STUDIES ON THE RATE OF TICK FEEDING IN RELATION TO DISEASE

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A Study of Host Tissues in Relation to Varying Feeding Rates of Individual Ticks

General Discussion of Tick Paralysis

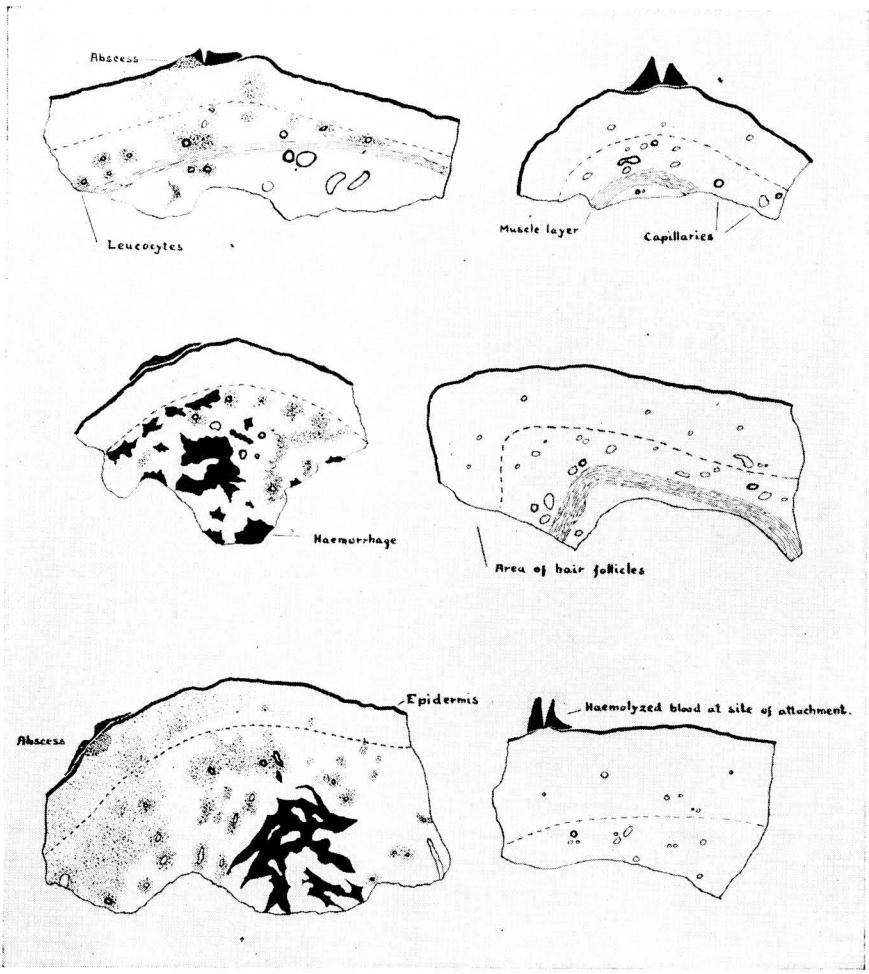
The ensuing studies have been made in an attempt to throw more light on the problem of tick paralysis. This disease is produced by a variety of ticks and its occurrence appears to be world-wide. Its mysterious nature, its seriousness, and the elusiveness of a causative factor has enticed numerous workers to spend more than a passing thought in connection with its etiology, but, although several conflicting theories have been advanced, no definite conclusions can yet be drawn that satisfactorily explain its cause.

A summary of the available data of tick paralysis is given here to acquaint the reader with the disease and to provide a basis for the experiments that are to follow.

The disease is prevalent in Southern Alberta and British Columbia, and throughout the Northwestern Rocky Mountain States of America. In these localities it is caused by the spotted fever tick, **D. andersoni.** In British Columbia, tick paralysis has attracted considerable attention, particularly among the large cattle ranches. Eight human deaths have to date resulted from the disease in this province, and every year there are minor cases among children. Sheep, dogs, and cattle are particularly susceptible to the tick, recent paralysis outbreaks in individual cattle ranches having involved, on two occasions, a hundred, and two hundred animals with a respective mortality of sixty, and thirteen percent.

Tick paralysis is prevalent in Australia and South Africa, proving a "veritable menace" to sheep farmers in many parts. The causative ticks in these countries are species of **Ixodes.**

Etiology: Tick paralysis may be produced in an animal by a single tick. The symptoms appear only when the tick has been engorging for about seven days and is nearing repletion. The onset is sudden and is characterized by a wobbly gait, and acute ascending motor paralysis. Pulse and breathing are rapid, there is slight glandular disturbance, and pain is absent. Death usually occurs in twenty-four to sixty hours from paralysis of the thoracic organs. If the causative tick is removed during paralysis there is rapid and complete recovery of the patient, normality



usually being attained in four to twenty-four hours, depending upon the seriousness of the disease. Exceptions to these observations are instanced in the case of a B.C. man, when recovery lasted over the period of three months, and in South African sheep which remain in a weakened condition for many weeks. There is considerable controversy as to whether an animal can be immunized against the disease. The writer has noted many instances where it has been impossible to induce paralysis even in young lambs with as many as a dozen rapidly feeding ticks.

The facts of rapid recovery negative necropsy findings, and negative inoculation tests point to the theory that a tick-secreted toxin is responsible for the paralytic symptoms. This is strengthened by experiments that have been performed in Australia in which it was found that an injection of crushed salivary glands from two and a half ticks proved to be the minimum lethal dose for the mouse. Opposing this

theory are the facts that the latter experiment has not been duplicated in B.C. by glands from as many as seven ticks, dissected in vivo or while frozen, and injected intravenously, subcutaneously, and intraspinally into mice, dogs, and sheep; that many ticks may feed upon an animal with no ill effect on the part of the host—or one tick may cause paralysis; and that a bacterial disease, similar in symptoms to paralysis, is produced in the moose by a closely allied tick.

Such is the present state of data on tick paralysis. It must be borne in mind, however, that owing to the wide distribution of this disease it is quite possible that the variations appearing in different countries, and even in the same provinces or states, are due to more than one type of disease. If this is true, then much of the confusing and conflicting data may be accounted for.

Variations in the Rate of Feeding of Adult Ticks and Relation of Such to Paralysis

Tick paralysis is generally thought to be due to a rapid injection of a salivary toxin by the tick into its host. This condition would logically accompany any rapid feeding on the part of the tick. Paralysis in B.C. is produced only by fast-feeding ticks that drop at the end of seven to eight days.

Attacking the problem from this end, the writer has endeavoured to discover the conditions that are conducive to rapid feeding of the tick.

It must first be noted that variations in the rate of tick feeding may be divided into two groups; an individual variation, present among certain ticks, and a general seasonal variation in which all ticks are affected. In the first case, a series of ticks of common origin, feeding under apparently identical conditions, will often show a variation in feeding period from seven to eighteen days.

In the second, it is noted that all ticks will feed readily in the spring months over an average period of about nine days, but towards the fall and during the winter months, although apparently willing to engorge, they exhibit a striking inability to do so.

It remains to be seen if there is any relationship between these two types of feeding phenomena. In the folowing experiment the writer will confine his studies to the first problem.

A Study of Host Tissues in Relation to Varying Feeding Rates of Individual Ticks

On June 11, 1935, a four-month old lamb was infested with twenty-eight pairs of adult **D. andersoni** ticks. These ticks were placed in groups of eight over the following areas of grease-free and closely-clipped wool and were covered by gauze infesting cages.

A. Directly behind the base of left ear.
B. Over left shoulder.
C. To right of spine in lumbar region.
D. To left of spine in pelvic region.
E. On right flank.
F. On right side of belly.
G. On scrotum.

By June 17th, the following engorging female ticks were in the indicated stages of repletion. (Ticks that had failed to attach during the first day were dessicated by the sun.)

A. 1 tick ½ replete.
B. 3 ticks ½ replete, 1, ½ replete.
C. 3 ticks ½ replete, 1 dropped replete.
D. 3 ticks ½ replete.
E. 3 ticks ½ replete.
F. 3 ticks ½ replete, 1, ½ replete.
G. 3 ticks ½ replete, 1 dropped replete.

These ticks were all of the same stock—a series of adults that were collected two months previously by dragging in a single area near Kamloops. They all commenced feeding on the same host at the same date, and were consequently under the same weather conditions. Each infested piece of skin was approximately 1 square inch in area, thus allowing the ticks of each group as little variation in skin structure as possible. Yet in spite of these conditions, similar for each tick, there appeared a great difference in their feeding rates, as shown above.

Immediately after repletion of two of the ticks (group C & G), the host was chloroformed. Pieces of skin ¼ inch deep and ½ inch square were incised around each tick, and, with the latter still attached, were placed in Bouin's fixative. To effect a rapid penetration of the fluid the dorsal integument of each tick was removed. The entire operation was completed as rapidly as possible, after which the animal was killed. Except for the two replete ticks that had previously detached themselves, not one of the parasites released its hold during the whole of the somewhat drastic procedure. All specimens were left in Bouin's for eighteen hours; removed to fifty percent alcohol for one hour; to sixty-five percent for six hours, and stored indefinitely in seventy-five percent.

A series of sections were made from the above-mentioned tissues. Where possible, these sections were taken through the site of attachment of the tick. Efforts to preserve the mouth-parts within the tissues were unsuccessful, due to their chitinous nature, but the depth of penetration could clearly be seen on certain slides, and was marked by a surrounding scab of dried blood. Very little mechanical disturbance appeared to result from the tick's feeding, the mouth-parts rarely penetrating beyond the epidermal layer.

Host tissue below fast-feeding ticks:

Sections dealt with here were made from the skin below two ticks that were replete at the end of seven days (groups C & G) and from tissues below a two-thirds replete tick (group E). All three series, being pathologically similar, will be described collectively.

The site of attachment of the parasite is surrounded by an area of dried haemolysed blood. Beneath this scab, in two of the three series, a small pocket of pus was present, representing probably a secondary infection. The whole of the dermis presented a picture of acute inflammation. The blood vessels and capillaries were tremendously dilated, and in two tissues had ruptured to form haemorrhagic areas of haemolysed blood. An edema was present throughout the tissue, filling lymph spaces with a thick transudate. Surrounding every blood vessel, and extending into the corium towards the tick, there appeared a vast collection of leucocytes. These foci consisted mainly of polymorphonuclears and fibroblasts, but contained a large percentage of eosinophiles, lymphocytes, and histocytes. In no instance could red blood cells be discovered, other than within certain of the unruptured capillaries. It

is believed by the writer that this whole area must be saturated with haemolysed blood, but no positive test for haemoglobin (Benzidene reaction) could be obtained outside of the haemorrhage to substantiate this probability.

Host tissue below slow-feeding ticks:

These three sections were taken from areas within half an inch from the above-mentioned ones. In each case the tick had only reached a semi-replete stage at the time the tissue was fixed. Histological examinations of sections through these areas showed that little change had taken place as a result of the tick. Edema and inflammatory processes were practically absent, and the capillaries were only very slightly dilated.

Discussion:

It has already been shown that an irregular rate of feeding may occur among a common stock of ticks while feeding under identical external conditions and on the same host. This variation was first thought to be due to the fact that certain of the ticks had tapped a blood vessel, and so gained an extra supply of nutritive fluid. This theory fitted very well with the fact that rapidly feeding ticks usually cause paralysis—any toxic secretion would be readily disseminated by such a position.

Studies from the previous experiment contribute the following data: Rapidly feeding ticks produce an acute inflammation in the underlying dermal tissues. Intense leucocytosis occurs around the blood vessels. The capillaries are very dilated, and a haemorrhagic area of haemolysed blood is usually present. Slow feeding ticks produce little or no change within the tissue. Capillary counts in both cases were similar.

These facts lend to an assumption that the inability of certain ticks to engorge rapidly during their feeding sason is not through an insuffciency of tissue blood. **It seems, rather, that the slow feeding ticks lack the power to produce sufficient disturbances within the tissue to cause a liberation of blood from the vessels.** Since the mechanical disturbance is very slight, and since the tick does not penetrate deeply enough to obtain blood from the capillary bed, it is entirely dependent upon the production of an edema and haemorrhage for its access to the blood fluid. It possibly produces these injuries by the elaboration of a powerful toxin, the evidence of which is suggested by the pathology of the tissues below the fast-feeding ticks.

The writer wishes to thank the Committee of Graduate Studies of the University of Alberta for their permission to present this paper, it

being a portion of a thesis which will shortly be submitted for the degree of M.Sc.

He is indebted to the Dominion Entomological Laboratory, Kamloops, for the use of material upon which the experiments are based.

NOTE: Recently, objects appearing to be symbiotic yeasts have been observed within the digestive epithelium of engorging ticks. It is probable that they play an important part in the assimilation of blood by the tick, and if so, may explain some of the irregularities that have been noted in the above-mentioned feeding rates.