The Annual Subscription for Volume 102 is 45s.

[Nos. 1223-25] [PRICE 15s. net.

APRIL/MAY/JUNE, 1966

THE ENTOMOLOGIST'S MONTHLY MAGAZINE

World List Abbreviation, 4th ed. (1963): *Entomologist's mon. Mag.*

VOLUME 102

'J'engage donc tous à éviter dans leurs écrits toute personalité, toute allusion dépassant les limites de la discussion la plus sincère et la plus courtoise.'—*Laboulbène.*

THE ENTOMOLOGIST'S MONTHLY MAGAZINE LTD.
7 THORNCLIFFE ROAD
OXFORD

This issue consists of 72 pages. *Published 16th Ja*

A. T. BROOME AND SON, 18 ST. CLEMENT'S

STUDIES ON THE BIOLOGY OF THE GERRIDAE (HEM., HETEROPTERA)
I: OBSERVATIONS ON THE FEEDING OF *LIMNOGONUS FOSSARUM* (F.)

By Lanna Cheng

Introduction

Very little is known about the feeding processes of Gerridae. Earlier studies relating to feeding were mainly on the morphology of the mouthparts (Ekblom, 1926), or anatomy of the alimentary canal (Baptist, 1941; Miyamoto, 1961; Goodchild, 1963). In general, the literature on the feeding mechanism of aquatic Heteroptera is rather scanty and no direct observations on feeding have hitherto been reported. Information on feeding mechanisms of bugs of medical and agricultural importance is, however, available (Flemion, 1958; Miles, 1958; Dickerson & Lavoipierre, 1959; Lavoipierre *et al.*, 1959). An account of the feeding of a predacious bug was given by Edwards (1960).

The present study is mainly concerned with direct observations on the mode of feeding of *Limnogonus fossarum* (F.). The functional morphology of the mouthparts and the anatomy of the alimentary canal are also discussed.

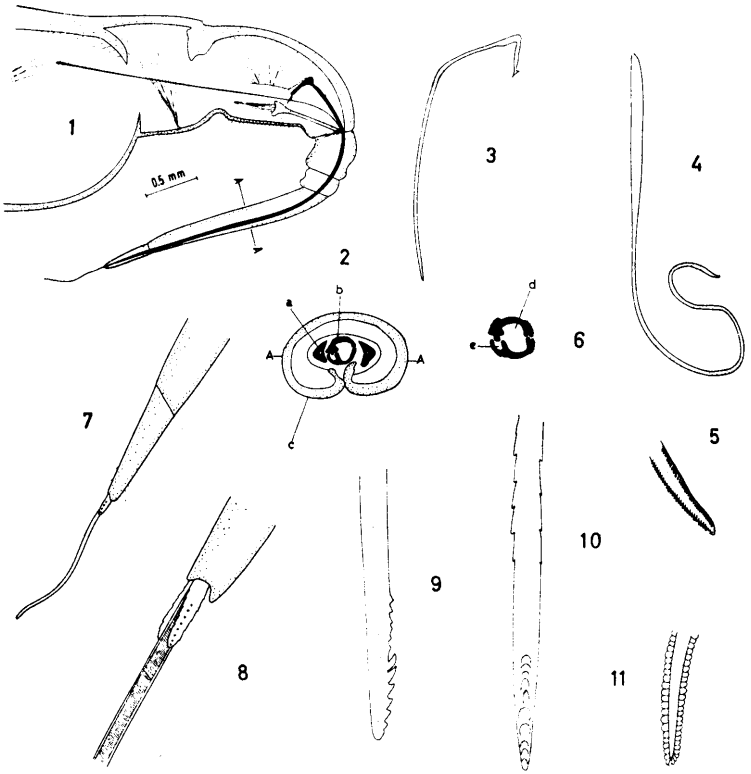
Material and Methods

Adults of *L. fossarum* collected from the pond in the grounds of the University of Singapore were used for the observations. The prey used was *Drosophila melanogaster* Meigen reared in the genetics laboratory of the Department of Zoology. At first, flies of varying ages were used for observations, but it was found that the dark-coloured integument rendered observations difficult, since the insects could not be transilluminated. Subsequently only newly emerged flies were used as these were very pale in colour and relatively transparent.

For direct observations, the insect was placed in a clean 'Perspex' container of dimensions 5 x 6 x 1½ inches. The water level was kept about 3 inches below the brim to prevent the insect from jumping out. A binocular microscope was rotated so that the objectives were at right angles to one side of the container, thus enabling the gerrid to be kept under observation in side view. The head of the microscope could be swung through an angle of about 90° in the vertical plane so that the whole field of the container could be covered. The movements of the insect in the container could therefore be easily followed. The angle between the container and the microscope objective could also be adjusted to any suitable position. A table lamp was used to provide illumination.

The gerrid was introduced into the container and left undisturbed until it had accommodated to the new environment, a matter of 5 to 10 minutes. When it had ceased making escape movements, a fruit fly, freshly killed with chloroform and with wings cut off, was dropped onto the surface of the water in the container.

Flies on which the gerrids had fed were examined for traces of muscle and other body contents in a drop of water immediately after feeding was over, and fresh flies were similarly examined for comparison. Specimens of each were also fixed and embedded for subsequent histological study.



Figs. 1–11.—*Limnogonus fossarum* (F.):
1, L.S. head and rostrum; 2, T.S. rostrum (a, mandible; b, maxilla; c, labium); 3, mandible; 4, maxilla; 5, tip of maxilla showing hairs; 6, T.S. maxillae (d, food canal; e, salivary canal); 7, tip of rostrum with mandibles and maxillae extended; 8, tip of rostrum showing mandibles and part of maxillae; 9, lateral view of mandible; 10, dorsal view of mandible; 11, labrum.

For studies on the gross morphology of the mouthparts, the insects were cleared in hot 10 per cent NaOH for one to two hours, washed in water, cleared in xylol after dehydration and finally mounted in Canada balsam. In about ten specimens, the maxillary and mandibular stylets were dissected and mounted for microscopic examination. Histological studies were made on sections prepared after embedding in paraffin wax. Thick hand sections were also cut using the technique described by Lavoipierre (1958).

Functional Morphology of the Mouthparts

The rostrum is the modified labium. It is 4-segmented, held pointing backwards under the head in a horizontal position in the non-feeding bug, and is hinged in such a way that it can be swung forwards and directed anteriorly. The first and second segments are short and broad, the third is long and slender whilst the last segment is rather short and tapers to a point (fig. 1). It is also much darker in colour than the other segments and very flexible.

The mandibles and maxillae are long and thin and are enclosed in the groove formed by the rostrum (fig. 2). The maxillae (fig. 4) are more than $1\frac{1}{2}$ times the length of the mandibles (fig. 3). They are needle-like with bluntly pointed tips, and are held together firmly by the hairs along their inner surfaces (fig. 5). They interlock to form two tubular canals, a broad food canal (fig. 6d) and a narrow salivary canal (fig. 6e). The mandibles are appressed to the maxillae which they flank (figs. 7 and 8). They have rather pointed tips which are barbed at the outer margins. Each mandibular stylet is fringed with small spines along almost its entire length (fig. 10). In addition, there are 8–10 large teeth near the distal end (fig. 9). The teeth and spines help to anchor the mandibles following their insertion into the body of the prey.

The labrum is short and in the resting bug lies ventral to the labium. It is highly ornamented with small rounded lobes along its sides (fig. 11). As suggested by Awati (1914) the labrum may help to keep the stylets in place and prevent their displacement while the bug is feeding.

Anatomy of the Alimentary Canal

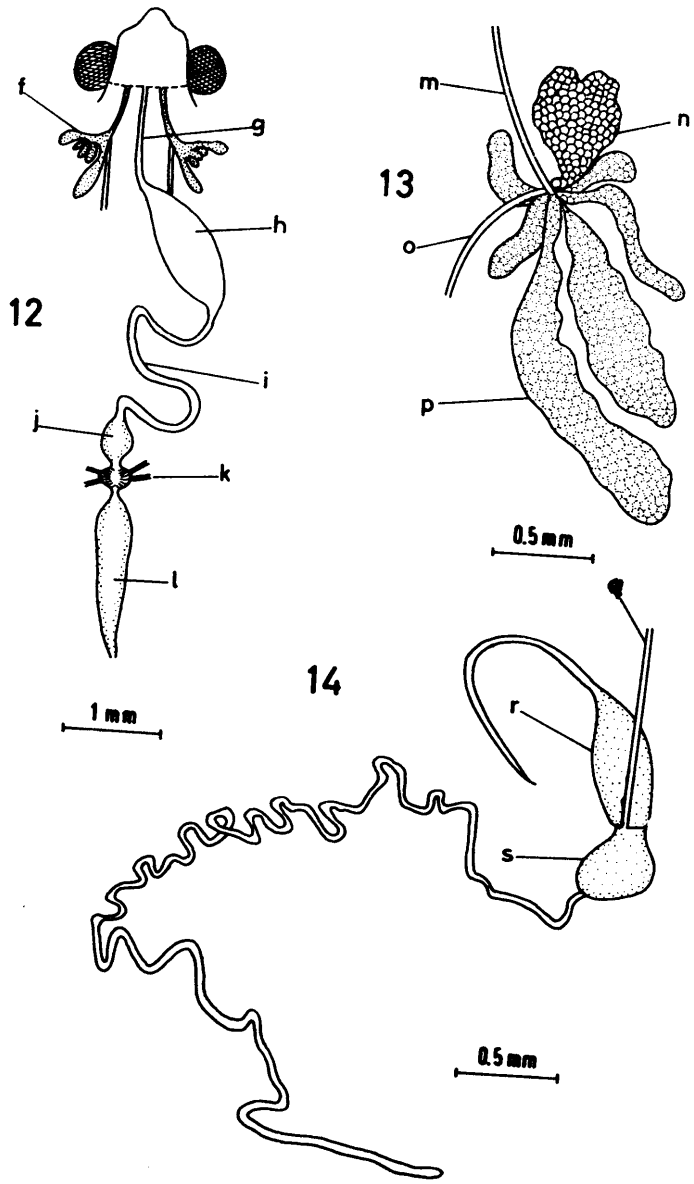
The salivary glands are paired and each consists of a principal and an accessory gland. The principal glands lie in the thorax, one on each side of the pharynx. The accessory glands are found much lower down in the body and are provided with long tubular processes.

Each principal gland (fig. 13) is divided into two lobes. The anterior lobe is undivided and yellowish in colour while the posterior lobe is whitish and made up of 6 lobules. These lobules are oval in shape and unequal in size, some being much longer than the others. The salivary duct arises at the junction of the anterior and posterior lobes. It passes forwards and joins the salivary duct of the other gland near the base of the head to form a common salivary duct which opens into the salivary chamber at the base of the head.

The accessory glands (fig. 14) are bilobed with less tracheal supply than the principal glands. The anterior lobe is more or less conical in shape with a long thin anterior tubular process which ends in a pointed tip. The posterior lobe is globular in shape with a thin and extremely long and convoluted tubular process. The accessory salivary duct arises at the junction of the two lobes, it travels forwards to join the duct of the principal gland near its origin.

The pH of the principal gland of *Limnogonus fossarum* was found to be 6.9 using the BDH capilator with bromo-thymol blue as the indicator. Baptist (1941) obtained a pH of 6.4 in *Gerris lacustris* (L.).

The salivary pump consists of a pump chamber and a piston. The pump chamber is triangular in shape and lined with a thick chitinous layer. The piston lies at the posterior end of the chamber and is a



Figs. 12–14.—*Limnogonus fossarum* (F.):
12, Alimentary canal (f, principal salivary gland; g, oesophagus; h, crop; i, small intestine; j, mid-gut; k, malpighian tubule; l, hind-gut); 13, principal salivary gland (m, principal salivary duct; n, anterior lobe; o, accessory salivary duct; p, posterior lobe); 14, accessory salivary gland (q, accessory salivary duct; r, anterior lobe; s, posterior lobe).

densely chitinised but elastic structure. It continues backwards to form a handle on which the pump muscles are attached. The common salivary duct opens into the chamber antero-ventrally, and the efferent salivary duct emerges antero-dorsally, the latter enters the salivary canal formed by the maxillary stylets (fig. 15).

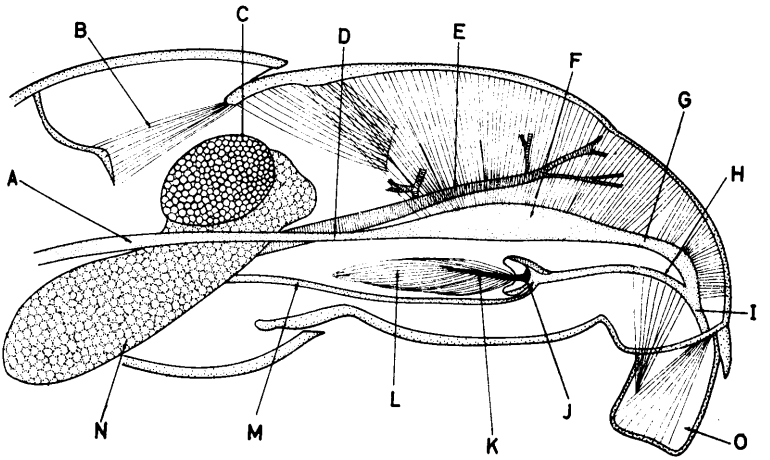


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Fig. 15.—*Limnogonus fossarum* (F.): L.S. head; A, oesophagus; B, muscle; C, anterior lobe of principal salivary gland; D, pharynx; E, tracheae; F, cibarial pump; G, food canal; H, efferent salivary duct; I, food meatus; J, salivary pump; K, pump handle; L, pump muscle; M, common salivary duct; N, posterior lobe of principal salivary gland; O, base of rostrum.

The food canal (fig. 12) opens into a very narrow oesophagus which widens tremendously to form the thin-walled crop which is quite transparent in the non-feeding gerrid. The small intestine continues from the crop, it is thicker-walled and loops forward once. This narrow small intestine opens into a bulb-like mid-gut which is short and followed by a constriction which is then followed by another bulb-like structure from which two long, thin, malpighian tubules are given off from each side. The hind gut is demarcated from the rest of the gut by a constriction and opens at the anus.

Direct Observations on Feeding

For direct observations, only one gerrid was used at any one time. Upon the introduction of a fly, if the gerrid was not ready to feed, it would just ignore the prey even if this was in the near vicinity, or touching it. It would simply rest on the water surface stroking its antennae or legs. This stroking process could go on for quite a long time, but the insect might be induced to feed after some persuasion such as moving it gently towards the prey. Very few gerrids used for this observation commenced to feed immediately a fly was introduced.

Prior to feeding it was observed that the rostrum which was held underneath the head and thorax in the non-feeding position, was swung forwards to touch the water surface and brought back again to the resting position several times. Whether this behaviour has any olfactory significance is not known. Following this behaviour, the bug then suddenly pounced on the fly and seized it by one or both of its front legs. The rostrum then swung forwards with the tip running over the surface of the fly. The last segment of the rostrum which was very flexible could be seen poking at various points on the body of the fly, searching for a suitable spot for the insertion of the stylets. The point of insertion was chiefly on the thorax or abdomen, rarely on the head.

Once a suitable spot was found, the rostrum could be seen pressed tightly to the cuticle of the fly. The movements of the mandibular stylets could not be observed. They only penetrated the superficial layers of the body wall and appeared to serve for anchorage. On the other hand, within seconds after the insertion of the stylets, the maxillae could be distinctly seen deep in the fly's body, describing wide sweeping movements. Owing to the transparency of the body wall of the newly emerged fly, the movements of these maxillary stylets could be followed easily. On one particular occasion, the insertion was in the mid-thoracic region. The maxillary stylets were seen bending in all directions, sucking out the contents of the fly, reaching the tip of the abdomen as well as the head. Even the red eye pigments of the fly were seen to be sucked up within seconds!

Once the feeding commenced, the gerrid usually disengaged its front leg from the prey which was now held by the mouthparts of the bug without any assistance from the legs. If undisturbed, the bug usually remained quite still while feeding, but it might stroke its body with its front legs or move slowly. When feeding was complete, the fly was rejected with the help of the front legs.

Specimens of gerrids were dissected in insect saline (Pantin, 1948) immediately after feeding was over. The distended crop could be seen pumping at a rather rapid rate and appeared pinkish in colour. The mid-gut was orange and the rest of the gut was dark brown. Microscopic examinations of smears of the crop revealed that the contents were semi-liquid with very little cellular material and no trace of muscle fibres. There were numerous fat globules of varying sizes (3.6μ-14μ in diameter), and a number of fat cells enclosed in envelopes. This suggested that protease was present in the salivary fluid and lipase was apparently absent. Protease has been reported in the salivary extract of *Gerris lacustris* (Baptist, 1941).

Flies on which the gerrids had fed were teased open in a drop of water under the dissecting microscope as soon as they were abandoned by the bug. In all the flies dissected, the body was empty except for traces of tracheae and gut. There was no trace of the prominent thoracic muscles present in fresh flies dissected for comparison. This suggested that the muscles and other body contents of the fly were liquified before being sucked up by the gerrid. Histological examinations were also carried out on flies fixed soon after feeding was over. These also revealed an almost empty body in contrast to fresh flies which were packed with muscles, gut, etc. (Plate VII).

Discussion

The classical view on the mode of feeding of the Heteroptera as proposed by Weber (1928) was that the mandibles are the effective piercing organs and that they take part in the feeding process. Recently, however, Qadri (1959) and Lavoipierre *et al.* (1959) found that in some bugs at least, the mandibles are mainly used for anchorage and take little or no direct part in feeding. In the present study, it was shown that the mandibles are anchoring organs and feeding is carried out by the maxillae. The recurved spines at the apex on the outer margins of the mandibles serve to anchor them to the integumentary tissues of the prey. The maxillary stylets serve the main functions of piercing as well as conveying food and salivary secretions.

The feeding mechanism of the gerrids is strikingly similar to those of blood-sucking bugs when feeding in mammalian tissues, the stylets showing the same remarkable flexibility. There is, however, considerable difference in the action of the digestive enzymes of the two groups. In the blood-sucking bugs, there does not seem to be any noticeable destruction of tissues of the host (Lavoipierre et *al.*, 1959), whereas in the case of *Limnogonus fossarum* the muscles and other body contents of the prey are almost entirely dissolved. This would appear to indicate that this species has a powerful cytolytic enzyme system which differs sharply from that of the blood-sucking bugs.

Acknowledgements

I am deeply indebted to Dr. M. M. J. Lavoipierre, Resident Co-ordinator in Singapore, of the International Centre for Medical Research and Training, University of California, for many valuable suggestions and criticisms. I wish to express my gratitude to the academic and technical staff of the Department of Zoology, University of Singapore, where this work was carried out, for their help in various ways. In particular, I would like to thank Prof. J. L. Harrison for his guidance and encouragement, and Mr. H. K. Yip for photographic assistance. I am also very gratefuly to Dr. B. M. Hobby, Hope Department, Oxford, for criticising the original manuscript.

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August 30th, 1966.

The Scientific Use of B.B.C. Wildlife Sound Recordings.—In view of the increasing interest in the study of bird and other animal vocalizations and the fact that 'The Ibis' and other scientific journals now consider it worthwhile to review commercially published sound recordings of birds, I would like to remind *bona-fide* students of bioacoustics of the availability of the B.B.C.'s extensive collection of wildlife sound recordings.

At present a complete set of all the B.B.C. recordings is deposited in the Subdepartment of Animal Behaviour, High Street, Madingley, Cambridge (enquiries to Professor W. H. Thorpe) and at the headquarters of the British Trust for Ornithology, Beech Grove, Tring, Herts. (enquiries to the Secretary). In addition all insect recordings are deposited with the Department of Entomology at the British Museum (Natural History) (enquiries to Dr. D. R. Ragge), but these cannot be sent out on loan. New records are automatically sent to these centres as they become available. The British Institute of Recorded Sound are planning to purchase a further set from the B.B.C. and this will be available for study in London (at the B.I.R.S., 29 Exhibition Road, London, S.W. 7.).

All the B.B.C. recordings are on disc; the old 12-inch 78 r.p.m. ones are now being systematically transferred to 7-inch 33 1-3 r.p.m. discs. The English and scientific names of each species are clearly stated on the labels, plus the type of vocalization, the place, month and year of recording, and the name of the recordist. In the case of recordings made in the British Isles, the recording details on the label are limited to the county, month and year for space reasons (e.g. Devon, August, 1964); for those made abroad the details given usually refer to the state, province or other similar area, the country and the month and year (e.g., Oost, Flevoland, Holland, June, 1963, or Tasmania, November, 1961). However, more precise details are available; indeed, every recording is as fully documented as possible and the information is kept on a card index in the Sound Archives Library in Broadcasting House, London. Duplicates of this index are kept in my office at Broadcasting House, Bristol, and at Cambridge and Tring. Where recordings have been heavily edited (e.g., to reduce long natural intervals between vocalizations), this is now being indicated on the label.

The B.B.C. collection comprises recordings acquired in the following ways:

1. made by B.B.C. staff;
2. purchased or acquired by exchange with other broadcasting organizations;
3. purchased from free-lance recordists, both amateur and professional.

The main purpose of the B.B.C. collection is to supply recordings for use in B.B.C. programmes and, therefore, priority must be given to programme needs rather than to their zoological interest. This explains the increasing number of atmosphere recordings, used as background to television and sound programmes of many kinds, which are being added nowadays. However, the B.B.C. recognises the scientific value of many of the recordings in the collection and has made sets available to the centres mentioned above, for research purposes, because the B.B.C. cannot set aside facilities on its premises for research work. I shall be glad to supply, if possible, additional information about any recording in the collection on request.

B.B.C. recordings must not be used for lecture purposes without prior permission from the Corporation. In this category are included any meeting at which an entrance fee is charged, meetings of a natural history society where they are used merely to illustrate a 'popular' lecture with no intention of making any scientifically relevant points; or as illustrations to W.E.A. or similar classes. However, they may be used at scientific meetings before non-paying audiences at the discretion of the centre supplying the discs. In all cases acknowledgment should be given to the person or persons who made each recording, and to the B.B.C.—J. F. Burton, Librarian and Field Research Assistant, B.B.C. Natural History Unit, Broadcasting House, Whiteladies Road, Bristol 8: *June 22nd,* 1966.

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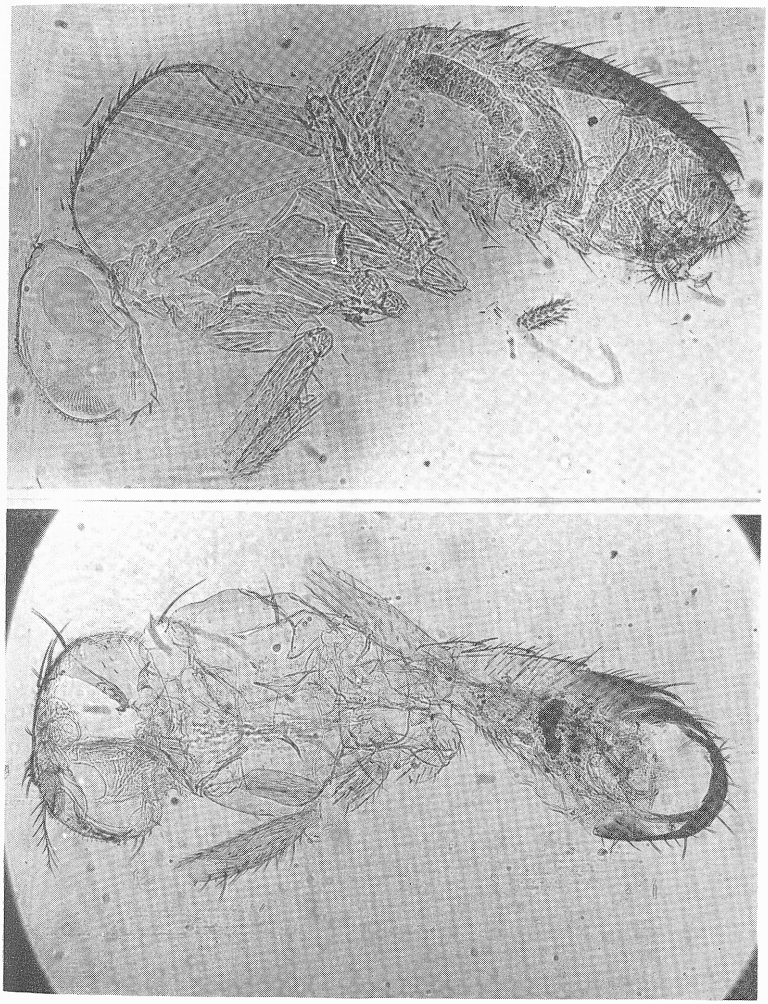
(1966, *Entomologist's mon. Mag.*, **102**: Pl. VII)

A



B

Photos H. K. Yip.

LONGITUDINAL SECTIONS OF *Drosophila melanogaster* MEIGEN

A.—Fresh fly showing thoracic muscles and gut.
B.—Rejected fly after the bug, *Limnogonous fossarum* (F.), had fed.

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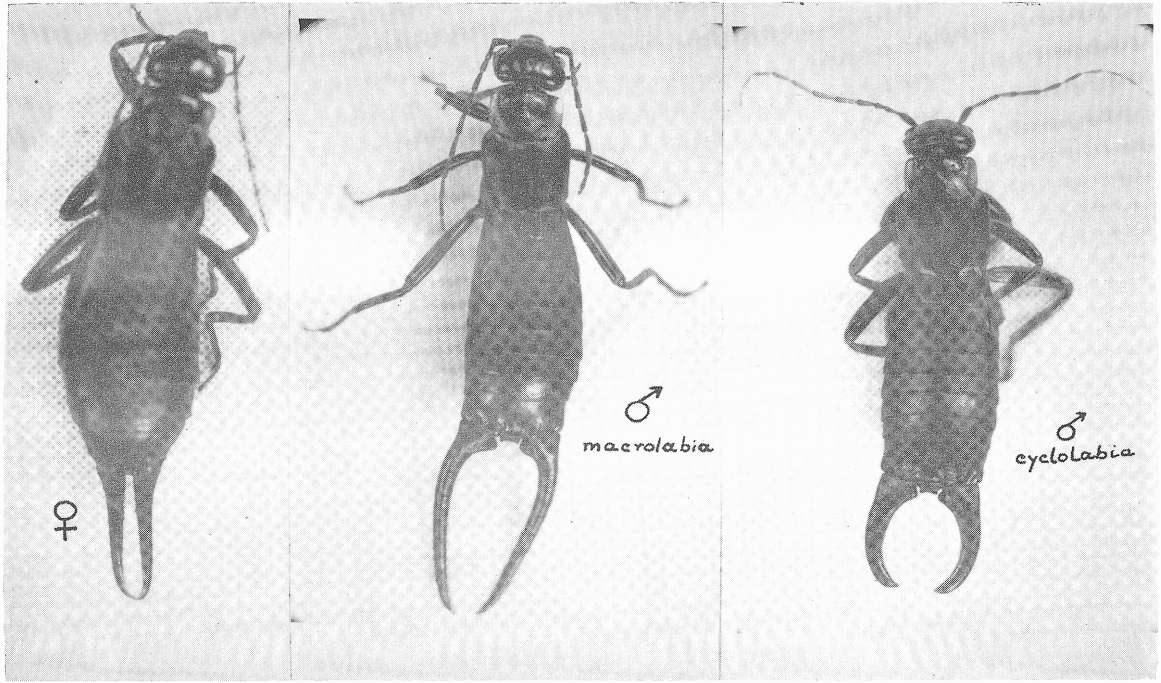

ANECHURA HIMALAYANA SINGH