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A CONSOLIDATION OF OUR KNOWLEDGE OF THE TRANSMISSION OF TICK-BORNE DISEASES.

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INTRODUCTION.

The realization of the important role played by ticks as ectoparasites, particularly in tropical and sub-tropical regions, dates back to mediaeval times. It is interesting to note that at the beginning of the last century stock owners began to discriminate between the so-called "tick worry" and specific diseases associated with these arthropods. By 1825 it was suspected that scrub ticks transmitted tick paralysis to calves in Australia, and by 1838 the bont tick (*Amblyomma hebraeum*) was already believed to spread heartwater in South Africa In the United States of America ticks were regarded as vectors of Texas fever as early as 1869.

The greatest impetus given to the study of tick-borne diseases occurred when Smith and Kilbourne (1893) proved the cattle tick (*Boophilus annulatus*) to be the intermediate host of *Babesia bigemina.* Similar discoveries followed and today a great variety of causal agents (protozoa, rickettsias, anaplasms, viruses, spirochaetes, bacteria and as yet undetermined types of "toxins") are known to be transmitted by members of the families Ixodidae Murray and Argasidae Canestrini. Despite the remarkable progress made during the last seven decades, studies on the biological transmission of tick-borne diseases are far from complete. This is shown by the large number of publications which have appeared in scientific journals during recent years.

A REVIEW OF THE LITERATURE.

The object of this article is to enumerate briefly the various ticks concerned in the transmission of diseases in livestock. For the sake of convenience the countries in which the studies were conducted, the vectors and their mode of transmission have been listed in the appended Tables I to VIII. As this form of presentation is self-explanatory only the salient features have been summarized in the text. Vectors, other than ticks, concerned with either the mechanical or cyclical transmission of certain diseases have also been mentioned. It is beyond the scope of this article to discuss the vertebrate host range of the ectoparasites and the infectious agents in detail. For this reason only those vertebrates that served as experimental animals for establishing the transmitters have been referred to.

A. *The Biological Transmission of the Piroplasms.*

1. According to the revised classification of the piroplasms by Neitz and Jansen (1955) the sub-order Piroplasmidea Wenyon, 1926, is represented by a single family Babesiidae, a single genus *Babesia,* and a large number of species.

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(i) *The vectors of the* Babesia *spp. of cattle.*

It will be seen from Table I (Sect. A) that *B. bigemina, B. bovis, B. argentina* and *B. berbera* are transmitted by one, two and/or three host ticks. A transovarial transmission has been established in all of them except in the case of *Rhipicephalus bursa* in which only stage to stage transmission of *B. berbera* within the same generation has so far been observed. The vectors of *B. major* need to be determined.

(ii) *The vectors of the* Babesia *spp. of sheep and goats.*

Observations on the transmission of *B. motasi* and *B. ovis* are mentioned in Table I (Sect. B). Both parasites are transmitted by *Rh. bursa,* in which a transovarial transmission also takes place. *B. ovis* can be retained for four generations in this tick. The transmission of *B. motasi* by *Dermacentor silvarum* and *Haemaphysalis punctata* has not been worked out in detail. The vectors of *B. taylori* (Sawar, 1935) and *B. foliata* Ray and Rhagavachari, 1941, both of which occur in India, need to be determined.

(iii) *The vectors of the* Babesia *spp. of solipeds.*

Not only has Enigk (1943, 1944, 1951) given an excellent account of the transmission of equine babesiosis but he has identified eight new transmitters in Europe. The nine vectors of *B. caballi* are recorded in Table I (Sect. C). Stage to stage transmission within the same generation has been demonstrated in all of them except in *Hyalomma anatolicum* and *H. volgense,* and hereditary transmission in all but *Dermacentor pictus, H. anatolicum* and *Rh. bursa.* It has also been established that *Rh. sanguineus* can retain *B. caballi* for four generations.

The nine vectors of *B. equi* are listed in Table I (Sect. C). In contradistinction to *B. caballi, B. equi* is only transmitted transovarially in one species of tick, namely *H. anatolicum.* In the remaining arthropods stage to stage transmission within the same generation takes place.

(iv) *The vectors of* Babesia *spp. of swine.*

Several species of ticks [*Boophilus decoloratus* (Africa), *Dermacentor reticulatus, D. silvarum, Rh. sanguineus, Rh. rossicus* and *H. marginatum* (Europe)] have been incriminated as possible vectors of porcine babesiosis. Successful experimental transmission has so far only been established with *B. trautmanni* by means of *Rhipicephalus turanicus.* Transovarial transmission occurs in this tick. Table I (Sect. D).

The vectors of *B. perroncitoi* (Cerruti, 1939) need to be determined.

(v) *The vectors of the* Babesia *spp. of the family Canidae.*

The six vectors of *B. canis* are listed in Table I (Sect. E). Transovarial transmission occurs in all the transmitters except in *Dermacentor pictus.* Stage to stage transmission within the same generation has been observed in *Haemaphysalis leachi, D. pictus* and *Rh. sanguineus.* Although the latter tick has a world-wide distribution, canine babesiosis has not yet been encountered in Australia.

B. gibsoni is transmitted by *Haemaphysalis bispinosa* and *Rh. sanguineus.* The available information given in Table I (Sect. E) shows that stage to stage transmission has been recorded in both ticks while transovarial transmission has only been observed in the former species.

(vi) *The vector of the* Babesia *spp. of the family Felidae.*

Circumstantial evidence in South Africa suggests that *Haemaphysalis leachi* is the vector of *B. felis* Davis, 1929.

(vii) *The vector of* Aegyptianella pullorum.

Aegyptianellosis has been encountered in fowls, geese and ducks. The causal agent is transmitted by *Argas persicus* (Table I, Sect. F.) The infection is acquired by the adult stage and possibly also by larvae and nymphae. It is transmitted by adults of the same generation.

2. According to the revised classification of the piroplasms by Neitz and Jansen (1956) the theilerias have been transferred to the sub-order Leucosporidea Neitz and Jansen, 1956. This sub-order is represented by two families, Theileridae and Gonderidae. A single genus and species, *Theileria parva,* is retained in the Theileridae. The family Gonderidae is represented by the redefined and reinstated genus *Gonderia* and the genus *Cytauxzoon.* Both genera comprise many species. Members of the latter genus have only been encountered in antelopes.

(i) *The vectors of* Theileria parva.

It will be seen from Table II (Sect. A) that seven *Rhipicephalus* spp. and three *Hyalomma* spp. have been proved experimentally to be vectors. Only stage to stage transmission within the same generations has been established. Infected nymphae loose their infection irrespective of whether they feed on a susceptible, insusceptible or an immune animal. *Rh. appendiculatus* is undoubtedly the chief vector in nature. There is every reason to believe that the remaining *Rhipicephalus* spp. may play a significant role in maintaining East Coast fever in nature.

There is no evidence that *Hyalomma* spp. transmit *Th. parva* in nature. The demonstration by Ray (1940-41, 1950) that *Hyalomma savignyi* can retain *Gonderia* (*Theileria*) *annulata* for five generations indicates that investigations should be undertaken to determine whether or not a transovarial transmission of *Th. parva* can take place in any of the *Hyalomma* spp. occurring in the enzootic East Coast fever areas. Should this prove to be the case, an explanation may be found for the sudden sporadic outbreak of this disease three to five years after the last death in cattle on farms where systematic dipping and rigorous quarantine measures had been applied.

(ii) *The vectors of* Gonderia (Theileria) annulata.

The vectors of Mediterranean Coast fever (Tropical theileriosis) are listed in Table II (Sect. B.). Six *Hyalomma* spp. are capable of transmitting the disease, and stage to stage transmission within the same generation has been proved to occur in all. Ray *et al.* (1940-41, 1950) claim to have proved that *G. annulata* is transmitted transovarially through five generations by *H. savignyi,* while Kornienko and Shmyreva (1944) state that hereditary transmission takes place in *H. turkmeniensa* (= *excavatum*). In this form of transmission transfer is effected by adult ticks.

(iii) *The vectors of* Gonderia (Theileria) mutans.

The ticks responsible for the transmission of benign gonderiosis (Marico calf disease, Tzaneen disease) are mentioned in Table II (Sect. C.). In the case of the two *Rhipicephalus* spp. stage to stage transmission within the

same generation occurs. Reichenow (1935) states that Miessner obtained *Boophilus annulatus* adult ticks from the United States of America, and succeeded in transmitting *G. mutans* with their progeny in Germany.

It has recently been established that the vector of *G. lawrencei*. which is responsible for Corridor disease, in South Africa, is *Rh. appendiculatus* (Table II, Sect. D.). The larvae and nymphae which engorged on a buffalo harbouring the infectious agent transmitted it in the ensuing stages.

(v) *The vectors of ovine and caprine gonderiosis.*

Two *Rhipicephalus spp.*, both of which are two host ticks, are vertors of *Gonderia (Theileria) ovis*. The infection is acquired by the larvae and nymphae and given off by the adults. *Rastegaieff* (1935) claims to have transmitted this protozoon with *Ornithodoros lahorensis*. If this information is correct then *G. ovis* is the only piroplasm known to be transmitted by an argasine tick (Table II, Sect. E).

The vectors of *Gonderia (Theileria) hirci* (Dschunkowsky and Urodschevich, 1924) need to be determined.

B. *The Biological Transmission of the Anaplasms.*

(i) *The vectors of* Anaplasma marginale.

It has been demonstrated experimentally that no less than sixteen species of ticks belonging to the family Ixodidae and one species of the family Argasidae are capable of transmitting malignant bovine anaplasmosis (Table III, Sect. A.). Transovarial transmission occurs in the five *Boophilus* spp., in *Dermacentor andersoni, Haemaphysalis cinnabarina punctata, Hyalomma excavatum. Ixodes ricinus* and *Rhipicephalus simus*. In the remaining ticks, *D. albipictus, D. variabilis, Rh. bursa, Rh. sanguineus* and *Argas persicus* only stage to stage transmission within the same generation has so far been recorded.

The role played by different species of ticks as vectors in nature has not been determined in every case. It is generally accepted that the *Boophilus* spp. are important transmitters. Rees (1934) and Dikmans (1950) state that the eradication of *B. annulatus* and *B. microplus* over a large area in the United States of America was followed by the eradication of babesiosis but not by that of anaplasmosis. Although it has been established that seven other species of ticks are vectors, Schmidt (1948) and Dikmans (1950) are doubtful whether they should be considered in the epizootology of anaplasmosis in the United States. They mentioned the *A. persicus, D. variabilis* and *Rh. sanguineus* are rarely found on cattle. *D. andersoni* is more or less limited to the Rocky Mountain States, and *D. occidentalis* to California. The geographical distribution of *D. albipictus* extends beyond the enzootic anaplasmosis area. In the case of *I. scapularis* the seasonal occurence of the adults (the only stage that feeds on cattle) cannot be correlated with the seasonal occurrence of the disease. These investigators are of opinion that mechanical transmission by blood sucking insects (*Tabanus* spp., *Stomoxys* spp., *Psorophora* spp., *Chrysops* spp. and *Aedes* spp.) and by surgical instruments may be more important than is generally accepted by epizootologists in other countries.

(ii) *The vectors of* Anaplasma centrale.

Only two ticks, namely *Boophilus decoloratus* in South Africa and *Haemaphysalis cinnabarina punctata* in Roumania have so far been established as vectors. Transovarial transmission occurs in both of them (Table III, Sect. B.).

(iii) *The vectors of* Anaplasma ovis.

The three vectors of *A. ovis* are mentioned in Table III, (Sect. C.). Stage to stage transmission within the same generation has been established in *Rh. bursa* and *Ornithodoros lahorensis*, and transovarial transmission in *Dermacentor silvarum*.

C. *The Biological Transmission of the Rickettsia spp.*

(i) *The vectors of* Rickettsia ruminantium.

Heartwater, a highly fatal disease of domestic ruminants, is widely distributed in Africa and Madagascar. The infected area is approximately five million square miles in extent. The transmission is exclusively effected by ticks belonging to the genus *Amblyomma*. Only stage to stage transmission within the same generation is known to occur. Of the sixteen African *Amblyomma* spp. which feed on mammals four have been proved to be vectors (Table IV, Sect. A.). It is of interest to note that although *A. variegatum* has been encountered in Mauritius, Reunion, West Indies and Guatemala, heartwater has not been observed in any of these countries.

(ii) *The vectors of* Rickettsia bovis.

The adult stages of an undetermined *Hyalomma* sp. and those of *H. excavatum*, which were derived from Iran, proved to be transmitters of *R. bovis* (Table IV, Sect. B.). Investigations are necessary to establish which stage acquires the infection, and whether hereditary transmission can take place.

(iii) *The vectors of* Rickettsia ovina.

The two vectors are mentioned in Table IV (Sect. C.). The infectivity of *Rh. bursa* was determined by injecting emulsified engorged adult ticks, derived from affected sheep, into susceptible animals. In the case of *Rh. evertsi* the infectious agent was transmitted by adults which had fed in the preceding stages on sheep reacting to benign ovine rickettsiosis.

(iv) *The vector of* Rickettsia canis.

So far only *Rh. sanguineus* has been found to be a transmitter (Table IV, Sect. D.). Stage to stage and transovarial transmission has been demonstrated in Algiers.

(v) *The vector of Tick-borne Fever.*

It will be seen from Table IV, (Sect. E.) that this disease is transmitted from stage to stage within the same generation by *Ixodes ricinus*. Sheep, cattle and goats are susceptible to the *Rickettsia* sp. responsible for tick-borne fever.

(vi) *The vectors of* Coxiella burneti.

C. burneti has been isolated from man, domestic and several wild animals. Ticks which may be directly or indirectly concerned in the transmission are listed in Table IV, (Sect. F.). The infectious agent has been

isolated from 22 species belonging to the family Ixodidae, and from 7 species of the family Argasidae. In the majority of cases their infectivity has been established by injecting emulsions prepared from ticks and/or faeces into guinea pigs. It appears that any tick feeding on an affected animal can become infected. In eleven species *R. bunreti* passes from the larvae to nymphae and thence to the adults. In four of these ticks studied the infection may pass transovarially from one generation to another. Infection results either from tick bites, invasion of the parasite through abraded and non-abraded skin, inhalation of the infected air, or by the placental route.

D. *The Biological Transmission of the Virus Diseases.*

(i) *The vectors of certain Arthropod-borne Virus Encephalitis.*

Most of these infections occur principally in vertebrates (mammalian or avian) other than man, the latter being more or less an accidental host. The viruses causing them have been isolated from mosquitoes, winged bugs, ticks or mites. The invertebrate hosts are the main vectors but several ticks can also act as reservoirs of infection. This has been determined in western equine encephalomyelitis, St. Louis encephalitis, Russian spring-summer encephalitis, louping ill and Czecho-Slovakian tick encephalitis.

(i) (*a*) *Western type of Equine Encephalomyelitis.*

Aedes spp., *Culex* spp., *Culisota* spp., *Triatoma* sp. and *Dermanyssus* spp. have been shown experimentally to be capable of transferring infection from infected to healthy animals by bite. Syverton and Berry (1941) proved that *D. andersoni* can transmit the disease and also act as a reservoir host. They demonstrated stage to stage transmission within the same generation as well as transovarial transmission (Table V.).

(i) (*b*) *St. Louis Encephalitis.*

Aedes spp., *Culex* spp., *Theobaldia* spp. and *Dermanyssus gallinae* de Geer are chiefly concerned as transmitters. Blattner and Heys (1941, 1943, 1944) have shown that *D. variabilis* can also act as a vector (Table V.). The virus may be transmitted transovarially to the third generation of this tick, and all stages are capable of transferring the infectious agent.

(i) (*c*) *Russian Spring-Summer Encephalitis.*

This disease is transmitted to man and animals, (cattle, sheep and rodents) in the virgin woodlands (taiga) of the eastern part of the Soviet Union through the bite of *Ixodes persulcatus*. Stage to stage and transovarial transmission has been established in this vector (Table V). In laboratory experiments, of unknown practical application, the virus has been found to survive in the following ticks: *Dermacentor silvarum* Olenev, *D. pictus* Herm., *D. nuttalli* Olenev, *Rhipicephalus turanicus* Pomerantzer and Matitashvily [= *Rh. sanguineus* (*Latreille*)], *Rh. bursa* Canestrini and Fanzago, *Haemaphysalis concinna* Koch, *Hyalomma asiaticum* Schulze (= *H. dromedarii* Koch), *H. turkmeniense* Olenev (= *H. excavatum* Koch) and the African tick *Ornithodoros moubata* Murray. Transovarial transmission has been observed in *D. nuttalli, Rh. turanicus, H. asiaticum, H. turkmeniense* and *H. dromedarii*.

A virus once thought to be that of spring-summer encephalitis has been isolated from larvae and nymphae of *Ixodes ricinus* in White Russia and Karelia (Table V). A close immunological relationship exists between this virus and those of louping ill and Czecho-Slovakian tick encephalitis.

(i) (*d*) *Louping Ill.*

This type of encephalitis has been encountered in Great Britain and Norway. Sheep, cattle, horses and man are susceptible. *Ixodes ricinus* is the natural vector in Britain. Only stage to stage transmission occurs. In South Africa laboratory experiments have shown that *Rhipicephalus appendiculatus* can also transmit the disease. Infective nymphae tend to lose their infection after feeding on immune animals, though some of the ensuing adults may still be infective (Table V).

(i) (*e*) *Czecho-Slovakian Tick Encephalitis.*

This disease is very closely related to louping ill and the tick-borne encephalitis occurring in White Russia and Karelia. Many cases have been encountered in man. The infectivity of *I. ricinus* has been determined by injecting tick suspensions into mice. Attempts to establish whether *Culex* spp., *Aedes* sp. and *Anopheles* sp. can act as transmitters have failed (Slonim and Kramar, 1956).

(ii) *The vectors of Nairobi Sheep Disease.*

This disease has been encountered in sheep and goats in Kenya and Uganda. Stage to stage transmission has been demonstrated in *A. variegatum, Rh. bursa,* and *Rh. appendiculatus.* Transovarial transmission occurs in the latter species which is also the chief vector. The survival of the virus in this tick has been determined by Lewis (1946). Unfed larvae retain the infectious agent for 245 days, unfed nymphae for 359 days and unfed adults for 871 days. During the process of feeding on an immune sheep ticks clean themselves. Also if fed on a susceptible sheep infected larvae that drop before the reaction commences clean themselves (Table V).

(iii) *The vector of Kisenyi Sheep Disease.*

Bugyaki (1955) encountered a highly fatal virus disease in sheep, not transmissible to goats, in the Kisenyi area of the Belgian Congo. Clinically it resembles Nairobi sheep disease very closely. The insusceptibility of goats caused Bugyaki (1955) to regard the Kisenyi sheep disease as distinct from Nairobi sheep disease. The infection was transmitted by the adults of *Rh. appendiculatus,* which became infected as nymphae (Table V).

E. *The Biological Transmission of the Borrelia spp.*

(i) *The vectors of* Borrelia theileri.

This parasite is widely distributed in the world and has been encountered in solipeds, cattle, sheep and goats. Transovarial transmission has been established in two *Boophilus* spp. and in *Rhipicephalus evertsi* (Table V.). In the latter species stage to stage transmission also takes place.

(ii) *The vectors of* Borrelia anserina.

Avian spirochaetosis has a world wide distribution. In nature it is mainly transmitted by *Argas persicus,* while *A. reflexus* appears to play a minor rôle. It has been shown experimentally that *Ornithodoros moubata*

can also transmit the infection. Stage to stage and transovarial transmission has been established in these ticks (Table VI). Gerlach (1925) proved that the fowl mite, *Dermanyssus avium* Gervais, can also act as vector.

F. *The Biological Transmission of Tick-borne "Toxins".*

The true nature of the causal agents responsible for either tick paralysis or sweating sickness (La Dyhydrose Tropicale) has not yet been determined. They cannot be transferred from affected to healthy animals by means of blood or organ suspensions. In many instances the symptoms of tick paralysis subside if ticks are removed before paralysis has progressed too far. In sweating sickness the severity of the disease is dependent upon the duration of the tick feeding period. Calves and piglets raised under tick free conditions develop either no reaction, an inapparent reaction or alternatively a relatively mild form of the disease when infected ticks are allowed to feed for periods varying from 72 to 96 hours. The development of an inapparent reaction was disclosed by challenging the immunity with known infected ticks. The reactions following a feeding period of 120 hours are fairly severe but animals tend to make a rapid recovery. Feeding periods of 144 hours and longer result in the appearance of the severe form of the disease which usually terminates fatally.

The behaviour of the causal agents of tick paralysis and sweating sickness is not in accordance with that observed in virus infections. Tick-borne viruses are capable of multiplying in the vertebrate and invertebrate hosts. The causal agents of the two diseases under discussion appear to develop only in the invertebrate hosts, and their timely removal is followed by a subsidence of symptoms and recovery. These agents will, therefore, be provisionally referred to as "Toxins" for want of a more descriptive term.

(i) *The vectors of Tick Paralysis.*

Tick paralysis has been recorded in man, domestic animals and birds. Ticks concerned in the transmission are listed in Table VII. Experimental and field observations have shown that in ixodid tick paralysis the "neurotoxin" is given off by the adult females, while in the argasine form of the disease the causal agent can be transferred by the nymphae of *Ornithodoros lahorensis,* and by the adults and possibly also by the nymphae of *Argas persicus.* Transmission to mammals is affected by eleven ixodid ticks and one argasid tick. In poultry only *Argas persicus* has so far been recognized as a vector.

Recovered animals develop a durable immunity. It needs to be determined whether or not an immunological relationship exists between the "neurotoxins" harboured by different vectors.

(ii) *The vector of Sweating Sickness.*

Sweating sickness occurs in Central, East and Southern Africa. The disease is transmitted by the adult stages of the stripe-legged tick, *Hyalomma transiens.* The immature stages feed on rodents and birds. So far only cattle, sheep, goats and pigs have been found to be susceptible. All ticks used for the studies at Onderstepoort were the progeny of a single female collected from a sick calf in Zululand. The "toxin" is retained by the ticks irrespective of whether the adults feed on a susceptible calf, immune calf or an insusceptible animal, the horse. Infected ticks reared on rabbits and cattle can transmit the disease transovarially for five generations. Recovered animals develop a durable immunity.

SUMMARY.

(1) Ticks concerned in the transmission of *Babesia* spp., *Aegyptianella* sp., *Theileria* sp., *Gonderia* spp., *Anaplasma* spp., *Borrelia* spp., viruses and "toxins" responsible for diseases in livestock have been enumerated.

(2) This information is presented in a series of tables.

(3) An attempt has been made to determine the correct names of various ticks.

(4) The vectors of *Babesia major, B. taylori, B. foliata, B. perroncitoi, B. felis* and *Gonderia hirci* need to be determined.

(5) In all diseases stage to stage transmission within the same generation has been established in one or more of the transmitters, except in those concerned with the transmission of tick paralysis and sweating sickness.

(6) Transovarial transmission has been established in one or more of the vectors except in those concerned with the transmission of *Theileria parva, Gonderia mutans, G. lawrencei, G. ovis, Rickettsia ruminantium, R. bovis, R. ovina,* tick-borne fever, louping ill, Czecho-Slovakian tick encephalitis and Kisenyi sheep disease.

(7) From this it is deduced that ticks do not only act as vectors but that they can also serve as reservoirs of certain infectious agents.

(8) Vectors, other than ticks, which are capable of transmitting the western type of equine encephalomyelitis, St. Louis encephalitis and *Borrelia anserina* are referred to in the text.

(9) Attention has been drawn to the fact that potential vectors of certain diseases (canine biliary fever, heartwater, louping ill, Nairobi and Kisenyi sheep diseases) do occur beyond the boundaries of the known enzootic areas. The danger associated with the introduction of affected animals into such regions is self-evident.

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C.—OVINE AND CAPRINE ANAPLASMOSIS.

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TABLE I.

The Biological Transmission of the Babesia *spp.*

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
A.—BOVINE BABESIOSIS. *Babesia bigemina* (Smith and Kilbourne, 1893)	*Boophilus annulatus* (Say).....	North America	1	X--	–X–	–X–	———	—)			Smith and Kilbourne (1893).
	Boophilus australis Fuller [referred to as *Boophilus microplus* (Canestrini) in Australian literature]	Australia.....	1	X--	–X–	–X–	———	—)			Hunt and Collins (1896). Pound and Hunt (1895).
	Boophilus australis Fuller [may actually be *Boophilus microplus*, (Canestrini)]	Panama.....	1	X--	–X–	–X–	———	—)			Clark (1918). Clark and Zetek (1925).
	Boophilus calcaratus Birula. [referred to as *Boophilus annulatus calcaratus* (Birula)]	North Africa...	1	X--	–X–	–X–	———	—)			Brumpt (1920). Sergent, Donatien, Parrot and Lestoquard (1945).
	Boophilus decoloratus (Koch)...	South Africa...	1	X--	–X–	–X–	———	—)			Koch (1898). Laveran and Vallee (1905).
				X-- —)	–X–	–X–	———	--)–	———	———	Theiler (1908, 1909).
	Boophilus microplus (Canestrini)	South America.	1	X--	–X–	–X–	———	—)			Lignières (1900, 1901). Ziemann (1902). Brumpt (1920). Rosenbusch and Gonzales (1924). Regendanz (1936).

NOTE.—X indicates the stage in which the infection is acquired.
) indicates the stage in which the infection is transmitted.
L = Larva; N = Nympha; I = Imago; and E = Egg.

TABLE I (*continued*).

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
Babesia bigemina (continued)	*Haemaphysalis punctata* Canestrini and Fanzago (referred to as *Haemaphysalis cannabarina punctata* Canestrini and Fanzago)	Europe.....	3		X–	—) X–	——	——	——	—)	Knuth (1915). Zeller and Helm (1923)
	Rhipicephalus appendiculatus Neum.	South Africa...	3		X–	—) X–	——	—)			Theiler (1909).
	Rhipicephalus bursa Canestrini and Fanzago	North Africa...	2	X–	–X–	—) X–	——	—)–	—)–	—)	Sergent (1931). Sergent, Donatien, Parrot and Lestoquard (1945).
	Rhipicephalus evertsi Neum...	South Africa...	2	X–	–X–	—) X–	——	—)			Theiler (1909).
Babesia bovis (Babès, 1888)	*Ixodes persulcatus* Schulze....	Russia.....	3			X–	——	—)–	—)		Gouseff, Rastegaieff and Soussko (1936).
	Ixodes ricinus (Linn.).....	Europe.....	3			X–	——	—) X–	—) X–	—)	Kosse, Weber and Miessner (1903).
Babesia argentina (Lignières, 1909)	*Boophilus microplus* (Canestrini)	Argentine.....	1	X–	–X–	–X–	——	—)			Lignières (1903).
	Boophilus australis Fuller [referred to as *Boophilus microplus* (Canestrini) in the Australian literature)	Australia.....	1	X–	–X–	–X–	——	—)			Legg (1935).

TABLE I (*continued*).

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
Babesia berbera (Sergent *et al.*, 1924)	*Boophilus* (*annulatus*) *calcaratus* Birula	North Africa...	1	X--	X-	X-	——	—)			Sergent, Donatien, Parrot and Lestoquard (1945).
	Rhipicephalus bursa Canestrini and Fanzago	North Africa...	2	X--	X-	—)					Sergent, Donatien, Parrot and Lestoquard (1945).
B.—OVINE AND CAPRINE BABESIOSIS. *Babesia motasi*, Wenyon, 1926	*Dermacentor silvarum* Olen....	Southern Russia	3	?							Rastegaieff (1936).
	Haemaphysalis punctata Canestrini and Fanzago	Sardinia.....	3	?							Pegreffi and Mura (1948).
	Rhipicephalus bursa Canestrini and Fanzago	Roumania.....	2			X--	——	——	——	—)	Motas (1904).
				X--	X-	—)					Rastegaieff (1933, 1936).
Babesia ovis (Babès, 1892)	*Rhipicephalus bursa* Canestrini and Fanzago	Russia.....	2	X--	X-	—)					Rastegaieff (1933, 1936).
						X--	——	——	——	——	Markov and Kurchatov (1940).
					——	——					
				——	——	—)					
C.—EQUINE BABESIOSIS. *Babesia caballi* (Nuttall, 1910)	*Dermacentor marginatus* Sulzer = (*Dermacentor reticulatus* Fabricius)	Southern Russia	3			X--	——	——	——	—)	Marzinowsky and Bielitzer (1909).
		Germany.....		X--	—)						du Toit (1919).
					X--	—)					
		European Russia			X--	—)					Enigk (1944).
	Dermacentor pictus Herm.....	European Russia	3		X--	—)					Enigk (1944).

TABLE 1 (*continued*).

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
Babesia caballi (*Continued*).	*Dermacentor silvarum* Olen....	European Russia	3	X--	——	——	——	——	——	—)	Markov, Bogoroditsky and Salyaev (1935).
		European Russia		X--	--X--	--X-	——	——	——	—)	Dzasokhov and Caprun (1939).
		Ukraine.....				X--	——	——	—)		Pohorilyi (1937).
						X--	——	——	——	—)	
	Hyalomma anatolicum Koch = (*Hyalomma excavatum* Koch, according to Delpy, 1949. and Feldman-Mühsam, 1954)	Greece.....	3	?	?	—)					Enigk (1943).
	Hyalomma dromedarii Koch...	North Africa...	3			X--	——	——	——	—)	Enigk (1943).
	Hyalomma marginatum Koch = (*Hyalomma detritum* Schulze, according to Delpy, 1949) = (*Hyalomma marginatum* according to Feldman-Mühsam, 1954)	Greece.....	3	X--	——	—)					Enigk (1943).
						X--	——	——	——	—)	
	Hyalomma volgense, Schulze and Schlottke	Ukraine.....	1 or 2			X--	——	——	——	—)	Enigk (1944).
	Rhipicephalus bursa Canestrini and Fanzago	Bulgaria.....	2	X--	--X--	—)					Enigk (1943).
	Rhipicephalus sanguineus (Latreille)	Greece.....	3	X--	—)						Enigk (1943, 1944).
						X--	——	——	——	—)	
						——	——	——	——	—)	
						—)					

TABLE I (*continued*).

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
Babesia equi (Laveran, 1901)	*Dermacentor marginatus* Sulzer = (*Dermacentor reticulatus* Fabricius)	European Russia	3		X--	—)					Enigk (1944).
	Dermacentor pictus Herm.....	European Russia	3		X--	—)					Enigk (1943).
	Hyalomma anatolicum Koch = (*Hyalomma excavatum* Koch, according to Delpy, 1949, and Feldman-Mühsam, 1954)	Greece.....	3	?	?	?	—) X--	——	——	—)	Enigk (1943).
	Hyalomma dromedarii Koch...	North Africa...	3	X--	—)						Enigk (1943).
	Hyalomma marginatum Koch = (*Hyalomma detritum* according to Delpy, 1949) = *Hyalomma marginatum* according to Feldman-Mühsam, 1954	North Caucasia Ukraine..... Central Asia... Greece.....	3	? ? X--	? ? ——	—) —)					Nikolsky (1933). Agrinsky (1937). Enigk (1944).
	Hyalomma uralense Schulze and Schlottke, 1929 = (*Hyalomma detritum* Schulze according to ~~Delpy, 1949~~)	Caucasia.....	1 or 2?	X--	——	—)					Enigk (1944).
	Rhipicephalus bursa Canestrini and Fanzago	Russia.....	2	X--	–X–	—)					Markov and Kurchatov (1940). Markov, Kurchatov and Dzasokhov (1940).

TABLE I. (*Continued.*)

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
	Rhipicephalus evertsi Neum....	South Africa...	2	X--	X--	—)					Theiler (1906).
	Rhipicephalus sanguineus (Latreille)	Central Asia... North Africa...	3	? X--	? —) X--	—)					Agrinsky (1937). Enigk (1943).
D.—PORCINE BABESIOSIS *Babesia trautmanni* (Knuth and du Toit, 1918)	*Rhipicephalus turanicus* Pomerantzer and Matitosvily [May be a synonym of *Rhipicecephalus sanguineus* (Latreille)]	Russia.....	3			X--	——	——	——	—)	Kurchatov and Markov (1940).
E.—CANINE BABESIOSIS. *Babesia canis* (Piana and Galli-Valerio, 1895)	*Dermacentor marginatus* Sulzer = (*Dermacentor reticulatus* Fabricius)	Europe.....	3			X-- X-- X--	—— —— ——	—— —— ——	—— —— —)--	—) —) —)	Brumpt (1919). Bielitzer and Markov (1930). Regendanz and Reichenow (1932).
	Dermacentor pictus Herm.....	Russia..... France.....	3		X--	—)					Enigk (1944).
	Dermacentor venustus Banks = (*Dermacentor andersoni* Stiles)	France *.....	3			X--	——	——	——	—)	Brumpt and Larrouse (1922).
	Haemaphysalis leachi (Audouin)	South Africa...	3		X--	X-- —)	——	——	——	—)	Lounsbury (1901). Brumpt (1938).

* Laboratory investigations.

TABLE I (*continued*).

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
Babesia equi (*Continued*).	*Hyalomma marginatum* Koch..	Russia.....	3	X--	——	——	——	——	——	—)	Enigk (1944).
	Rhipicephalus sanguineus (Latreille)	India.....	3	X--	—)	X--	——	——	--)—	—)	Christophers (1907). Shortt (1936).
					X--	—)					
		Germany*.....				X--	——	--)—	--)—	—)	Reichenow (1935).
		France.....				X--	——	——	——	—)	Brumpt (1919).
		South Africa...				X--	——	——	——	—)	Neitz (1952).
		U.S.A.....									Steinhaus (1947).
		Brazil.....									Regendanz and Muniz (1936).
Babesia gibsoni (Patton, 1910)	*Haemaphysalis bispinosa* Neum.	India.....	3		X--	—)					Swaminath and Short (1937). Shortt (1938).
						X--	——	—)--	—)		
						X--	——	—)			
				X--	—)						
					X--	—)					
	Rhipicephalus sanguineus (Latreille)	India.....	3	X--	—)						Sen (1933). Datta (1940).
					X--	—)					
F.—AEGYPTIANELLOSIS. *Aegyptianella pullorum* (Carpano, 1929)	*Argas persicus* (Oken).....	Tunis.....	Many			—	—)-)				Galli-Valerio, (1909) Bedford and Coles (1933).
		South Africa...					X—)				

* Laboratory investigations.

TABLE II.

The Biological Transmission of the Theileria *sp. and* Gonderia *spp.*

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
A.—EAST COAST FEVER. *Theileria parva* (Theiler, 1906)	*Rhipicephalus appendiculatus* Neum. Syn. (*Rhipicephalus nitens* Neum.)	Central, East and Southern Africa	3	X--	—) X--	—)					Lounsbury (1903); Theiler (1905); Montgomery (1913); Fotheringham and Lewis (1937).
	Rhipicephalus ayrei Lewis = ? (*Rhipicephalus compositus* Neum.)	East and Central Africa	3	X--	—) X--	—)					Wilson (1953).
	Rhipicephalus capensis Koch...	Southern Africa	3	X--	—) X--	—)					Lounsbury (1906); Theiler (1907).
	Rhipicephalus evertsi Neum.....	Central, East and Southern Africa	2	X--	–X–	—)					Lounsbury (1906); Theiler (1907); Fotheringham and Lewis (1937).
	Rhipicephalus jeanelli Neum. = (*Rhipicephalus kochi* Dönitz)	East and Central Africa	3	X--	—)						Wilson (1953).
	Rhipicephalus neavei Warburton = (*Rhipicephalus neavei punctatus* Warburton = *Rhipicephalus pravus* Dönitz)	East Africa....	3	X--	—) X--	—)					Lewis, Piercy and Wiley (1946).
	Rhipicephalus simus Koch.....	South Africa... East Africa.....		X--	—) X--	—)					Lounsbury (1906); Theiler (1905); Fotheringham and Lewis (1937); Neitz and Jansen (1950).

NOTE.—X indicates the stage in which the infection is acquired.
) indicates the stage in which the infection is transmitted.
L = Larva; N = Nympha; I = Imago; and E = Egg.

TABLE II (*continued*).

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
Theileria parva (*Continued*).	*Hyalomma anatolicum* Koch = (*Hyalomma excavatum* Koch, according to Delpy and Feldman-Mühsam 1954)	East Africa (Laboratory observations)	3	X--	—) X--	—)					Lewis and Fotheringham (1941).
	Hyalomma dromedarii Koch...	East Africa (Laboratory observations)	3	X--	—) X--	—)					Lewis and Fotheringham (1941).
	Hyalomma impressum near *planum* Lewis = (?*Hyalomma transiens* Schulze = *Hyalomma truncatum* Koch)	East Africa (Laboratory observations)	2 or 3	X--	—) X--	—)					Lewis and Fotheringham (1937).
B.—MEDITERRANEAN COAST FEVER. *Gonderia annulata* (Dschunkowsky and Luhs, 1904)	*Hyalomma detritum* Schulze Syn. (*Hyalomma mauretanicum* Senevet)	North Africa...	2	X--	–X–	—)					Sergent, Donatien, Parrot and Lestoquard (1928).
		Russia.....		X--	–X–	—)					Galuzo (1935).
		Kazakstan.....		X--	–X–	—)					Galuzo and Bespalov (1935). Tselishcheva (1940).
	Hyalomma dromedarii Koch. Syn. (*Hyalomma dromedarii asiaticum* Schulze and Schlottke, according to Delpy, 1949.	Central Asia...	2 or 3	X--	–X–	—)					Galuzo (1934).
	= *Hyalomma dromedarii* Koch, according to Feldman-Mühsam 1954)	Kazakstan.....		X--	–X–	—)					Tselishcheva (1940).

TABLE II (*continued*).

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
Gonderia annulata (*Continued*).	*Hyalomma excavatum* Koch Syn. (*Hyalomma anatolicum* Koch, *Hyalomma turkmeniense* Olenev, according to Delpy, 1949, and Feldman-Mühsam, 1954)	Asia Minor....	3	X--	—)						Delpy (1949).
					X--	—)					
		Transcaucasia.				X--	——	——	——	—)	Kornienko and Shmyreva (1944).
	Hyalomma impressum near *planum* Lewis (= ?*Hyalomma transiens* Schulze, according to G. Theiler = *Hyalomma truncatum* Koch, according to Feldman-Mühsam, 1954)	East Africa (Laboratory observations)	2 or 3		X--	—)					Fotheringham and Lewis (1936).
	Hyalomma rufipes glabrum Delpy (= *Hyalomma turanicum* Pomerantzer)	Asia Minor....	2	X--	—X—	—)					Delpy (1949).
	Hyalomma savignyi (Gervais) (= *Hyalomma marginatum* Koch, according to Feldman-Mühsam, 1954)	Asia Minor....	2 or 3		X--	—)					Delpy (1949).
		Kazakstan.....			X--	—)					Tselishcheva (1940).
	Hyalomma savignyi (Gervais) [referred to originally as *Hyalomma aegyptium* Neum. but according to Ray (1950) identified by Adler and Feldman-Mühsam as *Hyalomma savignyi* (Gervais)]	India.....	2 or 3			X--	——	——	——	—)	Ray (1940–41). Raghavachari, Shah and Ray (1944).
		(Hereditary transmission through four generations)				X--	——	——	——	—)	Ray (1950).
				——	——	—)	——	——	——	—)	
				——	——	—)					

TABLE II (*continued*).

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
C.—BENIGN BOVINE GONDERIOSIS. *Gonderia mutans* (Theiler, 1906)	*Boophilus annulatus* (Say).....	Germany, with ticks from United States of America	1	? X--	? –X–	? –X–		? ---)	? ----)	? —)	Miessner according to Reichenow (1935).
	Rhipicephalus appendiculatus Neum.	South Africa...	3	X--	X-- —)	—)					Theiler (1907, 1909); Neitz and Jansen (1950). Neitz (1938).
	Rhipicephalus evertsi Neum.....	South Africa...	2	X--	–X–	—)					Theiler (1907, 1909).
D.—CORRIDOR DISEASE. *Gonderia lawrencei* (Neitz, 1955)	*Rhipicephalus appendiculatus* Neum.	South Africa...	3	X--	—) X--	—)					Neitz (1955, 1955).
E.—BENIGN OVINE AND CAPRINE GONDERIOSIS. *Gonderia ovis* (Rodhain, 1916)	*Rhipicephalus bursa* Canestrini and Fanzago	Russia.....	2	X--	–X–	—)					Rastegaieff (1934, 1933).
	Rhipicephalus evertsi Neum....	South Africa...	2	X--	–X–	—)					Jansen and Neitz (1956).
	Ornithodoros lahorensis Neum.	Russia.....	Many			—)					Rastegaieff (1935).

TABLE III.

The Biological Transmission of the Anaplasma *spp.*

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
A. MALIGNANT BOVINE ANAPLASMOSIS. *Anaplasma marginale* Theiler, 1910	*Argas persicus* Oken.....	North America United States of America	Many		X--) X-- —) X--)						Howell, Stiles and Moe (1943).
	Boophilus annulatus (Say.).....	North America	1	X--	--X--	--X-	———	—)			Smith and Kilbourne (1893). Rees (1934).
	Boophilus australis Fuller [referred to as *Boophilus microplus* (Canestrini) in Australian literature]	Australia.....	1	X--	--X--	--X-	———	—)			Legg (1933); Mackerras, Mackerras and Mulhearn (1942).
	Boophilus calcaratus Birula [referred to as *Boophilus annulatus calcaratus* (Birula)]	North Caucasia	1	X--	--X--	--X-	———	—)			Yakimoff and Rastegaieff (1928). Yakimoff, Belawine and Nikolsky (1935).
	Boophilus decoloratus Koch....	South Africa...	1	X--	--X--	--X-	———	—)			Theiler (1910, 1912).
	Boophilus microplus (Canestrini)	South America.	1	X--	--X--	--X-	———	—)			Rosenbusch and Gonzales (1927). Brumpt (1931).
	Dermacentor albipictus Packard	North America.	3	X--	—)						Boynton, Herms, Howell and Woods (1936). Herms and Howell (1936).

NOTE.—X indicates the stage in which the infection is acquired.
) indicates the stage in which the infection is transmitted.
L = Larva; N = Nympha; I = Imago; and E = Egg.

TABLE III (*continued*).

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
Anaplasma marginale (contd.)	*Dermacentor venustus* Banks. Syn. *Dermacentor andersoni*	North America.	3		X--	—)					Rees (1932, 1933, 1934). Boynton, Herms, Howell and Woods (1936). Cowdry and Rees (1935)
						X--	——	—)			
	Dermacentor occidentalis Marx.	North America.	3			X--	——	----)	—)		Herms and Howell (1936). Boynton, Herms, Howell and Woods (1936).
	Dermacentor variabilis (Say)....	North America.	3	X--	—)						Rees (1932, 1934). Sanders (1933).
					X--	—)					
	Haemaphysalis cinnabarina punctata Canestrini and Fanzago	Europe.....	3		X--	—)					Helm (1924).
						X--	——	——	——	—)	
	Hyalomma excavatum Koch. Syn. *Hyalomma lusitanicum* Koch	North Africa..	3			X--	——	——	——	—)	Sergent, Donatien, Parrot and Lestoquard (1928).
	Ixodes ricinus Linnaeus.....	Europe.....	3			X--	——	—)			Zeller and Helm (1923). Helm (1924).
	Ixodes scapularis (Say).....	North America	3	X--	—)						Rees (1934).
	Rhipicephalus bursa Canestrini and Fanzago	North Africa...	2	X--	-X-	—)					Sergent, Donatien, Parrot and Lestoquard (1928). Brumpt (1931).
	Rhipicephalus sanguineus (Latreille)	North America.	3	X--	—)						Rees (1930, 1934).
					X--	—)					
	Rhipicephalus simus Koch.....	South Africa...				X--	——	—)			Theiler (1912).

TABLE III (*continued*).

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
B.—BENIGN BOVINE ANAPLASMOSIS. *Anaplasma centrale* (Theiler, 1912)	*Boophilus decoloratus* Koch....	South Africa...	1	X--	-X-	-X-	——	—)			Theiler (1912).
	Haemaphysalis cinnabarina punctata Canestrini and Fanzago	Roumania.....	3			X--	——	——	——	—)	Metianu (1951).
C.—OVINE AND CAPRINE ANAPLASMOSIS. *Anaplasma ovis* (Lestoquard, 1924)	*Dermacentor silvarum* Olenev..	Ukraine.....	3			X--	——	——	——	—)	Rastegaieff (1937).
	Rhipicephalus bursa Canestrini and Fanzago	Russia.....	2	X--	-X-	—)					Rastegaieff (1933).
	Ornithodoros lahorensis Neum..	Russia.....		X--	—)						Rastegaieff (1935, 1936).

TABLE IV.

The Biological Transmission of the Rickettsia *spp.*

Disease.	Vectors.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
A.—HEARTWATER. *Rickettsia ruminantium* (Cowdry, 1925)	*Amblyomma hebraeum* Koch..	South Africa...	3	X--	--)-- X--	--) --)					Lounsbury (1900). Alexander (1931).
	Amblyomma gemma Dönitz....	Kenya.....	3	X--	--)-- X--	--) --)					Lewis (1945).
	Amblyomma pomposum Dönitz.	South Africa... (Laboratory observation)	3	X--	--)--	--)					Neitz (1947).
	Amblyomma variegatum (Fabricius)	Kenya..... West Africa.... South Africa... (Laboratory observation, S.A.)	3	X--	X-- X-- --)--	--) --) --)					Daubney (1930). Mettam (1949). Neitz (1948).
B.—BENIGN BOVINE RICKETTSIOSIS. *Rickettsia bovis* (Donatien and Lestoquard, 1936)	*Hyalomma* sp. (Derived from Iran)	North Africa...	3		?—	—)					Donatien and Lestoquard (1937).
	Hyalomma excavatum Koch (Derived from Dr. Rafye, Iran)	South Africa...	3		?—	—)					Neitz and Jansen (1952).

NOTE.—X indicates the stage in which the infection is acquired.
) indicates the stage in which the infection is transmitted.
L = Larva; N = Nympha; I = Imago; and E = Egg.

TABLE IV (*continued*).

Disease.	Vectors.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
C.—BENIGN OVINE RICKETTSIOSIS.				?	?						
Rickettsia ovina Lestoquard and Donatien, 1936	*Rhipicephalus bursa* Canestrini and Fanzago	North Africa... (Tick emulsion injected into sheep)	2	—	—	—)					Donatien and Lestoquard (1936).
	Rhipicephalus evertsi Neum....	South Africa...	2	X-	-X-	—)					Neitz (1952).
D.—MALIGNANT CANINE RICKETTSIOSIS. *Rickettsia canis* Donatien and Lestoquard 1935	*Rhipicephalus sanguineus* (Latreille)	North Africa... (Tick emulsions injected into dogs)		X-	-)-	-)-	—	—)			Donatien and Lestoquard (1937).
E.—TICK-BORNE FEVER OF CATTLE, SHEEP AND GOATS. *Rickettsia* sp.....	*Ixodes ricinus* Linn.....	Great Britain...	3	X-	-)-	—)					Gordon, Brownlee, Wilson and Macleod (1932).
					X-	—)					Macleod and Gordon (1933).
		Norway.....		X-	-)-	—)					Macleod (1936). Thorshaug (1940).

TABLE IV (*continued*).

F. *The Vectors of* Coxiella Burneti (*Derrick*, 1937).

Q. FEVER.

Vector.	Number of Hosts.	Country.	Material Proved Infective by Injection.	Biological Transmission.	References.
Boophilus australis Fuller = *Boophilus annulatus microplus* Neum.	1	Australia....	Emulsion of ticks or faeces	—	Derrick, Smith and Brown (1942).
Haemaphysalis bispinosa Neum.	3	Australia....	Emulsion of ticks.....	Stage to stage.....	Derrick, Smith and Brown (1942).
Haemaphysalis humerosa Warburton and Nuttall	3	Australia....	Emulsion of ticks and faeces	Stage to stage and hereditary	Smith and Derrick (1940).
Ixodes holocyclus Neum..	3	Australia....	—	Stage to stage.....	Smith (1942).
Rhipicephalus sanguineus (Latreille)	3	Australia....	Faeces.....	Stage to stage.....	Smith (1941).
Ornithodoros gurneyi Warburton	Many	Australia....	Emulsion. *C. burneti* conserved for periods of up to 538 days after infective feed	—	Smith (1942).
Amblyomma americanum (Linn.)	3	United States of America	Emulsion of ticks.....	—	Parker and Kohls (1943).
Amblyomm cajennense (Fabr.)	3	United States of America	—	Stage to stage.....	De Rodaniche (1949).
Dermacentor andersoni Stiles	3	United States of America	Emulsion and filtrates of ticks	Stage to stage and hereditary	Noguchi (1926), Davis and Cox (1938), Parker and Davis (1938), Davis (1939).
Dermacentor occidentalis Neum.	3	United States of America	Emulsion of ticks.....	—	Jellison, Bell and Parker (1949).

TABLE IV (*continued*).

Vector.	Number of Hosts.	Country.	Material Proved Infective by Injection.	Biological Transmission.	References.
Haemaphysalis leporis palustris Pack.	3	United States of America	Emulsion of ticks.....	—	Jellison, Bell and Chalgren (1949).
Ixodes dentatus Marx.....	3	United States of America	Emulsion of ticks.....	—	Parker, Bell and Chalgren (1949).
Rhipicephalus sanguineus (Latreille)	3	United States of America	Emulsion of ticks.....	Stage to stage.....	Philip (1949), Parker and Sussman (1949).
Ornithodoros hermsi Wheeler, Herms and Meyer	Many	United States of America	Emulsion, *C. burneti* conserved for 979 days after infective feed	Stage to stage. Infective by bite for 772 days	Davis (1943).
Ornithodoros moubata (Murray)	Many	United States of America*	Emulsion. *C. burneti* conserved for 670 days after infective feed	Stage to stage and hereditary. Infective by bite for 428 days	Davis (1943).
Ornithodoros parkeri Cooley	Many	United States of America	Emulsion. *C. burneti* conserved for 852 days after infective feed	—	Davis (1943).
Ornithodoros turicata Duges	Many	United States of America	Emulsion. *C. burneti* conserved for 1,001 days after infective feed	—	Davis (1940).
Otobius megnini (Duges)..	1	United States of America	Emulsion of ticks.....	—	Jellison, Bell, Huebner, Parker and Welsh (1949).
Hyalomma mauretanicum Senevet	1 or 2	Algeria.....	Emulsion of ticks.....	—	Morocco, Ann. Rept. Inst. Pasteur (1948), Blanc and Bruneau (1949).
Haemaphysalis leachi (Audouin)	3	Belgian Congo	Emulsion of ticks.....	—	Jadin and Giroud (1950).

* *Ornithodoros moubata* is an African tick—Laboratory Observations only.

TABLE IV (*continued*).

Vector.	Number of Hosts.	Country.	Material Proved Infective by Injection.	Biological Transmission.	References.
Hyalomma dromedarii Koch	3	Egypt.....	Emulsion of ticks.....	—	Halawani, El Dine and El Fiki (1952), Taylor, Mount, Hoogstraal and Dressler (1952).
Hyalomma excavatum Koch	3	Egypt.....	Emulsion of ticks.....	—	Halawani, El Dine and El Fiki (1952).
Amblyomma variegatum Fab.	3	French Equatorial Africa	Emulsion of ticks.....	—	Blanc, Bruneau and Chabaud (1950).
Ornithodoros moubata (Murray)	Many	French Equatorial Africa	—	Stage to stage.....	Jadin and Giroud 1950).
Hyalomma dromedarii Koch	3	Morocco....	Emulsion of ticks.....	—	Blanc, Martin and Maurice (1946).
Hyalomma excavatum lusitanicum Koch = *Hyalomma excavatum* Koch	3	Morocco....	Emulsion of ticks.....	—	Blanc, Martin and Maurice (1946).
Hyalomma mauritanicum Senevet = *Hyalomma detritum* Schulze	1 or 2	Morocco....	Emulsion of ticks.....	—	Blanc, Martin and Maurice (1946).
Hyalomma savignyi (Gervais)	2	Morocco....	Emulsion of ticks.....	—	Blanc, Martin and Maurice (1946).
Hyalomma sp.....		Morocco....	—	Stage to stage and hereditary	Blanc, Bruneau, Martin and Maurice (1948).
Rhipicephalus sanguineus (Latrielle)	3	Morocco....	—	Stage to stage.....	Blanc, Bruneau, Martin and Maurice (1948).
Ornithodoros erraticus Lucas	Many	Morocco....	—	Stage to stage.....	Blanc, Bruneau, Martin and Maurice (1948).

TABLE IV (*continued*).

Vector.	Number of Hosts.	Country.	Material Proved Infective by injection.	Biological Transmission.	References.
Ixodes ricinus (Linn.).....	3	Germany....	Emulsion of ticks.....	—	Hengel, Mausche and Sheris (1950).
Ornithodoros moubata (Murray)	Many	Germany*...	Emulsion of ticks and coxal fluid	Stage to stage.....	Weyer (1949).
Rhipicephalus sanguineus (Latreille)	3	Lorraine (Strasbourg)	—	Stage to stage.....	Callot, Vermeil and Puech (1950).
Hyalomma rufipes glabrata		Portugal.....	—	Stage to stage.....	Fonseca, *et al.* (1951).
Hyalomma marginatum Senevet = *Hyalomma savignyi* (Gervais)	2	Spain.....	Emulsion of ticks.....	—	Perez Gallardo *et al.* (1949).
Hyalomma savignyi (Gervais)	2	Spain.....	Emulsion of ticks.....	—	De Prada (1949), Parker *et al.* (1949).
Rhipicephalus bursa Canestrini and Fanzago	2	Spain.....	Emulsion of ticks.....	—	Perez Gallardo *et al.* (1949).
Rhipicephalus sanguineus (Latreille)	3	Spain.....	Emulsion of ticks.....	—	Perez Gallardo *et al.* (1949).
Ornithodoros moubata (Murray)	Many	Switzerland*.	Emulsion of ticks.....	Stage to stage.....	Geigy (1951), Burgdorfer *et al.* (1951).

* *Ornithodoros moubata* is an African tick—Laboratory Observations only.

TABLE V.

The Biological Transmission of Virus Diseases.

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
Equine Encephalomyelitis (Western type)	*Dermacentor andersoni* Stiles. Syn. *Dermacentor venustus* Banks	North America United States of America	3	X--	--)--	--)--	———	--)--	--)--	—)	Syverton and Berry (1941).
St. Louis Encephalitis.	*Dermacentor variabilis* (Say)....	North America	3	X--	--)--	--)--	———	--)--	--)--	—)	Blattner and Heys (1941 1944).
				--)--	--)--	--)--	———	--)--	--)--	—)	
Russian Spring-Summer Encephalitis	*Ixodes persulcatus* Schulze.....	Far Eastern Soviet Russia	3	X--	--)						Chumakov and Gladkikh (1939). Chumakov and Seitlenok (1940). Pavlovsky and Soloviev (1940).
					X--	—)					
						X--	———	--)--	--)--	—)	
	Ixodes ricinus (Linn.).....	European Soviet Russia	3	--)							Chumakov and Naidenova (1944). Chumakov *et al.* (1944).
					—)						
Louping Ill.....	*Ixodes ricinus* (Linn.).....	Great Britain...	3	X--	--)--	--)					MacLeod and Gordon (1932).
					X--	—)					
	Rhipicephalus appendiculatus Neum.	South Africa (Laboratory observation)	3	X--	--)--	—)					Alexander and Neitz (1933, 1935).
					X--	—)					
Czecho-Slovakian Tick Encephalitis	*Ixodes ricinus* (Linn.) (Infectivity determined by injecting tick suspensions into mice)	Czecho-Slovakia	3	?	?	?					Gallia and Rampas (1949).

NOTE.—X indicates the stage in which the infection is acquired.
) indicates the stage in which the infection is transmitted.
L = Larva; N = Nympha; I = Imago; and E = Egg.

TABLE V (*continued*).

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
Nairobi Sheep Disease.	*Amblyomma variegatum* (Fabricius)	Kenya.....	3	X--—)	X--—)						Daubney and Hudson (1934). Daubney (1934).
	Rhipicephalus appendiculatus Neum.	Kenya.....	3	X--—)	X--—)	X--——)					Montgomery (1917). Daubney (1934). Daubney and Hudson (1934).
	Rhipicephalus bursa Canestrini and Fanzago. (Possibly either *Rhipicephalus pravus* Dönitz, or *Rhipicephalus hurti* Wilson)	Kenya.....	2		X--—)						Daubney and Hudson. (1934).
Kisenye Sheep Disease	*Rhipicephalus appendiculatus* Neum.	Belgian Congo.	3		X--—)						Bugyaki (1955).

TABLE VI.

The Biological Transmission of Borrelia *spp.*

Disease.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
SPIROCHAETOSIS OF CATTLE, SHEEP, GOATSAND SOLIPEDS. *Borrelia theileri* (Laveran, 1903)	*Boophilus australis* Fuller. May actually be *Boophilus microplus* (Canestrini)	Brazil.....	1	X--	–X–	–X——	———	—)			Brumpt (1919).
	Boophilus decoloratus (Koch)...	South Africa...	1	X--	–X–	–X——	———	—)			Theiler (1905).
	Rhipicephalus evertsi Neum....	South Africa...	2	X--	–X–	—) X——	———	—)			Theiler (1909).
SPIROCHAETOSIS OF POULTRY. *Borrelia anserina* Sacharoff, 1891	*Argas persicus* (Oken)..... Syn. *Argas miniatus* Koch *Argas victoriensis* Sweet	Many countries	Many	X--	–)?						Marchoux and Salimbeni (1903).
					X–	—)					Marchoux and Couvy, (1913).
						X–) X–)-)-) X——	———	–)–	–)-)–	–)-)	Ficker and Rosenblatt (1907). Tartowsky (1909).
				—	–)–	—)					
	Argas reflexus (Fabricius).....	Cyprus.....	Many	X--	–)?						Williamson (1908).
					X–	—)					Schellack (1908, 1909).
						X–) X–)-)-) X——	———	–)–	–)-)–	–)-)	
				—	–)–	—)					
	Ornithodoros moubata (Murray)	Europe (Laboratory observations)	Many		X–	—)					Fülleborn and Mayer (1908).
						X–) X–))-) X——	———	–)–	–)–	—)	Brumpt (1908). Neumann and Mayer (1914).
				—	–)–	—)					

NOTE.—X indicates the stage in which the infection is acquired.
) indicates the stage in which the infection is transmitted.
L = Larva; N = Nympha; I = Imago; and E = Egg.

TABLE VII.

Ticks Responsible for the Transmission of Tick Paralysis.

Animals Affected.	Vectors.	Country.	Number of Hosts.)	L	N	I	References.
Man, cattle, sheep, dogs..	*Dermacentor andersoni* Stiles.... Syn. *Dermacentor venustus* Banks	North America.	3			—)	Hadwen (1913); Todd (1914); Nuttall (1914); Moilliet (1936); Mail and Gregson (1938); Jellison and Gregson (1950); Jellison, Stoenner, Kramis and Beardmore (1951).
Dogs.....	*Dermacentor variabilis* (Say)....	North America.	3			—)	Eddy and Joyce (1947).
Calves, sheep, goats.....	*Haemaphysalis cinnabarina punctata* Canestrini and Fanzago	Serbian Macedonia	3			—)	Pavlov and Miljowski (1942).
Sheep.....	*Hyalomma aegyptium* [may be either *Hyalomma savignyi* (Gervais) or *Hyalomma scupense* Schulze]	Yugoslavia.....	?			—)	Oswald and Meinac (1947).
Man.....	*Hyalomma transiens* Schulze.....	South Africa...	2			—)	Erasmus (1952).
Man, calves, dogs.....	*Ixodes holocyclus* Neum.....	Australia.....	3			—)	Dodd (1921); Clunies Ross (1926).
Sheep, calves.....	*Ixodes pilosus* Koch (may actually be *Ixodes rubicundus* according to G. Theiler, 1947)	South Africa...	3			—)	Malley (1904); Borthwick (1905); van Rensburg (1928).
Sheep, goats, calves and an antelope (*Pelea* sp.).	*Ixodes rubicundus* Neum.....	South Africa...	3			—)	Mönnig (1938); G. Theiler (1947).
Sheep and goats.....	*Ixodes ricinus* (Linn.).....	Crete.....	3			—)	Blanc and Caminopeteros (1924); Tzortakis and Papadikis (1936).

TABLE VII (*continued*).

Animals Affected.	Vectors.	Country.	Number of Hosts.	L	N	I	References.
Sheep.....	*Rhipicephalus evertsi* Neum.....	South Africa...	2			—)	Clark (1938); Neitz and Jansen (1950).
Dog.....	*Rhipicephalus sanguineus* (Latreille)	Germany (Laboratory observations)	3			—)	Regendanz and Reichenow (1931).
Man (suspected cases in three human beings)	*Rhipicephalus simus* Koch.....	Somaliland..... South Africa...	3			—) —)	Veneroni (1928). Zumpt and Glajchen (1950).
Sheep.....	*Ornithodoros lahorensis* Neum..	Central Asia...	Many		—)		Rastegaieff (1936).
Ducks, geese, fowls.....	*Argas persicus* (Oken.).....	South Africa...	Many		—)?	—)	Coles (1947).

TABLE VIII.

The Biological Transmission of Sweating Sickness.

Animals Affected.	Vector.	Country.	Number of Hosts.	L	N	I	E	L	N	I	References.
Cattle (particularly calves) and sheep, goats, pigs	*Hyalomma transiens* Schulze (= *Hylomma truncatum* Koch, according to Feldman-Mühsam, 1954)	South Africa...	2	— — —	— — —	—)— —)— —)	— — —	— — —	— — —	—) —)	Neitz (1954, 1955).