Here again one must not expect of the serum-therapy what it is incapable of giving. Its action, as is always the case, is specific, and the possible limit of efficacy is marked by the proportion—at present undetermined—of gangrenes due to the septic vibrio and to the bacillus perfringens. Even in this case failures can be foreseen theoretically.

The systematic prevention of gaseous gangrene will perhaps be realised when one has determined its various etiological agents and obtained corresponding antibodies.

Up to the present the partial results can be discounted, and the treatment is justified by its absolute harmlessness.

SHEEP SCAB.¹

OBSERVATIONS ON THE LIFE HISTORY OF *PSOROPTES COMMUNIS*,
VAR. *OVIS*, AND SOME POINTS CONNECTED WITH THE EPIZOOTIOLOGY OF THE DISEASE IN SOUTH AFRICA.

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ALTHOUGH sheep scab has for many years been a scheduled disease in South Africa the efforts made to bring about its eradication have in the past met only with limited success. To a large extent this must be attributed to limitations in the matter of efficient control incidental to the area and character of the country and the diverse nature of its inhabitants.

There are, however, certain features of the disease which the generally accepted account of the life of the causal parasite fails to explain, and until exact information on these points is available the result of repressive measures must be very uncertain.

Reference to the literature of sheep scab shows that for practically the whole of our knowledge of the life-history of the acarus we are indebted to investigators who recorded their observations over fifty years ago; of these the chief are Hering (1835), Hertwig (1835), Delafond and Bourguigon (1854), and Gerlach (1857).

Later writers on the disease have to a large extent been content to quote the statements of these authorities, especially those of Gerlach, and, with the exception of observations published by Stockman while the present investigation was in progress, little attempt appears to have been made to ascertain whether the parasites exhibit similar biological characters in countries differing widely in climatic conditions from those in which the original observations were made.

This is certainly true of South Africa. Statements have been made regarding the vitality of acari or their eggs apart from the sheep, but the evidence brought forward in their support does not warrant the conclusions which are drawn.

¹ Reprinted from the "Third and Fourth Reports of the Director of Veterinary Research, Union of South Africa."

The observations recorded here were made with the view of obtaining more exact information on the development of the scab parasites on the sheep and of determining the correctness or otherwise of certain popular beliefs regarding the disease ; also, if possible, of discovering the true explanation of the occurrences which have given rise to these beliefs.

The subject will be dealt with under the following headings :—

(a) The life-history of the *psoroptes communis*, var. *ovis*, on the sheep.

(b) The interval to be allowed between dippings.

(c) The duration of vitality of acari and their eggs apart from sheep ; infectivity of kraals, etc.

(d) The possibility of the *psoroptes communis*, var. *ovis*, maintaining its existence on animals other than sheep or of the *psoroptes* of such animals producing scab in sheep.

(e) Variations in the rapidity of multiplication of the acari.

(a) THE LIFE-HISTORY OF THE SHEEP SCAB ACARUS.

Observations Made on the Sheep.

In order to observe the various phases of development through which the psoropt passes on the sheep, beginning with the egg and ending with the laying female, it was found necessary to provide a means of confining the parasites to a particular spot on the sheep where they could be watched unobscured by wool or crusts, but under as natural conditions as possible in regard to feeding and ventilation.

After several devices had been tried, the following method was adopted and has been found to give very satisfactory results : A number of covers were made by cutting rings 3 inches wide from a glass tube 2 inches in diameter and $\frac{1}{8}$ inch in thickness ; over one end of these rings a double layer of fine butter muslin was stretched and fixed with seccotine and thread, thus forming a miniature tambourine. The free edge of each ring was ground smooth and rounded to prevent it cutting the sheep's skin. To maintain a cover in position on a sheep's back, the wool was clipped from a circular patch the same size as the ring and the skin carefully shaved ; on this area the parasites or their eggs were placed, the cover, numbered for identification purposes, applied and melted paraffin wax run round it ; this last kept the cover in position and prevented escape of the acari. The surrounding wool was then gathered up and tied sufficiently firmly to prevent the ring from slipping, but not so tightly as to completely exclude air from the cover. The muslin top was found necessary for the escape of moisture from the skin, which otherwise condensed, causing softening of the epithelium, suppuration, and the death of the acari.

Every three or four days the parasites were moved to a fresh patch, as the growth of the wool and the formation of crusts soon made it difficult to observe them clearly.

While under observation the parasites were frequently removed from the skin and examined under the microscope to note the changes from one stage to another, but this treatment appeared to have little effect in retarding their development.

Seasonal variation of temperature is usually believed to have considerable effect in shortening or lengthening the duration of the life-cycle of the psoric acari, and in many species of animal this influence is probably considerable. The sheep, however, has a very efficient covering during the winter months, and it is doubtful whether the temperature of its skin is then much lower than in summer when its fleece is short. At all events the observations made in Natal during the past two years have shown that there is little difference in the length of time required for the complete life-cycle of the acarus at the different seasons of the year, provided alteration of the temperature of the air is the only variant factor present.

Life-History.

To obtain eggs of which the time of laying was known fairly exactly, numbers of adult female acari were placed under covers on a sheep and twelve hours later the eggs were removed and transferred to a freshly prepared patch or used for observations *in vitro*.

When in close contact with the sheep's skin the majority of the eggs hatch after an interval of two days from the time of laying, and usually no eggs remain unhatched at the end of three days. They have never been observed to hatch in less than two days. Eggs on the surface of thick crusts may not hatch for four or five days, but usually the eggs are deposited at the outside edge of the patch of affected skin where scab formation has not commenced.

To ascertain how long eggs might remain in the wool before hatching, a number of these were tied in a lock on a sheep's back, being separated about 2 inches from the skin; larvæ began to come out on the sixth day, and by the ninth all the eggs had hatched. The weather at the time was very warm, the temperature varying from a minimum of 60° F. to a maximum of 100° F. in the shade, and as the observation on eggs *in vitro* recorded later showed it was quite possible for hatching to occur without any additional source of heat being necessary. It is probable that in cold weather eggs in the fleece at a little distance from the skin would not hatch in that situation, and would only retain the power of doing so for the same length of time as those kept entirely apart from the sheep. The greatest length of time that eggs may remain on the sheep and still be capable of hatching is of importance in determining the interval to be allowed between dippings, but, as it is included in the much more important question of duration of vitality of eggs apart from their host, the observations will be recorded later in that direction.

As in all the acarina the larva is six-legged (hexapod), the two anterior pairs only being furnished with suckers, the posterior pair carrying two long bristles each. On hatching, the mites very quickly attack the skin, a minute vesicle, containing yellow serous fluid, marking the situation of each puncture. During the first twenty-four hours they enlarge rapidly, but the frequent moultings said to occur at this stage to allow of enlargement have not been observed.

It may here be remarked that complete shedding of the skin has only been seen to occur as a necessary accompaniment of change from one stage of development to another, and it is always preceded by a resting period of considerable duration.

The process of moulting is not merely a casting off of the old skin,

but is a fresh embryonic development inside the animal body, similar to that occurring in the impregnated ovum. All the internal tissues undergo liquefaction, with the exception of certain germinal cells, and from the rapid multiplication of these a new form arises which presently breaks through the old covering in the same way that the larva emerges from the egg.

While these changes are taking place the acari remain perfectly quiescent, the length of time they occupy varying from about twelve hours in the case of larvæ moulting to nymphæ, to nearly thirty-six hours in the later stages.

The larval stage is short, nymphæ usually appearing forty-eight hours from the hatching of the eggs and always within three days.

Nymphæ may easily be distinguished from larvæ by the presence of a fourth pair of legs, but when fully engorged they closely resemble the adult pubescent females.

They may be identified by the presence of slender suckers on the fourth pair of legs, and the absence of copulatory tubercles at their posterior extremity.

The nymphal stage lasts from three to four days, and during the first two days increase in size is rapid, while the period of quiescence preceding moulting is usually about thirty-six hours. At this time the sex of the next stage can frequently be determined by the size of the resting nymphæ, the smallest usually giving rise to males. It has also been noticed that pubescent females always appear before males; the former have been observed five and a half days after the hatching of the eggs, but the latter have never been seen earlier than the sixth day.

The pubescent female possesses two copulatory tubercles, one on each side of the cloaca at the posterior margin of the body; the third and fourth pairs of legs are furnished with two long bristles each in place of suckers.

The male acari are readily recognised by their smaller size, the long third pair of legs bearing suckers and a small fourth pair without; also by the presence of the posterior tubercles and copulatory suckers and the brown plates on the posterior half of the dorsal surface of their bodies. The males are much more active than the females.

The proportion of males to females was stated by Gerlach to be as one is to two; whilst this has been noticed in some cases, the females are more often three, or occasionally four, times as numerous as the males.

The acari feed for a short time after moulting and then copulation takes place; this has been observed just over six days from the time of hatching. The pair usually remain united for about twenty-four hours, though when the females greatly exceed the males in number a shorter time may be occupied. Frequently the male remains attached to the female for over two days or until the latter moults. This she usually does two days after the commencement of the attachment of the male.

The now ovigerous female is distinguished by the presence of a sub-thoracic valva and suckers on the fourth pair of legs; both the third and fourth pair of legs are longer and stouter than in the pubescent female, while the copulatory suckers have disappeared.

After feeding, the ovigerous female is considerably larger than any of the other forms, and, like the male, its body becomes quite opaque, losing the semi-transparent appearance of the younger stages.

The first egg may be laid twenty-four hours after the last moulting, or nine days from the time of hatching of the larva from the egg.

In one observation two male acari were placed under a cover with numerous nymphæ, of which the time of hatching was known. The pubescent females moulting out before the males of the same age mated with the two older males, and the first egg was found eight and a half days from the time the original eggs hatched on the patch.

Even in mid-winter the complete life-cycle, as observed under a cover, never occupied more than ten days, and in the great majority of cases occurred in little over nine days. In summer eggs were constantly found nine days from the time of hatching the original eggs.

It should be stated that sheep with heavy fleeces were always used to enable the glasses to be kept in position; thus the temperature of their skin may have been maintained at a higher point during the cold weather than would have been the case in sheep less well clothed.

Gerlach, who carried out his observations in 1857, but who is still almost the only authority quoted on the life-history of the sheep scab parasite, stated that the time required for a generation of acari to reach maturity was fourteen to fifteen days.

Other writers mention twelve to sixteen days, but there is a great lack of certainty and wide variation in the statements of the length of time required for the hatching of the egg and the duration of the various stages.

The observations here recorded have been repeated at intervals over a period of nearly two years, and they clearly show that so far as Natal is concerned the *psoroptes communis*, var. *ovis*, can mature much more rapidly than records of observations made in other countries have led us to suppose.

The complete life-cycle may be briefly illustrated by giving the details of an observation made towards the close of the winter season:—

3rd August 1912. A number of acari eggs, laid during previous night, placed under cover on sheep.

4th August (first day). No eggs hatched.

5th August (two days). Several larvæ present.

6th August (three days). No unhatched eggs observed, larvæ increasing in size.

7th August (four days). Two or three nymphæ present.

8th August (five days). All nymphæ (enlarging).

9th August (six days). Nymphæ enlarging, several quiescent.

10th August (seven days). Some pubescent females present, no males observed, a few nymphæ not yet moulted.

11th August (eight days). Two pairs in copula; numerous females; all transferred to fresh spot.

12th August (nine days). Four pairs in copula, numerous females.

13th August (ten days). Four pairs in copula, apparently different

females, as several others are enlarging and ready to undergo last moult.

14th August (eleven days). Numerous ovigerous females. Three eggs found nine days from time of hatching of original eggs.

Although each male acarus usually mates with from two to four females, it is apparently capable of fertilising more than this number; in one observation six females were fertilised by a single male.

The females continue to lay eggs for a considerable time, and since the observations carried out to determine the number of eggs laid by each female also furnish information as to the duration of their lives, these will now be described.

Here again the majority of writers are content to quote Gerlach's estimate of fifteen to twenty-four eggs from each female acarus, overlooking the fact that this was made from the *sarcoptes scabiei*, var. *hominis*, and is hardly applicable to the psoropt of the sheep.

There are two difficulties to be overcome before an actual enumeration of the eggs laid by a given female can be made.

Firstly, the acarus must be allowed to feed during the whole of the laying period. A considerable portion of the ovigerous females removed from their host will lay one or perhaps two eggs each, provided the temperature is not much below that of the body, but without feeding no further eggs will be laid; the only reliable method, therefore, of obtaining accurate information is to count the eggs actually laid by one or more females on the sheep itself.

The second difficulty arises from the fact that the period of egg-laying exceeds that necessary for the complete development of the acari, so that the second generation of parasites will mature and begin to lay eggs before the first generation has ceased to do so. By examining the patches and removing the eggs each day this possibility was avoided.

It was also found necessary to transfer the females to a freshly prepared area of skin every three or four days owing to the growing wool and crusts obscuring the eggs. Even then, eggs occasionally escaped detection until they hatched, but when this occurred the larvæ found were recorded as eggs laid two days previously.

When the females were removed, the old patch was examined for a further three days to ascertain whether any larvæ appeared from eggs that had been overlooked.

The following observations are recorded in full, as they show not only the numbers of eggs laid, but also the rate and duration of oviposition and the total life of the female acari:—

First Observation.—Five pairs of acari in copula, placed on clean sheep on 29th January 1913.

[TABLE

<i>Date.</i>	<i>Age of Acari in days.</i>	<i>No. of Females Laying.</i>	<i>No. of Eggs Laid.</i>	<i>Remarks.</i>
31.1.13 . .	8	—	—	Male acari removed.
1.2.13 . .	9	5	—	Patch not examined.
2.2.13 . .	10	5	—	Patch not examined.
3.2.13 . .	11	5	15	1 female missing, remaining 4 moved to fresh patch.
4.2.13 . .	12	4	9	1 female dead.
5.2.13 . .	13	3	12	
6.2.13 . .	14	3	21	
7.2.13 . .	15	3	23	
8.2.13 . .	16	3	14	
9.2.13 . .	17	3	6	
10.2.13 . .	18	3	20	
11.2.13 . .	19	3	19	
12.2.13 . .	20	3	10	1 female killed, crushed under edge of cover.
13.2.13 . .	21	2	11	
14.2.13 . .	22	2	9	
15.2.13 . .	23	2	4	
16.2.13 . .	24	2	8	
17.2.13 . .	25	2	11	
18.2.13 . .	26	2	11	
19.2.13 . .	27	2	9	
20.2.13 . .	28	2	9	
21.2.13 . .	29	2	4	
22.2.13 . .	30	2	18	
23.2.13 . .	31	2	6	1 female dead.
24.2.13 . .	32	1	6	
25.2.13 . .	33	1	6	
26.2.13 . .	34	1	2	
27.2.13 . .	35	1	0	
28.2.13 . .	36	1	1	
1.3.13 . .	37	1	0	
2.3.13 . .	38	1	3	
3.3.13 . .	39	1	0	Female dead.
		Total	267	

It will be seen that one female can only have contributed to the first fifteen eggs laid, though missing when the count was made, while another was dead at the second enumeration. It will therefore be fair if we assume that they only laid their share of these eggs, namely, six of the fifteen found on 3rd February 1913, and, say, three of the count of the fourth.

If these nine eggs are deducted from the total collected, the remaining 258 were laid by three females, or an average of 86 eggs each. Since one of the three was killed whilst still actively laying, it is not improbable that the two remaining females laid nearly 100 eggs each.

The first eggs were probably laid when the females were nine days old, and in one case oviposition was continued up to the thirty-eighth day, or for a period of twenty-nine days, the female dying the following day. Except during the four or five days preceding death,

the number of eggs laid each day is fairly constant throughout the laying period in this observation; the average number being about five eggs per day for each female from the thirteenth to the thirty-third day.

Second Observation.—Three copulating pairs placed on a clean sheep on 17th March 1913.

<i>Date.</i>	<i>Age of Acari in days.</i>	<i>No. of Females Laying.</i>	<i>No. of Eggs Collected.</i>	<i>Remarks.</i>
21.3.13 . .	10	3	5	
22.3.13 . .	11	3	14	
23.3.13 . .	12	3	13	
24.3.13 . .	13	3	10	
25.3.13 . .	14	3	12	
26.3.13 . .	15	3	15	
27.3.13 . .	16	3	20	
28.3.13 . .	17	3	15	
29.3.13 . .	18	3	14	
30.3.13 . .	19	3	12	
31.3.13 . .	20	3	10	
1.4.13 . .	21	3	13	
2.4.13 . .	22	3	6	
3.4.13 . .	23	3	3	1 female dead.
4.4.13 . .	24	2	3	
5.4.13 . .	25	2	0	
6.4.13 . .	26	2	0	
7.4.13 . .	27	2	1	1 female dead.
8.4.13 . .	28	1	1	
9.4.13 . .	29	1	0	
10.4.13 . .	30	1	0	Female dead.
		Total	167	

In this observation the average number of eggs per female acarus is 55.6.

The duration of the laying period is here seen to be much shorter than in the previous case, practically terminating when the females were twenty-three days old, although one acarus lived until the thirtieth day.

The two preceding observations were made during mid and late summer respectively. A third, carried out in early spring, is of interest in connection with the supposed influence of moisture on the rate of multiplication of the parasites. This point will be referred to later, but the details of the observation will be recorded here.

During the three winter months preceding the commencement of the observation, practically no rain had fallen, and in spite of the fact that the infected sheep were in poor condition owing to scarcity of feed, it was noticed that the parasites became less numerous on them and the disease was ceasing to spread. Two or three attempts were made at this time to repeat the egg-laying observations, but in every case the acari removed from scabby sheep and placed under covers laid only a few eggs and then died—it was also noticed that the females appeared smaller than normal. In the observation given below two copulating pairs of acari were placed under a cover on

15th September. On the 19th two eggs were found, and on the 22nd one egg. On the 24th one of the females was dead, but no further eggs were laid by the remaining acarid up to the 28th idem, when the long period of drought ended in a heavy downpour of rain—on this day two eggs were found. On the 29th idem it was still raining, and the patch was not examined, but on the next day twenty-four eggs were removed, and for the succeeding days the single female laid an average of seven eggs a day. Altogether this female laid ninety-three eggs, without counting the three found while the second female was alive. The commencement of active oviposition with the onset of the rains appears to be more than a coincidence in view of the small egg production in this and other observations made during the dry season, and the rapid laying exhibited by the acarid when the atmosphere became moist. The sheep themselves were not actually exposed to the rain, but kept in covered pens.

The following are the full details of the observation:—

Third Observation.—Two copulating pairs of acarid placed under cover on 15th September 1913.

<i>Date.</i>	<i>Age of Acari in days.</i>	<i>No. of Females Laying.</i>	<i>No. of Eggs Collected.</i>	<i>Remarks.</i>
18.9.13 . .	9	2	0	
19.9.13 . .	10	2	2	
20.9.13 . .	11	2	0	
21.9.13 . .	12	2	0	
22.9.13 . .	13	2	1	
23.9.13 . .	14	2	0	
24.9.13 . .	15	1	0	1 female dead.
25.9.13 . .	16	1	0	
26.9.13 . .	17	1	0	
27.9.13 . .	18	1	0	
28.9.13 . .	19	1	2	Raining heavily.
29.9.13 . .	20	1	0	Eggs not removed; still raining.
30.9.13 . .	21	1	24	Light rain.
1.10.13 . .	22	1	8	
2.10.13 . .	23	1	8	
3.10.13 . .	24	1	6	Slight rain
4.10.13 . .	25	1	8	
5.10.13 . .	26	1	7	
6.10.13 . .	27	1	6	Raining.
7.10.13 . .	28	1	5	Raining.
8.10.13 . .	29	1	4	
9.10.13 . .	30	1	2	Raining.
10.10.13 . .	31	1	4	
11.10.13 . .	32	1	2	Raining.
12.10.13 . .	33	1	1	Little rain.
13.10.13 . .	34	1	4	Little rain.
14.10.13 . .	35	1	1	
15.10.13 . .	36	1	1	
16.10.13 . .	37	1	0	
17.10.13 . .	38	1	0	
18.10.13 . .	39	1	0	Female dead.
		Total	96	

After the advent of rain, female acari were observed in several cases, and all laid eggs freely from the time they reached maturity.

In another observation three females lived for thirty-eight days, but the number of eggs laid was not determined; they were then accidentally allowed to escape from the cover, and so were lost.

It may be stated, therefore, that the number of eggs laid by the female psoropt varies within considerable limits, but under favourable conditions may exceed ninety eggs per female. Oviposition usually begins on the ninth day, and may continue with little interruption until the thirty-eighth day. A single female has been observed to lay twenty-four eggs in two days and seventy-six in ten days.

The life of the ovigerous female on the sheep is from thirty to forty days.

In his report for 1911, Sir Stewart Stockman, Chief Veterinary Officer, Board of Agriculture, draws attention to the fact that visible evidence of scab may not appear in a flock for several months after infection must have taken place, the acari apparently living on the sheep but producing no sign of the disease.

This question will be discussed later when other factors in the epizootiology of the disease are considered, but one point which may have a bearing on the matter will be dealt with here, as it directly concerns the life-history of the parasite on the sheep.

It is probable that in many cases of infection of clean flocks the number of acari gaining access to any sheep is very limited, possibly only a single acarus. Should this be an ovigerous female, eggs will be laid, and in time the disease becomes established; but in the event of its being a pubescent female or a male, or a young form developing into one of these, no increase can occur until it is joined by an acarus of opposite sex.

It is of some interest, therefore, to determine how long a pubescent female or a male is able to survive on the sheep.

To obtain known unfertilised females it was necessary to isolate single nymphs, until they moulted into adults, the two sexes thus being kept separate.

Considerable difficulty was experienced in keeping both forms confined under covers for any length of time. After the first day or two they became very restless, and owing to loosening of the covers some escaped, while others were crushed in attempting to do so.

The longest period for which a pubescent female was kept under observation alive on a sheep was seven weeks—the majority died or escaped three or four weeks after moulting from nymphæ.

Male acari were found to live for periods varying from twenty-two to thirty-four days after moulting from nymphs. The fact that they had fertilised female acari did not appear to affect the duration of their lives.

(b) FACTORS IN THE EPIZOOTIOLOGY OF SHEEP SCAB BEARING ON THE QUESTION OF ERADICATION.

Interval between Dippings.

Experience has shown that a single immersion of scabby sheep in an antipsoric fluid cannot be relied upon to effect a cure.

It is true that many cases of the disease will be cured by a single dipping in any of the several preparations in common use, but it is equally certain that this is not so with some dips, while probably there is no fluid that can safely be employed which is capable of curing all cases in one dipping. The necessity for second dipping is therefore generally admitted.

But the question of the interval to be allowed between the two immersions has given rise to much discussion and divergence of opinion.

The failure of the first dipping is usually attributed to the inability of the fluid to destroy the vitality of the acari eggs, and though this explanation has been questioned, as being based on theoretical considerations, the observations on the effects of various fluids on the eggs described later show that the belief is well founded.

Experiment has shown that the majority of preparations, proprietary and otherwise, fail to prevent the eggs from hatching; hence the second dipping must be given before the parasites from the eggs which have escaped the first dipping complete their development and themselves commence to lay.

In accordance with the generally accepted statement as to the length of time required for the acari to mature, the interval between dippings usually advised is fourteen to eighteen days, though in South Africa the time adopted is twelve to sixteen days.

The present observations have now shown that the complete life-cycle of the acari may only occupy nine days; owing, however, to the fact that sheep remain wet for some time after dipping, the period varying according to the length of their fleece, season, etc., an interval of ten days could probably be safely allowed. As will be shown later, this interval would ensure the hatching of all eggs capable of doing so before the second dipping.

The question may be asked, how it is that some dips will effect a cure in certain cases after one dipping, although they fail to destroy the vitality of the eggs.

The explanation appears to be that the eggs hatch, but, owing to the persistence of certain ingredients of the dip on the skin, the larvæ are poisoned shortly after hatching; this has been actually observed in several instances.

It has also been noted that this delayed lethal effect usually occurs in the case of dips containing an insoluble constituent in suspension which becomes deposited on the skin and in the wool of the sheep and remains after the animal has become dry.

Most commonly this insoluble agent is sulphur, and experiment has shown that a fine deposit of this material alone over eggs placed on the skin is sufficient to kill larvæ shortly after hatching.

Solutions of arsenic that can be employed with safety, 1 per cent. solutions of various coal tar disinfectants, and carbolic dips and tobacco extracts, have all been found ineffective by themselves in arresting the hatching and development of acari from eggs on the sheep.

The addition, therefore, of an ingredient like finely-powdered sulphur, which becomes deposited in the fleece, tends to increase the effectiveness of a dip, but its value is discounted somewhat by the difficulty of maintaining it in suspension in the fluid, and the fact

that it does not reach parasites or their eggs which are protected by overlying crusts or matted wool.

While the failure of a single dipping to cure scab owing to the escape of the eggs has been demonstrated and the necessity indicated for a shortening of the interval between the two dippings on account of the rapid development of the parasites, observation has also shown that in certain cases after one immersion in a recognised dipping fluid some adult parasites may survive, and unless destroyed by a further dipping continue the infection.

The escape of the parasites is usually due to the inability of the fluid to penetrate the hard crusts under which they lie, or, as is frequently seen in the bend of the tail of the fat-tailed Africander sheep, the protection of an excessive amount of fat is sufficient to prevent the watery solution from reaching the acari.

The increased softening and penetrating effect of slightly alkaline dips, such as the caustic soda and sulphur and lime and sulphur preparations, is of special advantage in such cases, but even with these fluids the second dipping should not be omitted.

When a flock has been badly infected for a considerable time and a number of sheep show old-standing crusts, even two dippings cannot be relied on to effect eradication; a few female acari may escape the first dipping and continue to lay eggs which the second immersion fails to destroy; or the protection of the crusts may allow adult parasites to survive even two immersions; in either case the infection persists, although it may not become evident for several months. Hence a third dipping ten or fourteen days after the second would greatly increase the chances of a complete cure, the softening effect of the two previous dippings on any hard crusts facilitating thorough saturation at a third immersion.

As previously mentioned, some allowance can be made when it is necessary to dip sheep having a considerable growth of wool, as their fleeces hold more of the fluid, and they usually remain wet for a day or two after dipping. Special care is also necessary with such sheep when an arsenical dip is being employed, owing to the increased risk of poisoning, and before the interval between the first two dippings is reduced, or a third dipping adopted, it will be necessary to ascertain, more particularly in respect to proprietary arsenical dips, whether these procedures can be safely carried out while following the directions given as to the dilution required under present circumstances.

(c) THE LENGTH OF TIME ACARI AND THEIR EGGS CAN RETAIN VITALITY APART FROM SHEEP.

The importance of possessing exact information on this point will be readily appreciated when it is recognised that on this depends the possibility of clean sheep becoming infected by any means other than direct contact with scabby sheep.

That the disease can be contracted from posts, kraals, sleeping-places, etc., to which infected sheep have previously had access is a well-established fact, but the very greatest divergence of opinion exists as to the period of time during which such infection can persist or after what interval it may safely be regarded as having ceased.

It has frequently been stated that sheep have contracted scab when placed in kraals occupied by infected sheep two or even three years previously, but which have been kept closed during the interval, and since this view is held by persons who have had wide practical experience of the disease in South Africa, their opinion cannot be lightly disregarded, although it must be admitted that the evidence adduced in support of prolonged infection of kraals is not convincing.

In regard to the vitality of the acari themselves apart from the sheep, numerous investigators record observations. Neumann states: "From the experiments of Hertwig and Gerlach, and particularly of Delafond, it results that the psoroptes of the sheep infecting crusts, portions of wool, or pieces of fresh skin, kept at a medium temperature, can live in these for ten to twenty days; also that they soon perish if exposed either to a high or low temperature."

Stockman records having found living acari up to thirty-one days after removal from the sheep, but these only showed slight movement on warming. He was unable in three attempts to infect sheep with parasites that had only been removed from sheep for fourteen days, although large numbers were employed. On the other hand, Salmon and Stiles write that "Cases are on record where they (acari) have lived three, four, or even six weeks when separated from the sheep; if the atmosphere is dry, they will generally die in about fifteen days; but death is often only apparent, for the mites may sometimes be revived by warmth and moisture even after six or eight weeks." However, the authors themselves do not appear to have made these observations, nor do they give their authorities for the above statements.

The observations made by the writer agree very closely with those quoted by Neumann.

Acari of all ages were removed from sheep and kept in large jars at room temperature with plenty of crusts and wool; a moderate degree of moisture was maintained by suspending a piece of blotting-paper in the jar and damping it every two or three days with water; muslin tied over the top of the jar allowed of ventilation.

After three or four days the acari began to die, first the young forms, later the adults; by the tenth day the majority of the parasites appeared to be dead, those still active being mostly ovigerous females. In one observation in which several hundred acari were employed, only a single female was feebly alive after being kept sixteen days away from the sheep, and next day this one was dead. In other observations acari have lived a day or two longer, and in one case a female acarus was alive twenty days after removal from its host; it was then placed on a sheep, but was found to be dead the next day.

When kept moist, but at body temperature (37° C.) in an incubator, the acari are very active for two or three days, and eggs present in the crusts hatch. But a day or two later the larvae and most of the older forms die, and very few survive more than six or seven days.

In an ice-box at 0° C. all forms were dead in four days, while in a desiccator in an atmosphere free from water, at room temperature, they did not live longer than six days.

The majority of the parasites leave the crust soon after removal from the sheep and endeavour to escape from the jars.

In the incubator a good number of the ovigerous females lay eggs, and occasionally this has been observed to occur at air temperature during the summer, but in no case at a longer interval than two days after removal from the sheep.

The acari appear to live no longer upon shed wool and crusts in the open. The wool and adhering crusts containing great numbers of acari were pulled from a sheep immediately after its death and allowed to remain in an empty pen. Ten days later living acari could still be found in the crusts, but fifteen days after removal all appeared dead, nor did they show signs of life when placed in an incubator.

In view of the observations on the acari themselves most writers were forced to admit that prolonged infection apart from sheep could not be due to this form of the parasite, and they fell back on the assumption that it must be the eggs which retain their vitality for long periods.

The older writers make no mention of experiments regarding the vitality of eggs, nor of the prolonged persistence of infection in sheep folds.

Salmon and Stiles state: "Experience has shown that in some cases apparently healthy sheep have been infected in places where no sheep have been kept for four, eight, twelve, or even twenty-four months. The conditions underlying this infection are not thoroughly understood. Possibly some of the eggs have retained their vitality a long time and then hatched out; possibly the vitality of the fecundated female has also played a rôle; while it is not at all improbable that an entirely new infection has accidentally been introduced by birds or other animals." They regard this latter as the probable explanation, and conclude by recommending that sheds and fields in which scabby sheep have been kept should not be used for at least four weeks (better six or eight).

Davidson, writing of scab in South Africa, also records observations in which acari failed to survive longer than twenty-one days, and concludes that persistent kraal infection must be due to the ova of the mites retaining their vitality. Details are given of a kraal proving infective after being closed for three years, but in this case it was the sarcoptic scabies of goats that apparently persisted for that length of time and not sheep scab.

To determine the length of time the eggs of the sheep psoropt can remain apart from the sheep and still be capable of hatching, a large number of observations have been made by the writer.

The eggs were obtained by placing ovigerous female acari under covers on a sheep and removing the eggs laid each morning; they were then kept for varying periods under different conditions, and to test their vitality they were again placed under a cover in contact with a sheep's skin and watched for several days. For each observation from ten to thirty eggs were employed.

Eggs kept at air temperature hatched after having been removed from the sheep for periods up to and including eight days. After nine days' removal, only one egg hatched out of twenty, and that one on the day after the eggs were placed on a sheep. Lots of eggs stored for ten, eleven, twelve, thirteen, and more days all failed to hatch.

Several batches of eggs were also placed on moist sheep faeces and returned to a sheep after ten or more days, but in no case did any of the eggs hatch.

When kept in an ice-box for ten days, the eggs retained their vitality, ten out of thirteen eggs hatching on being placed on a sheep. In this case germination in the eggs must have been arrested by the cold, as they did not commence to hatch until they had been on the sheep three days, and several did not do so until the fifth day; when stored at air temperature the larvae usually appeared one or two days after being returned to a sheep. After twelve days in the ice-box thirty eggs all failed to hatch, as also did those kept for longer periods.

During the summer months eggs have occasionally hatched at air temperature, frequently at 90° F. in the shade, while on exposure to direct sunlight a number hatched in four days, although this is stated to destroy their vitality; the larvae, however, soon perished.

Shortly after the above observations were carried out Sir Stewart Stockman published, in his Annual Report for 1911, the results of tests of the vitality of acari eggs after storage for varying periods; he found that no eggs hatched which had been kept longer than eight days away from the sheep, the vitality of the eggs being tested by placing them in an incubator.

It is therefore no longer possible to regard the acari eggs as being capable of maintaining their vitality for long periods apart from the sheep, and thus accounting for persistence of infection in kraals, etc.

It has often been reported that the removal of manure from kraals formerly occupied by scabby sheep has been followed by the appearance of the disease amongst animals coming in contact with it, although affected sheep may not have been in the kraals for many months.

The explanation given is that the acari remain alive in the manure, and are liberated when this is taken out in winter or becomes disturbed after drying.

Apart from the failure of both acari and their eggs to retain their vitality for longer periods when stored in sheep manure than under other conditions, there are two or three points which make it difficult to believe that prolonged kraal infection is possible in the absence of living hosts.

Firstly, an examination of the mouth parts of the parasite shows that these are only adapted for piercing and imbibing liquid nutriment by suction; like ticks, the acari have no means of dealing with either liquid or solid material except what they can obtain by puncturing the skin of an animal.

It is therefore not possible to imagine that they can feed on the sheep manure as has been suggested.

It is a recognised natural law that where an obligatory parasite is able to survive for long periods apart from its host this faculty is necessary for the development and maintenance of the species; thus, most varieties of ticks require to leave their host during moulting, and as the opportunities of reaching a new host may be infrequent, the newly moulted tick is able to live for several months without feeding. But such a provision is not necessary in the case of sheep scab. The

complete life-cycle of the parasite occurs on the sheep, and migration to a fresh host is only necessary when the number of parasites becomes excessive and the life of the host is threatened. But there is no need to provide for the prolonged existence of the acari during such migration, since owing to the gregarious habits of sheep opportunities of direct transmission from one animal to another are very numerous and quite adequate to ensure the maintenance of the parasites under natural conditions.

Lastly, the experience of the Australian colonies and of numbers of farmers in South Africa has demonstrated that the disease can be stamped out by ensuring the complete destruction of the parasites on the sheep, irrespective of whether grazing has been changed or not; two or three dippings at short intervals being sufficient to prevent re-infection during the period the acari are known to survive away from the sheep. Could the infection of sleeping places, etc., persist for two years or more, as is suggested, the eradication of scab would require the adoption of dipping measures similar to those necessary for the eradication of ticks, since re-infection would be frequent, but this has not been shown to be the case.

It is significant that most of the alleged examples of prolonged infection of kraals occur at a season of the year when sheep become poor in condition, and in flocks either previously treated for scab or in which all opportunity of infection apart from the kraal has not been rigidly excluded for some time past.

In those cases in which infection by other sheep has been impossible for a considerable period the occurrence of the disease can be explained by assuming that the acari have lived on the sheep since the last known opportunity of infection, but without increasing in numbers or producing visible symptoms of scab; when the conditions become favourable to the parasites rapid multiplication takes place and their presence is manifested. As will be shown later, such prolonged latent infection of sheep is known to occur, and in the writer's opinion accounts for the appearance of the disease in many supposed clean flocks without regarding the old kraals as the source of the infection.

In view of the importance of obtaining accurate information on the subject, it was decided early in the present investigation to carry out tests under as natural conditions as possible; accordingly two stone kraals were built, and pens and enclosures made which could be grossly infected by scabby sheep, and after being closed for varying periods tested as to their infectivity by having clean sheep placed in them.

The details of these observations are given in tabular form.

[TABLE

<i>Expt. No.</i>	<i>Particulars of Infection.</i>	<i>Interval between Removal of Infected Sheep from Kraal and Contact with Clean Sheep.</i>	<i>Length of Time Clean Sheep Remained in Contact.</i>	<i>Result.</i>
1	37 scabby sheep herded in kraal for 44 days	21 days	76 days	Sheep clean.
2	30 scabby sheep herded in kraal for 48 days	60 days	16 days	Sheep clean.
3	Do.	90 days	7 days	Sheep clean.
4	37 scabby sheep herded in kraal for 35 days	10 days	60 days	Sheep clean.
5	Infected sheep running in a kraal for several months	24 days	48 days	Sheep clean.
6	Wool crusts and acari spread in box	Box keep free of sheep for 20 days	4 months	Sheep clean.
7	Acari and pieces of fleece scattered in box	Box keep free of sheep for 15 days	4 months	Sheep clean.
8	Manure collected from a kraal in which infected sheep had been running up to 16 days previously	Clean sheep immediately put into— (a) clean kraal with manure (b) above sheep removed after 5 days and replaced by second lot of clean sheep	5 days 6 months	Sheep infected. Sheep clean.
9	2 scabby sheep running in a pen for 7 weeks. At the time of removal pieces of fleece and acari were spread on floor of pen	8 days	4 months	Sheep clean.
10	Do.	12 days	4 months	Sheep clean.

(d) THE POSSIBILITY OF THE PSOROPTES COMMUNIS, VAR. OVIS, MAINTAINING ITS EXISTENCE ON ANIMALS OTHER THAN SHEEP OR OF THE PSOROPTES OF SUCH ANIMALS PRODUCING SCAB IN SHEEP.

It has been suggested that the alleged persistence of sheep scab in the prolonged absence of sheep may be accounted for by the acari being able to exist on other animals, such as rodents, and subsequently regain access to sheep.

For this reason the question of the adaptability of the psoroptes to different species of host is worthy of investigation, but in South Africa it derives additional importance on account of the wide-spread occurrence of psoroptic otacariasis (ear scab) amongst goats.

It is very commonly believed that infection can be spread from one species of animal to the other, and the frequent presence of the disease in both sheep and goats grazing together appears to support that view; there are, however, many instances of mixed flocks in which one species is badly infected while the other remains quite clean.

The psoroptes of sheep, goats, and rabbits were employed in the present observations.

Psoroptic otacariasis of goats has received scant notice in works on parasitology. Neumann quotes the single observation of Pesas and Morot, by whom the acarus was found in the ears of two goats from the Western Pyrenees. Law gives the same reference.

In addition to the above, Neveu-Lemaire mentions the observation

of auricular psoroptes in goats in the Congo by Mense, who named the parasite *psoroptes congolensis*. Geddoelst, however, has shown this to be the same acarus as that found by Pesas. Neveu-Lemaire regards the disease as frequently fatal and the prognosis serious unless treated early.

In South Africa the occurrence of psoroptes in the ears of goats was first reported in 1911, since when it has been found to be very widely distributed in the subcontinent; it is probable, therefore, that it has existed unrecognised for a long time.

Up to the present only the common Kaffir goats have been found to be infected.

The parasites confine themselves to the interior of the ear, usually well down in the meatus and the fossæ at the base of the conchal cartilages; they have never been found on the skin outside the ears, and attempts to infect goats on the body have failed.

They do not appear to set up the intense irritation evident in sheep scab, but infected animals frequently shake their heads and many scratch the back of their ears with the hind feet.

There is an abundant desquamation of epithelium, which, with the cerumen, forms hard masses, sometimes filling up the interior of the ear, as in the case of rabbit otacariasis; in this material the parasites are often present in large numbers.

No instances of suppuration or of the other sequelæ that occur so frequently in otacariasis of the rabbit, dog, and cat have been met with.

The parasites differ but slightly from those of the same species in sheep. The adult forms are usually of a brownish colour, probably from their being able to pierce the thin lining membrane of the ear and obtain blood. Both male and females are slightly larger than the ovine psoropt; measurements made agreed very closely with those given by Neumann, viz., the male 470 microns to 640 microns long by 270 microns to 400 microns broad, and the ovigerous female 680 microns to 850 microns by 390 microns to 550 microns.

The destruction of the acari in the ear is easily effected, the best remedies being those containing a disinfectant mixed with glycerine or oil. Probably the simplest is a mixture of petroleum and cocoanut oil in the proportion of 1 to 2; one dressing with this is sufficient to destroy both the acari and their eggs.

Psoroptes Communis, var. Capræ, on Sheep.

When transferred to the skin of sheep, the goat psoroptes quickly begin feeding, pustules and crusts being formed as with the sheep acarus. The females lay eggs and these hatch after the same interval as that required by the eggs of the sheep psoropt, namely, two days. Similarly, eggs removed from a goat's ear will hatch when placed on a sheep.

The larvæ quickly develop and in two days moult into nymphæ.

At this stage, however, they usually begin to die, but in some instances further development has taken place and the nymphæ have moulted into adults.

In two observations only the young acari have mated, in one case five days after hatching; but in both instances the parasites died without eggs being laid.

Ovigerous females and males transferred from a goat's ear have remained alive on sheep up to ten days, but usually they die in from four to six days.

The young goat acari that have hatched on sheep are indistinguishable from sheep psoroptes and do not become dark in colour like those in the ears of goats.

In every case sheep that have had goat acari placed on them have been kept under observation for several months after the acari have died out and the covers been removed, and in two cases the covers were removed whilst there were large numbers of larvæ and nymphæ still alive, but in all the observations the sheep have failed to develop any evidence of scab.

The following details of sheep infected with *psoroptes communis*, var. *capræ*, may be given:—

Sheep 136.—19th August 1913. Five ovigerous female acari and three pairs in copula removed from the ear of goat No. 206, placed under cover No. 80 on back.

21st August 1913. Six females and male observed.

22nd August 1913. Six females and male observed, also several eggs.

24th August 1913. Numerous larvæ present.

25th August 1913. Only three live females observed, and a few larvæ and nymphæ.

27th August 1913. No living acari observed; several dead. Patch examined at intervals of several days, cover then removed; no acari.

27th August 1913. Four ovigerous female acari from goat No. 206, placed on cover No. 81 on back.

29th August 1913. Numerous eggs laid.

30th August 1913. The four females removed and placed under cover No. 85 on the same sheep, numerous eggs remaining.

1st September 1913. Several larvæ and few eggs.

3rd September 1913. Larvæ growing.

5th September 1913. A few nymphæ alive; several larvæ and nymphæ dead.

11th September 1913. Several dead nymphæ; no living acari observed; cover removed. No development of infection.

30th August 1913. Cover No. 85; four females from cover No. 81.

31st August 1913. Three females alive; one dead; no eggs.

1st September 1913. Three females dead. No development of infection.

1st September 1913. Four ovigerous female acari from ear of goat No. 206 placed under cover No. 86 on back.

3rd September 1913. Four females alive; several eggs laid.

4th September 1913. Four females alive; eggs numerous.

5th September 1913. Four females alive; larvæ hatched.

6th September 1913. Four females alive; numerous larvæ and eggs.

8th September 1913. Four females alive; nymphs and larvæ present.

9th September 1913. Two females dead; several nymphæ present.

11th September 1913. One pair in copula and several nymphæ growing.

The cover removed and acari allowed to escape.

This sheep, which had been infected four times with goat psoroptes, was examined at intervals for three months, but no acari were found on it after the removal of the last cover on 11th September 1913.

Sheep 134.—9th September 1913. Ten nymphæ from sheep 136, cover No. 86 (goat psoroptes) placed on back under cover No. 93.

10th September 1913. Ten nymphæ alive and growing.

12th September 1913. Two pairs in copula and five pubescent females.

14th September 1913. Cover torn off, sheep evidently had been biting at the spot; no acari could be found.

This sheep was also kept under observation for three months without showing any sign of infection.

Sheep 141.—24th September 1913. Six ovigerous female acari from ear of goat 208 placed on back under cover No. 106.

25th September 1913. Six females alive; a few eggs laid.

26th September 1913. Six females alive; a few eggs laid.

27th September 1913. Five females alive; one dead; no larvæ observed.

30th September 1913. Four females dead; one missing; no living acari observed; cover removed.

No infection occurred in this sheep up to three months from the time living acari were last observed.

In addition to the actual placing of goat acari on sheep, two clean sheep were kept closely penned with two infected goats for over three months without contracting scab.

Acari from the ears of goats were also placed in a sheep's ears on several occasions, but in every instance they quickly died or disappeared.

Conclusion.—The psoroptes communis, var. capræ, is able to live and reproduce itself on sheep, but all attempts to set up scab in sheep with the goat psoropt have failed; the original infecting parasites died out in less than ten days, while the second generation usually dies on reaching the nymphal stage, and in no case has a third generation been observed.

Psoroptes Communis, var. Ovis, to Goats.

Repeated attempts have been made to infect goats by placing all forms of acari taken from scabby sheep into their ears, but in no instance have the parasites been observed to live for more than two days. To prevent the goats from dislodging the parasites by shaking their heads, the ears were lightly plugged with wool after the parasites had been placed in the external meatus, and the edges of the concha loosely sewn together.

Goats that had been frequently infected with sheep acari and others kept in close contact with scabby sheep were examined at intervals for several months, always with negative results.

Sheep acari placed on the bodies of goats quickly died or disappeared.

Conclusion.—The psoroptes communis, var. ovis, is incapable of setting up otacariasis in goats or of maintaining its existence on this animal.

Psoroptes Communis, var. Cuniculi, to Sheep.

There are several references to the occurrence of psoroptic scabies in horses as the result of infection from rabbits.

Neumann quotes instances reported by Mathieu, Cagny, and Cadeac, and, while admitting the absence of precision in their details, thinks them sufficient to prove the identity of the psoropt of the rabbit with that of the horse.

From the particulars given, however, it would appear that the disease was of a temporary character, or that the horses were subject to repeated infection from the rabbits. The observations with goat psoroptes on sheep and those recorded below with rabbit psoroptes show that the production of symptoms and the brief existence of parasites from one species of animal on another are not sufficient evidence that the disease in the two hosts is caused by identical varieties of psoroptes.

When placed on sheep the rabbit psoroptes attack the skin and cause irritation and the formation of crusts in the same way that the goat ear psoroptes do; eggs are laid and hatch in two days. The young acari develop quickly, mating have been observed six days from the time of hatching.

But as with the goat psoropt, development does not proceed beyond the adult stage of the second generation. In one observation only was a single larva found which may have hatched from an egg laid by the second generation (*vide infra*).

Adult acari have lived for seventeen days on sheep, and during this time laid numbers of eggs, but, as stated, the second generation of acari have died out without reproducing themselves.

In several observations eggs only were placed on sheep. With the exception of the doubtful instance referred to above, the acari from those eggs all died before they reached the laying stage.

All the sheep used in the observations were examined at intervals for several months after infection, but in no instance did scab develop.

Similarly a sheep kept in a small run with several infected rabbits for over two months failed to show symptoms of scab.

Details of a few of the observations are given below:—

Sheep 163.—19th May 1913. A large number of acari (all stages) from ear of rabbit placed under cover on back.

20th May 1913 to 31st May 1913. Numerous eggs laid and young forms developing; majority of adults alive and active.

2nd June 1913. Several adults dead; numerous young forms active; some pairs.

4th June 1913. Many acari dead; several young forms alive.

9th June 1913. No living acari observed; cover removed. No subsequent development.

25th June 1913. Thirty acari eggs from ear of rabbit placed under cover.

27th June 1913. Twenty larvæ hatched.

29th June 1913. Larvæ developing.

1st July 1913. Nymphæ developing.

3rd July 1913. Nymphæ and young adults present; cover removed to allow acari to escape.

Sheep examined at intervals for several months. No development of scab.

Sheep 316.—5th July 1913. Six pairs of acari from ear of rabbit placed under cover.

7th July 1913. Four pairs still united ; a few eggs laid.

8th July 1913. Numerous eggs laid.

9th July 1913. A few larvæ hatched.

10th July 1913. Two females dead ; several larvæ developing.

14th July 1913. Only two females alive ; males and young forms dead ; eggs still being laid.

19th July 1913. No living acari observed ; cover removed. No subsequent development.

23rd July 1913. Forty-two acari eggs from ear of rabbit placed under cover.

26th July 1913. Numerous larvæ hatched.

28th July 1913. Larvæ developing ; some nymphæ.

21st July 1913. Three pairs mating ; numerous nymphæ.

2nd August 1913. Several adults ; no eggs.

5th August 1913. All adult acari dead ; one larva alive only ; no eggs observed.

6th August 1913. No live acari observed ; cover removed. No development of scab occurred.

Conclusion.—The *psoroptes communis*, var. *cuniculi*, is able to live on sheep for periods up to seventeen days, and during that time lays eggs and gives rise to symptoms and lesions similar to those caused by the ovine psoropt. The second generation of acari, however, die before reproducing themselves, and in consequence continuous acariasis of sheep cannot result from infection with the rabbit psoropt.

Psoroptes Communis, var. *Ovis*, to *Rabbits*.

As in the case of goats, all attempts to produce otacariasis in rabbits by infecting them with psoroptes from sheep failed.

Owing to the prevalence of the disease in rabbits it was necessary to isolate the animals some time before they were to be used and examine their ears at intervals to ensure their freedom from natural infection.

Acari of all ages and eggs were placed in the ears of rabbits, a little wool being inserted and kept in position by a few stitches to prevent the acari from being shaken out. In every case the acari died in two or three days, and no larvæ were ever observed to have hatched in the ears.

Attempts were also made to infect wild rats with the sheep psoropt by placing scabby wool and acari in their cages, but in every case the result was negative.

Psoroptic scabies has never been reported as occurring in pigs ; many South African farmers, however, believe that sheep can become infected with common scab from mangy pigs. It is quite likely that sheep may contract face scab (sarcoptic scabies) from pigs, since the different varieties of sarcoptic scabies are much more accommodating in the matter of host than are psoroptes.¹

¹ The author has produced sarcoptic scab in sheep with goat sarcopt and continued the infection through sheep and back again to goats ; pigs and cattle have also been infected with sarcoptic mange by means of the goats acarus.

Attempts were, however, made to infect a pig with psoroptic mange by keeping it closely penned with scabby sheep and placing large numbers of acari on it, but the result was entirely negative.

Conclusion.—There is no evidence to show that the sheep psoropt is able to maintain its existence on any animal other than sheep and so continue sheep scab infection in the absence of its particular host. All attempts to infect other species of animal with sheep psoroptes have failed.

(e) VARIATIONS IN THE RAPIDITY OF MULTIPLICATION OF
THE ACARI.

In Great Britain one of the most curious features of sheep scab is the almost complete disappearance of the disease during the summer months.

Sir Stewart Stockman, in his annual report for 1909, discussed this phenomenon, and gives several suggestions that have been offered in explanation, but none regarded as wholly satisfactory. Observations are quoted showing that, without treatment of any kind, certain infected sheep became spontaneously cured in the spring months, and remained free from the disease during the summer following.

Further observations are recorded in his report for 1911, and from these it is concluded that there is "nothing in connection with the habits of the parasites or the general condition of sheep to account satisfactorily for the apparent disappearance of scab in summer in the field."

Shearing was found to distinctly retard the progress of scab, and in some cases apparent recovery followed.

The disappearance of the disease in summer was accounted for mainly by shearing and dipping, and the increased outbreaks in the early winter are attributed to the latter operation being ineffective, except as checking the disease. The autumn sales lead to the distribution of such apparently clean sheep to previously uninfected farms.

In South Africa marked variations in the prevalence of sheep scab are also observable, but the conditions under which these occur are such that they cannot be explained in the same way as in Great Britain, since dipping and—in the case of Africander sheep—shearing are not carried out as general practices at definite seasons of the year.

The following is an instance:—

During the past two years a flock of scabby sheep has been maintained at the Laboratory to supply material for the experiments, and subjects for testing the efficiency of dipping fluids. As grossly infected animals were removed, others were drafted in to contract the disease, but a good proportion harbouring acari were always left to carry on the infection.

It was found, however, that in the early spring—August and September—each year the number of acari on the sheep began to diminish, so that on many which had previously been badly infected parasites could only be found after considerable search, while in some cases they could not be found at all. This decrease in the

activity of the parasites occurred in all the sheep, and was not confined to those in which the disease had spread over the greater part of the animal, thus rendering the skin distasteful to the acari, but was equally noticeable in those only recently infected.

As illustrating the rapidity with which the parasites are able to multiply, the computation made by Gerlach is often quoted. Assuming that each female lays fifteen eggs and that development occupies fifteen days, he estimated that one and a half million acari would arise from a single pair in three months.

When, however, we find that, in South Africa at all events, a female acarus can lay over ninety eggs and the life-cycle may be completed in eleven days, it is evident that even Gerlach's figure is far short of the actual possibility, given conditions favourable to the parasites.

Something approaching this extraordinary rate of multiplication has been observed in two or three natural cases, when in the course of a week acari in countless numbers have invaded the entire surface of a sheep's body and rapidly caused its death.

But such cases are uncommon and occur only when sheep are in very low condition.

In the great majority of sheep naturally infected the multiplication of the parasites is far short of that observed under experimental conditions, and very often the number present does not appear to increase at all for quite long periods. Under certain circumstances the infection may become less, as instanced above, or to all appearances cease entirely.

This fact is well known to sheep farmers in very dry areas, such as occur in the north-west of the Cape Province. Here at certain seasons of the year flocks that have been badly infected may become apparently clean and remain so for a month or two without treatment of any kind having been carried out. But when on account of drought the sheep lose condition scab makes its appearance, although no opportunity of reinfection may have occurred in the meantime.

The influence of the bodily condition of the host on the rate of multiplication of the parasites is well recognised, but no very clear explanation has been offered as to the exact way in which the development of the acari is checked.

The presence of grease in the fleece is believed by several South African authorities on sheep to be the chief determining factor. It is stated that when giving a demonstration on sheep scab the late Dr Hutcheon was once asked to attempt to infect some very fat pet lambs, and although a large number of acari were placed on each of these animals no development of the disease occurred—this result was attributed to the large amount of grease in the lambs' fleeces.

Most writers refer to condition, age, breed, and length of fleece of sheep and the season of the year as affecting the course of the disease, but they do not describe how these factors produce their effect.

In carrying out the observations on the life-history of the acari it was frequently noticed that development occurred just as rapidly on the washed and shaven patches on fat sheep as on those in poor condition, but when the covers were removed and the parasites allowed to spread to the surrounding skin, multiplication was much more rapid in the case of the thin sheep than on those with excess

of yolk in their fleeces, while in a few of the latter no development occurred at all.

In the same way some attempts to infect sheep with very greasy fleeces by placing numbers of acari on them have failed. The following instances may be quoted:—

Sheep 4420.—(Merino), with twelve months' growth of wool in good condition, fleece very greasy.

29th August 1914. Ten ovigerous female acari placed under two covers.

31st August 1912. Numerous eggs and a few larvæ present.

7th September 1912. Acari of all ages present.

8th September 1912. Covers removed, allowing acari to escape.

9th September 1912 to 30th October 1912. Sheep examined at intervals without any live acari being discovered.

31st October 1912. Eight ovigerous female acari placed on skin near rump.

1st November 1912. One acarus only found; sheep nibbling.

3rd November 1912. No acari found; sheep nibbling.

4th November 1912 to 22nd December 1912. Examined at intervals; no sign of infection.

23rd December 1912. Sheep shorn and thoroughly examined without a sign of acari being found.

Sheep 136.—(Merino-cross), with twelve months' growth of wool; fleece very greasy.

5th September 1912. Seven ovigerous female acari placed near rump.

6th September 1912 to 30th October 1912. Examined at intervals without any acari being found.

30th October 1912. Sheep shorn and carefully examined, without result.

When a small number, say five to ten, ovigerous female acari have been placed on sheep in only moderate condition and with little yolk in their fleeces the development of the disease has always followed—usually symptoms were exhibited ten or twelve days after infection.

In order to observe more closely the effect upon the acari of the presence of wool fat, two patches were prepared upon a sheep; one was washed and shaved in the usual way, but on the other the wool was only cut short, and in addition the patch was smeared with "yolk" obtained from the wool of another sheep. As each generation of acari began to develop on the ungreaed patch a number of the young forms were removed to a fresh area, so that the number of generations could be determined.

The following tabular statement gives the details of the observation:—

[TABLE

Development of Acari on Greased and Ungreased Patches.

<i>Date.</i>	<i>Greased.</i>	<i>Ungreased.</i>	<i>Remarks.</i>
2.10.12	6 ovigerous female acari placed on patch	6 ovigerous female acari placed on patch	2nd generation on ungreased patch.
3.10.12	A few eggs present	A few eggs present	
4.10.12	Numerous eggs present	Numerous eggs present	
6.10.12	Several larvæ and eggs	Several larvæ and eggs	
7.10.12	Larvæ and eggs present	Larvæ and eggs present	
9.10.12	Larvæ not so numerous, eggs still numerous	Numerous nymphæ, larvæ, and eggs	
10.10.12	A few nymphæ and larvæ and small number of eggs	6 original females removed, nymphæ growing	
13.10.12	1 female dead, 2 missing, only 14 nymphæ and larvæ found; original females removed	2 copulating pairs and numerous nymphæ, larvæ, and eggs; 14 acari, including the 2 young pairs, removed to a fresh patch	3rd generation on ungreased patch.
15.10.12	12 acari found still nymphæ	3 pairs and 8 females; several eggs laid	
16.10.12	9 acari found, nymphæ or pubescent females	1 female dead, 3 males and 10 females observed, numerous eggs	
17.10.12	9 nymphs or pubescent females	9 females and 3 males observed; numerous larvæ and eggs	
20.10.12	5 females and 1 male observed	20 nymphæ and larvæ removed to a fresh patch	
22.10.12	1 pair in copula and 4 females	Nymphs developing	
24.10.12	5 females observed, no eggs	Females observed	
26.10.12	1 adult female only observed, no eggs	2 copulating pairs and several oviporus observed.	4th generation on ungreased patch.
27.10.12	1 adult female only observed, no eggs	Several eggs found	
29.10.12	No live acari found	Numerous larvæ present	
31.10.12	Examined every 2 or 3 days without any acari being found	Numerous larvæ present. Acari developed as before, each cycle from egg to egg occupying 9 to 10 days	
18.12.12			

It will be seen that in both cases eggs were laid on 3rd October 1912, and larvæ were present on 6th October 1912. On the ungreased patch development occurred as usual, eggs being laid nine days after the appearance of the larvæ, and this cycle was continued for several generations.

On the greased patch, however, the majority of the larvæ died two or three days after hatching, while those that survived developed very slowly; thus it was not until 20th October 1912, fourteen days after hatching, that adult male and female acari were observed, and though fertilisation took place no eggs were laid and living acari were not observed after 27th October 1912. By this time the fourth generation of acari were developing on the ungreased area.

This observation has been repeated several times. When the skin was greased very slightly the acari developed as rapidly as on the ungreased area. In these cases the growing wool lifted, the first crusts formed, and these carried the fat with them, so that the acari were able to live on the dry skin underneath. However, when sufficient grease was present to soak down under the crusts development was very slow, and in every case the acari gradually died out, usually in about twenty days.

Under natural conditions the fat, being excreted by the skin, is

likely to have a relatively greater effect on the acari than when applied on the surface as in the above observations.

The point, however, to which it is desired to draw particular attention is not the lethal effect of wool fat on the acari, but that the presence of this material markedly retards the life-cycle of the parasites. In the experiments it was not possible to regulate the quantity of fat on the skin so as to check development and yet avoid actually killing the acari, but it seems reasonable to assume that under natural conditions such a moderate degree of fat excretion may occur. Should this be so, it would account for the observed variations in the rapidity of multiplication of the acari on infected sheep, and explain how the parasites may continue to live on sheep without giving rise to visible signs of scab for considerable periods.

The reappearance of scab in sheep several months after apparent recovery, either as the result of dipping or without treatment, has been frequently observed in South Africa.

Stockman gives numerous instances of the same kind in Great Britain.

In most cases no contact with other scabby sheep could have occurred. It has been usual in South Africa to explain such recurrences as due to reinfection from kraals and sleeping places. As has been recorded earlier in this report, no experimental evidence can be obtained in support of the theory of prolonged infection apart from sheep. In view of the observed persistence of acari on sheep without the production of visible lesions, either as the result of dip remaining in the fleece or (as is suggested by the present experiments) the excretion of an excess of fat by the skin, it appears to be more reasonable to explain recurrences of the disease in flocks that have not been exposed to outside infection since their apparent recovery as examples of latent infection of the sheep themselves, rather than to assume that the parasites have lived apart from their host for much longer periods than actual observation warrants. No doubt in many such cases the infection has actually been introduced from an outside source without the knowledge of the owner.

Other factors besides the presence of fat in the fleece appear to influence the rate of multiplication of the acari.

In detailing the observations on the egg production of female acari mention was made of the apparent effect of moisture, the onset of rain being followed by a great increase in the number of eggs laid.

Sheep farmers in the Cape Province many years ago recognised that the first rains were frequently followed by the appearance of scab in their flocks, and not unnaturally they attributed the disease to the moisture and young vegetation, its parasitic nature not being recognised.

Observations on acari kept in a desiccator have shown that they rapidly succumb when all moisture is removed from the air. An attempt was therefore made to keep them on a sheep, but in a dry atmosphere. With this object a cover was made, having a second chamber separated by a muslin division from that over the parasites. This was filled with calcium chloride, which was charged every day. In this way the skin and air over the acari were kept fairly dry from

moisture. The parasites, however, developed as rapidly as under an ordinary cover, though owing to the difficulty of maintaining the double chamber in position it was not possible to continue the observation longer than one generation—prolonged absence of moisture might have caused a decrease in the rate of multiplication of subsequent generations.

While it has not been possible actually to demonstrate any effect from the presence or absence of moisture in the air, there is evidence that under natural conditions the disease lessens in dry weather. This may, however, be mainly the result of accumulation of fat in the fleece, and in the same way the increased activity of the parasites following rain may be accounted for by the resulting washing of the fat from the fleece that then takes place. The increase of scab following prolonged drought is explained by the loss of condition of the sheep, in consequence of which the excretion of fat from the skin diminishes, thus allowing the parasites to multiply rapidly.

CONCLUSIONS.

One or two practical points suggested by these observations may be briefly mentioned.

They have shown that the all-important factor in the eradication of sheep scab is the destruction of every acarus on the sheep themselves, and to ensure this more efficient dipping is necessary than has usually been employed in the past. The necessity of reducing the interval between the two dippings from the fourteenth or sixteenth days—commonly considered adequate—to ten days has already been pointed out, and the advisability of giving a third immersion advocated. The expense of this additional dipping is slight compared to that occasioned by a recurrence of the disease, possibly some months later, owing to the survival of a few acari on one or two sheep that perhaps passed too rapidly through the tank or were not completely immersed.

In addition, a third dipping would greatly lessen the risk of reinfection from kraals or sleeping places. Acari are known to be unable to live for more than four weeks apart from sheep (in the experiments all were dead in twenty-one days), and eggs will not hatch after ten days, so that by the time the third dipping was given—say twenty to twenty-four days after the first—acari in the kraals would be either dead or too feeble to infect recently dipped sheep.

It would, of course, be unwise to neglect to disinfect thoroughly all places in which the scabby sheep have been confined, but absolute cleansing of the sheep is the essential point in the eradication of the disease.

The necessity of treating every sheep in the flock, and not only those visibly affected, is obvious.

When possible sheep should be dipped in early summer, shortly after shearing. They are then best able to stand the immersions and no damage is done to the wool, while scab and other parasites are most easily destroyed.

If the flock is only slightly infected or recently exposed to infection, dipping should not be delayed during the summer because of

the absence of signs of active scab. In the winter, when the sheep carry more wool and are probably in poorer condition, the disease will increase rapidly, and dipping will then have to be carried out under the most unfavourable conditions, both as regards the health of the sheep, damage to the wool, and the eradication of the disease.

The choice of a dip is a most important matter. A large number of dipping fluids—proprietary and otherwise—have been tested: the result of these tests will be reported at a later date.

One item of considerable interest may, however, be mentioned here. It has long been recognised that dipping fluids do not destroy the vitality of acari eggs, hence the necessity of giving a second dipping. In the observation all the fluids tested failed to prevent the hatching of eggs, with the exception of the lime and sulphur dip. This fluid, prepared according to the instructions of the Division of Sheep, and also when a weaker solution containing only 20 lb. of sulphur to 100 gallons of water was employed, destroyed the vitality of all eggs in a large number of tests, both on sheep and *in vitro*. The value of this property of the lime and sulphur dip cannot well be over-estimated, and it may partly account for the success attained in the eradication of scab from Australia; this dip was largely employed in effecting that happy result.

THE EARLY HISTORY OF VETERINARY LITERATURE AND ITS BRITISH DEVELOPMENT.

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Hon. Assoc. R.C.V.S.

(Continued from Vol. XXVII. p. 299.)

SEVENTEENTH CENTURY.

GERVASE MARKHAM 1568(?)–1637. That portion of Markham's literary life which occupied the last years of the sixteenth century has already been referred to and evidence brought forward to show the remarkable degree of activity he early exhibited. The history of Markham was intentionally deferred to the seventeenth century and must now be taken up.

There were at least two families of this name living in Nottinghamshire at the time this notice opens in 1568. They were not on good terms and their delinquencies have been mixed up, especially as the Christian names were much alike in each group, even to the extent of there being a Gervase in each family.

Gervase Markham was the third son of Robert Markham of Cotham. This Robert Markham was born in 1536¹ at Sireston, and succeeded his grandfather at Cotham. He was Knight of the Shire for Nottingham in 1571, High Sheriff in 1571 and 1583, and was a man greatly trusted by Queen Elizabeth. By his first wife he had a large family, five being sons, *i.e.*, Robert, Francis, Gervase, John,

¹ Herald and Genealogist, Vol. VII., J. G. Nichols.