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EXTERNAL MORPHOLOGY AND INTERNAL ANATOMY OF A  
LANTERN-FLY, *LYCORMA DELICATULA* WHITE.

光蟬之形態與解剖

K. O. VICTORIA LIEU. 劉君諤

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**Introduction.**

The lantern-fly, *Lycorma delicatula* White, is very common in Peiping and its vicinity, They occur abundantly from June to August; but their number decreases gradually from September. The material used was mostly collected from the grape-vine, the willow-tree, and the Tree of Heaven. Their nymphs were also found on the hollyhocks.

It was very difficult to keep the adults living for any length of time in cages. When the study of this problem was begun in the middle part of September 1932, the adults were decreasing in number and only one or two to at most eight specimens could be obtained in each collecting trip. If they were

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kept in a wire cage; they usually died in about two hours. But if they were put in a glass bottle, loosely covered with a cork stopper, they could live a little longer: a male could live for half a day while a female could live over night. If several of them were put together in one glass bottle, the inner surface of the bottle always showed the condensation of a good deal of water vapor within a few hours. This means that these insects suffer the loss of water contents very easily and this is probably why they died more quickly in a wire cage.

The systematic position of this species according to the *Fauna of British India* is as follows:

Phylum Arthropoda  
Class Hexapoda  
Subclass Pterygota  
Order Homoptera  
Family Fulgoridae  
Genus *Lycorma*  
Species *L. delicatula* White.

The drawings were made with the aid of the binocular microscope, the Edinger drawing apparatus and the delineascope, or with the binocular microscope and cross-section eye-piece.

## PART I. EXTERNAL MORPHOLOGY.

The two sexes of this species of Lantern-fly, *Lycorma delicatula* White, are very similar to each other, and they differ only in size and in the structure of the genitalia. Their measurements are as follows:

	Male.	Female.
Body length	18 mm.	22 mm.
Alar expansion	43 mm.	50 mm.
Length of abdomen	12 mm.	15 mm.
Width of abdomen	7 mm.	10 mm.

In studying the external morphology the complete specimens or their parts are heated in 20% KOH up to the boiling point. After the soft tissues are dissolved, they are washed in water and preserved in 95% alcohol. The external characters are then carefully studied and described. For the study of the genitalia, paper insectikins were also constructed to illustrate the parts and relations before the drawings were made.

### I. The Head.

The head is reflexed, being brownish in color, about 3 mm. wide and 7 mm. long. It is described in the following in a normal position (Figs. 3-5).

#### A. The Sclerites of the Head.

##### 1. The Epicranium.

The front, the vertex, the occiput, and the genae fuse together to form the head capsule, or the epicranium.

The EPICRANIAL SUTURE, or the Y-shaped suture, is not very distinct. The coronal suture is short and obscure, being on the median line of the vertex on the ventral surface. The frontal sutures are situated on the ridge which forms the posterior boundary of the front.

The FRONT is the large unpaired sclerite between the compound eyes and



the antennae. Its anterior portion is broad and smooth, and bounded by the clypeal suture. Its posterior portion is narrower and produced backward into a protuberance. Two parallel, longitudinal ridges follow the caudal extension to the ventral surface. Posteriorly it is bounded by the frontal sutures.

The VERTEX is the caudal portion of the epicranium. It is bounded dorsally by the frontal sutures and laterally by the compound eyes. Ventrally it is fused with the occiput. It is faintly divided into two parts by the coronal suture.

The OCCIPUT is the narrow region in the caudoventral part of the epicranium. It lies transversely between the genae, and is bounded dorsally by the vertex. Anteriorly it forms the caudal border of the occipital foramen.

The GENAE are the lateral portions of the epicranium. Each is bounded cephalad by the mandibular and maxillary sclerites, mesad by the fronto-genal suture and the antennal sclerite, caudad by the compound eyes and occiput, and ventrad by the occipital foramen. That part of the gena between the antennal sclerite and the compound eye carries a small ocellus.

### 2. *The Antennal Sclerites.*

On each side between the cephalo-lateral margin of the front and the gena there is a semi-circular sclerite, surrounding the base of the antenna. This is the antennal sclerite.

### 3. *The Clypeus.*

The clypeus is a large triangular sclerite, which is separated posteriorly from the front by the clypeal suture, and completely fused with the labrum in front. It curves downward on each side to join the mandibular sclerite. The clypeus together with the front constitutes the face.

### 4. *The Mandibular Sclerites.*

The mandibular sclerite is joined to the lateral margin of the clypeus on each side. It is elongated in shape, and bounded anteriorly by the labrum, posteriorly by the gena, and ventrally by the maxillary sclerite. To the ental surface of the dorso-caudal corner of the mandibular sclerite there is attached the mandibular seta, which continues to the tip of the beak in the form of a long bristle within the labium.

### 5. *The Maxillary Sclerites.*

The maxillary sclerite is the long, narrow, and pointed sclerite on each side below the mandibular sclerite and labrum. It is bounded posteriorly by the gena, and ventrally by the occipital foramen. It is curved downward and mesad to meet its fellow from the other side above the base of the labium. To its ental surface there is attached the maxillary seta, which also continues to the tip of the beak in the form of a long bristle with the labium.

## B. *The Eyes.*

### 1. *The Compound Eyes.*

On the caudo-lateral portions of the head there is on each side a large and somewhat ovoid compound eye, which is prominently bulging.

### 2. *The Ocelli.*

On the lateral portions of the head there are two ocelli, one on each side.



Each is situated on the gena between the antennal sclerite and the compound eye.

### C. The Appendages of the Head.

#### 1. The Antennae.

The antennae are inserted in the semi-circular antennal sclerites. Each consists of three segments, the scape, the pedicel, and the clavola. The scape is brown, chitinized at base and membranous at the distal part. The pedicel is red, thickened, and covered with sense-papillae. The clavola is black and sebaceous (Fig. 6).

#### 2. The Labrum.

The labrum is completely fused with the anterior border of the clypeus, without being separated by any suture. It is convex above and bounded by the mandibular and maxillary sclerites on the sides. Its cephalo-lateral corners are curved downward on both sides. In front of it is the membranous epipharynx.

#### 3. The Mandibles.

The two mandibles, together with the two maxillae, constitute the essential parts within the long tube-like labium for piercing and sucking. Each mandible consists of a long chitinized needle with a thickened basal part which is provided with a hook at the proximal end for attachment to the ental surface of the dorso-caudal corner of the mandibular sclerite and a long chitinized tendon for attachment to the muscles (Figs. 7,11).

#### 4. The Maxillae.

Each maxilla is also a long chitinized needle with a thickened basal part which is provided with some muscles in its middle part for attachment to the ental surface of the maxillary sclerite (Figs. 8,11).

#### 5. The Epipharynx.

The epipharynx is a triangular, membranous flap, projecting forward from beneath the labrum. It lies above the base of the beak (Fig. 9).

#### 6. The Labium.

The labium is five-jointed. It is heavily chitinized and dark brown in color. It is elongated and rolled up dorsally into a tube-like beak, being blunt at the tip and with a longitudinal groove on the dorsal side. Proximally, it is attached to the ventral side of the head by membranes. Within the tube are the two mandibular setae and the two maxillary setae, which can be seen after the removal of the epipharynx (Fig. 10).

## II. The Thorax.

The thorax is brownish. It consists of three segments, the prothorax, the mesothorax and the metathorax. Each segment bears a pair of legs on the ventral side, and each of the two posterior segments bears a pair of wings on the lateral sides.

There are two pairs of spiracles on the sides of the thorax, one pair between the pro- and meso-thorax, and the other pair between the meso- and meta-thorax.



## A. The Prothorax.

### 1. The Protergum.

The protergum is a transverse and narrow plate. Its dorsal surface is somewhat convex. It consists of four sclerites, the prescutum, the scutum, the scutellum, and the post-scutellum.

The PRESCUTUM is the narrow reniform sclerite on the anterior margin. The spindle-shaped sclerite lying immediately behind the prescutum is the SCUTUM. The SCUTELLUM is divided into two parts, one on each side of the scutum. The narrow sclerite on the posterior margin is the POST-SCUTELLUM. The scutellum and the post-scutellum are folded downward on the sides to meet the episterna and epimera (Fig. 13).

### 2. The Propleura.

The propleura constitute the lateral portions of the ventral surface of the prothorax. Each is divided into a mesal epi-sternum and a lateral epimeron by the pleural suture. An obscure transverse suture subdivides the episternum and epimeron into the anterior an-episternum and an-epimeron and the posterior kat-episternum and kat-epimeron.

### 3. The Prosternum.

The prosternum consists of only a single U-shaped sclerite, the STERNUM. On each side it is attached to the caudo-mesal portion of the kat-episternum. There are two furcal pits on the median part on the sternum, and from these furcal pits the first furca is invaginated dorso-cephalad into the thoracic cavity (Fig. 14).

## B. The Meso-thorax.

### 1. The Meso-tergum.

The meso-tergum is large, prominent, and exposed. It consists of four sclerites, the prescutum, the scutum, the scutellum, and the post-scutellum.

The PRESCUTUM is a very narrow, crescent-shaped sclerite, extending entad from the anterior margin as a transverse partition between the pro- and meso-terga. It is therefore the first thoracic phragma.

The SCUTUM is the large, pear-shaped, convex sclerite, the apex of which extends backward to cover the median part of the post-scutellum. On the cephalo-lateral corners are the anterior notal processes, to which the anterior margins of the fore wings are articulated.

The caudal prolongation of the scutum divides the SCUTELLUM into two portions and pushed them to the caudo-lateral corners.

The POST-SCUTELLUM is a long, narrow sclerite which curves backward in following the caudal prolongation of the scutum. On the sides it is produced into the posterior notal processes, to which the posterior margins of the fore wings are articulated (Fig. 15).

### 2. The Meso-pleura.

Like the propleura, the meso-pleura are each composed of two sclerites, a larger anterior EPISTERNUM and a smaller posterior EPIMERON, which are separated by the pleural suture. They are situated on the sides of the meso-thorax and the episternum continues ventrad to be partly fused with the



sternum on the ventral surface (Fig. 16).

### 3. The Meso-sternum.

The meso-sternum consists of a single sclerite, the STERNUM. It is located between the two coxal cavities and is slightly constricted in the middle. Cephalo-laterad it is fused with the episterna. It lies in a slanting caudo-ventral plane. There is a transverse ridge across the middle, and in front of the ridge there are two furcal pits, from which are invaginated the second furca. Behind the ridge there are two other pits (Fig. 17).

## C. The Meta-thorax.

### 1. The Meta-tergum.

The meta-tergum has its prescutum and its cephalo-lateral portions overlapped by the posterior part of the meso-thorax. It consists of four sclerites, the prescutum, the scutum, the scutellum, and the post-scutellum.

The PRESCUTUM is divided into two triangular pieces by a very deep notch and is invaginated inward and downward to form the second thoracic phragma.

The SCUTUM is a large triangular sclerite, with its lateral parts produced cephalo-laterad to form the anterior notal processes, and with its apex pointing posteriorly to dovetail into the scutellum.

The SCUTELLUM is divided by the posterior elongation of the scutum into two large, triangular portions. It is bounded cephalo-mesad by the scutum, caudad by the post-scutellum, and laterad by the pleura.

The POST-SCUTELLUM is a long, narrow, and transverse sclerite, bounded anteriorly by the scutellum, and posteriorly by the first abdominal segment (Fig. 18).

### 2. The Meta-pleura.

On each side the meta-pleurum is composed of two sclerites, the episternum and the epimeron, which are separated by the pleural suture but the posterior margin of the episternum overlaps the epimeron.

The epi-sternum is incompletely divided into two sclerites, the an-episternum and the kat-episternum. The epimeron is also divided into the an-epimeron and the kat-epimeron. The caudo-ventral part of the an-epimeron extends ventrad and mesad to almost the median line of the ventral surface (Fig. 20).

### 3. The Meta-sternum.

The meta-sternum consists of two sclerites, the sternum and the sternellum. The STERNUM is triangular in shape with its apex pointing posteriorly and its lateral portions joined to the ventral margins of the an-episternum.

The STERNELLUM is also triangular in shape, but with its apex pointing anteriorly and its posterior margin attached to the first abdominal sternite. It is almost entirely covered by the ventral prolongations of the an-epimera (Fig. 29).

## D. The Appendages of the Thorax.

### 1. The Legs.

Three pairs of legs are born by the three thoracic segments. The legs



are brown, slender, and flattened, and are covered all over with short hairs.

(a) *The Fore-legs.*

Each fore-leg is articulated dorsally to the propleurum by a larger and triangular and two very small and rounded ante-coxal pieces and ventrally by only one small triangular ante-coxal piece. Besides, on the membrane between the front legs there is another pair of elongated weakly chitinized patches.

The COXA is elongated.

The TROCHANTER is small and triangular.

The FEMUR has a short groove on the ventral side to receive the proximal portion of the tibia.

The TIBIA is thin and slender, and is longer than the femur.

The TARSUS is composed of three segments. The first and second segments are sub-equal in length, while the third or distal one is twice as long as the first or second, bearing a pair of claws and an empodium which projects between the claws (Figs. 24, 27).

(b) *The Mid-legs.*

Each mid-leg is articulated to the episternum by a small triangular ante-coxal piece.

The COXA is also elongated, and it bears a short spine on its dorsal side.

The TROCHANTER, FEMUR, TIBIA, and TARSUS are similar to those of the fore-leg (Figs. 25, 28).

(c) *The Hind-legs.*

The hind-leg is the longest of the three. It is articulated to the an-epimeron without any ante-coxal piece.

The COXA is short and ring-like. Its ventral margin fits into the curved posterior margin of the epi-meron of the metathorax. Its ventral margin fits into the curved posterior margin of the epimeron or the metathorax. From the ventral margin of the proximal end of the coxa a long chitinized process extends entad into the thoracic cavity in the form of a funnel. To this is attached the muscle for controlling the jumping motion of the hind leg.

The TROCHANTER is a very small triangular sclerite between the coxa and the femur on the posterior surface.

The FEMUR is similar to that of the fore-leg or the mid-leg.

The TIBIA is much longer than the femur and is provided on the dorsal margin with a number of spines, varying from 3 to 5. At the distal end of the tibia there are 7 tibial spurs on the posterior surface.

The TARSUS of the hind-leg differs from that of the fore-leg or mid-leg. Its first or proximal segment is sub-equal in length to its third segment. The second segment is shorter than either one of them. The first and second segments bear each a row of short teeth on the distal margin on the caudal surface. The third segment bears a pair of claws and an empodium (Figs. 26, 29-30).

2. *The Wings.*

Two pairs of membranous wings are born by the meso-thorax and meta thorax respectively.

(a) *The Fore Wings.*



The fore wings are long and narrow. In each of them, the proximal part is yellowish with conspicuous longitudinal veins and black dots, while its distal third is black with numerous, parallel accessory veins and cross-veins. When at rest, the fore wings meet in a straight line along the meson above and are held roof-like over the body (Fig. 22).

(b) *The Hind Wings.*

The hind wing is slightly shorter with enlarged anal area. Its basal half is red with black dots, its distal part is black and there is a narrow, and yellowish transparent median area between. In the pre-anal area, the proximal portion has only a few conspicuous longitudinal veins, while its distal portion has numerous, parallel accessory veins and cross-veins. In the anal area, there are only a few longitudinal veins but many cross-veins. When at rest, the anal areas of the hind wings are folded twice beneath the fore wings (Fig. 23).

(c) *The Venation of the Wings.*

In the fore wing, the costal and subcostal veins are fused together and located on the costal margin. The radial vein forks near the base with  $R_1$  extending to beyond the middle where it divides and subdivides into several branches near the apex. The  $R_s$  also gives off four branches which again divide and subdivide into many accessory veins. The media is four-branched and the cubitus is two-branched with  $Cu_2$  fused with 1A. The first and second anal veins are far apart at the base, but coalesce at the tips.

In the hind wing, the costal and subcostal veins are also fused together. The radial vein appears to fork at the base but  $R_2+3$  fuse with  $R_1$  so that both  $R_2$  and  $R_3$  come off from  $R_1$  near the apex.  $R_4+5$  extends outward beyond the middle to fork into  $R_4$  and  $R_5$ . The media forks at the middle and its first branch divides again into  $M_1$  and  $M_2$ , while the second branch extends to the margin as  $M_3+4$ .  $Cu_1$  and  $Cu_2$  are separate at the base. 1A and 2A arise together at the base and 1A is two-branched with its first branch extending forward to unite with  $Cu_2$  at the tip. 2A and 3A do not extend to the margin.

(d) *The Articular Sclerites of the Wings.*

In the fore wing, there are three axillary sclerites, a median plate, and a scale-like tegula.

The first axillary articulates with the anterior notal wing process and the bases of costa, subcosta, and radius.

The second axillary fuses anteriorly with the first axillary and it articulates distally with the base of radius and the median plate. Proximad of the second axillary, there is a detached part of it.

The median plate articulates proximally with the second axillary and the base of radius, and distally with the bases of the media, cubitus, and the first anal vein.

The third axillary articulates anteriorly with the second axillary and the median plate, posteriorly with the posterior notal wing process, and distally with the bases of the first and second anal veins.

In the hind wing, there are also three axillary sclerites and a median plate.

The first axillary articulates with the anterior notal wing process, the bases



of the costa, subcosta, radius, and media, and the median plate.

The second axillary fuses anteriorly with the first axillary, and it articulates distally with the median plate and posteriorly with the third axillary.

The median plate articulates proximally with the first and second axillaries and distally with the base of cubitus.

The third axillary articulates proximally with the posterior notal wing process and the second axillary, and distally with the bases of cubitus and anal veins.

### III. The Abdomen.

#### A. The Abdominal Segments.

The abdomen is provided with dark brown chitinized sclerites which are connected together by broad and yellow conjunctivae. It consists of eleven segments, all of which are visible from the dorsal side in both the males and females (Figs. 31-36).

Segment 1 consists of a tergite and a sternite which are very narrow and weakly chitinized. Segments 2-7 are normal and ring-like. Each is made up of three parts: (1) a dorsal tergite, (2) a ventral sternite, and (3) two lateral pleurites. These tergites and sternites are all rectangular in shape while the pleurites are only small chitinized patches on the lateral sides. Segments 8-11 are more or less modified into the genitalia.

Besides the two pairs of spiracles between the pro- and meso-thorax and between the meso- and meta-thorax, there are eight more pairs of spiracles in the abdomen. The first two pairs are located dorsally on the conjunctivae in front of the first and second abdominal segments respectively. The next six pairs are situated on the dorso-cephalal corners of the pleurites 3-8.

#### B. The Genitalia.

##### 1. The Male Genitalia (Figs. 37-48).

The EIGHTH SEGMENT: The eighth tergite is very narrow and the sternite is divided into two parts by the anteriorly produced ninth sternite (Figs. 31-32).

The NINTH SEGMENT: The ninth tergite and sternite are completely fused into a ring, through which the ejaculatory duct and the rectum pass posteriorly to their respective openings. The sternite is modified into a broad plate to protect the passage of the ejaculatory duct into the chitinized penis. This is the SUB-GENITAL PLATE.

The TENTH SEGMENT: The tenth tergite curves downward on the sides to form a complete tube for the passage of the rectum. The tenth sternite consists of two separate parts which are joined together on the median line by a membrane.

The ELEVENTH SEGMENT: The eleventh segment consists of two pairs of sclerites, an anterior and a posterior pair. Behind the posterior sclerites there is the anus opening on the membrane. Ventrally the anterior and posterior sclerites are produced forward and backward respectively into two pairs of chitinized processes. The posterior pair of processes are visible above and are fused together at the extreme posterior end.



The PENIS: The penis is heavily chitinized, consisting of a ventrally-concave plate and the posterior termination of the ejaculatory duct, which is thickened and chitinized and is divided into two branches. These branches are chitinized and enlarged at base into two bulbular structures which continue backward into a pair of chitinized tubes with the male genitalia openings at the tips. The penis is therefore a double structure. The penis is encircled at base by a chitinized girdle and is attached by a chitinized stalk on the ventral side to the membrane between the two parts of the tenth sternite. From the girdle there are produced backward four pairs of processes which are the claspers.

### 2. The Female Genitalia (Figs. 49-54).

The EIGHTH SEGMENT: The eighth tergite is also narrow, but broader than that in the male. The sternite is divided into two separate portions, one on each side. To the mesal and caudal margins of these are attached the ventral ovipositors.

The NINTH SEGMENT: The ninth tergite is broad, but emarginated on the caudal margin. The sternite consists of two lateral portions, which are connected together by a very narrow chitinized bar and a transparent membrane which is provided with two chitinized patches, one on each side, for the attachment of the dorsal ovipositors and the separate parts of the tenth sternite. This transparent membrane continues anteriorly, and turns ventrally to attach itself to the dorsal surfaces of the basal sclerites of the ventral ovipositors in order to form an elastic tube, which is continued with the vagina, for the passage of the well-developed eggs. This transparent membrane serves as the partition between the ovipositors and rectum.

The TENTH SEGMENT: The tenth tergite is similar to that of the male, except that it is located more posteriorly than in the male. The sternite consists of two separate portions, each of which is attached dorso-laterally to one of the chitinized patches on the transparent membrane of the ninth sternite. Each is then curved downward toward the meson.

The ELEVENTH SEGMENT: The structure and function of this segment are similar to those of the same segment in the male.

The OVIPOSITORS: There are four ovipositors, two dorsal and two ventral. The two dorsal ovipositors are fused together at base on the meson and are attached to a single basal sclerite. The two ventral ovipositors are each composed of two portions and each attached to a single basal sclerite, which is partly fused to the caudo-mesal margin of each separate portion of the eighth sternite.

## PART II. INTERNAL ANATOMY.

Though the external morphology of a few species of the lantern-flies has been studied to a certain extent by some writers, the internal anatomy of this family has not been worked out in detail. In the present work, six systems of internal organs of this species, *Lycorma delicatula* White, have been worked out and the descriptions of them are herewith presented in the following order:

- I. The Skeletal System.
- II. The Circulatory System.
- III. The Digestive System.
- IV. The Excretory System.



## V. The Secretory System.

## VI. The Reproductive Systems.

The various reagents used in preparing the specimens for study are mentioned in the descriptions of the systems. The most satisfactory fixative for the preservation of the internal organs is found to be the Diedrich's solution.

## I. The Skeletal System.

**METHOD:** The material used for the study of the endoskeleton is first heated in 20% KOH up to the boiling point, and all the soft tissues are washed away. After this, it is soaked in 95% alcohol for an hour or so, and then it is ready for study.

**DESCRIPTION:** The endoskeleton consists of all the invaginations of the body wall. Each invaginated part is generally termed an apodeme.

## A. The Tentorium.

The apodemes inside the head capsule are known collectively as the tentorium. It consists of three pairs of arms: the anterior, the posterior, and the dorsal arms (Figs. 55-56).

The ANTERIOR ARMS arise together from the tip of the chitinized and curved prolongation of the oesophagus beneath the labrum, and extend caudo-lateral along the inner surface of the maxillary sclerites to the region of the fronto-clypeal suture where they are united with the posterior arms to form the body of tentorium as the anterior border of the occipital foramen.

The POSTERIOR ARMS are very short and each extends from the caudo-ventral corner of the maxillary sclerite first caudad and then mesad to unite with the anterior arms to form the body of the tentorium as the anterior margin of the occipital foramen.

Each DORSAL ARM arises from the middle of the body of the tentorium and extends cephalo-laterad to the base of the antenna.

## B. The Endothorax.

The apodemes inside the thorax are known collectively as the endothorax. The apodemes from the thoracic tergites are called the phragmae; those from the pleurites, the lateral apodemes; and those from the sternites, the furcae (Figs. 57-59).

## 1. The Phragmas.

The phragmas are transverse partitions extending ventrad from the margins of the tergites. The first phragma is invaginated from the anterior margin of the meso-tergite, and is narrow and slightly indented on the meson. The second and third phragmae are invaginated from the anterior and posterior margins of the meta-tergite respectively. The second phragma is the largest, and the indentation on its median line is so deep that it is almost divided into two portions. The third phragma is long and very narrow in the middle.

## 2. The Lateral Apodemes.

The lateral apodemes are vertical partitions extending entad from the pleural sutures between the episterna and epimera. The first lateral apodemes are in the prothorax. They are very narrow, and are fused ventrally with the arms of the first furca. The second lateral apodemes are in the meso-thorax. They are



triangular in shape. The third lateral apodemes are in the meta-thorax. They are large and thickened and are irregular in shape.

### 3. The Furcae.

The furcae are bifid invaginations extending dorso-cephalad from the sternites. The first furca is in the prothorax. It is invaginated from the two furcal pits in the middle part of the pro-sternum. The second furca is in the mesothorax, and is invaginated from the two furcal pits in front of the transverse ridge in the middle part of the meso-sternum. The third furca is in the meta-thorax. It is a small fork, the apex of which is fused with the anterior apex of the meta-sternellum.

## C. The Endoskeleton of the Abdomen.

Besides the endoskeleton in the head capsule and the thorax, there is an apodeme in the abdomen. In the male, it is on the anterior margin of the ninth sternite (Fig. 32). In the female, it consists of two portions, one on the dorso-cephalal margin of each portion of the eighth sternite (Fig. 36).

## II. The Circulatory System.

**METHOD:** For this system, the fresh specimen is dissected in 0.5% normal saline. After the ventral body wall, the muscles, the internal organs, and the adipose tissues are carefully removed, the system can be seen. Then the specimen is fixed in Diedrich's solution, and stained with a few drops of 10% Delafield Haematoxylin until the alary muscles of the heart are made clear.

**DESCRIPTION:** The circulatory system is very simple in structure. It consists of the heart, the aorta, and the wings of the heart (Fig. 60).

The **HEART** is a simple, straight, tubular vessel, lying on the median line in the dorsal part of the body cavity, between the dorsal body wall and the alimentary canal. Its closed posterior end is attached to the anterior margin of the eighth abdominal tergum, and its open anterior end is continuous forward with the aorta. The **AORTA** is simply the prolongation of the heart, and it extends through the thorax into the head, where it opens into the sinus in front of the brain. The heart is divided into seven chambers by six constrictions, and is provided with seven pairs of triangular alary muscles, or the **WINGS OF THE HEART**. At each constriction there is a pair of ostia, one on each side, which can be seen after being stained with 1% eosin in 95% alcohol. Each wing consists of a bundle of fine muscle-fibers which converge to an apex and is attached to the intersegmental conjunctiva at a point half way between the heart and the lateral margin of the dorsal body wall. The apices of the seven pairs of wings are all attached to the intersegmental conjunctivae between the first and eighth segments.

The blood in the heart flows forward from the open cephalic end of the aorta into the head, passes through various sinuses, and returns to the heart through the ostia. Thus the circulation is completed.

## III. The Digestive System.

**METHOD:** The living specimen is etherized and dissected in 0.5% normal saline. After the careful removal of the dorsal body wall, the muscular and



adipose tissues, the secretory system, and also the ovaries in case of the female, the digestive system can be easily traced out in full.

**DESCRIPTION:** The digestive system is a very long, partly convoluted tube in the body cavity above the reproductive and the nervous systems. It can be distinguished into three principal regions: (A) the stomodaeum; (B) the mesenteron; and (C) the proctodaeum (Figs. 61-64).

### **A. The Stomodaeum or Fore-gut.**

The stomodaeum consists of (1) a sucking tube in the beak, (2) a pumping organ in the head (3) a buccal cavity, (4) an oesophagus, (5) a proventriculus, and (6) a crop. The last three mentioned are all of a milky white color.

#### *1. The Sucking Tube.*

The sucking tube is formed by the interlocking of the maxillary setae and is enclosed within the labium.

#### *2. The Pumping Organ.*

This organ is a highly specialized one, consisting of a pump, a convoluted salivary duct, and a chitinized support. It lies in the anterior cavity of the head capsule, being situated below the buccal cavity and bounded ventrally and laterally by the anterior portion of the anterior arms of the tentorium. The salivary duct extends from the pump forward above the chitinized support and below the buccal cavity to open through a small opening at a point beneath the labrum and epipharynx and above the maxillary sclerites.

#### *3. The Buccal Cavity.*

The buccal cavity is the posterior continuation of the sucking tube and it extends backward into the head from a point immediately above the opening of the salivary duct. It is a cavity bounded above by the labrum and clypeus and below by a slightly concave chitinized floor. Posteriorly in the region near the posterior margin of the mandibular sclerites it opens into a slender oesophagus.

#### *4. The Oesophagus.*

The oesophagus curves backward between the supra-oesophageal ganglion and the body of tentorium and enlarges gradually to form the proventriculus in the thorax.

#### *5. The Proventriculus.*

This is a straight tube in the meso- and meta-thorax. Its diameter is 3 or 4 times that of the oesophagus.

#### *6. The Crop.*

At the posterior end of the proventriculus there is formed a caecum-like crop which is directed forward and enlarged into a sac.

### **B. The Mesenteron, Ventriculus, or Mid-gut.**

Immediately following the proventriculus, the ventriculus is a very long, orange-yellow, convoluted tube about 90 mm. long with a fairly uniform diameter. In the mature male, it is mostly found in the abdomen; while in the female, it is crowded forward into the posterior half of the metathorax by the ovarian tubules. It is separated from the proctodaeum behind by a deep constriction. Near this constriction there are inserted four long, slender, thin,



and transparent Malpighian tubules two on each side (Fig. 61-63).

### C. The Proctodaeum or Hind-gut.

The proctodaeum constitutes the third and last division of the digestive system. It is a straight tube about 9 mm. long, and is thicker than the mesenteron. Posteriorly it narrows down to form the rectum, which passes through the ring-like 10th tergite to the anus opening on the membrane of the 11th tergite.

## IV. Excretory System.

**METHOD:** This system is dissected out in normal saline along with the digestive system.

**DESCRIPTION:** At the posterior end of the mesenteron, very near to the deep constriction between the mesenteron and the proctodaeum there are inserted four long, blind tubules, two on each side. These are the urinary or Malpighian tubules, which constitute the excretory system (Figs. 61-63).

They are very long, measuring about 60 mm. in length. They are also very thin, transparent, and milky white in appearance. They extend back and forth on the sides of the proctodaeum and above the coil of the mesenteron. They are entangled with the tracheae and the adipose tissues. Since they are very long and delicate, great pains must be taken in dissecting them out without breaking them.

The function of these Malpighian tubules is to absorb the waste material from the blood in the sinuses through the membranous wall and to discharge such wastes into the digestive tract for expulsion.

## V. The Secretory System.

**METHOD:** Dissections are made of the specimens that are injected with and preserved in Diedrich's solution. After the caudal part of the epicranium and the dorsal body wall are removed, the glands, the reservoirs, and the ducts can be traced.

**DESCRIPTION:** In the caudal part of the head capsule, the thorax, and the abdomen, there are four pairs of salivary glands above the digestive system.

The first pair is situated in the caudal part of the head capsule, and the second pair is situated behind it on the lateral side in the pro- and meso-thorax. The ducts of these glands on each side combine into a common duct. The third pair is situated in the meso- and meta-thorax, while the fourth pair is slightly convoluted and it extends as far back as the 5th abdominal segment.

On each side, the common duct from the first two glands and the ducts of the third and fourth glands all meet together at a point between the pro- and meso-thorax. This point of fusion is concealed by the glands above, and from this point two curved salivary ducts extend mesad to join two lobe-like reservoirs in the pro- and meso-thorax. From this same point a salivary duct extends into the head and unites with the other one on the other side to form a short common salivary duct just before it opens into the pumping organ (Figs. 64-67).

## VI. The Reproductive Systems.



**METHOD:** Immediately after the specimens are etherized, dissections are made in 0.5% normal saline. The specimens are fixed in the Diedrich's solution in both natural and disentangled conditions. After two hours they are preserved in 95% alcohol.

**DESCRIPTIONS:**

**A. The Male Reproductive System.**

The male system consists of the testes, vasa deferentia, seminal vesicles, accessory glands, an ejaculatory duct, and a penis (Figs. 68-69).

The two red **TESTES**, each consisting of six testicular tubes, occupy the dorsal portions of the 7th and 8th abdominal segments. Their proximal ends join together and are attached to the 8th segment. The rectum passes backward beneath them into the ring-like 10th tergite. Their distal ends extend cephalo-laterad and curve ventrad into the vasa deferentia.

The **VASA DEFERENTIA** are two very fine tubes, each being about 20 mm. long. They form many coils on one plane on both sides in front of the testes. Their distal ends enlarge gradually into the **SEMINAL VESICLES**, which connect with the ejaculatory duct in the 5th abdominal segment.

The **EJACULATORY DUCT** is a thick and straight tube, which extends backward on the floor of the abdomen to the ventral surface of the ventrally-concave plate of the penis, where it becomes thickened and chitinized, and is divided into the two-branched **PENIS**.

The **ACCESSORY GLANDS** are two thick ducts, each being about 110 mm. long. Their anterior ends join the ejaculatory duct at its junction with the seminal vesicles. They form coils between the second and seventh abdominal segments above the ejaculatory duct and the coils of the vasa deferentia. Their posterior ends are attached to the muscles at the cephalo-lateral corners of the ventrally-concave plate of the penis.

**B. The Female Reproductive System.**

The female system consists of the ovaries, oviducts, vagina, colleterial glands, spermathecum, spermathecal glands, bursa copulatrix, and ovipositors (Figs. 70-71).

The two **OVARIES** occupy almost the entire abdominal cavity. Each ovary consists of 12 ovarian tubes, each of which has a terminal filament. All the terminal filaments unite together into suspensorium which extends directly forward to the prothorax and is attached to the muscles there.

The two **VIDUCTS** are short, broad ducts, extending from the ovaries to the median line where they join together to form the vagina.

The **VAGINA** is a thick-walled organ, the anterior part of which is bent ventro-caudad to the 7th abdominal segment. Its posterior end extends to the 8th segment, and continues backward to join to elastic tube which is formed by the 9th segment.

The **COLLETERIAL GLANDS** are two groups of short, thin, and closed tubules. Each group is arranged in a circle surrounding the oviduct on each side.

The **SPERMATHECUM** or seminal receptacle is for the storage of the seminal fluid from the male. From the dorsal side of the vagina the thickened basal



part of the seminal receptacle extends forward for a short distance and curves dorso-caudad to narrow down into a short tube before enlarging again into two sac-like divisions.

The SPERMATHECAL GLANDS are two very fine capillary-like tubules. Both open into the spermathecum at its distal end.

The BURSA COPULATRIX is the organ for the reception of the penis at the time of copulation and is very large and thick-walled. It opens into the vagina from the dorsal side behind the spermathecum. Its base is very thick. It is directed backward to the 8th abdominal segment, and then curved directly forward to the 5th abdominal segment. It is always covered by the fine spermathecal glands and their free ends.

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### Index to Figures.

A .....	Anal vein.	bsdov.....	basal sclerite of dorsal ovipositors.
ac.....	axillary cord.	bsvov.....	basal sclerite of ventral ovipositors.
acp.....	antecoxal piece.	bt.....	body of tentorium.
ag.....	accessary gland.	C.....	Costal vein.
alm.....	alary muscle.	cc.....	coxal cavity.
an.....	anus.	eg.....	colleterial gland.
an-epm.....	an-epimeron.	cl.....	clypeus.
anp.....	anterior notal wing process.	crop.....	cr.p.
ant.....	antenna.	cs.....	claspers.
ants.....	antennal sclerite.	csd.....	common salivary duct.
ao.....	aorta.	Cu <sub>1-2</sub> .....	Cubital veins <sub>1,2</sub> .
at.....	anterior arm of tentorium.	cw.....	claw.
Ax <sub>1-3</sub> .....	axillary sclerites <sub>1-3</sub> .	cx.....	coxa.
bc.....	bursa copulatrix.		
beak.....	beak.		



dov .....	dorsal ovipositors.	proc.....	process.
dt.....	dorsal arm of tentorium.	prov.....	proventriculus.
e.....	compound eye.	ps.....	penis.
ejd.....	ejaculatory duct.	pscl.....	post-scutellum.
emp.....	empodium.	psct.....	prescutum.
epi.....	epipharynx.	pt.....	posterior arm of tentorium.
epm.....	epimeron.	pump.....	pumping organ.
eps.....	episternum.	R <sub>1-5</sub> .....	Radial veins <sub>1-5</sub> .
f <sub>1-3</sub> .....	furcae <sub>1-3</sub> .	rec.....	rectum.
fe.....	femur.	RS.....	Radial sector.
fr.....	front.	S <sub>1</sub> •S <sub>11</sub> .....	abdominal sternites <sub>1-11</sub> .
fp.....	furcal pit.	sbgp.....	subgenital plate.
ge.....	gena.	Sc.....	Subcostal vein.
hi.....	hind intestine.	scl.....	scutellum.
ht.....	heart.	set.....	scutum.
kepm.....	kat-epimeron.	sd.....	salivary duct.
keps.....	kat-episternum.	sg <sub>1-4</sub> .....	salivary glands <sub>1-4</sub> .
la <sub>1-5</sub> .....	lateral apodemes <sub>1-3</sub> .	sp.....	spiracle.
li.....	labium.	spi.....	spine.
la.....	labrum.	spm.....	spermatheca.
M.....	Medial vein.	spm <sub>g</sub> .....	spermathecal gland.
m.....	membrane.	sr <sub>1-2</sub> .....	salivary reservoirs <sub>1-2</sub> .
md.....	mandible.	stn.....	sternum.
mds.....	mandibular sclerite.	stnl.....	sternellum.
mp.....	median plate.	sv.....	seminal vesicle.
mt.....	Malpighian tubules.	t <sub>1-t11</sub> .....	abdominal tergites <sub>1-11</sub> .
mx.....	maxilla.	tar.....	tarsus.
mxs.....	maxillary sclerite.	teg.....	tegula.
o.....	ocellus.	tf.....	terminal filaments.
oc.....	occiput.	ti.....	tibia.
ocf.....	occipital foramen.	tr.....	trochanter.
od.....	oviduct.	ts.....	testes.
ce.....	oesophagus.	tsp.....	tibial spurs.
est.....	ostia.	v.....	vertex.
ot.....	ovarian tube.	vag.....	vagina.
ov.....	ovary.	vd.....	vas deferens.
p.....	pleurite.	vent.....	ventriculus.
ph <sub>1-3</sub> .....	phragmae <sub>1-3</sub> .	vov.....	ventral ovipositors.
pnp.....	posterior notal wing process.		

### Explanation of Plates.

#### PLATE I.

- Fig. 1. Dorsal view of the female.  
 2. Ventral view of the female, with wings and legs removed.  
 3. Dorsal view of the head.  
 4. Ventral view of the head.  
 5. Lateral view of the head.  
 6. Antenna.  
 7. Mandible.  
 8. Maxilla.



9. Epipharynx.
10. Ventral view of labium.
11. Ventral view of the head, showing the attachment of the mandibles and maxillae.
12. Dorsal view of the thorax and the first two abdominal segments.
13. Pro-tergum.
14. Pro-sternum, with pro-pleura.
15. Meso-tergum.
16. Meso-sternum.
17. Meso-pleurum on the left side.
18. Meta-tergum.
19. Meta-sternum.
20. Meta-pleurum on the left side.

## PLATE II.

- Fig. 21. Dorsal view of the meso- and meta-thorax with the wings spread out to show the articular sclerites.
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  23. Hind wing, showing the venation.
  24. Ventral view of the pro-thorax, showing the articulation of the fore-legs.
  25. Ventral view of the meso-thorax, showing the articulation of the mid-legs.
  26. Ventral view of the meta-thorax, showing the articulation of the hind-legs and their funnel-shaped processes.
  27. Caudal view of the fore-leg.
  28. Caudal view of the mid-leg.
  29. Caudal view of the hind-leg.
  30. Cephalic view of the hind-leg.
  31. Dorsal view of the male abdomen.
  32. Ventral view of the male abdomen.
  33. Lateral view of the male abdomen.
  34. Dorsal view of the last five abdominal segments of the female.
  35. Ventral view of the last five abdominal segments of the female.
  36. Lateral view of the last five abdominal segments of the female.

## PLATE III.

- Fig. 37. Dorsal view of the male genitalia.
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  39. Dorsal view of the male genitalia, with  $t_9$ ,  $t_{10}$ , 11th segment, penis, and claspers removed to show the ental surfaces of  $s_9$  and  $s_{10}$ .
  40. Ventral view of the penis and claspers.
  41. Ventral view of the penis.
  42. Lateral view of the penis.
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  44. Lateral view of the male genitalia.
  45. Lateral view of the male genitalia, with 9th segment removed and 10th segment distended.
  46. Sagittal view of the male genitalia.
  47. Dorsal view of  $t_{10}$  and 11th segment of the male.
  48. Ventral view of  $t_{10}$  and 11th segment of the male.
  49. Dorsal view of the female genitalia.
  50. Ventral view of the female genitalia.



51. Ventral view of the female genitalia, with 10th and 11th segments removed to show the ventral ovipositors (vov) and their basal sclerites (bsvov).
52. Ventral view of the female genitalia, with vov and bsvov removed to show the dorsal ovipositors and their basal sclerite.
53. Lateral view of the female genitalia.
54. Sagittal view of the female genitalia.

## PLATE IV.

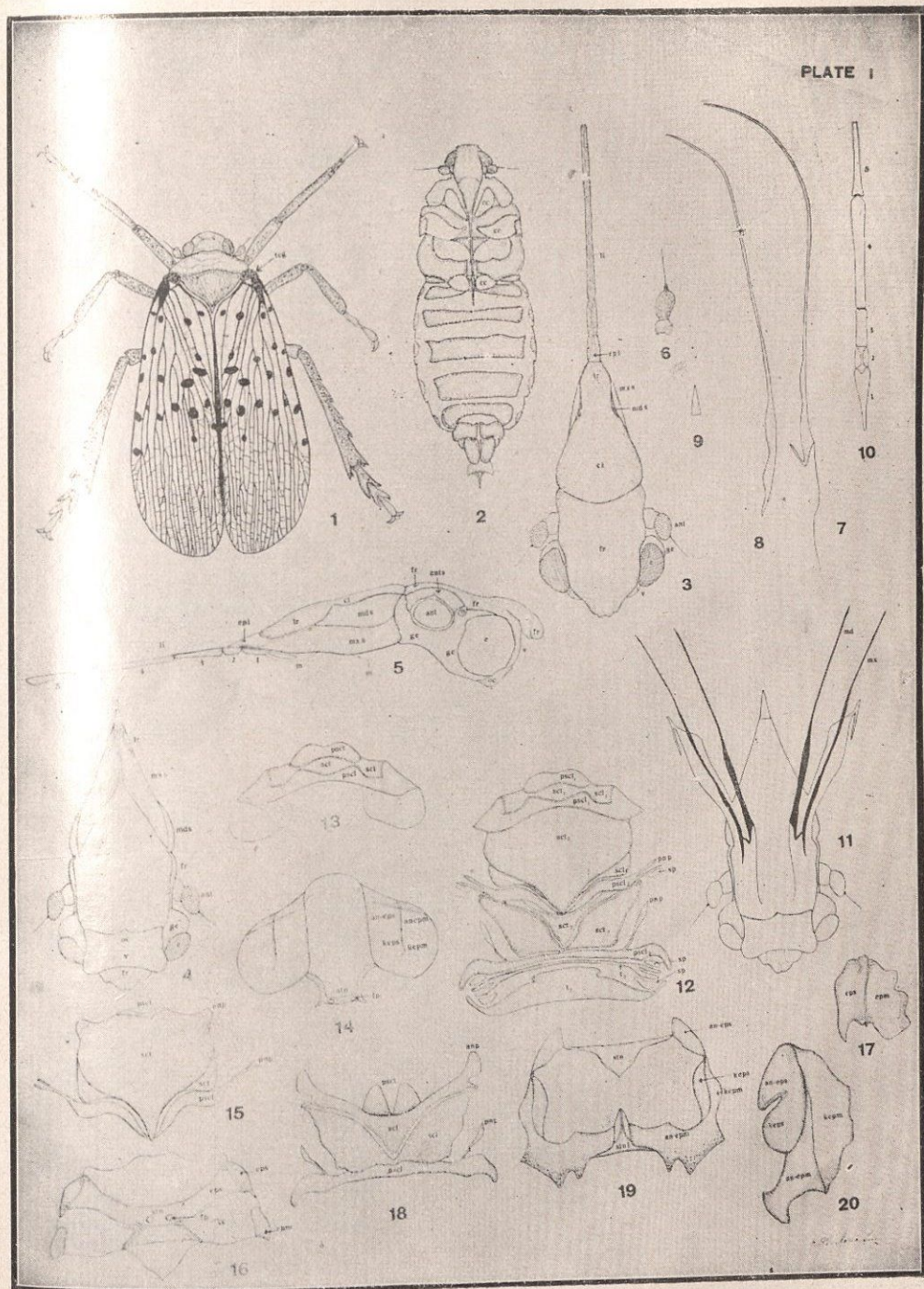
- Fig. 55. Ventral view of the tentorium.
56. Lateral view of the tentorium.
  57. Caudal view of the endoskeleton in the pro-thorax.
  58. Caudal view of the endoskeleton in the meso-thorax.
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  61. Dorsal view of the digestive system of the male.
  62. Dorsal view of the digestive system of the female.
  63. Dorsal view of the digestive system with its parts spread out.

## PLATE V.

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  69. Dorsal view of the male reproductive system with its parts spread out and with the testes pushed backward to show the penis.
  70. Dorsal view of the female reproductive system.
  71. Dorsal view of the female reproductive system with its parts spread out.



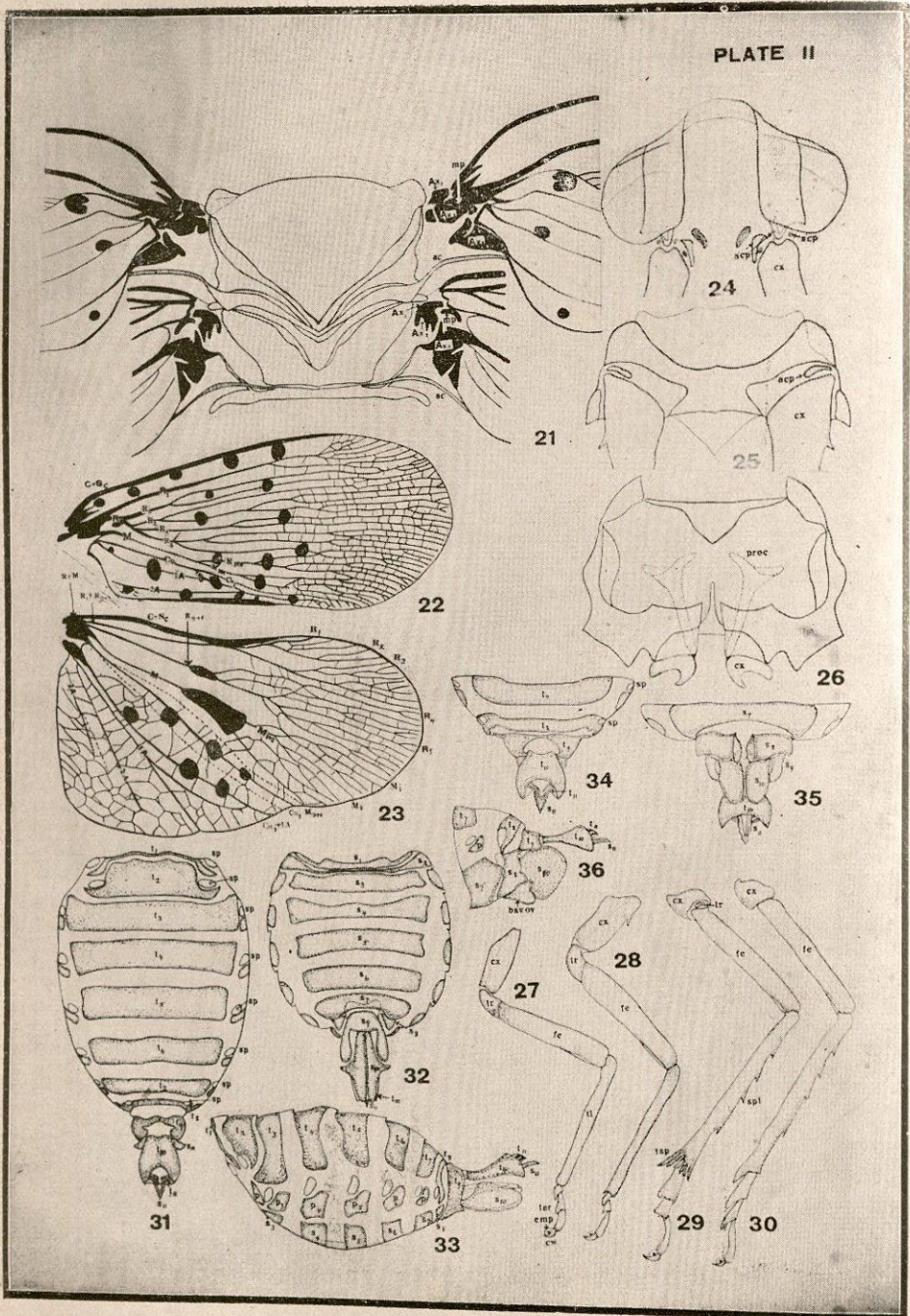
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PLATE II



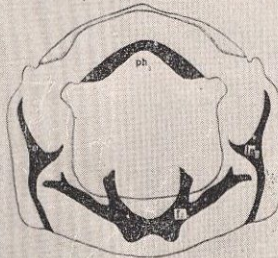
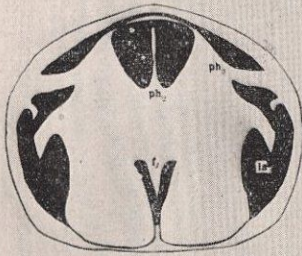
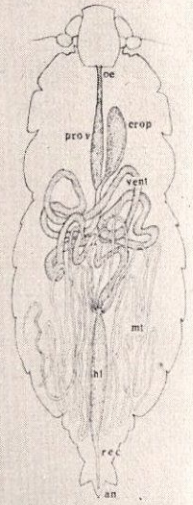
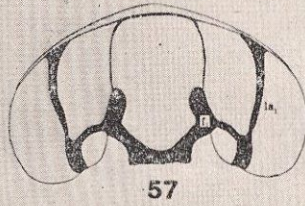
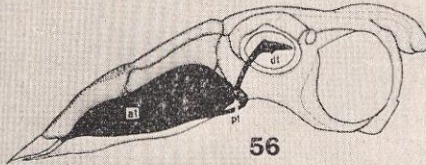
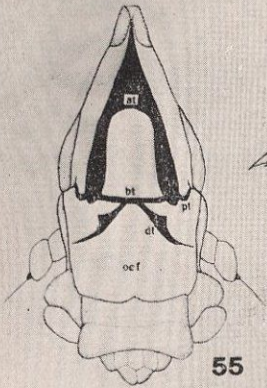
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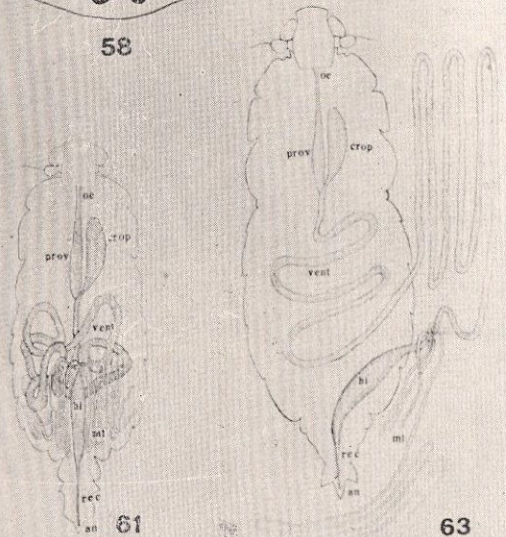
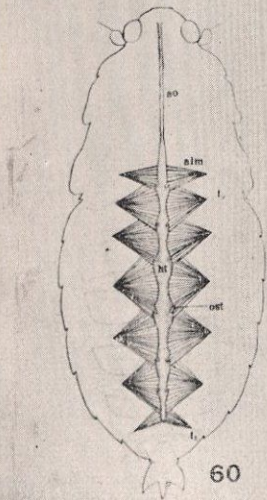
PLATE IV



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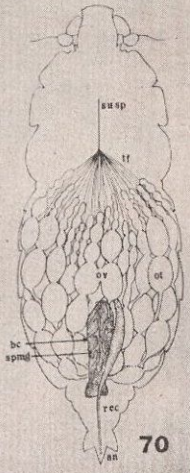
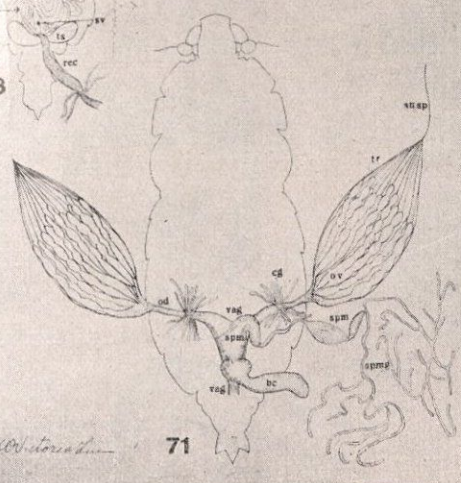
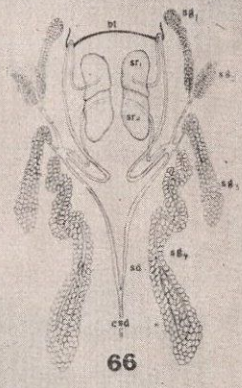
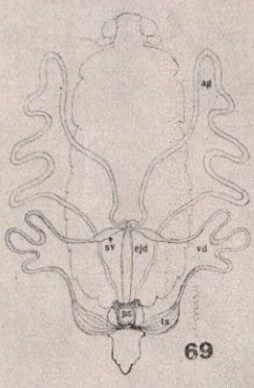
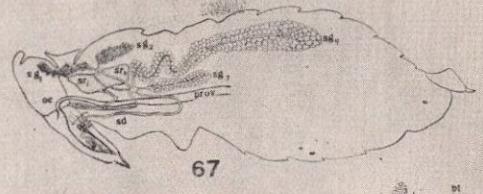
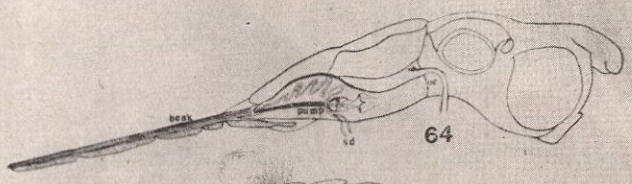
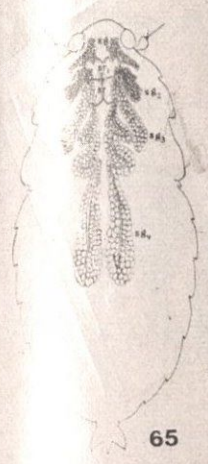
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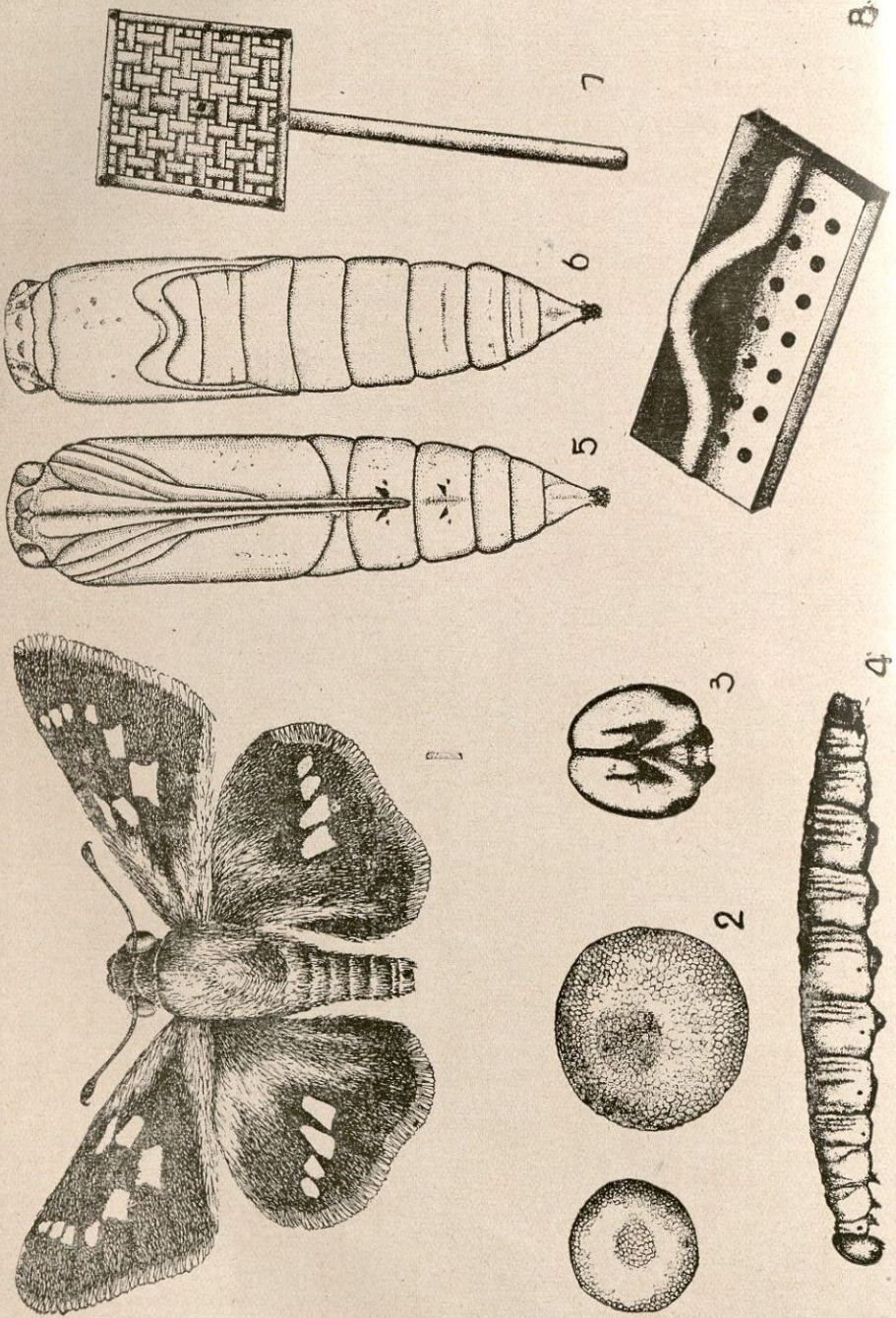
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PLATE V







柳支英：柳枝蟲之生活史及其防治法