

THE TICKS OF RODENTS AND THEIR NESTS, AND THE
DISCOVERY THAT *RHIPICEPHALUS SANGUINEUS*
LATR. IS THE VECTOR OF TROPICAL TYPHUS IN
KENYA

BY J. ISGAER ROBERTS, D.Sc., F.R.E.S.

From the Medical Research Laboratory, Nairobi.

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INTRODUCTION

THE rôle of ticks in transmitting pathogenic organisms either from animal to animal, or animal to man, is of importance, especially in the tropics, and it naturally follows that their habits and associations with any animal group will be also of importance.

Part I of this paper deals with ticks in relation to one group of animals (rodents) in Kenya, and the possibilities of their acting as vectors of disease from rodents to man or among themselves. At the period this particular investigation was carried out, we did not know why field rodents displayed an immunity to plague, and the possibility of a tick vector being responsible for conferring such an immunity was investigated. Ticks were already known to be the vectors of Tularaemia in the U.S.A., which is caused by a

Pasteurella. There was also the knowledge that certain native tribes of Africa recognised and employed a species of tick to confer immunity on themselves to relapsing fever, e.g. *Ornithodoros moubata*.

However, there appears to be no suggestion arising from this investigation that ticks are concerned in the carriage of plague among field rodents, or that they would be factors to be considered in perpetuating the disease in any other community of rodents. The results of the investigation have been mainly of interest in demonstrating the breeding places of certain species, and as the adults are obliged to feed on other hosts, there is the possibility still remaining of at least two species being capable of transmitting some organism, if present, from rodents to other animals. In view of the fact that Kenya rodents have been found to suffer from obscure diseases with a high mortality, the possibility of some existing relationship between the diseases of rodents and higher animals appears to exist.

Part II of this paper records an advance towards the solution of the incidence of tropical typhus among Europeans, which has been an interesting and elusive problem for some considerable time, and it also aids the classification of this disease, as it occurs in East Africa, among other typhus-like diseases occurring over the world. The difficulty in regard to tracing the vector can be largely accounted for as being due to the peculiar habits of *Rhipicephalus sanguineus*, both in its occurrence on man and in houses, and although a considerable amount of work remains to be done, it is significant that once the clue had been obtained for the vector, further detailed search in houses has revealed a condition in which this tick can almost be regarded as a "house" tick. The occurrence of *R. sanguineus* on man still remains rare in comparison with such a tick as *R. pulchellus*, but practically all houses where dogs are kept have yielded greater or lesser numbers of *R. sanguineus*.

The reservoir of the disease has yet to be determined for Kenya, but it is of some importance to note that cattle in certain areas carry quite a large population of *R. sanguineus*, and cattle in this colony are a privileged class with unrestricted license to wander over township areas, and even in gardens if herbage is available, and thus become a very potent factor in the distribution of ticks in residential areas. House dogs wandering in grass along roadsides and gardens gather up these ticks to carry them eventually into houses. In house searches in Kenya, an occasional *R. pulchellus*, a few *Haemaphysalis leachi*, and enormous numbers of *R. sanguineus* are the order and frequency of species encountered.

Dogs have been incriminated as reservoirs of the disease in Marseilles. As discussed in the following account, no arthropod, other than fleas and *R. sanguineus* from rat and dog respectively, is a possible vector to human beings in Kenya townships, and *R. pulchellus* may be a vector from wild game in the more open country. The evidence, so far, points to the likely reservoir being either cattle or dogs. The dog is certainly the chief menace owing to its relationship with man.

Tropical typhus of Kenya appears to group itself with "fièvre boutonneuse" and the South African tick typhus, in that all three forms of disease have a common vector, *R. sanguineus*, with similar symptoms, fever, rash, nerve symptoms and a primary ulcer in man; in guinea-pigs, after 4-5 days, fever occurs, followed by a marked oedema, redness and swelling of the scrotum. Circumstantial evidence is fairly strong that an even milder type of typhus does exist, which is associated with a tick, *R. pulchellus* and a primary lesion may be present or not at the site of the bite.

PART I. TICKS OF RODENTS IN KENYA

(a) TICKS FROM FIELD RODENT NESTS

The area surrounding the laboratory in Nairobi has an abundant tick fauna, and at certain seasons of the year there is an apparent fluctuation in the numbers of ticks taken from rodents and their nests. House rats, however, remain remarkably tick free.

An attempt has been made to correlate tick infestation of surface and underground nests with those obtained from rodents and man, to trace, if possible, any system of contact existing, that may point out the vectors of such obscure diseases as Kenya typhus fever, should the reservoir be proved to exist among rodents.

The only tick species taken from surface and underground nests have been *Rhipicephalus simus* and *Haemaphysalis leachi*, the same species being taken from field rodents. Man, however, in this neighbourhood has only been found to be attacked in any numbers by *R. pulchellus*, the commonly known minute "pepper" ticks being the larvae of this species, the other stages recorded being the adult males and females and nymphs (*hereinafter designated by the signs* ♂, ♀, ⊙ and L respectively), taken on numerous occasions from man.

This area is of more than passing interest in its tick fauna, in view of the opinion of many well acquainted with the distribution of Kenya typhus, that the district whence these ticks were obtained is a focus of the disease, and the possibility of the disease being tick borne cannot be disregarded.

The writer has on various occasions taken *R. pulchellus* ♂ and ♀ from himself after a walk in the area. These adult ticks have been observed to insert their mouth-parts in the body and, unless removed early, have been found most difficult to dislodge; they will remain feeding for several days. The result of feeding by the immature stages (L or ⊙) in some areas leads to sores or ulcers in many instances on human beings, but so far, only one case has been recorded where a sore or ulcer has resulted from the bites of ♂.

The distribution of *R. pulchellus* agrees with that of typhus fever, the main foci in Nairobi being the Kilimani and Parklands area, and in outside districts, the townships of Nakuru and Nyeri.

Tropical Typhus in Kenya

Though there is little support for the suggestion that *R. pulchellus* is in any way connected with the transmission of Kenya typhus fever, its rôle as a vector for other pathogenic organisms cannot be ignored, and the results of feeding by L and ⊙ causes sores and ulcers to occur among Europeans.

Several attempts have been made to rear *R. pulchellus* on various species of wild rodents, but these have failed in contrast to *R. simus* and *H. leachi*, which are easily reared on rodents as L and ⊙, but not in the adult stages, an observation also supported by the tick survey in nests and on rodents (see Tables I-III).

Table I. *Survey of rodent ticks carried out in 1930-1.*
Results obtained for surface nests

Rodent species	No. of nests examined	No. of nests infested	%	No. of nests with more than one species	No. of times tick spp. recorded			Double infestations	
					<i>R. simus</i>	<i>H. leachi</i>	<i>R. pulchellus</i>	<i>R. simus</i> and <i>H. leachi</i>	<i>R. simus</i> and <i>R. pulchellus</i>
<i>Mus coucha</i>	44	18	40.9	5	12	10	1	4	1
<i>Arvicanthis</i>	61	52	85.2	18	40	30	—	18	—
<i>Otomys</i>	25	14	56	4	7	10	1	4	—
<i>Lemniscomys</i>	7	2	28.5	2	2	2	—	2	—
	137	86	61.7	29	61	52	2	28	1

Table II. *Kilimani area. A more elaborate tick survey attempted in 1932, by taking the rat and its nest and comparing the fauna obtained from each. A representative collection of underground nests was examined. Only those rats which were tick-infested are detailed below, together with the total number of ticks obtained from their nests.*

No. of rats examined	Rodent species	Ticks taken from rat								Ticks taken from nest	
		<i>H. leachi</i>				<i>R. simus</i>					
		L	⊙	♂	♀	L	⊙	♂	♀		
8	<i>Mus coucha</i>	27	57	5	—	—	—	—	—	—	Nil
5	<i>Arvicanthis</i>	3	22	—	—	6	1	2	—	—	„
1	<i>Lemniscomys</i>	—	1	—	—	—	—	—	—	—	„
2	<i>Rhabdomys</i>	—	17	—	—	—	—	—	—	—	„
1	<i>R. rattus</i>	2	1	—	—	—	—	—	—	—	„

Table III. *Survey of King's African Rifles area*

Rodent species	No. of rats examined	Ticks taken from rat							
		<i>H. leachi</i>				<i>R. simus</i>			
		L	⊙	♂	♀	L	⊙	♂	♀
<i>Mus coucha</i>	30	9	64	2	—	1	1	1	2
<i>Arvicanthis</i>	40	43	94	1	—	7	63	—	1
<i>Otomys</i>	4	—	1	2	—	—	—	—	—
<i>Lemniscomys</i>	12	1	39	1	—	1	1	—	—

Table III (continued)

Rodent species	No. of rats examined	Ticks taken from nest							
		<i>H. leachi</i>				<i>R. simus</i>			
		L	⊙	♂	♀	L	⊙	♂	♀
<i>Mus coucha</i>	30	—	82	7	—	—	33	3	5
<i>Arvicanthis</i>	40	—	15	1	—	4	—	1	—
<i>Otomys</i>	4	—	5	2	1	—	1	—	—
<i>Lemniscomys</i>	12	—	—	—	—	—	—	—	—

(b) TICKS FROM INDIVIDUAL RODENTS AND THEIR NESTS

In the King's African Rifles barracks, four *Mus coucha* were found infested with *H. leachi* 6L, 6 ⊙, and *R. simus* 1 ⊙. Two *R. rattus*, infested with *H. leachi* 3 ⊙, were taken in Nairobi township.

From a total of twenty-six underground nests the following ticks were obtained: *H. leachi* 3 ⊙, 10 ♂, 15 ♀; *R. simus* 58 ⊙, 16 ♂, 5 ♀.

Large numbers of ticks were encountered in some cases:

M. coucha (on rat): *H. leachi* 25L, 32 ⊙, 5 ♂.

(in nest): *H. leachi* 33 ⊙.

(in nest): *H. leachi* 27 ⊙.

Arvicanthis (on rat): *H. leachi* 14 ⊙; *R. simus* 1 ♂.

(on rat): *H. leachi* 37 ⊙.

(on rat): *H. leachi* 27L, 3 ⊙; *R. simus* 1 ⊙.

M. coucha (on rat): *R. simus* 1 ♂, 2 ♀.

(in nest): *R. simus* 3 ♂, 3 ♀; *H. leachi* 44 ⊙.

Grass sweeping and collecting from calves

During grass sweeping with a net the only species obtained in the Kilimani area were *R. pulchellus*, *R. simus* and *H. leachi*.

Calves employed in the preparation of vaccine at the laboratory were searched and all ticks removed prior to their being turned out to grass. All animals were again searched on return in the evening, and on each occasion showed a great preponderance of *R. pulchellus* ♂♀. The following species were also taken, *Amblyomma variegatum*, *R. evertsi*, *R. simus*.

(c) NESTING CONDITIONS OF FIELD RODENTS AND THEIR INFLUENCE ON TICK SPECIES

It seems safe to assume that rodents act as hosts for larval and nymphal stages of *R. simus* and *H. leachi* in the Nairobi area, but that no adult tick has adopted this group as a host. Nesting conditions of the various rodent species also appear to influence the tick species infesting them, *R. simus* prefers *Arvicanthis* and its nest, and *H. leachi* prefers *M. coucha* and its nest.

Otomys spp. require a heavy cover of vegetation, mainly grasses, which will also serve as a food supply. They build surface nests in this dense cover, and have runs radiating out in various directions but mostly sheltered by the grasses. The runs are often almost tunnel-like. Different from other species they do not build a roof to the nest; it is made of coarse grass as a base and a lining of finer grass cut into small pieces, the whole giving sufficient clearance from surface water and soil. *Otomys* spp. also display parental care to a degree not often met with in the lower orders of the *mammalia*, the normal number of young being two, although as many as five embryos have been counted. The newly born attach themselves to the nipples of the mother and very seldom leave until weaned, and in this manner it is not uncommon to trap mothers with the young attached. The construction of the nest resembles that of a hare, but with different provision for the safety of the young, due to a different type of enemy. In the case of *Otomys*, snakes are the chief enemy, and the mother does not need to wander far to escape dangers; it is seldom necessary to leave the well-trodden runs near the nest. The young of this species are born blind, and the mother is forced to adopt this method of guarding her young, whilst away feeding, in contrast to the hare which is born fully able to cope with eventualities from a different type of enemy.

The absence of mother and young from nests for long periods and the search for food in the runs near the nest does not bring them into close contact with tick-infested areas. The type of nest and distance from ground-level make it possible to keep it clean, with very little accumulation of soil or debris during the rearing of young. The dense type of vegetation preferred by *Otomys* for nesting and feeding is not that usually chosen by domesticated animals.

Arvicanthis spp. build round nests with a small opening below in which the young remain until weaned. The nests usually contain a fair amount of soil and debris, probably due to continuous occupation, a factor which may well be of importance in the development of larval and nymphal stages of ticks, and they build closer to the soil surface, often in excavations of the ground, with finer materials than those of other species. The habits of *Arvicanthis* allow migrations some distance from nests and in localities most frequented by domesticated animals or near paths.

M. coucha is believed to be less infested generally than *Arvicanthis*. A factor which may contribute to this state of affairs is the clean habits of mothers and early development of the young, which allow long periods being passed without surface nests being occupied, although migrating individuals often resort to deserted nests. The nests are built of fine grasses with very little debris or soil, and are usually higher from the ground than those of other species, some even building on clumps of grass. The habits of the adults seem to play an important part in the degree of infestation, as this species has a tendency to enter houses or huts and frequent open spaces with sparse vegetation, preferring slight elevations of the ground at the base of shrubs in which to build their nests.

It seems that the tick fauna of rat nests is influenced mainly by the structure and position of nests, the length of time taken to rear the young and the migratory habits of rats into infested areas in search of food.

There is some indication that *H. leachi* prefers the surface nests and *R. simus* the underground nests.

(d) TRANSMISSION EXPERIMENTS WITH TICKS FROM PLAGUE-INFECTED ANIMALS AND WITH TICKS FROM RODENTS APPARENTLY IMMUNE TO PLAGUE

As a tick, *Dermacentor venustus*, acts as a vector of Tularaemia in America, tests were carried out with ticks (*R. pulchellus*, *R. simus* and *H. leachi*) having fed on plague-infected rats, to determine if they could transmit plague.

As the results were negative, details of each experiment are not given. The nature of the experiments is adequately illustrated as follows:

Exp. (a):

- 15. i. 32. (2.30 p.m.) Two *Arvicanthis* (*A* and *B*) inoculated with plague culture.
 - 16. i. 32. (11 a.m.) *R. simus* LL, recently hatched, placed on rats with camel hair brush, and tube containing some LL was also put in cage.
 - 17. i. 32. (8 a.m.) All LL had left tube and anchored on rats.
 - 21. i. 32. (8 a.m.) Rat *A* dead of plague.
 - 23. i. 32. (8 a.m.) Rat *B* dead of plague.
- Two more *Arvicanthis* (*C* and *D*) put in cage, both remained healthy.
- 11. ii. 32. Nine fully fed *R. simus* ⊙ recovered from sand.

Two crushed ⊙, cultured on agar and blood agar media yielded *Staphylococci* only in culture. Seven ⊙ crushed in sterile saline and injected intraperitoneally into two white rats (*A* and *B*).

- 19. ii. 32. Rat *A* killed. Autopsy: subcutaneous congestion—suprainguinal gland normal—suprarenals pinkish—spleen normal—liver highly necrosed—numerous micrococci found. Rat *B* remained well for 4 weeks and, when killed and examined, found negative.
- 19. ii. 32. On the same day twenty-one engorged *R. simus* ⊙ recovered from sand, crushed and injected intraperitoneally into two *M. coucha* (*C* and *D*) and two white rats (*E* and *F*).
- 1. iii. 32. Rats *C–F* killed and found negative.

Exp. (b):

- 1. ii. 32. Three *M. coucha* (*A–C*) inoculated with plague culture.
- 2. ii. 32. *R. pulchellus* LL brushed on to rats.
- 4. ii. 32. (8 a.m.) Rat *A* dead of plague.
- 4. ii. 32. (10 a.m.) Rat *B* dead of plague.
- 5. ii. 32. (7 a.m.) Rat *C* dead of plague.

Not a single L was found on dead rats *A–C*. Dead LL only could be found in sand and under cage.

Exp. (c):

- 1. ii. 32. Three *Arvicanthis* (*A–C*) inoculated with plague culture.
- 2. ii. 32. *R. simus* LL brushed on to rats.
- 6. ii. 32. (8 a.m.) Rat *A* dead of plague.
- 7. ii. 32. (8 a.m.) Rat *B* dead of plague.
- 10. ii. 32. (8 a.m.) Rat *C* dead of plague.
- 9. ii. 32. Several engorged larval ticks found in water at base of cage and transferred to an *Arvicanthis* in a glass jar. Engorged larval ticks found in sand transferred to two *M. coucha* (*D* and *E*), did not settle down on this species as readily as on two *Arvicanthis* (*F* and *G*), on which the remaining LL were brushed.

Rats *D–G*, killed on 1. iii. 32, were all found negative.

Inoculation tests with ticks obtained in the field

Exp. (1):

- 5. ii. 32. *R. simus* (33⊙) crushed in distilled water, one half filtered under pressure through asbestos, and inoculated into white rat *A*, the other unfiltered half inoculated into white rat *B*.

Exp. (1) (continued):

16. ii. 32. Rats *A* and *B* killed. Autopsy: suprainguinal glands enlarged with haemorrhages—slight congestion in veins of subcutaneous tissue—viscera yellowed—spleen slightly enlarged—suprarenals pinkish and small area congested—liver deeply pitted and necrosed—congestion in testicles—lungs normal. Smears negative microscopically.

Exp. (2):

5. ii. 32. *R. simus* (29⊙), crushed in saline and inoculated into two white rats.
16. ii. 32. Both rats killed. Macroscopical examination negative—no organisms found in liver and spleen smears—sections of tissue showed no changes.

Exp. (3):

13. ii. 32. *Arvicanthis* trapped and *R. simus* (37⊙) obtained.
16. ii. 32. Two *M. coucha* and the *Arvicanthis* (from which ticks were obtained), also a white rat, were inoculated with plague culture intraperitoneally. White rat dead of plague in 20 hours. The two *M. coucha* and the *Arvicanthis* lived 3 weeks; they were then killed and found negative on examination.
19. ii. 32. The nymphal *R. simus* were crushed in saline and fluid inoculated intraperitoneally into two *M. coucha*. Both of these rats, killed on 1. iii. 32, proved negative.

This experiment proved very interesting as three freshly trapped field rats proved to be immune to a dose of plague sufficient to kill a white rat in 20 hours. The ticks which had been feeding on an immune rat proved negative to plague in inoculation and cultural tests.

Exp. (4):

1. iii. 32. *H. leachi* (27L, 30⊙) taken from an *Arvicanthis*, crushed in 1 c.c. sterile saline and inoculated intraperitoneally into a white rat. Rat killed on 5. iv. 32. Negative.

Exp. (5):

1. iii. 32. *H. leachi* (4L, 4⊙) taken from an *Arvicanthis* crushed in 1 c.c. sterile saline and inoculated intraperitoneally into a white rat. Rat killed on 5. iv. 32. Negative.

Tests for plague were made concurrently with ticks and fleas taken from rodents in a field community, numbers of which have proved to be immune to the disease on several occasions. Inoculation and cultural tests of both fleas and ticks have been consistently negative.

It appears that some factor other than the actual transmission of the specific organism by fleas and ticks confers immunity on field rats to plague.

Owing to its strong affinity for human beings, *R. pulchellus* can be regarded as the most dangerous potential vector of pathogenic organisms in the Nairobi area. The ticks found infesting rats and their nests have not been found to attack man, so that there appears to be little or no danger in the transmission of rodent disease to human beings by the agency of ticks.

PART II. *RHIPICEPHALUS SANGUINEUS* FOUND TO BE THE VECTOR OF TROPICAL TYPHUS IN KENYA

The literature dealing with tropical typhus in Africa is meagre, although the disease has been recognised among Europeans for a number of years. For Kenya, with one exception, all the references obtainable, referring to the typhus-like disease (now recognised as caused by *Rickettsia*), show a marked similarity in their suspicions regarding the vector and reservoir of the disease respectively, and also with certain features associated with the areas where the disease occurs most frequently.

The authors of the most recent papers appear to deny the possibility of a tick vector, or any animal, excepting a rodent, being a reservoir, and most of them point to what appears to be some association between long grass or bush and the incidence of cases. These hypotheses are of doubtful value. Information collected by the writer from sources, other than existing literature, led to the present investigation being directed to other possible vectors.

The disease is commonly referred to as "tick fever" among persons resident in these areas. The failure of those who contract the disease to identify any of the larger arthropods, except in general terms, suggests that mites and immature ticks were to be suspected, especially as many patients stated that the primary lesion of the disease followed a "tick bite," and many sufferers asserted that an unmistakable tick had been removed by them from the site of the primary lesion.

Gilks, in 1920, was the first to describe the existence of a typhus-like disease among Europeans living in the Highlands of Kenya and he is the only author to suggest a tick might be the vector. His suggestion was unfortunately ignored and a fruitless search was made for other possible vectors. Gilks (1920) wrote as follows:

The point arises as to how the disease is spread and by what it is carried. Pediculosis, which is the curse of countries where typhus is endemic, is conspicuous here by its rarity, and the social type of the cases is not one which is, as a rule, affected by *pediculi*, or any other form of vermin. I myself had always imagined that the disease was insect-borne and that, most probably, a tick was the agent. My reasons for suspecting a tick were: (a) the slight epidemicity of the disease, not more than a single case having occurred in any one house, and (b) several of the cases have complained of and exhibited septic sores which they have described as the result of severe tick bites.

Five years later Anderson (1925) wrote that he was "unable to get any reliable evidence of the carrying agent."

Jewell and Cormack (1930) wrote:

It is difficult to believe that a tick is at fault, as tick bites are very common, especially in those who frequent the golf course or open plains, where these insects abound. . . . Tick bites are so well known that if the particular marks referred to as present in most cases and put down vaguely by the patient as "insect bites" were in reality caused by ticks, the patients would at once be able to identify them as such, although it is possible that an infected bite might be different from an ordinary bite. . . one patient stated that he picked

off a very small reddish insect "like a tick" from the spot that became the infected bite. But, so far, this has not been proved, although it seems evident that the vector must be such a small insect as to escape notice at the time of infection and we agree that it is probably a mite.

Jewell and Kauntze (1931) repeat these views in their book, and Kauntze (1931), in his annual report, adds the suggestion that rodents may act as animal reservoirs, with a mite as vector, and that there is a close association between cases of the disease and long grass or bush.

Tonking (1932) and Symes (1932), who repeated the views previously expressed, that there exists a close association between cases of the disease and long grass or bush prior to infection, added a rather hazardous suggestion that the disease is not uncommon among field rats. Lastly Tonking has since associated the seasonal incidence of the disease with an increase of surface water and grass and an increase in field rats and their fleas.

It appears that some of the authors mentioned have been misled by the enormous number of tick bites to be observed on Europeans, whilst but a small number of cases of the disease occur among them. We know, however, from insect-borne diseases, that the infectivity rate of some of the most efficient vectors may be slight. An instance of this is recorded in the annals of the Medical Laboratory, Nairobi, during one of the most severe epidemics of malaria known to occur in Kenya, when only a single *Anopheles costalis* was found to be infected out of 248 specimens examined for sporozoites, the rate therefore being only 0.4 per cent.

(a) RESULT OF INVESTIGATION CONDUCTED IN AN ENDEMIC TYPHUS AREA

The Kilimani area of Nairobi

An investigation conducted in the Kilimani area, Nairobi, for a considerable time, (a) mainly on ticks in relation to possible endemic plague among field rodents, and (b) secondarily, making a survey of arthropoda attacking human beings which could possibly act as vectors of pathogenic organisms from rodents.

The fact that this area is regarded as one of the endemic centres of tropical typhus called for an extensive survey of the ectoparasites (chiefly ticks) of animals which come most in contact with man.

Animals: rodents, though relatively few, are individually heavily infested with fleas, ticks and mites. House rats, such as *Rattus rattus kijabius* are very scarce, and the field rodents show slight seasonal fluctuations in numbers. Dogs, unless cared for, carry a large tick population and, in some instances, fleas. Wild game also invades the area during the drier periods of the year in search of more succulent herbage than that available on the Athi Plains. Zebra and wildebeeste are often reported as causing damage in gardens overnight; some of the smaller members of the antelope family are also fairly common, and all of these are often heavily infested with ticks. A search carried

out in their overnight resting places on the outskirts of the area is frequently very productive of ticks.

Men, resident or visiting the area, are attacked by the well-known "pepper ticks," especially when frequenting the golf links and forced to enter the long grass on the edge of the fairways. There are no indications that any of the inhabitants are attacked by lice, bed bugs, fleas or mites. The writer, living in the area, has on no occasion found any other arthropods than ticks attacking his person and likely to convey any pathogenic organisms. After a walk in the long grass or after a round of golf, *Rhipicephalus pulchellus* ♂♀ are commonly found on different parts of the body. An itch is caused on the legs by *pulchellus* LL ("pepper ticks"), which are extremely difficult to recognise with the naked eye. Children also suffer heavily at certain periods of the year from an itch due to these LL which are easily overlooked owing to their minute size (0.5 mm.) and other causes being blamed.

Only on one occasion has the writer removed any other species of tick from his person, *i.e.* *R. sanguineus* ☉.

Fowl fleas, *Echidnophaga gallinacea* West., and dog fleas, *Ctenocephalus felis strongylus* Jord., are often picked up by persons entering vacant houses, where chickens or dogs had been quartered close to the house.

Therefore the most probable disease vector to man would appear to be either *R. pulchellus* or *R. sanguineus*. The former species, however, has only been obtained from wild game, which are numerous on the outskirts of the area but sometimes forage in the vicinity of houses. The ticks found on rodents and in their nests have been *R. simus* and *H. leachi*, which have not been found to attack man. Dogs in the area are abundantly infested with *H. leachi*, and occasionally *R. sanguineus* is found in enormous numbers.

Mites have not been reported as attacking man, and the writer has only found mites on rodents.

The species of ticks collected by sweeping the grass with nets were *Amblyomma variegatum*, *R. simus*, *R. evertsi* and *R. pulchellus* (predominantly). Calves feeding in the area and searched morning and evening yielded the same species regularly.

Therefore the evidence pointed to *R. pulchellus* as the vector of tropical typhus to man and wild game acting as reservoirs. Many experiments wherein saline emulsions of crushed ticks were inoculated intraperitoneally into guinea-pigs and rats proved negative.

In spite of repeated failures with *R. pulchellus* in experimental transmission work, the circumstantial evidence appears to be sufficiently strong to merit further investigation being made with this species. In one recent mild typhus case, the patient (a medical officer), definitely pointed out the *pulchellus* ♂, from amongst other species, as being similar to the tick he removed from the site of the primary lesion at the onset of his fever.

Other features relating to the circumstantial evidence may also be given here.

It has already been stated that wild game forage in gardens of the Kilimani area during the drier periods of the year in search of food, and probably gorged females drop to the ground at such periods—these immediately precede the first appearance of typhus cases which have been noted to commence at the onset of the rains. During the seasonal dry periods and when the rains start, *R. pulchellus* is very abundant, but it becomes scarce when the rains are prolonged and surface water accumulates. This appears to be due to wild game remaining in their reserve when food is plentiful. It would seem as if the invasion of the area by wild game carrying *R. pulchellus* and the incidence of typhus fever were correlated.

The distribution of *R. pulchellus* and that of typhus fever coincide, the main foci being the Kilimani and Parklands areas in Nairobi, and the townships of Nakuru, Nyeri, Nanyuki and Naivasha. The distribution of this tick in before-mentioned areas is not general; it is confined to small pockets, which occur on black cotton soils.

It was only recently observed that *pulchellus* ♀ feed on man, though it is well known that males do so. The larvae and nymphs readily attack and feed on man, producing effects well known to those visiting black cotton soil areas. Usually small ulcers form at the sites where larvae or nymphs feed, but, so far, no such effects have been observed to follow the attacks of males. Ulcers due to the bites of other species of ticks have not been observed.

Whereas the writer has never been troubled by the attacks of immature stages of *pulchellus*, he has on several occasions removed adults (♂♀) from his person. Other persons suffer from many small ulcers on their legs and bodies, due to the bites of the immature stages and subsequent scratching of the parts, but they have never observed adults (♂♀) on their persons. Some individuals record having been attacked by all three stages. This variation in individual susceptibility of human beings to various stages of the tick cannot as yet be explained.

(b) EXTENSION OF THE ENQUIRY REGARDING THE RÔLE OF TICKS
IN DISEASE TRANSMISSION TO MAN

From the evidence which had been collected for the Kilimani area, it cannot be denied that further investigation concerning the vector of typhus was carried on with a definite bias in favour of ticks. The bites and resultant ulcers were very suggestive, and the primary lesions connected with actual cases of tick bite, as reported by some observers, were sufficiently convincing that a tick vector offered the greater chance of being proved to be responsible for the incidence of typhus-like fevers. It was believed that the circumstantial evidence was sufficient to warrant a departure from the prevailing ideas in suspecting the vector to be a mite and a rodent as reservoir and to concentrate studies on houses or gardens where cases had occurred.

It had been suggested that there appeared to be some association between so-called "doggy" houses and typhus cases. The failure to associate ecto-

parasites (especially ticks) of dogs with man was against this view at the time. *H. leachi*, the preponderating species on dogs, had not been found to attack man in what was then believed to be an endemic area, and *R. sanguineus*, which was known to feed on man, was rarely recorded.

The results of transmission experiments carried out with ectoparasites collected from dogs, rodents and grass, were all against the virus being present in *R. pulchellus* and *H. leachi*.

(c) TICK INFESTATION OF HOUSES IN KENYA

On 15. viii. 1932 a house in Nairobi was reported as heavily tick-infested. When searched, nearly every room and the verandah of this house was found to harbour ticks in the corrugated iron and wooden supports, and crevices in the dry and cracked paint on iron. It was an old-type wood and iron bungalow supported on concrete plinths standing about 3 ft. from the ground. Unfortunately an attempt had been made to reduce the infestation by means of a blow lamp, but there was evidence that female ticks had been ovipositing recently, and many nymphs were moulting. The house had been vacant for some time and there were no signs of infestation of the premises by rats nor were rat runs observed in the garden. The present occupants had only been in possession a few days, and immediately on entering the house had been attacked by these ticks. It was eventually found that the previous tenants had kept dogs. All the ticks obtained were *R. sanguineus* (identified by Dr A. E. Lewis). This was the first house in Kenya which was found heavily infested with this tick.

As *R. sanguineus* transmits a typhus fever (Marseilles fever) in countries bordering the Mediterranean, and "Tick typhus of India" (Megaw), this tick was viewed with suspicion although scarce in our endemic area.

Intraperitoneal inoculations of a male guinea-pig with a few emulsified ticks obtained from the house above referred to gave a negative result.

(1) Mombasa

Result of searches in houses where tropical typhus had occurred.

During September, 1932, four cases of tropical typhus were reported from Mombasa, and an investigation was made possible of the houses and vicinity where three of the cases had occurred. *R. sanguineus* was found infesting the houses. This gave some assurance that this species would prove to be the vector of tropical typhus in Kenya.

House A. The person who contracted tropical typhus from this house was engaged in sedentary work at an office on the island of Mombasa. His dress was usually white drill (or beach) suits, and he was not in the habit of wearing shorts. He had not travelled from the island to any point on the mainland for some months. His house had only been built recently, from concrete blocks, and the garden was well kept, although during rainy periods there was a fair

amount of long grass in the neighbourhood. No rodents were trapped either in the house or garden. Dogs were kept, but were not admitted to any part of the house except the dining-room. A search of door frames, walls and furniture was made for any arthropods likely to attack the occupants. Ticks were found in the door frame and on the walls of the dining-room, the only room the dog was allowed to enter. The ticks obtained comprised three newly oviposited ♀, three newly emerged ♀ and many L and ♂ of *R. sanguineus*.

The patient stated (a) that he had suffered from numerous bites on his body and legs and attributed these to ticks, and (b) that the primary lesion had developed from one of these bites.

House B. This case had occurred in a new double-storeyed house built of stone, and situated on the sea-front in the lighthouse area of Mombasa. The neighbourhood is not overgrown with long grass and the immediate vicinity of the house is very well kept. The person who contracted the disease is frequently on safari, and occasionally wears shorts. He had numerous bites on the legs and body. One tick had been found lodged in the armpit, but he had failed to remove it until the third morning after observing it, the site eventually developing into the primary lesion.

No rodents were trapped, either on the premises or in the garden. Dogs were kept, but only allowed to remain on the front verandah and were usually kept in a wooden shed close by the house. The only arthropods obtained and likely to attack human beings were ticks from the front verandah and the wooden shed where the dogs were kept. Twenty-one *R. sanguineus* in various stages were obtained from the verandah alone.

House C. This is a wood and iron house occupied by a European police constable; the immediate neighbourhood is not overgrown with grass or a likely place to afford cover and abundant food for rodents. No rodents were trapped either in the house or garden. The person who contracted the disease is occasionally on safari, and wears the regulation police uniform, with shorts and puttees. Dogs were allowed to wander freely to all parts of the house.

His shoulders and knees showed numerous bites from some arthropod. Ticks were found in every part of the house, and also at the police station where he spent part of his time—they were obtained in the joints of floor boards and on the walls. The patient, whilst off duty, did little else than read, usually in a favourite deck chair on the verandah. The search in this favourite chair yielded about *seventy* ticks, obtained from those parts where the canvas had been tacked down to the wooden framework. The position of the ticks on the chair agreed with the bites on the shoulders and knees.

About a hundred *R. sanguineus*, in various stages, were obtained from the house and police station.

The result of the searches in Houses A-C, where tropical typhus had occurred in Mombasa, agree in that (a) dogs were kept on the premises,

(b) *R. sanguineus* was found in large numbers, this tick being the only arthropod likely to have bitten the patients, (c) all three patients definitely associated a tick bite with the site of the primary lesion.

These results pointed to the need of further investigation upon the rôle of *R. sanguineus* and the dog as vector and reservoir respectively.

(2) Nairobi

Continuation of work in the endemic area.

The work in the old endemic area of Kilimani was concentrated on collecting ticks from dogs or houses, and injecting an emulsion of the ticks into male guinea-pigs and rodents. The preponderance of *H. leachi* and the scarcity of *R. sanguineus* on dogs in the area and repeated negative results of inoculation with tick emulsions (those of *R. pulchellus* included) indicated that little was to be gained from such general surveys even in a recognised endemic area, and that work would be better confined to houses where cases had actually occurred.

(3) Naivasha

Investigation of district where five cases of tropical typhus had been reported from one house

An outbreak which had occurred in the Naivasha district appeared to offer some chance of success, although a long period had lapsed since the outbreak. A survey was made in the area, including a collection of rodents and their ectoparasites from buildings and the open, a search for ticks in houses and furniture, dogs and any game obtainable. All ectoparasites obtained were sent alive to the laboratory at Nairobi for inoculation purposes (all ticks and most of the fleas travel well in moistened earth in tubes).

Table IV gives the record of rodents and ectoparasites taken from them.

Table IV. *Rodents and their ectoparasites*

Farm A.

Rattus rattus kijabius. 6 ♂, 8 ♀; 7 taken from stores, 7 from native huts.

8 ♂, 14 ♀ *X. cheopis*; 3 ♀ *E. gallinacea*.

Arvicanthis abyssinicus. 10 ♂, 4 ♀; 6 from native huts, 8 in the open.

4 ♂, 4 ♀ *X. cheopis*; 2 ♀ *C. cabirus*; 5 ♂, 5 ♀ *D. lyppusus*.

Ticks: 26 ⊙ *R. simus*.

Farm B.

R. rattus. 3 ♀; from native huts. Not infested.

Arvicanthis. 4 ♂, 6 ♀; taken in the open.

1 ♀ *X. cheopis*; 3 ♂, 10 ♀ *C. cabirus*; 4 ♂, 4 ♀ *D. lyppusus*; 1 ♀ *D. longifrons*.

Ticks: 27 ⊙ *R. simus*.

Otomys angoniensis. 1 ♂ and 1 ♀; taken in the open.

2 ♀ *X. cheopis*; 4 ♀ *D. lyppusus*.

Farm C.

R. rattus. 4 ♂ and 9 ♀; from native huts.

2 ♀ *X. cheopis*; 1 ♀ *D. lyppusus*.

M. coucha. 1 ♂ and 1 ♀; from the open.

1 ♀ *List. dolosus*.

Table IV (continued)

Farm D.

R. rattus. 6 ♂, 2 ♀; 3 from stores, 3 from native huts.
 25 ♂, 14 ♀ *X. cheopis*; 6 ♂, 3 ♀ *X. brasiliensis*; 1 ♂, 3 ♀ *C. cabirus*.
Arvicanthis. 3 ♀; taken in the open.
 4 ♂, 1 ♀ *X. cheopis*; 3 ♂, 2 ♀ *C. cabirus*; 1 ♀ *D. lypusus*.

Farms E, F, G.

R. rattus. 5 ♂, 9 ♀; 9 from stores, 5 from native huts.
 21 ♂, 48 ♀ *X. cheopis*; 3 ♂, 1 ♀ *X. brasiliensis*; 2 ♀ *D. lypusus*; 5 ♂, 7 ♀ *List. dolosus*; 2 ♂, 6 ♀
E. gallinacea.
Arvicanthis. 14 ♂, 11 ♀; 2 from stores, 2 from native huts, 21 from the open.
 15 ♂, 19 ♀ *X. cheopis*; 8 ♂, 1 ♀ *C. cabirus*; 15 ♂, 42 ♀ *D. lypusus*; 1 ♂, 2 ♀ *List. dolosus*;
 4 ♀ *E. gallinacea*.

Ticks: 4 ⊙ *R. simus*.

Otomys. 1 ♂, 1 ♀; taken in the open.

3 ♀ *C. cabirus*.

The ticks obtained from dogs were as follows:

Farm	No. of dogs	Ticks collected
A	7	<i>H. leachi</i> 7 ♂, 6 ♀; <i>R. simus</i> 2 ♂, 6 ♀
B	6	<i>H. leachi</i> 3 ♀; <i>R. sanguineus</i> 3 ♀
C	3	<i>H. leachi</i> 8 ♂; <i>R. sanguineus</i> 1 ♂, 1 ♀
D	4	<i>H. leachi</i> 1 ♂, 7 ♀
E	9	<i>H. leachi</i> 7 ♂, 53 ♀, 21 ⊙; <i>R. sanguineus</i> 2 ♂, 8 ♀, 1 ⊙
F	3	<i>H. leachi</i> 7 ♂, 38 ♀, 5 ⊙; <i>R. sanguineus</i> 1 ♀; <i>Ix. pilosus</i> 1 ♂
G	1	<i>Ix. pilosus</i> 1 ♀

Farm B is the area where five cases of tropical typhus were contracted in February and March, 1932. On all farms, European and native owned dogs, if available, were searched.

No ticks were obtained from houses or furniture.

Experiments with material obtained at Naivasha

- Exp. 1.* *R. simus* 26 ⊙, taken from *Arvicanthis* on Farm A emulsified in 2 c.c. saline and inoculated intraperitoneally to male guinea-pig. Result negative.
- Exp. 2.* *R. simus* 27 ⊙, taken from *Arvicanthis* on Farm B emulsified, etc. as in *Exp. 1*. Result negative.
- Exp. 3.* *R. sanguineus* 3 ♂, 5 ♀ part fed, 5 ♀ and 1 ⊙ gorged, taken from dogs on Farms C, E and F were emulsified in 5 c.c. saline. 2 c.c. and 1 c.c. of emulsion inoculated as under *Exp. 1* to two male guinea-pigs respectively. Result negative.
- Exp. 4.* *H. leachi* collected from dogs on Farms A, C, D, E and F emulsified in 10 c.c. saline. 2 c.c. and 3 c.c. inoculated intraperitoneally to two male guinea-pigs respectively. Result negative.
- Exp. 5.* *H. leachi* 3 ♀ (gorged) taken from dogs on Farm B, and eggs from 1 ♀ were emulsified in 4 c.c. saline. 2 c.c. inoculated as before to male guinea-pig. Result negative.
- Exp. 6.* *R. sanguineus* 2 ♀ part fed and 1 ♀ gorged, taken from dogs on Farm B, and eggs from the gorged ♀ were emulsified in 4 c.c. saline. 2 c.c. inoculated as before to male guinea-pig at 11 a.m. on 13. xii. 32. On 19. xii. 32 scrotal swelling noted in the morning. The animal's temperature rose from 100.6° F. at 9 a.m. to 103.0° F. at 7 p.m. On 20. xii. 32 at 9 a.m., temperature 101.8° F. Pig killed. Each of three male guinea-pigs inoculated intraperitoneally with 1.5 c.c. testicular extract of previous pig. All failed to react.
- Exp. 7.* Made with emulsions of commoner fleas only: *X. cheopis* and *D. lypusus* using the total number collected from all farms. Emulsions from *cheopis* and *lypusus* respectively were inoculated to two male guinea-pigs. Result negative.

Although about 8 months had elapsed since the tropical typhus cases had occurred at Farm *B*, the guinea-pig of Exp. 6 showed a similar syndrome to that obtained by Dr Tonking after inoculating material from primary lesions in man. Our Exp. 6 yielded the first positive reaction obtained in guinea-pigs inoculated with emulsified arthropods.

(d) INVESTIGATION IN HOUSE WHERE A CASE OF TROPICAL TYPHUS HAD RECENTLY OCCURRED. SUCCESSFUL EXPERIMENTS WITH MATERIAL FROM THIS SOURCE

Tropical typhus case in Nairobi

Whilst the work with the Naivasha material was still proceeding, a case of tropical typhus was reported (23. xii. 1932) as having occurred at the new Railway Quarters, Nairobi.

The house and vicinity were immediately investigated. The house, very recently built, lies centrally in the inhabited railway area, at a considerable distance from grass or bush land. The district is not of the type where field rodents occur, the whole area being well supervised and built on model village lines. The house where the case occurred was well kept and clean. There were four children in the family.

The mother stated that she distinctly remembered removing ticks from the head and body of her six-years-old boy about 10 days before the rash appeared on his body. One of the sites on the head had developed into a nasty looking ulcer after removal of the tick. Other members of the family also had removed ticks from their persons on many occasions recently. The mother had removed a tick from her armpit after some difficulty. (This is the second report of a tick in the armpit, *vide* House *B*, Mombasa.)

A three-months-old dog was kept and the infected child habitually played with it. The parents declared that the dog was frequently "ticked," which appeared to be borne out by the search, as no engorged ticks were found. The dog was excluded from the house but frequently slept or rested on the verandah chairs, where the children most frequently played with it. The dog, when examined, yielded: *H. leachi* 1 ♂, *R. sanguineus* 2 ♂ 1 ♀ (part fed), 1 ⊙, and *Ix. pilosus* 3 ♀.

No ticks were found on the verandah chairs, but *R. sanguineus* were present on the door frame immediately above one chair and in crevices of the rough-cast verandah walls, 1 ♀ (newly emerged) and 14 ⊙ (gorged) being collected. No ticks were found on furniture or walls inside the house.

Exp. 1. 23. xii. 32. (2 p.m.) *R. sanguineus* 1 ♀, 12 ⊙, taken from house, were emulsified in 5 c.c. saline and 2 c.c. inoculated intraperitoneally to two male guinea-pigs respectively. Result: 28. xii. 32. (9 a.m.) Scrotal swelling was noted in both guinea-pigs. Temperatures 104° and 104.2° F. respectively. One of these pigs was killed and passages were successfully maintained in other guinea-pigs.

Exp. 2. 23. xii. 32. (2 p.m.) *R. sanguineus* 1 ♂, 2 ♀, 1 ⊙, taken from the dog were emulsified in 2 c.c. saline and inoculated to male guinea-pigs. Result negative.

The writer, working in collaboration with Dr H. D. Tonking, found that the reaction obtained from *R. sanguineus* in guinea-pigs is pathognomonic of tropical typhus, both clinically and histologically, and the virus when passaged to the other guinea-pigs also gives typical reactions (see Roberts and Tonking, 1933).

(e) DISCUSSION

The investigation of the fauna of an area where tropical typhus cases occurred frequently, together with a survey of arthropods attacking man, suggested that the possible vector of the disease would be *R. pulchellus*. Numerous inoculation experiments on guinea-pigs and rodents with emulsions from this species have, so far, proved negative. A reliable person who contracted a mild form of the disease recently, has, however, identified the male of *R. pulchellus* from amongst other species of ticks, as being similar to the one he removed from the site of his primary lesion.

Further work is necessary to determine the rôle of *R. pulchellus* in the transmission of one of the unclassified fevers known to occur in human beings resident in certain areas of Kenya. There is some suggestion that the *pulchellus*-transmitted disease is of a milder type than that usually associated with the recognised tropical typhus.

In one area, whence most of the Nairobi typhus cases have been reported, *R. sanguineus* has not been commonly found during most of the time in which this work was conducted. In each instance, however, when premises were investigated after cases had been reported, *R. sanguineus* was found, often alone and in large numbers. In Mombasa, *sanguineus* prevails in houses during the colder months, for no reports of tick-infested houses have been received following the onset of warm weather. In Nairobi, however, tick-infested houses have been reported in the cool months of the year or during cold periods associated with heavy rainfall.

Records of tropical typhus in Mombasa during 1930 and 1932 show that more cases were reported in August than for other months of the year, whereas, in Nairobi, the incidence is higher during the colder months.

It has now been confirmed that *R. sanguineus* is a vector of tropical typhus in Kenya. The inoculation of emulsions of this tick has on two occasions caused a syndrome in male guinea-pigs, similar to that obtained by Dr Tonking with material from primary lesions in man. A positive result was obtained on guinea-pigs by inoculation of emulsions of ticks taken from dogs in the Naivasha district. A positive result was likewise obtained with ticks taken from the walls of the house at Nairobi (see Exp. 1, p. 17), but not with ticks taken from the dog. That the dog serves as a reservoir of tropical typhus in Kenya has not been established satisfactorily.

Preliminary observations recently made on dogs in the area at Nairobi where infective *sanguineus* were obtained, showed that the dogs were heavily infested with *sanguineus*, but harboured comparatively few *H. leachi*. A reversal in the predominance of these tick species was observed during and

after the period when tropical typhus was reported in the above-mentioned area, and also in other districts such as Kilimani. Quite a large proportion of ticks taken from dogs in Nairobi were *R. sanguineus*, and specimens have also been collected in houses where persons have not contracted the disease.

These observations concerning the maximum seasonal incidence of *R. sanguineus* suggest that the number of these ticks stands in relation to the periodical increase of tropical typhus cases in townships.

Following reports that a house was heavily infested with ticks, the premises were visited on 13. i. 1933. A dog was usually chained to a post on the front verandah. No ticks were found on the dog or where it rested. The dog was well cared for and rid of ticks regularly. The infestation complained of concerned the back verandah and kitchen, whence, according to the occupiers, the dog was excluded. The kitchen stands out from the house. Ticks were particularly numerous near the kitchen stove, fewer and fewer being found as the search was extended away from this source of warmth. A few ticks were taken from holes and cracks in the furniture. All the ticks obtained were *R. sanguineus* (5♂, 19♀, 3○—the last two stages were engorged).

Obviously the engorged females had dropped from the host and sought shelter and warmth prior to oviposition. The house tenants, who had been in occupation for some time, stated that they had not been worried by ticks until the heavy rains of December and January occurred.

The following rainfall and temperature records made at an observation station situated about 150 yards away from the house, indicate the unseasonable character of weather which prevailed at the time of the tick invasion, this time being usually regarded as the hottest and driest period of the year.

	Rainfall in.	Spread over
Dec. 1931	1.86	10 days
„ 1932	8.56	12 „
Jan. 1932	2.74	7 „
„ 1933*	3.45	9 „

* (Up to Jan. 18 only.)

The average rainfall (in inches) for this area is 2.39 for December (recorded over 15 years), and 1.57 for January (recorded over 16 years).

	Average temperature in ° F.		Monthly average
	Maximum	Minimum	
Dec. 1932	72	56	64
Jan. 1933	72	54	63

The average temperature for the whole year, in ° F. is 67.5, ranging between max. 79 and min. 56.

The variation in temperature and the wet nature of the ground had apparently led to the female ticks wandering to a more favourable spot for purposes of oviposition.

Preliminary observations indicate that periods of heavy rainfall and cold cause unfed *R. sanguineus* in all stages to wander in search of a host and

shelter; this may lead them to attack human beings in the absence of their regular host, the dog, especially when they find shelter and warmth in houses.

These observations appear to explain the marked seasonal incidence of tropical typhus in Kenya and they accord with known facts concerning its periodic occurrence in different areas. Tonking states that the disease "is commonest at the end of and just after the rains, which means it is a malady associated with, among other things, the increase of surface water and grass."

A detailed search conducted on all cattle grazing in areas whence typhus cases are most frequently reported, has shown that some herds are almost entirely tick free, whilst other herds living under apparently identical conditions are heavily infested, and in spite of the dense infestations of ticks experienced in houses, no *R. sanguineus* have so far been obtained from these cattle.

Clean or tick-infested conditions observed in different herds of cattle are attributable to differences in cattle owners. Somali-owned cattle were invariably tick free, whilst all the Indian-owned were heavily infested. Somali owners largely rid their herds of ticks by hand-picking, whilst the Indian makes no attempt to destroy or even remove ticks.

(f) SUMMARY

1. Earlier attempts to trace the vector of tropical typhus in Kenya failed. The only references to the subject in the available literature consist of mere suggestions that a mite would most likely prove to be the transmitter.

2. An investigation made in an area whence most Nairobi cases of tropical typhus were reported, suggested that a tick (*R. pulchellus*) would be the most likely vector.

3. Transmission experiments made in the belief that one of the unclassified fevers of man was conveyed by *R. pulchellus* have so far yielded negative results. There is, however, sufficient circumstantial evidence available pointing to this tick as vector of a form of mild typhus to man—this demands further investigation.

4. At Mombasa and Nairobi, houses reported to be heavily infested with ticks, or houses investigated after the occurrence of the tropical typhus in them, have yielded only *R. sanguineus*.

5. *R. sanguineus* (3♀), taken from a dog in a house where the last typhus case had occurred 8 months previously, gave a typical typhus syndrome when emulsified and inoculated into a male guinea-pig. *R. sanguineus* (1♀, 12♂), taken in a house where a child had recently contracted typhus, also gave a positive result with guinea-pigs and the virus was further transmitted by passage through other guinea-pigs.

6. The infestation of houses by *R. sanguineus* and the incidence of tropical typhus among human beings appear to be influenced by unfavourable weather conditions, causing the ticks to seek relatively dry and warm places for purposes of oviposition or metamorphosis, thus invading houses. In the absence of dogs, its usual hosts, the tick attacks man.

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(h) ADDENDUM

As a result of this investigation and the prevalence of tropical typhus among the employees of the Kenya and Uganda Railways and consequent disorganisation of staffing arrangements following the long convalescent period which resulted from this disease, observations have been made on the infestation of houses by ticks. Mr A. R. Dick, Sanitary Inspector, has kindly supplied the following data, summarising the results of his surveys. It is significant that when a thorough investigation had been made, following on the lines indicated in previous work, the results have consistently supported the view that *R. sanguineus* is a far greater danger than was ever previously imagined, and it has revealed a state of affairs which had been considered as non-existent or rare.

In each instance, *R. sanguineus* alone was found to be the tick infestating houses.

No. of house	Infestation with ticks		Furniture infested	Dogs kept
	Heavy	Light		
19	Yes	—	Yes	Yes
29	Yes	—	Yes	Yes
29a	—	Yes	No	Yes
18	Yes	—	Yes	Yes
31	—	Yes	Yes	Yes
31a	—	Yes	No	Yes
15	Yes	—	Yes	Yes
16	—	Yes	No	Yes
5J	Yes*	—	Yes*	Yes
6	—	Yes*	—	Yes
11	—	Yes†	—	Yes
12	Yes†	—	—	Yes
D	Yes	—	Yes	Yes
Da	Yes	—	Yes	Yes
I	Yes	—	Yes	Yes
18	Yes†	—	—	Yes
24	—	Yes	No	Yes
Miscellaneous		16	No	Yes

* Very heavy.

† Servants' quarters only.

Number of houses heavily infested, 10.

„ „ slightly infested, 23.

„ „ that keep dogs and infested, 100 %.

Each dog or dogs in infested houses were examined at the time of inspection, and every dog was found to be heavily infested with *H. leachi* and *R. sanguineus*.

The procedure adopted by Mr Dick in disinfesting houses has been as follows, and the method has proved to be very successful. The incidence of typhus among the staff of the K.U. Railways has also diminished considerably since these control measures were instituted.

(a) Warn the occupants of the danger of contracting disease if dogs are not kept free from ectoparasites and in a clean condition. Ticks when removed should be burned and not thrown into the garden.

(b) If the house is heavily infested, the skirting boards and picture rails are removed. Picture rails are generally found to harbour a dense infestation of larvae and eggs.

(c) All the walls, especially crevices and door supports, are burnt over with a blow lamp.

(d) The walls are then sprayed with a mixture of liquid soap, paraffin and water.

(e) Next day, the furniture is stored in one room, covered over by a carpet to form a canopy, and then exposed to HCN gas (Zyklon) for a period of 4 hours.

(f) The house is inspected at short intervals for a month and if no fresh invasion is noted, the picture rails, etc., are replaced.

The blow lamp has proved the best and cheapest method in use against ticks in houses, as it strikes directly at the seat of infestation in the picture rails and wall crevices.

Similar results were obtained by Mr Dick during a survey of houses at Mombasa, where about 90 per cent. of the residences were inspected.

House no. Mombasa	Infestation with ticks		Furniture infested	Dogs kept
	Heavy	Light		
28	Yes	—	Yes	Yes
42	Yes	—	Yes	Yes
62	—	Yes	No	Yes
38	—	Yes	No	Yes
89	Yes	—	No	Yes
31	Yes	—	Yes	Yes
6	Yes	—	Yes	Yes
8	Yes	—	Yes	Yes

Number of houses heavily infested, 6.

„ „ lightly infested, 2.

„ „ that keep dogs and infested, 100%.

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