ACARINE PARASITES OF MOSQUITOES. II. ILLUSTRATED LARVAL KEY TO THE FAMILIES AND GENERA OF MITES REPORTEDLY PARASITIC ON MOSQUITOES[1]

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ABSTRACT. An illustrated larval key to all families and genera of mites known or suspected as being parasitic on mosquitoes is provided. These include members of the terrestrial families Erythraeidae, Trombellidae, Trombidiidae and Johnstonianidae as well as 15 genera of aquatic mites. Each group is discussed with respect to known hosts and probable validity as mosquito parasites.

In a previous paper concerning the parasitism of mosquitoes by mites, a review of all known host records and their geographic distribution was presented (Mullen, 1974a). Many of the recorded cases involve mites of unknown identity, and many determinations are questionable. In some instances unfortunate misinterpretations have been made concerning mites, their true host ranges, and the nature of their parasitic relationship with mosquitoes. For any record to be of value it is imperative that a reliable determination of the mite, at least to family and genus, be made.

The following larval key has been prepared as an aid in the identification of the families and genera of mites known or suspected of being mosquito parasites. The basic structures of water-mite larvae are presented in Figure 1. An effort has been made to minimize the use of technical terminology so that the key can be used by individuals without previous experience in the identification of mites. Where certain morphological terms are unavoidable they are illustrated in the respective figures. Unless otherwise stated, all illustrations are original.

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[3] Refer to text for means of separating the two most common species in U.S., *Thyas barbigera* and *Thyasides sphagnorum*.

Larval mites which run about on the water surface or on land in search of a host are referred to as aerial or terrestrial larvae. Those which swim beneath the water surface are called aquatic larvae.

To use this key the mites must first be removed from the mosquito host and, because of their small size (usually less than 0.25 mm when unengorged), they should be slide-mounted in Hoyer's medium or some comparable medium for examination under a compound microscope. The use of phase contrast is recommended but not essential. See Mullen (1974b) for details concerning methods of collecting and preparing larval mites for identification, as well as techniques for rearing such mites for further study.

ILLUSTRATED LARVAL KEY TO THE FAMILIES AND GENERA OF MITES REPORTEDLY PARASITIC ON MOSQUITOES

1. Legs usually 6-segmented, excluding coxal plate, with femur divided into a basifemur and telofemur (Fig. 2); if 5-segmented, coxal plates 1 to 3 each separate from one another (Fig. 15B) *and* swimming hairs absent (terrestrial or aerial larvae) 2

   Legs 5-segmented, excluding coxal plate (Fig. 3). Coxal plates 1 to 3 exhibiting various degrees of fusion or may be completely separate from one another. Swimming hairs usually present (Fig. 3); if absent, coxal plates 2

and 3 at least partially fused together 9

2. Urstigma present between coxal plates 1 and 2 (Fig. 1B) 3

Urstigma absent between coxal plates 1 and 2. Dorsal plate usually bearing five pairs of setae, including two median pairs of sensilla (recognized by their enlarged basal sockets) (Figs. 10,-13) .....ERYTHRAEIDAE

3. Tarsi 2 and 3 each with a single claw (empodium) 4

Tarsi 2 and 3 each with two or three claws 8

4. Dorsal plate bearing one to three pairs of setae; all dorsal setae posterior to dorsal plate borne on small or inconspicuous platelets (Figs. 5,9).....5

Dorsal plate bearing four pairs of setae; remaining dorsal setae borne on large platelets (Fig. 12) ..... (THYASIDAE)..6

5. Dorsal plate bearing two pairs of setae; anterior two pairs of dorsal setae borne on a pair of moderate sized platelets flanking the dorsal plate anteriorly (Fig. 8). Cheliceral bases may be marked by conspicuous longitudinal striations (Fig. 9) HYDRYPHANTIDAE, *HYDRYPHANTES*

Dorsal plate bearing one (Fig. 23) or three pairs of setae. Cheliceral bases without longitudinal striations (Fig. 5) HYDRODROMIDAE, *HYDRODROMA*

6. Palpal tarsus (P5) short, terminating in three feather-like setae. Tibial claw of palp conspicuously bifid. Anterior pair of eyes noticeably larger than posterior pair ..... *EUTHYAS*

Palpal tarsus (P5) elongate and not terminating in three feather-like setae. Tibial claw of palp simple or bifid. Anterior pair of eyes not noticeably larger than posterior pair 7

7. Palpal tarsus (P5) extending only slightly beyond palptibial claw; P5 without broadly flattened, serrate seta; palpgenu (P3) may bear a trifurcate seta distally (Fig 4) ..... *PANISOPSIS*

Palpal tarsus (P5) extending well beyond palptibial claw; P5 bearing two large, broadly flattened, serrate setae; palpgenu (P3) without a trifurcate seta distally (Fig. 6) .....*THYAS* and *THYSASIDES*[3]

8. At least two median dorsal plates (scutum + scutellum) present (Figs. 14, 15A) ..... TROMBIDIIDAE

Only a single median dorsal plate (scutum) present (Fig. 11); this plate often characterized by an anteromedian projection or nasus (Figs. 24, 26, 27) TROMBELLIDAE and *JOHNSTONIANIDAE*

9. Coxal plates 1 to 3 separated from one another by membranous areas or sutures (Figs. 17, 25).....10

Coxal plates 2 and 3 on each side fused together (Figs. 18, 19, 21) *or* C2 only partially fused with C3 but together separated from C1 (Figs. 16, 20) ..12

10. Gnathosoma greatly enlarged and almost as wide as remainder of body (Fig. 17) ..... HYDRACHNIDAE, *HYDRACHNA*

Gnathosoma not greatly enlarged in comparison to rest of body 11

11. Body (idiosoma) circular in outline and covering most of gnathosoma dorsally (Fig. 22). Dorsal plate round to ovoid without anterior constriction. Long seta on palpal tarsus extending posteriorly little if any beyond base of the gnathosoma MIDEIDAE (*MIDEA*) and MIDEOPSIDAE (*MIDEOPSIS*)

Body (idiosoma) more ovoid in outline and not covering gnathosoma dorsally. Dorsal plate roughly drop-shaped with distinctly narrower, truncate anterior end (Fig. 1A). Very long seta on palpal tarsus extending posteriorly well beyond base of gnathosoma (Fig. 25) ..ARRENURIDAE, *ARRENURUS*

12. Coxal plates 1 to 3 on each side fused together (Figs., 18, 21).....13

Coxal plate 1 only partially fused or completely separate from C2-3 (Figs. 16, 19, 20) 14

13. Suture lines between coxal plates present (Fig. 21) .....LIMNESIIDAE, *LIMNESIA*

Suture lines between coxal plates not apparent (Fig. 18) ..... HYGROBATIDAE, *HYGROBATES*

14. Two pairs of setae situated on coxal plate 3 near or on its posterior margin (Fig. 19). Legs usually lacking swimming hairs .....LEBERTIIDAE, *LEBERTIA*

Two pairs of setae not situated on coxal plate 3 near its posterior margin (Fig. 20). Swimming hairs present .....(PIONIDAE)..15

15. Excretory plate with median pair of setae located on posterior half of plate (Fig. 29) ..... *PIONA*

Excretory plate with median pair of setae located on anterior half of plate (Fig. 28) 16

16. Suture line between coxal plates 2 and 3 extending nearly to median margin (Fig. 20) .....*HYDROCHOREUTES*

Suture line between coxal plates 2 and 3 not extending close to median margin (Fig. 16) ..... *TIPHYS*

Only four families of terrestrial mites have been reported from mosquitoes, (Fig. 2-29), Erythraeidae, Johnstonianidae, Trombellidae and Trombidiidae. All are members of the suborder Prostigmata (Parasitengona). With a few possible exceptions, these mites seem to be infrequent or incidental mosquito parasites for which very few records are known. As is the case with all other groups of mites associated with mosquitoes, it is only the larval stage which is actually parasitic. The nymphs and adults are typically free-living predators.

The Erythraeidae are ectoparasites of a

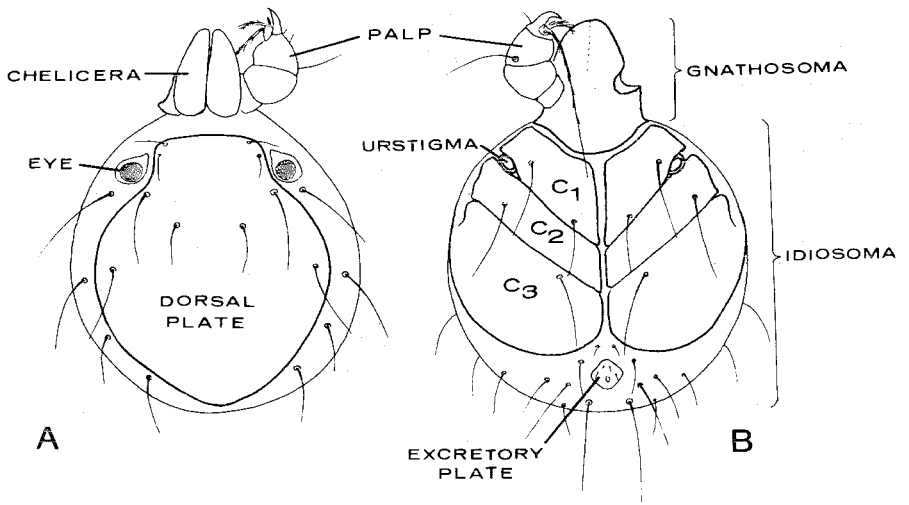
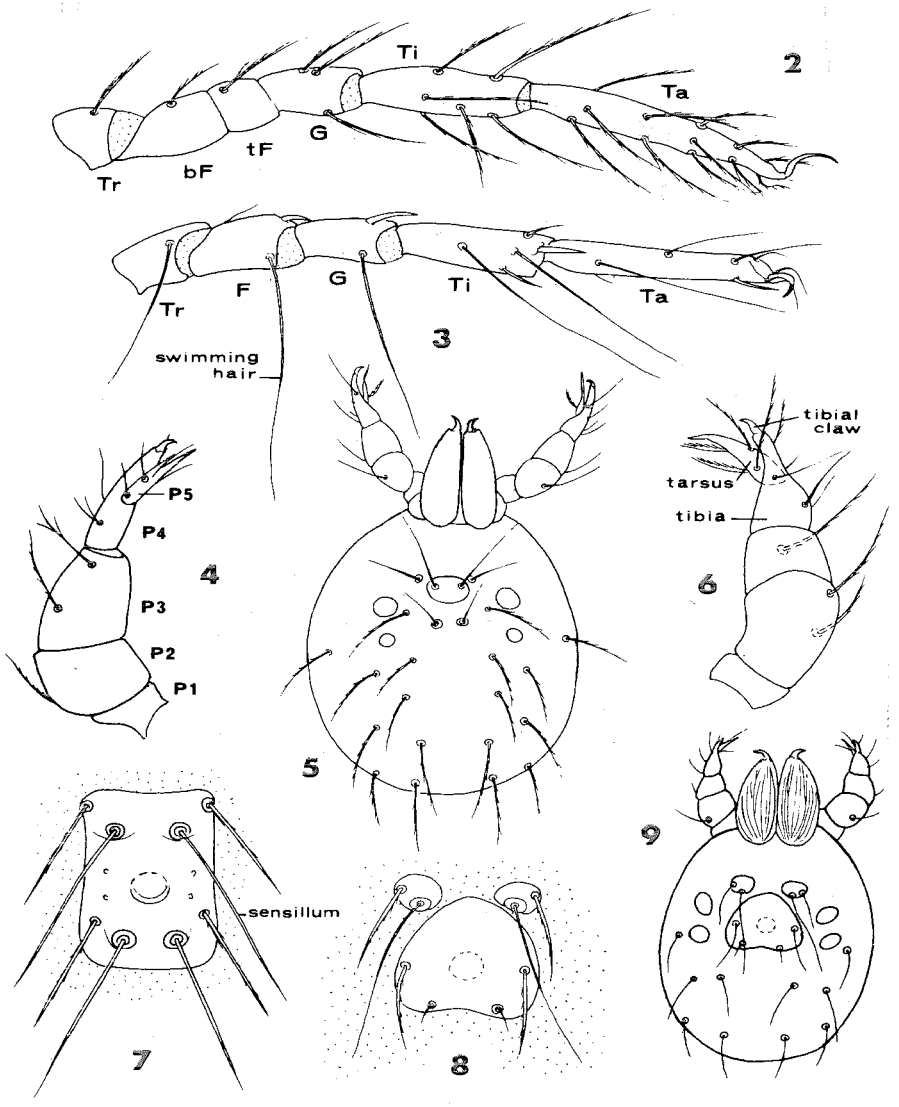
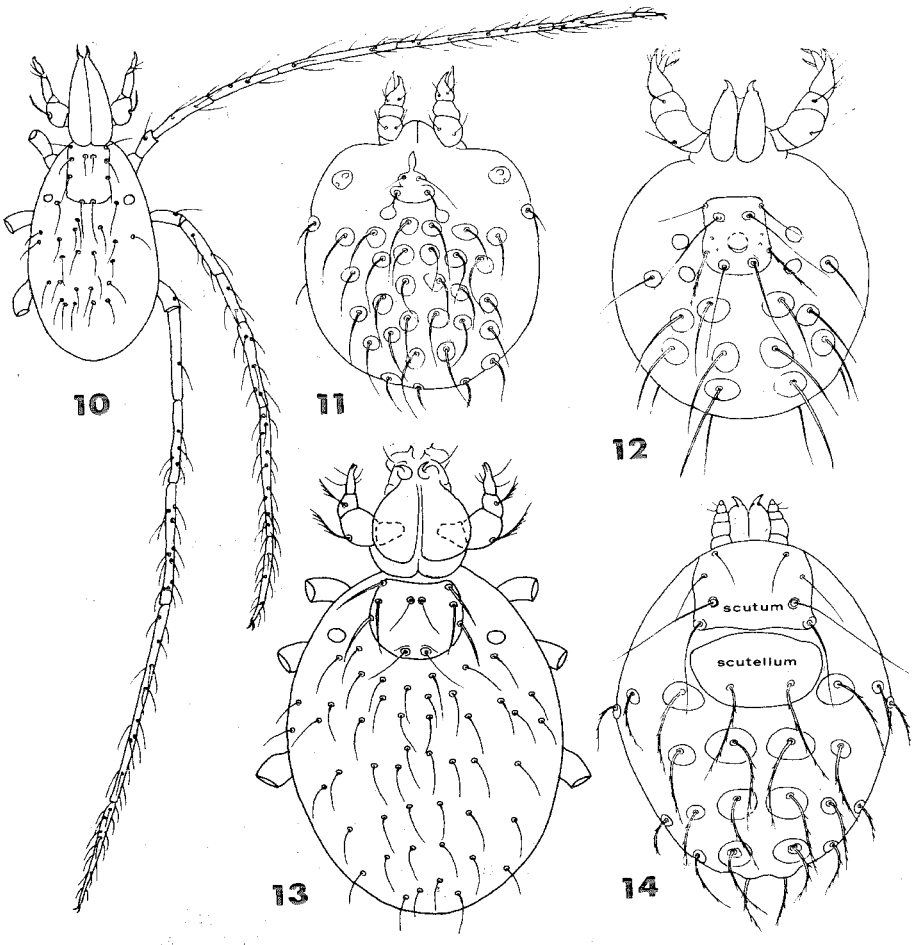


FIG. 1. General external morphology of a water-mite larva. A. Dorsum. B. Venter. The body is divided into two major regions, the gnathosoma comprised of the chelicerae, palps and their associated structures, and the body proper or idiosoma. The urstigma is a variously shaped structure situated between coxal plates 1 and 2, believed to serve as a humidity receptor. C_{1-3}, coxal plates.



FIGS. 2–9. Water-mite larvae. 2. *Thyas* sp., Leg 3. 3. *Arrenurus* sp., Leg. 3. 4. *Panisopsis* sp., palp. 5. *Hydrodroma* sp., dorsal view. 6. *Thyas* sp., palp. 7. *Thyas* sp., dorsal plate. 8. *Hydryphantes* sp., dorsal plate. 9. *Hydryphantes* sp., dorsal view. bF, basifemur; F, femur; G, genu; P_{1-5}, palpal segments; tF, telofemur; Ta, tarsus Ti, tibia; Tr, trochanter.



FIGS. 10–14. Larval mites, dorsal views. 10. Erythraeidae (*Callidosoma* sp.). 11. Johnstonianidae (*Centrotrombidium* sp.). 12. Thyasidae (*Thyas* sp.). 13. Erythraeidae (*Charletonia* sp.). 14. Trombidiidae (*Feiderium* sp.).

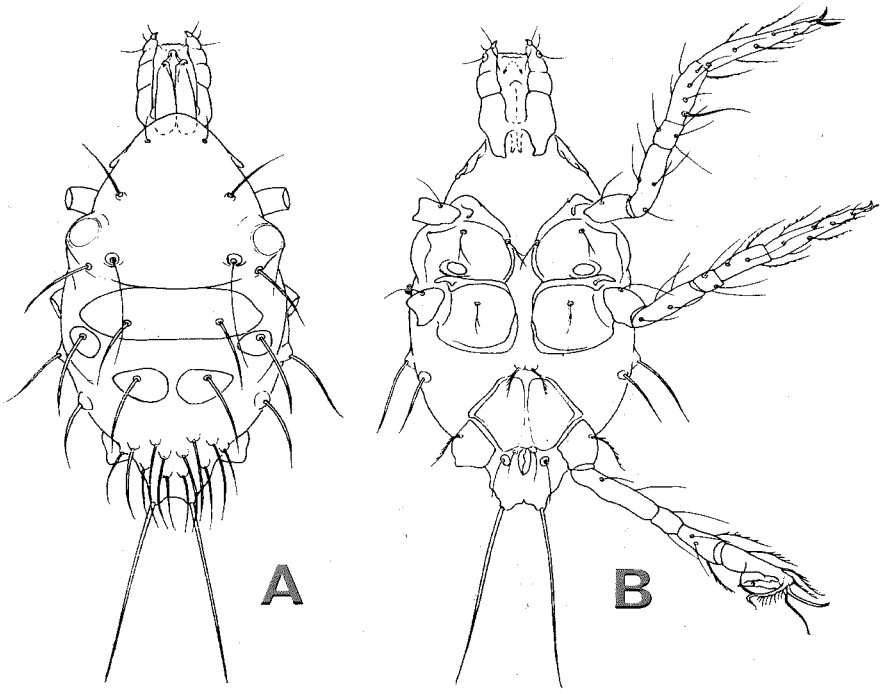
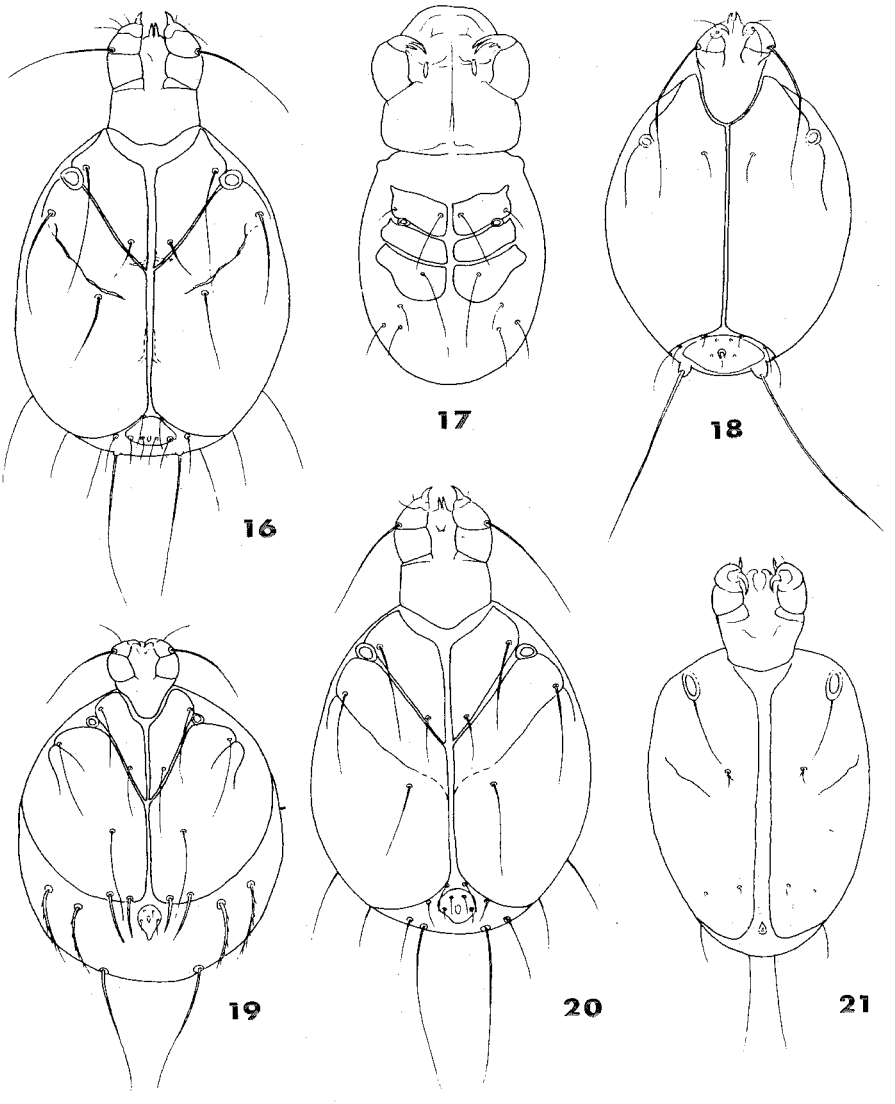


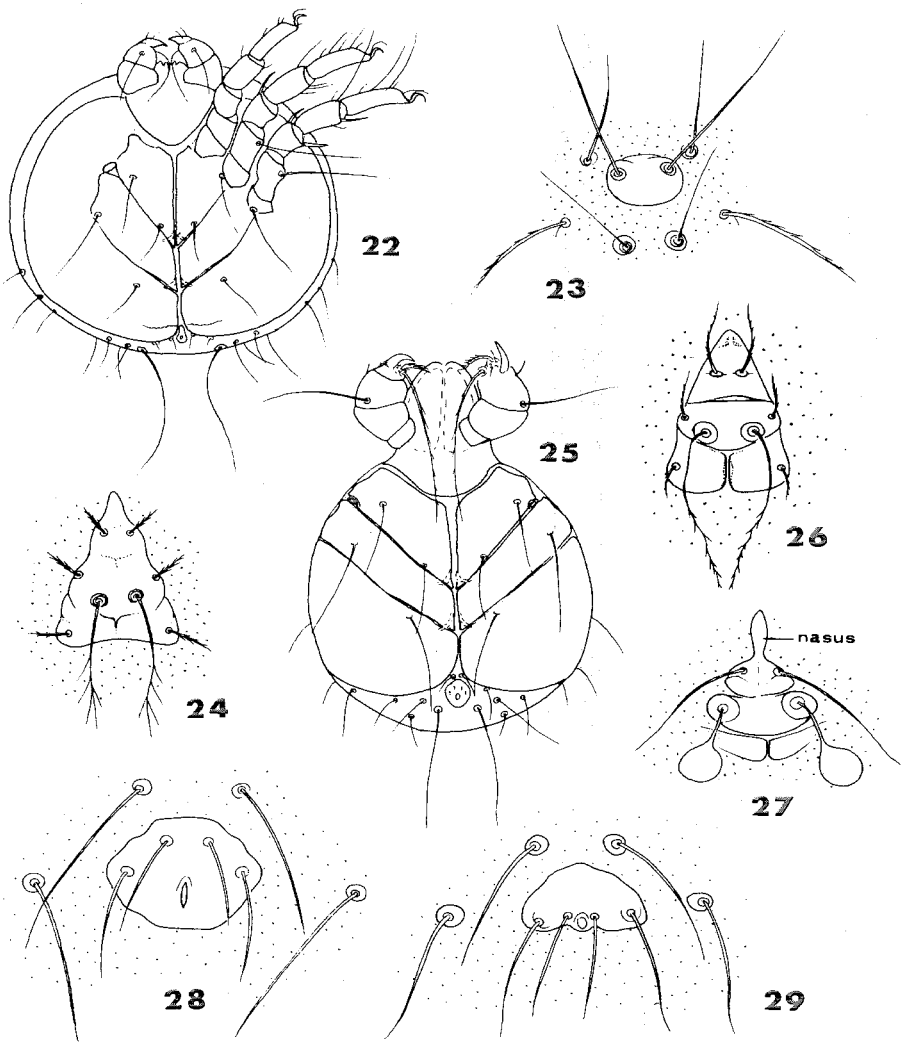
FIG. 15. Trombidiid larva, undescribed species from *Anopheles quadrimaculatus*. A. Dorsal view. B. Ventral view.

wide range of arthropod hosts. In addition to spiders, scorpions and harvestmen, erythraeid hosts are known to include members of the following insect orders: Orthoptera (especially Acridoidea), Homoptera (e.g. aphids, psyllids, cicadas), Lepidoptera, Diptera, and to a lesser extent Thysanoptera, Coleoptera and Heteroptera. Species in only 2 genera have been confirmed as parasites of adult mosquitoes—*Charletonia* and *Callidosoma;* both are members of the subfamily Callidosomatinae. *Charletonia* spp. are recorded only from *Aedes sticticus. Callidosoma* spp., however, have been found attached to several mosquito hosts including *Culex, erraticus, Coquillettidia perturbans* and *Psorophora ferox.* For further information on the taxonomy and biology of the Erythraeidae, including larval keys to the known genera, the reader is referred to Southcott's works (1946, 1961, 1966, 1972).

The family Trombellidae, formerly included as a subfamily of Trombidiidae, includes at least one genus, *Durenia,* with species known to be parasitic on mosquitoes. The genus was first described by Vercammen-Grandjean (1955) based on *D. bukavuensis* collected from *Aedes quasiunivittatus, Culex pipiens* and *C. bukavuensis* in the Belgian Congo. A closely related species, *Durenia singaporensis,* has since been described from *Aedes curtipes* in Singapore (Vercam-



FIGS. 16–21. Water-mite larvae, ventral views. 16. *Piona* sp. 17. *Hydrachna* sp. 18. *Hygrobates* sp. 19. *Lebertia* sp. 20. *Hydrochoreutes* sp. 21. *Limnesia* sp.



FIGS. 22–29. Larval mites. 22. *Mideopsis* sp., ventral view. 23. *Hydrodroma* sp., dorsal plates and associated setae. 24. *Durenia singaporensis,* dorsal plate (after Vercammen-Grandjean and Audy, 1959). 25. *Arrenurus* sp., ventral view. 26. *Durenia bukavuensis,* dorsal plate (after Vercammen-Grandjean, 1955). 27. *Centrotrombidium* sp., dorsal plate. 28. *Tiphys* sp., excretory plate. 29. *Piona* sp., excretory plate.

men-Grandjean and Audy, 1959). More recently a third, undescribed *Durenia* sp. has been found parasitic on *Anopheles quadrimaculatus* in the United States (Illinois). Larvae of this family are known only for *Durenia* and *Audyana,* with the remaining 19 genera known only as adults (Vercammen-Grandjean, 1973). As a result there is not enough information available concerning the larval morphology of the Trombellidae to enable one to separate reliably the larvae of this family from those of the closely related johnstonianids.

Members of the family Johnstonianidae are known primarily from aquatic and semi-aquatic situations where they have been observed to parasitize various Diptera (e.g. Tipulidae) and aquatic Coleoptera (Newell, 1957). The hosts for most of the species in the 14 genera in this family are unknown. No adequate published keys are available for johnstonianid larvae although a partial formula key to the adults of some genera is provided by Newell (1957). The only record of a johnstonianid mite parasitic on mosquitoes is a single specimen of unknown genus and species from *Aedes triseriatus* (Briggs, unpublished WHO document WHO/VBC/70.250). Since this specimen could not be located it has not been possible to obtain a verification. Johnstonianidae at best should be regarded as only rarely parasitic on mosquitoes.

Mites of the family Trombidiidae were first reported from mosquitoes by Blanchard (1905) in Wisconsin although the identity of the host was not indicated. In the same year Dyé reported what he believed to be a trombidiid mite on *Culex pipiens* in India. Since that time species in only 2 genera have been confirmed as mosquito parasites. Michener (1946) reported *"Microtrombidium maculatum"* from *Mansonia titillans* and *Coquillettidia nigricans* in Panama. Based on my own investigations in New York State, 2 species representing an undescribed genus of Trombidiidae are now known to be at least occasional mosquito parasites; one has been found parasitic on *Aedes vexans* whereas the second species is known only from *Anopheles quadrimaculatus.* Although larval trombidiids are parasitic on Orthoptera, Lepidoptera, Coleoptera, Diptera, and Heteroptera, hosts of the majority of species in the 56 recognized genera remain unkown. In fact, the larval stage has been described for members of only 19 genera comprising this very large family (Vercammen-Grandjean, 1973). With the exception of Thor and Willman's (1947) work which is now out-dated, there is regrettably no existing larval key for trombidiids, making the task of larval identifications exceedingly difficult.

All of the remaining mosquito-associated mites are aquatic and are collectively referred to as Hydrachnellae. At least 10 families and 13 genera have been confirmed as having species which parasitize mosquitoes.

The family Thyasidae includes the following 4 genera with species known to parasitize mosquitoes—*Euthyas, Panisopsis, Thyas,* and *Thyasides.* In general they are parasitic on *Aedes* hosts, especially those which breed in temporary woodland or vernal pools. The only known case of parasitism by *Euthyas* is a single *E. truncata* larva collected by the author from *Aedes excrucians* in New York. *Panisopsis* spp. have been reported from an undetermined mosquito host in Europe (Besseling, 1964) and from *Aedes ventrovittis* in California (Fenley, 1966). Neither of these thyasids appears to be common. An unidentified thyasid mite has also been reported by Corbet (1963) from *Coquillettidia* and *Mansonia* spp. in Uganda.

The two genera which include species frequently found on mosquitoes are *Thyas* and *Thyasides.* In North America alone, at least 13 *Aedes* species have been identified as hosts of *Thyas* mites. *Thyas barbigera* appears to be the major thyasid species parasitic on mosquitoes in the United States. The author has collected the larvae of this particular mite from ten *Aedes* species in New York. *Thyasides sphagnorum* has also been found by the author parasitizing 4 *Aedes* spp. and rarely *Culiseta morsitans* in New York. The adult mite is restricted primarily to bogs and swamps which is reflected by the mosquito species serving as larval hosts. The only previous record of *Thyasides* from mosquitoes is that of *T. dentata* on *Aedes flavescens* reported by Lundblad (1927) in Europe.

It is not improbable that other thyasid species may also be found on mosquitoes since virtually all of the mites of this family appear to utilize aquatic or semi-aquatic Diptera as hosts. In addition to Culicidae, several other dipteran families serving as hosts include Tipulidae, Ptychopteridae, Chloropidae and Empididae. However, owing to the fact that most species of thyasid larvae cannot be recognized, the exact nature of their respective host ranges remains to be demonstrated.

No morphological criteria have yet been established for reliably separating *Thyas* and *Thyasides* larvae at the generic level. Nonetheless the 2 species most commonly encountered on mosquitoes can be readily distinguished from one another by the relative lengths of the two pairs of sensilla on the dorsal plate. In *Thyas barbigera* these sensilla are very long, more than twice the length of the other dorsal plate setae. In *Thyasides sphagnorum* the sensilla are much shorter, noticeably less than twice the length of the other two pairs of setae.

Members of the genus *Hydryphantes* have been reported as ectoparasites of insects in 4 orders—Diptera, Plecoptera, Heteroptera, and Odonata. Only rarely are they found on mosquitoes. The Sergents (1904) reported what they thought to be a *Hydryphantes* sp. on *Anopheles* mosquitoes in Algeria. An unidentified *Culex* sp. has been reportedly parasitized by *Hydryphantes ruber* in Germany (Viets, 1936). With the exception of a reference to an unidentified hydryphantid larva on an undetermined mosquito host (Hughes, 1959), no other records of mosquito parasitism by *Hydryphantes* are known.

Although *Hydrachna* spp. have been reported from mosquitoes, the reliability of the mite determination in each case is questionable. The early report by Dyé (1905) of *Hydrachna* on *Mansonia uniformis* and *Anopheles maculipennis* is still unverified although Reinhard (1924) also reported a possible *Hydrachna* sp. from *A. maculipennis* in the Ukraine. Since the larvae of this mite genus are so distinctive these reports may in fact be correct and probably represent attachment to atypical hosts. *Hydrachna* mites are primarily parasites of aquatic Hemiptera and Coleoptera.

Hydrodroma spp are uncommon mosquito associates, the larvae most often occurring on aquatic Diptera (Chironomidae and Chaoboridae); however, they have been reported from *Aedes cantans* and *A. rusticus* in England (Marshall, 1938) and as a questionable parasite of an *Anopheles* sp. in Algeria (Sergent and Sergent, 1904). The author has collected larvae of a new *Hydrodroma* sp. from *Anopheles punctipennis* in New York.

Arrenurus is no doubt the most common genus of mites found parasitizing mosquitoes. This is by far the largest genus of water mites comprising more than 100 species in North America alone. Based upon the morphology of adult males, the genus has long been recognized as consisting of several subgenera including *Arrenurus, Megaluracarus, Micruracarus, Micrarrenurus* and *Truncaturus.* In recent years, however, there has been increasing support for elevating these groups to full generic status as Cassagne-Méjean (1966) has done. Since no means have yet been established for distinguishing the larvae of each of these subgenera, all of these mites are treated as *Arrenurus* in the above key.

With very few exceptions species of *Arrenurus* s. str. parasitize adult Odonata. However, at least 3 members of this subgenus have been reported from *Anopheles* mosquitoes in Europe, China and Japan. Host records for the remaining 4 subgenera are very poorly known although what evidence is available clearly suggests they are principally parasites of Diptera. *Micruracarus* and *Megaluracarus* spp. have been reared from both chironomid midges and mosquitoes. Although *Anopheles* spp. constitute the majority of the mosquito host records (Münchberg, 1936, 1938), Böttger (1962) observed *A. (Meg.) globator* parasitizing *Culex pipiens.* In New York I have found that the most common mite on several *Anopheles* spp. is an undescribed *Megaluracarus.*[4] Species of the subgenus *Truncaturus,* on the other

[4] Species has been identified as *Arrenurus* (Meg.) *pseudotenuicollis.*

hand, seem to be almost exclusively parasitic on mosquitoes. Although previously the host of no North American truncaturid was known, my investigations have revealed at least 5 *Truncaturus* spp., 4 of them new, which are parasitic on *Culex, Culiseta, Anopheles* and *Coquillettidia* adults. The hosts of *Micrarrenurus* remain unknown.

The literature contains numerous additional records of *Arrenurus* mites parasitizing mosquitoes but since rearings were not carried out to obtain adults the subgenus in each case cannot be determined. Nonetheless it is apparent that the genus as a whole has adapted itself to a wide range of mosquito hosts from all parts of the world. These hosts represent at least nine genera—*Anopheles, Culex, Culiseta, Coquillettidia, Mansonia, Aedes, Uranotaenia, Ficalbia* and *Hodgesia*.

All of the *Lebertia* host records are based on Marshall's (1938) account and include the following mosquito species: *Aedes annulipes, A. cinereus, Anopheles claviger, An. maculipennis* and *Culiseta morsitans*. The mites in each case were regarded as closely resembling *Lebertia tauinsignata* although no definite determination could be made. Owing to the unlikelihood that one mite species could parasitize such a wide range of hosts breeding in quite different situations, more than one species of mite is no doubt involved in the above cases. Also considering the meager knowledge available at that time concerning larval taxonomy of water mites, it is altogether possible that the mites were not even *Lebertia* but instead represented one or more other morphologically similar genera. Earlier Bruyant (1908) had reported a mite which was believed to be either *Lebertia* or *Hydrochoreutes*, further emphasizing the confusion which existed with regard to the identity of larval mites belonging to different genera and families. These *Lebertia* records should therefore be considered questionable. Members of this mite genus have been found parasitizing chironomid midges which probably represent their normal hosts.

With the possible exception of the *Hydrochoreutes* record noted above, only species of *Piona* of the family Pionidae have been reported from mosquitoes. Two *Anopheles* species have been cited as hosts of *Piona* larvae in France (Blanchard, 1905) while in North America at least one case involving *Culex tarsalis* has been reported (Linham, 1962). The only record of *Piona* species from *Aedes* hosts is that of Romney and Nielsen (1968) who indicate that the mite was "probably" *Piona*. In addition, a single *Piona* larva has been found on a newly emerged *Culiseta morsitans* male by the author in New York. Although *Piona* spp. are occasionally found attached to adult mosquitoes, their occurrence there seems to be quite incidental. Members of this genus appear to be chiefly parasitic on chironomid midges. Included in the above key are characters for distinguishing the two pionid genera, *Hydrochoreutes* and *Tiphys*, since these mites also occur where mosquitoes commonly breed and thus may represent potential parasites even though no confirmed records of such parasitism have been reported.

While *Limnesia* has not been recorded from mosquitoes in North America there is evidence to suggest that members of this genus, or at least the family Limnesiidae, are parasitic on mosquitoes in other regions of the world. Speer (1927) cites a record of *Limnesia* from a *Mansonia* sp. in Indonesia. Virtually all of the other records of Limnesiidae have been reported by Corbet (1963) based on his work in Uganda. There he recorded unidentified limnesiid mites from six *Coquillettidia* species. Limnesiid mites have also been found parasitizing *Anopheles implexus* in Uganda (McCrae, pers. comm.).

Only a single record of mosquito parasitism by a *Hygrobates* mite has been reported (Besseling, 1964); the host in this case was not determined. Since *Hygrobates* is known to utilize both chironomid and chaoborid midges as hosts, it is not unreasonable to assume that mosquitoes may occasionally be parasitized by these mites.

The few records which exist for *Unionicola, Eylais* and *Midea* (or *Mideopsis*) as mosquito parasites are in all probability misidentifications. A species of *Unionicola (Atax)* has been reported parasitizing two *Anopheles* spp. in Africa (Mira, 1940) but since mem-

bers of this genus are typically parasitic in fresh-water molluscs the identification is no doubt an error. *Midea* (or *Mideopsis*) is based on a single report of a mite on an undetermined mosquito host from Southeast Asia (Bruyant, 1908). Mosquito parasitism by *Eylais* is similarly based on a single questionable determination of a mite from an unidentified *Anopheles* sp. in Algeria (Sergent and Sergent, 1904). Normally the mites belonging to this genus are parasitic on aquatic Coleoptera and Hemiptera. Since it is doubtful that either *Unionicola* or *Eylais* ever occur on mosquitoes both genera have purposely been omitted from the above key.

In addition to the mites previously reported in the literature, it is possible that other genera of water mites may be encountered by individuals working with mosquitoes. In such an event the larval keys of Sparing (1959) and Prasad and Cook (1972) should be consulted.

Hopefully with the aid of the above illustrated key and the accompanying discussion investigators collecting mosquitoes parasitized by mites will now be able to provide reasonably reliable determinations of the mite genera involved. This is essential to any meaningful study of the association between mites and their mosquito hosts.

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