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NOTES ON THE LIFE HISTORY OF PROSPALTELLA PERNICIOSI TOWER

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NOTES ON THE LIFE HISTORY OF PROSPALTELLA PERNICIOSI TOWER[1]

By Daniel G. Tower, M. Sc., *Amherst, Massachusetts*

Introduction

The following notes were taken during the early spring, fall and winter of 1913, and the spring of 1914.

This parasite, a description of which, both male and female, was published in the Ann. Ent. Soc. Am., vol. VI, No. I, pp. 125–126, is a true internal parasite, the larval forms living within the body tissues of its host, the female San José scale, *Aspidiotus perniciosus* Comst., except during the last part of the second larval stage as at this time the entire contents of the host are consumed by the larva, which, after passing its waste, pupates in the empty skin of the scale.

Both male and female parasites emerge from the empty skins of second-stage and early third-stage female scales, but by far the largest number emerge from second-stage scales.

The following description of the life cycle of the parasite, which has been worked out, is that of a parasite maturing in and emerging from a second stage scale. No doubt the development of those which emerge from third stage scales is the same.

The Egg

Developed eggs are readily seen within the abdomen of the female parasite when examined under the microscope at the time of emergence, and many are even fully developed in the late pupal stage. They can also be examined as found in the bodies of first-stage and early second-stage scales.

The egg is ovate and has a distinct micropyle at the smaller end. The chorion is smooth and hyaline and the nucleus, located at the larger end, and the opaque granules, with which the egg is filled, show through.

The egg measures .085 mm. in length and .04 mm. in width.

The number of eggs deposited by an individual is not known, but 1,364 developed eggs were obtained from twenty females selected as they emerged, giving an average of sixty-eight developed eggs apiece. Of the twenty females examined, the smallest and largest number of eggs found in a single specimen was forty-six and 102, respectively, and in most of these females there were still undeveloped eggs.

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[1] Contribution from the Entomological Laboratory, Massachusetts Agricultural College.

Development of the Egg

The egg is usually found lying about medially in the scale and slightly nearer the pygidium end of the scale than the head end, although it may be found almost anywhere in the body. Here the egg swells in embryonic development to two to three times its size when laid and the young larva may be seen forming within it. The larva is practically fully developed before hatching and lies curled within the egg. On hatching it straightens itself out in the egg and the chorion, which has become very thin, is ruptured, allowing the larva to escape into the body of its host.

First Larval Stage

The larva, when hatched, is large compared with its host. Its mouth-parts, which were fully formed while in the egg, now become fully chitinized and the mandibles, which are the most prominent parts, are very sharp, strongly chitinized and decidedly hook-like.

The tracheal system, which lies close to the body surface and which was only partially filled with air when the larva was in the egg, now becomes filled and the two longitudinal main trunks, which lie on either side of the body meeting anteriorly and posteriorly, forming an oval, each show ten short stub-like branches.

Apparently there are thirteen body segments, the thirteenth or posterior segment lying partly within the basal portion of the tail. A distinct head region containing the mouth-parts is marked off. This region in the newly hatched larva is of the same diameter as the body, but subsequent growth enlarges the body, while the diameter of the head increases little if any. Thus the head region becomes more definitely marked off.

The tail is about one-fifth the length of the larva. It is seen in the embryonic larva lying close to the body, while in the hatched larva it is extended and is used for propulsion inside the host. A number of pointed folds or hyaline scales, which protrude slightly from the surface and point backward, are placed irregularly on the surface of the tail and these doubtless make the tail an even more efficient organ of propulsion.

Oxygen must be obtained through the skin or from the food eaten, as the larva lives submerged in a liquid medium having no connection with the tracheal system of its host or with the exterior, also its own tracheal system does not connect with the outside of its own body.

Feeding is carried on by means of a sucking pharynx aided by the mandibles. The ventral surface of the pharynx is a rigid chitinous plate extending from the mouth backwards to the posterior limits of the head. The membraneous dorsal wall of the pharynx is raised from the ventral wall of the pharynx by muscles situated in the dorsal region of the head. These induce wave-like motions in the dorsal wall of the pharynx, which suck in and carry the food through the pharynx to the œsophagus. Here it is passed down into the stomach by the contracting action of the walls of the œsophagus.

The stomach is a blind sac in which the food is, during the early life of this stage, churned or rolled about by the movements of the larva. Later the stomach muscles become developed and constrictions, which run in waves from one end to the other, roll and turn the food content over and over, thus aiding digestion.

The posterior portion of the alimentary tract or proctodæum is scarcely developed and there is no external opening, as waste is not passed during this stage.

The larva at first feeds on the blood and smaller fat globules and avoids the vital parts as the growth of the second stage scale is not arrested until maturity has been reached. At this time usually the first larval stage of the parasite becomes full grown and apparently attacks, during its last days of growth, the vital parts of the scale, thus interfering with its normal functions and preventing the second molt of the scale from taking place. The scale, which previous to this time has been normal in its development, now becomes swollen and distended and at this time begins to turn from its normal lemon yellow to a light orange. The first molt of the parasite usually takes place at approximately the same time that the scale takes on the orange color.

The molting of this form terminates the first larval stage.

Second Larval Stage

This larval form is tail-less and its mandibles are not at first well developed, but soon grow to full size and become chitinized. The head region is indistinct and the body segments are practically indistinguishable.

The tracheal system lies deep within the body and at first contains little or no air, but soon becomes filled and develops rapidly. The first, second and fourth to ninth inclusive short branches of each longitudinal main trunk grow rapidly and terminally at the surface of the body develop spiracles, while the third and tenth branches remain short and do not develop spiracles. The two main longitudinal trunks are joined posteriorly and anteriorly as in the first larval stage and from these and the bases of the twenty branches are given off numerous branches which ramify to all parts of the body.

Respiration during the early life of this form is carried on in the same way as that of the first larval stage, but later as the fluid contents of the scale is consumed and an air space forms in the scale, some of the spiracles which have developed no doubt open and function. Without doubt by the time all the fluid content of the scale is consumed all the spiracles are fully developed and function.

The stomach is, as in the previous stage, a blind sac well filled with food. Its contents is even more thoroughly churned by more powerful contractions of the stomach walls. These contractions may start at either end running the length of the stomach, or starting at both ends run to the middle, or again starting in the middle run to both ends. The contents are at first the same yellow color as the scale, due to the fat globules swallowed, but later they become at first, due to digestion, a light orange, changing to dark orange and previous to being excreted a deep red to black color.

Feeding is carried on in the same manner as has been described for the first stage larva except that in the last part of this stage the mandibles, which are blunter and less curved than in the first stage, are used in destroying the internal organs and in scraping clean the inside of the skin of the scale.

The proctodæum is partially developed in the early part of this stage, but does not become fully developed or open until after the larva has consumed the entire contents of the scale and has entered a short quiescent period during which the contents of the stomach completes its digestive processes and is prepared to be excreted.

Following this period the waste, which has been accumulating in the stomach during the life of the two larval forms, is passed and is usually deposited along the lateral margins of the skin of the scale or at the ends. The chitinous portions of the proctodæum are passed out with the last of the waste and no doubt the chitinous portions of the fore-gut and tracheæ are also gotten rid of at this time.

The larva, following the passing of its waste, is usually found lying on its back with its head at the head end of the swollen skin which has dried and become a hardened case in which the parasite now pupates.

Pupation and the Pupa

Rapidly following the passing of the waste the larva usually begins to show differentiation into the three principal regions: namely, the head, thorax and abdomen. Following this condition, which externally marks the beginning of the pupal stage, pigmentation begins in the antennæ and its segments commence to form.

This coloration is quickly followed by that of the eyes, the dusky band of the fore-wings and a small portion of the ventral abdominal plates. These last do not appear in any regular order. These areas continue to darken for the next few days and the surface of the pupa becomes wrinkled, indicating the formation of the legs, mouth-parts and sclerites. Following this the abdomen and other pigmented or darkened portions of the body rapidly darken and the pupa becomes nearly black.

Previous to emergence the antennæ, legs and mouth-parts become free and the last larval skin is kicked off and the now active insect soon starts cutting and gnawing its way out. There is considerable variability in the length of time it takes for the adult to emerge. Some very active ones emerge in about three hours while others take a day or more. In emerging, a hole is made through which the head is thrust and the insect then pulls and pushes itself out, working its body from side to side and forward and backward, all the time lifting and pushing with its legs.

After emerging the parasite walks a few steps and then cleans itself and straightens out its wings. The insect spends some time in this way and then starts crawling about and is ready for copulation.

Duration of the Life Cycle

The following data are based on rearings of parasites in the laboratory at room temperatures which averaged from 68° to 72°F.

In working out the length of the different stages of this life cycle it has been found that the variability in the length of the different stages indicates a very elastic life history, and one well suited for its life in the host. Hence, it is impossible to give more than average time lengths for the periods.

Examination of large numbers of scales, during the spring of 1914 at Amherst, shows that in general the scales survive the winter in two forms: first, that of well-grown, first-stage scales, which when parasitized contain eggs of the parasite; and, second, well-grown second-stage scales, which, when parasitized, contain well-grown first stage parasite larvæ.

It has been found by raising parasitized scales of the first stage that the parasites reached maturity in from thirty-six to thirty-nine days, while the parasites in the second stage scales matured in from nineteen to twenty-three days.

It is seen that the duration of the life cycle of those parasites raised from eggs compares favorably with that of the scale, thirty-three to forty days, as given by Marlatt. This is further supported by the observations of Dr. H. T. Fernald and the author that the scale in Massachusetts occurs in more or less distinct broods, and the examination of large numbers of parasitized scales indicates that the broods of the parasite coincide with those of the scale.

It has not been possible to work out the length of the egg and first larval stage, as while this work was in progress young scales were not available for experimentation; however, it was possible to work out the other stages, and these subtracted from the total leave an average of from fourteen to nineteen days for the egg and first larval stages combined. Again according to Marlatt the female scale molts for the second time on the average eighteen days from birth and observations made on non-parasitized and parasitized scales show that the majority of the first stage parasite larvæ molt at approximately the same time that the non-parasitized scales molt the second time.

The length of the second larval stage averages from six to eight days.

The waste passing period, which terminates the growth of the second larval stage and ends arbitrarily with the pigmentation of the antennæ, averages from one to two days.

The pupal stage averages from eleven to twelve days. Internal pupal development commences during the waste passing period.

Copulation

Sexual reproduction seems to be the rule as copulation has been observed to take place in hundreds of cases among insects that emerged both in the spring and fall. The percentage of males to females seems to be about equal, as of 463 insects selected at random as they emerged, 235 were males and 228 were females.

Copulation was found to take place as soon as the parasites had dried off after emergence and no doubt oviposition commences at once, for as stated earlier females previous to emergence contain developed eggs.

Males and females crawling about do not seem to locate each other from a distance by any apparent sense but more by accidentally coming very close or in actual contact. In such cases the male either pays no particular attention to the female or mounts her and is then either driven off or copulation takes place.

In copulation the male stands on the head and thorax of the female and rapidly pats and rubs her antennæ with his own and endeavors to draw the antennæ of the female to an erect position. The female may resist the male and drive him away; even in cases where copulation takes place the female usually resists at first, but occasionally not at all. When the antennæ of the female are raised to an erect position by the efforts of the male, assisted by the female, they are held behind and beneath those of the male and their tips are in contact with the underside of the first and second basal segments of the flagellum of the male antennæ. The act of raising the antennæ seems to be that of assent, for copulation always follows this act. The male now shifts his position backward and grasping the abdomen and wings of the female with his fore and middle tarsi he leans backward and resting partially on his wing tips bends his abdomen between his hind legs which rest on the branch, and beneath the wing tips of the female and copulation takes place. Often a number of attempts are made before copulation finally takes place and this lasts from seven to sixteen seconds, the average length of time being from eight to eleven seconds.

During the act of copulation the female may stand quietly but usually walks, dragging the male with her.

After copulation takes place, the male again mounts the female and, drawing the antennæ of the female beneath and behind him as previously, the antennæ of the female having remained erect during copulation, usually stands quietly at first, occasionally moving his feet and gently patting her antennæ with his. Later he becomes restless and flits and fans his wings and finally leaves her, having stayed on her back from three to six minutes or more.

Polygamy and Polyandry

Emerging males and females were confined separately before copulation could take place and were then used to ascertain if the males would copulate more than once. A male and a female were confined together and copulation took place. The fertilized female was then removed and an unfertilized female substituted and the male readily copulated again, thus showing that they are polygamous.

The females that had been fertilized in the previous experiments were confined with males which had not copulated and these were under observation for two to three hours but copulation did not take place. Again often three or four males will attempt to copulate with one female and violent struggles take place among them, but in the cases observed only one male finally copulated with the female.

These last experiments indicate that polyandry is not, or is not the usual case.

Oviposition

The few cases of oviposition observed took place in young scales which had just formed a scale covering. In these cases the parasite crawled over the material on which she was placed until she found a young scale. This was examined by tapping it with the antennæ. She then turned back to the scale and thrust her ovipositor downward and backward through the scale covering and into the scale until the tip of her abdomen almost touched the scale covering. While it was not possible to see the egg deposited in the scale it is evident that this takes place for, in the examination of first-stage scales, one finds the egg lying within the body.

The examination of mature first-stage scales, which are wintering over, shows eggs in all stages of development and even live larvæ may be found in the early stages of the second-stage scales as they are forming within the skin of the first-stage scales. From the large number of observations made upon first-stage wintering scales, which were brought into the laboratory to complete their development, it seems that the majority of the eggs hatch just as the second-stage scale is forming within the first-stage scale, although many hatch after the molt previous to the feeding period of the second-stage scale. Undeveloped and partially developed eggs have also been found in second stage scales after feeding and growth have begun. These scales developed from first stage scales in the laboratory and hence it is seen that these eggs were laid late in the life of the first-stage scale. The above data indicate that oviposition takes place all through the life of the first-stage scale, after it has settled down, and that normally the majority of the eggs are laid early in the life of the young scale and these complete their development in mature second-stage scales, while those eggs which are deposited late in the life of the first-stage scale hatch so late in the life of the second-stage scale that it would not be damaged enough by the parasite to prevent it from passing into the third stage. This, it is seen, would account for the fact that some of the parasites emerge from early third-stage scales. However, there is a possibility of the parasite ovipositing in second-stage scales, but this seems unlikely as even its early life is additionally protected by the first exuviium and in its later life it seems even less likely due to its large size as compared with first-stage scales normally oviposited in.

Large numbers of the scales are oviposited in twice and possibly even more times, but twice is the most that has been observed. As a rule when two eggs are found in one scale they are widely separated in development, showing that they were laid at different times and hence by different individuals. In other cases one often finds an undeveloped or a partially developed egg and a live feeding larva in the same scale. Only two cases of like development have been observed; one was in which the two eggs found were at the same stage of development, and the other was in which the two larvæ were of approximately the same age. However, from the large number of observations made, it should not necessarily be taken that the same adult laid the two eggs in the scale, but rather that the scale in these cases was oviposited in by a second parasite the same day that the first oviposition took place. These facts together with the fact that only one parasite matures in and emerges from a single scale certainly shows that normally this parasite is uni-oviparous.

In the cases where the hatching of the larva from the second egg deposited occurs long enough after the hatching of the first egg, so that the first larva has had time enough to nearly mature or to pass into its second stage before the second larva hatches or is able to seriously interfere with its feeding, then the second larva attacks the first and enters its body usually posteriorly and does not greatly injure the first larva at first, as the second larva has been observed many times within the body of the first, feeding on the stored granular substances of the older larva while it was still feeding on the scale. In the case of wintering over forms, which will be discussed later, and in cases which have been observed in the laboratory, the second smaller larva does not greatly injure the first larva until after it has passed its waste and then with the rapid development of the second larva (during its second larval stage) the first larva is consumed and the second then passes its waste, pupates and emerges.

Probably, in cases where the eggs laid are not separated by enough time for the above to take place, the hatching larvæ destroy each other, or, on the other extreme, the egg resulting from the second oviposition is destroyed before it hatches by the larva hatching from the first egg.

Large numbers of male second-stage scales were also examined for the eggs and larvæ of the parasite, but none were found. This seems rather strange as it does not seem possible that the parasite distinguishes between male and female first-stage scales. Owing to the comparatively small number of male second-stage scales found, it not being possible to distinguish male first-stage scales from the female scales, there being certainly far fewer males than females as compared with the statement given by C. L. Marlatt (Bull. 62, n. s., Bureau of Ent. U. S. Dept. of Agri., p. 43), that the male scales comprise 95 per cent or more of those wintering over, the only suppositions then left are that oviposition in male first-stage scales results in their death or that in the material collected here at Amherst the males are actually much fewer and are not oviposited in.

Wintering over Stages

As stated previously the parasites pass the winter as undeveloped and partially developed eggs in the bodies of first- and second-stage scales. The first larval stage also winters over in the second-stage scales and also in the bodies of second-stage larval parasites, in the latter case usually lying centrally within its body. These second-stage larvæ are not arrested in their development by the second parasite within them in such cases, until after they have completed their growth and passed their waste. In the spring these first-stage parasites continue their growth consuming the older second-stage parasite larvæ and after passing their waste pupate and emerge.

Older forms of the parasite such as the second-stage larva, pupa and adults have not been observed to winter over.

It will be readily seen from the above that dormant or winter spraying would not only kill the scale but also the parasite.

Distribution

This parasite has been reported from Massachusetts, Pennsylvania and the District of Columbia, and the examination of material received from Drs. E. P. Felt, P. J. Parrott and W. E. Britton, entomologists in the states of New York and Connecticut, show the parasite to be present in those states.

Length of Life of the Adult

It was noted that the adult parasite died on the average in two days, when confined in test tubes plugged with cotton. Previous to this time adults had been observed drinking or feeding on sap and also on the bodies of crushed scales, so an experiment was tried in which the insects were supplied with water. The parasites drank readily and lived on an average four days under this treatment. Honey water was also tried, but the parasites did not live longer than those given water.

Fungous Enemies

It has been noted that the same fungi which attacks the scales as readily attacked the larval and pupal stages of the parasite, also that a number of parasites confined in test tubes died from the attacks of a species of *Empusa*.

Predaceous Enemies

The predaceous enemies of the scale, as *Microweisia* (*Pentilia*) *misella*, are incidentally destructive to the parasite in all its stages of development except the adult stage. However, as yet predaceous enemies of the scale in nowise control it and thus there is little danger of the parasite being extensively destroyed even in newly planted colonies.

Parasite Enemies

No cases of true parasitism have been observed, but a type of parasitism does occur which may be termed incidental or accidental, as such external parasites as those belonging to the genus *Aphelinus*, which lie beneath the scale covering and suck out the entire contents of the second or third-stage San José scales; pupating between the scale covering and the empty skin of the scale and at the same time destroying the internal parasite as well.

Geotropism and Phototropism

The adult parasites show both positive geotropism and phototropism and these two reactions, together with the instinct of the parasite to search for scales, no doubt accounts for the fact that the scales on the smaller and outermost branches and twigs of infested material are well parasitized. This fact was also noted by H. E. Hodgkiss and P. J. Parrott (Jour. Econ. Ent., vol. VII, 227, April, 1914).

THE EXTERNAL ANATOMY OF THE SQUASH BUG, ANASA TRISTIS DE G.*

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INTRODUCTION

In writing this article the chief aim is to endeavor to supply a reference work on the external morphological characters of a typical Heteropterous insect. For this reason the common squash bug has been selected as it is widely distributed, well known as a pest, and is readily obtainable for study.

In order to make the paper as complete as possible the morphologists' and systematists' terms have both been used, except in referring to the wing venation (the systematists' terms being lacking in the fore-wing and the morphologists' in the hind wing).

At this point I wish to express my gratitude to Dr. H. T. Fernald and Dr. G. C. Crampton for their many helpful suggestions and assistance in preparing this paper.

ANATOMY

Head

The sclerites of the head capsule of the squash bug are solidly fused together making it impossible to do more than to describe the general regions of which the head is composed. Of these the occiput (occ), (Pl. LV, f. 1.) lies behind the ocelli (oc) and forms the posterior portion of the head surrounding the occipital foramen. It is marked off by a shallow transverse groove, from

* Contribution from the Entomological Laboratory, Massachusetts Agricultural College.

the vertex. The vertex or cranium (ec) comprises the dorsal region in front of the occiput and bears the ocelli. This area is not marked off from the frons (f), which lies above and between the bases of the antennae (ant). The anterior margin of the frons is united with the base of the clypeus or tylus (c).

Below and on either side of the compound eyes (e) lie the genæ (g) while the ventral posterior portion of the head capsule forms the basal plate or gula (gu). The clypeus, as has been previously stated, is fused at its base with the frons, and at this point is narrow, but as it curves forward and downward it widens at its tip to form the base of attachment for the labrum (lbr) from which it is separated by a narrow membranous ring.

The labrum is an elongate triangular sclerite. Its anterior surface is convex, while its posterior surface is flat and contains a groove which lies above the groove on the basal half of the anterior surface of the labium (lab).

On either side of the clypeus is a narrow prolongation of the frons called the fulcrum, jugum or zygum (fr). The fulcra lie close to the lateral walls of the clypeus, hiding them, but are not united with them except at their bases, where they fuse with the head capsule. The fulcrum is shorter than the clypeus, its anterior margin lying behind the swelling of the tip of the clypeus. Its ventral margin extends to the base of the antenna where it fuses with the base of the maxillary laminae (ml).

The maxillary laminae or gena postica lie below the base of the antennae. Their bases are fused with the genæ and their ventral margins are united with the bucculæ (bu), which are chitinous plates projecting from the anterior ventral side of the head on either side of the base of the labium. The bucculæ serve to protect the posterior membranous portion of the base of the labium.

The rostrum, vagina or labium (lab) articulates with the anterior ventral region of the head between the bucculæ and is made up of four segments, the terminal segment at its tip bearing numerous sensory organs. The labium contains, as stated above, a dorsal groove in which lie the setæ (s). The edges of the groove, distal to the overlying labrum, overlap, forming a closed tube, thus giving the enclosed setæ more support (Pl. LVI, f. 8 s.). At its basal end the groove becomes very shallow; the labium becomes filled with muscles, tracheæ and nerves, and the setæ in this portion of the labium gradually come to lie within the labrum, whose edges meet beneath and confine the setæ (Pl. LVI, f. 8 s. and Pl. LVI, fs. 21-24's). They then pass back through the articulating membrane, which lies between the labrum and clypeus, and between the lateral walls of the clypeus. The walls of the clypeus at its tip, turn under, and their edges interlock forming a narrow pair of supporting lobes above which the setæ pass. Upon emerging from these lobes the maxillary setæ (m) spread apart to receive the tip of the pharynx and the canal from the salivary pump, both of which enter the setæ at this point.

The setæ represent the mandibles (md) and the maxillæ (m). The maxillæ are fluted and interlocked so as to form two tubes, these being the upper or suction canal, and the lower or salivary canal (Pl. LV, f. 2). The mandibles are slightly shorter than the maxillæ and their tips are barbed. Their function is that of piercing the plant tissue and holding the setæ in place, while the tips of the maxillæ, which are acute and fluted, probe the plant tissues, take up the plant juices, and eject the saliva. The setæ, as stated, pass back into the head capsule and separate at their junction with the pharynx, going to either side of it. Their bases widening out form points of attachment for the controlling muscles.

The antennæ (ant) are composed of six segments. The third and fifth are ring joints (Pl. LVII, f. 16, r.), or reduced segments; therefore the antenna as a whole appears to be composed of only four segments. The fifth segment, or second ring joint, allows great freedom of motion to the terminal segment. The second and fourth segments are long and slender. The proximal segment is called the scape or radicula (sa). It is large and has a stalked base, which enlarges at its connection with the head to form a universal joint. The terminal segment is spindle shaped and covered with numerous sensory hairs. The other segments possess sensory hairs, but not as specialized as those of the terminal segment.

The compound eyes (e) are large and composed of many facets, and project prominently from the head. The ocelli are two in number.

The posterior portion of the head or the collum is set into the collar of the prothorax and is joined to it by a membranous neck.

Thorax

Prothorax.—The prothorax is a large chitinous segment whose sclerites are solidly fused together, with the exception of the episternum and epimeron which are separated for a short distance by the coxal cleft (b).

The notum (no) overlaps the prescutum, scutum, and a portion of the scutellum of the mesothorax dorsally; and the pleural region projects over a portion of the anterior part of the mesothorax laterally (Pl. LV, f. 1 and 4). The tergum or notum is of one piece, its sclerites being indistinguishably fused together. Its anterior portion is more or less irregular due to the attachments of the muscles of the fore leg to its inner surface. The union of the notum and pleuron forms a well defined ridge.

The Pleuron (pl) is divided, as stated above, by the coxal cleft into the epimeron (epm) and episternum (eps). The cleft extends only a short distance into the pleuron terminating in a groove. Above this the pleuron bulges out forming a larger cavity for the expanding muscles of the fore leg. This region of the pleuron is called the omium (om).

The sternum (st) is a small area lying between, and anterior to the coxal cavities, and is indistinguishably fused with the pleuron. The portion of the sternum projecting backward between the coxal cavities is called the mucro (mu). The anterior portions of the coxal cavities are formed by the inner surfaces of the epimeron, episternum, and the sternum; and are closed posteriorly by the extensions of the prothorax epimeron and sternum, together with the anterior portion of the mesosternum.

The legs show the usual five divisions into the coxa (co), trochanter or fulcrum (fr), femur (fe), tibia (t), and tarsus (ta), (Pl. LVI, f. 13). Since the fore legs are typical, although they are proportionately smaller, one description will be sufficient. At the base of the coxa hidden within the coxal cavity is a narrow plate called the trochantin (Pl. II, f. 9 ti). The coxa is a large swollen segment lying largely within the coxal cavity and is freely movable. The trochanter or fulcrum is a small segment which forms a ginglymus articulation with the coxa and is obliquely joined to the side of the femur. The femur is long and more or less spindle shaped; the tibia articulates with it by a ginglymus joint and is long and slender. The tarsus is composed of three segments. The first segment is called the Metatarsus (meta), and the terminal segment the ungula (u). This bears divergent claws called unguicula (ua) beneath each of which lies a pulvillus (pu) modified to form a concave adhesive pad (Pl. LV, f. 3).

Mesothorax.—The mesothorax is attached to the prothorax by the intersegmental membrane, and the two segments are easily separated, thus uncovering the anterior area of the scutellum and the scutum and prescutum. The covered areas, or the scutum and prescutum, are also called the dorsulum.

The scutum (sc) is divided longitudinally by a wide median furrow. In the scutum, on either side of the median furrow are two irregular longitudinal impressed lines (d), which are possibly homologous with the parapsidal furrows of the Hymenoptera. If this be the case, then the area lying between the two last mentioned impressed lines would be the prescutum (psc), while the areas lateral to the lines would be the scutum (Pl. LVI, f. 10).

Lying posterior to the scutum and separated from it by a transverse ridge is the scutellum (sct), which is triangular in outline and projects posteriorly over the metathorax and the first abdominal segment. On the lateral edge of the scutellum is a ridge called the frenum (fm) (Pl. LVI, f. 10).

The postcutellum (psct) of the mesothorax forms the anterior wall of the phragma (phr) situated between the meso and the metathorax, while the prescutum (psc) of the metathorax forms its posterior wall. Both of these sclerites are only slightly visible externally (Pl. LVI, f. 10).

The fore wings are characteristic of the suborder Heteroptera being partly membranous and partly coriaceous. Their bases articulate with the mesonotum by means of small chitinous plates called ossicula or axillaries.

The membranous and coriaceous portions of the fore wings are separated by a more or less broken oblique suture called the sutura membranæ (s-m). The coriaceous portion is marked off into three areas by two longitudinal sutures (Pl. LVIII, f. 19). These areas are as follows: the clavus (cl), which lies next to the mesoscutellum when the wings are in repose; the corium (cr), which lies between the two sutures; and the embolium or costal area (em), which lies beyond the second suture. The first suture or the one which marks off the clavus is called the sutura clavi or anal furrow (s-c). The suture separating the corium from the embolium is called the median furrow (m-f). The margin of the clavus, which when the wing is at rest lies along the lateral edge of the mesoscutellum, is called the margo scutellaris (m-s), while the margin of the clavus beyond the tip of the mesoscutellum, is called the commissura (cm).

There are three angles in the coriaceous portion, used in classification. These are as follows: the internal angle, angulus internus (a-i) formed by the meeting of the sutura membranæ and the sutura clavi; the angulus clavi (a-c), which lies between the sutura clavi and the commissura; and the angulus scutellaris (a-s), which is formed by the meeting of the commissura and the margo scutellaris.

The coriaceous portion of the wing has an inconspicuous venation to which the following names have been given. The costa (ca) is the longest vein, lying nearly parallel to the costal margin of the wing. The subcosta (sca) and radius (ra) lie posterior to the costa, their basal halves being coalesced. Behind or posterior to the coalesced subcosta and radius, lies the median vein (me) connected by a short cross vein (r-m) near its tip with the radial sector. The cubitus (cu) lies within the clavus; and the first anal vein (a) lies along the margo scutellaris except at its base where it extends into the clavus.

The anterior part of the mesopleuron is hidden under the prothorax. It is partially divided into two sclerites, the epimeron and the episternum, by the coxal cleft over the insertion of the mesocoxa. A third plate which is a marked off portion of the epimeron lies at the base of the fore wing and is wholly hidden by the prothorax. It is called the basalar plate (ba). A chitinous plate called the prealar bridge (o) connects the pleuron and the scutum near the juncture of the mesothorax with the prothorax. Below this plate lies the mesothoracic spiracle (sp) in the intersegmental membrane between the meso and prothorax. Posterior to the basalar plate is an invaginated triangular apodeme (ap) whose position is indicated externally by a cavity. A continuation of one of the angles of this cavity marks off part of the dorsal border of the pleuron causing it to appear as a sclerite. A membranous area extends from the base of the fore wing to the prealar bridge, and separates the scutum from the pleuron and its plates.

The sternum is of one piece solidly fused with the episternum. The coxal cavities are formed by the inner surfaces of the epimeron, episternum and sternum anteriorly, and posteriorly by the anterior margin of the metasternum and metæpisternum.

Metathorax.—The notum of the metathorax is well developed and is composed of three sclerites. The prescutum (psc), which has already been described, forms the posterior wall of the phragma between the meso and metathorax, and in its normal position is only slightly visible from the exterior. The scutum (sc) and scutellum (sct) are fused and the visible portions appear as an elongate triangular sclerite on either side of the mesoscutellum which hides the middle portion. The postscutellum (psct) lies behind this sclerite and is fused with it, its central portion being hidden beneath the projecting mesoscutellum.

The pleuron (pl) is partially divided by the coxal cleft into a large epimeron or pleurum and a very small episternum, the latter being indistinguishably fused with the sternum. At the upper end of the cleft lie the two light yellow scent glands (sg) separated by a pit which extends into the body cavity and into which flows the fluid secreted by the glands. Lying above the scent glands and hidden in the folds between the meta and mesothorax is the metathoracic spiracle. On either side of the dorsal margin of the metapleuron is a longitudinal grooved area called the cenchrus (Pl. LV, f. 4, cc and Pl. LVI, f. 10, cc), in which there lies a ridge, located on the ventral side of the costal margin of the fore wing.

The hind wings or alæ (hw) are joined to the metathorax although their bases appear to lie mostly above the mesopleuron when viewed laterally. Their bases articulate with the fused scutum and scutellum, whose posterior margin is continuous with the posterior margin of the wing. The alæ articulate with the metanotum by means of numerous small chitinous plates called ossicula or axillaries.

The wing is wholly membranous and distinctly veined. The venation given is the purely systematic one. The costa primaria (ca-p) is the large vein lying just posterior to and parallel with the costal margin in the basal half of the wing (Pl. LVIII, f. 20). The costa subtensa (ca-s) lies below the costa primaria and is more or less parallel with it. Near the distal end of the costa subtensa is a short incomplete transverse vein which nearly reaches the costa primaria. This is called the Hamus (ha). The distal ends of the costa primaria and subtensa are connected by a short vein, the costa connectens (ca-c). From the union of the costa primaria and costa connectens the costa apicalis (ca-a) extends outward toward the apex of the wing. Behind the costa apicalis and nearly parallel with it lies an unnamed vein which is usually unbranched although in an abnormal specimen a short branch vein has been noticed arising from it and extending outward between it and the costa apicalis. From the union of the costa subtensa and the costa connectens extends the costa decurrens (ca-d), a strongly curved vein. Behind the costa decurrens lie two nearly straight, short veins called the costa lineatæ (ca-l). Behind the costa lineatæ lie three veins in the anal area, the costa radiantes (ca-r). The first is not attached to the base of the wing while the second and third are so attached.

Abdomen

The abdomen is broadly joined to the thorax and its anterior portion is overlapped by the metathorax to such an extent that the spiracle situated in the pleural region of the first abdominal segment is completely hidden beneath the metapleuron. The first six segments of both male and female bear a pair of spiracles.

The first four and part of the fifth segments of the abdomen show clearly the marking off into four typical regions. The notum (no) is the flat, black, dorsal portion on which the wings rest. The pleural areas or connexivum which form the sides of the trough in which the wings lie when at rest are situated one on either side of the dorsal region, and extend to the prominent lateral edges of the abdomen. The sternal area is that forming the ventral and lateral portions of the abdomen. The spiracles (sp) are located near the dorsal edges of the sternum. The sclerites of the posterior portion of the fifth segment, and of the segments following, are more or less closely fused together and are specialized for reproduction in both males and females.

There are nine segments in the abdomen of the male. The seventh is not visible under normal conditions, but together with a large part of the eighth segment, is retracted within the sixth segment. The seventh segment is highly specialized for this purpose, being merely a collar of chitin which telescopes over the base of the eighth segment. The eighth or genital segment is also highly specialized, its sclerites being solidly fused together, except dorsally where the chitin is almost membranous just anterior to the rectal cauda (rc). Its shape is also greatly modified. The dorsal aspect presents a large pit or cavity, above which lies the rectal cauda and the genitalia. The chitinized tip of the rectal cauda is the much modified ninth segment. The rectal cauda projects posteriorly from the dorsal wall of the eighth segment, which is called the pygidium (pg). The basal half of the rectal cauda is membranous above and below, but slightly chitinous laterally. Its posterior half, which lies folded and hidden within the basal portion, is membranous except the tips which are chitinized, and open and close as do the edges of a purse. Beneath the basal portion of the rectal cauda lies the œdeagus, those chitinized portions of the male genital organs through which pass the membranous structures connected with the ejaculatory duct. Posterior to the œdeagus lie two movable appendages or styli (la). The ventral portion of the eighth segment which bears internally the lateral appendages and contains the œdeagus is called the hypopygium (pp).

Dorsally, the abdomen of the female presents ten segments. The tenth, which forms the chitinous lips of the rectal cauda, is hidden within the ninth, except when extruded, and is widely separated from the ninth by the membranous rectal cauda. The dorsal portion of the ninth segment is called the pygidium. Ventrally, the ten segments are not so easily recognizable, especially when the abdomen is extended, as the segments are variously modified for protective and reproductive purposes. Attached to the insides of the dorsal and ventral portions of the eighth abdominal segment are two pairs of chitinous appendages, the lateral appendages or styli, armed with stiff spines or hairs. These lie above and protect the soft portions of the genitalia when in repose. These appendages may function as claspers in copulation, but actual observation of this function will be necessary to determine this point. The ventral portion of the eighth abdominal segment is called the hypopygium.

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LETTERING OF FIGURES.

Numbers 1-10 denote number of the segment. Subscripts 1, 2, 3, pro-, meso-, metathorax, respectively.

a	anal vein.
a-c	angulus clavi.
a-i	angulus internus.
a-s	angulus scutellaris.
ab	abdomen.
ant	antenna.
ap	apodeme.
b	coxal cleft.
ba	basalar plate.
bc	bulb of antenna.
bu	bucculæ.
c	clypeus or tylus.
ca	costa.
ca-a	costa apicalis.
ca-c	costa connectens.
ca-d	costa decurrens.
ca-l	costa lineatæ.
ca-p	costa primaria.
ca-r	costa radiantes.
ca-s	costa subtensa.
cc	cenchri.
cl	clavus.
cm	commissura.
co	coxa.
cr	corium.
cu	cubitus.
d	parapsidal furrows.
e	eyes.
em	embolium.
epm	epimeron; mesothoracic epm = scapula; metathoracic epm = pleurum.
eps	episternum.
f	frons.
fe	femur.
fm	frenum.
fr	fulcrum, jugum or zygum.
fw	fore wing.
g	gula.
hw	hind wing, ala.
la	lateral appendages, styli.
lab	labium, rostrum, vagina.
lbr	labrum.
m	maxillary setæ.
m-f	median furrow.
m-s	margo scutellaris.
md	mandibular setæ.
me	median vein.
ml	maxillary laminæ, gena postica.
mta	metatarsus.
mu	mucro.
n	salivary canal.
no	notum.
o	prealar bridge.
oc	ocelli.
occ	occiput.
om	omium.

p	suction canal.	s-m	sutura membranæ.
pg	pygidium.	sa	scape.
phr	phragma.	sc	scutum.
pl	pleuron; abdominal pleuron = connexivum.	sca	subcosta.
		sct	scutellum.
pp	Hypopygium.	sg	scent glands.
psc	prescutum.	sp	spiracles, stigmata.
psct	postscutellum.	st	sternum.
pu	pulvillus.	t	tibia.
r	ring joints.	ta	tarsus.
r-m	connecting vein between ra and me.	ti	trochantin.
		tr	trochanter, fulcrum.
ra	radius.	u	ungula.
rc	rectal cauda.	ua	unguicula.
s	setæ.	v	vertex, cranium.
s-c	sutura clavi, anal furrow.		

EXPLANATION OF PLATES.

Plate LV.

Fig. 1. Lateral view of head, thorax and first segments of the abdomen.
Fig. 2. Cross section of the mandibular and maxillary setæ.
Fig. 3. Lateral view of a tarsal claw and the adhesive pad or modified pulvillus lying beneath it.
Fig. 4. Lateral view of the meso- and metathorax, as seen looking obliquely backward. the prothorax being removed and the wings raised and the abdomen abnormally extended to show the spiracle on the first segment.
Fig. 5. Dorsal view of the abdomen. The female genitalia are not extended.

Plate LVI.

Fig. 6. Maxillary setæ showing fluted and piercing tips; (see fig. 2 cross section of maxillary setæ).
Fig. 7. Mandibular setæ showing barbed and piercing tips.
Fig. 8. Cross section of labium at the tip showing how the setæ are supported.
Fig. 9. Coxa and trochantin.
Fig. 10. Dorsal view of the meso- and metathorax with the wings extended.
Fig. 11. Lateral view of the male genitalia extended.
Fig. 12. Ventral view of the male genitalia normally retracted.
Fig. 13. Typical leg.
Fig. 14. Lateral view of female genitalia normally retracted.

Plate LVII.

Fig. 15. Dorsal view of male genitalia extended.
Fig. 16. Antenna.
Fig. 17. Ventral view of the insect showing female genitalia.
Fig. 18. Lateral view of female genitalia extended.

Plate LVIII.

Fig. 19. Fore wing.
Fig. 20. Hind wing.
Figs. 21-24. More or less diagrammatic.
Fig. 21. Cross section of second segment of the labium, showing the position of the setæ.
Fig. 22. Cross section at the tip of the first segment of the labium, showing the position of the setæ.
Fig. 23. Cross section at about the middle of the first segment of the labium, showing the position of the setæ.
Fig. 24. Cross section at the base of the labrum, showing how the setæ are supported.

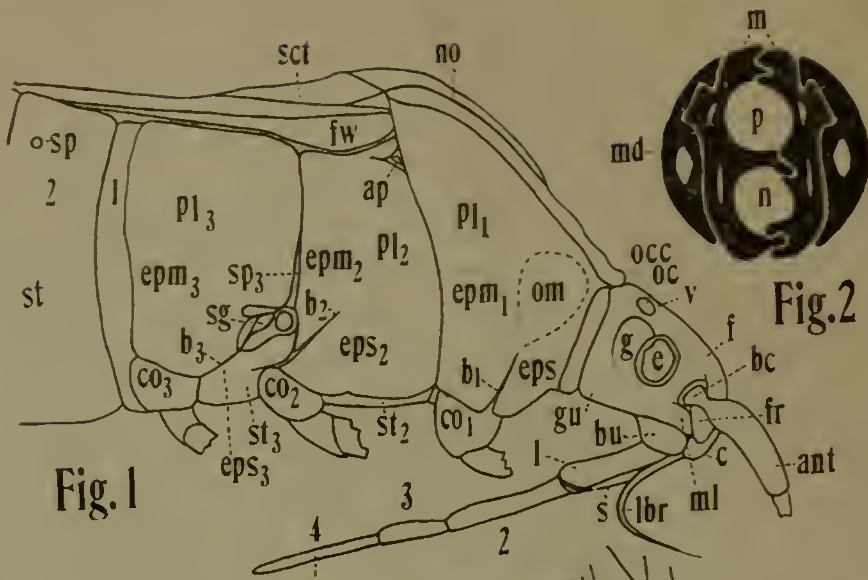
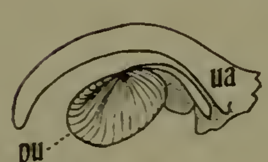


Fig. 1

Fig. 2



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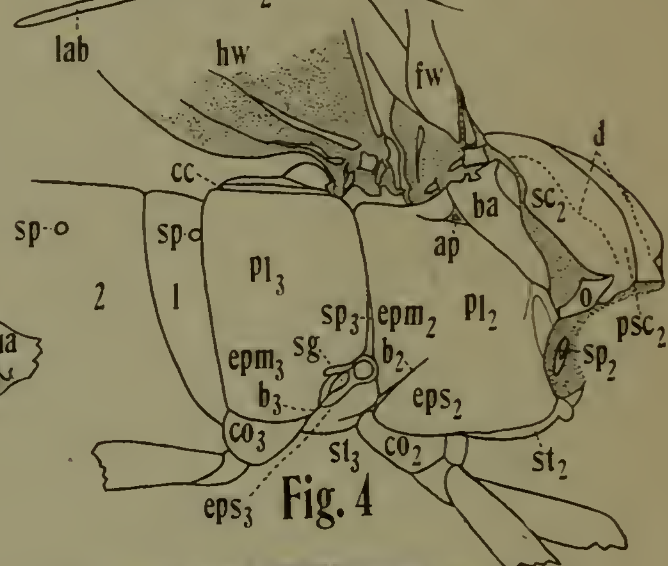

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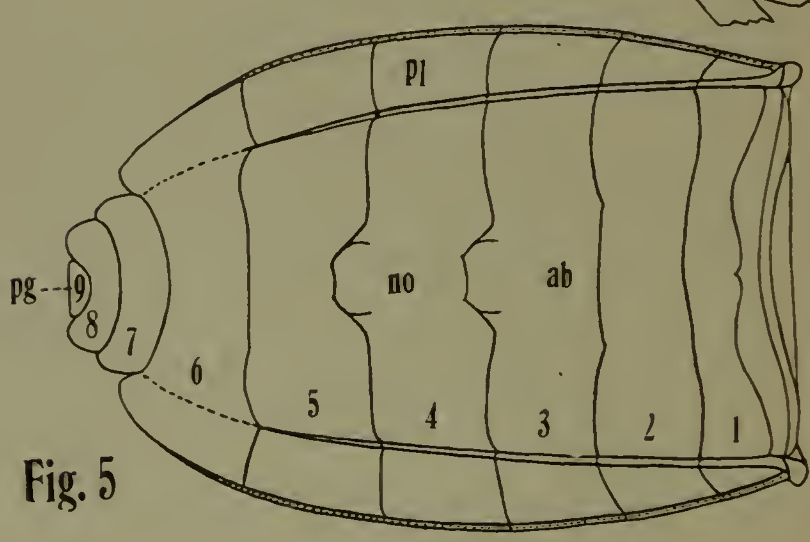

Fig. 5

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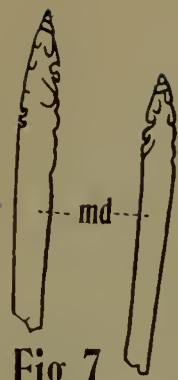
Fig. 6



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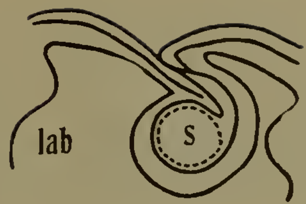


Fig. 8

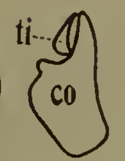


Fig. 9

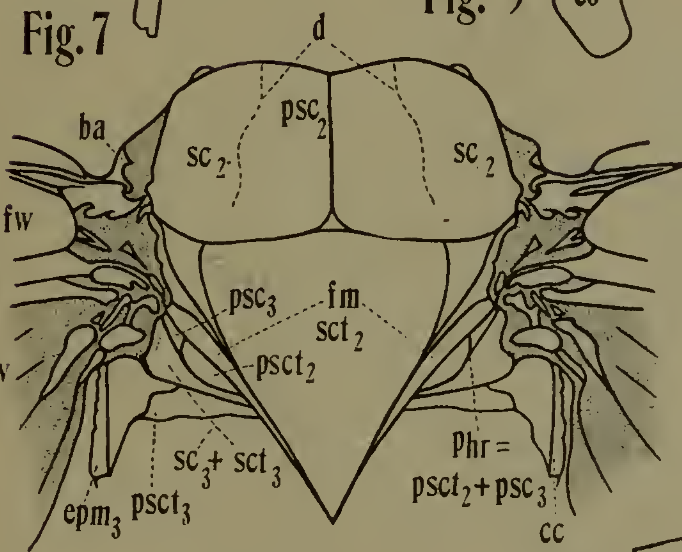
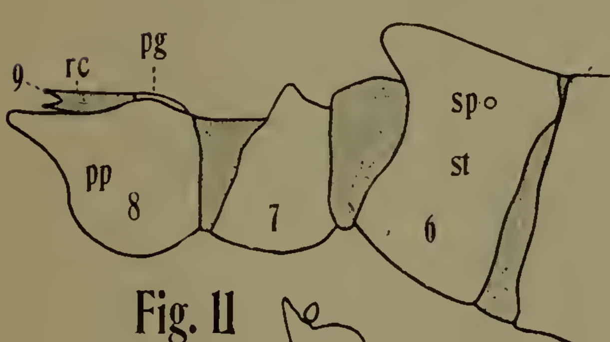


Fig. 10



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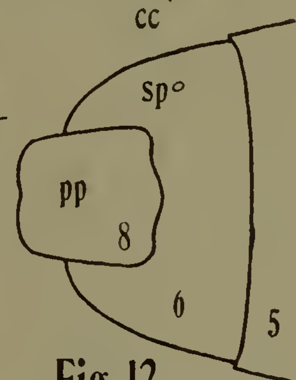

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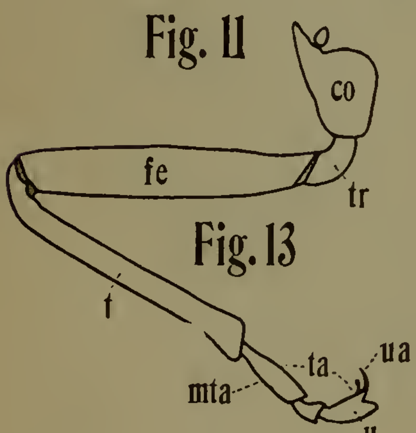

Fig. 13

Fig. 14

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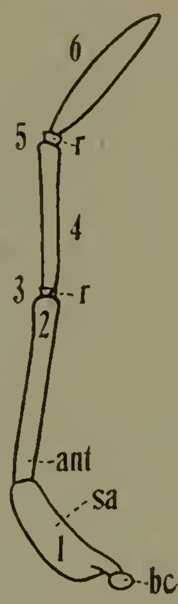
Fig. 15



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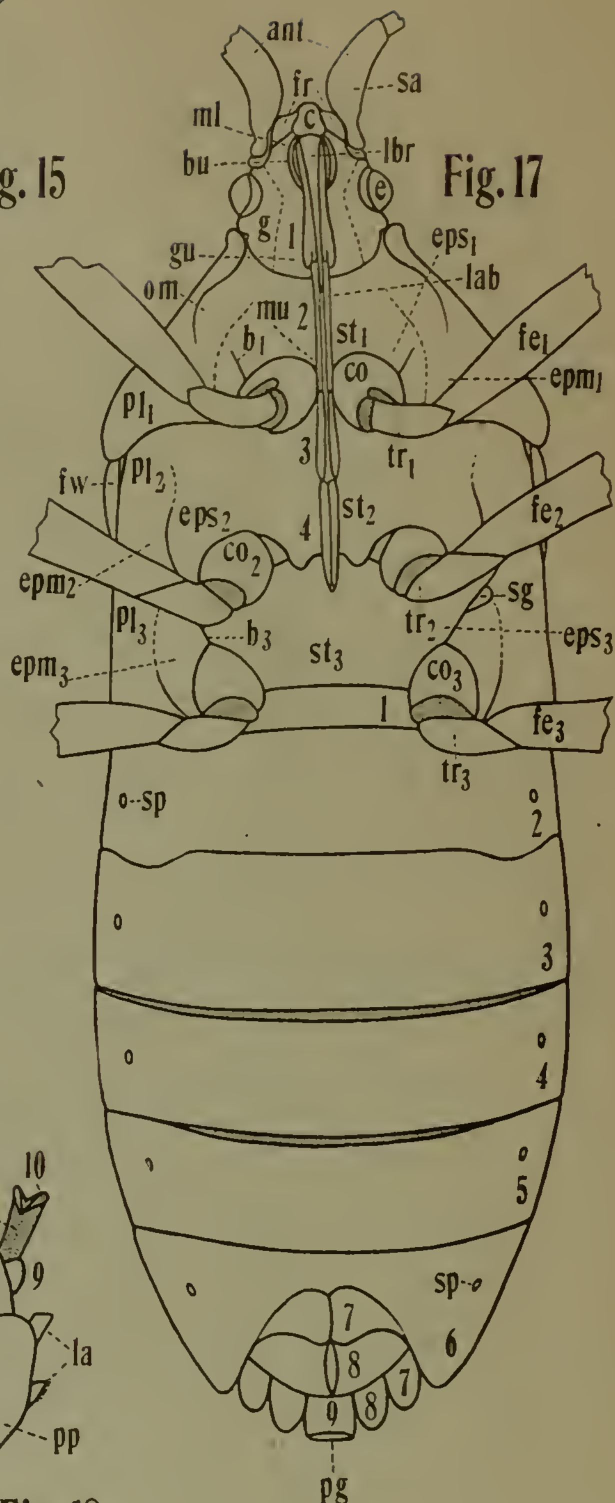
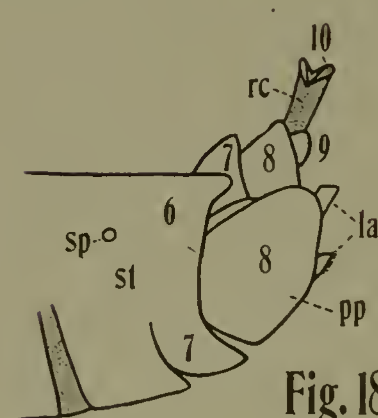


Fig. 17



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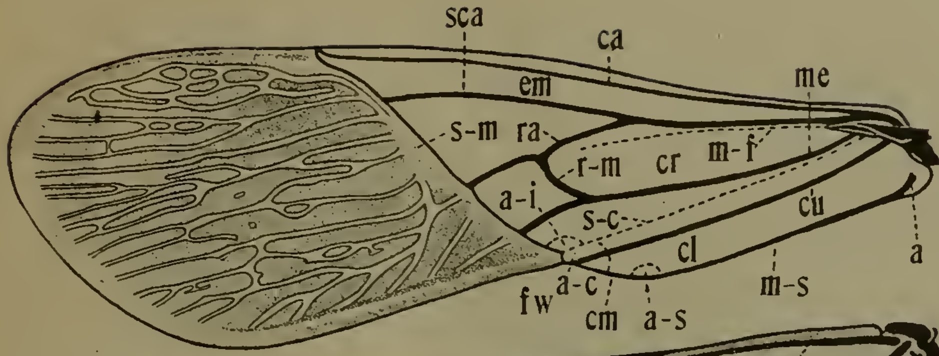


Fig. 19

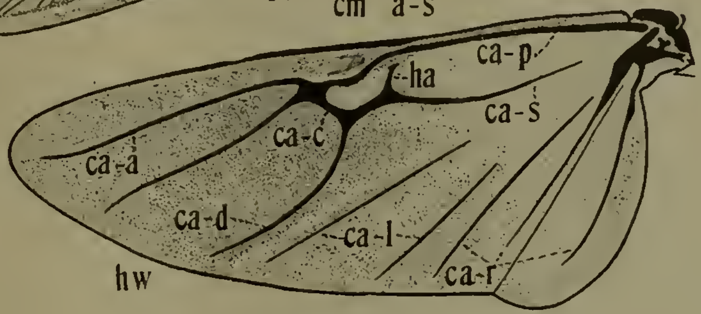
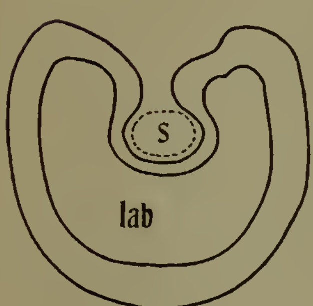


Fig. 20



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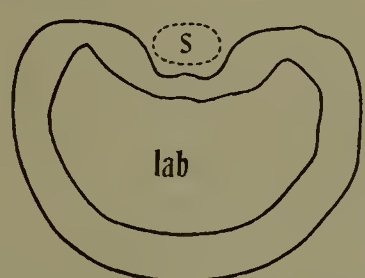

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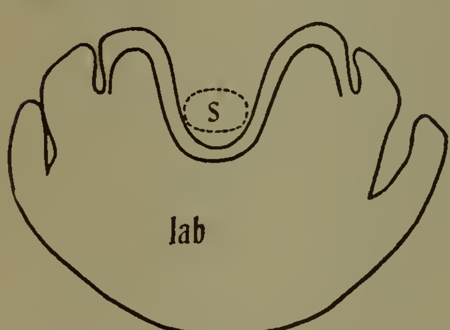

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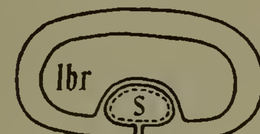

Fig. 24

D. G. Tower.

A NEW HYMENOPTEROUS PARASITE ON ASPIDIOTUS PERNICIOSUS COMST.

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A NEW HYMENOPTEROUS PARASITE ON ASPIDIOTUS PERNICIOSUS COMST.*

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This parasite was reared during October, 1912, from *Aspidiotus perniciosus* Comst. at Amherst, Mass. Specimens were sent to Dr. L. O. Howard, who returned them with the statement that they were a new species of *Prospaltella* and could safely be described as such. Acting on this advice the following descriptions of male and female have been prepared, under the supervision of Dr. H. T. Fernald.

This new species can be inserted in Dr. Howard's key to the species of *Prospaltella* (Ann. Ent. Soc. Am., I, 281, 1908), by adding a fourth alternative to section five as follows: "Wings with a broad dusky band below marginal vein, ... 6," and by adding to section six the alternative, "Wings with a broad dusky band below marginal vein: abdomen nearly black" which would lead to this species.

Prospaltella perniciosi n. sp.

Female: Length, 0.61 mm.; expanse, 1.73 mm.; greatest width of fore-wing, 0.25 mm. General color of living specimens black with the meso-scutellum showing as a prominent light dot. In zylol-balsam mounts the head and central portions of the thorax are light brown. Head: vertex yellowish brown; occiput dark; ocelli dark; eyes black and hairy, the hairs about as long as the diameter of a facet. Antenna: brownish yellow; bulb twice as long as wide, cylindrical and nearly hyaline; scape nearly five times as long as wide, nearly hyaline at each end, more or less cylindrical to spindle shaped; pedicle slightly longer than wide, narrow at its base, widest well toward its tip, its inner side much farther from the axis of the antenna than its outer side; first funicle segment connected with pedicle by a narrow somewhat elongate stalk, which is quite hyaline; this segment a trifle more than half the length of the next and irregular in outline; second and third segments of the funicle nearly equal in size and nearly cylindrical; segments of the club more closely articulated to each other than to the funicle or than are the segments of the funicle to each other; club slightly longer than funicle; first two segments about equal in length, their greatest diameter being at their outer ends; terminal segment elongate, triangular in outline, and longer than either of the other segments, bluntly pointed at tip; all segments of antenna bearing scattered hairs.

* Contribution from the Entomological Laboratory, Massachusetts Agricultural College.

Thorax: Pronotum dark; mesoscutum brownish yellow, darker near the anterior edge, mesoscutar parapsida same color or lighter than mesoscutum with a darker spot well forward toward the base of the fore-wing; scapula dark; mesoscutellum noticeably paler than mesoscutum. Behind the mesoscutellum are two narrow transverse plates dark toward their lateral margins and light near the middle, the posterior plate with a spiracle near each lateral margin. Marginal and submarginal veins of fore-wing nearly equal in length; end of stigmal vein obscurely pointed, not reaching wing margin, its upper side slightly emarginated, its anal margin broadly rounded; a broad dusky band crosses the fore-wing below the marginal vein; hind wing lanceolate; legs pale yellow except the coxæ, femora, and basal halves of the tibiæ, these being dark, the coxa being the darkest portion of each leg, those of the hind legs being the darkest; fore-legs as a whole the lightest and the hind legs the darkest; trochanters nearly hyaline.

Abdomen: Short, broad, nearly quadrangular in outline; quite dark with faint transverse lighter bands and a yellowish brown area near the genitalia: with spines directed backward evident on the sides (above and below also?).

Male: Length, 0.56 mm.; expanse, 1.54 mm.; greatest width of fore-wings, 0.26 mm. Living and mounted specimens appear the same as females, except that they are smaller, and the mesoscutellum is not as light in color. The antenna differs in that the first funicle segment is as long as the second, and its diameter at its distal end is greater than the diameter of either of the other two funicle segments. Its base is rounded and stalked, and it does not give the effect of a bead as does the corresponding segment in the female antenna. The articulation between the second and third segments of the club is not as evident as between the first and second segments, while in the female both articulations are very clear and well defined. The thorax as a whole is darker than that of the female, the only light portions being the mesoscutellum and the portion of the mesoscutar parapsida nearest it. The hind margin of the stigmal vein is more angular than in the female. The faintly cloudy band below the marginal vein is hardly distinguishable. The abdomen is short, much narrower than the thorax, truncate, dark and not showing lighter bands, but lighter near the genitalia which extrude, the tips of these being nearly hyaline.

Described from one female type and forty-three paratypes (on twelve slides) and one male type and four paratypes (five slides). The male type (one slide) and the female type with eleven paratypes (one slide) in the collection of the Massachusetts Agricultural College, Amherst.

One male and nine female paratypes (two slides) deposited in the U. S. National Museum (Type No. 15453).

The remaining paratypes male and female together with some female metatypes, have been retained by the author.

THE MECHANISM OF THE MOUTH PARTS OF THE SQUASH BUG

ANASA TRISTIS DE G.*

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In preparing a previous paper dealing with the external anatomy of the squash bug (Tower '13) it was found necessary to work out the structure of the mouth parts and internal anatomy of the head region. The mouth parts proved to be so interesting that a more detailed study than was possible in a general consideration of the anatomy has been made, the results being incorporated in the present paper.

A brief description of the external region of the head and its parts has also been included so that one may more readily orient himself as to the relation of the parts to one another.

At this point I wish to thank Dr. H. T. Fernald for his assistance and the loan of books and pamphlets from his private library; and Dr. G. C. Crampton, who has directed my work and greatly assisted me in preparing this paper for publication.

As the sclerites of the head capsule are solidly fused together the general regions are all that can be described. Of these the occiput (occ), see Pl. 1 f. 1, lies behind the ocelli (oc) and forms the posterior portion of the head surrounding the occipital foramen. It is marked off by a shallow transverse groove, from the vertex. The vertex or cranium (v) comprises the dorsal region in front of the occiput and bears the ocelli. This area is not marked off from the frons (f), which lies above and between the bases of the antennae. The anterior margin of the frons is united with the base of the clypeus(c).

Below and on either side of the compound eyes (e) lie the genae (g), while the ventral posterior portion of the head capsule forms the gula (gu).

* Contribution from the Entomological Laboratory, Massachusetts Agricultural College.

The clypeus, as has been stated, is fused at its base with the frons, and at this point is narrow, but as it curves forward and downward it widens at its tip to form the base of attachment for the labrum (lbr) from which it is separated by a narrow membranous ring.

The labrum is an elongate triangular sclerite. Its anterior surface is convex, while its posterior surface is flat and contains a groove which lies above the groove on the base half of the anterior surface of the labium (lab).

On either side of the clypeus is a narrow prolongation of the frons called the fulcrum (fr). The fulcra lie close to the lateral walls of the clypeus hiding them, but are not united with them except at their bases, where they fuse with the head capsule.

The maxillary laminae (lm) lie below the base of the antennae (ant). Their bases are fused with the genae and their ventral margins are united with the bucculae (bu), which are chitinous plates projecting from the anterior ventral side of the head on either side of the base of the labium.

The labium articulates with the anterior ventral region of the head between the bucculae. The labium contains, as stated above, a dorsal groove in which lie the setae (s). The edges of the groove beyond, or distal to the overlying labrum, overlap, forming a closed tube, thus giving the enclosed setae more support. At its basal end the groove becomes very shallow; the labium becomes filled with muscles, tracheae and nerves, and the setae in this portion of the labium gradually come to lie within the labrum, whose edges meet beneath and confine the setae.

The setae now pass back through the articulating membranes, which lies between the labrum and clypeus and between the lateral walls of the clypeus. The walls of the clypeus at its tip turn under, and their edges interlock, forming a narrow pair of supporting lobes above which the setae pass. Upon emerging from these lobes the maxillary setae (m) spread apart to receive the tip of the pharynx

and the canal from the salivary pump, both of which enter the setae at this point.

The setae represent the mandibles (md) and the maxillae (m). The maxillae are fluted and interlocked so as to form two tubes, namely the upper or suction canal (fc), and the lower or salivary canal (sc), see Pl. 1 f. 2. The mandibles are slightly shorter than the maxillae and their tips are barbed. Their function is that of piercing the plant tissues and holding the setae in place, while the tips of the maxillae, which are acute and fluted, probe the plant tissues, take up the plant juices and eject the saliva.

At the point where the maxillary setae diverge they are surrounded by a membranous sheath, which renders air tight their connections with the pharynx (ph) and with the salivary pump canal or efferent canal (ec). After separating,the maxillae together with the mandibles pass back, one of each on either side of the pharynx. The above mentioned membranous sheath also extends back on either side of the pharynx and encloses the setae, being fastened to their bases. Soon after the maxillary and mandibular setae have separated, at their junction with the pharynx, the mandibles separate from the maxillae and take up a position above them.

The bases of both the maxillae and mandibles widen posteriorly, forming attachments for the muxcles which operate them, especially the inner dorsal portion of the base of the maxillae. This becomes thickened to form a prominent ridge to which the chitinous rod (h),see Pl. 1 f. 7 and Pl. 2 f. 9, which articulates with the genae, is fastened by a short tendon. The rod runs downward between the setae and the side of the pharynx, turning under the setae,and here lies above the tentorial lobes, being embedded in a membrane which separates the muscles of the setae from these lobes. Laterally the end of this crescent shaped rod is fastened to the under side of a small internal knob on the genae (p) situated directly below the compound eye. Ventrally the rod is attached to the tentorial lobe, see Pl. 1 f. 7.

The maxillary setae are each controlled by two powerful muscles, both of which are attached directly to the bases of the maxillae. These are the protractor

muscle (pm), which extends anteriorly and is attached to the inside of the maxillary lamina and the side of the tentorial structure supporting the pharynx and salivary pump; and the retractor muscle which extends posteriorly and is attached to the occiput and also by a few fibres to the dorsal surface of the tentorial lobe (one on each side of the occipital foramen).

Each mandibular seta is controlled by two series of muscles. The two retractor muscles (rm), see Pl. 1 f. 3, are attached directly to the base of the seta. A short upwardly directed one is attached behind the ocelli, a longer one extends posteriorly and is attached laterally to the walls of the occipital foramen. The protractor muscle (pm) is attached to the inside of the frons. This muscle instead of being directly attached to the base of the mandible, is attached to a small chitinous triangular plate (b) which articulates at one corner with the gena near the anterior margin of the latter just anterior to the base of the antenna. This triangular plate likewise articulates with the mandible by means of a small rod (a) which is attached at its posterior end to the base of the mandible, while its anterior end articulates with the ventral corner of the triangular plate. The muscle in contracting pulls the mandible forward by means of the small connecting rod. These protractor and retractor muscles control the piercing and probing of the maxillary setae, and the piercing and holding of the plant tissues by the mandible.

The cavity of the pharynx (ph), which is larger in the middle than at either end, becomes continuous with that of the suction canal, in the setae, at the point of divergence of the maxillary setae. At this point the hypopharynx (hph), see Pl. 2 f. 12, or anterior portion of the ventral plate of the pharynx, (which is a slender chitinous trough-shaped process) enters the suction canal and lies on the ventral floor of the latter, while the epipharynx, or anterior portion of the dorsal plate of the pharynx, lies above the setae, fitting snugly over them, and extends anteriorly between the lobes of the clypeus. The

membranous sheath surrounding the union of the pharynx and setae make this union air tight.

The pharynx becomes constricted posteriorly as it passes between the circumoesophageal commisures, opening posteriorly into a membranous oesophagus. Posterior to this constriction the oesophagus is enclosed by a sheath made up of longitudinal muscles. This sheath is connected with the wall of the occipital foramen dorsally by two transversly attached muscles, given off dorso-laterally from the muscular sheath, and ventrally it is connected by two ventro-lateral muscles which diverge and are attached to the walls of the occipital foramen. This sheath extends from the posterior end of the pharynx back into the prothoracic region. The four muscles support the oesophagus in this region and probably by their movements of relaxing and contracting, together with the action of the longitudinal muscles of the sheath, play some part in passing the food down the oesophagus.

The pharynx is double U-shape in cross section, the dorsal plate (dp) and its lateral margins are attached to the dorsal edges of the rigid chitinous ventral plate. To the dorsal surface of the dorsal plate are attached the powerful pharyngeal muscles (phm), see Pl. 1 f. 6, which retracting draw up the dorsal plate creating a vacuum thereby drawing the plant juices up through the suction tube of the setae and into the pharynx.

The pharyngeal muscles are attached dorsally to the inside of the head capsule. There are three distinct series of pharyngeal muscles attached to the dorsal plate of the pharynx. The first or anterior series is short and composed of small muscles. They are attached to the dorsal plate just posterior to the epipharynx. The second is the longest series and is attached to the widened middle portion of the pharynx. The third or posterior series is attached to the more flattened upcurved posterior portion of the pharynx.

As the dorsal plate lies on the ventral plate, when the pharyngeal muscles are relaxed it seems reasonable to suppose that this pump acts in the following manner. The middle portion of the pharynx is filled when muscle series one contracts and is followed by the contraction of series two, the third series remaining relaxed while the middle portion of the pharynx is filling. When the middle portion is full the first series of muscles relaxes, allowing the dorsal plate to drop. The third series now contracts, opening the way into the oesophagus as the second series relaxes forcing the contents of the pharynx down into the oesophagus. Series three now relaxes to complete the emptying of the pharynx. At the completion of this series of contractions and relaxations at the posterior end of the pharynx, no doubt a new series of similar contractions and relaxations begin again, or possibly they start just before the completion of the first series. As the above description describes a wave-like motion and as no distinct valves have been found as are seen in the salivary pump, the above described process is no doubt the correct one.

Anteriorly the hypopharynx is marked off from the remainder of the ventral plate of the pharynx by raised irregular thickenings situated at the base of the hypopharynx on its lateral walls. The epipharynx is similarly marked off from the remainder of the dorsal plate by corresponding thickenings on the dorsal plate. The epipharynx is also well marked off from the remainder of the dorsal plate because at this point the flexable dorsal plate ends and the portion beyond or epipharynx lies above the union of the setae and bears ten papillae. These irregular thickenings on the lateral walls of the dorsal and ventral plate interlock on either side of the canal of the pharynx. Upon a superficial examination these interlocking thickenings appear to be valvular, but closer observation shows them to be lateral to the canal and that the canal is closed by the dorsal plate of the pharynx being pressed against the ventral plate. Situated on the

ventral surface of the epipharynx and above the diverging setae there is, as stated above, a series of ten minute transparent papillae arranged in pairs. It has been stated by some writers that these papillae or glands secret an oily substance which lubricates the setae, which at this point must necessarily move forward and backward and in close contact with the epipharynx and hypopharynx. Others state that these are taste organs. The balance of opinion seems to be in favor of the latter view although this point has not been sufficiently investigated.

Just posterior to the epipharynx on the dorsal plate of the pharynx there are four pairs of glands arranged in a line, each opening into the pharyngeal cavity. The nature of the secretions which these glands empty into the pharynx is not known, but probably they are digestive fluids. Above this series of glands is attached the first series of pharyngeal muscles.

Anteriorly and dorsally the pharynx is supported by two struts (n), see Pl. 2 f. 11 & 13, situated lateral to the lateral dorsal portion of the pharynx. These struts diverge and extending upward fuse with the lateral walls of the clypeus. In addition to these the anterior portion of the ventral plate is supported by upward extending diverging lateral struts which fuse with the inner walls of the fulcra, see Pl. 2 f. 12. At the point where the setae meet, the lateral walls of the clypeus pass down on either side of the epipharynx and setae and meet beneath the setae, thus forming the lobes of the clypeus (lc), see Pl. 2 f. 13. The pharynx is also supported by the tentorial structures, but this will be taken up later.

Below the anterior end of the pharynx lies the salivary pump (sp) supported by the tentorium. This very unique pump consists of a chitinous cylinder and piston. The cylinder is closed at its anterior end except for the two openings of the salivary ducts (sd) on its ventral side and the opening into

the salivary pump canal or efferent canal (ec) in its anterior dorsal surface. Within the cylinder is a valvular flop (iv) which is attached posterior to the salivary ducts. This valve covers these ducts and allows the salivary juices to enter the cylinder from the salivary ducts, but does not permit it to flow back. The dorsal opening is closed by a long valvular flop (ov) attached to the dorsal wall of the efferent canal, which extends forward. This allows the salivary fluid to pass out of the pump and into the efferent canal, but not to return again into the cylinder. Normally the cylinder is nearly filled by the piston head or plunger (pl), see Pl. 1 f. 5, to which is attached anteriorly and laterally the elastic flexible membranous posterior wall of the cylinder. Posteriorly the piston head or plunger is attached to a piston rod to which are attached two large muscles (k) which diverge posteriorly and are attached to the posterior ventral region of the head and also by a few muscle fibres to the ventral surface of the lobes of the tentorium. These muscles in contracting draw the plunger back creating a vacuum in the cylinder. This closes the dorsal outlet valve and opens the ventral or inlet valves causing the pump cylinder to fill with saliva from the salivary ducts. When the muscles relax, the elasticity of the posterior wall of the cylinder draws the plunger back into place, thereupon the ventral valves are closed and the dorsal one is opened and the saliva is forced out through the efferent canal and down the salivary canal in the setae and into the plant tissues.

It seems not unreasonable to suppose that these salivary juices act on the plant cells chemically, possibly as a poison, and cause them to yield their juices more readily, although this point has not yet been investigated.

The efferent canal after leaving the pump cylinder extends forward in a straight line (being supported by a portion of the chitinous tentorium and gradually itself becoming chitinized) until it reaches the membranous sheath about the setae which it penetrates, and then unites with the lower of salivary canal in the setae.

The tip of the efferent canal which is trough-like and chitinized enters the salivary canal at the separation of the maxillary setae and lies on the ventral surface of the salivary canal. The union is made air tight by the chitinous tentorial support of the efferent canal and the membranous sheath.

As these unions of the pharynx and the efferent canal with the setae must be more or less loose to allow for the forward and backward sliding movements of the setae, as they are used in feeding, the membranous sheath must fit tightly in and about these parts to insure that there be no leakage at these two joints.

The tentorial structures are variously modified. The middle region of the ventral plate of the pharynx is supported by two chitinous plates which abut against and are attached to the posterior portion of the head in the gula region. These pass forward and upward as broad curved narrowing plates. They converge as they approach the pharynx and their inner edges turn up so that the ventral surfaces of the turned up portion lie along the sides of the ventral plate and are united by tendons to the ventral plate of the pharynx, see Pl. 1 f. 4 & 7. These plates continue forward along the sides of the pharynx, their ventral surfaces extend further up the side of the pharynx. In cross section they appear somewhat crescent shaped as seen in Pl. 1 f. 6 (t). Lying on either side of the pharynx, they form a trough or bed in which the pharynx lies. Anteriorly the salivary pump lies below the pharynx and between these curved tentorial structures securely held in place by the connective tissue which surrounds it. Just anterior to the pump, portions of the two inner surfaces of the plates pass upward on either side of the efferent canal supporting it and continue with it to its connection with the setae. A portion of each plate passes forward and slightly downward, fusing medianly, with that of the other side, below the portions which support the efferent canal to form the plate to which is attached the dorsal anterior surface of the labium.

Opposite the anterior end of the salivary pump, the outer margins of the plates roll upward and over the fused central plates, and form the two black heavily chitinized horns of the tentorium (ht), each of which contains a groove, which acts as a guide to the converging setae, which meet over the tip of these horns and pass forward together above the lobes of the clypeus.

The horns of the tentorium separate posteriorly to allow the chitinized tip of the efferent canal and its supporting structures to pass upward between them and connect with the salivary canal in the maxillary setae at the point where the setae come together.

The lateral margins of the horns of the tentorium and the lateral margins of the plate to which the anterior dorsal surface of the labium is attached, are fused to the inside of the maxillary lamina and to the bucculae along the line of union of the lamina with the bucculae.

A very delicate chitinous rod (i) which broadens dorsally is situated internal to each compound eye. Each of these rods is attached to the dorsal surface of the same small knob-like projections of the genae below the compound eyes, to which the chitinous rod that articulates with the base of the maxillary setae is attached, see Pl. 1 f. 7 (p), and extending upward and slightly forward is attached just above the eye. These rods apparently act as protectors and supports of the eye structures and a few muscle fibres from the antennae are attached to them dorsally.

There are two thick strong struts projecting inward from the head capsule one on either side of the head located slightly anterior to and inward from each ocellus. These form the base of attachment for most of the antennal muscles.

The labrum is a very flexible sclerite. It contains numerous muscles, tracheae and nerves. The action of its muscular system has not been worked out.

The labium is controlled by two muscles, of these the protractor, or extensor, extends down the labium beneath the anterior surface and is attached

basally to a small process of the tip of the tentorial plate to which the labium is attached. The retractor muscle extends down the labium posteriorly and basally is fastened to the ventral surface of the plate with which the labium articulates.

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LETTERING OF FIGURES

a	chitinous rod at base of mandible
ant	antenna
b	chitinous triangular plate articulating with genae
b-ant	base of antenna
bu	bucculae
c	clypeus
dp	dorsal plate
e	eye
ec	efferent canal
f	frons
fc	food canal or suction canal.
fr	fulcrum
g	genae
gu	gula
h	chitinous rod connecting maxillary setae and genae
hc	head capule
hph	hypopharynx
ht	horns of the tentorium
i	chitinous rod behind eye
iv	inlet valve
k	retractor muscle of salivary pump
l	struts to which some of the antenna muscles fasten
lab	labium
lbr	labrum
lc	lobes of the clypeus

m	maxilla
md	mandible
ml	maxillary laminae
n	pharyngeal struts
oc	ocelli
occ	occiput
ov	outlet valve
p	internal knob below compound eye
ph	pharynx
phm	pharyngeal muscles
pl	plunger of pump
pm	protractor muscle of mandible
pm_1	protractor muscle of maxillae
pth	prothorax
rm	retractor muscle
s	setae
sc	salivary canal
sd	salivary duct
sg	salivary glands
sp	salivary pump
t	tentorium
v	vertex
vp	ventral plate

EXPLANATION OF PLATES

Plate I

Fig. 1 Side view of head.

Fig. 2 Cross section of setae.

Fig. 3 Mandibular seta showing its connection with the gena.

Fig. 4 Cross section through the middle region of the pharynx.

Fig. 5 Longitudinal section of salivary pump.

Fig. 6 Cross section of the pharynx and salivary pump as seen in fig. 10.

Fig. 7 Cross section through the eyes. A diagrammatic drawing of fig. 9.

Plate II

Figures 8 - 13 are microphotographs.

Fig. 8 Shows the salivary pump and efferent canal and the attachment of the labium. The horns of the tentorium are separated.

Fig. 9 Cross section of the head through the eyes.

Fig. 10 Cross section of the head through the bases of the antennae.

Fig. 11 Longitudinal section of the head showing the pharyngeal muscles, pharynx and salivary pump, their supports, and the position of the setae.

Fig. 12 Shows the ventral plate of the pharynx, and the hypopharynx, which are supported by the struts running to the fulcra.

Fig. 13 Shows the position of the pharynx and setae at their junction, behind the lobes of the clypeus.