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The tuberculosis of swine constitutes a definite and very interesting section of the general problem of the tuberculoses of warm-blooded animals. No one section of this general tuberculosis problem can be adequately solved without regard to all the other sections into which it may be divided. The disease in swine is perhaps the most outstanding example which illustrates this point. This animal, extremely susceptible to tuberculous disease, but without a type of infection specifically its own, derives its infection by contact with any of the types of tuberculosis of warm-blooded animals. Influenced above all by the artificial limitations placed upon the life period of domesticated swine, it is the one animal which on the whole does not contract tuberculous disease by contact with infected members of its own species. While the actual occurrence of transmission of tuberculous infection from swine to swine is freely admitted, the fact remains that the preponderating portion of tuberculous hogs obtain their infection from some other animal species.

It is not possible to eradicate tuberculosis completely from one species without eradicating it also from the others. In the tuberculoses of cattle and of poultry this may be somewhat of a hypothesis, but in the disease of swine it is a reality resting upon solid ground. Just as long as we have bovine, avian, and human tuberculosis, there will be tuberculosis of swine for the same reason that the elimination of human tuberculosis can never be complete as long as bovine infection remains as a real or potential source of mischief.

HISTORICAL

Our knowledge pertaining to the history of tuberculosis in swine is exceedingly meager and up to as late as 1875 no record can be found to show that any swine disease had been definitely identified as tuberculosis by scientific methods. It may be surmised, however, that the disease existed in swine from ancient times. The early domestication of the hog, its mode of feeding, and its habitual association with poultry, cattle, and man, with their high tuberculosis morbidity, per-

mits no other conclusion. The assumption of the antiquity of tuberculosis of swine receives further support from the etymology of the word "scrofula." The affection known under this name being common in swine (scrofa = sow) it is but natural that the name of the animal so frequently affected should have become the root for a name for a disease in man quite comparable to that in swine. It is a matter of fact that Aristotle mentions this disease as common in swine in his *History of Animals*. The term "scrofula" no doubt has also been applied to morbid conditions not identified with tuberculosis, but in the light of our present knowledge it can scarcely be doubted that this infection is at the root of a preponderating number of cases.

There was, however, no light thrown on the subject during the age preceding 1875, when Roloff rendered the first scientific description of the disease. In 1876 Semmer transmitted tuberculosis to a hog by means of an inoculation with bovine material and thus by actual experiment proved the connection which may exist between the disease of those species.

After the discovery of the tubercle bacillus in 1882, tuberculosis of swine became better known and gradually its relation to the tuberculosis of other animals began to be fully understood.

In many sections of the world where swine growing is a part of agricultural practice, the disease greatly increased after creameries became common and the skimmed milk and centrifuge sediment became a highly desirable feed for swine. For many years the bovine source of infection was the only one looked upon as of importance in explaining the occurrence of the disease. It was, of course, known that human tuberculosis could also be transmitted to swine with a considerable degree of facility.

In 1904 it became known that avian tubercle bacilli may have a causal relationship to swine lesions and in the years following the experimental proof of the susceptibility of swine to the bacillus of poultry tuberculosis was amply established.

For several years it was not thought that avian infection was at all an important source of swine tuberculosis, but in due course of time evidence came to light showing that indeed in some sections it may be a more prolific cause of tuberculosis among hogs than bovine infection. The latest information on this subject was furnished by this Experiment Station,[1]

[1] *An Inquiry into the Cause of the Increase of Tuberculosis in Swine.* Nebraska Experiment Station, Research Bulletin No. 30, February, 1925.

which during the last two years carried on some extensive investigations on the nature of certain types of swine tuberculosis.

The result of those investigations can be summarized as follows:

Total number of consignments examined	250
Shipments with negative results	31
Shipments discarded	2
Shipments showing tuberculosis of probable avian origin	8
Shipments permitting definite conclusions	209

Results obtained with the latter:

Infection types	*No.*	*Per cent*
Mammalian	11	5.21
Avian	185	88.51
Mixed	13	6.22
Total number shipments	209	99.94

No doubt if similar experiments were conducted in various parts of the world there would be marked differences in the results obtained. The kind of tuberculosis of swine is largely dependent on the type of infection to which the animals are most exposed. The Nebraska data, however, demonstrate most clearly the extent which avian infection may assume when circumstances are favorable for the exposure of swine.

GEOGRAPHIC DISTRIBUTION

Tuberculosis of swine can be found in all countries where the growing of cattle, hogs, and poultry go hand in hand and where bovine and avian tuberculosis are at all prevalent. Even without those common and prolific infection sources the contact of hogs with human cases would probably prevent any section of the country from being entirely free of swine tuberculosis.

MORBIDITY

The prevalence of tuberculosis among the swine population of the world is but imperfectly known. Only if extensive meat inspection results are made available can any opinion be formed with regard to the morbidity rate of the disease. Imperfect and incomplete as they are, the following data on morbidity may be of interest:

Great Britain. At the abattoirs at Brighton the percentage of swine tuberculosis was 2.73 per cent in 1913, while at Birmingham it was 2.7 per cent, and at Glasgow 5.6 per cent. Of 8,632 hogs slaughtered during the same period in different

parts of the country, 989, or 11.5 per cent, animals were affected with tuberculosis.

In *Holland, Belgium,* and *Luxemburg* the percentages of tuberculous hogs found upon slaughter, according to locality and year, range between 1 and 10 per cent.

Denmark shows a high morbidity rate for swine tuberculosis, and at the Copenhagen abattoir the toll during 1906 went as high as 27 per cent.

In *Sweden,* on the other hand, the morbidity rate of swine tuberculosis dropped from 9.75 per cent in 1905 to 4.20 per cent in 1907, as a result of the practice of sterilization of creamery by-products.

In *Germany* the percentage of hogs retained for tuberculosis in 1921 was 1.99 per cent and in 1922 it amounted to 2.13 per cent. The maximum morbidity was reported from Saxony with 3.82 per cent and 4 per cent for the years mentioned.

In *Hungary* the percentages obtained at the abattoir at Budapest range between 1.41 per cent and 2.6 per cent for the years of the period 1903-1913.

France shows a low morbidity rate for hog tuberculosis, the highest percentage being 0.33 in 1912.

In *New Zealand* 5.89 per cent of more than one hundred thousand swine slaughtered during 1907 were found to be affected with tuberculosis.

Tuberculosis of swine is common in the *Argentine Republic.* At the abattoir of Buenos Aires 4,319 swine of 48,077 slaughtered during 1905, or 8.98 per cent of the total, were found to be tuberculous.

As the following table on page 7 shows, tuberculosis of hogs has enormously increased in this country during the last 15 years.

The morbidity within the United States, no doubt, varies greatly in accordance with the locality, its type of agriculture, and the morbidity of bovine and avian tuberculosis of the various sections. It is high for the corn and dairy states, with their heavy hog population. The factor of avian infection appears to have been responsible for the great increase of swine tuberculosis in a large area of the country. Of nearly 2,000,000 hogs slaughtered in Wisconsin during 1923 more than 24 per cent were found to be tuberculous and for the first 6 months of 1924 the retention percentage ran even higher.

The prevalence of swine tuberculosis in Nebraska is indicated by the number of retentions at the packing center of South Omaha. The retentions for 1924 amounted to 13.70

Number of swine slaughtered during period 1907-1922 and number of animals retained and condemned. (Table prepared from data published in Yearbook of U. S. Department of Agriculture for 1922, p. 217.)

Year	Slaughtered	Retained		Condemned	
		No.	*Per 1,000*	*No.*	*Per1,000*
1907[1]	26,189,026	362,445	13.83	48,544	1.85
1908	35,113,077	719,279	20.48	77,554	2.20
1909	35,427,931	860,425	24.28	45,113	1.27
1910	27,656,021	792,176	28.64	28,880	1.04
1911	29,916,363	1,117,789	37.36	31,517	1.08
1912	34,966,378	1,643,100	47.00	42,267	1.21
1913	32,287,538	1,809,751	56.05	47,632	1.47
1914	33,289,705	2,201,005	66.11	48,252	1.44
1915	36,247,958	2,774,835	76.55	66,023	1.82
1916	40,482,799	3,687,817	91.09	74,109	1.83
1917	40,210,847	3,978,168	98.93	76,807	1.91
1918	35,449,247	3,494,587	98.58	59,740	1.68
1919	44,398,389	4,103,376	92.42	65,837	1.48
1920	38,981,914	4,262,719	109.35	65,609	1.68
1921	37,702,866	4,693,305	124.48	64,830	1.71
1922	34,416,439	5,640,061	163.87	70,304	2.04

[1]Covers 9 months from October 1, 1906, to June 30, 1907.

per cent of the hogs killed during the year. Apparently the morbidity of swine tuberculosis is improving in Nebraska and has receded from nearly 17 per cent a few years ago to the present level.

ECONOMIC IMPORTANCE

The actual money losses occasioned by swine tuberculosis cannot be accurately estimated for the country and state as a whole. That the losses are a conspicuous part of the annual waste occasioned by animal diseases there cannot be any doubt. The losses in federally inspected abattoirs on account of condemnations and retentions are only an indication of the importance of the disease, and to those losses must be added the ones sustained by local butchers and the ones occasioned by deaths and unthriftiness of the swine on farms.

In one abattoir, handling Nebraska swine largely, the annual loss occasioned by hog tuberculosis alone amounts to $180,000. It comes to $162,000 in another establishment, to $100,000 in a third, and to $35,000 in another packing house, all in accordance with the number of animals killed.

As far as can be estimated, the actual cost per hog slaughtered cannot be less than 16 cents per head for Nebraska swine and as much as 25 cents to 30 cents per head for Wisconsin.

If we accept the smaller figures as the average cost for the country at large, the loss sustained by the farmers of the United States by retentions at packing centers cannot be far from $5,600,000 per year. When to this item is added the losses among swine not killed under federal supervision, and the ones on farms occasioned by deaths and unthriftiness, the total loss caused by swine tuberculosis in this country cannot be far from $9,000,000 per year.

The actual money loss to Nebraska farmers arising from this source cannot be estimated at less than $1,000,000 per year. For one large market alone it has been calculated that Nebraska shippers would for every week of the year take home with them $10,000 more than they do now, if hog tuberculosis could be eliminated from their herds.

CAUSE

Tuberculosis of swine as well as that of all other animal species is caused by the presence, growth, and multiplication within the tissues and organs of the body of a specific germ, commonly designated as the *Bacillus tuberculosis*.

This organism occurs in the shape of straight or slightly curved rods, which may vary in length and thickness. Usually the length varies between one twelve-thousandth and one five-thousandth of an inch and in thickness between one seventy-five thousandth and one fifty-thousandth of an inch.

The ends of these microscopic rods are somewhat rounded and their substance has frequently a more or less beaded appearance. The germ is not endowed with the power of motion and it is not capable of forming spores.

In the tuberculous tissues the germ is always present, altho in variable numbers. Sometimes it can be readily shown to be present in great quantity, and then again the number is so small that it can be demonstrated by special methods only. In the body and body discharges it occurs either singly or united in groups, in which the bacilli are apt to lie side by side.

The bacillus of tuberculosis is not readily stained by the dyes commonly in use. Special methods are required for the purpose, but when this is once accomplished the organism retains the dye with the greatest tenacity. This feature is

taken advantage of in order to differentiate it from other bacteria when tissue and discharges are to be examined for its presence.

The tuberculosis germ can be grown on artificial culture media, but it always grows very slowly, and especially so immediately after its isolation from the animal body and before it has adapted itself to the new conditions. It grows best at the temperature of the animal body and in the presence of air.

The addition of a small amount of glycerin to the culture medium materially promotes its growth.

Two varieties of the tubercle bacillus share in causing the disease in swine. They are the bovine and the avian types. Swine are also very susceptible to infection with the human type, but there is no evidence to show that this is a common cause of swine tuberculosis in our state.

The bacilli found in tuberculous lesions of swine thus may show variations in accordance with the type to which they belong. Accordingly, when we have to deal with the bovine type we may expect to find the following characteristics:

On coagulated blood serum or on glycerin agar there appears toward the end of the second week a growth of very small, dull, grayish-white and dry granules. As the growth advances, the latter become surrounded by a lighter colored zone which becomes confluent with those in its vicinity until the whole surface is covered by a continuous layer,— dry, wrinkled, rough, and loosely adherent to the surface. The organism presents the same features when grown on glycerin potato, but there it is inclined to be drier and more crumbly. Cultures on glycerin beef broth present at first a delicate film on the surface, but this layer gradually thickens as the growth advances. When a maximum of growth has been reached, the thick layer becomes folded and corrugated and shows a tendency to extend itself on the side of the flask. The broth, however, remains clear thruout.

Bacilli of the bovine type are quite virulent for most mammals and especially for the guinea pig and the rabbit, while on the other hand fowls are quite resistant to this strain of bacilli.

When the lesions contain the bacillus of the avian type and when the latter is brought under artificial cultivation, it shows upon investigation, a capacity to grow and thrive at higher temperatures than any of the mammalian types. Most of the avian strains are characterized further by a smooth, moist,

and more or less slimy growth on the solid media thus differing from the cultures of mammalian bacilli, which have a tendency to be dry, raised, scaly, or corrugated.

Grown on glycerin serum they show in about ten days colonies of the shape of small white waxy spots, which enlarge in size and become confluent to form a whitish scum which can be readily removed from the medium. In the older cultures the growth becomes more slimy and of a somewhat fibrous texture, at the same time assuming a yellowish color.

In liquid media, such as glycerin-bouillon, they have a tendency to grow in the shape of a fine, whitish powder, which fastens itself to the sides and bottom of the flask and often forms a white pellicle on the surface. This pellicle may have a somewhat dry appearance in older cultures. The avian bacillus seems more capable of growing in depths of the liquid media than the one taken from the mammals.

The avian strain of tubercle bacilli is virulent not only for a considerable assortment of bird species, but also to certain mammals, including swine and rabbits. Guinea pigs, on the other hand, are quite resistant to the avian tubercle bacilli and often it is quite impossible to infect them with this organism.

The tubercle bacillus, no matter to what strain it may belong, does not multiply outside the body of its host. It is an obligate parasite requiring narrowly circumscribed conditions for its propagation.

On the other hand, it shows a considerable power of resistance against many of the factors which are adverse to germ life. Drying destroys the germ but slowly, and dried tuberculous material was found to be still virulent after from 102 to 180 days.

The bacilli contained in animal tissues were found to be alive after 167 days' burial in the soil, and cultures placed in water retained their virulence for 70 days. The germ remains alive in milk for 10 days, in sweet cream butter for 28 days, but in sour cream butter for only 10 to 15 days.

Direct sunlight is quite active in the destruction of tuberculous virus, and when the infection is present in a thin layer of transparent material it is rapidly destroyed when exposed to the sun's rays. The latter, however, are not very active on the virus when this is contained in anything but very thin layers or when the surrounding material is opaque. When kept in diffused sunlight the organism succumbs in from 5 to 7 days.

Low temperatures have no effect on it. Even a temperature of 350 degrees Fahrenheit below zero was not capable of killing the infection when the latter was exposed to it for periods ranging from a few hours to as much as 8 days.

On the other hand, the *Bacillus tuberculosis* is readily destroyed by heat. Boiling water or live steam completely sterilizes tuberculous material, either moist or dry, in from 5 to 15 minutes. When, however, dried tuberculous material is exposed to dry heat of the same temperature it requires an exposure of one hour before sterilization is complete.

Tuberculosis germs contained in milk are killed in one minute when heated to 150 degrees Fahrenheit in closed vessels. When heated in open vessels an exposure of 6 minutes to a temperature of from 158 to 176 degrees Fahrenheit was not sufficient to destroy the virulence.

The salting and smoking of tuberculous meat has only a slight effect on the organism and tuberculous organs are occasionally found to be virulent after pickling for 6 weeks.

Disinfectants destroy the bacilli with a varying degree of speed, but on the whole they are quite slow in their action and especially so when the germs are contained in tissues and excretions.

Carbolic acid in 5 per cent solution kills the bacillus in 5 minutes. The saponified cresols (liquid cresolis compound) have a similar action, while iodine and chlorine are more energetic. Corrosive sublimate and formaldehyde in solutions of one per cent kill in one hour. All those data, however, pertain to the action on cultures of the organism. When the latter is contained in the tissues, discharges, or stable filth the action of the disinfectant is much delayed and for many of them an exposure of from 2 to 24 hours would be necessary to make disinfection complete.

VIRULENT MATERIAL

When we speak of virulent material in connection with tuberculosis we generally have in mind any substance containing living tuberculosis bacilli capable of reproducing the disease when introduced into the body of a susceptible animal. The virulent materials represent thus the media in which the bacilli are contained. So far as the animal body is concerned, virulent materials may be classed in two principal groups. One of these consists of the fixed lesions of the disease and the other of substances which contain bacilli and which leave the body as excretions or secretions.

Tuberculosis in the majority of cases is a localized disease, which means that the body is not usually pervaded by the virus thruout, but that the latter is more or less confined in the lesions which characterize the disease. Bacilli are especially numerous in recent or young lesions and when the latter have become caseous or calcareous the number of germs present is commonly more or less reduced.

It would be a mistake, however, to suppose that the presence of bacilli in the body is necessarily always followed by the formation of lesions. In a small number of cases bacilli may be present without lesions or tubercles arising as a consequence. In such cases, the number of bacilli is usually small, altho the opposite is sometimes the case. Bacilli are likewise bound to be present from time to time in the lymph and bloodstreams.

There is reason to believe that as long as the lesions remain intact the bacilli are held imprisoned within them. When, however, the tubercles soften and tissue destruction takes place, the bacilli find their way into the various secretions and excretions and by them are conveyed out of the body. These substances constitute the virulent materials of the second group and owing to the part they play in transmission of the disease they require special mention even if in the tuberculosis of swine the tendency of their playing an important part in the spread of the disease is far less than in the case of bovine or poultry tuberculosis.

Of importance in this connection is the discharge which issues from the respiratory tract in cases of tuberculous lung disease. This must always be regarded as the principal means by which the germs of tuberculosis are eliminated from the body. Contained in the discharge mentioned, they may be directly cast out during coughing fits or by the slower discharge of mucus thru the nostrils.

This is, however, by no means the only avenue open to this virulent material for its escape from the body. In fact, the greater part of respiratory discharge is neither coughed out nor expelled thru the nose but is swallowed by the animal concerned; and while the mucus and other matter which constitutes its bulk may be subsequently digested, the bacilli for a large part are not affected by the process and appear in the feces alive and fully virulent.

Owing to this feature, therefore, the manure of animals affected with lung tuberculosis must be looked upon as being of an infectious nature. Needless to say, in tuberculous diseases of the intestines or the liver the same means of exit is open to the infection.

The milk must always be regarded as being infectious when udder tuberculosis is present; and even in cases of tuberculosis in other parts of the body, but with no appreciable udder lesions, the milk is frequently contaminated by the bacilli.

VEHICLES OF INFECTION

The possibility of swine becoming infected by a direct contact is indeed very small, and as a general rule the virulent materials find their way to the food or other substances in the environment, by means of which they may be taken into the body. Milk of tuberculous cows always has been an important vehicle by which tuberculosis can be introduced into a herd of hogs.

The discharges from the bowels, the lungs, or other parts of the body of infected cattle, poultry, or even swine scattered in stables and yards in which swine are apt to pick up their food are common means by which the infection is carried from animal to animal and even from place to place.

Carcasses of animals, especially of cattle, poultry, and swine themselves, as well as various types of slaughterhouse wastes fed in the raw state, are likewise excellent means for the conveyance of tuberculous infection. Table wastes and garbage may serve as a vehicle for the human tubercle bacillus in its transmission to hogs.

MODES OF INFECTION

The animal body presents various portals thru which the infection of tuberculosis may be introduced. The most common of these are the respiratory and alimentary tracts. Infective dust and droplets may be directly inhaled or be introduced into the pharynx, from which they can be readily passed into the digestive organs with the food.

Contaminated food and drink can introduce the bacilli directly into the intestinal canal, whence they are conveyed to other parts of the body thru the lymph and blood streams. Bacilli so introduced, entering into the substance of the intestinal wall, are apt to pass on without producing any lesions in those parts, altho occasionally they become localized and cause tuberculosis of the parts concerned.

Other avenues of penetration, such as the genito-urinary tract, the eye, the skin, and navel wound, while quite possible, are so uncommonly followed by the infection that they require but little consideration in connection with tuberculosis of swine.

In the light of our present knowledge, there is good reason to believe that in swine there is only one important mode or avenue of infection and that is thru the alimentary canal. The bacillus tuberculosis, thru infected food, enters the body by the mouth and from there, especially by the lymph channels, reaches the various organs in which the lesions are to be found.

In this infection mode consideration must be especially given to milk of infected cattle herds, to creamery wastes and by-products, to the exposure to which hogs are subjected when "following" the cattle in feeding yards, to feeding in lots and pens frequented by tuberculous poultry, and to the eating of carcasses of livestock including poultry as well as the offal of slaughtering establishments.

While the transmission of tuberculosis directly from swine to swine is apparently very uncommon, its possibility must be admitted and especially in connection with tuberculous brood sows, which are apt to infect their litters by means of the milk.

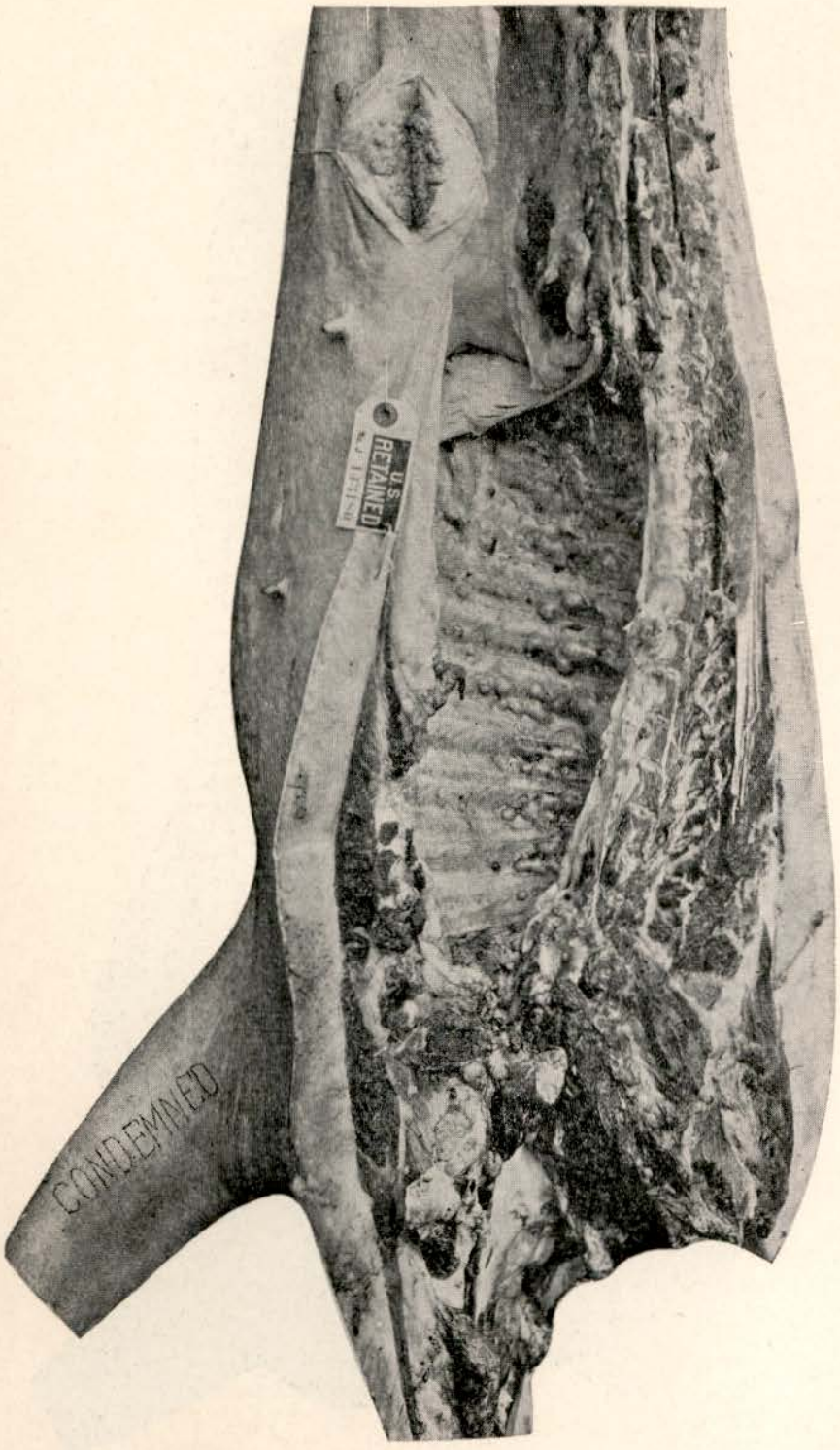
Human tuberculosis may likewise be communicated to hogs thru infected foodstuffs, among which uncooked garbage and table wastes occupy a prominent place.

There is no evidence to show that the respiratory passages are common avenues for the tuberculosis infection of swine, but on the other hand there is no good reason to believe that this possibility must not be given consideration. The dust of infected cattle or poultry yards as well as that of stables may serve as a means of bringing about respiratory infection in swine as well as in other animals.

Other modes of infection appear to play but little part in swine tuberculosis, altho infection which entered thru castration wounds is occasionally seen. Such an infection may be of human origin and be the result of the contamination of the wound by the spittle of a tuberculous pig gelder. Or a recent castration wound may become infected in yards or stables by bacilli of bovine or avian origin, which in all probability is what most frequently happens in cases of this nature.

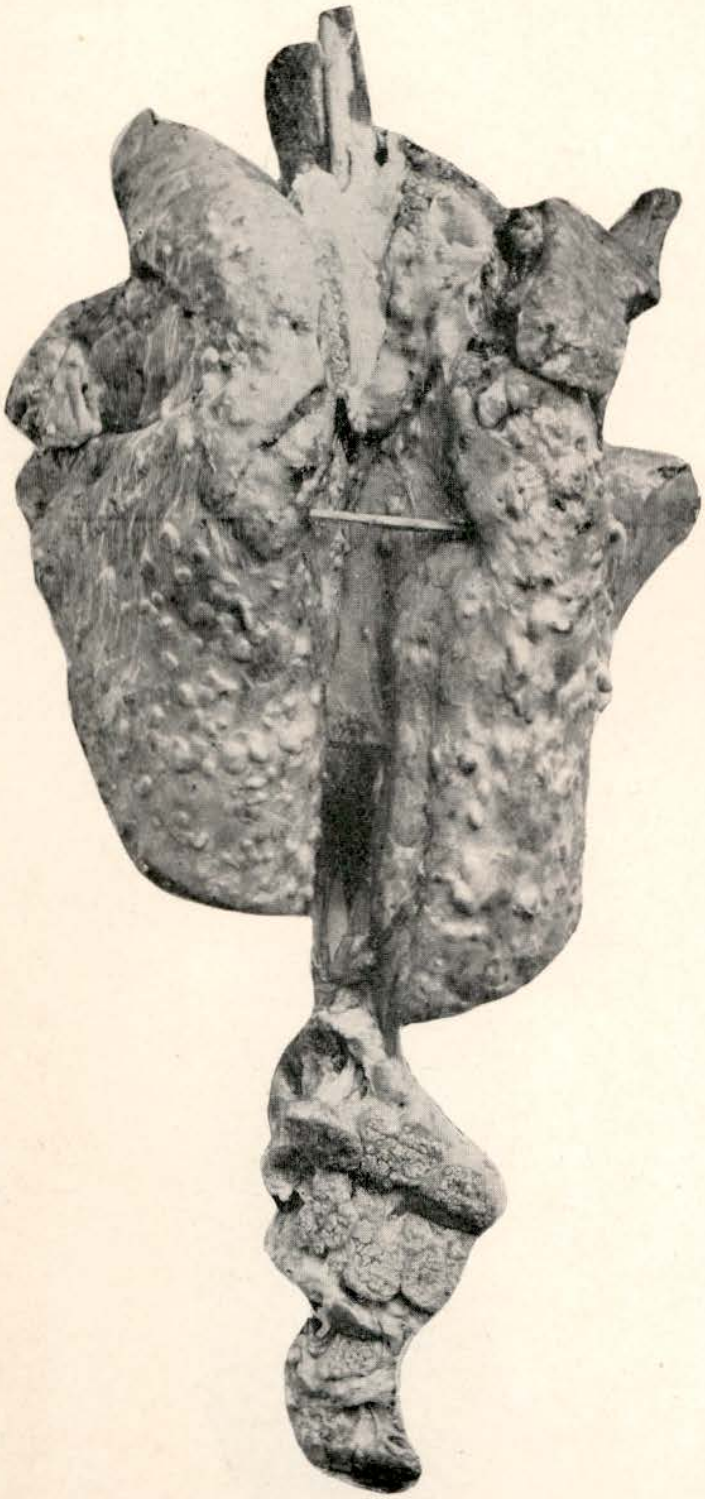
PREDISPOSING FACTORS

Tuberculosis is always primarily caused by the tubercle bacillus and without the latter the disease is utterly impossible. Any factors, however, which tend to increase the possibility of the infection must not be overlooked, when the pre-



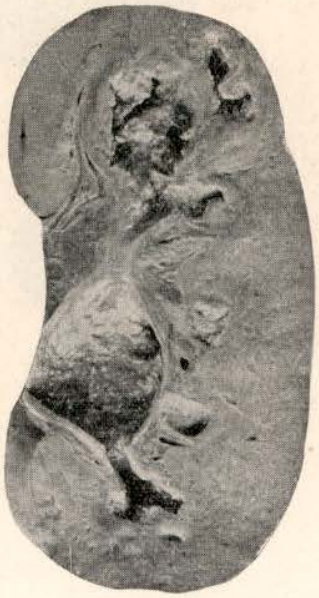
Half carcass of hog affected with generalized tuberculosis

Extensive tuberculous lesions of cervical chain of lymphnodes. Head partially severed, but still attached



Tuberculosis of lungs and mediastinal and bronchial lymphnodes. The lymphnodes attached to lung below are the portal ones, also affected with tuberculosis.

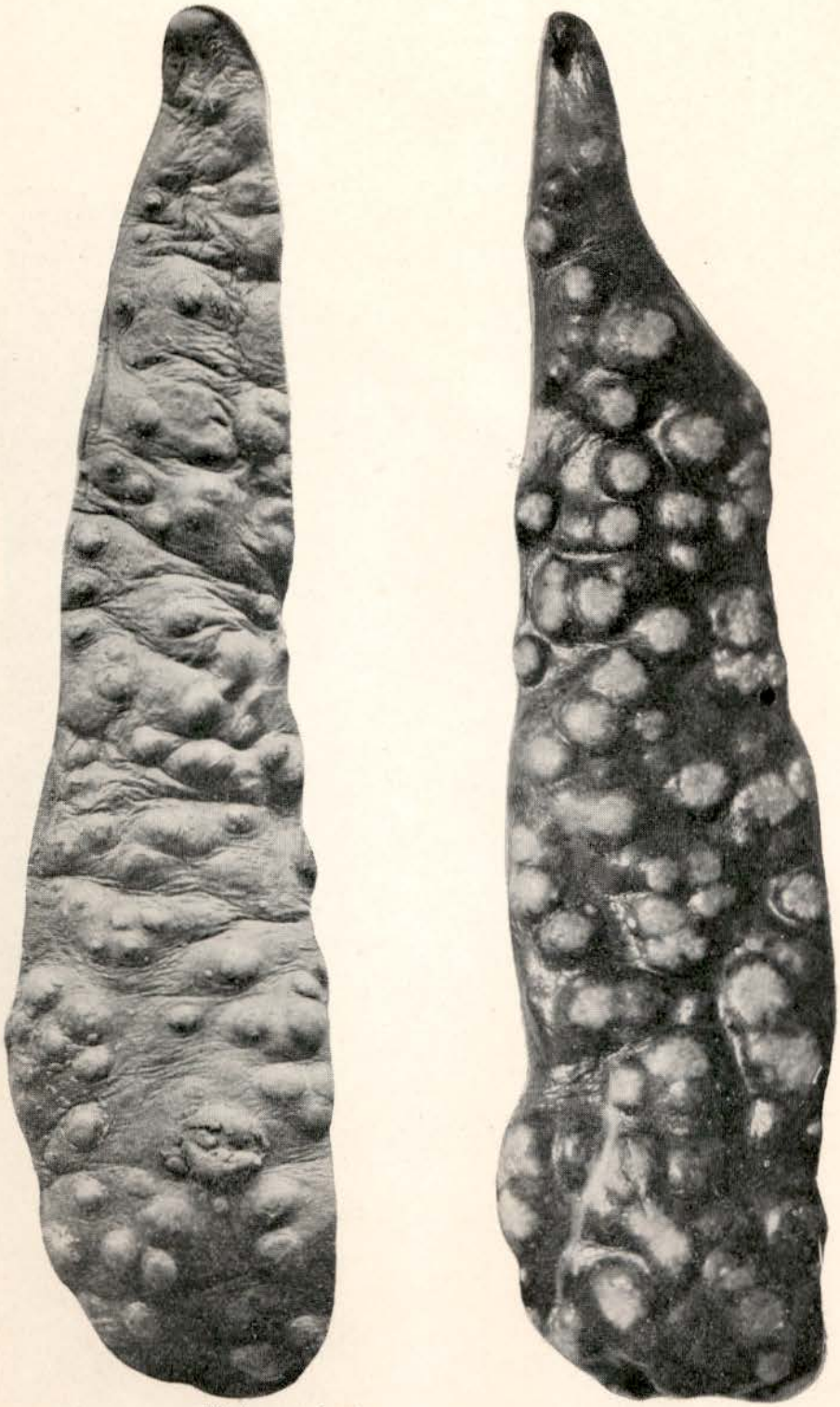
Pulmonary tuberculosis of hog



Tuberculosis of kidney of hog

Tuberculosis of liver of hog. Miliary type

Tuberculosis of spleen of hog



Tuberculosis of spleens of hogs

Reaction to tuberculin, skin test. (After Moussu)

vention of tuberculosis is to be undertaken. They are the so-called predisposing factors, and while in the tuberculosis of swine they do not play a part as important as in the propagation of the bovine and human disease, some consideration must be given to them.

Foremost among them is the influence of age. Many observations indicate that the younger swine show the greatest susceptibility. In young and old, the liability to contract the disease is quite marked; but while upon artificial infection the adult animal shows its resistance by a greater tendency to a localization of the lesions, by an arrest in the progress of the dissemination of the infection thruout the body, in the young pig the disease is far more inclined to assume a progressive type.

It has also been noted that the highly improved breeds contract the disease more readily than the ones of a less refined character.

Not all predisposing factors are associated with the animals themselves. In the case of swine the presence of tuberculous cattle and poultry on the same farm, above all, constitutes an important influence by which the chances of infection are greatly increased.

Unsanitary conditions in general have the same tendency and their elimination has its place among the measures directed against tuberculosis as well as against the other diseases to which swine are liable.

LESIONS

The formation of nonvascular cellular nodules or tubercles must be recognized as the most characteristic feature of tuberculosis. These nodules are the result of local inflammatory processes set in motion by the presence and vital functions of the invading germs.

In this process the connective tissue elements of surrounding tissues as well as the cellular constituents of the capillary blood vessels proliferate and group themselves as a spherical mass. The cells composing this microscopic nodule take on an epithelium-like character and often contain one or more bacilli in their interior. Either by the nuclear division of those epithelioid cells or by the fusion of a number of them, large cells with many nuclei arranged in a peripheral position are formed and are quite a characteristic of tuberculous lesions. Such cells are known as giant cells.

The microscopic nodule soon becomes surrounded by a zone of small, round cells,— leucocytes which have migrated from the blood vessels of the immediate vicinity. These cells increase in number, penetrate between the epithelioid and giant cells, and finally constitute the preponderating elements of the tubercle. At that stage the tubercle may be said to be fully developed and can be seen by the naked eye.

However, no sooner has this stage been reached than degenerative changes in the center of the tubercle become apparent. Owing to a lack of nutrition and to the presence of toxic substances produced by the bacilli, the central cells perish and their disintegration gives rise to the formation of a granular, cheesy material which at a later period may or may not become infiltrated with lime salts, so that the structures involved either become calcareous or remain caseous.

A fully developed tubercle appears as a nodule of the size of a millet seed, grayish in color, transparent and quite firmly adherent to the surrounding structures.

Even after the caseation has begun it may increase in size by the further migration of cellular elements or it may become fused with the adjoining ones. As the process of caseation keeps pace with the development or fusion of the tubercles a considerable amount of cheesy material may come about.

Masses of cheesy or calcareous material are commonly found to be surrounded by a more or less dense connective tissue capsule, an arrangement which tends to isolate the tuberculous focus from the remainder of the body.

The tubercle just described may be regarded as the fundamental unit of all tuberculous processes; but as one examines the various organs affected with the disease, the appearance by which the latter expresses itself are not the same under all conditions.

This is the result of modifications arising from the structure of the organs affected, the location of the disease, or the avenues by which it was disseminated thruout the body. While all tuberculous lesions are thus essentially of the same nature, the variations in their aspects have led to the recognition of various types.

One of those is known as miliary tuberculosis, a name suggested by the fact that in this type a considerable number of small (millet seed sized) tubercles are scattered thruout one or more organs. This type of lesion indicates that bacilli were conveyed at one and the same time to the parts involved by means of the blood current.

When the organs involved have become changed into a voluminous, dense mass of light or chrome yellow color, we may speak of the lesion as being a cheesy or cheesy-calcareous infiltration. This type, not infrequently met with, is associated with affected lungs and lymphnodes.

Structures presenting this type of lesion may ultimately undergo softening by the breaking down of the tuberculous mass, and then cavities may be formed.

Another type, known as fungoid granulomatous, may be observed when tubercles develop from a free, usually a serous, surface. In such cases there is a progressive and luxuriant growth of nodules, appearing as large nodular growths of grayish white or grayish pink or yellowish pink color.

There is a common tendency for the lesions to be extended to other parts. This may come about by the mere continuity of tissues or by distribution of the infectious agents by the blood and lymph streams. In the former case the infection slowly invades the parts adjacent to the initial lesion. Lesion complexes thus arising are usually designated as local ones, while in the cases in which the bacilli are carried to the more remote parts of the body, the term generalized tuberculosis frequently finds application and especially so when the blood stream was responsible for the transportation of the organisms. It is, however, not always possible to ascertain with any degree of exactness how the distribution of the lesions came about.

Tuberculous lesions of swine may be associated with any organ or tissue of the body, but while none are entirely exempt, there is a great difference in the frequency in which they are found to be affected. Some organs practically always participate in the disease, while in others it is extremely rare to discover evidence of the disease.

In tuberculous swine the lymphnodes are the organs most commonly affected and tuberculosis of those parts only is more frequent in the animal mentioned than in any other. Owing to the fact that the disease in swine is as a rule of alimentary origin, the lymphnodes associated with the digestive tube or receiving its lymph are the ones most commonly involved, altho no lymphnode of the body is exempt.

In a number of the affected lymphnodes, the organ is at first not notably enlarged, but when sectioned a few tubercles or nodules are found to be situated in the lymphatic tissue. From those small centers a process of caseation and calcification is extended outward, until there form within the lymph-

node, grayish yellow specks and areas sometimes surrounded by a transparent tissue.

It is not always easy to recognize those initial changes, but as the tuberculous process extends and the lymphnodes become enlarged the tuberculous character of the lesions becomes quite manifest. Usually this comes about by the various tuberculous areas becoming confluent, altho frequently they remain separated by the development of a thick fibrous connective tissue in which the caseous-calcareous material remains confined and which prevents further enlargement.

In other forms of lymphnode tuberculosis the structure enlarges from the first by an apparent increase of its cellular elements. Those are next subjected to a rapid caseation in which the whole lymphnode may eventually become involved. The cheesy mass either becomes dry and hard by the infiltration with lime salts or softens into a greasy pus-like mass kept confined by the capsule of the lymphnode.

As under ordinary circumstances the life of swine is quite limited, tuberculous processes do not always reach the state of development which they reach when the animals involved are permitted to attain a greater age. In such older cases the lymphnodes of the neck, being commonly the ones first infected, may become changed into nodular swellings, often quite hard on account of the density of the thickened, fibrous capsule which surrounds them. Those tumor-like masses are, especially by the older writers on the subject, referred to as "scrofula." It is not uncommon for them to break thru on the surface and thus discharge their softened, caseous content.

The lesions produced in lymphnodes as well as in other organs by the tubercle bacillus of the bovine type are apt to be more progressive and destructive, and while avian infection no doubt is also capable of producing marked and typical tuberculous changes, the latter are very commonly limited to the cervical and mesenteric lymphnodes and even in those they are commonly of a rather benign character.

In view of the fact that the tuberculosis of swine is nearly always of alimentary origin, the absence of lesions from the various sections of the digestive tube is noteworthy. On the other hand, the alimentary origin of the disease is well shown by very common involvement of the lymphnodes which receive the lymph drain from the digestive organs. Apparently the tubercle bacilli enter and leave the digestive apparatus without causing any damage in those parts.

Damage of a tuberculous nature is, however, occasionally encountered in connection with the alimentary tract, and this may consist of tubercles and ulcers of the tongue, the pharynx, the tonsil, and the walls and mucous membrane of the intestines.

Tuberculosis of the liver is by no means uncommon and the lesions presented by that organ may consist of a considerable number of small nodules scattered thru the organ or of larger, rounded tuberculous formations, more fibrous and denser in nature and usually present in smaller numbers.

The spleen in tuberculous swine with a varying degree of frequency shows lesions of a nodular type, the nodules being either softened and cheesy or hardened and of a fibrous, calcareous nature.

Less frequent is tuberculosis of the kidneys, while tuberculous disease of the reproductive organs of swine may be regarded as somewhat rare. In connection with tuberculosis of the abdominal organs involvement of the peritoneum is sometimes observed. This usually manifests itself by the presence of numerous small nodules projecting from the free surface.

Tuberculosis of the lungs is usually of a secondary nature and is characterized either by the presence of a more or less pronounced number of tuberculous nodules or by a caseous pneumonia involving considerable areas of lung tissue. Such lesions are always accompanied by marked changes in the bronchial lymphnodes and in the mediastinal ones also when the pleura shares in the infection. In the latter case there are either small tubercles projecting from the surface or larger spongy masses of a more conglomerate type.

Tuberculosis of bones and joints is frequently seen and is often associated with parts of the vertebral column and the ribs; also the bones and joints of the limbs are by no means exempt from tuberculous disease.

Of the more uncommon localizations of tuberculosis of swine, mention may be made of the mammary gland, the nervous system, the eye, the inner ear, and the skin.

SYMPTOMS

In only a relatively small proportion of the cases is it possible to identify definitely tuberculosis in living swine. No doubt certain manifestations of ill health may arouse the suspicion of tuberculosis being its cause, but as a rule the great majority of cases of tuberculosis among swine remain un-

recognized until discovered by the meat inspector or butcher at the time of slaughter. To a large extent the chronic course of the disease as well as the relatively short duration of the life of swine mitigates against the disease more frequently proclaiming itself by clear-cut symptoms.

Among the general signs of tuberculosis in swine there may be noted: a certain degree of unthriftiness followed by a decided loss of flesh; the mucous membrane becomes pale; the animal becomes dull, and after a time remains hidden under its bedding, while in accordance with the organs principally affected there may or may not be observed a rather distressful cough.

The condition which most often permits the recognition of the disease is that presented by the lymphnodes of the neck and head when they are involved in that form of tuberculosis which older writers were apt to designate as " scrofula." In such cases there are nodular swellings of the neck and between the branches of the lower jaws. Such enlargements are commonly hard and often fused to the surrounding tissues. The swellings are not tender upon pressure altho the affected animal is inclined to keep its head rigid as if painful to move it. In a number of such cases the enlargements become fluctuating and upon incision or spontaneous rupture yield a thick, cheesy, or purulent mass in which bacilli may be found. After such an evacuation there is a tendency of a fistulous opening to remain.

In tuberculosis of the abdominal organs, digestive disturbances expressed by alternating diarrhea and constipation may be observed and occasionally the enlarged mesenteric lymphnodes may be recognized by the manual examination of the abdomen which at the same time may be found to be painful upon pressure.

In marked disease of the liver the tuberculous formations may in a small number of cases also be felt thru the thin abdominal wall of wasted animals.

Tuberculosis of the lungs is most frequently shown by a dry, suppressed cough. Later on, this cough becomes more frequent and is apt to occur in regular paroxysms often followed by vomiting. At the same time there is either rapid or difficult breathing and the animal gradually loses in weight and vigor. Such symptoms, however, are seen in a number of other pulmonary infections of swine.

Tuberculosis of the bones of the spinal column may give rise to paralysis on account of involvement of the spinal cord,

but commonly it escapes observation altogether. Tuberculosis of the bones and joints of the limbs on the other hand is commonly manifested by substantial enlargements of the parts concerned.

Acute miliary tuberculosis is also very difficult to recognize as such. In common with other more or less acute infections it is accompanied by fever, rapid and difficult breathing, severe loss of flesh, and diarrhea.

Localization of the disease in such parts as the central nervous system, the eye, the inner ear, and the genito-urinary organs is scarcely ever recognized in the living animal.

DIAGNOSIS

While the progressive loss of flesh and certain other evidences of disturbed health in swine belonging to a herd in which tuberculosis is known to have occurred justifies the suspicion that the animals concerned may be affected with the disease, definite proof of its actual existence can only be rendered by more precise and specific methods of diagnosis.

Among those methods is included the microscopic demonstration of the tubercle bacillus in such discharges as are coughed up from the lungs or as can be secured by the puncture of enlarged lymphnodes. The finding of the typically stained tubercle bacillus establishes the identification quite definitely.

This method may be supplemented by the use of laboratory animals, inoculated with the type of material mentioned or secured at autopsy as the case may be. The inoculation method of diagnosis is particularly useful when the microscopic examination fails to reveal the presence of bacilli. Ordinarily the guinea pig is used for this purpose, as this animal is particularly susceptible to the disease. Various investigations, among them the ones recently reported by this department [1] especially applying to Nebraska swine, indicate, however, that in the case of the swine being infected with the bacillus of avian tuberculosis the identity of tuberculous infection may escape attention altogether if guinea pigs are the only animals used in the test. It is now well known that the cavia has but little susceptibility for avian tuberculosis. Thus, if tuberculosis is to be identified as such in swine by animal experiment it is necessary to use animals susceptible

[1] See *An Inquiry into the Cause of the Increase of Tuberculosis of Swine*, Nebraska Experiment Station, Research Bulletin No. 30, February, 1925.

to mammalian tuberculosis and animals susceptible to avian tuberculosis or animals which are susceptible to both. The simultaneous use of guinea pigs and fowls as test animals will, no doubt, yield the clearest indication of value in diagnosis. Rabbits, susceptible to infection by the bovine as well as the avian strains, are useful as test animals but are unsuitable for the identification of lesions which are the result of infection by the human type of tubercle bacillus.

The methods of diagnosis by microscopic examination and animal inoculation are, however, of no great value when the existence of the disease is to be searched for in the living animals. The majority of infected animals do not yield any material which can be used in laboratory tests even if the latter could find common practical application. Such tests may be valuable in scientific investigations and for the purpose of solving special problems, but as long as we have in the tuberculin test a very practical and sufficiently accurate means for the identification of tuberculosis in swine, they require no further consideration as a means of diagnosis.

TUBERCULIN

Tuberculin consists of a sterile extract of the cultures of the tubercle bacillus grown on broth. It is prepared as follows: The bacillus is grown for a period of from 2 to 3 months on a specially prepared broth containing 5 per cent of glycerin. When a suitable growth has thus been obtained, the flasks containing the cultures are exposed to the heat of running steam for 2 hours, during which time the bacilli are killed and some of their component parts extracted.

At the termination of the heating, the bacilli are separated from the broth by filtration. The clear fluid thus obtained, which represents the original broth and such bacillary products as entered in the solution, is then placed on an evaporating bath and kept there until its volume is reduced to one-tenth of the original one. The liquid obtained at the termination of this process constitutes the concentrated tuberculin and presents itself as a brown, syrupy, limpid, clear fluid having the pleasant aroma or fruit-like odor characteristic of cultures of the tuberculosis germ.

The concentrated tuberculin forms the base of the various tuberculins used in the detection of the disease. Since the discovery of tuberculin several methods of tuberculin testing have been developed. They are the subcutaneous or thermic

test, the intradermic or skin test, and the ophthalmic or eye test.

For the diagnosis of tuberculosis in swine the intradermic or skin test is to be given preference. In such a test a small quantity (0.1-0.2 c.c.) of tuberculin is injected into the substance of the skin by means of a fine needle. In swine it is convenient to select the skin of the ear near its base as the point of injection. The parts should be carefully cleansed before the injection is made. If the animal tested is not affected with tuberculosis, nothing unusual will be observed at the point of inoculation, but when the disease is present there will come about a swelling, reddish near the center, and varying in size and intensity. The swelling can, as a rule, be recognized 24 hours after the injection and reaches its maximum about the forty-eighth hour, which is a suitable time to make and record the observations. The skin reaction usually persists for 2 or 3 days. In severe reactions a superficial sloughing of a small area of the skin may be one of the results.

In connection with the application of the tuberculin test in swine it is of great importance to remember that when the infection happens to be due to the avian bacillus, a tuberculin of mammalian origin will in a considerable number of cases of tuberculosis fail to reveal the presence of the disease, and that in the same manner an avian tuberculin will not by any means always disclose the existence of a mammalian tuberculosis in the animal tested. In the testing of swine, therefore, two tuberculin injections should be made in each animal,—one with an avian tuberculin in the skin of one ear and another with a mammalian tuberculin in the skin of the other.

It seems, however, possible that the testing procedure in swine could be simplified by the use of a mixture of equal parts of the two tuberculins mentioned. There is as yet no evidence that this has ever been thoroly tried out.

FORECAST AND TREATMENT

As with the tuberculosis of most of our domestic animals, the disease in swine nearly always pursues a chronic course. Depending on the type of tuberculosis with which the animals are infected, the disease assumes a more or less progressive nature or is marked by lesions which remain localized and which detract but little from the animal's normal state of health.

When bovine infection has been transmitted to swine the latter as a rule sustain a rather virulent type of the disease,

leading to ill health, unthriftiness, and death if the animals are not marketed before the lesions become generalized and profuse. On the other hand, avian infection is more commonly followed by a more benign form of tuberculosis. No doubt, in quite a number of cases of avian infection, there may come about a progressive generalized tuberculosis, but not by any means with the regularity with which this happens thru mammalian infection.

In a fair proportion of cases of avian infection in swine the bacilli succumb after having caused small, initial lesions, and no doubt if such hogs were permitted to live they would ultimately recover from the disease. For practical purposes, however, such occasional recoveries can be disregarded.

There is no treatment which in the least influences the course of the disease or by which an ultimate recovery can be secured.

PROPHYLAXIS

In spite of the great susceptibility of swine to the three types of tuberculosis found in warm-blooded animals and the many facilities for the spread of the disease, there is good reason to believe that the prevention of swine tuberculosis can be accomplished with a considerable degree of completeness.

In the prevention of tuberculosis in swine two important factors must be given close attention. One pertains to the possible sources of infection and the other to the method by which a swine herd is being managed.

The sources of infection are fourfold, namely: First, tuberculous cattle; second, tuberculous poultry; third, tuberculous swine; and fourth, tuberculous man. The two sources named first are of preponderating importance while the two named last must not be overlooked altho they may be comparatively inert.

Both cattle and avian infection are very prolific of mischief, but the writer is not prepared to say that one is to be feared more than the other. It is probably correct to state that bovine infection is the cause of most of the outright condemnations at our markets, while avian infection is, no doubt, responsible for the greater number of retentions.

The above pertains particularly to the hog tuberculosis found in a large section of the United States, of which Nebraska is a representative part as far as its soil and type of agriculture are concerned.

Altho convinced of the great importance of bovine tuberculosis as a source of the disease in hogs, the writer can not escape the conclusion that if the avian source of swine tuberculosis were eliminated, the losses to Nebraska farmers arising from this disease would indeed be reduced to small proportions.

In the consideration of means and measures for the prevention of swine tuberculosis, it should be understood that while they must be mentioned separately, they should all find application simultaneously.

The infection of hogs from tuberculous cattle comes about in two ways, in the first place by the feeding of milk from tuberculous cows and in the second place by hogs " following " cattle in feed yards where tubercle bacilli are scattered about by means of the dung of infected animals. The means of control thus consist, above all, in eliminating cattle affected with tuberculosis. If there is no certainty that the cattle of a given farm are free from tuberculous infection, the milk of such animals should not be fed to hogs, while the latter should not be kept in the same lot or pen with the bovines concerned. No matter how important avian infection may be in many sections of the country, tuberculous neat cattle must be eliminated as an important and never failing fountain of infection of swine. Only after a tuberculin test of the cattle herd has established its freedom from tuberculosis should swine be admitted in the same yard for any purpose whatever.

The milk products of such a herd are safe to use as feed for pigs; but without this precautionary tuberculin testing, milk should not be fed unless previously sterilized or pasteurized. By-products of creameries, butter factories, dairies, and cheese factories should never be fed to swine in the raw state as long as bovine tuberculosis has not been eradicated from the herds contributing to such industries or from the territory in which they operate.

All measures applied against bovine tuberculosis will tend to reduce the disease in swine in proportion to the existing morbidity of the cattle disease.[1]

In the prevention of the spread of tuberculosis from poultry flocks to swine, the all-important factor again is the eradication of the fowl disease. The details of this have already been discussed in literature issued by this station.[2] Not

[1] See *Bovine Tuberculosis.* Nebraska Agricultural Experiment Station Circular 23, February, 1924.

[2] See *The More Important Poultry Diseases.* Nebraska Agricultural Experiment Station Bulletin 195, October, 1923.

only as a means of preventing serious losses among our poultry, but also as a means of making our hog raising more profitable, should this matter be given the most thoro consideration.

Another factor having its place in the prevention of swine tuberculosis is the advisability of doing away with the promiscuously perambulating poultry flock on our farms. There was a time when it was safe and proper to give a chicken flock the freedom of the farm, but that was before we had our present number of fowls and before poultry tuberculosis had reached its present day prevalence.

Poultry, like swine, should be kept in enclosures changed from year to year so as to give the soil time to free itself from microbic and parasitic mischief makers and to prevent tuberculous birds from depositing their droppings, usually rich in bacilli, into the feed and watering troughs of the pigs. Even the plea of economic maintenance in favor of the free wandering flock breaks down when consideration is given to the fact that the preventable loss of swine by tuberculosis of avian origin costs Nebraska farmers not far from $750,000 per year and that in addition the losses of poultry attributable to soil-born diseases of different kinds cannot be less than the amount stated.

It is thus of the greatest economic importance to keep swine and poultry separated in a most thoro manner. The avian infection which brings about tuberculosis of swine is to a large extent soil born, inasmuch as tubercle bacilli in soil may remain alive for long periods (one year), but there is also the danger of tuberculous poultry polluting feed and water by means of their droppings, while in addition the decrepit tuberculous bird devoured by a litter of pigs is quite certain to infect the entire number. All factors mentioned should be rendered impossible of operation.

In the prevention of tuberculosis of swine there is one feature which contributes materially to the success of our efforts and that is that hogs have but a short span of life; so short in fact, that in the majority of the cases of tuberculosis there is no time for lesions to break down so that the bacilli can be thrown out of the body. The turnover, so to say, is too rapid for this. About the only important case where the spread from hog to hog is to be feared is in that of older animals kept for breeding purposes, especially brood sows. It is therefore advisable to apply the tuberculin test to such animals as

are eligible for breeding purposes and only to retain such as prove to be free of the disease.

Human infection as a source of swine tuberculosis probably plays no conspicuous part in our state, but its possibility must be given consideration when consumptives are caring for swine or when garbage and table wastes of unknown quality are being fed in the raw state. Such materials should always be thoroly cooked for many other reasons, as well as that furnished by the tuberculosis hazard.

The influence of proper management of swine herds also has a marked bearing on the incidence of swine tuberculosis. The selection of safe quarters and feed, the rejection of carcasses as a food for swine, and above all the practice of hog lot sanitation, such as is now generally advocated for the prevention of the filth born pig diseases, are potent measures in the conquest of hog tuberculosis. In the mind of the writer there is no doubt that the progress in eradication of bovine tuberculosis in this state helped to bring about a reduction in our toll of swine tuberculosis, but that in addition, credit must be given to the more or less general adoption of the method of swine sanitation which sends the pigs to alfalfa pastures, away from the infected yards, quite early in life.

NOTE: In the preparation of this circular, many sources have been freely drawn from, but the customary bibliographic references and other acknowledgments have been omitted as a matter of economy in printing costs as well as space. L. V. E.

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