

On the STRUCTURE and BIONOMICS of  
PTINUS TECTUS (Boield.);  
with Experiments on its Respiration and Vitality.

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Thesis submitted by

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for the

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P A P E R. I.

On the STRUCTURE and BIONOMICS of

PTINUS TECTUS (Boield).

PLATES I to IX.

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PLACE in CLASSIFICATION.

Order - Coleoptera.

Sub-order - Adephaga.

Division - Serricor<sup>i</sup>na.

Family - Ptinidae.

Genus - Ptinus.

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INTRODUCTION.

The material on which the following notes and descriptions are made was originally supplied by Dr. R. S. MacDougall in June 1929. The origin of the material is unknown. The insects were in ground nut cake (*Arachis hypogea*) and had been lying in Edinburgh for three or four years.

This material supplied my stock during all the experiments and no difficulty was experienced in getting any of the stages of development at any time of the year.

For the purpose of making observations the insects were placed in circular glass topped tin boxes (3-4" diam. x 1" deep). These were more satisfactory than cardboard boxes of the same description as the insects can bite holes through cardboard.

The Ptinids are principally stored produce posts /

pests having world-wide distribution through being transported in articles of commerce.

Niptus hololeucus and Ptinus fur are well known cosmopolitan insects and are very destructive pests, doing a great deal of damage to stored products and textiles.

In common with other members of the family, the species under consideration is a stored product pest capable of doing considerable damage both in the adult and larval stages due to the fact that it can adapt itself to a wide variety of food material of animal as well as of vegetable origin.

Being a comparatively recent introduction to Europe, its economic importance has not yet been fully ascertained, although it is reported from various quarters doing considerable damage.

So far no work on the life-history and habits of Ptinus tectus, either in Britain or elsewhere, has been published. Several isolated records and observations are to be found in the literature, however.

As a thorough knowledge of the biology and life-history of a pest is essential for its successful control, it is to be hoped that the following investigation on the structure and biology of Ptinus tectus will contribute to this end.

The writer desires to express his great indebtedness to Dr. C. B. Williams and Dr. R. S. MacDougall for /

for help, advice and encouragement given throughout the course of this work.

#### METHODS and TECHNIQUE.

The material forming the stock was kept at room temperature and drawn upon as required.

Breeding Experiments: To determine the length of the various developmental stages and to make observations thereon, the eggs were kept in small shallow glass petri dishes (about 2" x  $\frac{1}{2}$ ") and kept in a dark cupboard at room temperature.

The newly hatched larva was transferred into similar sized petri dishes with food material. This method facilitates the finding of moulted larval skins and hence the number of moults. All the observations recorded were made under a binocular microscope.

As no reliable external differences exist between the male and female, pupae of each sex were bred separately to maturity. After emergence matings were made, the two beetles being kept together in tin boxes with food material to determine the number of eggs laid and the preoviposition period, etc.

Morphology and Anatomy: Descriptions and figures of the egg are based on natural untreated specimens viewed under compound microscope.

The Larva: General descriptions are based on living specimens with the aid of a high power (40 to 150 /

150 diameters) binocular microscope. As it is exceedingly difficult to make out the number of spiracles, specimens had to be killed by dipping in boiling water for three minutes, taken out and pricked with a needle to facilitate the penetration of 10% KOH solution in which the larvae were boiled for 10 to 15 minutes. In some cases, however, this was not sufficient to get rid of the contents of the alimentary canal, and it was found necessary to sever the head to rid the body cavity of all its contents. The larva, after boiling, was washed carefully in water and put in glacial acetic acid for 10 minutes. This penetrates the chitinous exoskeleton rendering it easy to stain with acid fuchsin in which the specimen was kept for about half an hour. After staining the specimen was transferred to a slide and the cuticle split into two symmetrical halves under the dissecting microscope. These were dehydrated in absolute alcohol, cleared in ~~Carbol~~ Carbol xylol and mounted in balsam for microscopic examination.

For detailed examination of head and mouthparts, specimens were boiled in caustic potash as described, and the various parts separated under dissecting microscope, dehydrated, cleared and mounted.

The larva (Pl. I. Fig. 2) is drawn from a specimen boiled in KOH, stained, but not mounted as this causes considerable /

considerable distortion and folding of the cuticle.

The Larvae Tracheal System. De Faure's

mounting medium (recommended by Dr. A. D. Imms, Bull. Ent. Res. XX. 1929) gives excellent results. It has the following composition :-

Gum Arabic	...	...	30 gms.
Chloral hydrate	...	...	50 "
Glycerine	...	...	20 ccs.
Distilled water	...	...	50 "
Chloral hydrate of Cocaine	...	...	50 "

The larva is killed and simply placed in an excavated slide with a few drops of the solution, cover slip fixed and the whole left for two or three days, then examined under the microscope. The whole system can be seen well defined against the pale cuticular background.

Anatomy. In dissecting the larval alimentary canal, a very useful method is to place the larva (after killing it) on a slide with a few drops of Isotonic salt solution under the dissecting microscope. The larva is straightened lying on its back; by means of a spear point dissecting needle a lateral longitudinal slit is made along one side of the cuticle when promptly a portion of the canal protrudes, leaving the other side deflated; a similar cut is then made along it. Now the cuticle can be easily separated doing little or no damage to the delicate parts.

In order to make a permanent preparation of the dissected/



dissected out digestive system, it is first fixed in Carnoy's Fluid for 10 minutes, treated with 90% Alcohol for 10 minutes and stained with Eosin (Alcoholic), dehydrated in absolute Alcohol, cleared in Carbol xylol or Clove oil, and finally mounted in Canada balsam. When desired to examine nuclei, as in the case of the salivary glands or malpighian tubules, a double stain is used. After fixing in Carnoy's, wash in 90% Alcohol - 70% - 50% - 30% - 5% - water, each stage occupying about 10 minutes, stain with Methyl Green for 10 minutes, wash in water, again stain with Carm alum for about half an hour, wash in water, 5% Alcohol - 30% - 50% etc. up to absolute Alcohol, clear and mount. This gives excellent results.

Ehrlich's and Delafield Haematoxylin were also tried, the method being the same as above; the double stain method, however, gives the best results.

The Pupa. General descriptions and figures are based on living specimens. Attempts were made to obtain permanent preparations but these were unsuccessful. Boiling in (KOH) to remove body fat causes the displacement of the appendages. Leaving specimens in xylol for a few days to remove the fat renders them very dry and fragile.

The Adult - Morphology. Description of the head of the adult is best done on a live specimen as the /

*This is  
incorrectly  
applied throughout  
the paper - it  
should be  
KOH*

*1939*

the mouthparts are withdrawn in killed specimens.

For the mouthparts, however, specimens were boiled in 10% KOH for about 20 minutes, dissected under the binocular, dehydrated, cleared and mounted. In the case of the thorax and abdomen boiled specimens were used. These were treated with acetic acid and stained with acid Fuchsin to stain the transparent membranous structures. This was especially helpful when studying the wings and their venation, as some of the veins are transparent and can not be made out with accuracy in unstained specimens. Such preparations were either mounted directly in De Faure's Fluid or dehydrated, cleared and mounted in Canada balsam.

Anatomy. The method for dissecting out, staining and mounting the digestive system is the same in the adult as for the larva.

The Male Reproductive Organs. For exposing these, a needle is pressed at the junction of the thorax and abdomen when the latter is easily separated. The abdomen is then placed dorsal side upwards on a slide with a few drops of salt solution and is ready for dissection under the binocular. The pleurae are carefully teased out to separate the tergites from the sternites, both these can then be removed leaving the organs in as near their natural position as possible. Great care is essential in dissecting out the /

the male organs because the least pressure on the aedeagus is enough to evert the internal sac which is delicate and rather transparent and is therefore apt to be broken off and lost, escaping recognition. Even with great care it gets broken off and lost in a good many preparations. A drop of aqueous Eosin added to the preparation is very helpful as it stains the internal sac, connecting membranes and other transparent structures. Having completed the dissection, it is then fixed, stained, dehydrated, cleared and mounted as described. Here again the best results are obtained by the double stain method.

With the Female Reproductive Organs the same procedure is adopted.

Figures were drawn with the aid of a Camera Lucida.

#### FAMILY CHARACTERS.

According to Fowler the name Bruchidae is given by several continental authors to the family Ptinidae which comprises about sixty genera and 400 species, having very wide distribution.

The following are the characters :-

- (1) Antennae 11-jointed, long, filiform or very faintly serrate and inserted upon the frons.
- (2) Thorax - narrower than elytra and usually constricted at base.
- (3) Elytra - completely covering the abdomen.
- (4) /

- (4) Legs - long and not retractile with femora clavate at apex.
- (5) Tarsi - five-jointed with the first joint not shorter than the second.
- (6) Abdomen - composed of five segments of which the first is not elongate.

The Genus *Ptinus* contains over 100 species, 50 of which occur in Europe of which 9 are included in the British List.

GENERIC CHARACTERS.

- (1) Elytra - punctured, pubescent and striated.
- (2) Scutellum - distinct.
- (3) Tarsi - with 5th joint long and narrow and a little longer than the 2nd.
- (4) Antennae - contiguous or almost so at base.

FOWLER'S DESCRIPTION of the SPECIES.

(Coleoptera of the British Islands, Vol. VI. p146, 1913).

Short, thick set, dark brown with thick yellowish pubescence which is easily rubbed off; in some specimens it is whitish especially on the scutellum - head almost as broad as thorax, antennae thick and comparatively short; thorax as long as broad, uneven, with longitudinal furrows and with strong prominences at the posterior angles. Sculpture rather coarse, concealed by the pubescence. Elytra oblong, acute and flatter in the male, and very convex in the female, with /

with strong and coarsely punctured striae ; legs rather long, ferruginous, more or less pubescent - Length  $2\frac{1}{2}$  to 3 mm.

Ptinus tectus was first described by Boieldieu in 1856, from Tasmania. It is now common all over Europe and widely distributed in Great Britain and Ireland.

It was first found in Britain in 1901, and described as a British species by Professor Hudson Beare in 1904.

MATERIAL DAMAGED.

In 1913 it was recorded by Durrant and Beveridge attacking ration biscuits.

In 1915 Walker recorded it breeding in chocolate powder and thriving on cayenne pepper.

In 1920 Scholz in Germany recorded it on dried meat.

In 1921 (Bur.Bio.Technology, Leeds. Bull.2, 1st Jan. 1921, p.52 (Abstract from R.A.E. Vol.9, Ser.A, p.145)).

It was recorded as doing damage to malt corns already mechanically damaged and it was stated that it prefers the wheat grains and other foreign seeds with less resistant husks.

In the same year Carpenter records it in Ireland in a store of Casein and also eating holes in carpets.

In /

In 1922 it was recorded by Knapp in Britain as a pest of Cocoa and by Zacher in Germany as a stored product pest.

In 1923 Walsh recorded it damaging packets of desiccated soup, also feeding on waste flour and dead flies.

In 1927 Zacher in Germany recorded it as a Cocoa warehouse pest.

In 1928 it was recorded by Theobald infesting stored hops in Britain.

In 1929 Von Langerken in Germany recorded it on poultry foods.

It would thus be seen that *Ptinus tectus* can adapt itself to food material of the most varied character.

The writer bred *Ptinus tectus* on various kinds of biscuits, oil cakes, linseed cake and casein in which latter the larvae bind the granules, giving the casein a matted appearance. Both larvae and adults destroy corks, reducing these into a powdery mass. They also eat holes in paper. I also saw them repeatedly in the laboratory feeding on dead blue-bottles and eating dead individuals of their own species. The larvae ate shallow oval pupation chambers in the wooden portions of a breeding cage.

Von Langerken in Germany records a similar case /

case of larvae boring into a wooden box for pupation and further adds that the adults on emerging continued to bore through to the outside. This raises the question whether the beetles, larvae or both can play the role of wood destructors.

It is known that the Ptinid Niptus hololeucus can attack wood previously damaged, and wool and similar fabrics impregnated with grease.

The following Experiments with Ptinus tectus were carried out :-

Experiment 1.

15 larvae kept in an observation box with pieces of very hard wood with smooth surfaces from a block previously attacked by wood-boring beetle sp. In a few days several larvae were noticed on the floor of the box covered with frass. Later several long, deep, irregular grooves were made through the smooth surface of the larger pieces. The smaller pieces were reduced to a fragile powdery mass and a considerable amount of frass was produced as a result. The grooves referred to were quite different from the regular shallow oval chambers bitten into the wood for pupation purposes.

Young larvae when kept under similar conditions sooner or later died, doing no damage to pieces of wood. Unlike the older larvae, however, the adult beetles /

beetles did no damage to pieces of wood of the same origin.

The fact that Carpenter records it eating holes in carpets suggests that Ptinus tectus can do damage to woollen material.

#### Experiment 2.

Four observation boxes with the following contents:-

1. With 15 beetles and unsoiled pieces of woollen material.
2. do. do. do. silk material.
3. do. and pieces of wool and silk soiled with animal fat.
4. do. and pieces of wool and silk soiled with olive oil.

These were examined after about one month. No sign of damage to the material was noticed in any of the boxes.

#### Experiment 3.

Three boxes with contents as follows:-

1. 10 larvae and pieces of unsoiled woollen material.
2. do. do. unsoiled silk material.
3. do. do. wool, silk, and sweetened biscuits (on which the larvae are known to feed).

The larvae were nearly full grown; the material was of the same origin as that given to the adults.

The boxes were examined after a period of about four weeks when it was found that in all cases the larvae ate several small round holes in the wool and silk material.

The /



The above Experiments lead to the conclusion that Ptinus tectus in the adult stage does no damage to wood, wool or silk material. The larvae, however, at least the older ones, do considerable damage to wood previously damaged, as well as to wool and silk material.

#### EXTERNAL ANATOMY.

##### The EGG.

The egg (Pl.I Fig.1) is oblong oval in shape, opaque, milky white and shining when newly laid. Eggs vary somewhat in shape and size, some are more elongate than others. As the time of hatching approaches the egg loses its shininess and becomes rather transparent, so that the larval head and mandibles can be seen through the shell. Viewed with a hand lens, the egg looks smooth, showing no pattern. Under the high power of a microscope, however, it shows a roughly hexagonal pattern.

##### Measurements of Fifteen Eggs :-

Length	Breadth	Length	Breadth	Length	Breadth
.53 mm.	.30	.52	.3	.49	.3
.6	.29	.5	.3	.4	.25
.57	.29	.5	.29	.45	.25
.56	.30	.53	.3	.46	.3
.53	.25	.5	.25	.46	.33

Thus the size varies from .4 x .25 mm. to .6 x .29 mm.,  
the /

the first laid eggs being of a larger size.

The eggs are laid singly; they are covered with a sticky secretion so that they are commonly found adhering to particles of food material and pieces of debris; they break easily when an attempt is made to free them.

The larva lies doubled up inside the shell.

Hatching: When the larva is ready to emerge, it bites a roughly circular hole in the shell, and by pressing its body against the walls of the egg the shell is split along the long axis; finally, the larva backs out of the egg. After emergence, the egg-shell still retains its original outline; often empty egg-shells are mistaken for whole eggs.

The Newly Emerged Larva is a small, hairy grub with a wrinkled body and 3 pairs of thoracic legs. It has a dull, rather transparent cuticle so that the alimentary canal can be seen through it. The head is proportionately large, extending beyond the outline of the body which is fairly densely covered with hair, increasing greatly in length at both body extremities. The outline of the segments is clearly marked; the spiracles are so minute that it is difficult to make them out.

The head differs in colour from that of the full grown larva. In the first stage larva the frons and genae /

genae or cheeks have the same colour as the epicranium which is straw coloured. In the older larva the frons and genae are dark reddish brown in colour.

The head measures .25 mm. across; the body measures 1.0 mm. long and .23 mm. broad.

The FULL GROWN LARVA.

The fully developed larva (Pl.I. Fig.2) is a fleshy, hairy grub with a curved, deeply wrinkled body. The dorsal surface is markedly convex, while the ventral is flattened, with the body bent in a semi-circular manner, almost cylindrical in cross section. The posterior part of the body is abruptly rounded off. The body colour is yellowish white, glistening, clothed fairly densely with fine outstanding hairs which reach their greatest density along the last abdominal segment. The colour of the head approaches that of the body.

Length in mm.	Breadth in mm.	Length in mm.	Breadth in mm.
5.5	1.5	5.75	1.75
5.65	1.5	5.4	1.4
5.5	1.5	6.0	1.75

The above figures are only approximate. As the larvae are bent in their natural position this does not enable their exact length to be determined. If the larva be stretched, one is apt to get fictitiously large figures.

The /

The larva is made up of a well marked chitinous head capsule and twelve segments. The posterior portion of the head is deeply sunk into the first thoracic segment.

The three thoracic segments are larger than the abdominal (with the exception of the last). The first eight abdominal segments are of equal size; the 9th is the largest. The last abdominal or anal segment consists of three lobes surrounding the anus, the opening of which is on the ventral face, and is marked by a red crescentic shaped area which stands out prominently from the pale cuticle.

The larva moves very slowly using the anal segment as an organ of locomotion.

Legs: There are three pairs of legs. Each leg (Pl.I. Fig.3) shows the following parts :- Coxa, trochanter, femur, tibia, tarsus with a strong claw.

Spiracles: There are one pair of prothoracic and eight pairs of abdominal spiracles. There are no spiracles on the last abdominal segment. The thoracic spiracle is the largest, measuring .21 mm. in diameter. The abdominal spiracle measures .15 mm. The abdominal and thoracic spiracles are biforous, i.e. each having two contiguous openings separated by a partition; one of the openings is round in outline, the other elongate with a rounded end, and measures .12 mm. along its long axis.

The /

The abdominal spiracles (Pl.I. Fig.4) are difficult to detect in fresh specimens.

The Head (Pl.I. Fig.5) measures 1.0 mm. in diameter. Viewed dorsally, it is almost spherical in outline, fairly thickly covered with fine outstanding hairs. It shows the following parts :-

The epicranium (Et) occupies about three quarters of the whole area of the head, with a medium groove running along its whole length. This groove is called the epicranial suture (Ets). When moulting takes place, the larval skin splits along this suture. Anterior to the epicranium is the Frons(Fr) of a dark reddish brown colour. The anterior part of the frons is darker in colour than the posterior where the margin is wavy. The surface of the frons is not smooth but is intersected with linear depressions. Anterior to the frons is the epistome (Ept) a raised thick band of chitin of the same colour as the neighbouring portion of the Frons.

Anterior to the epistome is the clypeus(Cly) and adjoining it is the almost hemispherical labrum(Lbr). The very deeply coloured, highly chitinised mandibles (Mn) can be seen on either side of the labrum, which, along with the clypeus, partially cover the inner margins of the mandibles. These meet along the median line when closed and move laterally.

When the head is viewed laterally, the antennae(A) can /

can be clearly distinguished, each situated on the extremities of the anterior border of the the frons, directly behind the mandibles. They are very minute and sunk in pits. Each antenna(Pl.I. Fig.6) is made of two segments - the basal is short, wide and pale in colour; the terminal, of a lighter reddish brown than the frons, conical in shape and without hairs or other sensory structures.

Lateral to the antennal pits, on either side of the head, are two raised tubercles which stand out more prominently than the frons. These are ocelli (Pl.I. Fig.5,0). Fowler, p.178, V.iv. states that in the Family Ptinidae, larvae have no ocelli, but this is most certainly incorrect for this species. The ocelli, four in number, occupy an extremely antero-lateral position, and it is probably on this account that they have been overlooked.

The ocelli can best be seen if a fresh larva is examined under the microscope, with the reflected light shut off and the transmitted light used. The ocelli can thus be clearly seen as four luminous spots, two on either side of the mandibles laterally. Or, if a larval head is boiled in KOH, washed, stained and the sides spread and mounted for microscopic examination, the ocelli can be seen protruding beyond the level of the frons. The light is transmitted through the anterior convex portion, i.e. the "lens" of /

of the ocellus.

Bordering the antennal pits laterally, the colour of the frontal patch disappears, assuming for a narrow strip the general colour of the epicranium. The colour appears again on the genae or cheeks.

The mouthparts are as follows :-

The epistome (Pl. I. Fig. 7, Ept) a narrow strip of chitin with a wavy margin, much darker in colour than the frons to which it is fused.

The clypeus (Cly) a broad transverse area about twice as broad as long, and almost devoid of hairs; it is fused with the labrum and has two Y-shaped chitinous supports. The two limbs adjoin the labrum while the single one adjoins the epistome.

The labrum (Lbr) semicircular in shape, nearly as broad as long, covered with small stiff bristles which reach their greatest density along the anterior and lateral margins.

The mandibles (Pl. II. Fig. 1); each mandible is a strong, robust, highly chitinous structure, almost black in colour; roughly triangular in outline viewed dorsally, quadrilateral when viewed ventrally. On the dorsal surface there is a groove running almost parallel to the lateral border of the mandible. The inner or cutting edge is produced into three blunt teeth, the apical being the largest. On the lateral (outer) /

(outer) margin of the mandible, there is a tuft of outstanding bristles. Each mandible is worked by two muscles - the extensor muscle(Exm) which is long and thin, attached to the dorso-lateral margin of the mandible, and the retractor muscle(Rt.m) attached to the ventral surface, this is the stronger and broader of the two. Each mandible articulates in a pit in the epistome by means of a strong round condyle(Co).

The maxillae (Pl.II. Fig.2). These are the outermost parts, lying on either side of the labium; each is composed of the following sclerites:-

- (a) The Cardo(Ca); a chitinous, roughly triangular plate, articulating with the head capsule and bearing a few lateral bristles.
- (b) The Stipes(Sti); a broad sclerite, articulating with the distal border of the Cardo and bearing numerous long bristles.
- (c) The Palpifer(Mxf); a feebly chitinised area carrying the maxillary palp(Mxp) a sensory structure, composed of three joints, the basal two are short and broad with a few bristles and sensory pits on their surface, while the apical joint is elongated and bears at its distal end sensory pits and papillae arranged like a crown.
- (d) The Galae(Ga); its apical end is closely beset with long, outstanding, curved bristles which give it a comb-like appearance.

(e) /



(e) The Lacinia(La) is a narrow toothed sclerite, situated inwardly next to the Galae.

The Lobium or fused second pair of maxillae made up of the following parts :-

- (a) Submentum(Sme) a large, rather feebly chitinous sclerite, bearing numerous long bristles.
- (b) Mentum(Me) has two well chitinised lateral areas which stand out more prominently than the median area.
- (c) The Labial Palpifer(Lf) carries a pair of labial palps(Lb.p); each palp is composed of two joints, a very narrow basal one and an elongate apical one. Between the palps is the ligula(Li), a narrow lobe closely studded with minute bristles.

#### THE PUPA.

(Pl.II. Fig.3).

The pupa is soft and easily crushed.

Colour: At first shining white, thus differing from the larva which is yellowish white. As the pupation period advances, the pupal colour darkens into a light golden, and finally into a dark golden colour.

The eyes are the first organs to become marked as two blackish spots, then the mandibles.

The pupa measures from 3.2 mm. to 4.28 mm. long x 1.4 mm. to 2.0 mm. at its broadest point.

The /

The Head(H) is strongly bent beneath the prothorax, so that it cannot be seen when the pupa is viewed dorsally. The antennae(A) arise from the front of the head between the eyes(Ey) and are directed backwards along the sides of the body, passing behind the femora of the first and second pair of legs, the terminal antennal joint lying near the outer margin of the Elytra(E1) above the femur of the 3rd pair of legs. Viewed dorsally, the various division of the body (except the head) can be seen.

The Thorax has a median groove running along its whole length; its sides are produced into two lateral protuberances. On the sides of the pronotum there are a few spines.

The scutellum, which is nearly triangular in outline, can be seen at the posterior end of the metathoracic segment, and a fairly wide, longitudinal scutellar groove is seen on the metathoracic segment.

There are 9 abdominal segments, each bearing a few short spines. A fairly long spinal process is borne on the posterior margin of the 9th tergite.

Number of Spiracles. There are two pairs of thoracic spiracles occurring on the meso and meta thorax. The abdominal segments bearing spiracles are the 1st to 7th inclusive. The total number is therefore nine pairs.

Viewed ventrally, the head and mouthparts are clearly /

clearly distinguishable; anteriorly lies the vertex (Ve), in the centre the frons (Fr) and on each side the genae (Ge).

The Mandibles (Mn) are attached to the frons; between them is the labrum (Lbr); below the mandibles are the labial palps (Lb.p); in the centre and on each side the maxillary palps (Mxp.).

The first pair of legs is attached to the prothoracic segment, and show the various parts, viz.-  
Coxa, <sup>(Cx)</sup> femur (F), tibia (Ti) and tarsus (Ta).

The legs are folded underneath the body. The femur and tibia of the first and second pairs of legs overlap the elytra which obscure the 3rd pair of legs. The elytra arise from the mesonotum, extending in a postero-lateral direction with their apices underneath the body at the end of the fifth sternite. The wings are attached to the metathoracic segment and are flat against the undersurface of the elytra, their tips projecting beyond the margin of the latter.

External Sexual Difference between Male and Female Pupae.

There is a strongly marked difference between male and female pupae. On the ventral face of the last abdominal segment of the ♂ pupa (Pl.II. Fig.4) there are two contiguous knob-like projections which are invisible dorsally. The female pupa (Pl.II. Fig.5) has in the same position two round projections, with two /

two finger-like processes arising from their centre. These finger-like processes probably form the ovipositor stylets in the imagines. These sexual differences were verified by isolating pupae possessing the respective characters referred to, breeding these to maturity and subsequently dissecting out the reproductive organs.

Measurements :-

Female pupae		Male pupae	
Length in mm.	Breadth in mm.	Length in mm.	Breadth in mm.
3.68	1.8	3.40	1.4
3.76	1.88	3.40	1.6
3.92	1.96	3.20	1.6
3.80	1.68	3.20	1.6
3.88	1.82	3.60	1.68
3.6	1.86	4.28	2.0
3.2	1.60	3.6	1.60

Thus, speaking generally, female pupae are slightly larger than male pupae, though occasionally ♂ pupae are larger or equal in size to the females.

A D U L T .

(Pl. III. Fig. 1.)

Head (Pl. III. Fig. 2).

The head is strongly bent beneath the prothorax and is roughly triangular in outline when viewed dorsally. The posterior part of the head is deeply sunk into /

into the prothorax, the margin of which overhangs the visible portion of the head. Close to the margin of the prothorax is the epicranium(Et) with its median, longitudinal epicranial suture(Ets.) dividing it into two epicranial plates. Laterally are the compound eyes(Ey) which take the form of two prominent tubercles, almost black in colour. Between the eyes are the antennae(A) which are almost contiguous at base and are composed of eleven joints in both sexes(Pl.III. Fig.3), the basal and terminal joints being the largest; the intermediate ones are of equal dimensions. Each antennal <sup>joint</sup> arises from the preceding one by a short neck(Pl.III.Fig.4,N).

Adjoining the epicranium is the Frons (Pl.III. Fig.2,Fr.) which starts between the antennal bases. It is not a flat structure, but has a median raised triangular area, the apex of the triangle lying between the bases of the antennae. Adjoining the raised area on either side are two oblique grooves for accommodating the basal portion of the antennae which are directed downwards at rest.

Anterior to the frons is the Clypeus(Cly), a narrow, transverse structure marked off from the frons by a suture, its anterior border being emarginate, overhanging and partly concealing the labrum and the bases of the mandibles.

The Labrum(Lbr) is retractile, at rest, only a narrow /

narrow portion of it can be seen; its anterior border is thickly set with fairly long bristles. The labrum overlies, concealing the sharp inner cutting edges of the mandibles (Mn) whose upper surface at this region is excavated to accommodate the labrum.

The Mandibles are convex structures dorsally, their tips overlapping at rest.

Looking at the head laterally, the genae are seen on either side of the head. They are separated from the fronto-clypeus by a suture; their antero-lateral portion, adjoining the clypeus, is swollen into a pouch-like projection to accommodate the maxillae when retracted and to allow for the lateral movement of the mandibles.

If the head is separated from the prothorax, its posterior hidden portion is revealed; it is much lighter in colour and has a smooth surface, not covered with pubescence like the rest of the head. The epicranial suture reaches as far back as the posterior margin of the head capsule which is round in outline.

Looking at the head of a living specimen ventrally, the labium and maxillae with their respective sclerites can readily be seen with a binocular microscope. During periods of inactivity, these structures are withdrawn into an arch-like cavity, the roof of which is formed by the strongly concave under surface /

surface of the mandibles and the sides formed by the genae or cheeks as described. The points of articulation of the maxillae and labium with the head capsule act like "ball and socket" joints, allowing these parts to be withdrawn and partly sunk into the buccal cavity, so that when the head of a quiescent or dead specimen is examined ventrally the only parts that can be seen are the maxillary and labial palps, the rest of the parts being obscured.

The Labrum (Pl.IV. Fig.1).

A slightly flattened spherical structure broader than long (.16 mm. x .12 mm.), its front margin is lighter in colour than the rest and is closely fringed with fine, long, outstanding bristles.

The Mandibles (Pl.IV. Fig.2).

Highly chitinous, almost black in colour, strongly convex dorsally. Their inner or cutting edges are produced into two sharp teeth, the apical of which is the more prominent having a marked curvature. On the outer margin are a few short bristles. The mandibles articulate with the head by a prominent globular condyle (Fig.2, Co) and are worked by two sets of muscles, the inner being the broader.

The Maxillae (Pl.III. Fig.5).

Divided into :-

1. /

1. Cardo(Ca), a roughly hemispherical sclerite, articulating with the head capsule, with long bristles scattered over its surface.

Articulating with the outer border of the Cardo is the

2. Stipes(Sti), a triangular sclerite covered with bristles, and bearing on its outer or lateral border the palpifer, on its inner border the parastipes.

3. The Palpifer(Mxf.), a slightly backwardly curved, subpyriform structure, narrowed proximally, broadening distally, its surface is scattered over with bristles. The palpifer bears two structures, viz.- the gal~~ae~~ and the maxillary palp.

4. The Maxillary Palp(Mxp.), arises from the inner margin, just before the apex of the palpifer. It is four-jointed; the first or basal joint is long and narrow and slightly curved, the 2nd and 3rd are smaller but stouter, the apical being the largest nearly as long as the preceding three, its apex bearing sensory papillae. Just below the origin of the palp arises a shelf-like process which carries the gal~~ae~~.

5. The Gal~~ae~~(Ga), a two-jointed structure. The basal joint is narrow and transparent, the apical dark /

ef-

ef- 2/-



dark in colour, and carries a patch of very closely set, long, curved, dark golden bristles which overhang, and can be distinguished from those of the lacinia.

6. The Parastipes(Pa), distinguishable as a distinct sclerite, narrow proximally, greatly broadening distally; its outer portion (adjoining the Stipes) is much darker in colour, consequently more highly chitinous than the inner portion. The parastipes carries the
7. Lacinia(La) which terminates in a row of closely placed, golden brown, short, curved bristles.

#### The Labium.

Divided into :-

Submentum(Sme), a fairly narrow transverse sclerite attached to the front margin of the gular plate. Above the submentum is the

Mentum(Me), a triangular, heavily chitinous plate with a concave outer surface bearing bristles. In the middle there is a kidney-shaped membranous area, the borders of which are very dark; this is probably the hypopharynx.

The Labial Palpifer(Lf..) is a feebly chitinous area beset with bristles, carrying the three jointed labial palps; between these is the ligula(li.) densely clothed with minute bristles.

The Gular Plate(G.p.) can be seen occupying a median position /

position on the ventral side of the head. On either side of the gula are the genae (Ge). The surface of these structures (gula and genae) does not bear bristles and presents a beautifully corrugated appearance under the microscope. These corrugations appear on the submentum and mentum, the surface of the latter bearing bristles.

#### T h o r a x .

The Prothorax (Pl.III. Fig.1,Pr.). The largest of the thoracic segments and is the only part visible externally (with the exception of the scutellum of the mesothorax) when the elytra are closed. It is freely movable on the rest of the thorax, with a median groove running along the whole of its dorsal surface. Its sides are prominently produced. The pronotum is made up of one single sclerite; the pleurae are likewise, not sub-divided, there being no suture marking off the notum from the pleurae.

Ventrally, the prosternum carries the first pair of legs; it is a narrow sclerite ending in a prominent blunt process on each side of which are the coxal cavities.

In the prothoracic legs (Pl.V.Fig.1) the Coxa (Cx) is spherical, covered with palish pubescence. Following the coxa are the trochanter (Tr) also round in outline /

line; the femur(F) clavate; the tibia(Ti) elongate; the tarsus(Ta) composed of five segments, the first larger than the second, third and fourth. The ~~last three~~ are of equal size; the fifth is long and slender and bears ~~double~~ claws(Cl.).

second, third  
fourth  
two/-

The Mesothorax.-

The Mesonotum (Pl.IV. Fig.3) measures .4 mm. in diameter. A highly chitinous structure, the colour being light golden brown; almost completely hidden partly by the pronotum and partly by the elytra when closed; it is differentiated into:-

Prescutum, Scutum and Scutellum.

The Prescutum(Ps) occupies a narrow anterior area. Behind the prescutum lies the Scutum(Sc). Its anterolateral corners are produced into pointed processes known as the prealar processes(P.p.) which articulate with the base of the elytra, while the postero-lateral corners of the Scutum are produced into two blunt processes(p) which articulate with the base of elytra.

also/-

The Scutellum(Scl.) occupies a median position terminating posteriorly in a prominent, dark coloured, sub-cordate process, commonly referred to as the 'Scutellum', which is the only visible portion of the mesonotum when the elytra are closed

Beneath the 'Scutellum' and on either side of it are two dark coloured lobes called the postergites(Pt). Arising from each postergite is an elongate process, called /

called by Snodgrass the yoke plate (Y.p), which articulates with the meta-prescutum.

Ventrally the Mesosternum (Pl.V. Fig.2, Str.2) is seen; it is differentiated by a well marked suture into an anterior portion called the Basisternite (Bs.2), and a posterior called the Furcasternite (Fs.2)

The Basisternite is a large median plate, in the middle of which there is a triangular groove

? depression

The Furcasternite is situated behind the Basisternite and consists of a median lobe with a pair of lateral excavations, the coxal cavities (Cc.2), on either side; into these the mesocoxae (Cx.2) are attached.

The Furcasternal Apophyses (F.a) arise from the antero-mesal corners of each coxal cavity ventrally. The coxae are spherical covered with pale pubescence, situated on the transverse suture marking off the meso and metasterna which are fused. The suture referred to is ventral.

The Mesopleurae consist of a pair of triangular plates on either of the mesosternum. These are :-

The Episternum (Eps.2) and the Epimeron (Epm.2).

The Episternum is a convex plate adjoining the lateral margin of the basisternite; it is produced antero-laterally into a pointed process which articulates with the ventral base of the elytra.

The Epimeron is a smaller triangular plate, lateral /

lateral to and adjoining the episternum; it gives support to the middle pair of legs.

Metathorax.

Much broader than the mesothorax. The dorsal surface, termed the metatergum; the ventral, the metasternum.

The Metatergum (Pl. IV. Fig. 3) measures 1.2 mm. in diameter. Differentiated into :-

The Notum(No), a broad, convex, chitinous structure, semi transparent, except for the dark coloured ridges marking off its various parts.

The Postnotum(Pn), a dark coloured, narrow, transverse band lying posterior to the notum.

The Notum shows the following sclerites :-

The Prescutum, Scutum and Scutellum.

The Prescutum(Ps), a narrow, transverse area lying most anteriorly and sloping ventrally; its anterior and lateral margins are dark in colour, being highly chitinous, the rest being feebly chitinous and consequently much lighter in colour. The middle portion is shaped for the reception of the mesonotum. On each side of the median line are two convex lobes, the prephragma (A.p.). Lateral to these, on either side, are two pointed processes, the lateral arms of the prephragma of Hopkins(D). These processes articulate with the yoke plates of the mesonotal postergite.

Proceeding /

Proceeding laterally, on either side, are two prominent round processes, situate on the oblique portion of the prescutum, these are muscle discs(M.d.). The extreme lateral margins of the prescutum are curved posteriorly, ending in a pointed process, in intimate connection with the lateral margin of the scutal lobes. Closely applied to the lateral end of the prescutum is a triangular process, 'The anterior notal wing process'(A.N.P.) which articulates with the first axillary sclerite of the wing. The prescutum is separated from the scutum and scutellum by a light coloured membranous area(M.a.).

The Scutum and Scutellum are situated posterior to the Prescutum, the scutellum occupying a median position, dividing the scutum into two separate plates, the Scutal Lobes(Sc.t.). At the middle of the scutellum there is a U-shaped depression 'The Median Groove'(M.G.N.) of the Notum, the sides of which are dark coloured, highly chitinised ridges. At its anterior end lies a dark area with minute bristles arranged in a triangular form. This area lies in very close proximity to the scutellar process of the mesonotum. The posterior portion of the median groove reaches as far down as the postnotum. On either side of the groove, internally, is a triangular oblique groove. These grooves are called by Snodgrass the Entodorsum(En). Anterior to the median groove there /

there is a transverse dark chitinous band, the transverse ventral ridge (T.V.R.) of Snodgrass, a branch of this on either side marks off the scutal from the prescutal lobes (Ps.l) Although the entodorsum and the transverse ventral ridge are internal structures, yet they are visible externally. There is a faint ridge running diagonally along the scutal lobes, along the ridge, and on this there is a group of minute bristles.

The extreme lateral margin of the scutal lobes is produced into a pointed process, the Posterior notal wing process (P.N.P.) which articulates with the third axillary sclerite of the wing.

The Postnotum (Pl.IV. Fig.4, Pn), a transverse strip of chitin, dark in colour, situated posterior to and attached to the notum. Laterally, it bears two processes on either side. The inner process is simple, directed ventrally and is in intimate connection with the first abdominal tergite which lies above it. The outer process is curved and is attached to the dorsal surface of the membranous meta-epimerum. Between the two processes is situated the first abdominal spiracle.

#### The Metapleura

Each metapleurum (Pl.IV. Fig.5) consists of two sclerites one above the other. The upper one is called /

on/-

called the epimerum(Epm.3), it is transparent and feebly chitinous and is hidden when the elytra are closed. The lower sclerite, the episternum(Eps.3), is well chitinised, adjoining the sternum and is partly visible when the elytra are closed. The episternum is made up of two areas; the lower is strongly chitinous, the upper being semi-transparent and feebly chitinous. The former area is visible when the elytra are closed, the latter is hidden.

Arising from the episternum is a chitinous Y-shaped process, the Parapterum(Pat.) which articulates with the heads of both costa and subcosta. The Pleural ridge(Pl.r.) runs along the internal surface of the episternum, terminating anteriorly in the Pleural wing process(Pl.w.p.) which articulates with the first axillary sclerite of the wing, and posteriorly in a coxal process closely applied to the metacoxa.

#### The Metasternum.

The Metasternum (PL.V.Fig.2,Str.3) is a large plate of chitin, situated posterior to, and fused with, the mesosternum. It is differentiated into two regions, viz.- the basisternite(Bs3), anteriorly, occupying almost the whole area of the metasternum, and the furcasternite(Fs3) posteriorly, occupying a small area at the posterior margin. The furcasternite consists of a median lobe with an elongate, excavated area on either side, these are the coxal cavities./



cavities. Arising from the furcasternite internally is a furcal apophysis composed of one single stem branching anteriorly into two long curved arms.

The coxae (Cx.3) are very elongate, reaching up to the coxal process of the episternum.

The Thoracic Spiracles. There is in the adult, as in the pupa, two pairs of thoracic spiracles, occurring on the meso and metathorax. No spiracles are present on the prothorax. Careful dissection is necessary for locating the spiracles as they are situated between the pleurites.

The mesothoracic spiracle (Pl.IV.Fig.6,Sp.2) is situated on a membranous area between the meso-episternum (Eps.2) and the basal portion of the elytra.

The metathoracic spiracle (Pl.V.Fig.2,Sp.3) occurs between the meta-episternum and the meso-epimerum.

#### Alary Polymorphism.

Kissenwetter and Seidlitz (1877), quoted by Miss Jackson (Trans.Roy.Soc.Edin.Vol.LV. Pt.III. No.27, p.721), state that in the Ptinini the hind wings are frequently reduced or entirely absent, either in both sexes or only in the females.

In the course of dissections of Ptinus tectus, it was found that all the individuals dissected possessed wings; some have large well developed wings folded underneath the elytra, others have reduced wings /

wings lying alongside the abdomen under the elytra. It is those specimens with the large wings that have been referred to as spreading out their elytra and making leaps by means of their outstretched wings. Occasionally, specimens are found with the tips of the wings protruding from the apical portions of the elytra. In order to investigate this point 112 specimens were examined for the condition of the wings, and in addition dissection of the reproductive organs made to find their sex. The result is given in the following table :-

<u>Brachypterous</u> (reduced wings)		<u>Macropterous</u> (well developed wings)		<u>Intermediate, i.e.</u> one long and one short wing.	
♀	♂	♀	♂	♀	♂
42	49	10	4	4	3

Thus, 12% of the specimens examined possessed fully developed wings. Referring to the table, it is interesting to note that 4 females and 3 males possessed different types of wings, i.e. a fully developed or macropterous wing on one side and a reduced or brachypterous wing on the other (Pl.V.Fig.3). One of the female specimens examined had one brachypterous and one large macropterous wing. This was much folded and could not be flattened out. This type of wing reduction is, as far as the writer is aware, unique /

unique amongst Coleoptera. No records of similar occurrence of this reduced condition could be traced in the literature.

The occurrence of both types of wings on the one individual probably represents the transitional form between the fully developed and the reduced condition.

No difference in the genitalia of the two forms could be detected and, as would be seen from the table, the variation is not connected with sex.

The only outward difference that could be detected <sup>between</sup> between the two forms is the degree of chitinisation of the metatergum of the two forms; in the <sup>brachy</sup>brachypterous specimens the metatergum is not as strongly chitinous as it is in the macropterous specimens.

Measurements :-

Macropterous Wing		Brachypterous Wing.	
Greatest length.	Greatest breadth.	Greatest length.	Greatest breadth.
3.5 mm.	1.0 mm.	2.5 mm.	.4 mm.
4.7	1.6	2.5	.5
5.0	1.5	2.2	.45
4.0	1.2	2.5	.4
5.0	1.5	2.5	.4
4.2	1.25	2.3	.55
4.8	1.5	2.4	.5

It would be seen that the macropterous wing varies greatly in size, while the brachypterous is remarkably constant, the latter wing being roughly half the dimensions of the former.

The Venation of the Macropterous Wing (Pl.V.Fig.4).

All the principal veins, viz.- the Costa, Subcosta, Radius, Media, Cubitus, Anal, are easily recognisable, the last, however, being very indistinct in unstained specimens but can be easily made out on staining. The anal area(Aa) is well defined.

The Costa(Cs) a distinct, fairly short vein arising from the wing base and running along the anterior margin for a short distance. It ends in a prominent curved head(H.cs.) which articulates with the parapterum of the meta-episternum. The costa is connected to the subcosta by a prominent chitinous hook.

? originates

The Subcosta(Scs.) about twice the length of the costa, arises from a prominent head(H.ScS) below the costa ; it runs along separately for a little distance and then very close to the costa for another short distance, going much further than the costa, till it fuses with the radius. The head of the subcosta articulates with the posterior process of the parapterum of the meta-episternum (Pl.IV.Fig.5).

The Radius(R) has its basal portion closely applied to the subcosta and its head, and has a Y-shaped process(Pl.IV.Fig.7,P) the two arms of which are directed towards the base of the wing. The anterior arm is closely applied to the subcostal head, while the posterior arm is connected with the radial plate of Hopkins /

Hopkins (Pl.IV.Fig.7,R.P.) which arises from the second axillary sclerite of the wing. The radius merges with the subcostal vein, continuing along the costal margin for some distance, up to about the middle of the wing, becoming expanded into a black triangular area, then for a short distance directed backwards and finally curving forwards forming the recurrent radial vein (Pl.V.Fig.4,R.R.) which lies in close proximity with the short branch of the media.

The Media (Pl.V.Fig.4,M.) is the most prominent vein, being much darker in colour than the others. It arises at the basal portion of the wing, below the radius, without going as far back as the latter. It is connected with the radius by a dark wavy strip of chitin, continuing its course behind this point, becoming much fainter and finally uniting with the medial plate (Pl.IV.Fig.7,M.P.). The media runs along the middle of the wing, terminating at the anal end. Before its termination it gives off a curved branch which lies very close to the recurrent radial.

The Cubitus (Pl.V.Fig.4,Cu.) arises from the 3rd axillary wing sclerite. It is connected with the media at its base by a thin strip of chitin arising from the medial plate. At its basal portion it divides into two parallel branches which run along for some /

in the posterior margin

some distance and then unite for a short distance, dividing into three branches which reach the anal margin. While the cubitus is typically three-branched, yet occasional specimens are met with with a three-branched cubitus in the one wing, and a four-branched cubitus in the other, such branches giving off two or more secondary branches near the anal margin.

The Anal (.A.V.) is a short vein running along the margin of the anal area.

The apical area of the wing is completely devoid of veins.

The Brachypterous Wing (Pl.V.Fig.5).

The apical area is very much reduced and truncated. The anal margin is continuous and not differentiated into a distinct anal area as in the case of the well developed wing. Some reduced wings are flat, others have transverse creases along their surface. The anterior margin is indented at a point about the apical termination of the costal vein.

The Veins - The Costa(Cs.), Subcosta( Scs.) and Radius(R) are clearly seen, following the same course as in the macropterous wing. The black triangular area is well marked. The Media(M) is well defined, but not as prominent as on the developed wing nor does it pursue the same course as in the latter. It runs along and branches close to the anal margin, terminating  
a /

a little distance before the apical margin; its branch does not lie close to the recurrent radial vein(R.R.).

The Cubitus(Cu.) is very indistinct. On staining it shows clearly, branching basally into two branches as in the developed wing and proceeding for some distance almost parallel to the anal margin where it terminates without giving off any branches.

The Anal is untraceable.

There are no veins in the apical truncated region, but a few dark lines are visible.

The principal difference between the two types of wings lies in the great reduction of the apical region in case of the Brachypterous wing.

Colour. The wings are transparent with minute dark bristles occurring all over the surface. A fringe of fine hairs occurs all along the anal margin, the posterior margin being free from hairs.

Articulation of Wings (Pl.IV.Fig,7).

The head of the Costa articulates with the parapterum of the metapleurum, and with the head of the subcosta by means of a chitinous hook.

The head of the Subcosta articulates with the head of the first axillary sclerite dorsally, and with the parapterum ventrally.

The 1st Axillary Sclerite (Ax.I), the scapular plate of Hopkins, articulates with the anterior notal wing /

wing process(A.N.P.) medially, with the pleural wing process and with the curved posterior end of the pre-scutum.

The 2nd Axillary Sclerite(Ax.II), the subscapular plate of Hopkins, is in intimate connection with the 1st Axillary. The thin, rather transparent, radial plate arises from its anterior end and connects it with the base of the radial vein.

The 3rd Axillary Sclerite(Ax.III), the flexor plate of Hopkins, is closely connected along its anterior margin with the medial plate(M.P.), a feebly chitinous triangular area, with well defined margins, which connects the 2nd and 3rd Axillary Sclerites with the bases of the media and cubital veins. The 3rd Axillary articulates with the 2nd Axillary and with the posterior notal wing process(P.N.P.).

The articulation of the wings is the same in the long and short winged forms.

#### The Abdomen (Pl.V. Fig.6).

There are five visible abdominal sternites and seven tergites; the true number of sternites, however, is eight. This can only be made out on severing the abdomen where the first true sternite is represented by a horizontal membrane; the 2nd is represented by a vertical keel or phragma, both modified to accommodate the elongate metacoxae.

The /



The first visible sternite is really the 3rd; the 4th, 5th, 6th and 7th are all visible; the last two can be bent either separately or together, their junctions with the preceding segments are so modified that they can act as a sort of a hinge. This is the case in both male and female abdomens, the bending taking place during the acts of copulation and egg-laying.

The true eighth segment (Pl. VIII. Figs. 1 & 3, S. 8) is completely withdrawn in to the abdomen and only protrudes during copulation or egg-laying, the ovipositor and the male genitalia protruding between its sternite and tergite. It is of great importance as its internal surface affords areas for the attachment of the muscles that actuate the ovipositor and the male genital organ. In the female the 8th sternite is fused with a long chitinous rod (Ro) that supports a band of muscles. In the male, the sternite is in intimate relation with the spiculum gastrale or fork. The posterior margin of the 8th abdominal segment is fringed with hairs, its colour being much lighter than the other abdominal segments.

The Abdominal Tergites. Seven well marked tergites are visible when the elytra are removed and one concealed, making eight. The first tergite is transparent due to its feeble chitinisation; its posterior /

posterior border, however, shows faint brown colouring. It is in intimate connection with the metapostnotum, to which it is attached by a dark process. The succeeding six tergites are all well marked, being of deep golden brown colour. The 7th tergite is in intimate connection with and completely conceals the 8th tergite at rest, while the latter becomes visible only when the 8th segment protrudes out of the abdomen.

The Pleurites. The lateral areas of both 1st and 2nd tergites carry spiracles. Their pleurites are untraceable, the first visible pleurite belongs to the true 3rd abdominal segment (the 1st visible sternite). The 3rd to 7th pleurites inclusive are all well marked and carry spiracles. Thus there are seven pairs of abdominal spiracles.

#### INTERNAL ANATOMY.

(Pls. VI. to IX.)

#### L a r v a .

Tracheal System (Pl. VI. Fig. 1). As mentioned before there are 9 pairs of spiracles, eight abdominal and one thoracic. Each spiracle <sup>is</sup> united with its neighbouring spiracle by means of a fairly thin unbranched tracheal tube, thus forming two lateral spiracular /

spiracular trunks on either side of the body, reaching as far forward as the prothoracic spiracle. Arising from each spiracle anteriorly and posteriorly are spiracular trachea which divide and redivide into branches within its segment. Although the meso and metathoracic segments are devoid of spiracles, yet they are fairly well supplied with tracheal branches arising out of the prothoracic and first abdominal spiracles.

? dorsally +  
ventrally  
ef

A stout spiracular trachea arising out of the prothoracic spiracle supplies the head capsule.

The Alimentary Tract (Pl.VI.Fig.2), a long tubular structure, occupying almost the whole of the body cavity and bending twice within it. It measures about 11 mm. which is about twice the length of the larva. It is divided into three parts:-

1. The Foregut(F.g.) consisting of :-

(a) The Oesophagus(Os), a simple tube passing from the buccal cavity into the forepart of the thorax; it begins to dilate to the crop at the posterior margin of the mesothoracic segment.

(b) The Crop(Cr); this is a dilatation of the hind portion of the oesophagus; it occupies the metathoracic segment and the 1st to 5th abdominal segments. At its hind end there is a slight constriction where it merges into the midgut. No gizzard is present.

2. /

2. The Mid-intestine or Midgut(M.i.): A long tubular structure, fairly uniform in diameter throughout its length. It runs along the hind portion of the body, bending upwards, continuing for some distance then joining the hind gut at a constriction.
3. The Hind-intestine or Hindgut(H.i.) - divided into three parts:-
- (a) The Ileum(Il.), a short pyriform structure lined with fine strands of chitin. It opens with a constriction into the -
  - (b) The Colon(Cn.), a tubular structure, at the forepart of which arises a large hollow, kidney-shaped structure "the Caecum(Cae.). The colon is followed by the hindmost part of the alimentary canal, namely, the rectum. There is no distinct line of demarcation between the two.
  - (c) The Rectum(Re.), a long, narrow, bent tube, lined with prominent strands of chitin which is thrown into irregular folds. The rectum terminates in the anus.

The Malpighian Tubules and Silk-producing Organ.

The malpighian tubules(M.T.) are six in number, long, fairly wide (measuring 0.7 mm. in diameter), delicate tubes lying in the body cavity. Their epithelial cells are characterised by their large size and the great /

great prominence of their nuclei. They open at their proximal extremities at the junction of the mid and hind intestines, singly. Their distal ends are not free but uniting to form a single stem closely attached to the wavy walls of the rectum (Pl. VI. Fig. 3), without, however, emptying into it. The common stem then divides into six branches the ends of which double up by bending and joining the main branch. These branches are so closely united together at their lower extremities that they form a regular pear-shaped, silk-producing organ (S.O.) which is sometimes free from the rectal walls, or with its proximal part firmly attached to the rectum, the distal part being free. Frequently one finds a silken thread protruding for some distance out of the distal extremity of the silk-producing organ, the threads being used for cocoon formation and are discharged through the anus. The organ is well supplied with trachea.

Salivary Glands (Pl. VI. Fig. 3). The salivary glands are pear-shaped structures communicating with the oesophagus by short slender ducts. On double staining, their large prominent nuclei can be seen closely congregated. These structures were found in all early stage larvae dissected. It is difficult to say with accuracy in which specific stage they occur as the number of moults, as pointed out, is variable. Careful search failed to find any glands in /

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e/-

P  
A  
P  
E  
R  
II.

in older, i.e. last stage, larvae. The glands probably become atrophied when the final stage is reached.

#### A d u l t .

The Alimentary Canal (Pl.VII. Fig.1) measures 6.75 mm. in length. It closely resembles that of the larva in essential structures but differs in detail. Salivary glands are not present. It is divided into :-

1. The Foregut(F.g.) begins with the oesophagus(Os.) which dilates into the Crop(Cr.) with extensible thin walls, capable of expanding into a large size. In natural (unstained) preparations it appears as a nearly globular, transparent bulb lined with fine striations of chitin. The crop is followed by the Gizzard(Gi.) which is lined with closely set strands of chitin.

2. The Midgut or Mid-intestine(M.i.) consists of a long, fairly wide tube, not as long as the corresponding structure in the larva. It is uniform in diameter throughout its length; it ends in a slight constriction where it joins the hindgut.

3. The Hindgut or Hind-intestine(H.i.) consists of the following parts:-

(a) The Ileum(Il.), very similar to the larval; at its hind end the tract bends upwards for some distance in the abdominal cavity and then downwards.

(b) /



(b) The Colon(Cn.) at its forepart arises a "caecum" (Cae.) which is pearshaped and small in size, differing from the larval coecum. In natural position the coecum is firmly attached to the structure corresponding to the larval silk-producing organ; it can, however, be easily separated. The remaining part of the colon is tubular. As in the larva, I could not make out a distinct line of demarcation between the colon and rectum.

(c) The Rectum(Re.), a long, tubular structure, terminating in the anus, and (is) not lined with strands of chitin. Closely attached to the rectal walls is situated a structure corresponding to the larval "silk-producing organ"; in older specimens it is firmly united with the walls of the rectum throughout its length, in younger specimens it is only united at its anterior end.

The Malpighian Tubules(M.T.), six in number, much narrower than the larval, measuring 0.3 mm. in diameter. They arise at the junction of mid and hind intestines, uniting distally to form a single stem which runs along the rectal walls for some distance and then forming the "silk producing organ".

The Male Reproductive Organs (Pl.VII.Fig.2).

The male reproductive organs lie on either side of the /

the abdomen ventral to the alimentary canal. These consist of :-

1. Paired testes.
2. " vasa deferentia.
3. " accessory glands.
4. " seminal vesicles.
5. Common or ejaculatory duct.
6. Aedeagus.

The Testes(Te.) are paired structures, each consisting of six blind tubes or diverticula, sub-pyriform in shape. When immature they are semi-transparent anteriorly and muddy coloured posteriorly. The tubes are separate and not closely bound together. When mature they are whitish, opaque in colour, fragile and closely bound together. (It will be noted that Fig.2 is drawn from an immature specimen).

The testes open into the genital ducts or Vasa deferentia.

The Vasa deferentia(V.d.) consist of two tubes leading from the testes to the common or ejaculatory duct formed by their union.

Seminal vesicles(S.v.); these are enlarged portions of the Vasa deferentia, arising close to the junction of the vasa with the testes.

The Accessory Glands(A.G.) are two blind diverticula tubular in shape which arise at the junction of the two vasa deferentia.

In mature specimens the testes, the vasa deferentia, the seminal vesicles and the accessory glands are /



are whitish opaque in colour, being full of spermatozoa, which have a pear-shaped head and a fairly long flagellum.

The Common or Ejaculatory Duct (E.d.); a fairly wide tube at first, tapering gently; it is ensheathed in a wide membranous tube which bends downwards and then upwards in natural position; it opens posteriorly into the internal sac, situated inside the median lobe. There is a chitinous structure at the junction of the ejaculatory duct and the internal sac termed "the transfer apparatus" (Pl.VII.Fig.7,T.A.).

The Chitinous Structures of the Male Genital Tube.

In the following description the writer was greatly helped by the Memoir of Sharp and Muir (1912); and the terminology used is that adopted by the same writers.

The Spiculum gastrale or fork (Fig.2,S.g.& Fig.4) lies most ventrally, close to the abdominal sternites, is in close connection with the termination of the alimentary canal and the 8th abdominal sternite. This is a caliper-shaped structure with two pairs of chitinous arms. The inner pair are broad basally, gradually tapering. The outer pair are thinner strands of chitin, closely applied basally to the outer margin of inner pair. The apical ends of both pairs of arms or prongs are flattened out for attachment to the membrane called the second connecting membrane /

membrane. The basal end of the spiculum is strongly curved and is firmly attached to a circular band of muscles at the base of the tegmen.

The Tegmen (Pl. VII. Fig. 3, Tg.) dorsal to the spiculum consists of :-

- (a) The basal piece,
- (b) The lateral lobes.

The basal piece (Fig. 3, B.p.), this is a curved band, the ventral and lateral portions of which are chitinous, while the dorsal portion is membranous. It encircles the base of the lateral lobes, and partly encircles a large bulb of circular muscles at the base of the median lobe.

The lateral lobes (Fig. 3, l.l. & Fig. 5) paired, lateral organs, roughly triangular in shape, broad at base, with a constriction which marks off the apical from the basal portions. They taper to a blunt point bearing hairs and articulate with the median lobe dorsally at the point of articulation (P.ar.); their blunt apices project slightly beyond the apex of the median lobe to which they are closely applied basally, their apical ends being free. The lateral lobes project outside the 8th abdominal segment, holding the female during the act of copulation. The curved basal piece, together with the base of the lateral lobes form a bulb enveloping the base of the median lobe.

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The Median lobe (Fig. 3, M.l. & Fig. 6), a funnel-shaped, curved structure, the dorsal and lateral sides of which are highly chitinous, the ventral portion membranous. Thus, its walls can be brought together by muscular action for the eversion of the internal sac. It is produced dorsally into a strong condyle, "the point of articulation" (P.ar.), with a "median foramen" (Fig. 6, M.f.) at its base, where the ejaculatory duct enters; and a median orifice (M.o.) near the apex on the ventral side where the internal sac is everted.

Between the median lobe and the lateral lobes lies the first connecting membrane. Within the median lobe is a set of muscles round the internal sac. The function of the median lobe is to act as a guide, bringing the internal sac into a position that it can enter the female genital tube.

The Internal Sac (Pl. VII. Fig. 7, I.s.) is the most intimate part of the copulatory mechanism; it is the only part of the male genital tube that enters the female genital tube, the median and lateral lobes acting merely as guides and protectors to the sac. Normally, it lies completely enclosed within the median lobe. As has been already pointed out, the greatest care is needed to demonstrate this structure. The mere killing of a specimen may be enough to evert the /

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the sac which is very easily broken off and lost during dissection. This was noticed on killing specimens while watching them under the dissecting microscope. The internal sac is a tubular membranous structure, the apical end of which is very complex, armed with patches of hairs and minute scales of chitin. Inside this portion there is a structure presenting the appearance of a long, coiled tube<sup>in</sup> which the flagellum is situated. The presence of this long flagellum was demonstrated by placing a cover slip on the dissected organ with a drop of aqueous Eosin when, by applying gentle pressure with a dissecting needle, instead of the sac protruding as expected, a long flagellum, nearly as long as the whole beetle, protruded at the median orifice.

The Female Reproductive Organs (Pls.VIII. & IX.)

The female reproductive organs lie on either side of the abdominal cavity ventral to the alimentary canal. They consist of :-

1. Paired ovaries.
2. Paired oviducts.
3. Unpaired oviduct or uterus.
4. Vagina.
5. Accessory gland.
6. Receptaculum seminis.
7. Bursa copulatrix.
8. Ovipositor.

The Ovaries (Pl.VIII.Fig.1,Ov.) are paired structures, each consisting of six ovarian tubules(O.t.) divided /

divided into ovarian chambers (Fig. 2, O.c.) posteriorly, nutritive chamber (N.c.) anteriorly, and a terminal filament (T.f.) apically. The ovarian chambers, two in number, each encloses one egg in different stages of maturity, anteriorly small undeveloped eggs, posteriorly large ones. The eggs pass from the ovarian tubules into the oviducts (Ovi.) which join to form a common duct, the uterus (U.). Following this is the Vagina (Va.) which passes into the ovipositor (Ovip.).

The Bursa copulatrix (B.c.) opens into the anterior end of the Vagina. It encloses the chitinous Receptaculum seminis (R.s.) and the Accessory gland (A.g.); both structures communicate with each other by a small duct and with the vagina by a long one. In order to ascertain the structure and respective position of the bursa copulatrix, receptaculum seminis and accessory gland, the organs were dissected out and doubly stained. On examination under the microscope the accessory gland with its large nuclei was traced. The receptaculum seminis, being ectodermic in origin, is lined with chitin. A fresh preparation of the reproductive organs with the accessory gland and the ovipositor cut off was treated with hot 10% KOH, which dissolved the ovaries etc. and the membranous pouch (the Bursa) surrounding the receptaculum, this being the only part remaining when examined after 24 hours.

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The Different Stages of the Female Reproductive Organs.

In a newly emerged female (Pl.VIII.Fig.1), the abdominal cavity is full of fatty matter which is drawn upon during the process of maturation and development of eggs. The ovarian tubules are small, transparent, more or less uniform throughout their length and are not differentiated into ovarian and nutritive chambers. The receptaculum seminis is empty. Gradually the ovarian tubules lengthen and become filled with a brownish substance, their posterior portions becoming constricted, the constrictions marking off ovarian chambers, and the oviduct enlarges. As egg laying approaches, the ovarian chambers become very much swollen (Fig.2) due to the presence of nearly mature ova. At this stage as many as six practically mature, full-sized, and three partially developed ova can be found in the ovaries. The receptaculum seminis is round; its accessory gland and communicating duct are prominent, due to their glistening opaque contents, the spermatozoa.

After egg laying (Pl.IX) the walls of the ovarian chamber, within which the egg developed, collapse and can be seen lying close together, remaining in this position till another egg from the neighbouring chamber passes through when the walls become temporarily swollen and then collapse again. After all the eggs are /

are laid the ovaries shrink up and contract, the receptaculum seminis assuming its original size.

The Structure of the Ovipositor.

The ovipositor (Pl.VIII. Fig.3,Ovip.) is a tubular chitinous structure, consisting, roughly speaking, of two hollow chitinous tubes, one inside the other. It is made up of several parts :-

1. A long internal chitinous tube(I.t.) into which the vagina passes. This represents the fused pair of inner valves, forming a tube through which the eggs pass.
2. A chitinous tubular sheath(Sh.) surrounding the inner tube; supported <sup>by</sup> two long chitinous rods(Su.). This represents the anterior pair of valves of the ovipositor.
3. A lowermost portion, the posterior extremities of which are drawn out and bear stylets(Sy.). This represents the lateral pair of valves.
4. A membrane(K) surrounding the external chitinous sheath.
5. A long curved chitinous rod(Pl.VIII.Fig.1,Ro.).
  - (1) The internal chitinous tube runs through almost the whole length of the ovipositor.
  - (2) The sheath surrounding it is fairly wide, supported by two long, almost parallel chitinous rods, running throughout its length. The rods are capable of /

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of being drawn very close to each other, their posterior ends almost touching. This is brought about by muscular action. In prepared specimens the number of the rods is apt to be mistaken for four instead of two, due to the infolding of the lateral walls of the sheath, giving the impression of an extra pair of rods. This is best investigated in fresh specimens under a high power dissecting microscope.

(3) The lower portion of the ovipositor consists of two broad, curved, arch-like plates (Fig. 3, Z) produced into two spoon-like processes (P) projecting inwardly and articulating with the posterior ends of the longitudinal chitinous rods of the outer sheath. Laterally, the plates thin out, becoming constricted at a point on the lateral margin. The constriction acts as a hinge, allowing the lateral movement of their long posterior drawn-out portions (bearing stylets) which can be brought very close together or apart by muscular action. The drawn-out portions end in stylets which are sensory in function, each bearing about three bristles on its apex, as well as a few sensory papillae. Sensory pits occur on the surface. Just before the stylets there are on each posterior plate 8 to 12 long bristles.

That the lower portion of the ovipositor is bent ventrally, almost at right angles to the anterior portion, during egg laying, has been observed by the writer /



writer, although actual oviposition has not been observed. On two occasions, while dissecting the reproductive organs of mature females, the stylets were seen moving towards one another, and on closer observation with high power (x 150) of dissecting microscope, the lower part of the ovipositor was seen to be bent at right angles at the spoon-like projections referred to. The posterior drawn-out plates were moving towards each other against the constricted area. On putting a drop of 5% KOH on the organs, the ovipositor assumed its normal straight position. The writer was fortunate in being able to observe the action of the muscles controlling the ovipositor.

A mature female ready to lay its eggs was killed and the reproductive organs dissected out in salt solution. The ovipositor was actually seen moving. On closer examination with high power, two sets of longitudinal muscles were clearly seen extending and distending. The specimen was laid ventral side upwards and it appeared that the two sets of muscles work independently and not simultaneously. The right set moves the lower part of the ovipositor in an upward, and slightly lateral, direction; in so doing, the outer chitinous sheath becomes constricted, its longitudinal chitinous supports coming very close, their /

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their posterior ends almost touching. This set of muscles is attached anteriorly to the vaginal walls and posteriorly to the internal surface of the 8th abdominal segment. The left set of muscles is attached anteriorly to the anterior end of the long chitinous rod, posteriorly it is attached to the last true abdominal segment. It brings about the lateral movement of the ovipositor. The muscular motion was continued for about three hours after it was noticed. On the following day all movement had ceased.

The chitinous rod is a long, slightly curved strip of chitin given off from the anterior margin of the 8th sternite, tapering anteriorly and branching into two arms posteriorly, with a median groove running throughout its length.

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B i o l o g y .(a) Larval Habits:

As soon as the larva hatches, it starts feeding at once; young larvae are more active than older ones. The larvae, in common with their parent beetles, are strongly negatively phototropic, moving away from direct light. When a strong light is shone on them they appear very uncomfortable and react by violent twisting of their bodies. The writer found this method very effective in locating the larvae, especially the small early stage ones feeding in powdery food material as they envelop themselves in the particles thereof, making it very difficult to distinguish them and thereby escaping notice. When the electric light is placed near them they begin to twist and move about, in this way they can be located. The larvae are usually hidden under lumps of food material or among debris where they get plenty of shelter.

In powdery or granular material, i.e. casein, powdered oil cake or biscuits, they feed internally, moving about below the surface. If insufficient shelter be provided they provide that for themselves by constructing loosely formed chambers in which they feed. The material used in constructing these chambers is not silk as used for cocoon formation, but is excretary /

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excretary material which comes out at the hind end of the larva in the form of long, coarse, fragile ribbons.

After the larva has fed for about a month, it ceases feeding and prepares for moulting. The first step to accomplish this is that the head is split along the median longitudinal groove; "the epicranial suture", up to about half its length; the head next splits along two laterally oblique lines, and the skin behind the head is split along the mid-dorsal line up to the beginning of the last abdominal segment. The larva finally rids itself of the moulted skin which is usually found close to the hind end, all crumpled up. In this moulted condition the larva lies on its side motionless, with head all one pale colour, legs fully stretched; if irritated it answers by giving a feeble twist of its body.

Number of Moults: This is very variable. Most of the larvae kept under observation moulted twice, some moulted three times, others four times but not more.

It seems that there is a good deal of controversy amongst writers regarding the variation in the number of moults. Some state that it is affected by temperature; the higher the temperature the more the number of moults. Others state that a lower temperature increases the number of moults, while others state /

state that the number of moults does not depend on temperature; among these Braune(1929), working on Niptus hololeucus, states that normally there are two moults but can be increased to three in case of starvation. Pohl (quoted by Marcus(1929)), working on the same insect, states that the number of moults is six.

The earlier larvae are softer bodied grubs, due to the comparative freedom of their body cavity from fat. When dissected at these stages, two thin layers of fat on either side of the alimentary canal are found, while the rest of the body cavity is free from fat. In the case of the adult larva, however, the body is firm, due to the heavy accumulation of pure white fat which completely fills the body cavity. When the larva becomes completely developed, it ceases feeding, and starts to spin a cocoon, wherein it moults finally, and changes into the pupal condition. Under favourable conditions, i.e. when the food supply is plentiful, the cocoon is constructed from the food material and the spinning threads secreted by the larva; such cocoons are oval and so densely walled that the individual inside them is invisible. The fact that the food material is mixed with the secreted threads has a biological significance, in so far as the emerging beetles could find an available supply of food at hand to tide them over possible adverse conditions /

conditions of food shortage. Several newly emerged beetles were dissected and their alimentary canal found to contain particles of food material. Under unfavourable conditions, the cocoon is made up of spinning threads alone, and is elongate oval, with thin walls through which the animal inside can be seen. Occasionally, two or more cocoons are found, fixed together by their outer walls, there being no internal communication between the individual cocoons. Larvae bred in observation boxes, or in glass vessels fix a portion of their cocoon to either the floor or walls of the vessel by means of a sticky secretion. The fixed portion is bare and not spun over, acting as a sort of window. The spinning material is soluble in water and not in alcohol, and is capable of absorbing moisture from the surrounding atmosphere. Under moist conditions, the cocoons may become <sup>so</sup>tough and leathery in texture that in some cases the beetles fail to emerge, getting imprisoned within the cocoon.

Within the cocoon, when the time for the final moult approaches, the larva assumes an elongate form, the hind end shrinks and straightens from its previous rounded form, and then later the skin becomes opaque, dull, shrinking so that the outline of the individual segments and their folds is obliterated, and finally the last larval skin is discarded, revealing the pupa. The /

The discarded skin lies very close to or remains attached to the hind end of the pupa.

If a larval cocoon be disturbed, the larva leaves it altogether, never returning to it; it may either construct another flimsy, thin walled cocoon or pupate without a cocoon; the last condition is very rare. During the whole of my breeding experiments and observations, only two larvae survived after pupating without a cocoon. Several others, however, changed into the pupal condition without a cocoon, but these sooner or later died without attaining the adult stage.

(b) Pre-emergence :

When the pupa has transformed into the fully developed imago, the latter does <sup>not</sup> emerge from the cocoon, but lies in it dormant for some time. At this stage the beetle is very pale in colour and soft bodied, the exoskeleton has not hardened yet, although the reproductive organs at this stage are fully developed. Gradually, the colour darkens, and the chitinous parts harden, until finally the normal dark brown golden colour is attained and the exoskeleton fully hardened; then the beetle is ready to emerge by biting a roughly circular hole through the cocoon. This "pre-emergence stage" occupies about three weeks at a temperature of 61°F.

(c) Sex Ratio :

The sexes are about equal in number - out of /

of 143 specimens dissected, 69 were females and 74 males. After emergence, the beetles start feeding till the reproductive organs become mature, then copulation takes place.

(d) Copulation ∴ takes place during the day or night. The writer never observed it take place at temperatures below 50°F. On the average it occupies about five minutes; a pair were noticed to remain attached for 10 minutes at 60°F.

In the act of copulation, the ♂ mounts the back of the ♀, heads in the same direction. The tip of the male abdomen is bent, the 8th abdominal segment protrudes, followed by the aedeagus, the lateral lobes of which hold the female stylets which protrude from the 8th abdominal segment. The ♂ keeps stroking the ♀ with its antennae all the time.

Copulation takes place repeatedly. It is difficult to differentiate between efficient and apparent copulation, unless dissection of the genital organs is resorted to. I noticed repeatedly newly emerged pairs in apparent copula; on dissection, no spermatozoa could be found in the ♀ receptaculum seminis or its gland, proving that effective copulation could not have taken place. In several cases, the apparently copulating pairs proved to be both males when dissected. It is known and verified by the writer that efficient /



efficient copulation could only take place after a period of feeding for the maturation of the reproductive organs. Pairs bred from pupae were isolated; after two weeks no spermatozoa were found in the ♀ organs.

(e) Egg Laying :

Copulation is followed by egg laying which takes place three to four weeks after emergence. This period is called the "Preoviposition Period" (see table), and it can be prolonged under unfavourable conditions. The eggs are found at all seasons of the year. I found them in all months except January and February. They are laid hidden among debris, lumps of food material, etc. In observation boxes a favourite place for egg laying is empty cocoons; the eggs are glued to the cocoons which they resemble somewhat in colour, making the eggs exceedingly difficult to detect. If the beetles are given such substances as wool, silk, or wood, which do not form suitable food material, no eggs are laid.

T a b l e

Number	Date of Emergence	Date on which first egg was seen.	Preoviposition period in days.	Date after which no eggs were found.	Oviposition period in days	Number of eggs counted.
2 (♂, ♀)	25.10.29	23.11.29	29	13.12.29	20	9
2 (♂, ♀)	8.4.30	30.4.30	22	1.6.30	32	11
5 (2♂, 3♀)	11.4.30	1.5.30	20	7.6.30	37	31
2 (♂, ♀)	30.4.30	24.5.30	24	18.6.30	25	8

It /

It would be seen from the above table that the number of eggs laid by each female varies from 8 to 11, averaging 9 to 10 eggs, and that the oviposition period occupies three to five weeks.

(f) Habits: The beetles are strongly negatively phototropic, and are strongly attracted to moisture. If moist pieces of cotton wool be placed in an observation box, in a short time the beetles swarm over them, lying flat and remaining thereon as long as half an hour. Where the insects are common moist rags or pieces of canvas can be used with advantage to trap them. They are very sensitive to temperature; at temperatures below 50°F. very little feeding and activity take place; in cold weather they lie congregated together in groups. The small rise of temperature, arising from holding an observation box in the hand, is enough to render them active; they also become more active when an electric light is shone on them. This method is effective when looking for live beetles in the food material, as they in common with other stored product pests sham death. In this condition they lie on their back quite motionless, with their antennae alongside and their legs folded in against the body, unlike really dead beetles whose antennae are curved and legs extended from the body. Gentle breathing on the death shamers renders them /

them active. When given solid food material, e.g. biscuits, oil cake, etc., they "mill" more of it than they consume. The greater part of the material is reduced into a fine powdery condition by the beetles.

(g) Flight : The question arises whether the beetles spread by flying or simply by being transported in articles of commerce.

Several specimens of Ptinus tectus were noticed standing on pieces of food material, in a characteristic attitude, with their antennae fully extended forward, expanding their elytra at right angles to the body, and by the use of their fully stretched, well developed wings they make leaps  $1\frac{1}{2}$  to 2 inches long. This can best be noticed when temperature is about 70°F., as when the beetles are kept near a fire for some time, although they were seen using their wings at room temperature (60°F.).

Dendy states that Rhizopertha dominica can easily be made to fly in captivity by bringing an electric light near them when they are warm and active; the same was tried with Ptinus tectus, but with negative result.

(h) Resistance to Starvation :

The beetles could remain alive without food for considerable periods; under such conditions they remain /

remain very quiescent unless disturbed. 12 beetles placed in a clean tin box with no food material on the 15/12/30, on the 23rd March 1931 nine out of the twelve were alive. The dead beetles were removed when noticed as Ptinus tectus are known to eat dead individuals of their own species.

(i) Longevity of Adults :

No. of beetles.	Date of emergence	Date examined.	Months.	Live adults.	Dead adults.	Remarks.
6	28 10 29	20 4 30	6	1	5	The live beetle died the following day.
14	23 4 30	6 11 30	6½	2	12	The live beetles were dissected; 1 male & 1 female.
12	May 1930	6 11 30	6		12	All dead.
6	May 1930	6 11 30	6	1	5	On dissection the live beetle was found to be male.

It will thus be seen that the beetles can live as long as 6 to 6½ months.

Life - History.

The Egg Stage.

Date of Laying	Date of Hatching	Egg stage in days	Temperature.
23. 7.29	8. 8.29	16	
24. 8.29	11. 9.29	18	59°
29. 8.29	17. 9.29	19	to
30. 8.29	19. 9.29	20	
10. 9.29	3.10.29	23	63°F.
22. 9.29	14.10.29	22	

Thus the egg stage occupied from 16 to 23 days, averaging about 19 days at room temperature.

The Larval Stage.

Date of Hatching.	Date of Pupation.	Larval periods in days.	No. of Moults.	Temperature.
8. 8. 29	7. 11. 29	91	2	
11. 9. 29	18. 1. 30	129	3	55°
17. 9. 29	20. 1. 30	121	2	to
19. 9. 29	16. 1. 30	119	2	
14. 10. 29	25. 2. 30	134	4	63°F.
19. 12. 29	7. 5. 30	138	4	

It would be seen that the larval period is very variable, ranging from 91 to 138 days. The number of moults is also variable.

The Pupal Stage.

Date of Pupation.	Date adult was first seen.	Pupal stage in days.	Temperature.
16. 1. 30	27. 2. 30	42	
18. 1. 30	28. 2. 30	41	55°
20. 1. 30	4. 3. 30	43	to
7. 3. 30	1. 4. 30	25	
10. 3. 30	10. 4. 30	30	60°F.
11. 3. 30	9. 4. 30	29	
14. 3. 30	17. 4. 30	34	
7. 5. 30	31. 5. 30	24	

The pupal stage thus varies from 24 to 42 days, averaging about 33 days at room temperature.

Pre /

Pre-emergence Stage.

Date adult was seen.	Date adult emerged.	Pre-emergence period in days.	Temperature.
4 . 3 . 30	26 . 3 . 30	22	
14 . 3 . 30	4 . 4 . 30	21	55°
1 . 4 . 30	16 . 4 . 30	15	to
10 . 4 . 30	29 . 4 . 30	19	
17 . 4 . 30	1 . 5 . 30	14	60°F.

This stage varies from 2 to 3 weeks. A pair of beetles ( $\sigma^1$  and  $\text{♀}$ ) bred from pupae emerged on 11/4/30, these were kept separately in a box with ample food material and left in a dark cupboard at room temperature all summer (temperature 55° to 68°F.) On the 7/11/30 the contents of the box were examined; the parent beetles were dead, and 9 live beetles (the progeny) were found; one of these was actually dissected out of the cocoon. Thus, the summer generation from beetle to beetle occupies about 210 days under the most favourable conditions, so that there can only be one annual generation in this country. There is such an overlapping of generations that it is possible to find all the stages at any period of the year.

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EXPLANATION of LETTERING.

A = Antenna.	E = Egg.
Aa.= Anal area.	El.= Elytron.
Abd.= Abdomen.	E.d.= Ejaculatory duct.
A.G.= Accessory gland.	Epm.= Epimeron.
A.N.P. Anterior Notal Wing Process.	Eps.= Episternum.
A.P.= Prephragma.	En. = Entodorsum.
A.V.= Anal vein.	Ept.= Epistome.
Ax.I. 1st Axillary Sclerite of Wing.	Et. = Epicranium.
Ax.II. 2nd do. do.	Ets.= Epicranial suture.
Ax.III. 3rd do. do.	Ex.m. Extensor muscle.
B.C.= Bursa Copulatrix.	Ey. = Eye.
B.p.= Basal piece.	F. = Femur.
Bs.2= Basisternite.	F.a.= Furcal apophysis.
Bs.3=	F.g.= Foregut.
Ca. = Cardo.	Fr. = Frons.
Coe.= Coecum.	F.s.= Furcasternite.
C.c.= Coxal cavity.	G. = Gula.
Cl. = Claw.	Ga, = Gal <del>l</del> e/
Cly.= Clypeus.	Ge. = Gena.
Cn. = Colon.	Gi. = Gizzard.
Co. = Condyle	G.p.= Gular plate.
Cr. = Crop.	H = Head.
Cs. = Costal vein.	H.i.= Hind intestine.
Cu. = Cubital vein.	H.cs. Head of Costa.
Cx. = Coxa.	H.scs.Head of Subcosta.
D. = Lateral arms of prephragma.	

*af*

Il. = Ileum.  
 I.S. = Internal Sac.  
 I.t. = Internal tube.  
  
 K. = Membrane of  
       Ovipositor.  
  
 L. = Leg.  
 La. = Lacinia.  
 Lb. = Labium.  
 Lb.p. = Labial palp.  
 Lf. = Labial palpifer.  
 Li. = Ligula.  
 Lbr. = Labrum.  
 L.l. = Lateral lobe.  
  
 M. = Media(vein).  
 M.a. = Membranous area.  
 M.d. = Muscle disc.  
 Me. = Mentum.  
 M.G.N. Median Groove of  
       the Notum.  
 M.l. = Median lobe.  
 M.i. = Mid intestine.  
 M.f. = Median foramen.  
 M.p. = Medial plate.  
 Mn. = Mandible  
 M.o. = Median orifice.  
 Mr. = Mesothorax.  
 M.t. = Malpighian tube.  
 Mxf. = Maxillary palpifer.  
 Mxp. = Maxillary palp.

N. = Neck.  
 N.c. = Nutritive chamber.  
 No. = Notum.  
 No<sub>2</sub> = Mesonotum.  
  
 O. = Ocellus.  
 O.c. = Ovarian chamber.  
 Os. = Oesophagus.  
 O.t. = Ovarian tubule.  
 Ov. = Ovary.  
 Ovi. = Oviduct.  
 Ovip. = Ovipositor.  
  
 P. = Process.  
 Pa. = Parastipes.  
 P.ar. = Point of Articulation.  
 Pat. = Parapterum.  
 Pl. = Pleuron.  
 Pl.r. = Pleural ridge.  
 Pl.w.p. = Pleural wing process.  
 Pn. = Postnotum.  
 P.N.P. = Posterior Notal  
       Wing Process.  
 P.p. = Prealar process.  
 Pr. = Prothorax.  
 Ps. = Prescutum.  
 Ps.l. = Prescutal lobe.  
 Pt. = Postergite.

R /

R	= Radius.	T	= Thorax.
Re.	= Rectum.	Ta.	= Tarsus.
Ro.	= Chitinous rod of Ovipositor.	T.A.	= Transfer Apparatus.
Rp.	= Radial plate.	Te.	= Testes.
R.R.	= Recurrent Radial vein.	T.f.	= Terminal filament.
R.S.	= Receptaculum Seminis.	Tg.	= Tegmen.
Rt.m.	= Retractor muscle.	Ti.	= Tibia.
		Tr.	= Trochanter.
		T.V.R.	Transverse Ventral Ridge.
S <sub>1</sub> - S <sub>9</sub>	= Segments 1-9.	U	= Uterus.
Sc.	= Scutum.		
Sc1.	= Scutellum.	Va.	= Vagina.
Scs.	= Subcosta.	V.d.	= Vas deferens.
Sc.t.	= Scutal lobe.	Ve.	= Vertex.
S.G.	= Spiculum Gastrale.		
Sh.	= Sheath.	W	= Wing.
Sme.	= Submentum.	W.p.	= Wing process.
S.O.	= Silk producing organ.	Y.p.	= Yoke plate.
Sp.	= Spiracle.		
St.	= Sternite.	Z	= Arch-like plate of ovipositor.
Sti.	= Stipes.		
Str.	= Sternum.		
Str.2	= Meso-sternum.		
Str.3	= Meta-sternum.		
Su.	= Chitinous Rods supporting ovi- positor sheath.		
S.V.	= Seminal Vesicle.		
Sy.	= Stylets.		

P A P E R   I I .

EXPERIMENTS on the RESPIRATION and VITALITY

of

PTINUS TECTUS.

Four Text Figures.

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### INTRODUCTION.

The experiments forming the subject of this paper were carried out in the Physiology Department of Edinburgh University, through the kindness of Professor Sir E. Schafer, F.R.S., to whom I desire to express my indebtedness. I am particularly grateful to Dr. P. Eggleton for the interest he has taken in the work, and for much valuable help and advice. My thanks are also due to Dr. C. B. Williams for many helpful suggestions.

Dr. R. S. MacDougall informed the writer that he had kept a Ptinid, Niptus hololeucus, in a tightly, glass stoppered bottle, with casein as food material, for eight years, during which time the bottle was left intact. The bottle was then opened and the contents turned out and examined when numbers of live pupae, larvae and adults were found. He therefore suggested to the writer that the study of the respiration of the Ptinid, Ptinus tectus, as to how far it can withstand oxygen deprivation and CO<sub>2</sub> accumulation would form a useful and interesting piece of work.

The material forming the stock was kept in three bottles varying from one to two litres in capacity, and in a biscuit tin (about 12" x 4") with a tight fitting lid. The material was reduced to a fine powdery condition, and it is remarkable to see larvae deep down in the compact mass, against the walls /

walls and bottom of the glass containers, as under such conditions the air space is bound to be very small indeed. The tin referred to above was left unopened for six months (the material therein being 8" deep); it was then opened, when the material was found in a fine powdery and slightly caked condition. From the very bottom of the tin, a lump of oil cake (1" x  $\frac{3}{4}$ " in diameter) and weighing about 6 gms., was taken out, broken up and found to contain no fewer than 12 live larvae, 2 live pupae and two adult beetles ready to emerge. Yet under such conditions of deprivation of air they can live and multiply. This suggests, at first sight, that the oxygen requirements of Ptinus tectus are very small, and that the beetles can live quite happily when the oxygen supply is very low.

The Effect of Hermetical Sealing on *Ptinus tectus*.

The effect of hermetical sealing on insects, particularly on grain pests, was studied by Barnes & Grove and Dendy; the latter demonstrated the inability of grain weevils to live in hermetically sealed vessels, under these conditions the insects succumb as soon as the oxygen supply has been used up and a corresponding amount of CO<sub>2</sub> produced.

The writer found that hermetical sealing kills both larvae and pupae of *Calliphora* (blue bottles). In fact pupae kept in air tight vessels showed no development /



development, and on dissection were found to contain a mass of fatty material. Hermetical sealing was also found fatal to the pupae of *Drosophila*; in one case 8 pupae were hermetically sealed in a 90 cc. glass jar; after some time, one fly emerged. On testing the jar, as shown later, it was found to have a minute leak in the parrafin wax.

#### METHODS and TECHNIQUE.

For hermetical sealing, the beetles, larvae or pupae were placed in small (40 cc) bottles with tight fitting glass stoppers, these, and the inside of the neck of the bottles, being heavily vaselined and a thick layer of melted parrafin wax painted round the junction of stopper and neck. The bottles were finally tested by immersion in warm water for 10 to 15 minutes and watching for air bubbles. The control bottles had the inside of the neck vaselined and muslin tied tightly round the neck. When desired to make analysis of the gases present, after the death of the animals, glass bulbs (25 cc. capacity) with two delivery tubes were used, the tubes being sealed by means of a blow pipe, and immersed in warm water to test for leakage. The food material was supplied in the form of sweet biscuits which stood at room temperature for a few days to absorb enough moisture for /

for the animals' requirements. All the experiments were carried out at room temperature which ranged from 55°F. to 68°F., averaging 60-62°F. Several experiments were carried out in an electric incubator kept constantly at 27.5°C. to 29°C., The mortality amongst the beetles was very high. The beetles in the control as well as in the sealed bottles died, despite the fact that they were well supplied with moisture in the form of an open glass jar filled with water, and kept in the incubator. The same results attended my breeding experiments in the incubator. These facts lead to the conclusion that constant temperature is fatal to Ptinus tectus, at least in the adult stage.

#### EXPERIMENT A.

##### Effect of hermetical sealing on Ptinus tectus.

4, 40 cc. bottles with 10 beetles and food material were sealed hermetically at room temperature (67°F.) on the 3rd July 1930 at 3.30 p.m.

4 other bottles with 10 beetles and food material in each acted as control.

The whole left in a dark cupboard. On the 8th August 1930, the contents of the bottles were turned out and examined.

Result: All the beetles in the sealed bottles were dead and failed to revive. In the control bottles:-

1 contained 8 live and 2 dead beetles.

1	"	10	"	and no	"	"
1	"	7	"	and 3	"	"
1	"	5	"	and 5	"	"

EXPERIMENT B.

Started the same day as A. 2 bottles each containing 15 larvae with food material were hermetically sealed, 2 more with the same number of larvae in each acted as control. They were kept in a small cardboard box at room temperature and not examined till the middle of October, when all the larvae in the sealed bottles were dead. In one of the control bottles, 15 live beetles were found and 12 live beetles in the other.

EXPERIMENT B1.

Repeated the above experiment on the 31/10/30 with 12 larvae in each bottle. On the 3/2/31 the contents of the bottles were turned out and examined. All the larvae in the sealed bottles were dead without forming cocoons, the food material being in a much matted condition. In the control bottles 10 live larvae in their cocoons were found in one bottle, and 9 live larvae in cocoons and one alive in the food material in the other.

EXPERIMENT C.Effect of sealing on Pupae.

On the 31/10/30, 10 pupae placed in a 40 cc. bottle and hermetically sealed; 10 more placed in a similar size bottle acted as control.

On /

On the 3/2/31, the contents of both bottles were turned out and examined.

In the sealed bottle - 4 dead beetles and 6 dead pupae were found.

In the control bottle - 7 live beetles,  
2 dead " in cocoons,  
1 not accounted for.

#### EXPERIMENT D.

The gases present in sealed vessels in which the beetles were killed.

3 glass bulbs (25 cc. each) with delivery tubes were used; each contained 10 beetles with about 1 gm. of food material. The bulbs were sealed by blow pipe at room temperature (63°F.) on 30/10/30 at 3.20 p.m. 3 tubes, each about 25 cc. capacity, with 10 beetles and 1 gm. of food material in each acted as control. Daily observations and records were kept.

Date	Temperature	Bulb 1.	Bulb 2.	Bulb 3.
7 11 30	55°F.	1 dead	1 dead	All alive
8 11 30	56	2 "	2 "	" "
9 11 30	56	2 "	2 "	" "
11 11 30	57	2 "	2 "	3 dead
13 11 30	58	5 "	2 "	3 "
14 11 30	60	5 "	3 "	7 "
24 11 30	59	all dead	8 "	all dead
30 11 30	53	" "	all dead	" "

In /

In the control tubes on 30/11/30 :-

1 contained 7 live and 3 dead beetles.

1 " 6 " " 4 " "

1 " 9 " " 1 " "

Result of analysis of gases in bulbs on 1/12/30  
(after 31 days).

Composition of atmospheric Air.

CO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>
0.03	20.93	79.04

Bulb 1.			Bulb 2.			Bulb 3.		
CO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub> (by differ- ence)	CO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>	CO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>
3.047	15.95	81.01	4.24	14.62	81.14	5.12	13.86	81.02

No beetles revived on testing.

The analysis were made by the use of Haldane's gas apparatus and carried out in the Biochemistry Department of Edinburgh Royal Infirmary, through the kindness of Dr. C. P. Stewart.

The results of the foregoing experiments indicate that Ptinus tectus in all its stages is killed in air tight vessels; a certain amount of the initial oxygen present is consumed and a corresponding amount of CO<sub>2</sub> produced.

Dendy states that grain insects (Calandra and Rhizopertha) in hermetically sealed vessels succumb as /

as soon as the supply of oxygen is exhausted and that before doing so they produce an amount of  $\text{CO}_2$  equivalent to the amount of  $\text{O}_2$  consumed. My experiments, however, do not show the same results; the beetles died in an atmosphere containing about 13 to 15% of oxygen, consuming about 5.7% of  $\text{O}_2$  and producing about 4%  $\text{CO}_2$ .

Effect of Diminished Oxygen Pressure.

In experimenting with gases and mixtures of gases on the beetles, it has to be remembered that they can lie perfectly torpid and motionless for a number of days without, however, losing their powers of recovery when conditions are more favourable. A good many of my experiments had to be repeated, owing to failure to realise this fact. It is impossible to tell whether the beetles are actually dead before turning them out and giving them a chance to revive under favourable conditions. The beetles after the period of the experiment were tried for revival by gentle breathing on them, and then left for 24 to 48 hours in a petri dish at room temperature and then again tested by gentle breathing; if they showed no movement it was concluded they were dead.

All the observations recorded in the following pages were made with the aid of a hand lens.

Survival /

Survival period of *Ptinus tectus*, in very low Oxygen Concentration, Zero, CO<sub>2</sub>, and normal water vapour pressure.

METHOD:- The inert gas used was pure Nitrogen supplied by the British Oxygen Co. and guaranteed 99.8% pure.

The Nitrogen from the cylinder was passed through an absorption tube, filled with sofrolite, to absorb any possible CO<sub>2</sub>. The Nitrogen was then passed into another tube fitted with ground glass stoppers containing the beetles, 8 in number, with food material, the 2 absorption tubes placed in a beaker full of water and finally the excess Nitrogen bubbled into water. The rate of flow of the Nitrogen was regulated by means of a fine adjustment valve attached to the compressed Nitrogen cylinder. At the start of the experiments a rapid current of N<sub>2</sub> was passed through for about 10 minutes to wash off the gases in the tubes and then the rate was slowed down to about 15 bubbles per minute, which rate was kept up right through the experiment.

EXPERIMENT /

EXPERIMENT E.

Started on 4. 2. 31. at 12.30 p.m.

5. 2. 31 - 3 p.m. All alive and moving.
6. 2. 31 - 11.15 a.m. 5 moving but rather feebly;  
1 quiescent, but showing movement  
of legs.  
2 motionless.
- 3.40 p.m. 5 alive and moving feebly.  
3 motionless.
7. 2. 31 - 12.10 p.m. 3 walking - the rest motionless.
9. 2. 31 - 10.15 a.m. 2 alive moving feebly; the  
rest apparently dead.
- 3.25 p.m. Only 1 moving feebly.
10. 2. 31 - 10.20 a.m. No movement seen; all appar-  
ently dead.

Taken out and examined for revival, 1 started to move feebly; the following day they were again tested with the same result.

EXPERIMENT F.

Started on 24.2.31 at 11 a.m.

- 25.2.31 - 11 a.m. All alive and active.
- 26.2.31 - -- All alive but slightly feeble.
- 28.2.31 - 10.30 a.m. 7 moving feebly, 1 motionless.
- 2.3.31 - -- 6 moving (climbing the vertical  
walls of the tube.  
2 motionless.
- 3 p.m. 5 moving feebly.
- 3.3.31 - 10.30 a.m. 5 alive, 3 moving and 2 very feeble,  
the rest apparently dead.
- 4.3.31 - 10.25 a.m. Only 3 showing movement.
- 5.3.31 - -- Only 2 " "
- 6.3.31 - -- All motionless.
- 7.3.31 - turned out and tested for revival; 2 showed  
very feeble movement.
- 9.3.31 - 2 alive and the rest dead.



EXPERIMENT G.

Started 6.3.31 at 11 a.m.

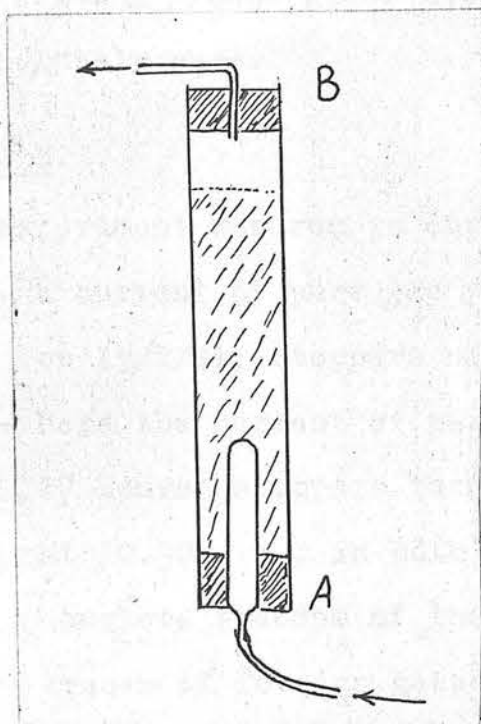
- 9.3.31 - All but one showing movement.
  - 10.3.31 - 2 motionless, the rest active.
  - 11.3.31 - 5 moving.
  - 13.3.31 - 3 alive.
  - 14.3.31 - All motionless.
  - 16.3.31 - Turned out and tested for revival, all apparently dead.
  - 17.3.31 - All dead.
  - 18.3.31 - All dead.
- 

The result of the last three Experiments indicate that Ptinus tectus could tolerate diminished oxygen pressure, as low as 1.5 mm. of mercury, for a period ranging from 5 to 10 days at a temperature of about 15°C. It would also be noticed that the deprivation of oxygen and not the presence of CO<sub>2</sub> is responsible for the death of the beetles.

Dendy states that with the purest nitrogen that could be obtained (99.22%) sealing grain weevils for 44 hours was sufficient to kill them.

Now seeing that the beetles could tolerate diminished oxygen pressure for about 8 days, it would be interesting to find out the survival period under anaerobic conditions. To achieve this, it was necessary to use an inert gas (Nitrogen) freed from all traces of O<sub>2</sub>. This was done by washing the N<sub>2</sub> thoroughly /

thoroughly in an alkaline solution of Sodium Hydro-sulphite.



METHOD:- A large glass cylinder (about 5 ft. long and 2" in diameter) fitted with 2 well fitting rubber stoppers, one at each end; a Berkfeldt filter with glazed top, fitted tightly through cork A, and a thin piece of glass tube through cork B. The glass cylinder stood upright with A downwards (see fig.); about 2 litres of the alkaline solution poured in, the glazed end of the filter being connected by a length of pressure rubber tubing to the fine adjustment valve on the N<sub>2</sub> cylinder. The N<sub>2</sub> was forced through the filter, frothing as it went up to the solution collected at B, washed in a bottle containing 10% Na<sub>2</sub>S to free it from any possible CO<sub>2</sub>, and finally /

finally passed on to the beetles contained in a U tube with well fitting ground glass stoppers, thus getting the N<sub>2</sub> absolutely pure.

EXPERIMENT H.

The experiment was run in duplicate -

Tube "a" - a current of pure gas passed for  $\frac{1}{2}$  hour on 19/2/31; stoppers closed at 4.20 p.m.

Tube "b" - here the current of gas was passed for 17 hours; stoppers turned off on the 20th at 10.30 a.m., in both cases ensuring the complete freedom of the tubes from any traces of foreign gases.

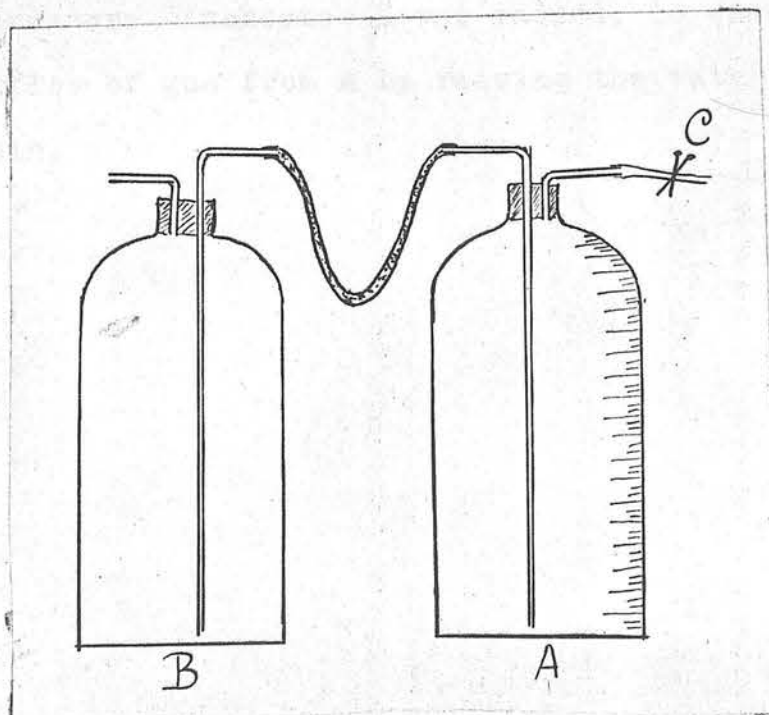
Date	"a"	"b"
20.2. -10.45 a.m.	All alive and	active.
21.2. - 9.45 a.m.	5 active 1 motionless	All alive and active.
23.2 - 1.45 p.m.	5 alive but feeble	all alive but rather feeble.
24.2. -12 noon	All very quiet, only 1 showing feeble movement of antennae. 5 hours later all movement ceased. Turned out & exam- ined for revival; all apparently dead.	all alive but very weak.
25.2. - 1 p.m.	All recovered and quite active.	Only one showing feeble movement of legs; the rest apparently dead.
26.2. - 1 p.m.	same	all movement ceased
27.2.	-	all motionless
28 /		

Date	"a"	"b"
28.2. -	All recovered and quite active.	Turned out and examined for revival; no result, all apparently dead.
2. 3. -	same	On being again tested for revival, one showing very feeble movement of legs, the rest apparently dead. The following day all dead.

It is obvious from Experiment H. that Ptinus tectus could live under absolutely anaerobic conditions for a period of at least six days.

Effect of Different Concentrations of Carbon Dioxide.

METHOD:- The carbonic acid gas used was supplied by the Distillers Co. and guaranteed 99.5% pure.



Two Winchesters of equal size (about  $2\frac{1}{2}$  litres capacity) each fitted up with a tightly fitting two-holed rubber cork, through which two glass tubes, one reaching to the bottom of the bottle, the other not projecting beyond the level of the cork, the two long tubes being connected by a length of rubber tubing; Bottle A being calibrated and then filled up with water, then the desired gas is introduced at C:, the pressure driving the water into B. until the level at A drops to a point representing the required percentage.

The mixture of gases was shaken up and allowed to stand for some time and then led on to the beetles contained in an absorption tube with well fitting ground glass stoppers and finally bubbled in water, the rate of gas flow being regulated by means of a screw clamp at C. After a few hours, the level of the pressure Winchester B was raised, to ensure an even flow of gas from A by raising the water level therein.

Observations.

No. of Expt.	Date	No. of Beetles	Composition		Period of Exposure in hours.	Observations.
			CO <sub>2</sub>	O <sub>2</sub> N <sub>2</sub>		
1	8.12.30	8	8	92 -	24	When mixture was passed, it did not have any effect on beetles which were quite active; 2 hours later they became quieter; after 4 hours all alive and active; at the end of the period, the same.
2	9.12.30	8	10	20 70	24	All alive and active at the end of the period.
3	9.12.30	8	18	82 -	90	Beetles lively when the mixture was passed; 10 minutes later four were motionless, but lying in their natural position; after 3 hours two lying on their back, the others moving about. After 72 hours all very quiet; on being disturbed, 7 showed movement but feeble. At the end of the period taken out and examined, all alive.
4	10.12.30	5	20	20 60	48	After five hours, 1 feeble, the rest active; after 24 hours, 1 apparently dead, the rest moving; after 48 hours, 2 motionless and 3 moving feebly. Examined for revival next day, all recovered and active.
5	3. 2.31	6	30	14 56 air	48	After two minute, activity ceased, beetles went on their back showing feeble movement of limbs; after 2 hours, 3 lying on their back motionless and 3 moving about feebly; after 4½ hours, 5 motionless and 1 moving; after 24 hours, 3 moving and 3 motionless, on being disturbed all showed movement. After 48 hours all alive on being taken out.
6	4. 2.31	6	40	12 48 air	24	Mixture had an instantaneous effect on the beetles, which ceased activity and fell on their back motionless; after one hour still no movement; after 24 hours no movement; on being taken out and examined all alive and active.

No. of Expt.	Date	No. of Beetles	Composition		Period of Exposure in hours.	Observations.
			CO <sub>2</sub>	O <sub>2</sub> N <sub>2</sub>		
7	6.2.31	6	50	10 40 air	68	After about one minute all lying on their back motionless, apparently dead; after 22 hours, same, no movement on being disturbed; after 68 hours still no motion. Taken out and examined for revival, 2 showed movement of antennae; 5 hours later all alive and active.
8	12.2.31	6	60	8 32 air	120	After about 2 minutes, beetles fell on their back, apparently dead; after 24 hours, all apparently dead, no movement seen; after 5 days taken out and examined for revival no result, all apparently dead; 2½ hours later 3 revived and started moving about; 24 hours later all alive and active.
9	17.2.31	6	70	6 24 air	168	After about one minute, all fell on their back, apparently dead; observed daily but no sign of movement could be detected; after 168 hours, taken out and tested for revival but with negative result; the following day two recovered, 4 apparently dead; after 24 hours still no revivals, 4 dead.
10	25.2.31	6	80	4 16	120	1-2 minutes all motionless, no movement seen though examined daily; after 120 hours turned out and examined, all apparently dead; 24 hours later 2 revived, the rest dead.
11	3.3.31	6	90	2 8	48	1-2 minutes all motionless, no movement seen; after 48 hours turned out and examined, 4 showed feeble movements of limbs; 24 hours later, 4 alive and active and 2 alive but feeble; same result 24 hours later.
12	5.3.31	6	90	2 8	96	1-2 minutes all motionless, no movement seen; after 96 hours taken out and examined, all apparently dead; 24 hours later, 4 recovered and 2 dead.

The gases used in Experiments 1 to 4 inclusive were chemically prepared; the Oxygen and Nitrogen were supplied by the British Oxygen Company; purity 99.8%.

The results of the last twelve experiments indicate that Ptinus tectus can tolerate very high concentrations of moist CO<sub>2</sub>; under such conditions they remain absolutely motionless, apparently dead, with their legs and antennae extended, during the whole period of treatment, without, however, losing their powers of recovery.

Cole records similar results for the grain weevils Calandra granaria and Calandra oryzae, and states that almost any concentration of CO<sub>2</sub> in the atmosphere in which the weevils live may be disregarded as a preventive agent. a/-

It remained to find out the effect of pure CO<sub>2</sub> (99.5%). Here a rapid current of the gas was passed direct from the cylinder into an absorption tube containing the beetles, and finally bubbled into water, the current being passed for 15 minutes, after which time the stopcocks were turned off. Before use the tubes were thoroughly tested for any possible leakage.

Effect /



No. of Expt.	Date	Period of exposure in hours	No. of beetles	Observations.
13	24.2.31	24	8	The gas had an instantaneous effect on the beetles which fell on their back motionless; after 24 hours turned out and examined, all apparently dead; 24 hours later again examined, all alive, 6 quite active and 2 feeble.
14	26.2.31	48	8	In about 1 minute, all motionless; after 24 hours, no movement; after 48 hours, turned out and examined, 7 alive and active and 1 apparently dead.
15	2.3.31	96	7	In less than 1 minute, all motionless, no movement seen although examined daily; after 96 hours, taken out and examined, all apparently dead; the following day 3 revived and the rest apparently dead; the following day, 1 more revived, the rest dead.
16	18.3.31	120	7	No movement seen; after 5 days, taken out and tested for revival, 4 began to move feebly; the following day, still alive but feeble.
17	15.3.31 to 2.4.31	360	12	After 5 days, 4 beetles were seen moving in the tube; after 15 days, 4 beetles alive.

It would be seen that *Ptinus tectus* can tolerate almost pure CO<sub>2</sub> for fairly long periods, the beetles lying dormant practically throughout the period of treatment without losing their powers of recovery.

Seeing that the beetles can tolerate very high concentrations of moist CO<sub>2</sub>, it was desired to find out whether concentrations of dry CO<sub>2</sub> had any effect.

The mixture of gases prepared as described was passed in a series of bulbs nearly filled with concentrated sulphuric acid, to dry the gas thoroughly; it was then passed on to the beetles as before.

Effect of different Concentrations of thoroughly dried CO<sub>2</sub>.

No. of Expt.	Date	No. of beetles	Composition of gases.			Period of exposure in hours	Observations.
			CO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>		
18	17.2.31	6	20	16	64 air	166	After 24 hours, all alive and active; After 48 hours all alive but rather feeble; after 72 hours, 3 moving, the rest apparently dead; after 96 hours, only 2 showing movement; after 166 hours, no movement could be seen - taken out and examined, no result; 24 hours later, 1 revived, the rest dead; no more revivals the following day.
19	25.2.31	6	20	16	64 air	144	After 24 hours all alive and moving; after 48 hours, 5 showing movement; after 120 hours, 3 moving; after 144 hours, no movement, taken out and examined, 1 moving feebly; the following day 1 more revived, making 2; no more revivals.
20	4.3.31	6	15	17	68 air	120	After 24 hours, 3 moving feebly, the rest motionless; after 48 hours, 2 showing movement but feeble; after 120 hours, all motionless - taken out and examined, 1 began to move feebly, the rest apparently dead; no more revivals 24 hours and 48 hours later.

Experiment 20 was carried out in exactly the same way as the other two, except that the absorption tube containing the beetles was thoroughly dried in a water oven, the food material supplied was of the same origin and moisture content (6.66%).

These experiments indicate that, although the beetles can tolerate high concentrations of moist CO<sub>2</sub>, yet low concentrations (15-20%) of dry CO<sub>2</sub> are fatal to them.

Cole, experimenting with grain weevils, states that pure dried CO<sub>2</sub> is very fatal, acting either as a poison or as a desiccator, or both, and not merely as an oxygen barrier.

Dendy, also experimenting on the grain weevils, states that CO<sub>2</sub> exerts a poisonous effect upon the weevils, apart altogether from the question of diminished O<sub>2</sub> pressure; he further adds that at 30-31°C. Calandra oryzae was killed in less than 12 days in an atmosphere containing 14.08 - 22.56% CO<sub>2</sub>, though 13.88% of Oxygen still remained. In his experiments he used moist CO<sub>2</sub> in order to eliminate the possible effect of desiccation.

Referring to Experiment J, it would be seen that Ptinus tectus could stand complete desiccation for much longer periods than those of Experiments 18 to 20. It is obvious then that the CO<sub>2</sub> exerted a poisonous effect /

a/-

effect on the beetles and that the question of desiccation can be disregarded .

Moisture Requirements of *Ptinus tectus*.

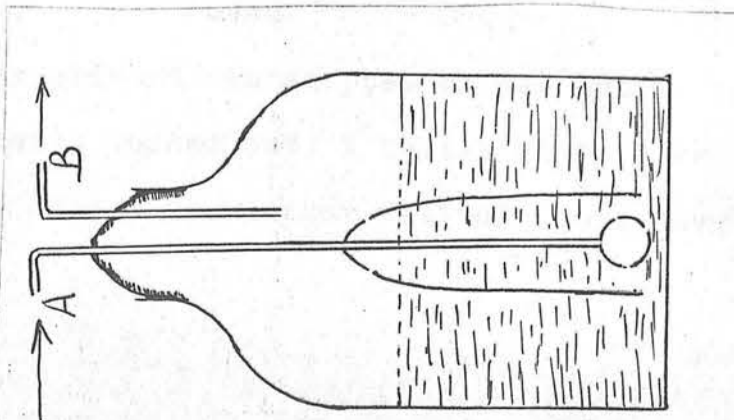
It is well known that a certain degree of humidity is essential for the existence of all insect life. Experiments carried out to determine the amount of moisture required for certain insects, involving the use of closed bottles to keep out moisture, are quite unreliable as no allowance has been made for the fact that hermetical sealing alone is fatal to insect life apart altogether from any other factor (Dendy).

The question was therefore investigated without resort to closed receptacles.

EXPERIMENT J.

Resistance of *Ptinus tectus* to Desiccation.

METHOD: Compressed air being used, the writer was informed that the air is delivered from the compressed air plant in a fairly dry condition; the air was further thoroughly dried by bubbling it into a special moisture trap, nearly filled with concentrated sulphuric acid.



The air was led in at A, washed thoroughly in the acid and then collected at B, passed through an absorption tube filled with "Sofnolite" to absorb any possible oxides of sulphur, passed on to the beetles contained in a U tube with well fitting ground glass stoppers (with food material) and finally bubbled into a beakerful of water, thus ensuring a constant current of thoroughly dried air. The beetles were seven in number, and the biscuits supplied for food had a moisture content of 6.7%.

7 beetles kept in a small glass tube acted as control.

The experiment was started on the 5th January, 1931 at 3.10 p.m.

- 6.2.31 - 11 a.m. All alive and active.  
           3.30 p.m. All alive, 6 active, 1 feeble.
- 7.2.31 - 11.40 a.m. Beetles very quiet; on being disturbed  
                     6 moving about, 1 apparently dead.
- 9.2.31 - 1 a.m. 6 alive and quite active; one dead.
- 10.2.31 - 10 a.m. Same.
- 11.2.31 - " " 6 alive but rather quiet; movement was  
                     seen daily.
- 2.3.31 - 10 a.m. 3 quite active, 1 alive but very feeble,  
                     2 apparently dead, making 3 dead.
- 10.3.31 - " " 3 alive and active, the rest apparently  
                     dead.

The experiment was stopped on the 16th of March 1931, contents turned out, 1 beetle alive, the rest apparently dead. No further revivals on subsequent testing.

In /

In the control tube - 6 beetles alive and 1 dead.

It would thus be seen that Ptinus tectus is extremely drought hardy, withstanding complete desiccation for about one month which is really remarkable.

The LOWER and UPPER LIMITS of TEMPERATURE.

The Lower Temperature Limits: Grain and stored product pests as a group are unable to withstand continued low temperatures in a dormant condition. Of the Ptinids, however, Ptinus fur may be able to stand dormancy (Payne).

Experiments on Ptinus tectus show that the beetle in both larval and adult stage is exceedingly cold hardy, and can withstand continued low temperatures for a fairly long time. The insects under such conditions are quite torpid (legs and antennae outstretched) lying dormant as long as the temperature is low. When conditions of temperature become more favourable, they start normal feeding and activity.

EXPERIMENT K.

On the 5th February, 1931, at 2.30 p.m., 8 adult beetles were placed in a small glass petri dish with food material, in an electric refrigerator, kept constantly at about freezing point; it was tested on several occasions, the temperature varying from  $-1^{\circ}\text{C}.$  to  $+ .25^{\circ}\text{C}.$

On the 9/2/31 at 10.45 a.m., the beetles were taken /

taken out and found quite torpid, revived by gentle breathing, 7 started crawling about feebly, later became active, 1 apparently dead. The same day at 11 a.m. 8 more beetles were placed in the refrigerator.

On the 17th, at 10.45 a.m. they were taken out and tested for revival, in about 5 minutes all began to move about; they were again put back.

On the 19th at 12.45 p.m. they were taken out and warmed by gentle breathing for about three minutes, 6 began to crawl, put back.

On the 23rd at 10.55 a.m. repeated above procedure. Immediately 3 began to move and then a fourth. They were kept at room temperature.

24.2.31. 4 alive but very feeble, 4 motionless.

25.2.31. 4 alive and very active and feeding, the rest motionless.

26.2.31. 2 revived, making 6 alive and 2 dead; no further revivals.

2.3.31. 6 alive and active and 2 dead.

#### EXPERIMENT K<sub>1</sub>.

6 larvae put in the refrigerator on

5.2.31 and left till the

28.2.31 5 alive and 1 apparently dead.

They were put back.

2.3.31 4 alive and 2 apparently dead. They were left at room temperature for 24 hours.

3.3.31 1 recovered, making 5 alive and 1 dead.

Experiments K and K<sub>1</sub> show that the adult beetles and the larvae can withstand a temperature of about 0°C., the former for a period of three weeks and the latter for about four weeks and probably much longer.

The Upper Temperature Limits.

The following experiments were carried out in a water oven, the temperature of which being regulated as desired. The beetles were placed in test tubes with food material.

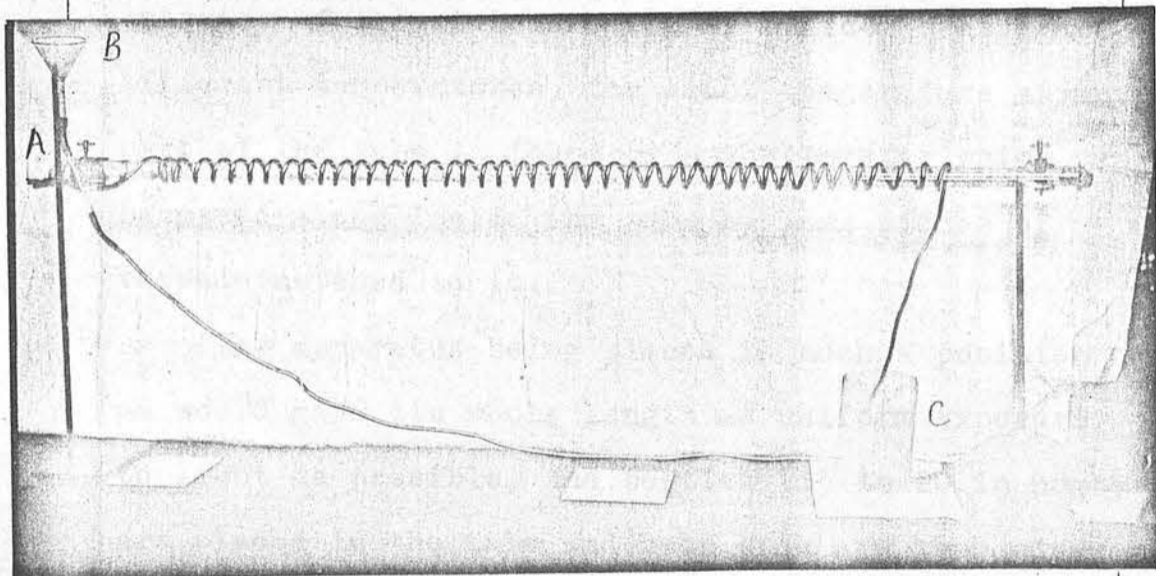
No. of Expt.	No. of beetles.	Period of exposure in minutes.	Temperature.	Remarks.
21	5	6	42.5-44°C.	Beetles put in oven at 42.5 C. for 3 minutes, all torpid when taken out; about 5 minutes later all began to move feebly; they were put back in the oven at 44°C. for 3 minutes; all torpid on being taken out; 10 minutes later all began to move; After 24 hours all alive.
22	6	6	44 - 45°C.	All torpid when taken out of oven; after 24 hours all alive but rather feeble.
23	5	3	48°C.	All torpid when removed from oven; about $\frac{1}{2}$ hour later one crawling; after 24 hours all alive.
24	8	3	50 C.	All torpid when taken out; after 24 hours, 1 walking feebly, 3 showing feeble movement of limbs, 4 motionless.
25	6	5	50.5°C.	All torpid when taken out; after 24 hours, all motionless; after 48 hours, tested for revival but with negative result.
26	10	3	54°C.	Same as No.25.

The same set of experiments was tried for the larvae. It was found that a temperature of 50.5°C. to 51.5°C. for 3 minutes kills the larvae, including those enclosed in cocoons.



Preferred Temperature.

In order to investigate this, a replica of a piece of apparatus, originally designed by Dr. C. B. Williams was used.



The apparatus consists of a long piece of glass tubing /

tubing, about 5 ft. long and 1" in bore, supported on two retort stands; a long piece of soft metal tubing tightly coiled spirally round the glass tube, the ends of the metal tubing being attached to a T shaped glass tube A connected to a funnel B by means of rubber joints, the whole system being filled with water which circulates round the glass tube at different temperatures when heated by a small Bunsen burner at C. The interior of the glass tube being thereby heated at different temperatures, the exact temperature at any part of the tube is found by a thermometer which can be moved along inside the tube by long pieces of thread fastened to it.

The apparatus being placed in such a position as would give its whole length as uniform exposure to light as possible, the beetles (15 to 20 in number) are placed in the tube and both ends are then plugged with pieces of cotton wool. The beetles can now wander at will, choosing a spot approximating to their preferred temperature. Some tend to settle in a position opposite the spot where the metal tubing comes in contact with the glass tube. The biggest number of beetles congregating in a position between the coils of the metal tubing, this spot is marked, the thermometer slid to it and the temperature recorded is the preferred temperature.

1. /

1. Started with 20 beetles; after one hour 9 congregated at a spot, the temperature being 25°C.
2. 25 beetles - 8 of these settled at 23.5°C.
3. 25 " - 10 " " " 22°C.

The preferred temperature thus varying from 22 to 25°C., averaging 23.5°C.

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tubing, about 5 ft. long and 1" in bore, supported on two retort stands; a long piece of soft metal tubing tightly coiled spirally round the glass tube, the ends of the metal tubing being attached to a T shaped glass tube A connected to a funnel B by means of rubber joints, the whole system being filled with water which circulates round the glass tube at different temperatures when heated by a small Bunsen burner at C. The interior of the glass tube being thereby heated at different temperatures, the exact temperature at any part of the tube is found by a thermometer which can be moved along inside the tube by long pieces of thread fastened to it.

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1. /

PLATE I.

- Fig.1. Egg. x 120  
2. Fully developed larva. x 33  
3. Leg. x 120  
4. Abdominal spiracle. x 360  
5. Dorsal view of head. x 120  
6. Antenna. x 650  
7. Frons and Epistome. x 90

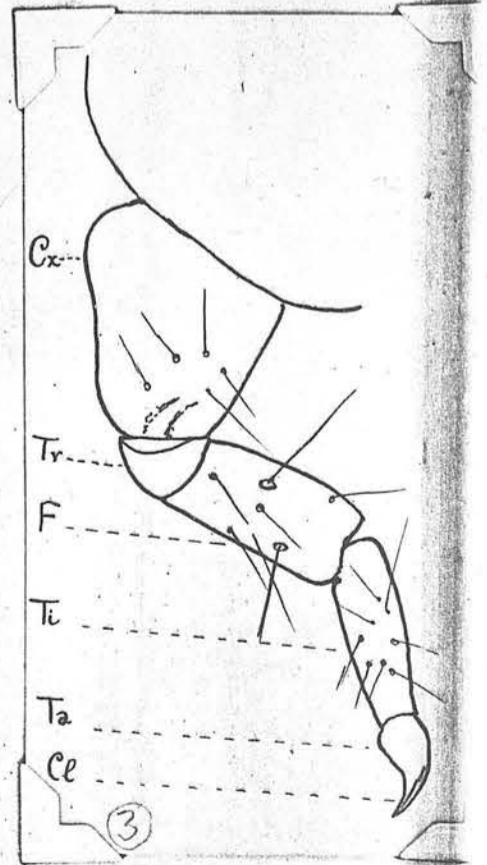
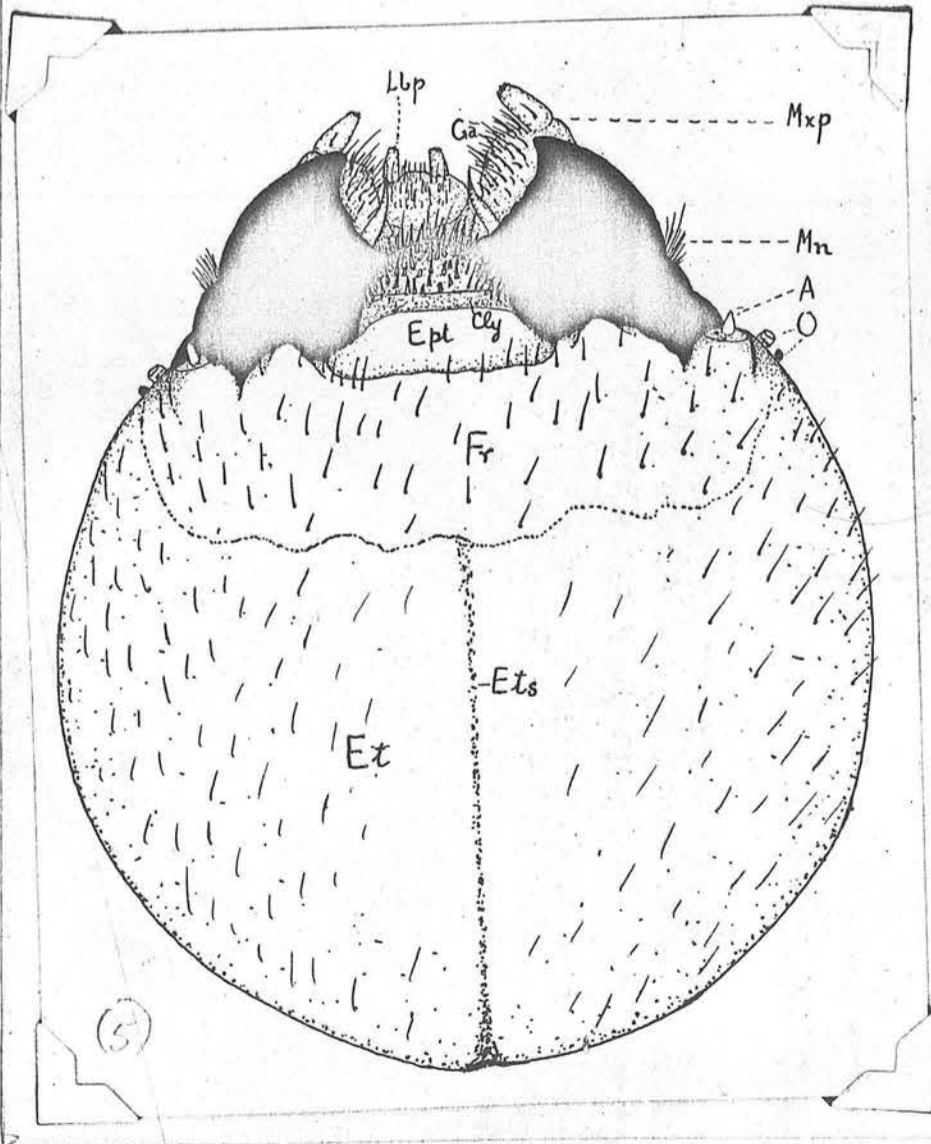
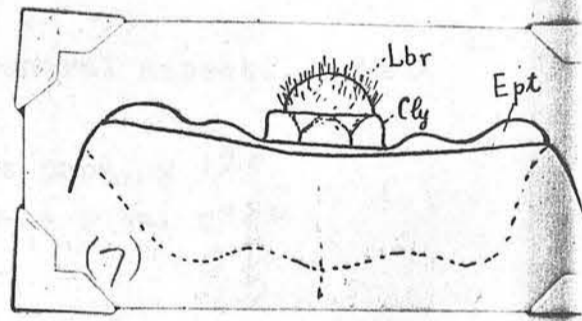
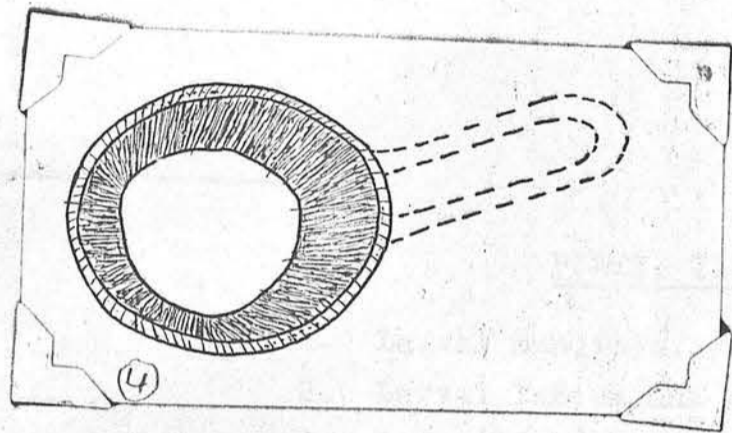
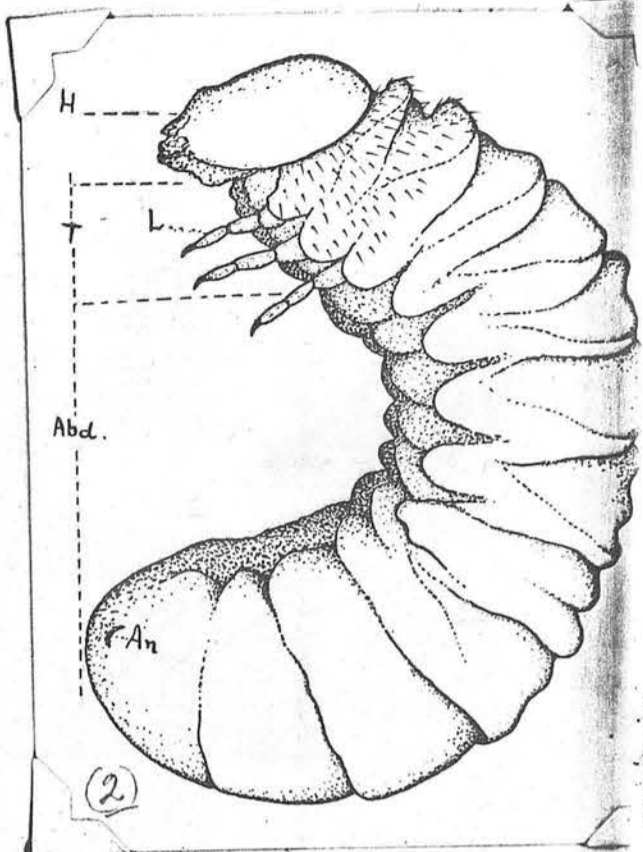
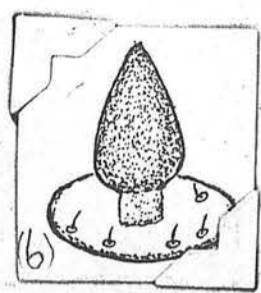
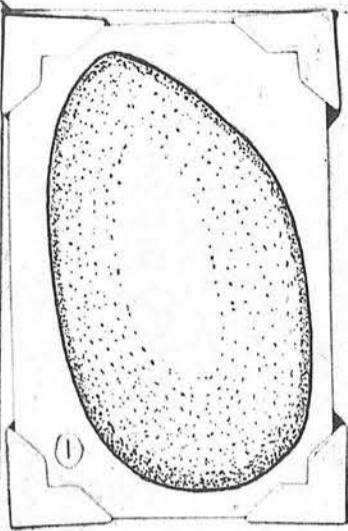


PLATE II.

- Fig.1. Larval mandible. x 90  
2. Larval labium and maxillae(ventral aspect). x 120  
3. Pupa (ventral aspect) x 40  
4. 8th and 9th Sternites of male pupa. x 120  
5. 8th and 9th Sternites of female pupa. x 120

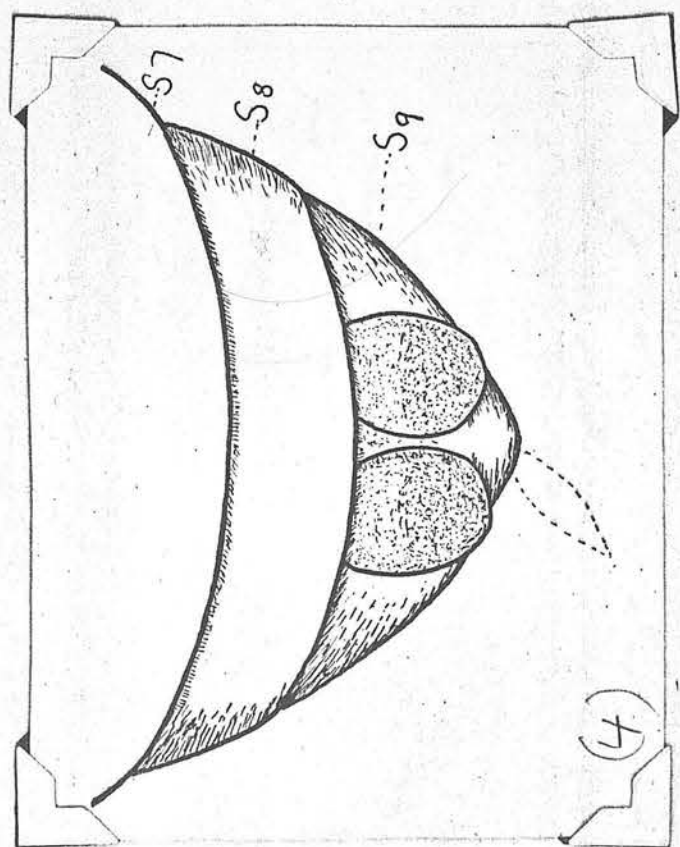
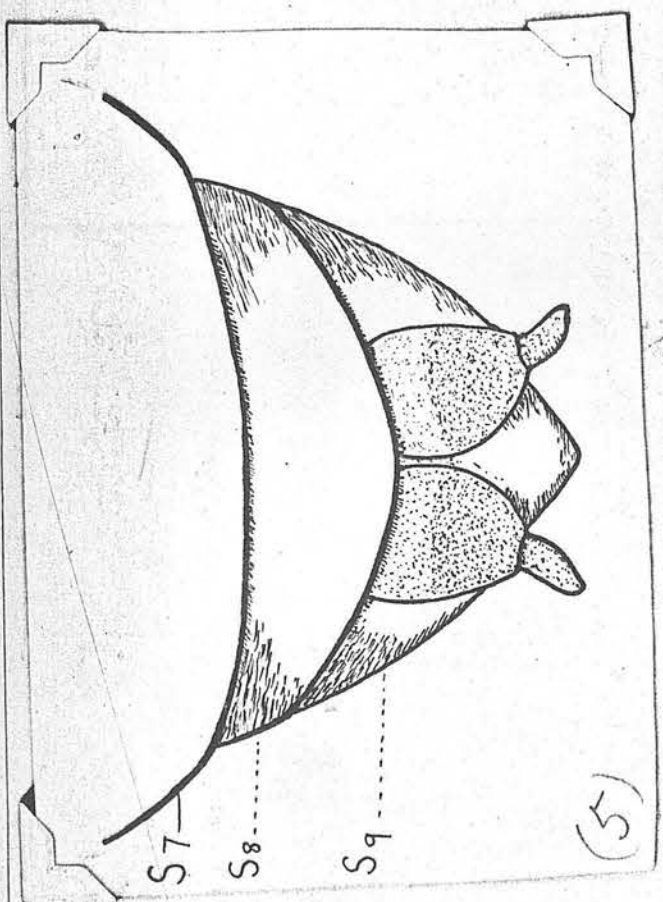
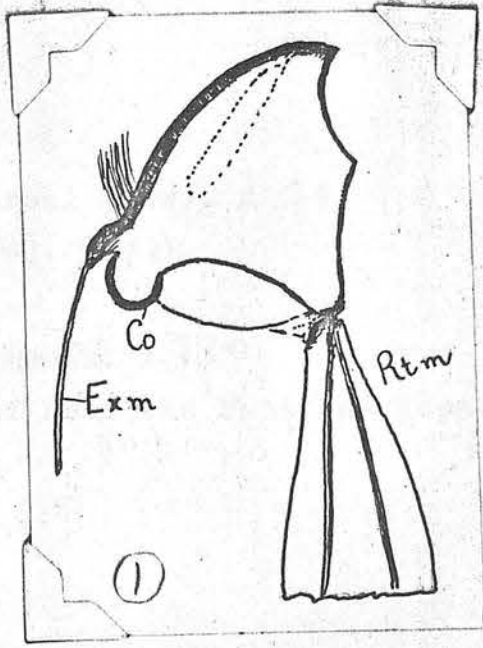
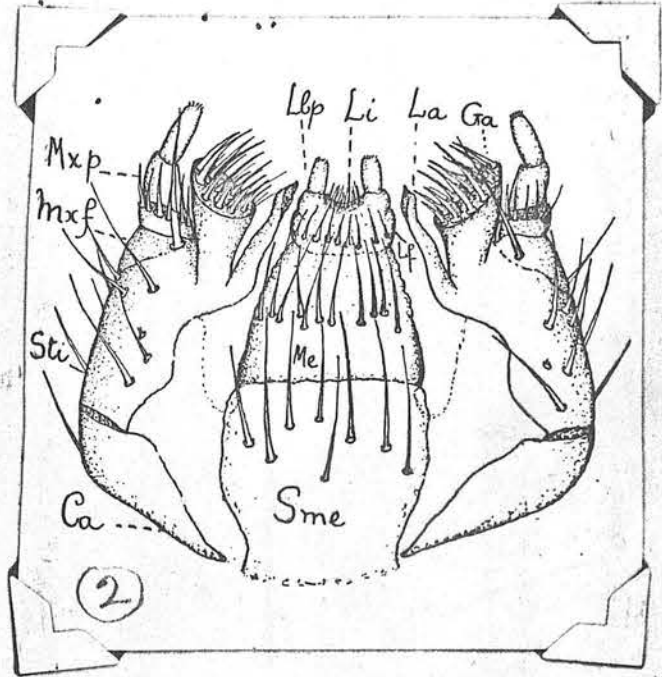
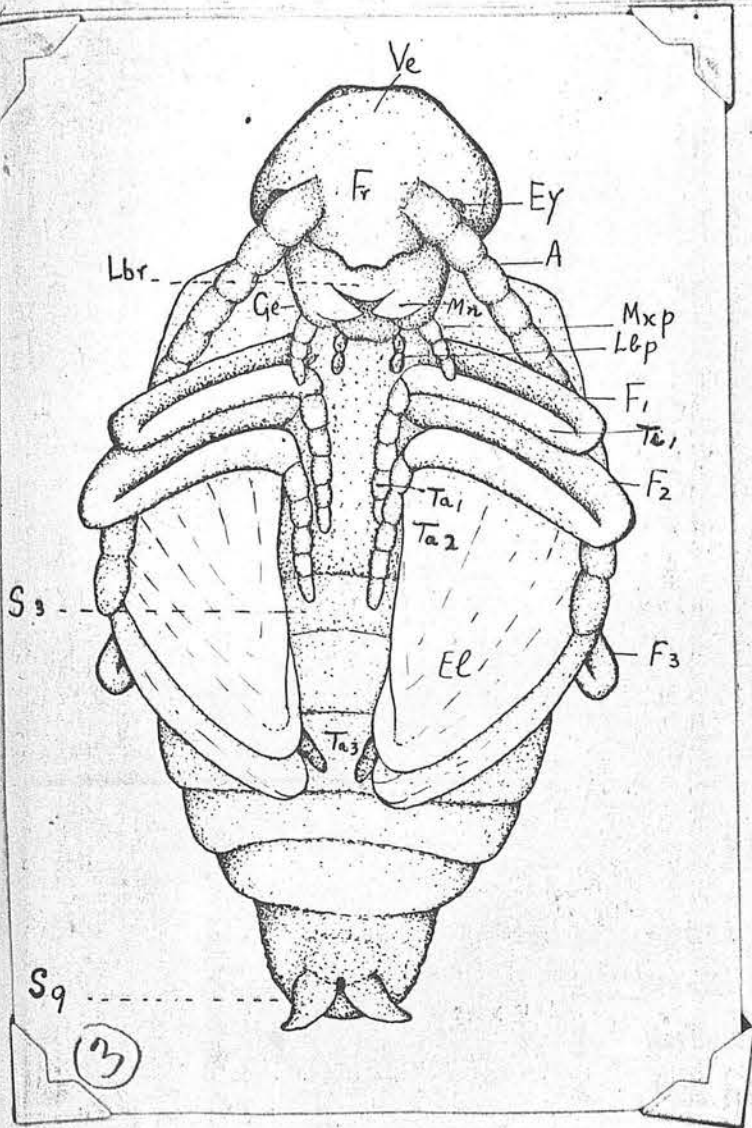




PLATE III.

- Fig.1. Adult beetle (dorsal view). x 30
2. Head (dorsal view). x 90
3. Antenna. x 60
4. Two antennal segments. x 120
5. Ventral aspect of head (the Maxillae separated). x 160

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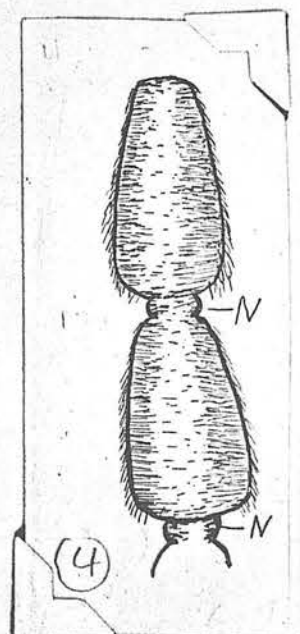
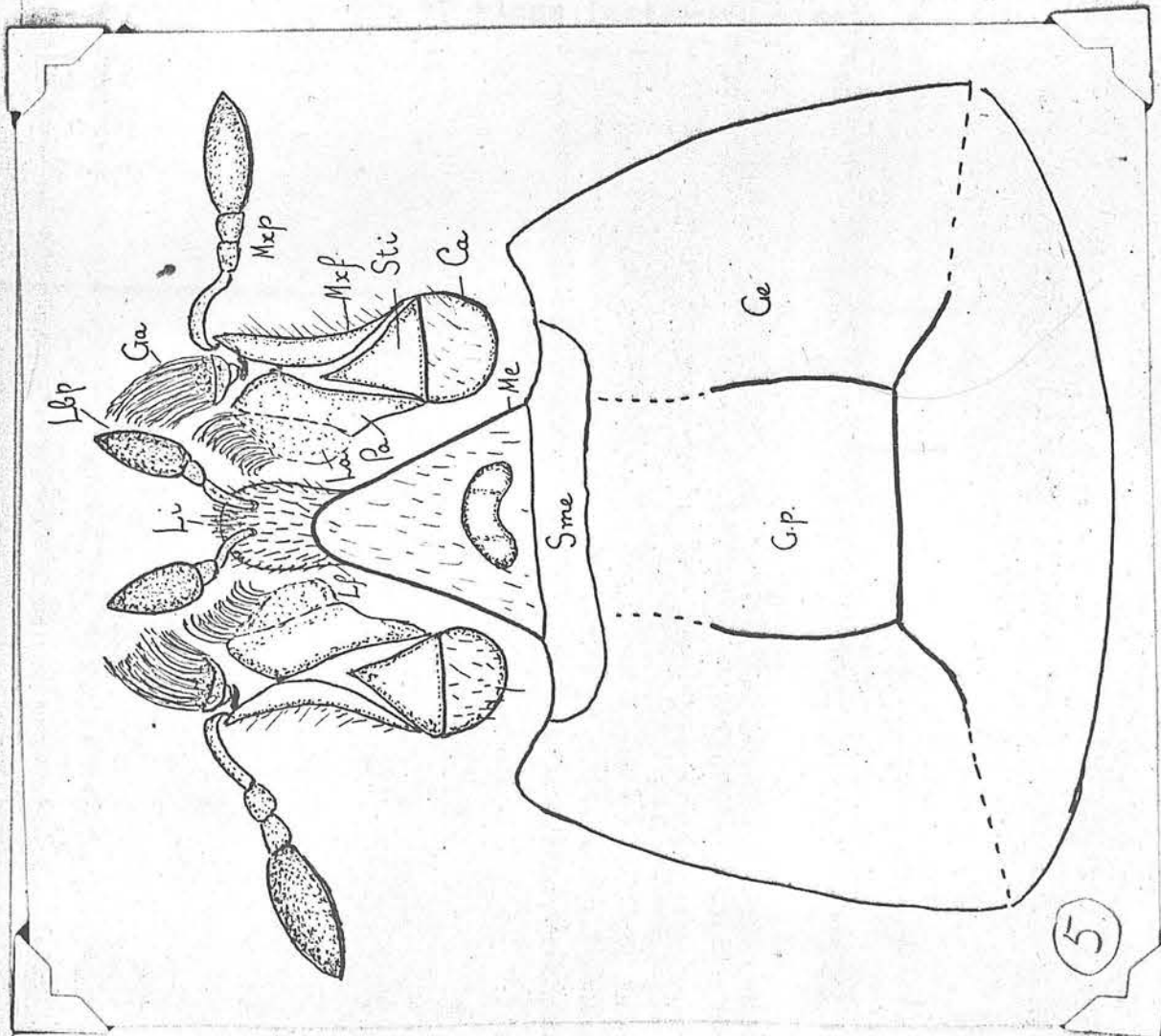
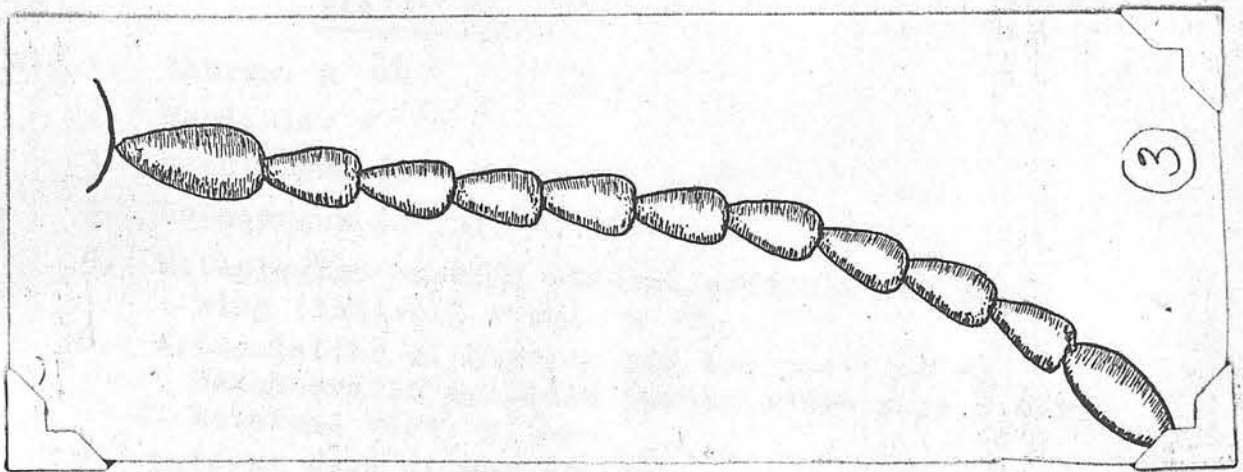
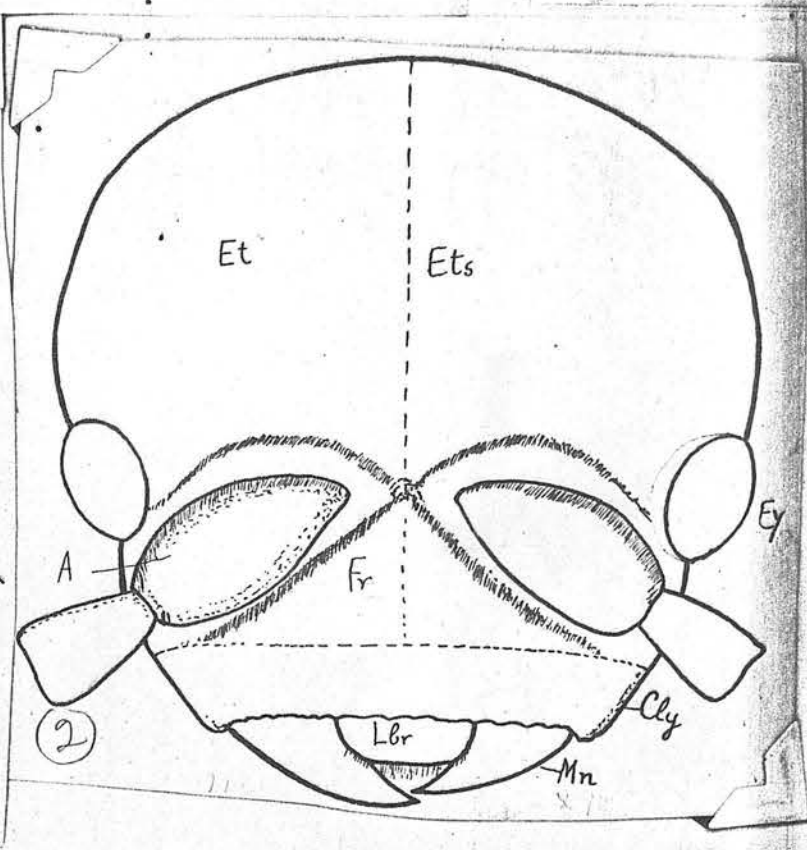
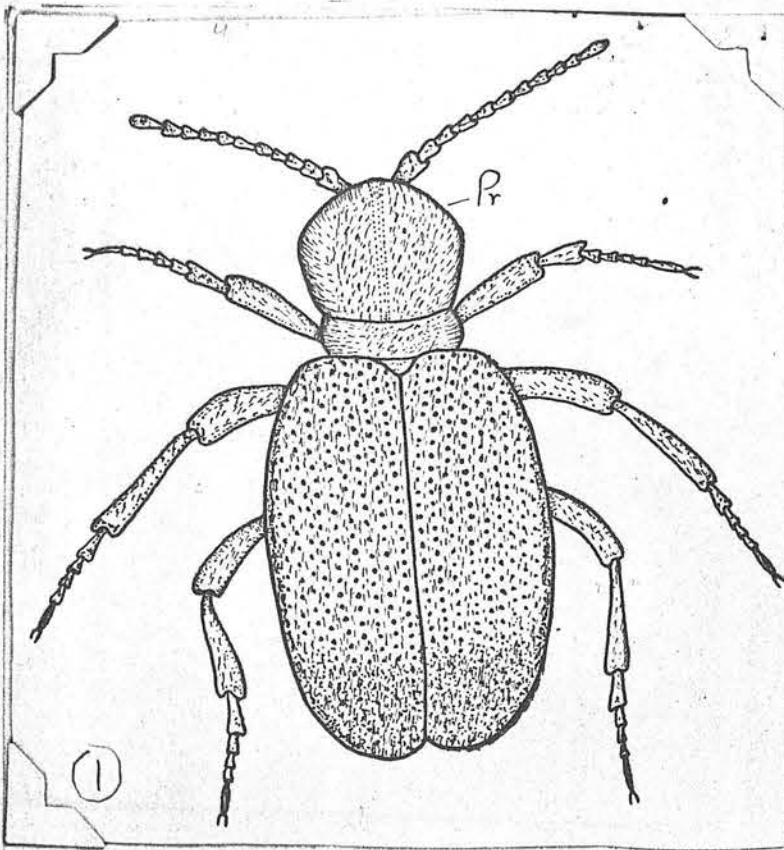
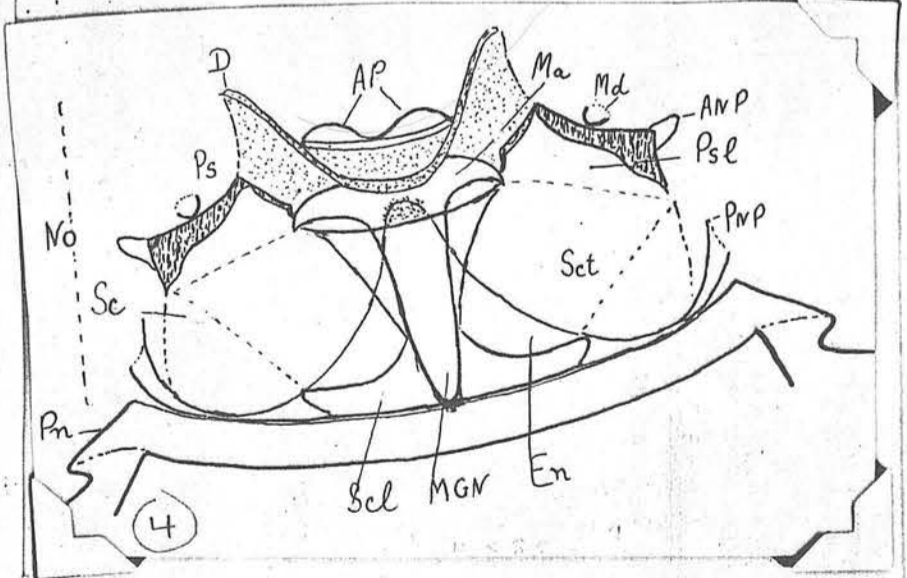
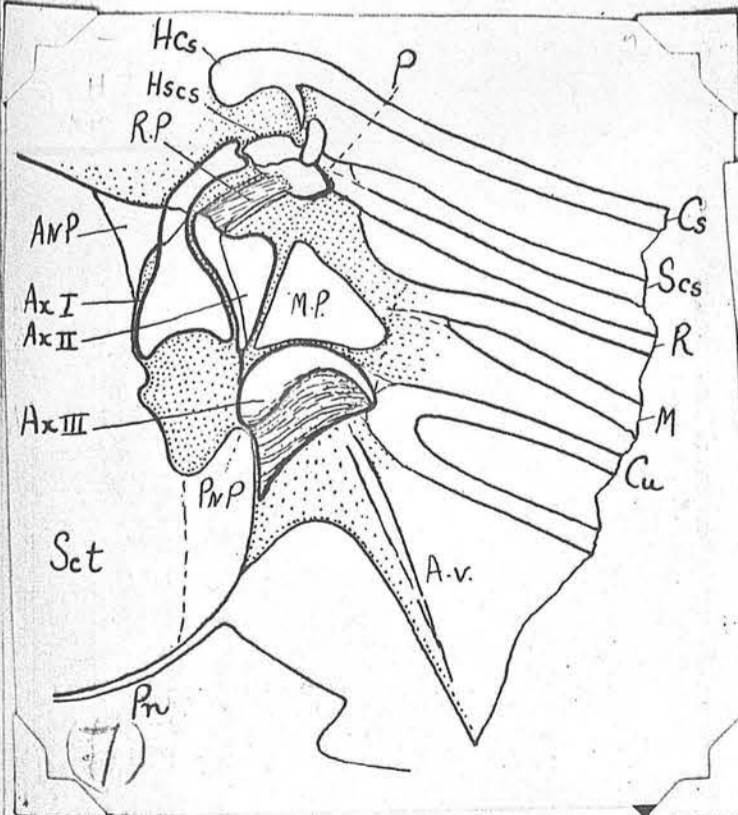
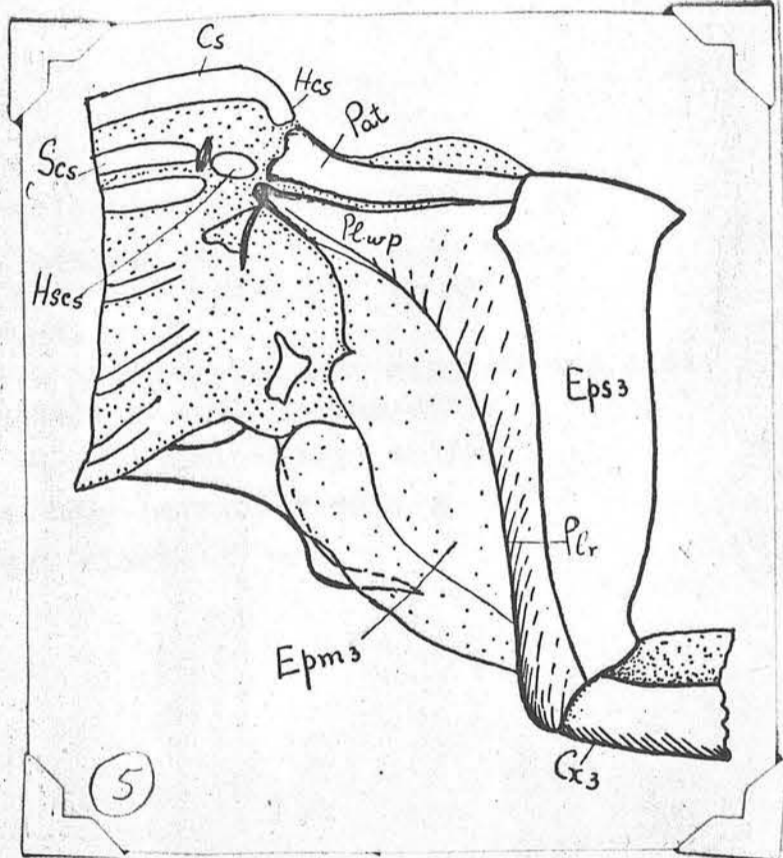
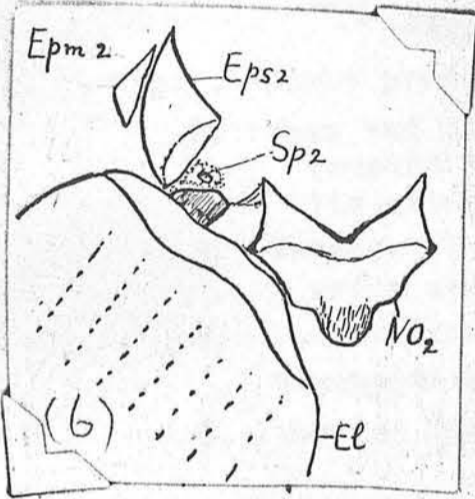
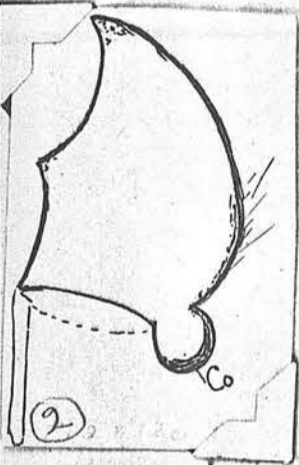
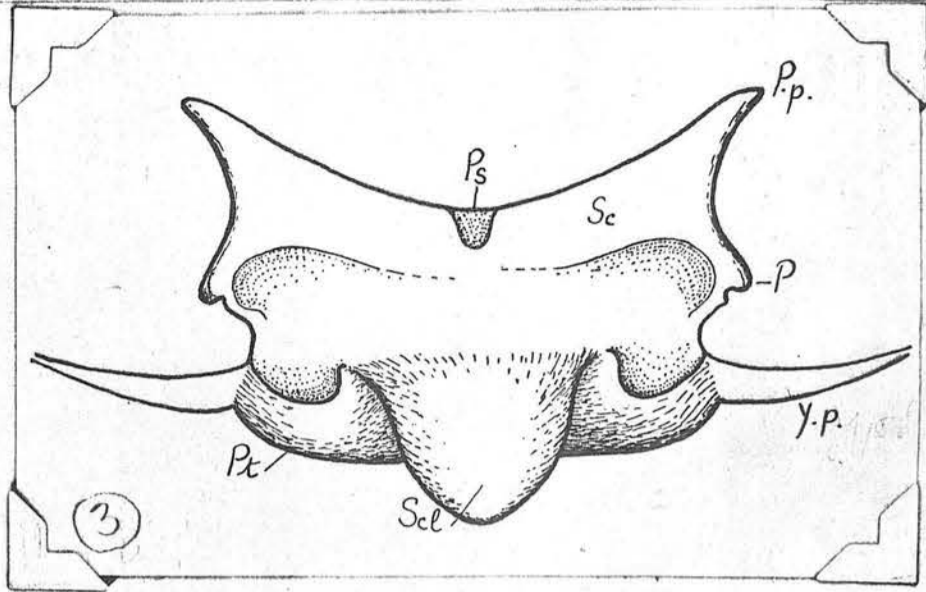
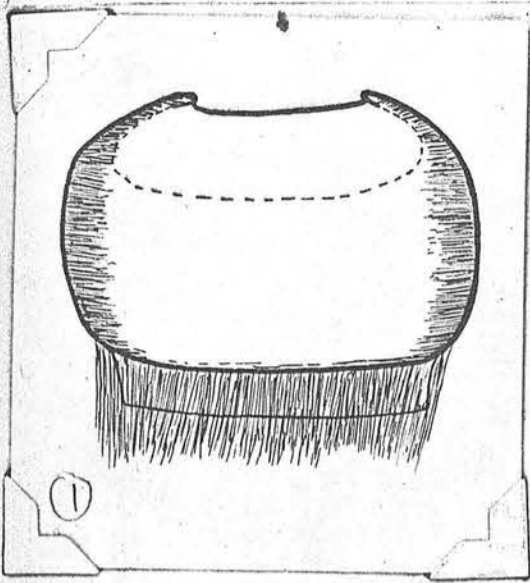


PLATE IV.

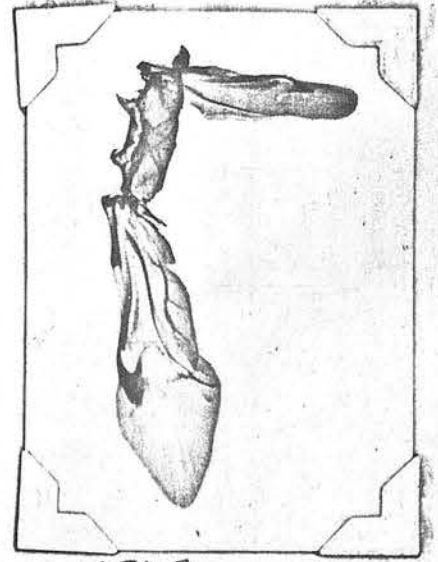
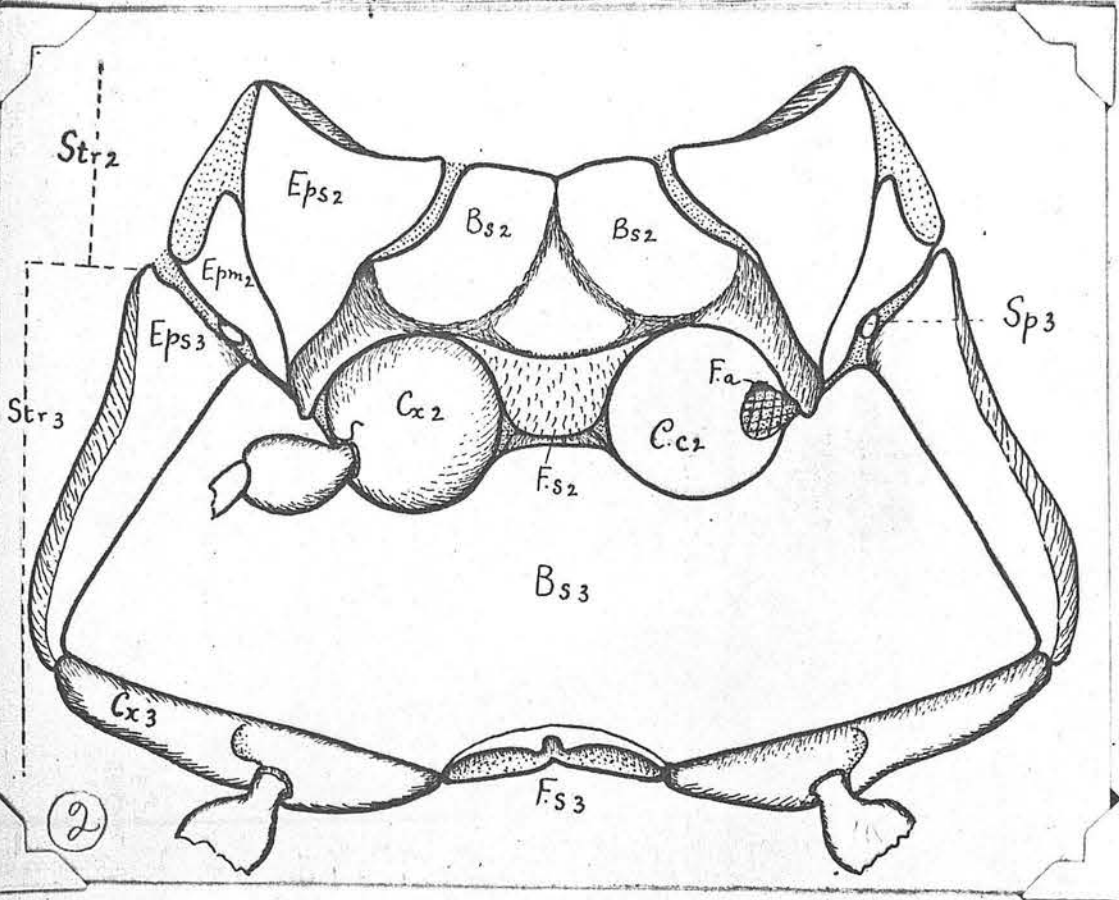
- Fig.1. Labrum. x 360  
2. Mandible. x 120  
3. Mesot<sup>notum</sup>tergum (dorsal view). x 180  
4. Metatergum (dorsal view). x 85  
5. Metapleuron showing pleural articulation of wing (internal view). x 330  
6. Articulation of Elytron and the position of Metathoracic spiracle (mesopleurae spread out) External view. x 80  
7. Lateral area of Metatergum to show notal articulation of wings (external view). x 330



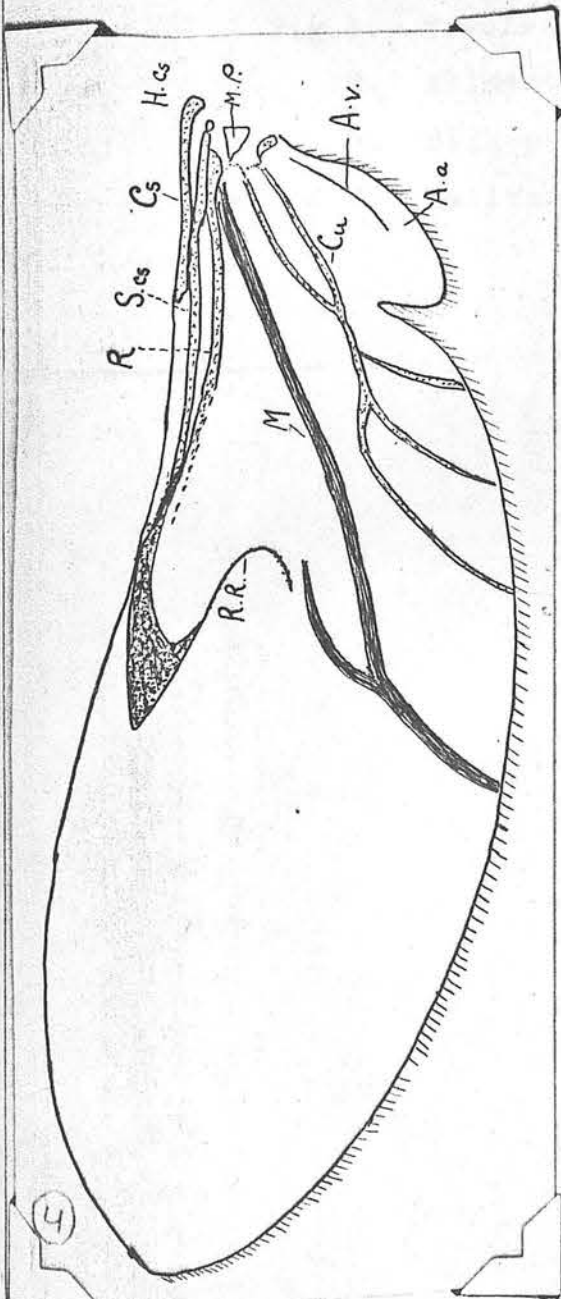
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PLATE V.

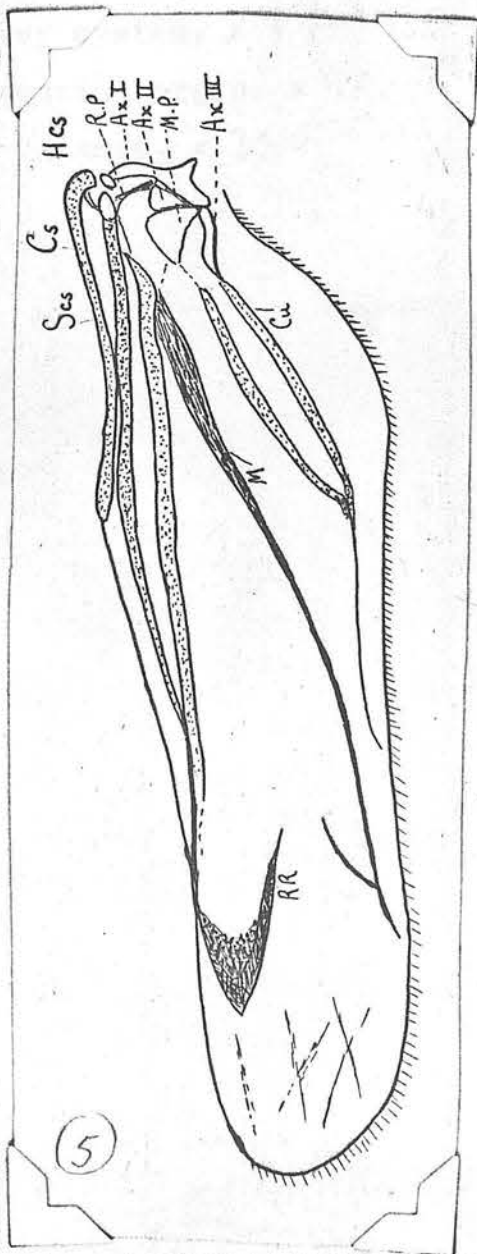
- Fig.1. Right prothoracic leg(dorsal aspect). x 90
2. Meso and meta sterna, the right meta coxa removed to show the coxal cavity and its attachment. x 105
3. Metatergum with a brachypterous wing on one side and a macropterous wing on the other.
4. Macropterous wing(dorsal view). x 40
5. Brachypterous Wing (dorsal view). x 85
6. Abdomen (dorsal view). x 40



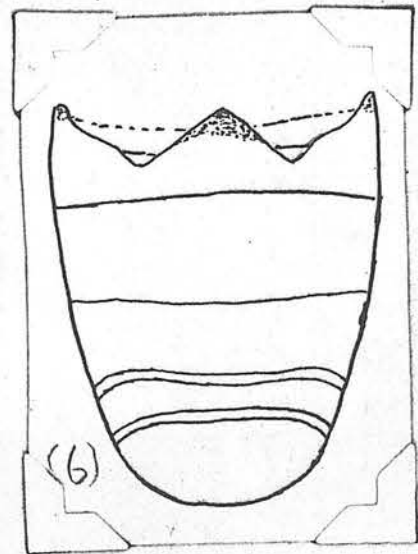
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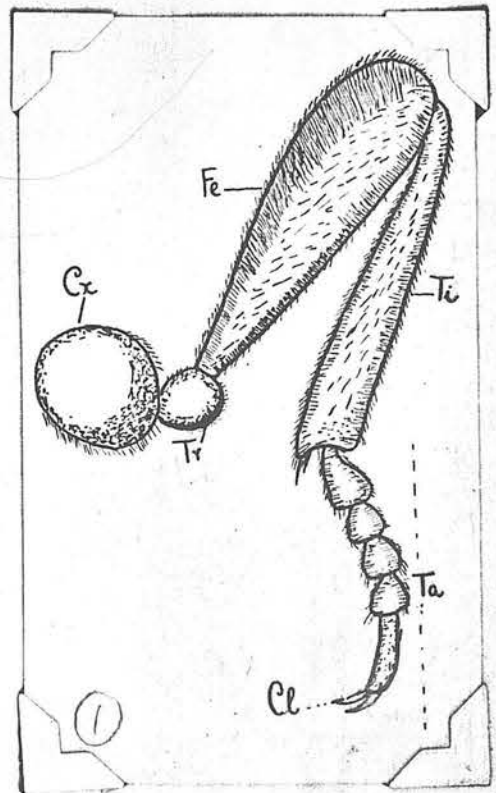
(4)



(5)



(6)



(1)

PLATE VI.

Fig.1. Tracheal system (diagrammatic).

2. Alimentary system. x 27

3. Silk-producing organ. x 90

4. Salivary glands. x 320

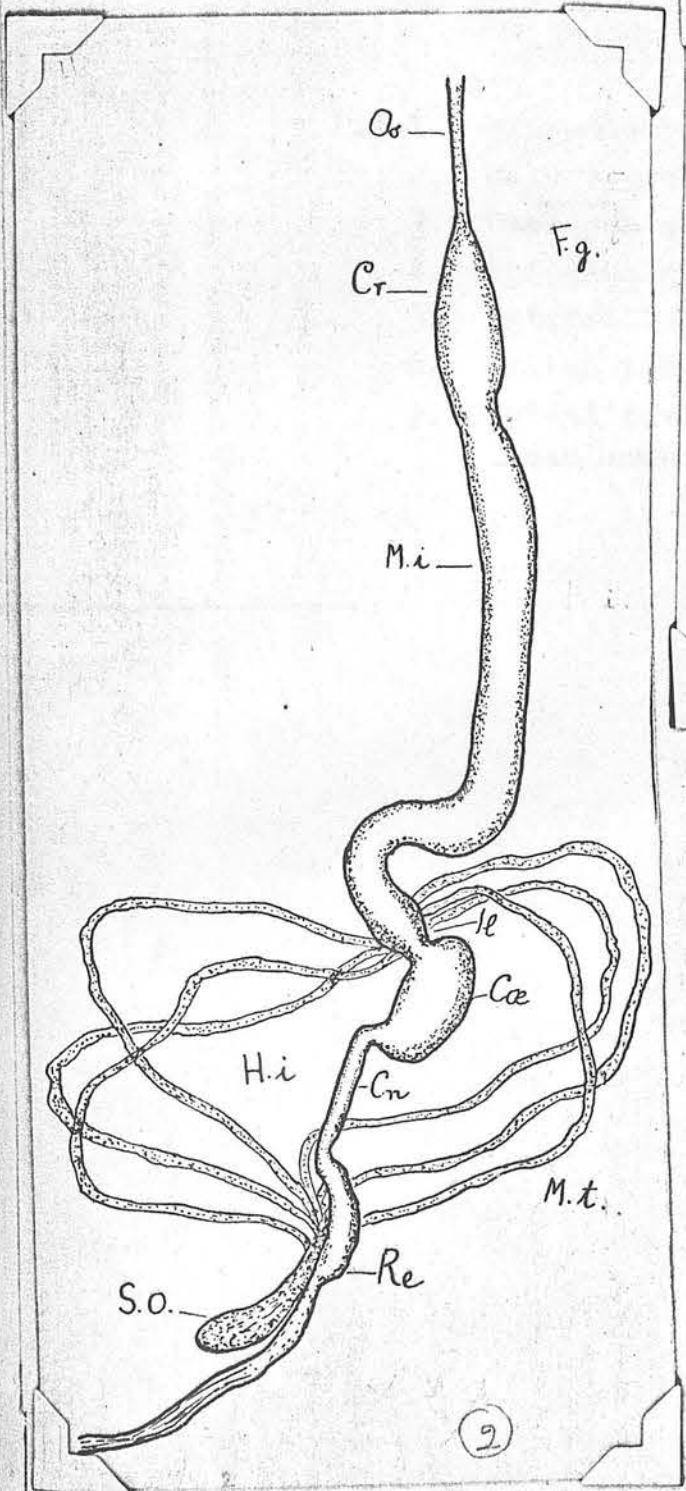
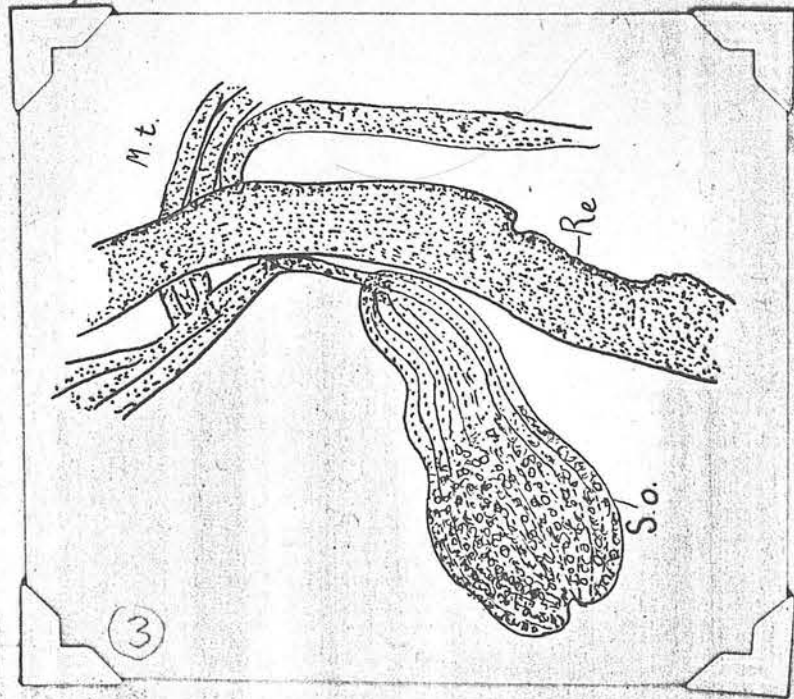
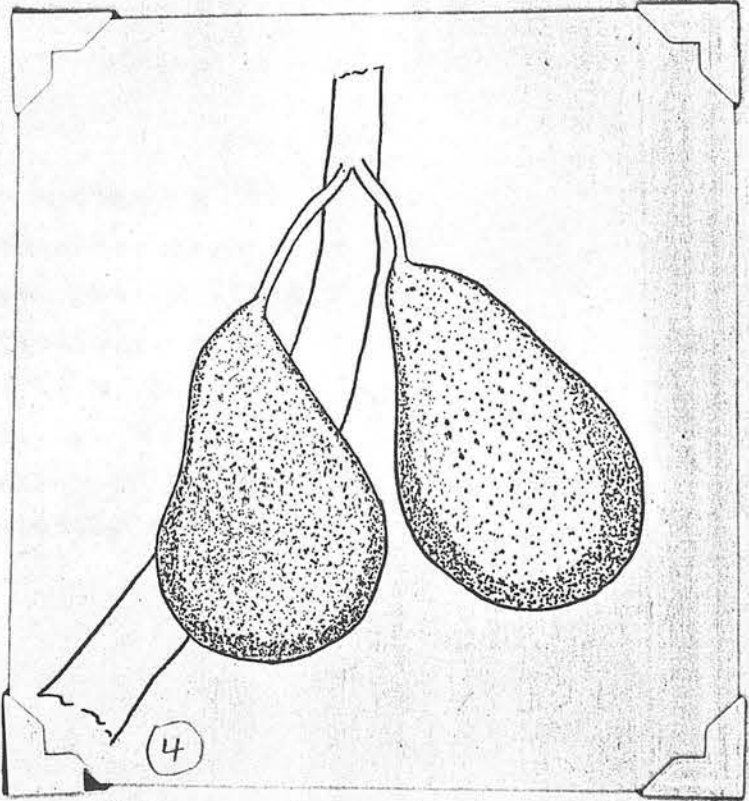
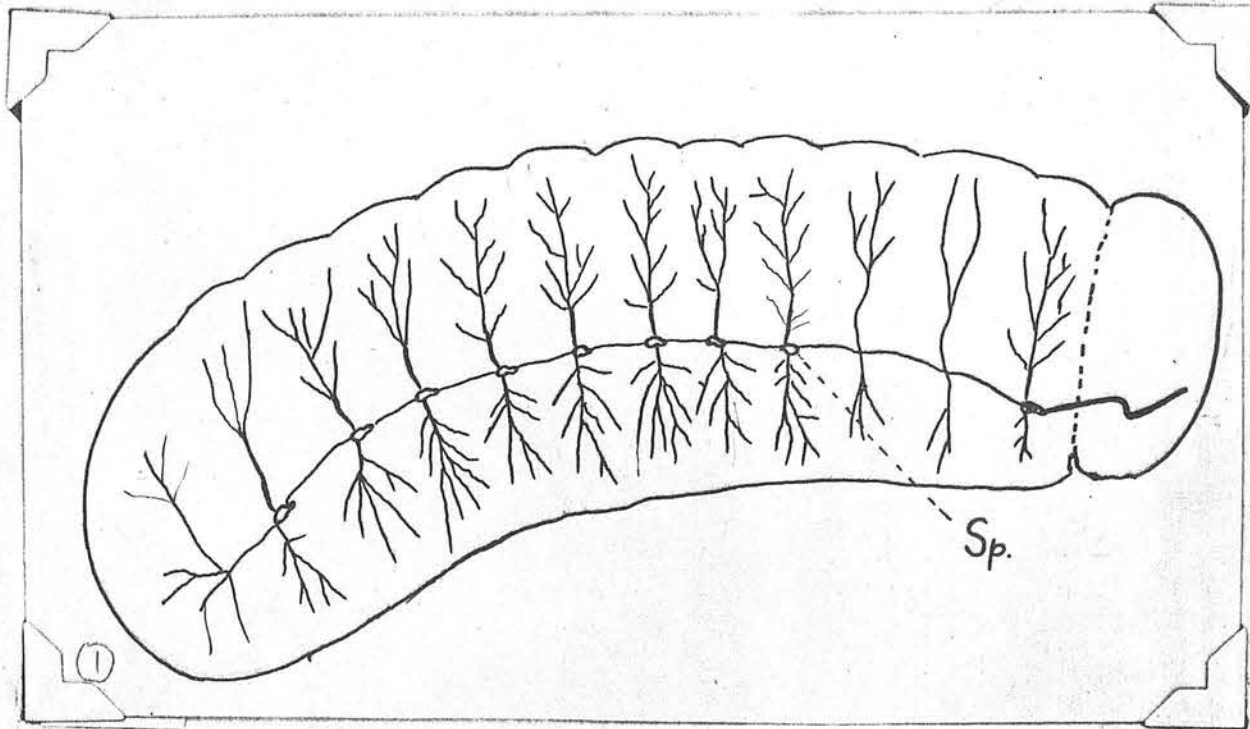




PLATE VII.

- Fig.1. Alimentary System. x 40
2. Male reproductive organs. x 40
3. <sup>Tegmen</sup> ~~Oedeagus~~ and median lobe. x 90
4. Spiculum gastrale. x 85
5. Lateral lobe. x 85
6. Median lobe. x 85
7. Apical portion of median lobe with internal sac completely everted. x 360

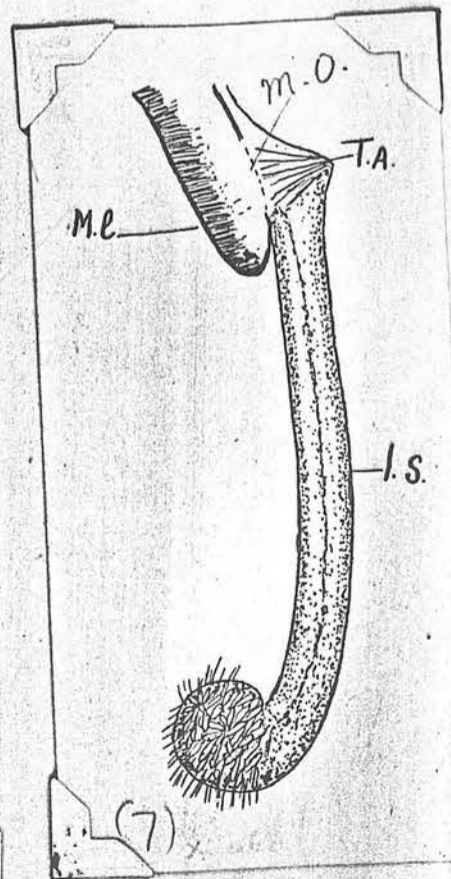
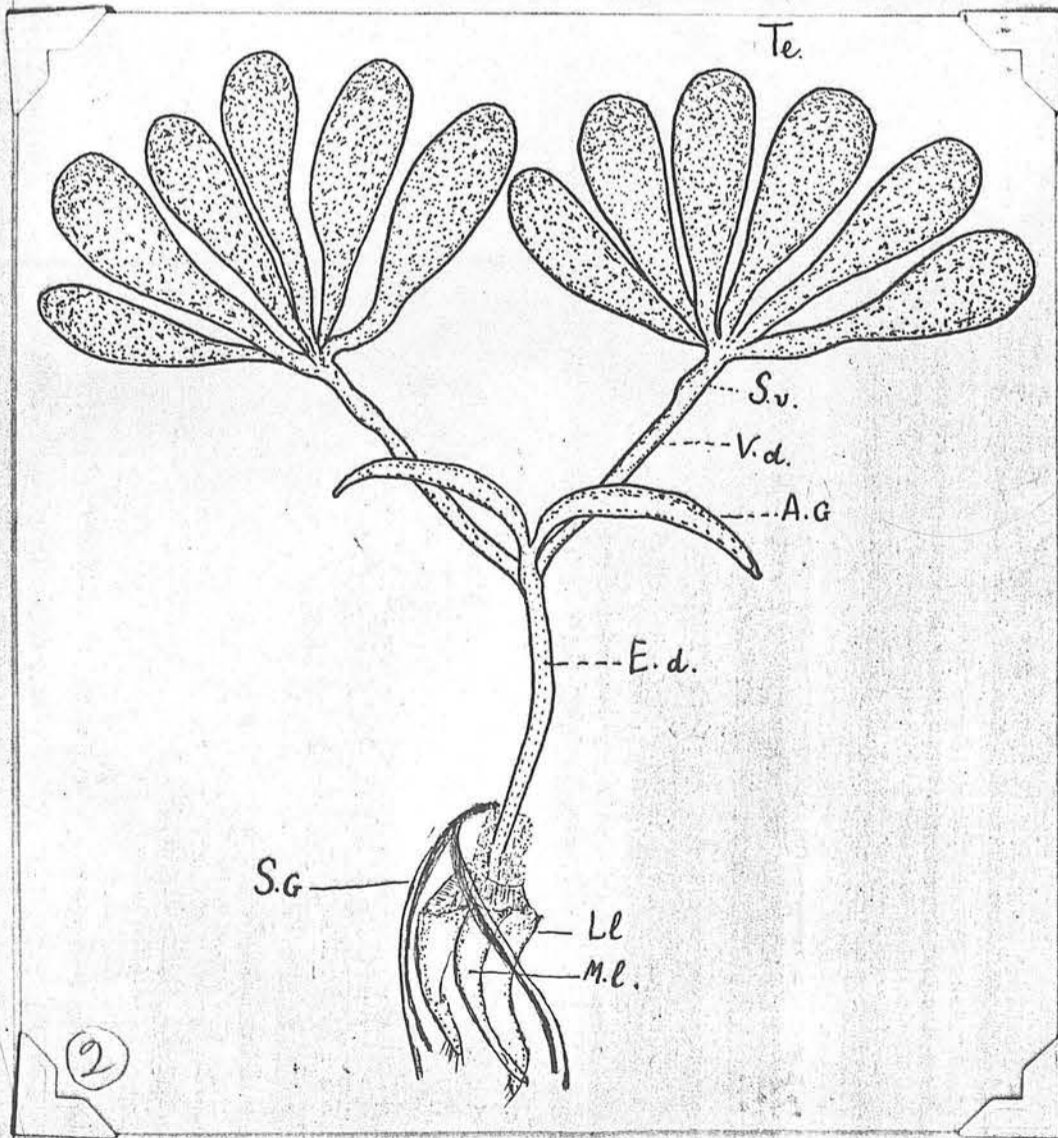
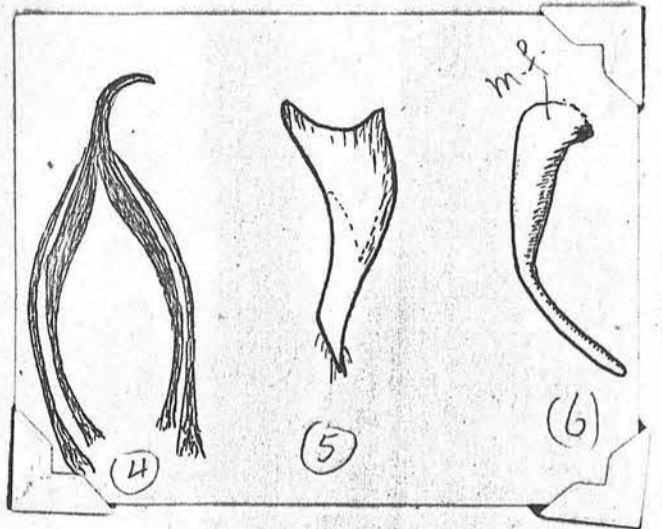
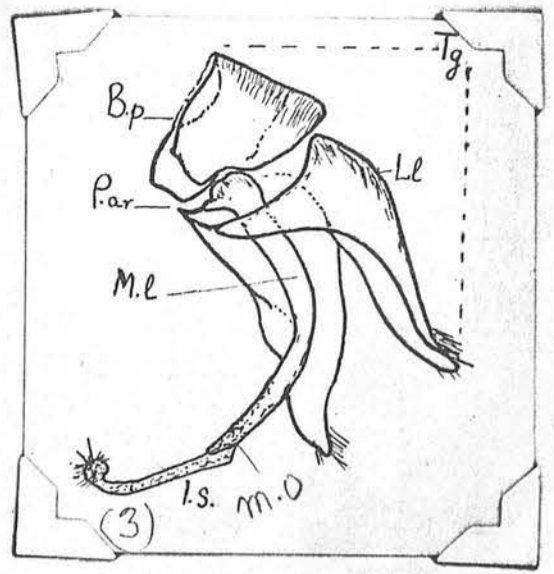
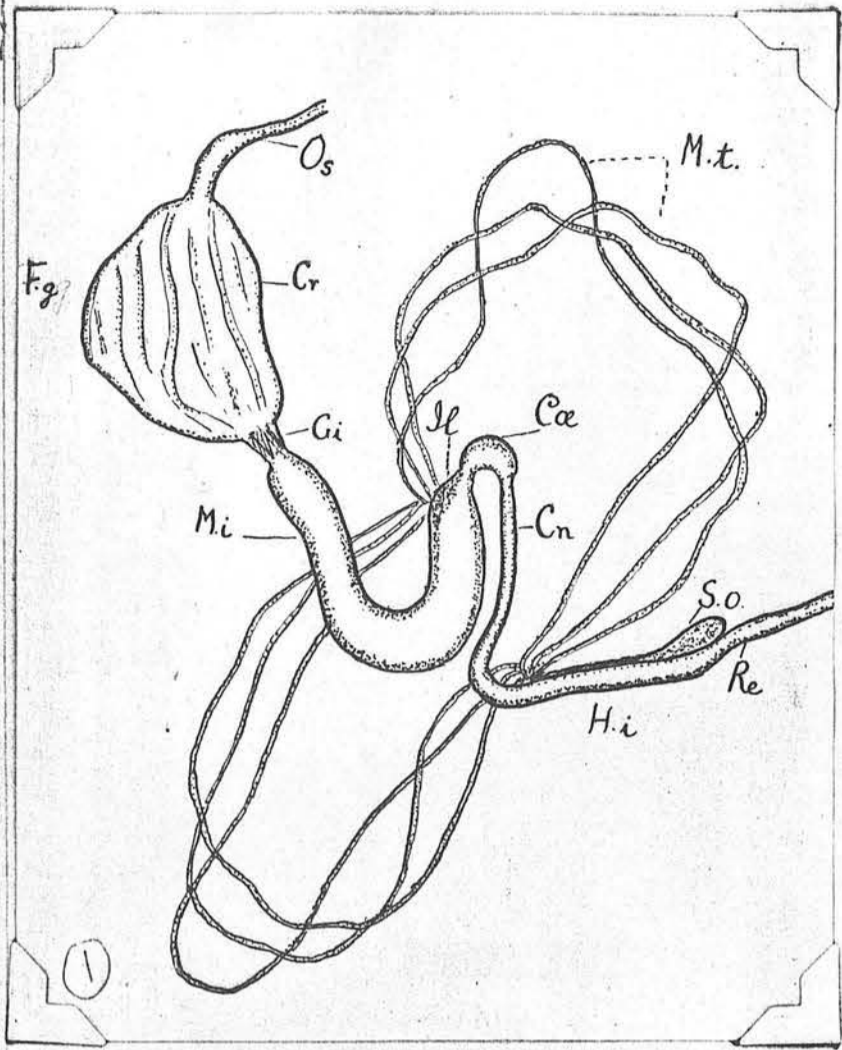


PLATE VIII.

- Fig.1. Female reproductive organs.  
(Immature, after emergence) x 70
2. Reproductive organs of a female ready  
to lay eggs. x 50
3. 8th Abdominal segment and Ovipositor. x 70

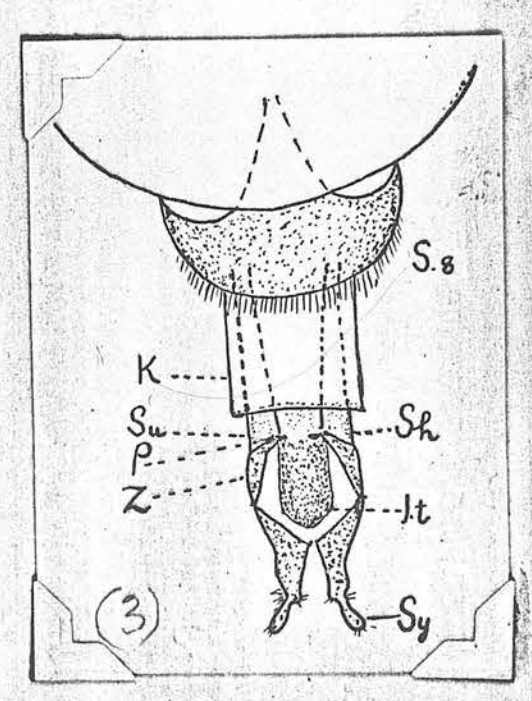
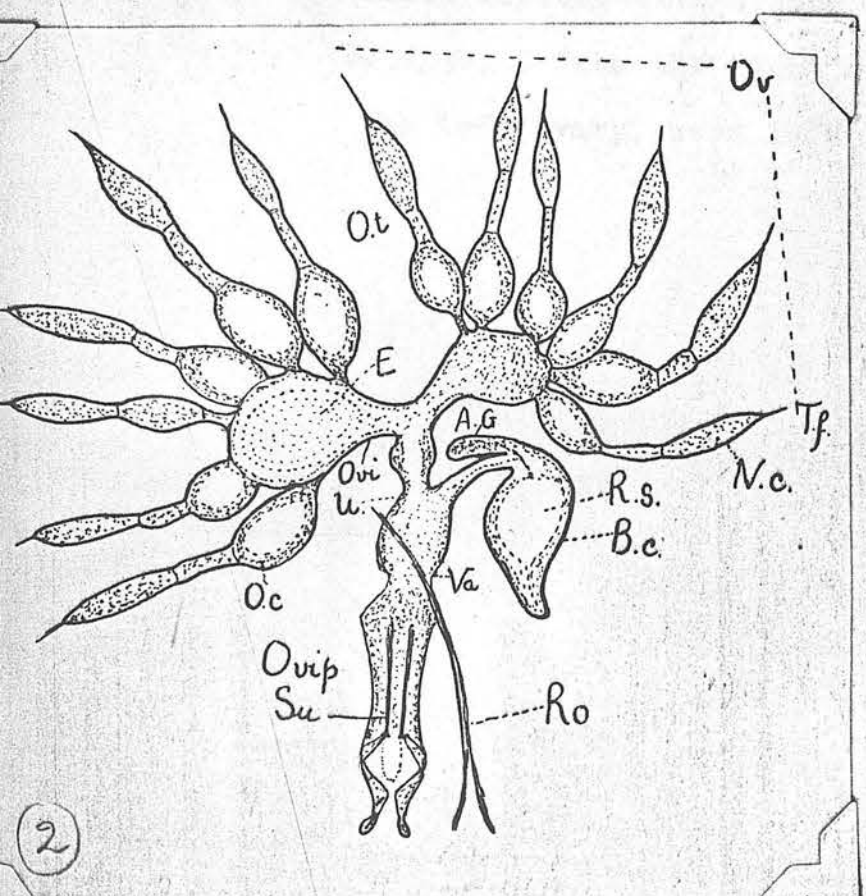
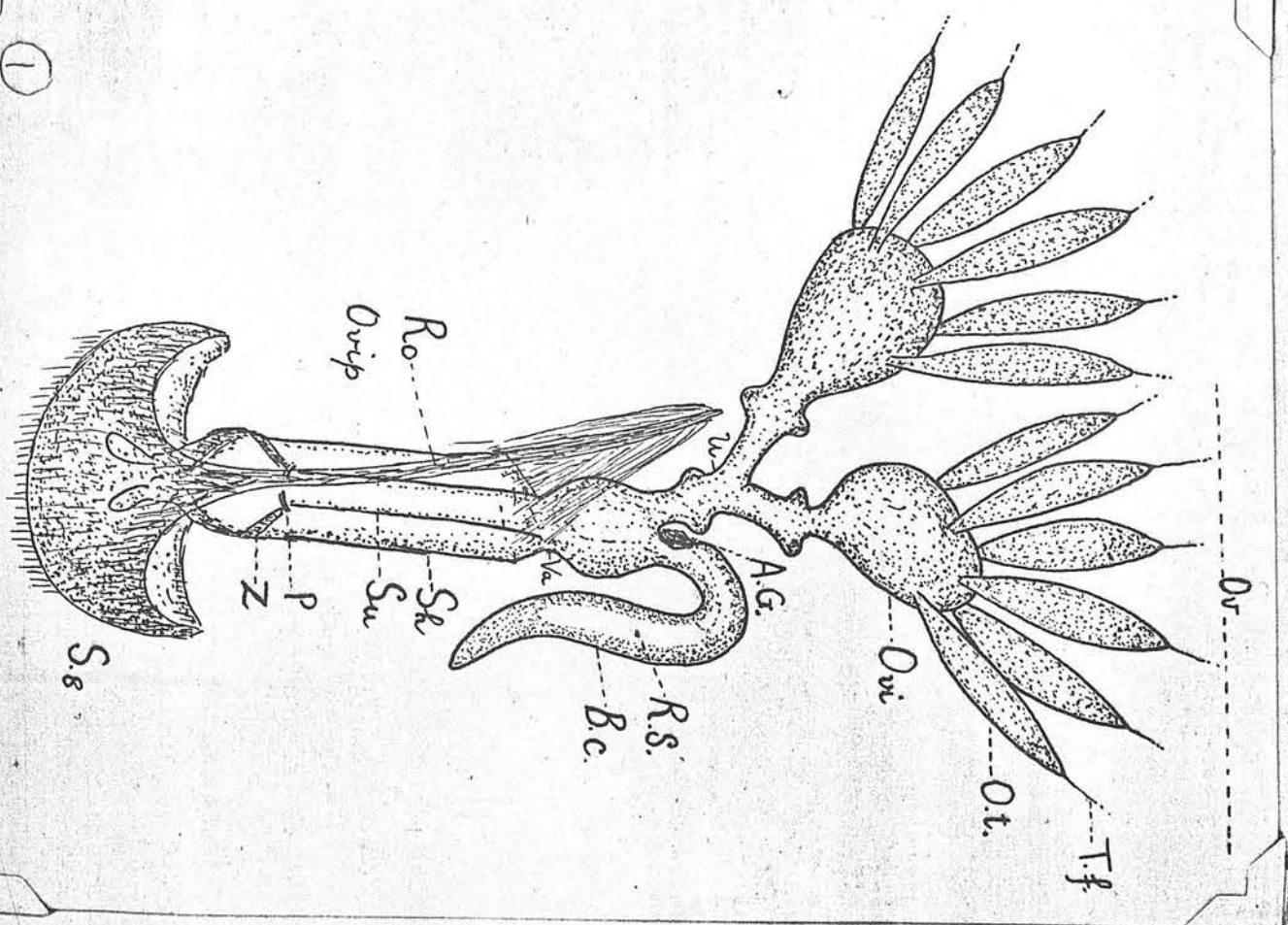


PLATE IX.

Female reproductive organs after egg laying.

(6 eggs, 2 from the right ovary and 4 from  
the left ovary, were laid). x 70

X

