions of their bodies; second, the circulating air carries away the carbon dioxide and the moisture given off from the animals' bodies, and leaves the stables dry and healthful; third, the air currents also carry away bacteria of all kinds which may be floating in the atmosphere of the stable, and in that way they reduce the chances of infection; and, fourth, fresh air and dryness are unfavorable conditions for the preservation of bacteria, and, consequently, well-ventilated stables are not so easily infected as others, and the infection dies out more readily in them.

Light.—It is just as desirable that there should be ample provision to let light into a stable as that there should be ventilation. The direct rays of the sun are of especial value for destroying tubercle bacilli and for increasing the resistance of the animals to their attacks. In addition to this the sun's rays aid in drying and disinfecting the stable. Light is also necessary to enable those who care for the stable to see the dust and filth and to put it into proper sanitary condition. Dark stables are almost universally dirty, damp, and unhealthful.

Pearson and Ravenel[2] say with reference to this subject that—

> It has been shown by Migneco, Straus, and others that tubercle bacilli are destroyed by light in a time that is in proportion to the intensity of the light and inversely as the thickness of their protective coating. In Migneco's experiments sputum con-

taining many bacilli were spread out on linen or cotton cloth and then exposed to sunlight. Subsequently the cloth was washed in sterile water and the wash water was injected into the peritoneal cavities of experimental animals. The virulence of the germs was greatly reduced in from ten to fifteen hours and when the layer was not too thick they were completely destroyed in twenty-four to thirty hours.

Sunlight has a decided effect on the chemical processes that take place in living tissues. In the case of plants this is very marked. Dammann states that animals expire smaller quantities of carbon dioxide at night than during the day. According to the experiments of Platin, which were made on rabbits, the increase in oxygen consumption and in carbon dioxide excretion under the influence of light is from 13 to 14 per cent. Dammann calls attention to the fact that this result is in full accord with the general experience that animals fatten best in dark stables, and it is also noticed that animals kept in dark places for long periods become sluggish. The pallor that is characteristic of miners, stokers on ocean vessels, and prisoners is also due to the absence of light. In darkness there appears to be a checking of the metabolism and tissue change, an indolence of excretory functions.

De Renzi has made some experiments to determine the effect of direct sunlight on tubercular processes. He inoculated 8 guinea pigs with tuberculous sputum and afterwards placed half of them in a glass box and the others in a wooden box. Both boxes were ventilated from below and were placed in the sun. The animals in the wooden box died on an average of twenty-seven days after the inoculation, while those in the glass box lived an average of fifty-seven days.

Similar experiments have been made in the laboratory of the Pennsylvania live stock sanitary board, and it has been shown that light prolongs the life of a tubercular animal.

Cleanliness.—A stable must be clean in order to be sanitary. Cleanliness is the first principle of sanitation, and it must be continually kept in view. Not only must the filth on the surface of the floors be removed, but there must be no channels by which it can gather between or beneath the flooring to ferment, putrify, and pollute the atmosphere with noxious gases. The dust which gathers upon the walls is often even more objectionable than the filth upon the floors. In infected stables the dust is certain to contain tubercle bacilli, and these are in a condition to be easily floated in the atmosphere and breathed into the animals' lungs. A stable to be sanitary should be so constructed that the floors, walls, and ceilings may be thoroughly cleaned and disinfected. It should be free from cracks, inaccessible ledges, and corners, and from decayed wood, all of which may harbor contagion. The first thing is to have the stable so constructed that it is possible to clean it thoroughly, and the second thing is to see that it is frequently cleaned and that it is occasionally disinfected. If there are tuberculous cows in a herd, the feed boxes and mangers soiled with the saliva of the diseased animals are the most dangerous parts of the stable. Next to these are the parts covered with thin layers of manure, which becomes dry and pulverized and is carried into the air as dust; and not less dangerous is the dust which has accumulated on the walls and in every part of the stable where it can lodge. In cleaning such a stable the walls and ceilings should be swept and washed as well as the floors, and the whole interior should be drenched with the disinfecting liquid.

To be in a sanitary condition a stable must, therefore, be well ventilated, but free from strong currents of air; it must be light and permit the entrance of the sun's rays during at least a part of the

day; it must be dry, with no stagnant water standing under or near it; and, finally, it must be clean, not only as regards the accumulations of manure in the gutters, but as to the less noticeable contaminations of the floors and walls.

If these conditions are realized, a long step will have been taken in the struggle against tuberculosis; the disease will not spread so rapidly in such a stable as in the ordinary kind, and it will be far more easy to eradicate the contagion from it. But no matter how perfect the stable or how unimpeachable the condition in which it is maintained, there is still danger of the disease spreading if a tuberculous cow is brought into the herd, and if a number of cows have become affected these animals must be discovered and removed before the disease can be suppressed. Tuberculosis can not be successfully combated by sanitary conditions alone.

Dr. Leonard Pearson[40] has made interesting investigations bearing upon the effect of bad stabling conditions in favoring the spread of tuberculosis among cows.

For the purpose of the investigation 2 herds were established of 6 cows each. Four in each herd were healthy and 2 in each herd were tubercular. One herd was kept in a roomy, light, clean, and well-ventilated stable. The stalls and partitions between the mangers in this stable were so constructed that the cows were kept apart from each other.

The other stable was small, close, poorly ventilated, rather dark, and not especially clean. The cows here were not separated by stall partitions, and they were all fed from the floor of the passageway in front of their stalls.

This experiment continued for five hundred and thirteen days, or about seventeen months, and at the close it was found that 2 of the originally healthy animals kept in the large light stable had contracted tuberculosis, and the other 2 of the originally healthy cows continued sound. Of the 4 originally healthy cows in the small dark stable all had contracted tuberculosis. The progress of the disease in each infected animal in the dark stable was greater than in the infected animals in the light airy stable.

THE DETECTION OF TUBERCULOSIS.

The detection of tuberculosis in any other way than by the tuberculin test is often difficult or impossible during the life of the animal. In the case of a herd of cattle we have three sources of information—the symptoms brought out by a physical examination of each of the individual animals, the tuberculin test, and the examination of the carcasses of such animals from the herd as die of disease or are slaughtered. Each of these sources of information is of great value, and none of them should be neglected in case there is any reason to suspect the existence of the disease.

PHYSICAL EXAMINATION.

The inspection of a herd of cattle affected with tuberculosis frequently reveals evidence strongly indicative of the presence of the disease. Some of the animals may be emaciated, the skin tensely drawn over the bones, the hair standing on end, rough, and lusterless. There is an undue amount of coughing in the morning when the animals are fed, when they are driven out of the stable into the cold

air, after drinking cold water, or when they are made to take rather violent exercise. The lymphatic glands located about the throat, in front of the shoulder, or in the flank may be enlarged. If the history of the herd shows that occasionally an animal lost flesh, yielded a decreased quantity of milk, and gradually pined away until it died or it became necessary to kill it, tuberculosis should be suspected.

In examining the individual animals the object is to learn the condition of the organs most frequently the seat of tubercular disease. As the lungs are affected in from 60 to 75 per cent of the cases, these organs should receive careful attention. With tuberculosis of the lungs the most prominent symptom is a cough; this is persistent, short, dry, strong, and often high in pitch, almost whistling. As the disease advances the cough is more prolonged, violent, convulsive, and may be accompanied by protrusion of the tongue. Auscultation reveals various modified and abnormal sounds in the lungs. There may be friction sounds, the result of disease of the pleura, increased respiratory murmur from bronchial irritation, loss of respiratory murmur from large tubercular deposits or adhesions, mucus râles from the inspired air being drawn through collections of mucus in the air tubes, and whistling sounds from thickening of the walls of the bronchial tubes. Percussion over the chest walls may in some cases show abnormal resonance from the tubercular deposits causing portions of the lungs to recede from the ribs, but in a larger number of cases there are areas of dullness corresponding to tubercular masses. In many cases with severe lesions of the lungs no satisfactory evidence can be obtained by either auscultation or percussion.

The mediastinal glands are situated between the lobes of the lungs and rest upon the esophagus. Very often in tuberculosis they are diseased and enormously enlarged, and in such cases they press upon the esophagus and cause digestive disturbance, more particularly chronic bloating, which may appear regularly soon after eating, no matter what the character or the quantity of the food taken. Habitual bloating, when the food is of good quality and taken in proper amount, and when there is no other evidence of disease of the digestive organs, is considered strongly indicative of tuberculosis with enlargement of these glands.

In tuberculosis of the stomach and intestines digestion is more or less interfered with, the appetite becomes poor or irregular, and there is frequently diarrhea, or diarrhea alternated with constipation. There may also be bloating and colicky pains.

With tuberculosis of the uterus and ovaries, and sometimes with peritoneal tuberculosis, the cow remains almost constantly in heat, but is often sterile. When the postpharyngeal glands are affected there is interference with the breathing, which becomes harsh and loud; there may also be difficulty in swallowing. It is sometimes possible to feel the enlarged glands by placing one hand on each side of the

throat and then pressing with both hands over the region of the throat above the larynx.

In case tubercles form in the brain or spinal cord the symptoms vary somewhat according to the part affected. The first signs are depression, soon followed by stiffness and unsteadiness of the gait. The animal lies down a great deal and rises to its feet with difficulty. As the disease advances there may be cramps of the muscles of the neck and local paralysis, causing difficulty of swallowing. The food is retained a long time in the mouth and is finally dropped into the manger. Sometimes the symptoms are those of acute meningitis, when the animal is nervous, excitable, frenzied, and may have convulsions and coma. Usually the spinal cord and brain are affected at the same time, the effect of disease of the cord being to make locomotion more and more difficult and to bring about paraplegia and paralysis of the posterior extremities.

With tuberculosis of the tongue the lesions may be localized or disseminated throughout the organ. In the former case the tongue preserves its mobility, but on examination a swelling may be detected in some part of it, which is hard and embedded in the tissue. As the tubercular process advances an ulcer forms on the upper surface of the tongue over the swelling, which is covered with a firm yellowish exudate. When the tubercular deposit is diffused through the organ the tongue loses its mobility, becomes hard, and has an appearance similar to the "wooden tongue," which occurs in actinomycosis. The diagnosis is made by a microscopical examination of the affected tissues.

Tubercular inflammation of the stifle joint, and less frequently of other joints, may occur during the progress of the disease. The affected joint is swollen, warm, and very painful. There is great lameness and the animal is hardly able to put its foot to the ground. Such inflammations of the joints in cattle and hogs should lead to the suspicion of tuberculosis.

Sometimes the tuberculous process is localized in the trachea and larynx, and this may occur either in connection with lesions of other organs or independent of them. The respiration is harsh and loud and accompanied by a mucus râle or gurgling sound caused by the accumulation of mucus in the trachea. In such cases there is a frequent and troublesome cough which is easily excited by pulling on the tongue or by slight pressure upon the larynx. The animal stands with the nose raised, the head extended upon the neck, and avoids lateral movements of the head and neck on account of the tenderness of the affected region.

The diagnosis of tuberculosis of the udder is a matter of extreme importance, on account of the danger from infected milk. Great attention has, therefore, been given to this subject by many investigators. A recent and very minute study of mammary tuberculosis has been made by Ostertag, Breidert, Kaesewurm, and Krautstrunk,[36]

and we are now able to speak with some confidence both as to the methods of examination and the symptoms which are usually found. Tuberculosis of the udder is indicated by swelling and hardening of one or more quarters. It usually begins in one of the posterior quarters and takes a chronic course. The swelling causes the teats of one-half of the udder to assume a parallel or converging direction, instead of diverging from one another. A healthy quarter feels soft or moderately firm throughout; in milch cows the normal elastic tissue often contains symmetrical, firm masses of varying size formed by the lobules of the gland. A tuberculous quarter feels irregular from the beginning of the disease. Certain portions, especially toward the back of the udder and over the milk cisterns, are firm, stiff, or as hard as wood. The firm parts form more or less sharply margined lobules, distinct from the normal elastic tissue. The tuberculous swellings increase in circumference, and in time their surface becomes nodulated.

When the udder is distended the tuberculous swellings are often difficult to detect, but in the relaxed condition of the organ after milking this difficulty disappears. The swellings are painless and of the same temperature as their surroundings. The milk of the diseased quarter may remain apparently normal for weeks, but as the tuberculous process extends and destroys the secreting tissue it changes in appearance, becomes thin, flocculent, and finally watery. At this time it often exhibits an alkaline reaction instead of the normal neutral reaction.

In exceptional cases tuberculosis of the udder may commence with acute inflammation, or may for a time assume an acute course. The lymphatic glands of the diseased quarter or half are always swollen. Their condition can most conveniently be examined by thrusting the skin covering the side of the diseased hind quarter upward, toward the flank, with the index, middle, or ring finger, and palpating the posterior and lateral aspects of the glands in question. When diseased, the glands are found to be enlarged in all directions; sometimes their surface is nodulated.

Disease simulating tuberculosis of the udder may be produced by chronic infection with streptococci or with actinomyces. In the chronic inflammation due to streptococci the lymph glands are greatly enlarged but are not nodulated. In actinomycosis of the udder the lymph glands are seldom much enlarged.

The clinical diagnosis of tuberculosis of the udder may be regarded as assured when one quarter of the udder and its attached lymph glands exhibit firm, hard, nodulated swellings without signs of inflammation. When the quarter and attached lymph glands exhibit only firm, hard swellings, without nodulation, the diagnosis is somewhat doubtful. Suspicion, however, will be increased if the milk from the suspected quarter is of apparently normal constitution, or appears, from the history, to have been of normal constitution at the com-

mencement of the disease. The probability of tuberculosis is again increased by the existence of any other clinical indications of the disease, such as (1) general falling off in condition; (2) continued fever without apparent acute disease; (3) painless nodulated swellings of the pharyngeal, prescapular, or precrural lymphatic glands without symptoms of inflammation; (4) frequent, spontaneous, weak cough, and pneumonic râles without apparent acute inflammation; (5) frequently recurring tympanites without apparent cause; (6) frequent œstrum and mucopurulent discharge from the vagina; (7) reaction to the tuberculin test. In rare cases symptoms of tuberculosis of the brain and tuberculosis of the vagina may lend additional weight to the suspicion of tuberculosis of the udder.

Portions of the prescapular and precrural glands may be removed without danger. Removal of portions of the mammary lymph glands is somewhat difficult on account of the deeper position of these parts, but is also without danger. Macroscopic examination of such fragments is often sufficient to reveal the tuberculous nature of the disease.

As a rule, bacteriological examination is indispensable for the conclusive diagnosis of tuberculosis of the udder. Of the various forms of examination undertaken with this object, inoculation of guinea pigs with suspected milk is the most reliable. One cubic centimeter of milk as withdrawn is sufficient. The milk should be injected into the muscular substance of the inner and posterior surface of the hind limb. This is as reliable as intraperitoneal injection, which was formerly the most widely employed, and was regarded by Rabinowitsch as the most conclusive, while it has the advantage of being much speedier. The experimental animal can be killed for further examination as soon as the lymph glands near the point of inoculation appear firm, hard, painless, and enlarged to the size of a small pea. This often occurs within ten days of inoculation; but should the lymphatic glands not become diseased, the experimental animals are killed six weeks after inoculation. The discovery of tubercle bacilli in the enlarged lymph glands or internal organs confirms the diagnosis. Intramuscular injection obviates sources of error due to the pseudotuberculous changes which so often follow intraperitoneal injection of milk accidentally containing acid-fast pseudotubercle bacilli. The entrance of acid-fast bacilli (which, by the way, can usually be recognized as such on account of their shape) can be avoided if, before withdrawing the milk, the udder be washed with soap and water, cleansed with 50 per cent alcohol, and rubbed dry with sterilized wadding. The first 10 c. c. at least of the milk should be thrown away. Finally, the intramuscular method has the great practical advantage over the intraperitoneal that much fewer experimental animals die from intercurrent diseases.

Examination of the milk by means of smear preparations and the bacterioscopic examination of harpooned fragments of the tissue of

the udder are uncertain. Despite the existence of the disease, a considerable number of such tests may fail. This conclusion, at least as regards smear preparations, is in harmony with the reports of Rabinowitsch and Müller. The last method of examination is only conclusive when it yields a positive result. Nevertheless, as stated by Bang and Müller, it is valuable for the rapid diagnosis of advanced tuberculosis of the udder. In certain exceptional cases harpooning of the udder may prove more reliable than inoculation. For bacteriological examination the milk should be passed through a centrifugal separator and the precipitate used.

Harpooning necessitates casting the animal. By carefully disinfecting the skin and using sterilized instruments, the operation is rendered harmless even if repeated several times. The skin and the fascia of the udder are first divided, the suspected portion of the udder grasped with the hand, the harpoon introduced into the supposed diseased part, rotated slightly, and rapidly withdrawn. A small fragment of tissue is sufficient, provided a tubercle can be recognized by macroscopic or microscopic examination. Harpooning may be resorted to when inoculation has failed to confirm an otherwise strong suspicion of tuberculosis, or when the milk has ceased to be secreted and therefore can not be employed.

In advanced cases of tuberculosis of the udder the secretion from the diseased quarter may be virulent even when diluted to the extent of 1 to 1,000,000,000. In incipient tuberculosis of the udder, and sometimes in advanced cases, the number of bacilli is very small and the virulence of the milk can be destroyed by dilution to a greater degree than 1 to 1,000.

In examining nasal, pharyngeal, and vaginal discharges for tubercle bacilli it must be borne in mind that these materials, like the feces, contain acid-fast pseudotubercle bacilli, and, therefore, that in doubtful cases the results must be checked by inoculation experiments.

With hogs the symptoms of tuberculosis brought out by physical examination are usually not clear. The principal symptoms are progressive emaciation and irregular diarrhea, sometimes accompanied by a cough. In most cases the glands of the neck are affected, and frequently their enlargement causes a very apparent swelling of the neck. Very often there is tuberculosis of a joint and consequent lameness. Animals showing these symptoms should be regarded as suspicious.

THE TUBERCULIN TEST.

Tuberculin is a product of the growth of the tubercle bacillus. It is prepared by sterilizing, filtering, and concentrating the liquids in which the tubercle bacillus has been allowed to multiply in the laboratory. This substance was first made and studied by Koch, and it was found that when injected into the tissues of a tuberculous animal it had the effect of causing a decided rise of temperature, while it had no such

effect upon animals free from tuberculosis. The value of tuberculin for revealing the existence of tuberculosis was tested by many investigators during the years 1890 and 1891. The injection of this new drug was at once recognized as a most remarkable and accurate method for the detection of tuberculosis, even in the early stages and while the animal appeared to be in perfect health. Our knowledge of the tuberculin test was built up through the most careful and thorough scientific experimentation and should be accepted as entirely reliable.

In practice the tuberculin test is conducted by first taking the temperature of the animal to be tested, at intervals of about two hours, a sufficient number of times to establish the normal temperature of the body under the ordinary conditions of life. The proper dose of tuberculin is then injected under the skin with a hypodermic syringe. The point of inoculation is not essential, but the side of the neck is usually selected for convenience and because of the thinness of the skin of that region. The injection is preferably made late in the evening, and the temperature is taken every two hours the following day, beginning early in the morning and continuing until late in the evening. De Schweinitz, in 1896, calculated the average temperature of about 1,600 tuberculous cows which were tested with tuberculin, and from this average it appears that in general the rise of temperature begins from five and one-half to six hours after the tuberculin is injected, reaches its greatest height from the sixteenth to the twentieth hour, and then gradually declines, reaching the normal temperature again by the twenty-eighth hour. When a chart is made showing graphically this gradual rise and decline of the animal's temperature after it has been injected with tuberculin, we have what is called the tuberculin curve.

In studying the variations of temperature which followed the injection of tuberculin into healthy and tuberculous cattle it was found that in order to diagnose tuberculosis safely there should be a rise of temperature of not less than 2° F., also that the temperature should at its highest point reach about 104° F. To avoid errors it was found to be important that a full dose of tuberculin should be administered and that a reaction should be considered to have occurred only when the temperature remained elevated for several hours.

Many of the supposed errors of diagnosis made from the tuberculin tests during the first years of its use were due to an insufficient search for the tuberculous lesion in the carcass of the slaughtered animal. Tuberculin proved to be a much more delicate test for the existence of tuberculosis in cattle than was at first appreciated, and it was not until the veterinarians learned that a single small tubercle in an obscure part of the body was enough to cause a reaction that they began making a sufficiently careful search to discover such a lesion in case of its existence. It is now generally admitted that a reaction seldom, if ever,

occurs without there being a tubercle somewhere in the animal's body. The errors of diagnosis arise not with the animals which react, but with the tuberculous animals which fail to show a reaction. Nearly all the animals failing to react although affected with tuberculosis may be grouped in two classes. The first of these classes consists of animals in an advanced stage of the disease and in most of which the disease may be recognized by physical examination. The second class consists of animals which have been injected with tuberculin one or more times and which have become insensible to it.

Tuberculin is of inestimable value for ascertaining whether tuberculosis exists in a herd of cattle at a period when it could not possibly be diagnosed by physical examination. For this purpose it is practically infallible in its indications, since when the disease exists in a herd of any size some of the affected animals are certain to show a reaction. There are very many cases on record where herds supposed by their owners to be free from disease were found by the tuberculin test to be seriously infected. The determination of the fact of the existence of tuberculosis in a herd is of the greatest importance, for it enables the owner to adopt at the earliest moment the measures which are needed for the control and eradication of the contagion. The animals which react to the test are certainly affected, and those in the same herd which fail to react must be regarded as suspicious until they have been kept for several months after the last reacting animal has been removed and have undergone subsequent tests without reacting.

The cows in a tuberculous herd which failed to react to the tuberculin test should be submitted to careful physical examination, and those which are emaciated, or have abnormal sounds in their lungs, or are frequently in heat, or which cough or have digestive disturbances, should be regarded as probably affected. The udder should also be examined with great care, and if hard, painless swellings are found in one or more quarters, and particularly if a hind quarter is affected, the trouble is probably caused by the tuberculosis bacillus. By this careful physical examination the cows in a more or less advanced stage of the disease which fail to react to the tuberculin test may be detected and measures taken to prevent the disease spreading from them.

The second class of cases from which errors are liable to occur—that is, the animals which have been injected with tuberculin until they have lost their sensitiveness to it—are not likely to be found in a herd tested for the first time, unless new animals have recently been purchased. The first test of a herd with tuberculin combined with a physical examination of the individual animals may therefore be accepted as reliable in its indications, not only as to the existence of tuberculosis in the herd, but also as to the healthfulness of the various animals composing the herd.

With newly purchased animals and those about to be taken into the

herd the case is different. A tuberculous animal may have been injected several times for the express purpose of putting it into a condition that will prevent its reacting at the time of sale, or it may have been injected a number of times in the ordinary course of procedure with a tuberculous herd. It is, therefore, unsafe to purchase an animal from a tuberculous herd, even if it fails to react when tested with tuberculin. A single injection with tuberculin may be sufficient to prevent an animal from reacting until a period of five or six months, or longer, has elapsed after the test was made; on the other hand, some animals react to every injection of tuberculin, even when there are but a few weeks' interval.

The results of the test and examination of the extensively diseased herd of the Soldiers' Home, at Washington, by the Bureau of Animal Industry, are of especial interest because of the great care which was exercised to secure accuracy. In this herd 60 animals were tested with tuberculin and all of them were afterwards slaughtered and thoroughly examined. The number of animals in the herd which reacted was 49, and the number which failed to react was 11. There was only 1 animal among those which reacted in which no tuberculous lesions were found. Of the 11 animals which failed to react, however, there were 5 that were found to be diseased. One of these which proved to have extensive tuberculosis had a high temperature (103.6° F.) the day before the test. This high temperature was sufficient reason for considering that the cow was probably tuberculous, and, moreover, the disease had been recognized from the external appearance of the animal and she had already been isolated from the herd. In the four remaining animals which were diseased but failed to react, the lesions were small and could not be detected by physical examination. This is an unusual proportion of such cases. The disease in three of these cows was apparently stationary, as the nodules were small and calcareous. In the fourth cow the lesions were also small, and so far as could be determined were confined to the glands.

In the carefully compiled statistics published by Voges[37] in 1897 it was shown that of 7,327 animals tested, and of which the accuracy of the tests was determined by post-mortem examinations, there were but 204 errors of diagnosis, or 2.78 per cent. Pearson[3] states that in the work of the State live stock sanitary board of Pennsylvania post-mortem examinations were made on about 4,400 cattle which had reacted to the tuberculin test, and that among all these animals there were but 8 in which no lesions of tuberculosis were found. He adds with reference to these that we are not justified in saying that tubercular lesions did not exist, for the reason that every portion of the carcass could not be examined; but it could only be said that they were not found.

That cattle which once react to the tuberculin test may fail to react on subsequent tests is a fact which should be borne in mind. Obser-

vations relative to this behavior of the animal body toward tuberculin have been made by many investigators. Some tests made at the Storrs Experiment Station are interesting examples of the failure of tuberculin under such conditions.

The following table shows the record made at the Storrs station in retesting cows belonging to the herd of the Connecticut Agricultural College:[26]

Failure of tuberculin in case of repeated injections.

Number of animal.	Number of tests previous to first response.	Date of first response.	Date of test after first response.	Date of second test after first response.
1	1	December, 1898	May, 1899 *a*	
3	2	do	do. *b*	
4	1	do	do. *a*	April, 1900. *a*
5	1	do	do. *a*	Do. *b*
6	3	December, 1899	April, 1900 *a*	
7	2	December, 1898	May, 1899 *b*	
8	0	do	do. *a*	Do. *a*
9	1	do	do. *b*	Do. *b*
10	3	December, 1899	April, 1900 *a*	
11	2	May, 1899	November, 1900 *b*	
12	3	April, 1900	do. *b*	
14	1	December, 1898	May, 1899 *a*	
15	3	do	do. *b*	
16	3	do	do. *a*	
17		do	do. *b*	
18	2	do	do. *b*	
Total	28		16 { *b* 8 / *a* 8	4 { *b* 2 / *a* 2

a Failed to react. *b* Reacted.

This table shows that 16 animals reacted, and that all but 2 of these had previously been injected from one to three times. From six months to a year after this first reaction these 16 animals were again injected, when 8 responded and 8 failed to respond. When eleven months more had elapsed 4 of these animals were tested for the second time after their first response, and of these 2 reacted and 2 failed to react. There were, therefore, 10 reactions and 10 failures to react to injections subsequent to the first reaction, or 50 per cent of failures.

Phelps,[24] of the same station, gives the following statement of the repeated testing of 4 tuberculous cows, taken for experimental purposes, during the four years they were kept at the station.

January 26–27, 1897, first tuberculin test (at station), all reacted.
April 26–27, 1897, second tuberculin test Nos. 1341 and 1344 reacted.
July 30–31, 1897, third tuberculin test, none of the cows reacted.
September 27–28, 1897, fourth tuberculin test, none of the cows reacted.
December 17–18, 1897, fifth tuberculin test, No. 1344 reacted.
April 11–12, 1898, sixth tuberculin test, No. 1343 reacted.
December 22–23, 1898, seventh tuberculin test, none of the cows reacted.
June 2–3, 1899, eighth tuberculin test, No. 1343 reacted.
December 1–2, 1899, ninth tuberculin test, No. 1341 reacted.
March 19–20, 1900, tenth tuberculin test, none of the cows reacted.
September 28–29, 1900, eleventh tuberculin test, No. 1341 reacted.

These cows, Nos. 1337, 1341, 1343, and 1344, had been tested before they came to the station by the State cattle commissioners, first in March, 1896, when none of them reacted and they were pronounced healthy, and they probably were free from tuberculosis at that time; and second in October, 1896, when they reacted and were condemned as tuberculous.

It was said by Regnér[21] at the International Veterinary Congress held in Budapest in 1905 that tuberculin is an invaluable and indispensable means for the extirpation of tuberculosis, but he who relies exclusively upon it for differentiating between tuberculous and nontuberculous animals will sooner or later have bitter cause to regret it. Not only tuberculosis permitting of clinical diagnosis, but also cases where tuberculosis is present in a decided but not very high degree, usually not easily to be detected, may with individual animals elude the tuberculin test, and in a relatively short time, under favorable circumstances, commit fearful ravages among the stock found free from reaction. Professor Svenssen, of Stockholm, has also proved by means of a long series of experiments that tuberculin is somewhat uncertain for repeated tests upon animals once found to react. These facts render a clinical and bacterioscopic diagnosis imperatively necessary. Suppressive measures must especially be directed against the lung tuberculosis, which is the most important factor of the dissemination of the pest among the cattle stalls.

Taking into account recent publications on the subject, Eber[38] formulates the following principles for judging the tuberculin reaction with cattle, which are based upon numerous observations of his own relative to the normal body temperature of cattle and its variations:

A. For young cattle up to 6 months old.—With young cattle up to 6 months old, if the temperature before the tuberculin injection is not found to exceed 40° C. (104° F.), all rises in temperature above 40° C. (104° F.) are to be looked upon as reactions, provided that the difference between the highest temperature observed before the injection and the highest observed after it is at least 0.5° C. (0.9° F.).

B. For cattle more than 6 months old.—1. Only such cattle are to be submitted to the tuberculin test as have a temperature not exceeding 39.5° C. (103.1° F.) at the time of the injection.

2. A rise of temperature to 39.5° C. (103.1° F.) after the tuberculin injection is not in any case to be regarded as suspicious.

3. With all cattle having temperatures not exceeding 39.5° C. (103.1° F.) at the time of the tuberculin injection, every rise above 40° C. (104° F.) is to be regarded as a reaction.

4. Further, all rises of temperature above 39.5° C. (103.1° F.) to 40° C. (104° F.) are to be considered reactions, when the total rise compared with the temperature before the injection is at least 1° C. (1.8° F.).

5. All rises of temperature above 39.5° C. (103.1° F.) to 40° C. (104° F.), when the total rise, compared with the temperature before the injection, is less than 1° C. (1.8° F.), should be regarded as doubtful, and the case judged on its merits.

The decision as to which of these cases are to be considered as reactions and which as nonsuspicious is to be made according to the nature of the case. It has been found by experience that important aids to forming a decision are furnished by the total increase compared with the temperature before the injection—which with reacting animals as a rule should be 0.5° C. (0.9° F.) at least—by the character of the temperature curve, and by an exact clinical examination, the necessity for which in doubtful cases is again emphasized.

6. For all those cases in which the tuberculin test is simply to serve as a means of ascertaining the dissemination of tuberculosis in a stock of cattle, with the object of separating the suspected animals from those which are not suspected, so as to carry on the suppression of tuberculosis, it is sufficient, according to Ostertag, to regard all those cattle as suspected the interior body temperature of which exceeds 39.5° C. (103.1° F.) after injection of the prescribed quantity of tuberculin—that being an increase of at least 0.5° C. (0.9° F.) above the highest temperature observed before the injection.

It has often been alleged, generally by persons who have had no great amount of experience in its use, that tuberculin has an injurious effect upon the animals into which it is injected. This is contrary to the almost unanimous opinion of the scientific men who have studied its effects and who have had most experience in testing cattle with it. Tuberculin has little or no effect upon healthy cattle and its action upon tuberculous cattle is not serious. The writer has elsewhere ([29]) collected the opinions of many experts upon this subject and would refer to that article for details which can not be given here.

A careful study of a great mass of literature on the subject has led to the conclusions which follow:

1. The tuberculin test for tuberculosis is wonderfully accurate in its results, and if an animal responds it is certainly affected with the disease.

2. The reaction to tuberculin is no indication of the extent of the disease in the reacting animal, and there is frequently a greater reaction in an animal with slight lesions than in another in which the disease is very much more advanced.

3. A small percentage of the cattle affected with tuberculosis fail for some reason to react to the tuberculin test.

4. Tuberculin in the doses used for making the test has no injurious effect upon healthy cattle; if it has any effect at all it slightly increases their power to resist the tuberculosis infection.

5. The effect of tuberculin upon cattle already suffering from tuberculosis is to cause a temporary fever with an increase of temperature of from 2° to 7° F., which usually lasts not longer than twenty-four hours. It is doubtful if tuberculin in this dose ever aggravates the tuberculous process in cattle, and there is some evidence that it may have a favorable effect.

Tuberculin is not much used as a test for tuberculosis in the smaller animals, such as swine,[a] sheep, and poultry, because the normal variation of temperature in these animals is so great that it is difficult to arrive at any accurate conclusions as to whether a reaction has occurred.

EXAMINATION OF THE CARCASS.

The carcasses of all animals which die or are slaughtered from a herd should be carefully examined to determine whether they are affected with tuberculosis. This is an important means of learning as to the existence of the disease, and may give an early warning when its presence has not been suspected. The examination of carcasses is especially necessary with swine, since the tuberculin test is not generally used and is rather unsatisfactory with these animals. An examination

[a] Experiments recently made by the Bureau of Animal Industry in testing hogs with tuberculin indicate that the application of the test to these animals is practicable, and that the results are as reliable as with cattle, provided the hogs are kept very quiet for some time before and throughout the test.

of the carcasses of all animals from a herd is an easy and accurate way of keeping informed as to the condition of health of that herd, and particularly as to the existence of any form of infection, or of any injurious parasites.

The examination of a carcass for tuberculosis must not stop with an inspection of the lungs. The bronchial and mediastinal lymphatic glands, which lie near the entrance of the bronchi into the lungs and along the course of the esophagus between the lungs, are more frequently affected than the lungs themselves. Of primary importance with swine are the glands of the neck, which are affected in a large proportion of the cases. In cattle the retropharyngeal, mesenteric, and portal glands should certainly be examined, as well as the liver, kidneys, and spleen. If the examination is made by a veterinarian, all of the accessible organs should be inspected. The yellowish nodules are easily seen in the principal organs of the body, and are also unmistakable in the lymphatic glands if these bodies are opened with the knife. Any farmer or dairyman should with a little practice be able to recognize tubercular lesions in most cases, or should at least be able to tell if there is anything having the general appearance of tuberculosis, and in case of doubt the affected organ may be saved and taken to a veterinarian for an expert opinion.

IMMUNIZATION OF CATTLE AGAINST TUBERCULOSIS.

The immunization of cattle against tuberculosis is a subject upon which investigators have been working for a number of years, with results that have inspired the hope that we shall have in the near future an additional means of combating the disease, and one that will greatly strengthen our present resources. The papers which have recently been published on this method of prevention, together with the discussions at the International Veterinary Congress held in Budapest in 1905, show that the ablest veterinarians in the world are confidently expecting that a practical and safe plan of procedure will soon be developed. If this expectation is fulfilled the operations against tuberculosis will not only be materially simplified, but the expense involved in the eradication of the disease and the loss falling upon the individual owners will be vastly reduced.

A method of prevention which promises so much is deserving of very careful consideration, even at this early stage of its development, for undoubtedly we shall soon be called upon to pass judgment as to its practicability. If it can be safely applied and is effective, it should be adopted and utilized as soon as it is perfected; but if, on the other hand, it is neither safe nor a satisfactory preventive, these facts should be made known as soon as possible. The value of the method can only be estimated when we have some knowledge of the investigations which have led up to it, and when we fully understand and appreciate the dangers which must be avoided.

EARLY EXPERIMENTS.

As long ago as 1889 Daremberg[41] made experiments with a view to the production of immunity from tuberculosis by inoculating guinea pigs and rabbits with sterilized cultures of the tubercle bacillus. The guinea pigs died and the rabbits were made sick; but some of the rabbits after recovery and upon inoculation with virulent tuberculosis germs showed considerable resistance to the disease, as compared with similar animals which had not received the preventive treatment. This investigator also made experiments to test the effect of small doses of virus, and in one series of experiments he used medullas as a vaccinating material. His results, in some respects, were very striking, and appear to have made a profound impression upon him, for his paper which gave an account of the investigations was concluded with these words:

> From all these facts it follows that tuberculous virus is a poison which can be treated in a like manner with mineral or organic poisons. Its toxicity may be increased or diminished almost at will. On the other hand, one may augment the resistance of the organism against its disorganizing action. And I firmly believe that the day will come when in this gamut of diverse virulences will be found the correct note which will transform the virus into vaccine, which will fix with precision the attenuation infallibly conferring immunity.

At the time this was written it seemed that the author was too sanguine and there were few who believed it possible to vaccinate successfully against a disease which ran so slow a course and which was fatal in so large a proportion of cases. If immunity were developed in the animal body by the multiplication of the tuberculosis germs, why did not this immunity show itself during the progress of the naturally acquired disease, thus making it a disease of limited duration, ending in recovery? It appeared incredible that a bacillus which in so many cases advances slowly and insidiously from one part of the animal body to another, often consuming years in its development to a degree where the life of the animal is destroyed, should by its normal biological processes confer a power of resistance upon the tissues of that animal body which would be effective against itself.

In the same year Grancher and Martin[42] made public the results of a series of researches of great interest in this connection because they demonstrated that at that early date they had discovered a reliable method of attenuating the tubercle bacillus. These authors say that they had applied themselves to the task of obtaining graduated virulences, even to the loss of virulence in the bacillus, and although the scale was in nowise mathematical it was sufficient to be utilized in about the same manner as were the dried marrows used in the method of Pasteur for the treatment of rabies. They designated under the name of virulence No. 1 the most virulent cultures in their series, which killed rabbits by intravenous injection in fifteen days or one month. Virulences Nos. 2, 3, 4, 5, 6, 7, 8, 9, and 10 were successively

decreasing. The cultures from No. 10 to No. 7, inclusive, resown in the culture apparatus, no longer developed, and were without effect upon rabbits. Virulences Nos. 2 and 3 were fatal, but at varying periods according to the resistance of the animal. They believed that they had succeeded in giving to rabbits the power of a prolonged resistance against the most rapid and the most certain experimental tuberculosis, and that they had also succeeded in conferring upon these animals an immunity against this same disease, the duration of which remained to be determined.

Late in the year 1890 Trudeau[43] contributed a paper to the Medical Record in which he gave details of two series of experiments made with a view of obtaining immunity. In the first series preventive inoculation with the nonliving chemical products of the life processes of the tubercle bacillus failed to afford any protection against subsequent infection with virulent living tubercle bacilli. In the second series preventive inoculation with an attenuated living germ, which was capable of producing in most cases only an indolent and localized tubercular process at the site of injection, failed to protect against subsequent inoculation with virulent tubercle bacilli.

In May, 1894, Trudeau[44] read a paper before the Association of American Physicians on the production of immunity with avian bacilli. He concluded that rabbits which survived the subcutaneous inoculation of living cultures of the avian tubercle bacillus of gradually increasing virulence and in graded doses undoubtedly acquired a certain degree of immunity against subsequent eye inoculation with the mammalian cultures, which immunity had in some animals under his observation persisted for over a year without the slightest evidence of a relapse. He also found that while the rabbit, which is very much more susceptible to the avian than to the mammalian bacillus, may acquire a certain degree of immunity against the latter by preventive inoculations of the former, the guinea pig, which can rarely and with great difficulty be killed by the avian microbe, is in no way protected by this treatment.

In December, 1894, De Schweinitz[45] published an article entitled "The Attenuated Bacillus Tuberculosis; Its Use in Producing Immunity to Tuberculosis in Guinea Pigs." In this article he gave the results of certain observations and experiments made by him in his work for the Bureau of Animal Industry, which were, briefly, as follows:

It was noticed by him that a strain of tubercle bacilli which had been grown on glycerin agar and in glycerin beef broth for fourteen generations no longer destroyed guinea pigs as readily as it had previously done. In the case of the fourteenth generation it required six months before the disease developed. He consequently inoculated a number of guinea pigs with the seventeenth, eighteenth, nineteenth, and twentieth generations of this germ. After some months the guinea pigs that had been inoculated with the attenuated germ remained quite well, and one which was chloroformed proved on examination to be free from disease. In order to test the immunity of these animals 4 guinea pigs which had been inoculated with the attenuated germ and 4 check guinea pigs which had received no treatment were all inoculated with material obtained from a tubercular cow which had just been killed.

After seven weeks the checks were all found dead from tuberculosis, while the treated animals all appeared perfectly well. One of these was then chloroformed and carefully examined, but no trace of the disease could be detected. Even the local lesion that was produced where the material had been injected had entirely healed. He fed these attenuated bacilli to a calf and injected them intravenously into a cow without any disease being produced.

He concluded from these experiments that "our attenuated germ may possibly prove very valuable in checking or controlling tuberculosis in animals, especially cattle."

The investigation of this attenuated tuberculosis bacillus was continued by De Schweinitz and Schroeder,[46] who in 1896 stated that their experiments showed conclusively that from an originally virulent germ they had succeeded in obtaining an attenuated germ which even in large doses was apparently harmless to guinea pigs, rabbits, cattle, horses, and monkeys. They had inoculated cows and calves with this germ in doses varying from 2 c. c. to 500 c. c. at a time without the production of tuberculosis.

The history of one of the animals in the experiments of De Schweinitz and Schroeder[47] is very interesting, since it clearly indicates the possibility of immunizing cattle against tuberculosis.

A cow which had been previously tested with tuberculin received on July 26, 1894, an intravenous injection of 16 c. c. of an attenuated culture of the human tubercle bacillus. Tested November 19, no reaction to tuberculin was noted. On November 28, 6 c. c. of an attenuated culture was injected into the abdominal cavity. The injections were repeated at various times, the animal being kept in the experiment for twenty-eight months and receiving altogether 20,870 c. c. of culture, of which as large an amount as 2,000 c. c. was given at one time. On February 22, 1898, this animal received an injection of virulent material taken from a cow affected with generalized tuberculosis. The injection was made into the thoracic cavity. The cow thus treated was killed September 20, 1898, and a careful autopsy, made by Doctor Schroeder, failed to disclose the slightest evidence of tuberculosis.

These experiments of De Schweinitz and Schroeder are in the nature of pioneer work for the immunization of cattle against tuberculosis. It is evident that they succeeded in obtaining attenuated tubercle bacilli which could be inoculated into guinea pigs and cattle without producing any disease. It is also evident that they produced immunity in guinea pigs by inoculating them with this attenuated material, since four of these pigs resisted perfectly inoculation with virulent bovine bacilli which killed all the checks in seven weeks. And, finally, it seems evident that they produced immunity in a cow, since this animal was able to resist an intrathoracic injection of active bovine tuberculosis virus; and not only did she show no symptoms of disease while living, but a careful post-mortem examination failed to reveal the slightest lesion of the disease at the point of inoculation or elsewhere.

M'FADYEAN'S EXPERIMENTS.

McFadyean[48] published some interesting experiments in 1901 which seemed to show that the animals used in his experiments had acquired a high degree of immunity.

The first animal was a yearling heifer which received 9 doses of tuberculin of 1 c. c. each, with intervals of three to eleven days. It was then given 3 doses of 10 c. c. each, and following this 6 doses of 20 c. c. each. Thirteen days after the last

dose of tuberculin was given this animal received an intravenous injection of 2 c. c. of a liquid very rich in tubercle bacilli, prepared by rubbing up some caseopurulent matter from the mesenteric gland of a horse with sterile water. On the same day (February 6, 1900) two other animals of about the same size and age were infected in the same way with a like quantity of the same material. These two animals, which may be regarded as checks, subsequently became ill, and when they were killed on the 10th of April their lungs were found to contain numerous tubercles, while the bronchial and mediastinal lymphatic glands were greatly enlarged and caseating. The first animal mentioned had reacted to the first, second, fourth, and sixth doses of tuberculin, and then failed to respond even to the large doses until after it received the infecting material, when it responded twice to doses of 1 c. c. Later it was treated with tuberculin in doses varying from 5 c. c. to 20 c. c. without any important rise of temperature occurring.

On May 22, 1900, this animal was killed, and a most searching post-mortem examination revealed no lesion anywhere except in one mesenteric gland, which contained a completely calcified tubercle about the size of a pea. The assumption was that this lesion had been in active condition when the animal was first tested, and that it was accountable for the reactions then obtained. It would appear that the experimenter was more or less justified in concluding that this animal had latterly a very high degree of immunity against tuberculosis.

The second animal was a heifer about 1½ years old. This heifer was tested with tuberculin on October 9 and 12 and November 27, 1899, and January 8, 1900, reacting each time. The dose of tuberculin was 1 c. c. on each occasion. On January 11 the animal received by intravenous injection 1½ c. c. of a liquid rich in bovine tubercle bacilli, and another heifer was inoculated in the same manner as a control animal. The control animal was killed on March 2, 1900, when it was very ill, and the post-mortem examination revealed a dense miliary tuberculosis of the lungs. The experimental heifer was treated with tuberculin as follows: January 15, 17, 21, and 24, and March 8, 20 c. c.; March 15, 10 c. c., and March 28, 20 c. c., without any distinct reaction occurring. April 5, 1900, this animal was again inoculated intravenously with 2 c. c. of a liquid obtained by triturating a portion of the fresh lung of a rabbit, which was dead as the result of inoculation with bovine tuberculosis, with sterile water. This inoculation did not occasion any recognizable disturbance, but the heifer reacted when tested with an ordinary dose of tuberculin June 13, July 18, and October 16. The test was repeated November 20, with an indecisive rise of temperature. November 28 a third intravenous injection of tubercle bacilli was made. The dose was 2 c. c. of a liquid obtained by triturating the tubercular material from the spleen of a horse with sterile water. The animal was tested with tuberculin December 19 and January 22 following, and reacted each time. January 30, 1901, the animal was inoculated for the fourth time intravenously with 5 c. c. of a rich emulsion of tubercle bacilli from an artificial culture (origin not given). On the day following the injection the temperature had risen to 104.2° F. and remained at about that point until February 4. Tested May 15, it did not respond. May 18, a fifth intravenous inoculation with tubercle bacilli was made. The dose was 5 c. c. of a rich emulsion of artificial culture (origin not given). The same day the heifer's temperature rose to 105.6° F., but it gradually fell and was normal May 21. On June 18, 1901, the animal did not respond to an ordinary dose of tuberculin. At the time of reporting, the animal appeared to be in perfect health and its general condition was good.

The third animal was a heifer about a year old at the time the experiment began. It was tested with tuberculin May 5, 1899, without reacting, and was inoculated intravenously May 10 with 2½ c. c. of an emulsion made from the tuberculous liver of a pheasant which had contracted the disease naturally. Between May 11 and October 26 the animal was tested with tuberculin nineteen times, reacting to the third, fourth, fifth, sixth, seventh, and eighth tests. November 11 the animal was inoculated intravenously with 2½ c. c. of liquid containing tubercle bacilli from the liver of a rabbit which had died after being inoculated with tubercular material from a horse. Between November 21 and January 8 she was tested five times with tuberculin without reacting. On January 11, 1900, the animal received the third intravenous inoculation with tubercle bacilli, the dose being 1½ c. c. of liquid containing bovine bacilli. As in the previous cases, the injection caused no obvious disturbance of the health. April 5 a fourth intravenous injection was given, the material being a suspension of bovine bacilli and the dose 3 c. c. No symptoms of illness followed the operation, but the animal reacted to some of the subsequent tests with tuberculin. On November 28, 1900, the heifer was inoculated intravenously for the fifth time, receiving 2 c. c. of liquid containing bacilli from the spleen of a horse. In the tests following this inoculation no rise of temperature occurred. January 30, 1901, it was inoculated intravenously, this time with 5 c. c. of emulsion from an artificial culture.

On March 23, 1901, the heifer was inoculated intravenously with 15 c. c. and on May 18 with 5 c. c. of an emulsion of a culture of tubercle bacilli. At the time of reporting, the general condition of the animal was fair and it appeared to be in good health.

The fourth animal was a Shorthorn cow about 4 years old. It was tested with tuberculin and failed to react. September 29, 1898, it was inoculated intravenously with 4 c. c. of a suspension of tubercle bacilli from the liver of a fowl. Following this inoculation the cow reacted to the tuberculin test. She was afterwards reinoculated intravenously with tubercle bacilli as follows: November 11, 1899, 4 c. c. of liquid containing tubercle bacilli from a horse; April 5, 1900, 3 c. c. of a suspension of bovine bacilli; March 23, 1901, 15 c. c., and May 18, 1901, 5 c. c. of an emulsion of a culture of tubercle bacilli. At the time of reporting, this animal was very fat, appeared to be in perfect health, and did not react to tuberculin.

The report which has just been summarized carries the experiment up to about July 1, 1901. At that time the condition of the three animals remaining alive was such as to lead to the conclusion that they had entirely resisted the inoculations with virulent tubercle bacilli and that they were consequently immune to the disease. The danger of reaching any conclusion in such cases in the absence of a post-mortem examination is strikingly illustrated by the subsequent history of these animals, for, although two of them appeared to be in "perfect health" and the third in "good health," all three of them died of tuberculosis within eight months from the time the report was made. Notwithstanding this unfavorable termination of the experiment, its history is instructive in many respects, and particularly in showing the difficulty of immunizing animals against tuberculosis. It is one of the failures which should be considered not less than the successes.

The first of these animals was given a sixth inoculation July 31. The material employed was an artificial culture of tubercle bacilli rubbed up with sterile water so as to form a turbid liquid. It was given a seventh inoculation October 24 of 10 c. c. of a liquid rich in tubercle bacilli made with the surface growth of a culture. December 16 the animal as usual appeared to be quite well, but in the early morning of the 17th it was found down in its loose box and it died almost immediately. The post-mortem examination showed widely distributed lesions affecting the lungs, pleura, kidneys, omentum, pia mater, and numerous glands.

The second animal received a ninth inoculation July 21, 1901, of 5 c. c. of a rich emulsion of tubercle bacilli from an artificial culture. A tenth inoculation was made October 5 of the surface growth of a culture rubbed up with sterile water, the quantity injected being 10 c. c. October 24 it was inoculated intravenously for the eleventh time, the dose being 10 c. c. of emulsion of tubercle bacilli from an artificial culture. This animal died suddenly and quite unexpectedly December 23, 1901. Post-mortem examination showed tubercles in the lungs, bronchial and mediastinal glands, kidneys, and pia mater.

The third animal received its sixth inoculation July 31 of 5 c. c. of the liquid used on that date for the preceding two cases, and the seventh inoculation October 5, which was also the same as was given to the other animals. An eighth inoculation was given January 22, 1902, of 4 c. c. of a liquid made by rubbing up a quantity of caseous material from the spleen of a horse with sterile water. On the morning of February 10 it was found that the cow was unable to rise, and the following morning, as death appeared to be imminent, she was destroyed by chloroform. The post-mortem examination showed tuberculosis of the kidneys, bronchial and mediastinal glands, lungs, pleura, tongue, and medulla oblongata.[49]

WORK OF PEARSON AND GILLILAND.

Important experiments were published by Pearson and Gilliland[50] in 1902. One of these experiments was conducted to determine the immunizing effect upon cattle of Koch's original tuberculin.

In this experiment 4 cows were used. Two of these cows were given daily injections of 5 c. c. of concentrated tuberculin for ten days from August 24 to September 2, 1901. All of the 4 cows were fed daily 100 grams of hacked tuberculous lung tissue from a cow for ten days from September 10 to September 19. The 2 cows that had received the preliminary treatment with tuberculin were each given 15 c. c. of concentrated tuberculin while they were being fed upon the tuberculous material.

One of the cows that had been treated with tuberculin and one of those that had not been so treated were killed November 25, 1901. The cow that had been treated with tuberculin showed lesions of tuberculosis in the postpharyngeal and mesenteric lymphatic glands. The control cow had lesions in the right lung and in the postpharyngeal, intermaxillary, bronchial, mediastinal, and mesenteric lymphatic glands. The lesions in this control cow were more widely distributed and more advanced than in the cow that had received large quantities of tuberculin.

The remaining 2 cows of the experiment were killed December 16, 1901. In the first of these cows which had received the injections of tuberculin no lesions of tuberculosis were found excepting in the mesenteric lymphatic glands. A few of these glands of both the small and large intestine showed small areas of caseation. The second, or control, cow showed lesions of tuberculosis in both lungs, in the bronchial, mediastinal, and postpharyngeal lymphatic glands, and in the lymphatic glands of the mesentery, the last-mentioned glands being more extensively involved than were those in the cow which had received the treatment with tuberculin.

The conclusion from this experiment was that the administration of the tuberculin had had some effect in increasing the resistance of these 2 cows to infection from feeding tuberculous material.

The next series of experiments reported was made to throw some light upon the question as to the quantity of culture of tubercle bacilli derived from human sputum which might be administered and the effect of repeated inoculations made in four different ways, it having been already determined that such cultures were usually comparatively nonvirulent for cattle. In these experiments there was used a standard suspension of tubercle bacilli in water, made in such proportions as to give an opacity equal to that of a 24-hour culture of typhoid bacilli in bouillon, and 1 c. c. of such a culture was estimated to contain the equivalent of 0.0013 gram of tubercle bacilli dried ten days in a desiccating chamber over calcium chloride.

The first animal treated was a Jersey heifer, shown by the tuberculin test to be free from tuberculosis. The inoculations of this animal were as follows:

September 29, 1900, 4 c. c. intraperitoneally; March 15, 1901, 13.5 c. c. intravenously; June 1, 1901, 10 c. c. intravenously; August 23, 1901, 20 c. c. (5 c. c. beneath the skin, 5 c. c. into the peritoneal cavity, 5 c. c. into the jugular vein, and 5 c. c. into the lung). These injections were repeated with intervals of seven to ten days until January 29, 1902, the dose being increased 10 c. c. with each successive inoculation, so that at the last, the eighteenth, the total quantity given was 160 c. c.

The total quantity of standard suspension of human tubercle bacilli administered to this heifer was 1,797 c. c. There was a rise of temperature of from 2° to 4° following each inoculation after the first one. The first inoculation caused no temperature reaction. The animal was in strong, thrifty condition at the completion of the series of inoculations, and continued to improve until it was killed, August 14, 1902. It was found free from tuberculosis.

The second animal treated was a grade Shorthorn bull, which did not react to tuberculin. This animal was inoculated as follows:

November 19, 1900, 16 c. c. intraperitoneally; March 17, 1901, 13.5 c. c. intravenously. Subsequent inoculations were the same as with the preceding animal, 18 being given between August 23, 1901, and January 10, 1902, the total amount being 1,710 c. c.

This animal reacted very much as the heifer, although somewhat more slowly. He remained in good condition and apparent good health. On January 18, 1902, this bull was inoculated intraperitoneally with 10 c. c. of a standard suspension of bovine tubercle bacilli. This culture had been tested and found to be fatal for cattle in doses of 5 c. c. intravenously or intraperitoneally within three to eight weeks. The bull remained in good condition until killed for examination August 13, 1902. The lungs were found to contain a few nodules about one-half inch in diameter, surrounded by thick walls and containing caseous pus in which were many tubercle bacilli. These nodules did not seem to be progressive, and appeared to be abscesses indicating the sites of previous inoculations. The lymphatic glands about the rectum were enlarged and caseous. The pleura and peritoneum were covered with a layer of partly organized fibrin.

It was thought that the results of the experiments with these two animals showed that the sputum tubercle bacilli, even in the very large quantities in which they were employed, were incapable of causing general tubercular infection, and that the

experiment with the latter (the bull) indicated that by treatment with such material the resistance to virulent bovine bacilli may be increased.

A further experiment, to test the immunizing value of repeated intravenous inoculations of sputum cultures of tubercle bacilli not virulent for cattle, was inaugurated in March, 1902. Four young cattle were used in this experiment, which were divided into two groups as nearly equal as possible in respect to age, size, and general condition. The animals of one group were inoculated intravenously seven times between March 24 and June 2 with gradually increasing quantities of from 10 c. c. to 25 c. c. of standard suspension of tubercle bacilli. In all 125 c. c. were administered, representing about 0.16 gram of tubercle bacilli.

Each of the four animals—the two that had been vaccinated and the two kept as controls—was inoculated July 29 by injecting into the trachea 10 c. c. of a standard suspension of bovine tubercle bacilli known to be virulent for cattle.

One of the vaccinated cattle was killed October 4 and a searching post-mortem examination revealed all of the organs to be free from all evidence of tubercular disease.

A control animal killed October 8 showed the following lesions: Beneath the skin at the point of inoculation there was a globular abscess three-quarters of an inch in diameter, containing cheesy pus. The lungs were studded upon the surface and upon cross section with grayish tubercles one-fourth to one-half inch in diameter, the centers of which were caseous. The apex of the right lung contained a caseous area 2 inches in diameter. The postpharyngeal, bronchial, and mediastinal lymphatic glands were enlarged and contained cheesy areas.

The second vaccinated animal was killed October 16, and all of the organs of the body were found free from disease with the exception of two globular swellings one-fourth to three-fifths of an inch in diameter, respectively, at the point of inoculation. One of these was made up of fibrous tissue and the other contained a focus of caseous material surrounded by thick, fibrous walls.

The second control (unvaccinated) heifer was killed October 16, and presented the following lesions: Beneath the skin at the point of inoculation was an abscess 2 inches in diameter that contained cheesy pus. All of the inferior cervical and suprasternal lymph glands, as well as the postpharyngeal, mediastinal, bronchial, and many of the mesenteric lymphatic glands were greatly enlarged and contained much caseous material. The mucous membrane of the trachea was, on its ventral half, thickly studded with oblong, red, and evidently young and progressive tubercular growths. The lungs contained many tubercles evenly distributed throughout their tissue and averaging 4 to 5 inches apart, the smaller of which were gray, while the larger had yellow, cheesy centers.

VON BEHRING'S INVESTIGATIONS.

A long series of investigations relative to the production of immunity in cattle has been made by Von Behring,[51] whose first paper on the subject was published in December, 1901. His method has been modified from time to time, but he has no doubt succeeded in producing a high degree of immunity in some of his experimental animals. His work has been of much value in showing the effect of different doses of human tubercle bacilli when inoculated upon cattle, as well as in directing attention to immunization as a practical means of combating tuberculosis in cattle. As the result of experiments with several hundred young cattle, he states that one of his weaker cultures in doses of one-tenth of a milligram injected intravenously does not produce the slightest effect upon the animal either as to its appearance or temperature. Infection with 1 milligram of this culture causes a slight rise of temperature, not exceeding 1° C., which as a rule is followed by a return to the normal temperature after two or three days. Doses of 1 centigram and larger amounts cause very threatening symptoms, but with the largest doses used the disease developed was not so great but that the animals made a complete recovery. The

post-mortem examination of an animal which had received an intravenous injection of 2 centigrams of this culture showed that no points of disease remained in the body.

The method first recommended for protecting animals in practical operations was to take cattle from 5 to 7 months of age that did not react to the tuberculin test and to give by intravenous injection, as the first dose, 1 milligram of a serum culture 4 to 6 weeks old. Four weeks later the animal was given in like manner a dose of 25 milligrams of the same culture. In his later papers Von Behring recommends the use of this same culture after it has been dried in a vacuum at a low temperature. In order to immunize cattle this is suspended in 1 per cent salt solution and given by intravenous injection. The first dose is 4 milligrams, and the second dose, which is to be given at the earliest twelve weeks after the first dose, is 2 centigrams.

The inoculation material, or "vaccine," is furnished in the dry powdered form, and is supposed to remain active for at least four weeks. The powder is of course made up of an enormous number of human tubercle bacilli, which are so minute and light that they are liable to be taken up by slight currents of air, and unless suitable precautions are taken they may be breathed by the persons present at the time they are examined or when they are being prepared for use in immunizing cattle. This form of vaccine is therefore considered objectionable and unsafe by some authorities, and the preference is given to immunizing material which is prepared in the laboratory in liquid form.

The cattle immunized by the Von Behring method appear to acquire a considerable degree of immunity, but some of them certainly have not had sufficient to enable them to resist fatal doses of the bovine tubercle bacillus. It is believed by Von Behring that immunization by this method will protect cattle against natural infection when they are exposed in stables to diseased cattle; but, unfortunately, some of the cattle reported upon as tested were not immunized by the latest process which he recommends, and consequently do not furnish an indication as to its value. Further experiments will be required to establish the efficacy of Von Behring's method, and particularly to determine the length of time that the dried tubercle bacilli will retain their activity under the different conditions to which they are likely to be exposed.

To protect the operator from the danger of manipulating bacilli used for the preparation of the vaccinal emulsion, and to render this as homogeneous as possible, Vallée and Panisset [52] recommend the following plan of procedure:

Grind the dried bacilli with 2 or 3 drops of glycerin in a short-necked Wurtz matrass, using glass balls, then emulsionize progressively in the desired quantity (2 c. c. for 4 milligrams of bacilli) of physiological serum having 8 per 1,000 of chloride of sodium to which is added 1½ grams per 1,000 of carbonate of sodium. The addition of this salt favors the homogeneousness of the emulsion and has no injurious effect upon the animals or upon the vaccine.

In November, 1902, Doctor Von Behring sent 2 bovine animals protected by his method from Marburg to the university at Leipzig for the purpose of being tested as to their degree of resistance against artificial infection with bovine tuberculous material. The tests were carried on during the autumn of 1904.

No. 1 had received intravenous injections of bovine tubercle bacilli, the activity of which had been diminished by treatment with trichloride of iodine, followed by intravenous injections of bovine tubercle bacilli dried in vacuo, and an injection into the anterior chamber of the eye of virulent human tubercle bacilli. The eye became tuberculous and was removed by operation. Finally the animal was subjected to a series of six injections with increasing quantities of fresh human tubercle bacilli.

No. 2 had previously been injected with dead human tubercle bacilli cultivated in the rat and with fresh human tubercle bacilli. Following this it had received an intravenous injection of fresh bovine tubercle bacilli, and finally it had been twice inoculated intravenously with avian tubercle bacilli dried in vacuo.

Both animals were gradually infected, subcutaneously and intravenously, with bovine tubercle material, 6 other tubercle-free young cattle being employed as controls. Two other young cattle were utilized for the purpose of controlling the method of feeding and the general hygienic conditions.

The general conclusion arrived at was that the animals treated by the Marburg method showed a greater degree of resistance against artificial, subcutaneous, and intravenous infection with bovine tubercle virus than those not treated. The grounds for this conclusion were:

1. The absence of any local change at the point of inoculation when infected with slightly virulent material, which in control No. 6 produced tuberculous infiltration at the point of inoculation and tuberculous enlargement and caseation of the neighboring lymph glands.

2. The very trifling changes at the point of inoculation and the absence of any tuberculous change whatever in the local lymph glands in No. 1 when subcutaneously inoculated with very virulent material, which caused in control No. 13 extensive infiltration and ulceration at the point of inoculation, extensive swelling and caseation of the neighboring lymph glands, and embolic tuberculosis of the lungs, liver, and spleen.

3. The absence of any kind of tuberculous change in neighboring lymph glands even in cases where subcutaneous injection of very virulent material led to the formation of a caseous tuberculous abscess at the point of inoculation and isolated embolic tubercles in the kidneys (No. 2).

In control No. 14 the subcutaneous injection of similar material produced extensive tuberculous infiltration at the point of inoculation, extensive tuberculous swelling and caseation of neighboring lymph glands, and embolic tuberculosis of the lungs and spleen.

4. When virulent tubercle bacilli were injected into the veins the increased resistance was principally shown by the trifling degree of general disturbance produced and by the speedy and substantial improvement in the condition of the protected animal, which continued to live for five months and three weeks longer. The animal was eventually slaughtered on account of acute brain disease, probably of tuberculous origin. Controls Nos. 21 and 22, injected with a similar amount of virulent material, died in twenty-eight and thirty-eight days, respectively.

The protected animals were by no means absolutely proof against the disease. When the quantity administered was sufficient both animals suffered from tuberculous infection.

The tuberculin test is unreliable in cattle previously treated with attenuated bovine or human tubercle bacilli unless a long period (not less than six months) has elapsed since the last infectious material was injected. The protected animals did not react to tuberculin even when they were suffering from tuberculous changes both at the point of inoculation and in their internal organs. As neither of the protected animals was immunized by the double inoculation method with weakened human tubercle bacilli according to Von Behring's present method, the foregoing conclusions must not be applied to this method.

Eber[53] considers the results so far obtained from this and other experiments as very encouraging.

EXPERIMENTS BY HUTYRA.

Some important experiments were made by Hutyra,[54] under commission of the Hungarian department of agriculture, in order to determine to what extent vaccination according to Von Behring's method increases the immunity of cattle against artificial infection with virulent bovine tubercle bacilli.

Two calves 9 months old were treated with Von Behring's vaccine. The first dose was 0.004 gram, and forty days later a second dose of 0.01 gram was administered. Two months after the second vaccination both of these animals, together with 2 control animals of the same breed, received an intravenous inoculation of 0.02 gram of virulent bovine bacilli. Two weeks after this infection the control animals were very sick, and one was killed at the end of four weeks and the other at the end of six weeks from the inoculation, both being in a dying condition. The examination showed with both animals an extensive miliary tuberculosis of the lungs and pectoral lymph glands. The vaccinated animals quickly recovered from the reaction following the infection, but had some fever afterwards, though their weight increased and they presented no other symptoms of disease. They were killed two and one-half months after infection, and examination showed in both cases slight tuberculosis in isolated parts of the lungs and in the pectoral lymphatic glands.

An animal of the same breed and age as those in the experiment just reported was likewise twice vaccinated. Two months after the second vaccination this animal and a control animal were given a subcutaneous injection of 0.02 gram of a culture of virulent bovine bacilli. The effect with the two animals was much the same, only there developed at the point of inoculation in the control animal a much larger swelling than with the vaccinated animal. The animals were killed two and one-half months later, and there was found in the vaccinated animal only a caseous spot the size of a bean at the point of inoculation, with enlargement of the corresponding prescapular lymph glands, while with the control animal there was not only an extensive lesion at the point of inoculation, but there were tubercles in the lungs, spleen, and kidneys, and the beginning of pearl disease on the pleura.

In another experiment 4 young cattle from 9 to 12 months old were twice vaccinated with Von Behring's material with an interval of forty days. After two months had elapsed these animals with two controls were fed with cultures of virulent bovine bacilli, which had no apparent effect upon their health. Five months after the second vaccination, and two months after the animals were fed with bovine culture, all 6 calves were given an intravenous injection of 0.025 gram of a culture of bovine bacilli. All of these animals gave a strong temperature reaction. While, however, with 2 of the inoculated calves the abnormal symptoms soon disappeared, with a third the fever continued and there was little gain in weight, and with a fourth the result was so serious that it was necessary to kill the animal five weeks later, it being then very sick, and the post-mortem examination showed extensive tuberculosis of the lungs and lymph glands. Both control animals became very sick after the infection, and on post-mortem examination were found to have extensive tuberculosis of the lungs and lymph glands, and one of them had besides tubercles and tubercular ulcers of the intestinal mucous membrane. The 3 vaccinated animals which remained living were killed three months after the intravenous infection and showed moderate tubercular lesions in the lymph glands of different parts of the body. With one there was a focus of catarrhal pneumonia in the lungs and with another there were soft growths up to the size of a bean upon the pleural and peritoneal surfaces of the diaphragm. Decided lesions from alimentary infection were only present in one case and with this the infection had occurred through the mucous membrane of the throat.

A final experiment was made with different stocks of tubercle bacilli; one of these was from a monkey and two from human sources. The cultures of the three stocks presented the peculiarities of human tubercle bacilli. For vaccination, cultures 4 weeks old which had been grown on glycerin potato were used without being dried, each animal receiving the first time 0.005 gram and five and a half weeks later 0.025 gram injected into the jugular vein. The animals were 3½ to 9 months old. There was no increase of temperature following the first injection, but after the second injection 2 animals had a fever lasting two days. Seven weeks after the second vaccination all 3 animals, with a control, received 0.02 gram of a glycerin-potato culture of virulent bovine bacilli by injection into the jugular vein. The vaccinated cattle had, as a result of this inoculation, a marked increase in temperature, which subsided and left the animals in a normal condition. Three months after the inoculation with bovine bacilli the 3 animals were killed, and showed on examination

insignificant tuberculous lesions in the internal organs. In one case the lungs were entirely healthy and only a fresh connective tissue growth on the costal pleura led to the suspicion that it was caused by the inoculation. In a second case the peribronchial lymph glands alone contained very small calcified tubercles. In this experiment the tubercle bacilli from the monkey and from the two human sources produced even more favorable results than were obtained in the first experiment with Von Behring's original vaccine.

A peculiar behavior toward tuberculin was observed with these cattle which had been twice vaccinated and afterwards infected with virulent bovine bacilli. Of 6 cases which were tested with tuberculin two and one-half months after the virulent infection, 5 cattle did not react at all, and with 1 only was there a rise of temperature from 39° to 40.8° C. Tubercular lesions were found in 5 of these animals at the post-mortem examination. This striking insensibility of the first 5 cattle to tuberculin recalls the similar behavior of cattle which as a result of natural infection are already very sick, as well as of those which had a short time previously received a larger dose of tuberculin, in which cases it often happens that no reaction occurs. It appears, therefore, that as a consequence of a heavy infection or a saturation of the organism with the toxic products of the tuberculosis bacilli the sensibility toward tuberculin, or at least toward small doses of tuberculin, becomes for a certain time lessened.

Hutyra[55] stated in his report to the International Veterinary Congress at Budapest in 1905 that his conclusions in regard to the immunization of bovine animals against tuberculosis were at follows:

An intravenous injection, once repeated, of human tubercular bacilli, after Von Behring's method or some similar one, increases to a very considerable extent the power of resistance in cattle to artificial pearl-disease infection.

The process is innocuous to sound cattle, and presents no difficulties in its carrying into practice.

The question whether, and if so, how far, the immunity produced in this way extends to natural infection, finds no solution in the results of past experience; to solve this problem accurate observations of inoculated animals, continued for years, will still be necessary.

A similar inoculative protection against artificial infection is apparently afforded by a single subcutaneous injection with cultures of human tubercular bacilli.

THOMASSEN'S EXPERIMENTS.

Experiments made by Thomassen[56] in 1902 indicate that considerable immunity may be produced by inoculating cattle with human bacilli.

A young bull received by intravenous injection January 9, 1902, 30 milligrams of human bacilli which had been cultivated on potato since July, 1900. The bacilli were given fresh. If dried they would have been reduced to about 6 or 7 milligrams, and besides, desiccation reduces the virulence of tubercle bacilli. Until January 22 the animal presented no symptoms, but on that date the temperature commenced to rise, and on the 23d reached 40.9° C. The temperature continued to fluctuate between 40° and 41° C. until the first days of February. The animal continued to drink milk but did not gain in weight and its appearance was not satisfactory. From the 7th of February the temperature became normal, and toward the beginning of March the calf gained in weight and appeared to be in perfectly normal condition. April 29 the animal was tested with tuberculin but did not react. The immunity was tested by intravenous injection June 12 of 40 milligrams of culture of bovine bacilli. The day of the injection a marked rise of temperature was noticed, which persisted for five days, but the appetite remained normal, the respiration did not increase in frequency, and there was no cough. The animal reacted when tested with tuberculin August 17, and was killed for examination September 25. The autopsy revealed about ten tubercles in each lung, some of which were as large as a pea, but the majority were the size of a millet seed. Guinea pigs inoculated from these tubercles died of generalized tuberculosis. A single bronchial gland contained some tubercles, but guinea pigs inoculated from this gland did not contract the disease. The clinical symptoms would indicate that the few lesions observed exclusively in the lungs, and that might be considered as in process of healing, had been produced by the infection with the human bacilli; but the tuberculin test, on the contrary, would lead to the conclusion that the slight infection which was found dated from the injection of the bovine bacilli. Even if the latter supposition were

correct, the animal appeared to possess a degree of immunity which is seldom seen in animals which have not been immunized.

As a control animal to determine the virulence of the bovine bacilli, calf No. 2 was used. This animal was given 30 milligrams of the fresh culture by intravenous injection on June 28. This inoculation caused at first but a slight increase in temperature, which increased July 9 to 41° C. and remained above that point for about a week. The animal remained constantly in a recumbent position and died July 17. On examination the lungs were found studded with recent miliary tubercles.

Calf No. 3 received March 4, 1902, by intravenous injection, 25 milligrams of human tubercle bacilli, which had been passed once through a guinea pig and cultivated for three months on potato. The only symptom caused by this inoculation was a slight rise in temperature. Without testing with tuberculin, this calf was infected June 11 with 40 milligrams of fresh bovine bacilli, such as were used in the inoculation of No. 2. The animal neither coughed nor lost appetite and its condition remained good. It was tested August 17 and reacted, and was again tested with a like result October 16. It received a third infection November 3 by intravenous injection of 45 milligrams of bovine bacilli, which produced no symptom other than a slight rise of temperature lasting about a week. This calf was killed December 18, and the examination revealed a considerable number of tubercles in the posterior part of the two lungs. These tubercles were all calcified to such a degree that it was impossible to make a section of them with a bistoury. After crushing and examining these tubercles no bacilli could be discovered. Three tubercles were found in a bronchial gland which were less advanced in retrogression, but it was not yet determined whether they contained tubercle bacilli.

Calf No. 4 was inoculated February 6, 1902, in the anterior chamber of the eye with a few drops of an emulsion of human bacilli. From February 15 to March 7 there was an increase of temperature varying from 0.5° to 1.7° C. Tested with tuberculin April 29 and August 17, it reacted on both occasions. September 3 this calf was given by intravenous injection 30 milligrams of a culture of bovine bacilli. During the twenty-four hours following this injection the temperature rose to 40.2° C., but no other symptom was noticed for several days. Beginning with September 12, the animal coughed and had frequent respiration, but these symptoms disappeared after a few days. October 11 it was tested with tuberculin and reacted. This calf was killed October 24, and the most careful examination did not reveal the least lesion in either the abdominal or thoracic organs. Two guinea pigs were inoculated with an emulsion made from a suspicious gland, but no effect was produced. The posterior chamber of the eye contained a caseous mass in which were some calcified points, and in this tubercular material the bacilli could still be found. A retropharyngeal gland was also affected.

Calf No. 5, 12 days old, was given 8 milligrams of a fresh culture of bovine bacilli September 8. During the first week the temperature rose a little above the normal, but it was only from the fifteenth day that there was a considerable rise. The temperature became normal October 30, but during this month there had been little or no gain in weight. November 3 it received an intravenous injection of 30 milligrams of the same culture, which immediately caused a marked rise in temperature. It coughed, drank only half of its milk, and had rapid respiration. From the eighth day after the inoculation its general condition considerably improved, and by the eleventh day it was very nearly in the condition in which it was before the second infection. Desiring to learn the character of the lesions produced by the injection of the 8 milligrams of bovine culture the investigator killed the animal on November 12, and the examination showed a number of miliary tubercles in the lungs containing bacilli capable of infecting guinea pigs. The bronchial glands were also affected.

From these experiments it was concluded that bovine animals bear very well a dose of 30 milligrams of a culture of human bacilli injected directly into the veins. Also that a first infection does not cause a rise of temperature until ten or fifteen days after the inoculation, while with the second or third infection with bacilli the increase of temperature appears within twenty-four hours.

After experimenting with different methods of immunization for more than three years, Thomassen [57] reaches the following conclusions:

1. It is now established that it is possible to obtain a certain degree of active immunity in regard to tuberculosis.

2. The immunization of young cattle is a powerful addition to the means of hastening the extinction of tuberculosis.

3. It should be undertaken, after testing with tuberculin, as early as possible—i. e., at the age of 6 weeks, when the animal has not yet been exposed to the danger of contamination.

4. The use for this purpose of human bacilli, of a low degree of virulence, and in a fresh condition, is preferable to that of other vaccines which are mentioned.

5. For the first injection 1 milligram of bacilli is used, which may be preceded by a few injections of bovine tuberculin (this is highly recommended, particularly for animals only a few weeks old). The dose is increased each time, at a month's interval, to 10 and then to 20 milligrams. The intravenous injection of bacilli should never cause the formation of an abscess at the point of injection.

6. Care should especially be taken to crush perfectly the bacilli, so as to prevent pulmonary lesions of embolic origin.

7. The application of the vaccination on a large scale will be attended, in practice, with difficulties; among others the danger resulting to man from the manipulation of virulent products.

8. It is very important to determine accurately the duration of the immunity following the vaccination.

9. It may be admitted that the animal will be better able to resist the influence of a natural infection than that of a large quantity of bovine bacilli of great virulence placed directly in the circulation.

KLIMMER'S INVESTIGATIONS.

Very important experiments in immunization have recently been reported by Klimmer,[58] of Dresden. This investigator made a number of experiments with reference to the modification of the virulence of the tubercle bacillus by passing it through different cold-blooded animals. By long-continued experiments with carp it was observed that by living in cold-blooded organisms the tubercle bacillus gradually lost its virulence, and when guinea pigs were inoculated with it the period of incubation and the duration of the disease were increased. By the use of a species of salamander in such experiments the tubercle bacillus finally lost entirely its virulence for mammals. The culture of this fully acid-fast avirulent tubercle bacillus had the same appearance as that of the human tubercle bacillus. Rabbits and guinea pigs inoculated with large quantities of this bacillus remained in a healthy condition. Even the intravenous injection of 1 centigram of the culture failed to produce any tubercular changes in the organs.

After the harmlessness for mammals of the avirulent tubercle bacillus became known, experiments were made with it for the immunization of animals against tuberculosis. For this purpose rabbits and cattle were used. The vaccinations were made partly by intravenous and partly by subcutaneous injection, and the testing of the immunity was conducted by natural as well as by artificial infection experiments. The rabbits immunized with the avirulent tubercle bacillus were in the first place tested by artificial infection with a stock of human tubercle bacilli which was pathogenic for rabbits, and it was demonstrated in this way that these animals had acquired absolute immunity against human tubercle bacilli. Afterwards the immunized rabbits were tested by infection with a very virulent bovine bacillus and proved to have acquired a very high or even absolute immunity against this active germ.

Cattle were given intravenous injections of the avirulent tubercle bacillus without causing any injury to their health, and tolerably large quantities were injected subcutaneously without producing either local or general disturbance. The immunization was carried out with several animals by intravenous injection and with others by subcutaneous injection, and the immunized calves were afterwards tested partly by natural and partly by artificial infection. These animals showed a complete resistance to natural infection up to the time of reporting, and during the period of a year which had elapsed, although the animals were repeatedly tested with tuberculin, none had reacted, while the control animals had shown 33 to 36 per cent of positive reactions. The experiments with artificial infection were not completed at the time of reporting.

Klimmer also used for immunizing cattle an attenuated human bacillus, which was harmless both for the persons using it and for the animals. It was obtained by making pure cultures directly from the original source and without passage through

any animal. In order that the use of this material for vaccination might be harmless for the veterinarian it was not furnished in the dry condition from which it is easily transformed into dust, thereby becoming dangerous, but was taken directly from the culture and made into a suspension in the laboratory where it was cultivated, so that it could be used in practice for immunizing without further manipulation. This suspension of bacilli remains unchanged and retains its immunizing value for four weeks. In order to reduce to a minimum the danger of infection through accidents and awkwardness, the tubercle bacilli are artificially attenuated in their virulence by heating at 52° to 53° C. Such an attenuation of the vaccination material does not affect its immunizing value.

The use of this suspension of attenuated tubercle bacilli by intravenous injection into cattle is harmless, and even subcutaneous injections produced no local swellings with calves, whereas suspensions of the unattenuated bacilli caused swellings from the size of a nut to that of a goose egg, with the formation of abscesses. From the experience so far obtained it appears that cattle may be immunized by subcutaneous injection of this attenuated vaccine material. This simplifies the operation, as the intravenous injection requires more time and is more difficult.

Klimmer is of the opinion that the tubercle bacilli used for this purpose should not have been cultivated too long on artificial media, and that they should have acquired as little as possible of the saprophytic habit of growth.

Such vaccine material made in the Dresden Hygienic Institute has been practically tested since 1903 on a royal estate near Dresden, where the avirulent bacillus has also been used. Over 80 per cent of the cows and over 40 per cent of the young cattle at this place reacted to tuberculin. The immunized calves were, therefore, exposed to a heavy infection, especially as they were stabled among the tuberculous animals. In the two years during which the investigations have been in progress it has been established that the immunization of calves with this vaccine is free from danger. No losses have occurred from vaccination. Of about 60 calves treated, some have been slaughtered and others have died from various causes, but in none of these could signs of tuberculosis be discovered. Neither have any of the immunized animals reacted to tuberculin. The immunized calves developed in a superior manner, proving that the immunization had no detrimental effect upon them.

The immunized calves and the control calves, which have been standing mixed together almost since their birth, have been tested with tuberculin. Of the control calves, which of course were not immunized, 14 were tested at one time and 6 reacted, and at another time 10 were tested and 3 reacted. Of the calves immunized with the Dresden vaccination material not a single one has reacted, neither when tested a month after immunization nor when the test was made one and one-half years afterwards.

WORK OF KOCH AND OTHERS.

In a recent and very important paper Koch, Schütz, Neufeld, and Mieszner[59] state that in their experimental investigations they gradually reached a simple and safe method by which animals could be given a high degree of immunity by one or two injections of living cultures of tubercle bacilli. With cattle they obtained a complete immunization with only two injections, using at first an attenuated culture of the bovine bacillus. The following striking experiment illustrates this fact:

Calf XIII, weight 345.4 pounds, received an intravenous injection of 1 centigram of an attenuated bovine culture on August 25, 1902. A second injection of a like amount of the same culture was adminis ered in the same manner October 17, 1902. The degree of immunity which this calf had acquired by these treatments was tested by injecting intravenously 1 centigram of a virulent bovine culture December 24, 1902, a control calf being inoculated at the same time and in the same manner with a like amount of the virulent culture. As a result of the inoculation with the virulent culture, the unprotected control calf died January 16, 1903, with miliary tuberculosis of the lungs. The protected calf resisted the inoculation, and when killed, on August 11, 1903, was found healthy.

A degree of immunity which is sufficient to protect completely an animal from such a virulent bovine germ as was used to test this calf, and which may be conferred by two vaccinations, is worthy of very

serious attention. A table has therefore been prepared by condensing a more complete one given by the authors which presents the important facts relative to a series of experiments since made by them.

All of the calves used in these experiments were first tested with tuberculin and none were taken which showed a rise of temperature of more than 0.5° C. The second vaccination generally was made after the calves had fully recovered from the effects of the first, which required from four to six weeks. After the first vaccination there was an increase of temperature to 40–41° C., which continued for several days, and following this a high normal temperature was observed for about two weeks, during which time there was either a marked gain or loss in weight. After this the temperature subsided and the animals recovered so completely that the second vaccination was made without hesitation. The second vaccination was followed by an immediate rise in temperature, which lasted only a few days and did not disturb the general condition of the animals.

In order to test the immunity the calves were inoculated intravenously with 2 centigrams of virulent bovine culture, which was so active that one-fortieth of this dose was sufficient to produce a fatal case of acute miliary tuberculosis in a calf within twenty to thirty days. This test is referred to in the table as the control injection.

The table follows:

Principal facts relative to recent immunization experiments reported by Koch, Schütz, Neufeld, and Mieszner.

No. of calf.	Weight of calf.	Kind of bacillus injected.	Dose first injection.	Days between first and second injections.	Dose second injection.	Days between second and control injections.	Days between control injection and death or end of test.	Gain in weight during experiment.	Result of final examination.
	Pounds.		*Centigrams.*		*Centigrams.*			*Pounds.*	
1	359.7	Human...	2	27	5	42	100	166.1	Healthy.
2	353.1	.....do....	1	27	5	42	96	39.6	Lung tuberculosis.
3	326.7	.....do....	2	26	5	42	100	249.7	Tuberculosis of serous membranes and kidneys.
4	449.9	.....do....	1	26	5	42	98	159.5	Do.
5	346.5	.....do....	2	32	5	37	100	141.9	Healthy.
6	260.7	.....do....	1	33	5	36	30	58.3	Miliary tuberculosis.
7	376.2	.....do....	2	34	5	93	246	470.8	Still alive.
8	289.3	.....do....	1	30	5	93	236	529.1	Healthy.
9	354.2	.....do....	2	49	5	90	221	371.8	Do.
10	309.1	.....do....	1	49	5	90	221	427.9	Still alive.
11	330.0	.....do....	2	50	5	90	220	451.0	Do.
12	321.2	.....do....	1	63	5	88	209	272.8	Healthy.
13	338.8	.....do....	1	52	5	88	209	178.2	A tubercular focus the size of a hazelnut in the lung.
14	290.4	.....do....	1	44	5	88	209	215.6	Healthy.
15	220.0	.....do....	2	54	5	91	194	308.0	Tubercular foci in the lungs.
16	270.6	.....do....	1	54	5	91	194	422.4	Still alive.
17	220.0	.....do....	2	39	5	87	184	316.8	Healthy.
18	264.0	.....do....	1	39	5	87	194	312.4	Still alive.
21	250.8	.....do....	3	103	.....	.....	117	217.8	Pleuritis and peritonitis villosa.
22	297.0	.....do....	2	103	.....	.....	127	323.4	Pleuritis villosa.
23	235.4	.....do....	1	103	.....	.....	119	255.2	Healthy.
24	325.6	Bovine ...	2	169	.....	.....	91	473.0	Still alive.
25	228.8	.....do....	1	169	.....	.....	91	310.2	Pleuritis chronica villosa, bronchitis and peribronchitis catarrhalis chronica lobularis.
26	321.2	.....do....	1	21	.....	.....	91	354.2	Bronchitis catarrhalis lobularis.

Each two calves, from No. 1 to No. 18, inclusive, were vaccinated with human bacilli of a different stock and consequently calves 1 and 2 constitute one experiment, calves 3 and 4 a second experiment, and so on. With calves 1 to 6 the period between the last vaccination with human bacilli and the control inoculation was about forty days, and this the authors think was too short and partly accounts for these experiments being less successful than the others. They also express the

opinion from the results of the experiments with calves 1 and 2 and 5 and 6 that 2 centigrams of culture for the first vaccination causes a more rapid development of immunity and makes this immunity more perfect than does 1 centigram. There was very little difference between calves 3 and 4; both developed tuberculosis with lesions of the same character. Contrasting strongly with the above animals are the calves from 7 to 18, inclusive, which were not inoculated with virulent bovine bacilli until three months had elapsed after the last vaccination with human bacilli. All of these animals remained healthy with the exception of two, which showed comparatively insignificant remains of old tubercular lesions. The only symptom which these animals presented was slight fever, lasting from three to five days. They developed well and increased in weight. Seven of the calves had been dissected after being held about a year, and with calves 8, 9, 12, 14, and 17 not the slightest appearance of tuberculosis was discovered by very careful examination. It was only with calves 13 and 15 that such appearances were seen, and these were of old standing and probably recovered cases. The five calves still living, Nos. 7, 10, 11, 16, and 18, are in excellent condition and free from any appearance which would lead one to suspect the existence of tuberculosis.

These investigators conclude that by the use of human tubercle bacilli in the manner described by them a high degree of immunity may be produced in cattle, but that a considerable time elapses before this immunity develops to the highest point and that the dose of the culture used in the first vaccination has a notable influence upon the rapidity with which the immunity is acquired. All of the stocks of bacilli used by them were capable of producing immunity, the only difference being that some of the stocks affected the calves more seriously than did others, and young cultures produced fever of longer duration than older cultures. The attenuated bovine bacillus, which was of slight virulence for cattle, produced immunity in the same manner as the human bacillus.

The animals above referred to, Nos. 1 to 18, were immunized by two vaccinations with bacilli of human tuberculosis. The second vaccination, however, had produced only a slight reaction and this led the investigators to believe that perhaps a single vaccination with a proper dose of human tubercle bacilli might cause with cattle a sufficient degree of immunity. In order to test this question the investigators chose a culture for the vaccination which in former tests had produced a moderately strong reaction, and vaccinated by intravenous injection calf 21 with 3 centigrams, calf 22 with 2 centigrams, and calf 23 with 1 centigram of a thirty-day culture. The general condition of the animals was not disturbed, and one hundred and three days later their immunity was tested by the injection of 2 centigrams of a culture of virulent bovine tubercle bacilli. Following this inoculation the animals had fever of several days' duration, and after its subsidence appeared entirely healthy. After a period of one hundred and seventeen to one hundred and twenty-seven days the three animals were all killed and examined, and proved to be entirely free from tuberculosis. These three calves had therefore developed a very high degree of immunity from a single vaccination with 1, 2, and 3 centigrams of the bacilli of human tuberculosis.

A similar result was obtained with calves 24 and 25, which were vaccinated intravenously with 2 centigrams and 1 centigram, respectively, of an attenuated stock of bovine bacilli, and one hundred and sixty-nine days later were tested by inoculation with the very virulent bovine bacillus. Calf 24, which had remained in an excellent condition, was still living. Calf 25 was killed and examined the two hundred and sixtieth day of the experiment, and, although affected with pleuritis chronica villosa, bronchitis, and peribronchitis catarrhalis chronica lobularis, no tubercle bacilli could be found.

The authors conclude that they have succeeded by a single vaccination with 1 to 3 centigrams of bacilli of human tuberculosis or of attenuated bacilli of bovine tuberculosis in producing in cattle an immunity against highly virulent bacilli of bovine tuberculosis. The bacilli as used up to this time and grown upon glycerin bouillon must be from 30 to 40 days old. They are dried between blotting paper, and the required amount is mixed with 10 c. c. of physiological salt solution and injected into the veins.

VALLÉE'S EXPERIMENTS.

On the initiative of M. Rossignol, and under the auspices of the Société de Médecine Vétérinaire Pratique, there was begun at Melun, in December, 1904, a series of experiments[60] on the antituberculous vaccination of young cattle by the method of Professor Von Behring, of Marburg.

These experiments, which were conducted under the direction of Professor Vallée, had for their object—

(1) To demonstrate the innocuousness of the method of vaccination.

(2) To verify the efficaciousness of the method.

(3) To establish its practical value and in particular the duration of the immunity.

December 5, 21 calves 4 to 6 months old were tested with tuberculin without reacting, and were held in places free from all contamination other than was received in the experiments.

December 11, they were given the first vaccine in the jugular.

About two months later one of the treated animals was attacked with "maladie des pulpes" and died. Its organs, examined by MM. Moussu and Vallée, revealed no indication of the existence of tuberculosis. The other animals remained in perfect health and showed normal development.

February 13, the 20 surviving animals were tested with tuberculin. Four animals reacted clearly, with regard to which Professor Vallée remarked that the reaction was no cause for anxiety or surprise, as the inoculated bacilli could not be absorbed without causing the formation of microscopic lesions sufficient to cause a reaction.

March 12, three months after the first vaccination, the 20 animals received the second vaccine.

At the beginning of June all vaccinated animals were tested with tuberculin. Only 1 animal reacted, and this failed to react to subsequent tests. This and 4 other vaccinated animals were put in a lot together with the object of testing the duration of the immunity.

June 15, the 15 vaccinated animals remaining were tested as follows: Six received 4½ milligrams each of a fresh culture of very virulent bovine bacilli; 7 were inoculated subcutaneously, and 2 were exposed by cohabitation with tuberculous bovine animals. Check animals which did not react to tuberculin and equal in number to the vaccinated ones were submitted to the same test.

Very soon a number of the check animals showed very marked symptoms, and 3 of those inoculated intravenously died in thirty to forty days.

The following is a brief résumé of the results of these tests:

A. Intravenous Tests.—(*1*) *Checks.*—Three died with considerable pulmonary lesions thirty to forty days after the inoculation. The 3 surviving ones showed on autopsy extensive and generalized lesions.

(*2*) *Vaccinated animals.*—Five were absolutely immune. The sixth, affected with pasteurellosis at the time of the test inoculation, and consequently having less resistance, presented five or six disseminated tubercles in the bronchial and mediastinal glands, but no visceral lesions.

B. Subcutaneous Tests.—(*1*) *Checks.*—Three showed enormous lesions of the corresponding prescapular gland. Four had in addition generalized lesions of the lungs and of the bronchial and mediastinal glands.

(*2*) *Vaccinated animals.*—With 5 of these no lesions were discovered in the glands nearest to the point of inoculation. With another there was found a tubercle in the prescapular gland. The seventh had an extensive tuberculous adenitis of this gland.

C. Tests by Cohabitation.—(*1*) *Checks.*—These had generalized tuberculosis following an infection from the digestive tract, as was proved by the lesions observed.

(*2*) *Vaccinated animals.*—These did not react to the tuberculin test and were preserved and left in contact with tuberculous animals.

Conclusions.—This method of vaccination appeared free from danger because none of the vaccinated animals reacted to tuberculin a few months after the second vaccination. As to the efficaciousness of the vaccination, it was shown that 5 out of 6 of the vaccinated animals developed no lesions when tested by intravenous inoculation, whereas the checks died or became tuberculous; 5 of the 7 tested by subcutaneous inoculation were immune, whereas the checks all had extensive lesions in the neighboring glands and several had generalized lesions in the lungs and annexed glands; and, finally, all of the vaccinated animals successfully resisted the test by cohabitation, which is the usual method of infection, whereas the check animals all became tuberculous.

Vallée concludes that it is experimentally possible to confer on young bovine animals a high degree of immunity in regard to tuberculosis. The duration of the immunity is being tested by further observation.

CONCLUSIONS REGARDING IMMUNIZATION.

It is evident from the investigations which have just been reviewed that great progress has been made in the development of a method for immunizing cattle against tuberculosis. The results of the different tests up to this time have not been as uniform as is desirable, but they are constantly improving in this respect, and there is good reason to expect that a safe and effective method will soon be available. At present there is considerable uncertainty as to the period of time during which the efficacy of the "vaccine" remains unimpaired, as to the proper degree of virulence for the vaccine and the number of doses required for protection against natural infection, and also as to the duration of the immunity.

The danger to the operator from using dry and powdered human tubercle bacilli as vaccine has been mentioned by several investigators and should receive serious consideration. The liquid form appears to be more efficacious and more simple in its manipulation. The dry vaccine is said to retain its properties unimpaired for a month, but considering the time required to put it in packages and ship it from Germany to the United States, it is to be feared that in many cases much more than a month would elapse between its preparation and its injection into American cattle.

This method of protecting cattle from tuberculosis is still so new, and has been used so little under practical conditions, that it should only be adopted by the cattle owner with much caution and under expert veterinary supervision. The danger of adopting hasty conclusions as to the degree of immunity conferred upon cattle by inoculation with tubercle bacilli has been shown by some of the experiments which have been mentioned in preceding pages. There is still much to learn about these "vaccines" and their effects, and the owner of cattle will be wise to avoid their use pending further investigations, except in the most urgent cases and under conditions where such treatment is clearly indicated.

THE CURATIVE EFFECT OF TREATMENT WITH TUBERCULIN AND WITH ATTENUATED TUBERCLE BACILLI.

Pearson and Gilliland[63] have published a report of some experiments made by them to test the effect of treatment with tuberculin and with tubercle bacilli of the human type upon young cattle which had reacted to tuberculin and which were presumably affected with tuberculosis in its early stages. In testing with tuberculin a large herd of Shorthorn and grade Shorthorn cattle in December, 1902, it was found that practially all of the members of the herd responded to the test. Among the animals so responding were 12 calves from 6 to 8 months of age. These calves were obtained for use in this experiment and were again tested February 2–3, 1903. All responded to the test.

They were then weighed and divided into two lots of 6 each, as nearly equal in respect to size, weight, age, and condition as possible. One of these lots was subdivided into two groups of 3 each.

The calves of one of these subgroups were given 7 intravenous injections of a standard suspension in water of tubercle bacilli of human type. The dosage began at 1 c. c. and was increased to 6 c. c. The intervals were six to twenty days, and the period covered was from February 9 to May 1, 1903. A final injection was given about a year later, March 29, 1904.

The 3 calves of the second subgroup were given subcutaneous injections of tuberculin at intervals of from one to ten days. The injections of tuberculin were repeated until the hypersensitiveness of the animal to tuberculin had disappeared, after which the calves received an intravenous injection of a suspension of tubercle bacilli in water. Following each intravenous injection of living tubercle bacilli the animal was given tuberculin a number of times until its hypersensitiveness to tuberculin again disappeared. The period of treatment extended from February 9 to April 30, 1903, inclusive, and the calves of this group, as of the group first described, were given an intervaneous injection of 5 c. c. of standard suspension of living tubercle bacilli March 29, 1904. Following this, tuberculin was administered five times at intervals of three or four days.

The remaining 6 calves were given no treatment whatever, but were at all times kept with the 6 calves under treatment, so that all of the 12 calves in this experiment were subjected to the same conditions of life and subsisted upon the same kind and quantity of food.

Two cattle, both controls, died; the first one May 5, 1903, the second September 13, 1904; two—1 control and 1 treated—were killed April 4, 1904, and the rest were killed in September, 1904. All were submitted to careful post-mortem examination.

The calves of the first group had from one to three small tubercular lesions each, which were the size of a pea or less. In the case of one calf only was one of these found in the lung; in the others they were confined to the lymphatic glands. The calves of the second group had still smaller and more insignificant lesions, confined in all cases to the bronchial glands. In both of these groups of animals the lesions were quiescent, encapsulated, and some of them calcareous. The calves of the third group, which received no preventive treatment, were affected in a much more serious manner. In 4 of the 6 the lungs were quite extensively diseased; in 2 only were the tubercular changes confined to the lymphatic glands. One of the animals presented a case of "pearl disease" in its most advanced form and widest distribution. There was consequently a decided difference between the 6 young cattle that were treated and the 6 that were not treated; and since the two lots of animals were comparable in every way, excepting in respect to the specific treatment, it appears reasonable to conclude that the treated animals were favorably influenced by the treatment. Not only does the disease appear to have been held in check by the treatment, but there was reason to believe that in some of the animals it had a decided curative effect.

In all of the treated animals the lesions were quiescent and encapsulated, but they nevertheless contained living tubercle bacilli which were capable of causing the disease in guinea pigs. The investigators remarked with reason that these experiments which were made on a few young cattle in the earlier stage of tuberculosis do not justify conclusions or inferences as to the probable effect of similar treatment on older and more extensively diseased animals.

These experiments confirm the results of experiments by various investigators as to the production of immunity by the treatment of cattle with tuberculin and cultures of human and other tubercle bacilli nonvirulent for these animals. As to whether it will be advisable to administer such treatment to diseased young cattle in general practice must be considered doubtful, in view of the fact that the diseased areas continue to harbor virulent living bacilli for a long time after the treatment has been concluded. Further studies of this subject must be made before positive recommendations can be offered; but even with doubt on this point, the experiments have much value as indicating how complete a degree of immunity may be developed by proper treatment.

ANIMAL TUBERCULOSIS AND THE PUBLIC HEALTH.

EARLY VIEWS.

There has been much difference of opinion as to the effect of animal tuberculosis upon the public health, and curiously enough the weight of numbers appears to have been with those who believed that there was little if any danger to be apprehended from this source. There were local laws in Munich more than five hundred years ago which prohibited the use of the flesh of animals affected with bovine tuberculosis, and similar ordinances were subsequently enacted in various German cities. There appears, however, to have been no great effort to enforce these ordinances, or, at most, they were only enforced spasmodically, until in the early part of the eighteenth century, when the opinion became prevalent that tuberculosis and syphilis were identical. While this idea was dominant the regulations concerning the sale of the meat of tuberculous animals were more stringently enforced.

In 1783, however, the health authorities of Berlin promulgated an opinion to the effect that tuberculosis and syphilis were different and distinct diseases, and permitted the sale of the carcasses of tuberculous animals for human food. This view appears to have been accepted by other German States and by Austria, and for a third of a century such meat was sold without question. The ideas in regard to tuberculosis were vague and erroneous, and it was not until 1811 that Laënnec proclaimed the unity of the different forms of tuberculous lesions. His views were vigorously contested, but they nevertheless made a strong impression upon the medical thought of the early part of the nineteenth century. Within a few years regulations were formulated in different places for the guidance of meat inspectors in judging the carcasses of tubercular animals. Gurlt (1831) recognized the tubercular nature of the "pearl disease" of cows.

About 1850 German histologists contested the views of Laënnec and denied any relationship between human and bovine tuberculosis. Reinhard, Virchow, and Niemeyer recognized a true tuberculosis characterized by the "gray granulation," and a caseous pneumonia resulting from postinflammatory degeneration (Nocard). However, Gerlach, Spinola, Fuchs, Förster, Leisering, and others declined to accept such views and produced observations to show the tuberculous nature of the "pearl disease" of cattle.

In 1866 Villemin introduced a new epoch in the discussion of questions relating to the nature of this disease by demonstrating the inoculability of tuberculosis not only from animal to animal within the same species, but from an animal of one species to an animal of an entirely different species, and even from man to animals.

Villemin's conclusions were soon confirmed by the results of experiments made by Chauveau, Gerlach, Günther and Harms, and other experimenters. As late as 1880, however, Virchow insisted at length that

essential anatomic and pathologic differences separated the tubercles of the pearl disease of cattle from those of consumption in man, and held that the existence of a virus in pearl disease had not been demonstrated.

It required another epoch-making discovery, that of the *Bacillus tuberculosis* by Koch, in 1882, to convince the medical world that tuberculosis was a communicable disease, and that an identical bacillus was found in the tubercles of man and many different species of animals. This discovery again attracted attention to the danger which might be connected with the tuberculosis of animals and led to more rigid enforcement of regulations to guard against any dangers which might threaten the public health through the sale of meat and milk from tubercular animals.

IDENTITY OF HUMAN AND BOVINE TUBERCULOSIS QUESTIONED.

Years passed, and it appeared to be definitely established that human and animal tuberculosis were identical, when Theobald Smith published (1898) the results of a comparative study of bovine tubercle bacilli and of human bacilli from sputum, in which it was shown that the bacilli from these two sources differed to such an extent that they might be considered as distinct types. Not only was there a great difference in the virulence of bacilli from the two sources, but there were marked morphological and cultural differences shown by the bacilli. These conclusions were soon confirmed by Dinwiddie and by Frothingham.

The observations were not entirely new, however, as Sidney Martin, in his experiments for the British Royal Tuberculosis Commission of 1895, had shown that sputum from man was far less virulent for animals than was bovine tubercular material. It could not be said from these experiments that human tuberculosis was not communicable to cattle, but only that it was communicated with difficulty, and when it was communicated the disease remained localized and did not result fatally. Of 6 calves to which sputum was fed by Martin, 2 showed no lesions, 1 had 53, 1 had 63, and 2 each had 13 tubercular nodules in the intestines. In one of these animals the mesenteric glands were also affected. In Smith's experiments there were also small lesions in some of the animals with which he experimented.

In an address before the British Congress on Tuberculosis, held in London in 1901, Koch expressed very radical views as to the difference between human and bovine tuberculosis. He held (1) that human tuberculosis differs from bovine, and can not be transmitted to cattle; (2) that while the susceptibility of man to bovine tuberculosis was not yet absolutely decided, he was nevertheless at liberty to say that if such a susceptibility really exists the infection of human beings is but a very rare occurrence. He estimated the extent of infection by the milk and flesh of tubercular cattle, and the butter made of their milk, as hardly greater than that of hereditary transmission, and he there-

fore did not deem it advisable to take any measures against it. He held that it was now possible to determine whether tubercular disease in the human subject was of human or animal origin. He said:

> All that is necessary is to cultivate in pure culture the tubercle bacilli found in the tubercular material, and to ascertain whether they belong to bovine tuberculosis by inoculating cattle with them. For this purpose I recommend subcutaneous injection, which yields quite specially characteristic and convincing results.

This unexpected announcement by so great an authority aroused great interest and led to tremendous activity among investigators in all parts of the world. As a result of the problem being attacked by many individuals and from different points of view the principal facts have already been ascertained and established.

INVESTIGATIONS BY THE GERMAN COMMISSION.

Koch announced in his London address that the German Government had already appointed a commission to make further inquiries on the subject. A preliminary report was made from this commission by Kossel in 1903. At that time the commission had tested 7 cultures of tuberculosis from cattle and hogs—4 from cattle and 3 from hogs. Two of these cultures proved acutely fatal to cattle after eight to nine weeks. Four of the cultures likewise produced a generalized tuberculosis, but which certainly had a more chronic course, while 1 of the cultures caused only an infiltration at the point of inoculation, with some caseous foci in the adjoining prescapular gland and in one of the mediastinal glands, and there was lacking the spreading of tuberculosis over the entire body, which they were accustomed to see after the injection of cultures of bovine tuberculosis. "Hence," said Kossel, "among bovine tuberculosis bacilli there can also occur differences with regard to the virulence."

The commission had also tested 39 different freshly made cultures from tuberculous disease in man. Nineteen of these cultures did not produce the slightest symptoms in cattle; with 9 others the cattle exhibited, after four months, very minute foci in the prescapular glands, which were mostly encapsuled and showed no inclination to progress; with 7 others there was somewhat more marked disease of the prescapular glands, but it did not go so far as a material spreading of the process to the glands next adjoining. There were 4 cultures, however, which were more virulent and caused generalized tuberculosis in the cattle inoculated with them.

It was therefore evident that, contrary to Koch's assertion, it was not always possible to determine whether a culture of the tuberculosis bacillus originated in man or in cattle by inoculating it subcutaneously in bovine animals. One of the bovine cultures failed to produce generalized tuberculosis in cattle, which according to Koch's contention it should have done; and 4 of the human cultures did produce this form of disease, which according to the same authority they should not have done. Moreover, while some of the human cultures caused

no disease at all, others led to the development of minute foci in the prescapular glands, and still others to somewhat more marked disease of these glands. There were, consequently, four degrees of virulence noted in these 39 cultures from human sources, and three degrees of virulence in the 7 cultures from animal sources.

It was definitely admitted that 4 of the human cultures caused generalized tuberculosis in cattle; but it was suggested by Kossel that it might be possible that the bacilli in cases of human tuberculosis under certain circumstances could likewise attain a very high degree of pathogenic activity for cattle without being for that reason bovine bacilli. The German commission was confronted by the two horns of a dilemma, either one of which was fatal to the views of Koch as stated with great positiveness at London. If the suggestion thrown out by Kossel was adopted it was necessary to conclude that Koch was wrong in his claim that human tuberculosis can not be transmitted to cattle, and thus with one stroke of the pen the commission would destroy the entire experimental support which he had for his argument before the British Congress on Tuberculosis. If, on the other hand, it accepted the conclusion which followed from the principle laid down by Koch for discriminating between human and bovine bacilli, it was necessary to admit that bovine tuberculosis is an extremely important factor in the etiology of human tuberculosis. Of the 39 cases of human tuberculosis tested, 4, or over 10 per cent, were virulent for cattle and would be classified as of bovine origin; but these 4 cases were all found among the 16 cases of tuberculosis in children which the commission investigated; and, therefore, 25 per cent of the cases tested of tuberculosis in children should by Koch's method be classified as of bovine tuberculosis.

These results were in accordance with researches made by other investigators. De Schweinitz, Mohler, and Ravenel in this country easily succeeded in obtaining human tubercle bacilli which caused generalized tuberculosis in cattle, and most of these originated in tuberculous children.

INVESTIGATIONS BY THE GERMAN IMPERIAL HEALTH OFFICE.

In 67 cases of tuberculosis in human beings studied up to the present time in the investigations of the German imperial health office,[61] and which were selected with the object of finding as many cases as possible of the bovine type, there were found in 56 cases bacilli of the human type alone, in 9 cases bacilli of the bovine type alone, and in 2 cases bacilli of both types were found in the same person. The 9 cases affected with bovine bacilli alone were all children under 8 years of age. Of the 2 persons affected with bacilli of both types one was a woman 30 years old and the other a child 5½ years old.

Eleven cases of tuberculosis in fowls were investigated, all of which were caused by the fowl tuberculosis bacillus. In 11 different cases

of tuberculosis in cattle there were found exclusively bacilli of the bovine type. In 7 cases of tuberculosis in swine there were found only bacilli of the bovine type. In one case in a 3-months-old pig which had shown no symptons of tuberculosis there were found fowl tuberculosis bacilli in the caseous mesenteric glands. In one case of general tuberculosis in a sheep there were found tubercle bacilli of the bovine type.

The German imperial health office[62] has recently given out the following summary of the results of the investigations relative to the danger to human health from animal tuberculosis:

I. Tuberculosis of Domestic Animals.—*A. Tuberculosis of cattle.*—1. Bovine tuberculosis is caused by tubercle bacilli of the *typus bovinus* (bovine type). It arises through infection with tubercle bacilli which have been excreted by diseased animals suffering from certain forms of tuberculosis.

2. The source for the infection of cattle is almost exclusively cattle which are suffering from tuberculosis of the udder, of the intestines, of the uterus, or of the lungs, and which excrete tubercle bacilli with the milk, with the contents of the intestines, with the secretions of the uterus, or simply through the respiratory organs.

3. The sickening of cattle is possible in consequence of the reception of tubercle bacilli of the *typus bovinus* which have been excreted by other diseased domestic mammals such as sheep, goats, and swine suffering from tuberculosis.

4. The tuberculous human being, in the rare cases in which he excretes tubercle bacilli of the *typus bovinus*, presents danger to cattle.

5. The tuberculosis of fowls seems, under ordinary circumstances, hardly to present any danger for cattle.

6. In combating tuberculosis in cattle the most important thing is to prevent the transference of the germs of infection from tuberculous to sound cattle.

B. Tuberculosis of swine.—1. In tuberculous swine, tubercle bacilli of the *typus bovinus* are almost without exception the only ones found in the disease centers.

2. Tuberculosis of swine has its principal origin in the tuberculosis of cattle, and in the second place in the transference of tuberculosis from one hog to another. Nor is it impossible for the tuberculosis of other domestic mammals and of fowls to be transferred to swine.

3. The tuberculous human being can give tuberculosis to swine, no matter what be the origin of his own disease.

4. As source of infection, the excretions and the flesh of diseased mammals in which living tubercle bacilli are contained come chiefly under consideration. The greatest danger comes from feeding swine with the separator refuse from the dairies.

C. Tuberculosis in the other domestic mammals.—1. The tuberculosis of the other domestic mammals is to be traced back in most cases to the tuberculosis of cattle.

2. It is to be expected that the repression of the tuberculosis of cattle will lead to a decrease of the tuberculosis of swine and the other domestic mammals.

D. Tuberculosis in domestic birds.—1. The tuberculosis of domestic birds (fowls, pigeons, ducks, and geese) is generally caused and spread by the fowl tuberculosis bacillus.

2. As the principal source of infection we must consider the intestinal excretions and parts of the bodies of diseased birds which have undergone tubercular changes.

II. Tuberculosis of Human Beings.—1. In parts of the human body affected by tuberculosis there are generally found tubercle bacilli of the *typus humanus* (human type).

2. It must be assumed that here the infection with tuberculosis has taken place chiefly through direct or indirect transference of tubercle bacilli from man to man.

3. Accordingly the measures recommended for combating tuberculosis are directed principally against the direct or indirect transference of the germ of infection from tuberculous to healthy people.

4. Besides this we must reckon with the possibility that tubercle bacilli of the *typus humanus* may be transferred to human beings through the flesh of tuberculous swine.

5. The fact that in a number of cases where organs of the human body have been found to have undergone a tuberculous change, the presence of tubercle bacilli of the *typus bovinus* has been proved, shows that the human body is capable of receiving the germs of infection from secretions containing tubercle bacilli (for example, milk) or from tuberculous flesh of domestic mammals.

6. The changes in the tissue brought about in human beings through tubercle bacilli of the *typus bovinus* are limited in a remarkable number of cases to the passage through which the germs have found entrance, and to the adjacent glands or to the latter alone. Nevertheless tubercle bacilli of the *typus bovinus* have also been found in cases where the disease had spread from the locality of entrance to distant parts of the body and had caused the death of the person in question.

7. The use of food, therefore, which comes from tuberculous animals and contains living tubercle bacilli of the *typus bovinus* is not to be regarded as being without danger for the health of human beings, especially when the latter are children.

8. A conscientiously conducted meat inspection constitutes an important protection against the transmission of the tubercle bacilli to human beings through meat; there is also protection afforded by the proper preparation of meat (thorough boiling or roasting).

9. The possibility of the transference of tubercle bacilli through milk or milk products to the human being may be considerably diminished by the efficient combating of tuberculosis in cattle. The tubercle bacilli contained in milk may be killed by heating the milk to the necessary temperature.

10. The tuberculosis in poultry used for domestic purposes appears to play no part in the propagation of the disease among human beings.

CONCLUSIONS NOW GENERALLY HELD BY SCIENTISTS.

These statements fairly represent the condition of our knowledge with reference to human and animal tuberculosis, but the conclusion should not be reached from this brief summary that the German investigators are entitled to all the credit for having elucidated this perplexing question. On the contrary, similar results were announced at an earlier date by the investigators of other countries, and especially by those of Great Britain, France, and the United States.

The following conclusions are, therefore, regarded as demonstrated by experimental investigations in which many scientists have participated, and these conclusions are now generally accepted by scientific men:

1. Bovine tuberculosis may be communicated to human beings, and in such cases it is usually children that are affected.

2. Tuberculosis of other domesticated mammals (hogs, sheep, goats, etc.) may also be communicated to human beings. It is usually, but not always, of the bovine type.

3. The tuberculosis of poultry is not communicable to human beings.

4. Parrots and some other varieties of cage birds may be affected with a type of tuberculosis communicable to human beings.

5. The tuberculosis of human beings, as a rule, is not communicable to cattle, but is communicable to pigs, dogs, and cats. The bacilli in a certain proportion of the cases of human tuberculosis, however, are virulent for cattle and produce in these animals a fatal generalized tuberculosis.

6. Precautions should be taken to protect human beings from animal tuberculosis by a careful inspection of meat-producing animals at the time of slaughter and of the cows from which milk, cream, and butter are produced.

PART II.—THE REPRESSION OF TUBERCULOSIS.

MEASURES THAT MAY BE ADOPTED BY INDIVIDUALS.

PREVENTION BY AVOIDING KNOWN CAUSES OF TUBERCULOSIS.

The first requisite for preventing tuberculosis is to provide roomy, well ventilated, light, dry, and clean stables for the animals. Tuberculosis will not originate even in dirty stables if the bacillus is not introduced in some manner; but there are so many ways by which it may enter a stable that the breeder and dairyman should always be prepared for it. There is much less danger of the disease spreading in a stable properly built and maintained than in an ordinary stable, and in case it spreads, its progress will be much slower, and the animals less severely affected.

There are a few points in the building of a stable to make it as secure as possible against tuberculosis which should receive special attention. It is preferable that the floor should be of concrete. Wooden floors are generally defective and allow liquid or even solid matter to work through them and collect in the space between double floors, or under the stable, creating in time a foul, fermenting mass of organic matter which keeps the stable damp and filled with noxious gases. In the disinfection of stables for pleuro-pneumonia and foot-and-mouth disease, the writer saw examples of filth between and under floors, even on good dairy farms, which has made him partial to concrete. And yet it is possible to put a good wooden floor in a cow stable and to keep the stable in a good sanitary condition.

The stables should have solid partitions separating completely the mangers and the greater part of the stalls. Tuberculosis is very apt to spread from animal to animal in the order in which they stand in the stable. The infection occurs through the small particles of mucus or of tuberculous material which are forcibly expelled into the air when an affected animal coughs, or through the saliva which soils the mangers or drinking vessels, or through the animals touching noses or licking each other. A solid partition as high as the animals' backs guards against such infection and does much to limit the spread of the contagion.

The method of watering also has considerable influence on the spread of tuberculosis. It is quite common to have a long trough in front of a row of stalls which extends the length of the row and is filled with water from one end. As the water runs into this trough it passes in front of every cow in the row and carries with it saliva or tuberculous

material which may have been deposited anywhere along its course. The last cow in the row receives water that may have been contaminated by any other cow in the row; and every cow in the row except the first one receives the washings from some other cow's manger. So long as the cows are all in good health this makes little difference, but if a tuberculous cow with virulent saliva is stabled in such a row the infection of the other animals in the stable is greatly facilitated. An individual drinking basin so arranged that the water is automatically kept at a certain level, or a common trough in the open air and sunshine which has running water and from which the surplus water is removed at the surface, is to be preferred.

Any kind of material may be used for the walls of the stable, but the inner surface should be as free from projections and as smooth as possible. The object should be to secure a wall that is easily cleaned and that has few cracks and projections to hold dust and dirt.

The amount of air space required per cow depends upon the effectiveness of the system of ventilation. In a stable with a commodious passageway in front and back of the cows, and with a free space over the partitions of the stables reaching 9 or 10 feet above the floor, there will be space enough if the air is renewed as it should be. There are different methods of ventilation available by which this may be accomplished without producing injurious drafts upon the animals, and the one should be selected which appears most suitable to the kind of structure that is to be erected.

A matter of some importance is to keep the cattle in the open air as much as possible. Not only does this improve the vigor of the animals and enable them better to resist infection, but there are fewer chances of infection at pasture or in open pens than there are in stables. The plan of keeping the cows in stables only at milking time in winter and of turning them into an open shed during the remainder of the time is to be recommended, except in very severe weather.

There should also be special attention given to food which is liable to be contaminated with tuberculous infection. The young calves should be given the milk of cows known to be healthy, or, in case this can not be done, the milk should be sterilized. Sterilization should also be practiced with skim milk fed to both calves and pigs. Hay contaminated with the dust from stables inhabited by tuberculous cattle is dangerous for healthy animals.

The most essential precaution to be observed to prevent the introduction of tuberculosis is to take proper measures to see that any cattle brought upon the premises are free from the disease. Such animals should be tested with tuberculin, but this alone may not be sufficient. Cattle which have been previously tested often fail to react to the tuberculin test even when they are affected with tuberculosis, consequently the herd from which the animals are to be purchased should

be examined as a whole, and if any members of it show signs of tuberculosis it is not safe to receive animals from that herd.

It should be remembered that tuberculosis is a very common disease, especially among dairy cattle, and that it is a difficult matter to add new animals frequently to a herd and at the same time avoid the introduction of this disease. A herd free from tuberculosis should therefore be renewed and increased by its own offspring so far as possible. To bring in animals from other herds, either temporarily or permanently, is to accept a risk that may prove disastrous.

ERADICATION OF TUBERCULOSIS FROM THE FARM.

If there is any reason to suspect the existence of tuberculosis in a herd, an effort should be made at once to determine definitely whether it is present and which animals are affected by it.

The general condition of the animal should furnish some indication. If any of the animals are not doing well, are losing flesh, and fail to yield the amount of milk which is to be reasonably expected, a careful examination should be made of them to determine whether their temperature is normal, whether there are signs of enlargement of the external lymphatic glands, and whether abnormal sounds can be detected in the lungs. The examination of the carcasses of any animals which may have died or are slaughtered is a valuable indication as to the existence of the disease in the herd.

The most reliable means of determining this question is, however, the tuberculin test. While this may occasionally fail to reveal tuberculosis in an individual animal, it may be relied upon with certainty to reveal the existence of the disease in a herd. If this test indicates that some of the animals are tuberculous, measures should be at once adopted to eradicate the disease from the herd, or at least to prevent its further spread. In case there are only one or two animals affected, and these are not especially valuable, the best plan is to slaughter them at once and thoroughly disinfect the stable in which they have been kept. If a large proportion of a herd is affected, and the animals are not especially valuable, the best and cheapest plan would be to separate the reacting animals from the healthy ones, and to have the former slaughtered under inspection as soon as they can be put in proper condition. It is probable that the flesh of most of these animals would be found fit for food, and the loss, therefore, would not be very great. In case the herd has been long affected and many of the animals are in an advanced stage of the disease, they are unfit for milk production, and the sooner they are slaughtered the less will be the loss.

If the herd contains animals which are valuable for breeding purposes, the Bang system of management or some modification of it may be profitably adopted.

The Bang Method of Eradicating Tuberculosis.

What is generally known as the "Bang method" of eradicating tuberculosis[64] is entirely voluntary on the part of the owners and consists essentially in testing the entire herd with tuberculin and in isolating as completely as possible the animals which do not react and which show no physical signs of the disease, and also in isolating the calves from reacting cows and feeding them upon the sterilized milk of reacting cows or upon the milk of cows which have not reacted.

In making the tuberculin test it was found that in Denmark, where approximately 50 per cent of the cows were tuberculous, 22 per cent of the herds tested were entirely free from this disease. In many other herds but a few animals reacted, and it was often an easy matter to put such animals in a separate place until they could be sold. In those cases in which almost all grown-up animals reacted, while most of the young cattle were sound, it was often possible to place the latter in a particular stable for young cattle, as such a stable may easily be made if it is not at hand. The greatest difficulty of isolation occurred when there were both a great many diseased and a great many sound cattle. In this case it was usually necessary to divide the stable by a solid partition. But not infrequently the construction of the stable was such that it was necessary to have doors in the partition to allow feeding or the removal of the manure. This arrangement did not prove to be a good one, as there was too much opportunity for contagion even if the doors were kept shut during the time they were not in use. In some cases good results were obtained even with such unsatisfactory stabling. When the sound animals were placed in completely isolated stables, and especially when these were in different buildings, the result was usually very satisfactory. The best manner of isolation was found to be to place the animals upon another farm from that occupied by those which reacted.

It is not the intention by this plan to exterminate tuberculosis promptly, but to reduce it gradually and without great expense to the owner of the infected herd.

If a stock of heavy milking cattle has been built up by years of selection, or if the herd is purebred, the blood may be retained and the breeding operations continued without interruption. It is in such cases that the method has the greatest value. With ordinary cows it would probably be to the financial advantage of the owner to establish a clean stable for the nonreacting cows and for newly purchased ones, all of which should of course be tested, and to turn off the reacting cows as soon as possible and without attempting to raise calves from them.

In formulating the Bang method it was assumed that animals reacting to tuberculin but showing no evident clinical signs of tuberculosis are in the majority of cases affected but to a limited extent and that

therefore it is not necessary to kill them. They may live and keep apparently healthy for years, their milk as a rule does not contain tubercle bacilli, and by pasteurization every danger of contagion can be avoided. Their flesh, also, will generally be safe for food, and if killed under inspection the dangerous carcasses may be condemned. In the immense majority of cases such cows will produce healthy calves.

Among the reacting cattle there will always be some subjects in which the disease develops, so that they become disseminators of contagion. The reacting animals must, therefore, be separated from the sound ones as thoroughly as possible. The newborn calves must be immediately removed from the stable where the reacting cows are placed, and they must have boiled or pasteurized milk. The sound section should be tested with tuberculin at least once every year, in order that the animals which have contracted tuberculosis in spite of the separation may be removed.

Writing with reference to two of the farms where this plan had been in operation several years, Professor Bang said that in spite of the separation every year several animals have fallen by renewed test of the sound division, some years very few, some years more. It can not be expected that every trace of the contagion will be excluded from the sound section when the two sections are near each other, since there are too many opportunities for the contagion to be carried in various ways, as by people, dogs, cats, rats, etc., and perhaps also through food, as in Danish stables the common hayloft is usually above the stable. Where it has been possible to place the two sections in quite different buildings or on separate farms the results are usually much better.

A MODIFICATION OF THE BANG METHOD.

Ujhelyi,[65] of Hungary, at the last International Veterinary Congress referred to a modification of the Bang method which he had practiced with success in his country.

The basis of the Bang method of tuberculosis suppression, he said, consists on the one hand in separation of those animals which respond to the tuberculin test from the others and on the other hand in artificial feeding of the calves with milk warmed to 80° to 85° C. In Denmark the artificial feeding was usual before, and the great number of dairy associations rendered it possible to return the skim milk pasteurized. The dairy associations in Hungary are, on the whole, smaller, and the purchase of pasteurizing machines can not be carried out; neither is it usual here to feed calves artificially. I have, therefore, while taking the Bang process as a basis for suppressive measures, adopted Hungarian conditions for its introduction upon several larger and smaller estates—that is, the expensive and complicated process of artificial feeding was abandoned and the calves given to be fostered by cows which did not respond to the test. When new drafts of cows arrived, the foster mothers were selected from these; if none could be found unresponsive to the test, the calves were fed by their own mothers, though these might be responsive; and care was taken meanwhile to allow the calves to be with their mothers only while feeding and to remove them from the cow house immediately after weaning. Of these calves fed of necessity, though under proper precautions, by mothers responsive to the test, hardly more, on a yearly average, than 10 per cent were found to react, while of those fed by nonreacting foster mothers the number reacting, on a yearly average, was 2 to 6 per cent—results that, even under the application of the original Bang process, could hardly have been bettered. At least, of the 10,533 young animals

artificially reared and half-yearly examined upon the Archduke Frederic's estate at Magyar-Óvár, 400—i. e., 3.7 per cent—were found to react to the test, while, on the other hand, during my own researches of 7,296 young animals only 239, or 3.3 per cent, reacted. It is to be noted that the examinations on three out of eight estates took place every nine months.

I lately had occasion to introduce and without much difficulty to apply the Bang process of suppression, especially in the form adapted to our peculiar conditions, not only to small establishments of some 70 head, but to places with a stock of 150 to 250 and to large establishments of 400 to 700. But the process has also been applied here in its original form at Mezöhegyes, for instance, on a farm of over 1,000 head, which was completely freed from the disease in four or five years; also, on the Magyar-Óvár estate, on a farm of over 5,000 head, where after five years' treatment three-fifths of the stock are free from tuberculosis.

SUCCESSFUL TREATMENT OF A WISCONSIN HERD.

Russell,[66] of the Wisconsin Agricultural Experiment Station, has given an interesting account of the successful treatment of an outbreak of tuberculosis in a herd of cows in that State. The measures were carried out in accordance with advice received from the experiment station.

Eight years before this account was written a thrifty farmer in one of the eastern counties of the State decided that he could have better cows than those which he then possessed. He did not sell all that he had and buy new ones to take the place of the old herd, but he purchased a few purebred animals that he had reason to believe were better milk producers than his own cows. With this influx of new blood he started, as thousands of dairymen have done, to "build up" a herd by gradual selection of the best animals.

When this purebred stock was first bought it was kept apart from the balance of the herd until three years later, at which time the herd was redivided on a basis of age, all young animals being kept together on one side of the barn, while the mature animals were stabled on the other side.

The following year some of the purebred cows began to fail, and within another year 2 of them died of what later was determined to be tuberculosis. The owner at this time was ignorant of the true nature of the malady, as the slow wasting away of the animals had not especially impressed him. When the character of the disease was ascertained by a post-mortem examination, a tuberculin test of the entire herd was at once made, under the auspices of the experiment station, and the surprising fact established that, with three exceptions (13 out of 16), all of the mature animals in the herd reacted. In addition to this, 3 head of young stock also responded to the test.

Supposing that some of the original cows were infected with the disease at time of purchase, it is probable that the malady was disseminated among the mature animals from 1894 to 1896. In this brief space of time the outbreak had spread so that nearly every mature animal in the herd was more or less involved. This had happened practically unsuspected by the owner.

Believing that in this case it was possible to restore the herd to a perfectly healthy condition and that it could be done with less expense than it would be to kill all the animals that reacted and fill their places with other stock, the following method was proposed to the owner and adopted by him:

Separate at time of test all reacting from nonreacting animals, keeping them practically as two independent herds. Breed these reacting animals under careful conditions, separating the calves at birth from their mothers, feeding them on thoroughly pasteurized milk of reacting cows (or milk from nonreacting animals). All healthy cows, and calves from both affected and healthy sections, to be kept in quarters known to be free from tuberculous contagion. The disposition of the product of the reacting herd may be varied to suit the exigencies of the occasion, but in any case it should be treated by pasteurizing so as to render it innocuous.

The conditions were such as might be found on hundreds of farms. No other building was available in which either the healthy or the affected part of the herd could be kept, and it was therefore necessary to arrange quarters in the original stable so as to prevent contact of one section of the herd with another. This was done by throwing a partition made of a single thickness of boards across the stable. The two sections of the herd were pastured in separate paddocks and watered in dif-

ferent tanks. It was somewhat hazardous to allow direct passage between the two compartments, and also to bring the food for the healthy section through the room occupied by the diseased stock, but such an arrangement under the circumstances was the only practical one that could be instituted.

Before the rebuilding of the herd was begun it was necessary to disinfect the whole stable thoroughly. All litter and loose material were first cleaned out, so as to give better penetration to the disinfectant; then the stalls and mangers were thoroughly washed with a hot solution of lye, the walls and ceilings being treated with a coat of milk of lime (a thin whitewash made from freshly slaked lime).

The first test was made January 2, 1896. On January 10 the herd was divided into two sections, and from that time these divisions were handled as two separate herds. Various animals were disposed of from time to time, and a final test of the entire herd was made in February, 1899. The following table shows the results of the different tests made of the two sections of this herd:

Actual condition of the herd at times of different tests.

Date of test.	Tuberculosis section and its progeny.		Healthy section and its progeny.	
	Healthy.	Diseased.	Healthy.	Diseased.
January, 1896	0	16	18	0
May, 1896	4	14	17	0
April, 1897	11	13	19	0
December, 1897	13	10	23	0
February, 1899	27	7	37	0

In no case did any of the animals, originally pronounced tuberculous, ever fail to react in any of the subsequent tests. It is also remarkable that no case of disease appeared in the healthy section of the herd. One of the striking facts noted in these investigations was the way in which the disease progressed in the individual animals. By 1896, two of the original cows had died. Of the 16 affected when the first test was made, several were killed for demonstration purposes. In 1896 and 1897, four had to be destroyed on account of the progress of the disease; in 1898, two more broke down, and up to August, 1899, one more succumbed.

It was noteworthy in those cases in which the disease gained the ascendency over the animal that the decline was generally rapid toward the last. The animal maintained itself in good condition until some set of causes threw it from a chronic latent tuberculosis into an acute stage. The intense cold of the last winter hastened this change in one case; in two other instances the inciting cause was evidently the strain of calving. A fact of great practical value was that the diseased condition generally remained comparatively quiescent for a number of years, the resisting powers of the body being able to hold the disease germ in check; then a sudden turn for the worse occurred, generally as a result of some external inciting cause.

ERADICATION FROM A CONNECTICUT HERD.

The eradication of tuberculosis from the herd of the Connecticut Agricultural College[26] is also an object lesson as to what may be accomplished by intelligent management of a tuberculous herd.

The healthy and reacting animals were separated and placed in adjacent barns; they also had separate yards and watering places, and at no point did they come in contact, except that the same service bulls were used for both herds. The barn in which the reacting herd was quartered was well ventilated and admitted considerable sunlight. As little passing as possible was permitted. The attendants who milked, fed, and cared for the herds were instructed to wait upon the healthy herd first and later upon the affected herd, and only in this order. The milk from the reacting herd was pasteurized and used for butter making. The calves from this herd were removed when dropped and quartered with the healthy herd.

In this case it was not practicable to remove the nonreacting animals to new quarters and leave the reacting animals in the old quarters, and therefore the old barn was thoroughly cleaned and disinfected with a 5 per cent solution of crude carbolic

acid. The following table shows the gradual elimination of tuberculosis from the herd:

Date of tuberculin test.	Number of animals tested in the herd.	Number of reactions.
December 28, 1898	49	12
May 22, 1899	35	3
December 7, 1899	36	2
April 16, 1900	35	1
November 24, 1900	48	0
March 20, 1901	47	0
February 17, 1902	35	0

It is not known whether the reactions which occurred after the first test were due to too lax a quarantine, to an inefficient disinfection of the old barn, or whether they were incipient cases that developed later. The advisability of testing once or twice a year is apparent.

The successful and rapid eradication of the disease in the herd of the Connecticut Agricultural College shows that the arrangements were well made and the quarantine rigidly enforced. The results of this method are not always so favorable, however, as is shown by the following instance related by Regnér[21] as having been observed in the tuberculosis work in Sweden.

RECOMMENDATIONS OF REGNÉR, OF SWEDEN.

In one locality the struggle against tuberculosis had been kept up for seven years in three herds with the result as shown in the table which follows:

Year.	Number of animals.	Number reacting.	Year.	Number of animals.	Number reacting.
1897	331	258	1901	312	22
1898	197	39	1902	391	15
1899	226	7	1903	408	2
1900	286	14	1904	416	83

Of the animals reacting in 1904, 80 were in a stable where there were only 123 head of cattle. Upon investigating the cause of this remarkable increase in the number of diseased animals it was found that a cow which had reacted in 1897, but after that year had not reacted, and which had been left with the sound stock, had developed open tuberculosis (lung and laryngeal tuberculosis) during the last year and had stood a part of the time at each of the four feeding places.

Regnér is of the opinion that a herd of cattle seriously affected with tuberculosis should not be tested with tuberculin, but that such animals as show signs of the disease by other tests should be removed, and that sound stock should be bred from the apparently sound stock in the tuberculous herd. He gives the following rules, supplementary to perfect isolation, infection-destroying treatment of milk food, and disinfection of cow houses, as deserving special emphasis:

1. That the old stock should from time to time be freed, by the use of clinical and bacterioscopic methods, from individual animals in which tuberculosis has shown itself.
2. That the newborn calves of this stock should be immediately brought to the protected stock.
3. That the raw milk should be taken from the mother with such precautions that exterior infection of it should as far as possible be rendered impossible.
4. That the calf should be tested as soon as possible with tuberculin—the first time when 8 days old, the second time when half a year old, and afterwards once a year.
5. That every animal so tested and found to react should be marked to prevent mistakes in isolating, and that a clinical examination should be held upon any animal whose appearance and behavior (especially in the case of repeated coughing) should give cause for it.
6. That the animals should be exactly numbered (first by earmarks, later by branding the number on one horn) and entered in books.
7. That animals from other stocks, no matter how young, should only be admitted into the protected establishment from stocks free from reaction, or, in case that this presents insurmountable difficulties, from other stocks only with certain precautions.

According to Regnér's observations a single incautious purchase for a herd free from reaction may in a short time bring to naught the the result of a year's or of many years' work devoted to rooting out tuberculosis in that herd. The condition generally made that the purchased animal should be free from reaction is not sufficient in itself. Should the purchased animal come direct from a stock well known to be free from reaction, and which has been for years subject to protective precautions, and should the animal have been born and reared in that stock, then all is well. In any other case the purchaser must demand such information as to the stock from which the purchase is to be made as may clearly show the prevalence of tuberculosis. The stock must therefore be tested and the result laid before the purchaser. Should the farmer decide to purchase from an infected herd animals free from reaction, and which have also been tested clinically with negative results, he would do well to disinfect the animal after its arrival at his farm, above all with regard to the hoofs and the lower part of the legs, and if possible keep it half a year in quarantine. Should local conditions not admit of this, the animal should be placed in a stall apart from the others and must not be removed from its place until it has undergone a new testing with a double quantity of tuberculin, which in any case must be made after the interval mentioned.

Immunization in Connection with the Bang Method.

It appears probable from the results which have been published of recent researches, the more important of which have been summarized above, that the immunization of bovine animals will be of great assistance in freeing a herd from disease when practiced in connection with the Bang method. In this case the young cattle which do not react to the tuberculin test, and all of the calves when a week old, would be given an immunizing injection and removed to a stable free from infection. If the method selected requires that two doses should be given, the second dose should be administered to the animals in the uninfected stable after a proper interval of time has elapsed. As several months

are required for the development of the immunity after the vaccine is injected, it is essential that there should be complete isolation from infected cattle during this period, as required by the Bang method.

It appears that calves may be very successfully immunized, but it is not certain that this is true of grown cattle, and therefore the tuberculin test and isolation must be relied upon with the adult animals. The duration of the immunity is yet uncertain, and for this reason it is difficult to estimate the degree of assistance which will be rendered by immunization.

The immunization of cows, assuming that investigations show that this may be successfully accomplished, would raise the question as to the danger which this method might cause to the consumer of the milk. The immunizing material is the human tubercle bacillus which has not been deprived of all its dangerous qualities, and when this is injected into the blood it causes an elevation of temperature and perhaps other signs of illness. Is there danger of this bacillus contaminating the milk during the period that it is circulating in the blood of the animal? And, further, does the illness caused by the immunizing dose of the vaccine have any injurious effect upon the composition of the milk which might render this liquid injurious to the consumer? These are questions of a serious nature, and they should receive a scientific answer before the immunization of milk-producing cows is practiced.

Assuming, for the moment, that the immunization of milch cows is practicable and proper, it would follow that all nonreacting animals should receive an immunizing injection when they are placed in the isolated stable. This should guard against the continued appearance of the disease in the healthy section of the herd, as has been so frequently the case where perfect isolation could not be maintained.

It is not probable, however, that isolation of the healthy animals can be altogether dispensed with. The long period which is required for the development of the immunity would make the chance of infection far too great if the nonreacting vaccinated animals remained in the same stable with those which were diseased. If, however, the vaccination were conducted during the season of pasturage, and the animals stabled only during milking, and particularly if but a small proportion of the herd reacted, it seems probable that the isolation might be omitted without serious consequences.

Experience with immunization is, as yet, so limited, and so many of the accounts published appear to be biased by commercial considerations, that it is too soon to predict definitely the extent of its usefulness as a practical measure for the control of tuberculosis. If it aids in any degree in eradicating this disease, or in lessening the burden which falls upon the owners of diseased herds, it will be a most welcome addition to our resources.

DESTRUCTION OF REACTING ANIMALS AND CREATION OF A SOUND HERD.

The objection to the Bang system and to all modifications of it is the length of time that tuberculous animals must be kept on the premises, injuring the reputation of the herd and causing much extra work in caring for two herds, sterilizing milk, and taking precautions to prevent infection of the healthy animals. It is true that the prescribed precautions are not always carried out, and equally true that in such cases there is usually not very marked success in getting rid of the disease. For this reason it has been considered best, where the cattle have no special value for breeding purposes, to slaughter reacting animals, and disinfect the stable and thus immediately to stamp out the disease. Most dairymen prefer this plan as the more economical of the two.

The eradication of tuberculosis from the herd of the Maine Agricultural College[67] is a valuable example of what may be done by this plan.

Since some years before 1886 until within two years, whenever the college has kept any cattle on the college farm some of them have been affected with tuberculosis. Before 1886 cattle occasionally died from this disease or, in absence of exact knowledge of their condition, were sold for beef or otherwise disposed of on account of age or unthriftiness. Well-bred young animals were sold to improve other herds and sometimes carried tuberculosis with them.

In 1886 the cattle were so badly diseased that it was considered best to kill the entire herd. After the herd was destroyed the barns were disinfected with some care and no new stock was introduced for about a year. In 1889 considerable new stock was purchased from different sources, and in less than a year from the time they were purchased two of the animals were found to be diseased and were killed. Again the barn was disinfected, but new cases of disease were frequently being discovered in the herd.

In 1892 tuberculin became available for the detection of tuberculosis, and experiments were soon made at the college to test its value.

By 1893, having become convinced of the value of tuberculin, every bovine animal on the farm down to the youngest calf was tested, and those that reacted to the test were killed. This made a large hole in the herd and required the sacrifice of some of the most valued animals, but it is believed the results have fully justified the course taken.

In order to meet the demands for dairy products it was considered necessary to replace the cows killed, and ordinary grade and native cows that answered the requirements were purchased from near-by sources. Every precaution was taken to procure sound animals, and before they were introduced into the barns they successfully passed the tuberculin test, but as it was late in the fall and the barn was full of hay and grain it was not considered practicable to disinfect the barn. The lintel was disinfected, but not the rest of the barn until the following summer.

During the winter of 1893–94 and the following spring several cases of tuberculosis developed, some of them being cows purchased the fall before from healthy herds, and, according to every known test, healthy animals themselves. They must have contracted the disease in the college barns. In the summer of 1894 the barn was disinfected, and since that time comparatively few cases of tuberculosis have been found, the last case being discovered in the fall of 1897. In 1896, the barn was again disinfected in a very thorough manner. Since then but two cases have been found, and both of them were discovered before it was possible that they should have infected their surroundings or other cattle. Since October, 1897, no new case has been discovered, although the entire herd was tested in 1897 and again in 1898. It is believed that since October, 1897, the herd has been entirely free from tuberculosis for perhaps the first time in its history. The herd now numbers 51 head of all ages, most of these bred on the farm.

The method of disinfection by which the barn was freed from the contagion is of much interest:

All the hay, grain, and farming tools were removed from the barns, the only exception being the hoes, shovels, and forks that had to be used there. Every mov-

able thing that had been in the barn with the diseased cattle, or after the diseased cattle were removed, before the barn was disinfected, was taken out, or, if left in the barn, was disinfected in the same manner as the barn itself. Then with brooms all dust and dirt that could be moved was swept into the basement or out of doors into the sunlight. Then with a hand pump mounted on a barrel, such a pump as is commonly used in spraying orchards or potato fields, the disinfecting solution was thrown with considerable force against every inch of the woodwork of the barn, into every crack and crevice where dust, laden with disease germs, might lodge. The workmen commenced in the roof and worked downward, making thorough work of it as they went along. By using the pump this was not a very expensive operation. Including the cost of the material and labor, the expense of cleaning and disinfecting a barn 50 by 100 feet with 18-foot posts and basement was about $25. This did not include the cost of the pump, which was but little injured, and had before and has since that time been used for other purposes. The disinfecting solution was made by dissolving 1 part, by weight, of corrosive sublimate in about 1,000 parts of water. The pump was mounted on a 50-gallon barrel and a little more than ½ pound of the sublimate was used for a barrel of water. The pulverized corrosive sublimate was purchased and this was dissolved in hot water, as it dissolves very slowly in cold water. The sublimate and its solution should be kept in glass or wooden vessels; it corrodes metal. The solution is poisonous if taken in sufficient quantities, so it should never be left uncovered where animals can get at it.

Another means that has been used in keeping this herd free from tuberculosis has been the testing with tuberculin of all animals purchased. By this means the purchase of diseased animals that were satisfactory in other respects has been avoided. When convenient the animals purchased were tested before they were brought to the farm. In other cases they were tested on the college farm before they were admitted to the barns with the other cattle. In two cases the introduction of tuberculous cattle into the herd was avoided by this very simple precaution.

A thorough disinfection is necessary, and this should be practiced immediately after the diseased animals are removed from the stable. Russell and Hastings[31] say that it is manifestly useless to eradicate this disease from a herd unless at the same time the infected quarters are subject to a thorough disinfection. One case that came to their attention sufficiently illustrates this point. Within the past two years a herd of cows was tested and the larger part of the herd condemned by the test and slaughtered. A post-mortem examination showed many of them to be badly diseased. A short time afterwards a new herd was purchased and introduced into the same quarters. In less than a year it was found that many of this second herd had also acquired this same disease. Undoubtedly they contracted the same from the infected quarters in which they were placed.

In order to carry out such a disinfection there should be first a thorough cleaning with brooms to remove all litter and dust, not only from the floor, but from the walls, the roof, and all projections where dust may lodge. All loose boards and decayed woodwork should be removed. The floor of the stable should be washed with water and the mangers and stalls with a hot solution of lye. The whole interior of the stable should then be sprayed with the disinfecting solution. Every crack and crevice should be filled with disinfectant and every part of the walls should be covered. There are many different kinds of spray pumps which are available for this purpose.

Poisonous disinfectants or those having a strong and lasting odor should, if possible, be avoided. A thin lime wash made from freshly burned lime is the most satisfactory disinfectant to use about a stable.

Its activity may be increased by the addition of 4 ounces of formalin to 1 gallon of lime wash. Corrosive sublimate and carbolic acid are often recommended for this purpose, but as both are dangerous poisons, and as the latter has an objectionable and persistent odor, it is deemed best to use lime wash and formalin, which probably are just as effective in destroying the tubercle bacillus.

In adding new animals to the herd they should be tested with tuberculin before purchasing, and then, if possible, they should be kept in a separate stable for six months and afterwards tested a second time before they are placed with the healthy cattle. This precaution will usually be sufficient to prevent the reinfection of the herd by the purchased animals. It should be remembered, however, that some of the animals of the herd which did not react may nevertheless have been infected, and to detect any cases of this kind there should be a second test made of the entire herd in about six months. If any reactions occur, the reacting animals should be removed and the stable disinfected as before. The herd should be tested at least once a year for two or three years after the last reaction has occurred.

With hogs the eradication of tuberculosis from a badly infected herd is a difficult matter. The best course to pursue is probably to destroy the entire herd, thoroughly disinfect the pens, and after a few months to start with a new herd known to be free from disease. A boar may be retained from the old herd, if considered very desirable, but it should be kept isolated from the new herd except during service. For the same reason it is well to keep newly purchased boars similarly isolated. This simple precaution may often prevent the infection of a herd. The increasing prevalence of tuberculosis in swine emphasizes the importance of precautionary measures being adopted by the breeders of these animals.

STATE AID FOR THE ERADICATION OF TUBERCULOSIS.

In the eradication of a disease so widely disseminated, and one which causes such serious losses to the animal industry of the country, there should be assistance offered by the State in order to relieve the burdens which fall upon the owners of live stock. A considerable number of States have shown a disposition to come to the assistance of farmers whose stock is affected, but the assistance has sometimes been coupled with conditions which made it unwelcome. In some States compulsory testing and the slaughter of reacting animals have been required, but this has not been a popular measure. It is essential that a plan should be devised which will meet with the approval of the stock owners and which will aid them without being too burdensome in its conditions. There are certain measures which have been adopted by individual States which have accomplished satisfactory results, but which would be far more successful if adjoining States would adopt the same or similar regulations. Among the reasonable measures

which a State may adopt for the repression of tuberculosis the following may be mentioned:

1. Cattle which are brought into a State for breeding or dairy purposes may be tested with tuberculin, and those which react may be refused admission to the State. In connection with this measure it should be provided that cattle which have been tested by the authorities of another State or of the Federal Government and found free from disease should be allowed admission without being retested. The testing of animals coming into a State is essential in any effort to control this disease, and is one of the first measures which should be enforced in any effort to eradicate it.

2. There should be an inspection of all slaughtered animals coming from breeding or dairy herds within the State in order to discover in what herds the disease exists. Animals from the greater part of the milk-producing herds are being continually sold for slaughter as their usefulness in the dairy is over, and an examination of the carcasses of these cows would serve to locate the existence of the disease in many herds where its presence is unsuspected. Unfortunately few of the animals killed in the small slaughterhouses are inspected, and in those cases where there is an inspection and tuberculosis is discovered it is seldom that the herds from which they came are traced and the owners informed of the discovery of this disease. In any effort to suppress tuberculosis it is almost essential that information of this kind should be obtained and an attempt made to persuade the owner to adopt proper measures for getting rid of the contagion.

3. Measures should be adopted for testing herds with tuberculin without expense to the owners. In the beginning of the work, at least, this should not be compulsory, but it should be made to the interest of the owner of a tuberculous herd to have it tested under the auspices of the State. Apparently it would also be wise and a great aid to stockmen for the State to test herds with tuberculin and certify to the healthfulness of animals from all those herds where no reactions occur. At present it is a difficult matter in most States for the breeder or dairyman to purchase cattle for his herd with any assurance that they are healthy. He may have them tested, but there is always a possibility that they have been treated with tuberculin a short time before and that for this reason they have not reacted. The loss which has fallen upon the breeders of the country through the introduction of tuberculosis in their herds has been tremendous, and it appears that it would be only a proper aid and encouragement to agricultural interests to assist breeders in obtaining animals free from disease. Not only would this encourage farmers to enter into breeding operations and increase the value of the industry within the State, but the certification of breeding animals would help to build up a market in other States for breeding animals.

4. In order to encourage the owners of cattle to eradicate tuberculosis, States should allow a reasonable compensation for the animals which it is necessary to slaughter on account of being affected with this disease. It is certainly a matter of great importance to any State to have its herds free from tuberculosis and its animals and animal products above suspicion. With the recent demonstration of the communicability of animal tuberculosis to man, a demonstration which has been made by so many investigators and on such competent authority that the fact can no longer be questioned, there is a disposition on the part of sanitary authorities to scrutinize more carefully those animal products which are liable to be infected. It is, therefore, becoming every day more important for every State to repress tuberculosis within its borders and in that manner to maintain the reputation of its animal products. Where it is not deemed advisable to provide for slaughtering of all reacting animals with sufficient compensation from the State to make this measure satisfactory to the stockmen, the State may provide for the supervision of herds handled according to the Bang method or some modification of it. For the protection of its own citizens who consume dairy products, if not for the protection of its customers in other States, every State should make some arrangement which would lead to the removal of cows with tuberculous udders, and those suffering from generalized tuberculosis, from herds which supply milk, cream, and butter for human food. This much is essential for the public health, but it would be wise to go further and provide for the slaughter of all cows which show evidence on physical examination of being affected with tuberculosis.

5. In cases where cattle owners are to have their tuberculous animals slaughtered in an effort to free their herds from disease the State should further assist them by disinfecting or at least supervising the disinfection of the contaminated stables. It is a somewhat difficult matter for persons not acquainted with the practical operations of disinfection to carry out this measure successfully, even after they have been given explicit instructions. It is impossible to impress sufficiently the importance of thoroughness upon persons who are lacking in experience in this line of work. As a consequence the majority of the premises disinfected by stockmen without the assistance of experts are imperfectly disinfected, and the disease breaks out again among the animals which are subsequently introduced. This is discouraging to the owner and serves to fix the impression that it is impossible to eradicate tuberculosis. This impression is already widespread, but it is essentially wrong, though it can only be removed by object lessons in the eradication of the disease under State supervision. There is no reason why tuberculosis should not be eradicated as pleuro-pneumonia was eradicated. The contagion is more widespread and the expense would be greater, but there are no inherent difficulties to prevent the success of such an undertaking.

6. When a herd has been freed from tuberculosis by the slaughter of all reacting animals, and the premises have been properly disinfected, the State should give further aid to the stock owner by testing without expense the animals which he desires to purchase for renewing his herd. This measure is essential to the success of any plan for lessening the prevalence of this disease or eradicating it. The expense of testing such animals is almost too great to be borne by the individual, and, moreover, private tests are often unsatisfactory and unreliable.

FEDERAL COOPERATION FOR THE ERADICATION OF TUBERCULOSIS.

The aid of the Federal Government is essential to the success of any efforts for the eradication of tuberculosis. The disease may be held in check by the exercise of the authority of the individual States, but the action of the States has been too spasmodic and not sufficiently general and harmonious to have much effect upon the prevalence of the disease in the country at large. There is needed a systematic plan of repression which shall be generally applied.

At no time has there been more public interest manifested in measures for reducing the mortality from tuberculosis in human beings than the present. Societies for furthering such measures are being formed in every part of the land and a propaganda of education is being conducted on a magnificent scale. It has already been shown that human tuberculosis and animal tuberculosis are communicable between persons and animals, and that a not inconsiderable proportion of the cases of human tuberculosis, and especially of the tuberculosis of children, is caused by infection from animal sources. It is important to the success of the efforts against human tuberculosis, therefore, that the continuous infection of human subjects by contagion from the lower animals should be prevented. The present is, consequently, an opportune time for the Federal Government to extend its aid to those States which are willing to cooperate for this purpose. Not only would such action be an aid to agriculture, but it would at the same time serve as a protection to human life.

The lines of work which the Federal Government might undertake may be formulated as follows:

1. Infected herds of cattle and swine could be readily located through the meat-inspection system and through the tuberculin tests that might be required for cattle that are to be shipped from State to State or to foreign countries. The meat-inspection service offers a magnificent opportunity for the discovery of affected herds by tracing the diseased animals, which are discovered daily, back to the farms upon which they were raised. There are probably but a small proportion of the shippers of tubercular hogs who know that they have this disease in their herds, and the evidence of the fact, which is discovered in the

abattoirs, is never brought to their attention. It is also true, as is proved by examples already given in these pages, that a herd of cattle may be affected for a long time and a large proportion of its members be diseased before the owner becomes aware of the existence of tuberculosis. A systematic effort on the part of the Government to discover the disease, followed by the communication of the information both to the owner and to the proper State authority, would prove of great value in furthering this work.

2. The Government might also very properly test with tuberculin breeding animals intended for interstate shipment upon the request of the owners and under suitable conditions. By doing this it would be preventing the interstate shipment of diseased animals, and at the same time adding greatly to its resources for discovering infected herds.

It would be a most important step to test breeding herds and certify to the healthfulness of animals from those which proved to be free from disease. There must be a large proportion of American herds which are not affected with tuberculosis. In Denmark, where 50 per cent of the cattle were affected, 22 per cent of the herds were entirely free from the disease. In the United States, with less than 5 per cent of the cattle infected, there should be at least 80 per cent of the herds in a healthy condition. This being the case, it would be of great importance to the owners of the vast majority of herds to have an inspection and to receive certificates showing the healthfulness of their animals. On the other hand, there could be no greater inducement to the owner of a diseased herd to put it into healthful condition than the fact that his herd was not registered as free from disease and that he could not obtain certificates as to the health of his stock.

3. It is doubtful if it would be advisable to cooperate with State authorities with a view to the compulsory slaughter of tuberculous animals. This work has succeeded better where the owner has voluntarily participated in eradicating the disease; and it appears important that he should be interested financially in accomplishing this object. The Government may stimulate this interest by testing his cattle without expense and by giving him expert advice as to the measures to be used in eradicating the disease. It may also agree to compensate him liberally for any animals which are found diseased and which it may be necessary to slaughter. But it probably should not cooperate with the States on the lines which were followed with pleuro-pneumonia and foot-and-mouth disease with a view to compel him to accept its terms. In some of our States and in several European countries the repression of tuberculosis is being conducted with considerable success by measures which are voluntarily accepted by the owners and which secure their cooperation not only in getting rid of the disease, but in guarding against a reinfection of the herd.

A departure from old methods, and one which promises valuable results, has been made by the Swedish Government, which, since November 1, 1903, has been engaged in forming breeding centers for cattle, one of its objects being to promote the industry by breeding animals free from tuberculosis. The formation of breeding centers for improving the live stock of certain sections of the country has already been discussed in the United States, and such a movement might well receive the encouragement of the Government and include within its sphere the development of herds free from tuberculosis.

Any or all of the measures enumerated are worthy of consideration in this connection. The prosperity of the live-stock industry in the United States will depend, for years to come, upon foreign markets for animal products. If we can compete in those markets in price, in quality, and in reputation for healthfulness, we shall continue to sell our meats; otherwise we shall lose the trade. It is not an age when markets can be held without striving for them; competition is fierce, and already our bacon and dressed beef trades seem to be yielding to the attacks of our competitors. Tuberculosis in our herds increases the cost of producing meat, and if other countries outstrip us in practical work for its eradication, as seems probable from efforts now in progress, that fact will be used to our disadvantage.

Fortunately the percentage of tuberculosis in our herds is still relatively low, and the conditions under which live stock is raised in this country are favorable for the eradication of disease. When public sentiment favors the eradication of tuberculosis in animals the task will not be found an impossible one.

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