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Dipping and Tick Destruction

(PART IV)

BY

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IN previous reports on the above subject I have endeavoured to show the nature and action of arsenical dipping fluids upon the life of the tick (Part I) and the effect upon those larger domesticated animals—the hosts of the tick—which have been subjected, with frequency, to the action of such fluids (Part II).

The solution of certain problems in connection with the methods of spread of disease by tick agency was broadly dealt with in Part III, while the present work is intended to deal more particularly with some of the details or mechanism of the actual attachment of the tick and the attendant infection of its host.

While these observations have been made solely upon the brown tick (*Rhipicephalus appendiculatus*), as being chiefly concerned in the spread of the disease East Coast fever, it is thought they may be found in the future to have a wider significance when applied both to other tick-borne diseases and other species of ticks. The reasonableness of such a surmise will be seen later when dealing with the circumstances governing the actual infection of the bovine host in the disease under consideration (East Coast fever).

The conditions governing this actual infection of the host have indeed hitherto escaped critical observation. It has been assumed in the past that infection ensues with certainty—provided undoubtedly infectious ticks, either in their nymphal or adult stages, gain access and attach themselves to the body of a susceptible bovine host. Such certainty of result, however, is, as will be shown below, dependent upon exact conditions, the absence of which must render abortive the infective process.

The ability of a tick to transmit the infection of East Coast fever depends primarily, as is well known, upon its having passed one of its previous immature or adolescent stages attached to a beast sick from the disease, and harbouring in its system the germs of the malady. A certain degree of maturity—length of time since hatching—seems further essential to infective ability.

For some time after moulting the newly hatched tick is disinclined to attach itself to its host either by reason of the mouth parts not being sufficiently hardened to effectively pierce the tough layers of epidermis of its host, or more probably because the need for sustentation in the young tick is not felt until some weeks of active life have developed an appetite or desire for food. That this desire for food in the young tick is not of the nature of a necessity or vital need the subjoined footnote will show.*

Some observers in the past have placed the commencement of the period of attachment (feeding) as early as from one day to six months.

The writer's experience would go to prove that neither of these periods are accurate, one day being quite an insufficient time for the newly hatched tick to attach itself, while six months errs as greatly in underestimating the period during which a tick may live in search of a host.

In several instances in the present work the influence of age in determining the infectivity of the tick has been noticed, for though ticks hatched recently (some weeks) have actually attached themselves to susceptible animals, they have failed to produce the disease, while other ticks of the same origin and taken from the same bottle a month later have proved infective. That such ability on the part of the tick to establish the infective process is not dependent upon temperature or seasonal influences seems to be shown by the fact that, in the instances quoted above, positive results (infections) were produced at the coldest period of the year, and during a period of lower temperatures than had been experienced a month earlier at the time when failure to infect had attended the attachment of the same batch of ticks.

Further, no evidence has come under the writer's notice tending to confirm a recently expressed theory that the infectivity of the tick is in any way influenced, still less controlled, by the season of the year or the temperature at which either the eggs were hatched or subsequent moultings took place.

The unexpected evidence given below as to the inability of the tick to establish infection within a certain time after attachment to its host lends strong support to the assumption that the factors governing the infective process are controlled by physiological principles in the system of the tick rather than by any physical conditions such as suggested.

In the light of our present knowledge, therefore, we may say that the factors governing the establishment of infectivity in the adult tick are:—

(*a*) Its actual infection (by attachment in a previous stage to a sick host).

(*b*) The necessity of the lapse of a certain length of time since moulting.

(*c*) The opportunity for attachment to its host for a given period before infection can be transmitted.

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* The writer has in his laboratory at the present time brown ticks active and eager to feed after more than thirteen months' captivity (i.e. thirteen months from time of moulting). If the tick retains its vitality after such conditions of life as captivity in a glass jar involves it must be reasonable to suppose that the life of the insect would under natural conditions be even longer. The point seems of some importance where the principle is resorted to of shutting up infected areas in order to kill all contained ticks by starvation, and the significance of the observation is rendered greater through a statement made by a well-known investigator of the disease as follows:—

"From observations made in connection with East Coast fever where the freeing of an area from the disease is probably due to starving out of the ticks, it can be deduced that a safe period is *fourteen months* [italics mine] and we can accept that this period will free any farm from tick life under the conditions of no host having access to it."

The period mentioned is—from our present evidence as to tick longevity—probably insufficient to ensure cessation of all life in infected ticks and in any case is too perilously narrow in its limits to warrant adoption.

As this last point—the period ensuing between attachment and infection—is one of some importance, it will be as well very briefly to recall a description of the mechanism by which the tick attaches itself to its host. Reference to the microphotographs at the end of the present report will show the head of the tick to be furnished with a powerful barbed organ for penetrating the tissues of its host (the hypostome or maxillo-labial dart). (See fig. 1*, Schedule VIII.) This organ lies in the middle line, while directly above and closely opposed to it are two mandibles, the chelicera or horney claws) which the tick first thrusts into the tissue to anchor itself firmly while driving the hypostome deep into the layers of the skin of the host.

When this process is once effected the tick is so firmly attached to its host that it is with difficulty it can be pulled away, the traction either leaving the head of the tick behind with its mouth parts buried in the tissues, or tearing away the tick with a piece of skin still attached to the strong, recurved barbs of the hypostome (see photo-micro. 3).

Reference to figures and photographs will show that the action of the tick in penetrating the tissues is not in the nature of a clean boring motion, but is rather a thrusting upheaving force, reminding one of the action of a pig rooting in soft ground (see photo micro. 4).

Observations (made by liberating hungry ticks upon a suitable host and watching their action by means of a hand glass) show that the process of attachment, i.e. the complete burying of the hypostome in the skin, can be effected in a very short space of time—a few minutes sufficing under favourable conditions.

Although the attachment of the tick is of so firm a nature as to require much force for its removal, the tick is able, apparently, after effective lodgment, to disengage its barbs at will from the tissue into which they have been thrust and seek either a fresh spot for re-attachment or even a fresh and more congenial host.

This migration from an original site of attachment is frequently noticed when limited numbers of ticks are being used and are being kept under close observation. The fact of the ease with which migration is effected after attachment (as well as the foregoing details of time and means by which such attachment is effected) will be seen later to have a significance in considering the factors governing the spread of the disease.

Having dealt with the main points which determine the infectivity of the tick and its ability to transmit such infection, it will be interesting to approach the question of infection from the point of view of the host—the ox.

It is not intended in this review to deal with the more intimate pathology of the infective process; such a line of inquiry, interesting and profitable as it might prove, is hardly within the scope of the present work, which latter has always had for its object the attainment of practical ends by which to control a disease which is costing South Africa so much.

Observations, therefore, on the infective process in the ox have been confined to the determination of the exact time of its onset and the possibility of averting or modifying the morbid process before it can establish itself in the system of the beast in an uncontrollable and fatal form.

In this connection it seemed desirable to ascertain whether the commencement of the infective process was local in its nature and dependent for its establishment upon changes and influences in the tissue at the site of the tick bite, or whether the disease germs upon leaving the tick became at once dispersed by the blood or lymph streams to distant parts of the body where the disease became established, independently of any such local influences at the site of inoculation.

The establishment of the infection through the agency of the blood-stream in natural cases of infection had never—so far as the writer knows—been demonstrated, although such a channel of dispersion was conjectured. The evidence against such dissemination occurring through the lymphatic system seemed great. Had the progression or generalization of the disease taken place through such channels, successive involvement of lymphic glands, in anatomical sequence, in a large percentage of cases, would have ensued, following natural, i.e. tick, inoculation at the predilection sites, those regions of the ox specially subject to attack by the brown tick. Such evidence, however, has been altogether wanting. In a series of infections made at the writer's laboratory by restricting the attack of infectious ticks to the tip of the tail, no involvement of the lymphatic glands draining the tail was observed (such as occurs in the usual inoculation for pleuro-pneumonia) nor were the larger posterior lymphatic glands enlarged before the involvement of the anterior glands (prescapular, etc.). Such absence of implication of the lymphatic structures in the early progress of the infection points with certainty to the blood-stream as the channel of dispersion.

This did not, however, entirely negative the possibility of local influences and changes being essential before final entry of the infection into the blood-stream, especially in view of the fact that all early efforts to produce fatal infection by means of the blood-stream had invariably proved negative.

There seemed, therefore, some reason for inquiry into the possible existence of local influences in the infective process. If the blood were to be looked upon as the sole channel of the conveyance of the disease, and the tick injected the *materies morbi* directly into the blood vessel (which it had penetrated in its search for food) then it would be expected that such germs would be carried away from the spot by the blood-stream in a direct manner, and in a short space of time and distributed throughout the system (to become arrested and ultimately develop in the appropriate lymphatic structures of the body generally).

Under such a supposition the surgical removal of the actual site of infection could not conceivably retard the development of disease germs, which would have, of course, rapidly passed beyond the reach of local influences. Such a procedure might reasonably be looked upon as a critical test as to whether generalization of the disease took place immediately upon the effective attack of the tick or whether local influences were concerned in the process of infection. Should this latter unexpectedly prove to be the case, some hope of modifying the disease process locally would be conceivable and lead possibly to the devising of some practical system of modifying the natural course of the disease.

In this latter hope, small as it was, the writer may at once state he was disappointed, but the experiments necessary to the proof or disproof of the question led to an observation of interest and practical use.

Infectious ticks bred at the laboratory and of proved virulence were attached to the extreme ends of the tails of several cattle, and the tips of these tails, together with their attached ticks, were amputated after lengths of time varying from one hour to twenty-four hours.* Two control beasts were taken at the same time and a similar number of ticks from the same source were attached to the tips of their tails also, and allowed to remain there. Both these control cattle died in due course from the disease, but no disease followed in any of the other cases, even where the infectious ticks remained attached for twenty-four hours before amputation.

Several lines of further inquiry arose from this result, which are dealt with later, but although the question was not yet proved as to whether any restraining local influence at the site of the tick attack existed, the question was decided satisfactorily that the tick could not inoculate within twenty-four hours of its attachment the germ of the disease directly into the blood-stream of its host.

In considering the infective mechanism and other details in connection with the attack of the tick, it seemed a point of some importance to determine to what extent such infection depended upon the degree of tick attack, in other words, whether the infective process was dependent upon the number of ticks attacking their host.

We had been led to suppose from the observations of previous workers that several ticks were necessary to the establishment of infection, and that one insect was unable to accomplish the same.

It had always appeared to the writer that such a supposition raised grave difficulties in the attempt to explain some of the outbreaks of disease coming under observation. In cases, for example, of single and isolated outbreaks of the disease occurring in a herd many miles from a known centre of infection it seemed difficult—if not impossible—to accept the explanation that one beast in the herd had been so unfortunate as to pick up a number of infected ticks from the new focus of infection, while the rest of the herd had escaped infection from the same source. A theory which presupposed the transference of *a number* of infectious ticks over a long distance from one spot to another was sufficiently difficult of acceptance without the further condition that many such ticks should ultimately gain access to one and the same host, an individual in a herd of many living under identical conditions. The circumstances indeed attending many outbreaks rendered such a supposition untenable.

If, however, it were demonstrated that a single tick could carry and establish the infection, difficulties would be removed and possible light thrown on many outbreaks in which the agency of a number of ticks would be impossible. A single tick from an infectious area could be transported with ease and without notice, in many ways and over long distances, and should such tick ultimately gain access to a susceptible bovine host the extension of the infection would be established and perhaps remain unrecognized until such time as the solitary infected beast had died, even without suspicion being

* This operation, which was performed with one blow of a keen axe and was almost unnoticed by the beast, removed about an inch of the end of the tail without affecting the brush.

aroused as to the real nature of the disease. The crop of infected ticks disseminated from the sick animal would, in due course, produce in the herd a grave and unmistakable outbreak, by which time the difficulties of tracing the original source of infection would have become greatly increased. Such would be the theory of many an outbreak, carrying with it the weight of practical corroboration.

The agency of the single tick therefore appeared to possess a significance in the spread of the infection which warranted a closer inquiry than seemed to have been bestowed on this question in the past.

Investigation rapidly showed* that—provided the ticks used were of assured infectivity and were not allowed to attack until a considerable period had elapsed since moulting—infection followed almost certainly.

In five animals to which single ticks were attached at different times all contracted the disease, one in a modified form from which recovery took place, the remaining four dying after a typical disease-course. In one of these latter instances, Chart I,† the period of incubation was unusually long, but no noticeable modification of the disease-course followed.

From such a result it may be concluded that a single tick will produce the disease with certainty provided it is at its normal degree of infectivity, and that, in at least 80 per cent. of such cases, a fatal result will ensue.

A recognition of this fact will help to explain many outbreaks otherwise obscure in origin in which single cases of death—recognized as East Coast fever or not—preceded the main outbreak.

In endeavouring to estimate the potentiality of the tick in producing and spreading the disease it is of interest, though perhaps of no great practical importance, to find that—contrary to our accepted notions—the individual tick is capable of infecting more than one host. Indeed, within a certain time limit there appears to be practically no restriction to the number of cases of infection a single tick is capable of producing.

The observation that a tick, if removed from its host, would seek at once to reattach itself, made possible the elucidation of the above point. This ease of reattachment seems remarkable in cases where the force necessary to effect the removal of the tick has sufficed to tear—with the tick—a piece of the epidermis from the skin of the host, such as in photo-micrographs 2 and 3. It would be conjectured such a degree of violence must have so injured or strained the mouth parts of the tick that immediate reattachment would be improbable. That this is not so, however, can be judged from the fact in the present experimental work—where a time limit had to be observed—it was found that the best way of securing a prompt and effective attachment of the insect was to allow it to fix itself for some days or hours to an indifferent host (such as a horse). It could then be removed and reapplied to its proper host with the certainty of a prompt and close attachment.

Such unexpected ease of reattachment rendered possible the observation as to the infection of successive hosts. Within a definite time limit this could always be effected with certainty. The practical significance of such reattachment however, is not confined to instances

* See Schedule I. † See Chart I, Schedule I.

of successive infection of a bovine host, as will be seen later when considering the factors governing the spread of the disease.

Instances of the production of the fatal form of the disease in more than one animal by the same ticks can be seen from the charts given in Schedule IV, which charts are the clinical records of two beasts infected by a second and third transference of the same ticks.

In extending our consideration of all the points governing the infectivity of the tick we must notice a minor fact somewhat in conflict with the previously expressed views of our investigators. We have hitherto understood that infected nymphae (infected, of course, as larvae) become innocuous ("cleaned" or disinfected as it has been called) by attaching themselves to their host, and are thereafter in their next or adult stage, incapable of conveying the infection. Such view of the infective capabilities of the tick is, however, too restricted, and depends entirely upon the fact as to whether the host to which the nymphae gained access was in an infectious or non-infectious condition. Where the latter condition obtained (i.e. where the animal is clean) the nymphal ticks infect and leave the body of their host before the beast becomes infective. The ticks are then harmless and live, after moulting into the adult stage, without the capability of producing future infection.

It is possible, however—though probably infrequent except in an extensive outbreak—that the infective nymph gains access, not to a clean, but to an animal already in an infected condition. In these circumstances reinfection follows and—as recent observations in the Natal Laboratory prove—the moulting nymph emerges as an infectious adult.*

In view of our broadening knowledge as to the habits of the tick and its ability to detach itself and seek a fresh host, it seemed of interest to determine whether its infective powers remained as long as its liability to emigrate, or whether its infectivity became exhausted before it had completed its life history and fell in a distended state from the body of its host. Such an inquiry was—as will be seen—a matter of some practical importance.

The point was determined by taking a series of animals and placing upon them infectious ticks which had previously been attached to other animals for certain carefully observed periods. The period of attachment of the adult tick upon its host varies considerably, but may be put down as about an average of nine days before complete engorgement and detachment. Taking this period as a basis for observation ticks known to be pathogenic were placed upon an animal and allowed to remain for periods of 168, 144, 120, 96, 72, 48, and 36 hours, or 8, 6, 5, 4, 3, 2, and $1\frac{1}{2}$ days. They were then removed and placed upon susceptible animals (see Schedule II). The results proved conclusive. Ticks which had already fed for 96 hours (or 4 days) could still transmit the disease (as did all the shorter intervals), but ticks which had been attached 120 hours (5 days) failed to convey the disease, as did all over that interval.

The practical application of this observation will show us that no direct transference of contagion from animal to animal by migrating ticks can be established after five days' isolation (or removal) of an

* Past observations on this point by some other observers have not been conclusive nor do the conclusions arrived at appear to the writer justified on the data available. The point, however, is a minor one and devoid of any great practical application.

infected beast from infected ground. If such a finding were restricted in its application to the ox its practical importance would be only limited, but it deserves more serious consideration in view of the question of the conveyance of disease ticks from infected areas by animals other than the ox, a point to be considered presently.

We have thus seen that a limitation exists to the tick's power of infection at one end of its phase upon the living host. It will now be interesting to inquire when such infectivity commences. If we know when this becomes established we shall be able to decide the duration of its infectivity within well restricted limits.

In the earlier pages of this report it was shown that the placing of infected ticks upon susceptible animals and allowing the former to remain for periods varying from one to twenty-four hours before amputating the site of the tick attack, was not attended by any reaction. Such a negative result might arise from one of two causes: (*a*) either the removal of the infection by the removal of the site, or (*b*) the inability of the tick to have established the infective process within the period before it was removed together with such site. We reviewed the theoretical grounds for supposing that the germs of the disease should be removed rapidly by the blood-stream as soon as they were liberated by the tick. The presumption therefore was, not that the germs were deposited and after some time developed at the point of tick attack, but rather that the tick had failed—within the period specified—to eject the germs of the disease from its body.

The latter surmise proved correct, and inquiry elicited an unexpected phase—of no little practical importance—in the process of infection.

An endeavour was at first made to show whether the removal of the tick by hand would be followed by the same results as the complete removal of the site of attack. This was found to be so, and it was further observed that clipping off the body of the tick and leaving the head *in situ* was not followed by the establishment of the infection. Hand-picking—a practical method sometimes resorted to where other means are wanting—even though it resulted, as it often does, in leaving the head of the tick in the tissues, would be as effective (provided it could be done thoroughly) as cutting off the tick or even of removing the actual site of its attack.

A reprieve of twenty-four hours in the infective process seemed a matter of much importance when estimating risks of infection after known exposure, decisions as to slaughter of straying cattle, etc. Further observations lengthened this period. Infectious ticks were attached to animals for thirty-six and forty-eight hours before removal, two animals being used in each test to control results. No infection followed. At sixty hours the result was the same, both animals failing to react, while controls contracted the disease. At a period of seventy-two hours one beast contracted the disease and one failed to become infected (see Schedule III). At ninety-six hours both animals succumbed, as also at one hundred and twenty hours. This observation was then checked by ascertaining whether the application of a spraying fluid would give a result similar to the removal of the infectious ticks by hand. This was found to be the case not only experimentally but where a beast was placed in a small infected paddock and allowed to run for two complete days before spraying.

A practical application was thus given to the above findings, inasmuch as the conditions of infection were in all respects natural, infectious ticks attaching themselves freely at all parts.

Beyond this period (i.e. up to sixty hours) it was not practicable to repeat the observation by reason of shortness of time and resource, but it is thought no practical purpose would have been served by so doing, as the main point was clearly established that the infectious tick is *not able to commence the process of infection until a period of at least forty-eight hours after its attachment.*

The cause of this long and unexpected delay at the commencement of the infective process is a question of more scientific interest than practical value. The writer, therefore, without the opportunity of more precise observation, suggests merely that the infective mechanism is dependent at first upon the digestive function of the tick, and that, until such digestive process has been evoked by the presence of the blood or lymph abstracted from the host during the early part of the tick's attachment, complete development and ultimate ejection of the agametes (Gonder) cannot occur.*

It seems reasonable to suppose that some similar period of quiesence will on inquiry be found to exist in other tick-borne diseases such as redwater, etc. The infectious life, therefore, of the adult brown tick after attachment to its host may be diagrammatically represented as shown in Schedule VI, where the shaded portion represents the period of potential infectivity amounting to often less than a third of its total life phase upon its host.

Recognition of the above limitations of the infective power of the tick would seem at first sight to hold out some prospect of modifying the stringency of quarantine regulations or the restrictions upon the movement of cattle. Consideration of the case, however, will show that application of the above knowledge is not likely to be of any great use in daily practice. Where the need for the removal of cattle through infected areas was found imperative this could be effected with safety provided the period of such transfer did not extend over forty-eight hours, and provided further that animals so transferred were on completion of this period treated in such a manner as to destroy all their ticks.

A further progression could then, if necessary, be made, lasting for not more than two days, when the same process of cleaning would have to be resorted to, and in this way it would be possible to traverse with safety and without loss considerable belts of infected country. The limits of such a system, however, would rapidly be found for long trekking, together with spraying every forty-eight hours in a solution sufficiently strong to ensure the death of all ticks would quickly react upon the beasts in a prejudicial manner. The dropping or crawling of unattached ticks along the route would be a risk, though a slight one, which would have to be considered.

Removal for short distances through infected areas could be effected with less difficulty, but it is doubtful whether such system could be systematically adopted without the adoption also of precautions so stringent as to render the procedure irksome and impracticable.

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* In cases where the arrest of the disease by the use of a spraying fluid was effected, it should be stated that the fluid used was made stronger than the usual laboratory dip, from 4 to 6 pounds of sodium arsenite per 100 gallons being used. This fluid produced no effect upon the temperature or skin of the majority of animals sprayed with it, but on one or two thin-skinned animals slight scalding ensued. Such a result (in a minority of cases) is of no moment compared to the certainty of preventing the development of the disease. In any case the procedure is one for emergency and not for every-day adoption.

While, therefore, it can hardly be hoped that any relaxation of precautionary measures with regard to transport, removal, etc., will attend the further knowledge concerning the limitations of the tick's power of infection, it seems reasonable to hope that some modification of our quarantine measures, etc., may be found possible, for the menace of straying cattle, or the results of unauthorized removals, etc., must, in certain known circumstances, be of less importance than formerly.

We can, of course, make no use of the period of innocuousness towards the end of the tick's attachment to its host, for though the adult ticks may have, in the absence of dipping measures, become harmless by lapse of time, other immature forms of brown tick may have gained access to the host (which itself will be nearing the end of its period of incubation when its utility will, of course, be terminated).

It would at first sight appear, therefore, that we are able to make but small use of the unexpected periods of innocuousness in the infectious tick. This, however, is hardly the case, as we see if we consider its use in conjunction with our dipping measures.

The infectious nature of the single tick, and the ease with which it was shown to infect, have already been dealt with. In this connection the difficulty may have occurred to the mind of the reader as to how, in a well-established outbreak where a great number of infectious ticks must be presumed to exist on the veld, it is possible for any animal grazing over the ground to escape infection. Observation has shown that where gross infection of the veld exists and no precautions are taken, herds grazing thereon are, as a matter of fact, generally exterminated in a rapid and complete manner.

Where, however, dipping is adopted as a routine practice, the mortality even on infected veld commences to decrease, such decrease being found to be in direct proportion to the frequency with which dipping measures are adopted.

As was shown in my last report (No. III), the adoption of so short an interval as three days between dippings should be attended by a great decrease of mortality, inasmuch as the interval suggested (three days) was adapted to certain phases of the brown tick's life, rendering its perpetuation from one life stage to another impossible. Such measures, however, were hardly expected to adequately guard against the attack of the adult infected tick, except in a general way, for it was felt the risk still existed of infectious ticks attaching themselves shortly after the dipping of a susceptible beast and succeeding in establishing the infection before the next dipping destroyed its (the tick's) life. The comparative rareness with which this occurred, even where conditions of veld infection were severe, led the writer to conjecture that some further salutary restraint existed of an unrecognized nature, for, as has been said, the three-day dipping, short as the interval was, did not seem to hold out in theory the prospect of frequent escape from the infectivity of the adult tick, a point which appeared of increased force when the infective agency of a single tick became evident.

We can now recognize in what form this restraint exists for the immunity of assault which the host enjoys (by reason of the tick's inability to infect for at least two days after attachment) greatly increases the chance of the animal's escape, and confines the opportunity for possible infection (under the three-day system) to the first or dipping day itself, when, as we know, tick attack is at its minimum. The attack of the insect made upon the second and third days being, as has been shown above, terminated by its death or incapacitation before it can succeed in establishing the infection.

The efficacy, therefore, of a system of dipping as a guard against East Coast fever depends, as we have already practically and widely experienced, upon the closeness of interval adopted between immersions, for where these latter are practised only at the longer intervals of a fortnight or ten days, all the practical advantages of cumulative effect (*vide* Report II), adaption to life history (*vide* Report III), and, finally, the period of tick inability, must be surrendered.

In a previous observation it was shown that the infectious tick was capable of being conveyed by the sheep (*vide* Report III). It was thought at the time that such conveyance was of mechanical nature (merely the entanglement of the tick in the fleece of the sheep). In the light, however, of our present knowledge as to the ease with which a tick loosens its hold and reattaches itself, we must view the possibility of the sheep being concerned in the transference of the tick in a less haphazard manner than that brought about by simple entanglement. That the brown tick readily attaches itself to the sheep is well known, but it has hitherto been considered that such act of attachment deprives the tick of its power of further infectivity. Such, however, is not the case, nor does the writer know how such a theory (as "cleaning" of the infectious tick, as it has been called, by attachment to a non-susceptible host) gained general acceptance. Such "cleaning" occurs, as shown above, only after attachment of the tick to its host for a minimum period of 120 hours (five days). Sheep from infected areas may in this time travel far through clean districts, and conceivably by scratching, nibbling, etc., disseminate ticks which will retain their infectivity. The very infrequent occasions, however, in which flocks of travelling sheep have come under suspicion of spreading the disease proves that in practice such detachment of infectious ticks rarely occurs, a fact possibly due to the dense nature of the animal's coat. The agency of the sheep, therefore, as a means of spread cannot be considered of great moment, though the possibility of such agency should, in the writer's opinion, always be born in mind.

The case, however, is very different where another non-susceptible host, the horse, is concerned. Here, again, we must abandon the reliance which we have hitherto put in the "cleaning" theory, for experiment proves that the horse is as capable of conveying the infectious tick as the ox itself, though not, of course, of propagating the disease in the same manner. The observation as to the ease of reattachment mentioned above led to the carrying out of a series of experiments concerning the ability of the horse to act as a host for the infectious tick. Such experiments proved conclusively that infectious ticks will readily attach themselves to the horse and as readily detach themselves and reattach to a susceptible bovine host (see Schedule V).

Another fact of great significance—which our recently attained knowledge of the infectivity of the single tick caused to be brought to light—is that a *single infectious tick* carried by the horse is capable of establishing the disease should it, the tick, become detached and gain access to a bovine host.