SOME ECOLOGICAL OBSERVATIONS ON WATER MITES

BY

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Fourteen Figures

1) Introduction

In spite of the large number of works on the classification of the water mites, only a few papers have been published dealing with the habits of the animal group. During my stay at the Laboratoire d'Evolution des Êtres Organisés in Paris from the end of March to the beginning of July, 1930, I made some ecological studies on several water mites collected in the neighbourhood of the city. As there is no opportunity for me in the near future to continue the work on the French examples, and though my observations may be somewhat fragmental, it seems to me that publishing these notes may be of some value and not entirely uncalled for.

Before proceeding further my hearty thanks should be offered to Professor M. CAULLERY, director of the laboratory, as also to Dr. AVEL of the same laboratory for the kindness shown me in the course of the research.

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The water mites considered here are as follows: *Diplodontus despiciens*, *Hydryphantes dispar*, *Limnesia fulgida*, *Piona carnea*, *Piona obturbans*, *Acercus ornatus* and *Arrhenurus* spp. Water mites belonging to various species were put in small separate aquariums with decayed leaves and water plants, such as *Elodea canadensis* and *Cladophora* sp. and fed mainly with Daphnids, Ostracods and several kinds of insect larvae. They lived in these aquariums for several months, clambering about over the surface of the water plants, swimming across from one stem or leaf to another, crawling on the wall or bottom of the aquarium and feeding on these animal prey.

2) Reaction to Sunlight

As is generally well known in the Hydracarina, water mites are active only in the daytime and mine were of no exception, since they did not display nocturnal habits at all.

Both *Hydryphantes dispar* and *Diplodontus despiciens* are not agile in swimming, and were often found crawling on the bottom and side wall of the aquarium or on pieces of decayed bark and leaves floating on the water surface, and moreover, they were often observed to swim near the water surface during fine days. In the evening or during rainy or cloudy weather, however, they hid themselves under decayed leaves, gathering together and attaching upon them upside down. A similar fact I observed for the Japanese water mite, *Hydryphantes uchidai*, which hides itself in the evening and during cloudy weather under dead leaves and bark on the bottom. For further evidence of the presence of remarkable thigmotactic tendencies in the water mite, it will be noticeable that several individuals of the mite were often found aggregated in a hull of rice half-buried in the muddy bottom.

Limnesia fulgida, one of the best active swimmers in the Hydracarina, swims about almost constantly in the daytime, whereas in the evening or during bad weather they come together around leaves and stems of water plants, upon which they rest by means of the three anterior pairs of legs, with the fourth pair of legs lifted perpendicularly

to the body. Before assuming the resting attitude, they continue to move the fourth pair up and down for 10–15 minutes and then come to rest remaining still until the next morning. It seems to me that in the Hydracarina the fourth pair of legs are quite different from the other pairs in their function and especially act as tactile organs. Not only in the resting state, but also while taking food and crawling on the bottom, *Limnesia fulgida* uses the first three pairs alone to support the body from the substratum or to locomote itself, whereas the fourth pair are always lifted upwards, being constantly moved forwards and backwards.

It was very interesting to me that *Piona carnea* was frequently perceived to bury itself under the mud, especially in the evening and during cloudy weather. At first they bore into the mud with their palpi and anterior legs and then creep into the mud head first, with their body nearly perpendicular to the substratum or with the ventral surface turning somewhat upwards, until the body becomes entirely buried in it. When they come out from the mud, however, their dorsal surface is always faced upwards. Because of this habit, they are seldom to be found in cloudy weather.

Arrhenurus spp. were also sensitive to the sunlight. Though they swam and crept actively near the bottom in the daytime, they came to rest in the evening and in bad weather, gathering together on the bottom of the aquarium under decayed leaves, with the dorsal surface upwards, unlike *Hydryphantes* and *Diplodontus*.

3) Cleaning

Cleaning was often observed in *Acercus ornatus*, *Piona carnea*, *Limnesia fulgida* and *Arrhenurus* spp. So far as my observations go, these water mites generally accorded with one another in the act, though that of *Limnesia fulgida* was the most remarkable among them. After they cease swimming and are attached to the wall of the aquarium or leaves, they repeat several times at first a rubbing of the two posterior pair of legs together and then in most cases again swim away. How-

ever, the cleaning was often more throughly carried out: at first they rubbed their legs together, beginning with the posterior and promoting to the anterior legs. When the cleaning of all the legs was finished, they rubbed the anterior portion of the body with the two anterior pairs and the posterior portion with one or two of the posterior pairs. The cleaning of either the anterior or the posterior portion was always repeated alternatively. The dorsal surface was always cleaned with the fourth pair and then the pair just used again by the third pair. The palpi were swept by means of the first pair which were successively cleaned by rubbing with the second pair. Moreover, it was observed in *Acercus ornatus* that after egg-laying the genital field was cleaned with special care by means of the posterior pair.

4) Food

It is well known that the water mites with some exceptions are generally predacious, but our knowledge is very meager as to how they seize their food-prey and on what kind of food each genus or species feeds. In 1928 MOTAS published a fine paper in which he gave detailed notes about foods of several water mites belonging to the following genera, *Lebertia*, *Sperchon*, *Hygrobates*, *Piona*, *Hydrochoreutes*, *Arrhenurus*, *Pontarachna* and *Megapus*.

Diplodontus despiciens and *Hydryphantes dispar* were often seen to come together and to eat dead insects belonging to the Hemiptera and Diptera but were never seen to attack living insects or Crustaceans. Probably on account of their comparatively sluggish motion they mainly seek dead animals on the bottom. These water mites, on the contrary, were often attacked by and became the prey to *Limnesia fulgida*.

Limnesia fulgida is very predacious in habit and feeds upon almost any aquatic animal, living or dead, which it may be able to capture and overpower. On account of its comparatively slow motion in swimming and shortness of the legs, the mite could very seldom catch Daphnids. However, as it is relatively large in size and provided with a pair of

large and robust palpus, it showed pronounced cannibalistic tendencies and was often seen to seize other mites, especially soft bodied forms, such as *Diplodontus despiciens*, *Hydryphantes dispar*, *Acercus ornatus*, and *Piona carnea*. Moreover, the mite attacked *Chironomus* larvae, Ephemerid larvae and *Asellus aquaticus*, if they were more or less injured in advance by the observer. While these comparatively large creatures, which are too weighty to be borne by an individual of the *Limnesia*, are struggling about on the bottom, they would at once be surrounded and attacked by several of the predacious water mites which perceive the presence of their prey probably on account of their chemical sense. While preying on these animals, *Limnesia fulgida* continues to lift the fourth pair of legs, constantly moving them forwards and backwards.

The method of hunting Daphnids by the female of *Acercus ornatus*, which considerably exceeds the male in size and is very predacious in nature, was very interesting. When the mite comes across a Daphnid, it would always take hold of the victim with all its legs and, taking advantage of the weight of the body, sink with the latter down to the bottom, where it ultimately holds the prey in easy position with its claw-like palpi and bearing it on its month swims again to the wall of the aquarium or to a leaf of a water-plant, on which the body of the Daphnid is pierced by the water mite by means of its mandible and the body-fluid sucked up by the latter. While obtaining the nutriment, the mite uses only its palpi to seize firmly the crustacean, and the three anterior pairs of legs to support the body on the substratum, and keeps the fourth pair lifted upwards at an angle of about 45° to the horizon, which quiver from time to time convulsively.

Piona carnea also fed mainly on Daphnids. Like other genera it seized and held the victim with its palpi and used the three anterior pairs of legs to support the body from the bottom, keeping the fourth pair lifted upwards and moving them constantly up and down.

Very small as the nymph may be, often caught it Daphnids which were larger than the former. At first the nymph used to cling to the

prey catching the appendages of the latter with all the legs and palpi. To make itself free from the enemy made the Daphnid every effort, but it would gradually be firmly arrested by the latter, and became consequently unable to swim and later to sink with the water mite to the bottom, where the victim fell into clutches of the nymph. When the Daphnid was not too large for the nymph, the latter swam carrying the victim in its mouth to the wall of the aquarium or to water plants whereon it fed quietly for almost half an hour. When the prey was too large for the nymph to bear, however, the latter remained on the bottom with the prey and took its nutriment there. In the latter case, its palpi alone were used to take hold of the Daphnid, while the four pairs of legs were outstretched in the water quite stiff and motionless.

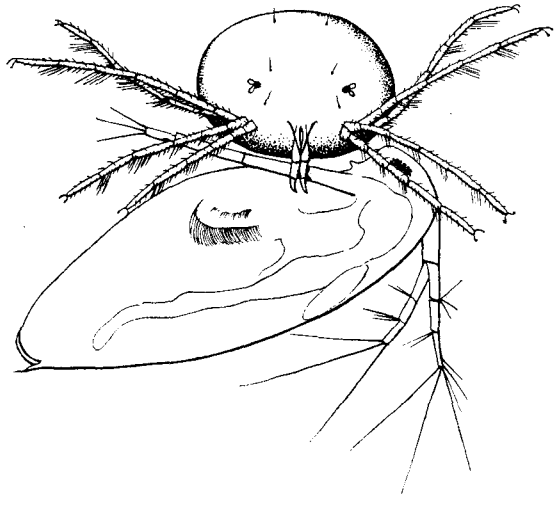

Fig. 1. Nymph of *Piona carnea*, preying on a Daphnid.

In accordance with MOTAS (1928) who reported that water mites belonging to the genus *Arrhenurus* especially fed on Ostracods, my water mites in the genus were very frequently observed to attack Ostracods. These water mites generally swam near the bottom, on which Ostracods were often found lying. When the mite came across an Ostracod, the former took hold of the latter with its pincer-shaped palpi, grasping the appendages which protruded out of the shell and

waited for a fairly long time until the Ostracod opened up. At the moment of opening the shell, the *Arrhenurus* pierced the Ostracod with its mandibles. While seizing or eating the prey it kept a firm hold of the latter's shell with the three anterior pairs of legs, always lifting the fourth pair perpendicularly.

5) Copulation

On account of its special mode and the presence of various types, the copulation of the water mites attracted the attention of several zoologists who happened to observe it. On perusal of the literature, I found that the copulation of the following genera was known: *Arrhenurus, Piona, Pionopsis, Acercus, Forelia, Hjartdalia, Feltria, Brachypoda, Aturus,* and *Midea.*

According to the relative position between the male and the female, one can divide these cases into four types as follows.

a) *Arrhenurus*-type: *Arrhenurus, Aturus.*
b) *Piona*-type: *Piona, Acercus, Pionopsis, Brachypoda.*
c) *Feltria*-type: *Feltria, Hjartdalia* (?).
d) *Midea*-type: *Midea, Forelia.*

a) The *Arrhenurus*-type is represented by several species belonging to the genus and by *Aturus scaber.* About the copulation of the genus *Arrhenurus* MOTAS (1928) has the following to say. "L'accouplement chez *Arrhenurus globater* est connu depuis O. F. MÜLLER. Il n'est pas rare de rencontrer différentes espèces de ce genre en accouplement. TOHRU UCHIDA (1922, fig. 8) a figuré l'accouplement chez une espèce japonaise, *A. tectus.* Nous l'avons observé chez beaucoup d'espèces, parmi lesquelles: *A. globator, bruzelii, radiatus, claviger, cuspidifer, denticulatus, cylindratus,* etc. Nous avons représenté (1925, p. 33) l'accouplement chez cette dernière espèce." In 1929 LUNDBLAD gave an important and detailed description about the pairing of three European species, *Arrhenurus globator, A. forpicatus* and *A. stecki,* and again in 1930 a curious case of homosexual copulation occurring be-

tween two males of *Arrhenurus mediorotundatus*. The mating of *Aturus scaber* was also reported by him (1929).

In these water mites copulation takes place with the male coming in front of the female, the posterior dorsal part of the former connecting with the posterior ventral part of the latter by means of the petiole or sticky glands of the male (in *Arrhenurus*) or the well-developed fourth pair of legs of the sex (in *Aturus*), and thence the dorsal surface of the male being brought to bear upon the ventral surface of the female. During the pairing the female remains immobile and is dragged by the male.

b) The second type occurs in the genera, *Piona*, *Acercus*, *Pionopsis* and *Brachypoda*. For the first time KOENIKE (1891) gave a detailed note about the copulation of *Piona fuscata* which was cited several times by later investigators. In 1900 PIERSIG merely reported that he observed the act in *Piona fuscata* and *Piona carnea* and, moreover, gave a figure about *Piona conglobata* (Taf. XIII. Fig. 35). MOTAS (1928) reported that he made observations about *Piona nodata*. MARSHALL (1929) described briefly the pairing of *Piona americana*. About the copulation of *Acercus ornatus* and *Pionopsis lutescens* VIETS (1914) and for *Brachypoda versicolor* MOTAS (1928) reported their close observations respectively.

In the copulation of the water mites above mentioned the male and female come together in a position to make a right angle between them, the ventral surface of both the sexes opposing each other and the anterior end of the female coming in contact with the posterior portion of the male. The female is taken hold of by the basis of the first or the second pair of legs by means of the fourth pair of the male which are of special form for the purpose in *Piona* and *Pionopsis*. In *Acercus* the sides of the female are grasped by the fourth pair of specialized legs of the male.

My observations made on *Piona carnea* and *P. obturbans* agree generally with the descriptions of the mating of *Piona fuscata* by KOENIKE and of *Piona americana* by MARSHALL, but there are some differences between them. KOENIKE describes on p. 254, ,, Die selt-

same Paarung wird nun derart vollführt, dass das Männchen sich mit der Brust gegen das Kopfende des Weibchens stemmt, den Kopf nach unten gerichtet;" „Mit den gekrummten Gliede des letzten Fusses umgreift das Männchen je einen *weiblichen Vorderfuss* am Grunde, wobei oben erwähnten strärken Borsten wesentliche Dienste leisten." MARSHALL reports her observations on *Piona americana* as follows "Pairing as observed here agrees with accounts given for other species of the genus and illustrates the use of the peculiarly modified legs of the male. The female remains passive with legs outstreched. The male rests on the anterior end of the ventral side of the female with the fourth legs flexed so that the concavities of the fourth segments are hooked over *the first legs of the female.*" VIETS who observed the copulation of *Pionopsis lutescens* mentions, „Die Fixierung der beiden Individuen erfolgt bei dieser Art nur durch die Hinterbeine des Männchens, indem diese, zwischen die ersten und zweiten Beine des Weibchens gebracht, unterhalb der Augen des Weibchens an der vorderen Seitenpartie mit der Dorsalseite der vierten Glieder an den weiblichen Körper hinangebracht werden und die Basis *des ersten weiblichen Beinpaares* umklammern."

According to my observations on *Piona carnea* and *P. obturbans*, the legs of the female seized by means of the fourth legs of the male were always *the second instead of the first*, differing from the descriptions of the three former authors. Judging from the facts, it appears to me that the male seizes by chance either the first or the second legs of the female. In the following my observations will be described. Very soon after emergence from their pupation they were often seen to copulate. Prior to copulation the male and female would come together and make wriggling movements for several minutes until the female becomes motionless and after that the act takes place, which would last for nearly an hour. While pairing the female remains almost passive with legs outstreched, but the male is very active in carrying its spermatophores to the genital aperture of the former. In the copulation the female generally lies upside down, its palpi and first pair of legs being turned ventral to the body due to the pressure exerted by

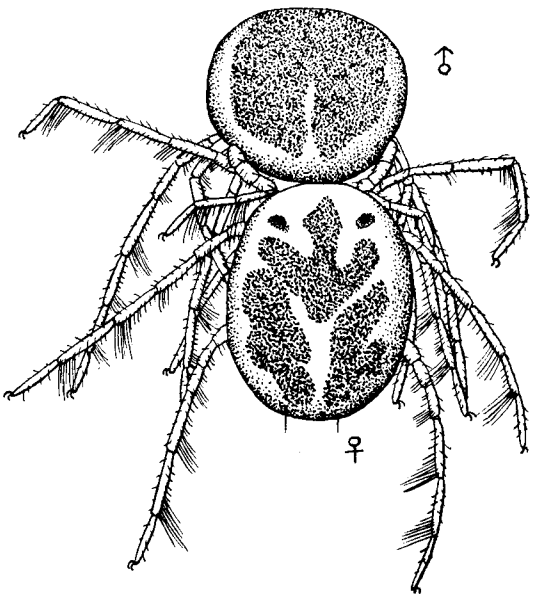

Fig. 2. Copulation of *Piona carnea*, dorsal view.

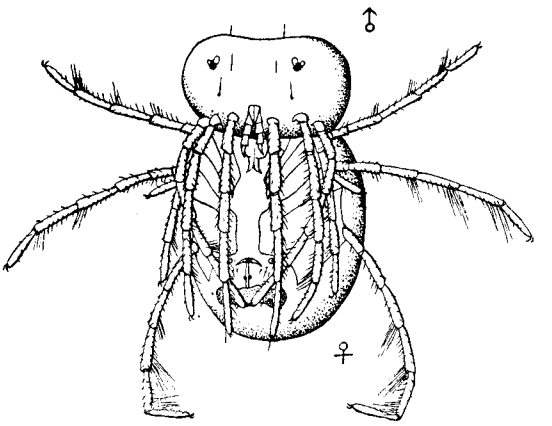

Fig. 3. Copulation of *Piona carnea*, ventral view.

the ventral surface of the male. The flexion of these legs takes place only at the basal joint and the remainder of the legs is extended straight to the posterior along the lateral margin of the body. The male hooks his fourth pair of legs over the first segment of the female's second pair of legs by means of a specialized hook arising from the modified third and fourth segment, while the third and the fourth pairs are outstreched posteriorly on both sides. The palpi of the male are placed on the ventral surface of the female, while the first and the

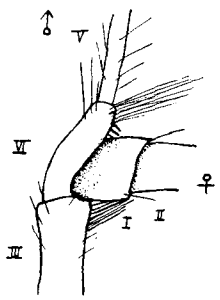

Fig. 4. Basal segment of the second leg of female hooked over by the fourth leg of male.

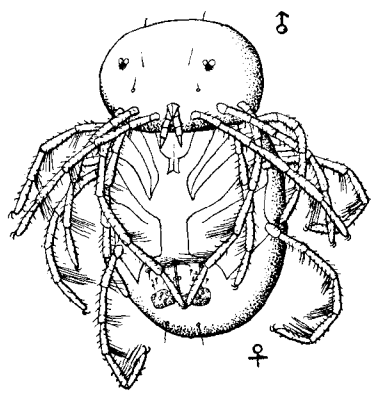

Fig. 5. State of exhaustion after copulation of *Piona carnea*.

second pair of legs are streched out stiffly above the ventral surface of the latter. During the pairing the claws of these legs are seen from time to time to quiver convulsively. The club-shaped distal segments of the third legs are held first upon the genital orifice of the body. The inner surface of these segments then transfers the sticky spermatophores, which are emitted from the genital orifice, to the genital opening of the female. As this is done, the club-shaped segments are rubbed vigorously together and also somewhat upon the genital opening itself. The fourth pair, which are specially modified, are bent like the letter S to hook over the second pair of the female, in the frontal view only two terminal segments being visible. In about 50 minutes the

spermatophores are stuffed into the genital pore of the female and by that time both sexes arrive at a state of exhaustion, remaining quite inactive, the legs of both being bent sluggishly. At this moment, however, if one prods either of the two, they suddenly awake from the state and swim quickly away from each other. The spermatophores in the species are in general similar to those described and figured by VIETS (1914) about *Pionopsis lutescens* and MOTAS (1928) about *Piona nodata*, and can be easily obtained from the male in the mating season, because when laid dorsally on a slide with a drop of water, the creature struggles in vain to raise himself up and at the same time rubs the genital orifice with the terminal segment of the fourth legs. After the continuation of the act for several minutes, the spermatophores are emitted from the organ.

The copulation of *Piona obturbans*, though generally similar to that of *Piona carnea*, did not take so long a time as in the former case.

c) The third type is represented by *Feltria georgei* and is described in detail by MOTAS (1928). In the water mite the male seizes the female by the anterior portion of the dorsal surface with the well-developed palpi. In taking this position the male is carried with its ventral surface downwards by the female upon the dorsal surface of the latter. THOR's description (1901) about the copulation of *Hjartdalia materna* is not clear as to whether the male and female come together ventral to ventral or whether the dorsal side of the female opposes the ventral side of the male, but the mode of copulation will perhaps be included under the category of the *Feltria*-type.

d) The fourth type is recorded by LUNDBLAD (1929) for *Midea orbiculata*, and briefly described by WALTER (1922) and MOTAS (1928) on *Forelia cetrata*. The copulation is simple but peculiar in this group of the Hydracarina; both the sexes oppose on their ventral surface mutually, the male seizing the female by her anterior ventral surface with its palpi and legs, so that the genital opening of the two comes into apposition.

6) Egg-laying

Though there are fairly numerous reports concerning the eggs of the water mites, satisfactory observations on the act of spawning are very meagre. Concerning egg-laying of the group, WESENBERG-LUND (1918) gave an interesting note on *Hydrachna Williamsoni* and afterwards SOKOLOW (1924 & 1925) described in detail about the act of *Piona carnea* and briefly that of *Eylais* sp. So far as I am aware, no further report has been hitherto published. In his second paper, SOKOLOW described that „Diese Beobachtung besagt uns nun, dass auch bei *Eylais* der Prozess der Hüllenbildung kein anderer als wie bei *Piona carnea* ist und wahrscheinlich auch bei allen übrigen Hydracarinen ähnlich verläuft." In regard to the mode of laying eggs, *Hydrachna Williamsoni* is, according to WESENBERG-LUND, somewhat different from the description of the water mites studied by SOKOLOW. However, my observations on *Acercus ornatus* agree generally with that of SOKOLOW as described later on.

While I was breeding several individuals of *Acercus ornatus*, I happened to observe several times the act of spawning. These water mites lay their eggs on the under surface of leaves of water plants or on the wall of the aquarium. The eggs are embedded in flat gelatinous substance in which they are arranged in a horizontal layer and apparently in several longitudinal, more or less, regular rows. The number of them in one deposit is generally from 50 to 100, but sometimes more than 300. The structure of the gelatinous substance is finely alveolar. When the mites were frequently fed with Daphnids, they laid eggs very often and in abundance. In several cases I observed the act of the water mite taking place on the glass wall of the aquarium, where observation was very easy. A female at first came to rest on the wall

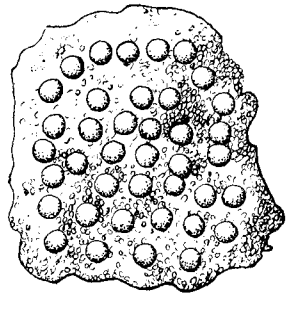

Fig. 6. Egg-mass of *Acercus ornatus*.

remaining there motionlessly for a few minutes and then began to lay eggs. During spawning it remained standing on the four pairs of legs and making a slow rocking movement from one lateral side to another in only the posterior portion of the body, keeping the head almost motionless. Two or three eggs were deposited from the genital orifice of the female per minute, and the eggs were somewhat regularly arranged in several rows, each having about the same length with the width of the body. If eggs are laid in the first row from right to left, they will be deposited in the second from left to right and in the third row again from right to left, and repeated in this way several rows finally are deposited. After the completion of the act the female usually remains still for less than a minute in this position and then swims sway to a leaf of *Elodea* or to the wall of the aquarium upon which it cleans its genital orifice with the fourth pair of legs.

The eggs thus laid adhere at once to the wall of the aquarium on account of a sticky substance, which is secreted in the genital organ and discharged with the eggs. At the moment of spawning the egg is destitute of any gelatinous substance, but the sticky substance produced with it coagulates in a few minutes in the water as the gelatinous substance, and swells gradually around the egg and at last coalesces around each egg. This action consequently forms a large flat gelatinous substance containing many eggs arranged in several rows. The emergence of the free swimming six legged larva occurs in about two weeks.

The eggs of *Piona obturbans* laid in clumps between *Cladophora* sp. were grape-coloured and few in number. Differing from those of *Acercus ornatus*, they were clustered in disorder in an irregular shaped jelly mass. The larva hatched out about 20 days later.

The eggs of several species of *Arrhenurus* and *Limnesia fulgida* were also laid on the wall of aquarium or on the leaf of the water plant *Elodea canadensis* in a flat gelatinous layer. But so far as my observations go, unlike those of *Acercus ornatus*, they were not arranged in several, more or less, regular rows. The eggs of the latter were orange in colour, round in shape, and deposited usually from 15 to 40 in

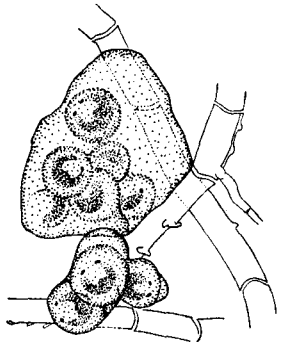

Fig. 7. Egg-mass of *Piona obturbans.*

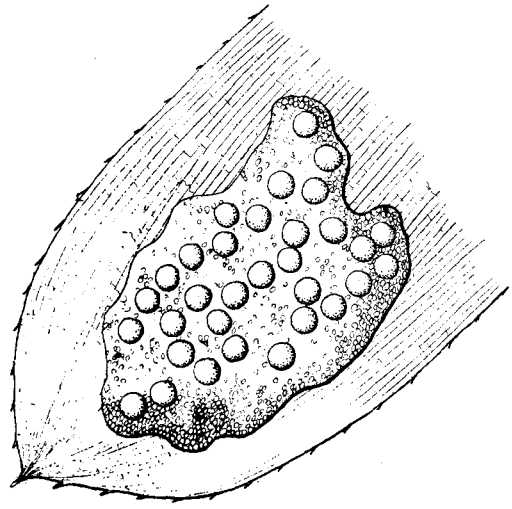

Fig. 8. Egg-mass of *Limnesia fulgida.*

number in a gelatinous mass, which was also alveolar in structure but more remarkable than that of *Acercus ornatus.*

7) Postembryonal development

It is generally known that newly hatched larvae of the water mites proceed at once to search for the host most adequatly suited to them to carry out the transformation to nymph. Though some hosts are reported in several kinds of water mites, our knowledge about them still remains considerably defective. VIETS (1923) describes, ,, Von den allermeisten Hydracarinen-Larven ist unbekannt, welche Wirtstiere von ihnen aufgesucht werden; es liegen jedoch zahlreiche Beobachtungen vor über das Zusammenleben parasitischer und auch synökischer Art von Milben-Larven mit Larven, Puppen und Imagines von Chironomiden u. a. Culiciden, Perliden, Ephemeridae, Phryganiden u. a. Ueber die Zeitdauer, während welcher die Hydracarinen-Larven in dieser Weise auf anderen Tierer verweilen, liegen bestimmte Angaben nicht vor.'' In respect to the facts our present knowledge is mainly based on the descriptions of WESENBERG-LUND (1918), LUNDBLAD (1927) and MOTAS (1928).

To make clear the fact concerning the water mites here dealt with, I put the newly emerged larvae, each separately according to species, in a small aquarium together with several kinds of insect larvae such as, Ephemeridae sp., *Chironomus thummi* and *Hydrophilus* sp. and afterwards examined which insect larva was parasitized by each larva of these water mites. As the result of the examination I made out that larvae of *Piona obturbans*, *P. carnea* and *Acercus ornatus* exclusively attached to *Chironomus* larvae and those of *Arrhenurus* spp., only on *Hydrophilus* sp., while *Limnesia fulgida* was not parasitic on any of these insect larvae.

With regard to the development of the genus *Acercus* PIERSIG (1900, p. 148) indicates that the larvae are parasitic on larvae of Coleopteran and fresh water Dipteran larvae. As regards the genus *Piona* it is known that larvae of several species belonging to the genus are parasitic upon several kinds of aquatic Coleopteran larvae and further that the nymph pupates on water plants. But there are no detailed descriptions ever published about these facts with the exception of

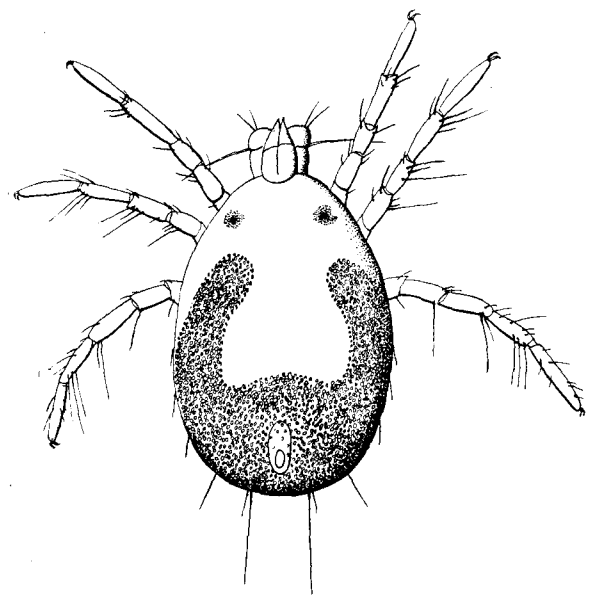

Fig. 9. Larva of *Acercus ornatus*, dorsal view × 147.

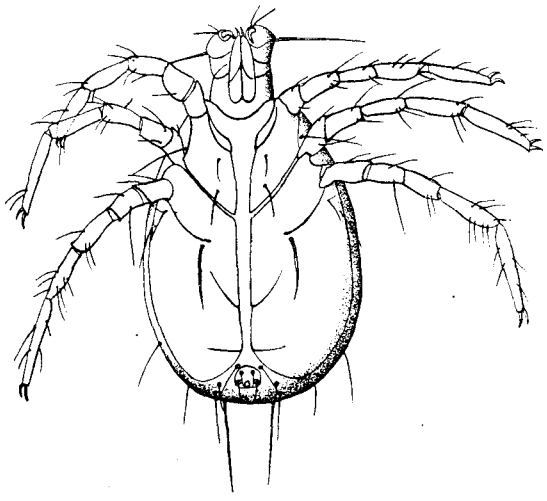

Fig. 10. Larva of *Acercus ornatus*, ventral view × 147.

the larva of *Piona disparilis* which is parasitic on the female of *Cricotopus biformis*, a chironomid, at the time of oviposition of the latter (Motas, 1928). The larvae belonging to *Acercus ornatus*, *Piona carnea* and *Piona obturbans* were used in my breeding experiment and it was revealed that they generally accorded with each other in the process of parasitism. These larvae were found exclusively to attach upon the pupa of *Chironomus thummi* as is described below. They are not as good swimmers as those of *Arrhenurus*, sometimes swimming in the water and sometimes crawling on the bottom. In the meanwhile, they attack the *Chironomus* pupa so violently that a *Chironomus* pupa was often parasitized by about two hundred of these larva mites. So far as my observations go, it was only the pupa and not the larva of *Chironomus thummi* that was attacked by the larvae of these water mites. The reason why the larva was not parasitized by young water mites is probably due to its agile movement and the presence, around it, of a membranaceous sac secreted by itself, which seems to prevent the parasites from boring through. When the *Chironomus* larva begins to throw away the larval moult to become a pupa, however, the parasites get at the anterior portion of the pupa, from which the moulting

is always carried on to the posterior portion. After invading into the membranaceous sac and the cast of the insect larva, the young water mites crawl for a while on the chitinous surface of the *Chironomus* and then fasten themselves on either the dorsal or ventral side of the host, which was usually found more violently infected by them on the posterior than the anterior portion. According to my observations, the parasites attach always to the intersegmental membranaceous portion of the host, having their head directed to the anterior portion of the host, clinging only by the mandibles which pierced the

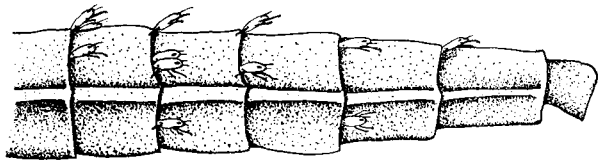

Fig. 11. Posterior abdomen of *Chironomus thummi* parasitized by larvae of *Acercus ornatus*.

host deeply through its integument, and with the antorior pair of leg holding the integument, while the other two pairs are outstretched on both sides of the body. They appear to obtain their nutriment at the expense of the host by preying on its juice through its entire pupal stage, because they gradually approach in body-shape the nymphophan stage observed in *Piona clavicornis* by LUNDBLAD (1927) and MOTAS (1928). After the liberation of the *Chironomus* pupa from the pupal cast as an adult or after the death of the host, the parasites leave and seek another host. As I could not observe the well-developed nymphophan in my species, I am at present unable indicate how long it takes for them to develop to a motionless nymphophan, but from my observations it can be surmised that these larvae change different hosts a few times before arriving at the nymphophan stage. During the breeding it was noticeable that the insect larva was often unable to complete metamorphosis on account of the parasitism. According to frequency of the infection there was quite a difference in their developmental stage at which they died : some died in the pupal stage, while

others died in the progress of their metamorphosis. When these larvae of the water mites were put in an aquarium with the *Chironomus* larvae, they were at first found swimming in the water or creeping on the bottom, but 20 hours afterwards scarcely one of them was seen swimming, because they searched after their hosts which dwelt generally under the muddy bottom.

The emergence of the adult of *Piona carnea* from its teleiophan I observed several times. The nymphs collected at the beginning of March, 1930, near Paris actively and frequently attacked Daphnids and gradually grew larger. When they reached due size, they sought their pupating place among *Elodea canadensis* and *Cladophora* sp. By means of their mandibles and palpi they fastened themselves on these plants, piercing through the leaf of *Elodea canadensis* by both the organs from the upper surface to the under one or taking hold on *Cladophora* sp. by their claw-shaped palpi, and always having the four pairs of legs widely outstretched. The contents of legs and palpi of these nymphs were gradually absorbed into the body-mass, which came to take on a spherical form in two or three days. In the meantime, there arose beneath the pupal skin the teleioderma (apoderma tertia), within which the metamorphosis proceeded apace and the body of the imago bulged out gradually. The imago within the pupal skin became coloured at first on the dorsal side and then gradually on the ventral, while the forerunners of the legs and palpi were marked as a number

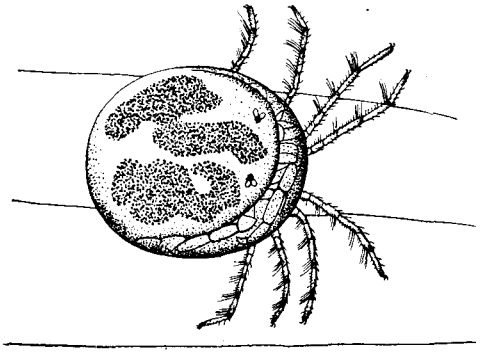

Fig. 12. Teleiophan of *Piona carnea* attached to *Elodea canadensis*.

of dark brown flecks arranged in semicircular form on the anterior ventral surface. These legs were doubled up within the pupal skin, and the terminal segments of them remained colourless just before the emergence from the teleiophan stage. Meanwhile, on account of growth and movement of the imago the pupal moult became distended to its full extent and consequently was ruptured on both sides and thus a new imago was liberated.

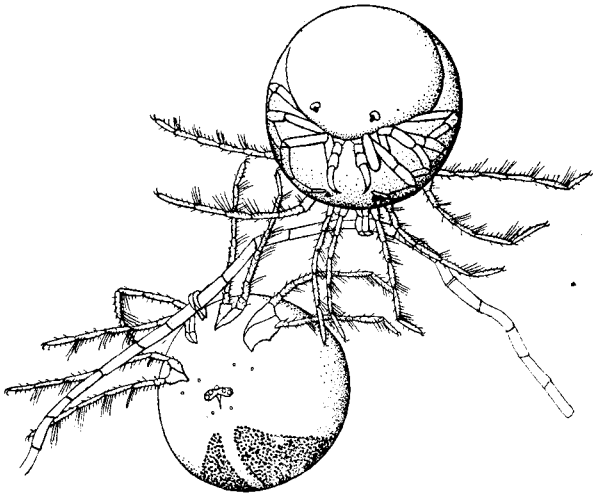

Fig. 13. Teleiophan of *Piona carnea* fastened to *Cladophora* sp.

With regard to development of the genus *Limnesia* WESENBERG-LUND (1918) describes that "Regarding this subfamily (Limnesiinae) various authors have pointed out that the six legged larval stage is not free but carried out either in the egg itself or perhaps in the hyalin capsule surrounding the eggs." The fact takes place probably in *Limnesia undulata* and *L. connata*, but PIERSIG (1900) indicates that *L. histrionica* = *L. fulgida* is parasitic upon larvae of the aquatic Coleoptera. The larvae of the latter which hatched out about two weeks after the spawning swam actively but mostly crawled on the bottom and did not parasite upon any of the larvae above mentioned.

According to former authors and WESENBERG-LUND (1918), larvae belonging to the genus *Arrhenurus* infect imagoes and nymphs of the

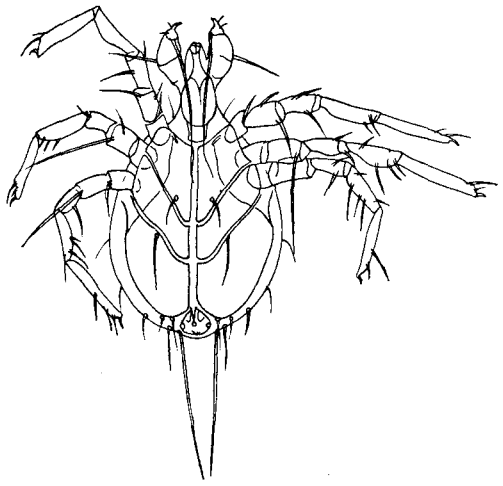

Fig. 14. Larva of *Arrhenurus* sp. × 147.

Odonata. MOTAS (1928) described a kind of *Arrhenurus* larvae parasitic on a *Hydrophilus* larva. Many larvae of *Arrhenurus* spp. hatched out at the beginning of May, 1930, were found to be exclusively parasitic on the *Hydrophilus* larvae among the insect larvae in my experiment. These larvae could attach to the host at different portions and at any stage of the latter, but according to my observations it was most favourable for them to become parasitic immediately after the moulting of the host and especially on its posterior portion as in the case figured by MOTAS (1928). After parasiting they became swollen out in two or three days, reaching double size in the free swimming stage and, though considerably active before, became sluggish and consequently unable to swim. As a means of attachment of the larvae on the *Hydrophilus* larva their mandibles only seemed to function, while the legs did not take much part in the purpose. After 4 to 5 days they separated from the host and remained motionless on the bottom of the aquarium as a nymphophan. To rear the nymphophan to a nymph was not successful in these breeding experiments.

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