THE EXTERNAL MORPHOLOGY OF THE ADULT OF *HYDROECIA IMMANIS* GUENÉE WITH NOTES ON THE BIOLOGY

by

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1. INTRODUCTION AND HISTORY

Hydroecia immanis Gn., the hop-vine borer, is a species indigenous to eastern North America. In the larval stage it is a pest of hops boring in the stems and roots of this plant. The first mention of what was probably this insect was made by Bethune (1872) who gave a description of a number of larvae taken from the roots of hops at Port Credit, Ontario, and also described their work. He attempted to rear these larvae but was unsuccessful and, accordingly, gave the insect no name. However, his description of the larvae and the injury that they did to the hop roots undoubtedly fits that of *Hydroecia immanis* Gn.

Dodge (1882) gave the insect its first common name, the hop-vine borer. Speaking of its history he said: "The pest has been known to the cultivators of hops for many years - indeed it is reported from Oneida County that it has always been known in the locality - and other hop growing districts have felt its presence for longer or shorter periods. In Juneau County, Wisconsin, it was first noticed in 1867, while the observer in Waupaca County had not noticed it prior to 1881." Dodge's knowledge was also restricted to the larval stage.

Comstock (1883) was the first to obtain adults and to record the hop-vine borer or 'hop-grub,' as he named it, as the species immanis. He obtained all stages of this insect except the eggs and gave an account of the life history. Fletcher (1892) exhibited at the twenty-third annual meeting of the Entomological Society of Ontario several specimens, male and female, of the moth together with pupae and larvae preserved in alcohol. These specimens were collected from Prince Edward County, Ontario. Howard (1897) gave the distribution of this insect as Canada, New England, New York and west to Washington. In his paper he summarized the literature to date. Hawley (1918) made an extensive study of H.immanis Gn. and pointed out some misconceptions of previous authors on the life history of this insect. He stated that the winter is passed in the egg stage and the adults do not hibernate, as was formerly thought to be the case. The eggs are laid on grass plants in the latter part of August and not on the tips of the developing vines in the spring. According to Hawley though borers are frequently found in grass stems in the early larval stages H.immanis Gn. is able to reach maturity only on hops. But he admitted there is evidence of

the possibility of other hosts.

A review of the literature revealed that papers on the morphology of the noctuidae are comparatively scarce. By undertaking the study of the external morphology of the adult of H.immanis Gn. it was hoped that the results would prove of value to workers in this family of Lepidoptera.

In the summer of 1938 the writer received larval specimens of a noctuid taken from corn on Isle Jesu, near Montreal. These were compared with hop-vine borers taken from hops in Fournier, Ontario, and no differences between the two could be found. It was later reported that these larvae had been successfully reared to maturity on corn. The moths were reported to closely resemble H.immanis Gn. Unfortunately, last year, adult material from Isle Jesu was not obtainable. It should be possible with a knowledge of the morphology of the adult of the hop-vine borer to establish the relationship of this corn feeding noctuid with the former species.

11. DESCRIPTION OF THE ADULT

The moth is a light brown with greenish or pinkish reflections in certain lights. The females, as a rule, are larger than the males. Smith (1899) described the species as follows:-

"Ground colour dull yellowish brown with a tendency to smoky. Collar with a central pale line and a pale line at tip. In some specimens a pale line also extends obliquely across the patagiae. The markings of the primaries are distinct, as a whole paler than the ground colour; the defining lines a darker shade of brown or tan. Basal line geminate, extending to the submedian vein; the included space pale, the inner line fairly well marked, the outer rather diffuse. T.a. line geminate, the included space paler, the defining lines well marked, as a whole upright, very even, except for a slight inward bend in the cell. T.p. line geminate, included space pale, the inner defining line well marked, the outer rather defined by differences in shade than in any other way. The line is abruptly bent on the costa over the reniform and then is almost evenly oblique inward to the inner margin. S.t. line blackish, distinct, a little irregular, broken only near the apex which is somewhat paler. The median shade is fairly well marked in most specimens, and is a little curved between the ordinary spots. Orbicular oval, almost upright, a little paler than the ground colour, very often incompletely outlined. The reniform is large, upright, kidney shaped or a little constricted centrally, a trifle paler than the ground colour, except that it is inferiorly a little darkened. There is a smoky brown line at the base of the fringes. The claviform is small, not visible in all specimens; but sometimes dark filled so that it becomes a recognized feature in the wing. Secondaries smoky, yellowish, darker in the female, with a dusky, followed by a paler median line. There is a narrow dusky line at the base of the fringes. Beneath powdery a little more reddish on the upper surface; both wings with a more or less well-defined outer transverse line, the secondaries sometimes with a small discal spot. Expanse 1.50-2 in.; 37-50 mm."

111. GENERIC HISTORY

The generic history of *Hydroecia immanis* Gn. is as follows:-

1852 - Guenée, A., Histoire naturelle des insectes 5: 128.....*Hydroecia* Gn.

1874 - Grote, A.R., Buffalo Soc. Nat. Sci. Bul. 2: 18.....*Gortyna* Ochs.

1883 - Comstock, J.H., Amer. Agr. 42: 275..*Apamea* Ochs.

1884 - Smith, J.B., U.S. Div. Ent. Bul. 4 (o.s.): 34.....*Hydroecia* Gn.

1885 - Lintner, J.A., New York State Ent. Rept. 2: 41.....*Gortyna* Ochs.

1893 - Smith, J.B., U.S. Nat. Mus. Bul.44: 175.....*Hydroecia* Gn.

1897 - Howard, L.O., U.S. Div. Ent. Bul.7: 40.....*Hydroecia* Gn.

1902 - Dyar, H.G., List N.A. Lep. p.175....*Gortyna* Ochs.

1909 - Howard, L.O., The hop, p.128.....*Gortyna* Ochs.

1910 - Hampson, G.F., Cat. Lep. Phal.,9:41.*Hydroecia* Gn.

1917 - Barnes, W. and McDunnough, J., Check List Lep. Boreal Amer., p.69..*Gortyna* Gn.

1918 - Hawley, I.M., Cornell Univ., Agric. Exper. Sta. Mem. 15.....*Gortyna* Gn.

1927 - Bird, H., Jr. New York Ent. Soc. 35: 179.....*Gortyna* Ochs.

1938 - McDunnough, J., Mem. S. Calif. Acad. Sci. Vol.1.....*Hydroecia* Gn.

As may be seen from the above list, the generic name of Hydroecia immanis Gn. has been changed many times. Whether Hydroecia or Gortyna is used depends upon the generic concept of the author, whether he considers the genotypes, namely micacea and flavago distinct or congeneric. If the differences are distinct then immanis should be placed in Hydroecia. If, on the other hand, the differences are not generic, then immanis should be placed in Gortyna as it has priority.

Guenée (1852) first described immanis under the genus Hydroecia. Grote (1874) apparently thinking Gortyna and Hydroecia were congeneric uses the former name for immanis as Gortyna has priority. (Gortyna was described by Oschenheimer in 1816 using flavago as the type. Guenée described Hydroecia in 1841 designating micacea as the type). Lederer (1857) showed the clypeal differences of the two genera and sharply defined them. Comstock (1883) considering a third genus Apamea congeneric, used this generic name. Bird (1927) compared the two genotypes of Hydroecia and Gortyna, micacea and flavago respectively and thought since their genitalia and larvae were similar, they were congeneric and consequently used Gortyna. McDunnough (1917) first considered the two genera were not distinct but recently (1938) his concepts have apparently changed and he now places immanis back in the genus Hydroecia. For the purpose of

this paper McDunnough's concept has been accepted as his is the most recent amongst authoritative works.

IV. PREPARATION OF MATERIAL

To examine the structural characters it was necessary to denude the specimens of the scales and hairs. This was accomplished by boiling the specimens inweak caustic potash. The hairs and scales which remained attached after this treatment were plucked off with fine forceps. The specimens were examined under water.

V. STRUCTURAL CHARACTERS

A. THE HEAD

The compound eyes are conspicuously large constituting about one third of the head (Plate 1,fig.1). They are surrounded by narrow ocular sclerites. The frons, lying in the front aspect of the head, is indefinite in its area since there are no sutures demarking its limits except for the frontal suture which runs from one antennal fossa to the other and marks its dorsal limit. This frontal suture is all that remains of the epicranial suture. The stem of the epicranial suture, the coronal suture is not present. The two typical arms of the epicranial suture appear to have migrated upwards to form a single transverse frontal suture. The frons is indefinitely bounded laterally by the parietals and ventrally by the

clypeus. The clypeus is that part of the front of the head lying above the labrum and below an imaginary line drawn between the two points in the head capsule where the distal ends of the anterior tentorial arms meet it. These arms are shown in Plate 1, fig.1. in dotted lines. This imaginary line would be the definitive position of the epistomal suture. The clypeus can be differentiated to a certain extent from the frons in that it is more weakly sclerotized and less densely punctate than the frons. A mound-like rise takes up most of the area of the frons (Plate 1, fig.3). On the lateral margins of the clypeus between it and the compound eyes are two very small subtriangular sclerites, the genae.

Because of the absence of the coronal suture the vertex of the head is not medially divided so that the two parietals come together in this position. They retain connection with their frontal portions by very narrow strips running between the antennal fossae and the compound eyes (Plate 111, fig.9).

The lateral ocelli lie in the vertex in a position just behind the antennal fossae near the compound eyes.

The occiput is a sub-rectangular sclerite. Its posterior-lateral margins are produced inwards towards

the occipital foramen. Here, at points near the posterior tentorial pits these extensions are met by two similar incurving lateral projections of the postgenae. The occiput is bounded by the transverse occipital suture which runs from one ocular sclerite to the other and separates the occiput from the parietals. The post-occipital suture runs around the margin of the occiput proximal to the occipital foramen and separates it from the small oval postocciput. That part of the parietals above the antennae is in a sub-horizontal plane. The occiput is strongly declivous meeting the parietals at a distinct angle, along which angle runs the transverse occipital suture.

The postocciput has suffered considerable desclerotization. The sclerotized portion appears as a small oval sclerite and the membranous area of the sclerite merges into the neck membrane without differentiation. The postoccipital suture which bounds the postoccipital margin distal from the occipital foramen, is the only distinct suture demarking the limits of this sclerite.

The postgenae constitute the posterior portions of the orbits of the eyes, and also the lateral portions of the hind aspect of the head (Plate 1,fig.2).

In well cleared specimens the tentorium can be readily distinguished. The anterior tentorial arms are

well developed extending forward to expand themselves on the inner lower side of the frons. Posteriorly they fuse with the tentorial bridge which runs transversely in the cavity of the head capsule. On this bridge can be seen from a posterior view, the minute posterior tentorial arms (Plate 1,fig.2).

The labrum is a narrow transverse lobe lying on the lower side of the clypeus. Its lateral angles are produced into densely bristled projections, the pilifers. The epipharynx can be distinguished as a very small median lobe attached to the ventral margin of the labrum (Plate 1, fig.1). As in all higher Lepidoptera, the basal part of the labium is represented by a membranous area. In H.immanis Gn. this area is triangular in shape. It is bounded posteriorly by the hypostomal bridge with which it is intimately united at its base, being separated from it by a very indistinct transverse suture (Plate 1,fig.4). From the base of the triangular labium project the conspicuous three-jointed labial palps. They are densely covered with scales which are thicker on the upper and lower surfaces, especially the lower surface. This arrangement of the scales gives the palps their characteristic blade-like form.

The galeae of the maxillae compose the typical long coiling sucking proboscis of the Lepidoptera. They

are grooved on their inner surface and hooked together. At the tip of the maxillae are sensory bristles (Plate 1, fig.6). There is a fixed basal portion of each maxilla, the combined cardo and stipes, from which arises a minute two-jointed palp (Plate 1,fig.1).

The antennae are not of a uniform structure throughout their whole length. The basal segments are typically moniliform. Through the median area of the antennae the segments are modified serrate with the points of the teeth truncate. These median segments gradually merge into the apical segments which are filiform. Different specimens show slightly varying numbers of antennal segments. The males have around 88 to 96 segments and the females 80 to 86. (These numbers are from counts of twelve individuals). The scape or basal segment is larger and more conspicuous than any of the following segments (Plate 1, fig.5).

B. THE CERVIX.

The membranous neck region or cervix is well developed (Plate 3,fig.9). A pair of lateral cervical sclerites are readily distinguishable. The anterior cervical sclerite articulates with the back of the head and is hinged posteriorly with the posterior cervical sclerite which articulates with the prothoracic episternum.

C. THE THORAX.

1. The prothorax. The notum of the prothorax is mostly membranous, the sclerotized portions being restricted to narrow areas separated by intervening membrane. On the anterior margin of the notum two lateral strips lie on each side of it, ending at the dorsal margin of the episterna. From these areas, in a dorso-lateral position, arise two sclerotized outgrowths which are densely covered with hairs. These are the patagia which appear when the moth is at rest, as two hairy flaps in the space between the back of the head and the anterior part of the mesothorax, overlying the notum of the prothorax, which they conceal (Plate V,fig.15). There is a median strip in the posterio-dorsal part of the notum which does not quite extend anteriorly to the two areas previously described. From the anterior margin of this part of the notum, two narrow sclerotized areas extend downwards on each side of the prothorax to end just before they reach the first thoracic spiracle, lying in the membrane behind the episternum (Plate 11,fig.7). In the foregoing figure, the prothorax is represented much more extended than it is when in a normal position. For this reason, the membranous areas appear bigger than they normally are.

The episternum is a distinct sclerite lying in an anterior position in the pleuron. Apparently the

epimeron is not present, its definitive position being taken up by membrane. Between the freely articulating coxa and the episternum is to be found a small triangular sclerite, the epicoxal piece.

The greater part of the sternum is taken up by the sub-triangular eusternum (Plate V,fig.15) which is narrowly produced posteriorly between the coxae to meet the intersegmental spinasternum. The eusternum is divided by a longitudinal median suture. The spinasternum is greatly desclerotized and, for this reason, is irregular in shape. The sclerotized portion appears as an inverted Y. The arms of the Y meet the preepisternum of the meso-thorax, being separated from it by two short transverse sutures. At the end of the stem of the Y lies a small rhomboid area. The stem of the Y is formed by the spinal invagination (Plate 1,fig.7).

2. Mesothorax. The notum of the mesothorax constitutes the greater part of the thoracic notum. The anterior antecostal suture is difficult to see because the anterior portion of the scutum overhangs it, but its presence and position is assured by the well developed first phragma distinctly visible from an internal view (Plate V,fig.14). The notum is sub-oval in shape,being divided into an anterior scutum and a posterior scutellum by a prominent v-shaped scuto-scutellar suture (Plate 1V,fig.11). The

The scutum is bisected by a somewhat indistinct median notal suture, which internally forms a median notal carina extending from the prescutum to the apex of the scutellum (Plate V,fig.14). Anterio-laterally, the scutum is extended to form the anterior notal wing process. The prescutum, although visible at the sides of the scutum, is very narrow in the middle, which part is overhung by the anterior margin of the scutum (Plate 111,fig.9 and Plate 1V,fig.11). From the base of each mesothoracic wing there projects backward a large sclerotized flap, the tegula, which is as long as the scutum (Plate 11,fig.7). Its point of attachment lies in a strip of membrane stretched from the prealar bridge to the lateral portion of the prescutum (Plate V,fig.16). A sclerotized arm arises from the prealar bridge, the purpose of which seems to be that of a brace for this strip of membrane. Most of the tegula lies on the base of the wing, but an anterior arm projects from its base beneath the base of the wing and rests on the dorsal edge of the pleuron. The scutellum extends laterally into the axillary cords on each side.

The postnotum is deeply invaginated and overlapped by the posterior margin of the scutellum (Plate 1V, fig.11). Its dorsal margin is limited by the antecostal suture which is clearly defined in position by the very large second phragma (Plate V,fig.14).

The pleuron is divided by the pleural suture which traverses it from the pleural wing process to the coxa, into an anterior episternum and a posterior epimeron (Plate 11,fig.7). The episternum is divided by a transverse anepisternal suture into an anepisternum and a katepisternum. Anterior to the katepisternum lies an elongate narrow sclerite, the preepisternum. The epimeron is secondarily divided by three sub-perpendicular sclerites into four parts. The posterior of these four parts is somewhat weakly sclerotized.

The coxa is partly fused to the body and is divided into the true coxa and the posterior part, the meron. A small triangular sclerite lying at the apex of the coxa is the epicoxal piece.

The pesition of the alar sclerites can be seen illustrated in Plate 11,fig.7 and Plate V,fig.16. The subalare is the largest and most prominent of the alar sclerites. The posterior basalare and the anterior basalare are only exposed if the tegula be detached (Plate V,fig.16).

The greater part of the sternum consists of a shield-shaped sclerite, the basisternum, medially divided by a distinct suture which internally is developed into a semi-transparent plate-like apodemal process (Plate 111,fig.10). Anteriorly on each side, the basisternum is bounded by the preepisterna (Plate 11,fig.8). Anterio-laterally it meets the katepisterna. The furcasternum, lying posterior to

the basisternum is difficult to differentiate. At this point the sternum is deeply invaginated. However, a sagittal section of the thorax,made a little to one side of the median line,throws light on the situation. The furcal arms arising from a common stalk diverge widely to fuse with the pleural apophyses and are readily distinguishable. The stalk of the furca apparently includes the intersegmental spina,which apophysis has no sclerite indicating its presence externally. At the point of union of the two furcal arms there is a small projection which extends forward in the body cavity. This is probably all that remains of the spina, which has assumed this position through invagination of the sternal wall and from the fusion of the spina with the furca.

3. Metathorax. From a dorsal view the notum of the metathorax consists of the narrow scutellum which extends laterally to the axillary cords (Plate 1V,fig.11). From a lateral view, however, the scutum can be seen lying below the scutellum of the mesonotum which projects posteriorly over it (Plate 11,fig.7). Laterally,the scutum is extended anteriorly and posteriorly to form the anterior and posterior notal wing processes respectively. Dorsal to the posterior notal wing process, the alula of the hind wing can be distinguished. Posterior to the scutellum lies a practically invisible sclerite, the postnotum, which is only revealed if the abdomen be pulled backwards. This is represented in this manner in Plate 1V,fig.11. In a

normal condition, the posterior margin of the scutellum overhangs the postnotum so that its limits are difficult to differentiate. It is bounded posteriorly by the antecostal suture whose position is clearly designated by the well developed third phragma visible from an internal view (Plate V.fig.11).

The pleuron presents a somewhat similar condition to that found in the mesothorax. The episternum is divided only into the preepisternum and the episternum proper. The epimeron is traversed by several faint sutures secondarily dividing it into irregular areas. The postero-dorsal portion of the epimeron presents a complex sculpturing associated with the tympanum. The whole tympanal region is deeply excavated (Plate 1V,fig.17). In the dorsal half of the meron faint sutures are to be found which, however, do not outline any definite sclerites. As in the mesothorax, the subalare is the largest and most prominent of the alar sclerites. Again two basalar sclerites are present designated as the anterior and posterior basalare. These two sclerites lie in the membrane cephalad to the pleural wing process (Plate 11,fig.7). Dorso-cephalad to the anterior basalare is situated the second thoracic spiracle.

In the metathorax the sternum consists of a basisternum whose lateral limits are overhung by the coxae of the

mesothoracic legs. The basisternum in this segment of the thorax is much smaller in area to the similar sclerite in the mesothorax, though like it, it is medially divided by a suture which internally is developed into a semi-transparent basisternal apophysis. The furcasternum is again invaginated giving rise internally to the Y-shaped furca. To see the pit indicative of the median furcal stalk, it is necessary to pry apart the converging coxae of the metathoracic legs which lie over the sternum, in this position.

D. THE THORACIC APPENDAGES.

1. The legs. (Plate VIII, figs. 23, 24 and 25) The coxae of the middle and hind legs are partly fused with the body. The femora of each leg bear long hairs, as well as scales, as do the coxae of the front legs. The other segments of the legs are covered with scales only. The fore tibia bears a leaf-like structure on its inner side, the epiphysis; this is covered with stiff bristles, and, according to Forbes (1920), serves mainly to clean the antennae and the tongue. At the base of each coxa of the front legs on the outer surface are to be found scent organs (Plate V, fig. 15). The mid and hind tibiae each have a pair of stout spurs of unequal length at their tips which articulate with the tibiae. The hind tibiae have a second pair of spurs near but below their middle. The tarsi are

divided into five tarsomeres, the basitarsus being longer than the others. All the tarsomeres are spined. The pretarsus ends in two articulated and curved claws, with an adhesive pad, the pulvillus, between them (Plate V11, figs. 21 and 22). On the inner side of each claw there is a sensory membrane, the paronychium.

2. The wings. (Plate V111,figs.27 and 28)

Attached to the humeral angle of the hind wing is the frenulum which consists of three spines in the female,and of several spines fused together in the male. The frenulum is held in place in the female by the retinaculum, a tuft of scales spread fanwise from near the base of vein Cu. on the fore-wing. In the male the frenulum is held in place by the frenulum hook, a membranous flap attached to the Sc. near the base of the forewing. The wing venation shows no specific characteristics. The nomenclature is given in Plate V111,figs.27 and 28. The position and names of the axillary sclerites are given in Plate 1V,figs.12 and 13.

E. THE TYMPANUM

The tympanum (Plate V1,fig.17) is located in the posterior part of the metathorax in the region between the epimeron and the parapleura. At its dorso-posterior corner the epimeron sinks inward and becomes membranous, thence passing over into the transparent tympanal membrane which is supported by a semi-elliptical framework open

anteriorly. Between the epimeron and the tympanal membrane is a small nodular sclerite which is attached to the tympanal frame. Facing the insinking of the thoracic wall is a similar opposing one on the first abdominal segment. The pleuron of this segment forms the posterior wall of the tympanal cavity and, in addition, has a secondary lateral development, the spiracular lobe which is an evagination extending laterally and anteriorly. Anterior to the spiracular lobe and under it, lies the first abdominal spiracle. A deep tympanal fova (the counter tympanal fova of Richards,1932) is located dorsad to the triangular parapleural sclerite and anterior to the tergum of the first abdominal segment. The excavation of the tympanum proper is roofed over by the alula which is an expansion of the scutellum of the metathorax continuous with the posterior margin of the hind wing. In fig.17 the alula is represented pulled forward so as to expose the tympanum. From the alula many long scales project posteriorly and ventrally over the tympanal cavity. Due to the rigidity of the tympanal frame there is a nonflexibility between the thorax and the abdomen. From the upper corner of the frame, the heavily sclerotized tergo-pleural groove of the first abdominal segment extends posteriorly as a thoracico-abdominal brace.

F. THE ABDOMEN.

In a state of rest there are eight abdominal terga recognizable. The ninth and tenth, which are greatly modified in connection with the genital armature, lie concealed more or less completely within the eighth. In Plate V11,figs.18,19 and 20,the last two segments have been exerted to show their form. There are spiracles present in the first seven segments. The sternum of the first segment is membranous and not distinguishable from the sternum of the second, with which it is closely united. On the first abdominal segment there are two heavily sclerotized lateral grooves, the tergo-pleural grooves (Plate V11, fig.18). In the male, at the junction of the pleuron and the sternum in the second segment, there is present a scent organ from which arises a bundle of long hairs (Plate V1,fig.17). The function of this bundle of hairs in sphingid moths is suggested by Rothschild and Jordan (1903) to be for spreading the scent.

G. THE GENITALIA.

The terminology as used by Pierce (1909) is followed in the description of the genitalia.

1. Male. (Plate V11,figs.21 and 22) The ninth abdominal segment consists of the tegumen, the base of which rests on the plane of the ventral surface of the abdomen, the upper part lies longitudinally in the plane of the dorsal

surface. It is ring-shaped, dorsally terminating in the uncus and basally in the vinculum, which itself terminates in the saccus. The uncus is a heavily sclerotized sickle-shaped hook which articulates in the middle of the tegumen, enabling it to be thrown backwards towards the head. On either side of the tegumen, laterally near the point of articulation of the uncus, is a lobed process densely clothed with hairs, the peniculus. Hinged on either side of the tegumen, below the peniculi are the harpes, the basal part of a harpe being a sacculus. The corona is a uniform row of incurved spines on the apex of the harpe. Occupying the central area of the harpe on the inner side is the clasper, a free moving arm ending in a finger-like process. The ampulla,a small shaft-like organ clothed with hairs at its apex also occupies a central position on the inner side of the clasper. The subscaphium is a process to be found attached at the base of the uncus. The anal process lies along the dorsal surface of the subscaphium. The aedeagus, the outside covering of the penis, is a stout tube from which the penis is everted, through a band-like sheath the juxta, which is decorated with a shield-shaped plate infront.

2. Female. (Plate V11,figs.19 and 20) On the anal edge of the seventh sternite there is a central plate, the lodix, which covers the strongly sclerotized sub-rectangular

genital plate leading to the genital tube. The anal opening lies medially in the ninth tergite. The ovipositor dorso-ventrally flattened is strongly sclerotized. It is apparently made up of two halves which are terminally pointed and which diverge at the apex of the ovipositor. In shape and structure, the ovipositor is well suited for depositing the egg masses in the position that they are found, between the leaf sheath and stem of grasses.

VI. BIOLOGICAL NOTES

A. INTRODUCTION

The growing of hops in Eastern Canada is almost entirely restricted to a comparatively small area around the village of Fournier, Ontario, which is some fifty miles south-east of Ottawa. Hop culture has been carried on here for the past forty years. The exact date when the growers first recognized the hop-vine borer has never been established, though, for several years, it has been known as a pest of economic significance. Two years ago the author, in the course of his duties as an officer of the Dominion Entomological Division, undertook the project of investigating the life history and biology of this insect, in the Fournier district, for the purpose of finally finding a feasible means of control. It is from this work, that the following notes were obtained. It must be mentioned

here, that Hawley (1918) worked out the life history of the hop-vine borer in New York State, and the following notes are only written because certain additions to the knowledge of the biology of this species were obtained.

B. LIFE HISTORY

A brief summary of the life history as described by Hawley for New York State, is as follows:-

Hydroecia immanis Gn. overwinters in the egg stage, the eggs being laid on grass in and around the hop yards. These hatch in the latter part of April or the beginning of May and the young larvae make their way into grass or hop plants. Those in grass eat their way into the stem at the ground level, working their way up and killing the central blade. They leave the grass at about the time other larvae leave the inside of the hop. Those in the hop enter the part that is most readily available and easy to penetrate. This may be the head, or any part of the vine. If the larva enters the head, it drops to the ground in about two weeks time and helps to increase the large number already working in the vine near the root. About the first of June, when the larva is in the third or fourth stage, it stops work inside and either feeds on the outside of the vine, nearly severing it, or makes a burrow in the root. In July, or the first part of August, the larva pupates and the moth

emerges the last part of August or the early part of September. The moths lay their eggs on grass, dying shortly after oviposition. The eggs overwinter, hatching in the early spring the following year.

This summary agrees in general with the life history of the hop-vine borer as found in the Fournier district.

C. BIOLOGICAL NOTES ON THE DIFFERENT STAGES OF THE LIFE CYCLE OF H. IMMANIS GN. AT FOURNIER.

The following notes were taken in the field on the life history of H. immanis Gn. in the Fournier district, during the seasons of 1937 and 1938.

1. Larvae. Overwintering egg-masses were found only on the dead stems of green foxtail grass (Setaria viridis L.). These eggs hatched on May 14 in 1937 and a few days later in 1938. The first indication of larval activity was noted six days later when the characteristic injury to the tips known as 'muffle heads' was seen. At the same time a few cases of first instar borers feeding in grass stems were encountered. These were much more numerous some two weeks later. Twitch grass (Agropyron repens L.), meadow fescue (Festuca elatior L.), and timothy (Phleum pratense L.), were the most common host plants, besides hops, but it is thought that almost any succulent

grass will serve as a host. These borers in grass were found not only in the hop yards and their headlands but in grass plants some fifty yards from the nearest hop plant. Borers unless able to migrate to a hop hill to complete their life cycle die and there is little doubt that a high percentage of the young borers succumbs before it is able to reach the hop plants. The presence of borers in hop-vines in the early part of the season is always indicated by dead or wilting vines. The entrance hole of the borer is marked by an accumulation of frass. Later, when larval feeding is restricted to the roots of the hop plants, there is often no visible sign that borer activity is taking place below the surface of the soil. Visible injury above ground depends upon the position of the feeding borers in the root. If they attack the base of a vine, the vine will show this injury by wilting and finally dying, but it is quite possible for a borer to restrict its feeding to parts of the root where it will not directly affect the vines. This is more especially true when the borers are in their sixth or last instar. At this time they feed deeper in the soil where there is less chance of their severing the vines from the roots.

2. Pupae. The first record of pupation was on July 20. Pupation is more general at the end of the month. The pupae vary greatly in size, from 27 to 33 mm. in length.

This variation is in no way correlated with sex. A quick glance through a microscope is sufficient to differentiate a male from a female pupa. In the female the anal opening is widely separated from the genital opening,whilst in the male it is not. In both sexes the anal opening is situated on the ventral side of the tenth segment mesally near the caudal margin,on the summit of a slight mound-like elevation. In the male the genital opening lies on the ventro-meson of the ninth segment in the centre of a plate-like elevation. In the female the mesal caudal margins of the eighth and ninth segments are strongly curved cephalad to the posterior end of the genital opening which is situated for the most of its length in the eighth segment,without any adjacent elevation.

The sex ratio is 1:1. Pupation takes place some three to four inches in the soil and, as a rule, close to the hop roots, within a radius of 12 inches of the crown. Hawley (loc, cit.) states that in the case of soils that pack easily,a pupal cell is formed by the larva at the time of pupation. In the Fournier district where the soil is a sandy loam, not readily packed even when wet,it was in accordance with this author's findings that no pupal cells were noted. The duration of pupation is at least 36 days, a more nearly average figure would be ten days longer than that.

3. Adults. The earliest emergence of an adult was noted on August 25 and the flight of moths was general around the end of the month. Oviposition commenced three or four days after the first emergence was seen. From adults that were reared from pupae and placed in cages outside, it was found that the average preoviposition period was 3.9 days and that the maximum number of eggs laid by one individual moth was 2055, the average being 1500. In the field, eggs are laid almost entirely on green foxtail (Setaria viridis L.). Though a careful search of other grasses growing in the yards at that time, such as yellow foxtail (Setaria glauca L.), barnyard grass (Echinochloa crusgalli (L.) Beauv.), old witch grass (Panicum capillare L.) and twitch grass (Agropyron repens L.) was carried out, with one single exception on twitch grass, egg masses were found on green foxtail only.

From one night's observations in a hop yard where a bait trap with a lure of half beer and half molasses and a light trap had been set up, the following notes on the flight of moths were taken. In the day the moths hide under piles of hop poles or dried vines or in the tall grass in the headlands. The flight of moths did not start until 10 p.m. E.S.T., the temperature at that time being 69° F. and there being no moon. Only every now and then would a single

individual be attracted either to the light or the bait. By the aid of a flash light moths could be seen flying high in the air and sometimes come close enough to be taken with a net. All the moths taken at the bait or light were males. Apparently the females were not attracted. Though it is thought that oviposition takes place at night, no definite instance of this activity was seen though a thorough search was made for ovipositing females, throughout the night with a flash light in the headlands and on the weed grasses in the yard. The length of life of the adults in the field was not established. In cages the average length of life was found to be 10.5 days. It is probable that this is exceeded in the field.

4. Eggs. The eggs are laid in masses inserted between the leaf-sheath and stem of green foxtail grass. The last internode is the favorite site but sometimes the masses are laid lower down the stems. An average egg-mass contains some fifty eggs. These are commonly arranged in a double row stuck together with a sticky matrix which shortly after oviposition becomes dry like skin. The largest mass found contained ninety-five eggs, all apparently viable. The eggs are flattened on the top and bottom. If the leaf sheath of the grass plant happens to grow

tightly around the egg mass, the eggs are more flattened and the impression of the veins of the leaf can be recognized in the skin like matrix. From a collection of 2600 eggs made in 1937 it was found that 75 percent were viable, 4 percent were apparently infertile, for they collapsed in a few days and 21 percent were parasitized. In 1938 the parasitism found in egg collections was slightly lower being about 17 percent.

D. SUMMARY OF STAGES OF THE LIFE CYCLE WITH DATES COMPARED WITH GROWTH OF THE HOST PLANT.

The following summary was prepared from data taken in the season of 1937.

Insect stages		Growth of host	
May 14	Eggs hatching		
		May 15	Hops starting to sprout.
May 20	First appearance of muffle heads indicative of larval feeding.		
June 4	2nd and 3rd instar larvae feeding in grass. First occurrence of boring in vines.	June 4	Hop-vines 5-12 ft. high.
		June 7	Laterals appearing on vines.
June 11	Borers common in hop vines and ground		
June 15	Borers in 3rd, 4th and early 5th instars.		

		June 20	Laterals on vines beginning to form flowers.
June 25	First 6th instar larva. No borers in grass after this date.		
July 3	Borers mostly in 5th and 6th instars.		
		July 8	Hop cones beginning to form on laterals.
July 20	Pupation starting.	July 20	Cones well formed.
Aug. 6	Pupation general.		
Aug. 7	Emergence of first moth from pupal collections.		
		Aug. 12	Hop picking started.
Aug. 25	First moth observed in field.		
Aug. 27	Oviposition started.		
Aug. 31	Moth flight general.		
Sept. 9	Moths still flying.		

E. PARASITES AND PREDATORS

1. An egg parasite. Mention has been made already of the percentage of parasitism in the collection of eggs. These parasites were reared and submitted to the Systematic Investigations of the Division of Entomology, Dominion Department of Agriculture for identification. They were tentatively identified by Mr.Walley as Trichogramma minutum Ril.. This identification was confirmed by Mr.A.B. Gahan of Washington to whom the same material was submitted.

It must be borne in mind that there is a possibility that these parasites might be T.pretiosa Ril.. As recently

as June 1938 Flanders in the Journal of Economic Entomology stated that T.minutum and T.pretiosa were distinguishable by their habitats, that of the former being arboreal and that of the latter in the open field. According to Flanders therefore, one would expect this chalcidoid to be T.pretiosa.

This is an interesting note of egg parasitism but there the matter rests. T.minutum and T.pretiosa both have such a wide range of hosts that any thought of using this chalcidoid as a biological method of control is out of the question.

2. A larval parasite. Another interesting note of the parasitism of this species is the record of three larval parasites reared in 1937 and identified by Mr. Walley as Sagiritis xanthotaenius Vier.. Little is known of this parasite as it was described by Viereck from a single specimen taken in Lancaster, N.Y., the host being unknown. From the rearing of these three specimens in the larvae of H.immanis Gn. the following notes were taken. (1) The average pupal stage of the parasite lasts eleven days: (2) in all cases pupation takes place in the third instar of the host: (3) prior to pupation of the parasite, the host larvae appear to feed quite normally: and (4) oviposition must take place in the first or early second instar of the host.

3. Insect predators. In the two years of investigation with H.immanis Gn. only one instance of a ground beetle

larvae feeding on a borer was discovered. It was thought that these predators of cutworms and other soft bodied insects would be more plentiful. The species of this ground beetle was likely Calosoma calidum Fab. It was not, however, reared to maturity.

Gryllus assimilis Fab., the field cricket, in 1937 became very plentiful in the hop yards at the time of pupation of the borers. Many instances of predatism of this species on the pupae were encountered.

4. Other predators. The crow is considered by the hop growers to search out the borers in the hop roots and eat them. Only a few instances of crows pecking around the hop hills have been seen by the author. The flicker and robin, on the other hand, were often seen searching the hop hills presumably for borers, but as none of these birds were shot and the contents of their crops examined, the evidence of their being predators is only circumstantial.

The skunk is reported by Hawley and other authors to be an important destroyer of borers. In 1937 and 1938 numerous hop hills were found where some animal had been digging amongst the roots but no skunks were actually seen though their characteristic odour often assailed the nostrils of anyone walking in the yards early in the morning. This digging in the hills was noticed from early in July until the latter part of August.

V11. SUMMARY AND CONCLUSIONS

1. A detailed study, illustrated with twenty-eight figures, describes the external structural characteristics of the adult of Hydroecia immanis Gn..

2. For the purpose of morphological study it was found that boiling specimens in weak caustic potash and then plucking the excess scales and hairs with fine forceps was a good method of preparing the material for examination.

3. H.immanis Gn., the hop-vine borer, a pest of hops, was first recorded by Bethune in 1872. Its common name was given to it by Dodge in 1882 and Comstock in 1883 recognized it as the species immanis. The distribution of this species is recorded as Canada, New England, New York and west to Washington.

4. The generic history reveals that the generic name has been changed many times. The reason for this changing of the generic name being due to the generic concepts of the authors.

5. The adult moth is a light brown with greenish or pinkish reflections in certain lights, with a wing spread of 37-50 mm.

6. A review of the life history as given by Hawley in New York State, along with the study of the biology of of this insect made by the author, reveal the fcllowing points in the life history and habits of the insect in the district of Fournier, Ontario.

(a) The eggs overwinter.

(b) Eggs hatch in the middle of May when the hop plants are starting to sprout.

(c) Young larvae feed both in hops and grass plants. Those in grass are found as far as fifty yards from the nearest hop plant, but only those borers that are able to reach hop plants by migration survive.

(d) Young borers in hops first feed in the vines and then bore in the roots. The larval stage lasts from eight to nine weeks.

(e) Pupation takes place in the soil lasting from six to seven weeks. Pupae vary greatly in size but this variation is in no way correlated with sex. Male and female pupae can be easily distinguished with a microscope. In the female the anal opening is widely separated from the genital opening, whilst in the male it is not. The sex ratio is 1:1.

(f) Adults start emerging in the beginning of August a few days before hop picking starts. Oviposition commences shortly after emergence. Eggs are laid in masses on grass, for the greater part on green foxtail. An average egg mass contains fifty eggs. The average number of eggs laid by individual females in cages was was 1500. Apparently female moths are not attracted to lights or baits.

(g) 21 and 17 percent parasitism of the eggs by Trichogramma sp. were recorded in 1937 and 1938 respectively. A few instances of larval parasitism by Sagiritis xanthotaenius Vier. were found.

(h) Insect predators feeding on borers were not numerous. Only one instance of a ground beetle larva as a predator was seen though field crickets destroying pupae were much more numerous.

(i) Birds such as crows, flickers and robins are suspected of preying on hop-vine borers. The skunk is recognized by the hop growers as an enemy of this insect and its excavations in the hop yards are a common occurrence.

VIII. ACKNOWLEDGMENTS

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P L A T E 1.

fig. 1. Frontal view of head.

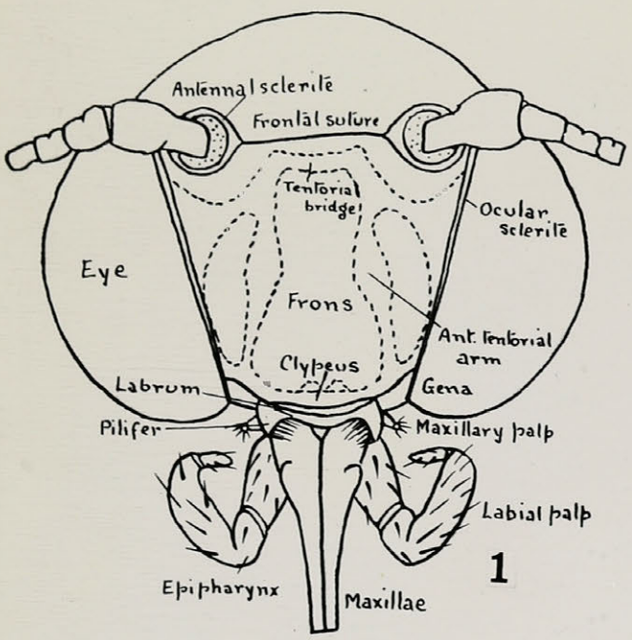
" 2. Posterior view of head.

" 3. Dorsal view of head.

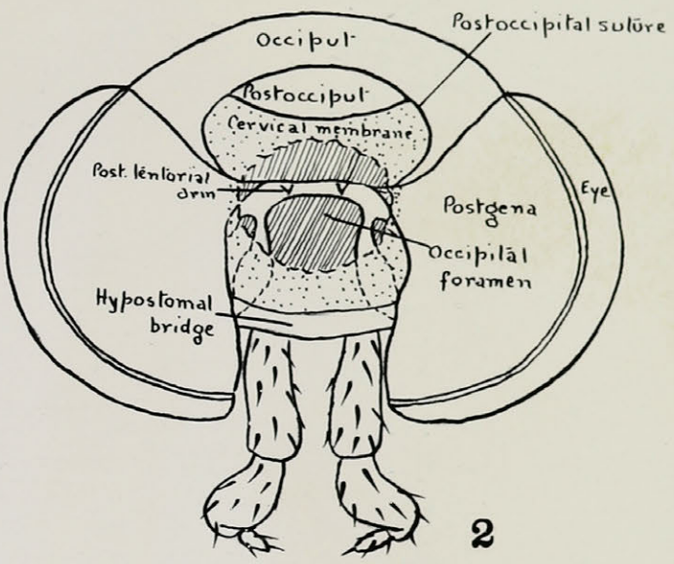
" 4. Ventral view of head.

" 5. Antenna.

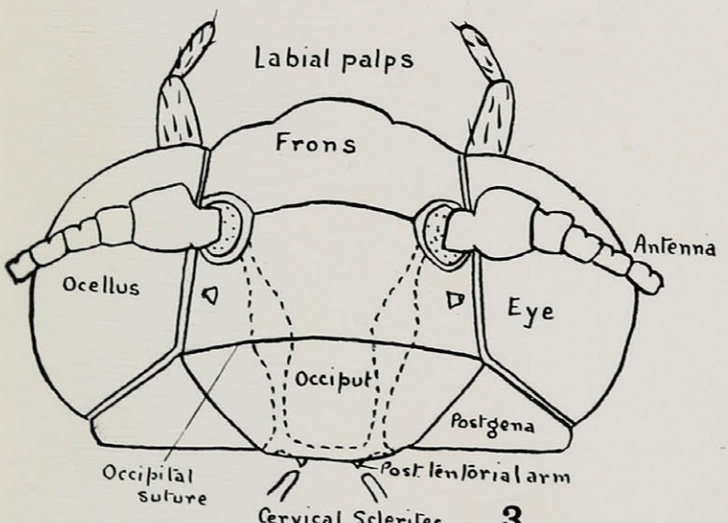
" 6. Tip of maxilla.


Antennal sclerite
Frontal suture
Tentorial bridge
Ocular sclerite
Eye
Frons
Ant. tentorial arm
Clypeus
Labrum
Gena
Pilifer
Maxillary palp
Labial palp
Epipharynx
Maxillae

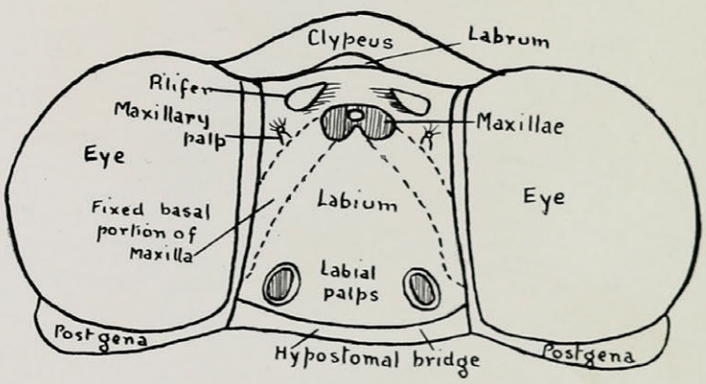
1


Occiput
Postocciput
Postoccipital suture
Cervical membrane
Post. tentorial arm
Postgena
Eye
Occipital foramen
Hypostomal bridge

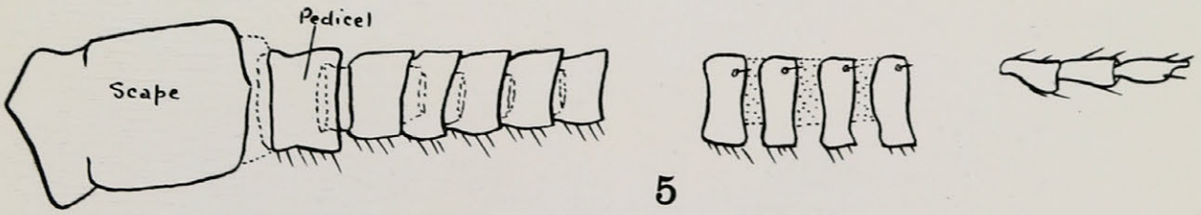
2


Labial palps
Frons
Antenna
Ocellus
Eye
Occiput
Postgena
Occipital suture
Post. tentorial arm
Cervical Sclerites

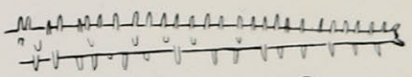
3


Clypeus
Labrum
Pilifer
Maxillary palp
Maxillae
Eye
Fixed basal portion of maxilla
Labium
Eye
Labial palps
Postgena
Hypostomal bridge
Postgena

4


Pedicel
Scape

5

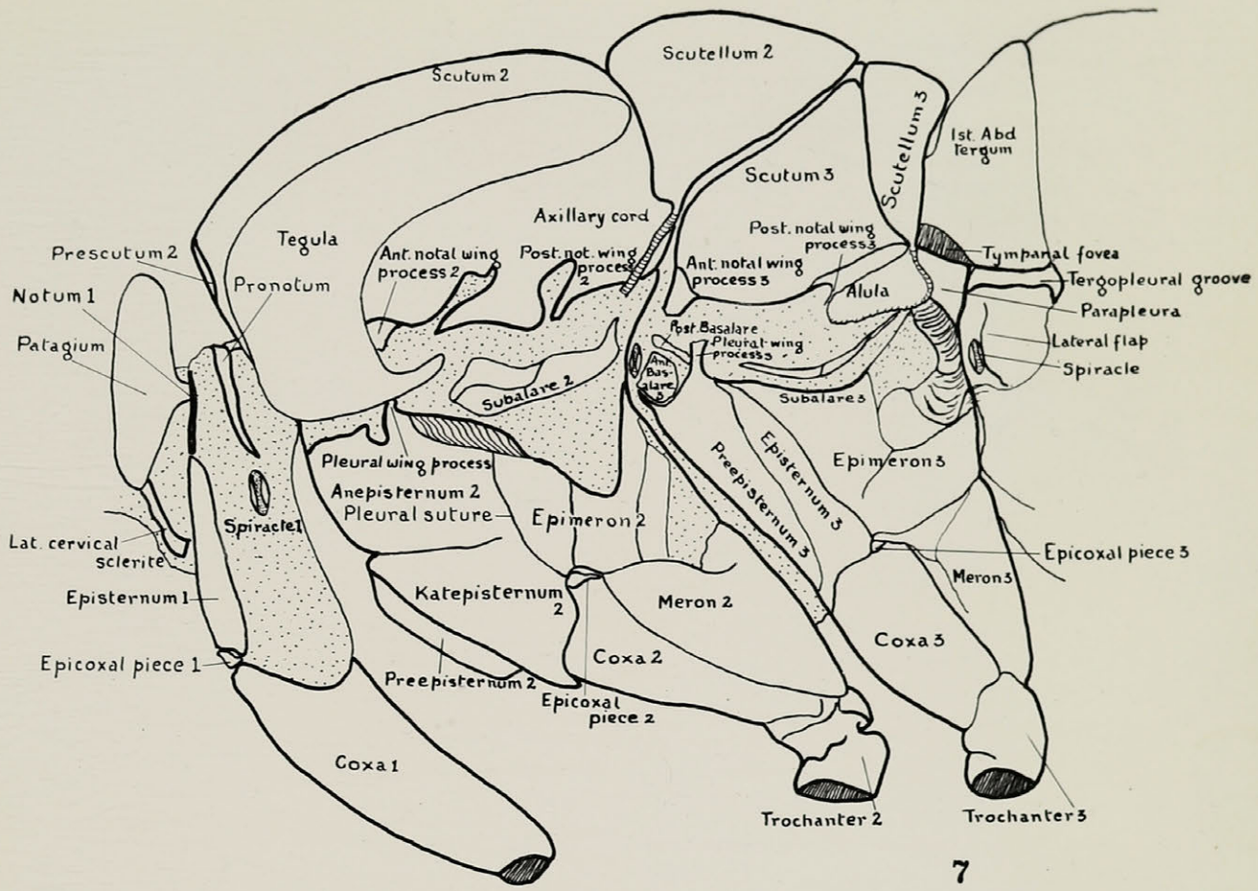


6

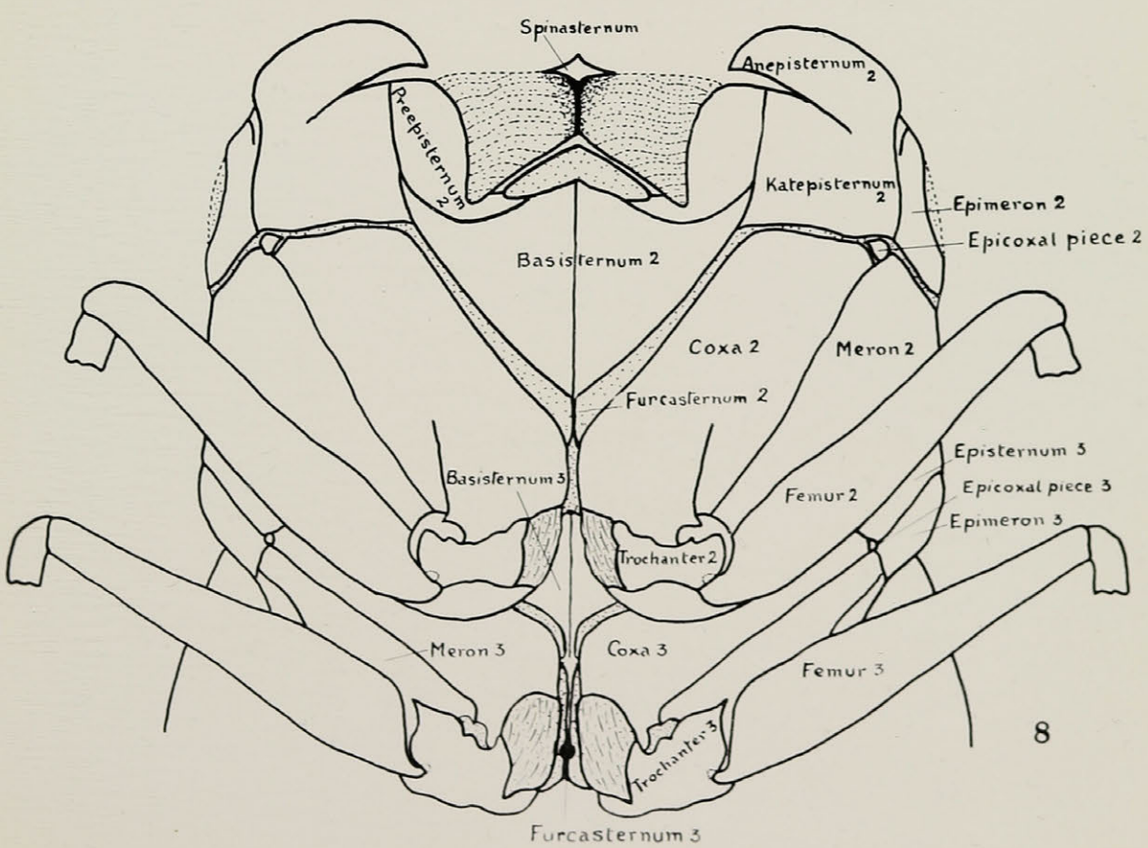
P L A T E 11.

fig. 7. Lateral view of thorax.

" 8. Ventral view of meso - and metathorax.


Scutellum 2
Scutum 2
Scutum 3
Scutellum 3
1st. Abd Tergum
Axillary cord
Tegula
Post. notal wing process 3
Prescutum 2
Ant. notal wing process 2
Post. not. wing process 2
Ant. notal wing process 3
Tympanal fovea
Tergopleural groove
Notum 1
Pronotum
Alula
Parapleura
Patagium
Post Basalare
Pleural wing process 3
Lateral flap
Spiracle
Ant. Basalare 2
Subalare 2
Subalare 3
Pleural wing process
Epimeron 3
Anepisternum 2
Pleural suture
Epimeron 2
Preepisternum 3
Episternum 3
Spiracle 1
Lat. cervical sclerite
Epicoxal piece 3
Meron 3
Episternum 1
Katepisternum 2
Meron 2
Coxa 3
Epicoxal piece 1
Preepisternum 2
Coxa 2
Epicoxal piece 2
Coxa 1
Trochanter 2
Trochanter 3

7

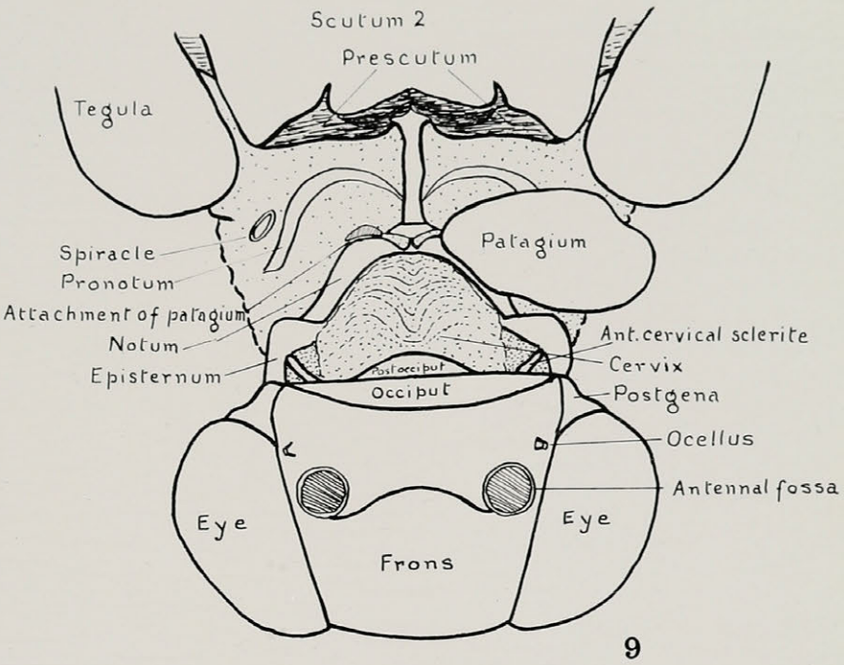

Spinasternum
Anepisternum 2
Preepisternum 2
Katepisternum 2
Epimeron 2
Epicoxal piece 2
Basisternum 2
Coxa 2
Meron 2
Furcasternum 2
Episternum 3
Basisternum 3
Femur 2
Epicoxal piece 3
Epimeron 3
Trochanter 2
Meron 3
Coxa 3
Femur 3
Trochanter 3
Furcasternum 3

8

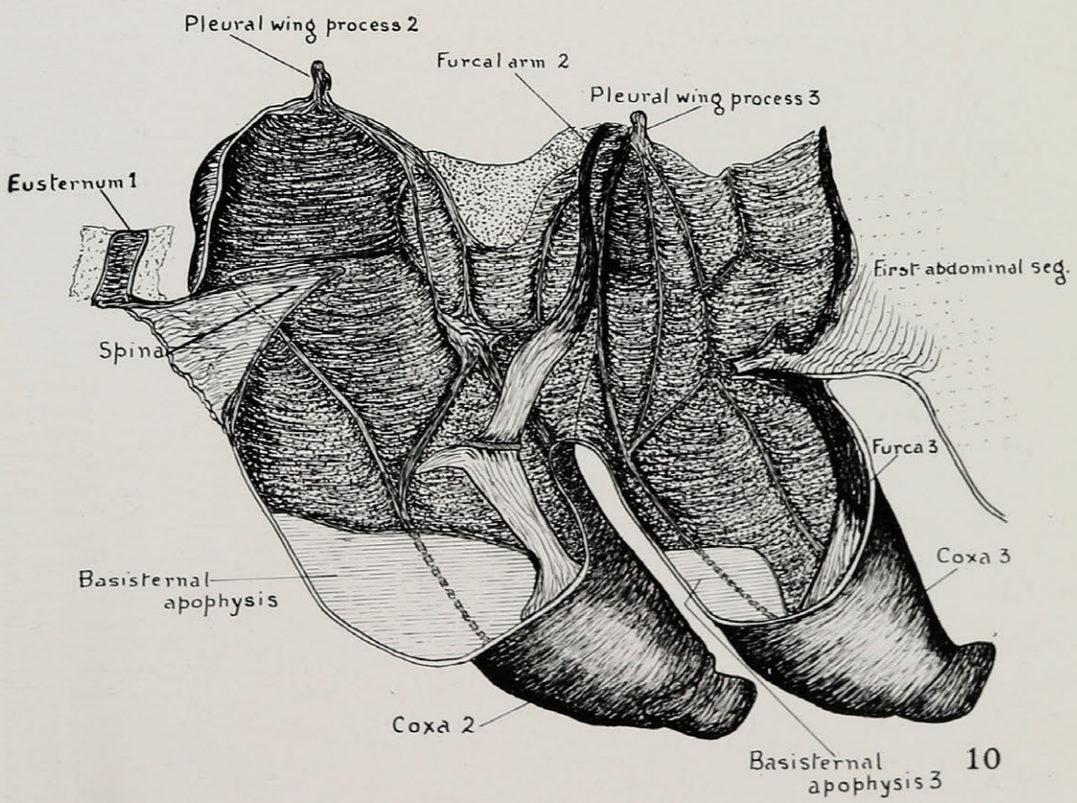
P L A T E 111.

fig. 9. Fronto-dorsal view of head, cervix and prothorax, with head pulled forward.

" 10. Internal lateral view of pleuron and sternum of thorax.


Scutum 2
Prescutum
Tegula
Spiracle
Pronotum
Attachment of paragium
Notum
Episternum
Paragium
Ant. cervical sclerite
Cervix
Postocciput
Occiput
Postgena
Ocellus
Antennal fossa
Eye
Eye
Frons

9


Pleural wing process 2
Furcal arm 2
Pleural wing process 3
Eusternum 1
First abdominal seg.
Spina
Furca 3
Coxa 3
Basisternal apophysis
Coxa 2
Basisternal apophysis 3

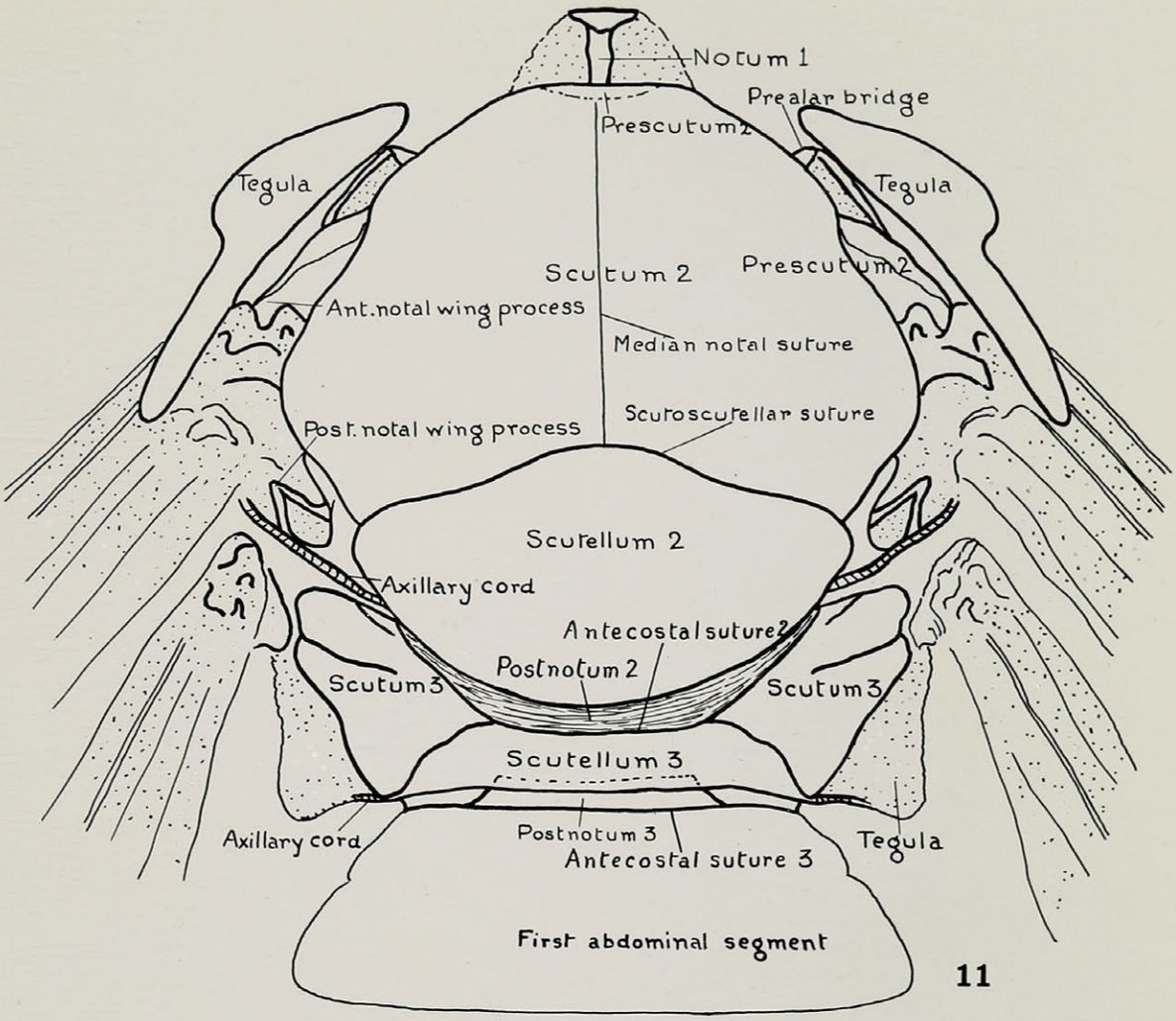
10

P L A T E 1V.

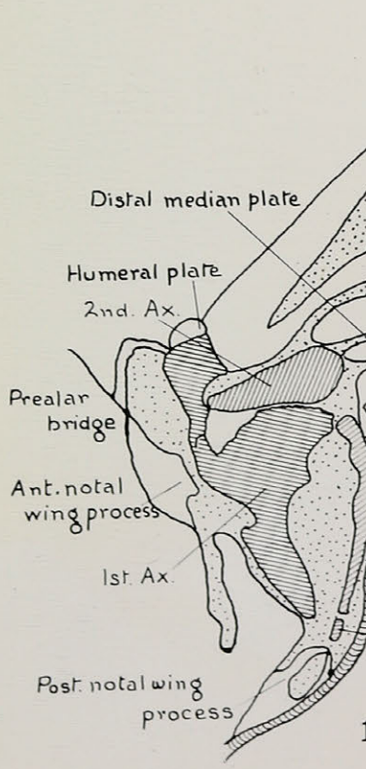
fig. 11. Dorsal view of thorax.

" 12. Base of forewing showing axillary sclerites.

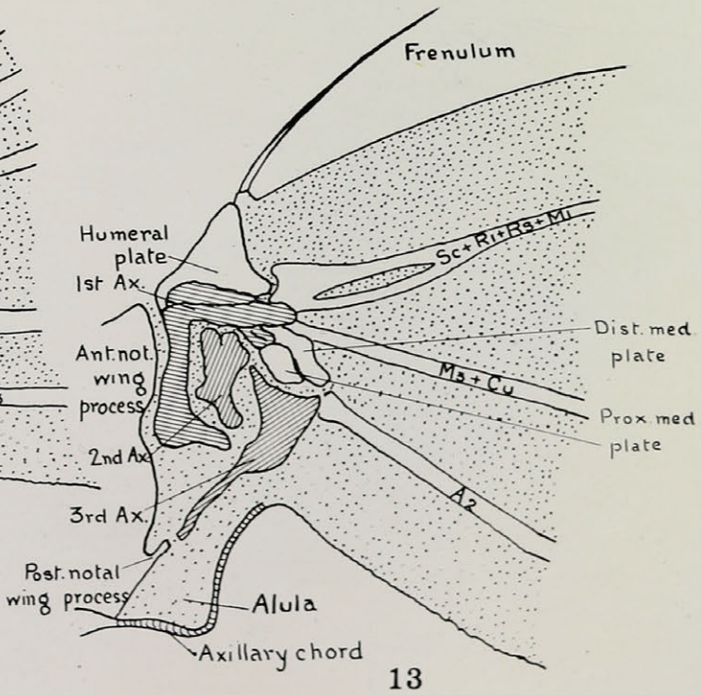
" 13. Base of hindwing showing axillary sclerites.


Notum 1
Prealar bridge
Prescutum 2
Tegula
Tegula
Scutum 2
Prescutum 2
Ant. notal wing process
Median notal suture
Post. notal wing process
Scutoscutellar suture
Scutellum 2
Axillary cord
Antecostal suture 2
Postnotum 2
Scutum 3
Scutum 3
Scutellum 3
Axillary cord
Postnotum 3
Antecostal suture 3
Tegula
First abdominal segment

11


C
Sc
R
M
Distal median plate
Humeral plate
2nd. Ax.
Prox. med. plate
A2
A3
Prealar bridge
Ant. notal wing process
1st. Ax.
3rd. Ax.
Axillary chord
4th. Ax.
Post. notal wing process

12


Frenulum
Humeral plate
1st Ax.
Sc+R1+Rs+M1
Dist. med plate
Ant. not. wing process
M3+Cu
Prox. med plate
2nd Ax.
A2
3rd Ax.
Post. notal wing process
Alula
Axillary chord

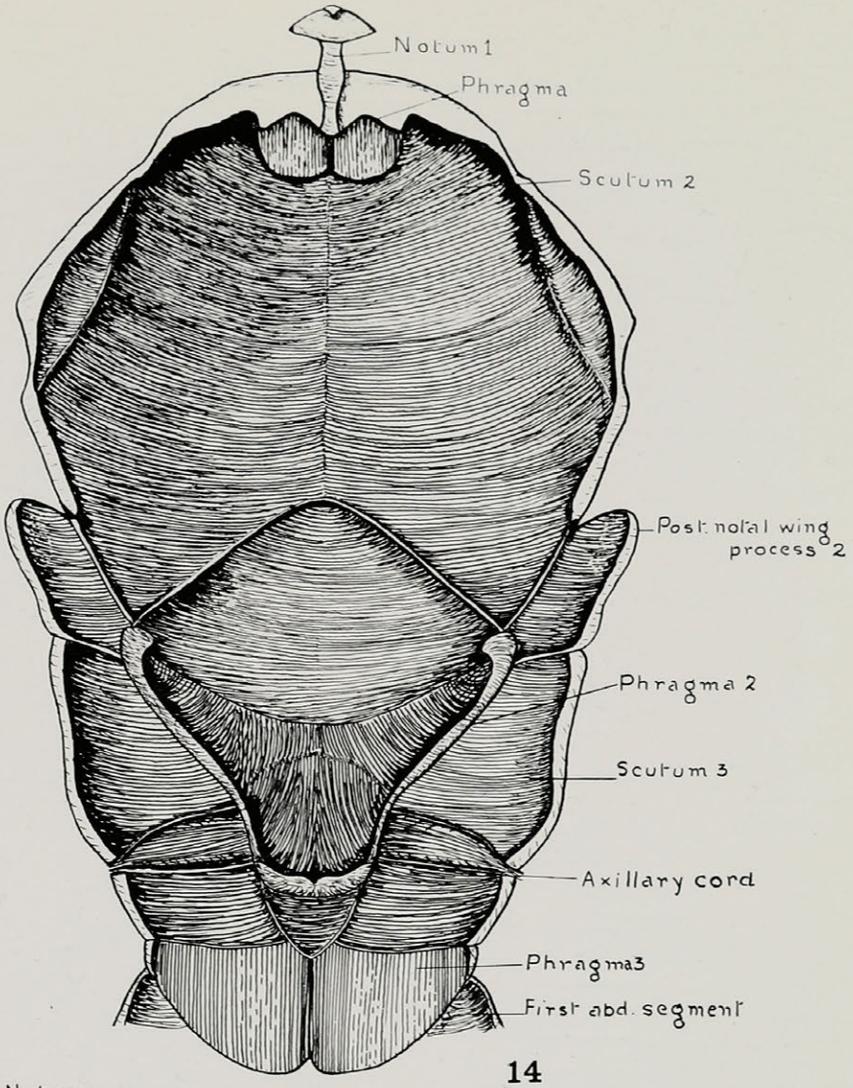
13

P L A T E V.

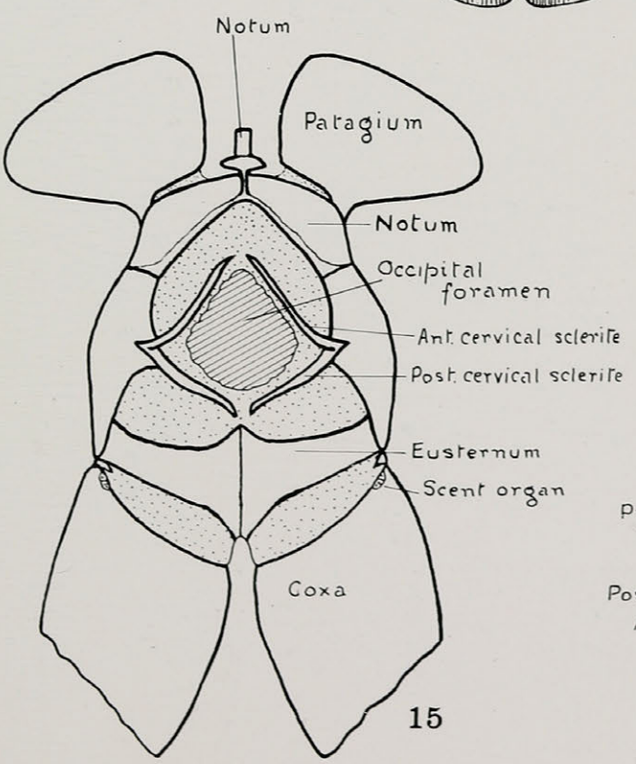
fig. 14. Internal view of notum of thorax.

" 15. Frontal view of thorax with head detached.

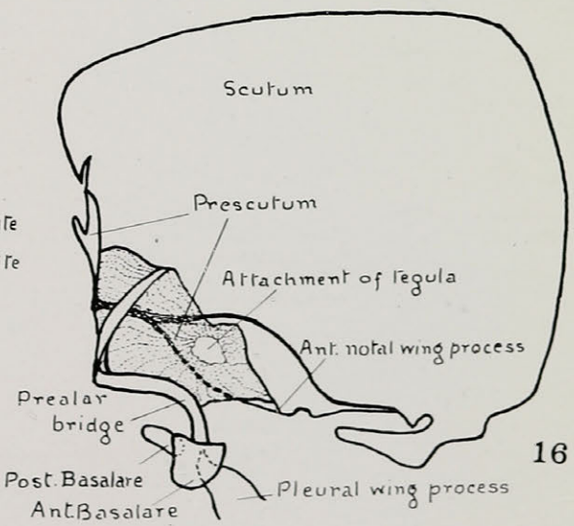
" 16. Attachment of tegula, tegula detached.


Notum 1
Phragma
Scutum 2
Post. notal wing process 2
Phragma 2
Scutum 3
Axillary cord
Phragma 3
First abd. segment

14


Notum
Paragium
Notum
Occipital foramen
Ant. cervical sclerite
Post. cervical sclerite
Eusternum
Scent organ
Coxa

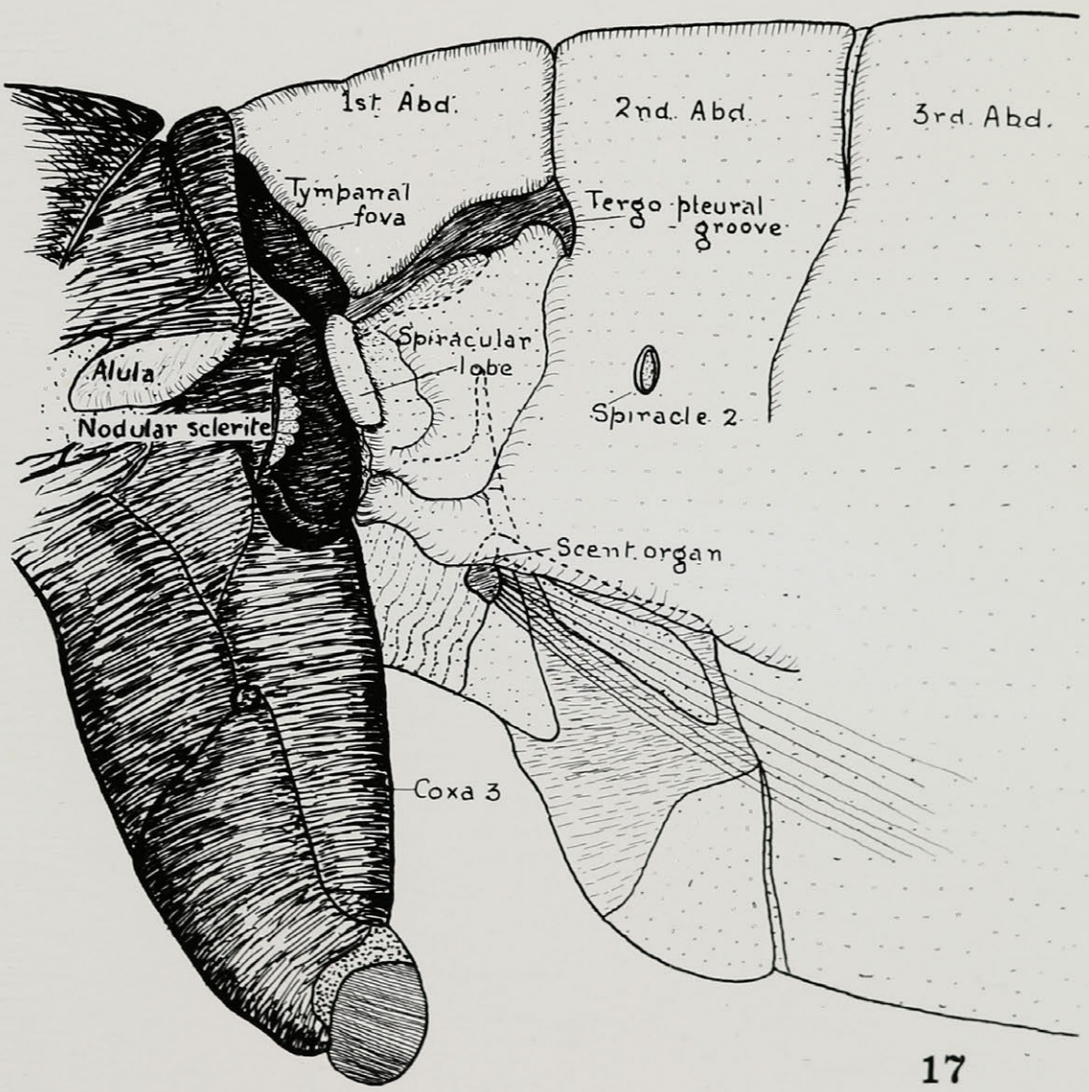
15


Scutum
Prescutum
Attachment of tegula
Ant. notal wing process
Prealar bridge
Post. Basalare
Ant. Basalare
Pleural wing process

16

P L A T E VI.

fig. 17. Tympanum.


1st. Abd.
2nd. Abd.
3rd. Abd.
Tympanal fova
Tergo-pleural groove
Spiracular lobe
Alula
Nodular sclerite
Spiracle 2
Scent organ
Coxa 3

P L A T E VII.

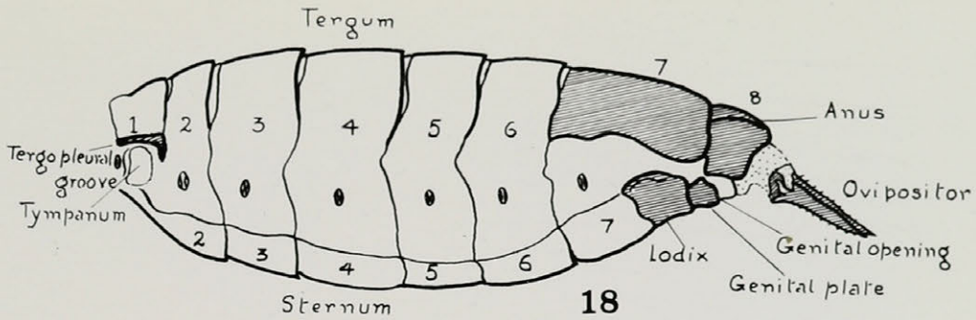
fig. 18. Lateral view of abdomen.

" 19. Dorsal view of female genitalia.

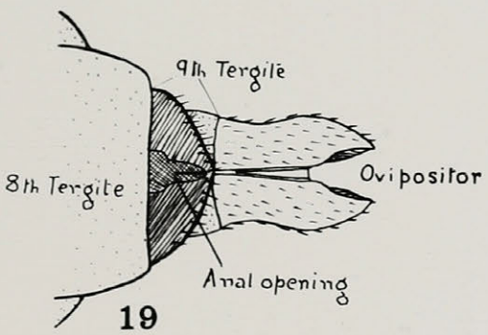
" 20. Ventral view of female genitalia.

" 21. Lateral view of male genitalia.

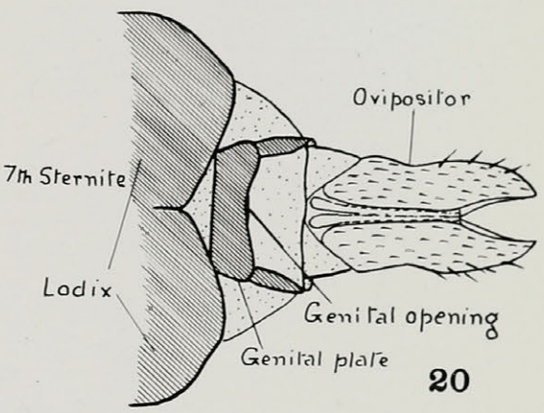
" 22. Male genitalia disected, harpes spread outward.


Tergum
1
2
3
4
5
6
7
8
Anus
Tergo pleural groove
Tympanum
Ovipositor
Genital opening
Lodix
Genital plate
Sternum

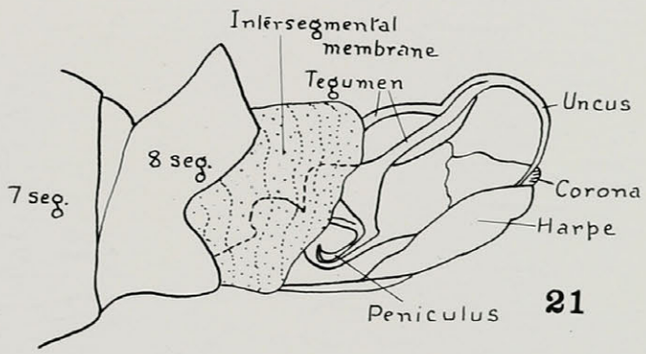
18


9th Tergite
8th Tergite
Ovipositor
Anal opening

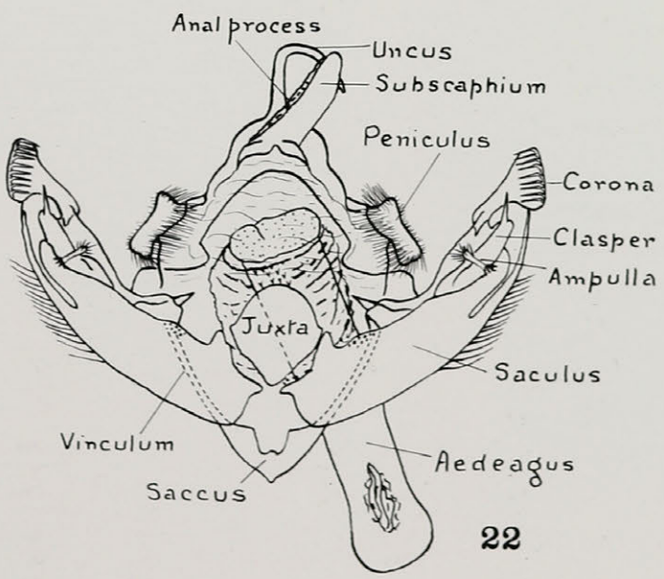
19


Ovipositor
7th Sternite
Lodix
Genital opening
Genital plate

20


Intersegmental membrane
Tegumen
Uncus
8 seg.
7 seg.
Corona
Harpe
Peniculus

21


Anal process
Uncus
Subscaphium
Peniculus
Corona
Clasper
Ampulla
Juxta
Saculus
Vinculum
Aedeagus
Saccus

22

P L A T E V111.

Fig. 23. Metathoracic leg.

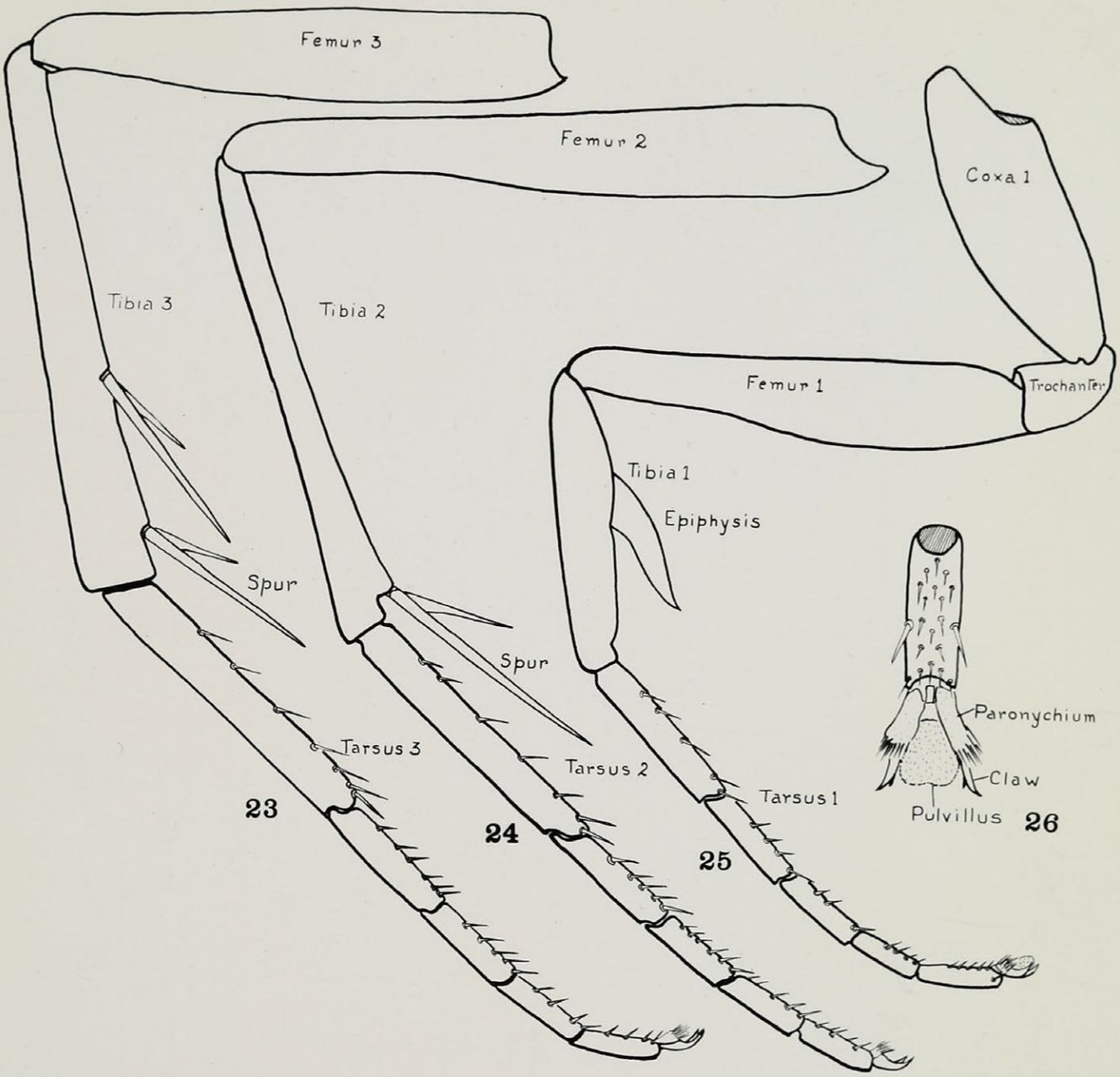
" 24. Mesothoracic leg.

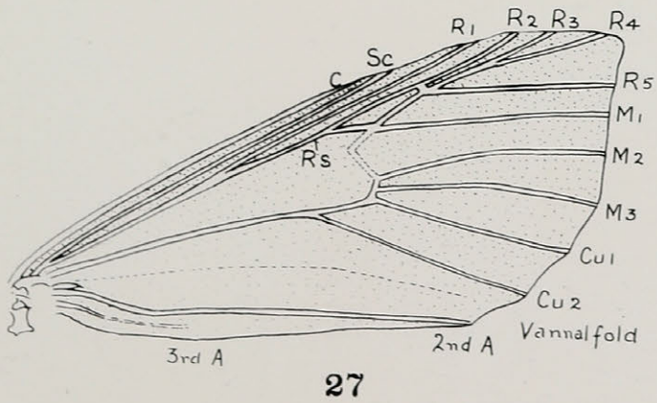
" 25. Prothoracic leg.

" 26. Pretarsus ventral view.

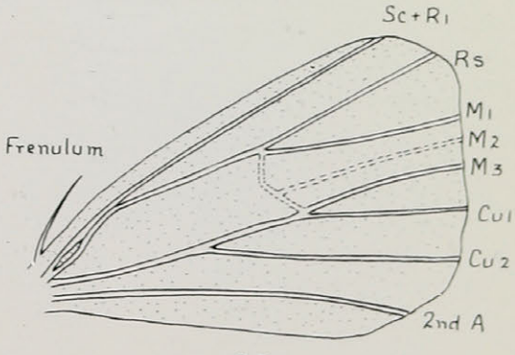
" 27. Forewing male.

" 28. Hind wing male.


Femur 3
Femur 2
Coxa 1
Tibia 3
Tibia 2
Femur 1
Trochanter
Tibia 1
Epiphysis
Spur
Spur
Tarsus 3
Tarsus 2
Tarsus 1
23
24
25
Paronychium
Claw
Pulvillus
26


R1
R2
R3
R4
Sc
C
R5
M1
Rs
M2
M3
Cu1
Cu2
Vannal fold
3rd A
2nd A

27


Sc+R1
Rs
M1
M2
M3
Cu1
Cu2
Frenulum
2nd A

28