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Observations on the Biology of Phyllobaenus Humeralis (Say) (Coleoptera, Cleridae) with Descriptions of its Immature Stages

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OBSERVATIONS ON THE BIOLOGY OF PHYLLOBAENUS HUMERALIS (SAY)
(COLEOPTERA, CLERIDAE) WITH DESCRIPTIONS
OF ITS IMMATURE STAGES

by

Clifford Pulaski

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MAY 1979

A Thesis Submitted to the Faculty of the Graduate School
of Loyola University of Chicago in Partial Fulfillment
of the Requirements for the Degree of
Master of Sciences

May, 1979

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VITA

The author, Clifford Pulaski, was born November 25, 1952, in Chicago, Illinois.

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While in Ethiopia as a Peace Corps volunteer, he worked for the World Health Organization Smallpox Erradication Program. From September, 1977, to April, 1979, he was a biology laboratory teaching assistant at Loyola University while studying for the Master of Sciences degree.

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INTRODUCTION

The group of beetles now known as the family Cleridae was organized by Latreille in 1804. It contains over 3,600 species worldwide. This family has substantial economic importance. The majority of clerids are predaceous as both larvae and adults. Others feed on foliage, pollen, fungus, and decaying organic matter. The clerids are often brightly and contrastingly colored. They have an elongate shape 3 - 24 mm. in length, and a prominent head, usually with bulging, emarginate eyes. They are characterized by a pubescent body, lobed tarsal segments, palps with enlarged apical segments, and a pronotum narrower than the base of the elytra. At the generic and species level the Cleridae are still in need of taxonomic revision, particularly in the South and Middle American fauna.

This thesis presents a number of significant facts on Phyllobaenus humeralis (Say), a clerid beetle. This species is distributed widely in the U.S. and Canada, from Maine to Manitoba, and from Wyoming to West Virginia. The adult was discovered in 1823, but the immature stages remained undiscovered until now. For this thesis, I set out to discover and describe these immature stages. I hypothesized that since the adults were numerous on Sweet Fern, Comptonia peregrina (L.), the immature stages could be found in the same relative area. I further hypothesized that C. peregrina might be the oviposition site for P. humeralis. This being so, the various immature stages could be obtained from these eggs

using laboratory rearing techniques.

C. peregrina is a monecious, aromatic shrub of the family Myricaceae (Fig. 16). It grows in dry, sandy, acidic soil in the Northeastern U.S. and Canada. I have studied the occurrence and behavior of P. humeralis on this plant, mainly under laboratory conditions, and have recorded pertinent biological data. It was considered important to record other insects occurring on C. peregrina since all have the potential of playing a part in the presence of P. humeralis on the plant. Data on these other insect families is presented in the appendix of this thesis.

REVIEW OF RELATED LITERATURE

Since Latreille's organization of the clerid beetles, considerable revision of the family has occurred. Notable taxonomic listings are by Klug (1842), Spinola (1844), LeConte (1849, 1861), Lacordaire (1857), Gorham (1882), Schenkling (1903, 1910), and Wolcott (1947). The Cleridae is currently divided into five subfamilies: Thaneroclerinae (Chapin, 1924); Clerinae (Spinola, 1841); Phyllobaeninae (Wolcott, 1944); Korynetinae (Schenkling, 1906); and Tarsosteninae (Crowson, 1964). There are 858 North American species.

Chapin's 1917 paper contributed much taxonomic information on the Phyllobaeninae. Wolcott revised this subfamily in 1944. The Phyllobaeninae contains three genera: Phyllobaenus (Dejean, 1837), 104 species; Isohydnocera (Chapin, 1917), 15 species; and Wolcottia (Chapin, 1917), 3 species. They are all endemic to the New World.

In their 1920 paper on the larvae of North American Cleridae, Boving and Champlain make the following statements about the Phyllobaeninae larvae:

Frons posteriorly limited by a transversal line. Epicranial suture not developed. Second antennal joint small, considerably shorter than both basal and apical antennal joints. Ventral mouthparts slightly retracted. Gula with plain surface. Preeusternal and eusternal areas not separated. Spiracles bifore. Ocelli, five on each side.

They summarize Phyllobaenus larvae as follows:

Body short, digitiform or oval, somewhat flattened; ninth abdominal segment semioval or semicircular. Chitinous parts well developed. Membranous parts unicolorous or variegated.

Setae numerous, scattered. Head capsule trapezoidal, posteriorly wider than anteriorly; somewhat wider than long. Frons smooth. Epicranium smooth. Ocelli five, anterior row bent slightly forwards. Length of basal, second and apical antennal joints proportioned as 3:1:3; supplementary joint twice as long as second joint. Mandible about half as long as frontal suture, length to width about as 6:5; pointed; apex somewhat retracted behind inner corner of mandibular base; posterior half of inner margin convex; retinaculum hardly developed; tooth behind apex low and blunt; with a single mandibular seta. Length of maxilla from end of palpus to posterior corner of cardo in proportion to gula about as 1:2; posterior parts of cardo and stipes without special chitinizations; maxillary palpus with small apical joint; length of basal, second and apical joints of maxillary palpus proportioned as 3:5:1; palpiger with plate-shaped chitinization. Gula about same length as frontal suture. Basal and apical joints of labial palpus proportioned about as 1:3. Prothoracic tergal shield well developed, along middle line about as long as frontal suture; prothoracic sternal plate large, subtriangular, anteriorly fused with the presternal chitinizations; posteriorly pointed. Legs well developed. Abdomen with normally developed intersegmental membranes; dorsal ampullae absent, but substituted by very small dorsal plates. Ninth abdominal segment dorsally slightly chitinized. Cerci absent. Spiracles small; the two spiracular tubes short and about circular.

The toothed tarsal claws distinguish adults of this genus from closely related genera (Knull, 1951). Boving and Champlain (1920) state that Phyllobaenus adults are found on low herbage, and that their larvae are predaceous on larvae of small woodborers and gallmakers.

P. humeralis was originally described as Clerus humeralis, by Thomas Say in 1823. The locality was given by Say as Missouri. Dejean used this species as the genotype when he erected Phyllobaenus in 1837. The adult is described by Knull (1951) as follows:

Rather robust; black to bluish black, humeral angles reddish yellow; mouth parts, antennae, and parts of legs sometimes brownish yellow. Head convex; surface finely punctate, strigate on vertex. Pronotum wider than long, widest in front of middle, strongly constricted at apex and near base; disk convex, a transverse depression back of apex and at base; surface irregularly, lightly punctured. Scutellum triangular. Elytra wider than widest

on apical third, covering abdomen; sides subparallel, apices broadly roundly, faintly serrulate; disk convex; surface closely, coarsely punctured. Length 5.2 mm.; width 2 mm. This species has a wide distribution in the United States and is abundant in parts of Ohio.

P. humeralis variety difficilis (Say) is a form of the above described organism which lacks the reddish humeral markings.

Adults of P. humeralis have been recorded on Myrica cerifera (L.), the common bayberry (Chittenden, 1890), and on Carya glabra (Mill.), hickory (Chapin, 1917). They have been collected in Lake, Starke, Elkhart, and Crawford counties, Indiana (Wolcott, 1910), and they were abundant on foliage at Put-in-Bay, Ohio, in July, 1935 (Knull, 1951).

To date, there is no published information on larvae of P. humeralis. There are some records of other Phyllobaenus larvae. The larva of Phyllobaenus pubescens (Lec.) has been recorded as predaceous on hymenopterous larvae of Microbracon mellitor (Say), and on larvae and pupae of the cotton boll weevil, Anthonomus grandis (Boh.) (Pierce, 1912). The larva of Phyllobaenus pallipennis (Say) has also been recorded as predaceous on larvae of A. grandis (Pierce, 1912). Larvae of Phyllobaenus verticalis (Say) have been recorded as predaceous on Cynipidae in galls of Quercus alba (L.) (Osten Sacken, 1861), and also from Celastrus, False Bittersweet, infested with Cerambycidae (Boving and Champlain, 1920). Unidentified species of Phyllobaenus have been recorded from wild grape infested with Phymatodes sp. (Boving and Champlain, 1920), and from hips of Rosa carolina (L.) preying on larvae of the cherry fruitworm, Grapholitha packardii Zeller (Baldus, 1959).

There is no published information on the pupa of P. humeralis.

Pupae of Phyllobaenus scabra (Lec.) were found among dead leaves in the crotch of an orange tree, and also in the cocoon of Carpocapsa pomella (L.) beneath loose bark of an apple tree (Coquillett, 1892). Pupae of Phyllobaenus tabida (Lec.) were found in the stems of annual plants infested with mordelid larvae (Boving and Champlain, 1920).

Major works on clerid history have been published by Westwood (1839), Sharp (1840), Wickham (1912), Boving and Champlain (1920), Balduf (1926, 1935), Linsley and MacSwain (1943), and Knull (1951). Westwood (1839), Sharp (1840), and Boving and Champlain (1920) all comment on the fact that clerid larvae construct prepupal chambers or webs.

Descriptions of Sweet Fern and its distribution, are given by Schuyler (1915), Rydberg (1932), Tehon (1942), Rosendahl (1955), Gleason and Cronquist (1967), and Hutchinson (1973). Useful products from Sweet Fern are given by Marx and Dugdale (1973). Specific locations of stands of C. peregrina are given by Fell (1955), Jones and Fuller (1955), and Swink (1969). Halim and Collins (1970, 1973) have done spectroscopic analysis of the volatile oil constituents of C. peregrina. The major constituents of the oil were 1,8 cineole, γ -terpinene, β -myrcene, β -caryophyllene, linalool, and α -pinene.

Brown (1943) records the Chrysomelid Arthrochlamys comptoniae Brown as phytophagous on C. peregrina.

MATERIALS AND METHODS

In the initial stages of this study, specimens of P. humeralis were examined from the collection of Dr. R. W. Hamilton. Verification of species identification was obtained by comparison with identified material in the collection of the Field Museum of Natural History, Chicago.

Collection sites for this study were The Illinois Nature Preserve, Thornton, Illinois, and Oak Openings Metro Park, near Toledo, Ohio. Field observations and sampling occurred approximately weekly at Thornton from April to August, and on two major visits to Oak Openings in May and July.

Entire C. peregrina plants, soil from varying depths around the bases of the plants, and insects on the plants were collected. These were brought back to the laboratory for further examination. Stems, leaves, runners, and flowers were dissected and examined for signs of predaceous insect activity. Soil and leaf litter samples were run through a modified Berlese funnel (Fig. 13) to separate insects, other arthropods, and other phyla from the soil. These organisms were preserved in 70% ethyl alcohol for future reference.

Insects were collected from plants in the field, by using a beating sheet and suction tube aspirator (Fig. 14). The sheet was held under the plant while the main stem was struck with a club. Insects jarred loose would fall onto the beating sheet and then be aspirated into the suction tube.

Approximately 60 P. humeralis adults were removed to the laboratory for further study. They were placed in mating cages which contained stems

and leaves of C. peregrina. The cages also contained a source of H_2O , and boiled egg yolk and albumin as a food source.

Adults were given the opportunity to copulate and oviposit on the stems and leaves in the cage. These stems and leaves were examined after two days, and replaced with fresh material. Upon discovery of eggs in bark crevices of the stems, the stems were transferred to smaller jars. After the eggs hatched, larvae were placed in vials fitted with strips of filter paper (Fig. 15), and fed a diet of boiled egg.

In an attempt to induce pupation in mature larvae, they were subjected to a cold period ranging from $-5^{\circ}C$ to $11^{\circ}C$, in a laboratory refrigerator for eight weeks. They were then returned in gradual steps to $23^{\circ}C$ where they remained until pupation and emergence.

No special regulation of humidity was maintained in rearing vials other than keeping a strip of filter paper moistened with five drops of H_2O in each vial at all times.

A twelve hour light/dark photo period was maintained for early instar larvae. During their cold period, mature larvae were subjected to either total darkness in a laboratory refrigerator, or natural daylight at a laboratory window. Following the cold period, one larva was retained in total darkness, and two others were retained in natural daylight, until pupation and emergence.

Specimens of each immature stage were preserved in 70% ethyl alcohol, or in FAA solution (ethyl alcohol, formaldehyde, glacial acetic acid, and distilled H_2O). These stages were photographed and illustrated. Other insects collected on C. peregrina were killed in a cyanide jar or in alcohol, and pinned in collection boxes.

RESULTS

Sixty P. humeralis adults were collected from C. peregrina at Oak Openings and Thornton from June to August, 1978, during daylight hours on both sunny and rainy days. During collection of specimens, adults were observed to drop to the leaf litter or fly away when disturbed.

In the laboratory these insects were inactive much of the time, standing under leaves, on twigs, in folds of filter paper, or on the glass sides of their cages. When exposed to bright light they became active within ten minutes, moving toward the light. During this time they would feed, copulate, oviposit, and fly around the cage. After five to ten minutes of activity they would stop for one to five minutes and then resume their activity.

They were observed to feed on living aphids and small hemipteran nymphs, but their attacks were usually put off by the slightest defense from the prey organism. P. humeralis were also observed to feed on a wide variety of dead insects such as orthopteran and hemipteran nymphs, and they also fed on sucrose, fruit, bread crumbs, and boiled egg yolk and albumin.

During their periods of activity, adults were frequently seen rubbing their elytra and wings in a posterior motion with their meso- and metathoracic legs. During copulation a female would walk about with a male attached to her abdomen by all six of his legs. Copulation lasted from one to three minutes, after which adults would resume their

walking and feeding activity.

In between acts of oviposition, females were observed to press their abdomens down with their metathoracic legs. They would drag their abdomens on twigs, probing them into cracks and crevices of C. peregrina bark. Eggs were found embedded in narrow spaces under the bark, laid singly or in clusters of up to ten. These eggs hatched in ten days under laboratory conditions of 23°C.

The egg of P. humeralis is elongate, 1.2 mm. by 0.3 mm. (Fig.1). It tapers at both ends, with one end tapering more than the other. The contents are pale yellow when laid, becoming translucent except for a centrally located wide orange band within five days, and becoming cream colored by the eighth day. The corion is smooth and transparent.

The larvae grew rapidly. When provided with fresh boiled egg, they would feed for long periods of time. They were usually inactive, staying in folds of filter paper unless disturbed. When exposed to bright light, larvae would crawl away from it to the undersides of any available object.

Molting to the next instar occurred approximately every fifteen days (Table 3). By using Dyar's Rule, it was possible to estimate the head capsule size of each larval instar. This rule states that the head capsule width of a larva increases by a factor of 1.2 to 1.4 with each consecutive molt. Those P. humeralis larvae molting five to fifteen days after hatching had head capsule widths of 0.2 to 0.25 mm. Those molting 20 to 26 days after hatching had head capsule widths of 0.24 to 0.35 mm. Those molting 31 to 42 days after hatching had head capsule

widths of 0.29 to 0.49 mm. before molting. Following this molt into the fourth and final instar, larvae would spend a considerable amount of time without feeding, during which they would construct an irregular whitish web about themselves between adjacent objects in their vial. They remained in these webs until adult emergence four to five months later.

The following description of P. humeralis is based on characters useful in studying clerid taxa at the specific level. The mature larva conforms to the generic description of Phyllobaenus given by Boving and Champlain (1920) with these exceptions. The mandible of P. humeralis has two mandibular setae on the outer margin, and a seta like projection on the inner margin (Fig. 7, 26). Boving and Champlain reported only one mandibular seta for this genus. They also reported before spiracles for Phyllobaenus. However, some abdominal segments of P. humeralis have spiracles with three spiracular tubes (Fig. 10, 11). Other segments do have before spiracles (Fig. 9).

The mature larva of P. humeralis is 5.0 to 5.5 mm. long. The head capsule is 0.49 to 0.65 mm. wide. The body is digitiform and dorso-ventrally flattened. The membranous areas are reddish orange, although some abdominal segments are occasionally white. The head capsule is pale yellow with a dark brown ocellar field. Dorsal sclerotized plates are dark brown. The pronotum is nearly covered by a dorsal shield. The shield has a narrow, longitudinal, median gap, and a pale yellow anterior margin. The meso- and metathoracic nota each bear a pair of sclerotized, irregularly shaped crescents (Fig. 8). The prothoracic pre-sterna and sternal shield are pale yellow. The tergum of the ninth

abdominal segment has a well sclerotized semicircular basal plate. Urogomphi are not present. Each coxa is sclerotized, and connected to a sclerotized hypopleurum by a condyle (Fig 20). Legs are pale yellow, the tarsi are dark brown. Each segment has many short dark setae. Abdominal segments 1 through 8 have a long, light colored seta on each lateral edge, originating in the alar area. The ninth abdominal segment has four long setae originating in its ventro-lateral area.

The principle difference between the four larval instars is in the shape of the head, and in the proportion of the head length and width to overall body length and width. The color and major sclerotizations are the same for each instar. As the larva develops, the head capsule becomes less rounded and more trapezoidal, the widest point appearing more posteriorly. (Table 4).

The first instar is 1.2 to 2.0 mm. long, with the abdomen about equal in length to the rest of the body. The second instar is 2.0 to 3.0 mm. long, with the abdomen about 1.5 times the length of the rest of the body. The third instar is 3.0 to 4.0 mm. long. The abdomen is about 1.5 times wider than the head or thorax at this time. The fourth instar is 4.0 to 5.5 mm. long. The abdomen is distended in this stage and is about 2.0 times wider than the head.

Fourth instar larvae pupated three to four weeks after being returned to 23°C from 0°C. Three pupae were induced in the larval webs. They were 4.0 mm. by 1.25 mm. The color of the newly formed pupa is deep red, with translucent head, prothorax, and appendages. The head and prothorax become red after three days. The head is folded under the prothorax (Fig. 3). There is one bar shaped dark brown spot in each

compound eye. Setae are scattered sparsely over most of the pupa, but occur more heavily at the abdominal apex. A pair of transparent protuberances occurred on the abdominal apex of two pupae (Fig. 5). One other pupa lacked these protuberances (Fig. 6). As the pupa develops, the eyes darken after three days, followed by the thorax and appendages after six days. The abdomen darkens only slightly by the ninth day. Six abdominal segments are visible ventrally. Two female adults emerged eleven days following the onset of pupation. See figures 27, 28.

Ten larvae identical to those reared in the laboratory were collected from samples of soil surrounding the bases of C. peregrina plants. One larva was found in April, seven in September, and two in October. No larvae were found in the soil from May to August. One of the September collected specimens appeared to be a late instar.

No larvae or eggs of P. humeralis were discovered during dissection of field collected stems, runners, flowers, and leaves of C. peregrina.

DISCUSSION

The significance of the observed behavior of adults of P. humeralis in the laboratory is in two areas. The first is that these beetles are able to be reared under artificial conditions. The second is that by rearing them in this way, clues to their natural oviposition site and natural diet have been obtained.

The fact that P. humeralis will oviposit under C. peregrina bark suggests that it oviposits in a similar if not exact situation in nature. When the larvae hatch from these eggs, they should be in the proper environment to continue their development. I can only speculate on what the larvae feed on at this point in their life cycle. Hopefully, more careful examination will reveal the nature of this food source, be it woodborers, gallmakers, or leafminers.

Laboratory observation has provided some clue as to the feeding behavior of the adult P. humeralis. This insect will eat many food substances in the lab, and has survived considerable periods of time on them.

Many other species of insects were collected on C. peregrina, particularly in June and July. Aphids, Hemiptera, and Orthoptera were extremely numerous on the plant during this time. Many lepidopteran larvae of the families Gelechiidae and Olethreutidae were observed feeding on Sweet Fern foliage and rolling its leaves. Many of these larvae were parasitized by hymenopterous parasites. Several species of Chrysomelidae in the subfamily Eumolpinae were observed feeding on

foliage. Eumolpine larvae are a very suitable size prey for a clerid. In the lab these species laid eggs in buds and folds of young damaged leaves. Eumolpine larvae in the lab crawled under the bark of twigs of C. peregrina.

A list of insect families collected on this shrub is presented in the appendix. P. humeralis could be feeding on any one of many insects, or even on pollen or foliage. There are clerids that feed on pollen, foliage, lepidopteran larvae, hymenopterous larvae, and coleopterous larvae. Predators found on Sweet Fern include spiders, lacewing larvae, and assassin bugs.

A final point to make about P. humeralis larvae is that they have been discovered in the soil. Perhaps they are there only to overwinter, as some clerids are known to do, or perhaps they are soil predators for part of their life. They exhibit preference for darkness under laboratory conditions. Soil samples from the Sweet Fern base have revealed large numbers of soft bodied dipterous, lepidopterous, and coleopterous larvae. There are also many predators in the soil.

Many interesting facts remain undiscovered about P. humeralis life history. However, with the information that I have provided, these other facts should be easier to determine.

CONCLUSION

The fact that adults of P. humeralis are regularly collected on C. peregrina in considerable numbers, and that their larvae are found in soil at the base of this plant, suggests that some association exists between this insect and this plant. The reason for the association has not been definitely determined. Perhaps the plants' aromatic oils attract P. humeralis to a common mating area, or attract prey for them, or perhaps the scragged bark of this plant provides an oviposition site for P. humeralis.

Further investigation of this subject should consider: gut content analysis of freshly collected adults and larvae; day and night field observations around C. peregrina for larval feeding, and adult feeding and oviposition behavior; and regular examination of C. peregrina plants and their surrounding soil for P. humeralis larvae, and for potential prey and competing predator species.

In overall larval morphology, P. humeralis exhibits the typical characteristics of the Phyllobaeninae. Its principle differences with respect to other Phyllobaenus species are in the color and shape of its dorsal sclerotizations. There are no records for comparison of P. humeralis eggs or pupae. Taxonomic data on the immature stages of P. humeralis will hopefully be useful in future attempts at revision of Phyllobaeninae genera.

Specimens of P. humeralis reared in the lab developed well on the

nourishment provided, attaining an adult length of 4.0 mm. — the size of many field collected specimens. Rearing techniques for predators of pest insect species can be an important tool in biological control of these pests. Development of these techniques can lead to a better understanding of predaceous insects.

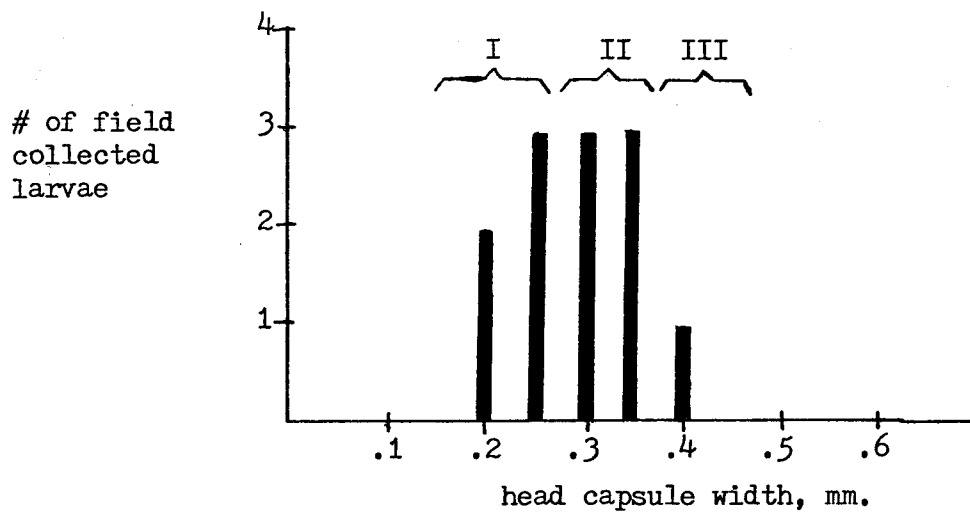


TABLE 1

ROMAN NUMERALS

REPRESENT INSTARS

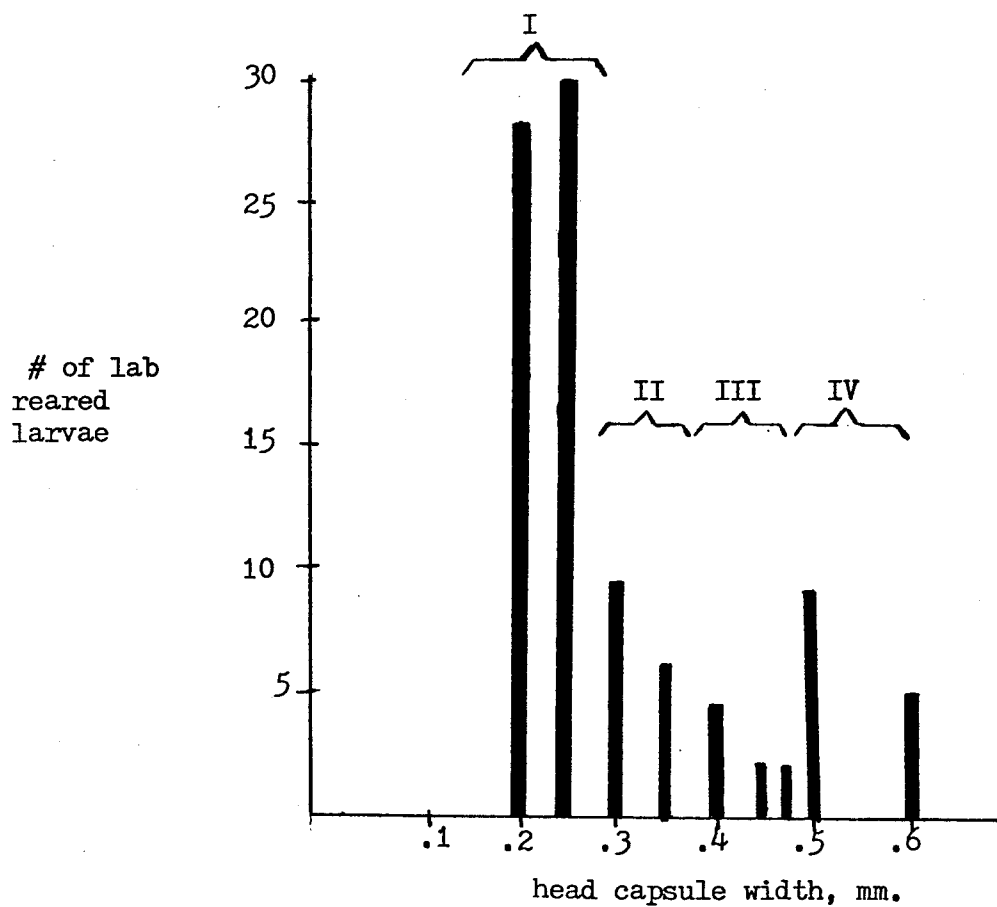


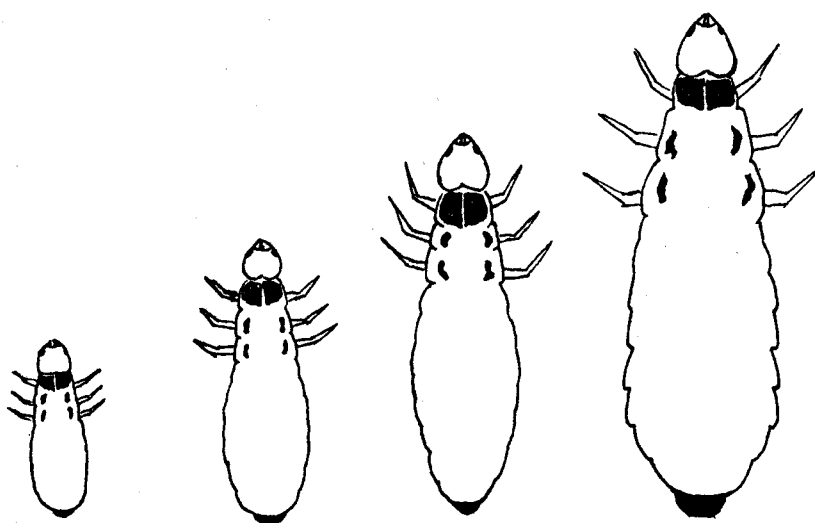
TABLE 2

DAYS FROM HATCHING UNTIL LARVAL MOLT

(each number represents a different laboratory reared larva)

To Second Instar	5, 10, 12, 12, 13, 13, 15	Mean 11
To Third Instar	20, 21, 22, 23, 25, 26	23
To Fourth Instar	31, 33, 33, 34, 35, 35, 36, 36, 37, 38, 40, 42	36
Days until web construction	56, 58, 64, 64, 68, 82	65

TABLE 3



Instar	1	2	3	4
Head Capsule Width	0.25	0.35	0.49	0.6
Body length	2.0	3.0	4.0	5.0
Abdominal Width	0.6	0.9	1.1	1.5 mm.

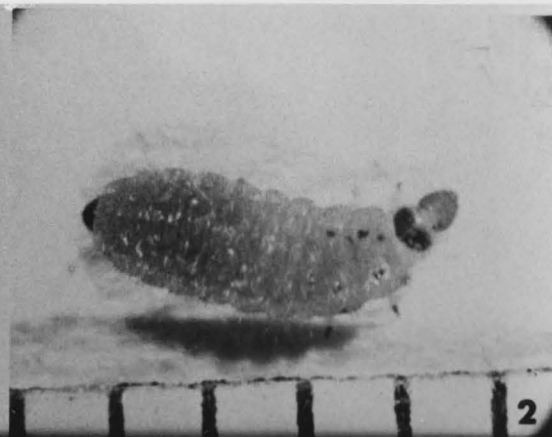
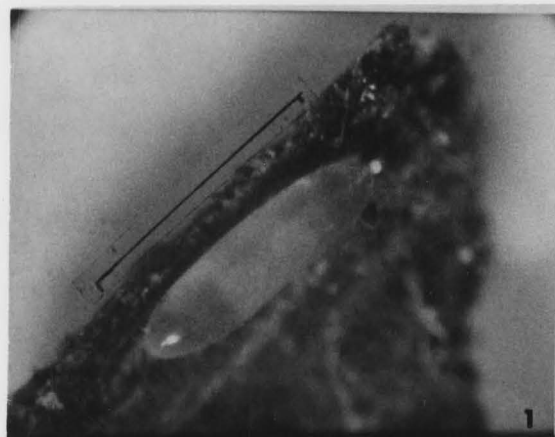
TABLE 4

A LIST OF ABBREVIATIONS USED IN THE FIGURES

A.....abdominal segment	msw.....mesothoracic wing
aa.....alar area	mtw.....metathoracic wing
Bpla.....basal plate	mxp.....maxillary palp
cd.....cardo	N.....notum
clp.....clypeus	ocf.....ocellar field
cx.....coxa	pmt.....postmentum
cxc.....coxal condyle	post.....poststernellum
epcr.....epicranium	prmt.....prementum
epil.....epipleural lobe	psc.....prescutum
es.....eusternum	pst.....presternum
f.....frons	sc.....scutum
fm.....femur	scl.....scutellum
fs.....frontal suture	se.....seta
gu.....gula	stp.....stipes
hypl.....hypopleurum	stpla.....sternal plate
lbr.....labrum	tb.....tibia
lg.....ligula	tr.....trochanter
lp.....labial palp	ts.....tarsus
ma.....mandibular articulation	tub.....tubercle
mal.....mala	

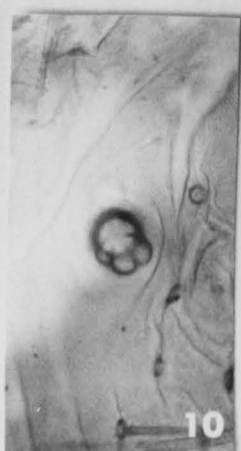
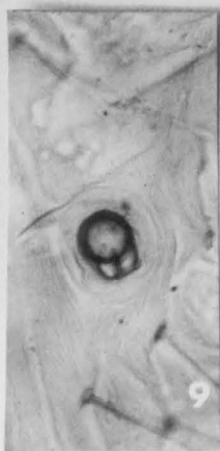
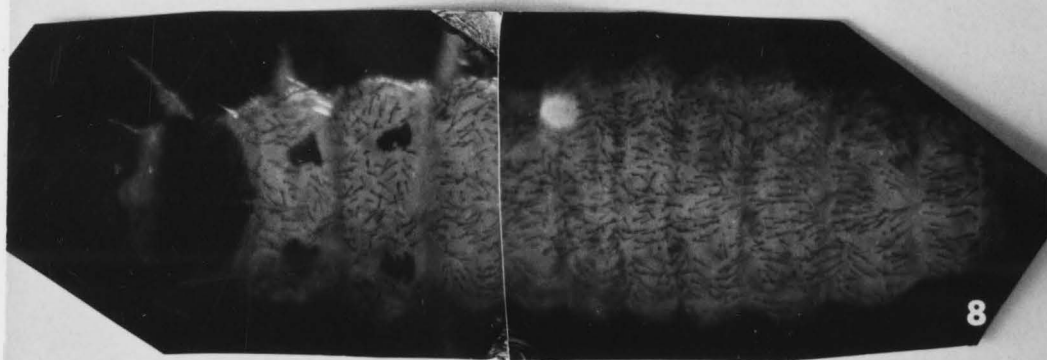
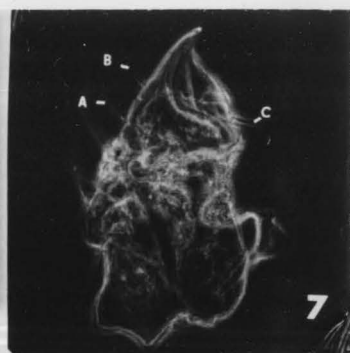
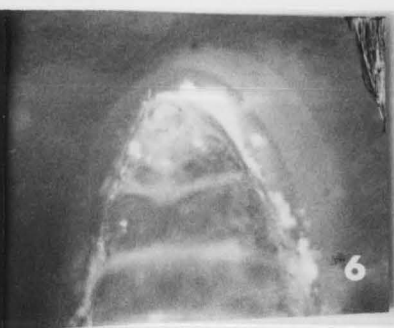
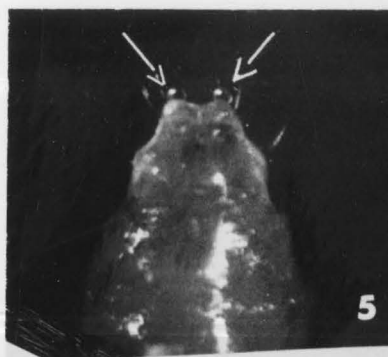
EXPLANATION OF FIGURES 1 - 4

- Figure 1. Four day old egg, laid under bark of C. peregrina. Line equals one millimeter. 40X
- Figure 2. Fourth instar larva, dorsal view. Millimeter scale. 10X
- Figure 3. Two day old pupa, ventrolateral view. Length is 4.0 mm. 20X
- Figure 4. Adult, collected 6/9/78 at Illinois Nature Preserve, Thornton, Illinois. Length is 5.0 mm. 7X



EXPLANATION OF FIGURES 5 - 12

- Figure 5. Posterior apex of female pupa, ventral view, showing two protuberances. 50X
- Figure 6. Posterior apex of another pupa, ventral view, showing no protuberances. 50X
- Figure 7. Mandible of larva, dorsal view, showing two setae, A & B, and a retinaculum, C. 200X
- Figure 8. Thoracic and abdominal dorsal setal pattern of third instar larva. 25X
- Figure 9. Spiracle of third abdominal segment of larva, with two spiracular tubes. 400X
- Figure 10. Spiracle of fifth abdominal segment of larva, with three spiracular tubes. 400X
- Figure 11. Spiracle of eighth abdominal segment of larva, with three spiracular tubes. 400X
- Figure 12. Field collected larva, probable first or second instar. Millimeter scale. 15X



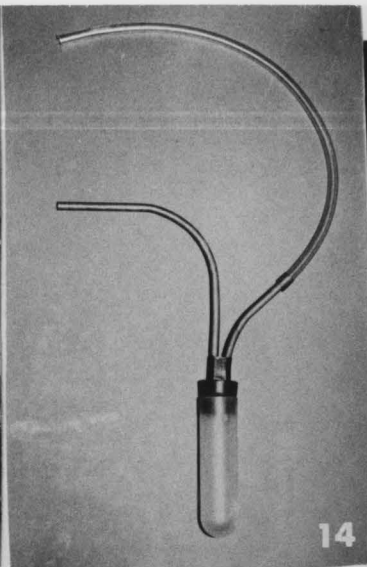
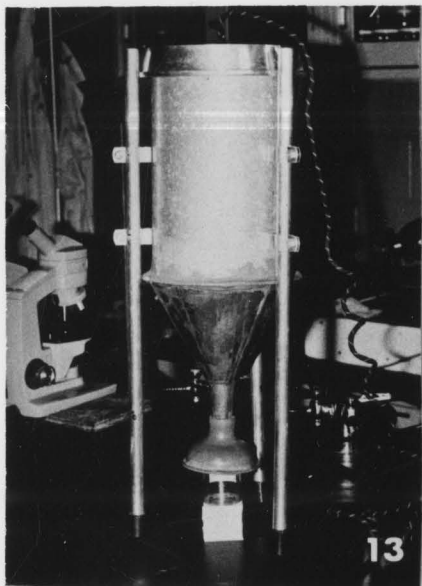
EXPLANATION OF FIGURES 13 - 16

Figure 13. Berlese funnel used in separating insects and other organisms from soil and leaf litter samples.

Figure 14. Suction tube aspirator.

Figure 15. Larval rearing tube.

Figure 16. Foliage of C. peregrina.



EXPLANATION OF FIGURE 17

Figure 17. Fourth instar larva, lateral view. 40X

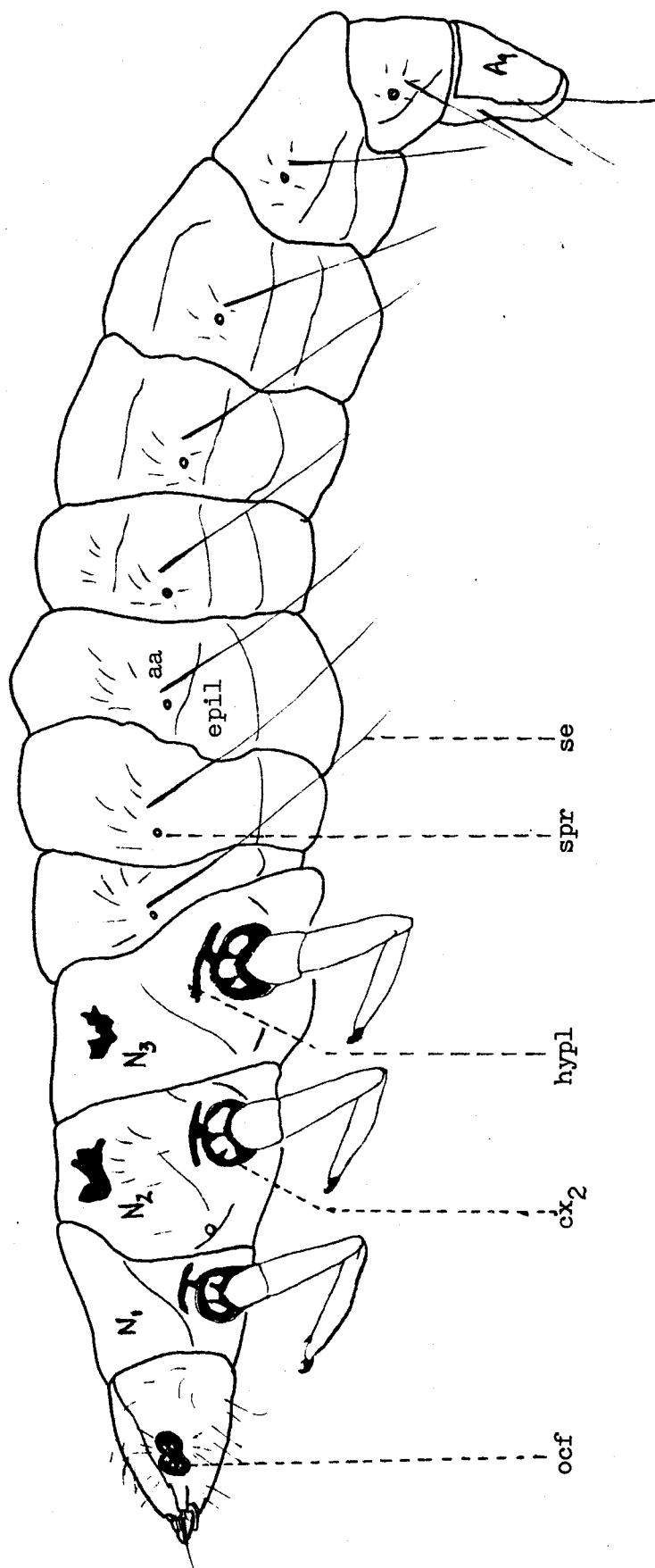


FIGURE 17

EXPLANATION OF FIGURES 18, 19

Figure 18. Larva, dorsal view, slightly diagramatic. 30X

Figure 19. Larva, ventral view, slightly diagramatic. 30X

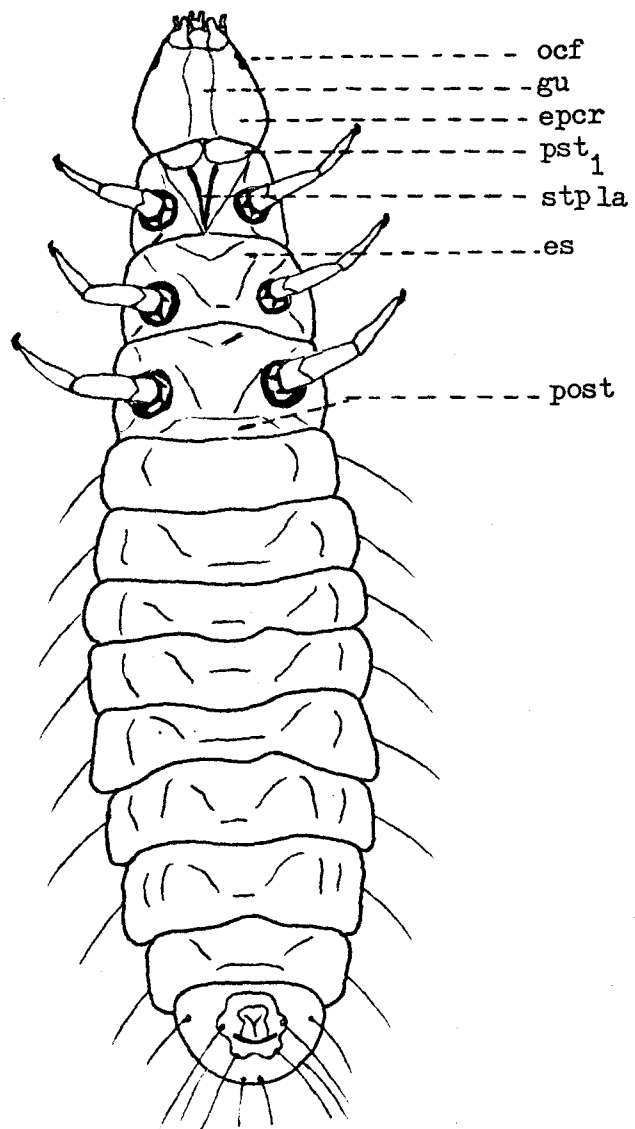


FIGURE 18

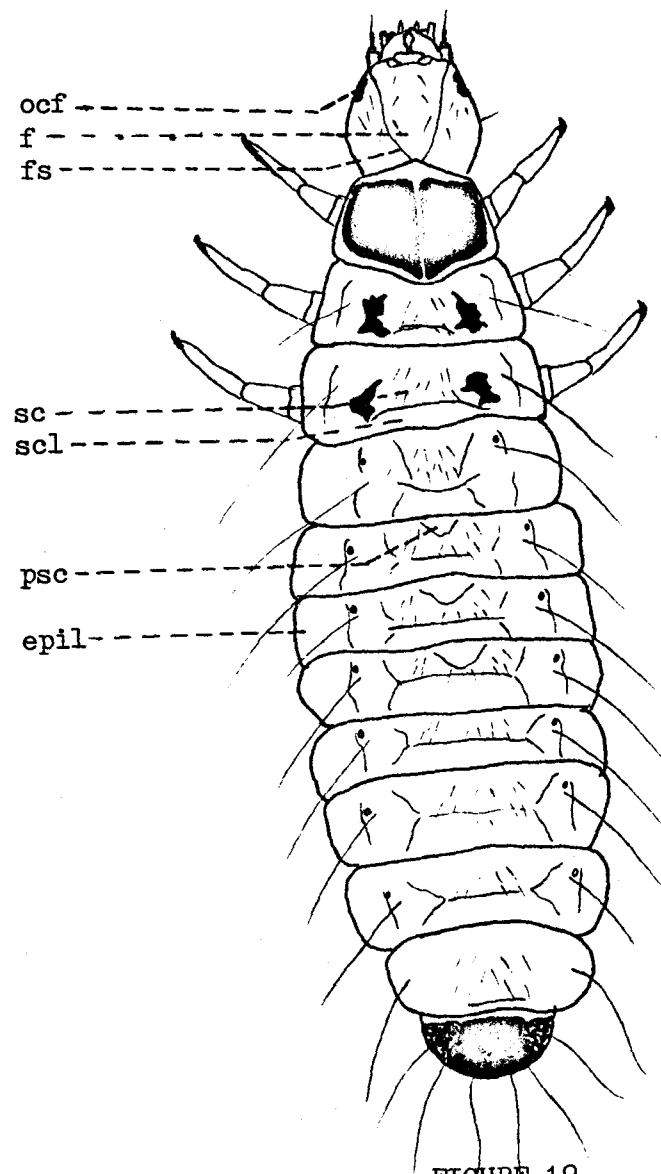


FIGURE 19

EXPLANATION OF FIGURES 20, 21, 22

Figure 20. Left mesothoracic leg of larva, posterior view. 160X

Figure 21. Right antenna of larva, dorsal view. 300X

Figure 22. Eighth, ninth, and tenth abdominal segments of larva,
lateral view. 160X

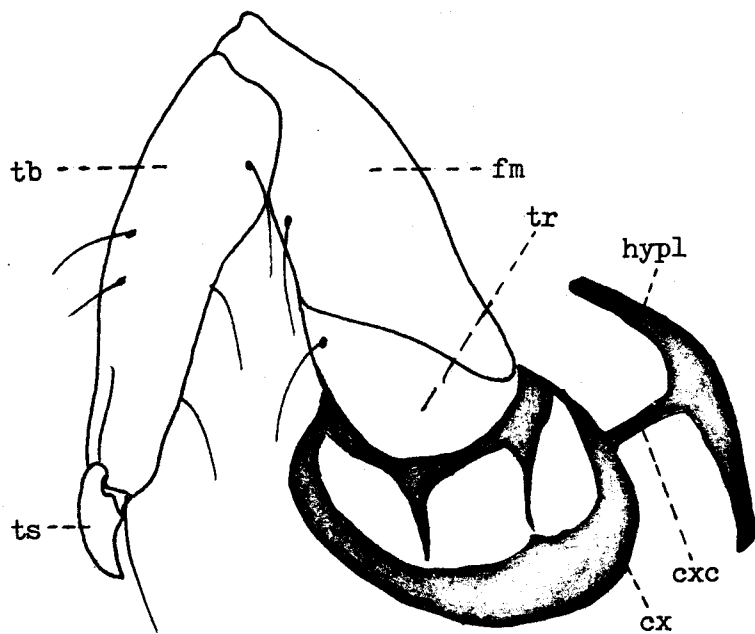


FIGURE 20

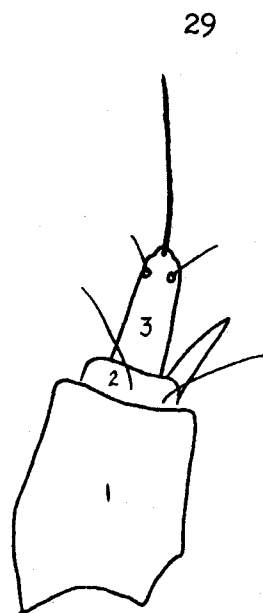


FIGURE 21

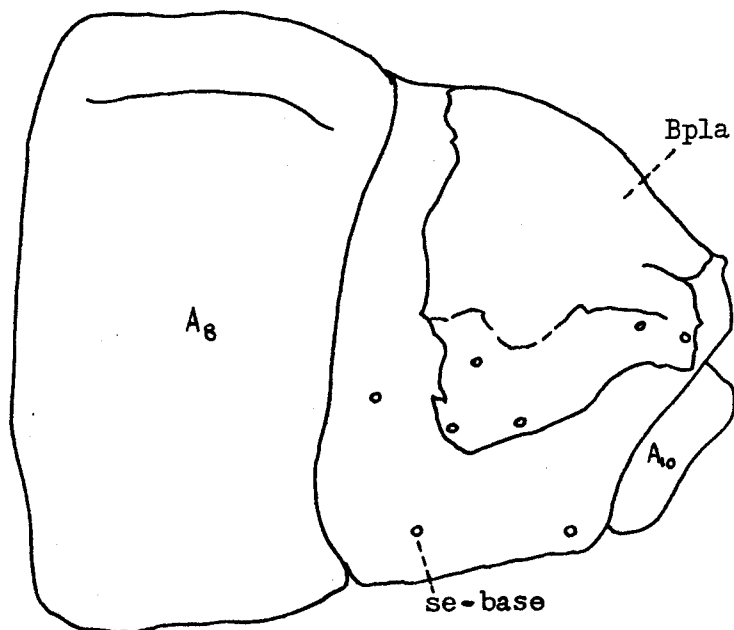


FIGURE 22

EXPLANATION OF FIGURES 23, 24, 25, 26

- Figure 23. Left maxilla of larva, dorsal view. 600X
- Figure 24. Labium of larva, ventral view. 600X
- Figure 25. Left maxilla of larva, ventral view. 600X
- Figure 26. Right mandible of larva, ventral view. 650X

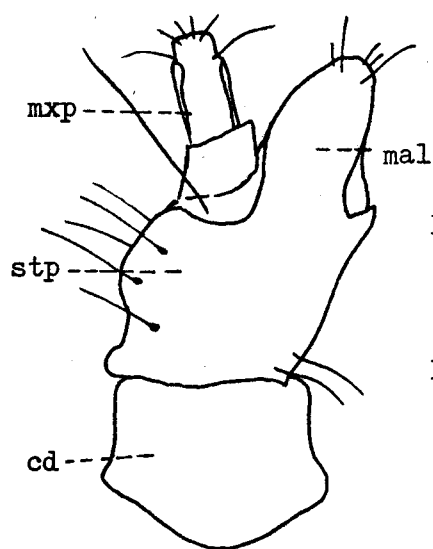


FIGURE 23

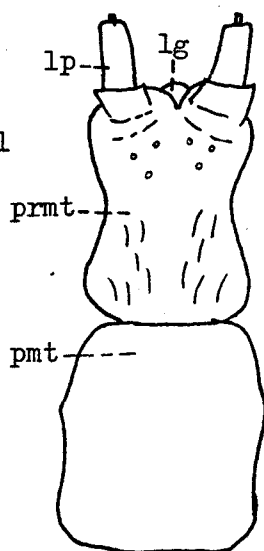


FIGURE 24

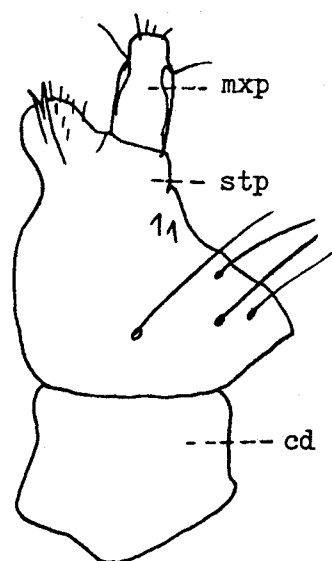


FIGURE 25

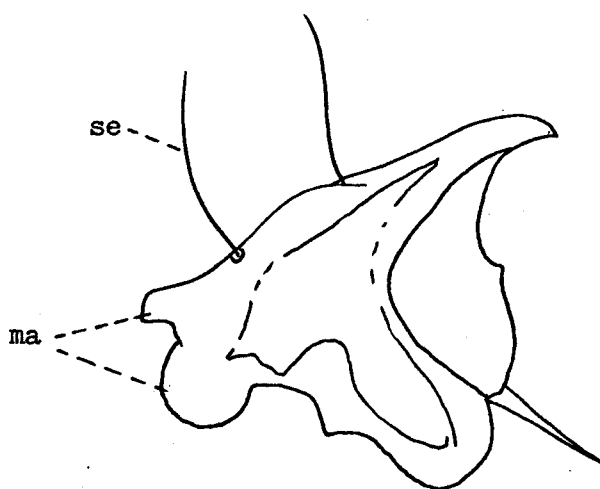


FIGURE 26

EXPLANATION OF FIGURES 27, 28

Figure 27. Pupa, ventral view. 40X

Figure 28. Pupa, dorsal view. 40X

FIGURE 28

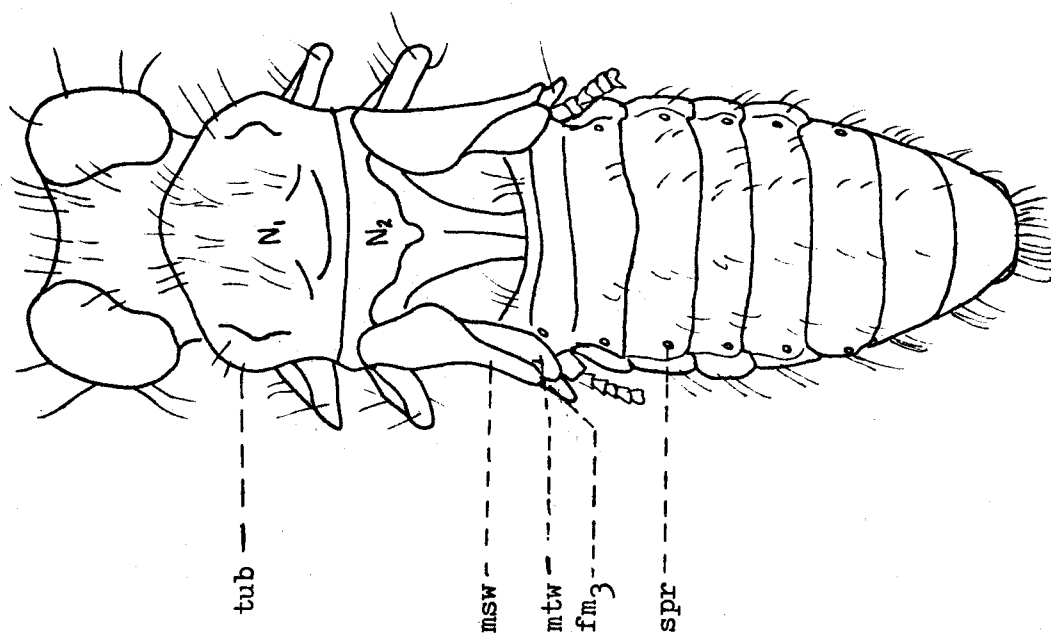
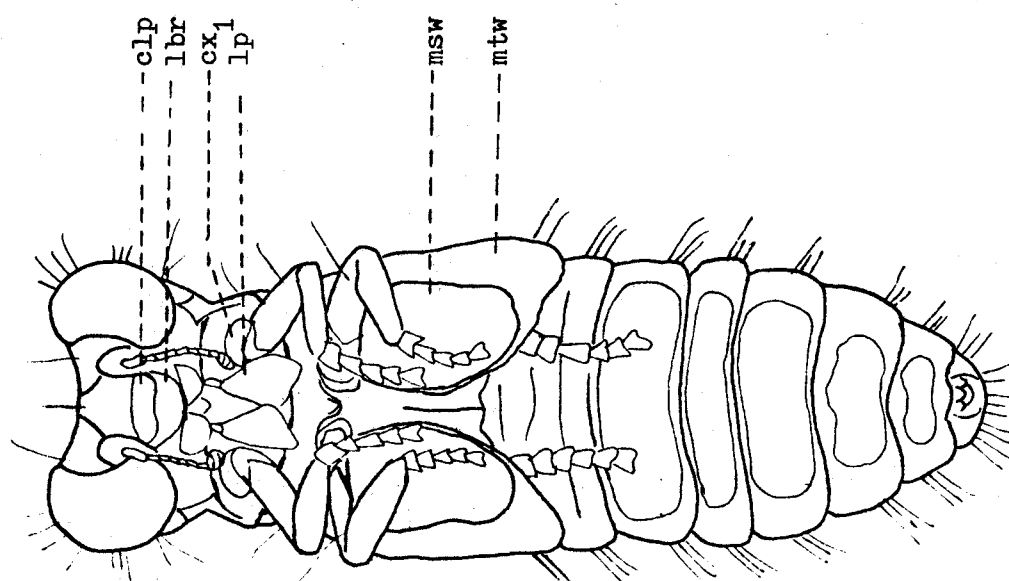


FIGURE 27



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APPENDIX

INSECTS COLLECTED ON C. PEREGRINA

COLEOPTERA

Family: Chrysomelidae

Subfamily: Chlamisinae

Arthrochlamys comptoniae Brown
Exema canadensis Pierce

Subfamily: Chrysomelinae

Calligrapha multipunctata (Say)

Subfamily: Eumolpinae

Paria canella (Fabricius)

Other Chrysomelidae: 14 species

Family: Cleridae

Subfamily: Phyllobaeninae

Isohydnocera curtipennis (Newman)
Phyllobaenus humeralis (Say)
Phyllobaenus humeralis var. difficilis (Say)
Phyllobaenus pallipennis (Say)
Phyllobaenus verticalis (Say)

Family: Scolytidae

Subfamily: Ipinae

Corythylus (Erichson)

Other Families:

Alleculidae

Cantharidae

Coccinellidae

Curculionidae

Cryptophagidae

Endomychidae

Histeridae

Lathridiidae

Nitidulidae

Phalacridae

Scarabaeidae

DIPTERA

Chloropidae
Lauxaniidae
Platystomatidae
Tachinidae

NEUROPTERA

Chrysopidae
Hemerobiidae
Mantispidae

HEMIPTERA

Corimelaenidae
Miridae
Pentatomidae
Reduviidae

HOMOPTERA

Aphididae
Cicadellidae (Typhlocybinae)
Membracidae

HYMENOPTERA

Braconidae
Eulophidae
Ichneumonidae
Pompilidae
Pteromalidae (parasitic on A. comptoniae)
Siricidae

LEPIDOPTERA

Gelechiidae
Olethreutidae
Pyralidae

APPROVAL SHEET

The thesis submitted by Clifford Pulaski has been read and approved by the following committee:

Dr. Robert W. Hamilton, Director
Associate Professor, Biology, Loyola

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The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that the thesis is now given final approval by the committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Sciences.

4-23-1979

Date

Robert W. Hamilton

Director's Signature