when applied once as a drenching spray to three cows. However, when similarly applied at 0.75 and 1.5 per cent. of gamma isomer, benzene hexachloride did affect and kill the cows. Two Hereford heifers, thoroughly sprayed in eight treatments at four-day intervals with 1.5 per cent. chlordane emulsion, were not affected.

In the same paper the authors reported that of ten cattle sprayed with a two per cent. suspension of chlordane at two-week intervals, three cows died after 10-12 days following the fourth spraying. Other cattle sprayed similarly with two per cent. of benzene hexachloride (12 per cent. gamma isomer) showed no apparent injury.

Radeleff and Bushland (1950) found that suckling calves were particularly susceptible to benzene hexachloride, toxaphene, and chlordane at various levels from 8.0 per cent. to 0.025 per cent. of the toxic ingredients. In this experiment the calves were sprayed until thoroughly wet.

The meagre published results of work on this phase of the toxicity of the newer insecticides emphasizes a need for further investigation. To aggravate the situation, no standardized method of applying the insecticides has been attempted, for each group of workers has a different set of problems. For example, in the present experiment only one litre of insecticide was sprayed on each of the cattle, whereas Radeleff and Bushland and Bushland *et al* wet their cattle thoroughly. Each group was guided by the limits of its purpose in performing one experiment.

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FURTHER STUDIES ON TICK PARALYSIS[1]

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Tick paralysis in British Columbia and adjacent territories, as in South Africa and Australia, has long remained a disease of baffling origin. Though it is generally conceded that the symptoms produced in the host are brought on by the injection of a toxin by the tick, the reason why ticks of the same species vary in potency is still a puzzle. The solution to this mystery has been complicated by a series of factors which have included such nebulous conditions as are involved in different host and tick species, host susceptibility, and host immunity. Zumpt (1950) even questions whether these factors are the only ones, and as he suggests, the physiological condition of the individual tick seems to be of considerable significance, a factor which has resulted in studies too frequently containing so many unknowns that no logical pattern is apparent. This, together with the shortness of the annual period of natural tick activity, has rendered progress in the etiology of the disease slow. Nevertheless, each year some advance has been made and considerable data gained toward the understanding of this interesting phenomenon.

In British Columbia tick paralysis is caused by the female of the Rocky

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Mountain wood tick, *Dermacentor andersoni* Stiles, and is mainly a disease of cattle. If these animals are pastured on tick-inhabited ranges during the active adult tick season of March and April, they become infested with large numbers of the parasites. These congregate in dense masses on the heads and shoulders of the victims and attach for their seven-to-ten-day blood meal. It is toward the end of this period, when they have become replete with blood, that they may paralyse their host. Sheep, dogs, and humans are also affected, but usually on these hosts there are few ticks or only one.

This species of tick mates while feeding, which, as shown by Gregson (1944), enables the female to engorge to repletion much more rapidly than when deprived of a male. The feeding period of a mated female is approximately seven days, after which it drops from its hosts, whereas an unmated tick remains attached, half-engorged, for several weeks. For some time it was thought that fast-feeding, mated females were more virulent than the slow-feeding, unmated ones. This view is, however, weakened by the facts that in human paralysis the male tick is rarely present and that in most instances the causative tick is only half-replete at the onset of paralysis.

TEST ON SUITABILITY OF HOSTS

During the past few springs further attempts have been made at the Kamloops laboratory to demonstrate the conditions responsible for the production of paralysis. Since so many factors appear to be involved in the occurrence of paralysis in tick-infested animals, one of the first steps was to find a host that is subject always to paralysis. To permit large-scale infestations involving animals on which ticks had not previously fed, small laboratory animals were sought. It was with some degree of surprise that white mice were discovered to be ideal hosts of the adult ticks, for never in nature has this stage of tick been taken from the numerous wild mice present in tick-infested areas known at the Kamloops laboratory. Though the ticks in the laboratory had to be protected from the actions of their hosts by large rubber discs placed around the animals' necks, the cleanly nature of mice does not prevent other species of ticks in nature from attaching and engorging. The successful application of this discovery was short-lived, for it was found that though rapidly engorging, mated ticks did kill the mice, death was apparently due to a severe anaemia, as shown by blood counts, and slow-feeding ticks produced no typical symptoms of paralysis. These results covered 37 infestations. Of 18 mice infested with mating ticks, ten died and eight grew only sluggish by the time the ticks became replete. Nineteen, infested with single female ticks, were unharmed, and at the end of the seven days (the normal period for paralysis to appear) bore half-engorged specimens. One mouse harboured five and another two females for the same period without apparent ill effects, though a third with four females died — presumably because of the large blood meals of the ticks.

Mice, then, apparently do not fill the need for a host susceptible to paralysis —unless, of course, the ticks used in this experiment were for some reason not capable of producing paralysis.

Rabbits and guinea pigs appear to be immune to tick paralysis, as is suggested by the lack of symptoms of this disease during the course of infesting these hosts with thousands of ticks in spotted fever studies at the Rocky Mountain Laboratory, Hamilton, Montana (W. L. Jellison, personal communication), and during smaller-scale infestations at Kamloops. Dogs are relatively susceptible to tick paralysis and would undoubtably form convenient test animals were it not for the difficulties of procuring and maintaining them in sufficient numbers. Infestations on each of six puppies caused a paralysis in three of the hosts, on which one, four, and two ticks had attached.

TESTS ON LAMBS

In 1951, 30 lambs were available for further adult tick feeding observations at Kamloops. Though previous experiments had shown that all tick-infested lambs do not necessarily become paralysed, at least some are paralysed under favourable conditions.

METHODS AND DATA OF INFESTATIONS

The ticks in these experiments on lambs were confined on the hosts by dome-shaped screen capsules, which were anchored to the surrounding wool by linen threads. To provide optimum conditions for the ticks, each capsule was placed over a clipped area that had been washed free from natural grease. A dampened pad of absorbent cotton served to maintain the humidity until the ticks had attached. Unless these precautions were taken a large number of the ticks died before attaching. Such mortalities were excluded from the studies, the results of which are tabulated below.

Summary of infestations of individual lambs, various feeding rates, and paralysing powers of engorging females (Complete data of this experiment are available from the author):

1. Infested April 4, 13, 27 with 5, 4, 2♀ and 5, 0, 2♂ respectively. Three* females fed rapidly. No paralysis.
2. Infested April 26 with one pair. Female fed rapidly without producing paralysis.
3. Infested March 28, 31, April 7 with 5, 1, 0♀ and 0, 0, 20♂ resp. None fed rapidly. No paralysis.
4. Infested April 16, 26, May 8 with 6. 1, 8 ♀ and 0, 1, 8♂ resp. Seven females fed rapidly. No paralysis.
5. Infested April 13, 13, May 3 with 4, 0, 6♀ and 0, 4, 10♂ resp. Two females fed rapidly. No paralysis.
6. Infested April 13, 13, 13, 25 with 6, 0, 1, 1♀ and 0, 12, 1, 1♂ resp. Two females fed rapidly. No paralysis.
7. Infested April 11, May 3 with 1, 1, ♀ and 2, 3♂ resp. Both females fed rapidly. No paralysis.
8. Infested April 14 with 10♀ and 0♂. None fed rapidly. No paralysis.
9. Infested April 16, 28, May 8 with 3, 2, 8♀ and 0, 1. 8 ♂ resp. The two females of the second group paralysed the lamb moderately when only half-replete. Recovery followed their removal. Five females of the last group fed rapidly, causing no further paralysis.
10. Infested April 14, 30 with 6, 1♀ and 3, 1♀ resp. Of the first group, one female fed rapidly, causing a slight paralysis which disappeared upon its release. Two subsequent females fed rapidly, causing no paralysis.
11. Infested April 14 with 3♀ and 0♂. None fed rapidly. No paralysis.
13. Infested March 28, 31, April 13, 30, May 10 with 5, 1, 5, 2, 10♀ and 5, 1, 0, 1. 0♂ resp. One female of the first group fed rapidly causing a slight paralysis. Four slow, and a subsequent fast feeder produced no symptoms. The lamb finally was paralysed severely by five slow-feeding ticks of the third group. Paralysis remained as the ticks were taken off at hourly intervals until the last was off. Two fast-feeding females of the fourth group and ten slow feeders of the last produced no further paralysis.
14. Infested April 11, 27 with 1, 1♀ and 2, 1♂ resp. Both females fed rapidly, the first producing a slight paralysis, the second none.
17. Infested May 3 with 3♀ and 2♂. Two females fed rapidly. No paralysis.
18. Infested April 12, 28, May 8 with 1, 1, 7♀ and 2, 2, 8♂ resp. First two females fed rapidly, causing no paralysis. Seven females of the last group fed rapidly, producing severe paralysis.
19. Infested April 30, May 8 with 2, 8♀ and 2, 8♂ resp. All females fed rapidly, each group producing a slight paralysis.
20. Infested April 25 with 2 pairs. Both females fed rapidly. No paralysis.

* Failure of all females paired with males to feed rapidly is probably due to a delay in mating.

21. Infested April 13 with 1 pair. Female fed rapidly. No paralysis.

SUSCEPTIBILITY OF THE LAMBS

The lambs used in these experiments were as uniform a group as practical inasmuch as they were much of an age and none had been exposed to ticks before. Some of the lambs that were unaffected by ticks during the first infestations were susceptible to paralysis later (lambs 9 and 18). It is, however, unlikely that this later response was due to sensitization since six others (lambs 1, 3, 4, 5, 6, and 7) did not become paralysed after repeated infestations during similar periods. Indifference to tick paralysis because of development of host immunity can probably be ignored also, since paralysis was produced twice within eight days in two lambs (13 and 19). These facts suggest that some factor in the tick, rather than in the lambs, was responsible for the paralysis in the above instances. Though this assumption is later moderated by indications of a host resistance, it does offer a theory that is valuable for further progress, in view of the scantiness of substantial evidence.

VIRULENCE OF THE TICK

If, then, the presence of paralysis is considered to be due to a condition within the tick, attention can be directed toward a comparison of the virulence of the sexes. Though males are frequently associated with females in paralysis cases, at the Kamloops laboratory there is no record of paralysis caused by males themselves. In the experiments under discussion 32 male ticks were fed on lambs without apparent symptoms of paralysis. Presumably the sparsely feeding male tick can be omitted as a direct causative agent in this disease. Indirectly, it was felt it might constitute a factor by increasing the feeding rate of the female.

Assuming, now, that paralysis is caused only by the female tick, an analysis can be made of the effects of mated and unmated ticks on the host to determine whether or not the feeding rate is related to the virulence of the tick. In 28 separate infestations involving 80 pairs of ticks (fed in single pairs or in series up to ten pairs on 16 lambs) 50 ticks mated and engorged rapidly enough to drop replete in seven days. Of these 50, only 11 were possibly involved in the production of the six cases of paralysis that resulted. It is possible that actually only one tick was involved in each case, so that the ratio of virulent mated ticks to benign ones might then be approximately one to eight.

In ten other infestations involving 52 females without males (fed in numbers from one to ten on eight lambs), paralysis occurred in one lamb (13) on which five ticks were feeding. The possibility that all these ticks were involved in the production of the paralysis cannot be dismissed, since the symptoms did not subside until the last tick was removed. If. however, only this last tick was implicated, the ratio of virulent unmated ticks to benign ones was one to fifty-two. The above data suggests that mated, rapidly feeding female ticks are more likely to cause paralysis in lambs than slower-feeding ones.

As judged from this laboratory's records, the fact that slow-feeding, solitary females are so virulent in human infestations, where a tick seldom engorges without causing paralysis, suggests that man is more susceptible to the action of the tick than lambs—a theory that agrees with the mentioned variation in susceptibility among different species of animals. Lambs, then, are moderately resistant, since, out of the eight cases of paralysis mentioned, only two were severe enough to produce a loss in the use of the limbs; the remaining lambs exhibited only an unsteady gait. In contradiction to the aforementioned apparent uniformity of hosts, this latter symptom suggests that certain lambs had a greater resistance to the toxin. This resistance may even have masked the potentialities of seemingly innocuous ticks. According to records at the Kamloops laboratory, paralysis in cattle is invariably caused only by clusters of ten to 50 ticks and it is doubtful whether these animals could be paralysed by solitary specimens. However, not all animals with heavy infestations will become paralysed — suggesting again an individual resistance.

The data for lambs 10, 13, 14, 18, and 19 substantiate a variation in virulence among ticks. At the same time, there is an indication that a paralysed animal is so weakened that it may then be affected by ticks, which on a healthy animal, would not be considered virulent. This is evident in animals on the range which often remain prostrate for several hours until the last ticks are removed, and then make a rapid recovery. This could be the case in lamb 13.

Lamb 9 presented an interesting opportunity for a further experiment in that paralysis commenced when the two engorging ticks were only half-replete. The ticks were transferred to lamb 1, which, though having been subjected to ticks, had not yet been paralysed. The virulent ticks attached, and dropped within a day—but did not cause paralysis. Similar results occurred in a previous year when a partially fed tick from a paralysed child was induced to attach to a mouse, whereupon it mated and fed rapidly without harm to its second host. Again there are too many unknowns to establish a reason for this behaviour. It appears that a virulent tick can paralyse only the host upon which it commences to engorge.

In summary, it is assumed that tick paralysis is brought about in the host by a toxin secreted by the engorging tick. It appears that the production of tick paralysis in an animal depends on a combination of host susceptibility and tick virulence; and that where the host is relatively resistant, as in sheep and cattle, only a certain portion of rapidly feeding ticks produce the symptoms, whereas in humans, considered to be more susceptible, solitary, slow-feeding ticks are sufficient to cause paralysis. The conflicting evidence concerning the varying resistance of the host and the unknown virulence of the ticks makes it difficult to arrive at any conclusion.

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A REVIEW OF STUDIES ON THE SYSTEMIC CONTROL OF LIVESTOCK INSECT PARASITES[1]

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If, without causing harm to the animals, it were possible for a stockman to introduce into the diet of his livestock some substance that was toxic to bloodsucking arthropods feeding upon these animals, he would find a solution to one of the important problems of animal husbandry. Economic entomologists have recently devoted a great deal of effort toward the attainment of this ideal, and the investigations seem to indicate that it may be possible to achieve it.

However, the problem is not simple. Many difficult biochemical and toxicological factors must be studied and their roles elucidated before the problem can be solved. Because of these factors, the entire matter must be approached with caution. A full discussion of these aspects is beyond the scope of this paper because it is my intention only to review some of the more important studies that have been made in the past.

The first important contribution is that of Knipling (1938), who reported

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