

The Morphology and Biology of the Mustard Sawfly  
ATHALIA PROXIMA KLUG.  
(Tenthredinidae, Hymenoptera.)

THESIS PRESENTED FOR THE DEGREE OF  
DOCTOR OF PHILOSOPHY  
IN THE  
Aligarh Muslim University.

BY  
*Surjit S. Dhillon*

DEPARTMENT OF ZOOLOGY,  
ALIGARH MUSLIM UNIVERSITY  
ALIGARH.



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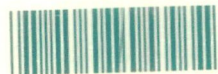
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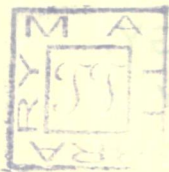
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The observations on the morphology of Athalia proxima Klug., ( Mustard Sawfly ) have been carried out on tegmental basis. A comprehensive study of the head region has been made including its sutures and the areas defined by them. Most of the sutures of the generalised insect cranium are recorded; and the 'paroccipital suture', which is so far undescribed in the Hymenoptera, has been discovered. The cranial appendages ( antennae and gnathal appendages ) are described with emphasis on their functions and relative associations with the cranium. The maxillo-labial complex is of simple type, and when studied in comparison with the complicated homologous structural unit of Clistogastrous Hymenoptera, makes me inclined to accept it as tentative basis for the evolution of Clistogastrous unit.

The skeleto-muscular mechanism of the thorax is done in considerable detail. A few new muscles pertaining to wings have been recorded and tentative functions have been assigned to them. The spinasternum, so far unreported in Hymenoptera, is present in the inter-sternal area between the pro- and the mesothoracic sterna. The meso- and meta postotal plates are easily detectable. The propodeum, forming the fourth segment of the thorax, has permitted secondary association of its tergum with the preceding adrotergal plate. This association is internally demarcated by the last phragma of the thorax. The overall study of the thorax helps in accepting the apparently generalised nature of A. proxima ( Tenthredinidae ).

The abdomen is found to consist of seven segments ( propodeum included ) whose skeleto-muscular mechanism has been studied on regional basis. These regions are arbitrarily named as 'pregenital', genital and postgenital regions. Greater emphasis has been laid on the external genitalia of both the sexes and probable modes of working have been attributed to them. The external female genitalia assist in assigning generalised status to A. proxima ( Tenthredinidae ). The components of the external male copulatory apparatus put the latter in the category of 'strophandrous genitalia' as opposed to generally prevailing 'stolidandrous' condition in Clistogastrous Hymenoptera.



It is suggested that the working of the male copulatory apparatus is based on the torsion and detorsion actions.

All the systems of the internal anatomy have been done in considerable details. Their anatomy, wherever possible, has been supported by histology. The cephalic stomodaeum with its extrinsic muscles has been studied. The three regions of the digestive tract ( stomodaeum, mid-gut and proctodaeum ) with structures separating them, have been dealt with. The body cavity, in the region of the abdomen is distinctly divided, by the dorsal and the ventral diaphragms, into the pericardial, visceral and perineural sinuses. The heart, leaving aside the aorta, is clearly eight chambered with necessary paired ostia. The spiracular mechanism, as well as, the tracheal anastomoses<sup>e</sup> have been done with an interesting conclusion that the air sacs, though profuse, but confined to the thorax only. Leaving aside the brain and the suboesophageal ganglion, the ventral nerve cord possesses <sup>ten</sup> ~~eleven~~ ganglionic centres ( thorax-3, abdomen-7 ).

The biology of A. proxima has been studied, both in the fields ~~and~~ as well as, under controlled conditions. This study besides being an account on general behaviour of both the adult and the larva also contains observations on 'food-selection', 'copulation', 'host-selection' 'oviposition' behaviour. The gross anatomy of the fully grown larva is also done with emphasis on the cranium and its appendages.

Efforts have been made to make this study of some utility to the agriculturist. Likewise, it may also be able to provide some material for the control of this pest.

It is regretted that due to great difficulty in procuring good quality of photographic materials, the photostat copies of the diagrams are not very satisfactory. However, the structural representations ~~be~~ there, though these may not be very lively.



THE MORPHOLOGY AND BIOLOGY OF *ATHALIA*  
*PROXIMA* (KLUG) (HYMENOPTERA,  
TENTHREDINIDAE) —  
MUSTARD SAW-FLY.

By

SURJIT S. DHILLON.

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C O N T E N T S	Page
Introduction	iv
Material and Technique	vi
Acknowledgement	vii
1. T h e H e a d	1
(i) External features of the head capsule	1
(ii) Sutures of the head capsule	1
(iii) Areas of the head capsule	9
(iv) Tentorium	12
(v) Antennae with their muscles	13
(vi) Labrum and Epipharynx	16
(vii) Mandibles with their muscles	17
(viii) Maxillo-labial complex	18
(ix) Maxillae with their muscles	18
(x) Labium and its muscles	24
(xi) Cephalic stomodaeum and its musculature	30
(xii) Mode of ingestion	34



	Page
2. T h e T h o r a x	36
(i) General features of the thorax	36
(ii) Structure of the prothorax	37
(iii) Musculature of the prothorax	45
(iv) Legs	49
(v) Structure of the prothoracic leg	50
(vi) Musculature of the prothoracic leg	55
(vii) Structure of the mesothorax	62
(viii) Musculature of the forewing	72
(ix) Structure of the mesothoracic leg	78
(x) Structure of the metathorax	80
(xi) Musculature of the hindwing	86
(xii) Structure of the metathoracic leg	92
(xiii) Thoracic wings and their sclerites	95
3. T h e A b d o m e n	107
(i) The pregenital region	108
(ii) The genital region	110
(iii) The postgenital region	112
(iv) The musculature of the abdomen	113
(v) The external male genitalia	120
(vi) Musculature of the male genitalia	125
(vii) Working of the genitalia	131
(viii) The external female genitalia	135
(ix) Musculature of the female genitalia	139
(x) Mode of egg-laying	144



	Page
4. The Internal Anatomy	146
(i) The digestive system	146
(ii) The Salivary gland	156
(iii) The excretory system	156
(iv) The circulatory system	157
(v) The respiratory system	160
(vi) The male reproductive system	171
(vii) The female reproductive system	174
(viii) The nervous system	179
5. Biology	184
(i) Introduction	184
(ii) Methods of rearing	185
(iii) Habits of adult	187
(iv) Copulation	189
(v) Host selection	191
(vi) Oviposition	193
(vii) Preimaginal stages	194
(viii) Mortality during development	207
(ix) Parthenogenesis <sup>e</sup>	209
(x) Longevity of the adults	209
(xi) Anatomy of the fully <sup>grown</sup> /larva	210
6. References	224
7. Abbreviations	243
8. Explanation of figures	263



## INTRODUCTION

The selection of Athalia proxima (klug) (mustard saw-fly) for this research project is based on some important factors. Firstly, the insect happens to be one of the commonest pests of agriculture, in India. Secondly, the agriculturists of the country, since ages, are fully acquainted with this insect which is also readily available in the fields. Thirdly, it is an ideal form, among the lower Hymenoptera, for a morphological study of monographic type. Finally, the structural study of this insect may produce some evidences on phylogenetical link between Chalastogastrous and Clistogastrous Hymenoptera.

A glance on the existing literature on insect morphology would reveal bankruptcy of informations regarding the morphology of Hymenoptera. This does not mean that the morphologists have deliberately or totally ignored this very well evolved group of Insecta. Some monumental works on Hymenopterous morphology, certainly, are available namely, Lubbock (1879), Janet (1893-1912), Boulangé (1924), James (1926), Morrison (1927), Grandi (1929), Duncan (1939), Snodgrass (1925, 1941, 1942, 1956) and Alam (1951, 1953). These, for years to come, are bound to act as guide for further researches on the morphology of this Order. However, one cannot deny the fact that all these classical works have brought to light informations pertaining to members of the Clistogastrous Hymenoptera. It is, thus, quite clear that the Chalastogastrous Hymenoptera have for one reason or the other,

not received adequate attention of the morphologists. However, Arora (1953) had studied the skeletal structures of Diprion pini (L) (saw-fly). This is followed by another work (1956) from him; and the two works together reveal interesting characters of phylogenetic significance.

The skeletomuscular mechanism of the adult A. proxima, besides being a detailed account, also lends immense support to an already existing view in attributing generalized (primitive) status to Tentareainidae in the Order Hymenoptera. Further, it also brings to light some interesting characters in the form of discovery of hitherto unknown muscles, as well as, new interpretations of structures. Efforts have also been made to explain the probable working of the body and its appendages with special reference to/<sup>the</sup> external genitalia. The structural and functional differences between the orthandrious and strophandrious male genitalia are also discovered.

The internal anatomy includes all the systems of the body. Their anatomical details are interspersed with essential histological observations, wherever necessary.

The biology of A. proxima covers almost all aspects essentially required for the understanding of the pest with the idea of its control. It is carried out, all the year round, both, under controlled conditions, as well as, in the fields. The behaviour of the pest with special reference to copulation,



oviposition etc., as initiated by Alam (1967, 1968a), has been studied with significant results. The gross anatomy of fully grown larva has also been explored.

#### M A T E R I A L   A N D   T E C H N I Q U E

The adult insects were kept in Picro-chloroacetic fixative for 12 hours. It was followed by the transfer of the material into 70% alcohol for preservation. Petrunkevitch was also used as another fixative. But, better results were obtained from the material fixed in Picro-chloroacetic fixative.

The skeletal study of the adult was made under binocular after treating it with 6% to 10% KOH. For obtaining transparency in the skeletal structures and for their ultimate staining the techniques evolved by Alam (1961) were followed. Accordingly, the skeletal structures were depigmented by putting them in a solution of  $K_2Cr_2O_7$  and HCl. The structures, so decolourized, were stained in Carbol-aniline and were further treated with Carbol-xylol for perfect dehydration. Similarly, for the purpose of making permanent and temporary preparations of the muscles with their points of origin and insertion fully differentiated, Alam's (1961) technique of Mallory's fluid was found to be very satisfactory.

The insects fixed in Picro-chloroacetic fixative were used for microtomy and the sections were normally cut at 7 microns.

These were stained in Heidenhain's Iron Haematoxylin, for nuclear differentiation, followed by alcoholic Eosin as cytoplasmic stain.

#### A C K N O W L E D G E M E N T

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## 1. THE HEAD

### (i) External Features of the Head Capsule (Figs. 1 & 2).

The hypognathous type of head capsule of Athalia proxima (Klug) is subtriangular in shape and black in colour. It consists of four surfaces : anterior surface (frontoclypeus), posterior surface (occiput), lateral surfaces (parietals) and dorsal surface (vertex). These surfaces can conveniently be spotted out by the presence of ocellar triangle, paired compound eyes (E), paired antennal sockets (Asoc) and unpaired foramen magnum (For) on the vertex. (Vx), parietals, frontoclypeus and occiput (Oc) respectively.

The vertex is a distinctly curved crest from which descend the other surfaces. The foramen magnum with thickened rim is almost rectangular and occupies the central portion of the posterior surface. The anterior tentorial pits (at) are distinct, whereas the posterior ones are almost obliterated. The ventral margin of the posterior surface emarginates to form a distinct oral fossa. This margin, in combination with the ventral margins of the lateral and anterior surfaces, functions as source of suspension for the gnathal appendages and the labrum (Lm).

### (ii) Sutures of the Head Capsule (Figs. 1 & 2).

There are few sutures on the head capsule, as compared with a generalized insect. However, the following sutures are traceable.

Epistomal suture (es). — It arches across the face running in between the two anterior articulations of the mandibles with anterior tentorial pits located on it and internally represented by the 'epistomal ridge'. Beneath this suture lies the frontal ganglion and the true mouth. Thus the epistomal suture can be taken as an external demarcation between the frons (Fr) and the Clypeus (Clp).

The various views held by different authors on the identity of the 'epistomal suture' are as follows :

According to Snodgrass (1935), "the anterior ends of the subgenal sutures are connected across the lower part of the face by an epistomal suture" DuPorte (1946) considers that "clypeus lies dorsal to the labrum and is separated from the frons by the transverse frontoclypeal suture sometimes called the epistomal suture, which extends between the anterior mandibular articulations". Again Snodgrass (1947) says, "the epistomal or frontoclypeal sulcus runs between the anterior mandibular articulations" and "it lies posterior to the muscles that pertain to clypeus and separates these muscles from those which arise above it on the frons". DuPorte and Bigelow (1953) observe "Snodgrass is correct in his concept of what constitutes the clypeus, but at fault in his explanation of its evolution and in his claim that the U - shaped epistomal suture, which bounds the clypeus dorsally and laterally, is merely the frontoclypeal



suture in a changed position. These studies have led us to conclude that the changed relationship of the clypeus to other facial structures has been brought about; not by the dorsal migration of the clypeus, but by a continuation of the ventral growth of the genal and postgenal regions of the head and the fusion of the mesal edges of the new genal regions with the previously free lateral edges of the clypeus. The fusion causes the formation of a pair of clypeogenal sutures lying between the genal and lateral edges of the clypeus, and extending from the anterior tentorial pits to the anterior mandibular articulations. The clypeogenal sutures, therefore, are formed as the result of the continuation of the same process which resulted in the formation of the frontogenal sutures and may be regarded as a ventral continuation of the latter beyond the tentorial pits". The same authors in the same paper further add, "It is evident that the frontoclypeal suture forms only the horizontal portion of the suture which borders the dorsal edge and much of the lateral edges of the clypeus; the portions containing the tentorial pits are parts of the frontogenal sutures while the vertical or oblique portions are clypeogenal sutures. It is obviously incorrect to call this compound suture the frontoclypeal suture, but we suggest that the term 'epistomal suture', though not accurately descriptive, can profitably be retained for it because of its somewhat less precise connotation". Still further in the summary of the same paper it is maintained'. "The epistomal suture consists of the

horizontal frontoclypeal suture, the bases of the frontogenal sutures containing the tentorial pits and the two vertical or oblique clypeogenal sutures". Bigelow (1954) agrees with Snodgrass when he says, "The System of grooves extending from one anterior mandibular articulation to the other and passing through the anterior tentorial pits is called the epistomal suture". DuPorte (1956), made a condensed review of the older interpretations of the median facial sclerites. He also puts forward his new interpretation of the same which runs as follows : "..... in many higher insects the ventral descent of the genal regions continues beyond the level of the mouth and that, as a consequence a pair of clypeogenal sutures is formed between the clypeus and the genae (DuPorte and Bigelow 1953). Consequently the sutures which in some insects I interpreted as the frontogenal are really the clypeogenal or the two combined. Since these sutures are continuous and formed as the result of same developmental process, the two combined may be termed the laterofacial suture". It is now clear that DuPorte finally maintains that the combination of the frontogenal and clypeogenal sutures with anterior tentorial pit at their junction results in the formation of the laterofacial suture. This means that the lateral portions of the conventional epistomal suture between the anterior articulation of the mandible and the anterior tentorial pit should no more be taken as a part of the epistomal suture and the latter consequently be reduced to a mere transverse suture running between

the frons and the clypeus. In other words the epistomal suture should be reduced down to the frontoclypeal suture.

The present writer holds that the epistomal suture is not a simple suture. As a matter of fact it is of compound nature and can conveniently be broken up into three components (two lateral and one median) which can rightly claim the status of independent sutures and should not be taken as mere secondary external grooves. This suggestion gets support from the fact that the components separate the entire clypeus dorsolaterally from more than one sclerotic area of the head capsule. In further elucidation of this view it may be pointed out that the median portion of the suture lying between the two anterior tentorial pits, coincides with the position of the frontal ganglion and the true mouth. Similarly the two lateral portions connect the anterior tentorial pits with the respective anterior articulations of the mandibles. Since the median portion separates the clypeus from the frons, it can rightly be called as frontoclypeal suture (frclps). Likewise, the lateral portions separating the clypeus from the genae can logically be named as clypeogenal suture (clpges). This may, however, be understood that the frontoclypeal suture cannot be a synonym for the epistomal suture.

Frontogenal suture (fgs). — The frontogenal suture starts from the upper border of the anterior tentorial pit. Standing

almost verticle in respect to the epistomal suture, it extends upwards to end on the mesal margin of antennal socket and possesses distinct internal inflection called the frontogenal inflection.

Subgenal suture (sgs) . — This suture is entirely represented by the incomplete hypostomal suture (hs) and the pleurostomal suture (ps). The former starts from the posterior tentorial pit and descends towards the upper portion of the rim of oral fossa. Without meeting the latter, the suture turns lightly outwards to take up a submarginal course along the lateral portion of the fossa and ultimately gets merged with it. All along it is internally represented by the hypostomal inflection. The hypostomal area (Hst) thus demarcated on the cranium by the hypostomal suture is like an inverted 'U' and provides articulation to the maxille-labial complex. This area in its distal portion is merged with the rim of oral fossa, and loses its entity there. Its basal portion, intervening between the foramen magnum and the oral fossa may be taken as hypostomal bridge (HB) which has a clear homologie with the 'hypostomal bridge' of stenobracon aeseae. The pleurostomal suture (ps) is completely merged with the ventral margin of the cranium and thus the pleurostomal area is wanting. Thus, for most of the part, the subgenal suture (distal part of the hypostomal suture and entire pleurostomal suture) is fused with the ventral margin of the cranium, thereby indicating the complex nature of the latter.



Postoccipital suture (pos) . — The postoccipital suture runs submarginal to the dorsolateral portion of the rim of foramen magnum, connecting the obliterated posterior tentorial pits. It is internally represented by broad postoccipital ridge, which is confluent with the rim of the foramen magnum. It is for this reason that separate identity of the postoccipital ridge in its major part cannot be safely claimed. However, a very short portion of the ridge, in the region of the posterior tentorial pit is independent of the rim on account of the course of the postoccipital suture.

Paroccipital suture (Paros) . — The paroccipital sutures emerging as distinct grooves from the dorsolateral angles of the postoccipital suture ascend upto the outer borders of lateral ocelli (O) so as to divide the conventional occiput into a median and two lateral occiputs. These sutures internally form a strong paroccipital ridges. Since this ridge is in continuation with the postoccipital ridge, it can conveniently be presumed that the two in combination provide great strength to the cranium to withstand stress and strain brought about as a result of action of powerful muscles originating from it.

Ferris (1942) has created a 'single sutural system' consisting of the postfrontal, temporal and the premandibular sutures. This, he names as 'great suture' of the head. According to him the 'great suture' always functions as line of separation between the ocular, antennal and mandibular segments.

The course and condition of this great suture appear to be nonconsistant in insect heads as is apparent from the description as well as diagrams given by Ferris. If the 'great suture' is accepted as a significant suture in the morphology of the insect head, obviously the paroccipital suture of A. proxima becomes identical to the 'temporal suture' of the single sutural system of the head. However, the term 'paroccipital suture' is retained till such time when the Ferris's concept of the areas of the insect cranium is finally accepted which would naturally mean deleting of the conventional occipital area and replacing it by the prementibular area of Ferris.

Ocular suture (os) . — There is a groove running submarginal round the ocular rim with a corresponding thin internal inflection. The groove is the ocular suture and its inflection, the ocular ridge.

Antennal suture (as) . — The antennal suture is submarginal to the antennal socket with a distinct internal ridge. The latter, however, is confluent with the rim of the socket along its internal edge and forms a wedge-shaped condition. The ventrolateral portion of the antennal rim possesses a distinct conical projection called 'antennifer', which articulates with the base of the antenna.

(iii) Areas of the Head Capsule (Figs 1 & 2).

Frons (Fr) . — In Athalia proxima, the frons looks like a rectangular sclerite extending from the vertex to the clypeus. On its course it embraces the mesal halves of the antennal sockets. It is limited ventrally by the frontoclypeal suture and laterally upto the antennal sockets, by the frontogenal sutures. The dorsal part of the frons, above the antennal sockets, remains undefined on account of its unobtrusive merger with the parietals.

According to Snodgrass (1947) "frons is a name rather than an anatomical reality". However, the origin of all the dorsal dilator muscles of the pharynx on this sclerite coupled with the fact that the frontal ganglion forms its ventral limit coinciding with the position of the mouth, is a good justification of the existance of frons in A.proxima. Nevertheless, such internal criterian cannot be conveniently used for justifying external limitations of this area. Hence, the present writer suggests that the frontoclypeal and frontogenal sutures should be considered as external limits of the frons subject to the condition that the 'dorsal dilators of the pharynx' owe their origin to this sclerite.

Clypeus (Clp) . — This crescent-shaped area is dorsolaterally limited by the entire epistomal suture. It is separated dorsally from the frons by the frontoclypeal suture and later-

ally from the genae by the clypeogenal sutures. Ventrally it is limited by the ventral margin of the facial area which is, more or less, straight and provides suspension to the labrum through a narrow conjunctiva. This line of attachment, in the wasp, has been named as 'labral suture' by Duncan (1939).

Parietals . — Vast area of the cranium is occupied by the two parietals which lie lateral to the frontoclypeal area and include the compound eyes, ocelli and lateral halves of antennal sockets. The dorsal portion of the parietals merging with the median occiput posteriorly and with the frons anteriorly can be taken as the vertex (Vx). The remaining portion of the parietals, demarcated anteriorly by the combination of clypeogenal and frontogenal sutures and merged posteriorly with the lateral occiputs and postgenae, can be taken as the genae (Ge). The latter, dorsally are continuous with the vertex and ventrally limited by the lateral portions of the ventral margin of the cranium.

Occiput (Oc) . — It forms the arched portion of the posterior surface of the cranium and is separated posteriorly from the postocciput by the incomplete postoccipital suture. Anteriorly its limits are not defined owing to the absence of the occipital suture. The two ascending paroccipital sutures, in their proximal halves, divide the occiput into a median (Moc) and two lateral (Loc) occiputs.



Postgena (Pge) . — The postgena is an incompletely defined area on the posterior surface of the cranium. Mesally, it is limited by the hypostomal suture and laterally it merges with the gena. Ventrally, it is bounded by a portion of the ventral margin of the cranium while dorsally it is continuous with the lateral occiput.

Postocciput (Poc) . — The post-occiput is a narrow arched sclerite collaring the foramen magnum and limited anteriorly by the incomplete postoccipital suture. Its lower margin is attached with the neck membrane. The entire dorsolateral portion of the postocciput is internally obscured because of the confluence of the postoccipital ridge with the rim of the foramen magnum. Only small ventral portion of the postocciput can be taken as a distinct sclerotic plate. Laterally, the rim of the foramen magnum develops a pair of triangular occipital condyles (Occ) which project into the foramen magnum to provide articulation to the pleural occipital processes of the prothorax.

Ocular sclerite . — Surrounding the ocular foramen, there is a thick but narrow marginal shelf. This is the ocular sclerite which in turn is demarcated from the parietals by the ocular suture.

(iv) Tentorium (Figs 1, 3 & 4).

The tentorium, which is the cranial endoskeleton, consists of the usual three pairs of arms. From the obsolete posterior tentorial pits, lying in the lateroventral angles of the foramen magnum, come out two thick sclerotic bar like posterior tentorial arms (PT). Running anteroposteriorly, the posterior tentorial arms meet the corresponding anterior tentorial arms (AT) to form a pair of continuous bars connecting the anterior and posterior surfaces of the cranium. The anterior tentorial arms appear in the form of a pair of distinct cranial invaginations on the facial area of the cranium and can externally be detected as broad elliptical anterior tentorial pits (at). These pits have highly raised margins and are placed just ventral to the antennal sockets at the junction of the frontoclypeal and frontogenal sutures. The anterior tentorial arms, penetrating through the cranial space as parallel bars, are thick at the base. These gradually become thin on their way to fuse with the corresponding posterior tentorial arms. The anterior tentorial arms give out from their distal ends a pair of thin dorsal tentorial arms (DT) which obliquely traversing the cranial space meet the facial area, dorsal to the antennal sockets. Their union with the wall can externally be located as feeble impressions and not invaginations. These are the tentorial maculae (dt). The base of the dorsal tentorial arm demarcates the anterior tentorial arm from the posterior tentorial arm.

The mesal surface of the anterior tentorial arms flattens out into two triangular projections (mf) which correspond with the 'mesal flaps' of the anterior tentorial arms of Steenobracon deesae (Alam 1951). These projections, however, in the present case are confined only to the distal portion of the anterior tentorial arms. Such flaps are absent in the honey bee and the wasp. The posterior tentorial arms shortly after leaving the posterior tentorial pits mesally develop a stout transverse tentorial bridge. (TB). The latter, all along its posterior surface, is soldered with the hypostomal bridge.

The tentorium functions as seat of origin to some important head muscles and assists the cranium to withstand stress and strain brought on it by the working of the muscles.

(v) Antennae with their Muscles (Figs 1,5,6,7,8,9,10,11 & 12).

The many-segmented, cylindrical antennae (Ant) are movably articulated with the cranium. Their bases<sup>are</sup>/lodged in the membranous area of the antennal sockets (Asoc), which lie on the lower half of the facial region. Each antenna consists of the scape (Sc), pedicel (Pe), funicle (Fn) and club (Cl).

The proximal rim of the scape (rs) is thickly emarginated. Its ventrolateral portion bears a prominent concavity (Acon) which provides articulation to the antennifer (af) projecting out from the rim of the socket. Distally, the scape

is distended to engulf the proximal end of the pedicel. Close to the distal rim (drSc) of the scape, there emerge, from its lateral walls, two shelf like projections (ArkSc) with shallow depressions to provide articulations to the corresponding articular processes (ArkPe) of the proximal rim of the pedicel (prPe). Such ball and socket like articulation permits only up and down movement to the antennae.

The funicle consists of six segments in both the sexes. This is followed by the unsegmented club. These segments of the funicle neither possess any muscle nor there are articulations with each other. Their association is maintained by the convex proximal end of one fitting into the concave distal end of the preceding segment.

Musculature of antenna. — Both, extrinsic as well as intrinsic, set of muscles are provided to each antenna. The four extrinsic muscles are as follows:

External levator of the antenna (No. 1). — This muscle arises from the middle of the dorsal surface of anterior tentorial arm, and is inserted through a tendon on the dorsolateral half of the proximal rim of the scape.

Internal levator of the antenna (No. 2). — This muscle consists of two bundles; one arising on the ventral surface of



the basal portion of dorsal tentorial arm and the other on the dorsal surface of the distal portion of anterior tentorial arm. These converge on a common tendon which is inserted on the dorsomesal half of the rim of the scape.

External depressor of the antenna (No.3). — It is a short stumpy muscle which originates from the dorsal surface of the proximal half of anterior tentorial arm. Its fibres converge to get attached through a tendon on the lateroventral half of the base of the scape, close to the antennal concavity.

Internal depressor of the antenna (No.4). — This muscle originates from the ventral and lateral surfaces of the dorsal arm of tentorium and its fibres converge to end by a tendon on the mesoventral half of the base of the scape.

These extrinsic muscles are homologous to the corresponding 'levators' and 'depressors' of S. qeesae.

The intrinsic muscles of the antenna are the 'levator' and 'depressor' of the pedicel.

Levator of the pedicel (No.5). — This muscle originates from the proximal half of the dorsal wall of the scape with its fibres converging on the dorsal half of the proximal rim of the pedicel. It corresponds to the 'levator of the flagellum' of S. qeesae.

Depressor of the pedicel (No.6). — This muscle also arises in the proximal half of the scape, but on its ventral wall. Running in a convergent manner it is inserted on the ventral half of the proximal rim of the pedicel. It is equivalent to the 'depressor of the flagellum' of S. deesae.

(vi) Labrum and Epipharynx (Figs 1, 13 & 14).

Labrum (Lm). — The semicircular labrum is suspended from the ventral margin of the clypeus. The membrane suspending the labrum is not visible ordinarily due to infolding of the clypeal margin. The labrum is capable of a limited up and down movement.

Epipharynx (Ephy). — The labrum is internally duplicated by a membrane which forms the epipharyngeal wall of the preoral cavity. The anteriorly broad epipharynx is attached to the anterolateral margin of the labrum. Posteriorly, it narrows abruptly and becomes continuous with the dorsal wall of cibarium (Cb). The epipharynx on its anteroposterior course gradually moves away from the labrum. From the base of the labrum there extends a pair of tiny sclerotic bars through the lateral angles of the epipharynx. These are the tormae (tr). The labrum is controlled by a muscle called 'retractor of the labrum' (No.7). This muscle arises on the frons, close to the antennal base and converges to end laterally on the torma. It is equivalent to the 'posterior frontal muscle of the labrum' of Periplaneta americana as shown by Snodgrass (1944).

(vii) Mandibles with their Muscles (Figs. 1, 15 & 16).

The stout mandible hangs from the ventral margin of the lateral portion of the cranium. The base of the mandible (rm) is provided with anterior (c) and posterior (a) points of articulation. The anterior point of articulation is a facet to provide articulation to the cranial articular knob. The posterior articulation is in the form of a stout condyle which fits into a corresponding concavity in the cranial ventral margin.

The mandible is of biting type with the mesal surface differentiated into basal molar area (p) and distal incisor area (o). The blunt molar area grinds the food while the teeth of the incisor area are used in cutting the food. The mandible is controlled by two extrinsic muscles which as follows:

Adductor of the mandible (No.9). — This muscle consists of two distinct bundles. One of the bundles arises on the vertex while the other originates on the occiput-cum-postgena. These converge on a stout apodeme which is soldered with the mandibular base, close to its anterior articulation.

Abductor of the mandible (No.10). — This muscle originates on the postgena of the cranium slightly below the origin of the second bundle of adductor muscle. Its fibres converge on an apodeme which is inserted on the mandibular base, close and mesal to the posterior articulation of the mandible.

(viii) Maxillo-labial Complex (Fig. 17).

The paired maxillae (Mx) and the unpaired labium (Lb) have associated themselves into a single functional unit known as 'maxillo-labial complex'. This association is mostly membranous, still the presence of sclerotic association between the labium and the laciniae cannot be denied. It is through the cardines (ac) that the unit is articulated with the cranium. The labium lacks sclerotic contact with the latter and is suspended from it through membrane. The maxillo-labial complex forms the floor as well as the lateral limits of the preoral space. The portion of the maxillo-labial complex, anterior to the stipito-cardinal hinges (StCdh) can flex forward and backward to change the dimensions of the preoral space.

The maxillae and the labium individually have retained most of the structures of the generalized insect. As such, these can be taken as basis for the more evolved types of the labium and the maxillae in higher Hymenoptera. Snodgrass (1935) has already pointed out that "the mouth parts of Tenthredinidae furnishes a basis for the more specialized lapping and sucking apparatus of bees".

(ix) Maxillae with their Muscles (Figs. 17,18,19,20,21,22 & 23).

Maxilla (Mx). — The maxillae, for most of the part, are of generalized type. These, lying on the sides of the labium, are composed of two main sclerites, the cardo (Cd), and the stipes



(St). The lacinia (Lc) and galea (Ga) form the distal lobes of the maxilla. The stipitocardinal hinge (StCdh) separates the two sclerites. The maxillary cardines flank the postmentum. The distal halves of stipes flank the prementum with which these are also connected through membrane.

Cardo (Cd). — The cardo is the proximal sclerite of the maxilla. It is bean-shaped with a notch in the middle of its proximal margin which provides articulation to the hypostomal knob of the cranium. These hypostomal knobs are contributed by the hypostomal margin of the oral fossa as is the case with the honey bee. This condition is different in S.deesae where a distinct hypostomal bridge is present with its lateral ends modified into articular knobs. Distally, the cardo is continuous with the proximal margin of the stipes along a curved stipitocardinal hinge (StCdh). All along the anterior surface, the cardo is concave. Its lateral margins are strengthened by distinct submarginal ridges.

Stipes (St). — Distal to the cardo and beyond the stipitocardinal hinge the maxilla continues as elongated stipes. Like cardo, the stipes is also depressed in the middle with its sides elevated. The elevation of the side walls is much prominent in the middle portions. In contrast to the lateral wall, the mesal wall is slightly raised only.

The lacinia (Lc) is the inner lobe of the stipes. It is borne on the mesal wall of the stipes, well removed from the base of the maxillary palp. It is mostly sclerotized and triangular in shape. Its sides are much drawn out distally into an elongated tip and are serrated. The lacinal base is bare which laterally continues with the stipital edge and mesally terminates into an articular knob (Arklc). This knob is faceted against a concave but shallow facet (ArcPrmt) developed proximally on the dorsolateral angle of the prementum. This serves as the sclerotic articulation between the maxilla and the labium. The lacinal base can be compared with the 'labio-maxillary jugum' of the wasp where it functions as sclerotic connection between the maxilla and the labium.

The outer distal lobe of the stipes is the galea (Ga). It is membranous and is covered over by setae of different sizes. The galea also bears two supporting sclerites. One is the 'basal sclerite' (bscl) which is gorget like with its outer end pointed. It becomes gradually broader towards its mesal end, as it forms the basal part of the galea. The other sclerite is roughly triangular and is located in the mesal wall of the galea. It can be called the 'mesal sclerite' (mscl). Just dorsal to the latter, the mesal wall of the galea, develops sclerotized teeth (sc1th). These are arranged in a row and are gradually reduced in size towards the base.

Six-segmented maxillary palp (MxPlp) originates laterally from the distal half of the stipes, opposite the lacinia.

Muscles of Maxilla.

Extrinsic Muscles :

First protractor of the maxilla (No.11). — The fibres of this muscle originate from the lateral occiput of the cranium. These descend vertically to end at the base of the cardo. On contraction, it pulls the cardo up, with the result that the flexed stipes is pushed forward. This muscle is represented in S.deessa, the honey bee and the wasp. It is also represented in Periplanata americana.

Second protractor of the maxilla (No.12). — This is a stout muscle with fibres arising on the midventral face of the anterior tentorial arm. Running obliquely it ends by a broad base on the distal portion of the cardo, near the, cardo-stipital hinge. This muscle on contraction pulls up the cardo which in its turn protracts the maxilla. It is present in P.americana, also as 'protractor of the maxilla'.

Flexor of the maxilla (No.13). — This muscle starts from the ventral face of the proximal half of the anterior tentorial arm. It is slightly posterior to the origin of the 'adductor of the labium'. The fibres of the muscle converge obliquely to a point on the proximal half of the mesal margin of stipes.

The course of this muscle is almost verticle. On contraction, it forces the stipes to bend up on the cardostipital hinge. It is represented in S.deesae and also in the honey bee. It is highly improbable for this muscle to act as protractor which is the function attributed to its equivalent in the honey bee by Snodgrass (1956). The present writer agrees with Alam (1951) who considers a corresponding muscle in S.deesae as flexor of the maxilla.

**Intrinsic Muscles :**

Extensor of the lacinia (No.14). — The fibres of this muscle commence from the proximal half of the lateral wall of stipes. These running forward, cross the stipes for insertion by a broad base on the lacinia. On contraction, this muscle will affect the flexed lacinia somewhat laterally so as to straighten it. Snodgrass (1956) shows such a muscle in the honey bee and ascribes it with the function of raising the lacinia.

Flexor of the lacinia (No.15). — The fibres of this muscle originate from the basal portion of the floor of stipes, mesal and proximal to the place of origin of 'the 'extensor of the lacinia'. Anteriorly the fibres converge, running mesal and ventral to the 'extensor of the lacinia' to end at the base of the lacinia. It is equivalent to the 'flexor of the lacinia' of the generalized insect. It is also represented in S.deesae.

Flexor of the galea (No.16). — This muscle starts from the lateral wall of the stipes, distal to the origin of the 'extensor of the lacinia'. Its fibres converge anteriorly on the base of the 'mesal sclerite of the galea'. Its course is ventral to that of the 'extensor of the lacinia'. It corresponds to the 'flexor of the galea' of generalized insect and is also homologous to the 'flexor of galea' of S.deesaa.

Levator of the maxillary palp (No.17). — The fibres of this muscle arise on the mesal wall, as well as, on the floor of the proximal half of stipes. These, running across the stipes, converge at a point on the posterior half of the basal rim of maxillary palp.

Depressor of the maxillary palp (No.18). — This short muscle arises in the distal half of the floor of stipes. Its fibres running backwards converge to end on the anterior half of the basal rim of maxillary palp.

The above two muscles of maxillary palp are also represented in P.americana. In S.deesaa, a similar muscle has been taken as the 'depressor of the maxillary palp'. In the honey bee, the maxillary palp is controlled by one muscle only.

Intrinsic flexors of the maxillary palp (Nos. 19a, 19b1, 19b2 & 19c). Each one of the three segments (2nd, 3rd and 4th) of the maxillary palp is provided with a flexor muscle. This

muscle arises on the proximal portion of one segment to end on the dorsal half of the basal rim of the succeeding segment. Apart from the usual flexor, the third segment also receives an 'accessory flexor' (1962) which originates in the first segment and running across the second segment makes a common insertion with the 'flexor of the third segment' (1961). This muscle is not represented in Hymenoptera. The other three flexors, structurally as well as functionally, are comparable with the 'intrinsic flexors of the maxillary palp' of S. deesse.

(x) Labium and its muscles (Figs. 17, 24, 25, 26, 27 & 28).

The labium is modified from the generalized type and consists of two distinct regions. The proximal region is formed by the postmentum (Pmt) which is represented mainly by membranous mentum (Mt) and a small sclerotic submentum (Smt). The distal region of the labium is the prementum, which is well developed and sclerotized. The distal half of the prementum bears a pair of four-segmented labial palps (LbPlp), median glossa (Gls) and paired lateral paraglossae (Pgl).

Postmentum (Pmt). — The postmentum is an extensive membrane connecting the ventral margin of the hypostomal bridge with the proximal margin of the prementum. Laterally, it extends upto the mesal margins of the maxillae. In this membrane lies a rounded sclerite which divides the postmentum



into a distal mentum (Mt) and a proximal submentum (Smt). The sclerite itself belongs to the latter. This contention is supported by the fact that the intrinsic 'retractors of the prementum' originate on this sclerite.

Prementum (Prmt). — It consists of distinct dorsal and ventral walls which are confluent along their anterior and lateral margins. The dorsal wall is sclerotized excepting a small midlongitudinal area which can be called as the 'median cleft' (Mclf). This cleft gradually widens in anteroposterior direction. The ventral wall of the prementum is flat and appears to consist of two black plates whose separate identity is based on the intensity of pigmentation. Except this pigment differentiation, there is no other evidence to justify their separate identity. However, in another saw-fly, Heteronidea ribesii, the line of union of the two plates composing the prementum is quite distinct (Snodgrass, 1925). In the distal half of the ventral wall are located the sockets which provide suspension to the four-segmented labial palpi (LbPlp). These sockets are actually contained by a pair of protuberances which in the honey bee are labelled as palpigers (Plg) by Snodgrass (1956). The palpigers are not shown by Duncan (1939) and Alam (1951) in the wasp and S. deesae respectively.

Distally the prementum bears the median glossa (Gls) containing the salivary orifice and two lateral paraglossae (Pgl). The free distal margin of the glossa is entire and there

is, no notch or longitudinal suture to represent the union of the lobes of the paired embryonic glossae. This united condition, however, is considered an advancement over the paired condition of the glossae of generalized insects. In the wasp, the notch in the glossa has been regarded by Duncan (1939) as a lingering mark of union between the paired second maxillae. The inverted cone-shaped membranous glossa contains a pair of sclerotic plates in the proximal portion of the its lateral walls. These may be taken as supporting sclerites (spscl). Each paraglossa also contains a proximally placed sclerite in its mesal wall, while the lateral wall possesses a sclerite in its distal half. The three lobes are velvety in texture. Their surfaces are studded with papillae, and numerous scattered hairs.

Hypopharynx (Hphy). — The hypopharynx is an extremely simple structure. It is in the form of a membrane stretching over the median cleft of the prementum. Apparently no sclerite is detectable in the hypopharynx. However, it is suggested that the rim (margin) of the median cleft of prementum may also be taken to represent the supporting base of the generalized hypopharynx. This must have happened by way of secondary merger of the supporting sclerites of the hypopharynx with the rim of the cleft. Consequently, it would be quite logical to consider the rim of the cleft as a composite structure contributed by the dorsal wall of the prementum, as well as, by the supporting sclerites of the hypopharynx. The hypopharyngeal membrane is

posteriorly continued with the ventral wall of the cibarium. The space underneath the cleft can be taken as lumen of the hypopharynx' (LumHphy). It is occupied by the salivarium (Slv), which is a mere dilatation of the distal end of the common salivary duct (SLD). The salivarium apically tapers to open through the salivary orifice of the glossa.

Musculature of the Labium.

The movements of the labium, alone, as well as in association with the maxilla, are brought about by extrinsic and intrinsic muscles.

Adductor of the labium (No.20). — The only extrinsic muscle is represented by the 'adductor of the labium' in this case. Its fibres commence ventrally from the ventral face of the proximal half of anterior tentorial arm (AT). Running downwards, these end on the proximal edge of the ventral wall of prementum.

Flexor of the glossa (No.21). — The fibres of this muscle start laterally on the proximal margin of the ventral wall of the prementum. These converge anteriorly to end at the base of the glossa. This is one of the generalized muscles and corresponds to the 'lingual flexor' of S.deesae.

Flexor of the paraglossa (No.22). — This muscle arises laterally in the proximal half of the ventral wall of the prementum. Anteriorly, the fibres converge to end at the mesal angle of the paraglossal base. This point of insertion lies in immediate neighbourhood of the insertion of the 'Flexor of the glossa'. The synchronized action of these muscles will flex the entire lingual region. Besides moving in association with the glossa, the paraglossa is also capable of moving individually. This muscle is comparable with 'the lingular flexor' of S.deesae; as well as, with the 'premental retractor of the ligula' and the 'anterior flexor of the ligula' of the honey bee and the wasp, respectively.

Muscles of the labial palp. (Nos. 23, 24a & 24b). — One extrinsic and two intrinsic muscles operate the labial palp. The fibres of the extrinsic muscle (No.23) arise laterally in the proximal half of the ventral wall of prementum. These converge anteriorly to end on the posterior half of the basal rim of the labial palp. The first intrinsic muscle (No.24a) arises within the first segment of the palp while the second intrinsic muscle (No.24b) originates in the second segment. Anteriorly these two muscles converge on the basal rims of the succeeding segments, the former ending on the lateral half of the rim while the other is inserted on the mesal half of the rim.

Posterolateral origin of the extrinsic muscle in relation to its insertion and consequently the course followed, make it the 'adductor of the labial palp'. On contraction, it will tilt the posterior half of the base of the palp laterally, and thus the anterior half will be tilted mesally. Consequently the entire palp is swung inwards. This action is also assisted through the contraction of the second intrinsic muscle which will flex the two distal segments of the palp. On relaxation, the 'adductor' and the 'flexor' muscles will swing the palp out. Simultaneously, the first intrinsic muscle, on contraction, will help the outward swing of the palp and hence it can be taken as the 'extensor of the palp'.

Dilator of the salivarium (No.25). — This muscle originates from the lateral area of the proximal half of the prementum. The fibres running almost parallel end by a linear insertion along the dorsal midlongitudinal area of the salivarium. On contraction, the muscle will dilate the walls of the salivarium, thus increasing the inner space to allow the flow of saliva. Its relaxation will help the salivarium to pump out the saliva through the salivary orifice. This muscle is equivalent to the 'dilator of the salivary syringe' of the honey bee; the 'dilator of the salivarium' of the wasp and the 'anterior dilator of the salivarium' of S. deesae.

Retractor of the prementum (No.26). — The fibres of this muscle start on the sclerotic portion of the submentum, and running anteriorly these end on the middle portion of the proximal edge of the ventral wall of the prementum. Since the sclerite of the submentum is extremely reduced, the two components of the paired muscle secondarily combine in their origin, though they maintain independent insertions. The common origin, however, should not mean that the 'retractor of the prementum' is unpaired. Equivalent of this muscle is represented in Gryllus assimilis (Orthoptera), as shown by Snodgrass (1935).

(xi) Cephalic Stomodaeum and its Musculature (Figs. 13,14,29 & 30)

The cephalic stomodaeum consists of the food meatus, cibarium (Cb) and the pharynx (Phy) which is continued with the oesophagus in the region of the foramen magnum. The pharynx is divisible into anterior (APhy) and posterior (PPhy) regions. The anterior pharynx in combination with the cibarium forms the cibariopharyngeal sucking pump. Anteriorly, the cephalic stomodaeum communicates with the exterior through the functional mouth.

Food meatus. — The food meatus is a space limited dorsally by the epipharynx, ventrally by the distal part of the labium and laterally by the mandibles. It commences with the functional mouth and ends with the cibarium.



Cibariopharyngeal sucking pump (CbPhySp). — The cibariopharyngeal sucking pump is in the form of a dorsoventrally compressed spacious tube. It is embraced, throughout, by the circular muscle fibres which function as its 'compressor muscles' (No.27). Similar condition of the presence of 'compressor muscles' on cibariopharyngeal region in the honey bee has been shown by Snodgrass (1956).

The cibarial portion of the sucking pump is continuous dorsally with the posterior margin of the epipharynx (Ephy) and ventrally with the hypopharynx (Hphy).

The pharyngeal portion of the sucking pump possesses the same dimensions as the cibarium. Its ventral wall is braced externally by an elongated plate (Phypl) which is comparable with the 'pharyngeal plate' of S.deesae. Anteriorly, this plate is notched and posteriorly it is produced into two arms which before ending turn up to become lateral to the pharynx. Posterior termination of the anterior pharynx is marked by a prominent diverticulum placed in its dorsal wall.

There is apparently no external demarcation between the cibarium and the anterior pharynx. These can be distinguished on the ground that the 'sensors of the cibarium' arise on the clypeus, while the 'sensors of the pharynx' originate on the frons. Besides, the frontal ganglion (frGng) lies on the dorsal wall of the stomodaeum between the cibarium and the pharynx. Further, the lumina of the two communicate with each

other through a wide passage called 'true mouth' which almost coincides with the position of the frontal ganglion.

Posterior pharynx (PPhy). — The posterior pharynx, beginning immediately behind the dorsal diverticulum of the anterior pharynx, is a narrow tube, which bends sharply to get underneath the brain. It is extended towards the foramen magnum where it joins the oesophagus.

Musculature of the Cephalic Stomodaeum.

Dorsal dilator of the food meatus (No.8). — This short muscle emerges from the inner surface of the labrum and is attached in a linear manner on the dorsal wall of the food meatus, close to its connection with the cibariopharyngeal sucking pump. On contraction it widens the opening. Besides, it may also function antagonistic to the 'labral retractor'.

Dorsal dilators of the cibarium (Nos. 28a, 28b & 28c). — There are three pairs of thick but short dilator muscles arising close to each other on the clypeus. These muscles running abliquely end on the dorsal wall of the cibarium along its midlongitudinal area. In the honey bee, five pairs of 'dilators' are shown, while in E. deesae only one such pair of muscles is recorded.

Dorsal dilators of the anterior pharynx (Nos. 29a, 29b & 29c).

There is another group of three pairs of dilator muscles which originate from the upper region of the frons and are attached on the dorsal wall of the anterior pharynx, along its midlongitudinal area. These are equivalent to the three pairs of 'frontal dilators' in S. deessae. There are only two pairs of 'frontal dilators' in the honey bee.

Dorsal dilator of the posterior pharynx (No. 30). — This

muscle arises from the median occiput and is inserted behind the brain on the dorsal wall of the posterior pharynx. Its counterparts in S. deessae, the honey bee and the wasp are, 'occipital dilator of the posterior pharynx', 'postcerebral muscle of the pharynx' and 'dorsal dilator of the posterior pharynx' respectively.

Lateral dilator of the anterior pharynx (No. 31). — This

slender muscle arises on the tentorial bridge. Running forward it ends on the distal extremity of the posterior arm of the pharyngeal plate. On contraction, it pulls down the pharyngeal plate and thereby assists the 'dorsal dilator of the posterior pharynx' to enforce complete expansion of the pharynx. It is comparable to the 'first ventral dilator of the anterior pharynx' of S. deessae.

(xii) Mode of Ingestion.

A. proxima feeds on liquid food whose ascent is controlled by the muscles of the cephalic stomodaeum. The apical end of the maxillolabial complex (glaeae, glossa, and paraglossae) bears numerous tubercles and setae to hold the food. The feeding behaviour is initiated by producing the maxillolabial complex forward to bring it in contact with the food. This is done by the contraction of the 'protractors of the maxillae'. The 'flexors of galeae, glossa and paraglossae' flex them inwards and make them to lie in the distal portion of the food meatus. At this stage the opening between the food meatus and the cibarium is widened by the contraction of the 'dilator of the food meatus'. This is followed by expansion in anteroposterior direction of the cibarial portion of the cibariopharyngeal sucking pump, as a result of the contraction of the 'dorsal dilators of the cibarium'. Thus, the food from the food meatus is sucked into the cibarium and this ascent of food is further assisted by the relaxation of the 'dilator of the food meatus'.

Now the 'dorsal dilators of the anterior pharynx' contract to widen the lumen of the pharyngeal portion of the sucking pump. Simultaneously the 'dilators of the cibarium' undergo relaxation. This relaxation of the 'dilators' coupled with the contraction, in anteroposterior direction of the 'cibarial compressors', push the food up into the anterior pharynx through the true mouth.

To push the food further into the posterior pharynx, the 'dorsal dilators of the anterior pharynx' will undergo relaxation and the 'compressors' of the same will contract in anteroposterior direction. This is assisted by the contraction of the 'lateral dilator of the anterior pharynx' to provide wide passage for the movement of food from the anterior pharynx to the posterior pharynx. The entry of food into the posterior pharynx is followed by the relaxation of the 'compressors' and 'lateral dilators' of the anterior pharynx with the result that the communication between anterior and posterior portions of pharynx is blocked.

Further movement of the food (descent) from the posterior pharynx to the oesophagus is controlled by the 'circular muscles' of the pharyngeal wall. At the same time the 'dorsal dilators of the posterior pharynx' undergo contraction to provide unhindered entry of the food into the oesophagus. This is followed by the return of the circular muscles as well as of the 'dilator muscles of the posterior pharynx' to their usual normal form.

## 2. THE THORAX

### (1) General Features of the Thorax (Figs. 31, 32 & 33).

The usual three thoracic segments in association with the first abdominal segment, known as propodeum (Π) form the thorax of the sawfly. All the segments are connected with each other through intersegmental membranes. The thorax is oval in shape with the dorsal surface prominently arched. The thorax is anteriorly connected with the head through the cervical membrane (Cerm). The latter is laterally traversed by occipital processes (OP) to develop sclerotic connection of the thorax with the head. Besides, these processes also support the head on the thorax. Posteriorly the thorax communicates with the abdomen through extensive intersegmental membrane. Being the locomotary centre, the thorax is a highly developed region of the insect body. It is a compact unit. This compactness is brought about by the close alliance of its sclerotic components. The latter are appreciably modified and possess distinct internal ridges. The protergum (N1), the mesotergum (N2), the metatergum (N3) and the propodeal tergum (Π), all these lie in close approximation. The protergum also laterally apposes the mesopleuron which at its posterodorsal angle communicates with the mesopostnotum (PN2). Similarly the metapleuron passes into the metapostnotum (PN3) through its posterodorsal angle while its anterior margin lies closely apposed to the posterior margin of the mesopleuron. Such



modifications appear to have taken place mainly to accommodate strong leg and wing muscles and to withstand the stress and strain brought on the thorax as a result of the action of these muscles.

(ii) Structure of the Prothorax (Figs. 32,33,34,35,36 & 37).

The sclerotic components of the prothorax are loosely associated with one another and in this respect, the prothorax differs from the rest of the thorax. The pleurosternal sclerites are shifted forward as a loose unit to articulate with the head and also to act as suspensorium for the prothoracic legs. The protergum lies well removed from the cranium and is interlocked with the pterothorax.

Protergum (pronotum) (N1). — The protergum (N1) consists of two triangular lateral lobes which are connected through a narrow median bridge (MB). The deeply concave anterior margin of the protergum is followed by a prominent submarginal ridge (smR) which at the ends merges with the margin. The thickened lateral margin of the protergum bends twice. In between the tergal lobe and the mesoepisternum, lie two spherical plates which are considered as detached portions of the protergum. The upper plate is called the 'spiracular plate' (sppl) as it conceals the first thoracic spiracle and may be compared with the 'spiracular lobe' of the honey bee. The lower plate is

named as 'occluser plate' (Opl) since it serves as the seat of origin of the attachment-peg for 'occluser muscle of first thoracic spiracle'. The lateral tergal margin, in between, as well as underneath, these plates comes in direct association with the anterior margin of the mesoepisternum, at two points. The lower point of association is more pronounced where the tergal margin extends in to a blunt process which abuts against a similar process of the propectus. Such associations, besides contributing towards general thoracic rigidity, also save the protergum as well as mesopleuron from undergoing dislocation under the pressure of muscular activity of the thorax. The lateral margin of the protergum curves round its posterolateral angles to be continuous with its posterior margin. The posterolateral angle is duplicated by deep internal inflection. The posterior margin of the protergum curves to follow the convex anterior margin of the mesotergum. Very close association of lateral and posterior margins of the protergum with the mesothorax has drastically reduced the intersegmental membrane in these regions.

Propectus . — The pleurosternal region of the prothorax anteriorly articulating with the head and also working as a suspensorium for the prothoracic legs, is the propectus.

Propleuron (P11). — Each propleuron is an elongated subtriangular sclerite occupying the lateroventral area of the prothorax and flanking the prosternum. On its way to articulate with the cranium it becomes the lateral sclerotic portion of the cervical region. Posteriorly it is in communication with the mesopectus through extensive intersegmental membrane. At its posteroventral angle, the pleuron bears the coxal articular knobs (CxLark) which fits into the concavity of the coxal rim of the first leg (CxLarc). From this articular knob emanates the pleural sulcus (pls) whose basal half is submarginal to the posterior margin of the dorsal plate of episternum (DplEps) while its distal half curves to end at the mesal margin of the same plate near its articulation with the prosternum (S1). The sulcus has a distinct internal ridge and divides the pleuron into an anterior larger episternum (Eps) and a posterior smaller epimeron (Epm). The latter is triangular in outline. There is no epimeron or pleural suture in S.deesae, though in the honey bee both are represented. Duncan (1939), too, mentions, though with restraint, the presence of reduced epimeron and pleural sulcus in the wasp. The pleural apophysis (PLA)<sup>is</sup> a stout bar which is directed posteriorly. It emerges from the basal half of the pleural ridge. Its surface is rough due to the presence of several prominent ridges, which apart from strengthening it, also make it adequate for the attachment of the muscles. The pleural apophysis occurs in the honey bee. Duncan (1939) calls a similar structure in the wasp as 'propleural arm'. It is shown to be absent in S.deesae.

The episternum is demarcated into an anteriorly placed occipital process (OP) followed by the extensive posterior portion. The latter consists of dorsal (DplEps) and ventral (VplEps) plates which are free mesally but laterally merge with one another along a linear convexity. Duncan (1939) regards this convexity as a definite carina in the wasp; but Alam (1951) adjudges the same in S.deesae as a mere bulge and not a carina due to the absence of a definite corresponding ridge. The dorsal plate is broad posteriorly but narrows anteriorly. Its mesal margin, though smooth, is thickened all along with its anterior portion distinctly curved. There is no horizontal apodeme as shown by Alam (1951) in S.deesae. Immediately anterior to the place, where the mesal margin embraces the pleural sulcus, a facet (EpsArc) is developed to articulate with the lateral tip of the basisternal wing. Anteriorly, the mesal margin ends by embracing the outer surface of the basal portion of the occipital process. The ventral plate is larger and in its posterior half, it mesally extends into a triangular lobe. Due to this, the ventral neck membrane which is bordered laterally by the free mesal margins of the two ventral plates, is constricted in this region. The mesal margin of the ventral plate is followed by a submarginal ridge (smR) which is externally represented by a groove. This submarginal ridge is posteriorly obliterated in the region of the triangular lobe, while anteriorly it expands to form the occipital process. The latter is, more or less, triangular with

one of its basal angles contiguous with the submarginal ridge of the ventral plate. The other basal angle is produced into a posteriorly directed cervical apodeme (CerAp) confined within the pleuron. The vertex of the occipital process is a rounded sturdy knob which articulates with the occipital condyle (Occ) of the head. The formation of occipital process presents <sup>conditions</sup> identical/as are found in S. deesae where submarginal ridge of the ventral plate anteriorly contributes to the formation of 'occipital process'. Duncan (1939) does not show any submarginal ridge in the wasp, where the anterodorsal angle of the propleuron is transformed into 'occipital process'.

Prosternum (S1). — The prosternum is located in the mid-ventral portion of the prothorax having extensive membranous connection with the propleura and mesopectus. It is also articulated in the basal portion of the mesal margin of episternal dorsal plates. The prosternum is divisible into a large, more or less, 'X'-Shaped basisternum (Bs) and a narrow plate like furcasternum (Fs). The two sclerotic areas are demarcated by the inverted 'V' - shaped sternal suture (K), whose two ends end close to the paired obsolete apophyseal pits while in its middle it meets the median longitudinal groove (msg) of the basisternum.

The basisternum consists of median and lateral portions. The anterior margin of the median portion is convex while its

sides are curved which posteriorly squeeze it into a narrow strip. The latter further expands laterally, immediately before the sternal suture, into a pair of elongated wings. These taper and end bluntly to abut against the facets on the mesal margins of the propleural dorsal plates. Thus the basisternum is the only prosternal part which is in articulation with the propleuron. The entire anterior and lateral margins of the basisternum are thickened. The median portion of the basisternum is traversed, along its midlongitudinal axis, by a groove which starts from its anterior margin and ends at the median tip of the sternal suture, thus dividing it into two lateral halves. This groove is the median groove of the basisternum (msg) and it is internally represented by a distinct ridge. The median groove has also been reported to occur in the wasp, honey bee and S. deessa.

The triangular furcasternum (Fs) is demarcated from the basisternum by the sternal suture which consequently forms its anterior limits. The posterior margin of the furcasternum is thin and continuous with the intersegmental membrane which separates the prothorax from the mesothorax. Externally, the furcasternum bears facets (CxVark) on either side to provide sternal articulations to the procoxae.

The proendosternum (Endst) consisting of a pair of sternal apophyses (SA) is rooted in the paired obsolete apophyseal pits. Each apophysis is a long and, more or less, conical internal

projection with its entire base borne by the corresponding arm of the sternal ridge. All along, the apophysis is traversed by a ridge (SAR) which though submarginal still is considerably separated from its mesal margin. In the prothoracic space, it lies mesal to the pleural apophysis and both are closely held together by the fibres of the 'mesofurcal protractors of the propectus' which end at their distal extremities. The sternal apophyses are unrepresented in S. deesae and the honey bee. In the latter thickenings bracing the median endosternal plate are considered to be equivalent to the sternal apophyses, by Snodgrass (1942). The bases of the two sternal apophyses are abridged by the furcasternum, so that the endosternum acquires the shape of U. The prothoracic ganglion lies within the space enclosed by the endosternal arms. The space is the neural foramen which is also represented in S. deesae (Alam, 1951) and the honey bee (Snodgrass, 1942). The endosternal arms are homologous to the supraneural bridge of the former.

Comparing the prosternum and endosternum with those of the honey bee, wasp and S. deesae, it can be concluded that the saw-fly exhibits least advanced form of these structures and consequently it should be taken as the generalized form of hymenoptera.



Trochantin (Tn). — In between the basisternum and the propleuron and not far from the procoxal bases, there lie a pair of rounded sclerites in the ventral membrane of cervix. These may be considered equivalent to the 'trochantins' of the generalized insects. This conforms with the view expressed by Weber (1926) in his paper entitled "Der Thorax der Hornisse".

Spina sternum (LSs). — In the extensive intersegmental membrane and lying in the vicinity of the mesopectus, is a small distinct sclerotic plate. This plate may be taken as intersegmental spinasternum which has moved very close to the mesothorax. Internally, it bears a distinct spina (spn). Matsuda (1956) in fig 1 of his paper entitled 'the comparative morphology of the thorax of two species of insects' shows a thin sclerotic strip occurring anterior to the first spinasternum and posterior to the prosternal plates in the thorax of Agulla, and labels it as presternum without indicating its parental segment. (This plate has not been discussed in the text). It cannot be considered to belong to the mesothorax, because of the spinasternum lying behind it. Similarly, it cannot be the presternum of the prosternum, since the anteriorly demarcated portion of the eusternum cannot spring back to occupy a position posterior to furcasternum. The latter is also shown to be well developed in Agulla.

(iii) Musculature of the Prothorax (Figs. 38 & 39).

The muscles of the prothorax, apart from operating the propectus and the prothoracic legs are also responsible for the movements of the head. The probable grouping of these muscles are as follows:

- I. Muscles responsible for the movements of the head.
- II. Intersegmental muscles between the pro- and mesothorax.
- III. Muscles controlling movements of the propectus.
- IV. Muscles operating the prothoracic legs.

First levator of the head (No.32). — The fibres of this muscle originate on the apical end of the anterior surface of sternal apophysis. These, running forward, converge on a tendon which ends on the dorsolateral angle of the rim of the foramen magnum. It is comparable with the 'first pair of levators of the head' and the 'endosternal levator or rotator of the head' of S.deesae and the honey bee respectively.

Second levator of the head (No.33). — The fibres of this muscle arise from the posterior half of the episternum along the area of confluence of the dorsal and ventral plates. Running obliquely these converge to end on the dorsolateral angle of the foramen magnum, very close and lateral to the insertion of the 'first levator of the head'. This muscle can

be held equivalent to the 'third pair of levators of the head' in S.deesae 'the pleural levator or rotator of the head' in the honey bee and the 'pleural elevator of the head' in the wasp.

Depressor of the head (No.34). — The fibres of this muscle commence from the anterior surface of the basal half of the sternal apophysis. Directed anteriorly and running mesal to the 'first levator of the head', it converges to end on the hypostomal lobe of the head. The 'depressor of the head' is present in the honey bee, wasp and S.deesae but is inserted on the ventral rim of the foramen magnum.

Depressor of the protergum (No.35). — This short muscle with parallel fibres connects the middle portion of the anterior submarginal ridge of protergum with the anterior surface of the mesoprephragma. This muscle is comparable with the 'first depressor of the pronotum' in S.deesae.

First retractor of the propectus (No.36). — This stout intersegmental muscle consists of parallel fibres which starting from the anterior surface of the base of mesofurcal arm, end on the basal portion of the prothoracic sternal apophysis. It corresponds to 'the retractor of the propectus' in S.deesae and the 'first mesofurcal retractor of the propectus' of the wasp. However, in the latter, Duncan (1939) shows it to end by a tendon.

Alam (1951) suggests otherwise on the basis of his own observation in S.deesae, as well as, that of Snodgrass (1942) in the honey bee. In the sawfly, too, this muscle does not end by a tendon.

Second retractor of the propectus (No.37). — This is another intersegmental muscle of parallel fibres, commencing on the middle of the anterior phase of mesofurcal arm and running dorsal to the 'first retractor of the propectus', it ends by two distinct bundles on the distal extremities of the proster-nal and propleural apophyses as these apophyses lie very close to one another. There is no parallel example of this muscle in the honey bee and S.deesae, but in the wasp, the 'second mesofurcal retractor of the propectus' is comparable with it.

Elevator of the propleuron (No.38). — This muscle arises on the lateral half of the pronotum. Its fibres ascending anteriorly end on the tip of the cervical apodeme of propleuron. On contraction, the muscle lifts the anterior half of the propleuron, which in turn will also elevate the head. It is equivalent to the 'elevator of the propleuron' in S.deesae, and to the 'anterior notal elevator of the propleuron and the head' in the wasp.

Depressor of the propleuron (No.39). — The fibres of this muscle commence from the ventral plate of the episternum.

Running obliquely these move up, to end on the tip of the cervical apodeme slightly mesal to the insertion of the 'levator of the propleuron'. This muscle functions antagonistic to the 'levator of the propleuron'. This appears to be a new muscle in the thoracic myology of Hymenoptera.

Protractor of the propectus (No.40). — This muscle with parallel fibres arises from the lateral one-third of the anterior margin of the protergum. The fibres proceed obliquely and are inserted on the distal end of the pleural apophysis, close to the place of insertion of the 'second retractor of the propectus'. This muscle is comparable with the 'third protractor of the propectus' in S.deesae and with the 'first pair of posterior notal protractors of the propleuron' in the wasp.

Levator of the propectus (No.41). — The fibres of this muscle arise from the lateral one-third of the pronotum, inbetween the 'protractor of the propectus' and the 'depressor of the protergum'. The fibres running obliquely downward, end on the posterior portion of the mesal margin of dorsal plate very close to the articulation of the basisternum with the propleuron. This muscle, on the basis of its point of origin and course of action is regarded as a 'levator of the propectus'. No corresponding muscle is shown to occur in the honey bee, wasp and S.deesae.

Retractor of the sternal apophysis (No.42). — This short muscle represents one of the ventral intersegmental muscles of the generalized type. Its fibres arising on the distal end of the spina, run outward to end on the mesal surface of the distal end of sternal apophysis. A corresponding muscle is reported in Locusta migratoria and Periplaneta americana by Albracht (1953) and Snodgrass (1959), respectively. This is a new muscle in Hymenoptera; its presence in the sawfly, confirms the generalized nature of the the latter among hymenopterous insects.

(iv) Legs (Figs. 40,41 & 42).

The legs of A.proxima are used for walking, climbing and holding the mating partner by the male during copulation. The three pairs of legs are articulated to the body by their coxae, which are placed almost at right angles to the body axis. The procoxae differ from the rest in this respect as their forward tilted condition has reduced the right angle by a few degrees. The coxae have developed both pleural (lateral) and sternal (ventral) articulations and the imaginary hinge line for coxal movements should pass through these two articulations. This line will, thus, divide the coxa into preaxial (anterior) and postaxial (posterior) halves. The leg movements, likewise, are confined to mere forward (production) and backward (reduction) swings. The three pairs of legs are

almost of the same size. The leg is composed of six segments viz. Coxa (Cx), trochanter (Tr), femur (Fm), tibia (Tb), tarsus (Tar) with five tarsomeres and the pretarsus (Ptar).

(v) Structure of the Prothoracic Leg (Figs. 40, 43, 44, 47, 48, 49, 51, 53, 54, 55, 56 & 57).

Coxa (Cx). — The coxa with smooth surface is subspherical in shape with broad proximal portion and narrow distal end. The thickened proximal rim (Cxr) of the coxa is oblong in outline. The margin all along the rim is slightly bent inward. The outer (lateral) angle of the coxal rim is flattened and develops a distinct concavity (CxLArc) on its dorsal surface to provide articulation to the pleural articular knob. The inner (ventral) angle of the coxal rim is narrow and bears a small depression (CxVArc) to provide articulation to the furcasternal articular knob. Apart from these points of articulation, the entire rim of the coxal base is suspended through conjunctiva from the rim of the socket. (CxC). Distally the coxal lumen is in communication with the lumen of the trochanter through a narrow suboval passage encircled by the distal rim of coxa. The anterior and posterior walls of the coxa extend a little beyond the distal coxal rim and thereby externally conceal the proximal rim of the trochanter (Trr). The anterior and posterior articular knobs (CxArk) are borne by the inner surface of these extensions to articulate with the corresponding trochanteral articular knobs (TrArk). The

latter are the modified anterior and posterior angles of the proximal rim of trochanter. Thus, the coxotrochanteral articulation may be taken as 'dicondylic type' which allows the trochanter to swing in up and down directions.

Trochanter (Tr). — The trochanter is the smallest joint of the leg with irregular dorsal surface and curved ventral surface. The proximal opening of the trochanter is considerably reduced due to distinct marginal inflection of the rim (Trr). The anterior and posterior angles of the rim are modified into articular processes (TrArk). The ventral half of the rim is drawn out into a blunt cone, which projecting into the coxal lumen provides insertion to the bell-shaped apodeme of the 'depressor muscles'. The dorsal half of the rim is slightly concave and functions as seat of insertion for the 'levator muscles'. The ventral wall of the trochanter is comparatively shorter than the dorsal wall with the result the distal rim becomes oblique. It is connected with the proximal rim of the femur (Fmr) through narrow conjunctiva. The dorsal angle of the distal trochanteral rim tapers out into a blunt process (TrP) which articulates with a corresponding facet (FmCon) present in the proximal rim of the femur. This is comparable with the dorsal trochanterofemoral articulation/<sup>of</sup> S.deesae. There is no ventral trochanterofemoral articulation which has been reported in S.deesae by Alam (1951). The honey bee also lacks it. Nowhere the distal rim of the trochanter receives any muscle.



The trochanterofemoral articulation imparts the movements of production and reduction to the femur.

Femur (Fm). — The femur is stout and cylindrical with both the ends tapering. A collar like constriction divides it into a small proximal portion (1Fm) and a long distal portion (2 Fm). Similar subdivisions occur in S. deessa in which Alam (1951) refuses to consider the proximal subdivision as part of the trochanter. He based his stand on the fact that the 'reductor muscle of the femur' neither arises in the proximal subdivision nor it ends on the collar. This argument is endorsed in A. proxima. The dorsal wall of the femur slightly runs over the tibial end while the ventral wall is emarginated to enclose a wedge shaped area filled with conjunctiva which connects the distal rim of femur with the proximal rim of tibia. The lateral walls of the femur develop two articular knobs (FmArk) on their inner surface and close to the distal rim. These provide articulation to the corresponding knobs of the tibia (TbArk) which are its modified lateral angles. Thus the femorotibial articulation can conveniently be taken as 'dicondylic'. Such femrotibial joint enables the tibia to undergo extension and flexion along a hinge line passing through the two points of articulation.

Tibia (Tb). — The tibia is the longest of all the leg segments. Its proximal half is narrow which gradually broadens distally. The proximal extremity of the tibia which also bears

the articular processes is marked by a thick rim (Tbr) of uneven surface. Due to unusually broad marginal inflection of the proximal rim, the connecting passage with the femur is reduced considerably. The central portion of the dorsal half of the rim is produced into a process (TbP) which lies in the femoral cavity. The sides of the rim develop the coincidental articular knobs (TbArk) to articulate with the femur. The ventral half is distinctly concave and receives the subtriangular genoflexor plate (gf). The distal extremity of the tibia ends by a reduced, small uneven circular rim which contains the proximal tip of the basitarsus. Slightly proximal to the rim and from the dorsal wall of the tibia, a short shelf-like plate projects abliquely into the tibial lumen. The posterior surface of this plate possesses a distinct concavity (TbArc) while its anterior surface is comparatively smooth. This concavity provides articulation to the articular knob (BtarArk) borne on the dorsal portion of the proximal rim of basitarsus. Thus the tibiotarsal articulation is of 'monocondylic type'. Besides this articulation, the basitarsus is in membranous connection with the distal rim of the tibia.

Tarsus (Tar). — The tarsus consists of five tarsomeres. The basitarsus (Btar) articulates with the tibia through rounded articular knob (BtarArk) borne dorsally on its uneven proximal rim. The narrow proximal end of each tarsomere fits into the broad distal end of the preceding one. The central portion of

the dorsal half of distal rim of the last tarsomere is thickened to form the 'unguifer' (Ur) whose ends fit into the articular concavities of the claws (Un.). The cavities of all the tarsomeres continue uninterrupted as a single cavity and is run across by the tendon of 'flexor of the claws'. There are no muscles to ensure independent movement of tarsomeres.

Pretarsus (Ptar). — The pretarsus constitutes the distal most portion of the leg and consists of a median oblong membrane-cum-sclerotic portion and two lateral claws (Un). Each claw is long curved structure with its basal half broader than the apical half. The base of the claw provides articular concavity for the unguifer (Ur). The dorsal surface of the median lobe is distinctly sclerotized to form the hoof-shaped manubrium (mn). The proximal edge of the manubrium is bluntly rounded for proper suspension from the unguifer. The distal edge is comparatively concave. The dorsal surface of the manubrium bears a pair of long setae, in its basal half. The ventral oblong membranous portion of the median lobe is in membranous continuity with lateral margins of the manubrium. Distal to the manubrium is a membranous lobe with a horse-shoe-shaped sclerotic band in its proximal portion. The apices of the band are directed dorsally to face one another. This membranous lobe and its sclerotic band are comparable with the 'arolium' (Ar) and 'arcus' (arc) of S. deesse, respectively (Alam, 1951). The ventral half of the distal rim of last tarso-

mere is distinctly concave and bears the basal end of the oval sclerotic unguitractor (Utr) which extends a little beyond the level of articulation of the claws. Distal to the unguitractor, is the sclerotic 'planta' (Pln), which extends in linear manner to end very close to the arcus. The unguitractor is apically in membranous continuity with the planta while basally it receives the small flat apodeme of 'flexor of the claws'. The entire ventral surface of the unguitractor and planta bears profuse growth of short setae while their lateral margins are fused with the membranous arolium.

Antenna cleaner. — The ventral wall of tibia, close to its distal end possesses two small pits which provide ball and socket like articulation to the basal end of two unequal sized spurs (sAcl). The spurs are curved with concave side directed towards the basitarsus to fit against the corresponding ridged portion of the latter's ventral wall. The free apical end of each spur is tapering. The antenna cleaner is comparatively much simpler than that of S.deesae. It functions more<sup>x</sup>-or<sup>x</sup>-less in similar manner described in S.deesae and as in the latter, there is no muscular control on it.

(vi) Musculature of the Prothoracic Leg (Figs. 38, 39, 43, 45, 46, 47, 50 & 52).

The prothoracic legs are provided with fairly elaborate extrinsic and intrinsic set of muscles. The extrinsic muscles

arising in the thorax end on the proximal rim of coxae and control the movements of the leg as a whole.

First promotor of the procoxa (No.43). — The fibres of this muscle arise from the posterior half of the ventral plate of propleuron. These take ventrally directed oblique course to end on the anterior half of the coxal rim, close to its pleural articulation. Its equivalents are the 'first promotor of coxa' in S.deesae, the 'lateral promotor of the forecoxa' in the honey bee and the 'pleural productor of the forecoxa' in the wasp.

Second promotor of the procoxa (No.44). — This muscle is comprised of numerous fibres which originate from the basisternum, as well as, along its median ridge. Running parallel, the fibres take up an arched course to get inserted by a broad base on the outer edge of the anterior half of coxal rim. It can be compared with the 'second promotor of coxa' of S.deesae, the 'mesal promotor of the forecoxa' of the honey bee and the 'sternal rotator of the fore coxa' of the wasp.

First remotor of the procoxa (No.45). — This muscle originates as two bundles on the protergal lobe flanking the origin of the 'elevator of the propleuron'. The two bundles take up a ventrally directed convergent course to end by single bundle on the outer edge of the posterior half of coxal rim, close to

its pleural articulation. It is similar to the 'first remotor of coxa' in S.deesae and to the 'first lateral remotor of the forecoxa' in the honey bee. Duncan (1939) in wasp has labelled it as 'pronotal adductor of the forecoxa' which normally should mean that it brings the leg forward and towards the body, through its action.

Second remotor of the procoxa (No.46). — This muscle arises from the distal half of sternal apophysis. While descending it takes an outwardly directed course to end on the outer edge of the posterior half of coxal rim, at a place slightly removed from the point of insertion of 'first remotor of coxa'. This corresponds to the 'second remotor of coxa' in S.deesae, to the 'second lateral remotor of the forecoxa' in the honey bee. Duncan (1939) calls it 'rotator' in the wasp.

Third remotor of the procoxa (No.47). — The fibres of this muscle originate on the mesal face of the basal half of pleural apophysis and descend through mesally directed course to end on the coxal rim, in line with its sternal articulation. It is represented in the honey bee by the 'mesal remotor of the forecoxa' and in S.deesae by the 'third remotor of coxa' which is shown to arise from the horizontal apodeme.

Spinal retractor of the procoxa (No.48). — This is an intersegmental muscle arising on the lateral face of spina of

the spinastermum. The fibres of this muscle run obliquely forward to end by a short tendon on the inner edge of the posterior half of coxal rim, in between the point of insertion of the 'first remotor of coxa' and the pleural articulation. This muscle is an addition to the myology of the prothorax of Hymenoptera.

Anterior levator of the protrochanter (No.49). — The fibres of this muscle arising from the lateral portion of the anterior wall of coxa, converge to end on the dorsal half of the proximal rim of trochanter, close to its anterior articulation. It is represented by 'anterior levator of trochanter' of S. geesae and by 'anterior levator of the foretrochanter' of the honey bee.

Posterior levator of the protrochanter (No.50). — This muscle originates from the lateral portion of the posterior wall of coxa. Its fibres converge to end on dorsal half of the proximal rim of trochanter, close to its posterior articulation. The 'posterior levator of the foretrochanter' in the honey bee are its equivalents.

Pleural depressor of the protrochanter (No.51). — The fibres of this muscle arise on the posterior half of the dorsal plate of propleuron. These converge while descending to end on a stout apodeme whose concave base fits over the semicircular crest of the ventral half of trochanteral proximal rim. It is

equivalent to the 'pleural depressor of trochanter' of S.deesae and to the 'thoracic depressor of the foretrochanter' of the honey bee. The latter is shown to arise on the pleural apophysis.

Coxal depressor of the protrochanter (No.52). — This muscle consists of two thick bundles originating on the mesal portion of the anterior wall of coxa. These are inserted on the lateral surfaces of the apodeme of 'pleural depressor of the trochanter'. As the two components have common origin, insertion and function, it would be desirable to consider them as two bundles of the same muscle. It corresponds to the 'coxal depressor of the trochanter' in S.deesae and to the 'coxal depressor of the foretrochanter' in the honey bee.

Profemoral reductor (No.53). — The fibres of the 'femoral reductor' arises on the proximal half of the ventral wall of trochanter including its rim. These take up a convergent course to end on the ventral half of the proximal rim of femur. Its equivalent in the honey bee is the 'reductor of the forefemur' and in S.deesae, the 'femoral reductor' which is shown to consists of parallel fibres.

Extensor of the protibia (No.54). — The 'extensor of tibia' is of typical pinnate type with fibres arising all along the dorsal wall of femur. The long apodeme of this muscle flattens out into a broad plate which rests on the median process (TbP)



of the dorsal half of the proximal rim of tibia. The 'extensor of tibia' in S.deesae and the 'extensor of the foretibia' in the honey bee are similar to it.

Depressor of the protibia (No.55). — This is also a pinnate muscle with fibres arising on the entire ventral wall of femur. The fibres are inserted on a long apodeme with a distinct subtriangular sclerotic genoflexor (gf). The latter is connected with the middle of the ventral half of the proximal rim of tibia. It is equivalent to the 'main depressor of tibia' in S.deesae and to the 'flexor of the foretibia' in the honey bee. Alam (1951) has shown additional muscles in the form of 'accessory depressors of tibia'. These muscles are not traceable in A.proxima, nor Snodgrass (1956) has so far recorded them in the honey bee.

Productor of the protarsus (No.56). — This muscle arises in the distal half of the anterior wall of tibia. Its fibres converge to end on the dorsal half of the proximal rim of basitarsus, slightly anterior to the tibiotarsal articulation. It is represented by the 'productor of tarsus' in S.deesae and by the 'productor of the foretarsus' in the honey bee.

Reductor of the protarsus (No.57). — It arises in the distal half of the posterior wall of tibia. Its fibres converge on a tendon which is inserted on the dorsal half of the proximal rim

of basitarsus, slightly posterior to the tibiotalar articulation. Similar muscles have also been shown in S. deessa and the honey bee.

Depressor of the protarsus (No.58). — The fibres of this muscle originate on the ventral wall of the distal portion of tibia. These converge to end on the ventral half of the proximal rim of basitarsus, directly apposite to the tibiotalar articulation. The 'depressor of tarsus' in S. deessa and the depressor of the foretarsus' in the honey bee are analogous to it.

Flexor of the claws (No.59). — This muscle arises from the ventral half of the proximal rim of femur. Its fibres converge to form a long tendon, which, passing through the distal half of the femur, also runs across the lumina of tibia and tarsus to end on the pretarsus. In the middle of the tibial wall it receives the tendon of a short muscle which may be taken as 'accessory flexor of the claws' (No.59a). The long tendon of the 'flexor' ultimately flattens out into an apodeme to end on the unguis plate. The 'flexor of claws' is similar to what have been described in S. deessa and the honey bee. In the latter, too, one bundle of muscle fibres is shown to have been contributed by tibia; though in S. deessa two such independent tibial bundles have been recorded. The basitarsal muscle, as shown in the honey bee, is absent in A. proxima.

(vii) Structure of the Mesothorax (Figs. 31,32,33,58,59,60  
61 & 62).

The mesothorax, bearing the second pair of legs and the first pair of wings, occupy the major portion of the pterothorax. The sclerotic components of the mesothorax have developed internal ridges which enable the segment to withstand the pressure brought upon it by the activities of the muscles.

Mesotergum (mesonotum) (N2). — The dorsal plate of the mesothorax is a large arched plate divisible into alinotum (AN2) and postnotum (PN2). The dominating alinotum is posteriorly separated from the narrow postnotum by the intervention of a thin intersegmental conjunctiva.

Alinotum (AN2). — The semicircular anterior margin of the alinotum abuts against the posterior margin of the protergum. The lateral margins lie close to the dorsal margins of the mesopectus. For the major portion, the alinotum is convex excepting the posterolateral areas which possess a pair of broad depressions. From the middle of the anterior margin of alinotum, obliquely suspends the prephragma (lPh). The latter is extremely narrow on sides and fairly broad in the middle where a notch is present as a passage for the dorsal aorta. In S.deesae, this notch is in the form of a slit that completely divides the prephragma into two halves. In the honey bee, the prephragma is crescent-shaped.

Prescutum (Prsc). — The prescutal suture (ts), running almost submarginal to the entire anterior margin and partly to the lateral margins of the alinotum, demarcates an anterolateral narrow 'prescutum' (Prsc). This suture near the base of the tegula (Tg) takes an inward directed course and later on turns outwards to merge with the lateral margins of the alinotum. This change in the course of the suture enables the prescutum to undergo posterolateral expansions which bear the base of the round flap like tegulae. Such prescutal origin of the tegulae confirms the view of Alam (1951) in Sadeesae. Further, his comments on the works of Snodgrass and Duncan on the location of tegulae are also endorsed. No prescutum has been reported in the honey bee or the wasp.

Scutum (Sct). — The 'V' shaped scutoscutellar suture (vs) is prominent and divides the alinotum into scutum (Sct) and scutellum (Scl). It is internally represented by strong notal ridge (VR). The lateral portions of the suture run close to and along a portion of the posterior margin of the alinotum while its middle portion is arched and directed forward.

The scutum is the largest plate of the mesonotum and is greatly responsible for the arched condition of the thoracic dorsum. Posteriorly it extends beyond the median portion of the scutellum, flanking it in the form of broad depressions. The depressions are shaped in such a manner so as to lodge

the anal lobes of the forewings, during repose. The present writer names them as 'anal pouches of the scutum'. There is no transscutal suture or fissure as has been reported by Alam (1951) in S.deesae. The lateral margins of the scutum (practically almost of entire alinotum) are not straight and bear a pair of short incomplete clefts (Scclcf) filled with conjunctiva. These combiningly become a substitute for the transcutal fissure which is a prominent feature of clistogastrous Hymenoptera. Since these do not tend to meet to form a continuous transverse fissure, nor are these connected by any suture, it would not be proper to consider them as forerunners of the transcutal fissure which is obviously wanting in A.proxima.

From the anterolateral angles of the scutum, extends a pair of short obliquely directed grooves which may be taken as incomplete 'parapsidal sutures' (ps). These are internally represented by 'parapsidal ridges' (PR). The parapsidal sutures incompletely divide the scutum into an anterior median plate and two lateroposterior plates. The latter may be referred as incomplete parapsides (Par). The parapsidal sutures are present in S.deesae, extending upto the trans-scutal fissure. In the wasp, these are also present but their anterior portions are obscured. The honey bee does not possess parapsidal suture. The anteromedian portion of the scutum is traversed by a suture, running in anteroposterior direction and dividing it into two equal halves. This is the incomplete 'median suture' (ms) with an internal ridge.

Immediately behind the scutal clefts, the lateral margins of the scutum develop a pair of slender 'anterior notal processes' (ANP) which articulate with the 'first axillary sclerites' of the forewings. There are no traces of 'prealar bridge'. There are also no distinct 'posterior notal processes', and the third axillary sclerites articulate with the alinotal margins through the intervening 'fourth axillary sclerites'.

Scutellum (Sc1). — The scutellum is the posterior most subdivision of the alinotum and is distinctly demarcated from the scutum by the scutoscutellar suture. Due to the anterior arching of the suture, the middle portion of the scutellum has encroached over the scutum. This extended portion is diamond-shaped and distinct from the remaining portion of the scutellum which is a narrow sclerotic plate. These two portions are also demarcated by a secondary furrow which is internally marked by a ridge and may be called as 'transcutellar furrow' (Sc1f). The thick posterior margin of the scutellum is straight except in the middle where it is distinctly convex to run over the median portion of the postnotum (PN2).

Postnotum (PN2). — The postnotum is in the form of an independent, intersegmental narrow sclerotic plate, separated from the mesoalinotum (AN2), as well as, from metanotum by complete membranous conjunctiva. Its straight anterior margin is almost smooth except in the middle where it is prominently

notched through which passes the apodeme of the 'auxillary elevators of the forewing'. The posterior margin is comparatively thickened to bear the internal mesopostphragma (2Ph). This condition is very close to the most primitive nature of the postnotum and thus supports the contention that the Tenthredinidae is primitive among the Hymenoptera. The postnotum is shown to be absent in S. deesae, the wasp and the honey bee. Laterally, the postnotum unobtrusively merges with the posterodorsal portion of the mesoepimeron. Such distinct communication between the postnotum and mesopleuron are also shown to occur in Pteronoidea ribesii and Cimbex by Snodgrass, 1942 (Fig. 20 G and H). However, in higher forms such continuation between the postnotum and mesopleuron is wanting due to the absence of the postnotum. In S. deesae, the 'anterior lamella of mesopostphragma' is in direct connection with the dorsal margin of the epimeron, probably because of the absence of a distinct postnotum. Similarly in the honey bee, the absence of the postnotum has enabled the mesopostphragma to develop direct contact with the epimeron, whereas, in the wasp, an intervening sclerite incompletely separated from the ramus of the phragma and lying beneath the subalare, puts the phragma in communication with the epimeron. The posterior margin of the postnotum is, more-or-less, like the anterior margin and is separated from the anterior margin of metanotum through a broad strip of conjunctiva.

Mesopostphragma (2Ph). — The posterior margin of the postnotum internally forms the extensive 'mesopostphragma'. It can be said that the postnotum with mesopostphragma is interteregal plate lying between the meso-alinotum and metanotum and maintains its separate identity by refusing to merge with either. This condition is different from what have been reported in higher Hymenoptera (Alam 1951, Snodgrass 1956, and Duncan 1939) and is a convincing proof of the fact that the family Tenthredinidae belongs to the generalized group of Hymenoptera. The mesopostphragma consists of a median and two lateral lobes. The 'V' shaped median lobe (2PhML) is outstandingly large. Its broad proximal margin is in communication with the antecostal suture (acs) while the narrow distal tip is deeply notched to become lobose. This notch is connected with the middle of the anterior margin of the phragma by a midlongitudinal ridge (2PhMR), running on its under surface. Its lateral margins are followed by similar submarginal ridges (2PhLR) which also run on the under surface. The entire concave undersurface of the median lobe offers adequate anchorage to the fibres of the dorsal longitudinal muscles of flight. The small lateral lobes (2PhLl) flank the basal portion of the median lobe. Snodgrass (1942) shows similar lobes in sirex and ciabex and names them as 'muscle bearing processes of second phragma'. These can also be compared with the 'anterior lamellae' of the mesopostphragma of S. deesae.



Mesopectus (P1S2). — In A.proxima, the ventrolateral regions of the mesothorax form one continuous plate called 'mesopectus'. There are no external indications to demarcate the pleuron from the sternum. It is only on account of muscle attachments that their limitations can be visualized. The fibres of dorsoventral muscles of flight, which connect the sternum with the tergum in insects, are attached to the ventral parts of the mesopectus of A.proxima. This area, therefore, can be considered as mesostrenum (S2). The remaining portion of the mesopectus lateral to the sternum and forming the sides of the mesothorax becomes the mesopleuron (P12). Ventrally, the mesopectal areas are limited by the intervention of the median sternal groove (msg).

The anterior margin of the mesopectus in the region of the basalare is not straight. This modification occurs to accommodate the 'spiracular plate' (sppl) and the 'occluser plate' (Opl) of the protergum. The spiracular plate is fused with the apodeme of the basalare (BaAp). Below the 'occluser plate' the pleural margin is extended into a blunt process which abuts against the similarly extended portion of the protergum. Beyond this process, the margin is smooth and is ventrally continuous with its counterpart of the other side. The anterior margin of the mesopectus is followed by a submarginal prepectal suture (Pcts) which is internally represented by a ridge. This suture starts from the base of the protergal

process of the mesopectus and ends mesally by merging with the anterior tip of the median sternal groove. Its submarginal nature anteriorly demarcates a narrow strip from the remaining mesopectus which can be taken as 'mesoprepectus' (PCT). In S. deesae, the mesoprepectus is shown as a small triangular plate.

The dorsal margin of the mesopectus lies between the pleural wing process (WP) and the epimeropostnotal bridge (EPmPN2B). This margin, on leaving the pleural wing process descends along a semicircular course and before ending with the epimeropostnotal bridge, it develops a small blunt process which brings the pleuron in communication with the alinotum. On account of the posterior position of this process in respect to the wing base, it can be taken as the incomplete 'postalar bridge' (Pa). The post alar bridge is absent in the wasp, honey bee and S. deesae. All along, this margin has undergone distinct inflection in the form of a narrow sclerotic shelf. In the vicinity of the postalar bridge, the marginal inflection expands into a wide plate which accommodates the second thoracic spiracle (2Sp). This plate is comparable with the 'spiracular lobe of second thoracic spiracle' of S. deesae.

The posterior margin of the mesopectus is convex. Dorsally it is in continuation with the posterior margin of the mesopostnotum instead of being in continuity with the dorsal margin of the mesopectus. Ventrally, the margin termi-

nates at the posterior extremity of the median sternal groove. The portion of the posterior margin close to the median sternal groove forms anterior sclerotic limit of the incompletely sclerotized mesocoxal socket (CxS).

The anterodorsal angle of the mesopectus is drawn out into a prominent pleural wing process (WP). The posterior margin of the mesopectus is produced as 'articular knob of coxa' (CxLark) which provides pleural articulation to the middle coxa. From this articular knob starts a suture which, ascending obliquely runs across the pleuron to terminate at the pleural wing process. This is the typical 'pleural suture' (pls) with a distinct pleural ridge (PlR). The dorsal half of the pleural ridge is broadened to form a deep pocket where the fibres of the 'flexors of the forewing' originate. Somewhere in the middle of the pleural suture and near the base of the pocket, lies the 'pleural pit' (Pla). This internally bears well developed pleural apophysis (PLA). The basal portion of the posteriorly directed apophysis is slender but the apical portion is flattened. The pleural suture divides the pleural plate into an extensive episternum (Eps) and smaller epimeron (Epm). The episternum which is anteroventral to the pleural suture, starts dorsally as an extremely narrow plate and gradually broadens to include the major portion of the mesothoracic pleuron. Ventrally it merges with the sternum. Its long anterior margin is the anterior margin of the mesopectus while its comparatively

shorter posterior margin forms anterolateral portion of the rim of mesocoxal socket. The epimeron is a small triangular plate lying dorsoposterior to the episternum.

Mesoendosternum (Endst). — The median sternal groove (msg) is anteriorly limited by the prepectal suture (pets) and posteriorly its lateral crests culminate into two strongly built condyles or knobs which provide sternal (ventral) articulation (CxVArk) to the mesocoxae. This groove is internally represented by distinct 'median sternal ridge' (MSR) which is broadest in its posterior half. The posterior face of the ridge is slightly flattened to fuse with the anterior face of the stem of the mesoendosternum. The mesoendosternum stands as a 'Y'-shaped structure in the thorax with its root in the furcal pit. This unpaired pit lies in between the sternal articular knobs of coxae and forms the posterior end of the median sternal ridge. The stem of the endosternum on leaving the median sternal ridge apically bifurcates into long divergent furcal arms (FA). The furcal arms distally taper with their flattened outer surfaces, and communicate with the pleural apophyses through tufts of short muscle fibres. The furcal arms in the middle develop small mesally directed lobes (Fl) which can be compared with the 'lobes of the mesofurcal bridge' of S. deaseae, though unlike the latter there is no elaborate mesofurcal bridge. This homologie seems all the more reasonable since the nerve cord is incompletely limited dorsally by these two lobes of the furcal arms.

(viii) Musculature of the Forewing (Figs.59,63,64,65,66 & 67).

Indirect and principal depressor of the forewing (No.60). —

This is the dorsal longitudinal muscle which is longest among all the muscles of the body. The fibres run obliquely across the mesothorax between the extensive concave surface of mesopostphragma and the anterior region of the alinotum (entire mesoprephragma, median portion of prescutum and anterior half of scutum). The two components of this muscle are hardly separable. The contraction of this muscle cause distinct arching of the mesotergum and consequently depresses the forewings.

Indirect and principal elevator of the forewings (No.61). —

This stout muscle is vertically placed in the mesothorax with its lower end attached to the undifferentiated sternum, close to the median sternal ridge. The fibres running abliquely upwards end on the parapsides. On contraction it pulls the tergum downwards which consequently elevates the forewings.

Secondary indirect elevator of the forewing (No.62). —

This muscle is composed of parallel fibres which running obliquely in anteroposterior direction connects the scutai portion, lying close to the apex of the scutellum, with the lateral portion of the mesopostnotum. The contraction of this muscle will cause incomplete depression of the alinotum which will amount to consequential raising of the wing. Accordingly,

it is suggested to regard it as 'secondary indirect elevator of the forewing'. This muscle is represented in Agulla adnixa (Matsuda 1956) but is absent in the honey bee, wasp and S.deesae. The 'dorsal ablique muscle' occurring in Diptera and some Homoptera (Snodgrass 1935) may be similar to it.

Secondary indirect depressor of the forewing (No.63). —

The fibres of this muscle arise from the dorsal surface of the middle portion of furcal arm. These, running abliquely in ventrodorsal direction, end along the outer margin of the lateral lobe of mesopostphragma. On contraction, it assists in depressing the wing. Alan (1951), in S.deesae, takes it as 'secondary indirect depressor of the forewing' while in the honey bee, Snodgrass (1942) calls it as 'muscle of the axillary lever'. Duncan (1939) describes a similar muscle as 'furcal retractor of mesopostphragma'. The present writer thinks that this feeble muscle can hardly act alone against the strong 'indirect and principal depressor of the forewing' by retracting the mesopostphragma unless it supports some other larger muscle. More over, its course further justifies its accessory role to the 'indirect and principal depressor'. This muscle also occurs in Agulla adnixa but Matsuda (1956) assigns no function to it.

Principal extensor of the forewing (No.64). — This is a large muscle with fibres arising from the ventral half of the episternum, lateral to the 'indirect and principal elevator of

the forewing'. Running upwards, its fibres converge to end on the undersurface of the apodemal plate of the basalare. On contraction, it pulls the anterior half of the basalare downwards, and consequently the tip of the latter working on the humeral plate, causes the extension of the forewing. A similar muscle has been reported in S.deesae. In the honey bee and the wasp, it is called 'basalare muscle of the mesothorax'. There, too, it is considered to cause extension of the forewing.

Secondary extensor of the forewing (No.65). — This inter-segmental muscle is quite feeble and short. The fibres arising on the pronotal peg, which also gives rise to the fibres of 'oculosar muscle' of the first thoracic spiracle, converge on the edge of the basalare apodeme. On contraction, it assists the 'principal extensor of the forewing'. This is equivalent to the 'secondary extensor of forewing' in S.deesae. The present writer agrees with Alam (1951) in assigning it the function of extension of forewing. In the honey bee and the wasp, it remains unrepresented.

First flexor of the forewing (No.66). — This muscle arises from the ventral half of the pocket of the pleural ridge. Running obliquely in ventrodorsal direction, it ends on the ventral face of the third axillary sclerite.

Second flexor of the forewing (No.67). — This muscle also arises in the pocket of the pleural ridge but from its dorsal half. The fibres running anteroposteriorly end on the ventral face of the third axillary sclerite, slightly lateral to the insertion of the 'first flexor of the forewing'.

Both the 'flexors', on contraction, cause a shift in the position of the third axillary sclerite which consequently flexes the forewing.

Third flexor of the forewing (No.68). — This is a spindle-shaped muscle with long tendons at both the ends. The lower tendon ends on the posterior half of the coxal rim, close to the pleural articulation, while the other ends on the subalare which in turn is in communication with the second axillary sclerite. In S.deesae (Alam, 1951), it is considered as 'flexor of the forewing' while in the honey bee (Snodgrass, 1942), it is described as 'coxal remotor', as well as, 'flexor' of the forewing. The present writer thinks that in all probability it should act more as 'flexor of the forewing' rather than 'remotor of the coxa' especially when its contraction definitely influences the second axillary sclerite.

Auxillary elevator of the forewing (No.69). — The fibres of this muscle are anteriorly attached to the posterior surface of the anterolateral portion of the notal ridge. Posteriorly,



these converge on a tendon. The tendons of the two muscles unite to form a stout common tendon which running still posteriorly ends in the median notch of the anterior margin of metanotum. The fact that the metatergal attachment of this muscle is distinctly at a lower level than its mesotergal attachment, it is clear that on contraction, this <sup>muscle</sup> will assist the mesotergum to return to its normal position. This may be taken as a prelude to the activity of the 'elevator of the forewing'. Similar function has been attributed to this muscle in the wasp and S.deesae.

Retractor of the mesopostphragma (No.70). — This is a broad and short muscle with its fibres originating on the anterior surface of the mesal lobe of prephragma of propodeum. The parallel fibres running forward across the metanotum are inserted on the dorsal surface of the median lobe of mesopostphragma. The contraction of this muscle is supposed to check the probable displacement of the mesopostphragma which is likely to happen by the action of 'indirect and principal depressor of the forewing'. In other words, the displaced mesopostphragma is helped in regaining its normal position.

Depressor of the tegula (No.71). — The fibres of this tiny muscle arise on the anterior margin of the prescutum, close to the anterior end of the parapsidal furrow and running backwards, these end in the middle of the tegular base. Functionally, it

appears to be responsible to depress the tegula. In the wasp, Duncan (1939) has described a similar muscle.

First furcopleural muscle (No.72). — This muscle, consisting of parallel fibres, connects the dorsal surface of the apex of furcal arm with the mesopleural apophysis and the neighbouring portion of the epimeron. It is comparable to the 'mesothoracic furcopleural muscle' of S.deesae, and to the 'mesothoracic furcopleural muscle' of the wasp.

Second furcopleural muscle (No.73). — The fibres of this muscle are attached in the middle of the ventral surface of the furcal arm. These fibres, running downwards, converge to end by a tendon on the pleural ridge, close to the coxal articulation. This muscle is comparable to the 'mesothoracic furcopleural muscle' and ligament of the wasp.

These two muscles, working simultaneously, do not allow the mesofurcal arms to undergo distortion as a result of contraction of the 'secondary indirect depressor of the forewing' and the 'mesofurcal extensor of the hindwing'.

Tergoapophysial muscle (No.74). — This muscle consists of vertically running parallel fibres connecting the posterior half of the lateral margin of the scutum with the pleural apophysis. It appears to check the displacement of the pleural apophysis from its normal position which may be caused by the

contraction of the 'first furcopleural muscle'.

Intersternal muscle between meso and metaendosternum (No.75).—

This muscle consists of parallel fibres, which are anteriorly attached to the posterior surface of the proximal half of mesofurcal arm and posteriorly end in the middle of the anterior surface of metafurcal arm. Due to its horizontal course, this muscle affects meso- and metafurcal arms equally by keeping them in normal position during the activities of other muscles associated with them.

(ix) Structure of the Mesothoracic Legs (Figs. 41,67,68,69,70 71).

The mesothoracic legs resemble the prothoracic legs in every detail except the size which is larger. The coxal and trochanteral muscles are as follows:

Lateral promotor of the mesocoxa (No.76). — The fibres originate from the pleural ridge near the base of the pleural apophysis. These converge on a long tendon which is inserted on the anterior half of the proximal rim of coxa, close to its pleural articulation. This is equivalent to the 'lateral promotor of the middle coxa' of the honey bee and S.deesae.

Mesal promotor of the mesocoxa (No.77). — This is short but broad muscle with fibres arising from the median sternal ridge and running parallel these are inserted by a broad base on the

inner margin of the anterior half of the coxal rim. This is similar to the 'mesal promotor of the middle coxa' of S.deesae and of the honey bee. Duncan, however, in the wasp has labelled it as 'productor of the middle coxa'.

Mesal remotor of the mesocoxa (No.78). — The parallel fibres of this muscle originate from the median sternal ridge, at a level lower to the origin of the 'mesal promotor of the mesocoxa' and end on the posterior half of the coxal rim, close to the sternal articulation. This muscle is comparable with the 'remotor of the middle coxa' of S.deesae, as well as, with the 'mesal remotor of the middle coxa' of the honey bee and the 'inner reductor of the middle coxa' of the wasp.

Lateral remotor of the mesocoxa (No.79). — This muscle arises from the posterior surface of the proximal half of furcal arm and running obliquely in dorsoventral direction, it ends on the posterior half of the coxal rim, lateral to the 'mesal remotor of the mesocoxa'. This is equivalent to the 'outer reductor of the middle coxa' in the wasp.

Pleural depressor of the mesotrochanter (No.80). — It is a prominent muscle of the trochanter, whose fibres arise from the middle of the epimeron. Running vertically downwards, it passes through the coxa to converge on an apodeme which is connected with the elevated central portion of the ventral half

of the proximal rim of trochanter. Similar muscle in the honey bee, wasp and S.deesae are shown to arise on the endosternum, instead of the epimeron.

Coxal depressor of the mesotrochanter (No.81). — This muscle consists of two bundles of fibres originating within the coxa. One of the bundles starts from the mesal wall while the other, from the mesal half of the anterior wall of coxa. The fibres of these bundles are inserted on the corresponding sides of the apodeme of the 'pleural depressor of the mesotrochanter'. In S.deesae, three bundles of fibres are shown to have comprised the 'coxal depressor of the trochanter'.

The remaining intrinsic muscles of the mesothoracic legs are identical to those described already in the prothoracic legs.

(x) Structure of the Metathorax (Figs. 31,32,33,72 & 73).

The metathorax is reduced and forms the second wing bearing segment of the thorax. It has a distinct dorsal plate, but its pleural and sternal areas are fused to form the metapectus.

Metatergum (metanotum) (N3). — The metanotum is a narrow plate placed transversely inbetween the mesopostnotum (PN2) and the propodeum (II). Like the mesonotum, the metanotum is also

subdivided into an anterior segmental alinotum (AN3) and posterior intersegmental postnotum (PN3). These two subdivisions of the metanotum are separated by a narrow strip of membrane which justifies their identification.

Alinotum (AN3). — The alinotum is a reduced transverse plate constricted in the middle and broad laterally. This modification is due to the deep concave nature of its anterior margin which is notched in the middle. The anterior margin is extraordinarily thickened on account of a marginal inflection (AmR) whose lateral portions are comparatively broader. Further, it bears a pair of rounded pad-like 'cenchri' (Cn) in its lateral halves. The posterior margin of the alinotum is almost straight except in the middle where it is slightly convex. This margin, too, like the anterior margin is prominently thickened (PmR). Laterally the thickened posterior margin is extended, beyond the lateral limit of the alinotum, in the form of a short stumpy process which articulates with the third axillary sclerite of the hindwing and may be regarded as the posterior notal process (PNP). The lateral margin of the alinotum is wavy. Immediately behind the anterolateral angle of the alinotum, the lateral margin is produced into an anterolaterally directed process which articulates with the first axillary sclerite of the hindwing. This forms the 'anterior notal process' (ANP).

The alinotum bears a short and thick semicircular internal ridge (aR) with its two ends lying on the middle portion of

the posterior marginal thickening. The middle of the ridge almost joins the anterior margin in the region of the median notch. The plate of the alinotum is depressed in its lateral half to accommodate the anal lobe of the hindwing while in repose. This lateral depression may be taken as 'anal pouch of the hindwing'. It is shallower than the 'anal pouch of the forewing'.

Metapostnotum (PN3). — The true intersegmental metapostnotum is a narrow plate lying inbetween the alinotum and the propodeum. Its almost straight anterior margin is separated from the posterior margin of the alinotum by a narrow strip of membrane, while its posterior margin is soldered with the propodeal anterior margin. This fusion is maintained along the antecostal suture (acs) which is internally represented by a broad antecosta. This is taken for 'prephragma of propodeum' (3Ph) as suggested by Alam (1951) in S.deesae. Laterally the metapostnotum extends to merge with the metaepimeron.

Metapectus (PLS3). — Like the mesothorax, the sternum and pleura of the metathorax are also fused to form the composite metapectus. The line of fusion of these two areas is absent, though in S.deesae, Alam (1951) shows the presence of sternopleural suture. The metapectus is in sclerotic continuity with the metapostnotum through narrow metaepimeropostnotal bridge (EpmPN3B). Save this, the metapectus is in <sup>membranous</sup> connection

with nearby lying parts of the thorax. Here, again, A. proxima differs from S. deesae, the wasp and the honey bee where metapleura are shown to be in sclerotic contiguity with the propodeum as well as with the mesopectus. This may be taken to justify the primitive nature of Tenthredinidae (chalastogastra) as compared to Braconidae, Vespidae and Apidae (Clistogastra). The ventral portion of the metapectus is regarded as the sternum (S3) while its lateral area as the pleuron (Pl3) of the metathorax.

The anterior margin of the metapectus descends from its anterodorsal angle along, more or less, smooth course and runs almost parallel to the posterior margin of the mesopectus, separated from it by intersegmental membrane. Ventrally it ends at the anterior extremity of the median sternal groove (msg). The dorsal margin of the metapectus starts from the anterodorsal angle along a concave course and is separated from the metanotum by the extensive membranous wing base. Its posterior end in association with the dorsal end of the posterior margin, forms the sclerotic 'metaepimeropostnotal bridge'. All along, the dorsal margin possesses a distinct marginal inflection. The posterior margin of the metapectus extending from the 'metaepimeropostnotal bridge' to the pleural articulation of the metacoxa (CxLark) is distinctly convex, while its portion forming the anterior boundary of the incompletely sclerotised metacoxal socket is slightly concave. The posterior margin is ventrally limited by the sternal articulation of metacoxa (CxVark).



The anterodorsal angle of the metapectus is drawn out into a thickly impregnated 'pleural wing process' (WP). The convex portion of the posterior margin ventrally develops the 'pleural articular knob' of metacoxa. The latter is connected with the pleural wing process by the metapleural suture (pls) which runs diagonally across the metapleuron. This suture internally develops the pleural ridge (PlR). In its dorsal half, the pleural ridge is more prominently elevated to form a pleural pocket which opens posterodorsally and serves as an area for the origin of the 'flexor muscles of the hindwing'. Immediately below the pleural pocket, the pleural suture bears the pleural pit (pla) which internally gives rise to the posteriorly directed pleural apophysis (PLA).

The pleural suture divides the metapleuron into a large metaepisternum (Eps) and comparatively smaller metaepimeron (Epm). The episternum lies anteroventral to the pleural suture. The ventral portion of the episternum is wide but dorsally it is narrowed on account of close proximity of the pleural suture with the anterior margin of the metapectus. In the ventral portion, the episternum is traversed by the 'transepisternal suture' (tes) which is internally represented by a distinct ridge. This suture divides the episternum into anteriorly placed 'anepisternum' (AEps) and the posterior 'katepisternum' (KEps). The anepisternum is an elongated narrow plate tapering at both the ends. The katepisternum is, more or less, rectangular in shape with its posterior margin forming the anterior

sclerotic boundary of the incompletely sclerotized metacoxal socket. The epimeron lies posterodorsal to the pleural suture and is somewhat rectangular in outline. Its dorsoposterior angle forms the 'metaepimeropostnotal bridge'.

Metaendosternum (Endst). — The median sternal groove traverses the metapectus midlongitudinally. In the posterior half it becomes wider and its two lateral crests taking up divergent course end at the sternal articular knobs of the metacoxa (CxVark). This groove is internally represented by the median sternal ridge (MSR), which is broader in its anterior half. It is here that the ridge abuts against the stem of the metaendosternum. Accordingly, it is in the anterior half of the median sternal groove that the furcal pit can be visualized to occur as the point of invagination for the metaendosternum. The metaendosternum, which consists of a stem and two furcal arms, is altogether free from the mesoendosternum like S.deesae and contrary to what occurs in the honey bee. The endosternal stem is quite short and distally bifurcates into sword-shaped furcal arms (FA). Each furcal arm extends towards the corresponding pleural apophysis with which it is associated through a set of muscle fibres unlike S.deesae where the two are loosely united or the wasp where the two are distinctly fused.

Propodeum (II). — The sclerotized dorsal portion of the propodeum represents the segmental tergal plate (first abdominal

tergum of the generalized insect). The ventrolateral areas are membranous. Its entire straight anterior margin is completely fused with the posterior margin of the metapostnotum. This fusion is externally represented by a groove which is regarded as the antecostal suture (acs) of the generalized insect, as it internally develops a prominent inflection, 'the prephragma of the propodeum' (3Ph). More or less similar 'prephragma of propodeum' is shown to occur in S. deessa and the wasp. The lateral margins of propodeal tergum are almost straight and free from sclerotic contiguity with the metapleura. This condition is contrary to what has been reported in S. deessa the wasp and the honey bee. The propodeal spiracle (3sp) is located on the propodeal tergum close to its anterolateral angle. Posteriorly, the propodeal tergum incompletely overlaps the abdominal tergum. The posterior margin of the propodeal tergum possesses a median cleft (Mclf) which roughly divides the tergum into two lateral plates. Besides, it is in conjunctival connection with the entire anterior margin of the second abdominal tergum.

(xi) Musculature of the Hindwings (Figs. 66, 74, 75 & 76).

Median dorsal longitudinal muscle (No. 82). — This muscle consists of stout bundles of fibres extending between the anterior face of the mesal half of propodeal prephragma and the anterior marginal inflection of the metanotum. It is

analogous to the 'indirect and principal depressor of the forewing'. In this case the metaalinetum is so reduced in size with thick ridges that its arching as a result of contraction of this muscle is not possible. However, it can be considered to counter the action of the 'auxillary elevator of the forewing' so that the metanotum may remain unaffected. This muscle is absent in clistogastrous insects (wasp, honey bee and S. deesae), but is of regular occurrence in orthopteroid insects. Accordingly the primitive nature of Tenthredinidae in the Hymenoptera on the basis of the retention of this muscle can be supported.

Lateral dorsal longitudinal muscle (No.83). — The fibres of this muscle running obliquely, connect the anterior face of the outer half of propodeal prephragma with the anterior marginal inflection of metaalinetum, lateral to the 'median longitudinal muscle'. It assists the latter, functionally. This muscle, likewise, is wanting in clistogastrous Hymenoptera but is well represented in orthopteroid insects.

First elevator of the hindwing (No.84). — This is a long, vertically running muscle which connects the peglike structure in the lower half of the anterior margin of the episternum with the lateral half of the alinetum, mesal to the anterior notal process. This muscle indirectly acts on the first axillary sclerite whose change in position brings about elevation of the wing. This appears to be a new muscle in Hymenoptera.

Second elevator of the hindwing (No.85). — This muscle consists of parallel fibres which originate on the dorsal face of the distal half of furcal arm and are inserted laterally on the postnotum, slightly mesal to the 'metaepimeropostnotal bridge'. It assists the 'first elevator of the hindwing'. This muscle also appears to be a new muscle in Hymenoptera. It is shown to occur in Agulla adnixa (Matsuda 1956).

First flexor of the hindwing (No.86). — This is a spindle-shaped muscle connecting the posterior tip of the subalare sclerite with the anterior half of the coxal rim, close to its pleural articular concavity. The main function of this muscle is to flex the hindwing. Snodgrass, in the honey bee regards it as 'flexor of the hindwing' as well as 'remotor of the hindcoxa'. But in S.deesae Alam (1951) describes it as the 'flexor of the hindwing'.

Second flexor of the hindwing (No.87). — The fibres of this muscle arise on the ventral portion of the epimeron, slightly above the pleural ridge. Running vertically, these converge to end on the ventral surface of the subalare sclerite, anterior to the 'first flexor of the hindwing'. This muscle is represented in the honey bee as 'pleurosubalare muscle of the metathorax'; in the wasp as 'pleural muscle of the subalare' and in S.deesae as 'second subalare muscle of the metathorax'.

Third flexor of the hindwing (No.88). — This is a short muscle arising in the dorsal half of the pleural pocket. Its fibres converge to end on the third axillary sclerite.

Fourth flexor of the hindwing (No.89). — This muscle is feebler as compared to the 'third flexor of the hindwing'. Its fibres emerging from the ventral half of the pleural pocket, are inserted on the third axillary sclerite, mesal to the 'third flexor of the hindwing'.

In S.deesae also, two pairs of 'flexors of the hindwing' are shown to be inserted on the third axillary sclerite. In the honey bee, only one 'flexor muscle' is shown with three bundles. Further, the flexor muscle does not end directly on the third axillary sclerite, but acts on it through a small module. In the wasp, the third axillary muscle consists of two bundles which arising on the metapleural ridge end by a common tendon on the third axillary sclerite.

First extensor of the hindwing (No.90). — The fibres of this muscle originate from the lower portion of the anepisternum. These converge vertically to end on the ventral face of the basalare apodeme. It is equivalent to the 'extensor of the hindwing' in S.deesae and also to the 'basalare muscle of the metathorax' in the honey bee.

Second extensor of the hindwing (No.91). — This is an intersegmental muscle with fibres arising on the dorsal face of the middle of mesofurcal arm, close to the place of origin of the 'secondary indirect depressor of the forewing'. These running obliquely upwards converge to end on the ventral face of the basalar apodeme lateral to the insertion of the 'first extensor of the hindwing'. This muscle has not so far been reported in the Hymenoptera.

Third extensor of the hindwing (No.92). — This is another spindle-shaped muscle of the metathorax. Its one end is attached on the ventral face of the basalar apodeme, mesal to the 'first extensor of the hindwing', while the other end is attached on the anterior half of the coxal rim, in between the 'first flexor of the hindwing' and the 'promotor of the metacoxa'. This muscle though mainly acts as 'extensor of the hindwing' also appears to assist the 'promotor of the metacoxa'. This muscle is shown in Dissosteira carolina, by Snodgrass (1935) as 'second promotor - extensor of the hindwing'. There is no parallel of the 'third extensor of the hindwing' in the elictogastrous Hymenoptera. This confirms the primitive nature of the family Tenthredinidae.

Metathoracic furcopleural muscle (No.93). — This muscle is slenderer and longer than its counterpart in the mesothorax. Its parallel fibres arise on the dorsal surface of the distal

half of furcal arm and running obliquely upwards, end on the ventral surface of the pleural apophysis. This muscle does not allow any displacement of the furcal arm which is likely to occur, as a result of the action of the 'remotors of metacoxa'. This muscle has not so far been reported in the Hymenoptera.

Median propodeal elevator of the abdomen (No.94). — This intersegmental muscle arises on the posterior face of the mesal half of propodeal prephragma. Running obliquely backwards, its fibres are inserted on the anterior margin of the second abdominal tergum, slightly lateral to its middle. On contraction, this muscle raises the entire abdomen beyond the propodeum. It is functionally equivalent to the 'propodeal elevator of the abdomen' in the wasp; to the 'median elevator of abdomen' in the honey bee and to the 'first elevator of the abdomen' in S.deesae.

Lateral propodeal elevator of the abdomen (No.95). — The fibres of this muscle start on the posterior surface of the outer half of propodeal prephragma. Running backward, these end by spreading along the anterior margin of the second abdominal tergum very close to its anterolateral angle. On contraction this muscle should assist the 'median propodeal elevator of the abdomen'. Any side-ways swing of the abdomen can also be attributed to it. It corresponds to the 'dorsal lateromotor



of abdomen' in the honey bee and to the 'propodeal torsion muscle of the abdomen' in the wasp, as well as, in S. degeese.

Metathoracic depressor of the abdomen (No.96). — This is also an intersegmental muscle arising on the posterior surface of the middle portion of the metafurcal arm. Its parallel fibres running backwards end in the middle of the lateral half of the anterior margin of second abdominal sternum. It acts antagonistic to the 'propodeal elevator of the abdomen'. Functionally it may be taken similar to the 'metafurcal depressor of the abdomen', and to the 'median depressor of the abdomen', of the wasp and the honey bee, respectively. Further, it appears to have assumed the responsibility of the 'depressors of the abdomen' of S. degeese.

(xii) Structure of the Metathoracic Legs (Figs. 42, 77, 78, 79, 80 & 81).

The metathoracic legs structurally resemble the mesothoracic legs except that these are comparatively larger in size and better built. The myology, specially with reference to the intrinsic muscles, is identical to what has been recorded in the prothoracic legs. The extrinsic muscles are as follows:

Principal promotor of the metacoxa (No.97). — This muscle is quite broad. Its fibres arise mainly on the katepisternum excepting a few fibres which originate on the median sternal ridge. These running backwards and parallel, end almost all

along the anterior half of the coxal rim. On contraction, this muscle exerts a forward pull on the coxa. It is similar to the 'lateral producter of the hindcoxa' in S.deesae; to the 'pleural producter of the hindcoxa' in the wasp and to the 'mesal promotor of the hindcoxa' in the honey bee.

Mesal remotor of the metacoxa (No.98). — The fibres of this muscle originate on the posteroventral face of the proximal half of the furcal arm, close to its base. These running parallel and downwards, are inserted on the mesal portion of the posterior half of the coxa rim. This muscle on contraction pulls up the posterior half of the coxal base, with the result that the entire leg is swung backwards. It is represented in S.deesae as the 'mesal reductor of the hindcoxa', in the wasp as the 'reductor of the hindcoxa' and in the honey bee as the 'mesal remotor of the hindcoxa'.

Lateral remotor of the metacoxa (No.99). — The parallel fibres of this muscle arise on the ventral surface of the middle portion of the furcal arm, lateral to the origin of the 'mesal remotor of the metacoxa'. Running downwards, these end on the lateral portion of the posterior half of the coxal rim. This muscle works in conjunction with the 'mesal remotor of the metacoxa'. It is similar to the 'lateral reductor of the hindcoxa' described in S.deesae.

Secondary remotor of the metacoxa (No.100). — This tiny muscle is intersegmental. Its parallel fibres connect the lateral angular portion of the anterior margin of second abdominal sternum with the posterior half of the hind coxa, very close to its pleural articular concavity. Since the abdominal sternum is slightly at higher level than the coxal base, hence its contraction may assist the 'remotors of the metacoxa'. This muscle has not been shown to occur in the Hymenoptera.

Thoracic depressor of the metatrochanter (No.101). —

This is a long stout muscle composed of two bundles of fibres. The first bundle originates on the lateral half of the alinotum, lateral to the 'first levator of the hindwing', while the second bundle starts from the ventral surface of the middle portion of the furcal arm. These take up a convergent course and on entering the coxa unite into a single bundle which ends on the tip of the trochanteral apodeme. This, laterally, also gives insertion to two bundles of 'coxal depressor' (No.102). The apodeme, being in conjunctival connection with the conical central portion of the ventral half of the proximal rim of trochanter, transmits the action of the muscles to the trochanter. In the honey bee, the 'thoracic depressor of the hind-trochanter' consists of only one bundle of fibres of endosternal origin and thus is comparable to the second bundle of this muscle. The latter is also comparable to one of the two

bundles of the 'thoracic depressor of the hindtrochanter' in S. deesae, which originate on the endosternum.

(xiii) Thoracic Wings and their Sclerites (Figs. 82,83,84,85, 86 & 87).

The wings of A. proxima are smoky and translucent. These are held over the abdomen in repose. In the forewing, the large sized pterostigma (St) is quite prominent, and the anal margin is demarcated from the apical margin by a distinct anal notch (An). Almost the entire anal margin of the forewing is thrown into a distinct fold called 'frenal fold' (ff). The hindwing is smaller but more broad than the forewing. Each hindwing possesses a distinct costal margin which is almost straight and is devoid of pterostigma. It bears fourteen 'frenal hooks' (fh) in a row which anchor on the 'frenal fold' of the forewing. Thus the 'wing coupling apparatus' ensures simultaneous movement of both the wings during flight. The apical and anal margins of the hindwing cannot easily be demarcated except by the anal notch (An) which separates them.

Regions of the forewing (Fig. 84). — The forewing is differentiated into the usual wing regions demarcated by the folds. The remigium (Rm) is largest of all the regions and is limited between the anterior wing margin and the vannal fold (vf). It contains all the veins, from costa to the cubitus, including their crossveins. The vannal fold separates it from

the 'vannus' (Vn). The latter is limited between the vannal fold and the posterior wing margin-cum-jugal fold and contains the anal veins. The posterior wing region is the jugum (Ju) which lies between the jugal fold (jf) and proximal portion of the posterior wing margin.

Venation of the forewing (Fig. 82 & 83). — The venation of the forewing is fairly of 'generalized type. The thick costal vein (C) does not extend beyond the pterostigma. The radius (R), media (M) and cubitus<sub>1</sub> (Cul) arise from a common stem (R+M+Cul) at the wing base. From this common stem, the media-cum-cubitus<sub>1</sub> (M+Cul) later on separate as a single vein, leaving behind the radius which runs close and parallel to the costal vein. It divides into two branches slightly before reaching the pterostigma. The anterior branch becomes radius<sub>1</sub> (R<sub>1</sub>) while the posterior one is the radial sector (R<sub>s</sub>). The former (R<sub>1</sub>) runs through the pterostigma and on emerging from it take up a submarginal course to end by joining the radial sector. The latter takes up a wavy course and is connected with the radius<sub>1</sub> by two cross veins (1r & 2r) in the region of the pterostigma. The media and the cubitus<sub>1</sub> after adopting a common track for a considerable distance, fall out. The media running forward meets the radial sector. These two veins turn back in a confluent state (R<sub>s</sub>+M) up to a short distance. Then the media, once again regains its independent status and adopts a wavy course until it ends very close to the apical margin. It is

connected with the radial sector by cross veins (1r-m) and (3r-m). The cubitus<sub>1</sub>, on leaving the media-cum-cubitus<sub>1</sub> (M+Cu), runs along a posteriorly directed course to reach close to the anal notch where it divides into the fairly long Cula and the short Culb. The latter ends by joining the distal end of the first anal vein (1A). The other (Cula), on its way takes a slight bend to end close to the apical margin. There are two mediocubital cross veins. One (1m-cu) connects the media with the cubitus 1 while the other (2m-cu) joins the media with the Cula.

The first anal vein (1A) runs close and parallel to the vannal fold and terminates by meeting the culb. It is connected with the cubitus<sub>1</sub>, through the cubito-anal (cu-a) cross vein. The second anal vein (2A) forms a loop with its two ends joining the first anal vein. The third anal vein (3A) is very short and runs close and parallel to the basal half of the jugal fold. A cross vein (cv) connects it distally with the second anal vein.

Nomenclature of the cells of the forewing (Fig. 82).

'Costal' cell (C). — It is a long narrow strip of space bounded by the 'costa' and the 'radius'.

'Radial' Cell (R). — It is more or less a rectangular space in the proximal half of the disc which is anteriorly limited by the 'radius' and posteriorly by the 'media-cum-cubitus<sub>1</sub>'.

The 'media' and the 'radial sector' form its distal limits.

'Radial' Cell (R<sub>1</sub>). — It is limited between the 'radial', and the radial sector'. This cell is subdivided into 'first radial' (1R<sub>1</sub>), second radial<sub>1</sub> (2R<sub>1</sub>) and third radial<sub>1</sub> (3R<sub>1</sub>) due to the presence of two radial cross veins (1r and 2r).

'Radial Sector' Cell (R<sub>s</sub>). — This cell lies in the distal half of the disc. It is anteriorly bounded by the 'radial sector' and posteriorly by the 'media'. It is open distally. Further, the radiomedial cross veins (1r-m and 3r-m) subdivide it into 'first (1R<sub>s</sub>), second (2R<sub>s</sub>) and third (3R<sub>s</sub>) radial sector' cells.

'Medial' cell (M). — This cell is present in the distal two thirds of the disc inbetween the 'media' and the 'cubitus<sub>1</sub>'. It remains open distally. Two mediocubital cross veins ('1m-cu' and '2m-cu') subdivide it into 'first (1M), second (2M) and third (3M) medial' cells.

'Media-cum-cubital' cell (M+Cu<sub>1</sub>). — This is a basal cell demarcated anteriorly by the 'media-cum-cubitus<sub>1</sub>', posteriorly by the 'first anal vein', and distally by the cubitus<sub>1</sub>, and cubito-anal cross vein.

'Cubital' Cell. — It is a compound cell consisting of two component cells — the 'cubital-a' cell and the 'cubital-b, cell. The proximal of the two (Culb) is enclosed inbetween the

cubitus<sub>1</sub>, the 'first anal' vein, the 'cubitoanal' cross vein and the 'Culb'. The distal cell (Cula) is limited by 'Cula', 'Culb' and proximal portion of the apical margin.

Proximal anal cell (PA). This narrow and elongated cell is bounded by the proximal portions of the 'first anal' and the 'second anal' veins, and by the 'third anal-cum-anal cross vein'.

Distal anal cell (DA). This cell lies inbetween the 'first anal vein' and the 'second anal vein'.

Regions of the hindwing (Fig. 85). — Basically the hindwing regions are the same as reported in the forewing. Leaving aside the difference in the areas of the respective regions; the important difference lies in the fact that the vannal region of the hindwing is posteriorly limited by the jugal fold alone.

Venation of the hindwing (Figs. 85 & 86). — The costa (C) ends far short of the distal extremity of the costal margin. The radius (R), the media (M) and the cubitus<sub>1</sub> (Cul) emerge from a common stem (R+M+Cu<sub>1</sub>). The radius on leaving the common stem runs submarginal to the costa and later on bifurcates into anterior radius<sub>1</sub> (R1) and posterior radial sector (Rs). The radius<sub>1</sub> turns slightly forward to become marginal beyond the terminus of the costal vein. The radial sector dives a little and then bends to take up apically directed course to join the



radius<sub>1</sub>. The media-cum-cubitus<sub>1</sub> (M+Cu<sub>1</sub>), before entering the distal half of the disc, divides into anteriorly directed media and somewhat straight cubitus<sub>1</sub> which ends close to the apical margin. The media bends after a short distance and extends laterally to end close to the apical margin. It is joined with the radial sector by the first and third radiomedial (1r-m C 3r-m) cross veins. Besides, it is also connected with the cubitus<sub>1</sub>, a little proximal to the third radiomedial cross vein, through the mediocubital (m-cu) cross vein.

The first anal (1A) and second anal (2A) veins are united proximally and also distally, through the intervention of the anal crossvein (cv) to enclose an ablong cell. Later on the first anal continues ending close to the anal notch. It is connected with the cubitus<sub>1</sub> through cubitoanal crossvein (Cu-a). The third and fourth anal veins (3A and 4A) emerge from a common stem. After a short distance the fourth anal vein separates out posteriorly and ends immediately afterwards, while the third anal further continues submarginal to the basal portion of the anal margin.

Nomenclature of the cells of the hindwing (Fig. 85). —

'Costal' cell (C). This cell is extremely narrow and elongated, lying inbetween the 'costa' and the 'radius'.

'Radial' Cell (R). It lies in the proximal half of the disc and is limited by the 'radius' and the 'media-cum-cubitus<sub>1</sub>'.

Distally it is bounded collectively by 'radial sector', 'radio-medial' cross vein and the 'media'.

'Radial<sub>1</sub>' Cell (R<sub>1</sub>). This is an oblong cell in the distal half of the disc enclosed inbetween the 'radial<sub>1</sub>' and the radial sector.

'Radial sector' cell (Rs). It lies posterior to the 'radial' cell. It is anteriorly marked by the 'radial sector', posteriorly by the 'media' and proximally by the first 'radiomedial' crossvein. Distally, it is not limited. It is further subdivided into first (1Rs) second (2Rs) 'radial sector' cells due to the presence of the thira 'radiomedial' crossvein.

'Medial' Cell (M). This cell occurs between the 'media' and the cubitus<sub>1</sub>, in the distal half of the disc. The 'medio-cubital' crossvein splits it into first (1M) and second (2M) medial cells.

'Media-cum-cubital' Cell (M+Cv<sub>1</sub>). It is a long cell which is anteriorly bounded by the 'media-cum-cubitus', posteriorly by the 'first anal' and distally by the 'cubito-anal' crossvein.

'Cubital' Cell (Cu<sub>1</sub>). This cell is bounded by the distal portions of the 'cubitus<sub>1</sub>' and the 'first anal'. Proximally it is limited by the 'cubito-anal' crossvein while distally it remains open.

'Proximal anal' Cell (PA) . This cell is enclosed between the 'first anal' and second anal-cum-anal cross vein.

Distal anal Cell (DA). This cell occupies a portion of the vannal area and almost entire jugal area. It is anteriorly bounded by the 'second anal' and distal half of the 'first anal' while posteriorly it is incompletely limited by the 'third anal'.

Articulation of the wings (Figs. 83,84,86 & 87). — The wings are in continuation with the lateral margins of the alinotum through axillary membrane. The axillary membrane, which is studded with a few sclerotic plates, is anteriorly restricted by the tegula (absent in the hindwing) and posteriorly by the axillary cord (AxC). The latter is in continuity with the anal margin of the wing.

Sclerites of the wing base. — There are four axillary sclerites in the forewing-base, while only three in the hind wing-base. Besides these, the basalare, subalare and humeral plates are also present in both the wing bases. The median plate is present in the forewing-base only.

First axillary sclerite of the forewing (1Ax). — The first axillary sclerite is the anterior hinge plate of the forewing. It bears three processes-anterior process, posterior process and lateral process. The anterior process is rounded and project

forward to articulate with the suppressed subcosta. The posterior process articulates with the anterior notal process of the alinotum. The lateral process is blunt and extends outward to develop association with the middle portion of the second axillary sclerite.

Second axillary sclerite of the forewing (2Ax). — The sclerite lies between the median plate and the third axillary sclerite. It consists of two distinct plates. One of them ends, anteriorly as well as posteriorly, into prominent lobes which are connected through a narrow bar. The posterior lobe fits into the lap of the third axillary sclerite while the anterior lobe lies in close association with the median plate. The other plate tapers at both the ends. The body of the sclerite ventrally articulates with the pleural wing process. The second axillary sclerite at its posteroventral angle is connected to the subalare sclerite (sa) through a cord.

Third axillary sclerite of the forewing (3Ax). — The third axillary sclerite is boat-shaped and lies in the lap of the axillary cord. Mesally it is produced into a thick process with a facet which provides articulation to the fourth axillary sclerite. Laterally it communicates with the common base of the anal veins. In the middle of the anterior face, its body is deeply concave and provides insertion to the 'first and second flexor' muscles of the forewing.

Fourth axillary sclerite of the forewing (4Ax). — It is in the form of a short sclerotic piece, lying between the third axillary sclerite and the alinotal margin. As the third axillary sclerite and the fourth axillary sclerite exist together in line with the posterior margin of the alinotum, these two collectively form the 'posterior hinge plate' of the forewing.

Basalare sclerite of the forewing (Ba). — This is an 'L' shaped sclerite resting on the 'pleural wing process'. Its stem is ventrally attached to a 'saucer'-shaped apodeme through a short and thick tendon like suspensorium. The apodeme (BaAp) provides insertion to the 'extensor muscles of the forewing'. The present writer sees justification in Alam's (1951) contention that the apodeme and the suspensorium should be taken as parts of the basalare sclerite. The curved arm of the sclerite lies very close to the humeral complex. This justifies the function of extension of the wings brought about through the operation of the basalare sclerite.

Subalare sclerite of the forewing (Sa). — This is a tiny oval sclerite, resting on the dorsal margin of the epimeron close to the 'epimeropostnotal bridge'. This sclerite is associated dorsally with the second axillary sclerite through a cord and ventrally receives the tendon of the 'third flexor of the forewing'. It can be, thus, suggested that the sclerite assists in bringing about flexion of the wing.

Median plate of the forewing (m). — This is a broad leaf like plate lying inbetween the suppressed 'subcosta' (Sc) and the second axillary sclerite. Distally it abuts against the common stem of 'radius', media, and 'cubitus<sub>1</sub>'.

Humeral complex of the forewing (HP). — The humeral complex consists of a set of four oval plates. Three of them occur in line with, and proximal to, the costal vein, while the fourth lies close to the suppressed subcosta (Sc). The humeral complex proximally develops association with the upper tip of the basallare sclerite.

First axillary sclerite of the hindwing (1Ax). — The umbrella shaped first axillary sclerite is placed obliquely in the wing-base. The proximal end bears a facet through which it articulates with the anterior notal process, while the distal end is associated with the second axillary sclerite.

Second axillary sclerite of the hindwing (2Ax). — The second axillary sclerite is irregular in out line and bears a prominent ridge. The ventral surface possesses a notch which provides articulation to the pleural wing process. Ventrally, the sclerite is also connected through a cord with the subalare sclerite. Prosteriorly it ends close to the anterior surface of the third axillary sclerite. Since the median plate is wanting, this sclerite anteriorly is directly articulated with the

common stem of 'radius', 'media' and cubitus<sub>1</sub>.

Third axillary sclerite of the hindwing (3Ax). — This sclerite lies obliquely in the wingbase close to the 'axillary cord'. Proximally it tapers to articulate with the 'posterior notal process' of the alinotum. Distally it is rounded and lies close to the base of the 'anal veins'. Its anterior surface is irregularly concave while the posterior surface is almost straight. Like the third axillary sclerite of the forewing, the deep concavity in the anterior surface provides insertion to the 'third axillary flexor muscles'.

Basalare sclerite of the hindwing (Ba). — The basalare sclerite is more or less sickle-shaped and it rests on the anterior margin of the pleural wing process. The handle of the basalare serves as an apodeme for the insertion of the 'extensor muscles of the hindwing'. The apex of this sclerite lies close to the humeral plate.

Subalare sclerite of the hindwing (Sa). — The subalare sclerite is a small oval plate lying on the dorsal margin of the epimeron, close to the 'epimeropostnotal bridge'. Ventrally and posteriorly the sclerite receives the tensions of the 'flexor muscles' while dorsally it is connected with the second axillary sclerite, through a cord.

Humeral plate of the hindwing (HP). — It is a small oval plate lying in the axillary membrane, in close association with the proximal extremity of the 'costa'.

### 3. THE ABDOMEN

The abdomen is bright yellow in colour, broadest in the middle and tapering posteriorly. It is dorso-ventrally compressed with slightly arched dorsum and flat venter. The abdomen of the female is larger in size and it is easy to distinguish it from that of the male because of black tipped ovipositor which ordinarily extends slightly beyond the apex of the abdomen. The abdomen is in continuation with the thorax without the intervention of a distinct petiole. The first abdominal segment has become the propodeum. Including this, the abdomen consists of complete nine segments in the males and seven segments in the females. The anus is borne on feebly sclerotized cone-like 'proctiger' (Ptgr). This is considered as incompletely developed 'tenth segment' of the abdomen. The segments 2-9 in the males consists of well sclerotized and independent terga (T) and sterna (S) while in the females, only six (2-7) such segments are present. The last sternum (ninth in the males and seventh in the females) forms the subgenital plate (Sgp). The terga being larger in size, laterally overlap the sides of the sterna. Apart from that, the lateral margins of terga are



also in membranous connection with the lateral margins of the sterna. There being no sclerotic plates in the connecting membrane. Thus it can be suggested that the entire pleural area is membranous, and the paired spiracles (sp) are borne by terga (2-8) near their anterolateral angles. The abdomen is differentiated into three regions due to structural modifications viz. (i) pregenital region (ii) genital region and (iii) postgenital region.

(1) The Pregenital Region (Figs. 88,89,90,91,92 & 93).

The segments forming the pregenital region are from 2 to 7. However, in the males the eighth segment is also included in this region.

Pregenital terga . — All the terga of pregenital segments laterally overlap the respective sterna excepting the second segment where the overlapping is wanting. The terga are almost of the same shape. Each tergum posteriorly overlaps a little of the succeeding tergum. The intertergal membrane is slightly exposed in the mid-dorsal portion on account of incomplete overlapping of the terga. The terga are in the form of narrow plates without sutures or ridges, with concave anterior (Tam) and almost straight posterior (Tpm) margins. The anterior margin excepting that of the second tergum, possesses a pair of broad-based conical projections (TAp) in their lateral halves which are analogous to the 'tergal apodemes' of S.deesae.

The second tergum (IIT) differs from rest of the pregenital terga in some other features too. It bears 'antecostal suture' (acs) running submarginal to the anterior margin. This suture is internally represented by a ridge and anteriorly demarcates the 'acrotergite (atg) from the remaining portion of the tergum which may be taken as 'scutum' (Sct). The anterolateral angles of the second tergum are extended forward to be overlapped by the posterolateral angles of the propodeal tergum (IT).

Pregenital sterna. — The sterna are narrow plates, comparatively smaller than the terga. These are separated from one another through moderately extensive intersternal membrane. The latter remains completely concealed due to the external backward extension of the sterna over the succeeding ones. The fifth sternum (VS) is the largest among the pregenital sterna and the sterna in front and behind it gradually decrease in size. The smallest among the pregenital sterna is the sixth sternum (VIS) in the females and the eighth sternum (VIIIIS) in the males. The anterior margins (Sam) of the sterna are concave while the posterior margins (Spm) are convex. The anterolateral angles of the sterna are modified into subconical projections called 'sternal apodemes' (SAp).

The second sternum (IIS) is usually of the same type excepting that the anterior margin is prominently concave and the 'sternal apodemes' are more slender and long.

The seventh sternum of the females forming the subgenital plate (Sgp) is subtriangular in shape. The base of the subtriangle (anterior margin) is concave and the vertex is rounded. The sides are formed by the continuation of the lateral (Slm) and posterior margins. The vertex runs under the basal portion of the ovipositor. Laterally, the seventh sternum is overlapped by the seventh tergum (VII T) but a portion of former conceals the lateral limits of the eighth tergum (VIII T).

The eighth sternum, in the males, possesses the usual form and shape of the pregenital sterna. However, its posterior margin, instead of being convex is deeply notched in the middle so as to accommodate the 'basal apodeme' (BAp) of the ninth sternum (Sgp). This notch incompletely subdivides the eighth sternum into two lateral lobes which communicate through a narrow median sclerotic bridge.

(ii) The Genital Region (Figs. 88, 89, 90, 91, 96 & 97).

The genital region of the males is represented by the ninth segment only, while in the females, both the eighth and ninth segments fall in it.

Genital terga. — The eighth tergum (VIII T) in the females is built up on the usual pattern excepting the fact that laterally it is more expanded and is overlapped by the seventh sternum

Further, its posterolateral angles lie very close to the first valvifers. (1V1f).

The ninth tergum (IXT) of the females is smaller than the eighth and does not possess spiracles. The anterior tergal apodemes are feebly developed. The anterior margin is followed by a faint groove (g) with an internal ridge. The present writer is not prepared to call it 'antecostal suture' because neither any dorsolongitudinal muscle originates from it nor ends on it. The posterior margin is deeply concave with a distinct median notch (Mn). The latter incompletely divides the plate into two lateral halves connected through a median bridge. Posteriorly it does not cover the proctiger. In higher Hymenoptera like the honey bee (Apidae), the wasp (Vespidae) and S. daesae (Braconidae), the ninth tergum is broken into two quadrate plates flanking the second pair of valvifers. The presence of the ninth tergum as distinct one continuous plate in A. proxima alludes to the more generalized condition of Tenthredinidae among Hymenoptera. Also, the median notch on the posterior margin, which incompletely divides the tergum in this case, suggests the manner in which further splitting up of the tergal plate might have occurred in other Hymenoptera. The lateral margins (Tlm) are oblique and the anterolateral angles are modified into a pair of facets (Tarc) which provide articulation to first valvifers. The ninth tergum, in the males, mostly resembles the typical pregenital tergum. But the posterior margin, like the ninth

tergum in the females, is deeply concave with a prominent median notch, in the middle. It also does not overlap the proctiger.

Genital sterna. — The eighth and ninth sterna in the females form the genital sterna. These, having lost the typical structural form, are modified into the first (1Vlf) and second (2Vlf) pairs of valvifers. As such, these form the basal mechanism of the external genitalia. The ninth sternum in the males, which is also the subgenital plate (Sgp), is suboval in shape with anterior margin thickened and convex. This margin in the middle is drawn out into a knob-like 'basal apodeme' (BAp) which fits into the notch of the posterior margin of the eighth sternum.

(iii) The Postgenital Region (Figs. 88, 89, 90, 96, 97 & 98).

The postgenital region is lobular. It is mostly membranous excepting a very narrow sclerotic band in its dorsum and a semisclerotized subtriangular plate in its venter which may be regarded as incomplete tergum and sternum, respectively, of the tenth segment. The whole structure can be taken as the proctiger (Ptgr). The dorsal band is labelled as rudimentary tenth tergum (XT). Its anterior margin is convex while the posterior margin is concave. Near the posterolateral angles, the posterior margin bears a pair of short, hairy, immovable 'socii' (Soc).

The venter of the tenth segment is extensively membranous excepting the incomplete tenth sternum (XS) represented by the above mentioned subtriangular plate. The completely membranous posterior portion of the postgenital region is conical with the apex clearly invaginated. This invagination receives the slit like opening of the rectum, the anus (An), and is completely devoid of any trace of sclerotization or muscles. It is comparable with the anal vestibule of S.deesae. In view of the fact that anal vestibule is completely membranous and lacks muscles, it is not desirable to consider it as rudimentary 'eleventh segment'. Instead, it should be regarded as a part of the tenth segment as maintained by Alam (1952) in S.deesae. However, Snodgrass (1941) has not altogether dropped the idea of considering the membranous lobular anal portion, lying posterior to the tenth tergum in Gilpinia polytoma (a saw-fly), as eleventh segment (labelled XII in fig. 3C and F). His view is disproved by the present writer by studying the larval anatomy of A.proxima. The fact that the abdomen consists of ten segments only, is recently confirmed by Farooqi (1963) in his study of the embryology of A.proxima.

(iv) Musculature of the Abdomen (Figs. 88, 94, 95 & 112).

The muscles of the abdomen, other than the spiracular muscles and the muscles constituting the dorsal and ventral diaphragms, fall in three categories on account of their origin and insertion : intertergal (dorsal) muscles, intersternal (ventral)

muscles and tergosternal (lateral) muscles. Functionally the intertergal and intersternal muscles are the 'extensors' and 'retractors' of the abdomen while the tergosternal muscles act as its 'dilators' and 'compressors'. All the pregenital segments show uniformity in their musculature excepting the second segment (already described). The musculature of the genital and postgenital segments while deviating from the musculature of a typical pregenital segment, also differs with the sex.

Dorsal internal median muscle (No.103). — The parallel fibres of this muscle arising from the middle portion of the anterior margin of a tergum, run backwards to end on the anterior margin of the following tergum. In the second tergum where the antecostal ridge is present, the fibres originate on it. This muscle occurs in the genital as well as postgenital segments. It is comparatively feebler in the tenth segment, where, in the males, it occupies the typical position while in the females, its fibres after originating from the middle portion of the ninth tergum and running obliquely, and in the middle of the lateral half of the tenth tergum. This muscle is represented in S.deesae, the wasp and the honey bee.

Dorsal internal lateral muscles (Nos. 104 & 105). — There are two pairs (inner and outer) of dorsal internal lateral muscles lying close to each other. These originate from the lateral portions of the anterior margin of a tergum and running con-

vergerly end on either side of the tergal apodeme of the following tergum. In the second tergum their origin is shifted to the antecostal ridge. These muscles are absent in the postgenital segment of males and in the ninth and tenth segments of females. Only one pair of such muscles is shown in S.deesae, the wasp and the honey bee. This may, however, be noted that neither of these two pairs can in any case be regarded as 'dorsal external median' muscle which is shown by Snodgrass (1935) in Dissosteira carolina.

Dorsal external lateral muscle (No.105). — This is a small muscle with the fibres arising from the posterior margin of a tergum. Running obliquely backwards, the fibres converge on the tergal apodeme of the succeeding tergum. The postgenital segment in the males and the ninth and tenth segments in the females lack this muscle. It is represented in S.deesae, the wasp and the honey bee.

The 'dorsal internal' intertergal muscles, the 'median' muscles as well as the 'lateral' muscles act as 'contractors' of the abdomen terga by bringing the adjacent terga close to one another. The 'dorsal external lateral' muscles working antagonistically pull the successive terga apart and are thus called the 'extensors' of the abdomen terga.



Ventral internal median muscle (No.107). — This muscle consisting of parallel fibres starts from the middle portion of the anterior margin of a sternum to end posteriorly on the anterior margin of the subsequent sternum. It is absent in genital and postgenital segments of both males and females. A similar muscle is reported to occur in S.deesae, the wasp and the honey bee.

Ventral internal lateral muscles (Nos. 108 & 109). — The 'ventral internal lateral' muscles consist of two pairs (inner and outer). Both the pairs arise from the lateral portion of the anterior margin of a sternum and running convergently end on the sternal apodeme of the following sternum. The inner pair is inserted on the mesal face of the apodeme while the outer pair ends at the tip of the apodeme. These muscles are unrepresented in the genital and postgenital segments excepting the ninth segment of males which possesses only outer pair (109) ending in the middle of the anterior margin of the ninth sternum (subgenital plate). In S.deesae, the honey bee and the wasp, there occurs only one pair of such muscles in each.

Ventral external lateral muscle (No.110). — This is a short muscle with fibres starting from the lateral portion of the posterior margin of sternum. The fibres running obliquely converge to end on the sternal apodeme of the following sternum. This muscle does not occur in any of the genital or postgenital

segments. Its equivalent muscles is present in S. deesae, the wasp and the honey bee.

Functionally, the 'ventral internal median' and the ventral internal lateral' muscles act as 'contractors' of the abdomen sterna while the 'ventral external lateral' muscles work as their 'extensors'. These bring about the movements of 'contraction' and 'extension' of the abdomen as a whole by working in co-ordination with their tergal counterparts.

Tergosternal compressor muscle (No.111). — This muscle consists of parallel fibres which start in the lateral half of a tergum, close to the spiracle. The fibres descend vertically to end by a broad base on the middle of the lateral margin of the corresponding sternum. On contraction, this muscle brings the sternum closer to the tergum. Thus the co-ordinate action of all the 'tergosternal compressors' will bring about contraction of the entire abdomen.

Tergosternal dilator muscle (No.112). — The parallel fibres of this muscle take up an oblique course to connect the posterolateral area of a tergum with the posterior portion of the lateral margin of corresponding sternum. As the areas of origin of these muscles are confined to the tergal portions which laterally overlap the sterna and the course of the muscle is obliquely lateromesal, it is presumed that these muscles on contraction

bring the lateral portions of terga and sterna together. But this is not sufficient especially when strong 'tergosternal compressor' muscles are present. It is therefore suggested that the position of the 'tergosternal dilator' muscles become dorsoventral as a result of the contraction of the 'tergosternal compressors'. To regain their normal position, the 'tergosternal dilators' undergo contraction and in its wake bring in the dilation of the entire abdomen. For these reasons the present writer has named these muscles as 'tergosternal dilator muscles of the abdomen'.

The second abdominal segment possesses an additional tergosternal muscle (No.113). This is comparatively long muscle consisting of parallel fibres which start close to the posterior margin of the second tergum and take up a course mesal to the 'tergosternal compressor'. Descending obliquely the fibres end at the tip of the sternal apodeme of the second sternum. The course followed by this muscle makes the present writer suggest that, in all probability, its function is antagonistic to that of the 'metathoracic depressor' of the abdomen. It helps the abdomen in restoring its normal position after the action of its 'metathoracic depressor'. The tergosternal muscles are absent in the genital segments of females, but the males possess them. These are comparatively strong and cross each other along their course to act more effectively.

Tergosternal abductor muscle of the male subgenital plate(No.114)

This muscle consists of parallel fibres which emerge from the lateral half of the ninth tergum close to its posterior margin. Running obliquely, it descends to end on the lateral margin of the ninth sternum (subgenital plate), close to its anterolateral angle. On contraction, this muscle pulls up the proximal portion of the subgenital plate, as a result of which the latter is lowered distally.

Tergosternal adductor muscle of the male subgenital plate(No.115)

The fibres of this muscle originate from the anterior margin of ninth tergum, slightly lateral to the tergal apodeme. These obliquely descend to take up a course mesal to the 'tergosternal abductor' and cross the latter to culminate on the lateral margin of the ninth sternum close to its posterolateral angle. On contraction, this muscle raises the distally lowered subgenital plate.

Both these tergosternal muscles are comparable with the muscles numbered 268 and 269 of the migratory locust (Albrecht, 1953).

Abductor of the subanal lobe (No.116). — A tergosternal muscle also occurs in the tenth segment of both the sexes and may be taken as 'abductor of the subanal lobe'. It consists of a few parallel fibres which start from the middle of the

lateral half of ninth tergum. These descend obliquely to end on the reduced tenth sternal plate. On contraction this muscle will pull up the sternal plate which will automatically depress the distal membranous ventral portion of the subanal lobe. Consequently, the anal aperture will be exposed.

(v) The External Male Genitalia (Figs. 99,100,101,102 & 105).

The heavily sclerotized external male genitalia are concealed except for the protruding apex. These are lodged in the ninth segment with the ninth sternum as subgenital plate. The surfaces of the genitalia are in extensive membranous connection with the margins of the subgenital plate. The unpaired basal ring (BR), paired parameral plates (lp) with their parameres (Pmr), paired volsellae (Vol) and unpaired medially placed aedeagus (Aed) combiningly constitute male genitalia. The special features occurring in the male genitalia of the Tenthredinoidea as reported by earlier writers (Boulange, 1924 quoted by Snodgrass, 1941) are fully represented in A. proxima viz., (i) the articulation of parameres is accompanied by the presence of specific parameral muscles, (ii) the absence of the 'cupping discs' in the parameres and (iii) the strophandrious (inverted) condition of the phallus. On account of the last feature (inverted phallus), the lower side of the genitalia is the primary dorsal surface while the upper side is the primary ventral surface. Because of this the 'foramen of the basal ring' becomes anteroventral, and the 'volsellae' and the 'groove of

the aedeagus' (Phtr) lie dorsally while the 'parapenial lobes of the parameral plates' take up a ventral position.

Basal ring (BR). — The basal ring forms the proximal most part of the genitalia. It is an annular sclerite containing the basal portions of the phallic structures and puts the phallic cavity in communication with the anteriorly lying extensive abdominal space through a circular aperture which may be called 'foramen of the basal ring' (BRf). In relation to the body axis, the basal ring can be split up into two distinct halves : the proximal half is anterodorsal in position while the distal half is posteroventral. The anterodorsal half is comparatively less broad with concave posterior margin and convex anterior margin. The latter is slightly irregular in outline and is extended in its middle into an anteriorly directed process called 'gonocodyle' (gc). The posteroventral half is in the form of a broad sclerotic strip with concave anterior margin and convex posterior margin. Its posterior margin lies very close to the anteroventral portion of the proximal margin of the parameral plate whose anterodorsal half lies within the 'foramen of the basal ring'.

Parameral plate (lp). — The parameral plate in association with its paramere (Pmr) forms the lateral boundary of the genitalia. It is a curved plate consisting of dorsal and ventral portions with distinct proximal, distal, mesal and lateral marg-

ins. The proximal margin is curved and in respect to its association with the basal ring, it can be demarcated into anteroventral and anterodorsal portions. The distal margin is almost flat and is in membranous connection with the paramere. The mesal margin is short and flat, and connects the mesal end of the distal margin with the ventral end of the proximal margin. Likewise, the lateral margin which is extensive, connects the lateral end of the distal margin with the dorsal end of the proximal margin. The anteroventral portion of the proximal margin is almost parallel to and in membranous connection with the posterior margin of the posteroventral half of the basal ring, while the anterodorsal portion is in extensive membranous connection with the corresponding margin of the other parameral plate and its dorsal end in association with the anterior end of the lateral margin forms an angular projection lying with in the 'foramen of the basal ring' very close to its counter part of the other parameral plate. The lateral margin lies parallel to and in close membranous association with the lateral margin of the volsella (Vol). The mesal margin of the parameral plate is in extensive membranous connection with the associated structures of the genitalia (aedeagus etc.). The mesally directed ventral triangular portion of the parameral plate, limited by the basal portion of the mesal margin and the mesal half of the anteroventral portion of the proximal margin, may be taken as the 'parapenial lobe' (Pa) of the Tenthredinoidea. The mesal tip of the 'parapenial lobe' lies in

close association with the mesal tip of its counterpart. This association is comparable with the 'sclerotised bridge' of S.deesae. The parameral plate is traversed in the middle by an anteroposteriorly running ridge (lpR). This ridge gives out a branch running submarginal to the anteroventral portion of the proximal margin of the parameral plate.

The paramere (Pmr) is a hollow triangular lobe which proximally is in membranous connection with the distal margin of the parameral plate.

VolSELLA (Vol). — The volsella secondarily acquires a dorsal position as a result of the strophandrious condition of the genitalia. It lies mesal to the parameral plate and is ventrally limited by the aedeagus. The basal third of the volsella lies within the 'foramen of the basal ring'. The volsella consists of an elongated plate and two distal lobes. The plate is the 'basivolsella' (lv) and the lobes are the 'cuspis' (cus) and 'digitus' (dig). The mesal and lateral margins of the basivolsella are irregular while the distal margin is concave which provides articulation to the distal lobes. Proximally, the basivolsella is produced into an angular extension (VolAp) comparable with the 'basal apodeme' of S.deesae. The lateral margin, which is followed by an incomplete submarginal ridge (vr), is in membranous association with the lateral margin of the parameral plate. The mesal margin possesses a complete



submarginal ridge (vR) and is also in conjunctival association with the dorsal surface of the aedeagus.

The cuspis (cus) is more or less spherical and occupies ventrolateral position in respect to the digitus (dig). Its extremely narrow base is in continuity with the posterolateral angle of the basivolsella. The digitus, on the other hand, is somewhat rectangular and basally articulates with the basivolsella.

Aedeagus (Aed). — The elongated unpaired aedeagus lies between the parameral plates and is incompletely covered dorsally by the paired volsellae. It is primarily a membranous structure barring the two elongated sclerotic bars which form its lateral limits (lateral walls) and may be taken as 'penis valves' (pv). The valves are held responsible for keeping the membranous portion of the aedeagus well stretched. These are club-shaped with their tapering proximal ends lying within the 'foramen of the basal ring'. Their broad distal ends are cupped over by fluffy structures which are considered as secondary modifications of the valves. The ventral wall of the aedeagus, stretched between the penis valves, is completely membranous and is devoid of any trace of sclerotization. The dorsal wall of the aedeagus is also membranous and possesses a midlongitudinal semisclerotized narrow area which is invaginated through its entire length resulting in a narrow groove (Phtr). The latter is studded with microscopic hair and is homologous to

the 'phalotreme' of S.deesae. The phalotreme basally receives the ejaculatory duct and distally ends in between the two fluffy lobes of the penis valves.

(vi) Musculature of the Male Genitalia (Figs. 103,104,105 & 106).

The muscles of the male genitalia are both extrinsic and intrinsic in nature.

There are three pairs of extrinsic muscles arising from the subgenital plate and are inserted on the basal ring. The 'strophandrious' nature of the genitalia has affected the normal course of these muscles.

First torsion muscle of the male genitalia (No.117). — The parallel fibres of this muscle arise from the anterolateral angle of the subgenital plate and running in mesal direction cross over to the other side to end on the opposite face of the 'gonocondyle'. The two associates of this paired muscle thus, pass each other forming a 'cross' near their points of insertion.

Second torsion muscle of the male genitalia (No.118). — This muscle also consists <sup>of</sup> parallel fibres originating on the outer face of the 'basal apodeme' of subgenital plate. Running obliquely in posterior direction, it ends almost in the middle of the anterior margin of the anterodorsal half of basal ring. The two components of this muscle cross one another half way along their courses.

Third torsion muscle of the male genitalia (No.119). — It is a short muscle with fibres arising on the dorsal face of the 'basal apodeme' of subgenital plate. Running in posterior direction it takes up somewhat S - shaped course before ending on the outer face of the 'gonocondyle', slightly posterior to the insertion of the 'first torsion muscle'. The two components of the paired 'third torsion muscle' coming from either side, cross one another near their points of origin.

These three extrinsic muscles of the genitalia are analogous to the three extrinsic muscles of genitalia reported in S.deesse (Alam 1963) in as much as their origin and insertion are concerned. Functionally these are not similar to those occurring in S.deesse because in the latter the genitalia is in 'orthandrious' condition (common feature of Clistogastrous Hymenoptera) while in A.Proxima the condition of the genitalia is 'strophandrious'. Consequently these extrinsic muscles, which in S.deesse act as 'protractors' and 'retractors' of the genitalia, in A.proxima function as 'torsion muscles' bringing about 'torsion' of the genitalia by their simultaneous contraction and 'detorsion' of the genitalia by their subsequent relaxation.

The intrinsic muscles of male genitalia include muscles of its various components (parameral plates, parameres, volsellae and aedeagus).

Muscles of the parameral plate. — There are four muscles which arise from the basal ring and operate the parameral plate.

First adductor of the parameral plate (No.120). — The fibres of this muscle arise laterally on the base of the 'gonocondyle' of basal ring. Running in posterior direction, these are attached on the angular projection of the parameral plate.

Second adductor of the parameral plate (No.121). — This muscle arises from the middle of the anterior margin of the posteroventral half of the basal ring. Its parallel fibres run posteriorly to end on the submarginal ridge of the parapenial lobe, close to its mesal tip.

Third adductor of the parameral plate (No.122). — The parallel fibres of this muscle start from the anterior margin of the posteroventral half of the basal ring slightly lateral to the 'second adductor', Running obliquely lateral as compared to the 'second adductor', this muscle ends on the submarginal ridge of the parapenial lobe.

Abductor of the parameral plate (No.123). — This muscle consisting of parallel fibres arises from the lateral portion of the anterior margin of the posteroventral half of basal ring. The fibres take up a lateromesal course to end on the dorsal wall of the parameral plate close to its angular projection.

The simultaneous action of the three 'adductor muscles' pulls the basal portions of the parameral plates deep into the foramen of the basal ring. This will make the parameral plates and the parameres to come very close to the aedeagus thereby narrowing the apex of the genitalia. The contraction of the 'abductor muscles' will pull the angular projections of the two parameral plates in mesolateral direction, which will consequently make the parameral plates and the parameres to fall out.

Flexor of the paramere (No.124). — This is a broad muscle consisting of parallel fibres. The fibres arise from the ventral wall of the parameral plate. Running posteriorly, these end by a broad base in the middle of the ventral wall of the paramere. As the paramere is movably articulated with the parameral plate, this muscle on contraction will flex the former. The relaxation of the muscle will help the paramere to regain its normal position. Such flexion of the parameres further assists in the over all narrowing of the apex of the genitalia.

Muscles of the Volsella.

Protractor of the volsella (No.125). — The fibres of this muscle arise in the distal portion of the dorsal wall of the parameral plate. These running obliquely in posteroanterior direction converge on the basal apodeme of the basivolsella.

On contraction this muscle protracts the volsella to expose it beyond the distal tip of the abdomen. It is comparable with the 'protractor of the volsella' of S.deesae (Alam 1953) and to muscle no. 18 of the generalized Hymenopterous phallus (Snodgrass 1941).

Retractor of the volsella (No.126). — This muscle arises from the middle of the longitudinal ridge of the parameral plate. Its fibres running in posterior direction converge to end on the lateral half of the distal margin of the basivolsella. This muscle, on contraction, brings back the protracted volsella to its normal position. It is comparable with muscle no.19 of the generalized Hymenopterous phallus (Snodgrass 1941).

Flexor of the digitus (No.127). — This is an intrinsic muscle of the volsella. Its fibres start from the basal apodeme of the basivolsella and running in posterior direction, converge on the basal angle of the digitus. On contraction, this muscle brings about flexion of the digitus. It corresponds to the 'first flexor of the digitus' of S.deesae (Alam 1953) and to muscle no.21 of generalized Hymenopterous phallus (Snodgrass 1941).

Muscles of the aedeagus.

First protractor of the aedeagus (No.128). — The parallel fibres of this muscle start from the proximal half of the ventral wall of parameral plate, close to its mesal margin. These run

obliquely inwards to end on the lateral face of the proximal tip of the penis valve of aedeagus. On contraction, this muscle pulls the aedeagus in posterior direction and exposes its apex. It is comparable with the 'first protractor of the aedeagus' of S.deesae (Alam 1953) and with the muscle no.8 of the generalized Hymenopterous phallus (Snodgrass 1941).

Second protractor of the aedeagus (No.129). — This muscle arises from the parapenial lobe and the fibres running in anterior direction and on the mesal face of the proximal tip of the penis valve. In action, it assists the 'first protractor of the aedeagus'. This muscle is comparable with the 'second protractor of the aedeagus' of S.deesae (Alam 1953) and with the muscle no.10 of the generalized Hymenopterous phallus (Snodgrass 1941).

First retractor of the aedeagus (No.130). — This muscle originates from the proximal half of the ventral wall of parameral plate slightly posterior to the 'first protractor of the aedeagus'. Its fibres take up posteriorly directed oblique course to end in the middle of the lateral face of the penis valve. On contraction, this muscle brings the protracted aedeagus back to its normal position. It is similar to the 'first retractor of the aedeagus' of S.deesae (Alam 1953) and to the muscle No.9 of the generalized Hymenopterous phallus (Snodgrass 1941).

Second retractor of the aedeagus (No.131). — The fibres of this muscle also start from the ventral wall of the parameral plate slightly posterior to the 'first retractor of the aedeagus'. It takes up a course which is almost the same as that of the 'first retractor of the aedeagus' and ends on the lateral face of the distal half of the penis valve. On contraction, this muscle assists the 'first retractor of the aedeagus'. It is equivalent to the muscle No.12 of the generalized Hymenopterous phallus (Snodgrass 1941).

Adductor of the penis valve (No.132). — This muscle originates from the parapenial lobe, close to its mesal tip. Its fibres ascend and take up a mesolateral course to end by a broad base on the mesal face of the distal half of the penis valve. On contraction, the two components of this muscle pull the penis valves and, consequently, the lateral walls of the aedeagus close to one another. Thus, temporarily, the cross-section of the aedeagus is narrowed. It corresponds to the muscle No.11 of the generalized Hymenopterous phallus (Snodgrass 1941).

(vii) Working of the Genitalia.

The entire working of the male genitalia, unlike in *Clistogastra* (Alam 1953), can be described in four stages, namely, (i) detorsion, (ii) entry of intromittent organs



(iii) withdrawal of the intromittent organs and (iv) retorsion. The first stage comprised of the 'detorsion' of the genitalia from 'strophandrious' to 'orthandrious' condition. The second stage deals with the actual entry of the intromittent organs into the vestibulum and the vagina and securing hold therein till the male reproductive product is discharged. The withdrawal of the intromittent organs forms the third stage and amounts to loosing grip of the genitalia on the vagina and the vestibulum and their ultimate retraction therefrom. The fourth stage is the 'retorsion', so that the abdominal apex and the components of the genitalia resume their normal relationship.

In A. proxima the male genitalia is of 'strophandrious' type. It is not an ideal state in which the copulation can take place successfully. In otherwords, a change from 'strophandrious' condition to 'orthandrious' condition of the genitalia must precede the actual copulation. It is quite reasonable to consider 'strophandrious' condition as more akin to generalized Hymenoptera. The present writer considers the 'strophandrious' condition as 'torsion' of the male genitalia, and its change over to 'orthandrious' condition as 'detorsion' of the same. It is in the 'orthandrious' condition that the components of the male genitalia collectively assume a proper position in respect to the components of the reproductive organs of the copulating partner.

Detorsion. — The 'detorsion' of the male genitalia is preceded by riding of the male over the female, followed by bending of the apex of male abdomen underneath that of the female. The 'detorsion' is brought about by the simultaneous contraction of the three pairs of 'torsion muscles' of the male genitalia. As a result of 'detorsion', the basal ring with its gonocoxite undergoes a swing through an angle of  $180^{\circ}$ , and thus the gonocoxite is brought to ventral position from its normal dorsal position. Such 'detorsion' is followed by the moving of the intromittent organs of the male genitalia along the same course and also through an angle of  $180^{\circ}$ . Thus every component of the genitalia as a result of 'detorsion' assume the orthopneustic condition. It is in this condition that the male genitalia are introduced into the vagina of the copulating partner.

The entry of the intromittent organs. — The 'adductor muscles of the parameral plates' contract so as to bring them, as well as the parameres, close to the aedeagus. This makes the apex of the genitalia narrow. The narrowing of the genitalia is further assisted by the contraction of the 'flexor muscles of the parameres'. The genitalia, in such narrow form traverse the vestibulum and the apex reaches the gonopore. The 'adductor muscles of the parameral plates' relax while their 'abductor muscles' contract to enable them to abut against the walls of the vestibulum. The parameres are made to anchor against the walls of the vestibulum as a result of the relaxation of their

'flexor muscles'. Now the role of the volsellae starts. The digiti are flexed due to the contraction of their 'flexor muscles'. This is followed by the contraction of the 'protractor muscles of the volsellae' to enable them to enter the gonopore. The 'flexor muscles of the digiti' relax so as to enable them to get firm hold on the walls (rami of the first valvulae) of the gonopore. This is followed by the simultaneous contraction of the 'adductor muscles of the penis valves' and 'protractor muscles of the aedeagus' so that the latter in its narrowed form passes through the gonopore to reach the vagina. Finally the 'adductor muscles of the penis valves' relax to allow the aedeagus to remain arrested in the vagina till the discharge of the male reproductive product is complete.

This is followed by the alighting of the male and turning its face in the direction opposite to that of the female. The change of surfaces of the apex of the male abdomen at the time of alighting is accommodated by the already 'detorsioned' condition of the male genitalia, thereby damaging no part of the apical region of the male abdomen or those of the genitalia.

Withdrawal of the intromittent organs. — The withdrawal of the intromittent organs is initiated through the contraction of the 'adductor muscles of the penis valves' so as to reduce the cross section of the aedeagus once more. After this, there occurs simultaneous relaxation of the 'protractors of the aedeagus' and the contraction of its 'retractors', so that

aedeagus is withdrawn into the vestibulum. This is followed by the contraction of the 'flexor muscles of the digiti' to make the volsellae lose their hold on the walls of the gonopore. The volsellae become free on account of the simultaneous relaxation of their 'protractor muscles' and the contraction of their 'retractor muscles'. Now the 'flexor muscles of the parameres' contract, while the 'abductor muscles of the parameral plates' relax and the 'adductor muscles of the parameral plates' contract to make the parameral plates and the parameres free from their entanglement. After this, the genitalia are completely withdrawn from the vestibulum. The muscles of the genitalia which were under contraction, now relax and the copulating partners separate.

Retorsion. — At the end of copulation and on the release of the genitalia, the torsion muscles undergo relaxation to permit the basal ring to swing back to its normal condition. Consequently the other components of the genitalia, which are in association with the basal ring, also return to their normal positions. In other words the entire genitalia have undergone 'retorsion' by swinging back through an angle of  $180^{\circ}$  to restore the 'strophandricus' condition.

(viii) The External Female Genitalia (Figs. 107,108,109,110).

The female genitalia, unlike S.deesae, remain mostly exposed ventrolaterally. Only a small portion of the base is

placed in the lap of the subgenital plate. The lateral portions of eighth and ninth terg<sup>e</sup> slightly flank the genitalia. The ninth tergum (IXT) is entire, a condition markedly different from Vespoidea (Duncan 1939), Apoidea (Snodgrass 1956) and Ichneumonidea (Alam 1953), where it is clearly split up into a pair of quadrate plates lying along the sides of the second pair of valvifers. The genitalia consist of one pair of triangular plates first pair of valvifers (1Vlf), one pair of oblong plates second pair of valvifers (2Vlf) and three pairs of valvulae (Vl).

The triangular plate (first valvifer) (1Vlf). — The triangular plate is completely sclerotized with its posterodorsal (base of the triangle) margin and dorsal two-thirds of the anterior margin heavily thickened. The dorsal angle, as well as, the posterior angle are modified into prominent articular knobs (TArk & VArk) articulating with the anterolateral concavity of the ninth tergum (TArc) and dorsomedian concavity of the oblong plate (VArc), respectively. It is from the neighbourhood of the dorsal angle that the ramus of the first valvula (rlvl) originates. The anterior and ventral margins form the sides of the triangle and their angular union becomes the vertex of the triangle. The convex ventral margin runs dorsal to and along the concave proximal half of the dorsal margin of the oblong plate (2Vlf) and is in narrow conjunctival connection with it. The posterodorsal margin runs almost parallel to the

anterior half of the lateral margin of the ninth tergum and is connected with the same through membrane. The anterior margin is free. The inner surface of the triangular plate possesses a broad ridge (1VlfR) extending between its posterodorsal and anterior margins.

The oblong plate (second valvifer) (2Vlf). — The oblong plate is somewhat kidney-shaped, lying ventral to the first valvifer and is much larger in size than the latter. Its dorsal margin, anterior to the articular concavity (VArc), is thick and concave while the remaining portion of the same is slightly convex. The concave portion accommodates the convex ventral margin of the first valvifer while the convex portion is overlapped by the ninth tergum without any articular connection with it. The dorsal margin in the vicinity of its dorsomedian articular concavity, develops a short thick ridge (2VlfR) directed ventrally and another long ridge (2VlfrR) extending backwards along the margins and beyond the apex of the valvifer. The anterior margin is anteriorly flanked by the ramus of the first valvula (r1v1) and curves round to become continuous with the smooth ventral margin. From the junction of the anterior and ventral margins, arises the ramus of the second valvula (r2v1). In Pteronocides ribesii, it is shown to arise from the anterior tip of the valvifer (Snodgrass 1935). The apex (posterior margin) gives out the immovable third valvula (3V1).

First valvula (1V1). — The semisclerotized ramus of the first valvula (r1v1) starts slightly below the dorsal angle of the first valvifer. It runs along the anterior margins of the first and second valvifers. Later on it becomes continuous with the body of the first valvula. There is no second branch of the ramus as shown by Alam (1953) in S.deesae. The body of the first valvula which is rightly called 'lancet' by Alam (1935) in S.deesae, forms the ventral valve of the ovipositor of generalized insect. The lancet (Lct) is elongated with alternating sclerotized and semisclerotized incomplete rings. It is slightly tapering at both the ends. The mesal surface of the lancet is distinctly concave. Such lengthwise concavities of two lancets in combination form the 'egg passage' for the descent of eggs. The dorsal margin is thick and setose while the ventral margin is serrated all along. Such serrations enable the lancets to tear out the leaf-tissue of the host plant.

Second valvula (2V1). — The two second valvulae by fusing along their dorsal margins form the 'stylet' (st1) which dorso-laterally covers the 'lancets'. The latter can freely move forward and backward within the groove of the stylet. The stylet is connected with the junction of <sup>the</sup> anterior and the ventral margins of the second valvifer through a short curved ramus (r2v1). The stylet possesses similar annulations as are present on the first valvula. It is elongated with the ventral surface concave along its entire length. This lengthwise concavity is

the result of union of the two semicircular concavities of the second valvulae. The basal end of the stylet expands to form the 'bulb' (B1) while its apex is pointed. The 'bulb' possesses lateral and mesal processes. It is the mesal surface of the lateral process where the ramus of the second valvula ends. The lancets enter the 'groove' in the region of the 'bulb'.

Third valvula (3V1). — The black and hairy third valvula (sheath of ovipositor) is oblong, semisclerotized and devoid of annulations. Its entire mesal surface is concave to accommodate the stylet. The dorsal margin of valvula is connected with its counterpart through a transverse sclerotic intervalvular bridge (V1B). This bridge is broad in the middle and provides insertion to the 'levator' and 'depressor' muscles of the third valvula. No such structure with elaborate muscles has so far been described in Hymenoptera

(ix) Musculature of the Female Genitalia (Figs. 111, 112 & 113).

Depressor of the stylet (No. 133). — This muscle originates on the mesal surface of the distal half of second valvifer. Descending obliquely, its fibres converge to end on the dorsal face of the median process of 'bulb'. This muscle, on contraction, brings about downward swing of the stylet and makes it change from horizontal to vertical position. It is, both



structurally and functionally, identical to the 'depressor of the stylet' of S.deesae and to the 'depressor of the shaft of the sting' of the honey bee.

Lavator of the stylet (No.134). — This is a short muscle with fibres arising from the second valvifer, close to its anterodorsal angle. These dive convergently to end on the anterior margin of the 'bulb' close to the lateral process. On contraction, the muscle exerts an anteriorly directed pull on the 'bulb', thus bringing the entire stylet back to horizontal position. It is similar to the 'levator of the stylet' of S.deesae and to the 'levator of the shaft of the sting' of the honey bee.

Levator of the third valvula (No.135). — This is a long muscle arising from the middle third of the ninth tergum, close to its posterior margin. The fibres running obliquely in mesal direction converge on the dorsal face of the median plate of intervalvular bridge. As the bridge is spldered with the third valvulae, the latter are made to swing upwards due to the contraction of this muscle and consequently the stylet is released by the third valvulae.

Depressor of the third valvula (No.136). — This is a short muscle whose fibres start from the lateral third of the ninth tergum, close to its lateral margin. Running inwards, these

end on the dorsal face of the median plate of intervalvular bridge, lateral to the 'levator of the third valvula'. On contraction this muscle brings the third valvulae down from their elevated position, so as to enclose the stylet.

Protractor of the lancet (No.137). — This muscle originates from the middle of lateral third of seventh sternum. Running obliquely in posterior direction, its fibres converge on the basal portion of the ramus of first valvula. On contraction, this muscle exerts a downward pull on the ramus of the first valvula which is consequently protracted.

Secondary protractor of the lancet (No.138). — The fibres of this muscle arise from the middle third of the anterior margin of seventh sternum. Running obliquely in posterior direction, these end on the middle third of the ramus of first valvula. On contraction, this muscle assists the 'protractor of the lancet' to bring about complete protraction of the lancet.

Retractor of the lancet (No.139). — The 'retractor of the lancet' starts from the lateral portion of eighth tergum close to its posterior margin. Taking up almost vertical course, the fibres converge on the basal end of the ramus of first valvula. On contraction of this muscle, the ramus will be pulled back to normal position from its displaced position caused by the action of the 'protractors'. Thus, the retraction of the lancet will

be brought about. This muscle is comparable with the 'secondary retractor of the lancet' in S.deesae.

It is interesting to note that the lancets in S.deesae are comparatively better equipped with muscles. This upholds the fact that in S.deesae more perfection in the function of the lancets is required, because of efficient stinging and oviposition activity of the insect as compared with that of A.proxima, where simple type of oviposition activity has been recorded.

Protractor of the stylet (No.140). — This is a broad muscle with parallel fibres arising from the submarginal ridge of the ninth tergum, close to its anterolateral angle. These fibres run obliquely in dorsoventral direction to end on the thickened dorsal margin of the second valvifer, posterior to its articulation with the first valvifer. On contraction, this muscle pulls the posterior half of the second valvifer along anteriorly directed course. Consequently, the anterior end of the second valvifer swings downwards. Thus, the second valvifer changes from horizontal to almost vertical position with its articulation with the first valvifer as pivot. Such change in position of the second valvifer results in protraction of the stylet.

Retractor of the stylet (No.141). — This is a long muscle consisting of parallel fibres which originate from the middle of the ninth tergum. Running along vertical course, the fibres

end on the dorsal margin of the second valvifer, anterior to its articulation with the first valvifer. This muscle acts antagonistic to the 'protractor of the stylet'. On its contraction, the second valvifer is restored to its normal (horizontal) position. This change in position results in the withdrawal of the stylet from the site of oviposition.

Dilator of the egg passage (No. 142). — This is a short muscle with fibres starting from the anterior half of the second valvifer and running mesally directed ends by a broad base on the ramus of the second valvula, close to its origin. This muscle, on contraction, pulls away the basal portion of the ramus. Since the two rami of second valvulae, in combination, guard the gonopore and the basal portion of egg passage hence their moving apart will dilate the latter for the descent of the eggs at the time of egg laying. This muscle has not been recorded in Hymenoptera.

First dilator of the vagina (No.143). — This is a slender muscle. Its parallel fibres start from the eighth tergum, close to its lateral margin and end on the dorsal wall of vagina. It is equivalent to the 'tergovaginal muscle of abdominal segment VIII (193)' of the honey bee recorded by Snodgrass (1942).

Second dilator of the vagina (No.144). — This muscle resembles the 'first dilator of the vagina' in every detail except

that its origin and insertion are posterior to those of the 'first dilator'. This muscle is comparable to the 'tergovaginal muscle of the abdominal segment VIII (194)' of the honey bee (Snodgrass 1942) and to the 'dilator of the vagina' of S. deesae.

Both these dilators contract simultaneously to expand the vagina so as to enable the latter to accommodate the eggs, during ovulation.

Compressor of the vagina. (No.145). — This is a short muscle consisting of parallel fibres. The fibres start from the anterior margin of the seventh sternum to end on the lateral wall of the vagina, immediately below the 'dilators of the vagina'. On contraction of the muscle, the vagina will be compressed dorso-ventrally and consequently it will push the eggs out through the gonopore. It is, thus, clear that this muscle helps in oviposition. The muscle is comparable with the 'median internal ventral muscle of the abdominal segment VII' of the honey bee recorded by (Snodgrass 1942).

(x) Mode of egg-laying. — A. proxima lays eggs in the leaf tissue, depositing them one after the other along the margins of the leaf. The insect holds the margin of the leaf by the prothoracic legs and bends the abdomen due to simultaneous contraction of dorsal external lateral (intertergal extensors), ventral internal median and ventral internal lateral (intersternal contractors) muscles of the abdomen. This brings the

abdominal tip in touch with the leaf surface. Prior to deposition of the egg, the genitalia undergo various movements. The 'levators of the third valvula' contract to lift them so as to release the stylet. The stylet and the lancets move together from horizontal to vertical position as a result of contraction of the 'depressor of the stylet' and the tip of the stylet, thus, touches the leaf surface. The sheath of the ovipositor is arched to grip the stylet due to the relaxation of its 'levator' and contraction of the 'depressor' muscles. Now the stage is set for puncturing the host leaf. The 'protractor' muscles of the lancets contract and the two lancets puncture the leaf surface to enter into the tissue. The penetration in stages, is helped by the serrations on the lancet. This is followed by the contraction of the 'protractor' muscles of the stylet so that it also penetrates the leaf. By this time the vagina has dilated due to the contraction of its 'dilator muscles' and the eggs have already arrived in it. This is followed by the contraction of the 'compressors of the vagina' and the eggs, consequently, reach the gonopore. Further descent of the eggs into the lumen of the egg-passage is enforced by the contraction of the 'dilators of the egg—passage'. The eggs pass through the lumen of the egg-passage to reach the tissue of the leaf. The 'retractor' muscles of lancets and the stylet undergo contraction to bring about their withdrawal from the leaf-tissue. This is synchronized by the relaxation of their 'protractors'. The 'depressors of third valvulae' undergo relaxation followed

by contraction of their 'levators'. This makes the sheath to dearch itself. The 'levators of the stylet' contract to bring the stylet and the lancets to their normal (horizontal) position. The 'levators of the third valvulae' now relax to enable the sheath to enclose the stylet. Finally, the entire abdomen is brought back from arched to its normal (horizontal) position as a result of relaxation of the 'dorsal internal lateral', 'ventral internal median' and 'ventral internal lateral' muscles of the abdomen, coupled with the contraction of the 'dorsal internal median', 'dorsal internal lateral' (intertergal contractors) and 'ventral external lateral' (intersternal extensors) muscles of the abdomen.

#### 4. THE INTERNAL ANATOMY

##### (1) Digestive System (Figs. 114,115,116,117,118,119,120,121 & 122).

The alimentary canal, running almost parallel to the longitudinal body axis, communicates with the exterior through mouth (Mth) and anus (An) at the anterior and posterior ends, respectively. Its cross section varies at various levels and is maximum in the crop region. It can be divided, on morphological and functional bases, into stomodaeum (Stom) mesentron (Ment) and proctodaeum (Proc).

Stomodaeum (Stom). — The stomodaeum puts the alimentary canal in communication with the cibarium (Cb) through the true mouth and is divided into the pharynx (Phy), oesophagus (Oe), crop (Cr) and proventriculus (Prvent). The last subdivision connects the stomodaeum with the 'mesentron' and the passage is controlled by the stomodaeal valve (Svl).

Pharynx (Phy). — The anterior most part of the stomodaeum is the pharynx which lies in the head, in the form of an inverted 'v'-shaped tube. It is roofed over by the brain. The precerebral portion of the pharynx receives the true mouth while the postcerebral portion communicates with the oesophagus in the vicinity of the foramen magnum. The pharynx is controlled by five pairs of 'dilator' muscles which help in the ascent of food into the oesophagus. The account of three muscles in relation to ingestion of food has already been given under 'cephalic stomodaeum'.

Oesophagus (Oe). — The pharynx posteriorly emerges from the head through the foramen magnum, as oesophagus. The latter is a narrow tube of uniform cross-section and passes through the voluminous muscles of the thorax to enter the abdomen. The wall of the oesophagus consists of an outer layer of circular muscle fibres (cmcl) which are internally followed by bands of longitudinal muscle fibres (lmcl). The epithelium (Epth) of the wall, surrounding the lumen, is thrown into internal folds



which gradually increase towards the crop. The epithelium consists of a single row of cubical cells with indistinct intercellular walls. It is internally lined by a continuous thin intimal lining (In) while externally it is supported on an inconspicuous basement membrane (bMb). The nuclei (nu) of the cells are sparingly granulated and the cellular cytoplasm also shows traces of granules.

Crop (Cr). — The oesophagus on entering the abdomen ends in to the pearshaped crop. The latter, under unfed conditions, looks like a crumpled sac with wrinkles on it. This condition, however, disappears as a result of feeding and the crop ultimately distends to its maximum. Consequently, the lumen of the crop is also affected. The muscular arrangement of the wall of the crop is the same as recorded in the oesophagus. The epithelium also contains cubical cells. However, the nuclei are smaller and the intercellular walls are distinct. The internal lining is thicker and is loosely attached with the epithelium.

Proventriculus (Prvent). — The proventriculus is a short and stumpy structure, connecting the crop with the mesentron. Its anterior end is telescoped into the crop to form four lipped orifice. Posteriorly, it is separated from the mesentron by the stomodaeal valve (Svl). The saggy condition of the crop conceals the proventriculus considerably. The proventriculus,

for its major portion, is internally thrown into four strong longitudinal folds supported by special set of muscles. Similar four folds have been shown in the honey bee (Snodgrass 1956), which anteriorly extend into the crop to form four lipped orifice of the proventriculus. In S.deesae (Alam 1953), their number is reduced to three. The presence of these folds gives the lumen of the proventriculus the shape of 'x'. The outer most layer of the wall of the proventriculus is formed of the generalized longitudinal muscles (lmcl) of the stomodaeum which can be taken as extension of the longitudinal muscle layer of the crop. The usual circular muscle layer of the stomodaeum is wanting. Besides the normal longitudinal muscle layer, the proventriculus contains strongly built special circular muscle layer (mcl) which is internally followed by special longitudinal muscles (ilmcl) layer. The latter extends anteriorly upto the tip of the lips of the orifice while the special circular muscle layer spreads posteriorly over the stomodaeal valve and further continues as the internal circular muscle layer of the mesentron. The proventriculus owes its toughness to these special muscles. Next to the special longitudinal muscles comes the epithelium (Epth) which consists of cubical cells. These cells with their nuclei, are almost devoid of granulation. Anteriorly, as well as posteriorly, the epithelium<sup>is</sup> continuous with the epithelium of the crop and of the mesentron, respectively. The intimal layer (In), in the region of the proventriculus is thick and its anterior portion is clothed with

backwardly directed strong hairs. The intima anteriorly continues with the intima of the crop and posteriorly terminates at the tip of the stomodaeal valve. In S.deesae (Alam 1953), the intima is an elaborate structure. It is in the form of a thick chitinous plate studded with long backwardly directed hairs.

Stomodaeal valve (Svl). — The stomodaeal valve hangs in the form of a short tube into the lumen of the mesentron, at latter's junction with the proventriculus. Histologically, it is a continuation of the proventricular wall excepting the fact that the two longitudinal muscle layers do not extend over it. The normal epithelial layer is the continuation of the epithelium of proventriculus with comparatively distinct cells. The outer surface of the valve is formed of another layer of epithelium which is in continuation with the epithelium of the mesentron. The cells of this layer are columnar with prominent nuclei and cytoplasmic granules. There is no intimal covering on them. Similar double epithelial layered stomodaeal valve is shown to occur in S.deesae (Alam 1953).

Function of the proventriculus. — The food stored in the crop is mainly in liquid form with torn bits of vegetative tissue. It is allowed to descend into the proventriculus as a result of the opening of the lips under the action of special longitudinal muscles. The special longitudinal and the special

circular muscles undergo simultaneous contraction and relaxation. This causes rapid change in the volume of the lumen, thereby enabling the food to pass through the hairs which unitedly act as a strainer. The liquid food further descends into the mesentron while the pieces of vegetative tissue are crushed by the intimal layer to facilitate their entry into the mesentron. This is also attributed to simultaneous contraction and relaxation of the special muscles of the proventriculus.

Mesentron (Ment). — The mesentron (ventriculus) is of uniform cross-section and connects the stomodaeum with the proctodaeum. Its wall is thrown into numerous transverse folds. The lumen of the mesentron is lined with a distinct epithelium (Epth) consisting of elongated columnar cells of irregular inner margin. These cells undergo distinct increase in length in anteroposterior direction. Their cytoplasm is thickly granulated while the nuclei (nu) are large with prominent granules. The free inner margin of the epithelium is finely striated (sb) with the hairs shorter than the cells which carry them. Similar striated border has been recorded by Frenzel (1886) in Cimbex (Tenthredinidae) where the hair like filaments are shown to be longer than the cells which bear them (vide Wigglesworth 1953). The epithelial cells are supported on a distinct basement membrane (bMb). This supporting membrane is externally bounded by the circular muscle layer (cmcl) which in turn is enveloped by the longitudinal muscle layer (lmcl).

Regenerative Cells (rg). — The regenerative cells occur in groups (nidi) which are basally arranged in the epithelial layer, under no definite plan. Each nidus has its own cellular wall and contains three to six regenerative cells. These cells are with nuclei and cytoplasmic granulation. The regenerative cells fastly divide to replace the epithelial cells of the mesentron which wear out soon on account of their secretory functions.

Peritrophic membrane (pMb). — The lumen of the mesentron containing food is surrounded by a clear sheet of membrane. This is the peritrophic membrane which for most of the part is secreted by the cells of the first fold of the mesentric epithelium. It is, however, supplemented at various levels by the epithelial layer through out the length of the mesentron. Thus the food in the entire mesentric lumen, from the stomodaeal valve to the pyloric valve, is ensheathed by the peritrophic membrane. This observation supports the finding of Alam (1953) and Snodgrass (1956) in S. deesae and the honey bee respectively. No positive function can be attributed to the peritrophic membrane. It is generally regarded as protecting the epithelium of the mesentron against the abrasion by solid food particles. This general observation can not go without exceptions as some liquid feeding insects are in possession of the peritrophic membrane. Similarly some solid feeding insects lack it. In A. proxima, where the food is mostly liquid, the peritrophic

membrane is regarded to avoid the direct contact of the food with the striated border of the epithelium and thereby protecting the latter from being damaged by food particles.

Pyloric valve (Pvl). — Like the opening between the stomachaeum and the mesentron, the opening between the mesentron and the proctodaeum is also guarded by a valve called 'pyloric valve' (Pvl). This valve allows the food to pass down into the proctodaeum but a reverse flow of the same is always checked. Externally, the site of the valve is indicated by a narrow depression around the junction of the mesentron with the proctodaeum. Internally, the valve looks like a circular ridge consisting of columnar epithelial cells (Epth) with striated borders (sb). Both the nuclei (nu) and the cytoplasm of these cells are almost free from granulation. There is no internal covering. The epithelial cells are supported on a basement membrane (bMb) which is externally followed by a weak layer of circular muscles (cmcl). The outer most layer of the valve is the weak longitudinal muscle layer (lmcl).

Proctodaeum (Proc). — The proctodaeum is anteriorly connected with the pyloric end of the mesentron while posteriorly it opens outside through the anus (An). It is subdivided into two parts, the anterior narrow tube like intestine (Int) and the posterior dilated 'rectum' (Rect).

Intestine (Int). — It is a slightly convoluted narrow tube with the wall thrown into small internal folds. At the base of the pyloric valve and proximal to the first fold of the intestine, there are the openings of the Malpighian tubules. The intestinal folds (villi) gradually become prominent in anteroposterior direction. The lumen of the intestine is lined by a single layer of epithelial cells (Epth) which are cubical in shape with distinct boundaries. The cytoplasm is free from granulation and the nuclei (nu) are placed in the middle of the cells. The epithelium rests on a basement membrane (bMb). Internally, it is lined by an intimal layer (In) closely adhering to it. The basement membrane is followed by the layer of circular muscle fibres (cmcl) which in turn are enveloped by a layer of longitudinal muscle fibres (lmcl). There are no regenerative centres in the intestinal wall. The epithelium appears to be an important site of absorption of digested food as the cells are of nonglandular nature.

Rectum (Rect). — The intestine posteriorly dilates to form the rectum which can undergo distension as a result of accumulation of the fecal matter. It opens by the anus (An). There are six oblong rectal pads (rp) in the middle of the rectal wall. The rectal wall histologically is similar to the intestinal wall excepting the presence of rectal pads. The intima ordinarily runs attached to the inner boundary of the epithelium but in the region of the rectal pads this condition is lost. Further, the epithelium connecting one rectal pad with the other has become

syncytial. The nuclei are markedly reduced in size and lie scattered in the epithelial layer.

Rectal pad (rp). — Each rectal pad is in the form of an anteroposteriorly placed tube, closed at both the ends and projecting into the rectal lumen. The muscle layers of the rectal wall surround the rectal pads also. The syncytial epithelium (sEpth) of the rectum forms the base of the pads. The cells of the rectal pad (rpc) are columnar in shape, consisting of distinct cellular walls and also possessing large nuclei (nu) laden with fine granules. The cytoplasm is also granulated. The rectal syncytial epithelium is stretched over the columnar epithelium of the pad as thin cytoplasmic extension with scattered nuclei, thereby enclosing a space between itself and the columnar epithelium. This space is the lumen of the rectal pad (Lumrp). The intima (In) is also carried along with the extended portion of the syncytial epithelium. These details conform with the findings of Alam (1953) in S.deesa. The function of the rectal pads seems to extract water from the faecal matter and pass it on to the blood by way of diffusion through the wall of the rectum.

(ii) Salivary Gland (Fig. 123).

The salivary gland is like a bunch of grapes lying in the prothorax. Its ampullae (amp) like structures open into short ductules (sd) which combiningly form the lateral salivary ducts



(1sd). The two ducts of the sides enter the head through foramen magnum and independently traverse the cranial space to reach the labium. In the proximal region of the labium the lateral ducts unite to form the common salivary duct (SLD) which on entering the hypopharynx dilates to form the salivary pump. The latter opens into the food meatus through an orifice in the base of the glossa. The glandular portion of the salivary gland consists of spaceous lumen surrounded by the epithelium of cubical cells. These cells possess granulated cytoplasm and prominent oval nuclei. The epithelial layer internally lined by the intima, is externally enveloped by the peritoneal layer. There is no muscle layer. The wall of the salivary duct consists of an epithelial layer of comparatively smaller cells and is internally lined by the intima. The external peritoneal layer is also present. The lumen of the salivary duct is much narrower in comparasion to that of the gland, and also its epithelial cells possess obscured nuclei and less granulated cytoplasm.

(iii) The Excretory System (Figs. 114, 120 & 124).

The excretory system is represented by long and slender malpighian tubules (Mal), loosely placed in the visceral sinus. These open into the proctodaeum, inbetween its first epithelial fold (Ief) and the pyloric valve (Pvl). The <sup>M</sup>malpighian tubules is almost of uniform crossection with its free distal end, rounded and blind. The narrow lumen (Lum) of the tubule, communicates

with the lumen of the proctodaeum. The epithelium (Epth), lining the lumen, consists of cubical cells with their broad bases resting on the basement membrane (bMb). The nuclei (nu) are very prominent. The inner border of the cells are striated (sb) in the manner of 'brush border'. The muscle layers surrounding the epithelium are observed with very great difficulty. The thin circular muscle layer surrounds the basement membrane. Next to it comes the feeble longitudinal muscle layer. Alam (1953), in S.deesae, suggests endodermal origin of the Malpighian tubules based on the nature of the epithelial cells and the absence of intima. The histology of malpighian tubules of A.proxima upholds Alam's view.

(iv) The Circulatory System (Figs. 125, 126 & 127).

The circulatory system consists of a tubular dorsal blood vessel and three sinuses. The sinuses appear as subdivisions of the body cavity due to the formation of the dorsal and ventral diaphragms during development. The simultaneous working of these parts results in the circulation of the blood. The dorsal blood vessel is stretched longitudinally and closely underneath the tergal plates, from the eighth segment of the abdomen to the head. This tube can evidently be divided into two parts : the long chambered heart (Ht) lying in the abdomen and the narrow entire tubular aorta (a) running through the thorax to end in the head region.

Dorsal blood vessel. — The heart is supported on the dorsal diaphragm (dDph). Anteriorly, it communicates with the aorta, underneath the propodeal tergum while posteriorly it tapers to end blindly in the eighth abdominal tergum. The heart, on the basis of dilatations and paired ostia, may be considered to be subdivided into eight chambers. These chambers are roughly distinguished from one another due to intervening constrictions. Each chamber communicates with the pericardial sinus through a pair of oblique dorsolateral ostia (Ost) present in its posterior region. Its tapering anterior end, functioning as interventricular passage, is engulfed by the posterior broad end of the next chamber. Such relationship in the consecutive chambers results in the formation of paired ostia which appear as narrow oblique slits on either side of the chambers. The last chamber anteriorly opens into the aorta. The latter is cylindrical and much narrower than the heart. The aorta passes through median notch of the mesopostphragma and after running across the latter, it dives to reach in the vicinity of the oesophagus. Therefrom it turns forward to run long the dorsal surface of the oesophagus till it comes to lie underneath the brain. Here it flattens to end by a transverse slit.

Body cavity. — The body cavity of the abdomen is subdivided into three longitudinal chambers viz., pericardial, visceral and perineural sinuses. These are demarcated by the dorsal and ventral diaphragms. However, in the thorax, the diaphragms

and consequently the sinuses are absent with the result that the body cavity becomes one continuous space interrupted here and there by the muscles.

The long shallow pericardial sinus is limited between the terga and the dorsal diaphragm. It accommodates the heart, and is in communication with the visceral sinus through lateral gaps closely sandwiched in between the roots of alary muscles. The dorsal diaphragm is a membranous sheet stretching from the eighth abdominal segment to the second abdominal segment. Laterally it is fused with the inner surface of the terga, at the roots of the alary muscles which means incomplete lateral fusion of the dorsal diaphragm with the terga. The gaps between adjacent alary muscles act as communicating passages between the pericardial sinus and the visceral sinus. The dorsal surface of the dorsal diaphragm is transversely run over by fibres of fan-shaped alary muscles (dDphMcl). The narrow roots of these muscles are fused with the terga while their broad apices end by spreading on the sides of the chambers of the heart.

The spacious visceral sinus contains the digestive, excretory and reproductive organs.

The perineural sinus is extremely narrow and lies between the sterna and the ventral diaphragm. It contains the ventral nerve cord. The membranous ventral diaphragm (vDph) stretches from the eighth abdominal sternum to the second abdominal sternum in male. Since eighth sternum is absent in female, the ventral

diaphragm, there, commences from the seventh sternum. The dorsal surface of the diaphragm is transversely run over by thin bundles of muscle fibres which are seven pairs in male and six pairs in female. The bundles fuse laterally with the sterna by their convergent roots. This condition enables the ventral diaphragm to fuse laterally with the sterna at intervals. The gaps, thus formed between the roots of the adjoining muscles, become the connecting passages between the visceral and the perineural sinuses.

(v) The Respiratory System.

The respiratory system consists of 10 pairs of spiracles-- the first two pairs are thoracic and the rest are abdominal--and elaborate system of tracheae and airsacs. The general pattern of the respiratory system is different from the honey bee (Snodgrass, 1956) and Monodontomerus dentipes (Bucher, 1948). It is, however, more or less, similar to what has been recorded in S. laevis (Alam, 1953). Accordingly the head and the abdomen are profusely supplied with tracheae and their branches while the thorax contains combined system of tracheae and air-sacs. There are two main lateral trunks running between the first and the last spiracles. These also extend anteriorly, as well as posteriorly, into the head and the last abdominal segment, respectively. All the spiracles are connected with the trunks through short oblique spiracular tracheae. There is uniformity of the

tracheal pattern in the pregenital segments of the abdomen.

This, however, undergoes modifications in the remaining abdominal segments to meet the requirements of the structures there.

Spiracles (sp) (Figs. 34,64,73,74,88,94,128,129,130,131,132 & 133

First thoracic spiracle (1sp). — The first thoracic spiracle, lacking atrium, opens in the intersegmental membrane between the spiracular lobe of protergum and the corresponding dorsal half of the anterior margin of mesopectus. The broad spiracular lobe, as a matter of fact, conceals the spiracle. The spiracular opening (spop) is almost oblong in outline and is surrounded by feebly sclerotized spiracular rim (spr). The posterior half of the rim is normal while the anterior half is flattened out into a fairly broad flap which may be taken as movable 'anterior lip' (Alp). The mobility of the latter can be visualized along a line of flexion which not only connects it with the anterior half of the rim, but is also a zone of weak sclerotization (ws) helping in its movements. The 'anterior lip' dorsally ends into a pointed tip while ventrally before ending, it bends at a right angle to form a triangular process (spP) which receives the 'occluser muscle' (No.146). This muscle originates on the apodeme of the 'occluser plate' of the protergum' and its fibres ascending vertically converge to end on the triangular process of the spiracle. On contraction, the 'occluser muscle' swings the 'anterior lip' in such a way so as to enable it to close the usually open spiracle.

Second thoracic spiracle (2 sp). — The normally open second thoracic spiracle, too, is devoid of any atrium and opens in the intersegmental membrane between the mesopectus and metapectus. It is placed in the lap of the spiracular lobe of the mesoepimeron. The spiracular opening (spop) is suboval with completely sclerotized rim (spr). The anterior half of the rim is soldered to the inner face of the spiracular lobe to save the spiracle from displacement. This half also functions as a base for the semilunar sclerite with which it is hinged through narrow conjunctiva. This sclerite is the movable 'anterior lip' (Alp). The posterior half of the rim is free and may be regarded as the immovable 'posterior lip'. The dorsal and ventral ends of the 'anterior lip' are pointed. The fibres of the 'occluser muscle' (No.147) arising on the epimeron in close proximity of the spiracle, ascend to converge on the ventral end of the anterior lip. On contraction, the 'occluser muscle' makes the anterior lip swing inwards to meet the posterior lip, thereby, temporarily closing the spiracle. Such swing of the anterior lip is rendered possible due to the conjunctival hinge.

Propodeal spiracle (3sp). — The closing mechanism of the propodeal spiracle is different from that of the thoracic spiracle. The propodeal spiracle is situated close to the anterolateral angle of the propodeal tergum. It is in communication with the exterior through an oval aperture (spop) lodged in distinct peritrema. This aperture may be called the 'atrial

orifice' which puts the atrium in communication with the exterior. The peritreme itself is formed by secondary elevation of the tergal surface. The thick walled shallow atrium (Atr) communicates with the spiracular trachea (spt) at its inner end. The junction of the atrium and the spiracular trachea is guarded by an occlusor apparatus (Oapp). The latter consists of mesally directed semicircular elastic sclerotic bow with its ends connected through nonsclerotic movable bar. The bow and the bar are in continuity with the corresponding walls of the atrium, as well as with those of the spiracular trachea. The mouth of the spiracular trachea (Traop) is controlled by the activity of the occlusor apparatus. The posterior end of the elastic bow at its junction with the corresponding end of the bar is slightly flattened, whereas the fusion of its anterior end with the bar is normal. The two ends of the bow are also connected through a narrow band of muscle fibres, placed lateral to the movable bar. This is the occlusor muscle' (No.148). Another muscle, which is inserted on the flattened end of the bow, arises on the propodeal wall close to its lateral margin and may be taken as the 'dilator muscle' (No.149). The activity of the spiracle is controlled by the 'occlusor' and 'dilator' muscles. The closing is brought about by the 'occlusor muscle' which on contraction pushes the bar into the lap of the bow, as the latter also undergoes acute arching, thereby bringing its ends close to one another. Consequent to this activity, the inward movement of the bar closes the tracheal opening. To open the same the 'occlusor muscle' returns to its normal form and simultaneously the 'dilator



muscle' contracts. The combined action of these muscles enables the bow and the bar to regain their normal positions thereby opening the passage of the tracheal end.

There is a tergo-sternal muscle, the 'accessory muscle of the propodeal spiracle' (No.150), which brings about the full exposure of the propodeal spiracle as the latter normally remains concealed due to the turning down of the lateral margin of the propodeum. This is a short fan-shaped muscle starting from the posterior margin of the metapectus and ending on the propodeal tergum slightly mesal to the propodeal spiracle. This muscle, on contraction, pulls down the propodeal tergum in the immediate neighbourhood of the spiracle thereby straightening the turned down portion so that the spiracle is fully exposed. This muscle has not been reported to occur in other Hymenoptera.

Abdominal spiracles. — Each of the seven abdominal spiracles which opens through tiny oval operature, is placed in the middle of the lateral portion of the abdominal tergum. It resembles the propodeal spiracle in every detail excepting that the movable bar instead of being lateral is mesal to the bow. And also the 'occluser muscle' (No.151) arises from the tergal plate while the 'dilator muscle' (No.152) starts ventrally from the lateral margin of the corresponding sternal plate. Both of these muscles however, converge on to the flattened posterior end of the bow.

Tracheation of the abdomen (Figs. 134 & 135).

The two main tracheal trunks (LT), in the region of the abdomen traverse the insect body laterally underneath the abdominal spiracles. The short spiracular tracheae (spt) open in them segmentally. The plan of tracheation in the pregenital segments (2 to 8 in male and 2 to 7 in female) is similar. The details of the tracheation in the pregenital segments are as follows:

In each segment, slightly posterior and mesal to the spiracular trachea, two tracheae come out from the dorsal surface of the trunk. The anterior among the two enters into the pericardial sinus and supply branches to the heart, diaphragm and skeleto-muscular portion of the dorsum. This may be called as 'dorsal trachea' (dt). The posterior branch ascends into the visceral sinus where it ramifies over the internal viscera and may be named as 'visceral trachea' (vst). Mesal to the origin of above two branches, the lateral trunk gives rise to a mesally directed trachea 'the ventral trachea (vt), which on entering the perineural sinus divides into three branches. These, on the basis of origin and course are called as 'anterior' (ab) 'posterior' (pb) and 'mesal' (mb) branches. The anterior branch extends forward to meet the posterior branch of the preceding segment. Like wise, the posterior branch runs backwards to join the anterior branch of the succeeding segment. Such union of the anterior and posterior branches constitute a supplementary

longitudnal trunk in the abdomen which is named as 'ventral longitudinal trunk' (VT). The presence of the 'ventral longitudinal trunk' lends support to the primitive nature of the family Tenthredinidae among Hymenoptera. Almost similar condition is reported in Periplaneta americana. The honey bee and S.deesae lack the ventral longitudinal trunk. The mesal branch runs transversly across the sternum, submarginal to its anterior margin, and meets its counterpart of the other side to form the 'ventral commissure' (vc) which supplies branches to the nerve cord, ventral diaphragm and the skeleto-muscular system of the venter. The 'ventral commissure' remains intra-segmental while the anterior and posterior branches of the ventral trachea are intersegmental in their course.

The tracheation of the genital and postgenital segments show deviation from the typical plan. In the male, the ninth segment receives the lateral trunk which ends there by giving branches to the reproductive organs, segmental dorsum and to the remanent of the tenth dorsum. The 'anterior' and 'posterior' branches of the ventral trachea are lost but the 'ventral commissure' persists. It supplies to the usual structures of the segment, as well as, to the external genitalia and the remanent of the tenth venter. The 'dorsal' and 'visceral' tracheae of the lateral trunk are absent. In the female, the lateral trunk, in the eighth segment, ascends obliquely to supply branches to the segmental dorsum, as well as, to the remanents of the dorsum of the ninth and tenth segments. The ventral

trachea lacking 'anterior' and 'posterior' branches forms the 'ventral commissure' which gives out branches to the usual structures. It also supplies to the corresponding portions of the female reproductive organs and to the remnants of the venter of ninth and tenth segments. Further, the ventral trachea gives out another branch (vtb) which exclusively ramifies in the external genitalia. The 'dorsal' and 'visceral' tracheae, as in the male, are also absent.

Tracheation of the thorax (Fig. 136).

The lateral trunk (LF) on leaving the abdomen enters the propodeum and receives the spiracular trachea (spt), close to the tergal anterior margin. The ventral trachea (vt) coming out from the lateral trunk, traverses a short distance to end into a large air-sac (A) which on union with its counterpart forms saccular ventral commissure (vc). It is analogous to the 'ventral commissure' of the abdomen where it is of normal tracheal form. From the base of the airsac is anteriorly given out a spindle-shaped airsac (B) which puts the propodeal ventral commissure in communication with the ventral commissure of the metathorax. This is comparable with the anterior branch of the ventral trachea of the abdomen. The usual 'dorsal' and 'visceral' tracheae of the lateral trunk are absent. This has favoured the ventral commissure to assume the responsibility of supplying air to the propodeal segment, as well as, to the structures associated with it. This assignment is carried out through

numerous short tracheae coming out from the dorsal and ventral walls of the airsacs. The dorsal branches go to the dorsolateral area while the ventral ones ramify over the ventrolateral area of the segment.

In the metathorax, the lateral trunk gives out the 'ventral trachea' which forms the 'ventral commissure' of the type, formed in the abdomen. The ventral trachea gives rise to the posterior branch (pb) which meets the anterior branch (ab) of the propodeal segment. The ventral commissure as usual, supplies branches to the nerve cord, venter of the segment and structures associated with it excepting the leg which receives an independent trachea, metathoracic leg trachea (3lt), originating on the outer wall of the lateral trunk at the level of the ventral trachea. In the posterior portion of the segment, the lateral trunk gives out, from its mesal wall, a spindle-shaped airsac (C) which on meeting its counterpart forms a commissure. The latter occupies a comparatively dorsal position in respect to the 'ventral commissure' and is labelled as 'dorsal commissure' (dc). A pair of small airsacs (D) are given out from the dorsal surface of the 'dorsal commissure'. These sacs branch out to supply air to the segmental dorsum and also to the structures associated with it, including wing and leg muscles.

Immediately on entering the mesothorax, the lateral trunk dorsolaterally receives the spiracular trachea (spt) of the second thoracic spiracle. From the mesal wall of the lateral

trunk, in the region of the spiracular trachea, come out two mesally directed tracheae (dvt & vvt) which after running together to a short distance, take up divergent course to open independently into a large, square air-sac (E). This air-sac occupies almost the entire mesothoracic venter and appears as a result of swelling of four mesally directed identical tracheae originating from the lateral trunks. The present writer regards these tracheae as the usual 'ventral tracheae' in duplicate. The trachea, which is dorsal (dvt) gives out a branch (d) to the venter and other allied structures including wing and leg muscles of the segment. Likewise, the dorsum, the wing and leg muscles and other associated structures are supplied with branches from a dorsal branch (dE) coming out of the dorsal wall of the air-sac. From the ventral wall of the air sac and very close to its posterior angle, originates a branch (1lt) going to the prothoracic leg. This additional prothoracic leg trachea, before entering the leg, receives another branch (1lt") coming out from the ventral wall of the air-sac, at its anterior angle. The mesothoracic leg trachea (2lt), originating from the outer wall of the lateral trunk somewhere in the middle of the segment, goes to the mesothoracic leg. The 'dorsal and 'visceral' tracheae, in this segment, are also wanting. It is clear that the tracheal plan of the mesothorax is quite different from the typical tracheal plan in the abdomen.

The lateral trunk on entering the prothorax, dorsally receives the prothoracic spiracular trachea (spt). In the same

region, the ventral wall of the lateral trunk gives out the usual prothoracic leg trachea (1lt) which enters the leg independent of the 'additional prothoracic leg trachea' (1lt'+1lt"). From the mesal wall of the lateral trunk, <sup>slightly above the</sup> seat of origin of the prothoracic leg trachea starts the usual 'ventral trachea' (vt) which running obliquely inwards, puts itself in communication with its counterpart thereby forming the 'ventral commissure' (vc), which crawls across the prothoracic venter. The lateral trunk, before entering the head, gives rise to another short trachea from its mesal wall which is regarded as 'second ventral trachea' (vt). This trachea expands into a bulbous air-sac (F) whose posterior tip receives a branch from the usual 'ventral trachea'. The two air-sacs are joined through a small transverse trachea, the 'second ventral commissure' (vc). These air-sacs are responsible for supplying branches to the entire prothoracic region excepting the legs. Like other thoracic segments, this segment also lacks the usual 'dorsal' and 'visceral' tracheae.

Tracheation of the head (Fig. 136).

The lateral trunks converge to enter the head through foramen magnum. In the region of the foramen magnum each trunk bifurcates into dorsal and ventral tracheae (Dt & Vt). These further bifurcate to form four short tracheae. These branches ultimately ramify to supply air to the structures enclosed within the head.

(vi) The Male Reproductive System (Figs. 137,138,139,140,141 & 142).

The male reproductive system consists of paired testes (Tes) with vasa deferentia (Vd), seminal vesicles (Vsm), accessory glands (AcGl) and an unpaired ejaculatory duct (Dej).

Testis (Tes). — The bunch-like light yellowish testis<sup>e</sup> lies on the side of the hindgut, entangled in the Malpighian tubules. The bunched condition of the testis is due to globular nature of the testicular follicles (tf) which possess broadly rounded apices. This condition of the follicles is responsible for the uneven surface of the testis. The follicles are contained in an investing peritoneal sheath with islands of nuclei distantly placed. The globular follicles are arranged in obliquely longitudinal manner with the result that their apices are little removed from the base of the vas deferens. The free end of each follicle is drawn out into a short passage called vas efferens. Since Snodgrass (1956) has also shown the presence of multifollicular condition of the testis of the honey bee, while Alam (1953) has reported its absence in the testis of S. deessa, it can be concluded that Braconidae is better evolved than Apidae and Tenthredinidae. The follicular wall consists of syncytial epithelium (sEpth) with scattered nuclei. The follicular epithelium forms 'interfollicular septum' (ifs) in between the two adjacent follicles. Due to non-tubular nature of the follicle, it is quite difficult to differentiate the various zones based on spermatogenesis. However,



at least two distinct zones are easily marked out, viz, germarium and zone of transformation. The area lying in between these zones may be taken as the zone of growth-cum-maturation.

Vas deferens (Vd). — The tubular vas deferens can conveniently be divided into three portions : (i) proximal vas deferens (pVd) (ii) seminal vesicle (Vsm) and (iii) distal vas deferens (dVd). The proximal vas deferens emerges from the base of the testis as a narrow tube and obliquely traverses the body cavity till it meets the proximal tip of the seminal vesicle. Its lumen is in the form of a narrow passage which is surrounded by a thick wall made up of a strong circular muscle layer (cmcl). The latter is internally followed by an epithelial layer (Epth) supported on a basement membrane (bMb) while externally it is ensheathed by the peritoneum (p). The epithelial cells are cubical with feebly granulated cytoplasm and small nuclei lying in the middle. The free inner margins of the cells are non-striated. The intima is also wanting. The distal vas deferens, in all respects, is identical to the proximal vas deferens except that the former is longer and receives the opening of the accessory gland. Its lumen puts the lumina of seminal vesicle and ejaculatory duct in communication with one another.

Seminal vesicle (Vsm). — The seminal vesicle is formed as a result of convolutions in a portion of the vas deferens which are enclosed within the peritoneum. Histologically the seminal

vesicle resembles the vas deferens. However, its lumen is much wider and the muscle layer comparatively weaker as compared to that of the vas deferens.

Accessory gland (AcGl). — The distal vas deferens, on its way to the ejaculatory duct, receives at its bend, the opening of the kidney-shaped accessory gland. The latter is enclosed in a peritoneal layer (p) which is in continuation with the peritoneal layer of the vas deferens. The thick wall of the gland is contributed by the epithelial layer (Epth) of columnar cells with distinct nuclei (nu). Basally, the epithelium is limited by the basement membrane (bMb) and its inner surface is devoid of intima. The basement membrane is surrounded by a thin layer of circular muscle fibres (cmcl). The longitudinal muscle layer, as in S.deesae, is absent.

Ejaculatory duct (Dej). — The two vasa deferentia converge to open into the unpaired tubular ejaculatory duct, with their peritoneal sheath (p) also extending over the latter. The fact that the vasa deferentia maintain separate entity at the time of their openings into the ejaculatory duct is justified by the presence of two separate lumina in the proximal portion of the ejaculatory duct. The lumen of the ejaculatory duct is encircled by the epithelium (Epth) which is supported on the basement membrane (bMb). The cytoplasm of the cubical cells is faintly granulated with the nuclei (nu) centrally placed. The

inner margin of the epithelium is run over by a distinct intima (In). The basement membrane is externally surrounded by a strong circular muscle layer (cmcl). As in S. deessa, the longitudinal muscle layer is absent. The ejaculatory duct runs through the entire length of the aedeagus to end at the base of the phallosome and thereby forming the only cellular portion of the aedeagus.

(vii) The Female Reproductive System (Figs. 143,144,145,146, 147,148,149 & 150).

The female reproductive system consists of two yellowish white ovaries (Ov) with short lateral oviducts (Odl), common oviduct (Odc), vagina (Vag), unpaired spermatheca (Spt) and the accessory gland (AcGl).

Ovary (OV). — The ovary is placed from second to sixth abdominal segment for most of the part, underneath the digestive tract. It is composed of ten polytrophic ovarioles (Ovl) in which oocytes (occ) and nurse cells (NrCl) are arranged in alternate manner. The terminal filaments of the ovarioles twist round each other to form a group of filaments commonly known as ovarian ligament (Lg). The two ovarian ligaments unite to form the median ligament which suspends the ovaries from the ventral face of the dorsal diaphragm, in the second abdominal segment.

Ovariolo (Ovl). — A mature ovariolo consists of the terminal filament (TF) germarium (Grm), vitellarium (Vtl) and the pedicel (Pdcl). The terminal filament (TF) is the thinnest part of the ovariolo. It is cylindrical and contains undifferentiated mass of cells enclosed within the peritoneal sheath. It is followed by the germarium (Grm) which is cylindrical and unchambered. The histology of this region reveals that the entire portion is externally enclosed by the peritoneal layer (p). Next to it, is a layer of syncytial epithelium with scattered nuclei which may be taken as inner wall of the germarium. The terminal portion of germarium is filled with primordial germ cells (Gcl) which are in the process of active division. Differentiation in structures, as a result of divisions, is more marked in the basal portion of germarium, where developing ova (oocytes) (Ooc), primordial nurse cells (trophocytes) (Nrcl) and developing follicular cells (cystocytes) (Fcl) have assumed their own shape. The follicular cells are in the process of migration to form the follicular layer. It is suggested that the follicular layer actually appears in the basal part of the germarium. The vitellarium (Vtl) occupies the major portion of the ovariolo. It is longer, as well as, wider than the germarium and acquires beaded condition due to the alternate arrangement of oocytes and nurse cells. This indicates chambered condition of vitellarium. Normally, the oocyte chamber is larger than the nurse chamber. These are always differentiable from each other by distinct constrictions at their junctions which are due to the inward

pushing of the follicular layer. The oldest oocyte lies at the base of the vitellarium while the youngest lies at the apex. The outer most lining of the vitellarium is the usual peritoneal sheath (p) which is the continuation of the same layer of germarium. It is followed by a distinct syncytial layer (sEpth) with scattered nuclei. This layer is similar to the syncytial epithelium of S.deesae (Alam 1963) and to the inner tunicapropria of Nezara viridula (Malouf 1933). Next comes the distinct follicular layer (Fcl). The cells of the follicular layer are cubical with big nuclei. The cell granulation is easily detectable. Similar condition has been reported in S.deesae. The externally visible circular constriction is internally represented by an infolding of the follicular epithelium (Ff). This drags in the syncytial and the peritoneal layers also. There is not much difference in the histology of the wall of 'oocyte chamber' and the 'nurse chamber'. However, it cannot be ignored that the follicular cells are poorly developed in the 'nurse chambers' as compared with those of 'oocyte chambers'. Each oocyte chamber contains a single developing oocyte (Ooc) which is supposed to get nourishment from the nurse cells (Nrcl) occupying the preceding nurse chamber. The lumina of the two chambers are in communication with one another through a circular passage corresponding to the external constriction. The developing oocyte is always enclosed in a noncellular transparent chorion (chr) which is secreted by the follicular cells. The chorion is very distinct in the oldest oocyte which obviously occupies the lower most chamber of the ovariole and is separated from the pedicel by

the intervention of the plug (pg). Each ovariole has a short pedicel (Pdcl) connecting the vitellarium with the lateral oviduct (Odl), which remains plugged with cellular mass.

Oviducts. — The pedicels of the ovarioles independently open into a short lateral oviduct (Odl) which bends inwards to meet its counterpart from the other side, underneath the rectum, to form the common oviduct (Odc). The last abdominal ganglion rests on the junction of the lateral oviducts with the common oviduct. The wall of the lateral oviduct is thrown into folds so as to accommodate the descending eggs. The epithelial layer (Epth) is suspended from the basement membrane (bMb). The cells are cubical possessing small nuclei and faint cytoplasmic granulations. Outside the basement membrane, is an extremely thin layer of circular muscle fibres (cmcl) which is obscure at places. This muscle layer is externally covered over by the peritoneal sheath (p) which is a continuation of the peritoneal layer of the ovarioles. Similar is the histological condition of the common oviduct.

Vagina (vag). — The common oviduct posteriorly leads into a spacious vagina which opens outside through gonopore (Gpr), at the base of the ovipositor (first pair of valvulae). The wall of the vagina is quite similar to the wall of the oviduct except that in this region the epithelium is internally separated from the lumen by the presence of a distinct intimal layer (In).

Spermatheca (Spt). — The spermatheca opens by a short duct into the dorsal wall of the common oviduct, quite close to its union with the vagina. It is sac-like with narrow and short spermathecal duct. The spermatheca has lumen which is surrounded by the epithelial layer (Epth). The latter consists of cubical cells possessing small nuclei and are without granulation. Externally, the epithelial cells rest over the basement membrane (bMb) while internally these are covered over by a thin intima (In). The entire body of the spermatheca is enveloped by a peritoneal sheath (p).

Accessory gland (AcGl). — The accessory gland is Y-shaped, with the stem of the 'Y' forming its duct and the divergent arms becoming the body of the gland. It is dorsal to the vagina with its duct opening almost at right angle in the vaginal dorsal wall. The duct of the gland dilates slightly, before opening into the vagina. The gland is enclosed within peritoneum (p). The epithelial layer (Epth) rests over a thin basement membrane (bMb). The epithelial cells possess big nuclei (nu) containing chromatin granules. The cytoplasm is distinctly granulated. Internally, the epithelium is covered over by thin intima (In). Histologically, the duct is similar to the glandular region except that the epithelial cells are cubical with smaller nuclei and faint cytoplasmic granulation.

(viii) The Nervous System.

The nervous system of A. proxima, consists of the central nervous system, the peripheral nervous system and the sympathetic nervous system. The main components of the central nervous system are the brain, lying above the stomodaeum, and the suboesophageal ganglion, placed below the stomodaeum in the cranium followed by ten ganglia of the trunk region borne by the ventral nerve cord. These give out branches which ramify over various parts of the body.

Brain (Fig. 151). — The brain comprises of the usual three regions viz., the protocerebrum (1Br), the deutocerebrum (2Br) and the tritocerebrum (3Br). The external demarcation between the protocerebrum and deutocerebrum is distinct, whereas, the tritocerebrum is not easily detectable.

The protocerebrum (1Br) is the largest among the subdivisions of the brain, forming its entire dorsal half. A faint groove (g) runs across its anterior face to justify its paired nature. The dorsal surface of protocerebrum is arched in the middle and depressed on the sides. The three ocelli (O) are carried on and innervated by the elevated portion, whereas, the optic lobes (OpL) are continuous with the sides of the protocerebrum. The optic lobes extend to the sides of the cranium to innervate the ommatidia of the compound eyes (E).



The deutocerebrum (2Br) is ventroanterior to the protocerebrum. It is a paired ganglionic centre whose two lobes are well demarcated externally and combiningly attribute to the oval shape of the deutocerebrum. Its anterior surface possesses a pair of small pear-shaped antennal lobes (AntL) which give origin to the antennary nerves (AntNv). These nerves enter the antennae to innervate them, as well as, to their extrinsic and intrinsic muscles.

The tritocerebrum (3Br) is the smallest portion of the brain forming its ventral area. Its paired condition is externally visible. Lateroventrally, it gives out two short and thick circumpharyngeal connectives which dive and flanking the pharynx, join the suboesophageal ganglion (SoeGng). Apart from these connectives, the tritocerebrum supplies paired nerves (frcon & LmNv) to the frontal ganglion and labrum. The labral nerve innervates the muscles of that region as well.

Suboesophageal ganglion (Fig. 151). — The lobular compound suboesophageal ganglion (SoeGng), lying underneath the pharynx and confined to the head capsule, is suspended from the tritocerebrum through the paired circumoesophageal connectives. It is composed of three pairs of ganglia which are very closely packed within a common external covering so as to assume its present compound nature. These ganglia are the mandibular, maxillary and labial ganglia. The suboesophageal ganglion is notched at both ends. Either side of the notch gives rise to

the posteriorly directed paired ganglionic connectives, connecting the suboesophageal ganglion with the first thoracic ganglion. The three ganglionic centres laterally give out paired mandibular (MdNv), maxillary (MxNv) and labial nerves (LbNv) which innervate the respective gnathal appendages.

Ventral nerve cord (Fig. 162). — There are ten ganglia (Gng) arranged in linear manner along midventral longitudinal line of the trunk. These ganglia are interconnected through short and paired interganglionic connectives (GngCon) and in association with the latter these form the ventral nerve cord (VNC). Each ganglion is paired with the two constituents enveloped in common external covering. The first three ganglia are confined to the venter of the thorax and are called the <sup>pro-</sup>meso- and <sup>metathoracic</sup> (1tGng, 2t Gng, 3tGng) ganglia. The remaining seven ganglia are the abdominal ganglia (aGng) which are placed in the venter of the abdomen.

The thoracic ganglia are comparatively larger than the abdominal ganglia. The prothoracic ganglion (1tGng) rides the proendosternum and laterally gives out four pairs of nerves which ramify in the prothorax excepting the posterior most among them which traverses across the segmental venter to enter the prothoracic legs. The mesothoracic ganglion (2tGng) lying on the mesoendosternum, also gives out four pairs of lateral nerves. The anterior pair goes to the forewings while the posterior pair enters the mesothoracic legs. The remaining two pairs innervate

other segmental structures. The metathoracic ganglion (3tGng) is the biggest of all and supplies nerves to the metathorax and propodeum. There is no separate ganglion for the propodeum, though in the larva, it possesses a ganglion. This condition suggests that the metathoracic ganglion is a combination of paired metathoracic and first abdominal ganglia of the larval stage. It gives out paired nerves to the hindwings, metathoracic legs and other structures of the metathorax. Besides, the posterior pair of nerves coming out from the posterior end of the ganglion, go to the propodeum and ramify over the propodeal structures.

The seven abdominal ganglia (aGng) are segmentally arranged in the middle of second to eighth sternum. Each ganglion gives out a pair of lateral nerves which ramify within the segment concerned. All the ganglia are of simple nature excepting the last one (VIII aGng) lying in the eighth abdominal segment which is complex and is the largest amongst them. In the female, where the eighth sternum is absent, this ganglion lies above the seventh sternum, close to the common oviduct. Apart from supplying a pair of nerves to its own segment (eighth segment), it posteriorly gives out additional two pairs of nerves. The anterior pair among them, goes to the ninth segment. Besides supplying to the muscles of the segment it also gives out branches to the internal reproductive organs. The posterior pair, consisting of comparatively thick nerves, ramifies over the external genitalia.

Stomatogastric nervous system (Fig. 153). — The stomatogastric nervous system is built on the same pattern as in Sceliphron cementarum (Dickley 1942) and S.deesae (Alam 1963). The unpaired frontal (FrGng) and hypocerebral ganglia (hGng) lie anterior and posterior to the brain respectively. The frontal ganglion is placed dorsal to, and at the junction of the cibarium with the pharynx. It is connected with the tritocerebrum by a pair of frontal ganglionic connectives (frCon). The frontal ganglion gives out anteriorly an unpaired frontal nerve (fNv). Likewise, posteriorly it gives birth to an unpaired recurrent nerve (rNv). The latter running backwards, along the dorsal surface of the pharynx, passes underneath the brain and the aorta to end on the hypocerebral ganglion which is distinctly oval in shape. The paired corpora cardiaca (Cc) lie dorsolateral to the hypocerebral ganglion. The close proximity of the hypocerebral ganglion with corpora cardiaca has concealed the interconnecting nerves. The corpora cardiaca are anteriorly connected with the protocerebrum through a pair of nerves called 'paracardiac' nerves (pcNv) while posterolaterally, these are connected with the corpora allata (Ca). The connecting ducts between corpora cardiaca and corpora allata are hardly detectable. The hypocerebral ganglion from its posterior face gives out a pair of recurrent nerves (rNv) which adhered to the dorsal surface of the stomodaeum, runs backwards upto the posterior half of the crop where these end by a pair of swellings called 'stomachick ganglia' (SmGng). These ganglia send out fine nerves to the associated portions of the stomodaeum and midgut.

## 5. B I O L O G Y

### (1) Introduction.

The mustard saw-fly (Athalia proxima Klug.) is one of the commonest species of insect-pests of Indian crop, in the plains. It has also been reported from hills. The adults of this pest do not impair with the vegetable crops; it is the larval forms which are responsible for their destruction. The larvae feed on green and tender leaves of crucifer plants viz., Raphanus sativus (radish), Brassica napas (turnip) and Brassica sp. (mustard) and occasionally on Brassica oleracea (cauliflower) and Brassica oleracea var. (cabbage). The wide range of hosts is responsible for year-round occurrence of the pest in the fields excepting January, May, June and December. This absence of the pest may be attributed to extreme weather conditions. Though A. proxima is commonly known as mustard saw-fly but its association with radish plants is more pronounced.

The life-cycle of A. proxima has been reported by Lefroy (1909) which involves no periodic specifications. After a long gap, Martelli (1932) published an account on the biology of a sister species, Athalia colibri. It includes general observations on the behaviour of the insect which, in no way, is a comprehensive work. Considerable works have been published on one or more aspects of the biology of other saw-flies; Miles (1932, 1935, 1936) on Hoplocampa testudinea klug., korsakova

(1927) on Nematus ventricosus klug., Fintescu (1928) on Hylotoma rosae, Bodenheimer (1932) on Cimbex quadrimaculata, D' Rozaria (1940) on Nematus ribesii, and Lejaune, Fell and Burbidge (1955) on Pristiphora erichsoni.

Although neglect of the detailed study on the biology of 'Indian mustard saw-fly' has encouraged the initiation of the present work which contains observations on the life cycle of the insect in fields, as well as, under controlled conditions. Besides, efforts has been made to record full observations on certain aspects of the behaviour of insect, viz., food selection, copulation, host selection and oviposition. This is done because no importance has, so far, been attached to the behaviour of insects, in India. Alam (1952) has recently drawn attention of entomologists towards this aspect of insect life. The present writer feels that more information on insect behaviour is likely to help in exploring their control measures. Gross study of larval morphology has also been done.

(ii) Methods of Rearing.

Glass jars of 6" x 5" x 3" size were selected for rearing purposes. Each rearing jar contained a specimen tube of 3" x 1" size filled to its one half with knop's solution. The mouth of the tube was plugged with cotton which was pierced through by a young radish plant so as to allow its roots to be submerged in knop's solution. By the side of the specimen tube, a piece

of cotton soaked in sugar solution was kept for the adults to feed upon. Two changes of the food was made in 24 hours. The males and females were liberated in the rearing jar and their escape was prevented by wrapping muslin piece round the mouth of the jar. The muslin piece was held in position with elastic rubber band. The rearing jars were placed in glass cages, each of 15" x 15" x 21" size. The cage contained two compartments, the upper bigger one for the rearing jars and the lower one for controlling the humidity of the cage. The humidity controlling lower compartment possessed rectangular glass troughs filled with aqueous KOH for maintaining almost constant humidity (65% to 70%). It was covered over by a sliding and perforated lid to prevent the insects from being drowned in the solution. The temperature was maintained between 70°F and 80°F throughout the breeding period by switching on electric bulbs fixed in the lid of the cage.

The adults in the rearing jars copulated and the females laid eggs inside the tissue of radish leaves. The specimen tubes along with the plants infested with the eggs were transferred to another set of circular jars, called pupation jars, of the size of 8" x 4" each. These jars contained sand filled to one third of their depth and had muslin pieces wrapped around their mouths. For regular supply of fresh food to the developing larvae, the leaves were changed twice a day. The sand in the pupation jar was provided for pupation. The adults, so emerged, were used as stock.

All the field experiments were conducted during the months of August and September when humidity and temperature were most suitable for the development of the insect.

(iii) Habits of the Adult.

It is quite easy to locate the adult of A. proxima in the field on account of its bright yellow and shining black colours which become more conspicuous against the green background of the fields. Generally the adult insect sallies forth, from plant to plant, <sup>in</sup> all the green fields. However, radish and mustard fields are chosen as favourable abode, for the simple reason that these provide the most favoured food of the larvae. Since the pests are in abundance in these two fields, it is obvious that successful copulations may occur there without the insects going in long search for the mating partners. This is, consequently followed by egg laying on the plants. Ordinarily, one would find the adult insect hunting down every approachable planted field in search of nectar. Sometimes the latter is not easily available which compels the adults to cut the margins of plant leaves. This results in oozing of the cell-sap which is sucked as food. The insect is not commonly visible on cloudy, as well as, on extremely hot and dry days. It is most active when the morning sun is flooding the green fields of summer and winter with dew-drops still persisting on plants, or else during rainy season when the sun has just unveiled itself after shaking off the clouds.



Usually the males are with peaceful disposition. This is not true for females who try to eliminate the rivals after a grim struggle while selecting egg-laying sites. The two such rival females prior to fighting face one another with their antennae wavering up and down. The clash is initiated by the collision of the heads followed by entanglement of the forelegs with the wings fluttering. They try to dislodge one another and finally the weaker one gives way and flies off.

The adults appear in the field in late February or early March after making way through silky puparia. The normal activities of the insects remain suspended twice in a year due to unfavourable conditions. This is done once in summer (May and June) and once in winter (December and January), when the temperature either rises or falls to the extent of intolerance. At both these occasions the insects hibernate in pupal form which is passed under the soil.

The average temperature at Aligarh is 77°F in the first week of March which rises to 95°F in April. By the beginning of May the relative humidity also falls to 14%. Under such hot and dry conditions, the insect finds it difficult to carry on normal activities. The larvae, by now having entered into the final larval stage, bore into the soil for pupation. The emergence is, however, delayed due to unfavourable conditions till the onset of rainy season. This behaviour of the insect is called 'summer hibernation'.

By the beginning of December the temperature again goes much below the limit of tolerance (average 45°F) for the insect. This initiates the usual 'winter hibernation' which lasts till first week of March.

Keeping in view the hibernating periods, the insect undergoes five life-cycles in a year. The first life cycle is completed before summer (May and June) while the remaining four occur after summer. Accordingly the present writer names them as 'pre-summer generation' and 'postsummer generation'.

It is interesting to observe that a break through 'winter hibernation' is possible under controlled conditions (temperature between 70°F 80°F and relative humidity between 65% and 70%), and the insect can continue breeding generation after generation without any break. Similar attempts could not be made for breaking the 'summer hibernation' due to unavoidable difficulties.

#### (iv) Copulation.

The following observations on the copulation behaviour of A. proxima are based on 40 pairs. Pupae were kept singly in separate tubes for emergence. The adults so emerged were kept in pairs, in separate rearing jars, for copulation. Due to the availability of food, the insects first impulse was to feed without bothering about the presence of the other sex. After emergence, the male, goes out in search of the mating partner. After

spotting the female, the male threw himself by her side like lightening. In case the female was not located, the male waited with great patience in one corner of the jar. With antennae standing erect, he remained keenly watchful. As the time slipped, his gestures betrayed impatience and the head moved sideways while the wings started fluttering. The movements ceased on the approach of female. Waiting no longer, the male came nearer her. Some of the males were observed getting to the females while these were still flying, and forced them to come on the ground.

Prior to actual copulation, both the male and female tapped each other by their antennae and forelegs. Usually the females took the initiative. During the play, the male moved to the side of the female to mount her, without any loss of time. This action of the male was accompanied by the fluttering of the wings. After obtaining firm hold on the female, the male arched its abdomen. Simultaneously the female raised its own, and the tips of the two abdomens met one another to initiate copulation. After this, the male came down and moved in a circle so as to stand with the female facing in opposite direction. This state of copulation lasted for about two minutes. At the end of this period, the female started sideways movements, simultaneously trying to push away the copulating male with the help of her hindlegs. This ultimately results in the separation of the mating partners.

The pre-mating period was found to be of one hour duration. The interval between two successive matings ranged from two to twelve hours with an average of four hours.

(v) Host Selection.

The experiment on host selection behaviour of A. proxima was carried out under controlled conditions (temperature-75°F to 80°F, humidity - 65% to 70%) in two stages. The plants used in the experiments were radish, turnip, cabbage, carrot, tomato, brinjal and luffa, planted in the specimen tubes filled with knop's solution (as described earlier).

First stage. — In this experiment seven glass jars, 8" x 4" each, were used. Each jar contained a specimen tube with one kind of plant and its mouth was covered with muslin piece. Five newly emerged females, after copulations, were allowed to remain in each jar for 12 days. At the end of this period the food plants were examined and eggs laid on each plant, if any, were recorded. The experiment was repeated ten times which obviously means that fifty young copulated females were provided with one kind of plant for egg laying. This experiment showed that carrot and tomato plants were totally neglected; leaves of brinjal and luffa plants were perforated but no eggs were laid, and radish, turnip and cabbage leaves were found to contain eggs. On the count of the eggs the probable liking for host plants came to radish, turnip and cabbage, in order of preference (Table No.1).

Table No.1

S.No.	Name of plant	Average number of perforations by female.	Average number of eggs laid by female
1.	Radish	4	60
2.	Turnip	7	40
3.	Cabbage	25	3
4.	Brinjal	16	nil
5.	Luffa	10	nil
6.	Carrot	nil	nil
7.	Tomato	nil	nil

Second stage. — In this experiment only radish, turnip and cabbage plants were used, since these were preferred in the first experiment. A circular glass trough of 15" diameter was selected and a circle of 12" diameter was drawn in its bottom. Twelve host plants mounted in specimen tubes, with their roots dipped in Knop's solution, were put alternately at equal distance from each other, on the circumference of the circle. Twenty young copulated females were released in the centre of the circle and the trough was covered with muslin cloth. The females were kept in the trough for 12 days to lay eggs on the available plants. This experiment was repeated 10 times which means that 200 females were given 120 plants for host selection. The result shows that the first preference of A. proxima goes to radish. It

is followed by turnip and cabbage as second and third preferences respectively (Table No.2).

Table No.2

S.No.	Name of plant	Average number of perforations, by female.	Average number of eggs laid by female.
1.	Radish	3	56
2.	Turnip	7	32
3.	Cabbage	10	null

(vi) Oviposition.

The average duration of the preoviposition period was  $7\frac{1}{2}$  hours with the maximum as 9 hours and minimum as 6 hours. The female, usually, selected tender leaves to deposit eggs. She started the process by tapping the upper face of the leaf with her antennae to discover the suitability of the spot. The spots, already used for egg laying were discarded. For egg laying, she held the leaf between her forelegs and by bending the abdomen round the margin, punctured the under surface. After a bit of drilling activity by the ovipositor, the egg was deposited inside the leaf, very close to its margin. The entire process took from 15 to 20 seconds. After oviposition, the ovipositor was withdrawn. Sometimes the ovipositor was withdrawn without the egg being laid. This was how the 'perforations' were made by the female.

In one sitting the female laid from 2 to 20 eggs with an average of 12 eggs. She could revisit a leaf and deposit eggs in it but well removed from the spots already containing eggs. However, the eggs were always deposited submarginally and in a single row, in each sitting. In the field, where the insect was free to move about from one plant to another, not more than two or three eggs were laid on one leaf and these were also considerably spaced, as compared to the conditions in laboratory where the eggs were too closely laid and their number per leaf was also greater.

The rate of egg laying by a female varied from 1 to 29 eggs per day, with an average of 7 eggs. This was quite low in the early days of the oviposition period with an average of 3 eggs per day. Later on, the rate increased to touch the average of 7 eggs per day.

There was also a lot of variation in the amount of eggs laid by different females during their life-times. The maximum number of eggs laid by a single female came to 131 while the minimum number was 12 eggs. However, the average number of eggs laid by a female was 61.

(vii) Pre-imaginal Stages.

Egg stage (Fig. 154). — It is quite easy to detect the eggs along the margin of the host leaf. These are arranged in a row with portion of leaf surface covering them. The eggs appear in

the form of yellowish green tubercles over the leaf surface.

The mature egg<sup>is</sup>/oval in shape, measuring about 2 mm in length. It is of cream colour but the colour changes to black with the age of egg.

In the laboratory, the eggs were allowed to hatch under suitable conditions of temperature and humidity (temperature-70°F to 80°F, humidity-65% to 70%). The incubation period ranged from 97 to 106 hours.

Larval stage (Figs. 155,156,157,158 & 159). — The newly hatched larva moved about for a while within the leaf tissue. Later on, it ate its way out of the tissue.

The larva immediately after hatching is light grey in colour with black head (H). The body, apparently, is not differentiated into thorax and abdomen. But the presence of three pairs of jointed thoracic legs (L) could be taken as proof of the identity of the thoracic region. On the other hand the abdomen possesses seven pairs of prolegs (1). These are borne by segments 2-8; while the first, last and penultimate segments are devoid of them. There are ten pairs of spiracles (sp). The two pairs of thoracic spiracles are intertergal in position lying between first and second, and second and third segments, respectively. But in abdomen, the paired spiracles are borne by the first eight terga on their sides.



There are five larval stages which took from 13 to 16 days to be completed (Table no.3). The colour of the larva immediately after moulting is light grey which changes to dark grey just before the next moulting. The larvae of all stages grow rapidly but proportionately in size.

The rate of consumption of food increased with the size. The voracious feeding nature of the larvae was also demonstrated by releasing 10 fully grown larvae in separate jars, each containing sufficient amount of radish leaves. It was discovered that within 12 hours they consumed 60 sq. inches of food area. This observation was also supplemented by field observations which showed that young radish plants were stripped off their leaves with in few days of infestation. Such devastating attack was followed by migration of larvae to the adjoining fields where food was available in good quantity. This migratory instinct had been confirmed<sup>in</sup>/experimental plots.

Experiments were also conducted to record larval stages and their durations in the field. For this purpose 30 circular spots, each of 18" diameter, were carved out in the experimental plot containing young radish plants. Each spot was covered with a shallow metallic drum open at both ends. The upper opening of the drum was covered with a thin piece of muslin cloth for easy flow of light and air to the interior. Fertilized females were released in these drums, for oviposition. In each drum, 10 eggs were allowed to develop. Observations showed that the

incubation period, in the field, ranged between 4 to 5 days. The larval stadia took 15 to 18 days for completion (Table No.4). Out of a total of 250 larvae, six cases of prolonged larval duration were recorded. This duration extended to an average of 27 days. Since only 2.4% of the total cases underwent prolonged larval duration, it would be quite reasonable to regard them as abnormal cases.

Table No. 3.

S.No.	Larval instar	Minimum duration	Maximum duration
1.	I	2 days	3 days
2.	II	2 "	3 "
3.	III	3 "	4 "
4.	IV	3 "	3 "
5.	V	3 "	3 "

Table No. 4.

S.No.	Larval instar	Minimum duration	Maximum duration
1.	I	3 days	3 days
2.	II	2 "	3 "
3.	III	4 "	4 "
4.	IV	3 "	4 "
5.	V	3 "	4 "

Food selection by larvae. — The larvae, in the course of their study, was detected feeding on a variety of plant leaves. This instigated the desire to carry out experiments on larval food selection behaviour and accordingly following experiments were conducted under controlled conditions.

First experiment. (Graph No.I). — In the first experiment 10 different kinds of plant leaves belonging to the families Cruciferae, Solanaceae, Malvaceae and Cucurbitaceae were selected. The plant leaves, of each type, measuring 50 sq. in. were placed in 10 glass jars each 8" x 4" in size, with open ends covered with muslin cloth. The measurements of the foods were made by drawing a rectangle of 10" x 10" on glass plate and leaves were arranged in it before being transferred to the jars. Thus, the rectangle was used as a measure for food. Ten larvae belonging to fourth instar were liberated in each jar for 24 hours. But before release, the larvae were starved for 24 hours. Six hourly observations were made to record the quantity of food consumed in each jar, and then food was also changed once after every six hours so that the larvae always got fresh supply of food. The experiment lasted for 24 hours (Table No.5). It is quite clear that preference for food comes in the following order: radish, mustard, turnip, and cauliflower. The remaining six plants (luffa, tomato, gourd, carrot, brinjal and ladiesfinger) were neglected altogether.

Table No.5

S.No.	Name of the plant used as food.	Total area of the leaves consumed by 10 larve during 24 hours.
1.	Luffa ( <u><i>luffa aegyptica</i></u> )	nil
2.	Radish ( <u><i>Raphanus sativus</i></u> )	72 sq. in.
3.	Tomato ( <u><i>Lycopersicon esculentum</i></u> )	nil
4.	Gourd ( <u><i>Lagenaria sp.</i></u> ).	nil
5.	Turnip ( <u><i>Brassica napus</i></u> )	59 sq. in.
6.	Carrot ( <u><i>Daucos carota</i></u> ).	nil
7.	Cauliflower ( <u><i>Brassica oleracea</i></u> )	9.8 sq.in.
8.	Brinjal ( <u><i>Solanum melongena</i></u> ).	nil
9.	Ladiesfinger ( <u><i>Abelmoschus esculentus</i></u> ).	nil
10.	Mustard ( <u><i>Brassica juncea</i></u> ).	69 sq. in.

Second experiment. — The second experiment was carried out in three stages. It was designed to find out the preference of food by larvae when both the fancied and despised foods were simultaneously made available to them. For this purpose a glass <sup>T</sup>though of 15" diameter was selected and a circle of 12" diameter was drawn in its bottom which was further divided into six sectors, each of 60°. The open end of the <sup>T</sup>though remained covered with muslin cloth.

First stage (Graph No.II). — On the periphery of the marked sectors, equal quantities of six types of leaves (including radish, mustard, turnip, carrot, tomato and brinjal) were put in such a manner so that the fancied foods alternated with the despised ones. Fifty larvae belonging to the 4<sup>th</sup> instar, after being starved for 24 hours, were released in the centre of the circle and allowed to make their own selection of food. This experiment lasted for eight hours. The results (Table No.6b) show that the larvae preferred radish, mustard and turnip leaves.

Table No.6a

(showing leaf arrangement in first stage).

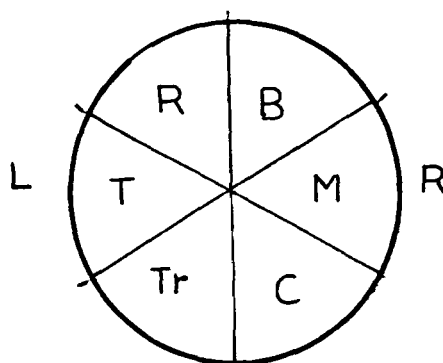


Table No. 6b.

S.No.	Type of plant leaves.	Total area consumed during eight hours.
1.	Radish (R)	65.34 sq.in.
2.	Tomato (T)	nil
3.	Turnip (Tr)	24.22 sq.in.
4.	Carrot (C)	nil
5.	Mustard (M)	59.12 sq.in.
6.	Brinjal (B)	nil

Second stage (Graph No.3). — In the second stage another set of fifty larvae of 4th instar, starved for 24 hours, was selected to be released in the centre of the circle. This time the six types of plant leaves were arranged on the periphery of the sectors in a manner so as to set the fancied foods in three adjoining sectors on the left side while the despised foods were put in the remaining three sectors on the right side, of the trough. The observations, recorded after eight hours, show that the larvae preferred radish, mustard and turnip over other foods (Table No. 7b).

Table No. 7a

(showing leaf arrangement in second stage)

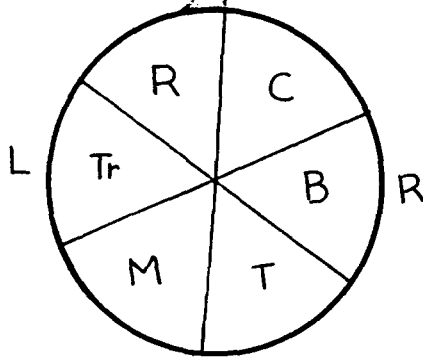


Table No. 7b

S.No.	Type of the plant leaves.	Total area consumed during eight hours.
1.	Radish (R)	74.52 sq.in.
2.	Turnip (Tr.)	41.44 "
3.	Mustard (M)	58.00 "
4.	Tomato (T)	nill
5.	Brinjal (B)	nill
6.	Carrot (C)	nill

Third stage (Graph No.4). — In the final stage the leaf arrangement differed from that of the second stage to the extent that the fancied foods were put on the right side, in the three adjoining sectors, while the three adjoining sectors on the left side contained the despised foods. Another batch of fifty larvae belonging to 4th instar, after being starved for 24 hours, were released in the centre of the circle. The amount of different foods consumed by them was recorded after eight hours (Table No.8b). It was observed that the change of sides did not affect the larval choice for food.

Table No. 8a

(showing leaf arrangement in third stage).

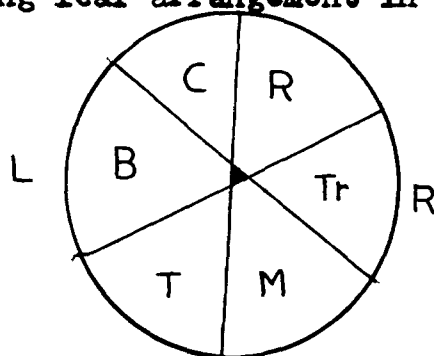


Table No. 8b

S.No.	Type of the plant leaves	Total area consumed during eight hours.
1.	Carrot (C)	nill
2.	Brinjal (B)	nill
3.	Tomato (T)	nill
4.	Mustard (M)	60.34 sq.in.
5.	Turnip (Tr)	45.1 sq.in.
6.	Radish (R)	83.22 sq.in.

The results obtained in the second set of experiments support the findings of the first experiment, which show that the larvae of A. proxima prefer radish, mustard, turnip and cauliflower leaves for their food and totally ignore the leaves of luffa, tomato, gourd, carrot, brinjal and ladiesfinger plants. These observations are fully endorsed by the study of the larval behaviour in the fields containing mixed crops of radish, turnip, cauliflower, tomato and carrot, which shows the order of preference for food, there, to be the same, i.e. radish, turnip and cauliflower. Since normally, mustard is not sown along with radish etc. in the same field, hence this food could not be included, for field study.

Soil selection for pupation (Graph No.5). — Eight kinds of soils of different compactness were selected for the experiment to find out larval preference of soil for pupation. These soils were, dry moulding clay, wet moulding clay, dry sand, wet sand, gravel, softly dried clay prepared by drying wet clay in bright sunlight for five days and clay baked to the hardness of brick. The eighth type of soil was the ordinary soil from a radish field. This soil was taken as standard for comparative purposes. The soils were put in eight circular rearing glass jars (8" x 4" in size) to one half of their depths. In each rearing jar a batch of 20 final instar larvae were kept and green radish leaves were provided as food. The mouth of each jar was covered with muslin cloth.



The resistance of the soils were tabulated by subjecting them to 'unconfined compression test'<sup>1</sup>. The relative value of the force applied by the machine and the penetration (deformation) into the soil gives the amount of resistance offered by the soil.

The relative resistances of the soils and the number of larvae boring into them for pupation are indicated in table no.9.

It is quite clear from table no.9, as well as from graph no.5 that the larvae are absolutely incapable of boring into a soil of very high resistance (baked clay). It is also clear that there is a tendency on the part of the larvae to prefer soil of low resistance for penetration, as the maximum penetration is recorded in a soil of 5lbs/in. resistance. With this trend of preference of soil the maximum penetration should normally have occurred in 'gravel' having unmeasurable low resistance. However, the readings show that penetration percentage is only 65% in gravel. This marked deviation from the general trend has been attributed to the large sized gravel pieces which might have obstructed the boring by the larvae. This explanation gets strength from the experiment with sand

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1. The text was brought about by 'stress measuring' machine designed by K.C. Productions, Fulham, London, which is installed in 'Civil Engineering Laboratory' of the 'Engineering College', A.M.U. Aligarh. The testing experiments were carried out under the supervision of Dr. Bahaudain of the Civil Engineering Department.

where the penetration was of great success presumably due to very fine size of sand particles which could not obstruct the boring.

Table No. 9.

S.No.	Type of soil.	Resis- tance of soil.	No.of larvae relea- sed.	No.of larvae penetr- ated soil.	Penetration percentage.
1.	Standard soil (from radish field).	12 lbs/in.	20	18	90%
2.	Dry moulding clay.	18 "	20	15	75%
3.	Wet moulding clay.	12 "	20	18	90%
4.	Dry sand.	5 "	20	19	95%
5.	Wet sand.	5 "	20	19	95%
6.	Gravel.	unmeasurable low resis- tance.	20	13	65%
7.	Softly dried clay.	16 lbs/in.	20	16	80%
8.	Baked clay.	unmeasurable high resis- tance.	20	nil	0.0%

Pupal stage (Figs. 160 & 161). — After about three days of active feeding, the fifth instar larva prepared to enter into the soil for pupation. On entering the soil, the larva construc-

ted an elliptical silk cocoon round its body, measuring from 7 m.m. to 10 m.m. in length and 4 m.m. to 6 m.m. in breadth. On the exterior of this cocoon, foreign bodies like sand grains or bits of vegetation got stuck giving coarse appearance to it. The cocoons occurred in the soil at various depths and could be traced from the surface of the soil upto a depth of  $3\frac{1}{2}$ ".

Within the cocoon, the last larval moult remained sticking to the body till the fourth day of pupation. On the fifth day the moulting skin detached from the body of the larva and the latter changed into nonpigmented 'prepupa'. Thus the larval period inside the cocoon was of four days duration. The prepupal body was subdivided into cephalic, thoracic and abdominal regions. This subdivision was based on annular constrictions between head and thorax, and between first and second abdominal segments. The internal appendicular buds also became evaginated. On the sixth day, the moulting skin was completely casted off. This synchronized with the change of 'prepupa' into a 'pupa'. The prepupal duration lasted for two days (fifth and sixth days of pupation).

The pupa resembled the adult with three distinct tagmata regions and their developing appendages. On the eighth day of pupation the pigmentation started from the paired eyes and gradually the entire body assumed the colouration of the adult. At the end of the 10th day, the emergence occurred. Accordingly, the pupal period lasted for four days.

The entire quiescent period ranged between 10 and 15 days with an average of 13 days.

In the fields, the quiescent period lasted from 10 to 20 days with an average of 15 days. Sometimes, the quiescent period got prolonged upto 28 days. This abnormality was attributed to heavy rains.

(viii) Mortality during Development.

The females were collected from fields and were put in the glass cages along with the males, for 24 hours, for copulation. The females observed copulating in captivity numbering 40, were selected for egg laying. These were released in 40 glass jars (6" x 4" x 3" in size) covered over by muslin cloth and possessing young radish plants growing in specimen tubes with Knop's solution. All the females laid 2300 eggs on the radish plants within the glass jars till their death. After every 24 hours, radish plants infested with eggs were removed to the rearing jars for further development and new plants were placed in their place, for egg laying. The rearing jars contained standard soil from the radish field for pupation. The food of the developing larvae were changed twice a day till all of them pupated and finally emerged as adults. At every stage of their transformation a record was maintained. This is indicated in table no. 10, which shows that during development eggs suffered a mortality of 25%, larvae only of 4% while pupae of 38%.

To record the rate of mortality during development in the field, experimental plots with very young uninfested radish plants were covered by metallic drums of 18" diameter. All the developmental stages of the insect were observed within these drums. The record of these observations is shown in table no.10, by which it can be concluded that in all the stages, the rate of mortality in the field was higher than what it was under controlled conditions. The eggs showed a death rate of 39%, larvae of 38% and the pupae of 50%. In the field the higher death rate among eggs may be attributed to the early withering of egg-bearing leaves either due to physical injury or else due to insufficient supply of food. The higher mortality at the larval stage can be due to the presence of predators including ants. Further, higher mortality in the pupal stage may be due to some barriers caused in the natural condition of the soil.

Table no. 10.

Observations		Eggs.	Larvae	Pupae	Adults
Under controlled conditions.	Actual number observed	2300	1724	1652	1032
	Rate of mortality	---	25%	4%	38%
in the field	Actual number observed	980	596	368	183
	Rate of mortality	---	39%	38%	50%

(ix) Parthenogenesis.

Thirty females, immediately after their emergence, were isolated to avoid every chance of copulation. These were released in separate glass jars (6" x 4" x 3" in size) covered by muslin cloth and possessing young radish plants growing in specimen tubes containing Knop's solution. Each female laid, at an average, 60 eggs. All these eggs subsequently developed into males only.

Similarly isolated females were liberated in the experimental plots with young radish plants covered over by metallic drums. There, too, the eggs were laid by uncopulated females which finally developed into males.

These observations are contrary to the view expressed by Lefroy (1909) who considers that parthenogenesis, though of common occurrence in the family Tenthredinidae, should not occur in A. proxima as their males are commonly found.

(x) Longevity of the Adults.

Under normal conditions the males survived from 9 to 17 days with an average duration of 12 days. However, the longevity of females much depended on their egg laying opportunity. Normally, these died on laying the entire lot of eggs, after an average duration of 14 days. But the life-span of females increases slightly if these are not allowed to deposit eggs. In that case the life-span varies from 12 to 24 days with an average of 17 days.

(xi) Anatomy of the fully grown Larva.

External structure of larva (Figs. 165,166,167,168,169,162,  
163,164,165 & 166).

The larva is soft, dark grey and cylindrical with 13 segments (3 thoracic and 10 abdominal). There are 10 pairs of spiracles (sp). The first two thoracic spiracles are intersegmental while the rest are borne by the first eight abdominal segments. There are three pairs of thoracic legs (L) followed by seven pairs of prolegs (l) in, second to eighth abdominal segments.

The hypognathous head (h) is shining black in colour and suboval in form. The face is traversed by an inverted Y-shaped scapsial line (Y) whose two arms end on the anterior tentorial pits (at) while the stem running across the top of the head ends in the middle of the post-occipital suture (pos). The four segmented short antennae (Ant) are based lateral and close to the anterior tentorial pits. The paired lateral ocelli (O) are located slightly lateral and dorsal to the antennal bases.

The epistomal suture (es), running between the two anterior mandibular articulations and bearing the anterior tentorial pits (at), demarcates the crescent-shaped clypeus (Clp) from the rest of the face.

The subgenal suture (sgs) starts from the lower end of the postoccipital suture and is separated from the latter by posterior tentorial pit. While descending, it becomes submarginal before taking a turn to crawl over the anterior face of the

cranium for ultimately ending above the anterior mandibular articulation, where it joins the epistomal suture. The entire suture can be subdivided into hypostomal (hs) and pleurostomal sutures (ps), the former running from the posterior tentorial pit to the posterior mandibular articulation and the other, from the posterior mandibular articulation to the anterior mandibular articulation. The narrow submarginal areas so demarcated become the hypostoma (hst) and pleurostoma (Pst), respectively. The hypostoma, above the base of the maxilla, and under the foramen magnum, is drawn in as a narrow plate which may be regarded as incomplete hypostomal bridge.

The inverted U-shaped postoccipital suture (Pos ) runs almost marginal to the foramen magnum (For), with its two ends merging with the subgenal suture.

The paroccipital suture (paros) starts from the postoccipital suture and running across the top of the head ends at a place, far removed from the arms of the ecdysial line. Thus, the generalized occiput is subdivided by the two paroccipital sutures into a median (moc) and two lateral (Loc) occiputs.

There is no distinct frons separable from the parietals (genae) due to the total absence of frontogenal suture. However the ventral limit is well demarcated by the epistomal suture. It is therefore suggested that the entire facial area, dorsal to the epistomal and pleurostomal sutures, may be regarded as frons-cum-genae (FrGe). On the basis of locations, the antennae



and the ocelli could be taken as genal in position for the sake of convenience. The small top area of the cranium flanked by the anterior ends of the paroccipital sutures is regarded as the vertex (Vx). This is contiguous anteriorly with the median portion of the frons-cum-genal area and posteriorly with the median occiput.

The tentorium consists of paired anterior arms (AT), posterior arms (PT), and dorsal arms (DT). The dorsal arm, emerging from the distal end of the anterior arm, ascends to meet the facial wall just dorsal and mesal to the antennal socket. The anterior and posterior pair of arms are stout with their bases in the anterior and posterior tentorial pits. The basal portions of the posterior tentorial arms mesally extend to form the body of the tentorium.

The mouth is dorsally protected by the labrum (Lm), ventrally by the labium (Lb) and laterally by the paired maxillae (Mx) and mandibles (Md).

The labrum (Lm) is semicircular, semisclerotized plate hanging from the ventral margin of the facial region. From its posterolateral angles, extend a pair of 'tormae' on which are inserted the 'retractor' muscles (No.153). The latter originate from the lateral portions of the frons-cum-genal area

The mandible (Md) is well sclerotized and triangular in out line. The impregnated basal rim (r) is in articulation with the ventral margin of the cranium through 'anterior' (c) and

'posterior (a) articulations. The pointed apex of the mandible is dentated. The mandible is controlled by 'adductor' and 'abductor' muscles. The two bundles of 'adductor' muscle (No. 154) originate in the region of 'vertex' and 'occiput' and are inserted, through an apodeme, on the basal rim of the mandible, close to its anterior articulation. The fibres of 'abductor' muscle (No.155) start from the postgenal area and end on the basal rim of the mandible, behind its posterior articulation.

The maxilla (Mx) is feebly sclerotized with cardo articulating with hypostomal bridge. The cardo (Cd) and stipes (St) are contiguous through flexible hinge line (StCdh). The stipes is split up into two longitudinal plates due to the intervening incomplete fissure. The lateral plate bears four segmented palp (MxPlp), while the mesal one ends in distal lobes. The outer and larger lobe is the galea (Ga) while the inner and the smaller one is the lacinia (Lc).

The maxilla is controlled by five extrinsic muscles. Three of them originate from anterior tentorial arm (AT) and running obliquely downwards, these end on the two plates of the stipes and on the cardo close to the hinge line. Out of these muscles, the anterior most is the 'first adductor of maxilla' (No.166). It is inserted on the lateral plate in its middle. The middle one is the 'second adductor of maxilla' (No.157) which ends on the proximal region of the mesal plate. The

posterior one is the 'third adductor of maxilla' (No.158) which is attached in the distal portion of cardo. The promotor of maxilla' (No.159) originating from the posterior wall of the cranium descends and is attached through an apodeme on the proximal end of cardo. The fifth extrinsic muscle becomes the 'first flexor of lacinia'. (No.160). It arises on the cranial wall to end on the base of lacinia.

There are three intrinsic muscles of the maxilla. One of them is regarded as 'second flexor of lacinia' (No.161), originating in the proximal portion of the mesal plate of stipes, to end on the base of lacinia lateral to the 'first flexor of lacinia'. The remaining two are the 'levator' (No.162) and 'depressor' (No.163) muscles of maxillary palp. Both of them arise from the middle portion of the lateral plate of stipes and running almost parallel, end in the basal angles of the maxillary palp. The outer among them, on the basis of origin and insertion, is regarded as 'levator'.

The musculature of the maxilla in the present case is comparable with the musculature of maxilla of Periplaneta americana (Snodgrass 1935). The latter consists of two stout 'adductors' arising on the tentorium and inserted in the cardo and the stipes. These are comparable to the comparatively feebler 'first', 'second' and 'third adductor' muscles of the maxilla. The 'first' and 'second flexor' muscles of lacinia in the present case may be compared to the 'cranial flexor' and

the 'stipital flexor' muscles of lacinia in P.americana, respectively. The 'promotor of the maxilla', and the two muscles of the maxillary palp are also represented in P.americana.

All the maxillary muscles of A.proxima are represented in Xiphydria prolongata as shown by Short (1952). The 'first adductor of maxilla', 'second adductor of maxilla' and 'third adductor of maxilla' are equivalent to muscles numbered as 13, 12 and 11 respectively, in X.prolongata. The 'promotor of maxilla', the 'first flexor of lacinia', the 'second flexor of lacinia' the 'levator of maxillary palp' and the 'depressor of maxillary palp' are comparable to muscles numbered as 10,14,15, 17 & 18 respectively in, X.prolongata.

The feebly sclerotized labium (Lb) is subdivided by a distinct labial suture (lbs) into a large distal prementum (Prmt) and a small proximal postmentum (Pmt). The postmentum is a sclerotic plate while the prementum is a combination of sclerotized and membranous areas. The latter is confined to the mesal portion of the dorsal surface of the prementum. The lateral limits of the prementum are raised into two convergent ridges, which enclose an inverted vase-shaped membranous area. The ridges become the walls of the hypopharynx (Hphy) whereas the enclosed membranous area forms its roof, which is actually the mesal portion of dorsal surface of prementum. Three segmented labial palps (LbPlp) hang from the sides of the prementum. The distal lobe of the prementum is not differentiable into

glossa and paraglossae. However, its tip contains the orifice of the salivarium (Slv).

The entire prementum is controlled by the following three muscles. The 'first adductor of the labium' (No.164) originates on the tentorium and ends on the labial suture. It is equivalent to the labial adductor' (2adlb) of Gryllus assimilis (Snodgrass 1935). The 'second adductor of the labium' (No.165) also commences from the tentorium which ends on the undivided distal lobe. Thus, it is comparable to the 'labial adductor (laalb) of G.assimilis. The 'retractor of the prementum' (No.166) arises on the middle portion of the proximal margin of postmentum and is inserted on the labial suture, mesal to the 'first adductor of labium'. This muscle is comparable to the 'retractor of the prementum' (rst) of G.assimilis.

The labial palp is controlled by a 'levator' and a 'depressor' labial muscles. The 'levator' muscle (No.167) of the palp, starting from the lateral wall of the prementum, is inserted on the outer basal angle of the palp. Likewise the 'depressor' (No.168) of the labial palp originates on the prementum but mesal to the 'levator' muscle and ends on the mesal basal angle of the palp. These two muscles are equivalent to the 'levator' (lplp) and 'depressor' (dplp) muscles of labial palp in G.assimilis.

The 'dilator of the salivarium' (No.169) consisting of parallel fibres, originates on the lateral wall of prementum.

Running obliquely inwards, the fibres end in a line on the dorsal surface of the salivarium.

In Sirex cyaneus, Short (1952) has shown the following labial muscles : 'posterior or ventral retractor of the prementum' (23), 'anterior or dorsal retractor of the prementum' (24), 'dorsal muscles of the salivarium' (15) and 'median muscles of the labium' (rst). These are considered similar to the 'first adductor of the labium', the 'second adductor of the labium', the 'dilator of the salivarium' and the 'retractor of the prementum' respectively, in A. proxima.

Internal anatomy (Figs. 167,168,169,170 & 171).

The digestive system. — The alimentary canal consists of usual three subdivisions, foregut, midgut and hindgut. The foregut is extremely narrow, cylindrical and tubular in form. It anteriorly communicates with the preoral food chamber through the true mouth (Mth). The region of foregut within the cranium is the pharynx (Phy) which may be split up into anterior pharynx and posterior pharynx, according to its position with respect to the brain. The portion of the foregut leaving the cranium is the oesophagus (Oe) which is extremely short and is immediately followed by the midgut (MG). The latter is the broadest and longest portion of the alimentary canal and is of uniform thickness throughout its course. The malpighian tubules (Mal) open in the alimentary canal, at the junction of the midgut and the

hindgut. The latter consists of two distinct portions, the anterior one is called 'intestine' (Int) and the posterior one, rectum (Rect). The rectum tapers to end as anus (An), at the posterior tip of larval body.

Silk gland. — The silk gland is profusely branched, filling almost entire body cavity. There are two main tubes which ramify into secondary branches bearing numerous ampulla-like structures (amp). The two main tubes, the lateral salivary ducts (lsd), independently leave the prothorax to enter the head where they immediately fuse to form the 'common salivary duct' (SID), which, in the region of prementum dilates to form the 'salivarium'. The latter anteriorly opens through an orifice borne by the tip of the distal lobe of labium.

Excretory system. — There are ten long cylindrical Malpighian tubules (Mal) which lie in the visceral sinus, parallel to the wall of the gut in postero-anterior direction. These open in a circle, at the junction of midgut and hindgut. These are cream ~~in~~ colour and are closed at their free ends.

Respiratory system. — It consists of two main tracheal trunks (LT) traversing the body laterally underneath the rows of spiracles. These receive dorsolaterally short spiracular tracheae (spt) from the spiracles.

The tracheation plan is similar in the first eight abdominal segments. Two tracheae come out dorsally from the lateral trunk, slightly posterior to the segmental spiracular trachea. The anterior of the two, is the 'dorsal trachea' (dt) which ascends to supply to the heart in the pericardial sinus and to the dorsal portion of the segmental wall. The posterior one is called the 'visceral trachea' (vst) which supplies to the viscera in the visceral sinus. The lateral trunk, from its mesal wall gives out a mesally directed trachea, the 'mesal trachea' (mt), which on entering the perineural sinus immediately divides into 'anterior (ab), posterior (pb) and 'mesal' branches (mb). The anterior branch of one segment meets the posterior branch of the preceding segment with the result that two supplementary longitudinal trunks are formed which can be called as 'ventral longitudinal trunks' (vt). The mesal branch transversely runs across the venter and after joining its counterpart on the other side, it forms the 'ventral commissure' (vc) which gives out branches to the structures lying in the perineural sinus. In the ninth abdominal segment the lateral trunks move towards one another and fuse to form the 'ventral commissure' of the segment. Due to the absence of normal branches in the ninth segment, it gets tracheal ramifications from the segmental tracheal branches of the eighth segment. The ninth 'ventral commissure' posteriorly gives out tracheae for the tenth segment.



The lateral trunk, on entering the metathorax, gives out the mesal branch (mb) which remains undivided and forms the 'ventral commissure' (vc) after meeting its counter part of the other side. Structures in the lower half of metathorax are supplied by the tracheal branches coming out from the 'ventral commissure', as well as, direct from the lateral trunk. In mesothorax, apart from receiving the spiracular trachea (spt) and giving out mesal branch (mb) to form the 'ventral commissure' (vc), the lateral trunk also gives out a 'dorsal trachea' (dt) which bifurcates into 'anterior' (adt) and 'posterior' (pat) branches. The former, loops forward to again meet the lateral trunk in the prothorax, slightly anterior to the first spiracular trachea. On its way, this trachea gives out branches to the structures in the upper half of mesothorax, while the remaining mesothoracic structures are supplied by branches coming out from the 'ventral commissure' and also direct from the lateral trunk. The posterior branch of the dorsal trachea also forms a loop and joins the lateral trunk in the region of metathorax, opposite to the mesal branch. On its way, it gives out branches to the structures in the dorsal half of metathorax. In the region of prothorax, the lateral trunk besides receiving the spiracular trachea (spt), gives out mesal branch (mb) which forms the 'ventral commissure' (vc). This commissure supplies branches to the prothoracic structures.

The lateral trunk, before entering the head, bifurcates. The four branches of the lateral trunks, enter the head through foramen megnum. These again divide and the eight tracheae, so formed, supply air to the structures in the head region.

On the basis of the number of ventral commissures Alam (1958) has attributed better evolutionary status to Encyrtidae over Braconidae. Applying the same, it can safely be said that Tenthredinidae is more primitive than Braconidae.

Circulatory system. — The circulatory system is composed of three sinuses, eight chambered heart and aorta. The pericardial (dorsal) sinus and the perineural (ventral) sinus are separated from the visceral (middle) sinus by the membranous dorsal and ventral diaphragms. The heart (Ht) runs midlongitudinally, in the lap of the dorsal diaphragm (dDph) whose weak alary muscle fibres (dDphmcl) are fastened laterally on the undersurface of terga. The spaces, between consecutive points of attachment, allow the flow of blood from the visceral sinus to the pericardial sinus. The fibres of each alary muscle starting from their point of attachment on the tergum take up a divergent course to end by spreading, on the side wall of the heart. The segmental arrangement of the paired alary muscles corresponds with the number of heart chambers. Since there are eight pairs of alary muscles, thus the heart is also eight-chambered, which is stretched from eighth to the first abdominal

segment with its chambers placed segmentally. Its first (posterior) chamber is blind posteriorly while the eighth (anterior) chamber on entering the thorax tapers into a short aorta. Each chamber, at its junction with the following chamber, is provided with a pair of lateral ostia (ost). Thus, in all, eight pairs of ostia are present. The aorta runs across the thorax, under the dorsum, to enter the head capsule where it ends by flattened aperture.

The ventral diaphragm, stretching over the perineural sinus, extends from the first thoracic segment upto the ninth abdominal segment. It is attached to the body wall, on the sides, only at places, so that the attachments are alternated by intersegmental open spaces which allow flow of blood from the perineural sinus to the visceral sinus. Frail muscle fibres transversely run over the ventral diaphragm.

Nervous system. — The central nervous system consists of the brain (Br), sub-oesophageal ganglion (SoeGng) and nerve cord (NC). The brain, though shows a dorsal median depression, is undifferentiated. Anteriorly, it gives out a pair of thick antennal nerves and ventrally a pair of circumpharyngeal connectives (PhyCon) which join it with the suboesophageal ganglion after encircling the pharynx. The suboesophageal ganglion, posteriorly gives out paired nerve cord which extends through the entire body excepting the last two segments. The eleven ganglia (Gng),

belonging to eleven body segments, lie on the nerve cord. The three thoracic ganglia are bigger in size and each gives out two pairs of nerves, while the abdominal ganglion gives out only one pair, in each segment. The exception is the last abdominal (eighth) ganglion which is comparatively bigger than others and also gives out four pairs of nerves. The latter branch out in the eighth, ninth and tenth abdominal segments. Moir (1963) has also shown the presence of twelve segmental ganglia, including suboesophageal ganglion, in full grown embryo of A. proxima.

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7. ABBREVIATIONS

The Head.

a	.....	Posterior articulation of mandible.
ac	.....	Cardine.
Acon	.....	Antennal concavity.
af	.....	Antennefer.
Ant	.....	Antenna.
Aphy	.....	Anterior pharynx.
ArcPrmt	.....	Articular concavity of prementum.
ArkLc	.....	Articular knob of lacinia.
ArkPe	.....	Articular knob of pedicel.
ArkSc	.....	Articular knob of Scape.
as	.....	Antennal suture.
Asoc	.....	Antennal socket.
AT	.....	Anterior tentorial arm.
at	.....	Anterior tentorial pit.
bscl	.....	Basal sclerite of galea.
c	.....	Anterior articulation of mandible.
Cb	.....	Cibarium.
CbPhySp	.....	Cibariopharyngeal sucking pump.
Cd	.....	Cardo.
Cl	.....	Club.
Clp	.....	Clypeus.
clpGes	.....	Clypeogenal suture.
drSc.	.....	Distal rim of scape.
DT	.....	Dorsal tentorial arm.



dt	.....	Tentorial macula.
E	.....	Compound eye.
Ephy	.....	Epipharynx.
es	.....	Epistomal suture.
fgs	.....	Frontogenal suture.
Fn	.....	Funicle.
For	.....	Foramen magnum.
Fr.	.....	Frons.
frclps	.....	Frontoclypeal suture.
frGng	.....	Frontal ganglion.
Ga	.....	Galea.
Ge	.....	Gena.
Gls	.....	Glossa.
HB	.....	Hypostomal bridge.
Hphy	.....	Hypopharynx.
hs	.....	Hypostomal suture.
Hst	.....	Hypostomal area.
Lb	.....	Labium.
LbPlp	.....	Labial palp.
Lc	.....	Lacinia.
Lm	.....	Labrum.
Loc	.....	Latepal occiput.
Lumiphy	.....	Lumen of hypopharynx.
Mclf	.....	Median cleft of prementum.
Md	.....	Mandible.
mf	.....	Mesal flap of anterior tentorial arm.
Moc	.....	Median Occiput.

mscl	.....	Mesal sclerite of galea.
mt	.....	Mentum.
Mx	.....	Maxilla.
MxPlp	.....	Maxillary palp.
o	.....	Ocellus.
Q	.....	Incisor area of mandible.
Oc	.....	Occiput.
Occ	.....	Occipital condyle.
os	.....	Ocular suture.
p	.....	Molar area of mandible.
paros	.....	Paroccipital suture.
Pe	.....	Pedicel.
Pge	.....	Postgena.
Pgl	.....	Paraglossa.
Phypl	.....	Pharyngeal plate.
Plg	.....	Plapiger.
Pmt	.....	Postmentum.
Poc	.....	Postocciput.
pos	.....	Postoccipital suture.
Pphy	.....	Posterior pharynx.
Prmt	.....	Prementum.
prPe	.....	Proximal rim of pedicel.
ps	.....	Pleural suture.
PT	.....	Posterior tentorial arm.
rm	.....	Basal rim of mandible.
rs	.....	Rim of scape.
Sc	.....	Scape.

sc1th	.....	Sclerotic teeth of galea.
sgs	.....	Subgenal suture.
SlD	.....	Common salivary duct.
Slv	.....	Salivarium.
Smt	.....	Submentum.
spscl	.....	Supporting sclerite of glossa and paraglossa.
St	.....	Stipes.
StCdh	.....	Stipitocardinal hinge of maxilla.
TB	.....	Tentorial bridge.
tr	.....	Torma.
Vx	.....	Vertex.

T h o r a x

acs	.....	Antecostal suture.
AEps	.....	Anepisternum.
AN	.....	Alinotum.
AmR	.....	Anterior marginal inflection of metanotum.
ANP	.....	Anterior notal wing process.
aR	.....	Ridge of metanotum.
Ba	.....	Basalare.
BaAp	.....	Basalare apodeme.
BS	.....	Basisternum.
CerAp	.....	Cervical apodeme.
Cerm	.....	Cervical membrane.
Cn	.....	Cenchri.
CxC	.....	Coxal socket.
CxLArk	.....	Lateral articular knob for coxa.

CxVArk	.....	Ventral articular knob for coxa.
DplEps	.....	Dorsal plate of proepisternum.
Endst	.....	Endosternum.
Epm	.....	Epimeron.
EpmPNB	.....	Epimeropostnotal bridge.
Eps	.....	Episternum.
EpsArc	.....	Articular concavity of episternum.
FA	.....	Furcal arm.
F1	.....	Furcal lobe.
FS	.....	Furcasternum.
K	.....	Sternal suture.
KEps	.....	Katepisternum.
MB	.....	Median bridge of pronotum.
Mclf	.....	Median cleft of propodeum.
ms	.....	Median suture.
msg	.....	Median sternal groove.
MSR	.....	Median sternal ridge.
N	.....	Notum (tergum).
OP	.....	Occipital process.
Opl	.....	Occlusor plate.
Pa	.....	Postalar bridge.
Par	.....	Parapside.
pCT	.....	Mesoprepectus.
pcts	.....	Prepectal suture.
Ph	.....	Phragma.
2PhLl	.....	Lateral lobe of mesopostphragma.
2PhLR	.....	Lateral ridge of mesopostphragma.

2PhMl	.....	Median lobe of mesopostphragma.
2PhMR	.....	Median ridge of mesopostphragma.
Pl	.....	Pleuron.
PlA	.....	Pleural apophysis
pla	.....	Pleural pit.
PlR	.....	Pleural ridge.
PlS	.....	Pleurosternal area.
PmR	.....	Posterior marginal inflection of metanotum.
PN	.....	Postnotum.
PNP	.....	Posterior notal wing process.
PR	.....	Parapsidal ridge.
Prst	.....	Prescutum.
ps	.....	Parapsidal suture.
S	.....	Sternum.
SA	.....	Sternal apophysis.
Sa	.....	Subalare.
SAR	.....	Sternal apophysis ridge.
ScI	.....	Scutellum.
ScI <sub>f</sub>	.....	Scutellar furrow.
Sc <sub>t</sub>	.....	Scutum.
Sc <sub>t</sub> c <sub>f</sub>	.....	Scutal cleft.
smR	.....	Submarginal ridge.
sp	.....	Spiracle.
spn	.....	Spina .
sppl	.....	Spiracular plate.
Ss	.....	Spinasternum.
IT	.....	Propodeum.

tes	.....	Transepisternal suture.
Tg	.....	Tegula.
ts	.....	Prescutal suture.
VplEps	.....	Ventral plate of proepisternum.
VH	.....	Notal ridge.
vs	.....	Scutoscutellar suture.

L e g s.

AF	.....	Arolium.
arc	.....	Arcus.
Btar	.....	Basitarsus.
BtarArk	.....	Articular knob of basitarsus.
Btarr	.....	Rim of basitarsus.
Cx	.....	Coxa.
CxArk	.....	Articular knob of coxa.
CxLArc	.....	Lateral articular concavity of coxa.
Cxr	.....	Rim of coxa.
CxVArc	.....	Ventral articular concavity of coxa.
Fm	.....	Femur.
1Fm	.....	Proximal portion of femur.
2Fm	.....	Distal portion of femur.
FmArk	.....	Articular knob of femur.
Fmcon	.....	Femoral concavity.
Fmr	.....	Rim of femur.
gf	.....	Genuflexor plate.
mn	.....	Manubrium.
pln	.....	Planta.

Ptr	.....	Pretarsus.
sAcl	.....	Spur of antenna cleaner.
Tar	.....	Tarsus.
Tb	.....	Tibia.
TbArc	.....	Articular concavity of tibia.
TbArk	.....	Articular knob of tibia.
TbP	.....	Tibial process.
Tbr	.....	Rim of tibia.
Tr	.....	Trochanter.
TrArk	.....	Articular knob of trochanter.
TrP	.....	Trochanteral process.
Trr	.....	Rim of trochanter.
Un	.....	Claw of pretarsus.
Ur	.....	Unguifer.
Utr	.....	Unguitractor.

W i n g s .

A	.....	Anal vein.
Ax	.....	Axillary sclerite.
AxC	.....	Axillary cord.
C	.....	Costa.
C	.....	'Costal' cell.
Cul	.....	Cubitus.
∕ Cul	.....	'Cubital' cell.
Cu-a	.....	Cubito-anal cross vein.
Cu <sub>a</sub>	.....	Cubital-a branch.

Cula	.....	'Cubital-a' cell.
Culb	.....	Cubital-b branch.
Culb	.....	'Cubital-b' cell.
cv	.....	Anal cross vein.
DA	.....	Distal anal cell.
ff	.....	Frenal fold.
fh	.....	Frenal hooks.
HP	.....	Humeral complex of forewing.
HP	.....	Humeral plate of hindwing.
jf	.....	Jugal fold.
Ju	.....	Jugum.
M	.....	Media.
M	.....	'Medial' cell.
m	.....	Median plate of forewing.
M+Cul	.....	Media-cum-cubitus.
M+Cul	.....	'Media-cum-cubital' cell.
m-cu	.....	Mediocubital cross vein.
PA	.....	Proximal anal cell.
R	.....	Radius.
R	.....	'Radial' cell.
r	.....	Radial cross vein.
R <sub>1</sub>	.....	Radius 1.
R <sub>1</sub>	.....	'Radial <sub>1</sub> ' cell.
Rm	.....	Remigium.
r-m	.....	Radiomedial cross vein.
R+M+Cul	.....	Common stem of radius, media, and cubitus.
Rs	.....	Radial sector.



Rs	.....	'Radial sector' cell.
Rs+M	.....	Radial sector-cum-media.
Sc	.....	Subcosta.
St	.....	Pterostigma.
vf	.....	Vannal fold.
Vn	.....	Vannus.

A b d o m e n .

acs	.....	Antecostal suture.
An	.....	Anus.
atg	.....	Acrotergite.
BAp	.....	Basal apodeme of ninth sternum.
g	.....	Groove of ninth tergum.
Mn	.....	Median notch of ninth tergum.
Ptgr	.....	Proctiger.
R	.....	Ridge of ninth tergum.
S	.....	Sternum.
Sam	.....	Sternal anterior margin.
SAP	.....	Sternal apodeme.
Sct	.....	Scutum.
Sgp	.....	Subgenital plate.
SIm	.....	Sternal lateral margin.
Soc	.....	Socii.
sp	.....	Spiracle.
Spm	.....	Sternal posterior margin.
T	.....	Tergum.
Tam	.....	Tergal anterior margin.

TAp	.....	Tergal apodeme.
TArc	.....	Facet of ninth tergum.
Tlm	.....	Tergal lateral margin.
Tpm	.....	Tergal posterior margin.

Male genitalia.

Aed	.....	Aedeagus.
BR	.....	Basal ring.
BRf	.....	Foramen of basal ring.
cus	.....	Cuspis.
dig	.....	Digitus.
gc	.....	Gonocondyle.
lp	.....	Parameral plate.
lpR	.....	Ridge of parameral plate.
lv	.....	Basivolsella.
pa	.....	Parapenial lobe.
Phtr	.....	Phalotreme.
Pmr	.....	Paramere.
pv	.....	Penis valve.
Vol	.....	Volsella.
VolAp	.....	Volsellar apodeme.
vr	.....	Mesal volsellar ridge.
vr	.....	Lateral volsellar ridge.

Female genitalia.

Bl	.....	Bulb of stylet.
Lct	.....	Lancet.

r1V1	.....	Ramus of first valvula.
r2V1	.....	Ramus of second valvula.
st1	.....	Stylet.
IXTArk	.....	Articular knob of triangular plate for ninth tergum.
VArc	.....	Facet of oblong plate.
1V1	.....	First valvula.
2V1	.....	Second valvula.
3V1	.....	Third valvula.
V1B	.....	Bridge of third valvulae.
1V1f	.....	Triangular plate.
2V1f	.....	Oblong plate.
2V1fArk	.....	Articular knob of triangular plate for oblong plate.
2V1fmR	.....	Marginal ridge of oblong plate.
1V1fR	.....	Ridge of triangular plate.
2V1fR	.....	Ridge of oblong plate.

I n t e r n a l   a n a t o m y .

A	.....	Air-sac of propodeum.
a	.....	Aorta.
ab	.....	Anterior branch of ventral trachea.
AcG1	.....	Accessory gland.
aGng	.....	Abdominal ganglion.
Alp	.....	Anterior lip of spiracle.
amp	.....	Ampullae of salivary gland.
An	.....	Anus.

AntL	.....	Antennal lobe of brain.
AntNv	.....	Antennary nerve.
Atr	.....	Atrium of spiracle.
B	.....	Spindle-shaped air-sac of prododeum.
bMb	.....	Basement membrane.
1Br	.....	Protocerebrum.
2Br	.....	Deutocerebrum.
3Br	.....	Tritocerebrum.
C	.....	Spindle-shaped air-sac of metathorax.
ca	.....	Corpora allata.
Cb	.....	Cibarium.
cc	.....	Corpora cardiaca.
chr	.....	Chorion.
cmcl	.....	Circular muscle fibres.
Cr	.....	Crop.
D	.....	Air-sac of metathorax.
d	.....	Branch of dorsal trachea of mesothorax.
dc	.....	Dorsal commissure.
dDph	.....	Dorsal diaphragm.
dDphmcl	.....	Alarymuscles of dorsal diaphragm.
dE	.....	Dorsal branch of air-sac of mesothorax.
Dej	.....	Ejaculatory duct.
Dt	.....	Dorsal trachea of head.
dt	.....	Dorsal trachea.
dVd	.....	Distal vas deferens.
dvt	.....	Dorsal trachea of mesothorax.

E	.....	Compound eye.
E	.....	Air-sac of mesothorax.
Ief	.....	First epithelial fold of intestine.
Epth	.....	Epithelium.
F	.....	Air-sac of prothorax.
Eel	.....	Follicular layer of ovariole.
Ff	.....	Follicular fold.
fNv	.....	Frontal nerve.
frCon	.....	Frontal ganglionic connective.
FrGng	.....	Frontal ganglion.
g	.....	Groove of brain.
Gcl	.....	Germ cells of germarium.
Gng	.....	Ganglion.
GngCon	.....	Ganglionic connectives.
Gpr	.....	Gonopore.
Grm	.....	Germarium.
hGng	.....	Hypocerebral ganglion.
Ht	.....	Heart.
ifs	.....	Interfollicular septum.
ilmcl	.....	Special longitudinal muscles of proventriculus.
In	.....	Intima.
Int	.....	Intestine.
LbNv	.....	Labial nerve.
Lg	.....	Ovarial ligament.
lmcl	.....	longitudinal muscle fibres.
LmNv	.....	Labral nerve.
lsd	.....	Lateral salivary duct.

Lt	.....	Main tracheal trunk.
1lt	.....	Prothoracic leg trachea.
2lt	.....	Mesothoracic leg trachea.
3lt	.....	Metathoracic leg trachea.
Lum	.....	Lumen.
Lumrp	.....	Lumen of rectal pad.
Mal	.....	Malpighian tubule.
mb	.....	Mesal branch of ventral trachea.
mcl	.....	Circular muscles of proventriculus.
MdNv	.....	Mandibular nerve.
Ment	.....	Mesentron.
Mth	.....	Mouth.
MxNv	.....	Maxillary nerve.
Nrc1	.....	Nurse cells of ovariole.
nu	.....	Nucleus.
O	.....	Ocellus.
o	.....	Orifice of proventriculus.
Oapp	.....	Occlusor apparatus of spiracle.
Odc	.....	Common oviduct.
Odl	.....	Lateral oviduct.
Oe	.....	Oesophagus.
Ooc	.....	Oocytes.
OpL	.....	Optic lobe of brain.
Ost	.....	Ostium.
Ov	.....	Ovary.
Ovl	.....	Ovariole.
p	.....	Peritoneal layer.

pb	.....	Posterior branch of ventral trachea.
pcNV	.....	Paracaraiac nerves.
Pdcl	.....	Pedicel.
pg	.....	Plug.
Phy	.....	Pharynx.
pmb	.....	Peritrophic membrane.
Proc	.....	Proctodaeum.
Prvent	.....	Proventriculus.
pVd	.....	Proximal vas deferens.
Pvl	.....	Pyloric valve.
Rect	.....	Rectum.
rg	.....	Regenerative cells.
rNV	.....	Recurrent nerve.
rp	.....	Rectal pad.
rpc	.....	Cells of rectal pad.
sb	.....	Striated border.
sd	.....	Ductules of salivary gland.
sEpth	.....	Syncytial epithelium.
SLD	.....	Common salivary duct.
SmGng	.....	Stomachic ganglion.
SoeGng	.....	Suboesophageal ganglion.
sp	.....	Spiracle.
spop	.....	Spiracular opening.
spP	.....	Spiracular process.
spr	.....	Spiracular rim.
Spt	.....	Spermatheca.

spt	.....	Spiracular trachea.
Tes	.....	Testis.
Tf	.....	Terminal filament of ovariole.
tf	.....	Testicular follicle.
tGng	.....	Thoracic ganglion
Traop	.....	Tracheal opening.
vag	.....	Vagina.
ve	.....	Ventral Commissure.
Vd	.....	Vas deferens.
vDph	.....	Ventral diaphragm.
VNC	.....	Ventral nerve cord.
Vsm	.....	Seminal vesicle.
vst	.....	Visceral trachea.
VT	.....	Ventral longitudinal tracheal trunk.
Vt	.....	Ventral trachea of head.
vt	.....	Ventral trachea.
vtb	.....	Branch of ventral trachea.
Vtā	.....	Vitellarium.
vvt	.....	Ventral trachea of mesothorax.
ws	.....	Zone of weak sclerotization.

L a r v a l   a n a t o m y.

a	.....	Posterior articulation of mandible.
ab	.....	Anterior branch of mesal trachea.
adt	.....	Anterior branch of dorsal trachea.
amp	.....	Ampullae of salivary gland.



An	.....	Anus.
Ant	.....	Antenna.
AT	.....	Anterior tentorial arm.
at	.....	Anterior tentorial pit.
Br	.....	Brain.
c	.....	Anterior articulation of mandible.
Cd	.....	Cardo.
Clp	.....	Clypeus.
dDph	.....	Dorsal diaphragm.
dDphmcl	.....	Alary muscles of dorsal diaphragm.
DT	.....	Dorsal tentorial arm.
dt	.....	Dorsal trachea.
es	.....	Epistomal suture.
For	.....	Foramen magnum.
FrGe	.....	Frons-cum-gena.
Ga	.....	Galea.
Gng	.....	Ganglion.
H	.....	Head.
Hphy	.....	Hypopharynx.
hs	.....	Hypostomal suture.
Hst	.....	Hypostomal area.
Ht	.....	Heart.
Int	.....	Intestine.
L	.....	Thoracic leg.
l	.....	Proleg.
Lb	.....	Labium.

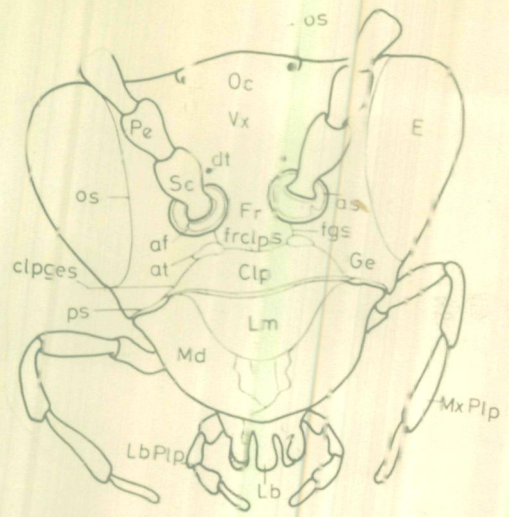
LbPlp	.....	Labial palp.
lbs	.....	Labial suture.
Lc	.....	Lacinia.
Lm	.....	Labrum.
Loc	.....	Lateral occiput.
lsd	.....	Lateral salivary duct.
LT	.....	Main tracheal trunk.
Mal	.....	Malpighian tubule.
mb	.....	Mesal branch of mesal trachea.
Md	.....	Mandible.
MG	.....	Midgut.
Moc	.....	Median occiput.
mt	.....	Mesal trachea.
Mth	.....	Mouth.
Mx	.....	Maxilla.
MxPlp	.....	Maxillary palp.
NC	.....	Nerve cord.
O	.....	Ocellus.
Oe	.....	Oesophagus.
Ost	.....	Ostium.
paros	.....	Paroccipital suture.
pb	.....	Posterior branch of mesal trachea.
pdt	.....	Posterior branch of dorsal trachea.
Phy	.....	Pharynx.
PhyCon	.....	Pharyngeal connective.
Pmt	.....	Postmentum.
pos	.....	Postoccipital suture.

Prmt	.....	Prementum.
ps	.....	Pleurostomal suture.
Pst	.....	Pleurostomal area.
PT	.....	Posterior tentorial arm.
r	.....	Basal rim of mandible.
Rect	.....	Rectum.
sgs	.....	Subgenal suture.
SLD	.....	Common salivary duct.
SoeGng	.....	Suboesophageal ganglion.
sp	.....	Spiracle.
spt	.....	Spiracular trachea.
St	.....	Stipes.
StCdh	.....	Stipitocardinal hinge.
vc	.....	Ventral commissure.
vst	.....	Visceral trachea.
VT	.....	Ventral tracheal trunk.
Vx	.....	Vertex.
Y	.....	Ecdysial line.

8. EXPLANATION OF FIGURES

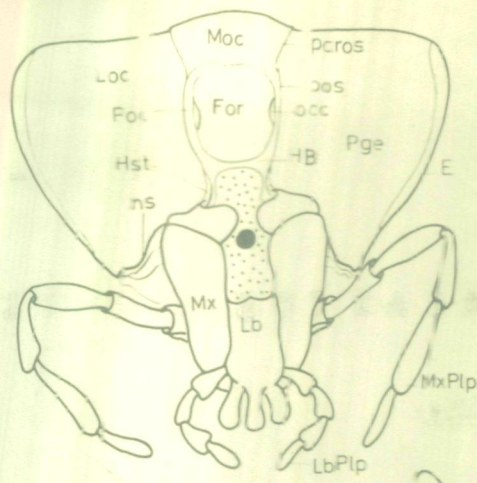
PLATE 1. Head.

- Fig. 1. Anterior view of head capsule.  
Fig. 2. Posterior view of head capsule.  
Fig. 3. Posterior view of tentorium.  
Fig. 4. Lateral view of tentorium.  
Fig. 5. Anterior view of antennal sockets.  
Fig. 6. Basal rim of scape.  
Fig. 7. Antennal articulation with antennal socket.  
Fig. 8. Antenna.  
Fig. 9. Scapo-pedicelar articulation.  
Fig. 10. Antennal muscles.  
Fig. 11. Basal rim of scape with muscles.  
Fig. 12. Muscles of pedicel.  
Fig. 13. Anterior view of labrum  
Fig. 14. Posterior view of labrum.  
Fig. 15. Mandible.  
Fig. 16. Mandible with muscles.  
Fig. 17. Dorsal view of maxillo-labial complex.  
Fig. 18. Dorsal view of maxilla.



5 mm

Fig. 1



5 mm

Fig. 2

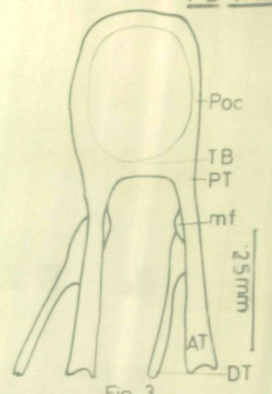


Fig. 3

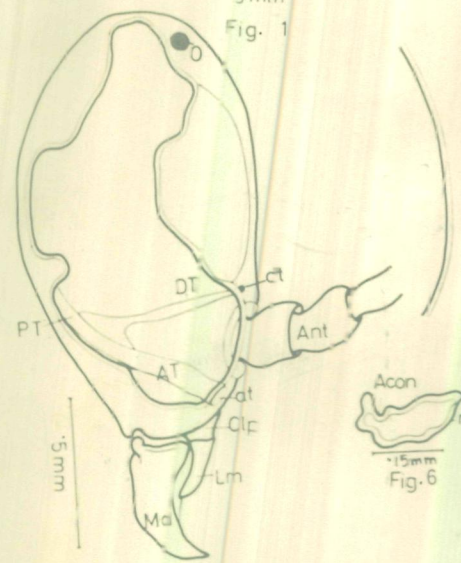
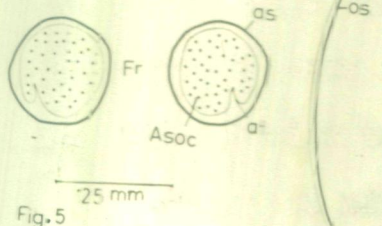


Fig. 4



25 mm

Fig. 5



5 mm

Fig. 8

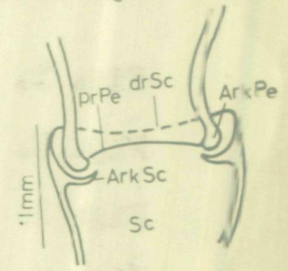
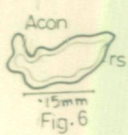
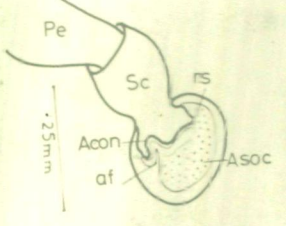


Fig. 9



15 mm

Fig. 6



25 mm

Fig. 7

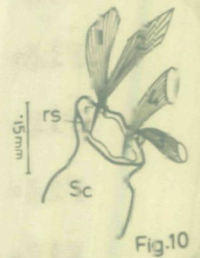
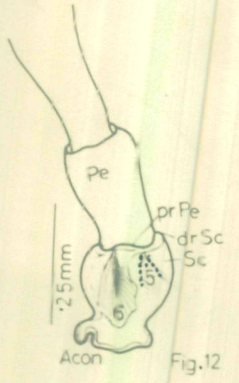
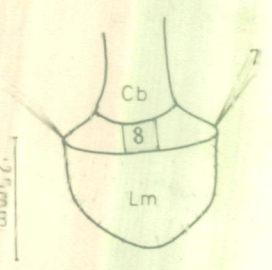


Fig. 10



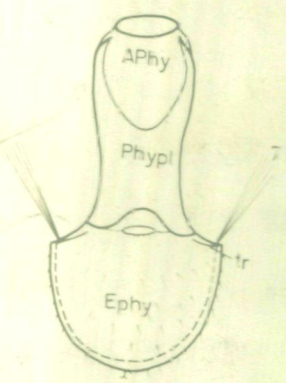
25 mm

Fig. 12



25 mm

Fig. 13



25 mm

Fig. 14

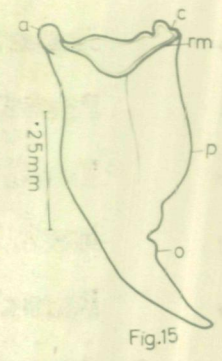


Fig. 15

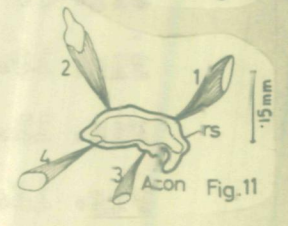
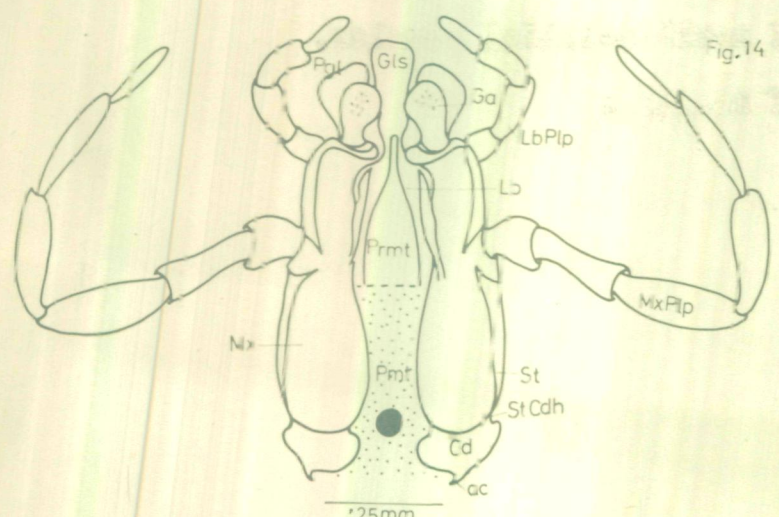
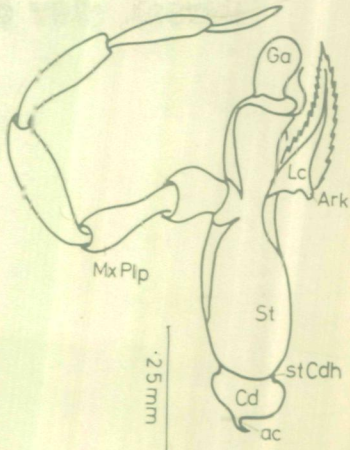


Fig. 11



25 mm

Fig. 17



25 mm

Fig. 18

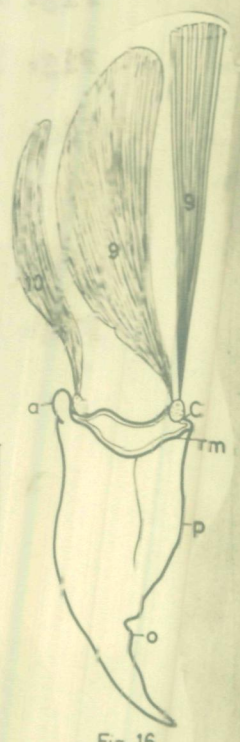


Fig. 16



PLATE 2. Head (Contd.).

- Fig. 19. Dorsal view of galea.  
Fig. 20. Dorsal view of lacinia.  
Fig. 21. Basal portion of lacinia articulating with labium.  
Fig. 22. Dorsal view of maxilla with muscles.  
Fig. 23. Lateral view of maxilla with muscles in relation to cranium.  
Fig. 24. Dorsal view of labium.  
Fig. 25. Ventral view of labium.  
Fig. 26. Dorsal view of labium with muscles.  
Fig. 27. Dorsal view of labium with muscles.  
Fig. 28. Lateral view of labium with muscles.  
Fig. 29. Dorsal view of cibarium and pharynx with muscles.  
Fig. 30. Lateral view of cibarium and pharynx with muscles in relation to cranium.

Thorax.

- Fig. 31. Dorsal view of thorax.  
Fig. 32. Ventral view of thorax.



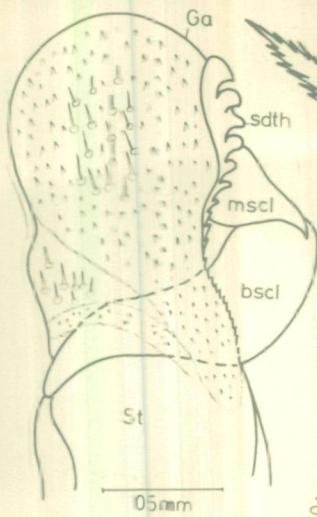


Fig. 19



Fig. 20

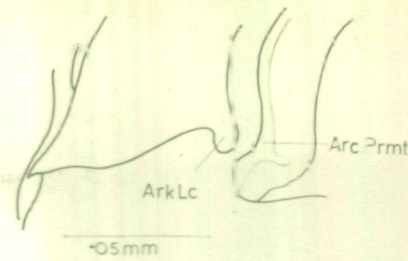


Fig. 21

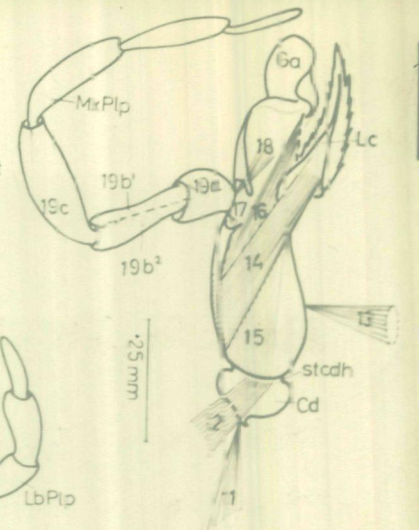


Fig. 22

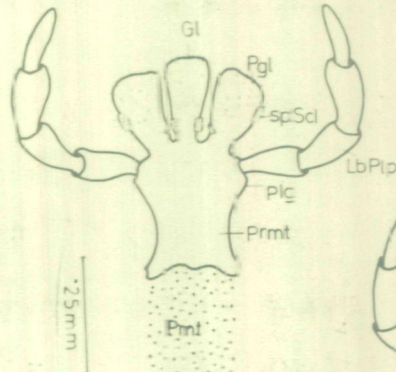


Fig. 23

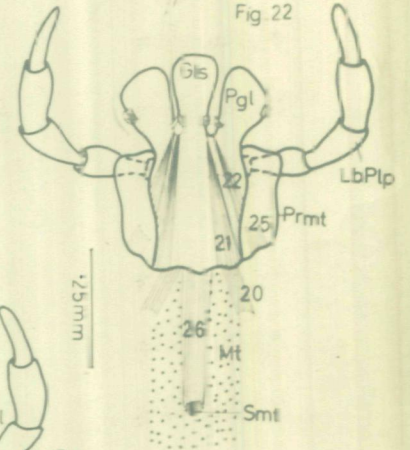


Fig. 24

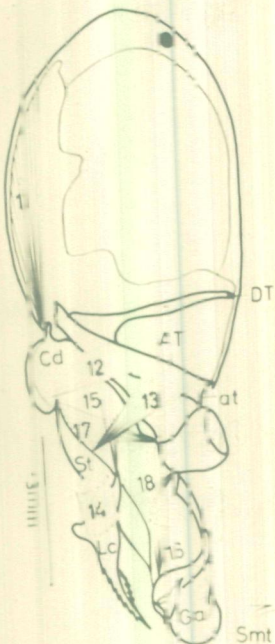


Fig. 25

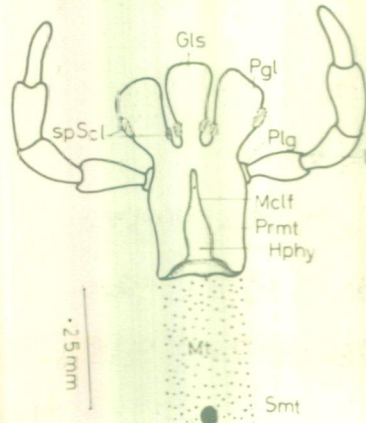


Fig. 26

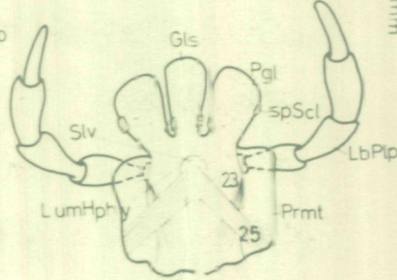


Fig. 27

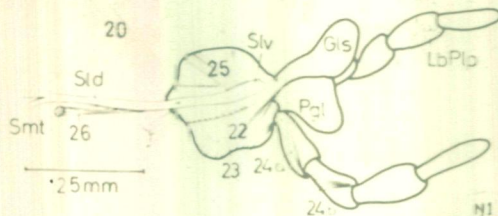


Fig. 28

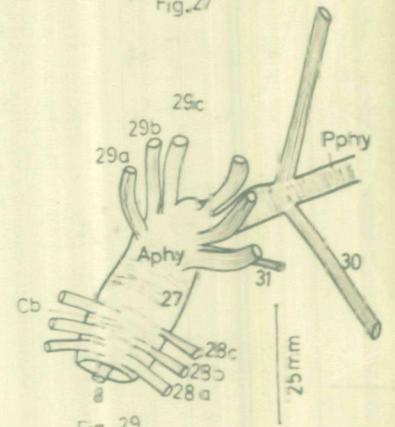


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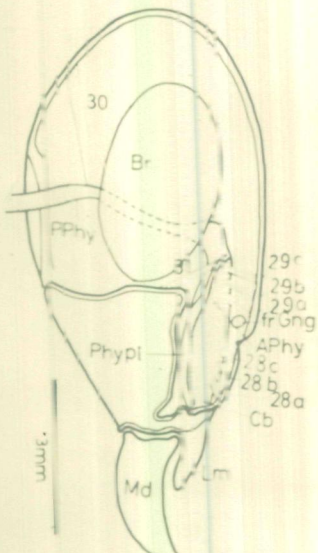


Fig. 30

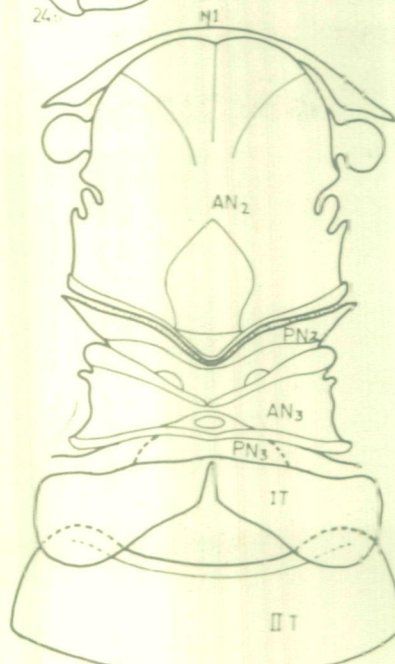


Fig. 31

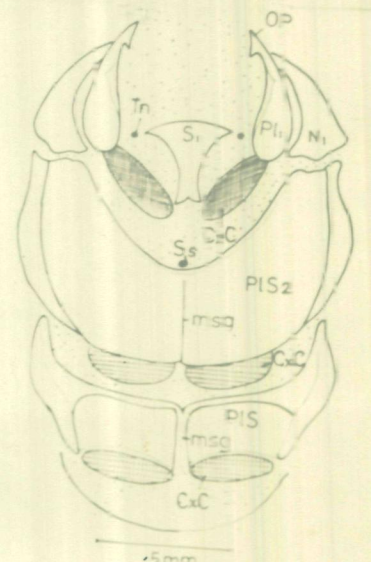


Fig. 32



PLATE 3. Thorax (Contd.).

- Fig. 33. Lateral view of thorax.
- Fig. 34. Ventral view of protergum.
- Fig. 35. Propleuron in relation to foramen magnum.
- Fig. 36. Posterodorsal view of propectus.
- Fig. 37. Dorsal view of propectus.
- Fig. 38. Prothorax with muscles.
- Fig. 39. Lateral half of prothorax with muscles.
- Fig. 40. Prothoracic leg.
- Fig. 41. Mesothoracic leg.
- Fig. 42. Metathoracic leg.
- Fig. 43. Procoxa with muscles.
- Fig. 44. Prococo-trochanteral articulation.
- Fig. 45. Protrochanter with muscles in relation to coxa.
- Fig. 46. Protrochanter with muscles.
- Fig. 47. Protrochantero-femoral articulation.
- Fig. 48. Proximal rim of profemur.
- Fig. 49. Profemoro-tibial articulation.



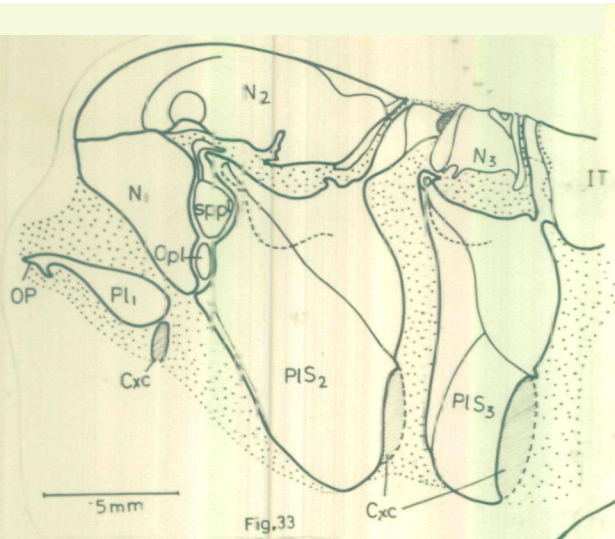


Fig. 33

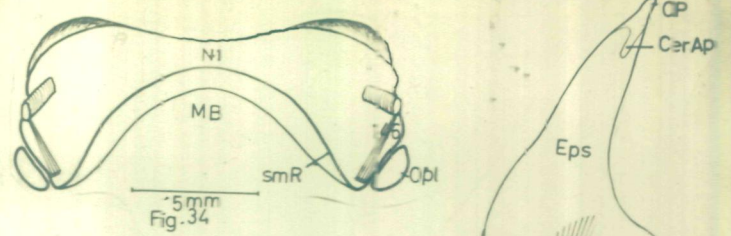


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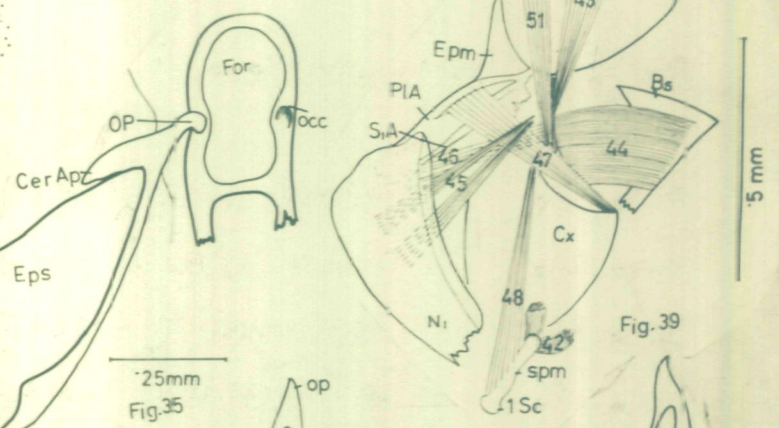


Fig. 35

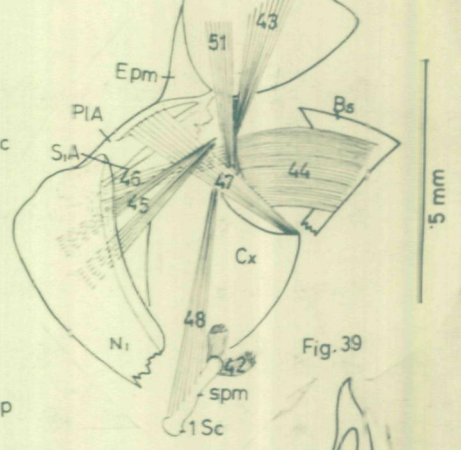


Fig. 39

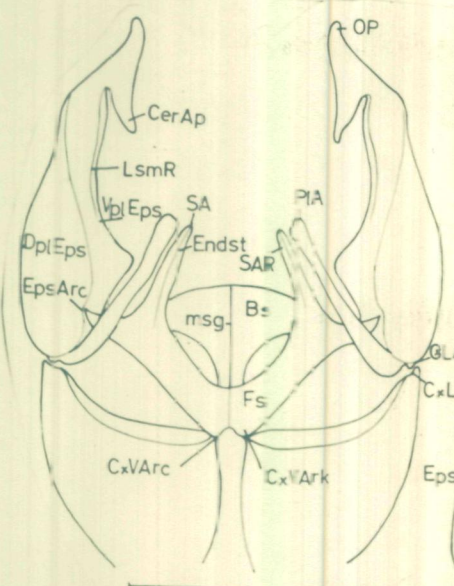


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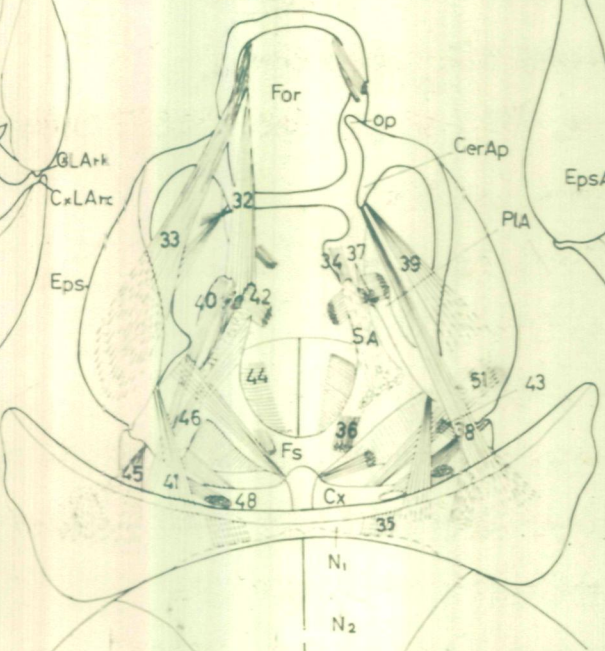


Fig. 38

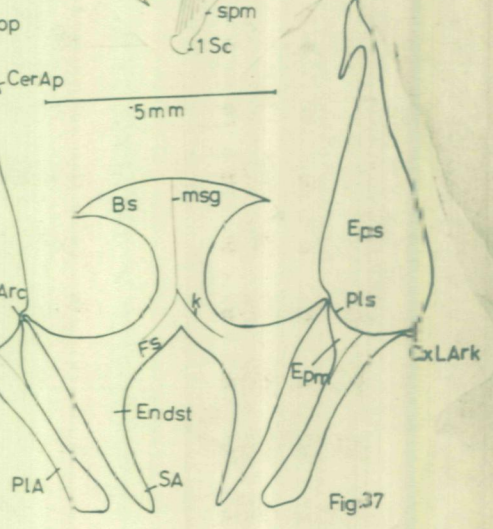


Fig. 37

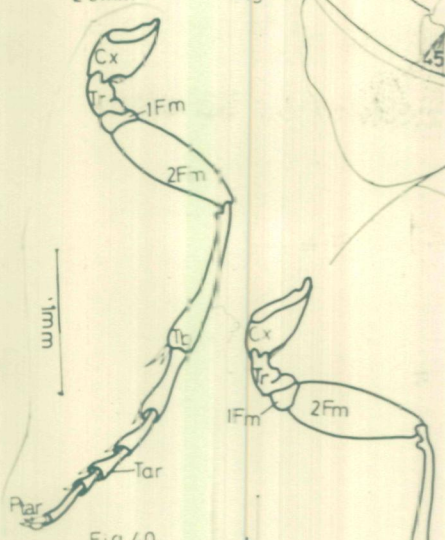


Fig. 40

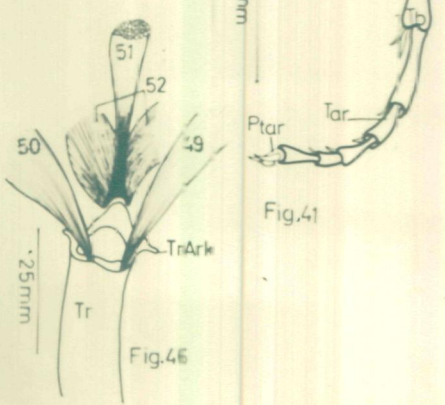


Fig. 41

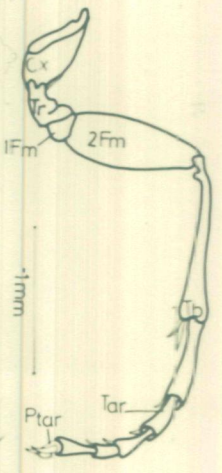


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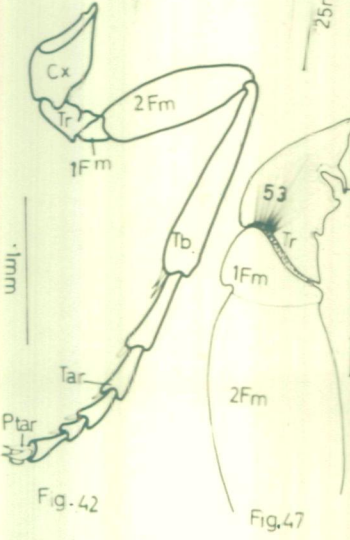


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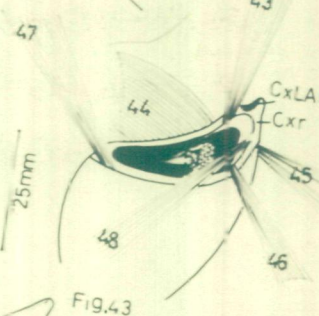


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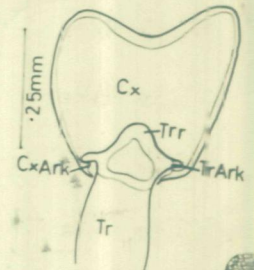


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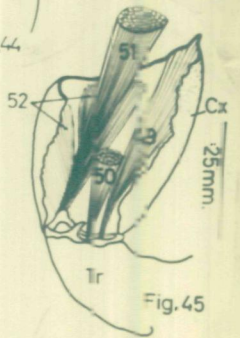


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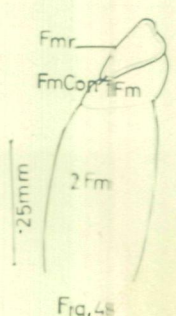


Fig. 47

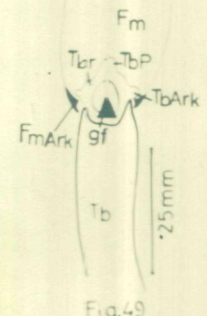


Fig. 48



PLATE 4. Thorax (Contd.).

- Fig. 50. Protibia with muscles in relation to femur.  
Fig. 51. Protibio-tarsal articulation.  
Fig. 52. Probasitarsus with muscles in relation to tibia.  
Fig. 53. Protarsus with pretarsus.  
Fig. 54. Dorsal view of propretarsus.  
Fig. 55. Ventral view of propretarsus.  
Fig. 56. Lateral view of propretarsus.  
Fig. 57. Lateral view of propretarsal claw.  
Fig. 58. Dorsal view of mesotergum.  
Fig. 59. Dorsal view of mesopostphragma.  
Fig. 60. Lateral view of mesothorax.  
Fig. 61. Inner lateral view of mesopectus in association with protergum.  
Fig. 62. Posterodorsal view of mesoendosternum.  
Fig. 63. Mesotergum with muscles.  
Fig. 64. Mesothorax with muscles.  
Fig. 65. Mesothorax with muscles.



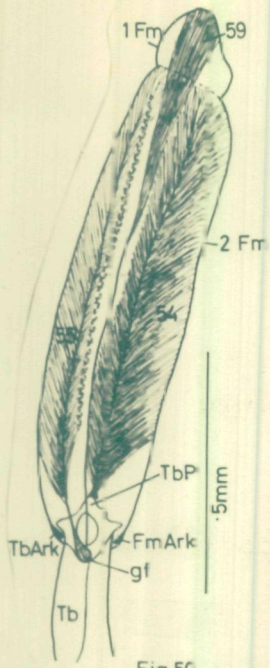


Fig. 50



Fig. 51

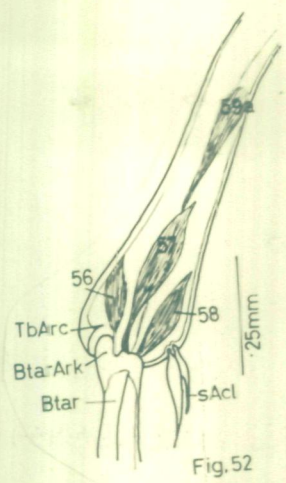


Fig. 52

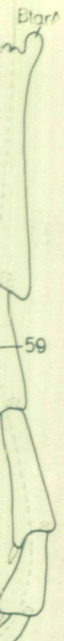


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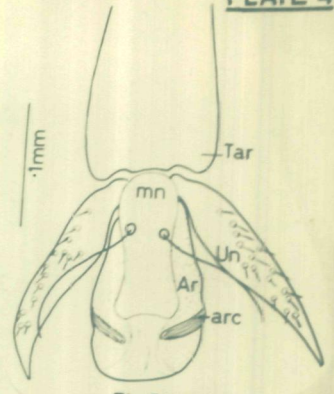


Fig. 54

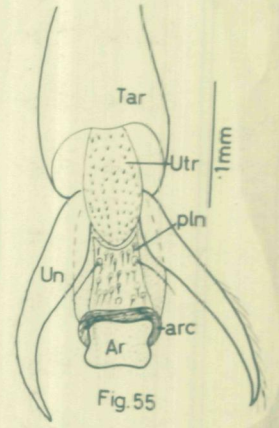


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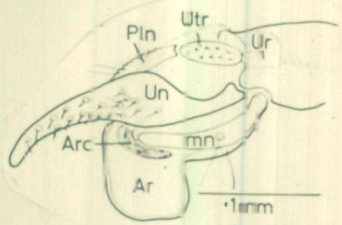


Fig. 56

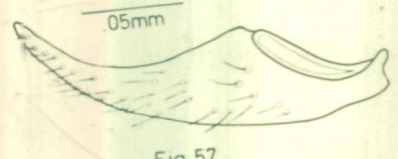


Fig. 57

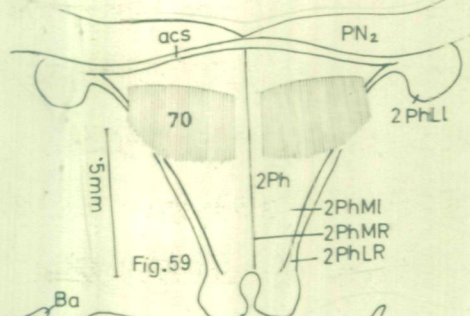


Fig. 59

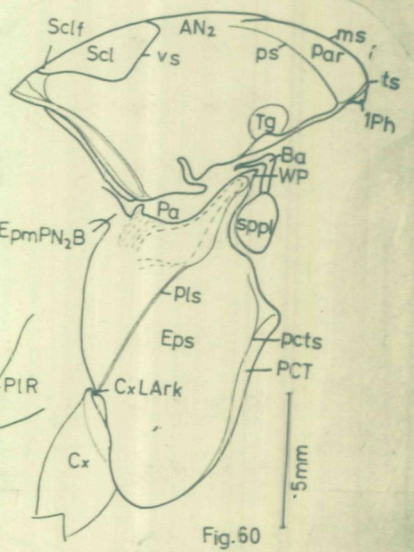


Fig. 60

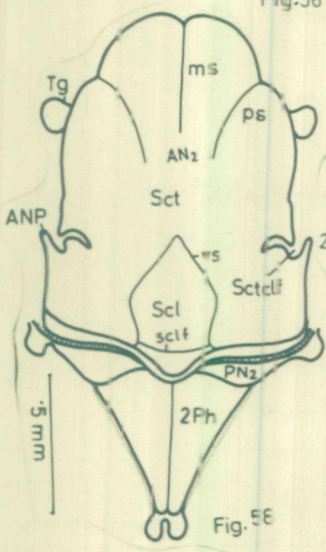


Fig. 61

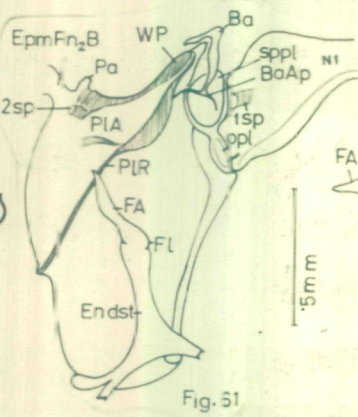


Fig. 62

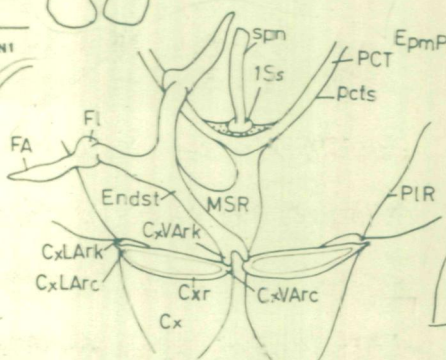


Fig. 63

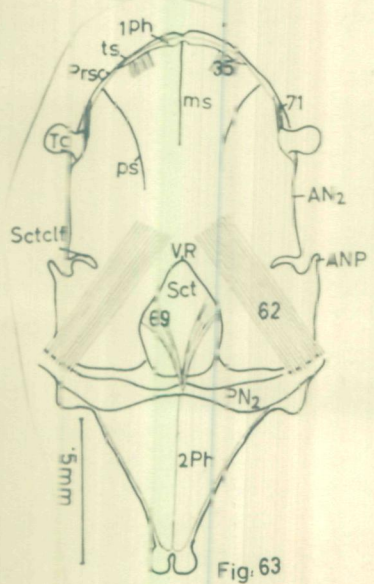


Fig. 64

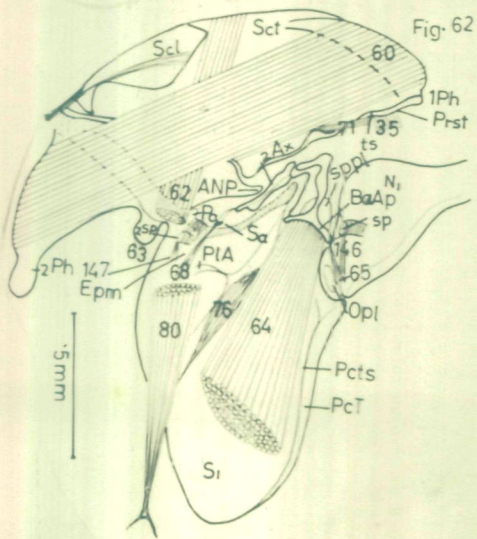


Fig. 65

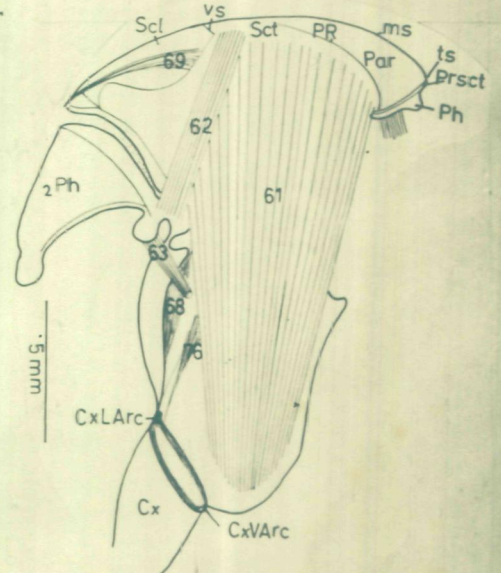


Fig. 66



PLATE 5. Thorax (Contd.).

- Fig. 66. Mesopectus and endosternum with muscles.
- Fig. 67. Mesocoxa with muscles in relation to endosternum.
- Fig. 68. Mesotrochanter with muscles in relation to coxa.
- Fig. 69. Mesotrochantero-femoral articulation.
- Fig. 70. Mesotibia with muscles in relation to femur.
- Fig. 71. Mesobasitarsus with muscles in relation to tibia.
- Fig. 72. Dorsal view of the metatergum and propodeum.
- Fig. 73. Inner lateral view of metapectus in relation to metatergum and propodeum.
- Fig. 74. Metathorax with muscles.
- Fig. 75. Metathorax with muscles.
- Fig. 76. Metapleuron and third axillary sclerite with muscles.
- Fig. 77. Metacoxa with muscles.
- Fig. 78. Metatrochanter with muscles in relation to coxa.
- Fig. 79. Metatrochantero-femoral articulation.
- Fig. 80. Metatibia with muscles in relation to femur.



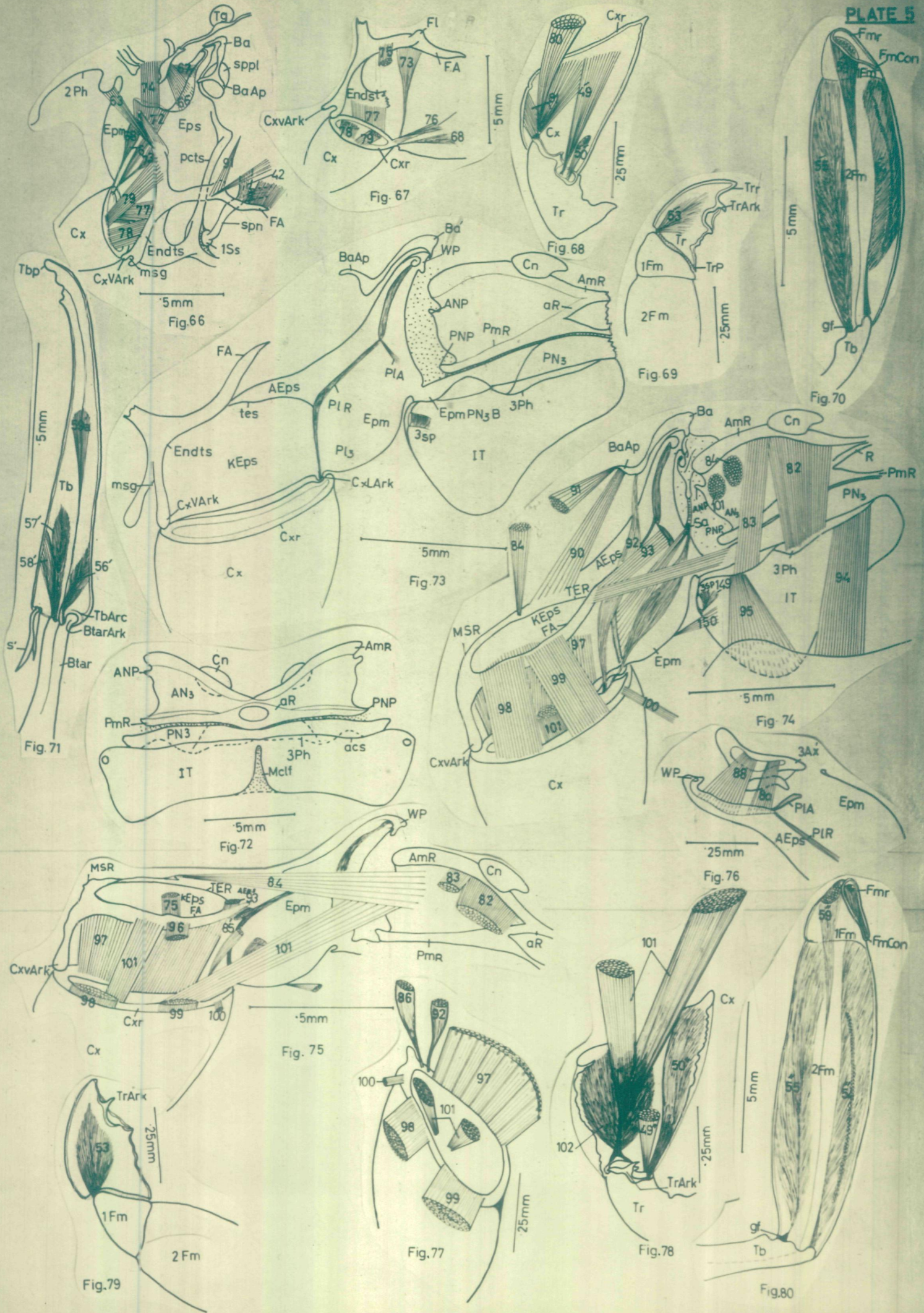




PLATE 6. Thorax (Contd.).

- Fig. 81. Metabasitarsus with muscles in relation to tibia.  
Fig. 82. Fore-wing.  
Fig. 83. Fore-wing base in relation to tergal margin.  
Fig. 84. Fore-wing axillary sclerites in relation to pleural margin.  
Fig. 85. Hind-wing.  
Fig. 86. Hind-wing base in relation to tergal margin.  
Fig. 87. Hind-wing axillary sclerites in relation to tergal margin.

Abdomen.

- Fig. 88. Inner lateral view of male abdomen with muscles.  
Fig. 89. Lateral view of female abdomen.  
Fig. 90. Ventral view of male dorsum.  
Fig. 91. Dorsal view of male venter.  
Fig. 92. Ventral view of sixth abdominal tergum.  
Fig. 93. Dorsal view of sixth abdominal sternum.  
Fig. 94. Sixth abdominal tergum with muscles.  
Fig. 95. Sixth abdominal sternum with muscles.  
Fig. 96. Lateral view of posterior half of male abdomen.  
Fig. 97. Ventral view of seventh, eighth, ninth and tenth terga of female abdomen.



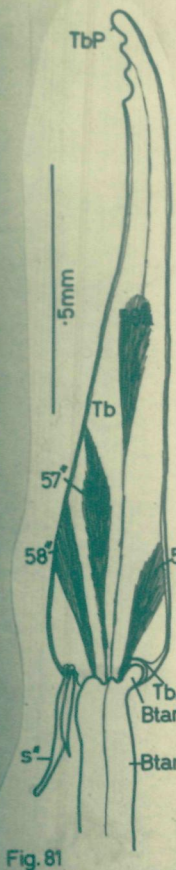


Fig. 81

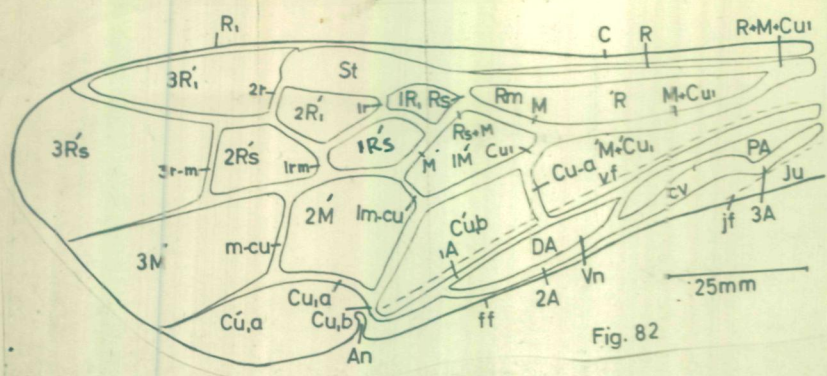


Fig. 82

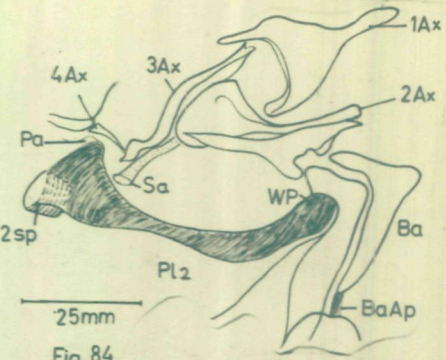


Fig. 84

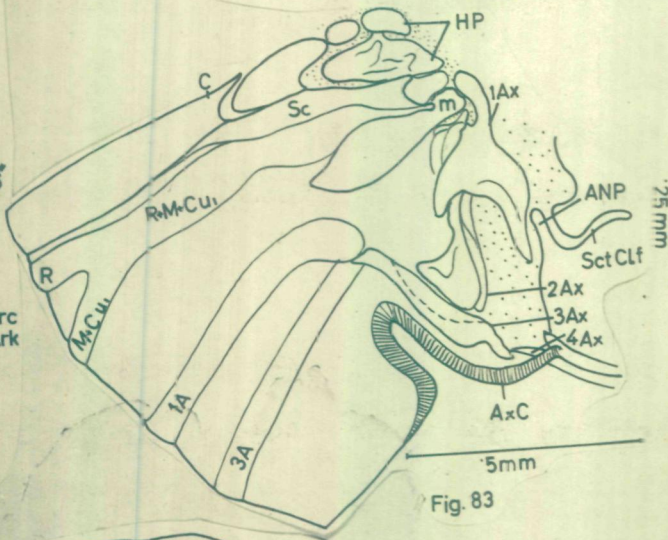


Fig. 83

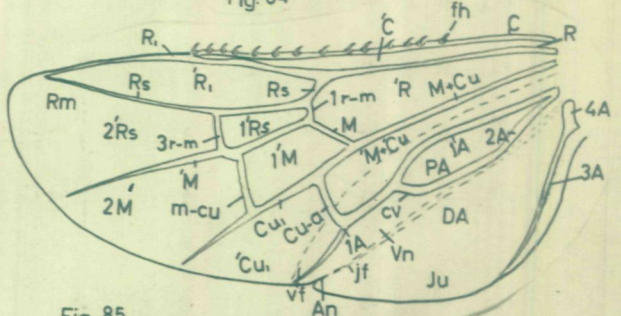


Fig. 85

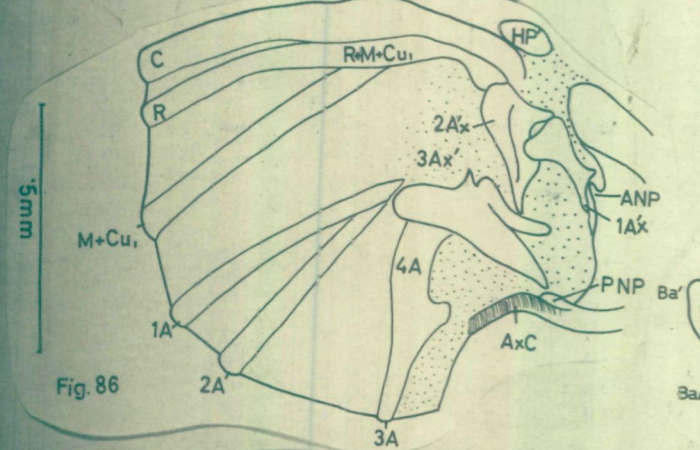


Fig. 86

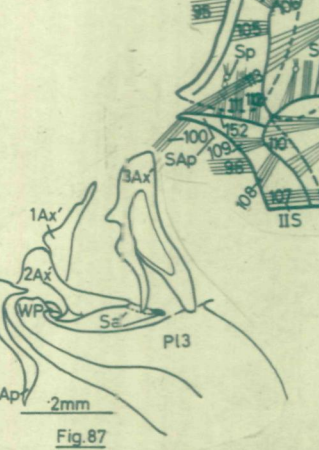


Fig. 87

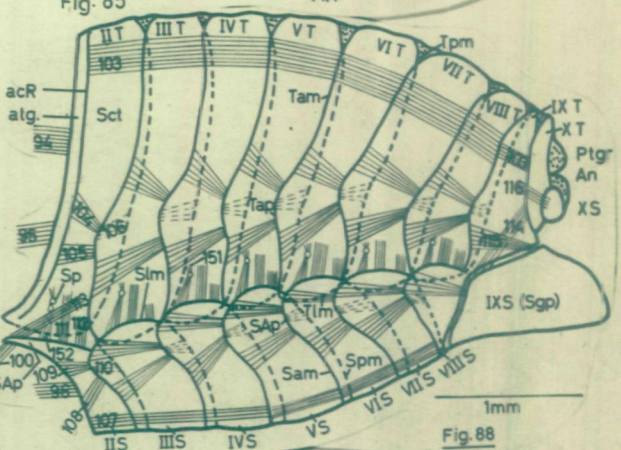


Fig. 88

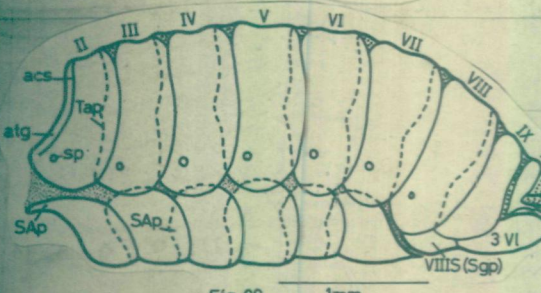


Fig. 89

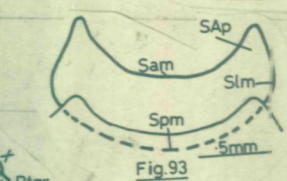


Fig. 93

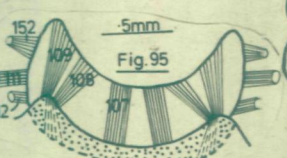


Fig. 95

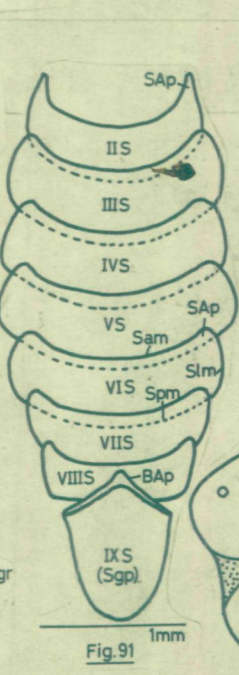


Fig. 91

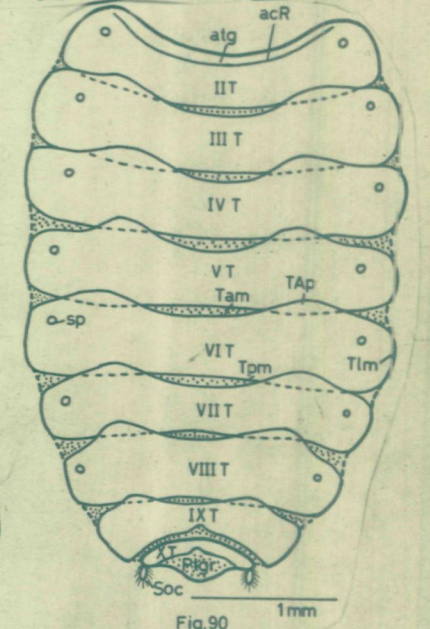


Fig. 90

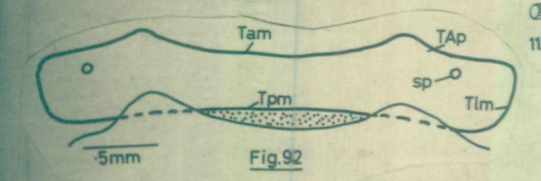


Fig. 92

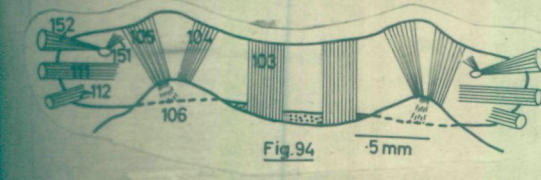


Fig. 94

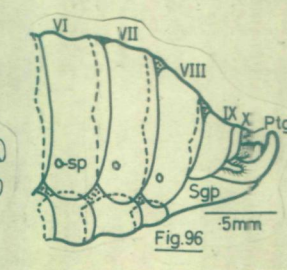


Fig. 96

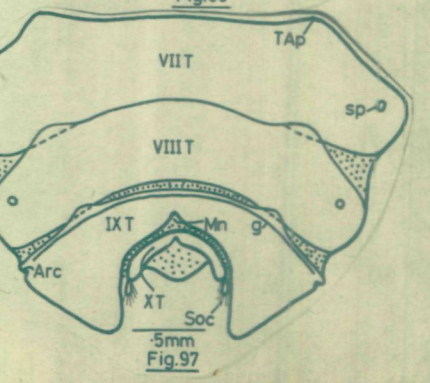


Fig. 97



PLATE 7. Abdomen (Contd.).

- Fig. 98. Dorsal view of subanal plate with tenth tergum cut in the middle.
- Fig. 99. Dorsal view of male genitalia.
- Fig. 100. Ventral view of male genitalia.
- Fig. 101. Dorsal view of volsella.
- Fig. 102. Penis valve.
- Fig. 103. Basal ring with muscles in relation to subgenital plate.
- Fig. 104. Parameral plate and volsella with muscles.
- Fig. 105. Parameral plate and parameral lobe with muscles.
- Fig. 106. Parameral plate, volsella, and penis valve with muscles.
- Fig. 107. Dorsal view of female genitalia with ninth tergum cut apart into two.
- Fig. 108. Inner lateral view of female abdomen in the posterior region.
- Fig. 109. First and second valvifers in relation to first valvula.
- Fig. 110. Second valvifer in relation to second and third valvula.
- Fig. 111. Female genitalia with muscles.
- Fig. 112. Female genitalia with muscles in relation to eighth and ninth terga and seventh sternum.
- Fig. 113. Dorsal view of vagina with muscles.

Internal anatomy.

- Fig. 114. Alimentary canal.
- Fig. 115. T.S. Oesophagus.
- Fig. 116. T.S. Crop.



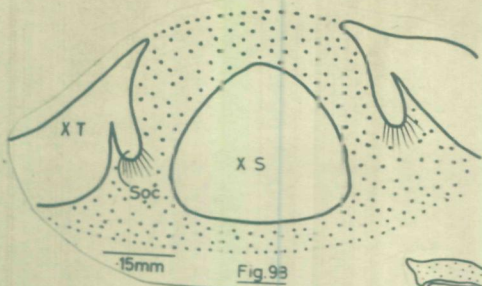


Fig. 98

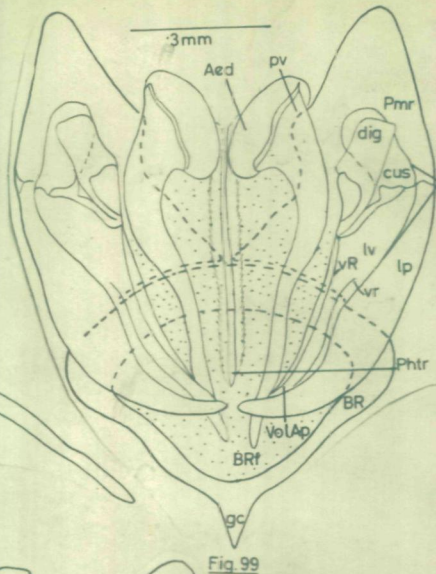


Fig. 99

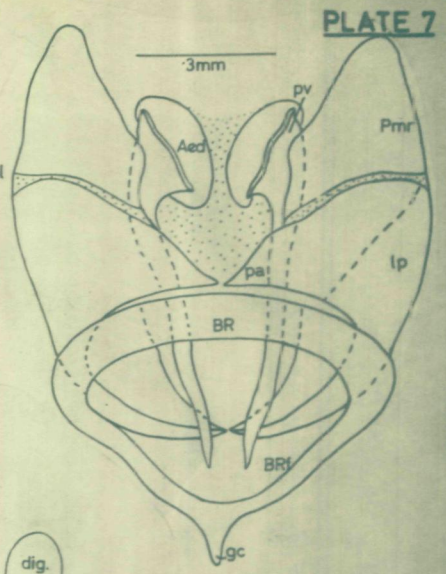


Fig. 100

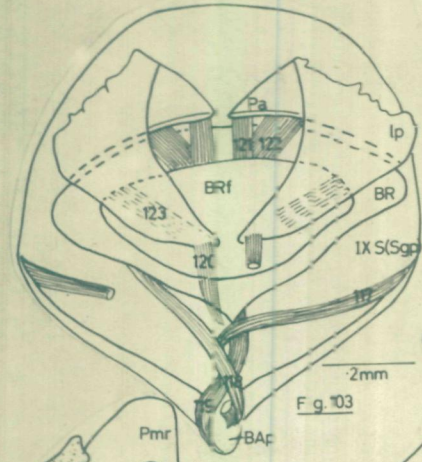


Fig. 103

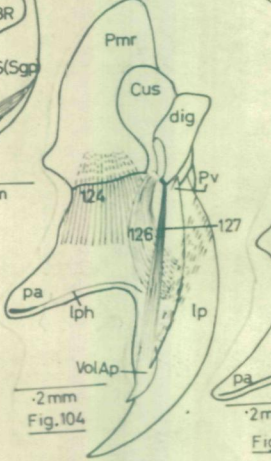


Fig. 104

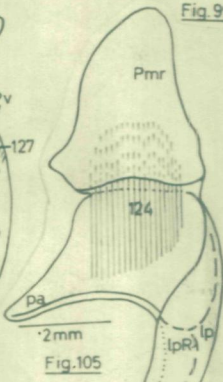


Fig. 105

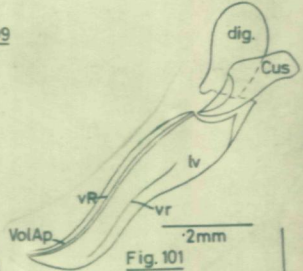


Fig. 101

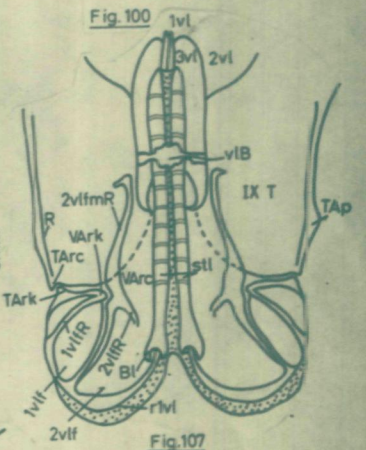


Fig. 107

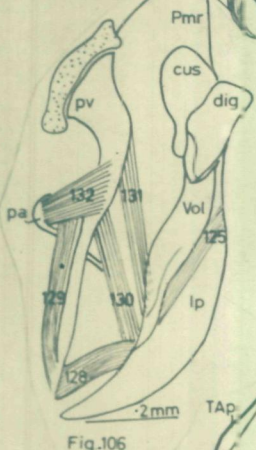


Fig. 106

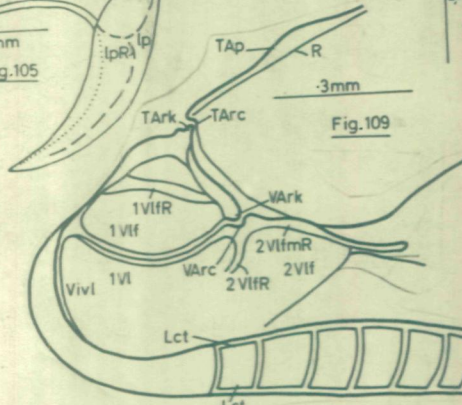


Fig. 109

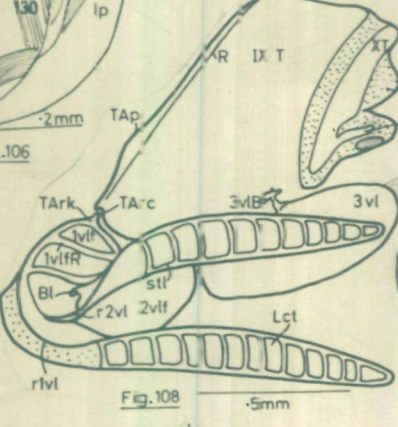


Fig. 108

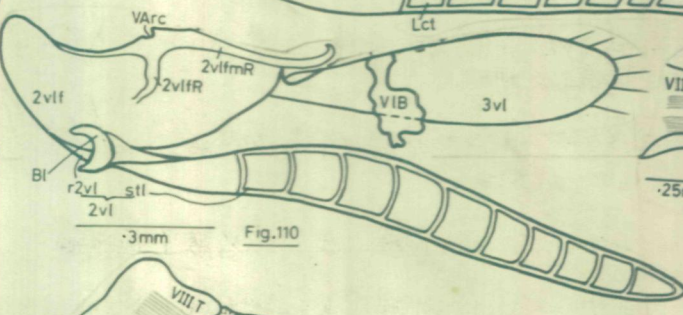


Fig. 110

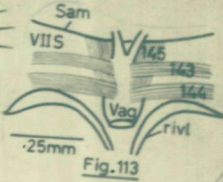


Fig. 113

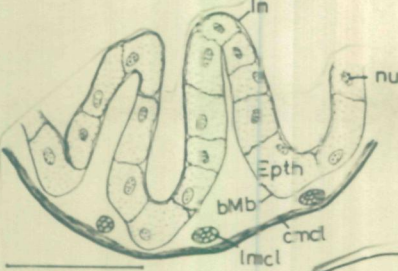


Fig. 115

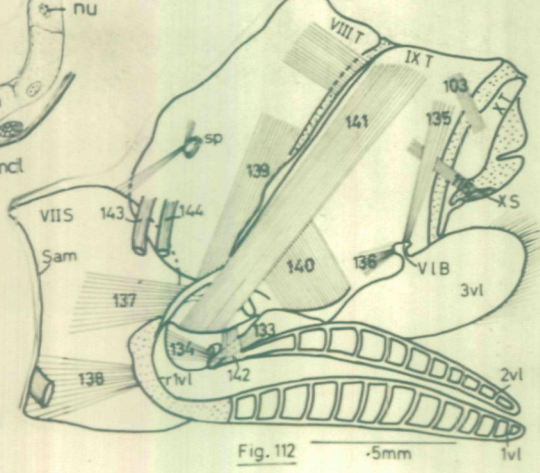


Fig. 112

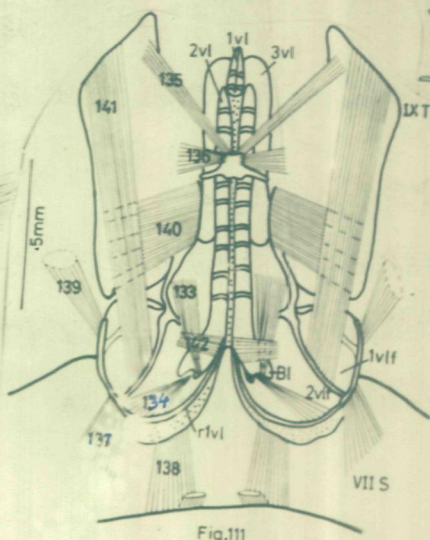


Fig. 111

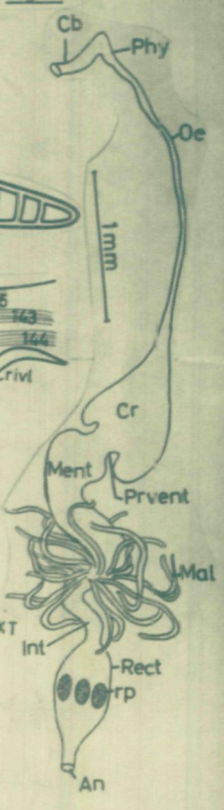


Fig. 114

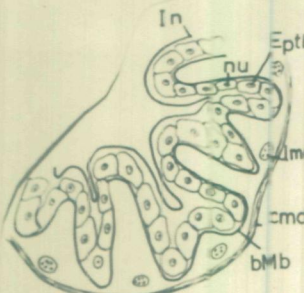


Fig. 116



PLATE 8. Internal anatomy (Contd.).

- Fig. 117. T.S. proventriculus.
- Fig. 118. L.S. junction of proventriculus with mesenteron showing stomodaeal valve.
- Fig. 119. T.S. mesenteron.
- Fig. 120. L.S. junction of mesenteron with intestine.
- Fig. 121. T.S. intestine.
- Fig. 122. T.S. rectum in the region of rectal pad.
- Fig. 123. Salivary gland.
- Fig. 124. T.S. malpighian tubule.
- Fig. 125. Dorsal blood vessel.
- Fig. 126. Heart in relation to dorsal diaphragm.
- Fig. 127. Heart chambers with ostia.
- Fig. 128. Anterior view of first thoracic spiracle.
- Fig. 129. Lateral view of first thoracic spiracle.
- Fig. 130. Anterior view of second thoracic spiracle.
- Fig. 131. Lateral view of second thoracic spiracle.
- Fig. 132. Dorsal view of propodeal spiracle.
- Fig. 133. Dorsal view of second abdominal spiracle.
- Fig. 134. Dorsal view of the respiratory system in male abdomen.
- Fig. 135. Dorsal view of the respiratory system in the posterior region of female abdomen.
- Fig. 136. Ventral view of respiratory system in thorax and head.
- Fig. 137. Male reproductive system.
- Fig. 138. T.S. testis.



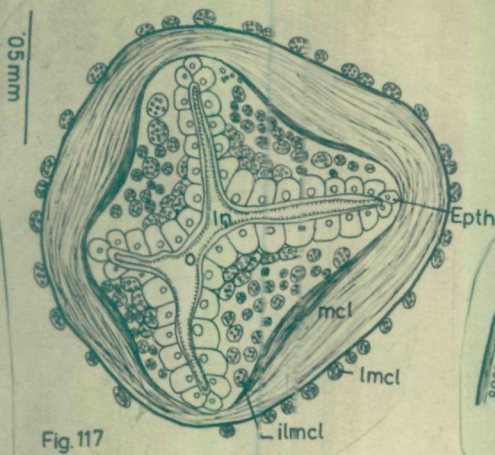


Fig. 117

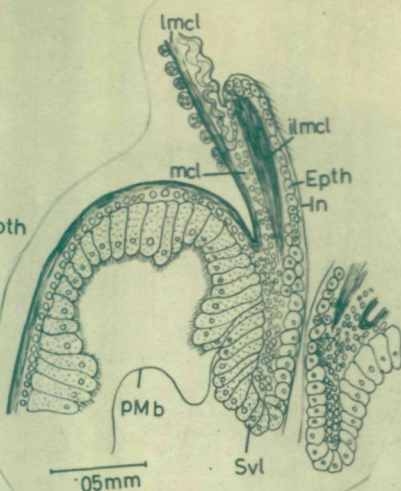


Fig. 118

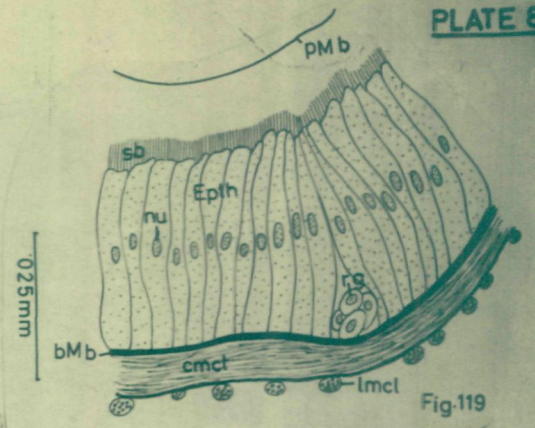


Fig. 119

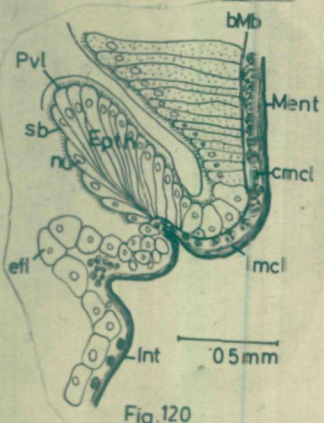


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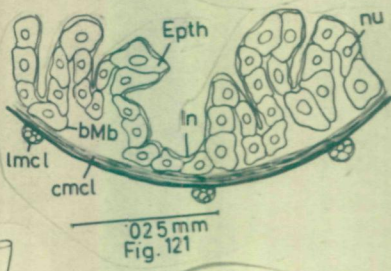


Fig. 121

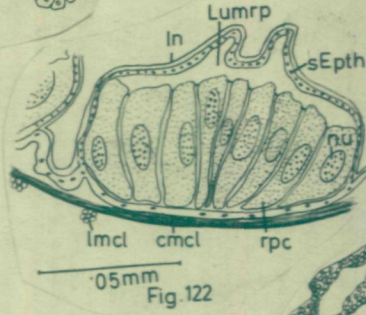


Fig. 122

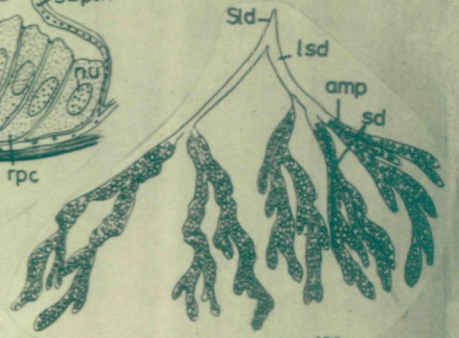


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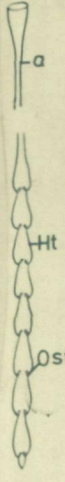


Fig. 125

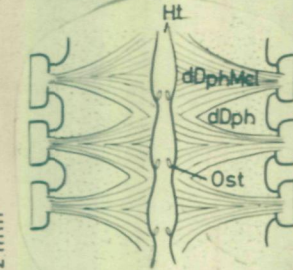


Fig. 126

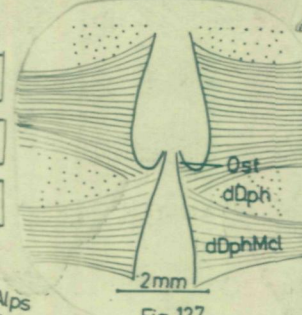


Fig. 127

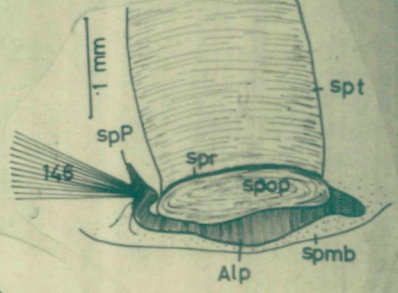


Fig. 128

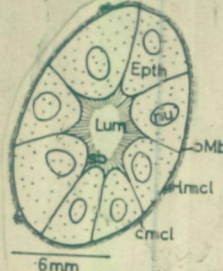


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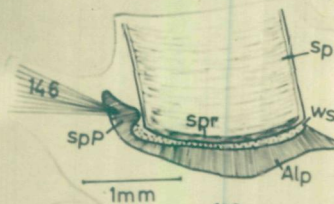


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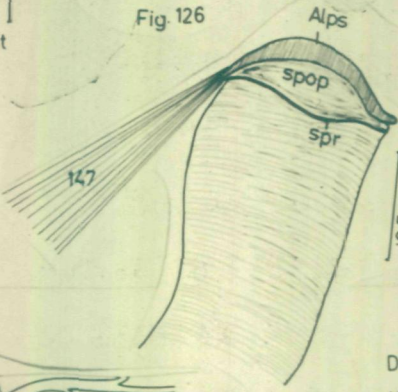


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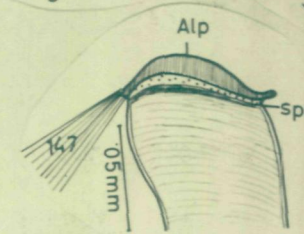


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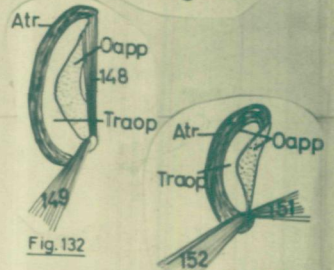


Fig. 132



Fig. 133

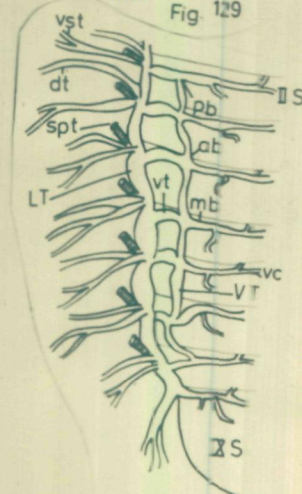


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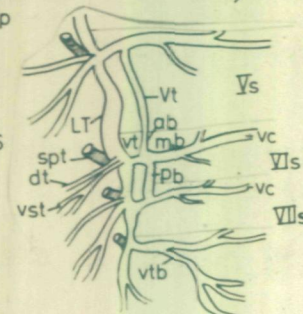


Fig. 135

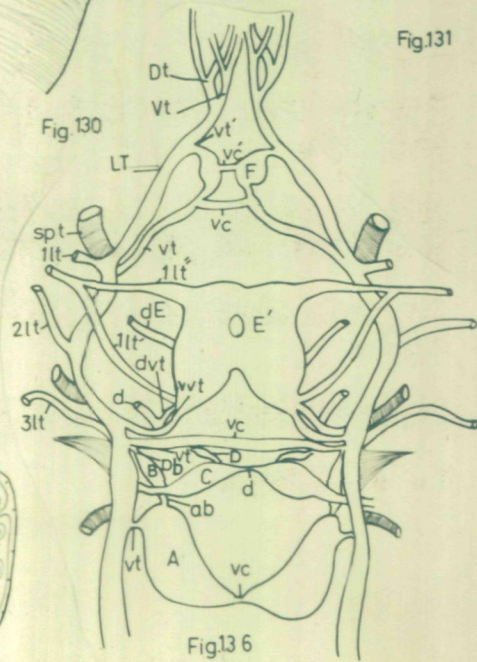


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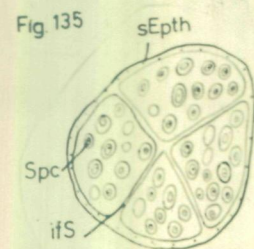


Fig. 138

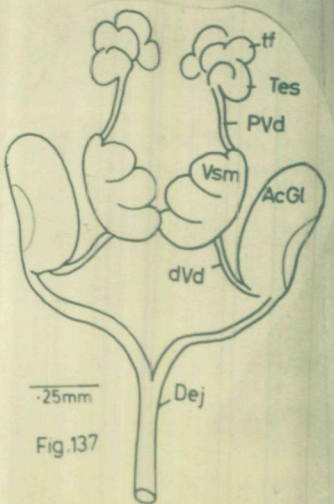


Fig. 137



PLATE 9. Internal anatomy (Contd.).

- Fig. 139. T.S. vasdeferens.  
Fig. 140. T.S. tubule of seminal vesicle.  
Fig. 141. T.S. accessory gland (male).  
Fig. 142. T.S. ejaculatory duct.  
Fig. 143. Female reproductive system.  
Fig. 144. Ovariolo.  
Fig. 145. L.S. Ovariolo in the region of germarium.  
Fig. 146. L.S. Ovariolo in the region of vitellarium.  
Fig. 147. T.S. Oviduct.  
Fig. 148. T.S. Vagina.  
Fig. 149. L.S. spermatheca.  
Fig. 150. T.S. accessory gland (female).  
Fig. 151. Brain and suboesophageal ganglion.  
Fig. 152. Dorsal view of nervous system.  
Fig. 153. Stomatogastric nervous system.

Larval anatomy.

- Fig. 154. Mature egg.  
Fig. 155. Lateral view of first instar larva.  
Fig. 156. Lateral view of second instar larva.  
Fig. 157. Lateral view of third instar larva.  
Fig. 158. Lateral view of fourth instar larva.  
Fig. 159. Lateral view of fifth instar larva.  
Fig. 160. Dorsal view of prepupa.  
Fig. 161. Dorsal view of pupa.  
Fig. 162. Anterior view of larval head.



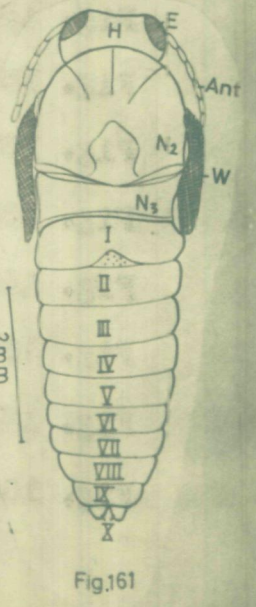
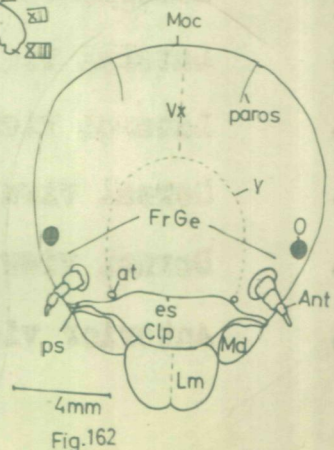
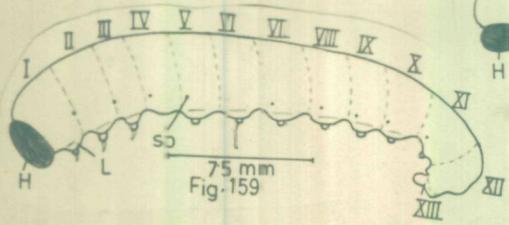
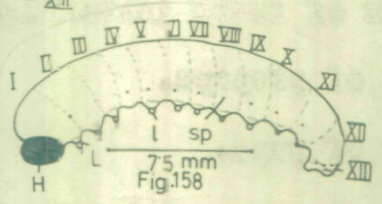
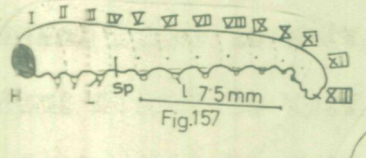
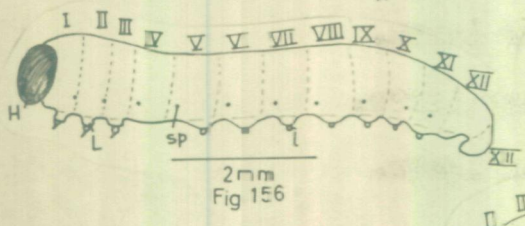
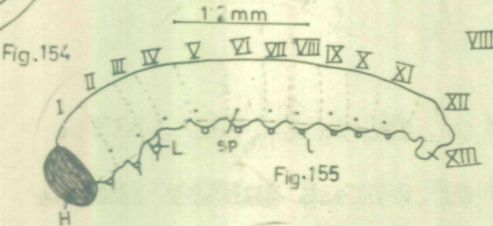
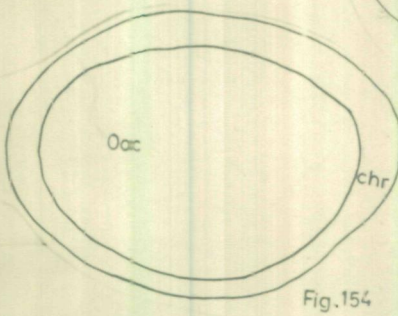
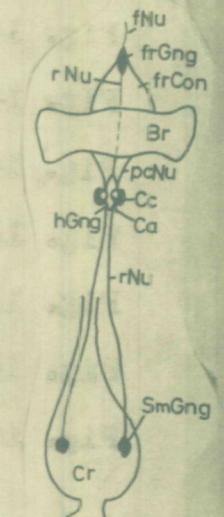
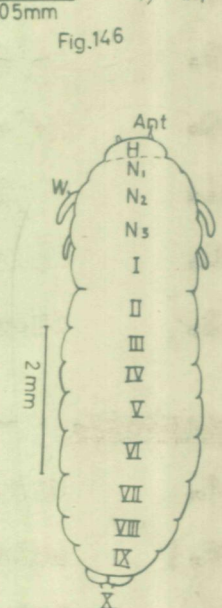
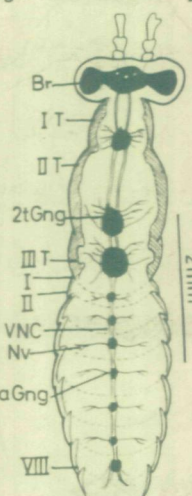
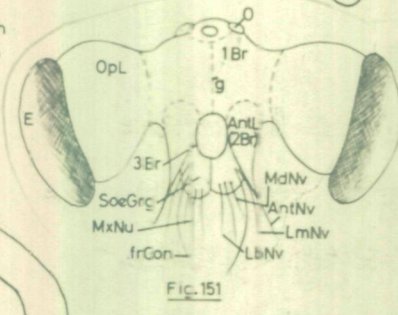
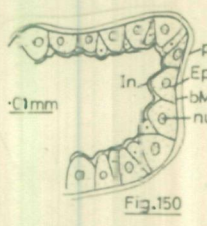
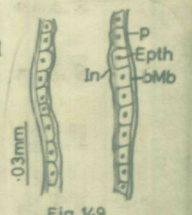
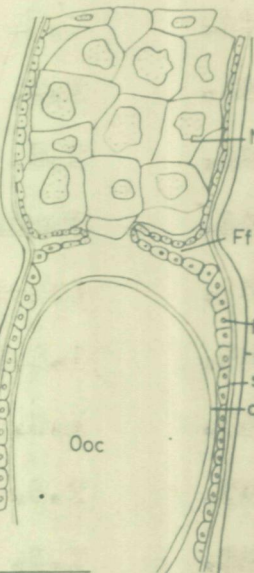
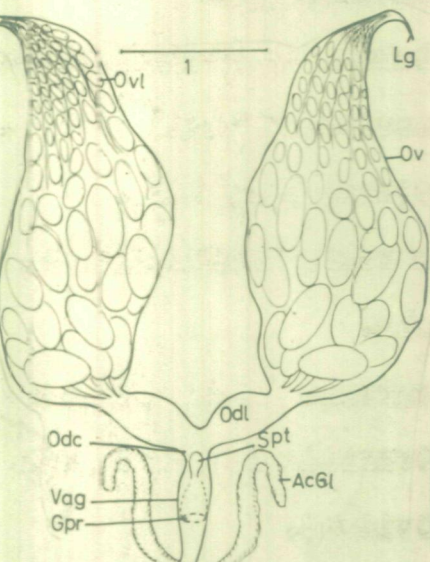
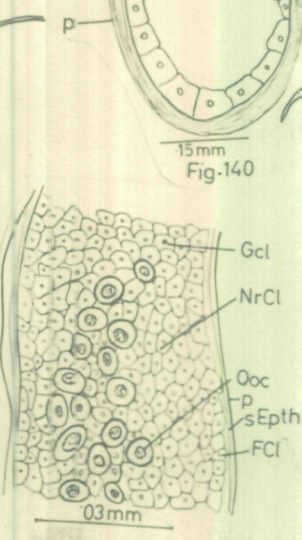
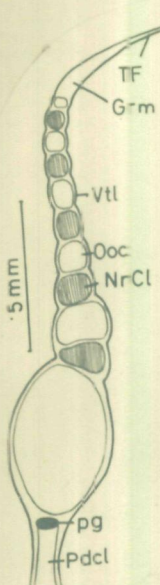
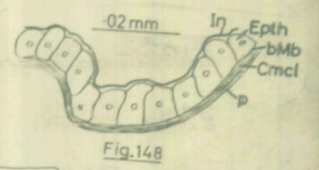
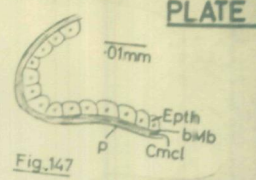
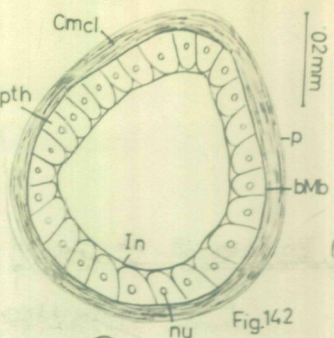
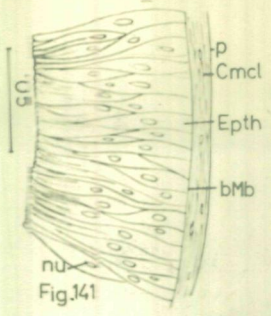
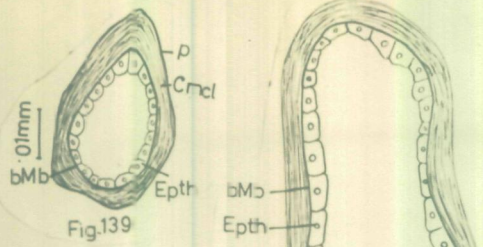




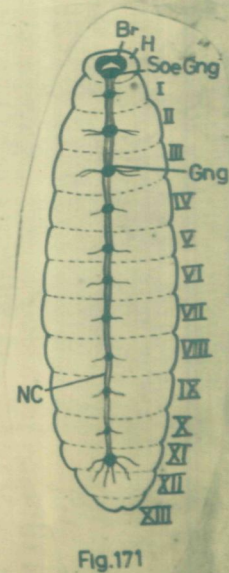
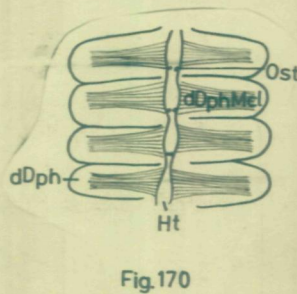
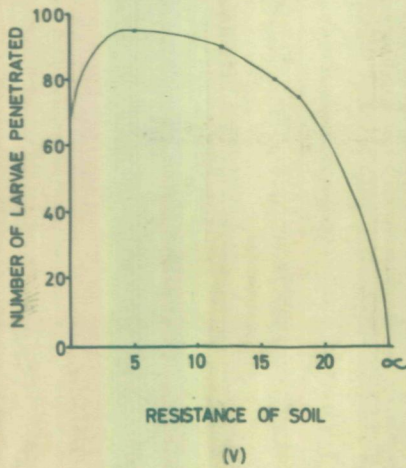
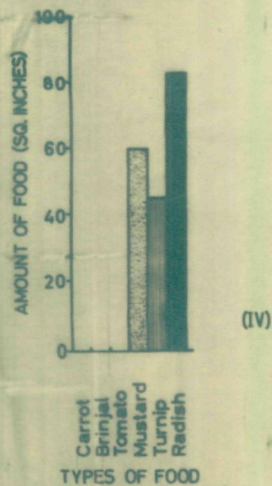
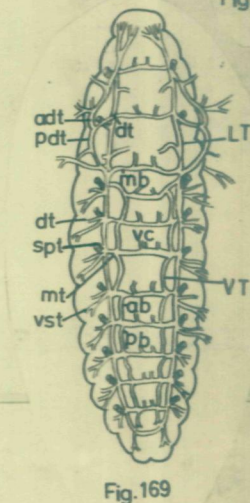
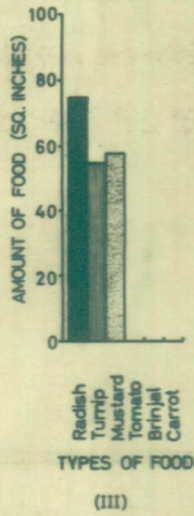
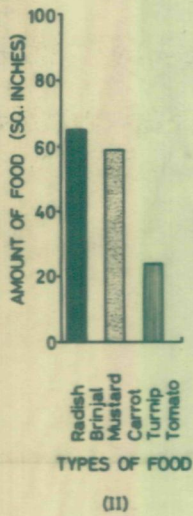
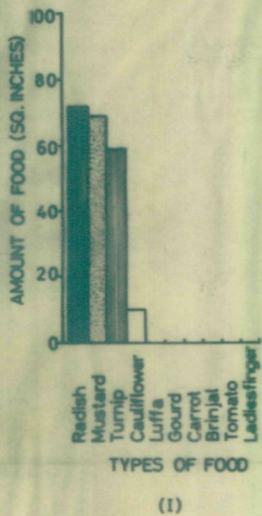
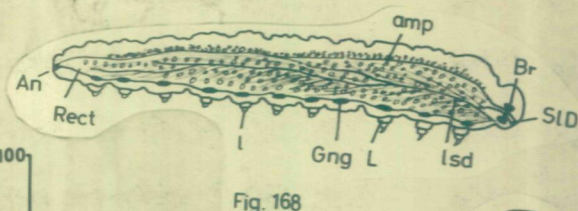
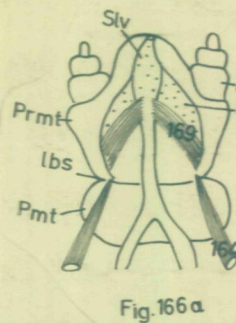
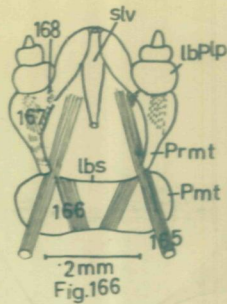
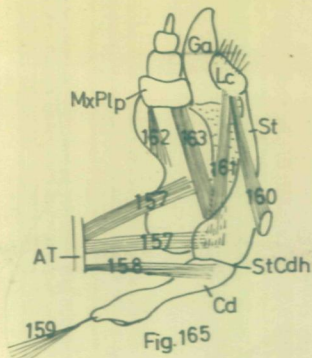
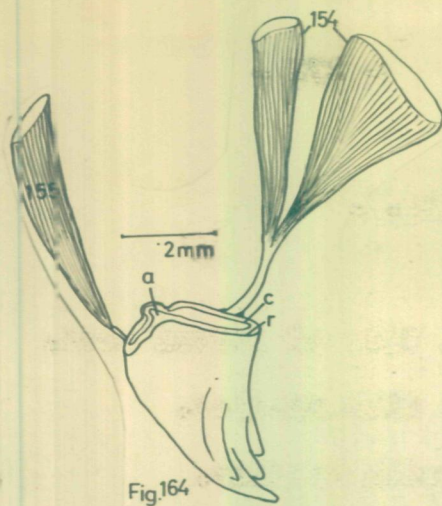
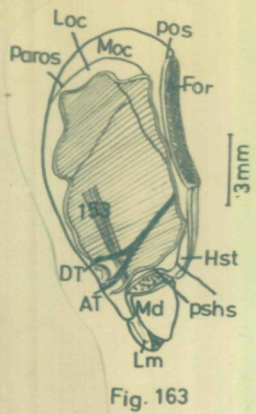
PLATE 10. Larval anatomy (Contd.).

- Fig. 163. Inner and lateral view of larval head.  
Fig. 164. Mandible of larva with muscles.  
Fig. 165. Maxilla of larva with muscles.  
Fig. 166. Labium of larva with muscles.  
Fig. 166a. Labium of larva with muscles.  
Fig. 167. Larval alimentary canal.  
Fig. 168. Inner lateral view of larva showing silk gland.  
Fig. 169. Dorsal view of larval respiratory system.  
Fig. 170. Larval heart in relation to dorsal diaphragm.  
Fig. 171. Dorsal view of larval nervous system.

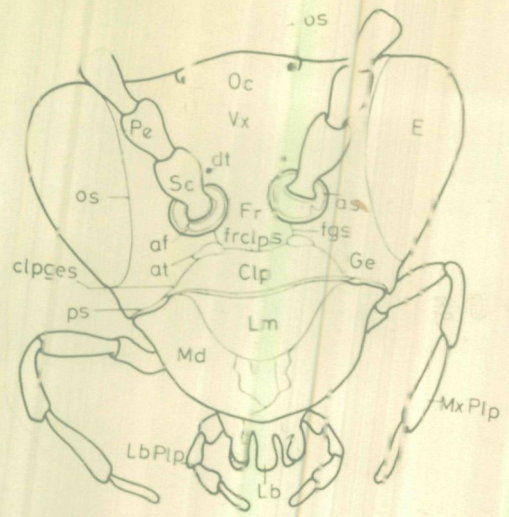
G r a p h s.

- I Food selection by larvae.  
II " " " "  
III " " " "  
IV " " " "  
V Soil selection for pupation.



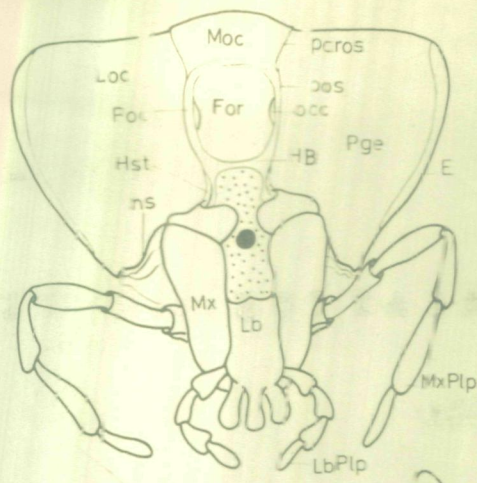






5 mm

Fig. 1



5 mm

Fig. 2

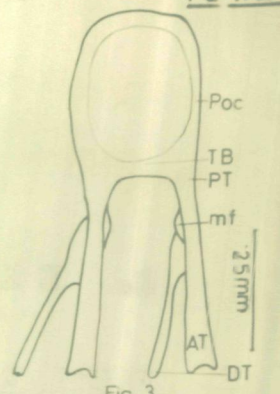
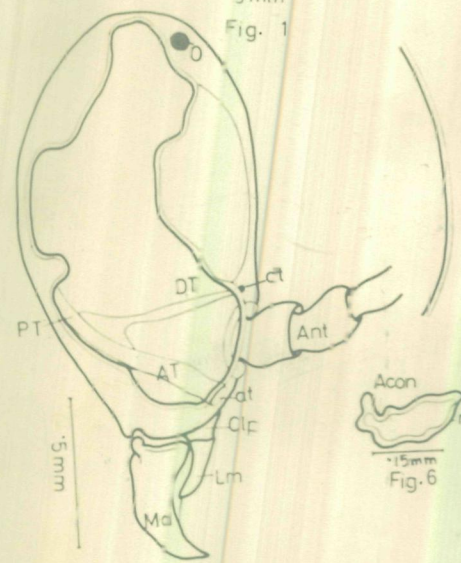
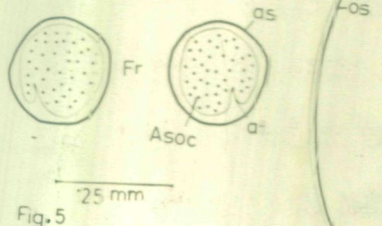


Fig. 3



5 mm

Fig. 4



25 mm

Fig. 5



5 mm

Fig. 8

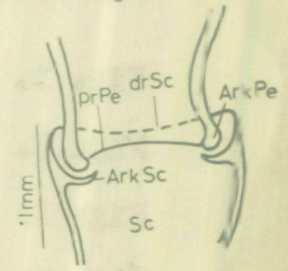
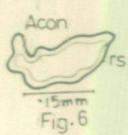
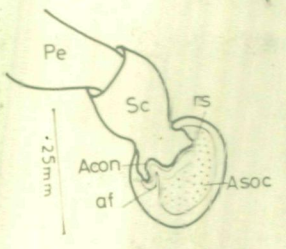


Fig. 9



15 mm

Fig. 6



25 mm

Fig. 7

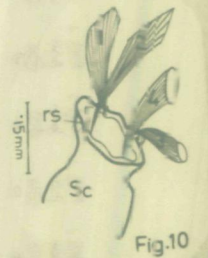
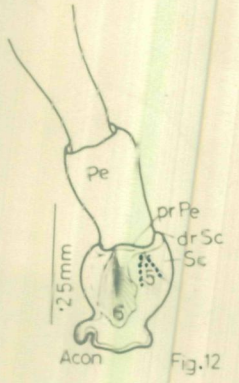
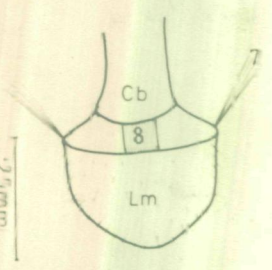


Fig. 10



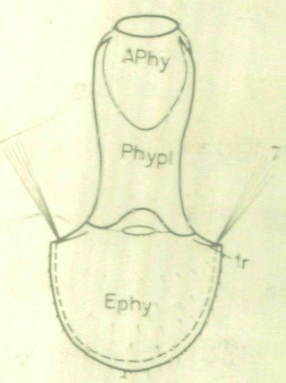
25 mm

Fig. 12



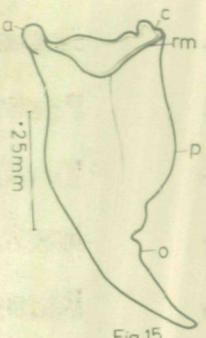
25 mm

Fig. 13



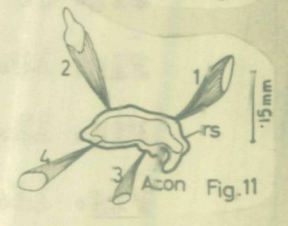
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Fig. 14



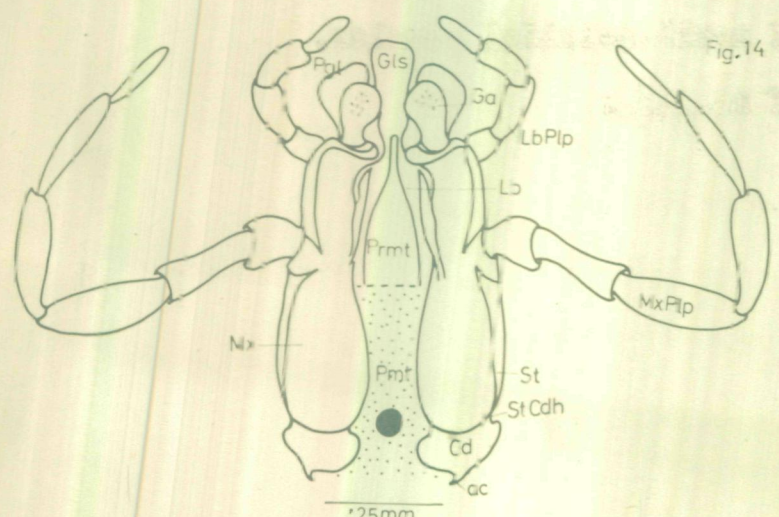
25 mm

Fig. 15



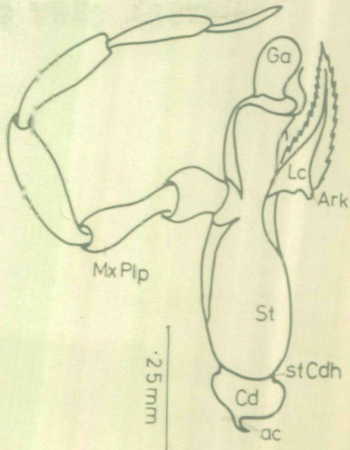
15 mm

Fig. 11



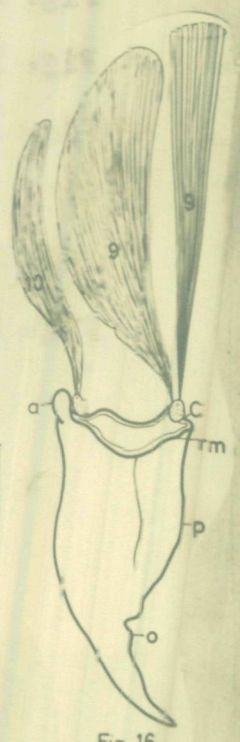
25 mm

Fig. 17



25 mm

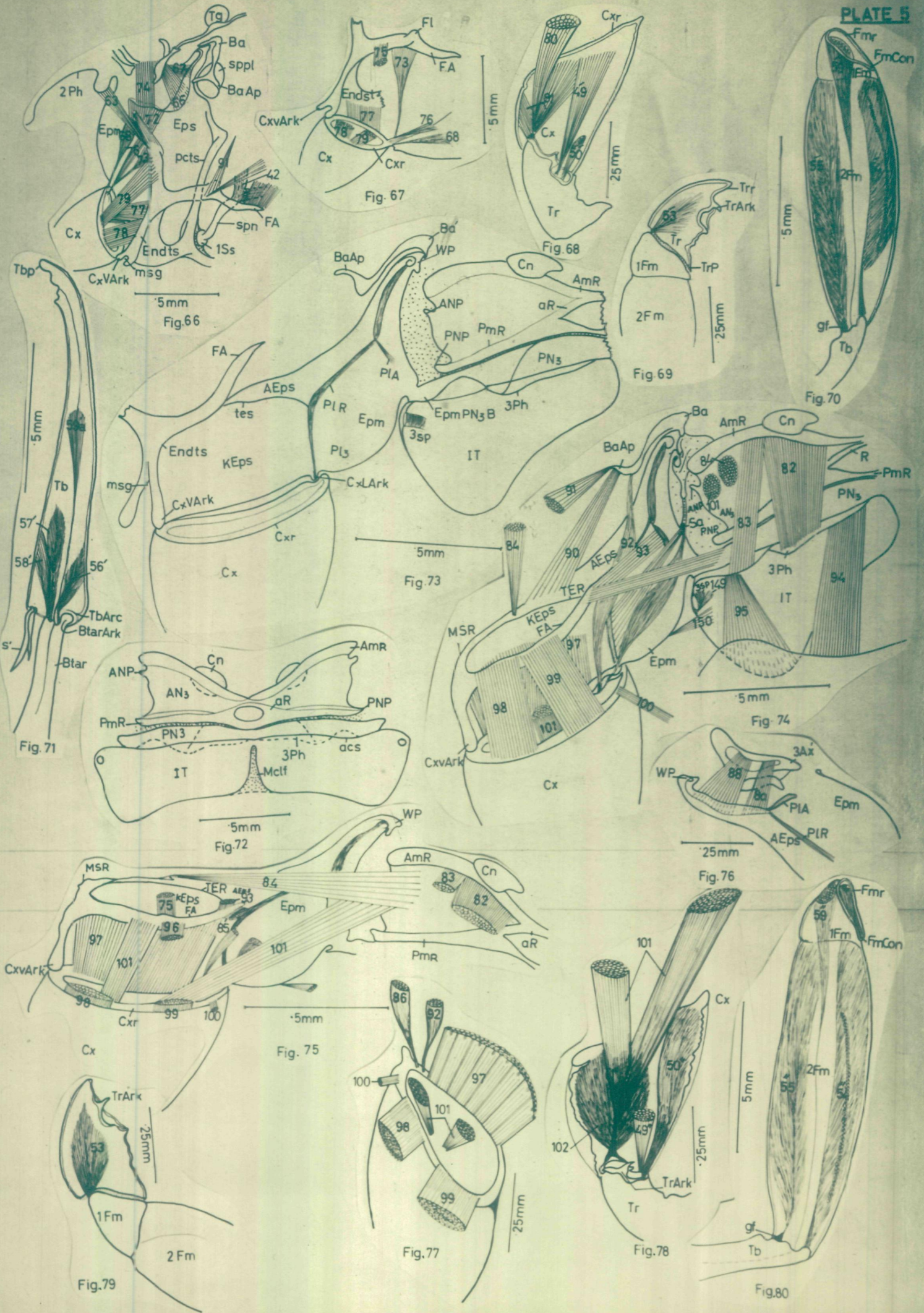
Fig. 18



25 mm

Fig. 16







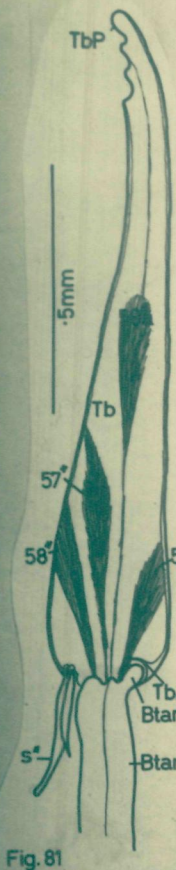


Fig. 81

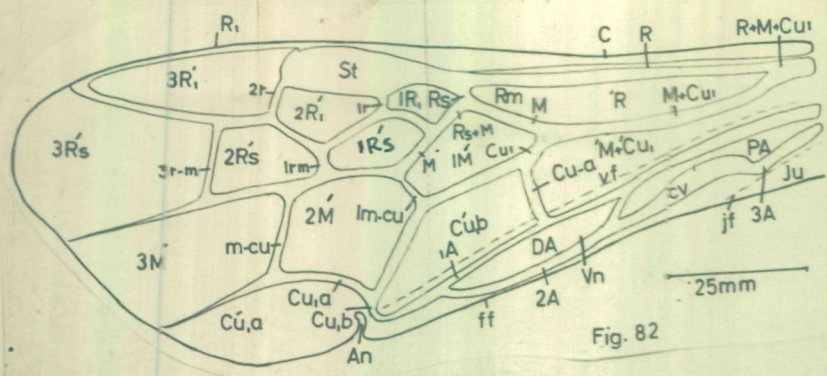


Fig. 82

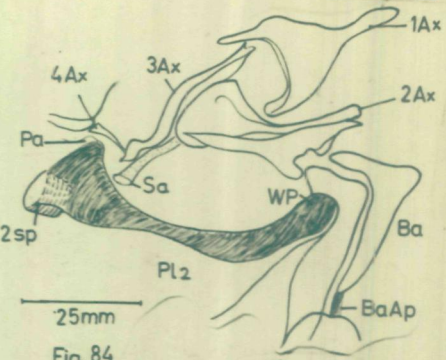


Fig. 84

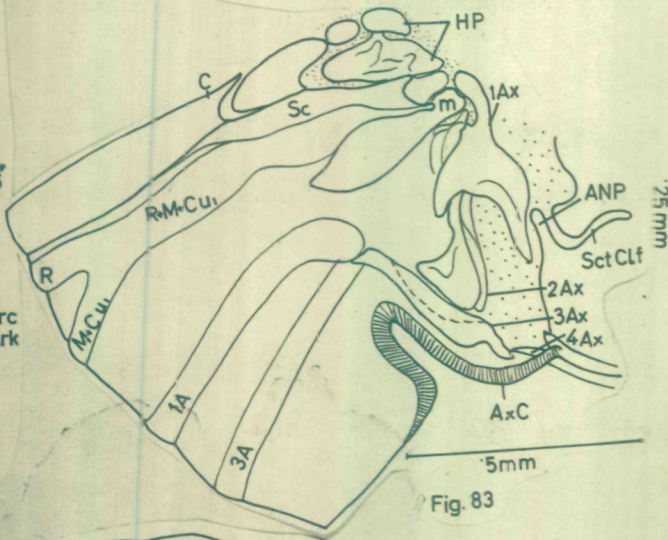


Fig. 83

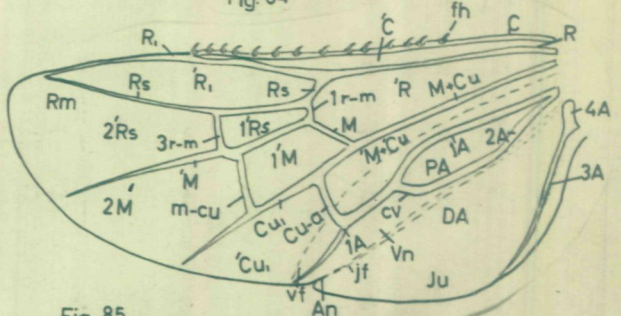


Fig. 85

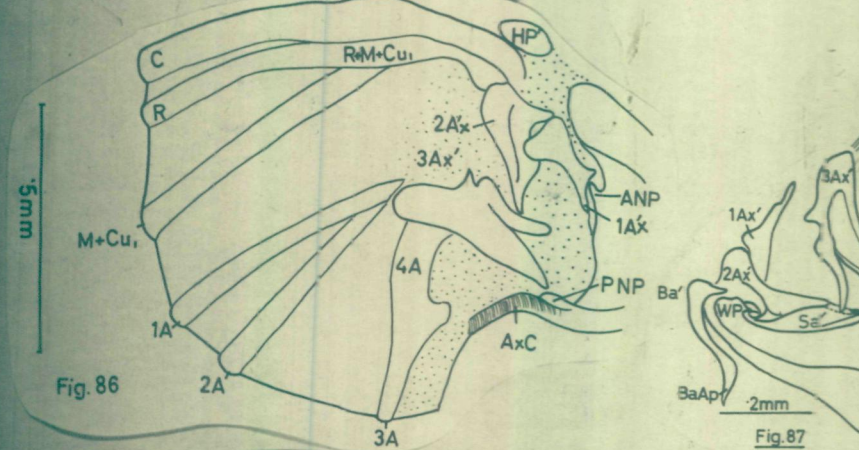


Fig. 86

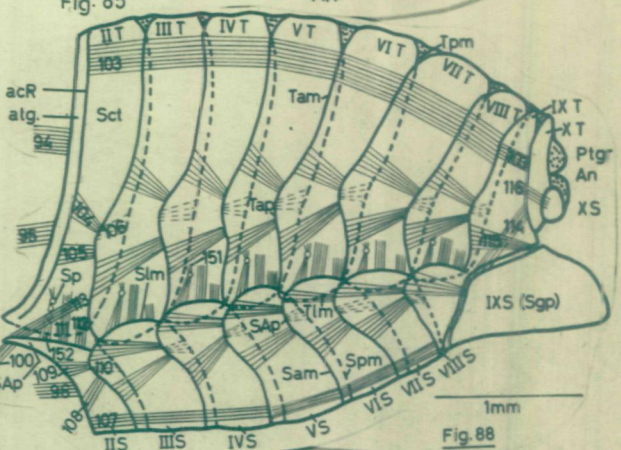


Fig. 88

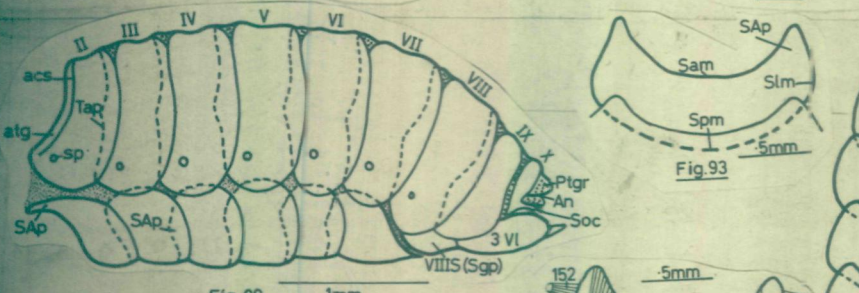


Fig. 89

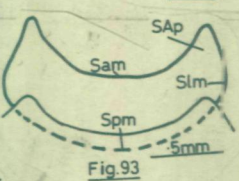


Fig. 93

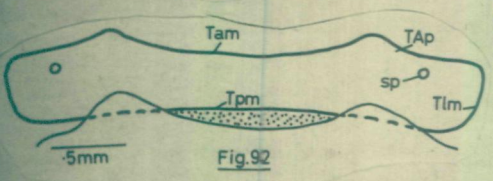


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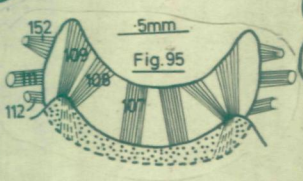


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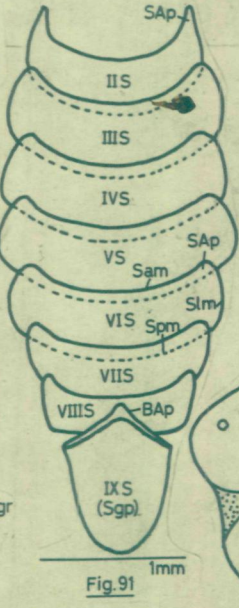


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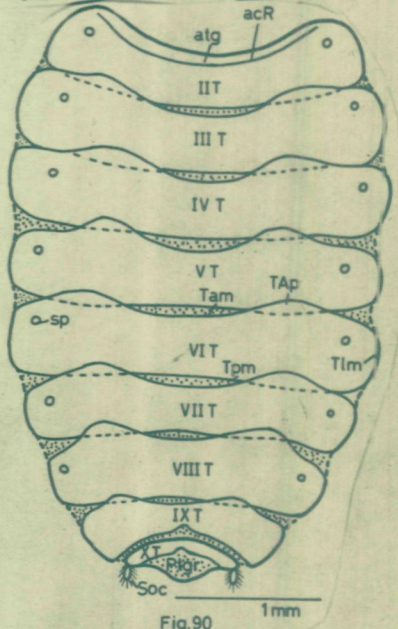


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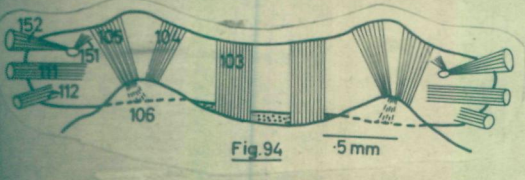


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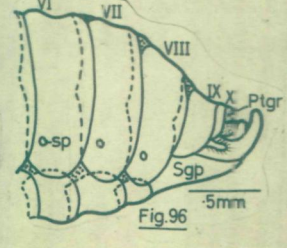


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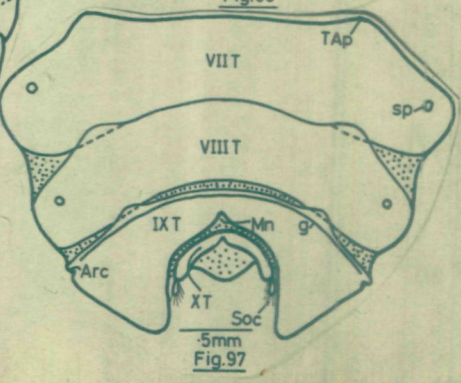


Fig. 97



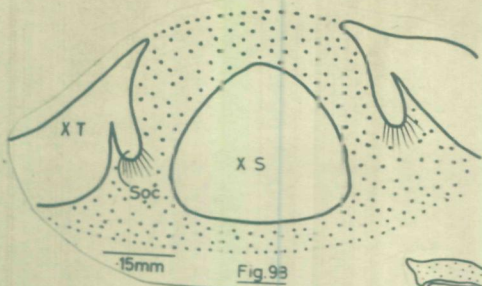


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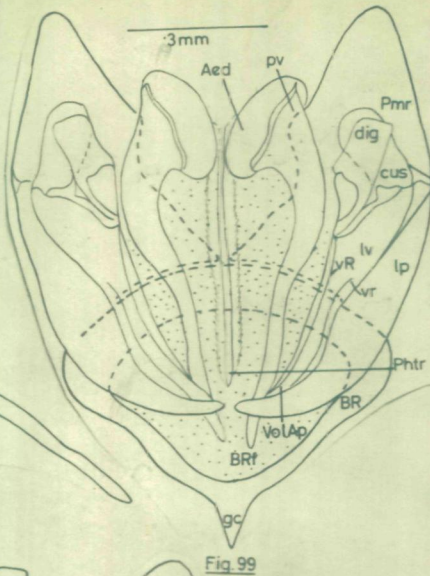


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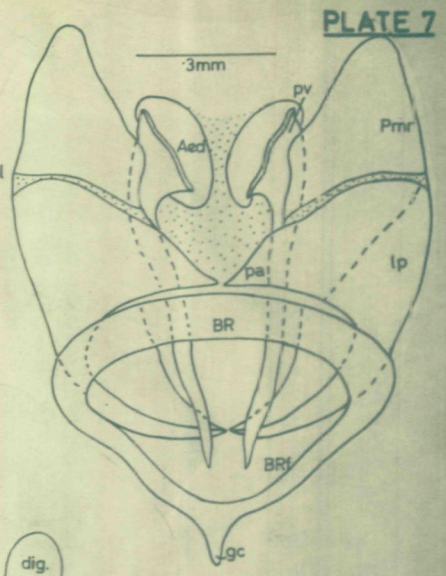


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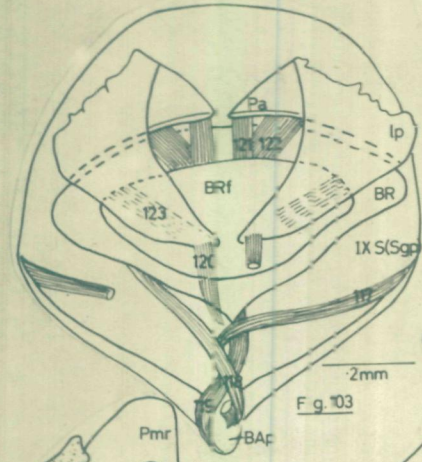


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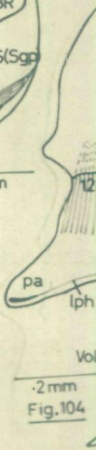


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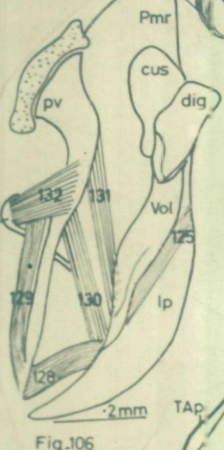


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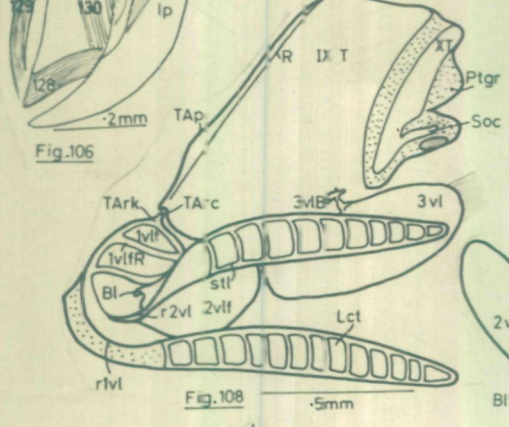


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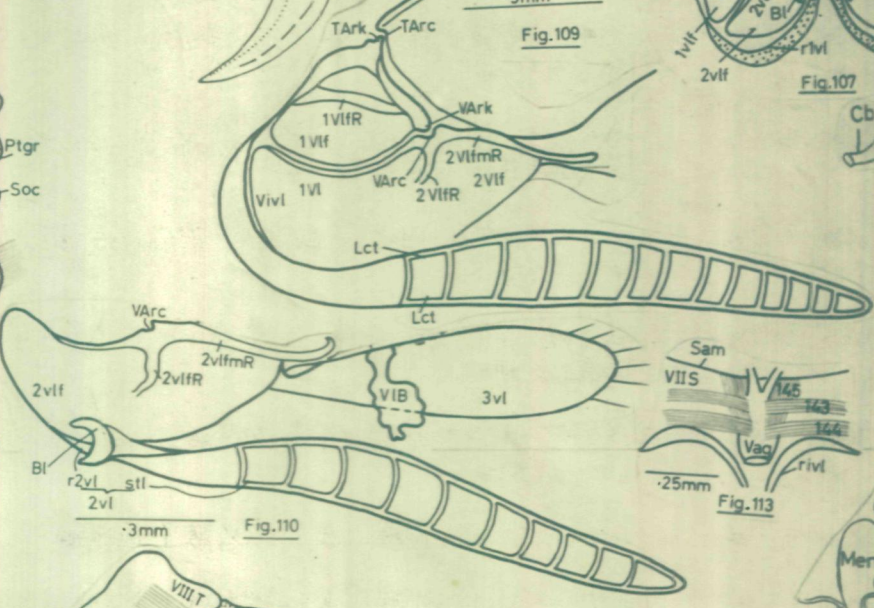


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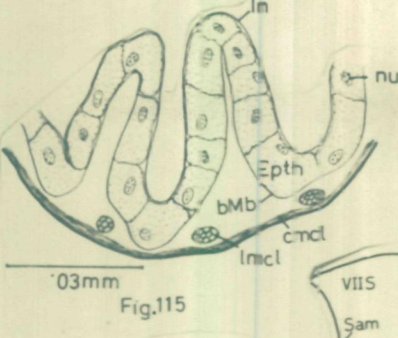


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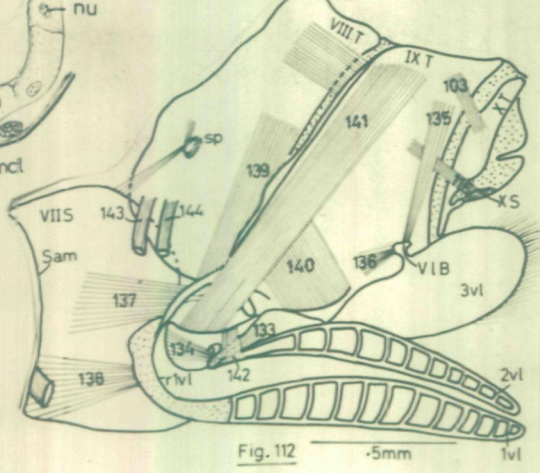


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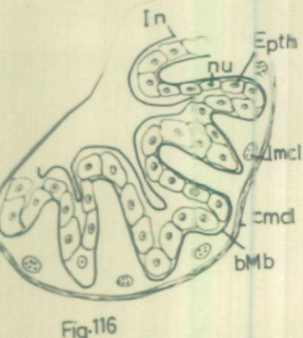


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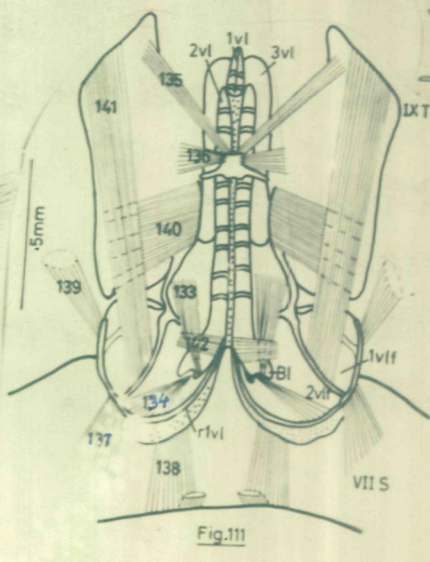


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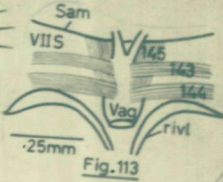


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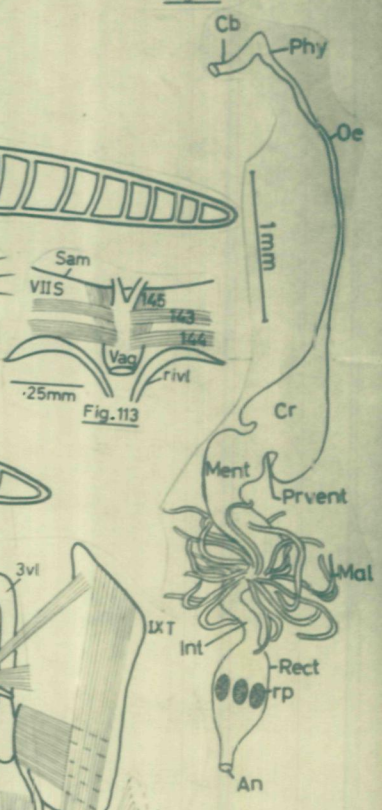


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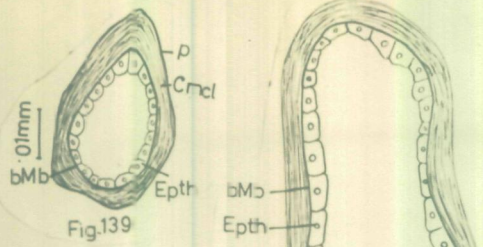


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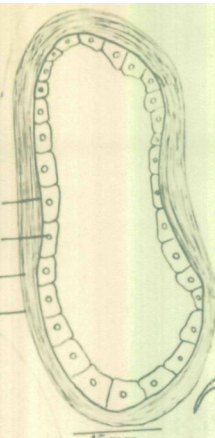


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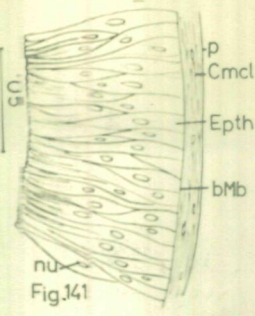


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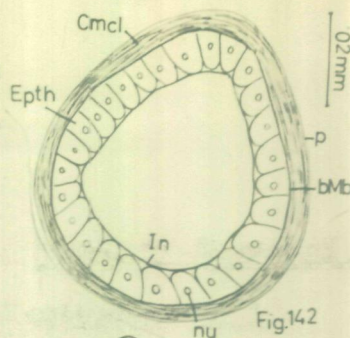


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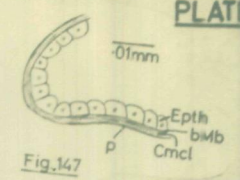


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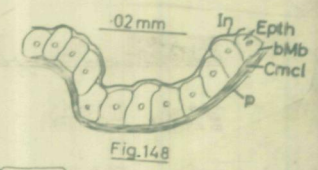


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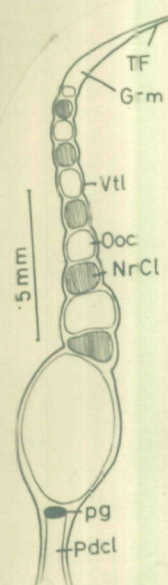


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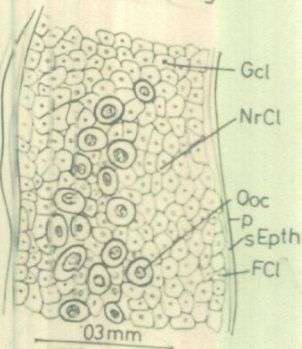


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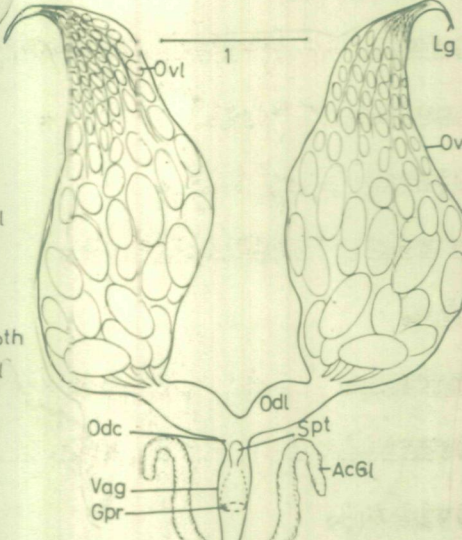


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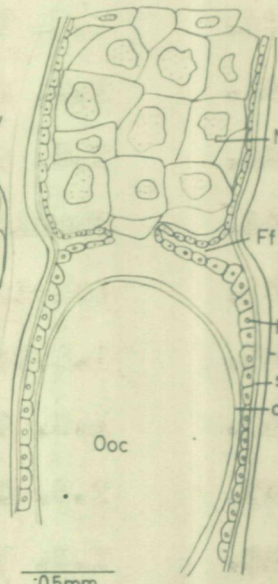


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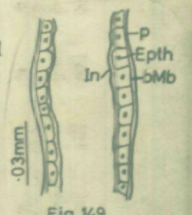


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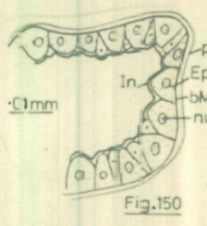


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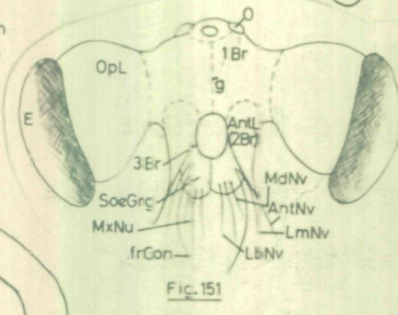


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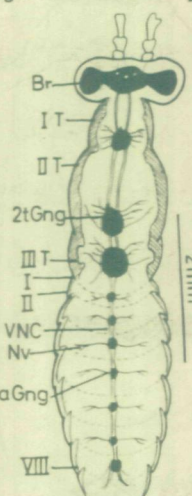


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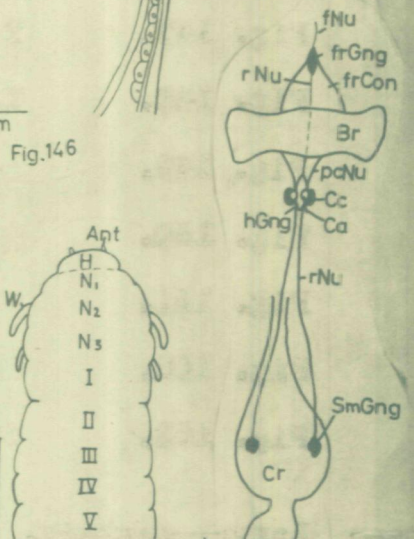


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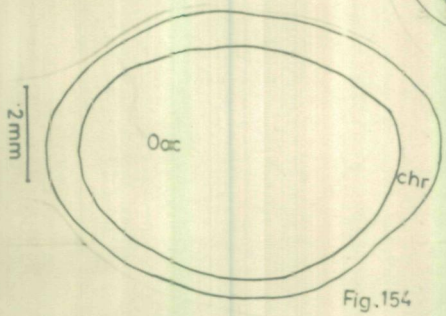


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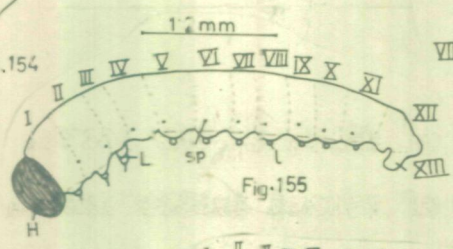


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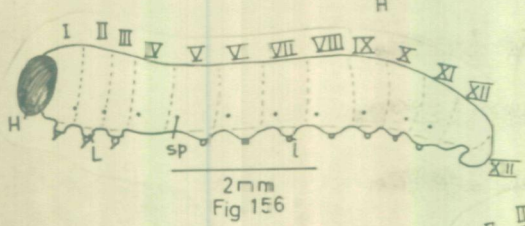


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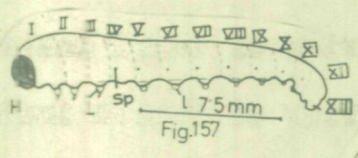


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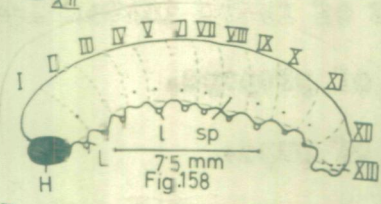


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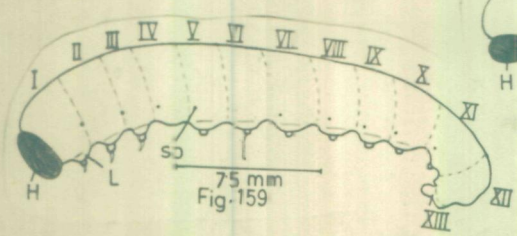


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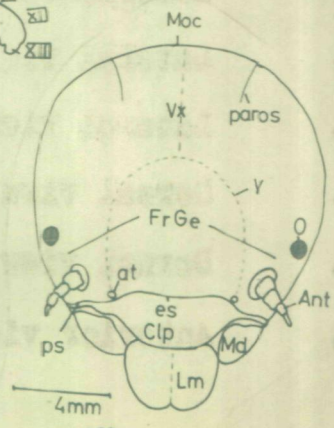


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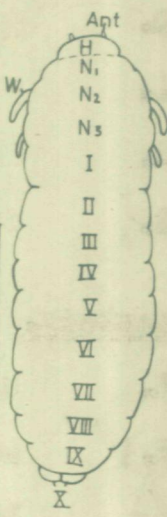


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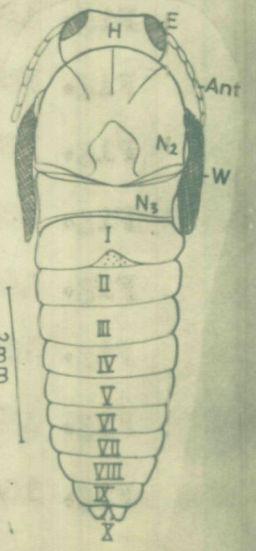


Fig. 161



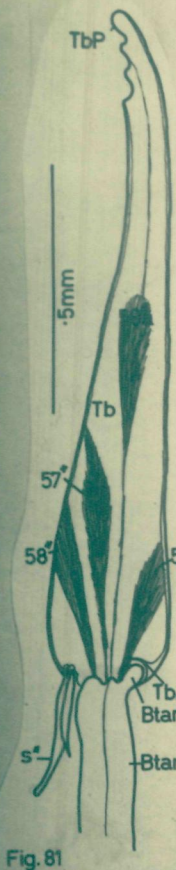


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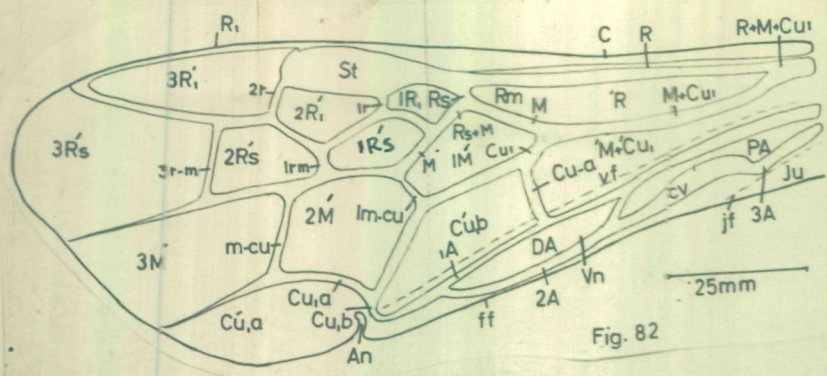


Fig. 82

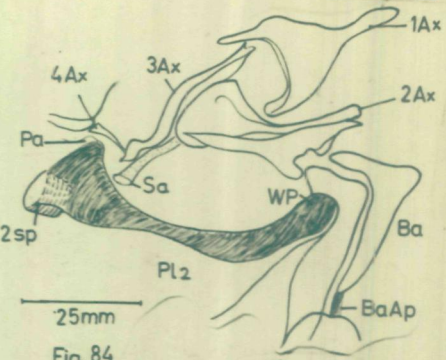


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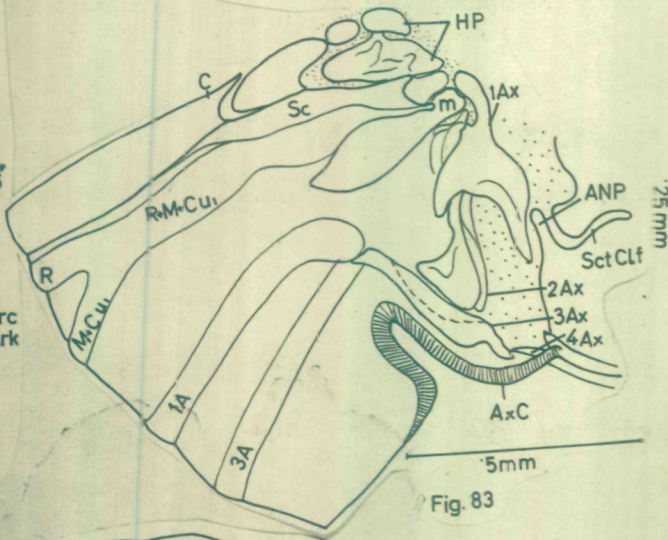


Fig. 83

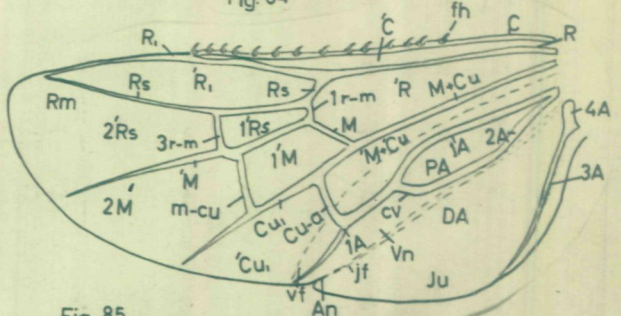


Fig. 85

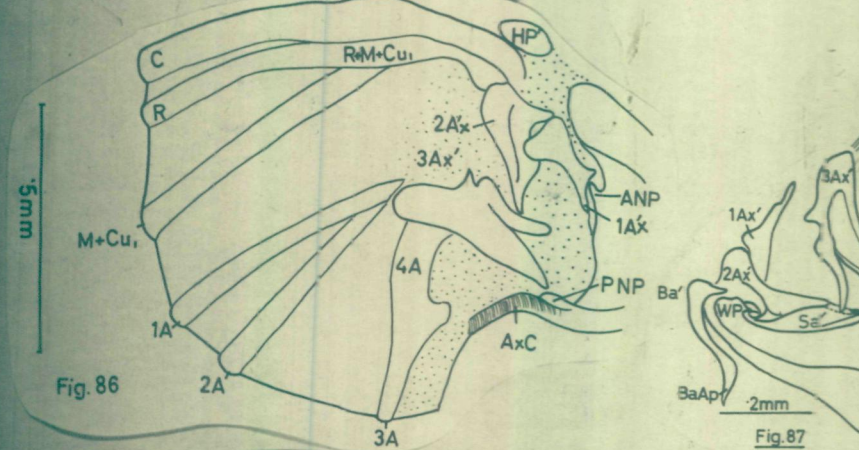


Fig. 86

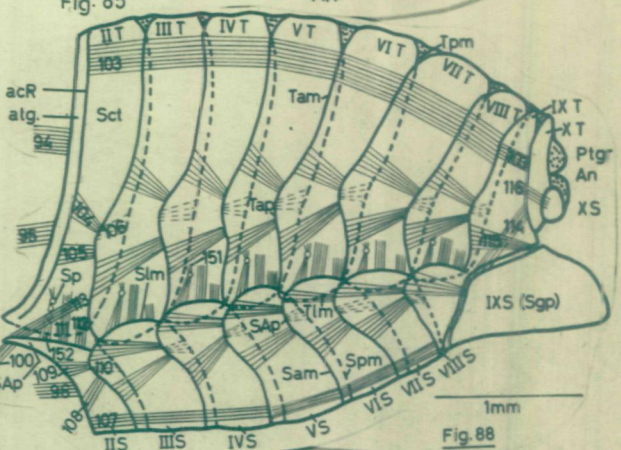


Fig. 88

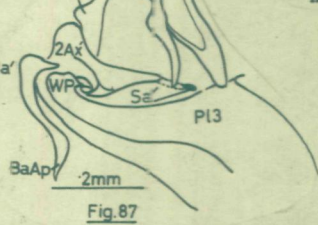


Fig. 87

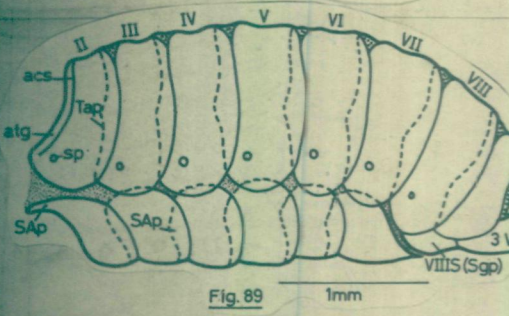


Fig. 89

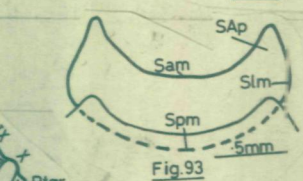


Fig. 93

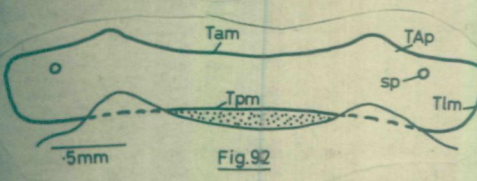


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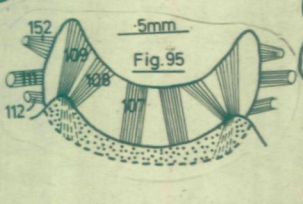


Fig. 95

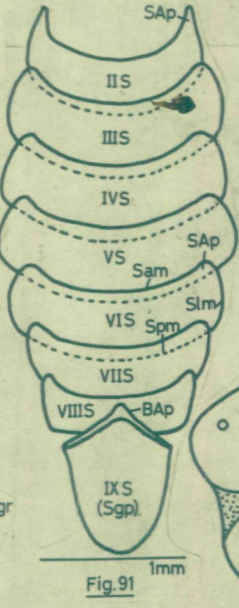


Fig. 91

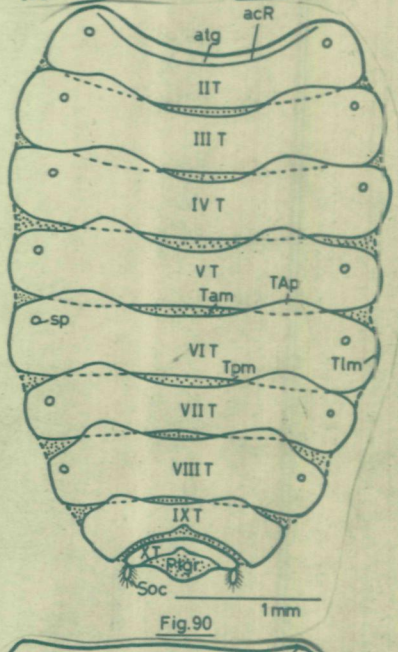


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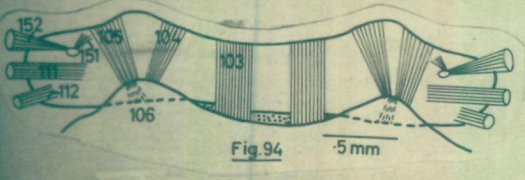


Fig. 94

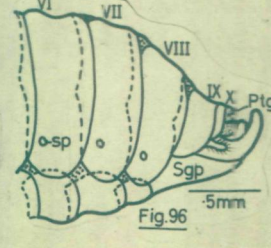


Fig. 96

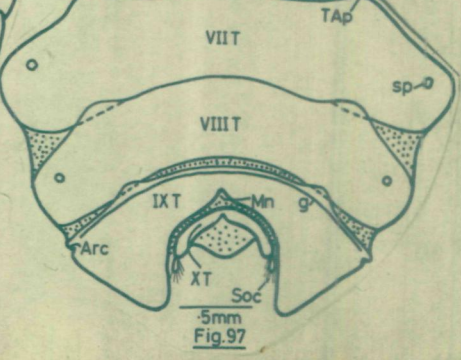


Fig. 97



