ANATOMY OF GRYLLUS PENNSYLVANICUS

The Anatomy of Gryllus pensylvanicus Burm.

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Introduction

Gryllus pennsylvanicus Burm. is one of the commonest of the field crickets on the island of Montreal. It is a gregarious species and large numbers may be found in the fields and along the roadsides in the late summer and in the fall. The adults lay their eggs in the fall and die after the frost sets in. The eggs hibernate, although an occasional nymph found in the spring indicates that some of the eggs may hatch in the fall. The majority of the eggs, however, hatch in the following summer, and the nymphs live in burrows in the soil, becoming mature in the autumn.

Owing to the fact that the adults all die in the autumn, it was found impossible to obtain fresh material for dissection during the winter, so that most of the work was done with preserved specimens which are in many respects unsatisfactory. Because of this, and also of the comparatively short time at my disposal, this study is not quite as full as was at first planned, the muscular and respiratory systems in particular, not having been very fully studied.

Methods

Fresh specimens were used in the autumn as long as they were obtainable. After this preserved specimens were used. The preservative solutions used were alcohol and five percent chloral hydrate. Neither of these proved very satisfactory. I have heretofore found chloral hydrate an excellent medium for the preservation of material for anatomic study, but in this case the tissues of most of the specimens decayed in spite of the fact that incisions were made in the integument to allow the preservative to bathe the internal organs. The alcohol was somewhat more satisfactory, but in it the organs hardened and became rather brittle which increased the difficulty of dissection.

For a study of the mouth parts the head was boiled in 10 percent potassium hydrate which removed everything except the chitinous structures. The mouth parts were then removed, mounted on a slide and examined under the low power of a compound microscope. Boiling in potassium hydrate was also employed for a study of the sclerites and other integumental structures.

For the histological studies the insect was anaesthetized with ether, cut open under a dissecting microscope and the required organ removed. It was then fixed in Gilson's alcoholic sublimate or in Bouin's picro-formol. The stain used was Delafield's haematoxylin. Good sections of the entire insect were not obtained owing to the hardness of its chitinous integument. Henning's solution and picro-nitric acid were used as fixing agents ~~and~~ but neither seemed to have much effect in softening the chitin. Owing however to the lack of fresh specimens the attempt was not repeated. Better results would undoubtedly be obtained by using freshly moulted insects, but such material was not obtainable at the time this investigation was undertaken.

For the study of the internal organs the insect was opened along its venter, dorsum or pleuron according to what organ was to be studied. It was then pinned in a dissecting dish, lined with cork over which a layer of paraffin had been poured. The organs were stained with some stain such as haematoxylin or methylene blue, preferably the latter. The dissection was performed in distilled water under a Zeiss binocular dissecting microscope

Special Method for studying the nervous system.

The following extract is taken from the author's paper on the Nervous System of the Larva of Sphida obliqua.

" On account of the transparency of the fresh tissues it was found necessary to fix or stain before tracing the course of the nerves.

Fixing. Gilson's alcoholic sublimate gave good differentiation but was not found convenient for dissecting on account of the corrosive action of the mercunic chloride on metal.

" Picro-formol (P. Bouin) was used to good effect as it fixes and stains rapidly. The formula of this fixing agent is,

Picric acid	sat. aq. solution	75 parts
Formalin		25 "
Acetic acid		5 "

" Maceration . For a study of the pheripheral nerves it was found necessary to macerate in distilled water for several days or in dilute nitric acid for a shorter time. The muscular tissue could then be easily teased out leaving the integument and its nerves exposed, the latter being more resistant than the muscles to the macerating action of water. Specimens thus treated were always hardened afterwards in picro-formol.

Staining. Several stains were tried with varying success. A weak solution of Delafield's Haematoxylin gave fair results but did not prove satisfactory for the finer details. The only really satisfactory stains of the nervous tissue were obtained with methylen blue. The strength used was .5% in physiological salt solution. In most cases where fresh specimens were used the nerves were stained intra vitam. About two cubic centimetres of the staining solution were injected into the living caterpillar. In from thirty to sixty minutes the insect was etherized and opened. On opening the caterpillar it was usually found that several of the nerves were unstained. Indeed it was extremely difficult ever to obtain a perfect stain of all the nerve tissues. ~~Shilick~~ Ehrlich who first used the intra vitam method of staining nervous tissue pointed out that the sensory nerves were stained while the motor nerves remained colourless. The motor nerves however will also stain if given sufficient time. The same worker also states that methylin blue in contact with reducing agents in alkaline solution is reduced to its colourless leucobase. Because of this, tissues after they have attained their maximum degree of coloration lose the blue colour rapidly. It might however be brought back by an oxidizing agent or by exposure to air. The above statements explain the difficulty of obtaining a perfect stain.

In several cases the caterpillar was killed and pinned before staining. The stain was poured on to the insect in the dissecting dish and left for about half an hour or longer. As long as the tissues were fresh I obtained a stain equally as good as by Ehrlich's <u>intra vitam</u> method. Indeed I could see no advantage in this latter method over staining of the dead but fresh tissue.

Specimens stained with methylin blue lost their colour very readily in water and it was found necessary to permanently fix the blue colour in the tissues. The method used in fixing the stain ~~used~~ was that devised by Bethe. The fixing agent was a solution of ammonium molybdate made up according to the following formula.

Ammonium molybdate	1 gm
Distilled water	10 cc
Hydrogen peroxide	5 cc

A drop of hydrochloric acid is added to the solution and a precipitate of molybic acid forms but readily redissolves on agitation. To prevent maceration a few drops of a one percent osmic acid solution were added to the above solution and also to the water in which the dissection was carried out. The tissues of the stained caterpillar were bathed in physiological salt solution and the freshly made fixing solution, cooled to near zero, was then poured on and left for several hours. Occasionally part of the solution precipitated on being poured on the caterpillar but this did not interfere with the fixing properties. //

Methods

The plants containing the caterpillars were cut off about nine inches above the ground in the late fall and the lower portions dug up, brought indoors and planted in wet sand. The caterpillars were removed as needed. Several specimens were also preserved in chloral hydrate.

The usual methods of dissection were followed. The insect was first etherized and then cut along the mesal line of the dorsum and pinned along the cut edges in a small dissecting tray. The pins were cut off close to the insect in order that they might not interfere with the free manipulation of the dissecting instrument. The abundance of adipose tissue is a great hindrance in dissecting, and to remove it without breaking the nerves requires careful and patient manipulation.

Preserved Specimens. During the winter months specimens preserved in chloral hydrate were used after the fresh material was exhausted. The caterpillars had been etherized and placed in 5% chloral hydrate for a day. At the end of a day small slits were made in the dorsum so as to allow the liquid to enter the body cavity and bathe the viscera. Chloral hydrate proved to be an excellent medium for preserving the internal organs. The finest nerves were found to be in good condition after months of preservation. The entire lateral sympathetic system was traced in preserved material.

The dissection of preserved material is somewhat less difficult than that of fresh material as in the former the muscles and fat body have shrunken considerably.

While it has been held by most workers that nervous tissue will not take the methylin blue stain unless living or freshly killed, I have succeeded in obtaining fairly good stains with preserved materials. The stain is of course much more difficult to obtain than with fresh material and when obtained is not so good. The nerves leading from branch of the lateral sympathetic system to the tracheae are very minute and difficult to trace, but I first succeeded in finding them in a preserved specimen.

External Anatomy

The Head

The head (Figs. 1-4) is about 6mm. deep and 5 wide. It is directed downwards so that the buccal cavity and appendages form its ventral side. It articulates with the prothoracic segment by means of a narrow flexible neck membrane which permits a limited movement of the head. This membrane however is not externally visible as the pronotum projects forward as far as the epicranium covering both the neck membrane and the occipital and post-genal region of the head. Thus the insect appears to be absolutely neckless. Viewed from in front the head is broadly ovate. The epicranial region is semicircular and the clypeus and mouth parts narrow downwards.

The front is prominent and bears the median ocellus. The vertex is broad and rounded. From each lateral ocellus a line runs mesodorsad. The two lines unite in the median line of the head and ~~run~~ from this point a third line runs dorsad along the median line and is gradually lost in the vertex. The Y-shaped suture thus formed is the epicranial suture (Fig. 1. e.s.)

The clypeus is articulated to the ventral edge of the front. A post-clypeus (figs.1,3,&5 C.p.) and an ante-clypeus (C.a.) may be distinguished although the suture does not extend to the median line. A suture-like crease runs along the median line of the ante-clypeus to near the base of the labrum. Here it divides into two and each branch bends upwards towards the latero-dorsal angles of the ante-clypeus. At the distal edge of the ante-clypeus, the labrum arises. (Figs.1,3 & 5,L) This is a movable flap somewhat broader than the clypeus. There are three deep creases in the labrum, two curved ones running from the base ventrad~~ly~~ to near the middle on either side of the median line, and a transverse one immediately beneath these. In the middle of the distal edge there is a shallow sinus, the edge of which is closely fringed with setae.

The Epipharynx or Labrum-epipharynx (Fig.6.) This organ is not a free appendage as in Diptera and other haustellate insects but is a palate-like lining of the labrum and clypeus, forming the roof of the mouth, as is the general rule among mandibulate insects. There is no suture between the portion lining the clypeus and that lining the labrum but a clypeal and labral region may be observed. In the epipharynx there are two paired and one unpaired chitinous structures. At each indentation corresponding to the ends of the clypeo-labral suture there is a thickened chitinized plate constricted in the middle and continued laterad into the clypeal region as a slender chitinous filament. A curved chitinous rod running from the clypeal to the labral region crosses each of these plates. The unpaired chitinous plate is a median one lying immediately beneath the clypeo-labral suture.

The following sense-organs and setae are present in the epipharynx.

1. Large, strongly chitinized bristles, arising from a circular cell, with linear edges and blunt ends, situated in the labral region mesad of the curved chitinous rods, and on the distal edge of the epipharynx. These probably serve as a protection to the tastecups.

2. Somewhat smaller setae, strongly chitinized, with acute ends. They are situated near the latero-ventral edges of the epipharynx and form three or four irregular rows on each side. These also are probably protective.

3. Slender whitish tomenta abundant in various parts of the epipharynx.

4. Large, round taste cups, one row on either side of the median line of the labral region.

5. Similar but somewhat smaller cups situated in the median portion of the clypeal region, laterad of each curved chitinous rod in the labral region, and immediately dorsad of the sinus mentioned above in connection with the labrum.

6. A large number of minute triangular end organs occupying the space between the setae (2) and the curved rods in the latero-ventral portions of the labral region. ¶ The genae or cheeks (fig.3 G) are well developed and comprise the sides of the head behind the eyes, extending ventrad to the base of the mandibles. On the inner side they serve for the attachment of the mandibular muscles.

The caudal aspect of the head is shown in figure 2. The occipital foramen (F.O.) lies near the dorsal side and serves for the passage of the oesphagus, ventral chain, salivary ducts and other organs from the head into the trunk or vice versa. On each side of the occipital foramen is a broad sclerite the post gena (P.C.) The occiput (O) forms a narrow ring around the occipital foramen.

The neck membrane is provided with a number of chitinized plates, the cervical sclerites. The two large lateral sclerites serve internally for the attachment of muscles. The five ventral ones are shallow, pouch-like chitinized evaginations of the cervical integument, are provided with hairs and supplied by nerves from the first thoracic ganglion.

The Tentorium (Fig. 4) or endoskeleton of the head consists of a triangular plate from which five processes arise, three of which are also triangular. These plates are thicker and more strongly chitinized around the edges. The plane of the central plate is parallel to the dorsal and ventral planes of the insect. Its dorsal side supports the oesophagus and is therefore somewhat concave to adapt itself to the shape of this organ. From its apex an unpaired triangular process (1) runs candad in the same plane, its base forming the ventral border of the occipital foramen. From each of the basal angles of the central plate another triangular process (2) is given off. This runs forward and its broad base extends along part of the clypeo-frontal suture, and the mandibulo-epicranial suture to the edge of the post gena. From the basal angles of the central plate a second pair of processes (3) originate. They run cephalo-dorsad and are attached to the epicranium at the dorsal side of the antennal socket between the latter and the eye. These processes differ from the others in being much smaller and linear rather than triangular. The central plate, the unpaired process and the paired triangular processes form two lateral foramina (fig.4 F.L.) through which the mandibular muscles pass from their origin in the genae to their insertion in the condyles of the mandibles. The central plate, the paired triangular processes and the ventral edge of the front form an anterior foramen (F.A.) through which the oesophagus passes in descending to the mouth. So that, including the occipital foramen, there are altogether four foramina in the head.

Appendages of the Head.

Antennae (figs.1 & 3a) . These are about 30 mm. long and very slender. They are inserted on each side of the front in a shallow fossa contiguous with the ventro-mesal border of the pompound eyes. They are filiform and consist of a stout basal joint with a large number of smaller ones distad of this. The antennae are plentifully supplied with short tactile hairs, and judging by the active manner in which the insect uses them, they are efficient organs of touch.

The mandibles (figs. 7 & 8,figs.1,2,&3 md.) are a pair of strong, highly chitinized jaws. They are articulated to the head by means of a ginglymus joint. This consists of two condyles and a ginglymus cavity. A condyle (figs. 1&7 m.c.1) on the outer edge of the base of the mandible is inserted into a pan at the basal corner of the clypeus. The second condyle (figs. 2 & 8,m.c.2) is situated at the outer corner of the caudal side of the base (i.e. the side next the maxilla). It is inserted into a pan in the end of the post-gena near its outer edge where it merges into the gena. (fig.4 p.) The ginglymus cavity of the mandible is found at the hinder side of the mesal angle of the base of the mandible. It serves for the insertion of the large tendon (fig. 8 ad.t.) to which the adductor muscles are attached. The tendons of the abductor muscles (ab.t) are attached at the second condyle. These are much smaller than the tendons of the adductor muscles. A thin chitinous membrane (fig. 7 mb) stretches from the inner edge of the mandible to the clypeus. The opposable edges of the mandible are armed with densely chitinized teeth. The arrangement of the teeth is not constant, differing even in the two mandibles of the same insect. As a rule, however, the distal teeth are sharp resembling somewhat those of carnivorous beetles, while the proximal teeth are molar-like and fitted for crushing. This arrangement is adapted to the feeding habits of the cricket, an omnivorous insect, apparently feeding on a hard grain of wheat with as much gusto, as on a delicate morsel from a dead companion, or on the wool from a man's coat.

At the base of the mandible there is a narrow triangular sclerite cut off from the gena by the lateral prolongation of the clypeo-frontal suture.

The maxillae (fig.9) are attached on the caudal side of the head to the post genae, behind the mandibles. Each maxilla consists of six distinct sclerites. The cardo or basal division is composed of two sclerites, the outer one (fig. 9c.) is triangular, the inner one (c 2) is kidney shaped. The stipes (st) articulates with the cardo and is at right angles to it. At the distal end of the stipes the galea (figs. 1, 2, 3 & 9 g) and lacinia (l) are borne. The lacinia lies cardo-mesad of the galea. It is concave on its inner edge and convex on its outer. It is broad at the base and gradually tapers to a sharp strongly chitinized tooth at the distal end. Proximad of this tooth, on the concave edge are two others, followed by a row of stiff setae. The galea joins the stipes latero-cephalad of the articulation of the lacinia. This also is concavo-convex but is of uniform thickness throughout and the distal end is rounded. It is not so densely chitinized as the lacinia is destitute of teeth and sparsely covered with delicate hairs. The palpifer (pf.) is articulated partly to the outer edge of the stipes and partly to the basal segment of the cardo. The maxillary palpus (p.m.) is given off at the distal end of the palpifer. This appendage is antenniform and consists of five segments of which the two basal are together shorter than either of the three succeeding. The segments of the palpus are all covered with tactile hairs. The distal segment is clavate and more densely clothed than the others. At its extreme end is cut off a more sensitive portion which is not as strongly chitinized as the remainder of the palpus and which is very densely clothed with short tactile hairs. A thin, transparent membrane (mb_2) unites the inner edges of the stipites and cardines to each other and to the outer edges of the labium.

The Labium (fig.10) forms the lower lip of the insect. It originates from near the ventral border of the occiput. The submentum (figs.2, 3 & 10, sm.) is a large shield-like sclerite. The mentum (m) is joined to the ventral edge of the submentum and is a much narrower sclerite. A large sclerite with a deep median groove, joined to the ventral edge of the mentum probably represents the fused bases of the para glossae. The glossae (fig.10 gl) and para glossae (p.gl) arise from its distal edge. These, the homologues of the lacinia and galea are not unlike these organs except that the paraglossae are two-jointed, and the glossae are not toothed nor strongly chitinized as in the case of the lacinia. The palpiger (pg.) is dorsad of the origin of the paraglossa and bears the labial palpus (p.l.). The palpus is three jointed, the basal joint being about one-half the length of the second and little more than one quarter the length of the distal segment. The ~~vestibule~~ vestiture is similar to that of the maxillary palpi, the specialized apical portion of the distal segment being armed as in the case of the latter, with very fine sensitive hairs.

The Hypopharynx (figs. 10 & 11 hyp.) forms a stout tongue-like projection from the inner surface of the labium. It is provided with taste-cups, setae and other sensillae similar to, but even more varied than those of the epipharynx. The salivary duct passes through the hypopharynx and opens into the mouth through its caudal side, next the labium.

The Thorax

As in other orthopterous insects the prothorax is well developed. The pronotum projects cephalad over the neck membrane to the base of the head; caudad, its projecting edge covers the mesonotum. The sides of the pronotum are bent ventrad at right angles to the back, obliterating all traces of the pleural sclerites. The prosternum is not uniformly chitinized. Two narrow chitinous plates, behind the cephalic border, form an inverted V and mark the position of the attachment of the entosternites. Caudad of this there is a small shield-like sternellum (fig.12 stl)

Although the front wings are more highly developed than the hind wings and in the male are used extensively in stridulating, still the mesothorax is much smaller than the metathorax, contrary to the rule in most of the winged insects (Hymenoptera, Diptera, Lepidoptera, etc.). The length of the mesonotum is about 1 mm. while that of the metanotum is about 2.7 mm. This difference in size is due to the great development of the hind legs. The mesonotum is divided into two narrow sclerites, the scutum (fig. 13 sc_2) & scutellum (fig.13 sc_3). The scutum is broader at the lateral ends and constricted in the middle. The opposite description is true for the scutellum. The mesopleurum consists of three sclerites. The episternum (fig.14 e.s.) is the largest and lies cephalad of the others. Its dorsal portion is concealed by the pronotum. The epimeron (e m_2) lies caudad of the episternum. At the ventral edge of the epimeron there is a small sclerite, the peritreme (p.) which bears the mesothoracic spiracle. The meso-sternum is broadly shield-shaped, with a notch in its caudal end.

The metathorax, as stated above, is much larger than the mesothorax. The metanotum is differentiated into three regions, the scutum (sc_3) scutellum (scl_3) and the post scutellum ($p.scl_1$) The scutum is large and bi-lobed caudad. The scutellum is a large triangular sclerite, the anterior portion of which is wedged into the hinder part of the scutum. The postscutellum is a narrow bandlike sclerite lying caudad of the scutellum and stretching uninterruptedly across the segment from wing to wing. The metapleural sclerites are similar to those of the mesothorax but are larger and lie obliquely across the pleurum. The sternum resembles that of the mesothorax.

The Endoskeleton of the Thorax.

There is considerable ambiguity and inconsistency in the nomenclature of the internal chitinous processes of the thorax. The terms in common usage are almost without exception lacking in definiteness. Thus apodeme is used to denote pleural processes or as a general term for all the ental sclerites. Phragma , as used by some writers, indicates the dorsal processes, by others it is restricted to the inflexed hinder edge of the prothorax on those insects in which the prothorax is movable. Apophysis sometimes used for the sternal processes is several times preoccupied and is not desirable. Much the same may be said of furca. Other terms applied to the sternal processes are entothorax, endosternite and entosternite. Of these the word entothorax seems to me too general in its implication and endosternite has been used for a special portion of the process, viz. the part arising from the intersternal membrane.

I have therefore used the following terms in describing these processes. Endothorax, the collective name for all of the internal thoracic processes, Entosternite , the processes of the sternum, entopleurite the ental processes of the pleurum, and entotergite, those of the tergum. As the terms endothorax and entosternite have before been used exclusively with the meanings here given them, I am not proposing an altogether new nomenclature but merely one that is consistent and at the same time descriptive.

In the prothorax there are three entosternites. The two anterior ones (fig.15 st.r,) form a pair of similar, elbowed processes, the proximal sections of which, attached to the prosternum, together form an inverted V. The distal, free sections consist of a stalk-like part at the end of which is a flatter blade-like section. The third entosternite (a) is median and unpaired and arise caudad of the origin of the paired processes. It consists of a flattened, irregularly lobed plate attached by a short stalk to the pro-sternellum. There is one pair of entopleurites (fig.15 pl.) in the prothorax; they arise at the cephalic edge of the front legs and extend into the back. These processes are somewhat scoop-shaped and give off a small spathulate process at their bases.

The homologues of the three entosternites of the prothorax have, in the mesothorax, apparently fused to form a single furcate process (st.2) having between its arms a median process similar to the median entosternite of the preceding segment. Each arm consists of a proximal stalk and a distal folded portion, the distal posterior leaf of the fold being much larger than the anterior. The entopleurites (pl2) are flattened, tongue-like, pointed processes which are attached to the cephalo-ventral edge of the epimeron and extend inward fitting into the folds of the ento-sternites.

The endosclerites of the metathorax are similar to those of the metathorax. The arms of the entosternite (st.3) are somewhat closer together and the median process is missing. The entopleurites (pl.3) are curved and somewhat smaller than those of the mesothorax.

Appendages of the Thorax

Wings Two pairs of wings are present. The hinder ones are very much reduced in size owing to the fact that the insect does not use its wings in flight. The fore-wings are bent downwards at the sides so as to fit closely to the body. In the female the forewings (fig.17) are smoky in colour. The numerous cross veins anastomosing with the longitudinal veins give the dorsal portion of the wing a reticulated appearance. In the lateral portion (i.e. the part pressed against the side of the insect) the venation is much simpler as there are no crossveins and consequently no closed cells. In this part of the wing the veins are light in colour and the intervenal spaces dark.

The fore wing of the male (fig.16) is much larger than that of the female owing to the fact that its dorsal surface is specialized to form a stridulating organ. The distal end is reticulated as in the female but the greater portion of the dorsal part of the wing exhibits a peculiar venation which may best be understood by reference to the figure. The ridge which runs obliquely across the wing is provided on the under side with a number of teeth shown enlarged in figure 18. The chirp is produced by drawing the ridge of one wing over the veins of the other. The lateral part of the wing is somewhat similar to the corresponding part in the female but a few closed cells are present in the distal end.

Legs The size relations between the three legs may be seen from the following table. The figures are approximate.

	I.	II.	III.
Coxa	mm. 3	1.5	2.5
Trochanter	1.1	1.5	0.5
Femur	4 x 1.4	4.6 x 1.4	11.5 X 3.8
Tibia	3.8	4.2	9.2
Tarsus	3.5	3.7	6.0

As the insect progresses chiefly by leaping, the greatly enlarged hind femora are highly adaptive.

In size and general appearance the first pair of legs does not differ markedly from the second. The chief differences may be observed by reference to figs. 19 and 20 and to the table given above.

The auditory organ is situated at the base of the fore tibiae in both the male and the female insect. Exteriorly it consists of an oval, transparent membrane on each side of the tibia, that on the outer side being much larger than the inner one. The tibia is clothed with minute hairs and bears two large spurs on the distal end. The Tarsus is three-jointed, the middle joint is very short and the length of the proximal segment is equal to the combined length of the two others. The distal joint bears a pair of strong claws.

In the posterior legs the trochanter is a very small sclerite visible only on the ventral side between the coxa and femur. The femur is nearly three times as long and as broad as the front femur. The tibia also is correspondingly enlarged. It is sulcate on its upper edge and on each ridge of the sulca there is a row of strong spines. The other side of the tibia is armed with stiff bristles. At the distal end, where it articulates with the tarsus, the tibia bears a pair of very large strong spines and five smaller ones which are doubtless effective in supplementing those of the tarsus in gaining a good purchase on the surface from which the insect leaps. The hind Tarsus is four-jointed. The second joint is very small and barely visible on the lower side between the spurs. The proximal and longest segment of the Tarsus bears two rows of short spines and at its distal end a pair of strong spines.

THE ABDOMEN.

Tergum. There are ten readily distinguishable tergites in the abdomen. The first tergite is smaller than the succeeding five, and each of the seventh, eighth and ninth is narrower than the one preceding it. The seventh is widest at the sides, where it joins the pleur~~um~~on, while the eighth is narrowest at this point. The ninth tergite is very narrow in the back but widens laterally forming a caudad-projecting lobe on each side. The tenth tergite or suranal plate is a triangular sclerite dorsad of the vent.

Sternum. There are eight sternites concerning the identity of which there can be no doubt. The first is a small oval sclerite, inconspicuously situated between the bases of the hind coxae, immediately caudad of the metasternum.

The second is somewhat larger and semi-circular in outline. The third to seventh inclusive are more or less similar, four-sided sclerites. The eighth sternite is a movable triangular flap attached only at its base. It fits around the ventral portion of the base of the gonapophyses and conceals the vulva. A narrow strip across the caudal edge of each sternite and tergite differs from the remainder of the sclerite in being smoother and glossier. Part of this border is usually folded under so that each sclerite projects slightly over the one behind it. This permits the telescoping of the segments to a limited extent and increases the movability of the abdomen. Sternites and tergites are sparsely covered with hair.

<u>The Pleur~~um~~on</u> (fig.14,pl.) consists of a wide membranous strip stretching from the first abdominal segment to the eighth. It is not divided into segments by sutures and is not strongly chitinized. The abdominal spiracles are borne by the pleur~~um~~on. Between the second and third abdominal segment there is an oval membrane (fig. 14, a) resembling the tympanum of the Acrididae, which occupies a somewhat similar position. I have not yet determined whether or not the membrane is supplied with an auditory nerve, thus serving as an auditory organ in addition to the one in the tibia. Midway between each

spiracle and the one next it there is a small black dash; and near the ventral border of the pleur~~um~~on there is a similar spot at the cephalic and caudal ends of each segment. Their function has not yet been determined.

<u>Extremity</u>. It is difficult to accurately homologise the extremity of the abdomen without careful ~~au~~ontogenetic study. Following, however, is an attempted homology. The suranal plate (figs. 22 & 23 sp.) is without doubt the tenth abdominal tergite. It bears the cerci, which, according to Packard, are always borne by the tenth segment. The sides of this sclerite are bent downwards forming a ring (sp 2) around each cercus. On the mesal side of each ring a movable sclerite, the podical plate (figs. 22 & 23,p.p.) is attached. Huxley regards the podical plates of Orthoptera as representing the eleventh tergite. On the other hand "both Cholodkowsky and Haase maintain that the tenth abdominal segment is suppressed in the male, the tergal portion being fused with the suranal plate (the latter in this case, as we understand it, being the remnant of the eleventh segment of the embryo.)"* In both sexes of the cricket the suranal plate is divided into two parts by a ridge which crosses it caudad of the base of the cerci. If we accept the view of Cholodkowsky and Haase we may regard this ridge as an indication of the fusion of the two tergites. Ventrad of the base of the podical plate is

* Packard '98

a narrow transverse ridge (figs. 22 & 23 i.l.). This sclerite is almost continuous with the ventral edge of the suranal plate and I have therefore regarded it as the tenth abdominal sternite. It is probably homologous with the infra-anal lobe which Packard describes as occurring directly beneath the vent in geometrid larvae. Concerning it he says, " whether this lobe is the modified ventral portion of the ninth urite we will not undertake at present to say." Ventrad of the infra-anal lobe there is a broad sclerite (fig. 22,9) which is directly attached on each side to the lateral lobes of the ninth tergite. The dorsal gonapophyses are attached partly to this sclerite and partly to the ninth tergite. For these reasons I regard this sclerite as the ninth sternite On its ventral edge it bears a pair of sur-rhabdal lobes (fig. 22,sr.l.) which project between the divergent bases of the dorsal gonapophyses.

- Appendages of the Abdomen.

The Cerci (fig. 14 c.pg.24) are borne at the base of the suranal plate. They are about 7 mm. long, stout at the base, tapering gradually to a point. They are sparsely clothed with long slender hairs, and more densely covered with short hairs. On the inner side near the base there are several club-shaped sensillae (fig. 24,s.) The insect uses the cerci in much the same manner as it does its antennae. They appear to be very sensitive and are doubtless sensory organs. During excitement they are often waved vigorously to and fro. Packard has called the cerci of the cockroach "abdominal antennae" and Graber, by means of decapitation has proved that these organs form the seat of smell in the cockroach. Whether this is the case with Gryllus has not yet been determined.

The Ovipositor (fig. 25) is a narrow spear-shaped organ about 13 mm. long. It consists of two pairs of gonapophyses, the ventral pair borne by the eighth abdominal segment and the dorsal pair by the ninth. A groove in the edge of the ventral gonapophyses receives a tongue in the edge of the dorsal. The dorsal pair is more strongly chitinized than the ventral. The end of the ovipositor is enlarged to form a "spear-head" which ends in a sharp, strongly chitinized point, admirably adapted to boring into the loose soil in which the insect lays its eggs.

The genital armature of the male insect will be described in connection with the reproductive system.

INTERNAL ANATOMY

The Muscular System. (fig 26)

The muscular system has not been studied in very great detail owing to lack of time, so that only a general account of the chief muscles will be given here.

Abdominal Muscles

In the abdomen the muscles are segmentally arranged and are similar in each segment, except at the extremity. Here the musculature is much more complicated and there are several systems of strong muscles, which supply the cerci, ejaculatory duct, genital armature, etc.

Tergal Muscles. There are two kinds of longitudinal cutaneous muscles in the dorsum.of the abdomen. In the middle of the back there is a row which extends from the anterior to the posterior suture. On each side of this is a row of muscles which are only half as long, being attached in the middle of the segment and extending to the posterior suture. The tergal muscles help to bring about the movements of the abdomen. They are innervated by nerve A of the abdominal ganglia.

Sternal Muscles. On each side of the nervous chain there are several longitudinal muscles attached at the anterior and posterior ends of the segment. They are not developed on the median line beneath the ventral chain. They also assist in the movements of the abdomen and are innervated by nerve A.

Transverse Muscles. In each segment there is a transverse muscle, which stretches, dorsad of the nerve cord and longitudinal muscles, from one side of the sternum to the other. Nerve, the proximal branch of nerve A.

Tergo-sternals. These are a row of muscles extending across the pleurum from the edge of the tergum to that of the sternum. Action, to raise and depress the abdomen during respiration. Nerve, the transverse nerve of the ventral sympathetic system.

Thoracic Muscles

The sternal muscles of the Thorax are attached to the entosternites. From the median entosternites radiating muscles pass to the base of the legs, to the arms of the entosternites, and from one median entosternite to another. Muscles also pass from the arms of the entosternites to the ventral integument.

Tergal Muscles. In the back of the pro- and meso-thorax there are several longitudinal muscles. These muscles are also found in the meta-thorax but are larger and not developed in the median line. There are also oblique muscles above the longitudinal ones.

Leg Muscles. These are the chief muscles of the thorax. Their origin is in the sides of the scutum. There are three sets of muscles to each leg. The cephalic set forms the adductor of the coxa and is inserted at the front of the base of the coxa. The middle muscles pass into the leg and are the external femoral muscles. The third muscle is the abductor of the coxa; this is inserted at the hinder part of the base of the coxa.

Wing Muscles. These originate from the base of the epimeron and episternum near the coxa and are inserted at the base of the wing.

Head Muscles.

Within the head there are the muscles of the mouthparts and antenna. By far the largest muscles are those which form the addugtor of the mandibles. They originate on the inside of the genae and, passing through the lateral foramina are inserted at the inner side of the base of the mandibles. The abductor muscles of the mandibles are also quite large and are inserted on the outer side of the base of the mandible.

Organic Muscles.

Like the voluntary muscles, the organic muscles are also **striated.** The chief of these are the circular and longitudinal muscles of the digestive canal, and the alary muscles of the pericardium.

NERVOUS SYSTEM

Central Nervous System.

In the cricket, as in other insects, the nervous system consists of a number of segmentally arranged ganglia, which, together with the commissural strands connecting them, form a ventral nerve chain connected with the two ganglia in the head. As would be expected in a member of one of the more generalized orders of insects, the nervous system of the cricket does not show the degree of specialization and concentration observable in the higher orders. The pairs of longitudinal commissures are free from each other throughout their entire length, a condition more generalized than in many of the larvae of the holometabolous insects; for in most caterpillars there is partial fusion of the connectives, and in some muscid larvae the limit of concentration is reached for the primitive neuromeres are represented by a single ganglionic mass, as Hewitt has observed in the larva of Musca domestica and the writer in the larva of Pegomyia vicina.

In ~~Gizllus abbreviatus~~ Gryllus pennsylvanicus there is a ganglion in each thoracic segment, and one in each of segments two to five of the abdomen. The ganglia beyond the fifth segment are fused into a single large ganglion which lies in the seventh segment. ~~The~~ In the abdomen the ventral chain is surrounded by a mass of adipose tissue which has to be dissected away before the ganglia and commissures are exposed to view.

Michels 'so pointed out that in insects the longitudinal commissures are continuous through the ganglia from the brain to the terminal ganglion. He says, "The commissures take their origin neither out of a central punctsubstance (or marksubstance) nor from the peripheral ganglion cells of the central ganglia, but are continuations of the longitudinal fibres which extend anteriorly through the commissures, forming the oesophageal ring, to the brain". (from Packard). may be observed in the cricket without histological study. Within the ganglion the two [illegible] of commissural fibres
This continuity of the commissural fibres present a more solid and opaque appearance than the remainder of the ganglion, and are evidently a continuation of the extra-ganglionic portions of the commissures. In this case the commissures do not terminate in the last abdominal ganglion but continue as the nerves of the cerci. Of course the ultimate verification of this lies in cytological study but the gross appearance is strongly indicative of the continuity of the commissural fibres.

The <u>Brain or Supra-oesophageal Ganglion</u>. (Fig. 27, Br. Fig 28) is situated in the head just beneath that portion of the front in which the antennae and ocelli are placed. It consists of two large hemispheres, united along the mesal line of the head. From the lateral portion of each hemisphere a stout, short nerve, the <u>optic nerve</u> (O.N.) is given off. This terminates in the <u>optic ganglion</u> (O.G.) a large, somewhat conical mass, the base of which lies immediately beneath the compound eyes. The dorsal portion of each cerebral hemisphere forms a large rounded lobe, the <u>procerebral lobe</u> (Fig. 28 P.L.) This gives rise to the nerve of the lateral ocellus (OC.L.), which, in appearance, is not unlike the optic nerve, but is of course much smaller. A similar nerve (OC.M.) originates from the median line of the cephalic side of the brain and innervates the median ocellus. Immediately cephalo-ventrad of the origin of the optic nerve is a small lobe, the <u>antennal lobe</u> from which the <u>antennal nerve</u> (A) originates. From the ventral side of each hemisphere the <u>clypeo-labral nerve</u> (Fig.28 CL).arises in connection with the <u>arched nerve</u> (Ar.) The common nerve trunk soon divides, the mesal branch forming the arched nerve, while the lateral branch, the clypeo-labral nerve, runs ventrad, innervating the clypeus, labrum and labrum-epipharynx. A nerve from the ventral side of each hemisphere unites the brain with the lateral ganglia of the sympathetic system. The lobes from which the <u>crura cerebri</u> (Figs. 29 & 30 C.) arise are situated caudad of the antennal lobes. The crura run one on each side of the oesophagus, and unite with the ganglion, thus completing the suboesophageal

suboesophageal ring. After leaving the brain the crura converge towards each other so that they lie quite close together when they enter the suboesophageal ganglion. A short cord (Fig. 29 AC.) passing beneath the oesophagus, connects the two crura. In an earlier paper on the Nervous System of the Larva of Sphida obliqua, Wlk., I have named this nerve the accessory commissure. It is the suboesophageal commissure, commissure transversale, quercommissur, schlundring &c. of other writers. As pointed in the paper mentioned, the new name was suggested because of the lack of uniformity in the usage of writers, and because most of the names used were either cumbersome or descriptive of only a limited number of cases.

The Suboesophageal Ganglion (figs. 29 & 30) is a roundish, bilaterally symmetrical mass of nerve tissue lying in the head caudad of the oesophagus. It is connected with the supra-oesophageal ganglion by means of the crura cerebri which enter it at its cephalo dorsal end. The chief function of this ganglion is to innervate the mouth-parts. It is connected with the first thoracic ganglion by means of a pair of stout commissures (Com.)

The Mandibular Nerve (Figs. 29 & 30 Md.) arises latero-dorsad of the insertion of the crura. It is the stoutest nerve of the ganglion owing, no doubt, to the fact that the mandibular muscles are the strongest and largest in the head. Ventrad of the crura the maxillary nerve (Mx) is given off. The labial nerve (Lb) originates from the ventroca~~n~~udal side of the suboesophageal ganglion. It enters the hypopharynx where it innervates the gustatory organs. It also sends branches to the labium and the muscles of this organ. Latero-ventrad of the labial nerve a fourth nerve (s) takes its origin. This is the salivary nerve. It innervates the salivary duct, one branch~~ing~~ running candad into the thorax to the thoracic region of the duct. It ~~the~~ is the "unknown nerve" of Packard '80.

Thoracic Ganglia. There are three large ganglia in the thorax, connected by short stout commissures. The median entosternites are situated between the commissures at the anterior ends of the ganglia. As stated above the two commissures of each pair are quite free from each other. From each connective a nerve (Fig. 27 n.c.') arises, which runs cando-laterad and anastomoses with a branch of the first nerve of the succeeding ganglion.

Nerves of the First Thoracic Ganglion. (Fig.27, I)
In the following account of the nerves, similar letters applied to different nerves do not necessarily denote homology, but the lettering is applied according to sequence of position. Thus A is the cephalic nerve of its ganglion, B the one next behind, and so on.

There are three nerves given off from this ganglion. Nerve A arises from the cephalo-lateral border of the ganglion and runs latero-cephalad. The first branch is joined by the nerve from the commissure and runs cephalad to the neck sending branches to the cervical sclerites and also to the cervical muscles. The main branch of nerve A goes to the back and its muscles are distributed among the dorsal muscles of the pro-thorax and the precoxal muscles near their origin in the back. Nerve B originates caudad of A. It runs laterad to the anterior edge of the pre-coxa. Nerve C is the stoutest nerve of the ganglion being indeed equal in thickness to the commissure. It originates from the caudo-lateral side of the ganglion and runs obliquely towards the coxal opening near which it sends off a small branch. The two enter the leg, innervating the muscles and auditory organs.

The second Thoracic Ganglion (Fig.27,II). Nerve A arises as in the first thoracic ganglion. Near its origin it sends a small branch (a) to the mesothoracic spiracle. The principal branch innervates the muscles of the forewing. The other branches are distributes among the tergal muscles of the mesothorax. Nerve B as in the first thoracic ganglion goes to the coxal muscles. Nerve C is the nerve of the leg. Nerve D is a minute nerve arising candad of the origin of the nerve of the leg. It runs cando-laterdad around the base of the leg and innervates the abductor of the coxa.

The Third Thoracic Ganglion (Fig. 27.III). This is the largest of the three ganglia in the thorax and is evidently formed by the fusion of the two ganglia, the third thoracic and the first abdominal. Consequently, it is more complicated than the two preceding ganglia. Its chief nerves are the following:- Nerve A is similar in origin and distribution to Nerve A of the second thoracic ganglion. Nerve B arises from the dorsal face of the ganglion and runs in a lateral direction.

It innervates the sternal muscles in the first part of its course and, continuing into the back, sends nerves to the dorsal muscles of the metathorax. Nerve C, arising from the lateral border of the ganglion is the stout nerve which supplies the large leaping hind leg. It is similar to nerve C of the preceding ganglia. Nerve D originates dorsad of the origin of the nerve of the leg. It runs cando-laterdad, innervating the abductor muscles of the coxa, and is thus similar to nerve D. of the second thoracic ganglion. Nerve E arises from the dorsal side of the ganglion near the median line just cephalad of the base of the commissures. Its course lies cando-laterad. The first branch is given to the ventral muscles. It terminates in the muscles of the second spiracle. Nerve F. is given off from the caudal end of the ganglion just laterad of the commissure. It runs latero-candad into the first abdominal segment, passes beneath the first ~~abdominal~~ transverse sternal muscle near the insertion of the latter and then bends laterad and dorsad running into the back of the segment. At the bend it sends short branches to the transverse sternal muscle and to the sternal recti. In the pleurum it send branches to the tergo-sternal muscles and in the back it innervates the tergal muscles.

<u>Abdominal Ganglia & Nerves</u> (Fig.27 1-5.)

In the abdomen the ganglia are situated in the second, third, fourth, fifth and seventh segments. The first to the Fourth ganglion, are similar in appearance and in the number of nerves they bear. They are quite small as compared with the thoracic ganglia and the fifth abdominal ganglion. This latter, owing to the fact that it results from the fusion of several neuromeres, and to the specialization of the appendages of the terminal segments, is a very complex ganglion as large as the thoracic ganglia.

<u>First to Fourth Abdominal Ganglia</u>: (Fig.27, 1-4). Two nerves arise from each of these ganglia. Of these, the anterior nerve <u>A</u> is the larger of the two. It is given off from the cephalo-lateral side of the ganglion and its course and distribution are similar to that of nerve F of the third thoracic ganglion, i.e. it innervates the sternal, pleural and tergal muscles of its segment. <u>Nerve B</u> is a slender nerve, given off from the ventral side of the ganglion, and innervates the sternal portion of its segment.

Fifth Abdominal Ganglion (Fig. 27, 5.) As stated above, this is a complex ganglion formed by the fusion of the neuromeres caudad of the fifth segment. The shape is triangular, the last pair of longitudinal commissures entering it at its apical (cephalic) angle. This pair of connectives is the longest in the chain owing to the absence of the ganglion in the sixth segment. Owing to its complex nature the last ganglion bears several nerves not present in the others. Following is a description of the principal nerves. Nerves A & B are the homologues of nerves A & B of the preceding abdominal segments and evidently belong to the (primitive) ganglia of the sixth segment. They originate near the base of the commissures, A from the lateral, B from the ventral side. They run cephalad to the sixth segment where their distribution is similar to that of the homologous nerves of the other ganglia. Nerve C originates from the side of the ganglion and runs laterad to certain of the muscles in that region. Nerve D arises from the dorso-lateral face of the ganglion. The first branch (a) goes to the last spiracle. The nerve continues into the back. Nerve E arises immediately ventrad of the origin of the nerve to the cercus. It terminates in the muscles at the base of the cercus. Near its origin it gives off a branch r which goes to the reproductive organs. Nerve F is a stout nerve from the basal angles of the ganglion. As stout as the commissures it appears to be a direct continuation of the commissural fibres. It enters the cercus where it innervates the numerous sensillae of this organ. Before entering the cercus nerve F gives off a stout branch (int.) which runs cephalo-mesad to the intestines. The intestinal nerve enters the intestines at the junction of the rectum and small intestine. Here it branches, one branch runs caudad along the rectum, the other cephalad along the small intestine.

The Sympathetic Nervous System.

There are three different systems of sympathetic ganglia and nerves in the insect. These are, (1) The median or unpaired system, (2) the paired lateral system and (3) the ventral or superadded system.

The Median Sympathetic System.

This system consists in most insects of two or three median, unpaired ganglia. In the case of the insect under consideration, however, the system consists of two unpaired ganglia and one paired. The median sympathetic system is also known as the vagus or stomatogastive system. It is connected with the central nervous system by means of the arched nerves.

The Arched Nerve (Figs. 28 and 31. Ar.) originates from the ventral side of the cerebral hemispheres and, at its origin, is united with the clypeo-labral nerve. These two nerves soon separate. The arched nerve curves inwards and enters the frontal ganglion, thus forming, with the fellow of the opposite side, the arch from which it derives its name.

The Frontal Ganglion (Figs. 28 and 31 f.g.) is a small ganglion situated on the oesophagus ventrad of the brain. From its ventral side a slender nerve, the frontal nerve (f.n.) is given off. This runs ventrad into the clypeus.

The Recurrent Nerve (figs. 28 and 31 r.n.) arises from the dorsal end of the frontal ganglion and runs dorsad along the oesophagus passing beneath the brain. Beneath the brain it enters the second unpaired ganglion of the system (g2). Hitherto the recurrent nerve had been median and unpaired, but on leaving the second ganglion it divides into two. These run along the sides of the oesophagus and crop and terminate in the *vagus* or *stomachic ganglia* (g3), a pair of small ganglia on the sides of the caudal end of the crop. They give rise to the stomogastric nerves (s.n.) which innervate the proventriculus and mesenteron, In most insects the vagus ganglion is a median unpaired ganglion. Berlese '07 states that the recurrent nerve is typically double but becomes sungle through coalescence. The cricket is one of the few insects in which this nerve retains it primitive double condition. It does not retain it perfectly however as it is unpaired for the short distance between the frontal ganglion and the second unpaired ganglion.

The Paired Lateral Sympathetic System. The paired sympathetic system had not been studied in detail owing to the unsatisfactory nature of the preserved material. In insects generally, this system consists of two pairs of lateral ganglia on the sides of the oesophagus. The two ganglia on each side may be connected by a commissure or may be partially fused as was found in the case of the larva of *Sphida obliqua*. In *Gryllus pennslvanicus*, however I have found only one pair of lateral ganglia,

(Fig. 31, l.g.). These ganglia are fairly large roundish masses and may be the result of the complete fusion of the two ganglia on each side. They are situated behind the brain and are attached by a short commissure to the second unpaired ganglion of the median system, and by another commissure, to the caudal side of the brain.

Packard '80, (Plate IX, figs. 2 and 4, p.s.g.) figures, but does not describe the lateral ganglia of Galoptenus femur-rubrum. In his figures there is a single large ganglion, very similar to that found in Gryllus.

The Ventral or Superadded System.

The ventral sympathetic system consists of a median and a transverse nerve in each segment, except the first and second thoracic. The median nerve (Fig. 27 m.n.) originates typically from the median point of the caudal end of the ganglion between the commissures, and runs caudad terminating in a similar position in the cephalic end of the next ganglion. Sometimes however it is partially united with one of the commissures. The transverse nerve (fig.27 tr.n.) is a slender paired nerve which is given off from the median nerve, usually shortly cephalad of the posterior ganglion. Sometimes, however, it arises from the end of the median nerve on the dorsal face of the ganglion. The transverse nerve runs laterad to the pleurum and innervates the respiratory muscles.

The Digestive System.

The alimentary canal (figs. 32 and 33) consists of a tube running through the body from the mouth at the cephalic end to the anus at the caudal end. Owing to the fact that there are only two small coils in the food canal, its length does not greatly exceed that of the insect as is the case in certain other insects. The mouth is on the ventral side of the head; its cavity is bounded by the labrum-epipharynx, the hypopharynx, labium, mandibles and maxillae. Dorsad of the oral opening there is a slightly enlarged portion the pharynx (fig. 22, ph.). It narrows into the oesophagus (oes) which runs dorsad passing through the anterior foramen of the head and then bends caudad above the central plate of the tentorium (fig. 32, T.) passing into the trunk through the occipital foramen. In the thorax the oesophagus merges into the crop (c) which is merely a dorsal dilation of the oesophagus. When distended with food the crop is very large, filling the thoracic cavity and extending into the anterior end of the abdomen. On the ventral side the crop is a straight continuation of the oesophagus, but the dorsal side is dilated into a large pouch. It is largest at its caudal extremity and tapers gradually cephalad. When the crop is not filled with food it does not retain its shape and the walls become wrinkled and folded. <u>The Proventriculus</u> (p.v.) arises from the ventral side of the crop continuing the straight course of the oesophagus. It is divided into two portions, an anterior tubular portion which merges into a large oval division. Following the proventriculus comes the mesenteron (m) the so-called "chylific stomach". At the point where the proventriculus and mesenteron join, the latter forms a cephalad-projecting fold which surrounds the base of the proventriculus. The lateral portions of this fold extend cephalad as far as the caudal end of the crop forming two large diverticula or gastric caeca (g.c.).

These are quite large having a diameter equal to, or even greater than, that of the mesenteron. A ligament attached at the anterior end of each caecum, runs forward sends a branch to the crop and terminates in the pronotun, in the anterior part of which its other end is fastened. At the base of the diverticula the stomach is of considerable width. Here there is a constriction which serves to mark off the diverticula from the stomach proper. Caudad of this constriction the mesenteron narrows considerably and retains a more or less uniform width until it enters the small intestine. Under the dissecting microscope the mesenteron is seen to be divided into two partions differing in gross appearance and also, as will be shown below, in histological structure. The anterior portion has the same outward appearance as the diverticula, and its surface is smooth and even. The hinder half however has an uneven surface thrown up into folds, and beneath the surface a number of small yellow bodies may be observed. At the junction of these two portions a funnel-shaped muscular valve projects from the fore portion into the hinder. Externally at this point there is a slight constriction, and it is surrounded by a narrow band of longitudinal muscles.

The mesenteron merges into the ileum, a narrower tube. At the juntion the uriniferous duct opens into the canal. At its distal end the uriniferous duct bears numerous uriniferous tubules. The ileum and the hinder part of the mesenteron are involved in two small coils.

The ileum is quite short and is followed by the large intestines which may sometimes be divided into a colon and rectum. The rectum opens to the exterior by means of the anus situated at the dorso-caudal extremity of the insect.

Structure of Digestive Organs.

The Crop. (Figs. 34 and 35.) The walls of the crop consist of three layers, the muscular layer (figs. 34 & 35 mc.), the chitinogenous epithelium (ep) and the cuticula or chitinous intima (in). The muscular layer consists of several layers of striated circular muscles. The number of layers vary. The epithelium consists of large Columnar cells with large nuclei containing two or more nucleoli. The nuclei are arranged near the inner ends of the cells so that they form a wavy line beneath the cuticula. Occasionally the nucleus of individual cells is found in the other end of the cell next the muscular layer. The inner surface of the cuticula is not smooth but shows numerous tooth-like projections in cross-section (fig.35). When empty the crop contracts and the wall is thrown into numerous folds which disappear when the crop is full. This however does not leave a level internal surface as there are several longitudinal hollows and ridges. At the ridges the epithelial cells are much larger than at the hollows. Sometimes they disappear entirely at the bottom of the depressions in which case the intima is in direct contact with one muscular layer. The intima is fairly uniform in thickness throughout, but where the depressions are very narrow the thickness decreases so that the intima may accommodate itself to the narrow depression which it lines. The intima does not show a cellular structure. Near the hinder end of the crop the number of ridges increases and they lie nearer to each other.

<u>The Oesophagus</u> is similar in structure to the crop.

<u>The Proventriculus</u> (Figs. 36 - 41). consists of two divisions, an anterior tubular portion next the crop and a larger oval division next the gastric caeca. The inner surface of both divisions is thrown up into six longitudinal ridges. In the anterior division each ridge is armed with ten transverse rows of stiff, brownish yellow, caudad - projecting bristles. Occasionally, in the middle of a row of bristles, there is a small chitinous tooth. Caudad of the tenth row or bristles, near the union of the two divisions

of the proventriculus the surface is bare and the ridges not so well developed. In the posterior division of the proventriculus the ridges are again well marked, and are armed with a complicated set of chitinized teeth (Fig.38) The cephalic end of each ridge is unarmed except for a soft yellow down which gives it a velvety appearance. Between each ridge and the neighbouring one there is a chitinous partition (Fig. 38 & 39, p)

In each ridge there are three rows of teeth. The two outer rows are similar and relatively simple. Each consists of ten teeth (Fig. 38 & 39, a) quadrangular at the base: These teeth are not very strongly chitinized and are blunt except for a curved projection on the apex. This projection is triangular in cross section. It projects caudad and is strongly chitinized, especially on the curved caudal edge. It is well fitted for cutting or tearing pieces of food. Behind the chitinous projection each tooth bears a small tuft of stiff hairs.

The middle row also consists of ten teeth, though a rudimentary eleventh is often developed. These teeth are very much more complicated than the others just described. Each tooth consists of lateral processes, or denticles, and an unpaired median denticle. The median denticle (fig. 38 & 39,e) is the one which projects farthest into the lumen of the proventriculus. It is inclined caudad, as are all of the denticles and teeth. The median denticle is conical at its base and its apex is flattened, very densely chitinized and armed with three to six sharp projections. These projections are, typically, symetrically arranged, but may vary through different asymmetric combinations. On each side of the central process, there is another smaller process (c) This is a simple, spinelike denticle, and is also densely chitinized. The second paired process (d) of the middle row of teeth is a peculiar curved denticle situated immediately cephalad of the simple processes last described. Viewed from the inner side (i.e. from the direction of the central process) they are narrowly wedge shaped. From the outer side they present a narrow curved surface, semi-circular in outline. On the convex ~~xxxxxxx~~ edge of this surface, eight small processes are borne at right angles to the surface. It will thus be seen that this surface is eminently fitted for grinding or crushing any solid pieces of food in the proventriculus. The last pair of processes (b) are quite different from the others. They are laterad of the median process and caudad of the others. They are large, padlike, not very strongly chitinized with blunt ends. For the most part they are covered with a short yellow pubescence but on the anterior side the hairs are longer, stiffer, and dark brown in color owing to their denser chitinization.

The hinder end of the proventriculus narrows and projects within the fold of the gastric caeca. The six ridges become much narrower in this position, are not toothed and project farther inward within the lumen almost closing it (fig. 41) On the caudal end of the proventriculus, there are six to eight flaps (fig. 40 & 41, v.) which form a valve ~~which~~ closing the passage from the proventriculus to the mesenteron. This valve opens only outwards into the mesenteron. It is prevented from opening inwards by the ridges of the proventriculus.

A cross section of the proventriculus (fig. 36 & 37) shows the following tissues. On the outside there are several layers of circular muscles, three or four in the anterior division and ten or more in the hinder part. The inner surface is lined with a thick densely chitinized intima. Next to the intima is a layer of epithelial cells. These cells, as in the case of the crop, contain large nuclei with several nucleoli. Unlike the epithelium of the crop, however, these nuclei are placed in the outer end of the cells away from the intima. The epithelial cells are small between the ridges and lie directly between the intima and the inmost layer of circular muscles. In the ridges the cells are elongated and much larger, and between the fold of the epithelium and the layers of circular muscles there is a mass of longitudinal muscle fibres (fig.37,m.l)

Opinions vary as to the use of the proventriculus. Earlier writers regarded it as ~~an~~ a analogous ~~of~~ to the gizzard of birds and held that its function was to triturate and comminute the food so as to make it more readily acted on by the digestive juices; hence, the German name "Kaumagen". Graber in support of this view, stated that food found in the proventriculus was finer than that taken from the crop.

Other writers have rejected this view and held that the teeth of the proventriculus simply act as a strainer to keep large particles from the stomach. Plateau, Forel, Emery and other well known anatomists have adopted this view. Goldfuss (according to Kolbe) states that in the Orthoptera the food is already liquid in the oesophagus so that there is no need for trituration. I do not know from which of the Orthoptera Goldfuss deducted this generalization, but it certainly does not hold for Gryllus pennsylvanicus, besides one is inclined to point out that if food is ~~xxxxxxx~~ fluid in the oesophagus there is as little need for the straining action as for the triturating one.

My study of the proventriculus of Gryllus has led me to believe that the proventriculus in this insect, while it may have a straining action has also a triturating one. The elaborate system of teeth and powerful circular muscles are not necessary for straining the food. On the other hand I fail to see how any solid pieces of food (unless very hard), caught between the densely chitinized teeth when the proventriculus is contracted by the powerful ~~xxxxxxxx~~ annular muscles, can escape some degree of comminution. Indeed some of the teeth, as pointed out above, seem specially adapted for crushing.

It is however imprudent to generalize from a single study or even from several studies, except of widely different forms. It is quite possible that the proventriculus may in some cases be a strainer, in others a crusher, or may combine the functions of both.

Gastric Caeca (fig. 43). The caeca show only two layers in cross section. The outer layer consists of muscular fibre and the inner layer of epithelial cells. There is no intima. The epithelium is thrown up into a number of irregular folds which practically fill the cavity of the caecum. The epithelial cells are narrow and crowded together. Their limits are not well defined. They contain large nuclei with one or two large nucleoli and several smaller granules. They are collected together in groups separated by connective tissue which forms a cup-like receptacle for each group. Two such "cups" are shown in Fig. 44. When the cells are viewed end to, the connective tissue has a reticulate appearance. At the bottom of the cups (i.e. next the muscular layer) there are several sperical bodies, which are not as large as the nuclei and take a very deep homogeneous stain with haematoxylin.

The Mesenteron. Minot '80 says, "It has been commonly stated that the caeca do not differ in structure from the stomach, a statement which though quite incorrect is repeated by so exact an author as Milne - Edwards ... yet, that there is a great difference had been noted in 1846 by H. Meckel, whose observations are also cited by Leydig ... Sirodot repeats the old and incorrect statement while Graber expressly states that their structure is not the same as that of the stomach ... More recently M.F. Plateau has again called attention to the incorrectness of the old view".

This again seems to be a case of too hasty generalization, because in *Gryllus pennsylvanicus*, except that the epithelium is not thrown up into folds, the structure of the anterior half of the mesenteron (fig.45) is precisely the same as that of the *crop*. The case may be different in other insects and it is conceivable that each of the above workers may have been correct according to the insect he studied.

The posterior half of the mesenteron (Fig.42) however differs entirely from the anterior half in its structure. The circular and longitudinal muscular layers are similar to those of the anterior half. The cells of the epithelial layer are placed side by side but are not very distinctly delimited. The reticulum of connective tissue is absent. The nuclei are large and distinct. The inner margin of the epithelium is undulatary. A thin intima is present. Inside the epithelium there is a thick uneven, homogeneous layer (Fig.42 h.l.) This shows no cellular structure and takes a deep purple stain with haematoxylin. Within this layer there are several oval glands, already referred to in the general account of the digestive canal. They are hollow within, opening by a narrow mouth towards the epithelium. The inner end is blind. The hollow of the gland is lined with an invaginated portion of the epithelium and intima. The walls of the gland are formed of elongated radiating cells. It is difficult to make out the structure of these cells as they take a deep purple stain similar to that of the surrounding homogeneous mass. On the inside of the mesenteron, next the homogeneous layer there is a thin membranous layer surrounding the lumen (Fig. 42,m.).

Lack of time and of suitable fresh material, prevents the study of these structures in greater detail at the present time. The inner membranous layer is doubtless the <u>peritrophie membrane</u> of Ramdohr.

<u>The Intestines</u>. Within the intestines the epithelium is thrown up into several folds. The number and arrangement of the folds differ in different parts of the canal. A section of the small intestines is shown in figure No.46. It will be observed that there are two layers of circular muscles and several longitudinal strands. A chitinous intima is also developed.

<u>The Salivary Glands</u> (Fig 33 s.g.) Each salivary gland consists of several lobulate masses of tissue lying ventrad of the oesophagus and crop, and extending caudad as far as the metathorax. Into each division of the gland a branch of the salivary duct enters. This divides within the tissue into a number of smaller branches which go to all parts of the glandular tissue. The branches from each gland unite to form a common duct (fig.33 s.d.) In the anterior portion of the insect the two ducts lie, one on each side of the first pair of commissures. They pass into the head beneath the oesophagus but do not follow the course of this organ through the anterior foramen. Instead they pass ventrad of the suboesophageal ganglion and unite to form a short common duct the outlet of which lies in the hypopharynx on the caudal side next the labuim (Fig.26 s.d.)

THE CIRCULATORY SYSTEM

Pl. IX

The heart (fig.47 h) is an elongated tube which lies in dorsal side of the insect extends from the eighth abdominal segment to the base of the mesothoracic segment. Here it narrows to form the aorta (ao)a straight slender tube which runs cephalad to the base of the head. The heart shows segmentally arranged constrictions. These mark the position of the inter-ventricular valves but I have not yet performed the dissection necessary for a description of these valves. The heart lies in a pericardial chamber which is bounded dorsally by the larger longitudinal tergal muscles and ventrally by the pericardium, a thin membrane of connective tissue. In the pericardium there are ten pairs of pericardial or alary muscles (fig 47,a.m.) These have the usual triangular shape; their bases are attached near the heart but not to the heart. The two caudal pairs are very small and close together. The six succeeding pairs of abdominal muscles are larger and uniform in size. The next pair situated in the metathorax is the largest, being about twice the size of those behind it. The cephalic pair, in mesothoric, is also larger than the abdominal ones.

THE RESPIRATORY SYSTEM

There are ten pairs of spiracles in the cricket, one in each thoracic segment and one in each of segments 2 to 8 in the abdomen. In the abdominal spiracles the cephalic border of the valve is narrow, crescent shaped and slightly overlap the other lip. The lips of the first and second thoracic spiracles do not overlap and are quite simple, lacking the chitinous structures of the abdominal spiracles. The third thoracic spiracle is similar to the abdomianl but larger.

From each spiracle three tracheal branches arise. One of these (Fig. 48 & 49 a) runs along the center and unites with the ventral longitudinal tube (V). Another, the dorsal branch (b) runs along the dorsum to the dorsal longitudinal tube. The third, or mesal branch (c) supplies air to the viscera. In most insects a lateral longitudinal tracheal tube on each side connects the spiracles. In Gryllus pennsylvanicus these tubes are absent. Instead of these, however, there is a pair of ventral longitudinal tubes, one on each side of the ventral chain and a second pair in the dorsum, one on each side of the heart. In the abdomen the ventral tubes run parallel to each other and there are no transverse trachael commissures connecting them except in the eighth segment. In the thorax the ventral tubes diverge from each other until they reach the second thoracic spiracle with which they are directly connected. From this spiracle they again converge, running in a cephalo-mesad direction.

At their nearest point they are connected by a tracheal commissure and again bend outward, terminating at the protheracic spiracle where another large commissure connects them. From this spiracle two large tubes run forward into the head.

From the ventral longitudinal tubes numerous small branches are given off. These supply the ventral muscles, leg muscles and nervous chain.

The dorsal longitudinal trachael tubes (Fig.49,1) unlike the ventral are connected by segmentaily arranged tracheal commissures in the abdomen but not in the thorax. These commissures, as well as the branches connecting the spiracle with the longitudinal tube, have a much greater diameter than the longitudinal tubes. The commissures, however, are much narrower at their ends where they join these tubes. In the thorax the dorsal longitudinal tubes increase in diameter and converge towards each other in the third segment. In the mesothorax, however, they diverge again, they continue into the head.

Branches from these longitudinal tubes supply the dorsal muscles, pericardium &c.

REPRODUCTIVE SYSTEM

Male reproductive organs

The testes. (Fig.50,1, Fig 51.) There are two testes present in the male of *Gryllus pennsylcanicus*. They are situated in the back of the abdomen, immediately above the gastric caeca, proventriculus and the anterior end of the mesenteron. The testes is irregularly ovoid in form. The wider anterior end is supported by the suspensory ligament (fig.50, susp.) The cephalo-lateral edges of the two testes are in contact in the mesal line of the dorsum. A layer of connective tissue, forms a scrotum surrounding the testes (fig.51. scr.) The outside of the testes is well supplied with trachea. The finer branches of these pierce the scrotum and supply air to the testicular follicles within. A longitudinal section through one of the testes has the appearance shown in figure 51. The vas deferens (v.d.) originates at the anterior end and runs through the testes, leaving it at its posterior narrow end. The anterior end of the vas is enlarges and from it arises a large number of testicular follicles (t.f.). These follicles (Fig.52) are clavate, attached to the vas deferens by a narrow tubular stalk, and project backwards to the scrotum. They are loosely joined to each other by strands of connective tissue. There are about three hundred follicles in each testes.

Minot '80 has described the follicles of the locust as being divisable into four parts; (1) A distal cellular portion, (2) The next section containing several wedge shaped bundles, the heads of the spermatozoa, (3) A section containing the tails of the spermatozoa, and (4) The proximal segment filled with granules. The follicles of *Gryllus pennsylvanicus* are very similar to those of *Caloptenus* described by Minot. In the distal end are numerous spermatoblasts (Fog.52 sp.b.) their cellular structure may be observed by making a cross section through the tip of the follicle. In the proximal portion of this first section the spermatoblasts are in various stages of transformation into spermatozoa and gradually assume an elongated shape. Next to the spermatoblasts comes the second division of Minot, containing numerous wedge-shaped bodies (s.h.) These are the heads of the spermatozoa which collect together in bundles. An isolated bundle of spermatozoa is shown in figure 53. Next to the spermatoblasts the heads are still in process of differentiation and have a granular appearance. They are also rounded rather than wedge shaped. Further down the tube, however, they are well developed and the bundles are distinctly wedge shaped, the apex of the wedge pointing towards the apex of the follicle. The tails of the spermatozoa (s.t.) are long, slender and sinuous. They occupy the third division of the testicular follicle. This third division, however, is not well demarkated from the second, as the heads of bundles passing out of the follicle may be found in both the third and fourth division. The heads and tails are easily distinguished as the former take a much deeper stain with haematoxylin. The proximal end of the follicle is filled with numerous small granules which stain deeply with haematoxylin.

The <u>vasa deferentia</u> (Fig.50 and 51 v.d.) arise in the distal end of the testes, run through the testes within the scrotum and leave at the caudal end. They run ventro-caudad as far as the base of the intromittent organs and then turn cephalad entering the seminal vesicle on its ventral face. At the base of the intromittent organs the vas is kept in position by means of longitudinal muscles, the nerve of the cercus and tracheal branches which pass mesad of it. The vasa are narrow, straight tubes until they reach the ventral side of the seminal vesicle. Here their diameter increases greatly and they make several folds before they open into the vesiculus.

The seminal vesicle. This is a large round sac situated on the ventral side beneath the coils of the intestinal canal. The surface of the vesiculus is covered by numerous accessory glands. These are of two kinds, elongated ones the utriculi majores (Fig.50 u.maj.) and smaller ones the utriculi breviores (u.br). The larger glands arise chiefly from the lateral and ventral sides, while the smaller arise chiefly from the dorsal and cephalic. Those on the cephalic side are very small, often mere wartlike protruberances. In cross section (fig.57) the accessory glands are seen to consist of a single layer of secreting cells not very well defined but with distinct nuclei. They secrete the mucilaginous substance which serves to form the envelope of the spermatophores.

The ejaculatory duct (Figs.50, 55, 56 e.d.) is a stout tube leading from the caudal end of the visicle to the copulatory organ.

The spermatophores (Fig.59) consist of bundles of spermatozoa, glued together by the mucilaginous secretion of the accessory glands. They are pear shaped, slightly notched at the breader end. The other end is drawn out into a long slender tail.

The Male Copulatory Organs. (Fig.50, 55 & 56).

The external opening of the male organs is bounded ventrally by a pair of lobes (figs. 55, & 56 v.c.) which are united proximally but free at their distal ends. The two distal lobes are concave on the inside and together form a cup-like hollow into which the spermatophore rests at the time of copulation. The dorsal border of the genital opening is formed by a plate which on its distal edge, bears five chitinous processes. The first of these processes (figs.55 & 56 d.p.) is borne on the dorsal side. It is an unpaired triangular, upcurved tooth. On the lateral edges there are two pairs of tooth-like chitinous processes, one (i.l.p) borne just inside of the other (e.l.p.) A slender chitinous spine lies along the roof of the dorsal plate. This is the penis, but it is not perforated and has thus lost its original function. It is probable however, that it serves to orientate and direct the spermatophores. Above the dorsal plate there is a second cup (d.c.) Just before the extrusion of the spermatophore its head lies between the lobes of the ventral cup while its tail is coiled up in the dorsal cup (fig. 56 sph). Pending further studies I have temporarily termed these cups the dorsal and ventral spermatophore cups.

FEMALE REPRODUCTIVE ORGANS

Ovaries (Fig.58 O.) There are two ovaries present situated latero-dorsad of the alimentary canal. The anterior end of the ovary presses against the hinder end of the crop. The two ovaries meet in a point in the back caudad of the crop and dorsad of the proventriculus and gastric caeca. They then diverge from each other and run ventro-caudad one on each side of the alimentary canal, terminating in the oviducts.

The ovary is composed of a large number of ovarian follicles, surrounded by a thin membrane of connective tissue. The ovarian follicles (fig.62) are elongated tubes divided into compartments. The size of the compartments vary according to the presence or absence of eggs in them or according to the size of the contained ova. The walls are distensible so that the chambers can undergo considerable increase or decrease in size to accomodate the eggs which they contain. The compartments next the oviducts are usually largest as they contain fully formed eggs. Distad of this the size decreases progressively and the follicle ~~formally~~ finally ends in a terminal thread. The terminal thread of all the follicles of each ovary unite to form a suspensory ligament. This runs cephaled and divides into two branches. One branch is attached in the pericardium near the heart, the other at the insertion of the second alary muscle in the thorax.

The walls of the ovarian tube consists of a single layer of cells with large muclei (fig.63). The cells are largest in the proximal portion of the follicle. There are no nutritive cells developed.

The ova (Gig.64) are yellow, cylindrical, with rounded ends. Usually they are slightly convex on one side and straight or somewhat concave on the other. The surface of the chorion is finely reticulated, which is doubtless due to the impress of the cells of the ovarian follicle.

The ovarian follicles of each ovary unite to form a common tube, the oviduct (Fig.58.od.) The two oviducts run caudad and converge towards each other. They unite ventrad of the rectum and form a short vagina. (fig. 58-60 vag.) This is formed partly by the united bases of the oviducts and partly by a cup-like structure on the dorsal side of the base of the oviducts. This is continued caudad as the bursa copulatrix (Fig. 60 b.c.) a shallow pouch-like organ, which receives the copulatory organs of the male.

Attached, at its anterior end to the vagina, there is a tongue-like flap (Fig.59 f, fig 61) which projects backwards into the bursa. In side view (Fig.61) the dorsal side, which lies against the roof of the vagina and bursa, is convex and strongly chitinized. The ventral side is concave and not so densely chitinized. Near the tip of the ventral surface there is a circular pore (m.d.) which marks the mouth of the duct (d) from the receptaculum seminalis. The receptaculum (fig. 58 r.s.) lies to the right of the mesal line cephalad of the vagina. It is an ovoid body with its larger end pointing cephalad. Near the smaller end the duct (d) is given off. This is a long slender tube containing many coils. It enters at the cephalic end of the vagina and passing through the tongue like flap described above, has its outlet near the apex of the latter organ. The vulva or external genital opening has on each side a thick lip (fig. 58 & 59 vul.) formed by the fleshy bases of the ventral gonapophyses. A thick wedge shaped appendage of the vagina, attached at its broad end to this organ, extends over the vulva and forms a movable lid over the orifice. This organ may be termed the operculum vulvae. It does not seem to be invariably present.

Thus far no sebaceous, cement or colleterial glands have been found. In most other insects these glands exist as accessory glands of the vagina. In Gryllus pennsylvanicus, however, they do not seem to be present. Such glands would indeed be unessential in this insect as the eggs are laid loosely in the soil not attached to each other, nor to any object, nor do they seem to be coated over with any special cement.

BIBLIOGRAPHY

Home E. 1824. On the internal structure of the Human Brain when examined in the microscope as compared with that of Fishes, Insects and Worms. Phil.Trans.Roy.Soc.Lond.T.114.

Newport G. 1832 On the Nervous System of the Sphinx Ligustri.Linn.,and on changes that it undergoes during a part of the metamorphosis of the insect. Phil.Trans.Roy.Soc.Lond., Vol.122. pp.363-398.

1834 On the Nervous System of the Sphinx Ligustri.Linn. (pt.11) during the later part of its pupa and its image state and on the means by which its developement is effected. Loc.cit.Vol.124 pp.389-423.

1839 Insecta. Todd's Encyclopedia of Anatomy and Physiology. London.

Burmeister, H.1836. A manual of Entomology. Transl.by W.E.Shuckard. London.

Brandt.Ed.1876 Recherches anatomiques et morphologiques sur le système nerveux des insectes hymenopteres (Hymenoptera) Compts rendus de l'Acad'des Sc.,Paris. 1.83.pp.613-616.

Huxley, T.H. Manual of the Anatomy of Invertebrated Animals.

Yung.E. 1876 Recherches sur la Structure Intime et les Fonctions du Système Nerveux Centrale chez.les Crustacées Decapodes. Archiv. de Zool. Exp. et Gen.T.V11.pp.501-534.

Lienard.V. 1880 Recherches dur le Syeteme Nerveux des Arthropodes.-Constitution de l'Anneau oesophagien.Archiv.de Biologie i.pp.381-391.

Minot, C.S.1880 Histology of the locust (Caloptenus) And the Cricket (Anabrus) (Plates 11 - V111 Second Report Ent. Comm. Wash. pp.183-222.

Foettinger.Alex. 1880 Sur les termination des nerfs dans les muscles des insectes. Archivs. de Biol.i. pp.279-304

Packard. A.S. 1880. The Brain of the Locust. Second Rep. U.S.Ent. Commission,Washington,pp.223-242

1880. Anatomy of the Western Cricket (Anabrus) Loc.cit.pp.170-178.

1898. Text Book of Entomology.N.Y.

Comstock and Kochi (1882) Skeleton of the Head of Insects. Am. Nat. XXXVl. No.421 pp.13-45.

Miall.L.C. and Alfred Denny.1886 The Structure and Life History of the Cochroach. London.

Miall.L.C. and Shelford R. 1897 The Structure and Life History of Phalocrocera replicata. Trans. Ent. Soc. Lond. pp. 343-366. Pl. VIII-XI.

Viallanes H.1887 Sur la Morphologie Comparée du Cerveau des Insectes et des Crustacées.Compt. Rendus de l'Academie des Sciences.Paris T.CIV.pp.444-447.

Kolbe. H.J. 1893 Einfuhrung in d.Kenntnis d.Insekten, Berlin.

Comstock.J.H. and Kellogg.V.L.1895 Elements of Insect Anatomy. Ithaca. N.Y.

Kenyon.F.C. 1897 On the Optic Lobes of the Bee's Brain in the Light of Recent Neutological Methods. Am.Nat. Vol.XXXl.pp.369-376.

Sharp.D., 1901 Insecta, Part 1.Camb.Nat.Hist., Vol.V.

Cary.L.R. 1902 The Grass Thrips. Bull.83. Maine Agr. Expt.Sta.

Henneguy.L.F.1904 Les Insectes,Morphologie, Reproduction, Embryogénie. Paris.

Janet.C. 1905. Anatomie de la Tête du Lasins niger. Limoges.

1909 Sur la morphologie de l'Insecte. Limoges.

Berlese A.,1907 Gli Insetti,loro organizzione, Sviluppo, abitudini e rapporti coll' uomo. Milano 1907.

Hammar.A.G., 1908 — On the Nervous System of the Larva of Corydalis cornuta. L.Ann.Ent.Soc.of America. Vol.1.pp.105-127.

Severin H.H.P and Severin H.C.M. 1908. — The Internal Organs of Reproduction of the Male Sawfly Cimbex Americanus Leach. Annals. Ent. Soc.Am. Vol.I. pp.196-205.

Folsom J.W. 1909 — Entomology with reference to its Biological and Economic Aspects. Philadelphia.

Hilton. W.A.1909 — The Tracheal Supply of the Central Nervous System of the ~~Lava~~ of Corydalis /Larva Cornuta L. Annals Ent.Soc.Am.Vol.11. pp.46-60.

Hewitt. C.G. 1910 — The Housefly. A Study of its Structure. Developement, Bionomics and Economy. Manchester. Also quarterly Journal Mic.Soc.Vol.51.pp.395-448.Vol.52.pp. 495-545. Vol.53,pp.347-414.

Snodgrass R.E. 1910 — Anatomy of the Honey.Bee U.S. Dept.Apr. Bur.of Ent., Tech.Ser.Bull.18.

Wheeler. W.M. 1910. — Ants. Their Structure, Developement and Behaviour. New York.

Peterson.A., 1912 — Anatomy of the Tomato Worm Larva, Protoparce carolina. Ann.Ent.Soc. of Amer. Vol.V. pp.246-272.

Sharp.D. and Muir F. 1912. — The Comparative Anatomy of the Genital Tube in Coleoptera. Trans. Ent.Soc.Lond. pp. 477-642. Pl.XL11 - LXXV111.

EXPLANATION OF FIGURES

Fig.1. Head, Cephalic view.

" 2. " Caudal "

" 3. " Lateral "

" 4. " Ventral view with mouth parts.removed showing tentorium.

" 5. Clypeus and Labrum.

" 6. Labrum - epipharynx.

" 7. Mandible, cephalic view.

" 8. " caudal view.

" 9 Maxilla.

" 10 Lab~~ui~~ium.

" 11 Lab~~ui~~ium and Hypopharynx, side view.

Caption Figs 1 - 11.

a. Antenna. Ab.t. Abductor of mandible.
ad.t Adductor of mandible. C.a. Ante-clypeus.
C.p. Post-clypeus. C 1., C 2. The two sclerites of the cardo.
E. Epicranium. e. Compound eye. e.s. Epicranial suture.
F.A. Anterior foramen. F.L. Lateral foramen. F.O. Occipital foramen. G. Gena. g. Galea. gl. Glossa. hyp Hypopharynx
L. Labrum. l. Lacinia. m. Ment~~r~~um. mb. Membrane attaching mandible to clypeus. mb 2. Membrane attaching maxilla to outer edge of labium. M.C.l. Anterior condyle of Mandible.

M.C.2. Posterior condyle of mandible. Md. Mandible.

O. Occiput. o.l. Lateral occellus. o.m. Median occellus.

p. Pan into which posterior condyle of mandible fits.

pf. Palpifer. pg. Palpiger. P.G. Postgena. p.gl. Paraglossa. p.l. Labial palpus. p.m. Maxillary palpus.

s.d. Outlet of Salivary duct. s.m. sub-mentum. st. Stipes

T. Central plate of tentorium. 1, 2, 3. Arms of tentorium.

Fig. 12. Ventral view of thorax.

" 13. Dorsal view of thorax, with the caudad - projecting edge of the pronotum removed to show mesonotum. Wings also removed.

" 14. Lateral view of thorax and abdomen.

Caption figs. 12-14

C. Cercus. Cox.1. Cox.2. Cox.3. Coxae of 1st. 2nd. ~~&~~ and 3rd.legs.

Em_2 Epimeron of mesothorax. Em_3 Epimeron of metathorax.

Es_2, ES_3. Episternum of meso - and meta-thorax respectively.

ovp. Ovipositor. pron. Pronotum. p.scl. Praescutellum of mesothorax. Scl_2, Scl_3. Scutellum of meso and metathorax respectively, Sc_2, Sc_3. Scutum of meso and metathorax. St_2, St_3. Sternum of meso and meta-thorax.

Stl. Sternellum of pro-thorax. W_1, W_2, Base of Wings. 1,2,3 &c. Abdominal tergites. 1^1, 2^2, 3^3, &c. Abdominal Sternites.

Fig. 15. Endothorax. a. Median entosternite of prothorax. b. Median process of meso-entosternite. pl_1, pl_2, pl_3, Ento pleurites of pro- , meso- and meta-thorax respectively, st_1, st_2, st_3, Entosternites of pro-, meso-, and meta-, thorax.

Fig. 16. Left fore wing of male.

" 17. " " " " female.

" 18 Stridulating ridge and teeth from male wing.

" 19 Fore leg.

" 20 Hind leg.

Caption Figs. 16-21

C. Coxa. f. Femur. S. Stridulating ridge.

t_1, t_2, t_3, t_4, Joints of tarsus tm. Tympanum. tr. Trochanter

Fig. 22. Caudal view of Abdomen of Female.

" 23 " " " " " Male.

" 24 Basal portion of cercus.

" 25 Base and apex of ovipositor.

Caption figs. 22-24

C. Cercus. d.g. Dorsal gonapophyses.

g.a. Genital armature of male. i.l. Infra-anal lobe.

p.p. Podical plate. s. Club-shaped sensillae of cercus.

s.p. Sur-anal plate . $s.p^1$. Lateral portion of sur-anal plate. sr.l. Sur-rhabdal lobes v.g. Ventral gonapophyses.

7^1, 8^1, 9^1, 7th. 8th and 9th. abdominal sternites.

Figure 26. Side view showing principal muscles of thorax and abdomen.

abd. c. Abductor coxae. Ad.c. Adductor coxae.

Ext.fem. External femoral. l.st. Longitudinal sternals.

t_1, t_2, Longitudinal tergal muscles of abdomen.

th.t. Longitudinal tergals of thorax.

tr.st. Transverse sternals. t.s. Tergo-sternals.

Figure 27. Nervous System - Brain and ventral chain.

1, 11, 111. Thoracie ganglia 1,2, - 5. Abdominal ganglia A.B.C.&c. Nerves arising from various ganglia (For their distribution see text)

Br. Brain. int.n. Intestinal nerve. Oes. Oesophagus. O.G. Optic Ganglion. O.N. Optic Nerve. Mn. Median nerve. N.C. Nerve of Commissure. r. Nerve to reproductive system. tr.n. Transverse nerve.

Figure 28. Cephalic view of Brain.

" 29. Sub-oesophageal ganglion. Dorsal view.

" 30. " " " Lateral view.

" 31. Median and lateral sympathetic systems.

Caption Figs. 28-31

A. Antennal nerve. A.C. Accessory commissure. Ar. Arched nerve. C. Crus. C.L. Clypeo-labral nerve. Com. Commissure between the sub-oesophaneal and first thoracic ganglia. f.g. Frontal ganglion. F.n. Frontal nerve. g.2. Second ganglion of median sympathetic system.

g.3. Third ganglion of median system. L. Labial nerve. l.g. Lateral ganglion. Md. Mandibular nerve. Mn. Median nerve. Mx. Maxillary nerve. OC.L. Nerve to lateral occellus Oc.M. Nerve to median ocellus. O.G. Optic ganglion. O.N. Optic nerve. r.n. Recurrent Nerve. S. Salivary nerve. s.n. Stomogastric nerves.

Figure 32. Digestive system *in situ*, lateral view.

" 33 Digestive system, dorsal view.

Caption figs. 32 & 33.

an. Anus. C. Crop. Col. Colon. g.c. Gastric caeca.

gl. Gland of posterior division of mesenteron showing through muscular layer. il. Ileum. m. Mesenteron.

M.V. Muscular Valve, of mesenteron. Oes. Oesophagus.

p.v. Proventriculus, anterior tubular division.

p.v.'' Proventriculus, posterior oval division. rt. Rectum.

s.d. Salivary duct. s.g. Salivary gland. n.d. Urinary duct.

u.t. Urinary tubules.

Figure 34. Cross section of crop showing the three layers.

" 35. " " " " " Structure.

" 36 " " " tubular division of the proventriculus showing the six ridges.

Figure 37. Cross section through two ridges of the tubular division of the proventriculus.

Figure 38. Part of one of the ridges of the posterior portion of the proventriculus, the chitinous partitions (p) between the ridges and four teeth in each of the three rows.

Fig. 39. Cross section of posterior division of the proventriculus.

" 40. The proventriculus and gastric caeca, the upper half of the latter removed to show the proventriculus valve.

" 41. Longitudinal section through proventriculus (diagrammatic)

" 42. Cross section of posterior division of the mesenteron.

" 43. Cross section of gastric caesum.

" 44. Section through two "cups" of the epithelium of the anterior division of the mesenteron.

" 45. Cross section through anterior division of mesenteron.

" 46. Cross section of small intestines.

Caption figs. 34-46

a. Lateral teeth or proventricular ridge. b.c.d.e. Processes of median teeth. Conn. Connective tissue between epithelial cells of caeca and of mesenteron. ep. epithelium. g. Glands in posterior portion of mesenteron. h. Hairs lining the ridges of the enterior division of the proventriculus. h.l. Homogeneous layer of mesenteron. in. Intima. m. Peritrophic membrane. m.c. Circular muscles. m.l. Longitudinal muscles. p. Chitinous partition between ridges.

Figure 47' Circulatory Organs.

a.m. Alary muscles, ao. Aorta. h.Heart.

Figure 48. Viscera removed showing Ventral tracheal system.

" 49. " " " Dorsal " "

Caption figs. 48 & 49

a. Ventral tracheal branch b. Dorsal tracheal branch. c. Visceral branch. D. Dorsal tracheal trunk. d.c. Dorsal tracheal commissures. V. Ventral tracheal trunk.

Fig. 50. Male Reproductive Organs, dorsal view.

Fig. 51. Longitudinal section of testes.

Fig. 52. Testicular follicle.

Fig. 53. Bundle of spermatozoa.

Fig. 54. Spermatophore.

Fig. 55. Copulatory Organs, lateral view.

Fig. 56. " " longitudinal section

Fig. 57 Section through accessory glands. A. Longitudinal, B. Lateral.

Caption Figs. 50-56

d.c. Dorsal spermatophore cup.

d.p. Dorsal chitinous lobe of genital armature.

e.d. Ejaculatory duct. e.l.p. External lateral chitinous plates.

g. Granules in testicular follicle. i.l.p. Internal lateral plate. scr. Scrotum. sp.b. Spermatoblasts

sph. Spermatophore. susp. Suspensory ligament. T. Testes

t.f. Testicular follicles. u.br. Utriculi breviores.

u.maj. Utriculi majores. v.c. Ventral spermatophore cup.

v.d. Vas deferens.

Figure 58. Female Reproductive organs, ventral view.

" 59 Genital atrium with operculum vulvae removed, showing spermathecal flap.

Fig. 60. Side view of female organs.

Fig. 61. Spermathecal flap.

Fig. 62. Ovarian follicle.

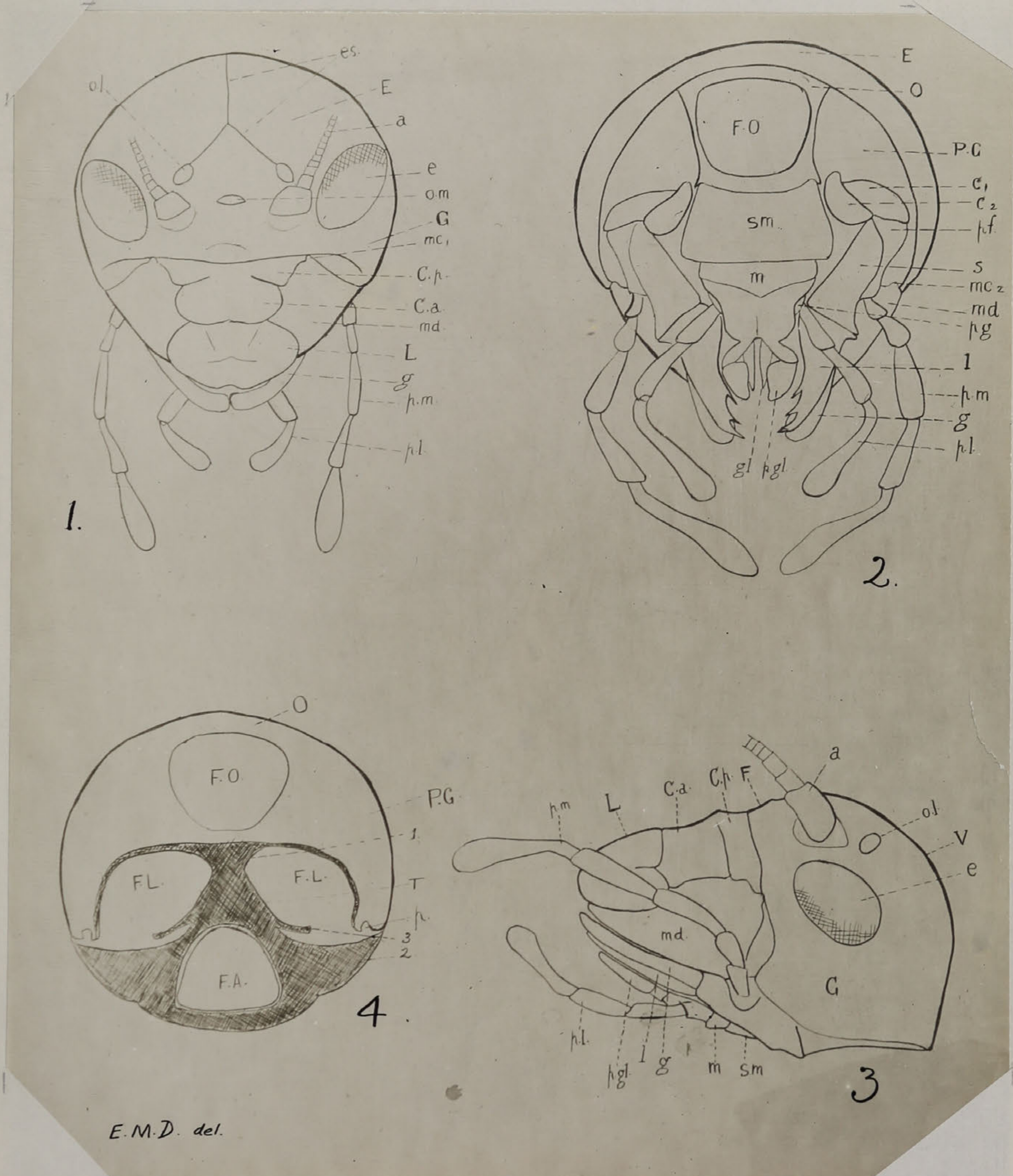
Fig. 63. Cross section of ovarian follicle.

Fig. 64. Ovum.

Caption figs. 58-64

bc. Bursa copulatrix. d. Duct of receptaculum seminalis. f. Spermathecal flap. m.d. Outlet of Spermathecal duct. O. Ovary. Od. Oviduct. op.v. Operculum vulvae. ov. Ova. r.s. Receptaculum, seminalis, or spermatheca. vag. Vagina. vul. Lips of the ~~valve.~~ vulva

Plate I



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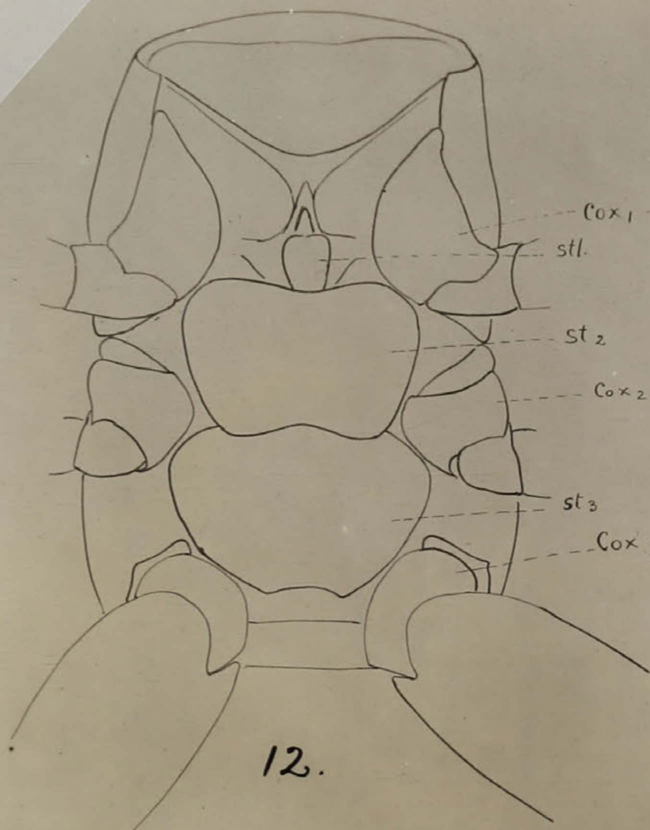

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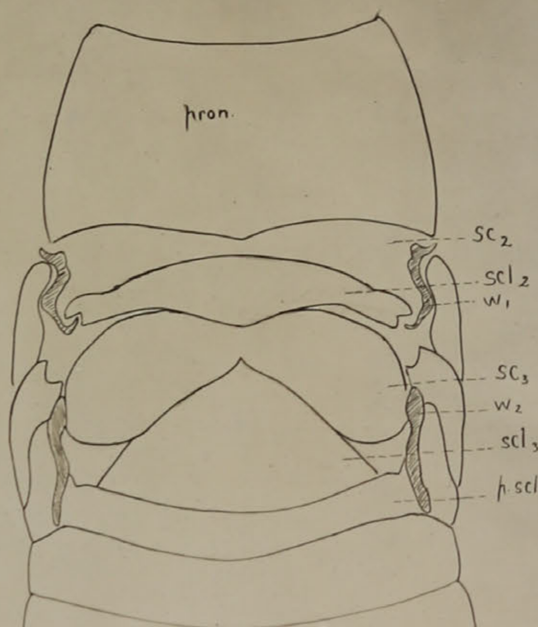

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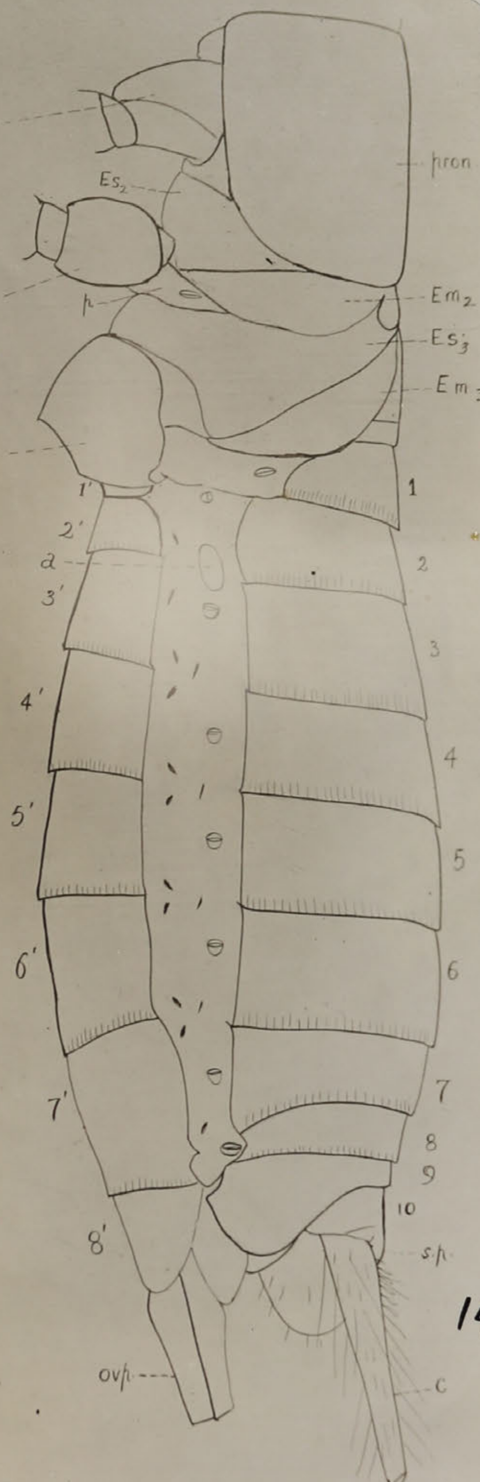

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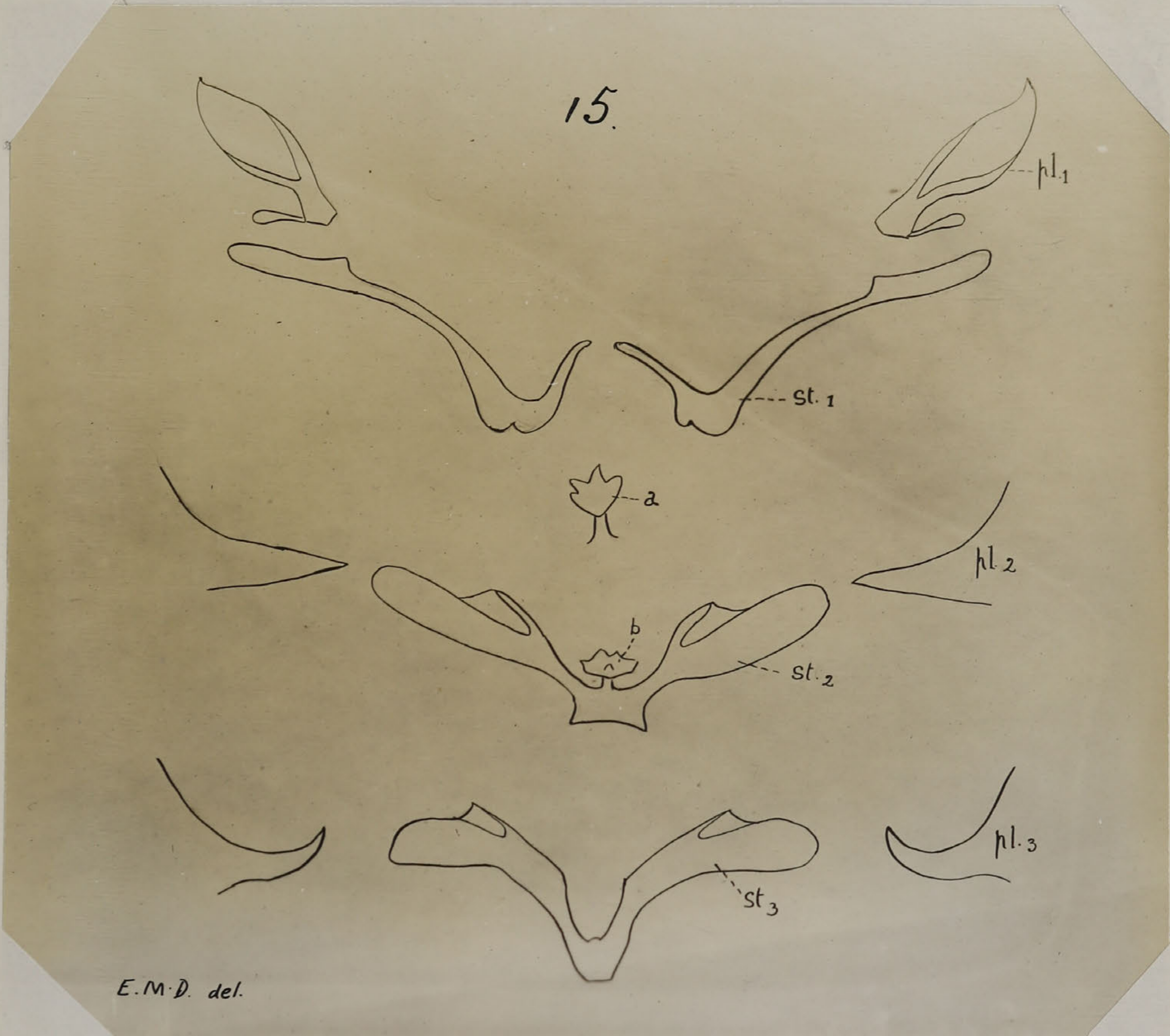

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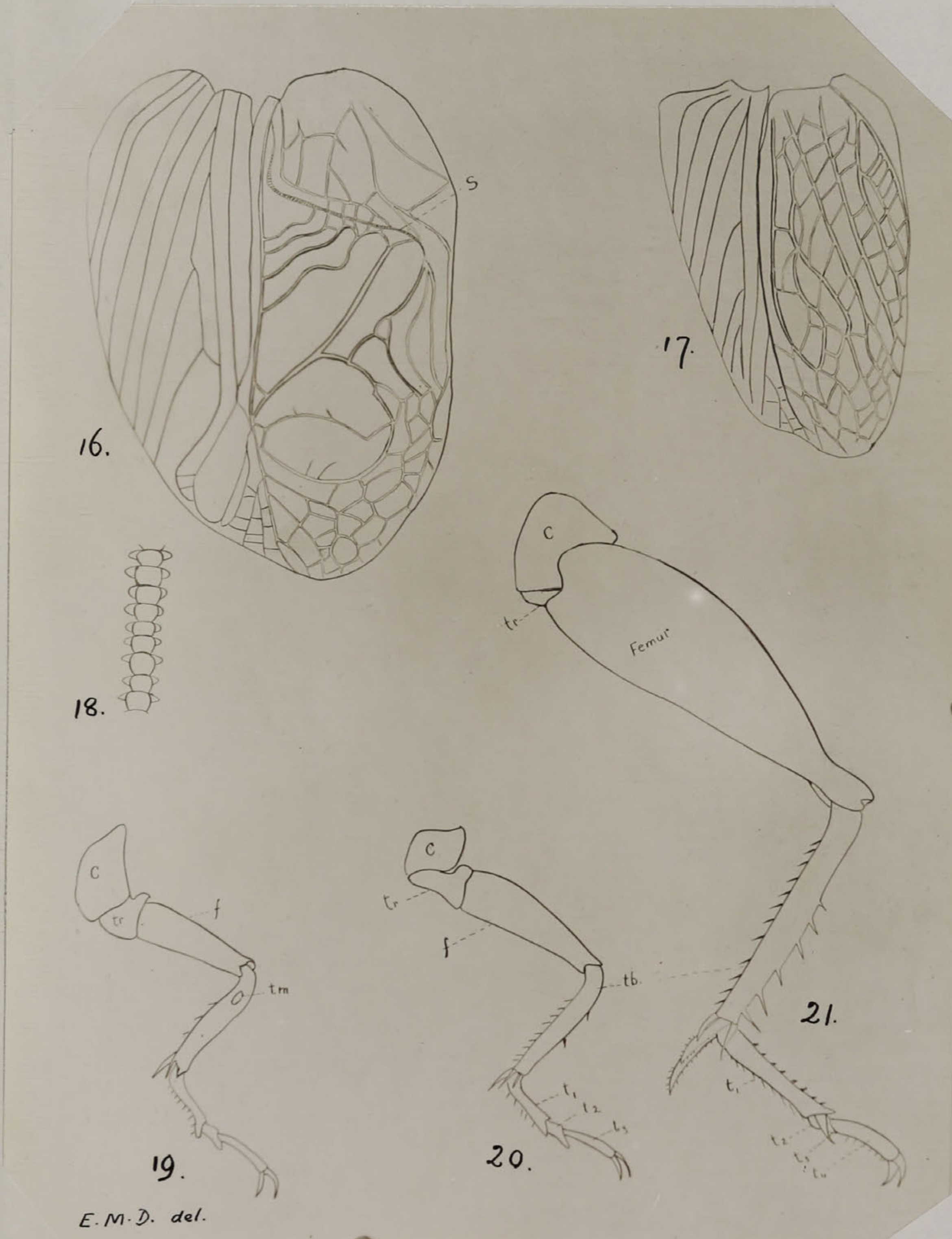

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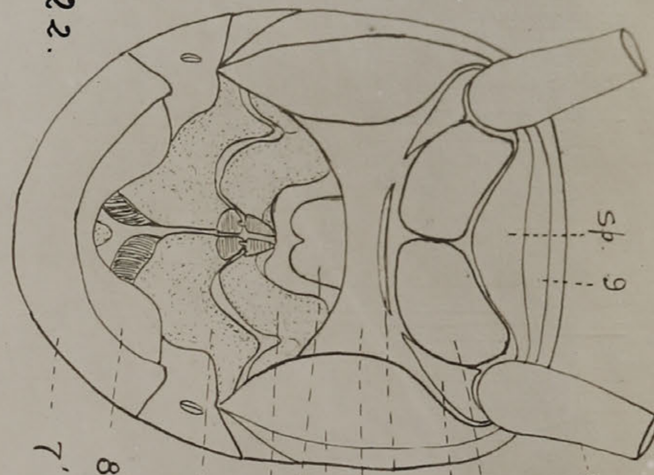

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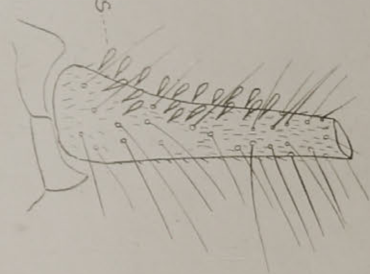

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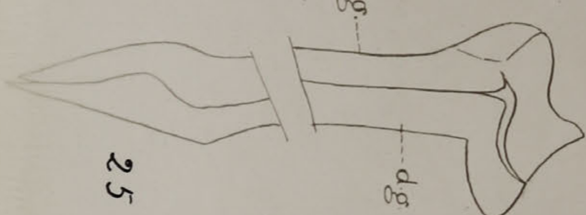

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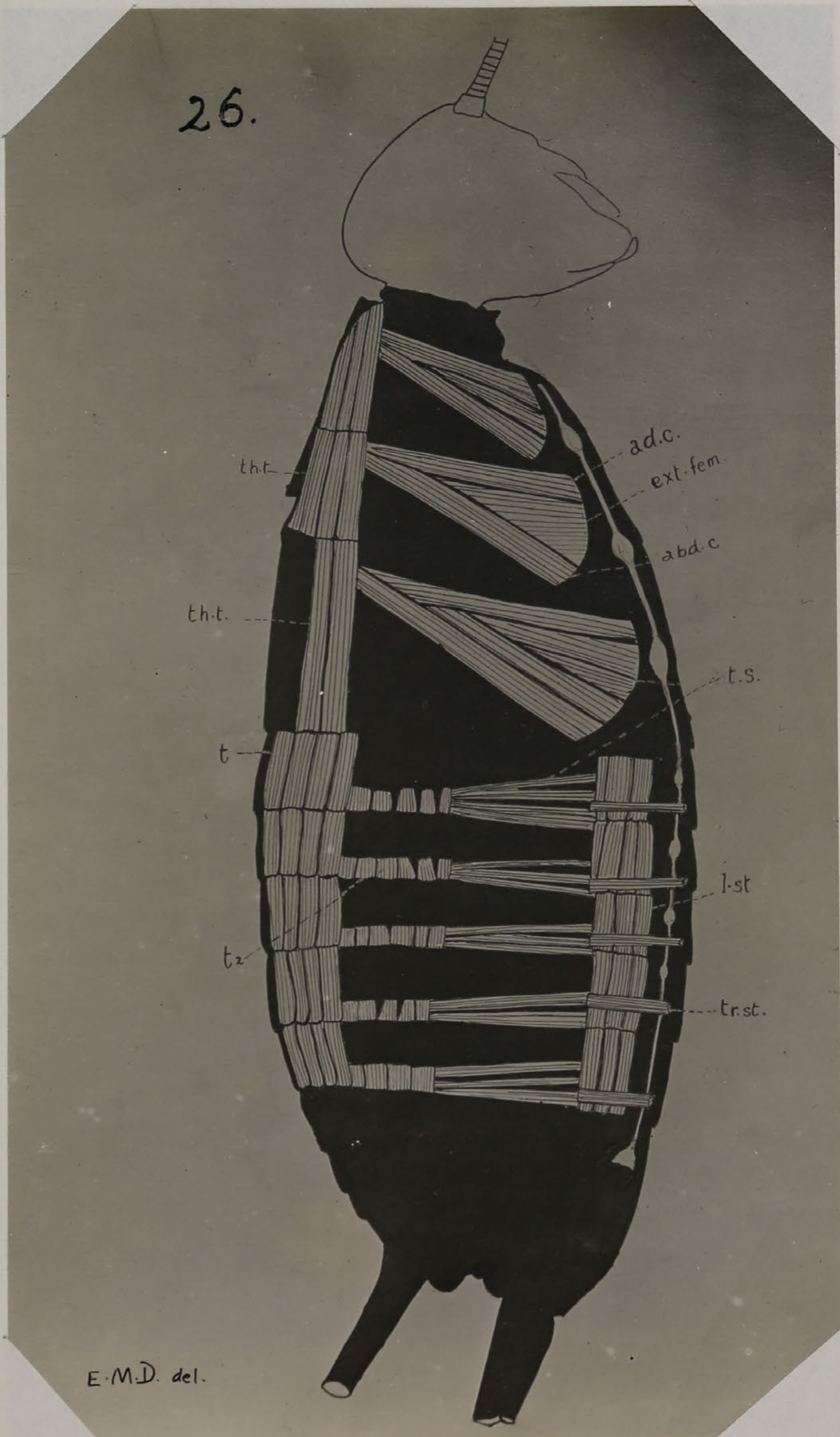

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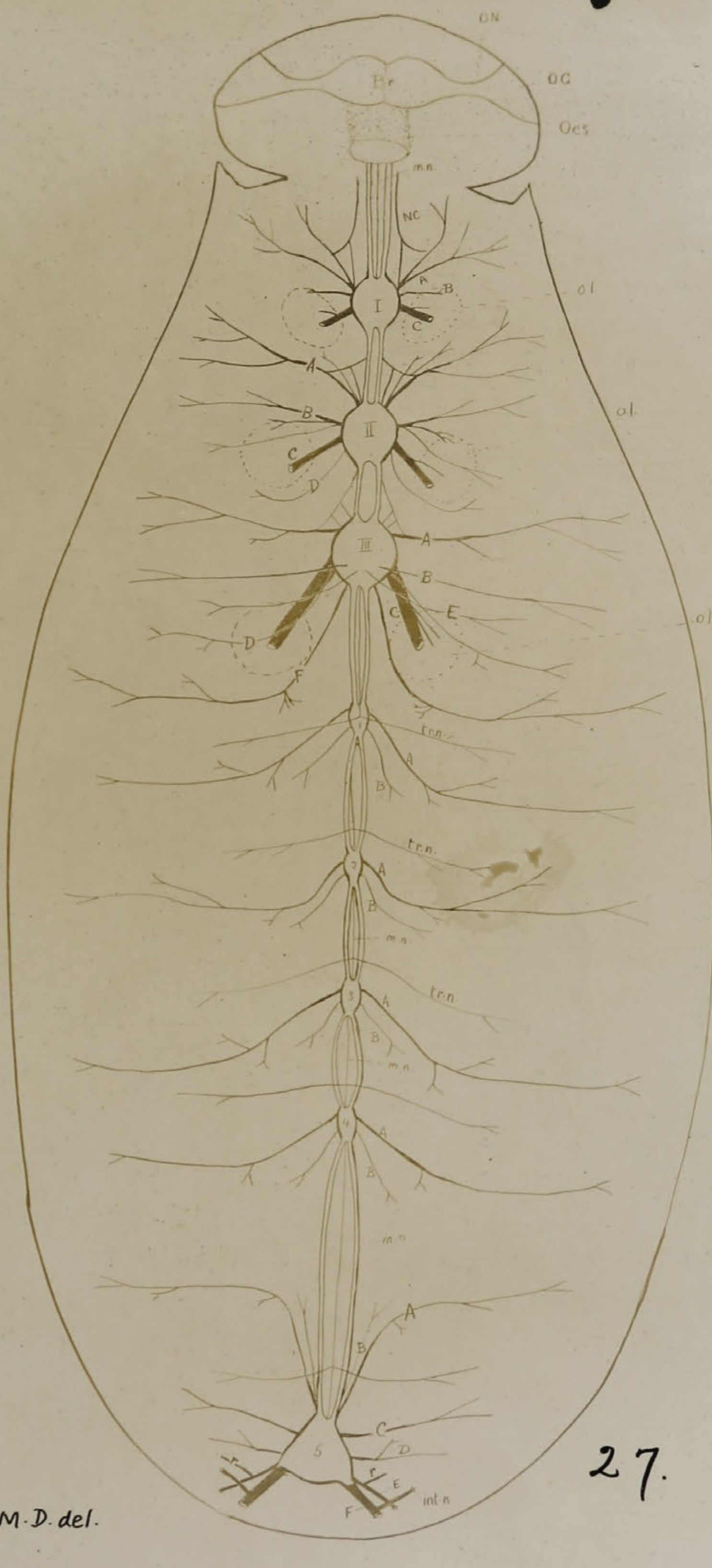

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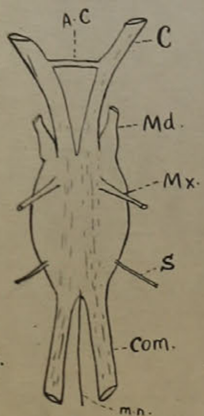

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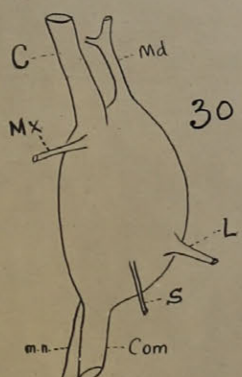

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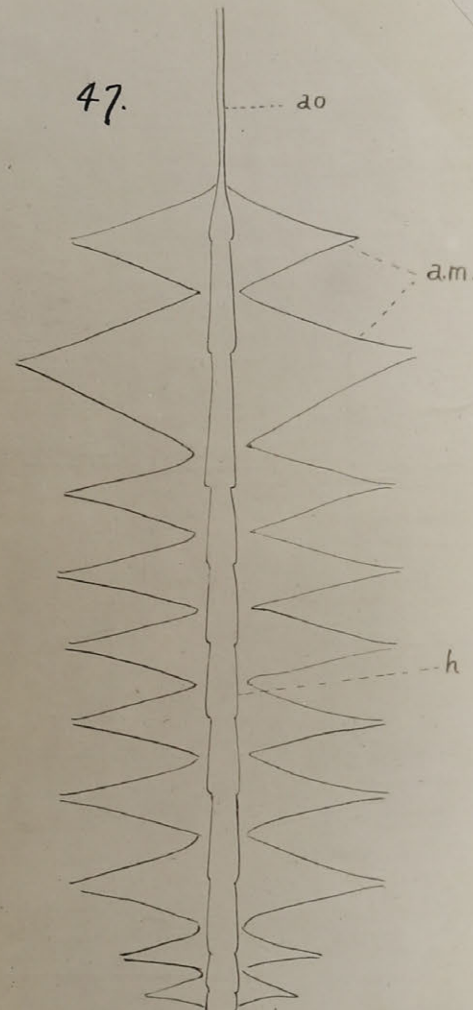

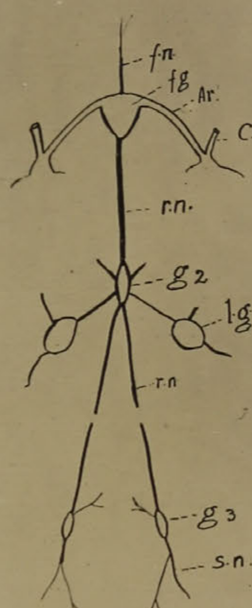

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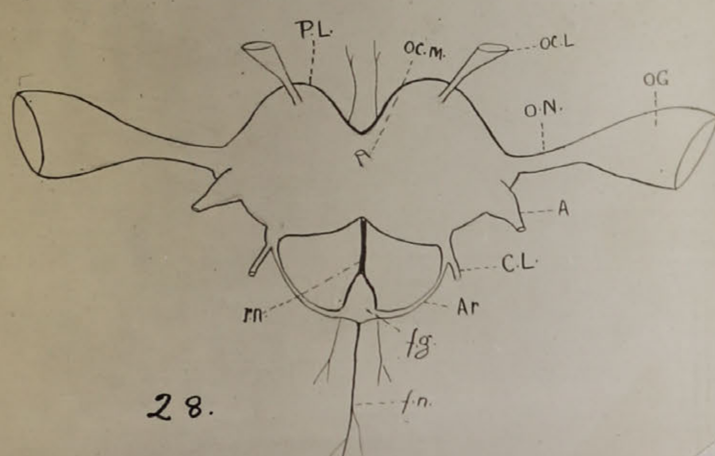

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Plate X

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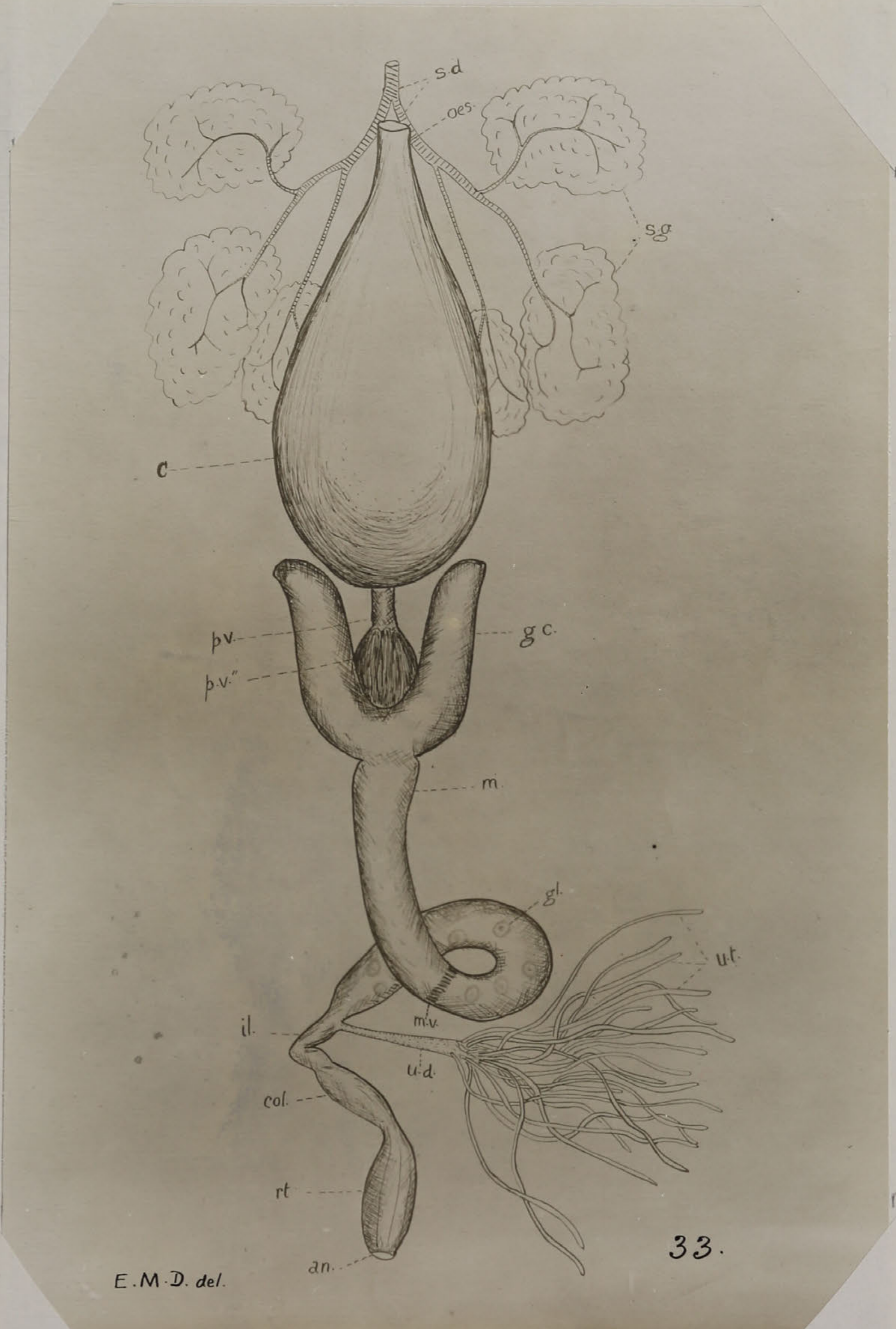
Plate XI



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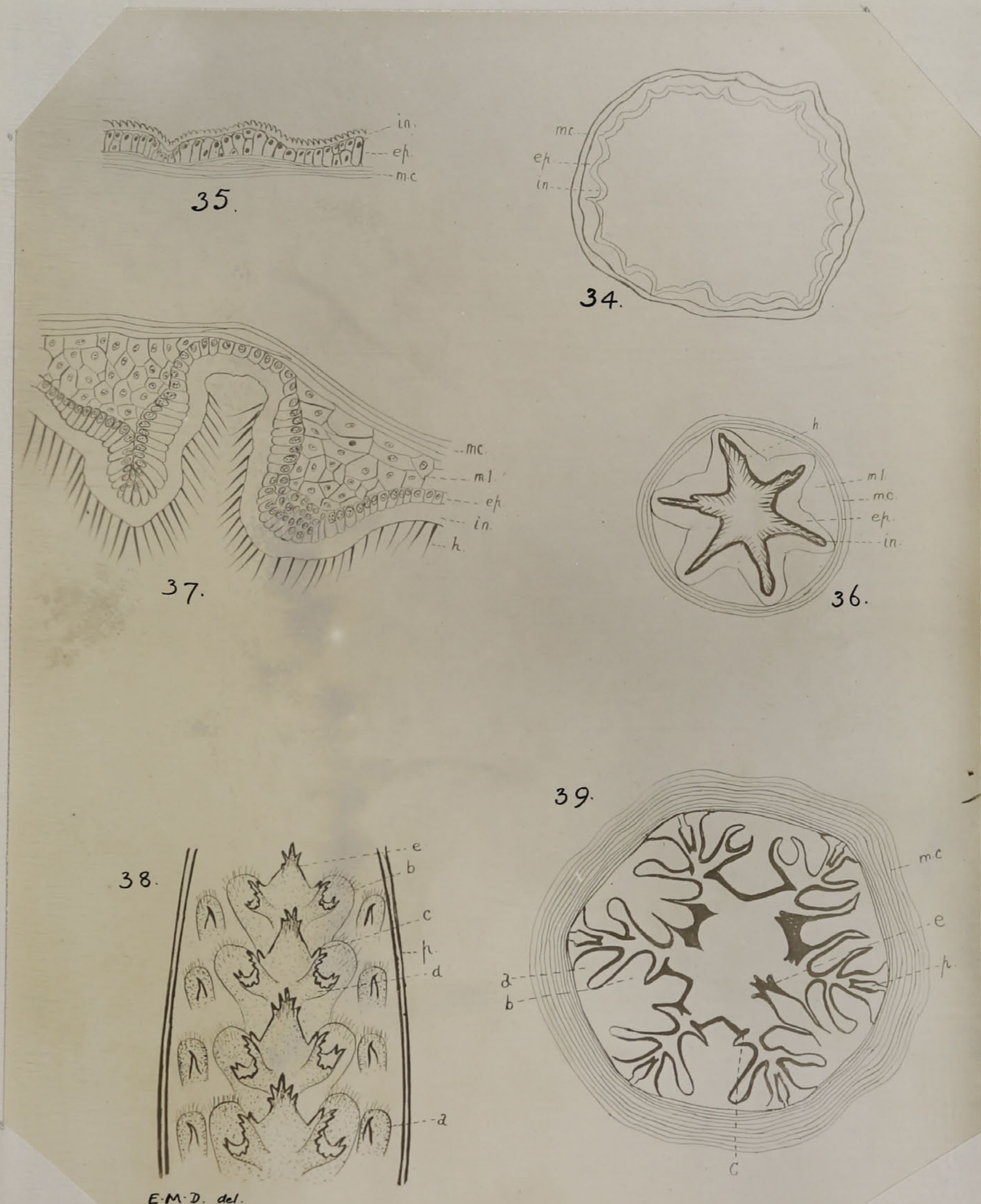

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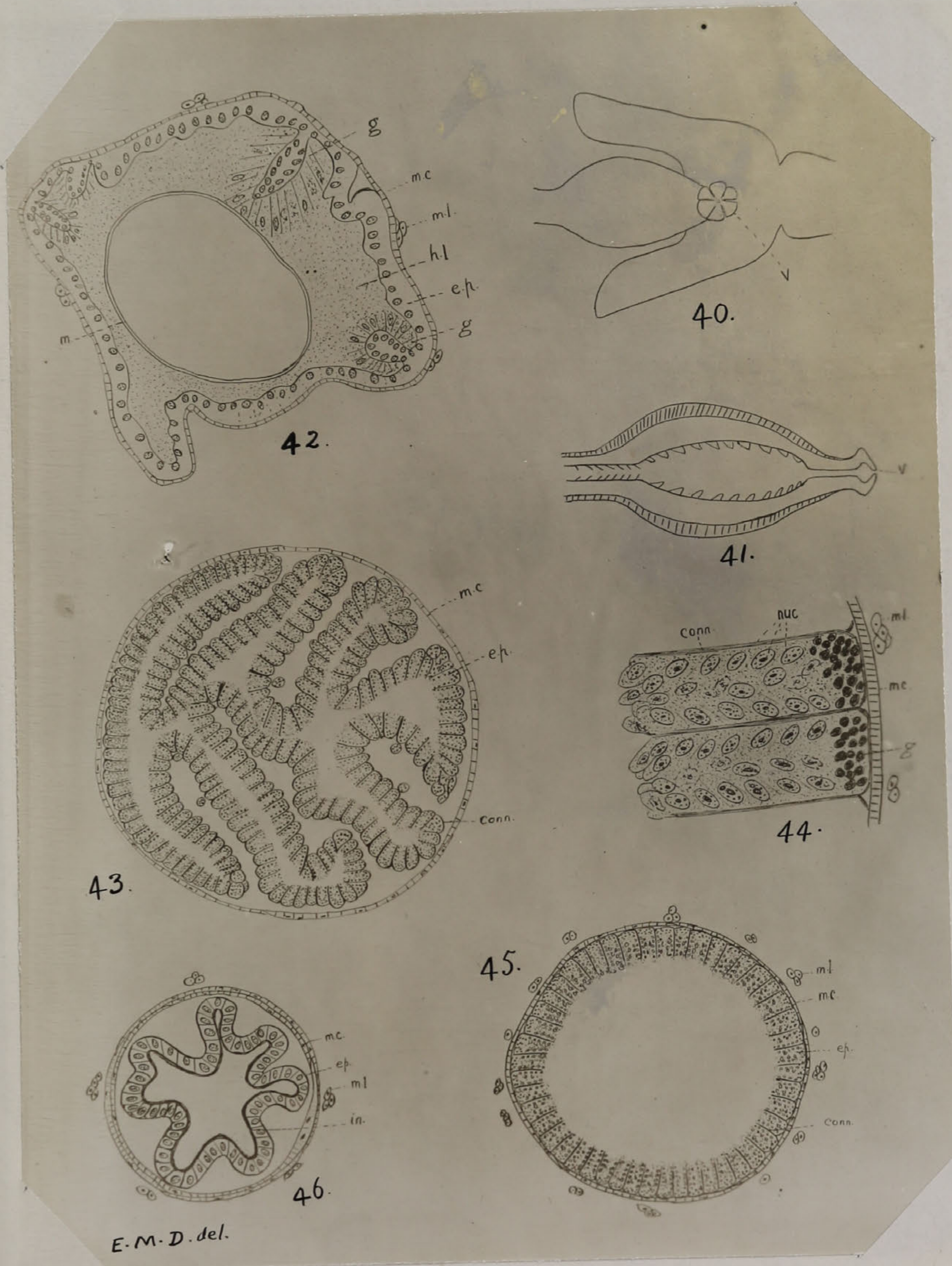
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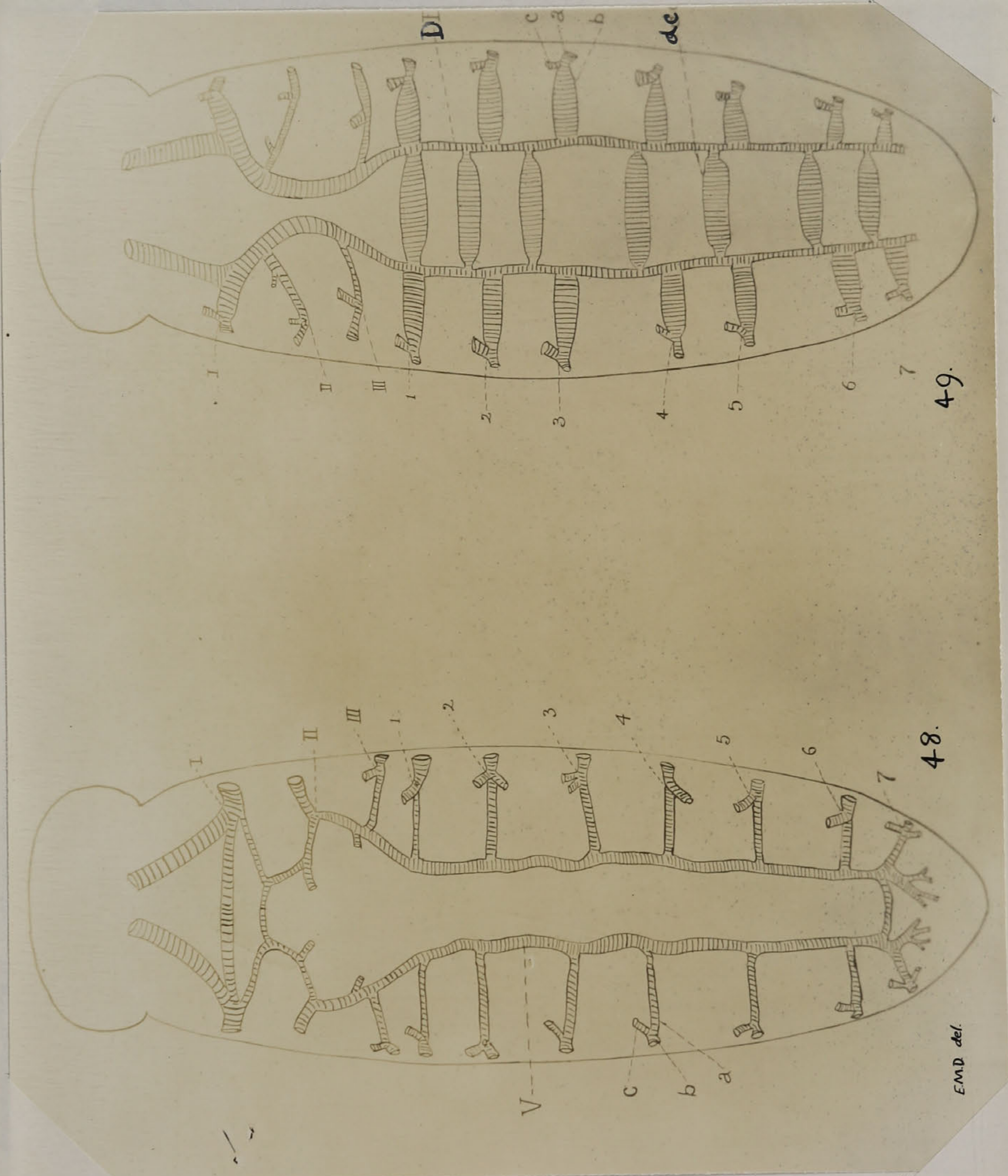
Plate XIV.



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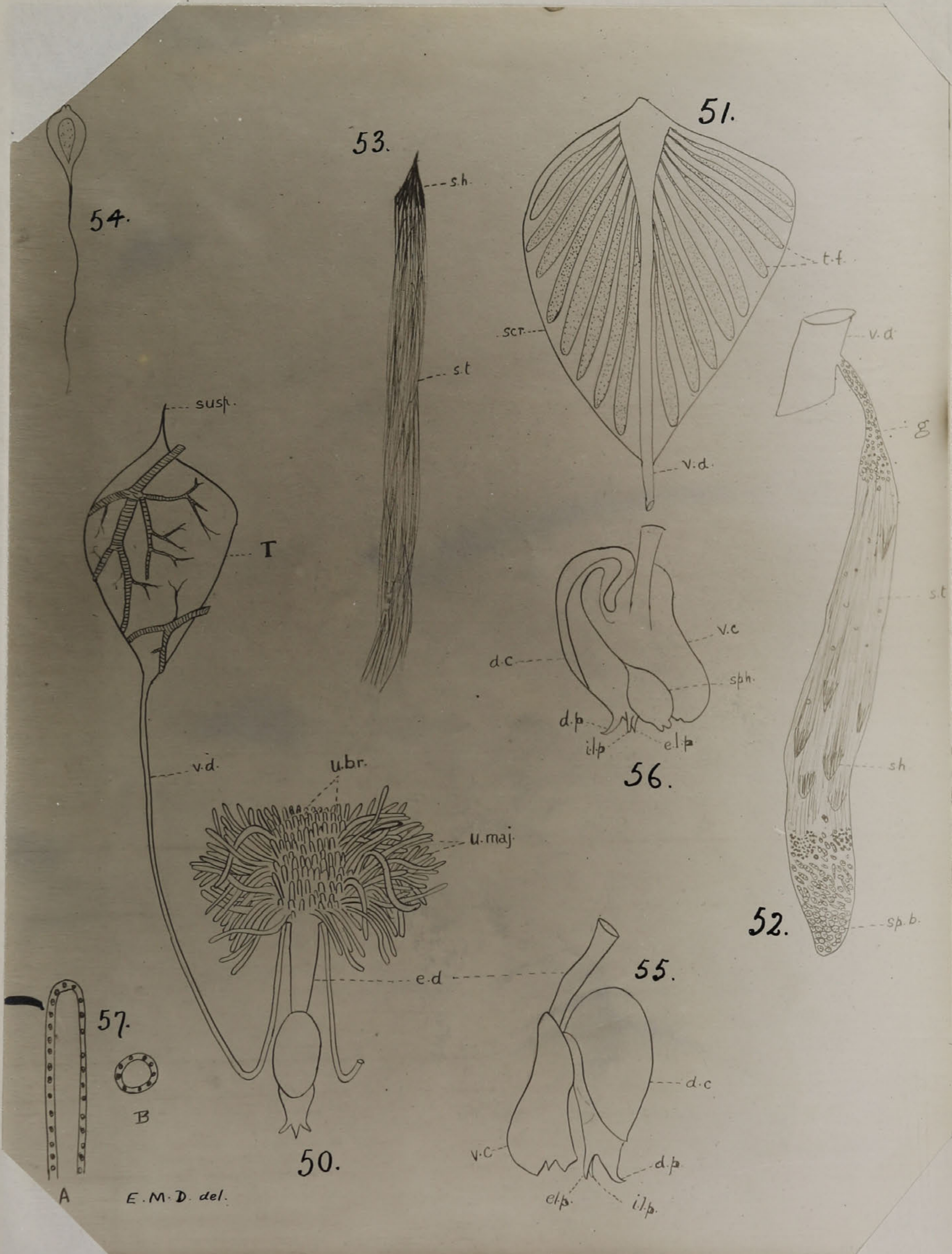

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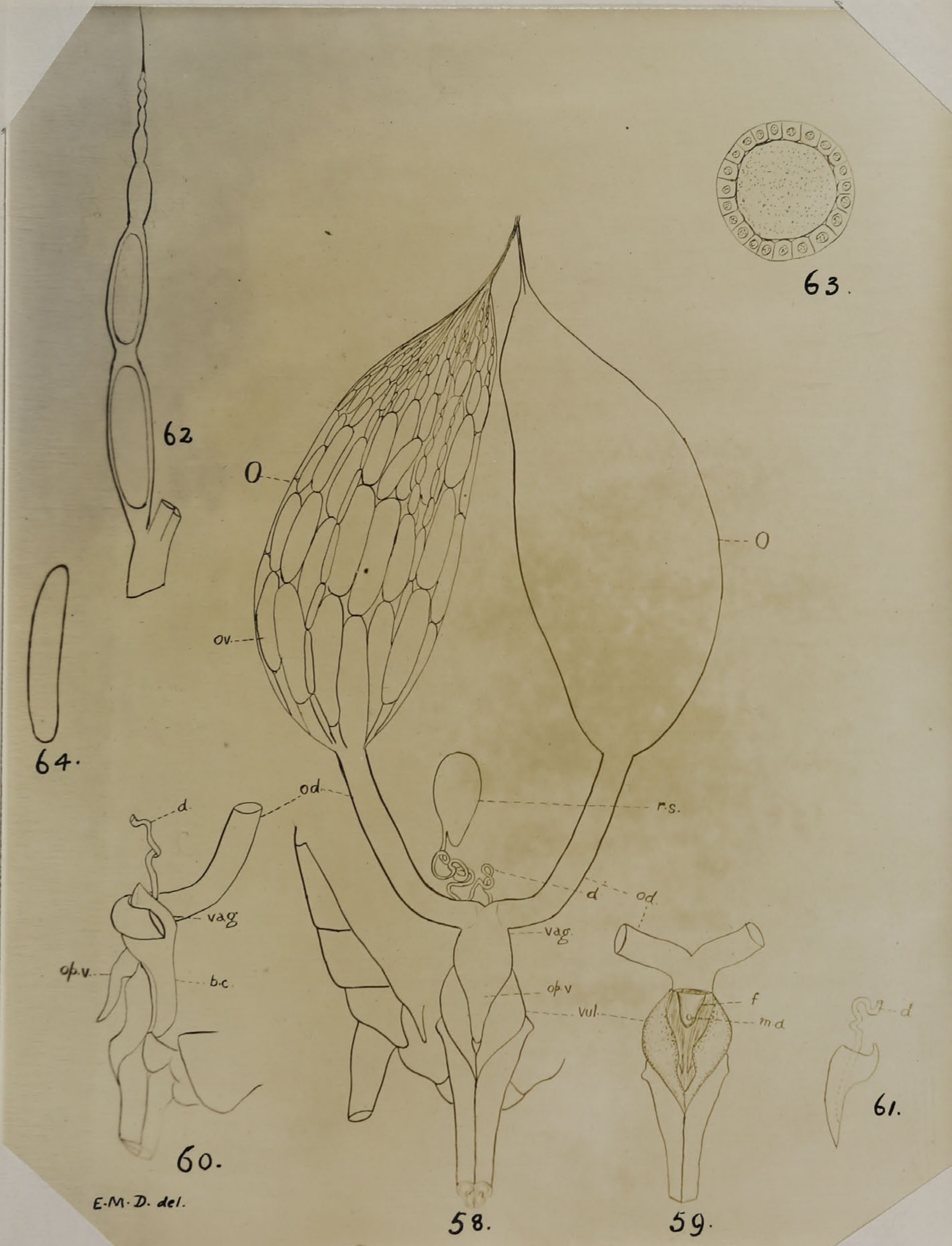
Plate XVI



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