the family, the somewhat uncertain position of *Seioptera* would not affect the names of either *Ulidiinae* (*Ulidiidae*) or *Ceroxydidae*, and a continuity of concept would be maintained for the well known 'Ortalidae' of authors.''

Considering all the complications, it is believed that Mr. Steyskal's proposed name is the simplest and most direct solution to the problem. It has therefore been recommended that *Musca urticae* Linnaeus be declared the type of *Ortalis* Fallén, either by accepting type by elimination (Hendel's argument), or by suspending the Rules to suppress Westwood's designation of *vibrans*, and thereafter to designate *urticae* as type of *Ortalis*. Since *Ortalis* Fallén is preoccupied, and since it would be isogenotypic with *Ceroxys* Macquart under these actions, the latter name would then replace *Ortalis* and the family name would become Ceroxydidae (= Ortalidae of authors and also Ortalidae *sensu strictu*).

Undoubtedly, many other complex situations exist in the class Insecta and elsewhere. Eventually, the difficult cases would probably come to light and be decided, each on its own merits. It is believed, however, that the prompt initiation of a comprehensive effort to discover and settle the problems and to organize an ''Official List of Family Names in Zoology'' would be a real contribution to stability and an orderly nomenclature.

THE VECTORS OF TSUTSUGAMUSHI DISEASE

By Lt. G. W. Wharton H(S) USNR,[1] *U. S. Naval Medical Research Unit No. 2*

Tsutsugamushi disease is caused by a rickettsia that is carried to man by certain larval mites, chiggers, of the family Trombiculidae. The disease has been found on the mainland of southern Asia and northern Australia and the islands that lie between them. As a result of the military campaigns recently completed in these areas, tsutsugamushi disease became important to Americans. Womersley and Heaslip (1), Farner and Katsampes (2), Ewing (3), and Blake *et al.* (4) present a splendid review of the available literature on the disease and the trombiculid mites that occur in the areas from which the disease has been reported.

A study of specimens of most of the species of trombiculids known from areas where tsutsugamushi disease is endemic was

[1]On military leave from Duke University.

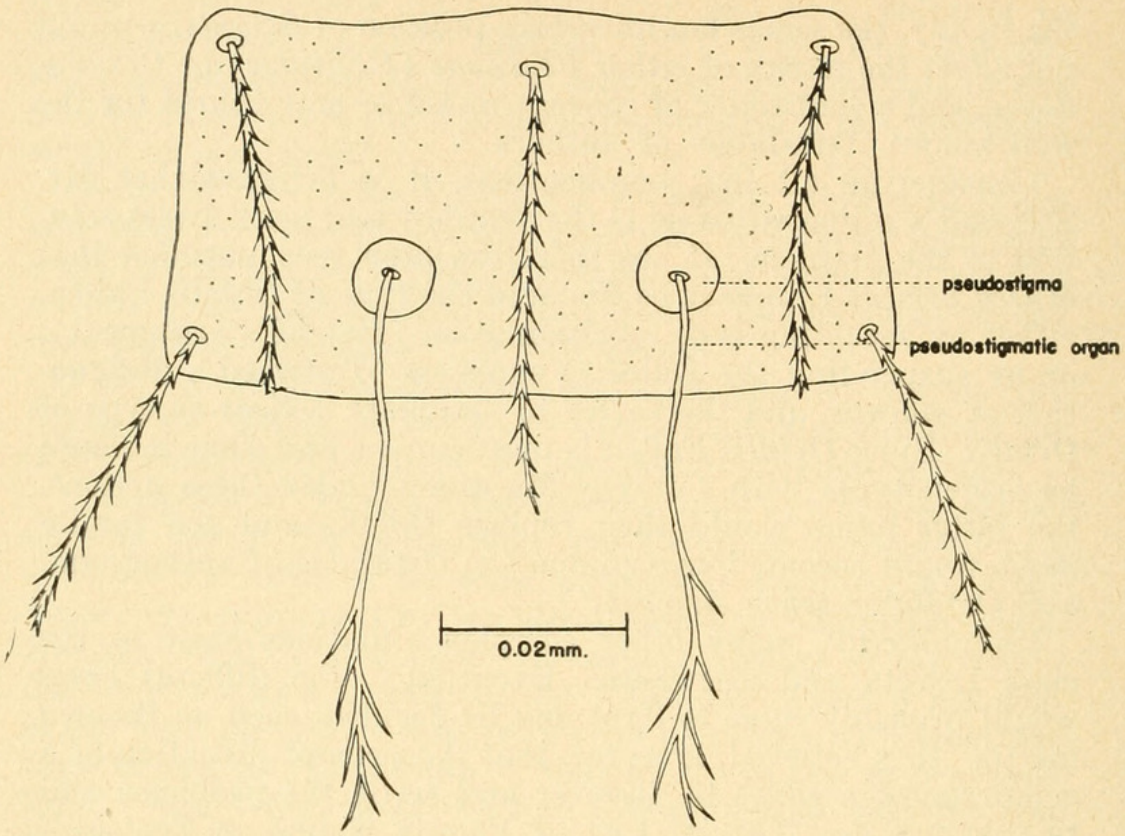

Figure 1. Scutum of *Trombicula akamushi* (Brumpt 1910).

greatly facilitated by the directors and staffs of the South Australian Museum, Australian Museum, School of Public Health and Tropical Medicine University of Sydney, and the U. S. National Museum. The two eminent authorities on the Trombiculidae Dr. H. E. Ewing and Mr. H. Womersley were particularly helpful. During the course of the study, it soon became apparent that only a few of the many species were known to be involved in the transmission of the disease and that these few species were all closely related.

Nagoya *et al.* (5) pointed out that there were five species of chiggers on the ears of voles in areas in northwestern Japan that were known commonly as "tsutsugamushi." They described these carefully and included them in a tsutsugamushi group without defining the limits of the group. Walch (6) in an English version of his 1922 Dutch paper in which he described *Trombicula deliensis* pointed out that it definitely belonged to the tsutsugamushi group. In 1924 Walch (7) described a second species, *Trombicula keukenschrijveri,* that he also placed in the tsutsugamushi group. Subsequent authors ignored the existence of this group. The tsutsugamushi group as here defined are mites of the genus *Trombicula* that have larvae with a lightly pitted, rectangular or nearly rectangular scutum (Figure 1); palpi with a feathered seta on segment

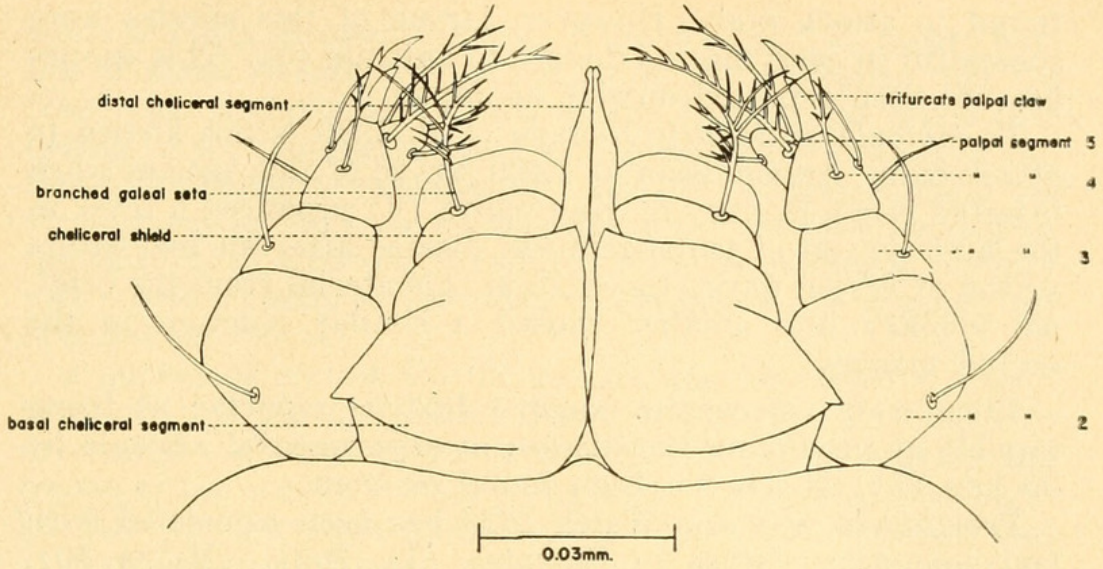

Figure 2. Gnathosoma of *Trombicula akamushi* (Brumpt 1910).

one, a nude seta on the dorsal aspect of segment two, a nude seta on the dorsal aspect of segment three, a feathered seta on the dorsal aspect of segment four, a nude seta on the lateral aspect of segment four, a nude seta on the ventral aspect of segment four, and several setae on segment five; chelicerae with a lateral angular expansion on the basal segment; and feathered galeal setae on the cheliceral shields (Figure 2).

Of the many species of trombiculid mites described, the only species that can definitely be placed in the tsutsugamushi group as here defined are: *Trombicula akamushi* (Brumpt 1910), *Trombicula pallida* Nagayo *et al.* 1919, *Trombicula scutellaris* Nagayo *et al.* 1919, *Trombicula intermedia* Nagayo 1920, *Trombicula deliensis* Walch 1922, *Trombicula fletcheri* Womersley and Heaslip 1943, *Trombicula obscura* Womersley 1944, and *Trombicula fulleri* Ewing 1945.

Trombicula akamushi (Brumpt 1910) is reported by Nagayo *et al.* (5) to be the only species that carries the disease to man in northwestern Japan. Rickettsia that are the same as those which cause tsutsugamushi disease in man have been recovered from this species and the ability of the larva to infect experimental animals by its bite has been demonstrated (5). *T. akamushi* is recognized as the vector in Formosa and the Pescadores Islands (2). In the Federated Malay States Gater (8) reports *T. akamushi* as common on man and probably the principal vector of tsutsugamushi disease in that area. Specimens from Malaya labeled *T. akamushi* were described as a new species *T. fletcheri* by Womersley and Heaslip (1). A specimen from Gater in the U. S. National Museum is the same as *T. fletcheri.*

Trombicula pallida Nagayo *et al.* 1919 has infrequently been

found to attack man. However, larvae of this species were successful in carrying the disease to animals (5). This species has not been reported outside of Japan.

Trombicula scutellaris Nagayo *et al.* 1919 is not known to attack man. An emulsion of 1,400 larvae of this species when injected into a monkey by Kawamura (9) produced a fever in the host typical of tsutsugamushi disease after an incubation period of fifteen days. Inoculation of material from the original monkey into another caused a similar reaction in the second monkey.

Trombicula intermedia Nagayo 1920 is reported as being capable of producing the disease in experimental animals by its bite (5). It has not been found on man.

Trombicula deliensis Walch 1922 has been associated with tsutsugamushi disease in Sumatra (7), India (Mehta 10), Australia (Heaslip 11), Malaya (8), New Guinea (Kohls *et al.* 12), and Bat Island (Philip and Kohls 13). Under the synonym (13) *Trombicula walchi* Womersley and Heaslip 1943, *T. deliensis* was shown to harbor the rickettsia of tsutsugamushi disease in New Guinea (12). Philip and Kohls (13) also found the rickettsia in *T. deliensis* from Bat Island which is south of the Admiralty Islands.

Trombicula fletcheri Womersley and Heaslip 1943 has been reported from Malaya where it was originally confused with *T. akamushi* (see above), and from New Guinea. Blake *et al.* (4) recovered strains of rickettsia from *T. fletcheri* that were found to be identical with strains from human cases of tsutsugamushi disease. *T. fletcheri* is considered by them to be an important vector in New Guinea.

Trombicula obscura Womersley 1944 occurs in New Guinea where tsutsugamushi disease is also present.

Trombicula fulleri Ewing 1945 is reported from Burma. Tsutsugamushi disease has been found in Burma (2) but Ewing's (14) record is the first of a trombiculid mite from Burma that belongs to the tsutsugamushi group.

It has been suggested (5) that the species in Japan that carry the disease to animals but not to man, may be important in maintaining a high level of infection in the vertebrate "reservoir" host. It should be mentioned here that no reservoir host has yet been demonstrated for tsutsugamushi disease. Animals have been found that harbor rickettsia by Kohls *et al.* (12) that are identical with those that produce the disease in man, but it has never been demonstrated that a larval mite can become infected by biting a host that harbors the rickettsia. On the other hand it was shown by Miyajima and Okumura (15) that larvae transmit the disease the first time that they attempt to feed. Presumably the rickettsia are passed from

adult to larva through the egg. Nagayo *et al.* (5) report having obtained rickettsia from the adult. It is possible that the free-living nymphs and adults of the trombiculid mites that belong to the tsutsugamushi group pick up the rickettsia and that the infected vertebrates are incapable of transmitting the virus to the larvae or are unnecessary for the maintenance of the rickettsia. However, available evidence points to cricetid and murid rodents as the main reservoirs of the disease, but it is not conclusive.

A survey of certain Pacific islands was conducted by members[2] of U. S. Naval Medical Research Unit No. 2 in order to determine the distribution of trombiculid mites. During the course of the survey certain areas were investigated thoroughly. At Cape Torokina, Bougainville Island three endemic foci of tsutsugamushi disease were found. All of them were outside the area held by American forces in 1944, but were within the area covered by patrol activity. Within the occupied area trombiculid mites were common. *Schöngastia blestowei* Gunther 1939 was a pest and frequently produced scrub-itch. Opportunity was afforded to examine one of the foci of infection when a road block was established at the mouth of the Jaba River. At this location where many cases of tsutsugamushi disease had been contracted (Anderson and Wing 16), the rats were heavily infested with a subspecies of *Trombicula deliensis* that typically has a bifurcate rather than trifurcate palpal claw. At Guiuan, Samar, Philippine Islands tsutsugamushi disease was widespread as were murid rodents which carried large numbers of a local representative of *Trombicula deliensis* in their ears. Ponam, a small island in the Admiralty group where numerous cases of tsutsugamushi disease had been contracted was visited after vigorous control measures had halted the appearance of new cases. The only species of trombiculid found was *Eutrombicula buloloensis.* No reports of tsutsugamushi disease on Guam, Rota, Okinawa, Iwo Jima, Ulithi, Peleliu, Truk, or Guadalcanal were found. While trombiculid mites were collected on all these islands, none belonged to the tsutsugamushi group.

Gunther (17) suggested that *Eutrombicula buloloensis* (Gunther 1939) might be the vector of tsutsugamushi disease in New Guinea. Blake *et al.* (4) and Kohls *et al.* (12) could find no evidence in support of this theory, and the fact that the prevalence of scrub-itch caused by the attachment of the larvae of *E. buloloensis* and *Schöngastia blestowei* was not associated with the prevalence of tsutsugamushi fever seems to

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deny the validity of Gunther's suggestion. Walch and Keukenschrijver (18) reported *Schöngastia schüffneri* (Walch 1922) as a vector since they found the typical primary eschar of tsutsugamushi disease at the site on a laborer where they had previously collected a specimen of *S. schüffneri*. *S. schüffneri* is closely related to *S. blestowei* and epidemiological evidence presented by Walch and Keukenschrijver (18) indicates that its activities are similar to those of *S. blestowei*. In other words there was no correlation between the prevalence of *S. schüffneri* and prevalence of tsutsugamushi disease.

There are several other species of trombiculids that are closely related to the tsutsugamushi group and one which may in reality belong to it. However, no evidence is available indicating that they are involved in the transmission of the disease. *Trombicula keukenschrijveri* Walch 1924 is incompletely known. Walch (7) had only a single specimen from Sumatra, while Gater (8) found only three in Malaya. Gater (8) reports that the pseudostigmatic organs of all specimens were broken off, therefore the generic position of this species is in doubt since the type of pseudostigmatic organs is one of the most important generic characters of the trombiculids. The setae on the palps and cheliceral shields are like those of the tsutsugamushi group, but two of the setae on palpal segment four have not been described so their character remains in doubt. *Trombicula palpalis* Nagayo *et al.* 1919 was included in the tsutsugamushi group originally. It does not fit into the group as here defined because it has a feathered ventral seta on palpal segment four instead of a nude ventral seta. *T. palpalis* is the only species of the original tsutsugamushi group from which rickettsia have not been reported. *Trombicula japonica* Tanaka 1916, *Trombicula californica* Ewing 1942, and *Trombicula microti* Ewing 1928 comprise a "japonica" group that is close to the tsutsugamushi group. *Trombicula burmensis* Ewing 1945 is also close to the tsutsugamushi group but different from it in type of palpal setae.

In certain areas tsutsugamushi disease is known to be endemic but surveys for the vectors have not yet been made. The disease is known from Java, but no certain records of mites of the tsutsugamushi group are known. It is interesting though that Womersley obtained a slide of *Trombicula deliensis* from Java. No collection data were on the slide, however, so the locality from which the specimen came is unknown. As far as can be determined no trombiculid mites of any kind are known from Ceylon, the Maldive Islands,[3] China, or Indo-China where tsutsugamushi disease is endemic (2). Trombi-

[3]Radford, 1946, Parasitology 37:46-54, reports *T. deliensis* from Ceylon and the Maldive Islands.

culid mites have been collected from from Borneo and Celebes. Although tsutsugamushi disease occurs in these islands no mites of the tsutsugamushi group have yet been found. Walch (19) collected trombiculid mites from rats near Macassar in Celebes. Farner and Katsampes (2) report that the area where tsutsugamushi disease is found is around Minahassa at the opposite end of the island from Macassar. Species from Borneo were all collected on a mouse deer and are discussed by Gunther (20).

The material in this paper can be summarized in a few general statements. The rickettsia that cause tsutsugamushi disease have been recovered from mites that belong to the tsutsugamushi group and from no other mites. In areas where trombiculid faunas are well known tsutsugamuchi disease has been found associated with mites of the tsutsugamushi group. In many areas where the disease does not occur, no mites of the tsutsugamushi group have been found. For these reasons it is suggested that mites of the tsutsugamushi group may be the sole vectors of tsutsugamushi disease. It is realized that this hypothesis still remains to be proved, but the evidence indicates that mites of the tsutsugamushi group play the same role in the transmission of the disease that is taken by anopheline mosquitoes in the transmission of malaria.

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