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SOME UNUSUAL HOST RELATIONS OF THE TEXAS FEVER TICK.

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HABITS AND LIFE HISTORIES OF TICKS.

Prior to the discovery of the important relations which ticks bear to certain diseases of man and other animals they were comparatively little studied, and their habits and life histories were known only very imperfectly, and this in the case of but a few species. The facts which had been determined in the life histories of these forms were commonly accepted as generally applicable to all ticks. They may be briefly summarized as follows:

The six-legged larval tick, as soon as opportunity offers, attaches itself to some animal, preferably a small animal, a bird, reptile, or small mammal, and, after feeding for a few days, during which it grows considerably, it falls to the ground and lies quiescent for a variable length of time, finally casting its skin and coming forth as an eight-legged nymph. At the next opportunity it again fastens upon some host and grows and falls to the ground as before to undergo the second molt, after which it is adult and sexually developed as a male or female. On finding another host the tick fulfills its sexual functions and, if a female, undergoes a very great increase in size. Finally, the engorged female falls from her host and deposits her eggs to the number of some thousands and then dies.

Boophilus annulatus was the first tick whose connection with disease was demonstrated; Smith and Kilborne, of the Bureau of Animal Industry, proving that it is the transmitter of Texas fever. Curtice, also of the Bureau of Animal Industry, was the first to work out the life history of this tick, and he showed that it did not correspond to the scheme outlined above, which was at that time looked upon as typical of all ticks. Curtice's investigations demonstrated that the Texas fever tick attaches itself to cattle as a larva and grows, molts, changes into a nymph, grows, molts again, and completes its development as an adult, all upon the same animal to which it attached itself as a larva.

More recently the life histories of a considerable number of other species have been determined. Some of these forms have a life

history somewhat different form either of the two schemes already mentioned, in that the tick remains on its host during the first molt from larva to nymph, but falls to the ground to undergo the second molt. One other variation may be easily imagined, though I believe it has not actually been demonstrated for any species, namely, that in which the tick falls from its host before the first molt, but, having reattached itself as a nymph, remains upon the body during the second molt.

To summarize, then, there are three, or, with the supposed case, four, different modes in the life histories of ticks belonging to the family Ixodidæ, as follows:

1. The larval, nymphal, and adult stages may be passed on three different hosts.

2. The larval and nymphal stages are passed upon the same host and the adult stage upon another.

3. The larval stage is passed upon one host, and the nymphal and adult stages are passed upon a second host—a supposed case not yet demonstrated to be of normal occurrence.

4. All three stages are passed upon a single animal.

While *Boophilus annulatus*, as Curtice and others have amply demonstrated, normally has a life history corresponding to the last-mentioned mode, recent experiments have indicated that under certain conditions and in rare instances this tick may conform to any of the other three modes, that is, it may undergo its larval, nymphal, and adult stages on three different animals, or its larval and nymphal stages together on one animal and its adult stage on another, or its larval stage on one and its nymphal and adult stages upon a second animal.

DETAILS OF EXPERIMENTS.

In the first experiment three cattle, numbered 301, 307, and 354, were placed in a field pen (No. 10) at the Experiment Station of the Bureau of Animal Industry, Bethesda, Md., and infested March 30, 1905, with larvæ of *Boophilus annulatus*. These larvæ belonged to a lot which began to hatch about March 1 from eggs deposited by ticks which had matured at the Experiment Station on cow No. 152 and were collected October 6, 1904. During incubation these eggs were kept at the temperature of the laboratory.

April 10, it was found that many of the ticks placed on the cattle had arrived at the period of the first molt. Cow No. 152 was placed in a second field pen (No. 9), and a number of newly molted ticks were transferred to her from the other cattle.

April 15, steer No. 277 was placed in field pen No. 9.

April 17, ticks which had undergone the second molt were transferred from the cattle in field pen No. 10 to steer No. 277, in field pen No. 9.

April 18, more ticks were transferred to steer No. 277, as on the previous day, those transferred the day before being still present. Likewise those

which had been transferred to cow No. 152 on April 10, following the first molt, were still present and growing.

April 19, ticks still present on cow No. 152. Those transferred to steer No. 277 on April 17 were still present, but those transferred April 18 had disappeared.

April 24, ticks were still present on both steer No. 277 and cow No. 152.

May 6, all ticks had fallen from steer No. 277. On cow No. 152 one female tick still remained.

May 9, tick still present on cow No. 152.

May 12, tick still present, but not fully engorged.

May 13, 8 a. m., tick had fallen off and could not be found.

In a second experiment cows Nos. 307 and 354, in field pen No. 10, were infested June 12, 1905, with larval ticks which had hatched on and after May 15 from eggs deposited by ticks collected April 4 at Corpus Christi, Tex.

June 19, ticks which had just undergone the first molt were transferred from these animals to cow No. 301, in field pen No. 9.

June 20, more ticks were transferred, as on previous day.

June 28, cow No. 307 was dead of Texas fever. Most of the ticks on this animal were at the period of the second molt. A number which had molted were transferred to cow No. 152, in field pen No. 9.

July 6, one adult (but not fully engorged) female tick was taken from cow No. 152. This tick was one of those transferred following the second molt from cow No. 307, on June 28.

July 8, four adult (but not fully engorged) female ticks were collected from cow No. 301. These ticks were some of those transferred on June 19 and 20, following the first molt, from cows Nos. 307 and 354.

In the third experiment cow No. 354, in field pen No. 10, was infested August 7 with larval ticks which had begun to hatch July 30 from ticks collected June 29 from cow No. 224.

August 15, about three dozen ticks which had just undergone the first molt were collected from cow No. 354.

August 16, these ticks were placed upon cow No. 378, in pen No. 9.

August 22, about two dozen of these ticks were removed from cow No. 378. The second molt had not yet taken place.

August 23, a number of ticks which had just undergone the second molt were removed from cow No. 354 and placed upon cow No. 377, in pen No. 9.

August 28, the ticks collected from cow No. 378 on August 22 had undergone the second molt. A number of them were returned to this animal, and they immediately attached themselves. The experiment was interrupted at this point, and I have no notes concerning the further history of the ticks in question.

AUXILIARY OBSERVATIONS AND EXPERIMENTS.

In connection with the foregoing experiments a number of auxiliary observations and experiments were made, as follows:

June 28, 1905, a large number of nymphs of *Boophilus annulatus* about to molt were collected from cow No. 307, dead of Texas fever. Within the next three days practically all of these nymphs had molted.

July 12 (two weeks later), some of them were still alive and active.

July 13, a female placed on my arm immediately took hold, sucked blood, and remained in place from 12 to 5.30 o'clock. A number of females placed on a rabbit sucked blood and were still present next day.

August 28, several male and female ticks (*Boophilus annulatus*) collected as nymphs from cow No. 354 on August 23, having molted, were placed on my arm, where they immediately attached themselves and sucked blood.

August 29, several other male and female ticks of the lot just referred to were placed on a rabbit, to which they attached themselves. One female attached herself to my hand between two fingers and began sucking blood. The presence of this tick upon my hand was not noticed until attention was called to the fact by a slight pain and itching sensation at the point of attachment.

August 30, the tick which had fastened to my hand was still present. It was removed after having been attached for about twenty-four hours.

August 31, the ticks which were placed on the rabbit August 29 were still present. Mr. Graybill, assistant in this laboratory, states that the ticks fell off within the next few days without undergoing apparent growth or development.

A number of unsuccessful attempts were made to rear ticks by placing the larvæ on rabbits. One attempt to rear ticks from the larval stage on a dog was unsuccessful. The animal scratched, rubbed, or shook off the ticks almost as soon as they were put on. Experiments with cats were more successful.

July 25, 1905, larval ticks hatched June 15 from eggs deposited by adults which were collected May 14 at Fort Worth, Tex., were placed upon a cat.

July 31, a number were still present which had grown and were about ready for the first molt.

August 8, larval ticks hatched July 30 from eggs deposited by ticks collected June 29, from cow No. 224 were placed upon a half-grown cat.

August 12, these ticks were still present and growing.

August 19, ticks present which had undergone first molt.

August 22, ticks (nymphs) still present.

August 30, only one tick could be found, an adult female. None of the ticks developed on the cat to the stage of engorged ovigerous female.

RESULTS OF THE EXPERIMENTS.

Although the results of these experiments are somewhat fragmentary, due in part to the impossibility of devoting the proper amount of time to carrying out all the observations desirable, they show a number of things:

1. Texas fever ticks removed from one animal just after the first molt will continue to develop to the adult stage if placed upon another animal. Furthermore, it is not necessary that these ticks be placed immediately upon the second animal; a period of at least twenty-four hours may intervene.

2. Texas fever ticks removed from one animal just after the second molt will continue to develop if placed upon another animal.

3. Texas fever ticks removed from an animal just before the occurrence of the second molt will molt, and when returned to their host several days after having been removed will reattach themselves.

4. Texas fever ticks removed from their host shortly before the second molt will molt and live unattached for at least two weeks.

5. Texas fever ticks removed from their host as nymphs and afterwards molting will attach to human beings and to rabbits, even after a lapse of two weeks, and suck blood.

6. Texas fever ticks will attach, as larvæ, not only to cattle, horses, mules, and asses, but also to cats, and will develop to the adult stage upon the latter.[1]

PROBLEMS RELATING TO THE TRANSMISSION OF TEXAS FEVER.

Although the above facts are probably not of great practical importance, they open up a number of interesting possibilities which deserve consideration.

Texas fever is transmitted to cattle by the offspring of Texas fever ticks which have matured upon other cattle whose blood contains the causal agent of the disease, *Piroplasma bigeminum.*

Since it has been shown that *Boophilus annulatus* may under some circumstances pass the parasitic portion of its life history upon more than one animal, the question arises whether it may not transmit Texas fever as a nymph or as an adult, as well as during its larval stage. If so, certain outbreaks of Texas fever difficult to account for on the basis of our present knowledge would find a more or less plausible explanation. Of such nature are cases of Texas fever which have been known to occur in the cattle of northern localities, far above the Texas fever quarantine line, within a few days following the introduction of tick-infested southern cattle, the intervening period being scarcely longer than the minimum period of incubation of tick eggs and not sufficiently long to include also the minimum period of incubation of the disease after tick infestation; but if the nymph or adult, as well as the larva, is able to transmit the disease, such cases of fever might find an explanation in the reattachment to the northern cattle of ticks which, at the time of the first or second molt, had lost their hold upon their former hosts, the southern cattle. After each molt the Texas fever tick has to reattach itself just as do other species which fall from their host and molt on the ground, but, unlike the latter, it is in a position to settle down again

[1]It is generally assumed that cattle, horses, mules, and asses are the only animals which serve as hosts for *Boophilus annulatus*, but the collection of the Bureau of Animal Industry contains specimens collected from a dog, from which host Francis (1894) seems to have been the first to report it; and it may also be noted that the original description of the species by Say (1821) is based upon specimens collected from a deer in Florida. The closely related species of South Africa and Australia, *Boophilus decoloratus* and *Boophilus australis*, occur more or less commonly upon all the domestic mammals, and it may be accepted as a probability that the fever tick of this country will be found not only upon the animals already mentioned, but occasionally, even though very rarely, upon sheep and goats.

immediately after molting, while the latter must first regain a host. During most of its stay upon its host the Texas fever tick is very firmly attached and is dislodged only with great difficulty, but during the molting periods its hold is readily broken, and it can be removed with comparative ease. As the experiments have shown, ticks thus removed will reattach themselves if they succeed in regaining a host within twenty-four hours and possibly longer in the case of the nymphs, and within a time which may extend to nearly two weeks in the case of the adult.

In view of the ease with which molting ticks may be detached from their host and the readiness with which they reattach themselves to other animals, it seems not unlikely that under natural conditions ticks may sometimes become dislodged while molting, and, circumstances being favorable, may regain a host and continue their development. This, for example, might happen when cattle were closely crowded and rubbing against one another, or by cattle rubbing against posts, trees, and other objects, the molting ticks thus dislodged being directly transferred to other individuals in the one case, and in the other case falling to the ground and later reattaching themselves to an animal which chanced to lie down upon the spot where they had fallen.

The transmission of Texas fever by nymphs or adult ticks, if it occurs, would be somewhat analogous to what occurs in the case of another disease of cattle, the so-called African coast fever or tropical piroplasmosis, due to a parasite known as *Piroplasma parvum*. This disease, as Lounsbury, Robertson, and Theiler have shown, is transmitted by a tick, *Rhipicephalus appendiculatus*, which falls from its host before each molt. Either the adults which have fed as nymphs or nymphs which have fed as larvæ upon sick cattle may transmit the disease. A second species of tick, *Rhipicephalus simus*, with a life history similar to that of *R. appendiculatus*, transmits the disease in a similar fashion. The progeny of adults of *R. appendiculatus* which have fed upon cattle sick with coast fever are not infectious, either as larvæ, nymphs, or adults, nor will the progeny of adults of *Boophilus decoloratus* (the South African species corresponding to our Texas fever tick, and a transmitter of Texas fever) which have fed upon sick cattle transmit the coast disease. These facts may be taken as an incidental argument against the likelihood of the transmission of Texas fever in the manner suggested, to the effect that since tropical piroplasmosis, which is transmitted by nymphs and adult ticks, can not be transmitted by larval ticks in the manner of Texas fever, it is not likely that Texas fever can be transmitted by nymphs or adult ticks in the manner which has been suggested. It may be noted, however, as a distinct point of difference in regard to the transmissibility of the two diseases,

that whereas tropical piroplasmosis is, so far as known, transmitted only by ticks, and apparently can not be inoculated, Texas fever may be readily transmitted by inoculation as well as in the usual manner by ticks.

The modes of transmission of the piroplasmosis of sheep and dogs are of considerable interest in the present connection. "Carceag," the ovine piroplasmosis of southern Europe, is, like Texas fever, transmitted by the progeny of ticks which have matured upon infected sheep, the ticks in this case belonging to the species *Rhipicephalus bursa*, but, as has been shown by Motas (1902, 1903), its transmission, unlike that of Texas fever, is not accomplished until the ticks have reached the adult stage. As the ticks of this species fall from their hosts before the second molt, it happens that the animal upon which an infectious tick passes its larval and nymphal stages is not affected, and the disease appears only in the animal upon which the tick finally fastens as an adult.

Likewise, as Lounsbury has demonstrated, ticks of the species *Hæmaphysalis leachi*, which is concerned in the transmission of canine piroplasmosis, are infectious only when they reach the adult stage, and neither the larval nor the nymphal stage is able to transmit the disease. In this species the tick falls from its host before the first molt, as well as before the second, and consequently may live upon three different hosts during its life history, two of which, even though susceptible, remain free of disease, while the third becomes infected.

These facts would also seem to argue against the transmission of Texas fever by ticks in any other but the usual mode, on the ground that since it has been shown that the ticks *Rhipicephalus bursa* and *Hæmaphysalis leachi* transmit their respective diseases only during one stage of development, it is little probable that Texas fever can be transmitted by other than one stage of the Texas fever tick. On the other hand, as already referred to, *Rhipicephalus appendiculatus* may transmit tropical piroplasmosis either as a nymph or as an adult, and a still closer parallel is found in the case of the European piroplasmosis of cattle. Recent investigations (Kossel, Weber, Schutz, and Miessner, 1904) have shown that the latter disease is transmitted by a species of tick known as *Ixodes ricinus*, a form which lives upon a great variety of hosts, among which, besides cattle, may be mentioned sheep, goats, horses, deer, dogs, cats, foxes, ferrets, hedgehogs, rabbits, bats, birds, and man. This species is one which normally falls from its host before each molt. It has been proved in regard to it that the progeny of adults which have fed upon sick cattle are infectious not only as larvæ, but also during their nymphal stage, and this is analogous to what has been suggested as of possible occurrence in the case of the

Texas fever tick. From an academic standpoint, therefore, the chances seem to be as much in favor of as against the possibility of the transmission of Texas fever by nymphal or adult Texas fever ticks, and the question accordingly remains open, awaiting the definite solution which can only be reached by actual experiment.

Whether other ticks as well as *Boophilus annulatus* and its allied forms of the genus Boophilus may not transmit Texas fever in this country is a question which deserves serious consideration and investigation on account of the fact, just mentioned, that the European form of Texas fever is transmitted by *Ixodes ricinus*, a species which, moreover, is not uncommon in the United States.

Mayo, and since Morgan, failed to transmit the disease with the lone star tick (*Amblyomma americanum*), and the innocuousness of this tick in so far as concerns Texas fever may be considered as settled.

Other questions are suggested by the results of the experiments above recorded, one of which at least is of interest in its relation to the problem of tick eradication and may be here referred to, namely, to what extent are animals other than cattle (the principal host) responsible for the dissemination of Texas fever ticks? So far as horses and other equines are concerned it is certain, and is generally admitted, that they not uncommonly act as hosts for *Boophilus annulatus*, and the spread of ticks by these animals must be taken into consideration in whatever scheme of eradication may be employed. On the other hand, it is still uncertain whether other animals, such as sheep, goats, deer, dogs, cats, etc., some of which, as shown above, are able to act as hosts of *Boophilus annulatus*, must also be taken into account in the application of methods of eradication, or whether the part they play is so small that they can be practically neglected.

OUTLINE OF FUTURE WORK.

In connection with the study of the Texas fever tick inaugurated by the Bureau of Animal Industry it is intended not only to continue our general investigations upon variations in its life history, but also to extend our work along the lines suggested in the present paper, namely, to determine (1) whether other stages of *Boophilus annulatus* besides the larvæ are able to transmit Texas fever; (2) whether other ticks occurring in this country, especially *Ixodes ricinus*, may act as agents of transmission; and (3) whether other animals besides cattle and equines may not under natural conditions be partly responsible for the dissemination of Texas fever ticks.

Approved:

JAMES WILSON,
Secretary of Agriculture.

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