

country prior to their discovery, made it uncertain whether infection took place before or after importation.

On 1st April 1917, an old-standing case of pulmonary tuberculosis in an Algerian camel which had been recently imported came to our notice. In addition to numerous discrete tubercles in the lungs, there were large caseous masses surrounded by fibrous tissue, evidently of an age greatly exceeding the time which had elapsed since the date of arrival, which cannot have been prior to 22nd February 1917, the date of arrival of the first consignment. Tubercle bacilli were found in considerable numbers in the younger tubercles and in the exudate found in the bronchial tubes.

SCRAPIE.

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PART I.

IT is at first sight very remarkable that, in spite of its serious character, the ovine disease termed scrapie should until recently have been almost entirely unknown to the veterinary profession in this country. The fact cannot be explained by the supposition that the disease is a new one, for, thanks to Sir Stewart Stockman's researches,¹ it is now known that it has been in existence in Great Britain for well over a century. There is no doubt that the disease has hitherto received little or no professional notice simply because it has been the almost invariable habit of flock-owners to conceal its existence. Now that the folly of this policy has been recognised by many of the breeders in those parts of the country in which the disease prevails, it is reasonable to hope that properly planned investigations will before long clear up many points which are at present very obscure, especially with regard to the manner in which it is spread.

As Sir Stewart Stockman has shown, the same disease occurs among sheep in certain parts of Germany and France, and in both these countries its existence can be traced as far back as the latter half of the eighteenth century. According to the same author, it is probable that it was first brought to England with Merino sheep imported either from Spain or Saxony, and it appears to have spread gradually from Norfolk towards the north, until it reached its present limits. So far as is known, the disease has now ceased to exist in this country except in Northumberland and the adjacent Border counties of Scotland. That the disease, without any concerted method of dealing with it, should have disappeared from the other counties in which it once was common is remarkable, but the explanation is probably to be found in the fact that the disease finds the conditions most favourable for its spread in the large hill flocks, and in the further fact that in such flocks it is easiest to conceal its existence.

The chief purpose of this article is to place on record the experiments in connection with the disease which have been carried out

¹ See this Journal, Vol. XXVI., 1913, pp. 317-327.

at the Royal Veterinary College during the last seven years. The details of these experiments are given in Part II., but it appears to be desirable to set out here the known and probable facts with regard to the disease as it occurs in this country, and to discuss the principal views that have been advanced as to its cause.

Incidence of the Disease as regards Locality and Breed.—As already stated, there is reason to believe that at the present time scrapie is confined to the extreme north of England and the south of Scotland. As there is still quite naturally a general tendency towards concealment, it is not possible to form any estimate as to the proportion of farms on which it occurs, but available information indicates that within the above area the distribution is very irregular. In some places it would appear that only a minority of the flocks are affected, but in one district an owner of a diseased flock assured me that in his opinion it was very doubtful whether any of his neighbours for miles around were not in a similar position. That the existence of the disease may be concealed for years will be readily understood when it is remembered that it is especially prevalent on the large tracts of hill pasture, where throughout their lives the sheep are seldom or never seen except by the owner and his shepherds. As might have been expected, when knowledge of the existence of the disease on a farm does leak out, that can often be traced back to information passed on more or less casually from one shepherd to another.

It might have been supposed that the disease would be difficult to conceal because its existence would be likely to be disclosed by the sale of sheep from an infected flock, since some of these would in all probability develop the disease in the possession of their new owner. As will afterwards be shown, the existence of scrapie on a particular farm has on some occasions actually been traced in this way, but the very long period of incubation tends to lessen the likelihood of detection when sheep are sold from an infected flock.

There is no reason to suppose that any breed of sheep is naturally immune against scrapie, or that the susceptibility of different breeds varies. At the present time in this country the disease affects principally the Cheviot and half-bred flocks, but that no doubt is attributable to the fact that the bulk of the sheep in what may be termed the enzootic area belong to these breeds. The Border Leicester and Scotch black-faced sheep have also suffered from the disease, and the Merino and many other foreign breeds furnish victims on the Continent of Europe.

There is also no evidence suggesting that one sex is more susceptible than the other. Naturally the great majority of the cases occur in ewes, because rams form only a very small proportion of the entire sheep stock where the disease prevails, but rams have often contracted the disease on infected farms.

I was not able to obtain any history of cases among wethers, but at the present day, in practically the whole of the enzootic area, the wether lambs are sold off their native farms when about six or seven months old, and come into the hands of butchers before they reach the age of eighteen months. Therefore, as the disease seldom or never shows itself in animals under that age, the fact that no cases of scrapie are observed in wether sheep on infected farms

in no way indicates that these animals are less susceptible to the disease than ewes. In this connection it is interesting to note that of the two sheep which developed the disease at the College more than a year after removal from their native pasture one was a male and the other a female.

So far all the statements made with regard to the incidence of the disease are, I believe, not open to dispute; but certain points regarding which different opinions are held have now to be considered.

The first of these is the age incidence of the disease. What is the earliest age at which cases have been observed? With one exception, no owner whom I have interviewed or with whom I have been in correspondence has ever seen a case in an animal under a year old. In the exceptional case the owner, who has had a long experience of the disease, informed me that one year, before he had learned the hopelessness of treatment, he had a few affected ewes brought down from the hill when near lambing in order to have them dipped with various mixtures. The ewes lambled all right but did not derive any benefit from the treatment, "and in a few weeks several of the lambs also showed symptoms of the disease, one being very bad." Both ewes and lambs were killed. My informant added that he had known one or two other isolated cases among lambs, but that the occurrence of the disease at that age was unusual. The great experience and exceptional intelligence of the owner who furnished this information naturally inclines one to accept implicitly his opinion that lambs born of a ewe affected with scrapie may, when only a few weeks old, develop pronounced and unmistakable symptoms of that disease. The fact, if it were established beyond doubt, would be entitled to the greatest possible weight in any endeavour to fathom the nature of the disease, but if the opinion is erroneous its acceptance as a fact might have the unfortunate effect of directing investigations into an entirely wrong path. For that reason it appears to me to be better to regard the possible development of the disease in young lambs as still doubtful, and to wait for further evidence. This attitude is permissible because of the possibility of error in diagnosing scrapie in lambs of only a few weeks old, and because it is difficult to avoid the conclusion that, if any cases of scrapie occur in quite young lambs, there ought to be more among older lambs and yearlings. In other words, it appears to be impossible to reconcile the alleged occurrence of the disease in lambs only a few weeks old with the fact that scrapie is unknown at any age between a few weeks and fifteen months; and even if it were demonstrated that there are rare or occasional cases in which the disease manifests itself between these age periods, it would still be difficult or impossible to construct any theory which would reconcile the rarity of such cases with the occurrence of the fully developed disease in quite young lambs.

While it therefore appears to be prudent to leave it an open question whether the disease ever shows itself in lambs, there is no room for any doubt that it is seldom seen in animals under eighteen months old. All the evidence which I have been able to collect from owners of infected flocks was to that effect.

The next point to be noted—and it is one of great importance—

is that there appears to be no upper limit to the age at which sheep may be attacked. The owner whose opinion I have already quoted with regard to the occurrence of cases in young lambs assures me that he has seen the disease develop in his ewes at all ages up to six years, which is about the maximum age to which sheep are kept in hill flocks. This refers to farms on which the disease has been in existence for at least several years.

Although it is not possible to quote any figures in support of the statement, it appears to be the rule that far more cases occur in the so-called gimmers or two-year-old ewes. As will presently be shown, when it first appears on a farm the disease may be confined to animals of this age, but the rule appears to apply also to flocks in which the disease has been in existence for years. April is the lambing month in the enzootic area, and it is customary to put the young ewes to the ram when they are about nineteen months old. The earliest cases of scrapie among the animals of this class are usually seen when they are within a month or two of lambing, and fresh cases may continue to crop up after lambing and during the ensuing summer months, and indeed at any later period.

Although there is less evidence with regard to young rams, what is obtainable indicates that in them also the disease is most likely to show itself when they are about two years old.

With regard to the seasonal incidence of the disease, it may be said that the spring and early summer months form the period during which the majority of cases develop, but that fresh cases occur at all times of the year. There is reason to think that the greater frequency with which sheep are attacked during the period stated is determined by the fact that gimmers or two-year-old ewes furnish the majority of the victims, and that there is less regularity in the season at which the symptoms are first exhibited by older sheep.

Symptoms and Course.—In spite of the fact that the actual cause of the disease is still unknown, and that its diagnosis therefore lacks the precision and certainty which are possible in diseases caused by demonstrable parasites, there is little danger of mistaking scrapie for any other affection except during its earliest stage. For convenience of description it may be said that the symptoms are partly cutaneous and partly nervous, although it must be admitted that the former may also have their origin in disturbance of the central nervous system.

The primary cutaneous symptom is an itchiness of the skin, manifested by the animal's inclination to rub itself against walls, posts, or other solid objects. This itchiness appears to affect the whole integument, as is shown by the fact that scratching of any part of it with the fingers, even at an early stage of the disease, will cause the animal to evince signs of gratification. In consequence of the rubbing movements, the fleece, especially along the sides or above the root of the tail, soon becomes more or less ruffled, and by this sign shepherds are usually first led to suspect an animal. The itching rapidly increases in intensity, and extends to the legs and head. To relieve the irritation the hind feet are used to scratch the head, and with the same object the animal gnaws or bites its legs.

Eventually the diseased sheep is reduced to the pitiable condition of having to spend nearly the whole of its time in scratching, rubbing, or biting, in an obviously futile attempt to allay the constant, tormenting itch from which it suffers.

The itchiness appears to be a genuine pruritus, in the sense that it is not preceded by, or attributable to, any visible alteration in the structure of the skin. At the more advanced stages of the disease actual cutaneous lesions in the form of scratches, excoriations, scabs, and loss of wool are always present, and in some cases multiple abscesses of considerable size are found in the subcutaneous tissue. All these abnormalities, however, can be referred to the mechanical injury of the skin by rubbing, scratching, or biting, and occasional local infection with some of the common pyogenic bacteria.

Except in the most acute cases, in which nervous symptoms predominate and death occurs after an unusually short period of illness, extensive loss of wool becomes a pronounced symptom. In part this may be attributable to mechanical causes, but complete depilation often occurs on considerable areas of skin that appear to be otherwise perfectly normal. Finally, in some cases in which the animal as yet presents only nervous symptoms and the fleece is quite unruffled, scratching of the skin with the fingers will produce the usual evidence that pruritus already exists.

In the more chronic cases in which the animal survives for several months, and almost the entire original fleece has been shed, a new growth of wool may take place on areas of skin that were for a time absolutely bare.

In some cases the itching appears to be less intense in the last stages, when nearly the entire fleece has been shed.

Although the disease has been termed "lumbar prurigo," and the first considerable loss of wool often occurs in the region of the loins, it is doubtful whether the pruritus is ever confined to that part of the body, and, at any rate, it soon becomes universal.

Nervous Symptoms.—It is a little curious that, whereas in this country the disease came to be known as scrapie because pruritus was considered the most common and characteristic symptom, both in Germany and in France the symptoms pointing to disturbance of the nervous system have attracted most attention and been assigned the greatest importance from a diagnostic point of view. Hence the origin of the German name "Traberkrankheit" (travelling disease), and the French "La tremblante" (the trembles). There can be little doubt that it was the emphasis laid upon the nervous symptoms by French and German writers which so long prevented recognition of the fact that the Continental disease was identical with the one termed scrapie in this country.

In the great majority of cases both cutaneous and nervous symptoms are already presented when animals are first observed to be affected with the disease, but, at least in this country, the pruritus and depilation dominate the picture throughout the greater part of the illness.

Save in the two cases in which the disease began in animals which had been kept at the Royal Veterinary College for more than a year before they were attacked, I have not had an opportunity to observe

the disease from its onset. In the other cases, numbering about twenty, the disease had been in existence for weeks or months before the animals were brought to the College, and in all of these except one the before-described cutaneous symptoms were already pronounced at the time of their arrival. In many of them nervous symptoms of any kind never became prominent. In all of them there was steady progressive emaciation and increasing weakness, but without any definitely localised paralysis. A few died rather suddenly, that is to say without previous inability to stand or get up, and in the other cases the animals were killed because they were unable to stand and death appeared to be imminent. In all of these the muscular inability appeared to be the result of general exhaustion.

When the animals were observed while they were not engaged in scratching or rubbing themselves some of them showed a marked tremor of the whole body and legs, like a strong shivering; but as a rule these symptoms were not aggravated by handling or fright, and nothing of the nature of convulsive seizures was ever observed.

The exceptional case referred to above was a half-bred ewe which was first seen on the farm where it had recently developed symptoms of the disease. At that time there was no loss of wool, but that pruritus had already begun was made manifest when the animal's skin was scratched with the fingers. When standing undisturbed with a number of other sheep this ewe appeared to be perfectly normal, but when a dog was sent round the lot she fell over on her side, and continued to move her limbs in attempts to get up. Even when lifted up she was unable to stand, but when left to herself for a few minutes she succeeded in regaining her legs. The dog was sent round her a second time, and with exactly the same result. The symptoms exhibited by the ewe when thus excited were suggestive of extreme giddiness.

A few days later this ewe was brought from Scotland by train, and on arrival at the College she was found to be unable to stand. She remained paralysed, and died thirty days later.

On the same farm on which the case just described occurred I was shown another which had been diagnosed as one of scrapie by the experienced shepherd. This ewe, which had been ill for only a few days, was unable to get up or stand, but pricking with a pin provoked reflex movements of the legs. The fleece appeared normal, but here again the ewe showed marked indications of pruritus when the skin was scratched.

In the two cases in which the disease actually began in animals in confinement at the College (*see* pp. 123 and 125) rubbing and slight ruffling of the fleece were the first symptoms noticed, and no marked nervous symptoms developed in either. When the wether (Lamb 109) was observed without attracting its attention, while standing at rest in the loose-box with other sheep it sometimes held its head rather high, with the ears slightly inclined backwards, the eyes fixed and widely open, and an attitude suggestive of listening. This, however, may merely have been the result of the intense pruritus from which it was suffering.

In addition to the symptoms just noticed, Continental authors

include among the nervous disturbances dilatation of the pupils, spasmodic contraction of groups of muscles, a peculiar high action of the fore limbs when running, paralysis, especially of the hind quarters, and epileptiform seizures.

Diagnosis.—As in the case of most other diseases, diagnosis may present difficulty at the outset and in cases that die at an unusually early stage; but as a rule the intense pruritus without antecedent skin lesions, the rapid loss of wool, and the steady loss of condition, soon make it impossible to mistake scrapie for any other disease. Needless to say, the chance of error is still further reduced when nervous symptoms are also exhibited.

Unfortunately, diagnosis cannot yet attain to absolute precision in single cases, because the actual cause of the disease is unknown.

As a negative character which is of assistance in diagnosis, it ought to be noticed that *post-mortem* examination does not reveal any visceral lesions which can be regarded as part of the disease.

Lastly, it may be said that in actual practice the fact that the disease when once it has appeared in a flock tends to claim an increasing number of victims as time goes on greatly reduces the chance of error in diagnosis. In other words, the succession of cases suggests, if it does not prove, that the disease is contagious. But that is a point to be dealt with under the next heading.

ETIOLOGY.

Some of the earlier opinions regarding the cause of scrapie can now be dismissed as obviously erroneous. One may thus unhesitatingly put aside the views which ascribed the disease to climatic or dietetic causes, to in-breeding, to special predisposition inherent in particular breeds, or to peculiar delicacy of constitution resulting from what is vaguely termed irrational or unnatural methods of breeding and rearing sheep. All opinions of that kind have been arrived at by following false scents. As has happened in the case of many other diseases, erroneous opinions with regard to the etiology of scrapie were often the outcome of a too narrow experience, with consequent ignorance of the varying circumstances under which the disease occurs. With only a local knowledge of the disease it was quite natural to fix upon some peculiar circumstance in connection with the flocks in which it occurred, whereas a wider acquaintance with the disease would have prevented the error by showing that the particular circumstance incriminated was not invariably present in flocks affected with the disease.

The alleged causes referred to above no longer need to be considered, since it is known that the disease has continued to exist under the most varied conditions of breeding and rearing sheep in Great Britain, France, and Germany for over a century, and that it has prevailed among many different breeds, including those as widely apart as the Merino and Border Leicester on the one hand and the Cheviot and Scotch black-faced on the other. It is true that at the present time in this country the disease does not occur in the majority of breeds, but that is easily explained by the fact that

most pure breeds are more or less confined to particular parts of the country, and are now to a large extent out of the way of infection. Besides, the very fact that the disease is now nearly or quite confined to the Border Leicester and Cheviot and the crosses between these almost entirely removes any risk of it being communicated to the other pure breeds which are never crossed with any of these. There is, in fact, absolutely nothing to suggest that any breed of sheep is more resistant or more susceptible to scrapie than any other, and in this connection the alleged occurrence of the disease among goats deserves to be mentioned.

When a disease occurs in enzootic form, but under conditions and circumstances so varied that they negative breed, climate, diet, and soil as causes, as must now be admitted with regard to scrapie, one naturally considers whether the hypothesis that it is parasitic in its nature will explain the facts of the case. But before applying this to any particular disease one must endeavour to obtain assurance about the most important facts, and especially to collect evidence with regard to the circumstances connected with the first appearance of the disease in a flock.

Unfortunately, it is very rarely that any really useful information with regard to that point can be obtained. The flocks in which the disease has been in existence for many years are obviously useless for this purpose, and in those cases in which the disease is of recent origin inquiry is difficult because at the outset owners almost without exception are inclined to conceal the fact that their flocks are infected.

Fortunately, I had the opportunity in 1912 to be brought into touch with two owners whose flocks had been infected recently, and was able to gather from them valuable information while the important facts were still fresh in their memories.

The following facts were ascertained with regard to the first of the flocks, owned by Mr A.

Mr A. had been tenant of the farm for eleven years prior to 1907, and during that period he never had a case of scrapie. Up to that time also the disease, so far as he was aware, did not exist on any of the neighbouring farms.

In the autumn of 1907 Mr A. bought 140 Cheviot ewe lambs at a public auction sale in a neighbouring town. They had been bred by a Mr X. on a farm in another county, and it was subsequently ascertained that scrapie existed in this stock.

These lambs were put to the rams in November 1908, along with thirty other young ewes of the same age (so-called gimmers), which had been bred by Mr A. on his own farm.

The total ewe stock, including these gimmers, was about 560. The flock had a very wide run of hill pasture, on which, however, there was no strict separation between any of the different lots of sheep.

In February and March of 1909, following the usual custom, the pregnant ewes were taken off the hill pasture and folded together on turnips.

The first symptoms of scrapie in the flock were seen in February 1909, and during the next six or seven months about thirty ewes

were lost from the disease. Without exception, all of the ewes attacked belonged to the lot of 140 which had been bred by Mr X. and bought by Mr A. in the autumn of 1907.

In the autumn of 1909 Mr A. determined to endeavour to eradicate the disease, and with that object he fattened and sold all the surviving ewes of this lot, and at the same time he sold the whole of their lambs. Hence, after the autumn of 1909 none of the ewes bred by Mr X. and none of the lambs out of these were left on Mr A.'s farm.

From October 1909 till April 1911 Mr A.'s farm appeared to be free from scrapie, but in April 1911 two ewes were attacked. Two more were attacked in the summer, and several more were noticed to be affected in November.

From that time onwards cases cropped up at intervals, and at the time of my visit in August 1912 four ewes were affected.

In the autumn of 1909 Mr A. sold a number of lambs out of ewes which had been bred by himself or had been on the farm before the lambs from Mr X.'s stock were purchased in the autumn of 1907. These were sold to different purchasers, and save in one case no complaint with regard to the development of scrapie among them was received by Mr A. In this one case the purchaser reported that some of the lambs developed scrapie in 1911.

The remarkable fact about the history of the disease on Mr A.'s farm up to this point is the entire absence of scrapie from the farm between October 1909 and the spring of 1911.

In the autumn of 1909, and also in 1910, Mr A. had bought ewe lambs from a farm on which he afterwards heard the disease occurred, and, as he did not believe that the disease was contagious, he thought it possible that these purchases were responsible for the occurrence of the disease in 1911 and 1912. He admitted, however, that some of the cases which occurred in these two years were among animals that had been bred on the farm, or were on it prior to the autumn of 1907.

Although Mr A. was of opinion that the disease might have been spread in his flock by the agency of the rams, he never had a ram which developed any symptom of scrapie.

The number of rams in use in the flock was eleven, and the number was kept up by buying three or four young rams each year. As a rule, therefore, each ram was used for three or four successive seasons.

On the second farm, tenanted by Mr B., there was an almost identical history with regard to the origin of scrapie.

Mr B. had also been free from the disease up to the spring of 1909, and all the cases of scrapie which occurred in his stock in that year were among gimmers which had been bought as lambs in the autumn of 1907. These lambs, like those purchased at the same time by Mr A., had been bred by Mr X. on a farm in another county.

Feeling greatly alarmed by the occurrence of the disease on his farm, Mr B. determined to root it out, and in the autumn of 1909 he sold all the surviving ewes which had been bred by Mr X., and also all their lambs. After this there was no disease on Mr B.'s

farm until the spring of 1911, when it broke out again among ewes that had been in his possession before the autumn of 1907.

Mr B.'s flock consisted of about 600 Cheviot ewes.

Although it was only in the case of the above two farms that I was able to obtain particulars regarding the origin of the disease at first hand, it may be mentioned that on the occasion of my visit to the district in 1912 I was informed that a third farmer, who in the autumn of 1907 purchased ewe lambs bred by Mr X., had an exactly similar experience to Mr A. and Mr B., that is to say, his flock had previously been free from the disease, but in the spring of 1909 cases began to develop in the flock, and they were confined to the gimmers which had been bred by Mr X.

Leaving the last-mentioned farm out of account, the facts which have been stated above may be summarised by saying that in two large stocks of sheep the disease was, according to testimony that appears to be quite trustworthy, introduced by the purchase of apparently healthy lambs from an infected flock; that a notable proportion of these lambs developed the disease when they were about two years of age; and that, in spite of the sale of all the animals of this lot and their progeny before the next breeding season, the disease subsequently developed in the other ewes, and in fact established itself on the farms.¹

It will probably be generally conceded that if the facts were as stated above and none of importance has been omitted they suggest that scrapie is caused by the multiplication of some parasite in the sheep's body, and is spread by the direct or indirect transference of this parasite from the diseased to the previously healthy.

But before engaging in speculation with regard to the nature of this parasite certain other facts besides those stated in connection with the history of the disease on the two particular farms must be taken into consideration. These are:—

(1) That according to all the available evidence the disease does not spread in spite of the closest contact between diseased and healthy sheep confined in a house. The result of the experiments recorded at the end of this article are in harmony with that view, though it cannot be said that they prove it.

(2) That an affected farm can be cleared of the disease by selling the infected flock and re-stocking, even if the latter follows immediately. I include this as a fact, but admit that I have not been able to investigate personally any case in which the disease has been eradicated in this way. An opinion to that effect is, however, very widely held among breeders in infected areas in this country at the present time, and two cases in which the method appears to have been successful have been brought to my notice by Sir Stewart Stockman.

Dr J. P. M'Gowan, in a recently published report on scrapie,² has put forward the view that the disease is caused by a heavy

¹ Information which I have recently obtained is to the effect that there was no diminution in the number of cases during the past year, 1917, on the first of the two farms.

² "Investigation into the Disease of Sheep called 'Scrapie.'" By J. P. M'Gowan, M.A., M.D., B.Sc., M.R.C.P.E. William Blackwood & Sons, Edinburgh, 1914.

infection of the muscular tissue with sarcosporidia. In his opinion this infection is brought about by the system of breeding in vogue in the regions where scrapie is in evidence—namely, keeping up of the ewe stock by means of the ewe lambs derived from the gimmers or two-year-old ewes. This, it is stated, is the age period at which a heavy sarcosporidial development occurs, and the heavily infected mothers pass on a heavy infection to their progeny.

He sums up the evidence in support of this view as follows:—

“1. The sarcocyst is always present in the skeletal muscles of scrapie sheep in large numbers; and the more advanced the case the larger is the number of the sarcocyst present.

“2. Pruritus (or itching), the chief symptom in scrapie, can be reproduced in rabbits by injection into them of sarcosporidial emulsions.

“3. Careful clinical examination of typical cases makes it highly probable that the paretic phenomena of the disease are due to a primary muscle lesion.

“4. There is an absence of any condition *post-mortem*, except extensive sarcosporidiosis, sufficient to or of a nature likely to cause the phenomena observed in the disease. In this connection one would specially note Cassirer's findings in cases of the Traberkrankheit in Germany.”

Dr M'Gowan ventures the opinion that no single view can explain so well the symptomatology and epizootiology of the disease as the one which refers the disease to heavy infestation of the sheep with sarcosporidia.

It ought to be noted that in Dr M'Gowan's opinion scrapie is not contagious, and his theory as to its cause is partly framed to account for this fact. He reasons that if the disease had been contagious it would now be widely spread, and it would not have been possible to eradicate it by the simple method of selling off the old ewes and recruiting the flock by the purchase of young sheep from clean flocks, for in such circumstances the diseased and healthy mingle freely with one another; “and yet when the last of the diseased stock has been sold the disease has been stamped out.”

It may be difficult to frame any theory which will explain what Dr M'Gowan calls the epizootiology of scrapie, but it is easy to show reasons for doubting the one which he has advanced.

The first is that the most important of his premises, namely that the disease never spreads from diseased to healthy sheep on the same pasture, can no longer be maintained. The facts which I have described in connection with two different farms show that the sale of all the animals which imported the disease into a previously clean flock is by no means a certain method of eradication.

The view put forward that an infected flock can be freed from the disease by the less drastic method of gradually selling off the old ewes and buying in a corresponding number of fresh young ewes from clean flocks is not supported by any evidence, and therefore cannot be admitted. But even if it had to be admitted that scrapie does not spread except from mother to offspring, Dr M'Gowan's conclusions with regard to the nature of the disease would have to be rejected, first, because they are largely based on other assumptions

which are unproved and improbable, and, secondly, because they leave absolutely unexplained some of the most important and generally admitted facts in connection with the disease.

It seems very strange that anyone well acquainted with the facts regarding the past and present distribution of scrapie in this and other countries should put forward the view that the disease is caused by a parasite which is almost universally present in the sheep in all parts of the world.

It would probably be impossible anywhere to find a flock in which the great majority of the sheep do not harbour sarcosporidia in their muscles, and no one dare suggest that the infestation of the ovine species with these parasites is now either commoner or rarer than it was at any time in past history. When one is asked to believe that, notwithstanding its universal distribution, this parasite is the cause of a disease which has always been decidedly enzootic in character, questions that immediately spring to the mind are, (1) Why has the disease ceased to occur in breeds and localities in which it once was common although the parasite remains? and (2) Why does it persist and even extend in the Cheviot and Leicester breeds and the crosses between these in Northumberland and the Border counties in Scotland?

Dr M'Gowan makes no attempt to answer the first of these questions, possibly because he thinks it is inferentially dealt with in his answer to the second. This he disposes of by suggesting that the heaviest infestation with sarcosporidia occurs at about two years of age, that the common or exclusive method of infection in sheep is by the passage of the parasites from the muscles of the pregnant ewe through the wall of the uterus to the lamb, that the lambs of gimmers are therefore more heavily infected at the time of birth than those borne by older ewes, and, finally, that scrapie is at present common among the British breeds mentioned because in these it is the custom to recruit the ewe stock by means of young ewes bred from gimmers.

The first defect of this explanation is that it includes a hypothesis that has little probability, namely, that sarcosporidia pass from the ewe to the lamb while the latter is still in the womb. Nothing approaching proof of this view has yet been produced with regard to the method of infection with these parasites in the ovine or any other species, and the known facts, including the successful infection of mice by feeding, makes it much more probable that in the sheep infection occurs by way of the alimentary canal, and therefore during extra-uterine life.

A more serious defect of the explanation is that it appears to make two assumptions that are contrary to fact, namely, that all the flocks in which scrapie has ever existed have had the ewe stock recruited by two-year-old ewes which were themselves borne by gimmers, and that scrapie is bound to develop in sheep that are thus bred. It is disappointing to find that although the whole theory put forward by Dr M'Gowan hangs upon these two points he makes no attempt to substantiate them. Apparently it had not occurred to him that his theory laid him under the obligation of proving that in all the other breeds of British sheep in which

scrapie once occurred, and in all the Continental breeds in which it now exists, this system of recruiting by means of gimmers out of gimmers has been practised. So far as regards the British breeds, the suggestion is certainly incorrect, and in the absence of any evidence to the contrary one may assume that it is equally erroneous in regard to the French and German breeds in which the disease has been observed.

It ought to be stated that although Dr M'Gowan does not attempt to prove that the particular method of breeding here referred to has invariably been in operation in German, French, and British breeds in which scrapie has occurred, he asserts that "in other parts of Scotland, indeed, where the practice is to keep up the ewe stock by drawing the *best* ewe lambs from *all* the ages the disease has not appeared." The italics in this quotation are in the original, but the words that really deserved to be emphasised are "in other parts of Scotland," for obviously flocks remote from the present enzootic area may owe their escape from scrapie to the fact that opportunities for infection by the introduction of diseased animals have not yet occurred.

But here again it may without disrespect be said that the author has failed to see the logical conclusion of his own statement of fact, for if it is true, as he alleges, that scrapie never breaks out in flocks bred according to the method of which he approves (and which hardly needs recommendation, since it is almost universally practised), the fact is not evidence that his theory with regard to the etiology of the disease is correct, but actual proof that it is wrong.

The theory, it must again be stated, is that what may be called breeding in series from gimmers brings about a concentration of sarcocysts in the muscular tissue of the sheep thus bred, and that what is called scrapie is simply the outward evidence that this concentration has reached a dangerous degree. Of necessity, the author has to admit that this implies the possible *de novo* or sporadic origin of the disease in any flock in which the condemned system of breeding is practised, but he has failed to recognise that the dangerous concentration of sarcocysts cannot be entirely avoided by "drawing the best ewe lambs from all the ages." There are hundreds of flocks in which the ewes are discarded after their fourth pregnancy, and in which therefore at least a fifth of the breeding stock must constantly be composed of gimmers. In such a flock a fourth of the selected best ewe lambs in any given year will be out of gimmers, and at the next annual selection some of the lambs out of these will again be chosen for breeding, and so on.

It is safe to say that there are many counties in Scotland, not to speak of England and Wales, which have remained exempt from scrapie, although at any time during the last fifty years the flocks in them must have contained thousands of ewes whose maternal ancestors for several generations were out of gimmers. It is obvious that this fact is absolutely fatal to the Dr M'Gowan's theory as to the cause of scrapie. On the other hand, it falls into line with other facts in indicating that the disease is never sporadic, and therefore presumably not caused by any parasite which, like the

Sarcocystis tenella, is found more or less abundantly in sheep throughout the world.

Like the older views which ascribed scrapie to in-breeding, improper diet, or special climatic or geographical conditions, the view that the disease is caused by sarcosporidia must therefore be rejected.

All the known facts with regard to the disease suggest that it is contagious as opposed to sporadic, meaning thereby that it never arises in a previously healthy flock otherwise than by the introduction of an infected animal. The matter may be put even more strongly than this, for it is not too much to say that on no other hypothesis does it appear to be possible to account for the past and present geographical distribution of the disease. The precise circumstances under which it disappeared from parts of England in which it was apparently once a fairly common disease cannot now be ascertained, but such disappearance is in no way opposed to the view which has just been expressed.

Unfortunately, owing to the lack of evidence bearing on the point, it is not yet possible to form a confident opinion regarding the manner in which the disease is transmitted from the diseased to the healthy, but a number of facts and the possible interpretation of them may be briefly discussed.

In the first place, it is unquestionable that in many cases the cause of the disease is passed on from the ewe to her lamb. This, indeed, is said to be the rule, but the observations described in the latter part of this article suggest that it may have more exceptions than has been generally supposed. In these observations, of eleven lambs out of ewes which developed symptoms of the disease before or soon after parturition, and were all at an advanced stage before the period for weaning, only two became visibly diseased, the others remaining apparently well until they were well past two years old. Although it is not certain that in these cases the ewes were visibly diseased at the time of lambing, there can be no doubt that they were then infected, and near, if not actually past, the end of the period of incubation.

It may be as well to state here that a breeder has informed me that on one occasion he retained in the stock a lamb whose mother developed the first symptoms of the disease in July. The lamb was immediately separated from its mother, but it developed the disease in October of the following year, when it was about eighteen months old.

The question which now arises is whether in those cases in which the lambs out of diseased ewes themselves develop the disease when about two years old the infection has occurred before or after birth. In this connection it must be remembered that even if all lambs were born healthy it would still be reasonable to expect the disease to be much more frequent among those out of diseased ewes than among the progeny of healthy ones, owing to the much closer association of the diseased ewes with their own than with other lambs.

There is one recorded observation¹ which if it could be relied

¹ Quoted by Sir Stewart Stockman, *loc. cit.*, p. 325.

upon would compel one to accept the view that when the lambs of infected ewes develop the disease their infection must have taken place before birth. The observation is to the effect that thirty lambs out of healthy ewes sucked for a month the same number of ewes affected with scrapie and failed to become infected. The facts are said to have occurred many years ago in a French flock, and apparently it was not stated how long the lambs were afterwards kept under observation before concluding that they had escaped infection. Having regard to this, it would be very unsafe to accept the observation as proof of infection before birth.

Dr M'Gowan¹ states that scrapie mothers give rise to scrapie lambs almost without exception, and that "this happens when the lamb is suckled on a healthy foster mother."

In support of this opinion he quotes the above French observation, and one experiment conducted by himself, in which four lambs out of diseased ewes were obtained as soon as they were born and reared on cows' milk. It is stated that twelve or thirteen months after its birth one of these lambs "appeared to be already rubbing itself," and that its tail was "at present bared of wool." I am not aware what subsequently happened to these four lambs, but venture the opinion that the itchiness exhibited by one of them was too early to be a symptom of scrapie.

The opinion, not merely that some lambs are born infected, but that intra-uterine or congenital infection is the exclusive method by which the disease is spread, is held by many breeders in this country at the present time. This, however, does not appear to be supported by any evidence save that the lambs out of diseased ewes frequently become affected, and that disease in a flock can be held in check provided the progeny of diseased ewes are sold as lambs, and therefore before the symptoms have had time to develop in them. Obviously, however, things would be likely to happen in this way even if no lamb were infected before birth, and one may therefore accept the fact without admitting the conclusion founded on it.

The matter may be summed up by saying that it is necessary to preserve an open mind with regard to the possible infection of lambs before birth.

The facts which have already been described in connection with the occurrence of the disease on two farms seem incapable of explanation except on the view that animals may be infected after birth, for the information obtained in both cases was to the effect that some of the ewes which became visibly affected in 1911 had been in the flock before the introduction of the infected lambs in 1907.

I am in a position to place on record a case which points very strongly in the same direction. In this instance a Border-Leicester ram bred in a sound flock was used for service in a Cheviot flock known to be infected with scrapie, and subsequently developed the disease.

In another case reported to me the facts indicated that a pre-

¹ *Loc. cit.* p. 89.

viously sound flock was infected by the agency of a ram. The flock in question was one of Border Leicester ewes, and in the autumn of 1910 seven Cheviot rams were put with it for service. These rams were believed to be from a healthy flock, but soon after they came in from the ewes one of them developed scrapie. In the early part of 1912 the disease began to show itself among the half-bred ewe lambs (now gimmers) got by these rams. It was supposed that all the cases were among the progeny of the diseased ram, but that could not be definitely ascertained, as there was no record to show what ewes had been served by each ram.

Sir Stewart Stockman has also recorded cases in which rams from an infected flock introduced the disease into previously healthy flocks.¹

It may here be pointed out that there are no *a priori* reasons for considering it impossible that scrapie may be transmitted both by congenital or intra-uterine infection and by contact after birth. The known facts with regard to tuberculosis are of interest in this connection. That disease is usually contracted by contact, but, at least in the bovine species, infection with it during intra-uterine life occurs, and is indeed common when the disease in the cow reaches an advanced clinical stage during the period of pregnancy. It is therefore quite conceivable that in scrapie also both methods of infection are in operation, and that infection before birth occurs only in cases in which the disease in the pregnant ewe is near the end of the period of incubation or has already manifested itself by the usual outward symptoms.

It thus appears to be impossible to deny that the disease may be contracted after birth, and the question which next arises is the exact manner in which infection takes place in such cases. Is the sexual act the sole method of transmission? or does the disease spread independently of this, by contact of diseased and healthy animals on the same pasture?

Unfortunately it is exceedingly difficult to obtain from owners evidence that will furnish an answer to these questions. Apart from the reluctance of many owners to disclose the fact that their flocks are diseased, and the general omission of breeders to keep a written record of the parentage and history of each animal that develops the disease, there are inherent difficulties due to the remarkably long period of incubation in scrapie, and the fact that in the breeds now mainly affected in this country few or no castrated male sheep over a year old are kept in the flocks or allowed to run with the ewes. Further difficulty arises from the fact that practically the whole of the female animals retained in the flocks are put to the ram when about a year and a half old, after which, of course, it becomes impossible to distinguish between infection from simple contact and infection from copulation.

If any considerable number of wethers over two years of age were allowed to mix with the ewes, or if ewes also not less than two years old were kept barren but allowed to mix with the breeding ewes except during the tupping season, observation would probably

¹ *Loc. cit.*, p. 324.

soon show whether service by the ram is necessary for infection or not. If in such circumstances any considerable number of cases of scrapie occurred among the wethers or the barren ewes, the occurrence of infection by simple contact would have to be admitted, because the age of the animals at the time when the disease developed would make the supposition that they had been infected prior to birth highly improbable.

The negative result of the contact experiments described in the latter part of this article are in keeping with the view that the disease is transmitted solely by copulation, but the number of animals employed was too small to justify a hard and fast conclusion.

Another question to which at present no decided answer can be given is whether the disease is transmissible, either by copulation or by contact, from an infected animal before the development of any symptoms of the disease—that is, during the period of incubation.

The circumstances in connection with the early history of the disease in the flocks belonging to Mr A. and Mr B. (*see* pp. 109-111) suggest that, at least as a rule, infected animals are not dangerous until the outward symptoms are developed. In Mr A.'s case 140 ewe lambs bred by Mr X., at least thirty of which were already infected, were in the autumn of 1907 mixed with thirty ewe lambs of his own breeding, and after October 1908 the whole of these lambs were incorporated with the ewe flock. The first cases of scrapie in the flock occurred in February 1909, and if the infection had been passed on to any of the native stock before that date some of these ought to have developed symptoms of the disease between March 1909 and March 1910—that is reckoning the period of incubation at eighteen months. But the first cases of scrapie among the native stock occurred in April 1911, and, again allowing for the ordinary period of incubation, these ewes must have been affected after, and not before, the disease broke out among the animals bought in as lambs.

Another fact in connection with the occurrence of the disease on these farms is deserving of notice here, *viz.*, that lambs born in the spring of 1909, out of ewes in the flock before 1907, were sold by Mr A. to a neighbour, who complained that some of them developed scrapie as gimmers in 1911 and thus infected his previously healthy stock. Now, assuming this statement to have been correct, these ewe lambs must have been infected before they were sold; and unless they were infected by contact with the ewes bred by Mr X. which developed scrapie in 1909 the disease in them must have been contracted before birth, in which case their dams must have been infected in the autumn of 1908 by rams which also served infected gimmers bought from Mr X. But, having regard to the usual period of incubation, the result of infection of these ewes by the rams in 1908 ought to have shown itself in 1910, whereas no case of scrapie occurred in Mr A.'s flock that year. The probability would therefore appear to be not that the ewes were infected by the apparently healthy rams and bore infected lambs while they themselves

remained apparently healthy, but that the lambs were born healthy and afterwards infected by contact on the pastures with scrapie ewes before Mr A. sold them.

Closely connected with the preceding is the further question whether, as in many other diseases, infection may in some cases be permanently latent. At first sight this may appear very improbable, but, having regard to what is known in other diseases (tuberculosis, for example), it cannot be declared impossible. The question has been previously discussed in Sir Stewart Stockman's paper.

A case may be mentioned here which it appears to be impossible to explain except on the assumption that the period of incubation is sometimes considerably over two years or that the disease can be contracted without the agency of the ram. A breeder has informed me that it is a not uncommon practice in the Cheviot breed to keep back the smaller and thinner gimmers and not allow the rams with them until they are two years and a half old, and that in his own flock he has had a good many cases of scrapie among these when they were three years old.

Among other uncertainties with regard to the disease is the want of knowledge as to whether there is any marked difference in susceptibility to infection at different ages. As previously stated, scrapie develops in ewes of all ages up to the maximum one in the flock, but it is quite possible that young lambs are most easily infected, and this may be partly accountable for the greater frequency with which the disease develops in gimmers.

After what has been said it must be evident that very few points in connection with the etiology of scrapie can yet be considered settled and free from doubt. Researches have hitherto failed to reveal the causal parasite, or even to show in which part of the body of an affected animal it is located. The most baffling fact up to the present is not this failure to detect any microparasite which can be accepted as the cause of the disease, but the negative results of the attempts which have been made to transmit it by inoculation with blood, cerebro-spinal fluid, and other materials taken from animals at the most advanced stages (see the experiments described later). It cannot be said, however, that the investigation along these lines has been exhaustive, and it is very desirable that efforts to discover a certain method of transmitting the disease should be continued. How very unsafe it is to found conclusions on the negative results of a small number of experiments is indicated by the observations recorded at the end of this article. Only two of eleven lambs out of diseased ewes developed the disease, and therefore if only four such lambs had been kept under observation probably all would have remained healthy. Unfortunately, the long period of incubation is a very serious obstacle to the experimental investigation of scrapie.

In the meantime an endeavour should be made to collect from breeders, and especially from those in whose flocks the disease has recently broken out, the most detailed information with regard to the circumstances attending its introduction and spread. It is impossible to doubt that if all the facts which are already known

to owners of infected flocks, or which they could within a few years observe and record, were sifted and collated by persons experienced in the investigation of animal diseases, much that is at present obscure in connection with the disease would soon be cleared up.

PREVENTION.

Dr M'Gowan recommends that in heavily infected flocks the disease should always be dealt with by gradually getting rid of the old ewes and replacing them by fresh young ewes from clean flocks, and states that this "is an efficient if expensive way of getting rid of the disease." The opinion, however, is not supported by reference to even a single instance in which the disease has been eradicated by this comparatively simple and inexpensive measure. It is very probable that by proceeding in this way the disease can be to a large extent controlled and held in check, but in the absence of well-authenticated evidence to the contrary it must be considered very doubtful whether the plan would ever bring about its extermination in large hill flocks.

It would appear that Dr M'Gowan thinks this plan imperative only in the case of heavily infected flocks. Unfortunately, he does not specify how the disease should be dealt with in more lightly infected stocks, but his other recommendations may have been intended for such cases. These recommendations are:—

(1) That the ewe stock should be kept up from the progeny of the older ages of ewes, and that the progeny of the gimmers, and possibly the two-crop ewes, should be sent to the butcher;

(2) That diseased animals should at once be killed to prevent any possibility of their being used as breeding stock; and

(3) That in-breeding should be conducted with very great caution.

The first of these precepts has very little to distinguish it from the advice given with regard to heavily infected flocks, and it appears to be not quite consistent with one of the author's own assertions which I have already quoted, namely, that the disease has not appeared in other parts of Scotland "where the practice is to keep up the ewe stock by *drawing* the *best* ewe lambs from *all* the ages." (The italics are in the original.) Remembering that in Dr M'Gowan's opinion scrapie is not contagious, one cannot understand why it should be necessary to ban the progeny of both gimmers and three-year-old ewes for replacing the older ewes in a scrapie flock if the disease can be kept out of healthy stocks by selecting the best ewe lambs from ewes of all ages.

The second recommendation is manifestly superfluous for the declared object, first because the sale of visibly affected ewes is practically impossible; and secondly because, according to all published experience, no such ewe ever survives long enough to be bred from again. It is, however, possible to agree fully with the advice for another reason, namely, that visibly diseased sheep must in the meantime be regarded as dangerous to healthy ewes and lambs on the same pasture.

As to in-breeding, one can only say that there is not the least

reason to suppose that the closest breeding that has ever been practised has either produced the disease by what Dr M'Gowan calls the *de novo* method, or aggravated its virulence in cases arising otherwise. It is a notorious fact that the disease has often played havoc in half-bred flocks.

My own study of the disease leads me to think that the only certain method of eradicating it from a large flock is to dispose of the whole of the sheep, young and old, and restock with ewes and rams obtained from sound flocks. It must be frankly admitted that such a course involves a heavy initial sacrifice, and that even when this has been made it may be difficult to restock with absolute assurance that no infected animal is included in the new purchases.

It is quite right that, in the case of a disease of which the starting point without exception appears to be introduction of an animal from an already infected flock, the methods by which the owner of such a flock can get rid of the disease should receive the first attention, but it is equally necessary to consider the means by which the disease may be prevented and to impress their importance upon those whose flocks are still healthy. Where a healthy flock is, or can be made, self-supporting in the matter of breeding the young stock, prevention must be comparatively easy. New blood must be introduced from time to time, but that can be effected by the purchase of rams, if possible from flocks guaranteed to be free from the disease.

As the disease appears in the majority of cases to be either congenital or contracted during the first few months after birth, and to show itself before the animal attains the age of two years, it would be an additional safeguard against the introduction of infection if rams purchased to bring fresh blood into the stock were not put with the ewes until they are in their third year.

Where the ewe stock has to be replenished by the annual purchase of a considerable number of ewes or ewe lambs, these should not be bought without a warranty that the farm on which they were bred is free from scrapie. At present this may be considered an impracticable proposal; but, in view of the serious consequences of buying an infected animal, the practice of giving such a warranty ought to be advantageous not only to buyers, but also to the owners of healthy flocks who have to sell.

PART II.—EXPERIMENTS.

Experiment I.

On the 28th September 1911 a lamb about six months old, No. 21, was inoculated subcutaneously inside the right elbow with 3 cc. of citrated blood (2 cc. blood, 1 cc. $\frac{1}{2}$ per cent. pot. citr. in normal saline solution) taken during life from a sheep in the last stages of scrapie.

At the same time another lamb, No. 93, had administered to it as a drench part of the contents of the small intestine of the same diseased sheep taken immediately after death.

As the object of the experiment was to transmit the disease experimentally by any method, and not specially to test the infectivity of the blood or intestinal contents, the two lambs were placed together in the same loose-box with another sheep at an advanced stage of scrapie. This diseased sheep remained in contact with the above two lambs until the 1st November following (thirty-four days), when it died from the disease.

Lambs Nos. 21 and 93 never developed any symptom of scrapie, and they were sold to a butcher on 12th February 1914, two years and five months after the beginning of the experiment.

Experiment II.

On the 15th March 1912 a ewe, three years old, was killed when near the point of death from scrapie.

Just before death a syringe of blood was withdrawn from the jugular vein, and 3 per cent. pot. citr. was added to it in the proportion of 1 of the citrate to 4 of the blood.

Half an hour afterwards two yearling sheep, Nos. 49 and 54, were inoculated subcutaneously inside the left thigh with 10 cc. each of the citrated blood.

At the *post-mortem* examination the above ewe was found to be pregnant, and a yearling sheep, No. 42, was inoculated subcutaneously with 3 cc. of liquid from the allantois, mixed with scrapings from a number of the foetal cotyledons.

Another yearling sheep, No. 47, was similarly inoculated with 1.5 cc. of cerebro-spinal fluid from the ewe.

Two other yearling sheep, Nos. 46 and 61, were similarly inoculated subcutaneously with water in which was suspended material obtained by scraping deeply a number of the bare patches on the ewe's skin.

Seventeen days later a further attempt was made to infect No. 49 of the above animals by rubbing into the slightly scraped skin of its neck material obtained on the same day from another ewe at an advanced stage of scrapie. The material in question was obtained by scraping some of the diseased areas of skin, and thoroughly triturating the scrapings with nutrient gelatine in a mortar.

None of these animals developed any symptom of scrapie. The whole of them, when in apparent good health, were sold to a butcher on 15th September 1914, or over two years and five months after the beginning of the experiment.

Experiment III.

On the 21st May 1912 a Cheviot ewe, which had contracted scrapie naturally on a farm where the disease prevailed, was found to be in a dying condition. Blood was drawn off from the animal's jugular vein and mixed with 3 per cent. pot. citr. solution (2 of blood to 1 of citrate), and two yearling sheep of the Oxford Down breed, Nos. 96 and 98, were each inoculated immediately into the jugular vein with 5 cc. of the citrated blood.

These two sheep, one a wether and the other a ewe, never

developed any symptom of scrapie, and they were sold to a butcher in apparent good health on the 26th October 1914, or two years and five months after their inoculation with blood.

Experiment IV.

On the 19th August 1912 the following animals were placed together in the same loose-box, No. 41:—

Ewes Nos. 100 and 101. These ewes were severely affected with scrapie, and had recently been brought from Scotland.

Lamb No. 102. This was the ewe lamb of ewe No. 100, and it was apparently healthy.

Lamb No. 103. This was the ewe lamb of ewe No. 101, and it was apparently healthy.

Lamb No. 104. This was a healthy ewe lamb recently purchased in England for experiment.

Lamb No. 105. A healthy wether lamb, also recently purchased for the purpose of this experiment.

The above ewe No. 101 died from scrapie on the 23rd August 1912, or four days after the beginning of the experiment.

Ewe No. 100 died on the 23rd September 1912, or thirty-five days after the beginning of the experiment.

On the 24th September 1912 there thus remained only the two lambs belonging to the two diseased ewes and the two healthy lambs which had been exposed to contact with the latter.

The subsequent history of these four animals is as follows:—

Lamb No. 103. On the 10th December 1912 this animal, then about nine months old, was transferred along with certain other sheep to another loose-box (No. 43), which also contained a ram. It remained there until its death.

Towards the end of April 1914, when it was about two years old, symptoms of scrapie was first noticed in this sheep. At times its respirations appeared to be hurried, and it had begun to rub itself against the walls.

On the 14th May 1914 it gave birth to a lamb, and after this the symptoms of scrapie developed rapidly. The ewe was constantly nibbling her legs, had a restless appearance, and frequently used her feet to scratch her head, with resulting loss of hair between the ears and down the centre of the face (*see fig. 1*).

As the ewe had very little milk, the lamb scarcely grew at all, and remained weakly. It died on the 21st June, and the *post-mortem* examination showed no disease of any of the organs.

The ewe died on the 1st July 1914.

At the time of death there had been extensive loss of wool, and at many places the bare skin showed scabs, obviously as the result of scratching. There were also some subcutaneous abscesses varying in size from a pigeon's egg down to a pea; these contained creamy pus, and were apparently the result of accidental infection of the skin abrasions.

Lamb No. 102. On the 10th December 1912 this animal was also transferred to another loose-box which contained a ram, and it had two lambs, Nos. 0 and 51, on the 16th March 1914. One of

these lambs, No. 0, died on the 14th July 1914, and on *post-mortem* examination the abomasum was found to contain seven wool balls, the largest being about the size of a hen's egg. There was some congestion of the small intestine, and part of the apex of the right lung was hepatised. The skin and other parts appeared quite normal.

The second lamb, No. 51, died on the 7th June 1916, when it was two years and three months old. Until about a week before its death it had appeared to be perfectly healthy, and had not exhibited any symptoms suggestive of scrapie. When noticed to be not

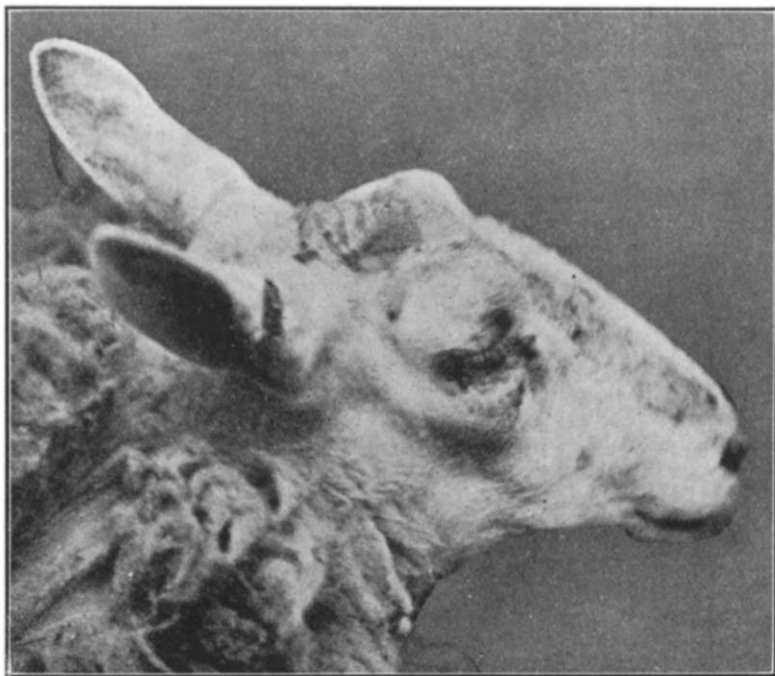


FIG. 1.

Head of Sheep No. 103, taken 16th May 1914, shows the result of rubbing between ears and down centre of face. (Photo by Mr A. L. Sheather, B.Sc.)

feeding very well and looking dull it was placed in a separate loose-box.

The *post-mortem* examination showed extreme dropsy of the pleural, pericardial, and peritoneal cavities, and the liver was cirrhotic. There was some collapse towards the apex and along the lower edge of each lung.

No. 102 also had a lamb, No. 58, the following year, viz., on the 3rd March 1915. This lamb developed quite normally, and it was sold to a butcher along with its dam, both in apparent good health, on the 5th July 1916.

Lamb No. 104. This animal was also transferred to another

loose-box which contained a ram on the 10th December 1912. It had a lamb, which died soon after birth, on the 17th May 1913. The ewe remained apparently healthy, and was sold to a butcher on the 26th October 1914.

Lamb No. 105. This animal also remained healthy, and was sold to a butcher on the 26th October 1914.

The interesting fact in connection with this experiment is that No. 103, which was the lamb of a scrapie ewe, and had contact with its dam from the time of its birth in April 1912 until the 23rd August 1912, and which also was in contact with another ewe affected with scrapie from about the middle of August until 23rd September 1912, developed a typical attack of scrapie when it was about two years old, and over twenty months after its removal from the farm on which it was born.

In other respects the results of this experiment were negative.

Experiment V.

On the 19th August 1912 the following animals were placed together in the same loose-box, No. 42:—

Ewes Nos. 106 and 107. These animals had contracted scrapie naturally on a farm in Scotland, and had recently been brought to the College; they were both severely affected with the disease.

Lamb No. 108. This was a ewe lamb belonging to the above ewe No. 106; it had been brought from Scotland along with its dam, and appeared perfectly healthy.

Lamb No. 109. This was a wether lamb belonging to the above ewe No. 107; it also appeared perfectly healthy.

Lamb No. 111. This was a healthy cross-bred wether lamb recently purchased in England for the purpose of the experiment.

The above scrapie ewe No. 107 was killed when near the point of death from the disease on the 24th September 1912, and the other naturally infected ewe No. 106 died from the disease on the 9th November 1912.

On the 10th December 1912 lamb No. 108 was transferred to another loose-box with other sheep, including a ram.

On the 14th February 1914 No. 108 gave birth to a lamb, No. 49. This lamb developed normally, and appeared quite well until December 1915, when it was one year and ten months old. It was then noticed that it was losing condition, but there was no loss of wool or any other symptoms suggestive of scrapie. It died on the 15th December 1915, and the *post-mortem* examination showed that the carcase was somewhat dropsical, the liver was in a condition of marked fatty degeneration, the middle lobe of the right lung was completely hepatised, and there were a number of smaller hepatised areas in other parts of the same lung. Some hæmorrhage appeared to have occurred from the solid lung, as many of the smaller bronchi contained string-like clots of blood.

Ewe No. 108 never developed any symptoms of scrapie, and it was sold to a butcher in apparent good health on the 5th July 1916.

Lamb No. 109. The above wether lamb of the scrapie ewe No. 107 remained apparently healthy until the end of January 1914,

when it was noticed for the first time that at some places the wool was becoming detached. On examination it was found that at these places the skin appeared somewhat hyperæmic, but otherwise normal. After this the cutaneous symptoms of scrapie developed steadily, and in the month of May the greater part of the fleece had been lost (*see* fig. 2).

On the 25th May 1914, when death appeared imminent, the wether was killed.

The *post-mortem* examination showed no visceral lesions. Over the whole of the body except the neck the long wool had been lost, but at some places a crop of new wool had started to grow on the

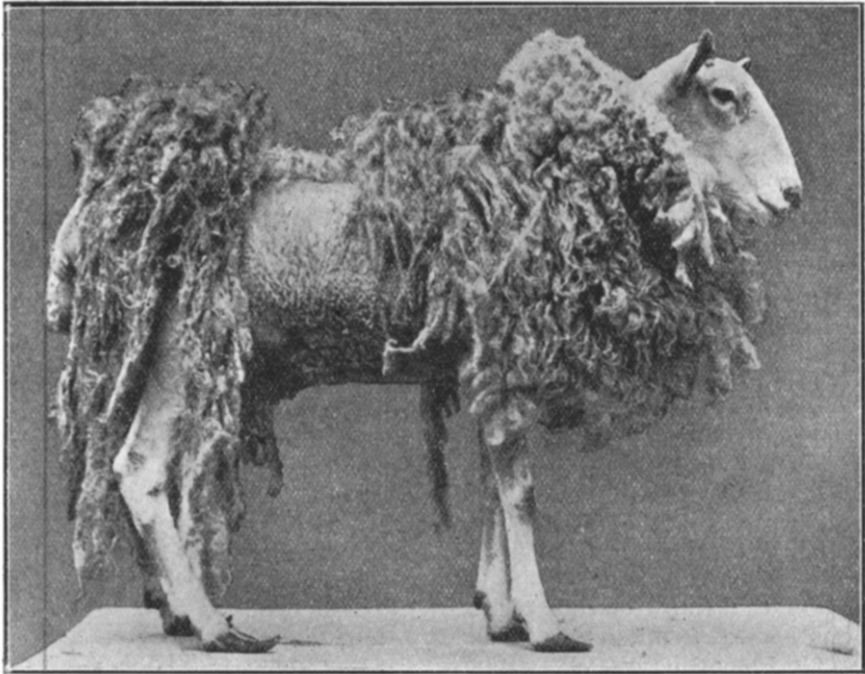


FIG. 2.

Sheep No. 109. Taken 16th May 1914. (Photo by Mr A. L. Sheather, B.Sc.)

places from which it had been shed at an earlier stage of the disease. At various parts of the body, head, and limbs there were scabs, obviously the result of scratching.

Lamb No. 111 never developed any symptoms of scrapie, and it was sold to a butcher in apparent good health on the 26th October 1914.

This experiment, therefore, had negative results except in the case of lamb No. 109.

In that case the facts were almost identical with those of lamb No. 103 of the preceding experiment, that is to say, the animal which developed scrapie was out of a ewe that had contracted the disease naturally before the lamb was born.

The exact date of the lamb's birth was not known, but presumably it was in the month of April 1912, and the last contact between the ewe and the lamb was on the 24th September of that year. The lamb, however, had contact until 9th November with the other infected ewe in the same loose-box.

It will be observed that the first symptoms of the disease were noticed in this sheep when it was about twenty-two months old, about seventeen months after its removal from the farm on which it was born, and about fifteen months after its last contact with an infected animal.

Experiment VI.

On the 19th August 1912 the following animals were placed together in the same loose-box, No. 43:—

Ewes Nos. 112 and 113. These animals had recently been brought from a farm in Scotland and were at the time severely affected with scrapie.

Lambs Nos. 114 and 115. These were the lambs respectively of the above two ewes, and they appeared to be quite healthy. The first was a ewe lamb and the second a ram lamb.

Lambs Nos. 116 and 117. These were two healthy cross-bred ewe lambs recently purchased in England for experiment.

The above scrapie ewe, No. 112, died from the disease on the 22nd September 1912, and the other scrapie ewe, No. 113, also died from the disease on the 21st October 1912.

On the 10th December 1912 the remaining four sheep, viz., the two lambs out of the two scrapie ewes and the two experimental lambs, were transferred to another loose-box with a ram. The subsequent history of these four animals was as follows:—

Lamb No. 114. This animal never developed any symptom of scrapie, and it was sold to a butcher in apparent good health on the 5th July 1915. It had had two lambs, Nos. 53 and 54, which were born on the 6th March 1914.

Lamb No. 53. This animal died on the 11th December 1915, when it was about nine months old. It had not been thriving for some considerable time. The *post-mortem* examination showed no distinct abnormality of any of the internal organs, but the body was markedly emaciated, and the whole of the tissues were slightly dropsical. The mucous membrane of the fourth stomach was very œdematous, but not inflamed, and no parasites could be found in the stomach. The animal had not exhibited any symptoms suggestive of scrapie.

Lamb No. 54. This lamb developed normally and appeared to be quite healthy until it was two years old, although latterly its general condition was poor. On the 21st March 1916 it was found to be down and unable to rise, and as there was no improvement on the following day it was killed.

The *post-mortem* examination showed about 10 ozs. of clear, dropsical liquid in the peritoneal cavity, about half that amount in the pleural sacs, and about 2 or 3 ozs. in the pericardial sacs; the body generally was very anæmic, and the liver was in an advanced stage of fatty degeneration. The anterior and middle lobes of the ht lung were partly collapsed.

During life the animal had not exhibited any symptom suggestive of scrapie.

Lamb No. 115. This lamb remained apparently well until the 24th June 1914, on which day it showed symptoms of colic. It was found dead on the following morning, and the *post-mortem* examination showed that death had been the result of cystitis and obstruction of the urethra by a calculus.

The animal had never exhibited any symptom of scrapie.

Lamb No. 116. This animal never developed any symptom of scrapie, and it was sold in apparent good health on the 26th October 1914.

Lamb No. 117. This animal also remained quite healthy, and it was sold to a butcher on the 26th October 1914. On the 26th May 1914 it had a lamb which developed normally, and was sold in apparent good health along with its dam.

Experiment VII.

On the 19th August 1912 the following animals were placed together in the same loose-box, No. 45 :—

Ewes Nos. 118 and 119. These animals had recently been brought from Scotland and were severely affected with scrapie.

Lambs Nos. 120 and 121. The first of these was a ewe lamb belonging to ewe No. 118, and the other was a ram lamb belonging to ewe No. 119.

Lamb No. 123. A healthy cross-bred ewe lamb recently purchased in England for the experiment.

The above scrapie ewe No. 119 died from the disease on 1st September 1912, and the other ewe No. 118 also died from the disease on the 19th December 1912.

On the 10th December 1912 the ewe lambs, Nos. 120 and 123, were transferred to other loose-boxes, each of which contained a ram.

The subsequent history of these three animals was as follows :—

Lamb No. 120. On the 6th March 1914 this animal, then two years old, gave birth to two lambs, one of which was born dead. The other, No. 50, died from pneumonia on the 2nd April 1916, when it was two years and one month old. At the *post-mortem* examination the right lung was extensively consolidated, and contained a number of cavities occupied by greenish-yellow, thick, muco-purulent material. There was one similar lesion in the middle lobe of the right lung, and some fatty degeneration of the liver; the other organs appeared normal.

The animal had never shown any symptom suggestive of scrapie.

The dam of this last sheep, the original lamb No. 120, died on the 15th March 1915 during lambing. One dead lamb had been taken away on the 14th March 1915, but the ewe died on the following day, and the *post-mortem* examination showed a second lamb in one of the horns of the uterus. There was severe metritis, and a large solid area of pneumonia in the right lung.

Lamb No. 121. This wether sheep remained perfectly well until the 27th December 1914, on the afternoon of which day it was quite unexpectedly found dead.

The *post-mortem* examination showed no obvious disease of any

of the internal organs, and the cause of death was not ascertained. The animal had not exhibited any symptom of scrapie.

Lamb No. 123. This animal never developed any symptom of scrapie, and it was sold in apparent good health on the 18th August 1915. It had had a lamb, No. 52, on the 24th March 1914, which developed normally, and was sold in apparent good health at the same time as its dam.

Experiment VIII.

On the 6th February 1914 blood was withdrawn from the jugular vein of a Scotch ewe at an advanced stage of scrapie and mixed with one-fourth of its volume of 3 per cent. citrate solution.

Two yearling sheep, Nos. 32 and 33, were each inoculated intravenously with 25 cc. of the citrated blood.

The ewe from which the blood was taken died from scrapie nine days afterwards.

Sheep No. 33. This sheep, then about three years old, died on the 3rd May 1916.

The *post-mortem* examination indicated that it had died from an accumulation of wool in the stomach. The quantity of wool in the rumen formed a mass rather larger than a man's head, but food materials were intimately mixed with it. There was no solid food in the fourth stomach, but its mucous membrane was congested.

The fleece of this sheep was very ragged, and at places there was a growth of short wool where the old wool had been lost. For several months before it died it had been noticed that the other sheep, No. 32, in the same pen with it had acquired the habit of pulling out wool from its back and eating it.

Sheep No. 32. In spite of the above-mentioned habit of eating wool, this sheep remained in apparent good health, and it was sold to a butcher on the 5th July 1916.

Experiment IX.

On the 28th May 1915 three ewes, each with a lamb at foot, were brought to the College. The ewes had contracted scrapie naturally on farms in Scotland, and were at the time of admission at an advanced stage of the disease.

The ewes and lambs were all put together into the same loose-box.

One of the ewes, No. 63, was killed when near the point of death on 9th June 1915. The second, No. 62, died on the 14th June, and the third, No. 61, died on the 17th June 1915.

The three lambs out of these three ewes were kept until the 4th June 1917, when they were sold to a butcher in apparent good health.

Experiment X.

On the 7th June 1915 blood was withdrawn from the jugular vein of ewe No. 63 mentioned in the previous experiment. The blood had added to it one-fourth of its volume of 3 per cent. citrate solution.

A healthy lamb, No. 68, was inoculated intravenously with 5 cc. of the citrated blood, and another healthy lamb, No. 69, was at the same time inoculated subcutaneously with 10 cc. of the same citrated blood.

Two days later, viz., on the 9th June, after the death of ewe No. 63, the cerebro-spinal fluid was collected, and 7 cc. of it was injected into the jugular vein of a third lamb, No. 70.

These three lambs were English lambs recently purchased for the purpose of the experiment.

The above lambs were kept under observation till 4th June 1917; they had never shown any symptom of scrapie and were sold to a butcher on that date.

SUMMARY OF EXPERIMENTS.

Inoculation with Blood.

No. 21.	Subcutaneous;	2 cc.
No. 49.	"	8 cc.
No. 54.	"	8 cc.
No. 69.	"	8 cc.
No. 96.	Intravenous;	$3\frac{1}{3}$ cc.
No. 98.	"	$3\frac{1}{3}$ cc.
No. 32.	"	20 cc.
No. 33.	"	20 cc.
No. 68.	"	4 cc.

Inoculation with Cerebro-Spinal Fluid.

No. 47.	Subcutaneous;	1·5 cc.
No. 70.	Intravenous	7 cc.

Inoculation with Materials from Diseased Skin.

No. 49.	Subcutaneous.
No. 46.	"
No. 61.	"

Inoculation with Liquid from Allantois and Scrapings from Fœtal Cotyledons.

No. 42.	Subcutaneous.
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Intestinal Contents administered by the Mouth.

No. 93.	
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Contact Experiments with Sheep in the Last Stages of the Disease.

No. 21.	34 days.
No. 93.	34 days.
No. 104.	35 days with one sheep and 4 days (concurrent) with another.
No. 105.	Ditto.
No. 111.	82 days with one sheep and 36 days (concurrent) with another.
No. 116.	63 days with one sheep and 34 days (concurrent) with another.
No. 117.	Ditto.
No. 123.	92 days with one sheep and 12 days (concurrent) with another.

In all the above cases the animals survived for at least eighteen months after the beginning of the experiments without developing any symptom of scrapie.

The whole of the experiments therefore had negative results.

It will be noticed that some of the sheep figure under different headings, as different methods of attempting to infect them were employed.

None of the rams used in connection with the experiments became infected.

Natural Transmission from Diseased Ewes to their Lambs.

Out of eleven lambs which were borne by infected ewes and which sucked their dams until they were over four months old only two developed the disease.

A NOTE ON PIROPLASMOSIS OF THE DONKEY.

By J. A. GRIFFITHS, Veterinary Officer, Nyasaland.

PIROPLASMOSIS has been recorded as occurring in the donkey by observers in various parts of Africa. In German East Africa it was recorded by Schellhase¹ in 1914.

My observations of the disease have been made in the North Nyasa district of Nyasaland and in the New Langenburg and Iringa districts of German East Africa.

The disease appears to affect more severely the white Zanzibar donkey and crosses of this breed with the native grey donkey, while the latter breed has a high degree of natural immunity. This immunity, or at least greater power of resistance, which the grey donkey has, is probably due to the breed being more hardy in every way, and better able to withstand the rough conditions of both climate and food.

In its most common form the disease runs a chronic course, and parasites are not usually plentiful in smears of the peripheral blood.

The parasites vary considerably in shape—amoeboid, round, ring, and match-shaped forms being noted at different periods during the course of an acute attack, in the order mentioned. Pear-shaped parasites were rare. Occasionally parasites were seen in pairs, these being either leaf-shaped or match-like forms, and in several cases, where the parasites were joined at the extremities away from the nucleus, a small granule of chromatin was seen at the point of junction.

The nucleus, which is usually towards the periphery in the amoeboid, round, and ring forms, is in these cases much smaller than in the pear-shaped and match-like varieties, where it consists of a darkly stained, irregularly rounded mass at one end of the parasite.

¹ Extract in "Tropical Veterinary Bulletin," June 1914, No. 2.