THE CASEMOTH,

LIOTHULA OMNIVORA

(PSYCHIDAE : LEPIDOPTERA)

A THESIS

PRESENTED IN PARTIAL FULFILMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN ZOOLOGY

AT MASSEY UNIVERSITY

THEAN CHOOI OOI

1967

ACKNOWLEDGEMENTS

The author wishes to thank his supervisors Mr D.E. Gaskin and Mr M.J. Winterbourn for the assistance and advice given throughout this project. The interest and guidance of Mr P.S. Dale is also gratefully acknowledged. Dr. W.C. Clark, Mr L. Gurr, Dr T.J. Brown and Mrs G. Beardsell gave much invaluable help and advice. Thanks are particularly due to Mr M. Mannering for his technical assistance and other members of the Zoology Department at Massey University.

The author is indebted to many members of the Massey University Library, particularly Miss M.G. Campbell and her library staff for assistance in obtaining literature.

Grasslands Division, D.S.I.R., Palmerston North supplied the meteorological data.

Thanks are also due to Mr J. Dugdale and Mr E. Valentine of D.S.I.R., Nelson, for the identification of insect parasites; Dr. A. Watson of the British Museum (Natural History) for locating the type specimen; and Mr P.S. Yalden for his assistance in the identification of the host plants.

Special acknowledgement is due to Miss M. Bishop for typing this thesis.

Finally thanks are due to the New Zealand Government for supplying research facilities including the services of the Central Photography Unit at Massey University.

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CHAPTER I

INTRODUCTION

Liothula omnivora, one of the two known casemoths endemic to New Zealand, belongs to the Lepidopteran family Psychidae. It is distributed throughout the country, and can be found on a large number of host plants (see later). The other N.Z. casemoth, *Orophora concolor*, has been found on Wild Irishman and cassinias in the river beds of the South Island (Miller, 1955).

L. omnivora was first described by Fereday in 1878, but Meyrick (1890) transferred it to the genus *Oiketicus* (Guilding, 1827) mis-spelling it *Oeceticus*. Dr. Allan Watson (1967, pers. comm.) of the British Museum (Natural History) considers that this species should belong in the genus *Liothula* and the writer has adopted Watson's view in calling it *L. omnivora*. The type of *L. omnivora* is in the Canterbury Museum, Christchurch (Entomologische Beihefte 4, Horn and Kahle, 1937). Descriptions of the external morphology of the adult male and female have been made by Fereday (1878), Meyrick (1890) and Hudson (1928). Fereday and Hudson also described the larva, the pupa has been described by Hudson and Quail (1901), and the appearance of the egg briefly noted by Hudson.

Smith (1898) observed the locomotion of the larvae in his house and Hudson (1928) made observations on case repairing by larvae. Hudson (1928) also described the larval case, observed the suicidal crushing of adult males in captivity and the helpless condition of the adult females and was the first person to describe briefly the life history of this species. He recorded four insect parasites and Gourlay (1930) also recorded four including two species not found by Hudson. Miller (1955) noted that the Maoris called _L. omnivora_ by the names _Kopa_ (to shut), _whare atua_ (spirit house) or _Raukatauri_ (flute of the goddess of music, _Raukatauri_).

This species is of little or no economic importance although Gaze (1891) reported that larvae defoliate and ring branches of currant plants, Miller (1917) found that larvae do minor damage to the leaves of N.Z. flax, and Clark (1932) observed a slight amount of damage was caused to _Pinus radiata_ by larvae feeding upon the needles.

In this study, the anatomy, life history, general biology, case building, case function and studies on insect parasites have been undertaken.

CHAPTER II

ANATOMY

EXTERNAL ANATOMY

THE EGG (Figure 1A)

Length, 0.85 - 1.00 mm., width 0.50 - 0.65 mm., same width across both extremities; both ends rounded; without micropylar process. Chorion thin, shining, translucent, pale yellow in colour. Chorion surface smooth, without alveolis, pattern or longitudinal ribs.

THE LARVA

HEAD

HEAD CAPSULE (Figs. 1B, 2 & 3) - White with irregular black markings, width ranging from o.47 mm., on hatching to 4.75 mm., before pupation, very rounded in first instar. Median epicranial cleft shallow. Adfrontals separated from epicrania in third instar. Clypeus not separated from frons; frontoclypeus triangular. Six ocelli, sixteen setae, four punctures, and a row of four parietal tubercles present on each epicranium.

ANTENNAE (Fig. 4) - Second joint longer than broad, and also longer than third joint. Seta 1 absent on second joint. A seta, two sensory cones and third joint present on distal membranous surface of second joint. Three sensory cones present on distal end of third joint; one of these cones carrying a microscopic seta.

LABRUM (Fig. 5) - Outer angles broadly rounded, median notch about one-fourth total height of labrum, tip of indentation obtuse. Twelve setae present. M_2 at a lower level than M_1; M_3 next to edge of epipharyngeal thickening and slightly medial to M_2; L_1 marginal, slightly higher than M_2; L_2 closer to L_3 than to L_1; L_3 submarginal; lateral to M_2. Tormae 3-jointed. Sensory pits absent. Epipharyngeal membrane bearing ten sensory cones and numerous minute sensory structures.

MANDIBLES (Figs. 6 & 7) - Projecting far beyond labrum, short, sub-quadrate, with broad base, outer edge slightly convex. Cutting edge armed with four teeth, all teeth sharp, third one most prominent. Mandibular setae 1 and 2 close together at end of lower third of mandible.

MAXILLAE (Figs. 8 - 10) - Cardo small, triangular. Stipes broad, massive, the inner edge elongated where it joins mentum. Seven setae present on distal portion. Semicircular sclerites two in number, each carrying a seta; lower sclerite, sclerite 2, also with a two-jointed maxillary palp and a lobarium. Lobarium with five setae (three large ones of equal length and two smaller ones), a semicircular basal sclerite, and two cylindrical maxillary lobes. Maxillary lobe with a sense-cone at tip.

LABIUM (Figs. 11 & 12) - Characterised by strong development of chitinous sclerites of mentum. Mentum situated between hypostoma and distal end of stipes, with two short setae near median line. Submentum triangular, without setae. Prementum wide, with five tubercles on either side. Labial palpi 3-jointed, slender; second joint carrying a short setae (0.18 - 0.20 mm. long); third joint with a long seta (0.38 - 0.40 mm. long).

THORAX (Figs. 13 & 14A) - Black colour of definite pattern present on white ground colour. Each segment with a dorsal chitinous shield. Prothoracic shield pierced by prothoracic spiracle. Vertical intersegmental and lateral longitudinal grooves present. Spiracle circular in first instar but oval in later instars.

THORACIC LEGS (Fig. 15A) - Coxa with seven setae of different lengths (0.3 - 1.00 mm.). Femur with a long seta (1.5 mm. long). Tibia with six setae of different lengths (0.7 - 2.7 mm.). Tarsus with four setae of different lengths (0.5 - 1.8 mm.). Pretarsus pointed.

ABDOMEN (Figs. 13, 14A & B) - Of ten segments, last two fused to form anal segment. Sclerites absent. Maximum trunk width at segments 3 - 5. Eight pairs of spiracles present on segments 1 - 8, A pair of prolegs present on segments 3 - 6 and 9 - 10.

ABDOMINAL LEGS (Fig. 15B) - Planta with 19 - 22 crochets (10 - 12 in first instar). Arrangement of crochets corresponding to penellipse of Fracker (1915). Crochets of variable lengths, long hooked ones on middle of arc and short straight ones on either end of arc. An additional collar-like sclerite present between planta and coxa in all instars.

CHAETOTAXY

A. CRANIAL SETAE (Fig. 16) - Identical in number and in position from first to ultimate instar. Primary tactile setae present on anterior and lateral parts of epicranium. Minute proprioceptor setae absent on posterior margin of epicranium. Only two primary sensory pits present on each epicranium. Each epicranium has sixteen tactile setae and two primary sensory pits. All setae without barbs and without branches. Setae and pits of posterior group absent on anterolateral part of each epicranium.

1. LATERAL GROUP - Only two tactile setae present, L_1 four times longer than L_2, L_2 posterolateral to L_1. Pits lacking.

2. ANTERIOR GROUP - Three tactile setae present. A_1 anteroventral to L_1. A_1, A_2 and A_3 in a straight line directed anterodorsally, A_1 three times longer than A_2 (0.25 mm. long) and slightly shorter than A_3. Pits absent.

3. OCELLAR GROUP - Three tactile setae present, O_1 vertically beneath L_2, O_2 posterodorsal to O_1, O_3 posteroventral to O_2 and at same level as O_1, O_2 five and a half times longer than O_1 and O_3 (0.05 mm. long). Pits absent.

4. SUBOCELLAR GROUP - Three tactile setae present, anteroventral

to ocellar group. SO_1 vertically beneath mid-point of line joining L_1 and L_2, SO_2 vertically above SO_1, SO_3 posterior and equidistant to SO_1 and SO_2, SO_2 as long as SO_1 but half length of SO_3 (0.10 mm. long). Pits absent.

5. <u>VERTEX GROUP</u> - Absent.

6. <u>GENAL GROUP</u> - Absent.

7. <u>CLYPEAL GROUP</u> - Two tactile setae present C_1 anteroventral to A_1, C_2 anterodorsal to C_1 and above level of A_1. C_1 longer than C_2. Pits absent.

8. <u>FRONTAL GROUP</u> - Only a tactile seta, F, and a pit, Fa, present. F vertically above C_2 and above level of A_2, longer than C_2. Fa anteroventral to F and C_2.

9. <u>ADFRONTAL GROUP</u> - Named only when frontal suture present in 3rd. instar. Two tactile setae AF_1 and AF_2, and three pits, AFa, AFb, and AFc present. AF_1 posterodorsal to F. AF_2 anterodorsal to AF_1 and vertically above F. AF_1 one-seventh length of F and one-fifth length of AF_2.

B. <u>THORACIC AND ABDOMINAL SETAE</u> - Both long tactile setae and minute proprioceptors present. Number of secondary setae increasing at each moult. Setae similar to cranial ones, comprising of only a shaft tapering distally. Proprioceptor setae all primary, at anterior intersegmental margin of most segments and on posterior dorsal margin of prothorax.

FIRST INSTAR LARVA (Fig. 17)

PROTHORAX - Ten tactile setae, five proprioceptor setae, and one pit present on each side. XD_1 posterodorsal to XD_2. MXD_1 posterior to XD_2 and an intersegmental membrane. SD_2 well beneath XD_2. SD_1 anteroventral to MXD_1. SDa vertically beneath MXD_1 and posteroventral to SD_1. L_1 vertically beneath SD_2, above level of spiracle. L_2 anteroventral to spiracle. L_3 posteroventral to L_2. L_3, L_4 and L_5 in a straight line directed posteroventrally. SV_2 vertically beneath L_3, SV_1 posteroventral to SV_2. MV_2 anteroventral to SV_2. MV_3 anteroventral to MV_2. V_1 posterior to coxa. Five primary setae present on coxa, one anterior to coxal suture and four posterior.

MESO- AND METATHORAX - Chaetotaxy of these two segments identical. Each segment with six tactile setae and five proprioceptor setae on each side. MD_1 close to anterior margin of segment, MD_2 posteroventral to MD_1. SD_1 vertically beneath MD_1 and anteroventral to MD_2. L_1 at level of spiracle and slightly anteroventral to SD_1. L_2 posteroventral to L_1 and in mid-line of segment. SV_2 vertically beneath L_2 and anterior to SV_1. MV_1 anterodorsal to SV_2. MV_2 anteroventral to MV_1, MV_3 vertically beneath MV_2. V_1 posterior to coxa. Six primary setae present on coxa, two anterior to coxal suture and four posterior. Sensory pits absent.

ABDOMEN

SEGMENT 1. - Eight tactile and two proprioceptor setae present. MD_1 close to anterior margin of segment. D_1 posterior to MD_1. D_2 (1 mm. long) longer than D_1, and anteroventral to it. SD_1 vertically beneath D_2 and slightly longer than it. L_1 vertically beneath spiracle, half as long as SD_1. L_2 posteroventral to L_1 and slightly longer than it. L_3 vertically beneath L_1, anteroventral to L_2, as long as L_1. MV_1 anteroventral to L_3, slightly longer than L_3. SV_1 posteroventral to MV_1, vertically beneath L_2, as long as MV_1. V_1 vertically beneath SV_1, half length of SV_1. Sensory pits absent.

SEGMENT 2. - Eight tactile setae present. Relative positions of these setae similar to those of corresponding setae in segment 1. Proprioceptor setae and pits absent.

SEGMENTS 3 - 5 - Chaetotaxy of these segments identical. Seven tactile setae present. Differing from segment 2 in absence of L_2 and L_3 and in presence of SV_2. Relative positions of D_1, D_2, SD_1, L_1 and V_1 similar to those of corresponding setae in segment 2. SV_1 anteroventral to L_1, as long as L_1. SV_2 anterodorsal to SV_1, vertically beneath SD_1, slightly longer than SV_1. Proprioceptor setae and pits absent.

SEGMENT 6. - Seven tactile setae and two proprioceptor setae present. Relative positions of D_1, D_2, SD, L_1, SV_1, SV_2 and V_1 similar to those of corresponding setae of segment 2. MV_2

anterodorsal to V_1, MV_1 posterodorsal to V_1, MV_1 and MV_2 equal in length but shorter than V_1. Sensory pits absent.

SEGMENT 7. - Six tactile setae, one proprioceptor seta and two pits present. Relative positions of D_1, D_2 and SD_1 similar to those of corresponding setae of segment 2. L_1 vertically below SD_1, posteroventral to spiracle. Pit La posteroventral to L_1, Lb vertically below La. SV_1 vertically below L_1, slightly longer than L_1. V_1 anteroventral to SV_1. MV_1 posteroventral to SV_1 and posterodorsal to V_1.

SEGMENT 8. - Six setae present. Relative positions of D_1, D_2, SD_1, L_1, and V_1 similar to those of corresponding setae of segment 2. SV_1 posteroventral to L_1 but posterodorsal to V_1.

SEGMENT 9 + 10 - Fourteen tactile setae and one proprioceptor seta present. MD_1 short, close to posterior margin of segment. D + SD group comprising seven tactile setae, posterior to MD_1. L_1 beneath D + SD group. L_2 posteroventral to L_1, slightly longer than L_1. L_3 vertically beneath and slightly shorter than L_2. SV_2 anteroventral to L_3, slightly longer than L_3. SV_1 posteroventral to and shorter than SV_2. SV_3 anteroventral to SV_2, below level of SV_1, half length of SV_2. V_1 anteroventral to and as long as SV_3.

Setal maps of other instars are shown in figures 18 - 23. The increase in number of setae at later instars is shown in table 1.

TABLE 1 NUMBER OF SETAE OF DIFFERENT INSTARS OBSERVED AT PALMERSTON NORTH 1967

Segment	Setal group	Instars I	II	III	IV	V	VI	VII
PROTHORAX	SD	2	2	2	2	2	2	2
	L	5	5	6	6	6	6	6
	SV	2	3	3	3	3	3	3
	V	1	1	1	1	1	1	1
	XD	2	2	2	2	2	2	2
	MXD	1	1	1	1	1	1	1
	MV	2	2	2	2	2	2	2
	COXA	5	7	7	7	7	7	9
MESOTHORAX	SD	1	1	2	2	2	2	2
	L	2	4	4	4	4	4	4
	SV	2	2	2	2	2	2	2
	V	1	1	1	1	1	1	1
	MD	2	2	2	2	2	2	2
	MV	3	3	3	3	3	3	3
	COXA	6	7	7	7	7	7	7
METATHORAX	SD	1	1	1	1	1	2	2
	L	2	4	4	4	4	4	4
	SV	2	2	2	2	2	2	2
	V	1	1	1	1	1	1	1
	MD	2	2	2	2	2	2	2
	MV	3	3	3	3	3	3	3
	COXA	6	7	7	7	7	7	8
Ab. 1	D	2	2	2	2	2	2	2
	SD	1	1	1	1	1	1	2
	L	3	3	3	3	3	3	3
	SV	1	1	2	2	2	2	2
	V	1	1	1	1	1	1	1
	MD	1	1	1	1	1	1	1
	MV	1	1	1	1	1	1	1
Ab. 2	D	2	2	2	2	2	2	2
	SD	1	1	1	1	1	1	2
	L	3	3	3	3	3	3	3
	SV	1	1	2	2	2	2	2
	V	1	1	1	1	1	1	1

Ab. 3	D	2	2	2	2	2	2	2
	SD	1	1	1	1	1	1	1
	L	1	2	3	3	3	3	3
	SV	2	2	2	2	2	2	3
	V	1	1	1	1	1	1	1
Ab. 4	D	2	2	2	2	2	2	2
	SD	1	1	1	1	1	1	1
	L	1	2	3	3	3	3	3
	SV	2	2	2	2	2	2	3
	V	1	1	1	1	1	1	1
Ab. 5	D	2	2	2	2	2	2	2
	SD	1	1	1	1	1	1	1
	L	1	2	3	3	3	3	3
	SV	2	2	2	2	2	2	3
	V	1	1	1	1	1	1	1
Ab. 6	D	2	2	2	2	2	2	2
	SD	1	1	1	1	1	1	1
	L	1	3	3	3	3	3	3
	SV	2	2	2	2	2	2	3
	V	1	1	1	1	1	1	1
	MV	2	2	2	2	2	2	2
Ab. 7	D	2	2	2	2	2	2	2
	SD	1	1	1	1	1	1	2
	L	1	2	3	3	3	3	3
	SV	1	2	2	2	2	2	2
	V	1	1	1	1	1	1	1
	MV	1	1	1	1	1	1	1
Ab. 8	D	2	2	2	2	2	2	2
	SD	1	1	1	1	1	1	1
	L	1	2	2	2	3	3	3
	SV	1	1	1	1	1	1	1
	V	1	1	1	1	1	1	1
Ab. 9 + 10	D + SD	7	8	10	10	11	11	11
	L	3	3	5	5	5	6	7
	SV	3	3	5	5	5	6	6
	V	1	1	1	1	1	1	1
	MD	1	1	1	1	1	1	1

THE PUPA

Marked sexual dimorphism present. Male smaller than female. Male tapering, three times longer than broad at mesonotum. Female tapering-cylindrical, five times longer than broad at abdominal segment 4.

MALE

HEAD (Figs. 24 - 26) - Black, rugose truncated anteriorly, somewhat deflected ventrally. Vertex semicircular, extending backwards as internal postoccipital ridge covered by pronotum, with transverse carina at anterior extremity, with a seta on either side of mid-line. Anterior tentorial pit located between labrum and 'pupal eye'. 'Pupal eye' glaborous. Antenna-cases tapering posteriorly, shallowly sulcate, with transverse striae corresponding to segmentation divisions, reaching nearly to end of prothoracic legs. Frontoclypeus trapezoidal, bearing two pairs of setae. Paraclypeus large, distinct, directed medially. Labrum rectangular. Maxillary palpi large, trapezoidal. Maxillae-long, directed posteriorly, reaching to half distance from labium to tip of second leg. Labium broadened and bilobed distally; labial palpi short, rounded.

THORAX (Figs. 24 - 26) - Black. Three thoracic segments visible externally. Pronotum small resembling inverted 'V', transversely striae, without setae, anterior edge sulcate. Mesonotum large, very convex dorsally, anterior edge pointed, two setae and a pit on either side of mid-line, wing cases reaching to middle of third abdominal segment. Metanotum narrow, with two punctures, lateral anterior angles high, narrowly rounded, with three setae on either side of mid-line, wing-cases posterior to mesonotal wing-cases and reaching caudad only as far as posterior edge of second abdominal segment. Poulton's line on posterior margin of wing-case. Ridges on wing-cases corresponding to future imaginal venation. Prothoracic spiracle internal (i.e. covered by fore wing-cases). Leg-cases not detached. First two pairs of leg-cases medio-ventral to antennae. First leg-cases arising beneath bases of antennae, tapering towards mid-line. Second leg-cases reaching only to just below first. Third leg-cases covered by mesonotal wing-cases.

<u>ABDOMEN</u> (Figs. 24 - 27) - Transversely rugose, segment 9 + 10 deflected ventrally. Segments 1 - 7 black, 8 - 10 brown; posterior margins broad, smooth, and light coloured. Segments 1 - 2 covered by wings, immobile. Articulations between segments 2 and 3, 3 and 4, 4 and 5, 5 and 6, 6 and 7, 7 and 8 present; hence segments 3 - 8 mobile, showing jerky movement. Segments 8 - 10 fused, immobile, forming cone with faint trace of segmentation. Spiracles on segments 1 - 8, protruding, elongate dorsoventrally, surrounded by oval of thin cuticle, first and second spiracle covered by wings, last spiracle closed and non-functional, spiracular apertures as vertical slits, guarded by setose projections. Scars of larval prolegs visible as low swellings on ventral surface of segments 4 - 6. Future anus present as an inverted T-shaped groove on ventral prominence of segment 10. Future genital pores present as a groove on segment 9, flanked by two mounds. No trace of cremaster armament present. Anal prolegs developed into two divergent, flattened,

conical plates, compressed laterally, and each ending in a strongly curved hook directed cephalo-ventrad. Setae in pattern, comparable to primary setae of caterpillar. Proleg subventral. Ventral setae covered by wings on segment 3. Setae absent on segment 10. Proprioceptor setae absent. Anterior edge of segments 5 - 8 with a dorsal row of strongly chitinised spines directed caudally and arranged in crescent-shaped line. Spines absent on segments 1 - 4, 9 + 10.

FEMALE

HEAD (Figs. 28 - 30) - Black, rugose, deflected ventrad, concealed under prothorax. Vertex with a seta on either side. Eye-, antenna-, and maxilla-cases vestigial. Frontoclypeus quadrate, with a pair of setae and a darkened area around seta on either side of mid-line. Paraclypeus small but distinct, triangular. Labrum quadrate. Labium small, labial palpi not prominent.

THORAX (Figs. 28 - 30) - Black, sometimes brown; coarsely rugose. All segment-cases visible externally. Pronotum (o. 32 mm. wide) semicircular, ribbon-shaped, without setae. Mesonotum (1.23 mm. wide) larger than pronotum, semi-circular, ribbon-shaped, with a pair of setae far apart and on either side of mid-line, wing-cases absent. Metanotum, (1.35 mm. wide) larger than mesonotum, semicircular, ribbon-shaped, a pair of setae on either side of mid-line, lateral setae anterior to medial setae, wing-cases absent. Legs rudimentary, showing as short, compact, flattened, paired, free appendages on a broad base, arising from ventral part of thorax.

ABDOMEN (Figs. 28 - 31) - Transversely rugose. Segments 1 - 7 black, 8 - 10 brown. Articulations between segments 1 and 2, 2 and 3, 3 and 4, 4 and 5, 5 and 6, 6 and 7, and 7 and 8; hence segments 1 - 8 mobile, showing jerky movement. Segments 8 - 10 fused as in male, immobile, forming cone with faint trace of segmentation. Spiracles on segments 1 - 8, elongate dorsoventrally, surrounded by oval of very thin cuticle; spiracular apertures vertical slits, guarded by setose projections; last spiracle closed and non-functional. Scars of larval prolegs as low swellings on ventral surface of segments 3 - 6. Future anus as an inverted T-shaped groove on ventral prominence of segment 10 as in male. Openings of bursa copulatrix and oviduct united, seen as a groove on segment 8 at extremity of angle projecting from 9th segment. Oviducal pore in genital groove. Cremaster consisting of four thick stems, two on each side, each stem with 1 - 3 hooks at its distal end and directed in various directions. Tactile setae on segments 1 - 9, comparable to primary setae of caterpillar. No tactile setae on segment 10. Proprioceptor setae absent. Segments 2 - 5 with a dorsal row of minute hooks on edge of caudal declivity while segments 6 - 9 with only one row of dorsal hooklets near cephalic end, 11 on segment 6, 18 on segment 7, 3 on segment 8 and 9. Segment 1 unarmed.

THE IMAGO

Extreme sexual dimorphism present.

Male

HEAD CAPSULE (Fig. 32) - Hypognathous, mean ratio of head height to head width 1.12 (range : 0.95 - 1.25), anterior margin with two cones. Clypeolabral suture short. Compound eyes occupying one-fifth of head width. Ocelli absent. Frontoclypeus quadrate. Anterior tentorial pits oval. Antennae bipectinate, tapering distally, with 44 - 48 segments; scape tapering cylindrically; pedicel with whorl of setae at distal rim; pectinations 0.05 - 0.10 mm. long and at 80° angles to one another; flagellum stem without setae. Labrum with very convex anterior margin. Mandible absent. Paraocular area small and elongate. Postgena narrow. Foramen magnum occupying half width of head capsule. Maxillae present, maxillary palpi short, stipes elongate. Labium small; labial sclerite triangular. Labial palpi 4-jointed, segments cylindrical, tip of last segment rounded.

PROTHORAX (Fig. 33) - Small, deflexed ventrally, dorsal surface very convex, anterior two-thirds of dorsal aspect covered by triangular patagia. Lateral ends of prothorax fused laterally with pleuron, sternal parts narrow. Tips of curved cervical sclerites present in front of prothorax. Propleuron rectangular. Prothoracic spiracle prominent. Presternum triangular. Pre-episternum also triangular. Discrimen ventral, 1.5 mm. long. Furcasternum bilobed posteriorly. Spinasternum triangular.

MESOTHORAX (Fig. 33) - Very large, anterior end deflexed ventrally, dorsal aspect very convex. Tegulae oval, 1.95 mm. long (range : 1.86 - 2.12 mm.), pilose particularly along posterior margin, anterolateral to scutum. Prescutum absent. Scutum hexagonal, length to width ratio 0.83, anterolateral margins concave, posterolateral margins slightly convex, posterior margin concave and notched in middle. Suralare pointed anteriorly and notched posteriorly. Adnotale triangular. Subalare club-shaped. Posterior wing process curved. Tegular arm tapering anteriorly. Basalare trapezoidal. Prealar portion of epimeron curved upwards. Anepisternum trapezoidal. Katepisternum 'V'-shaped. Pre-episternum elongate and slanting. Scutellum oval, its anterior and lateral ends pointed, its posterior margin convex. Postalar plate curved and tapering anterolaterally. Postnotum convex dorsally, semicircular. Postalar portion of epimeron triangular. Postcoxa absent. Discrimen 1.5 mm. long. Second spiracle in mesothoracic fold.

METATHORAX (Fig. 33) - Smaller than mesothorax but larger than prothorax. Scuti irregular in shape. Scutellum triangular, located above scuti, anterior margin convex, posterior margin concave. Postnotum larger than scutellum, its dorsal aspect with a transverse groove. Postalar plate fused with posterior notal wing process, descending anterolaterally. Postalare rectangular. Subalare curved, tapering dorsoanteriorly. Posterior wing process large, lanceolate. Basalare triangular, upper half of its anterior margin concave, ventral margin also concave. Postalar portion of epimeron situated laterally, curved, with two pointed anterior ends. Prealar portion of epimeron pentagonal, its anteroventral and posteroventral margins concave, its dorsal margin straight, dorsoposterior margin convex. Katepisternum comma-shaped, tapering anteriorly. Pre-episterni triangular, tapering laterally. Discrimen 1.5 mm. long.

(1) WINGS AND WING ARTICULATION

(A) FOREWING BASE (Fig. 34) - First axillary oval. Second axillary lateral to first axillary, trapezoidal. Third axillary posterior to second axillary, notched anteromedially. Fourth axillary posterior to third axillary, curved. Basal sclerite quadrate. Costal sclerite pentagonal and connected to veins C and Sc. Radial sclerite rectangular, connected to veins Sc, R, and M. Cubital sclerite oval and connected to veins Cu_2 and Cu_3. Third axillary in contact with veins Cu_3, 1 dA and 2 dA. Fourth axillary in contact with veins Cu_3, 2 dA and 3 dA. Posterior notal wing process tapering at either end. Postalare elongate and curved. Axillary cord 'S'-shaped and connected to vein 3 dA anterolaterally.

FORE-WINGS (Fig. 35) - Elongate, triangular, costa vein straight, and margin curved. Subcosta separate, with a small branch at proximal end. Veins R_1, R_2, R_3, and R_5 stalked. Veins R_3 and R_4 also stalked. R_4 occasionally absent. Veins M_1 - M_3 and veins Cu 1 - 2 from same stem. Cross vein M_{1-2} elbowed. M_2 and M_3 stalked. Vein 2 dA separate, arising from junction of two anal stems, posterior one of these giving a small branch. Vestigal veins present between Radial stem and Medio-cubital stem, also between Medio-cubital stem and anal stem. Scales (Fig. 36) on termen broadly oblanceolate; scale apices variable, usually bidentate, tridentate or quadridentate. Scales over rest of wing also broad and strongly dentate.

(B) HIND-WING BASE (Fig. 37) - First axillary sclerite elongate, second axillary 'T'-shaped, third axillary irregular in outline, fourth axillary triangular. Basal and costal sclerites irregular in shape. Frenulum sclerite quadrate. Subcostal sclerite connected to Subcosta and Radial veins. Medial sclerite connected to Medial vein. Fourth axillary connected to veins Cu, 2 dA and 3 dA. Axillary cord sinuate, connected to medio-anterior end of 3 dA. Anterior end of posterior notal wing process serrated.

HIND WINGS (Fig. 38) - Rounded. Frenulum curved, 4.3 mm. long. Costa moderately arched. Anal margin slightly curved. Veins Sc and R, anastomosed, with a branch connecting Costa in front. Veins R_5 and a branch from Radial stem to Sc + R_1 stalked. Veins M_2 and vestigial M_3 stalked. M_2, M_3 and Cubital veins Cu_1 and Cu_2 from same stem. Anal veins 2 dA and 3 dA stalked. A Radial and a Medial present between Sc + R_1, and M_2-Cu_2 stems. Anal vein 1 dA present between M_2-Cu_2 and 2 dA - 3 dA stems, its two branches joined by a cross vein and atrophied. Cross veins present between R_5 and M_1, M_1 and M_2, Cu_1 and Cu_2, Cu_2 and a branch from 1 dA.

(2) LEGS - Pilose, large dark brown, without epiphysis or tibial spurs.

(A) PROTHORACIC LEG (Fig. 39A) - Length 10.8 - 11.2 mm. coxa mobile, tapering. Trochanter tubular. Femur large, tapering at both ends. Tibia long (12.6 mm.), slender. Tarsomeres 5 - jointed : one barsitarsus, three mediotarsi and one distotarsus. Pretarsus with two claws, a circular sclerite, and a whorl of eleven setae; arobar absent.

(B) MESOTHORACIC LEG (Fig. 39B) - Length 10.6 - 11.1 mm. Coxa highly developed, immobile, with triangular meron and triangular eucoxa, but without postcoxa and without basicoxite. Trochanter rectangular. Femur large, tapering at both ends. Tibia long, slender. Tarsi and pretarsus as in prothoracic leg.

(C) METATHORACIC LEG (Figs. 39C, 40A & B) Length 6.3 - 6.5 mm., thickened. Coxa 'U'-shaped, immobile, large. Trochanter large, with a groove on dorsal aspect. Ratio of length to width of femur decreased. Tibia thick. Tarsus 5-jointed, thick. Pretarsus thick.

ABDOMEN - Dark brown, length 11.3 - 12.2 mm., tapering. Segments 1 - 8 with tergite, pleurite and sternite. Segments 9 - 10 modified to form genitalia. Chitinisation decreasing from segments 3 to 8. Tergite semicircular, convex dorsally. Pleurite membranous, irregular in outline, trapezoidal or rectangular. Sternite arched, convex ventrally. Tympanum absent. First and second sterna fused. Spiracles present on pleurite of segments 1 - 7, absent on segments 8 10, circular, overlapped by pleurite when closed.

GENITALIA (Figs. 41 - 43) - Uncus present, with dorsal setae, broad at base, terminating posteriorly in a blunt hook. Gnathos absent. Valvae setulose, usually symmetrical and elongate, broad at base, with distal end divided into two lobes. Vinculum 'V'-shaped, saccus large. Aedaegus nearly straight and cylindrical; surface of visica irregular when inflated. Anus projecting beneath uncus on a membranous tuba analis. Anellus cylindrical, elongate, covering whole ventral surface and lower half of dorsal surface of aedaegus. Juxta absent.

FEMALE

HEAD CAPSULE (Fig. 44) - Rounded, directed ventro-caudad, mean ratio of head height to head width 0.91 (range : 0.79 - 0.95), entirely concealed under prothorax. Anterior margin very convex, with two pairs of setae. Lateral areas trapezoidal strong, with 7-8 setae. Lateral margin with four setae. Anterolateral sulci parallel to anterior margin. Anterior cones minute, two in number, central in position, with three conical segments. Anterior tentorial pits oval. Compound eyes, ocelli, maxillae, maxillary palpi, mandible, labial pilifers and clypeolabial suture vestigial. Vertex, frontoclypeus, and labrum fused into one piece. Antennae two in number, slender, pointed, slightly diverging, arising from vertex, 2-jointed, basal segment short, distal segment long and with four setae. Labium circular; labial palpi without setae and one-segmented.

PROTHORAX (Figs. 45 - 47) - Small, deflexed ventrally, with tips of curved cervical sclerites in front, its ventral and anterior portions membranous, its lateral and dorsal aspects chitinised. Patagia absent. Pronotum semicircular, its anterior margin straight, posterior margin very convex, lateroanterior portion triangular. Prothoracic spiracles prominent, opposite anterolateral angles of pronotum.

MESOTHORAX (Figs. 45 - 47) - Large, slightly deflexed ventrally, its ventral half membranous, dorsal half chitinised. Mesonotum large, anterior margin straight, posterior margin very convex, triangular with a pair of setae on its dorsal aspect.

METATHORAX (Figs. 45 - 47) - Smaller than female mesothorax but larger than female prothorax. Sternal and pleural portions membranous while middle portion of dorsal aspect chitinised. Postnotum brownish black, its anterior margin straight, posterior margin slightly convex, with a pair of setae on its dorsal aspect. Metathoracic spiracle rounded, prominent, lateral.

THORACIC APPENDAGES

(1) WINGS AND WING ARTICULATIONS - Absent.

(2) LEGS - Yellowish white, rudimentary, represented by a minute papilla, surrounded by a chitinous ring, with or without setae, development variable in individuals.

PROTHORACIC LEG (Fig. 48A) - Length 0.48 - 0.51 mm., compressed. Setae and tarsus absent. Coxa tubular, mobile. Trochanter and femur also tubular. Tibia tapering. Pretarsus consisting of a minute hooklet.

(B) MESOTHORACIC LEG (Fig. 48B) - Length 0.80 - 0.90 mm. Coxa large, cylindrical. Trochanter and femur also cylindrical. Tibia with four setae. Tarsus 3-jointed. Pretarsus comprising a single hooklet only.

(C) METATHORACIC LEG (Fig. 48C) - Length 2.0 - 2.2 mm. Coxa large, mobile. Trochanter cylindrical. Dorsal aspect of femur grooved. Tibia with six setae, longer than coxa. Tarsus 2-jointed.

Pretarsus consisting of a hooklet only.

ABDOMEN (Figs. 45 - 47) - Yellowish white, distended, sac-like, length 12.6 - 13.6 mm., tapering - cylindrical, only dorsum of segment 1 and ovipositor (segments 8 - 10) chitinised, other regions membranous. Internal organs such as ovarioles and nerve ganglia visible externally. Tergite of segment 1 brownish black, trapezoidal, convex dorsally, anterior margin straight and shorter than posterior margin, posterior margin moderately convex. Tympanum absent on segment 1. Demarcations between segments 1 - 7 obscure. Segments 2 - 7 of equal size, segments 8 - 10 modified to form genitalia. Body abruptly truncated at posterior end from segments 7 - 8. Articulation present between segments 7 and 8, hence ovipositor mobile. Spiracles present on lateral walls of segments 1 - 7 on either side, with chitinised rim, oval. A pair of setae on dorsal aspect of segments 1 - 2. Hairs yellow, forming an incomplete ring on segment 6, a complete ring on segment 7, also an inverted 'V'-shaped tuft on dorsal aspect of segment 8, also present on lateral and posterior margins of segment 8. Segment 9 narrow, tubular. Segment 10 annular. Segments 9 and 10 finely pubescencent. Pubescence absent on other segments. Segment 8 much smaller than preceeding ones, annular, bearing genital opening ventrally on a small membranous cone directed forwards. Genital armature absent. Ovipositor truncated ventrally, two-jointed.

GENITALIA (Fig. 49) Segment 8 ring like, tapering. Segments 9 and 10 smaller than segment 8, cylindrical, with oviporus as distal aperture, anal papillae cylindrical and setulose. Anterior and posterior apophyses well developed, slender. Ostium bursae large, surrounded by sclerotised wall of segment 8. Ductus bursae large. Corpus bursae white, very large, membranous, sac-like. Spermatheca white, bean-shaped. Ductus seminalis sinuate, short. Glandula sebacea small, two-branched. Ovarioles consisting of eight long tubes, four on either side of ductus seminalis.

INTERNAL ANATOMY

THE LARVA (Figs. 50 & 51)

ALIMENTARY SYSTEM - Almost straight from mouth to anus, tubular. Oesophagus long, cylindrical. Fore-gut in the male spindle-shaped, as long as oesophagus, four times broader than oesophagus, and can be distinguished from mesenteron; in female cylindrical, as long as oesophagus, six times broader than oesophagus, and can not be distinguished from mesenteron. Crop lacking. Mesenteron tubular, of wide and uniform calibre, with peritrophic membrane, extending from metathorax to middle of eighth abdominal segment in male and to seventh abdominal segment in female, distended with dark brown substance only in female; enteric caeca or diverticula not seen. Proctodaeum extremely short in male but longer in female, without convolution; ileum absent; colon oval and cylindrical in male but distended and modioliform in female; rectum narrow, tubular, tapering to anus, short in male but long in female. Six malpighian tubules present, in groups of three each, each group entering proctodaeum by a common duct. Silk glands smaller and shorter in male than in female, without accessory glands, paired, very conspicuous, elongate, cylindrical, longer than body length, converged and united anteriorly before entering spinneret, its anterior half straight, its posterior half coiled twice over itself, anterior region of posterior half broader and less coiled than posterior region. Mandibular glands paired, tubular, fairly straight, of uniform diameter, not convoluted, extending posteriorly to hind margin of metathorax in male and to abdominal segment 1 in female.

CIRCULATORY SYSTEM - Dorsal vessel tubular, slightly concave ventrally, sinuate dorsoventrally, narrower in female than in male, extending from 8th abdominal segment into head. Aorta in thorax, with two swellings in male and three swellings in female, broader in male, extending from metathorax to head, tapering anteriorly.

RESPIRATORY SYSTEM - One thoracic and eight abdominal spiracles present on either side. Spiracular arrangements holopneustic. Longitudinal tracheal trunk on each side, giving off 3 - 5 main branches at each spiracle; main branches ramifying to anastomose with main branches of longitudinal trunk on other side. At prothoracic spiracle another extremely short tracheal trunk with its branches going anteriorly into head capsule, parallel to longitudinal trunk. Air sacs absent.

NERVOUS SYSTEM

BRAIN - Composed of two pear-shaped lobes joined in mid-line by deep sulcus in male, and of two oval lobes joined together by anterior emargination in female, without division into optic and antennal lobes, its white surface with reddish patches. Ocellar nerves large, prominent. Antennal nerves slender. Frontal nerves larger than antennal nerves. Labral nerves large.

VENTRAL NERVE CORD AND GANGLIA - Ganglia twelve in male, ten in female, with pinkish patches on white background. Suboesophageal ganglia oval, distinct, connected to brain by widely separated circumoesophageal connectives, giving off well-developed mandibular, maxillary, and labial nerves laterally. Pro-, meso-, and metathoracic ganglia discrete, connectives between them double and widely separated. Abdominal ganglia oval, discrete; eight in male extending over first eight abdominal segments; six in female, extending over first six abdominal segments; connectives between them double; each ganglion with a pair of lateral nerves; ganglia 7 and 8 in male and ganglia 5 and 6 in female closer to each other than are other pairs of ganglia, but not coalesced; all ganglia of equal size.

REPRODUCTIVE SYSTEM - A pair of gonads present in 5th abdominal segment on either side of dorsal vessel; gonads with four follicles each and enclosed in a sheath containing reddish pigment granules in male and with four rudimentary ovarioles in female. A fine duct extending from each to mid-ventral line in segment 9 in male, gonoduct on each side extending around 7th abdominal spiracle to mid-ventral line of that segment in female. Rudimentary penis process-like, attached to integument of segment 9, visible externally as a white patch with a central depression, receiving ducts from both gonads. Female gonoduct attached to integument of abdominal segment 7 where it meets gonoduct of opposite side.

THE PUPA (7-day)

MALE (Fig. 52) - Apart from differences in size, no other differences are found between internal organs of different aged pupae.

ALIMENTARY SYSTEM - Oesophagus as in larva but very narrow. Foregut atrophied. Crop lacking. Mesenteron as in larva but shortened, reduced in diameter, extending from 1st to 6th abdominal segment, without enteric caeca or symbiont - containing structures. Proctodaeum as in larva but lengthened; ileum absent, coiled, and of uniform diameter; colon tubular, tapering posteriorly; rectum very long. Malpighian tubules of same number and arrangement as in larva but shortened. Silk glands degenerated. Mandibular glands absent.

CIRCULATORY SYSTEM - Dorsal vessel colourless, extending from 7th abdominal segment to head. Thoracic aorta with one swelling.

RESPIRATORY SYSTEM - Ten spiracles present on each side, the two thoracic and first two abdominal spiracles with internal openings. Abdominal spiracles 3 - 7 functional, 8th abdominal spiracle non-functional. Longitudinal tracheal trunk as in larva but the short tracheal trunk arising at prothoracic spiracle in larva absent. Two pairs of air sacs present between abdominal segments 2 - 5.

NERVOUS SYSTEM

BRAIN - Consisting of two oval lobes joined together, white with reddish patches. Optic lobe small, optic nerve large. Ocellar nerves absent. Antennal and frontal nerves large. Labral nerve slender.

VENTRAL NERVE CORD AND GANGLIA - Eleven ganglia present, their surfaces with pinkish patches. Suboesophageal ganglion discrete, connected to brain by well-separated circumoesophageal connectives, each of its lateral borders giving off maxillary and labial nerves. Mandibular nerves atrophied. Pro-, meso-, and metathoracic ganglia discrete, their connectives double. Ganglia present in abdominal segments 1 to 7; each ganglion with a pair of lateral nerves; connectives between ganglia double; spacing between ganglia equal; all ganglia of equal size. Tympanal nerves absent.

REPRODUCTIVE SYSTEM - Testes oval, twice as large as testes in adults; enclosed in a common scrotum. Vasa deferentia rudimentary, slightly transparent, slender. Vesiculae seminales of uniform diameter. Accessary glands short, sinuate. Ductus ejaculatorius very short, not coiled. Aedeagus shorter and thinner than adult aedeagus. Viniculum soft.

FEMALE (Fig. 53) - Apart from differences in size, no other differences are found between internal organs of different aged pupae.

ALIMENTARY SYSTEM - Oesophagus as in larva but reduced in diameter. Fore-gut and crop absent. Mesenteron extending over abdominal segments 2 - 6, with food contents, enteric caeca or diverticula absent. Proctodaeum increased in length; ileum absent; colon oval, tapering posteriorly; rectum long. Malpighian tubules as in larva but forming a network over posterior surface of mesenteron. Silk glands and mandibular glands degenerated.

CIRCULATORY SYSTEM - Dorsal vessel as in larva but thoracic aorta with only one spindle-shaped swelling.

RESPIRATORY SYSTEM - Spiracles relatively larger than in larval and adult stages, two thoracic and eight abdominal; all spiracles functional. Longitudinal tracheal trunk as in adult but smaller in diameter and with less extensive branching. Short tracheal trunk arising at prothoracic spiracle in larva absent. Wing tracheae and air sacs absent.

NERVOUS SYSTEM

BRAIN - Comprising two oval lobes as in larva but with division into antennal lobes. Other features as in adult.

VENTRAL NERVE CORD AND GANGLIA - Eleven ganglia present. Suboesophageal ganglion distinct, connected to brain by widely separated circumoesophageal connectives, giving off vestigial labial nerves. Mandibular and maxillary nerves absent. Pro-, meso-, and metathoracic ganglia and abdominal ganglia discrete and connected by double cords. Abdominal ganglia of equal size; spacing between ganglia equal; each ganglion with a pair of lateral nerves. Tympanal nerves absent.

REPRODUCTIVE SYSTEM - Ovarioles four on either side, separate, differing from adult ovarioles in having short, distended, oval, distal filaments; ligaments absent; developing eggs visible externally after 14 days in pupal stage. Calyx present. Lateral oviducts narrower than in adult. Common oviduct absent. Bursa copulatrix rudimentary. Vagina shorter and narrower than in adult, of uniform diameter. Spermatheca prominent. Glandula sebacea rudimentary, bilobed. Ductus seminales very short, without convolution. Ductus bursae narrower than in adult.

The differences between internal structures (excluding reproductive system) of male and female pupae are summarized in table 2 below.

TABLE 2. DIFFERENCES BETWEEN INTERNAL STRUCTURES (EXCLUDING REPRODUCTIVE SYSTEM) OF MALE AND FEMALE PUPAE.

Structures	Pupa	
	Male	Female
Mesenteron	Abdominal segments 1-6; without food contents	Abdominal segments 2-6; with food contents
Thoracic aorta	Oval-shaped	Spindle-shaped
Wing tracheae	Present	Absent
Air sacs	2 pairs	Absent
Antennal nerve	0.5 mm. long	0.2 mm. long
Optic nerve	0.6 mm. long	Absent
Maxillary nerve	1.2 mm. long	Absent
Labral nerve	2.0 mm. long	0.4 mm. long
Labial nerve	1.1 mm. long	0.6 mm. long
Mandibular nerve	0.3 mm. long	Absent

THE IMAGO

MALE

PROTHORAX (Fig. 54) - Profurca Y-shaped, large; furcal arms curved dorsally, tips of furcal arms approaching one another. Phragma present above furcal arms, transverse. Pronotum large, immediately above phragma, curved ventrally, partly covered by scutum. Propleuron curved, extending ventrally to meet coxa.

MESOTHORAX (Fig. 55) - Mesofurca Y-shaped; with two furcal arms directed dorsolaterally to meet postalar portion of epimeron of irregular outline. Phragma large, transverse E-shaped, above mesofurca and separated from it by thoracic cavity. Phragma pit prominent. Postnotum inverted U-shaped and above phragma. Scutellum curved, convex dorsally. Scutum larger than scutellum. Meron trapezoidal, directed dorsolaterally.

METATHORAX (Fig. 56) - Metafurca weak, with two V-shaped arms directed dorsally towards each other. Postnotum transverse, above tips of metafurcal arms. Scutellum inverse V-shaped. Postnotum above scutellum, posterior aspect of each side triangular. Postalare beneath postnotum, its posterior aspect triangular. Subulare beneath postnotum, its posterior aspect trapezoidal. Postalar portion of epimeron beneath subulare, metafurca and apophyseal pit, V-shaped. Apophyseal pit transverse lanceolate. Prealar portion of epimeron paired, triangular, directed dorsolaterally. Coxae paired, slender, directed dorsolaterally.

ALIMENTARY SYSTEM (Fig. 57) - Mouth opening lacking. Oesophagus slender, crop and proventriculus absent. Mid-gut tapering at both ends, with tubular distended part in middle, without enteric caeca or symbiant-containing structures; tubular part longer than distended part. Hind gut coiled, reverse S-shaped, shorter and narrower than mid-gut, narrow at junction with mid-gut, then broadened to form a swelling, abruptly contracted before formation of another swelling. Colon tubular and distended. Rectum tapering to anus. Six long malpighian tubules inserted in two groups of three tubules each on each side of hind gut lateroventrally, each group with a common duct. Salivary glands paired, tubular, of uniform diameter, one on either side of fore gut, extending throughout length of thorax.

CIRCULATORY SYSTEM (Fig. 57) - Dorsal vessel inconspicuous, colourless, tubular, extending from 7th abdominal segment to head. Pulsative chamber of aorta in mesothorax, distended, oval, supplying mainly wings and wing muscles. Heart (posterior part of dorsal vessel) of uniform diameter, extending from 7th to 2nd abdominal segments, maintained in position by six pairs of alary muscles attached to tergites 2 - 7.

RESPIRATORY SYSTEM - Two thoracic and eight abdominal spiracles present on each side. Spiracular arrangement holopneustic. Longitudinal tracheal trunk single from head to 8th abdominal segment, giving off 4 - 5 branches in two groups beneath each spiracle; dorsal group (3-4 branches) anastomosed with that of longitudinal tracheal trunk of the other side in the mid-dorsal line; ventral group (2-3 branches) anastomosed with that of the longitudinal tracheal trunk of the opposite side in the mid-ventral line. Wing tracheae large. Two pairs of air sacs present in abdomen between segments 2 and 3, and 3 and 5. Tympanal air sac absent.

NERVOUS SYSTEM (Figs. 57 - 59)

BRAIN - Highly developed, transverse 8-shaped, with a shallow anterior emargination, larger than other ganglia, its white surface with pinkish patches. Vertical median sulcus present anteriorly in mid-line. Optic lobe large, triangular, paired, forming main bulk of brain; optic nerves cylindrical. Ocellar nerves not seen. Antennal lobes prominent, present as slight swellings on either side of median sulcus; antennal nerve cylindrical. Frontal nerve large. Labral nerve very slender.

VENTRAL NERVE CORD AND GANGLIA - Eleven ganglia present, white, with pinkish patches. Suboesophageal ganglion oval. Circumoesophageal connectives well separated, lateral border giving off maxillary and labial nerves. Mandibular nerves absent. Pro-, meso-, and metathoracic ganglia discrete, connected to one another by two separate connectives. Tympanal nerves lacking. Abdominal ganglia also discrete; each ganglion with a pair of lateral nerves; ganglia 1 - 4 connected by double connectives, ganglia 4 - 7 connected by single nerve cord; 1st and 6th ganglia small; 7th ganglion largest, pear-shaped and drawn out posteriorly.

REPRODUCTIVE SYSTEM (Fig. 57) - Occupies greater width of abdominal segments 3 - 9 + 10. Testes spherical, each containing 4 follicles, apposed, above alimentary canal, single-lobed, enclosed in a common scrotum. Vasa deferentia in abdominal segments 3 - 5, tubular, coiled, of different diameters, fused at proximal ends before entering fused proximal portions of vesiculae seminales. Vesiculae seminales not transparent, well-developed, distal portions apposed, proximal portions twice diameter of distal portions but of equal length. Accessory glands paired, long, coiled, entering vesiculae seminales anteriorly. Ductus ejaculatorius in abdominal segments 5 - 6, cylindrical, short, coiled, narrow anteriorly to middle, broadened before entering proximal end of aedeagus, thinner than vas deferens. Aedeagus very long, extending over abdominal segments 6 - 9 + 10, cylindrical, slightly convex dorsally, narrowed towards vesica. Vinculum extending over abdominal segments 6 - 9 + 10, situated beneath aedeagus.

FEMALE

PROTHORAX (Fig. 60A) - Pronotum occupies one-eighth height of prothorax, and three quarters of circumference of prothorax, curved ventrally to meet thickened cuticle (lower quarter of circumference of prothorax). Prothoracic cavity large, its greater width occupied by portions of ovarioles. Coxae attached to thickened cuticle ventrally. Profurca and phragma absent.

MESOTHORAX (Fig. 60B) - Oval, its cavity large and filled mainly with ovarioles. Mesonotum inverse U-shaped, covering dorsal part of mesothorax, occupies one-tenth height of mesothorax. Thickened cuticle covering remaining lower part of mesothorax, with coxae attached directly and ventrally. Mesofurca and phragma absent.

METATHORAX (Fig. 60C) - Oval, its cavity large and filled mainly with ovarioles. Postnotum curved downwards, covering dorsal half of metathorax, occupies one-tenth height of metathorax. Thickened cuticle covering lower half of metathorax, with coxae attached ventrally. Metafurca and phragma absent.

ALIMENTARY SYSTEM (Fig. 61) - Mouth opening lacking. Oesophagus three times shorter than that in male, tubular. Crop and proventriculus absent. Mid-gut larger than that in male, distended uniformly, cylindrical, narrowed anteriorly and posteriorly, without enteric caeca or symbiont-containing structures. Hind gut tubular, narrow, broadened twice along its length, narrowed distally, broadened parts spindle-shaped; colon distended and cylindrical; rectum narrow.

CIRCULATORY SYSTEM (Fig. 61) - Dorsal vessel inconspicuous, colourless, tubular, extending from 7th abdominal segment to brain. Pulsative chamber of aorta in thorax distended, oval. Heart narrow, tubular, extending from 7th to 1st abdominal segment.

RESPIRATORY SYSTEM (Fig. 62) - Two thoracic and eight abdominal spiracles present on each side. Spiracular arrangement holopneustic. Longitudinal tracheal trunks lateral, one on each side, giving off 4 - 5 branches in two groups beneath each spiracle, dorsal group (3 - 4 branches) anastomosed with that of longitudinal tracheal trunk of other side in mid-dorsal line, ventral group (1 - 2 branches) anastomosed with that of longitudinal tracheal trunk of other side in mid-ventral line. Tracheae to wings absent. Air sacs (e.g. Tympanal air sacs) absent.

NERVOUS SYSTEM (Figs. 61, 63, 64A & B)

BRAIN - Indented slightly on middle of anterior surface, transverse 8-shaped, with pinkish patches on white background. Optic lobes obscured, and ocellar nerves absent. Antennal lobes poorly developed, antennal nerves vestigial, frontal nerves small, labral nerves vestigial.

VENTRAL NERVE CORD AND GANGLIA - Ganglia eleven, white with pinkish patches. Suboesophageal ganglion oval, connected to brain by long, well-marked circumoesophageal connectives. Labial nerves vestigial. Mandibular and maxillary nerves absent. Pro-, meso-, and metathoracic ganglia discrete, connected to one another by double cords; pro- and mesothoracic ganglia close to each other. Tympanal nerves absent. Abdominal ganglia also discrete; each with a pair of lateral nerves; ganglia 1 - 4 connected by double cords; ganglia 4 - 7 connected by fused cord; 2nd and 6th ganglia small; 7th ganglion largest, pear-shaped, and drawn out posteriorly.

ANTERIOR SYMPATHETIC NERVOUS SYSTEM - Frontal ganglion inverted pear-shaped, with frontal nerve anteriorly and recurrent nerve posteriorly. Labral nerve vestigial. Antennal nerve sinuate, lateral to labral nerve. Optic and ocellar nerves absent. Corpus cardiacum paired, connected anteriorly to brain by a single nerve and to recurrent nerve medioposteriorly by another single nerve. Corpus allatum paired, larger than and posterolateral to corpus cardiacum.

REPRODUCTIVE SYSTEM (Fig. 61) - Occupies greater width of body cavity from head to 9 + 10 abdominal segment. Ovarioles four in each ovary, three of these arising at a higher level than lower one, with filaments but without ligaments. Calyx present. Lateral oviduct short, paired, connected to vestibulum directly, common oviduct absent. Bursa copulatrix very large, well-developed, projecting, not chitinised, shorter than vagina but oval in shape, narrowed apically, with a basal neck. Vagina long, tubular, broader anteriorly, elongate and narrow posteriorly, not sclerotised, appearing prolonged when genital segments are pulled out. Spermatheca on right side of vagina, with capsule not sclerotised; vesiculate; smooth; with long collum but without ramus; spermathecal ducts very long, coiled, narrow, entering vestibulum dorso-laterally on right-hand side. Glandular sebacea bilobed, posterior to and smaller than spermatheca, surface of each lobe deeply indented, ducts from lobes joining common duct before entering vagina. Ductus seminalis very long, coiled, tubular, of uniform diameter. Ductus bursae narrow, elongate, entering ostium bursae posteriorly on abdominal segment 8.

Differences in internal structures (excluding reproductive system) of male and female imagoes are summarized in table 3.

TABLE 3 DIFFERENCES IN INTERNAL STRUCTURES (EXCLUDING REPRODUCTIVE SYSTEM) BETWEEN MALE AND FEMALE IMAGOES.

	Imago	
Structures	Male	Female
Furca	Present	Absent
Phragma	Present	Absent
Mesenteron	Diameter 4 mm., Abdominal segments 3 - 4	Diameter 0.5 mm., Metathorax to 4th abdominal segment
Thoracic aorta	With two swellings	With a single swelling
Wing tracheae	Present	Absent
Air sacs	2 pairs	Absent
Antennal nerve	0.6 mm. long	0.2 mm. long
Optic nerve	0.6 mm. long	Absent
Maxillary nerve	1.2 mm. long	Absent
Labral nerve	3.0 mm. long	0.5 mm. long
Labial nerve	1.2 mm. long	0.6 mm. long
Mandibular nerve	0.4 mm. long	Absent
Ventral nerve cord	21.3 mm. long	23.2 mm. long
Mesothoracic wing nerve	3.0 mm. long	Absent
Metathoracic wing nerve	2.0 mm. long	Absent

ABBREVIATIONS FOR FIGURES 1 - 64

ab. g.	abdominal ganglia
ab. seg.	abdominal segment
ab. te.	abdominal tergite
acc. gl.	accessory gland
acl.	anteclypeus
ad.	adnotale
ae.	anepisternum
aed.	aedaegus
an.	anus
anel.	anellus
ant.	antenna
antco.	antacoria
ant. n.	antennal nerve
a. n. w. p.	anterior notal wing process
ao.	aorta
ao. ch.	mesothoracic pulsative chamber of aorta
apo. ant.	apophysis anterioris
apo. po.	apophysis posterioris
ap. p.	apophyseal pit
a. s.	air sac
a. t. p.	anterior tentorial pit
ax.	axillary sclerite
ax. c.	axillary cord
ba.	basalare
br.	brain
b. scr.	basal sclerite

bt.	basitarsus
bu. cop.	bursae copulatrix
C.	costa
ca.	cardo
cal.	calyx
cir. oes. c.	circumoesophageal connective
cl.	claw
cn.	cranium
co.	'collar'
col.	colon
con.	cone
cond. a.	articulation surface for mandibular condyle
corp. all.	corpus allatum
corp. card.	corpus cardiacum
cr.	crochets
crem.	cremaster
c. scr.	costal sclerite
Cu.	cubitus
cu. scr.	cubital sclerite
cv.	cervix
cv. s.	cervical sclerite
cx.	coxa
cx. s.	coxal suture
dA.	anal vein
dt.	distotarsus
du. bu.	ductus bursae
du. ej.	ductus ejaculatorius
du. sm.	ductus seminales

e.	compound eye
ecx.	eucoxa
epcr.	epicranium
f. a.	furcal arm
fcl.	frontoclypeus
fe.	femur
fg.	fore-gut
fge. infl.	frontogenal inflection
f. m.	foramen magnum
fr.	frenulum
fr. g.	frontal ganglion
fr. n.	frontal nerve
fr. s.	frontal suture
g.	ganglion
ge.	gena
ging. a.	articulation surface for ginglymus
gl. S.	glandula sebacea
g. o.	genital orifice
gon.	gonad
gond.	gonoduct
h.	hair
hk.	hook
hkl.	hooklets
hst.	hypostoma
hst. s.	hypostomal suture
hyp.	hypopharynx
il.	ileum
jt.	joint

ke.	katepisternum
la.	labrum
lab.	labium
la. n.	labral nerve
lab. n.	labial nerve
lat. n.	lateral nerve
leg.	thoracic leg
lf. s.	laterofacial suture
lob.	lobarium
long. tra. t.	longitudinal tracheal trunk
l. p.	labial palp
l. pf.	labial palpifer
l. s.	labial sclerite
M.	media
mand.	mandible
mand. gl.	mandibular gland
mand. se.	mandibular seta
max.	maxilla
max. n.	maxillary nerve
mcr. infl.	midcranial inflection
me.	meron
me. g.	mesothoracic ganglion
me. l. n.	mesothoracic leg nerve
mes.	mesenteron
met. g.	metathoracic ganglion
met. l. n.	metathoracic leg nerve
met. w. n.	metathoracic wing nerve
me. w. n.	mesothoracic wing nerve

mf.	mesofurca
mi. se.	microscopic seta
m. l.	maxillary lobe
m. p.	maxillary palp
Mp. t.	Malpighian tubules
m. scr.	medial sclerite
msnt.	mesonotum
ms. w.	mesothoracic wing
mt.	mediotarsus
mtf.	metafurca
mtm.	mentum
mtnt.	metanotum
mt. w.	metathoracic wing
n. mb.	neck membrane
o.	ocellus
o. bu.	ostium bursae
oc.	occiput
oes.	oesophagus
op.	ovipositor
op. l.	optic lobe
op. n.	optic nerve
ovl.	ovariole
ov. la.	oviductus lateralis
ovp.	oviporus
p.	peritreme
pa. an.	papillae anales
pcl.	paraclypeus
p. a. p.	postalar plate

pat.	patagium
pe.	pre-episternum
pge.	postgena
ph.	phragma
phar.	pharynx
ph. p.	phragma pit
pl.	planta
pm.	prementum
p. n. w. p.	posterior notal wing process
poc.	postocciput
Poul. l.	Poulton's line
pr.	fringed processes of lips of spiracle
pr. ep.	prealar portion of epimeron
pr. g.	prothoracic ganglion
pr. l. n.	prothoracic leg nerve
prl. sc.	scar of ventral proleg
prnt.	pronotum
prof.	profurca
prpl.	propleuron
pt.	pretarsus
pta.	postalare
pt. ep.	postalar portion of epimeron
ptn.	postnotum
p. t. p.	posterior tentorial pit
pu. ca.	pupal case
p. w. p.	pleural wing process
R.	radius
re.	rectum

r. n.	recurrent nerve
r. scr.	radial sclerite
sal. gl.	salivary gland
s. ap.	silk aperture
sb.	subalare
Sc.	subcosta
scl.	scutellum
s. co.	sensory cone
scr.	sclerite
sc. scr.	subcostal sclerite
scu.	scutum
scx.	subcoxa
se.	seta
seg.	segment
sil. gl.	silk gland
sm.	submentum
s. oes. g.	suboesophageal ganglion
sp.	spiracle
sp. a.	spiracular aperture
sper.	spermatheca
spi.	spines
spin.	spinneret
st.	stipes
su.	suralare
sul.	sulcus
ta.	tarsus
t. br.	tentorial bridge
te.	tergite

teg.	tegula
teg. a.	tegular arm
tes.	testes
t. fil.	terminal filament of ovariole
th. cu.	thickened cuticle
ti.	tibia
t. l. m.	tergal longitudinal muscles
tor.	tormae
tr.	trochanter
tra.	tracheae
tu.	tubercle
tu. an.	tuba analis
un.	uncus
v.	vertex
va.	valva
vag.	vagina
vas. def.	vas deferens
ves.	vesica
ves. sem.	vesiculae seminales
vest.	vestibulum
vin.	vinculum
v. n. c.	ventral nerve cord
wi.	wing

FIGURE 1.

A. EGG.

B. HEAD CAPSULE OF 7TH INSTAR LARVA, ANTERIOR ASPECT.

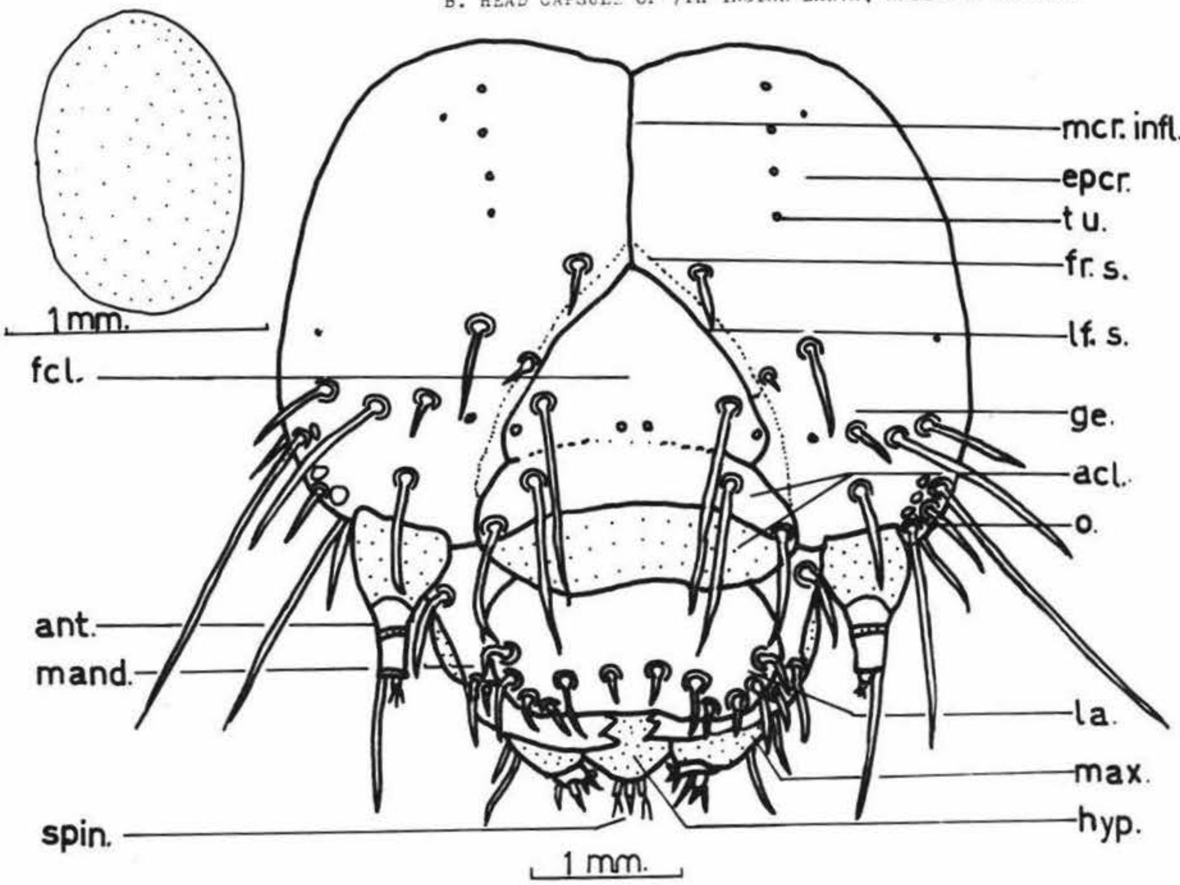


FIG. 2. HEAD CAPSULE OF 7TH INSTAR LARVA, POSTERI R ASPECT.

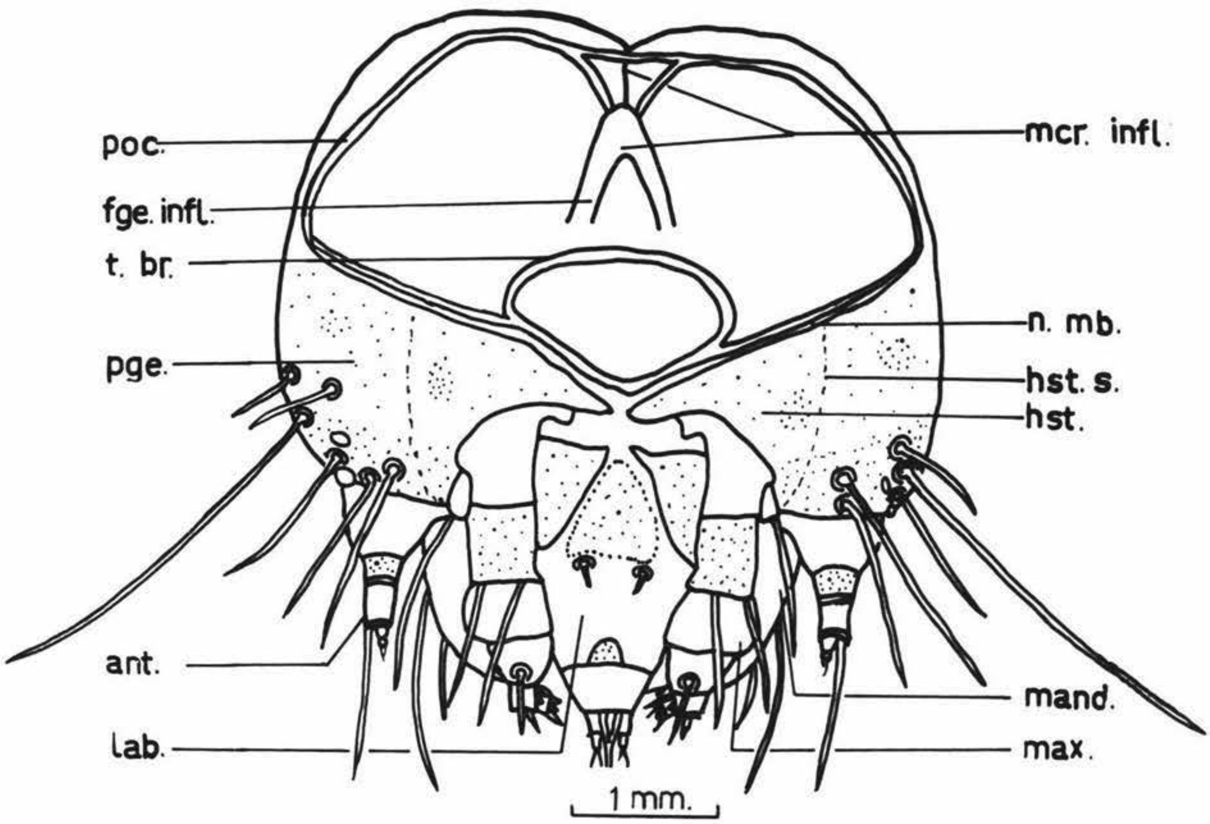


FIG. 3. HEAD CAPSULE OF 1ST INSTAR LARVA, ANTERIOR ASPECT.

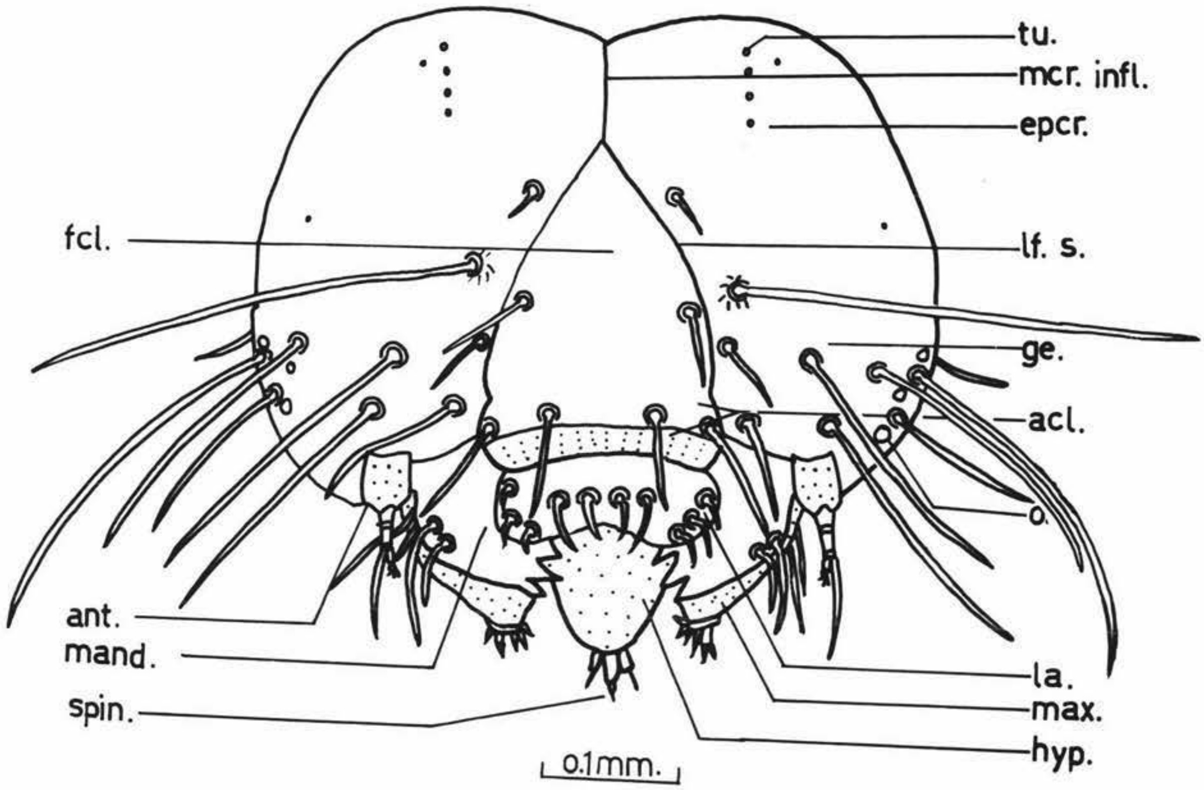


FIG. 4. LEFT ANTENNA, 7TH INSTAR, DORSOLATERAL ASPECT.

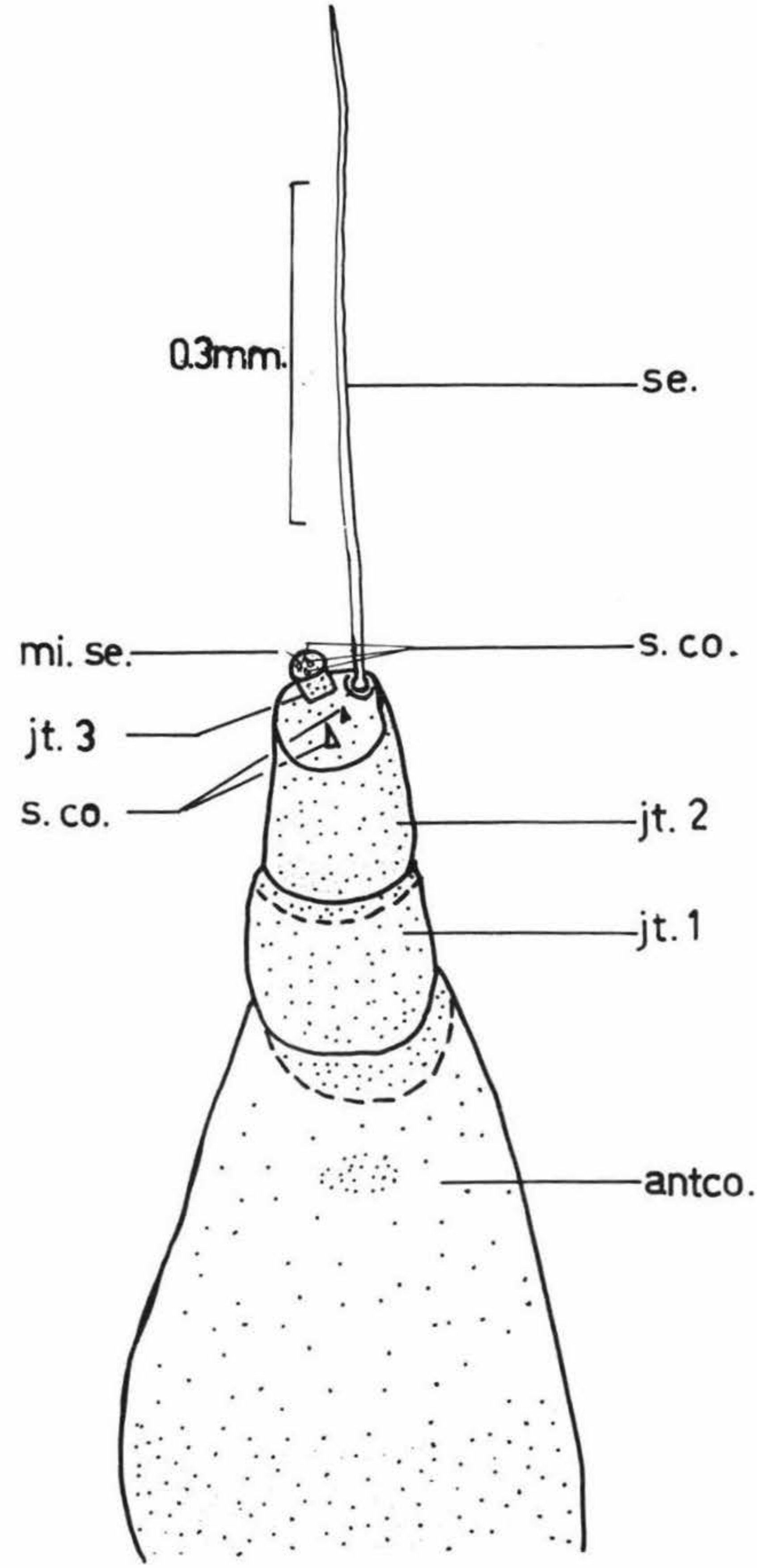


FIG. 5. LABRUM, 7TH INSTAR, ANTERIOR ASPECT.

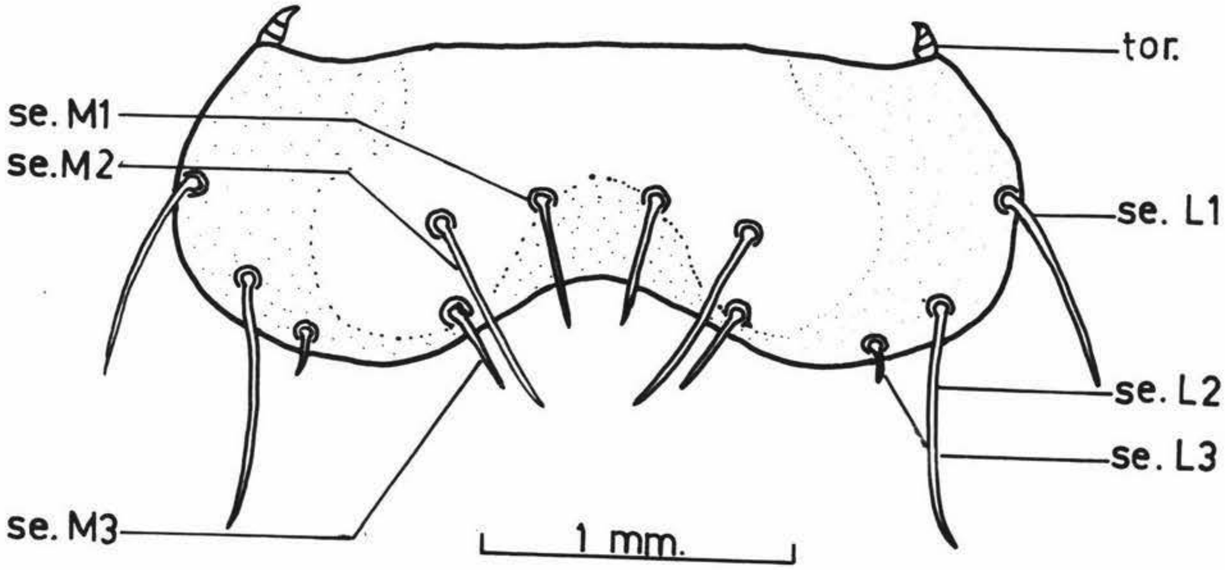


FIG. 6. LEFT MANDIBLE, 7TH INSTAR, ANTEROLATERAL ASPECT.

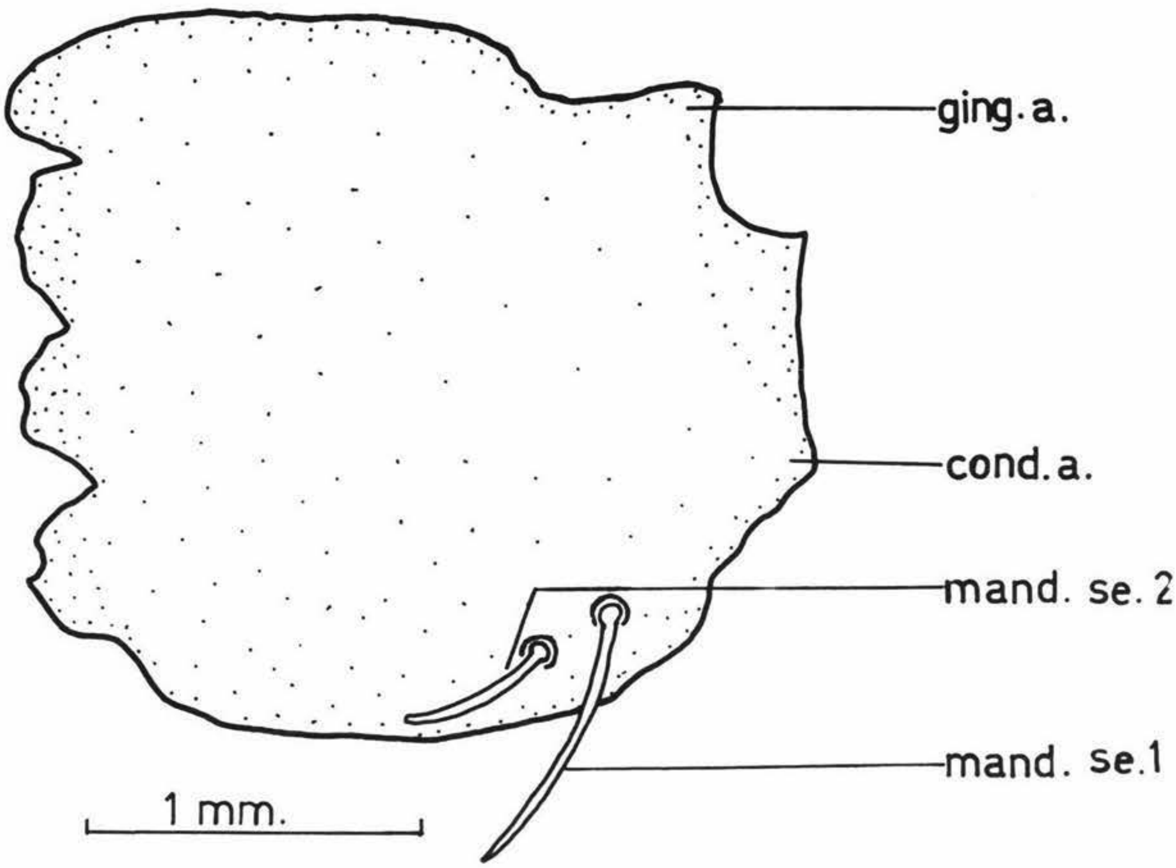


FIG. 7. LEFT MANDIBLE, 7TH INSTAR, POSTERIOR ASPECT.

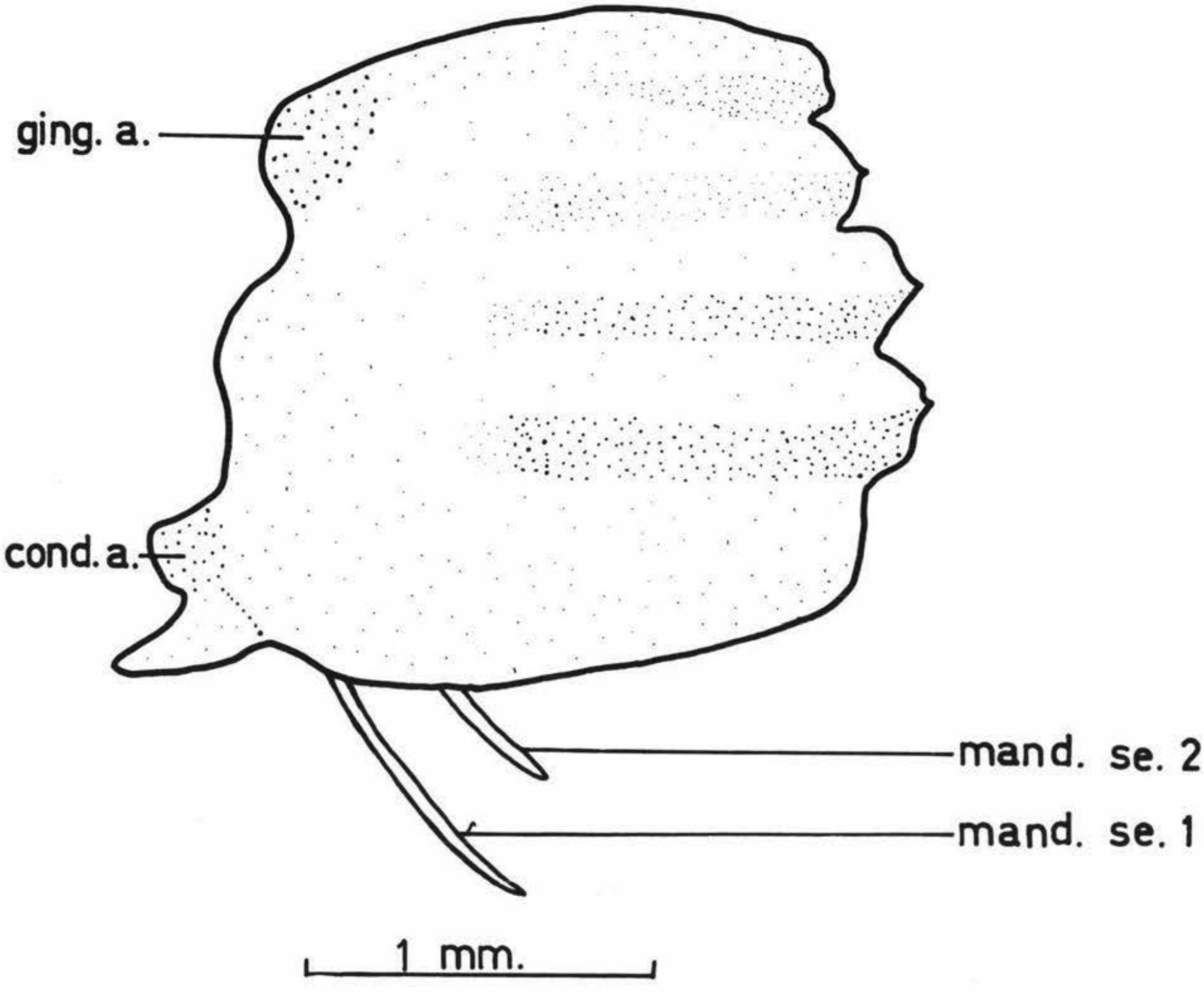


FIG. 8. MAXILLOLABIAL-HYPOPHARYNGEAL COMPLEX, POSTERIOR ASPECT.

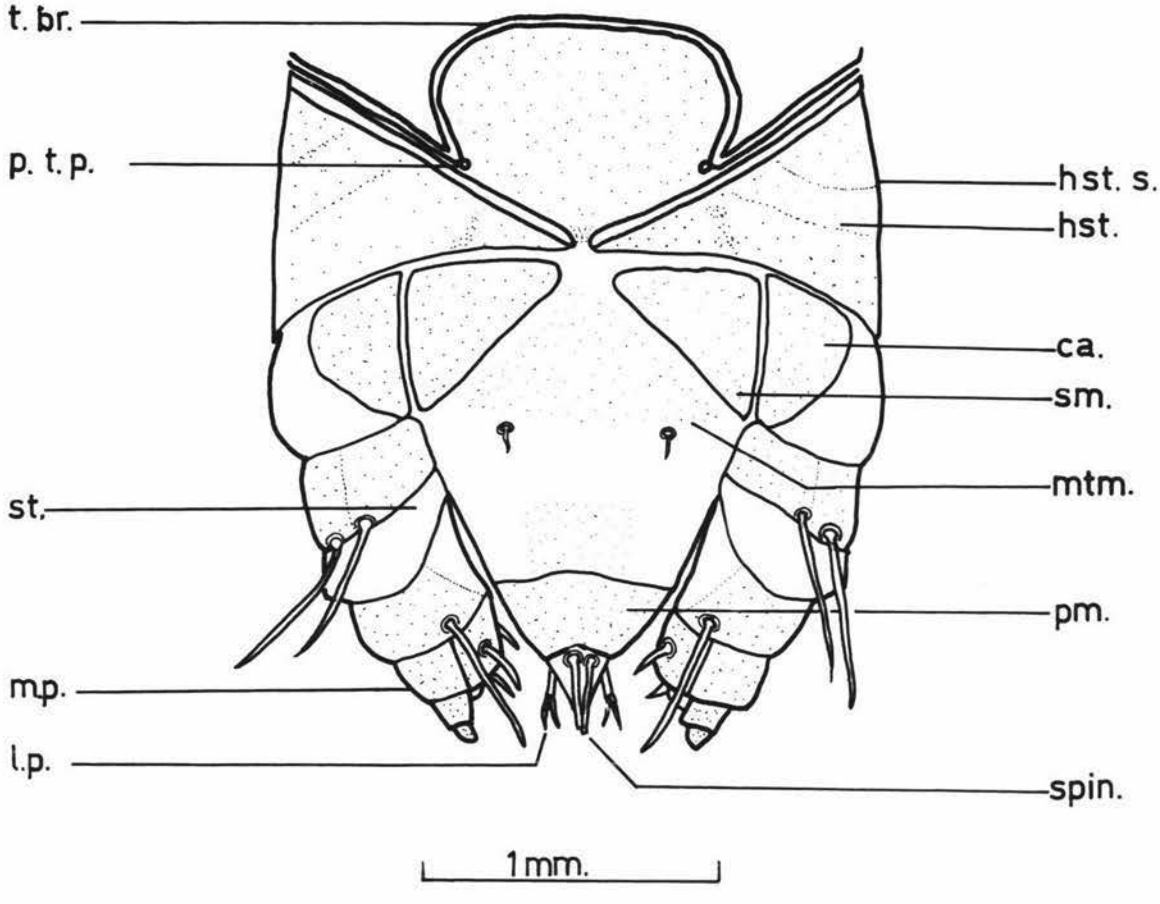


FIG. 9. LEFT MAXILLA, 7TH INSTAR, DETAIL OF DISTAL PORTION, ANTERIOR ASPECT.

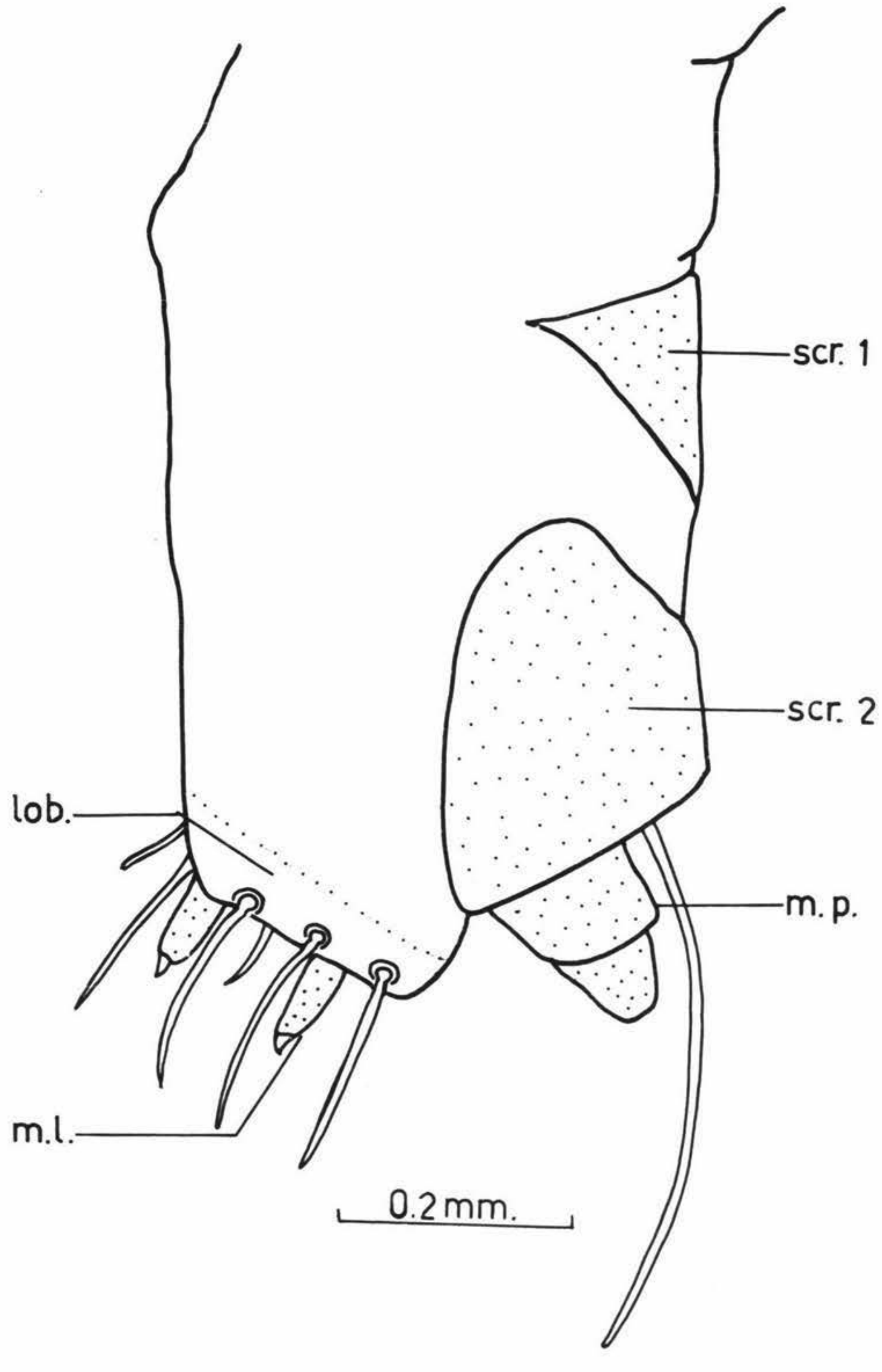


FIG. 10. LEFT MAXILLA, 7TH INSTAR, DETAIL OF DISTAL PORTION, POSTERIOR ASPECT.

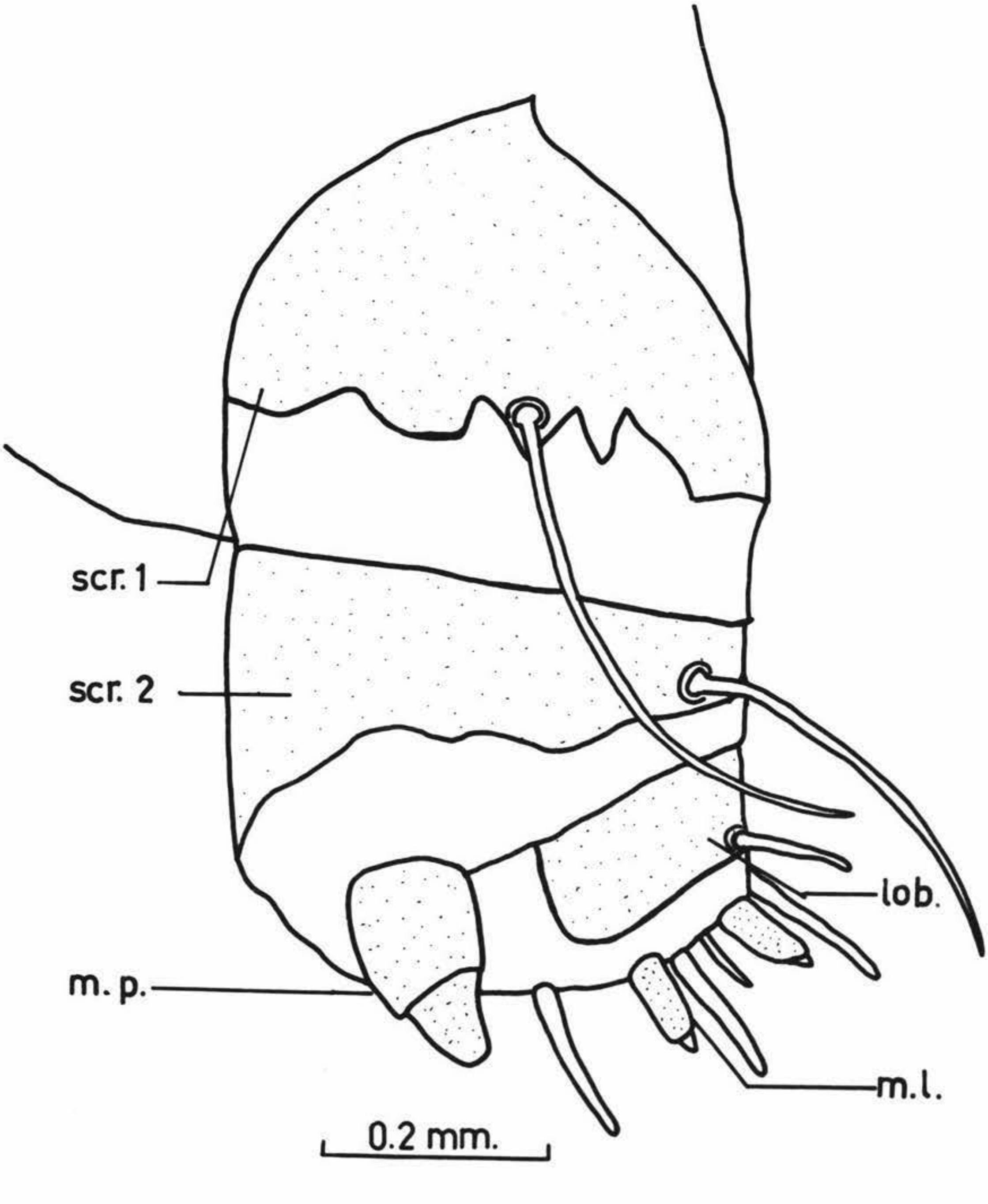


FIG. 11. LABIUM, 7TH INSTAR, DETAIL OF DISTAL PORTION, VENTRAL ASPECT.

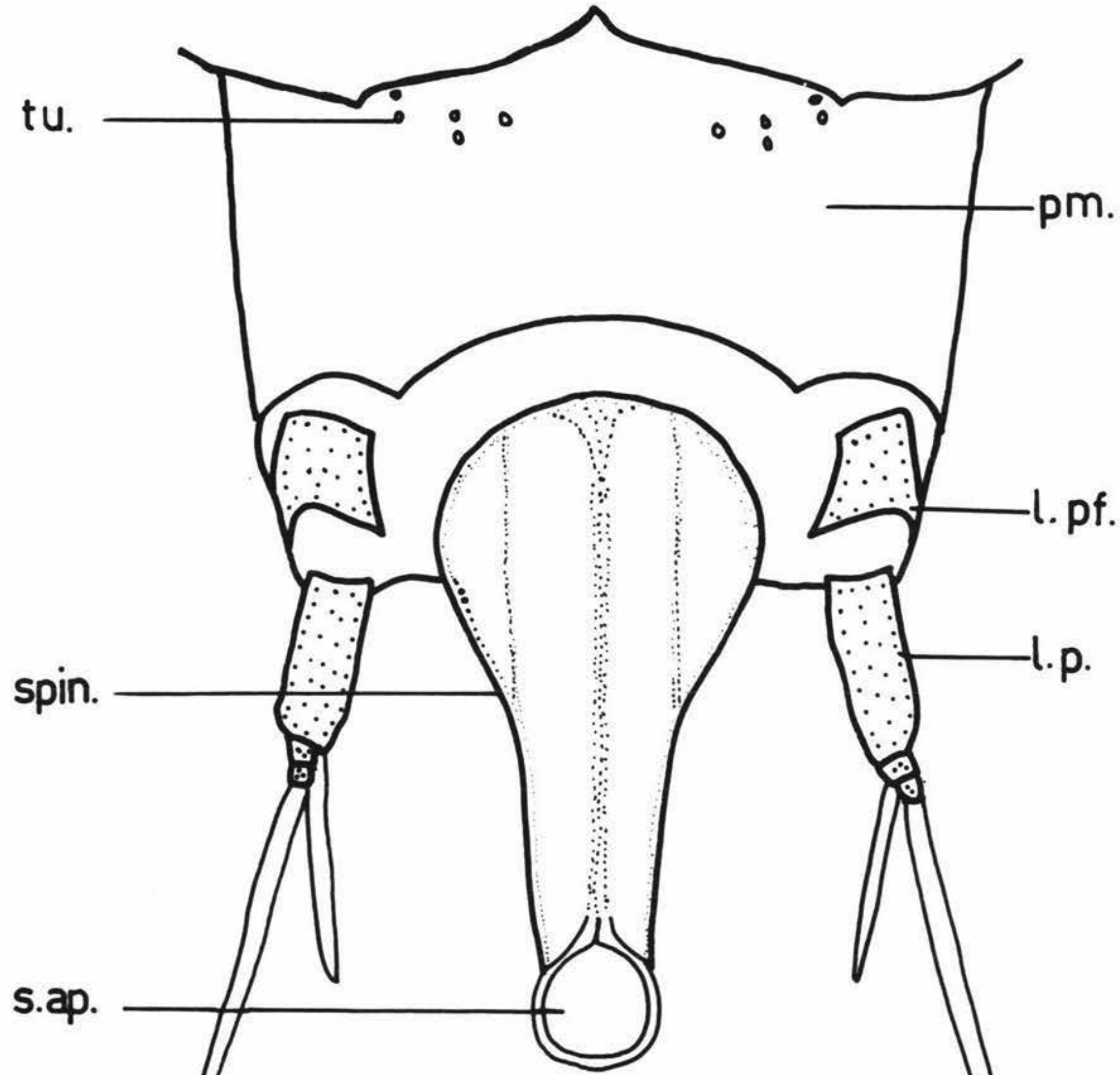


FIG. 12. SPINNERET, 7TH INSTAR, LATERAL ASPECT.

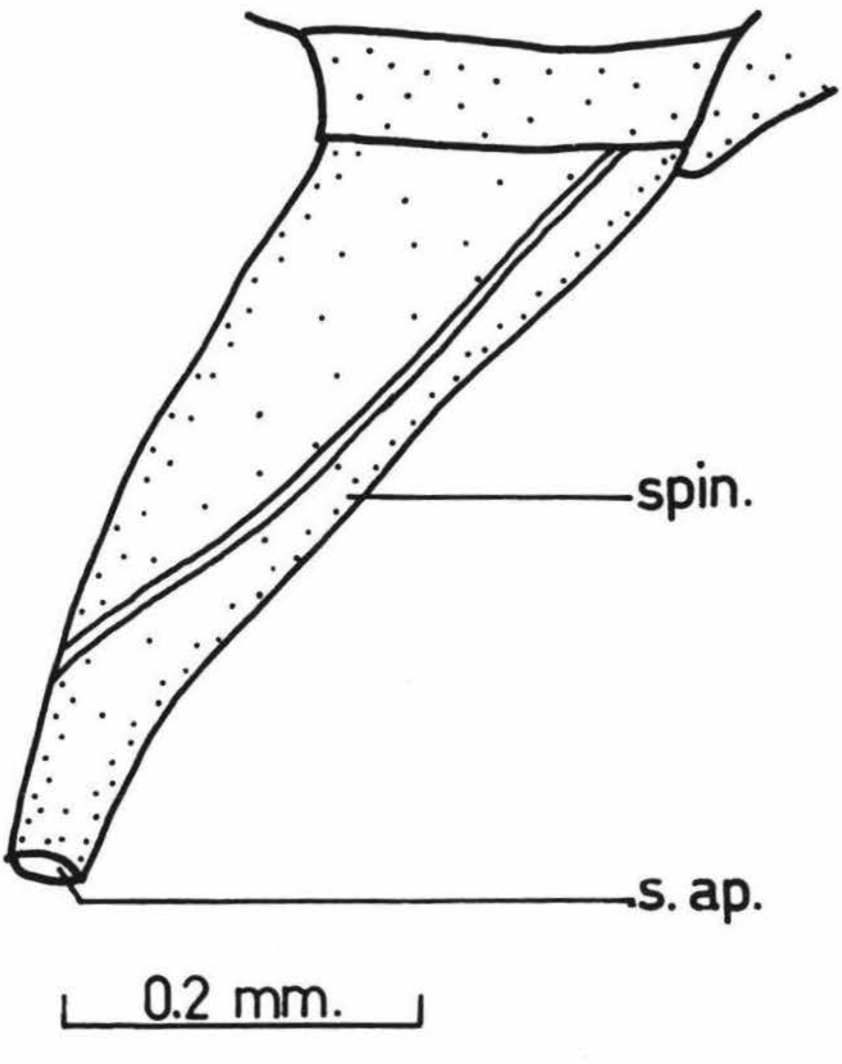


FIG. 13. 1ST INSTAR LARVA AT TWO DAYS, LATERAL ASPECT.

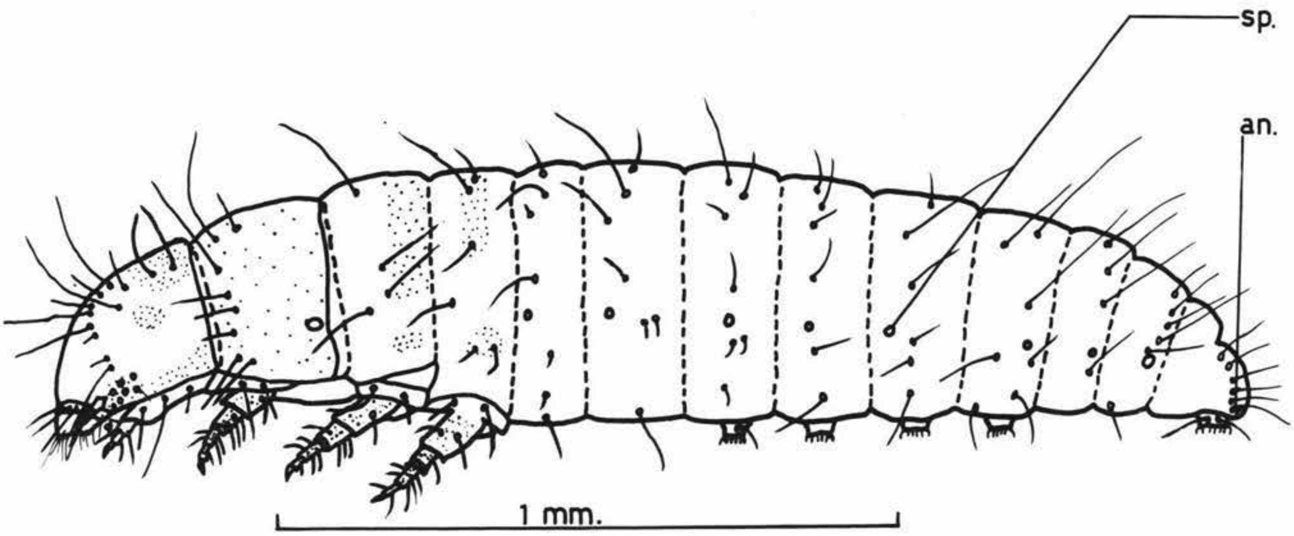
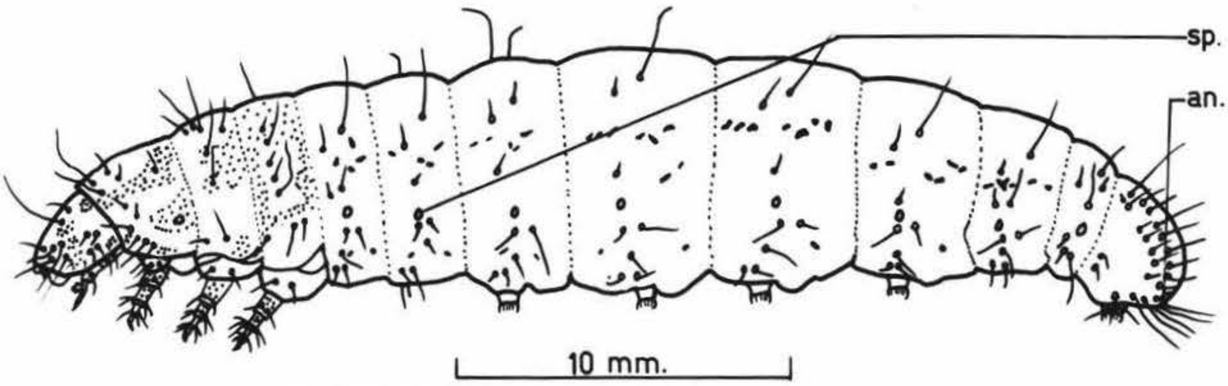


FIG. 14.

A. 7TH INSTAR LARVA, LATERAL ASPECT.



B. 2ND ABDOMINAL SPIRACLE OF 7TH INSTAR LARVA.

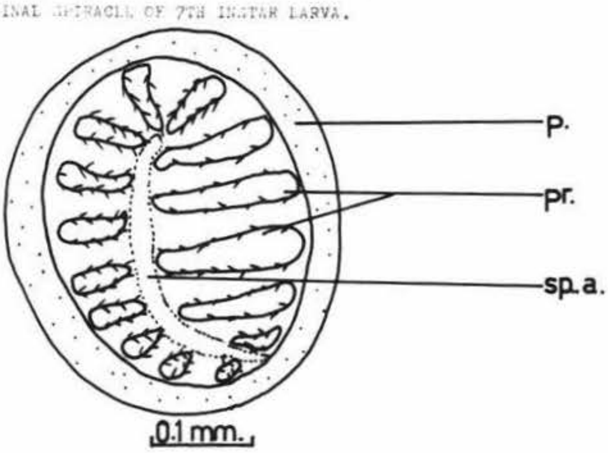
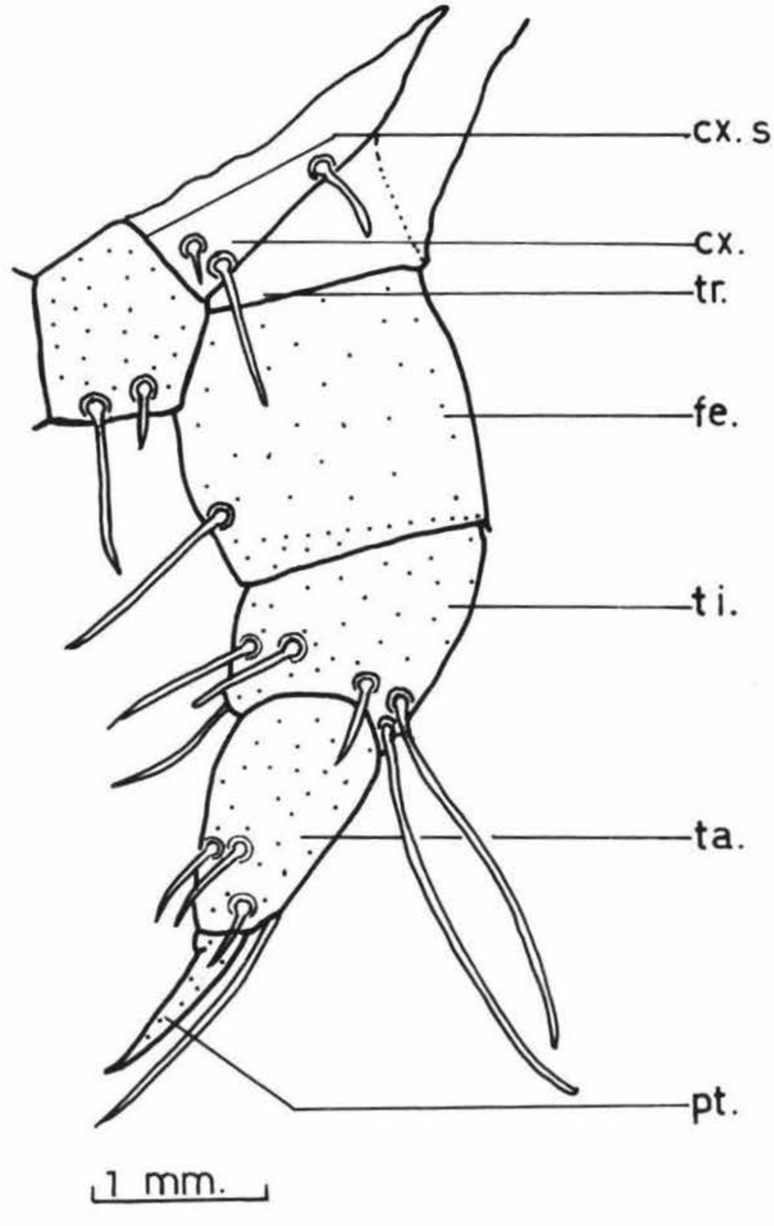


FIG. 15. A. LEFT THORACIC LEG, 7TH INSTAR, ANTERIOR ASPECT.



B. LEFT VENTRAL PROLEG, 7TH INSTAR, LATERAL ASPECT.

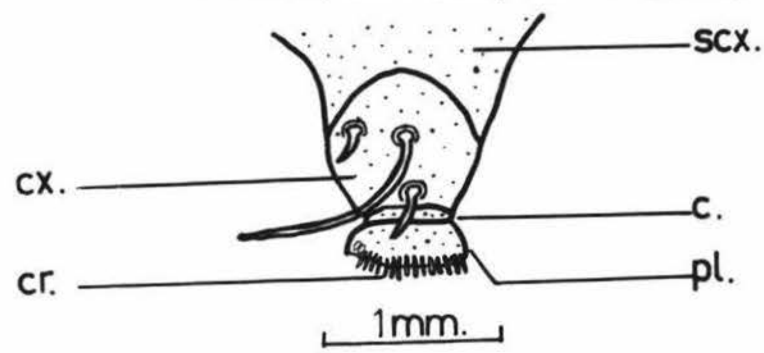


FIG. 16. CRANIAL CHAETOTAXY. ANTEROLATERAL ASPECT.

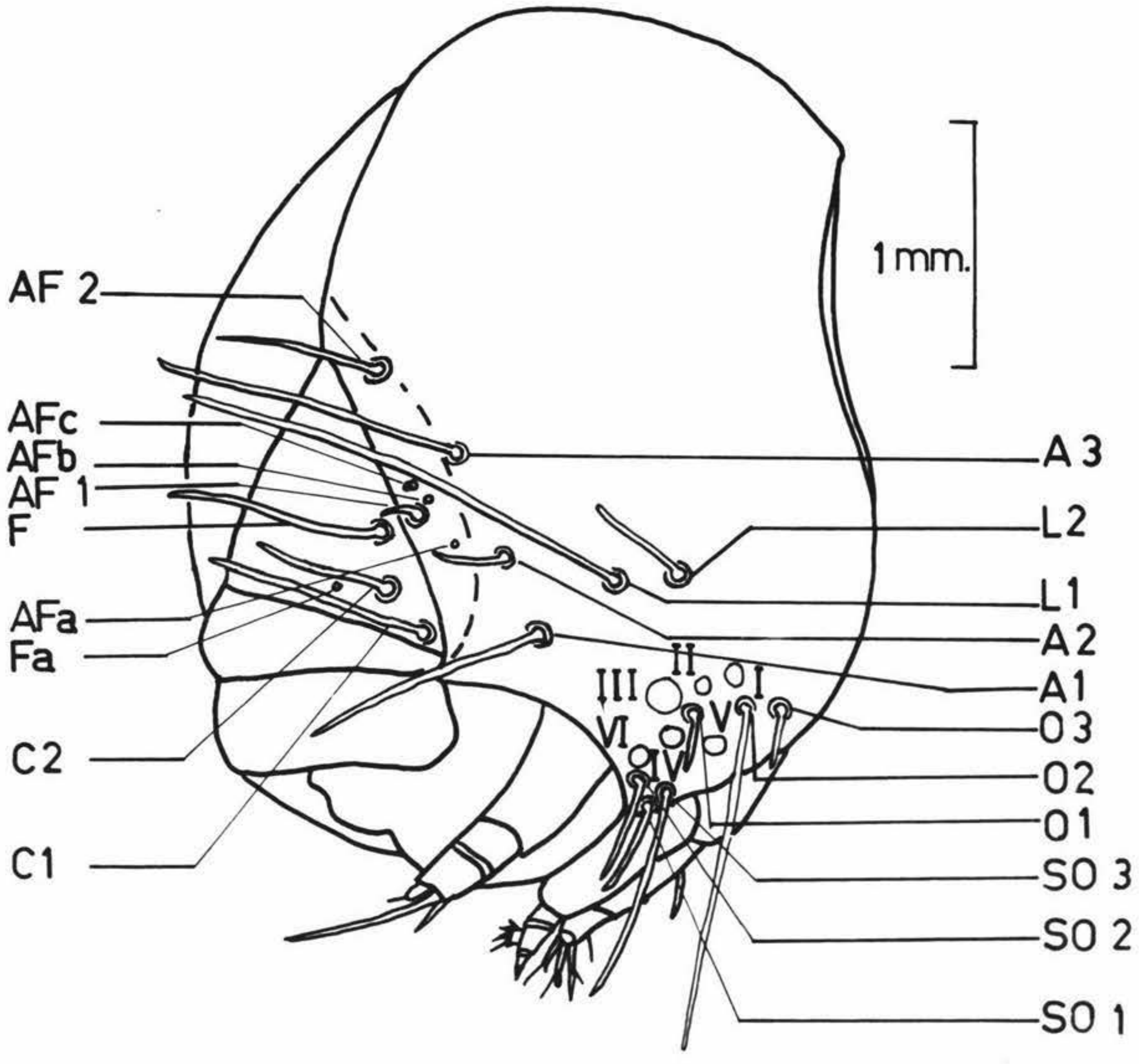


FIG. 17. SETAL MAP OF 1ST INSTAR LARVA.

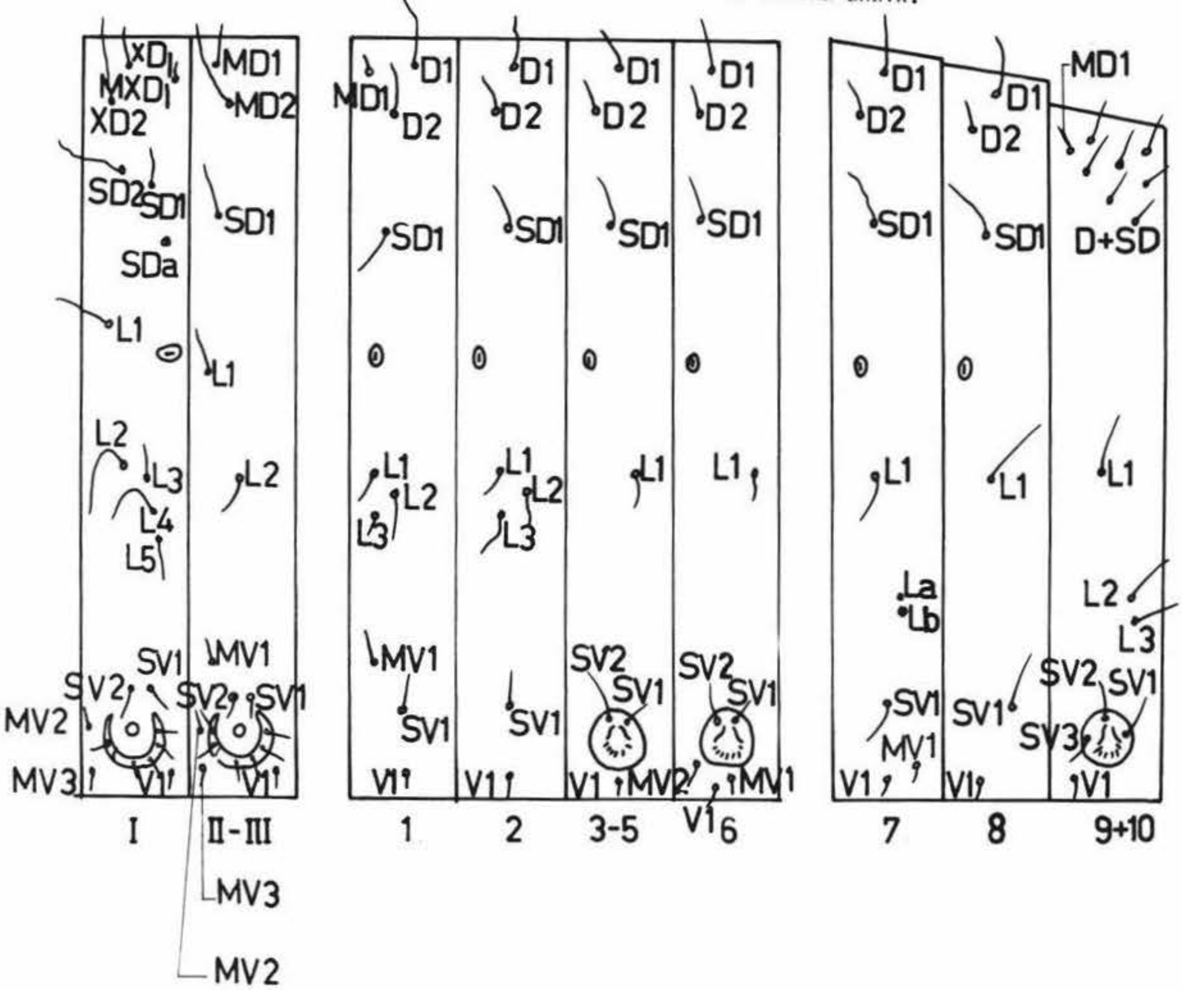


FIG. 18. SETAL MAP OF 2ND INSTAR LARVA.

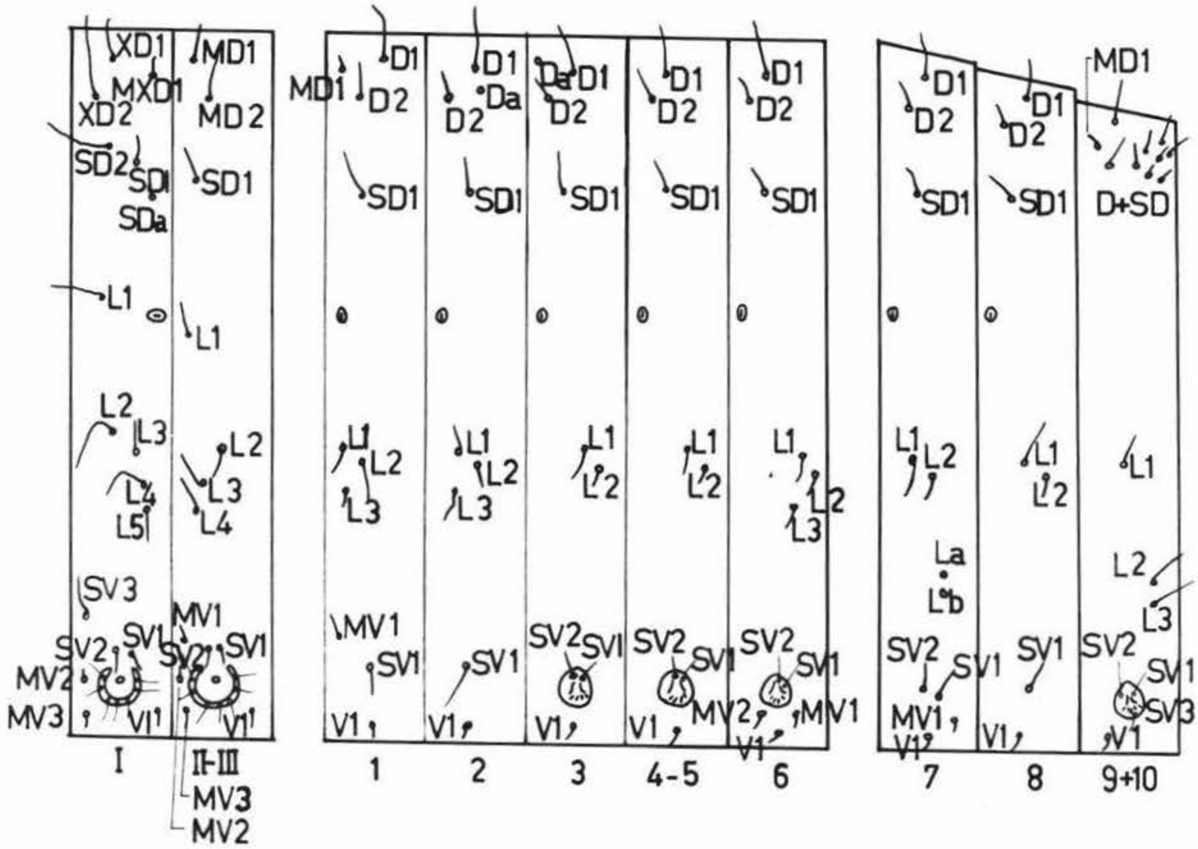


FIG. 19. SETAL MAP OF 3RD INSTAR LARVA.

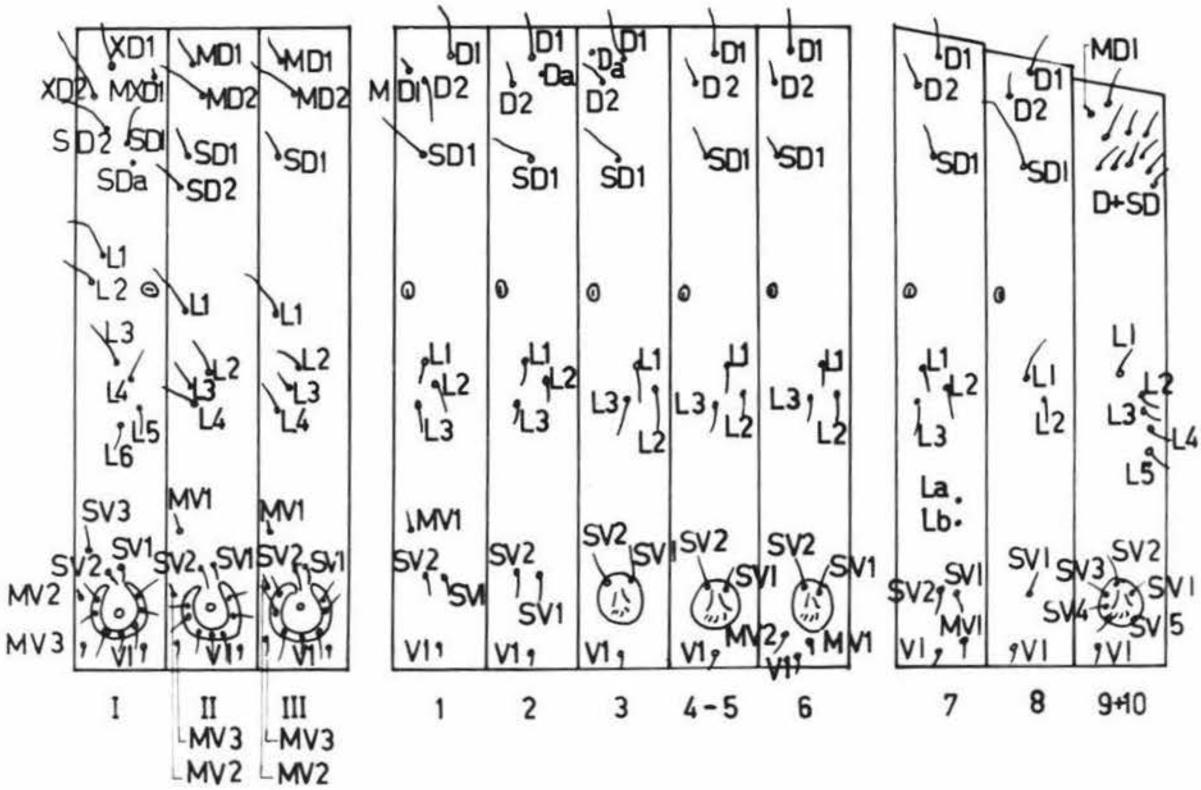


FIG. 20. SETAL MAP OF 4TH INSTAR LARVA.

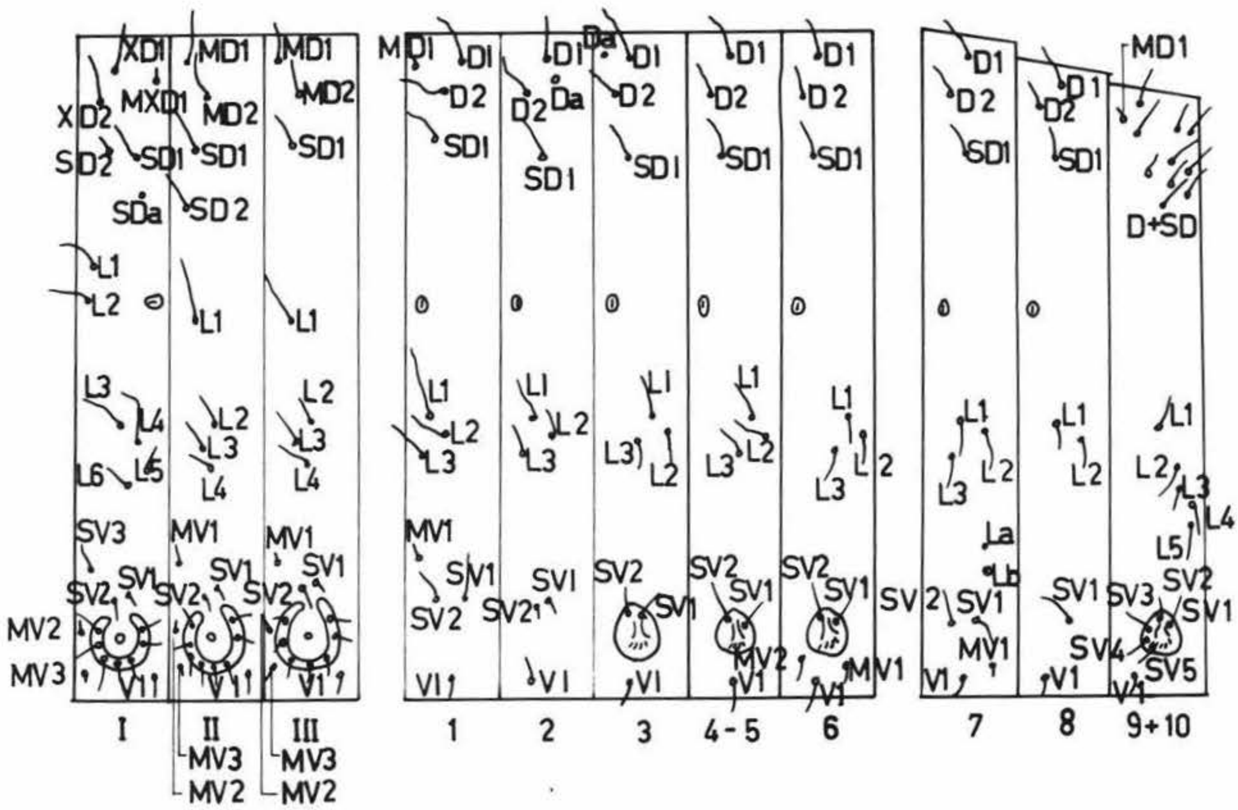


FIG. 21. SETAL MAP OF 5TH INSTAR LARVA.

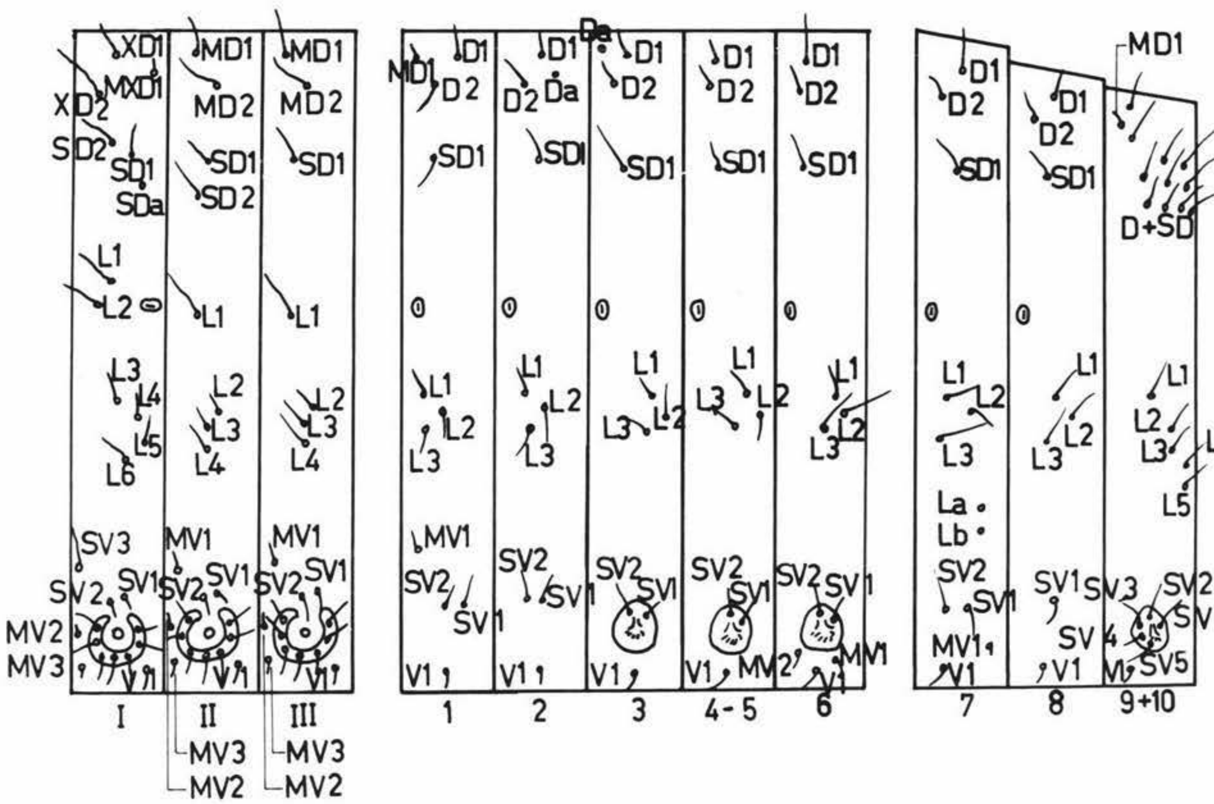


FIG. 22. SETAL MAP OF 6TH INSTAR LARVA.

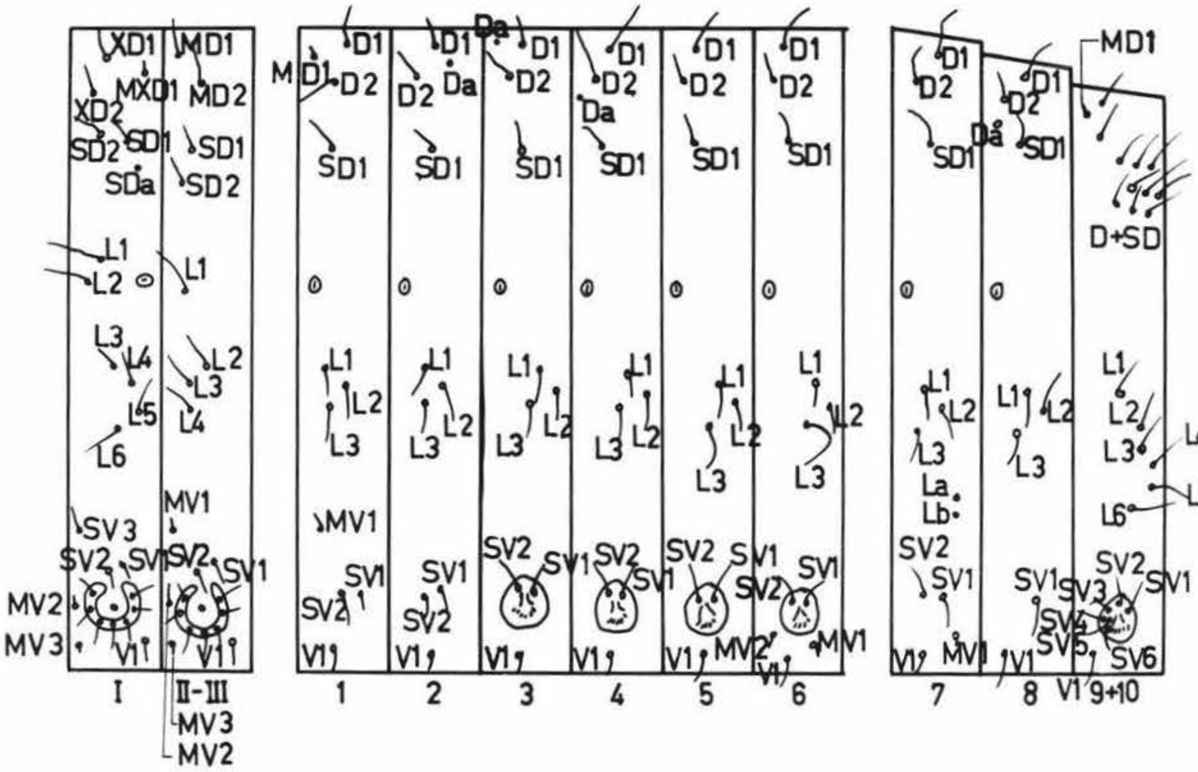


FIG. 23. SETAL MAP OF 7TH INSTAR LARVA.

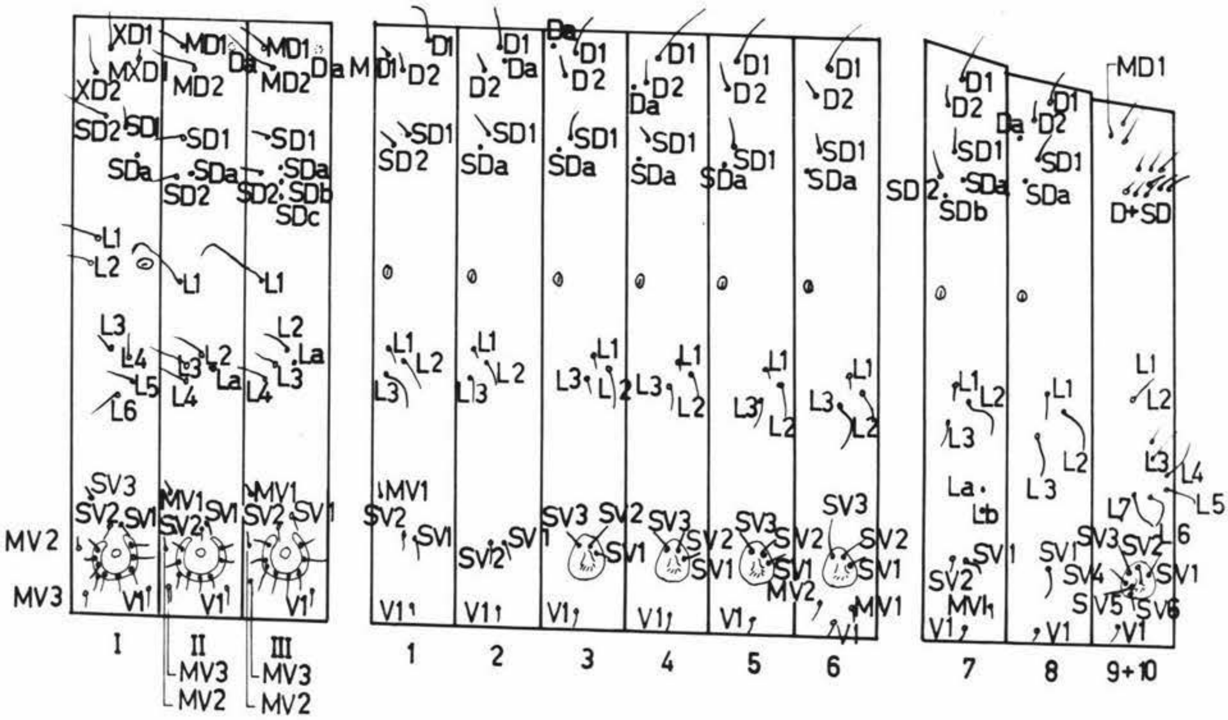


FIG. 24. MALE PUPA, VENTRAL ASPECT.

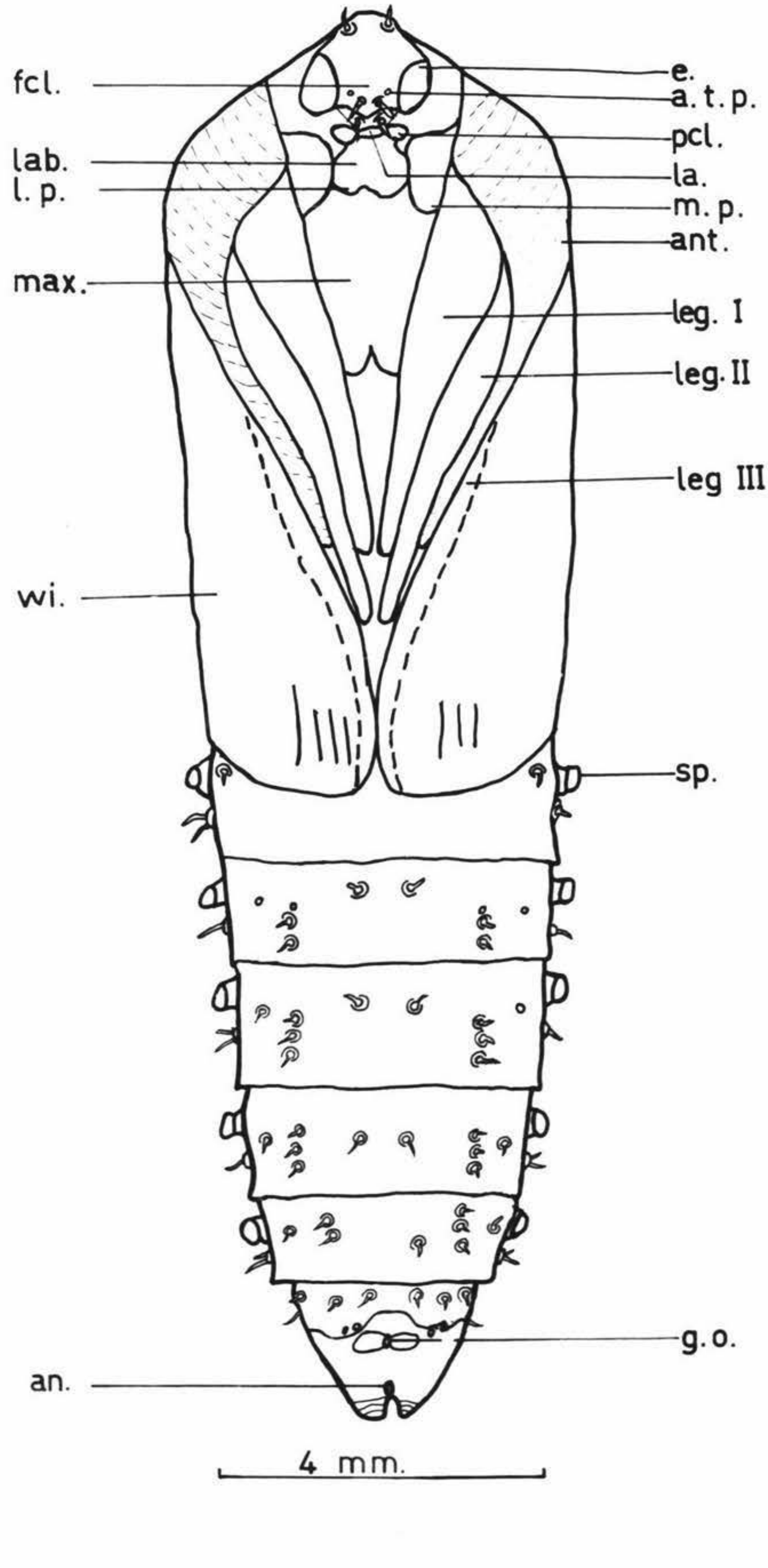


FIG. 25. MALE PUPA, LATERAL ASPECT.

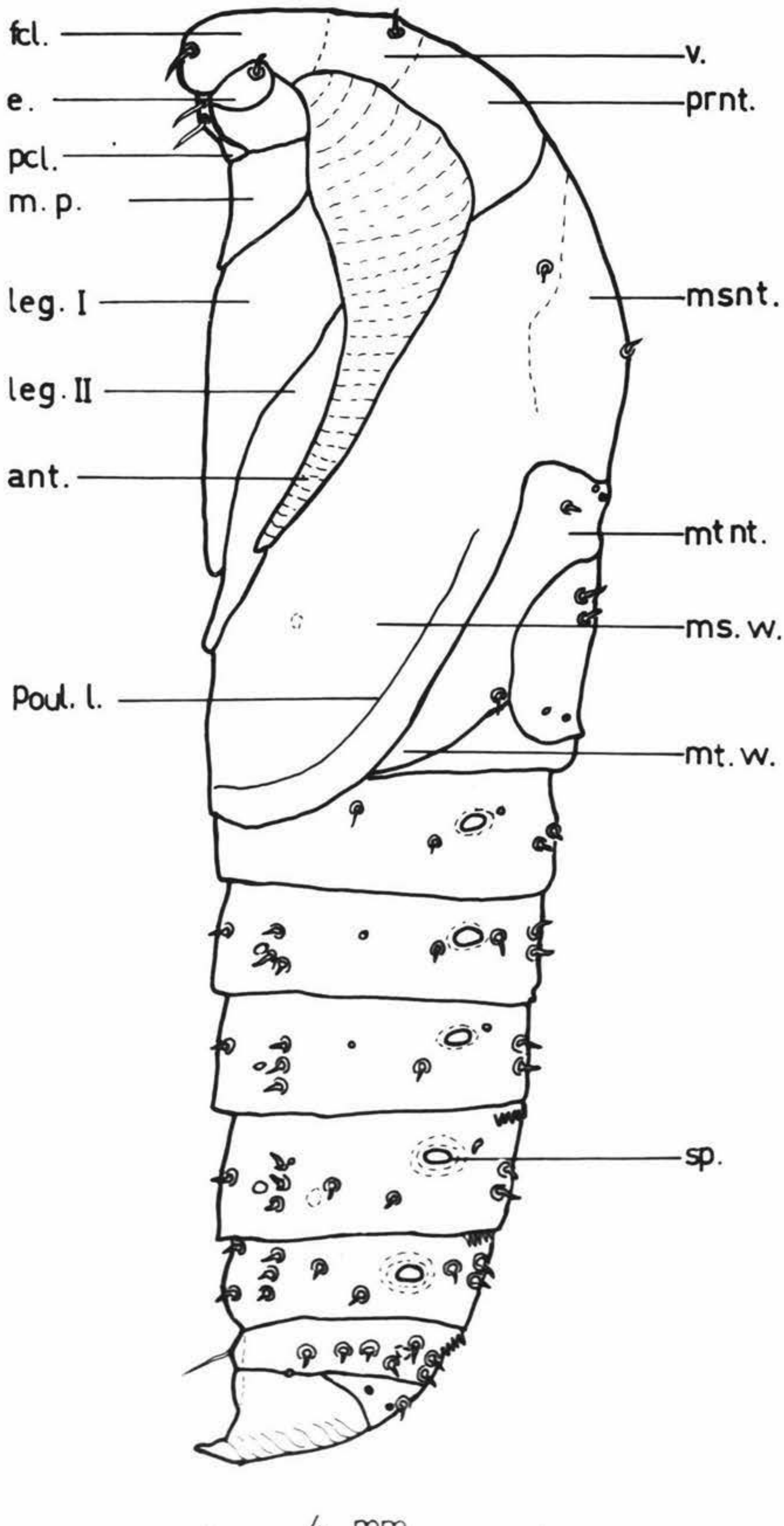


FIG. 26. MALE PUPA, DORSAL ASPECT.

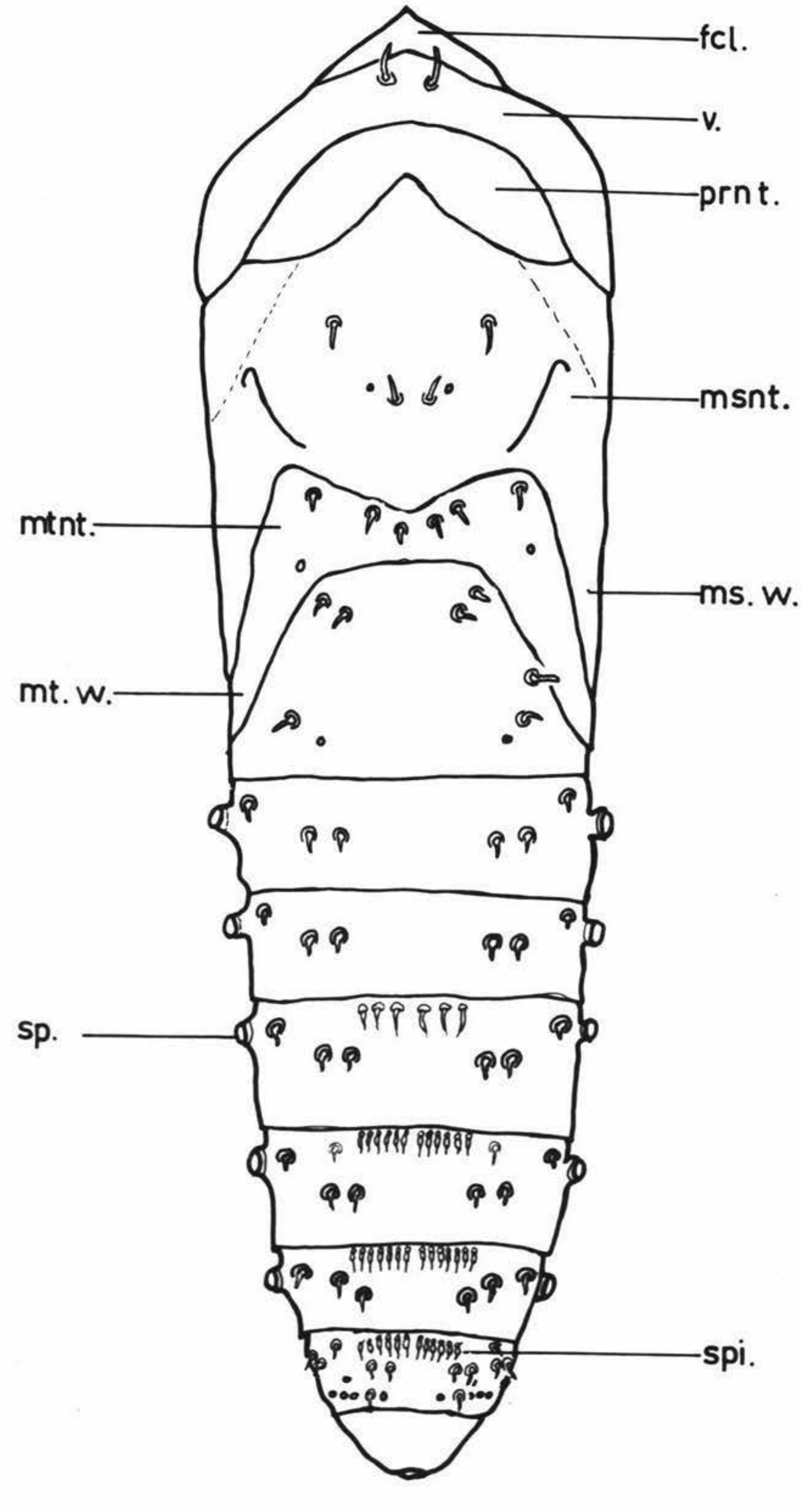


FIG. 27. GENITAL SEGMENTS OF MALE PUPA, VENTRAL ASPECT.

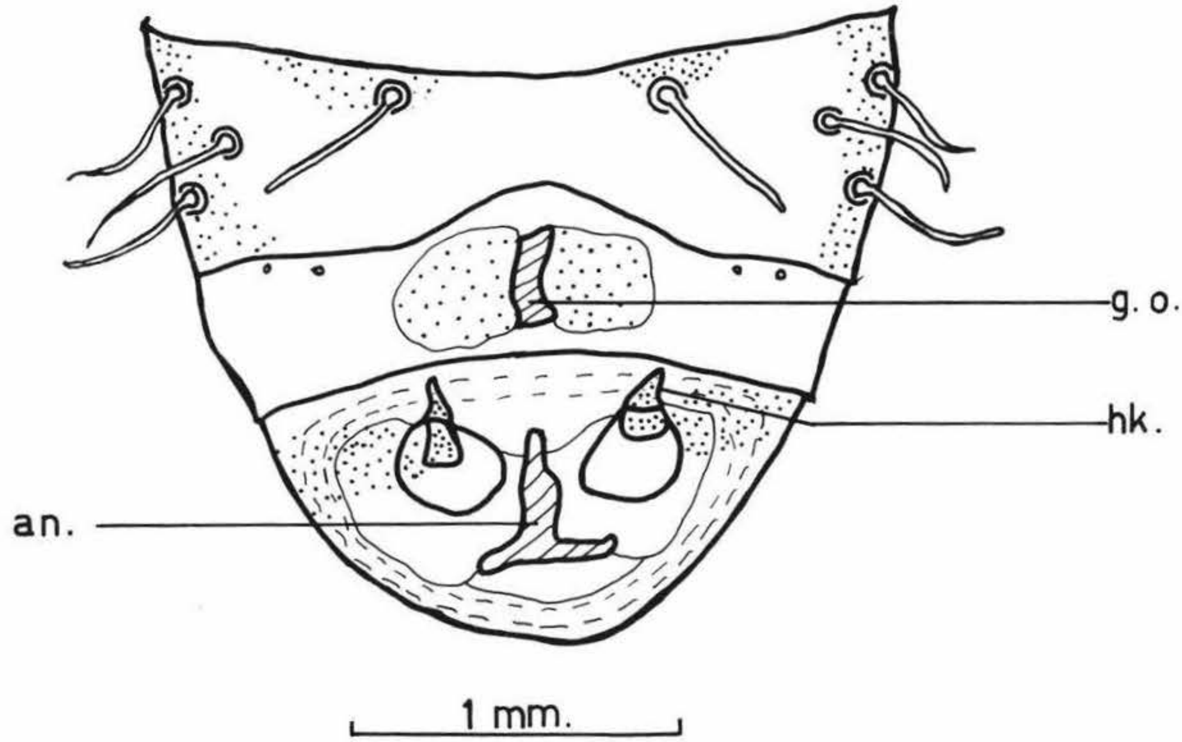


FIG. 28. FEMALE PUPA, VENTRAL ASPECT.

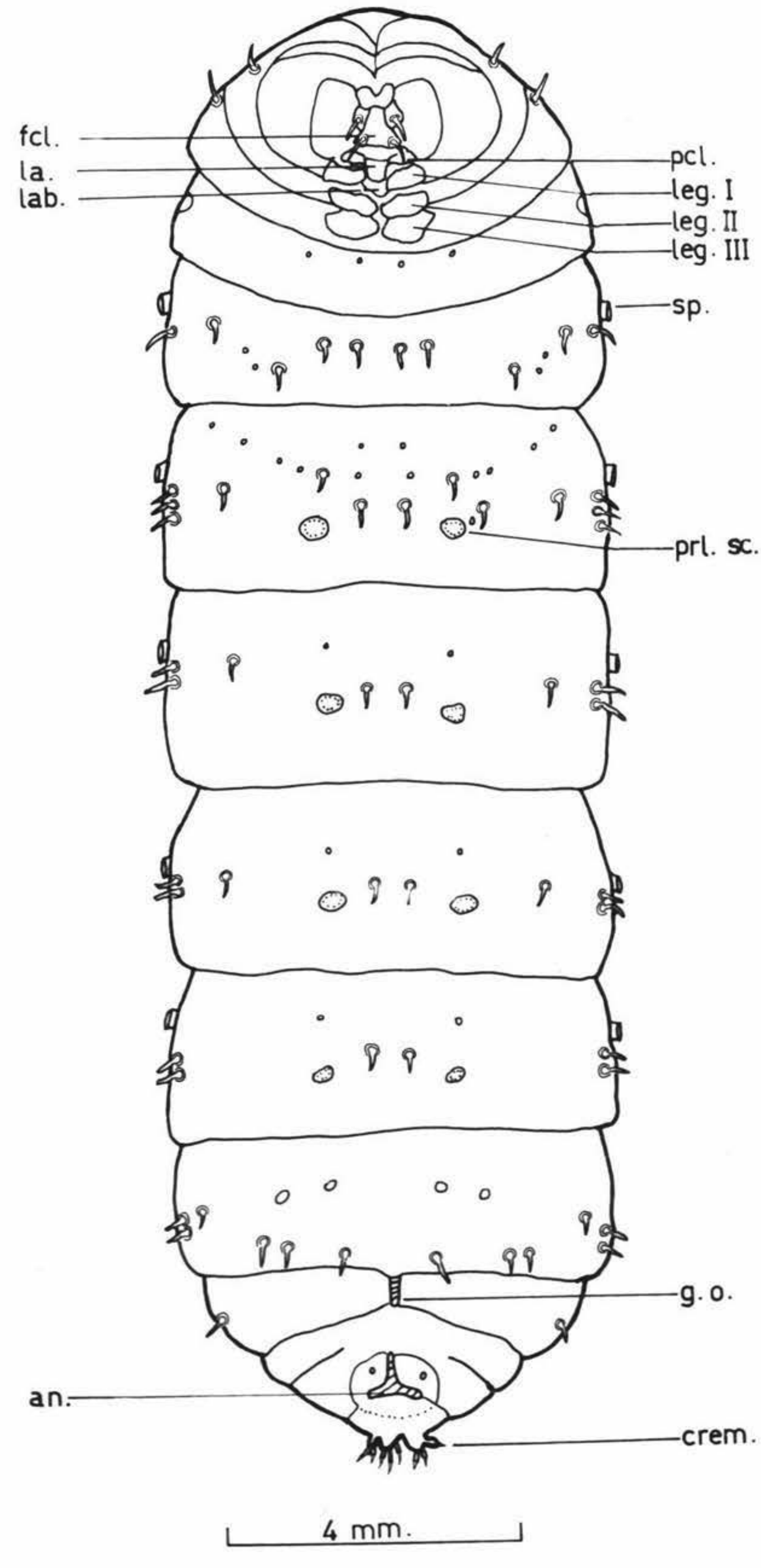


FIG. 29. FEMALE PUPA, LATERAL ASPECT.

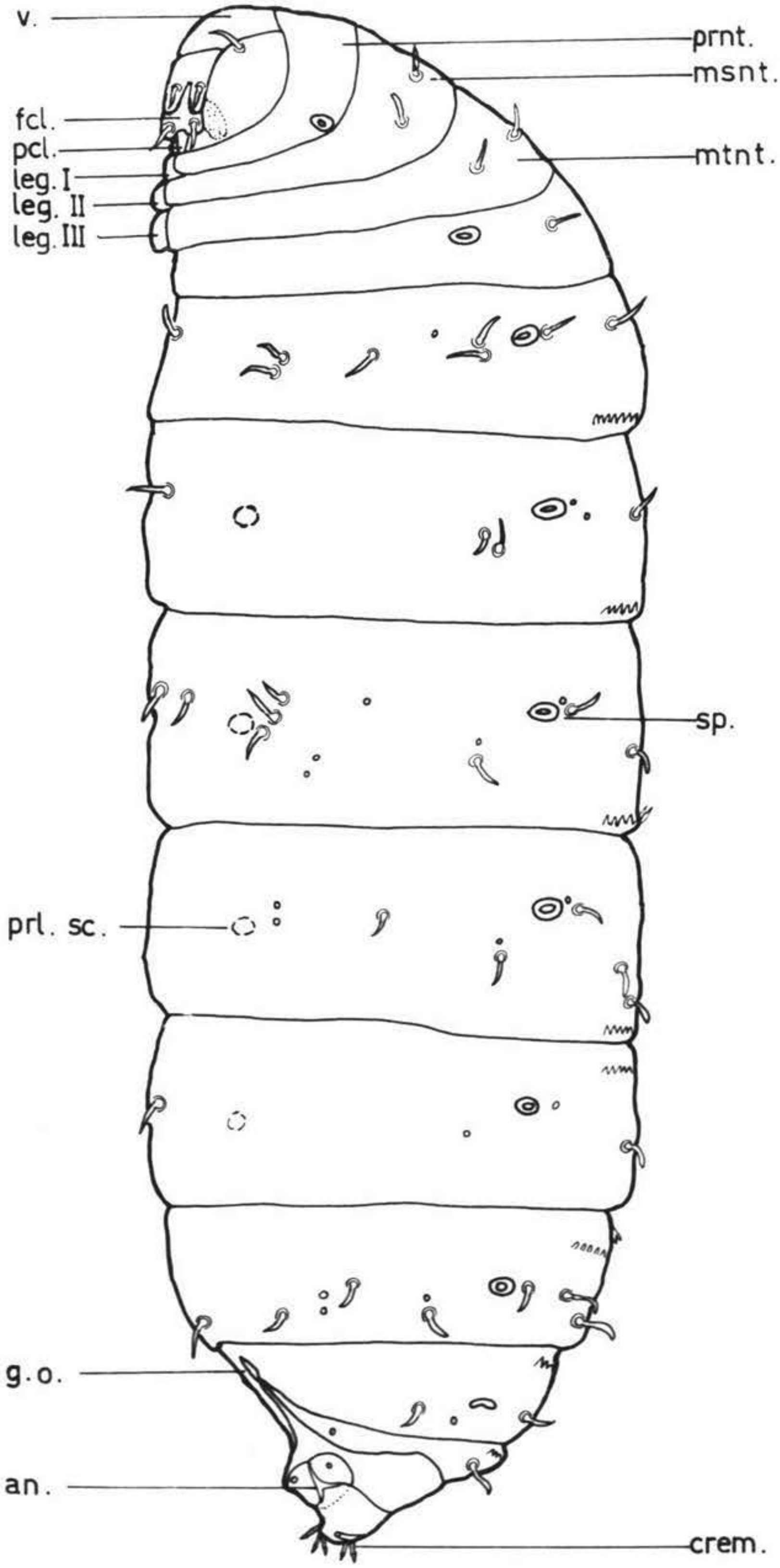


FIG. 30. FEMALE PUPA, DORSAL ASPECT.

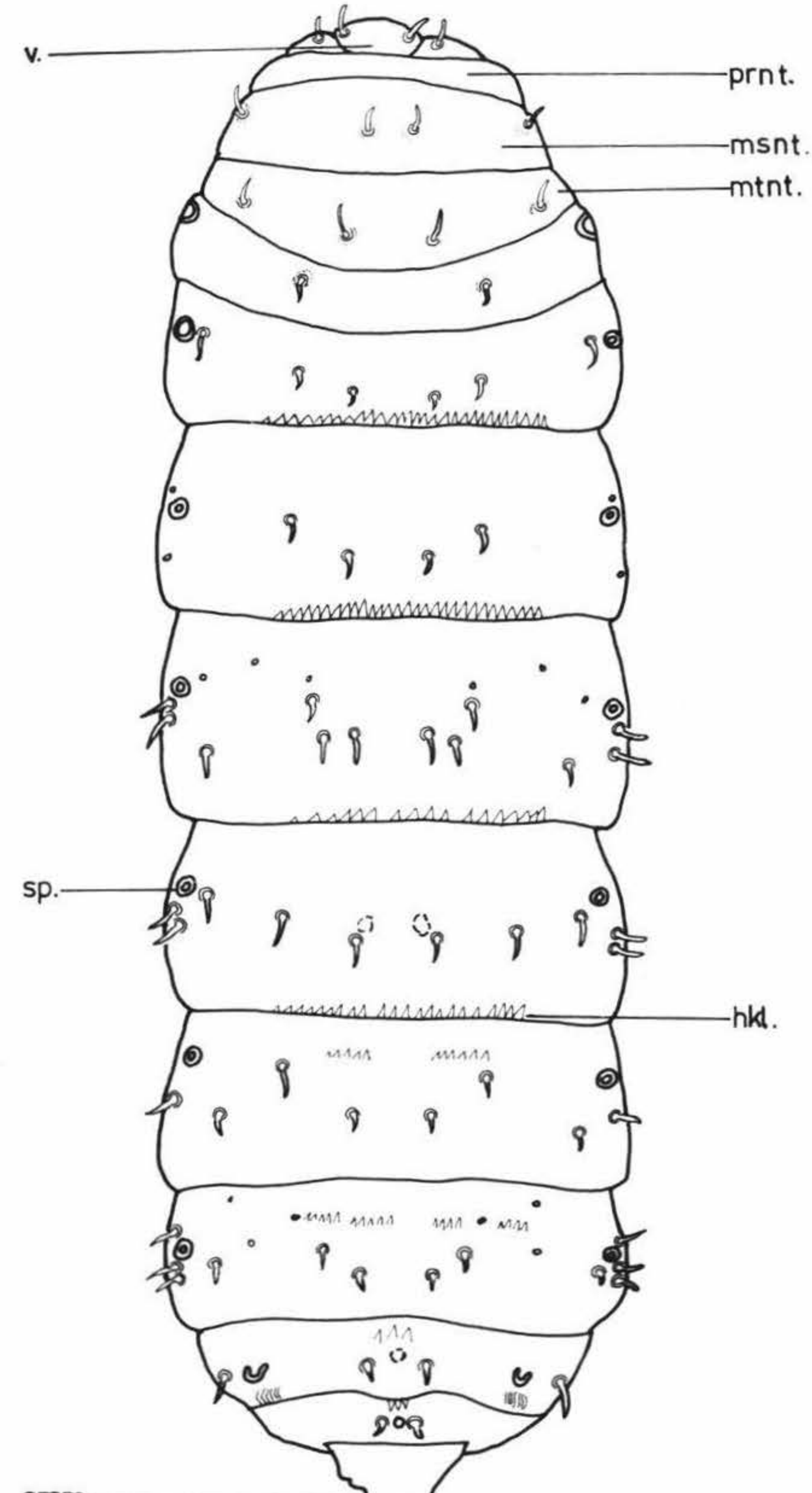


FIG. 31. GENITAL SEGMENTS OF FEMALE PUPA, VENTRAL ASPECT.

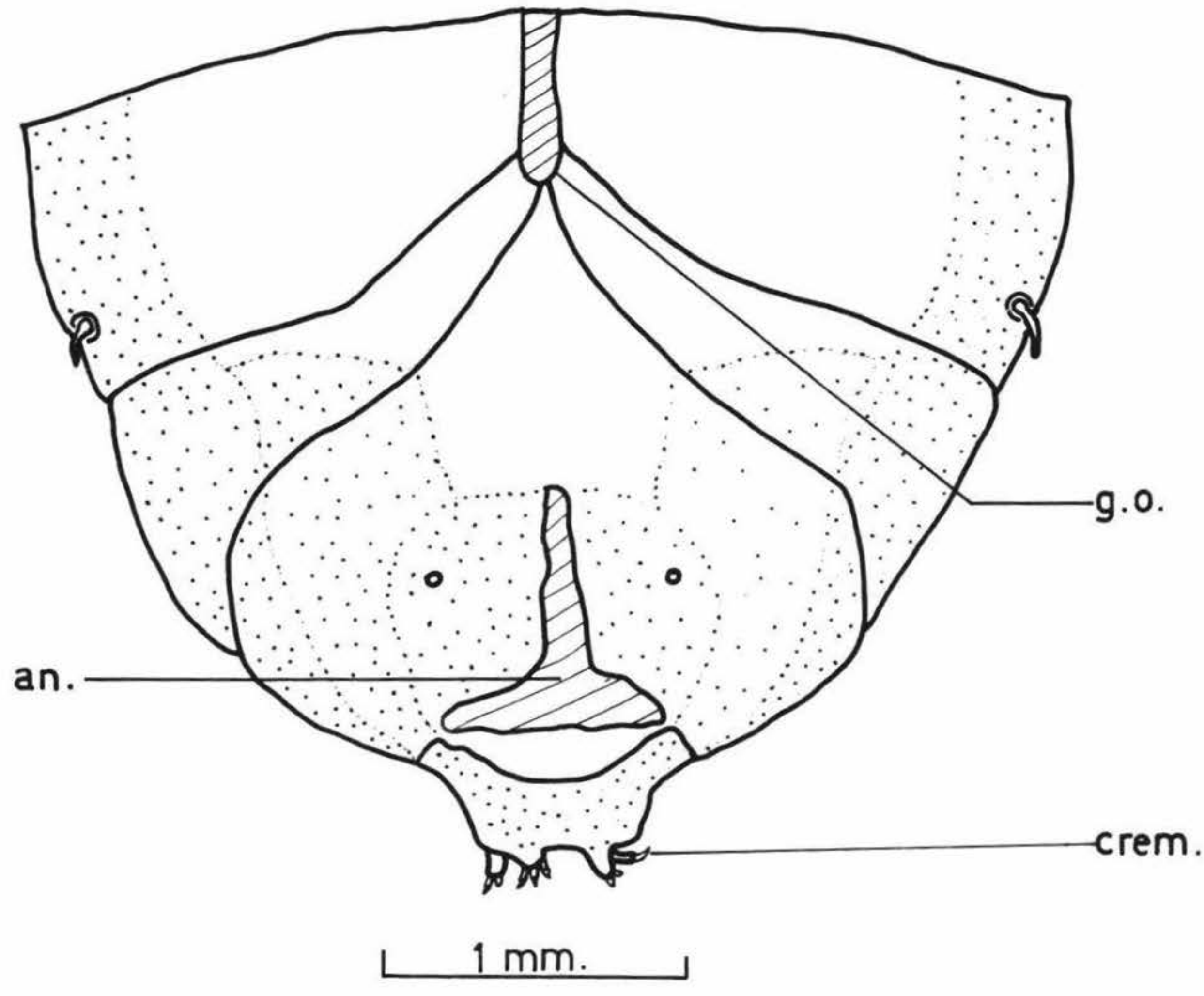


FIG. 32. HEAD CAPSULE OF ADULT MALE, VENTRAL ASPECT.

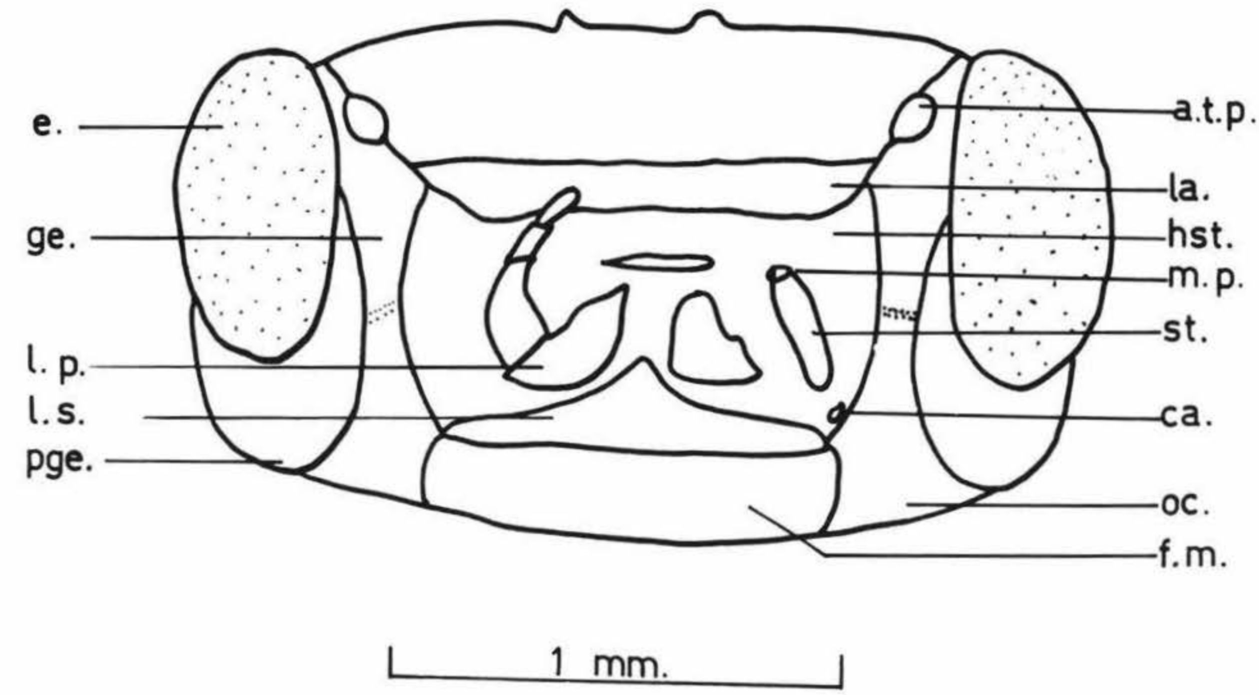


FIG. 33. THORAX OF ADULT MALE, LATERAL ASPECT.

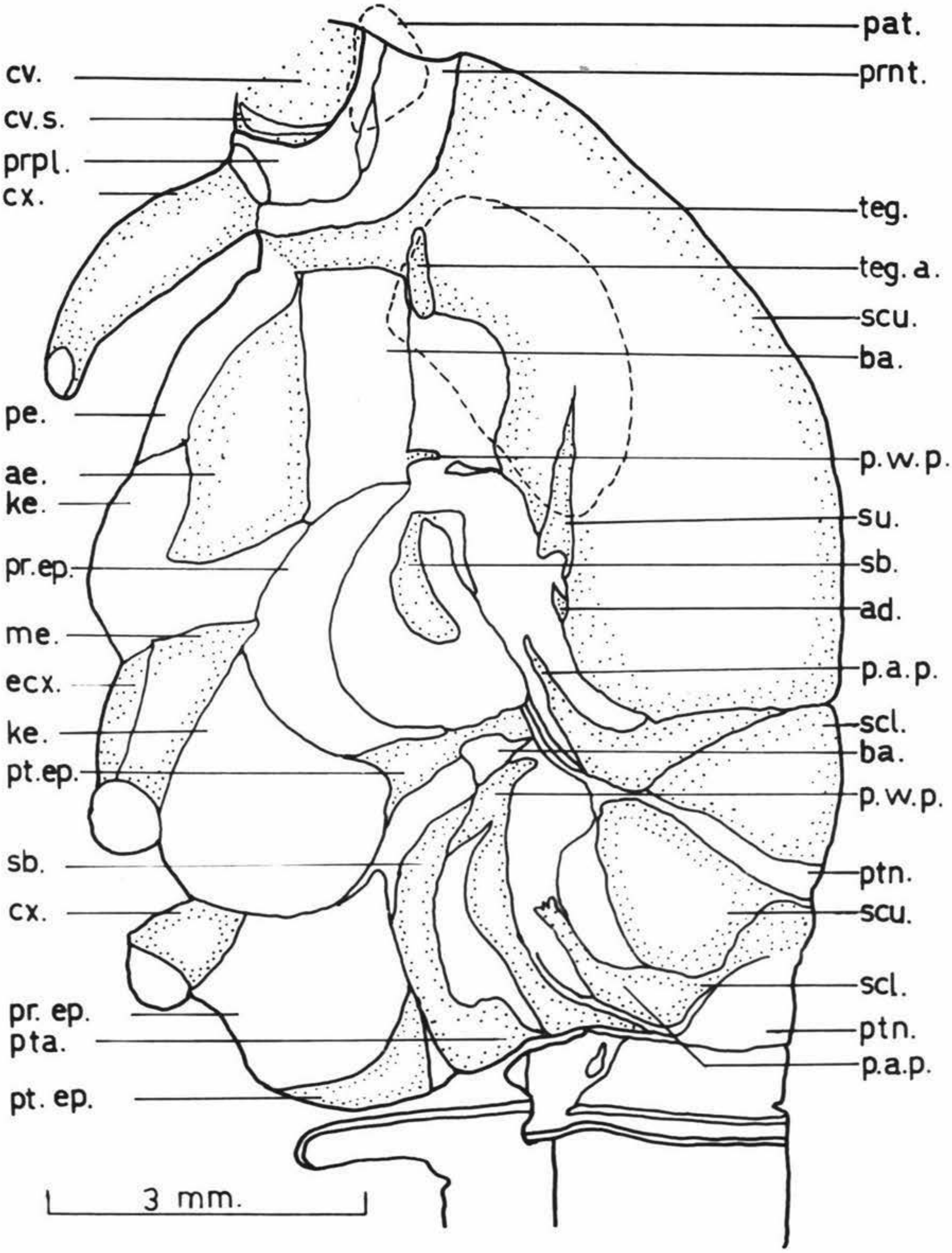


FIG. 34. FOREWING AXIL OF ADULT MALE, DORSAL ASPECT, WITH WING OUTSTRETCHED LATERALLY.

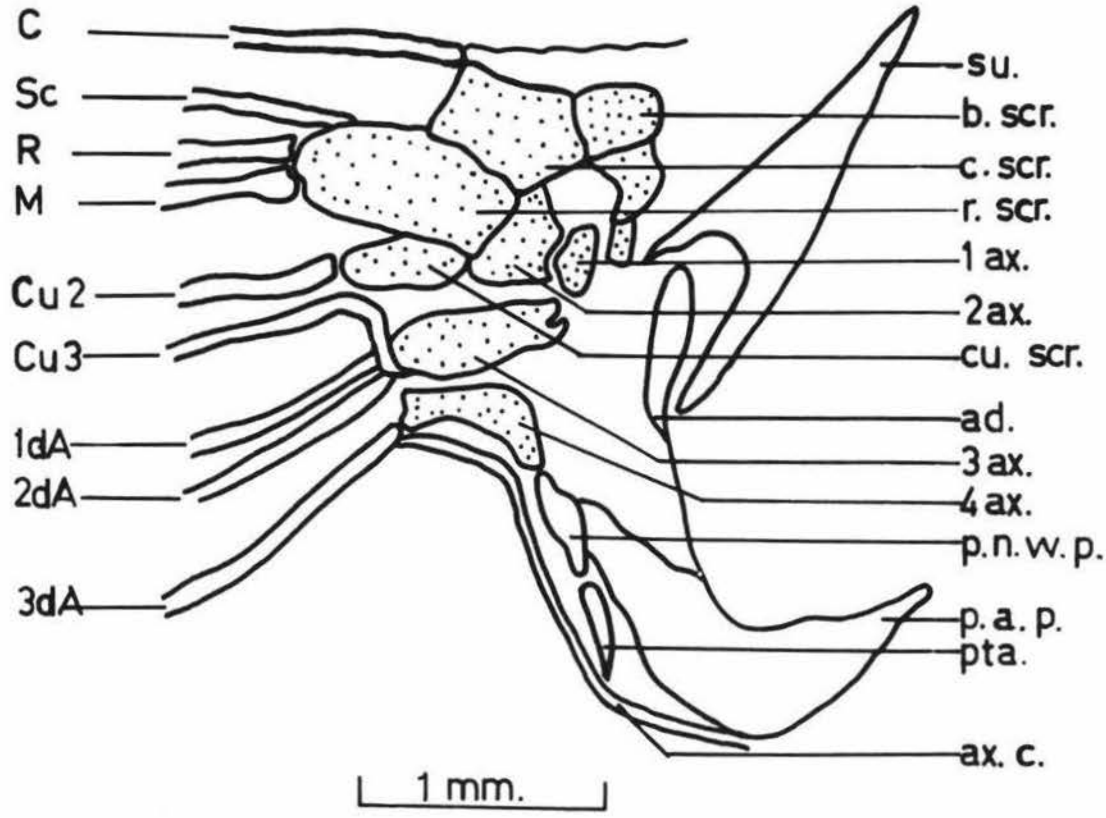


FIG. 35. FOREWING OF ADULT MALE (AFTER HUDSON, 1928).

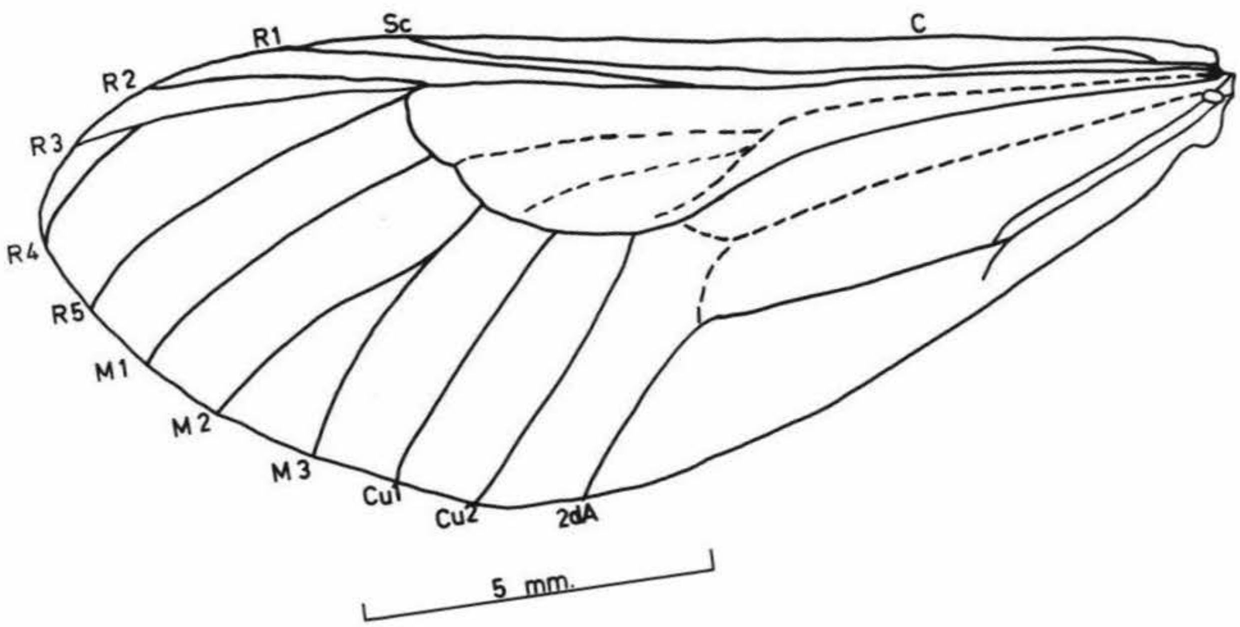


FIG. 36. WING SCALES FROM TERMEN OF FORE-WING.

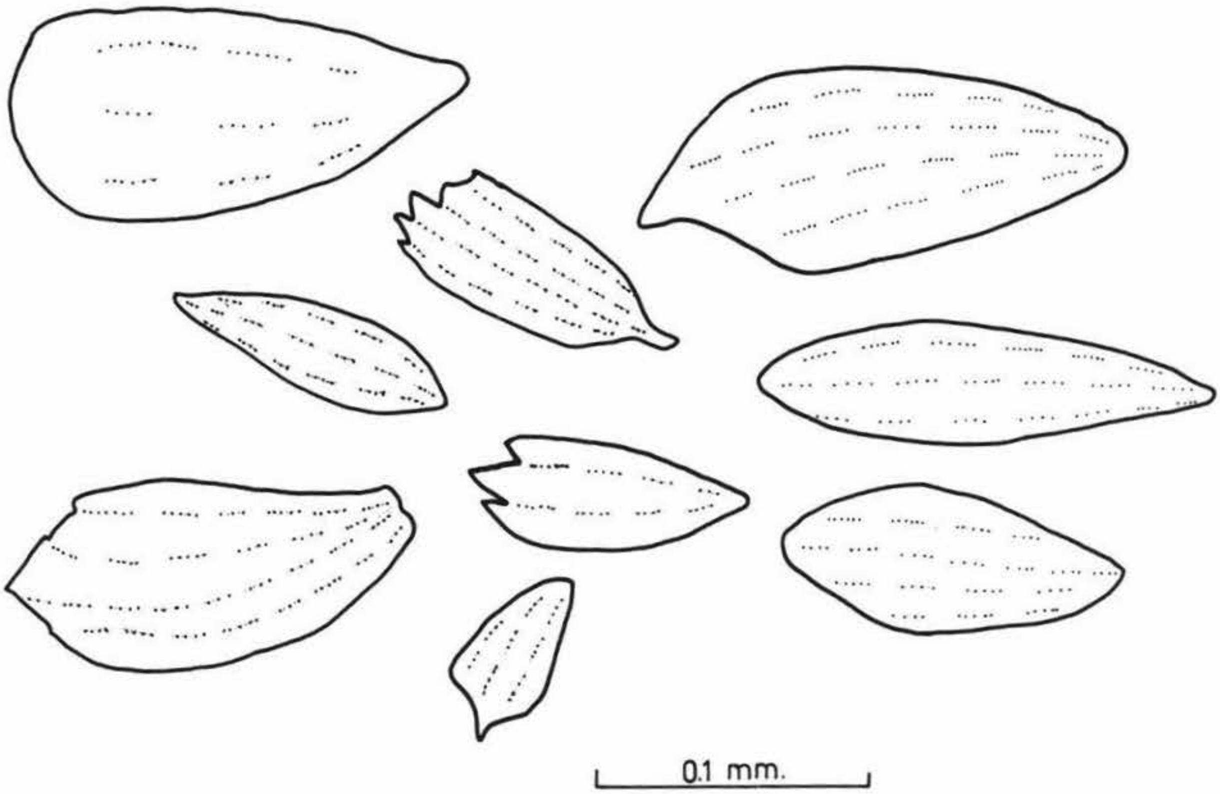


FIG. 37. HINDWING AXIL OF ADULT MALE, DORSAL ASPECT, WITH WING OUTSTRETCHED LATERALLY.

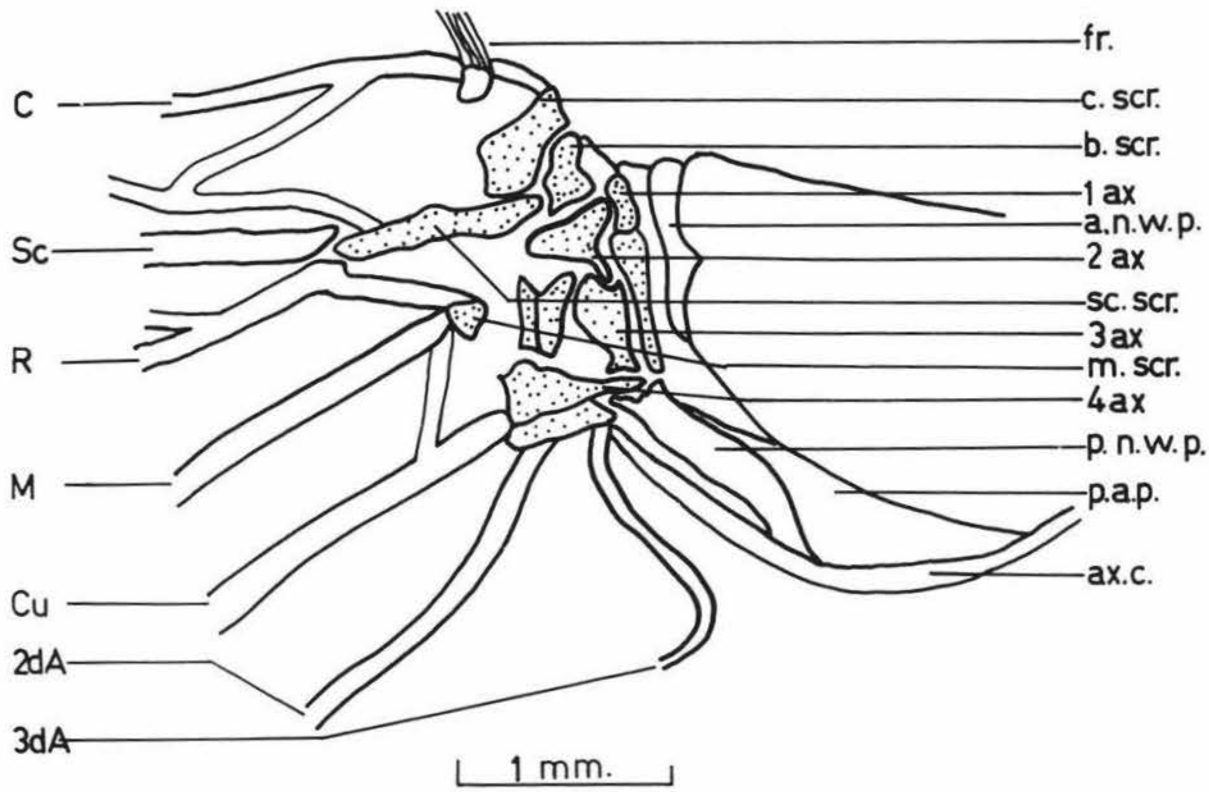


FIG. 38. HINDWING OF ADULT MALE (AFTER HUDSON, 1928).

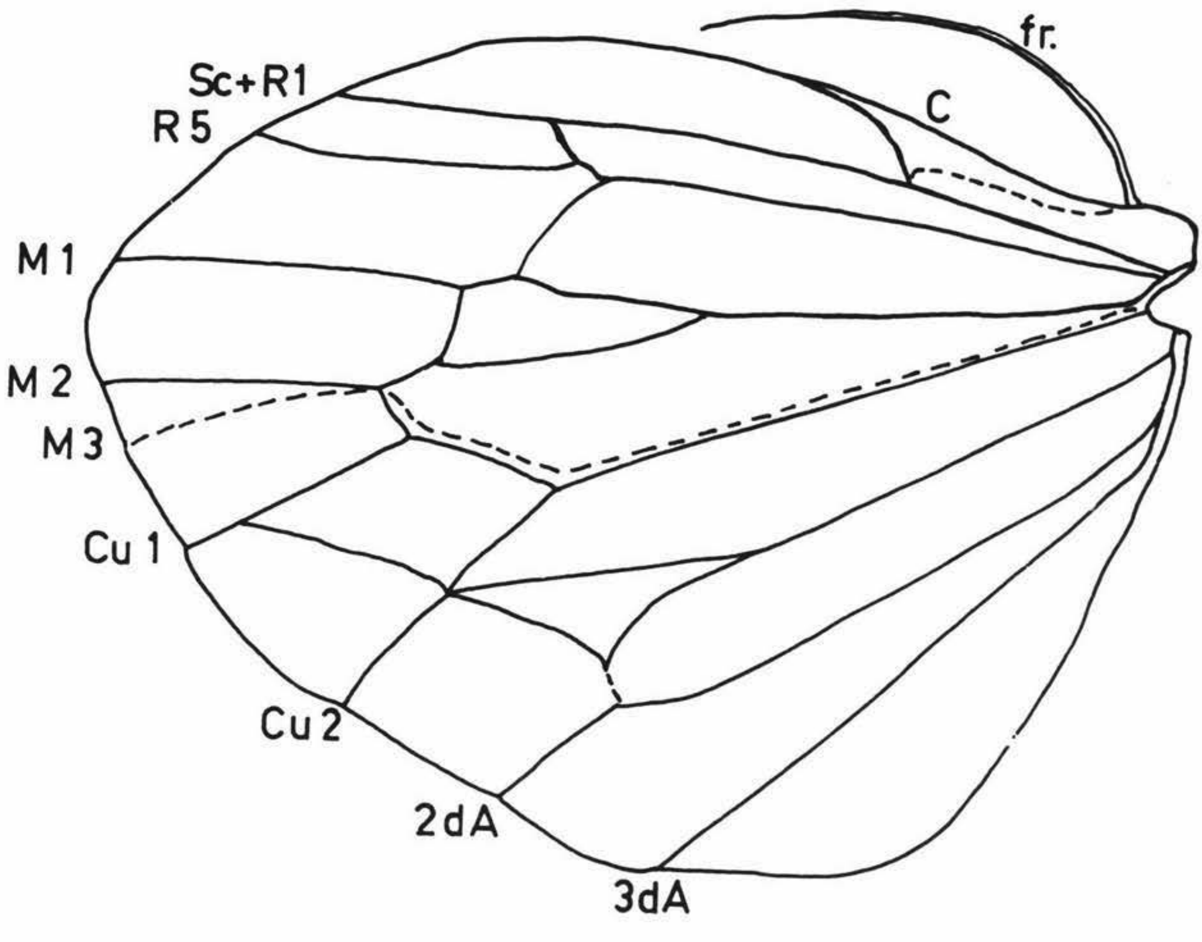
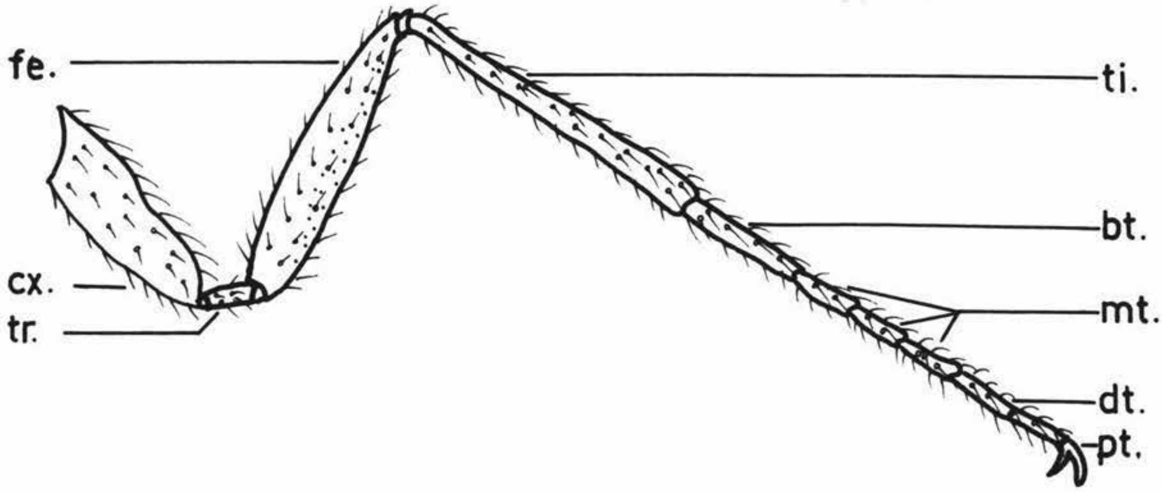
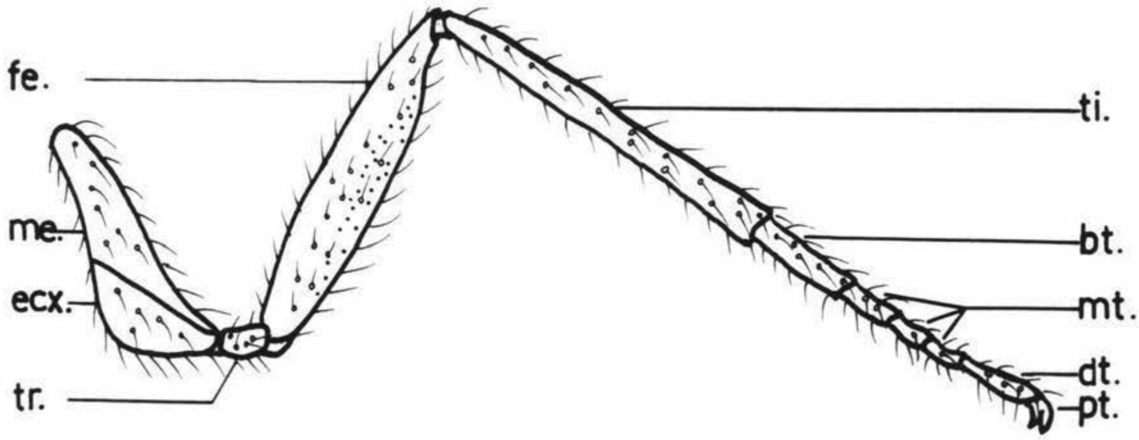


FIG. 39. A. PROTHORACIC LEG OF ADULT MALE, ANTERIOR ASPECT.



B. MESOTHORACIC LEG OF ADULT MALE, ANTERIOR ASPECT.



C. METATHORACIC LEG OF ADULT MALE, ANTERIOR ASPECT.

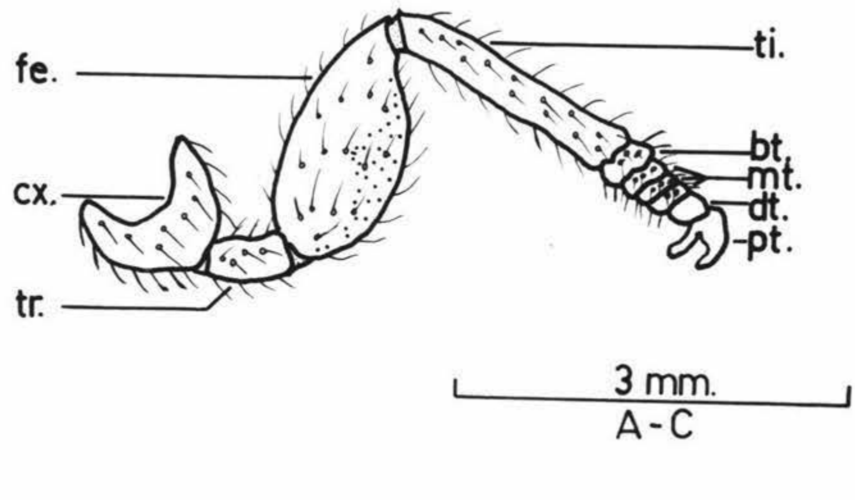
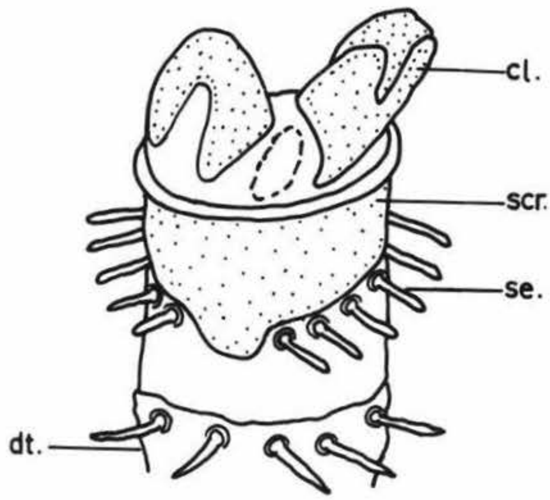


FIG. 40.

A. METATHORACIC PRETARSUS OF ADULT MALE, VENTRAL ASPECT.



B. METATHORACIC PRETARSUS OF ADULT MALE, LATERAL ASPECT.

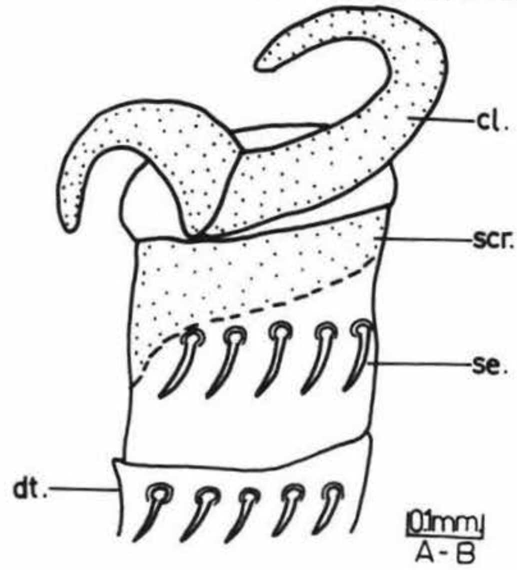


FIG. 41. GENITALIA OF ADULT MALE, LATERAL ASPECT.

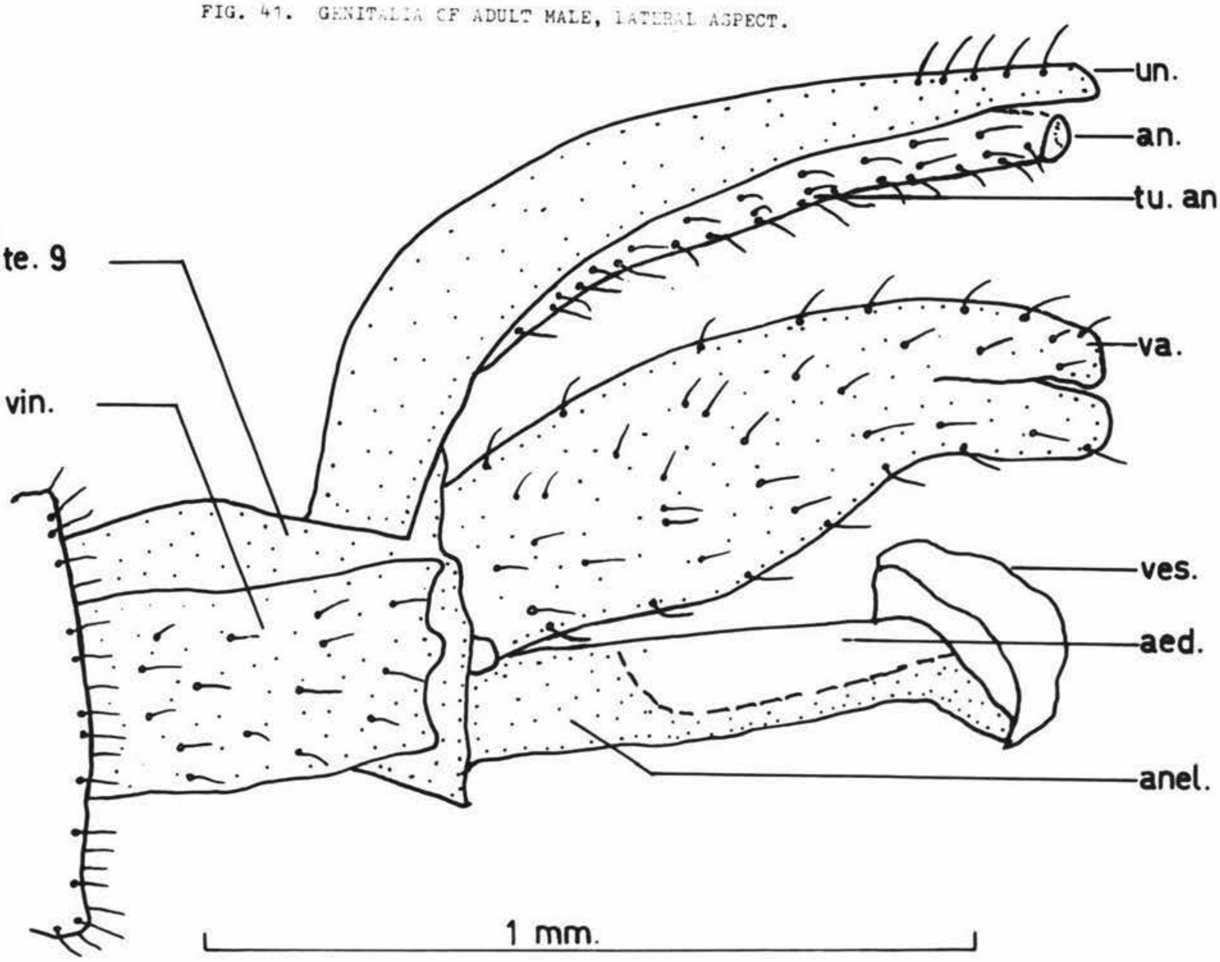


FIG. 42. GENITALIA OF ADULT MALE, VENTRAL ASPECT.

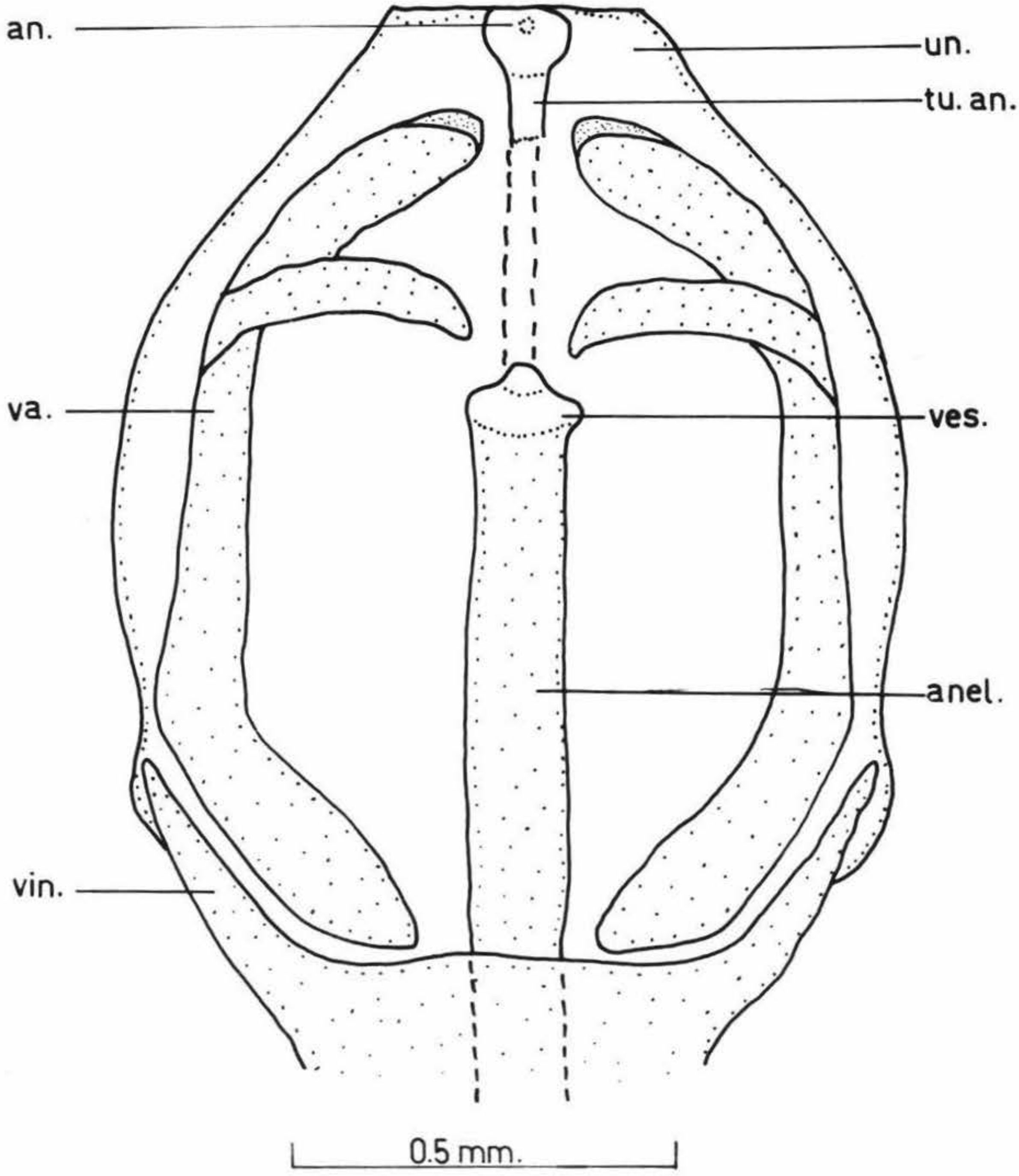


FIG. 43. AEDEAGUS OF ADULT MALE, LATERAL ASPECT.

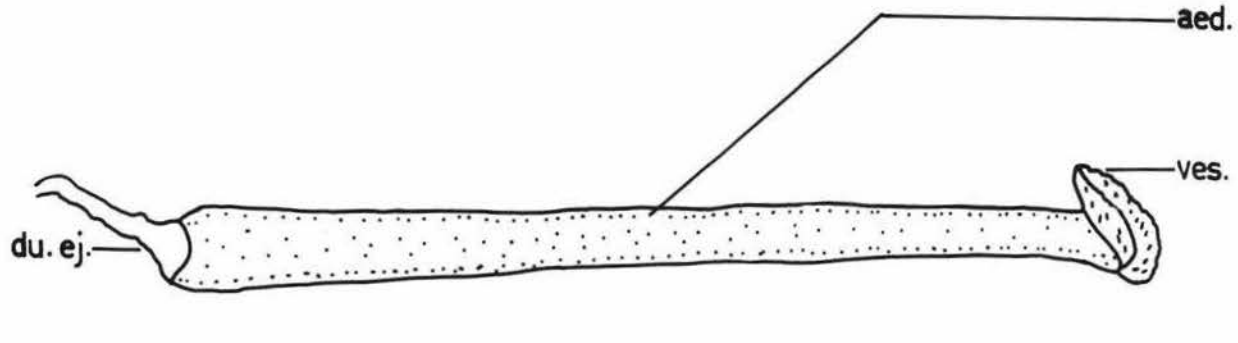


FIG. 44. HEAD CAPSULE OF ADULT FEMALE, ANTERIOR ASPECT.

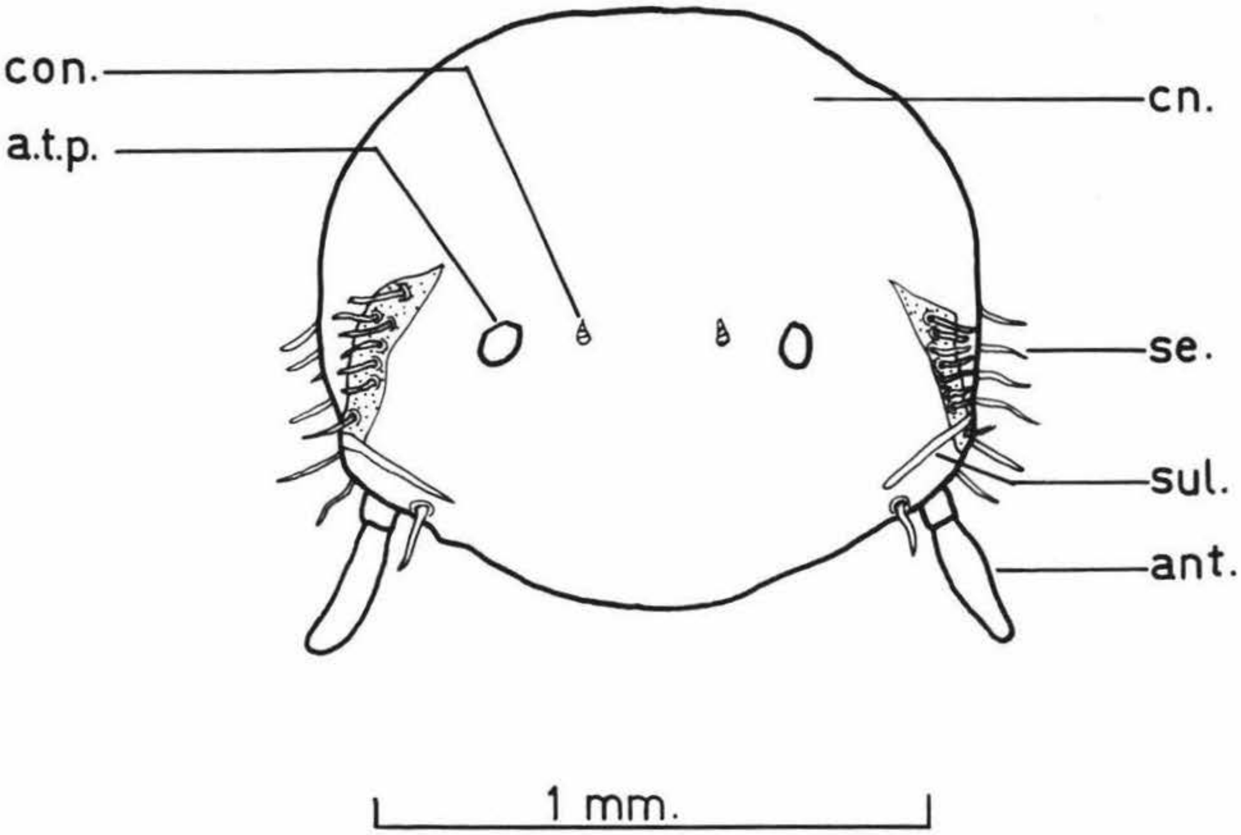


FIG. 45. ADULT FEMALE, VENTRAL ASPECT.

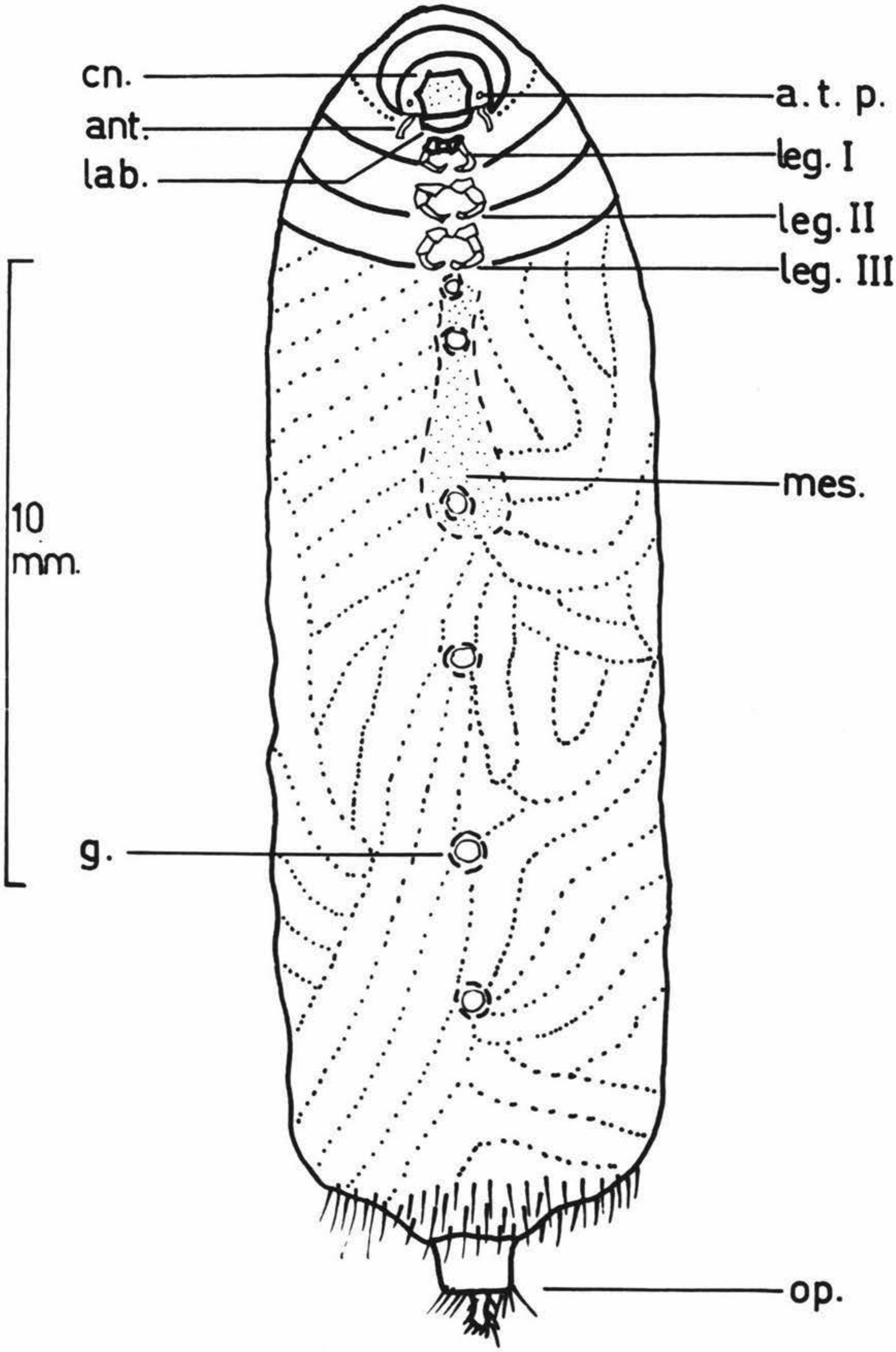


FIG. 46. ADULT FEMALE, LATERAL ASPECT.

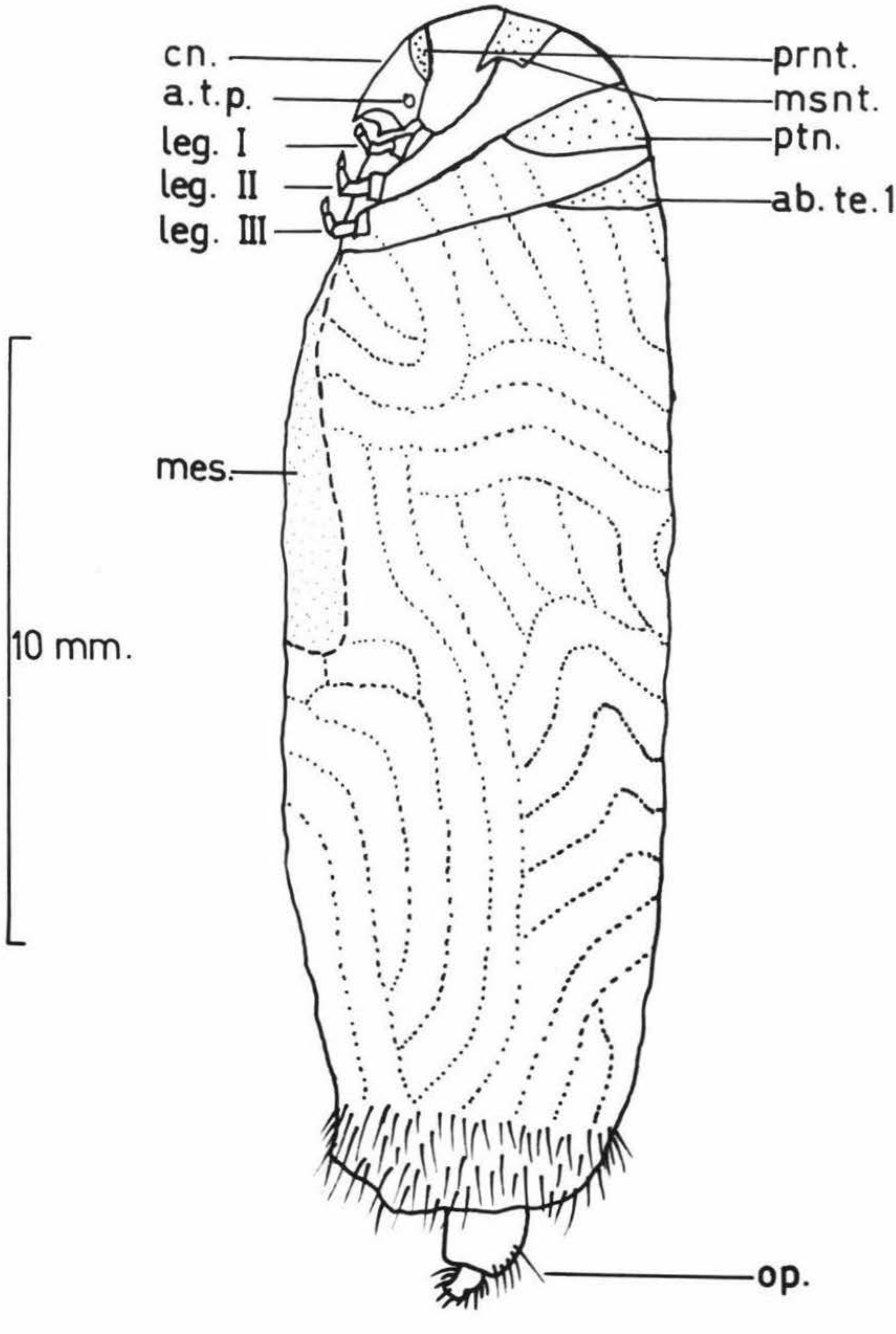


FIG. 47. ADULT FEMALE, DORSAL ASPECT.

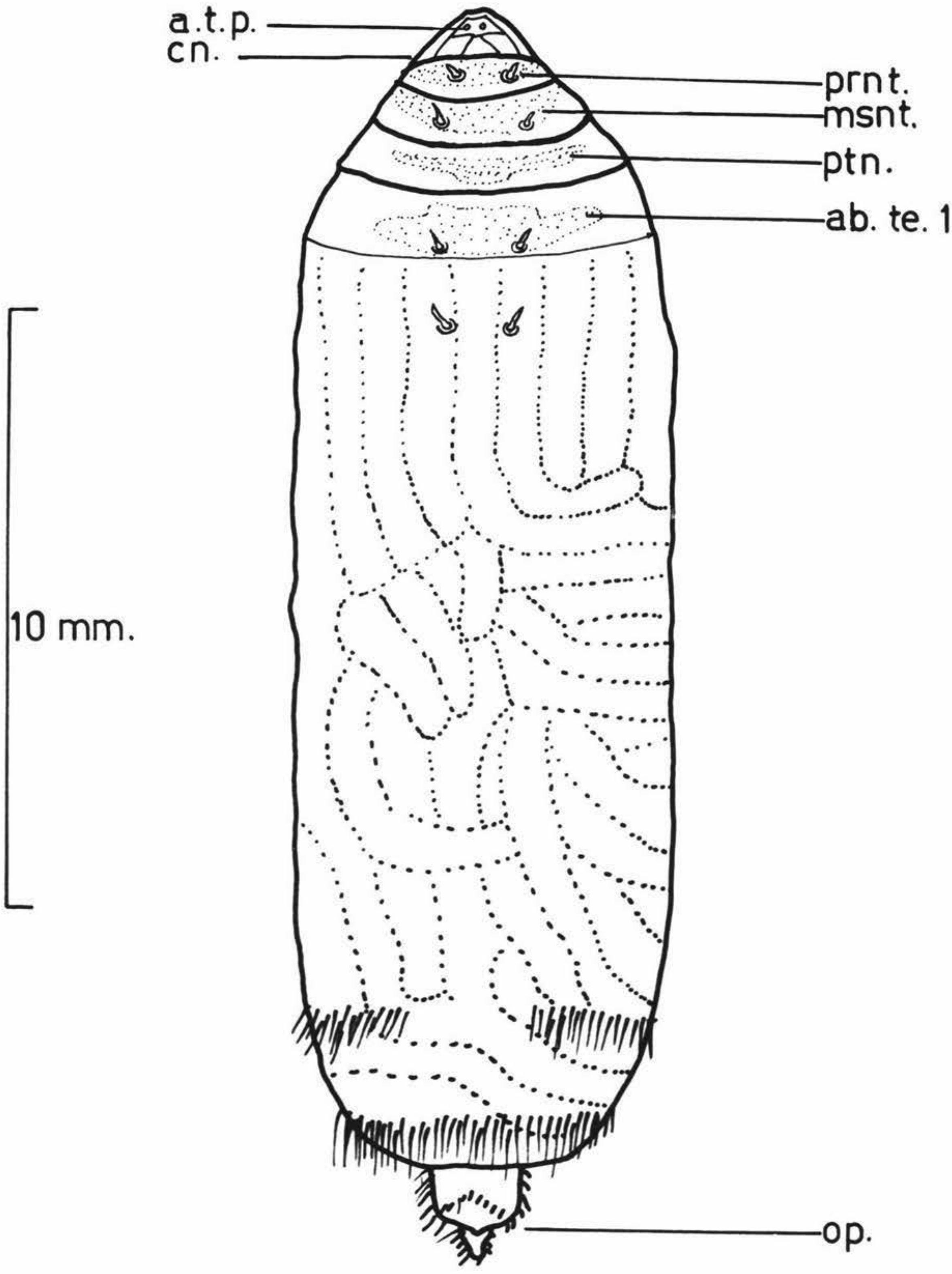
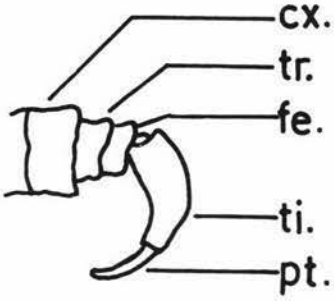
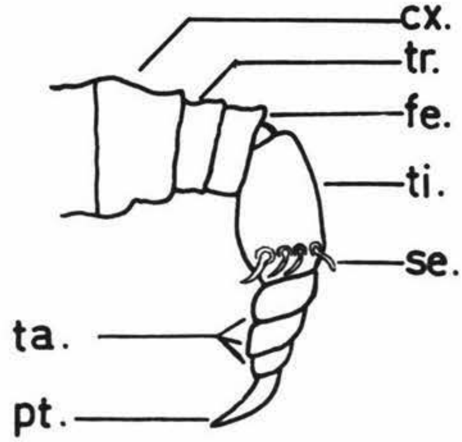


FIG. 48. A. PROTHORACIC LEG OF ADULT FEMALE, ANTERIOR ASPECT.



B. MESOTHORACIC LEG OF ADULT FEMALE, ANTERIOR ASPECT.



C. METATHORACIC LEG OF ADULT FEMALE, ANTERIOR ASPECT.

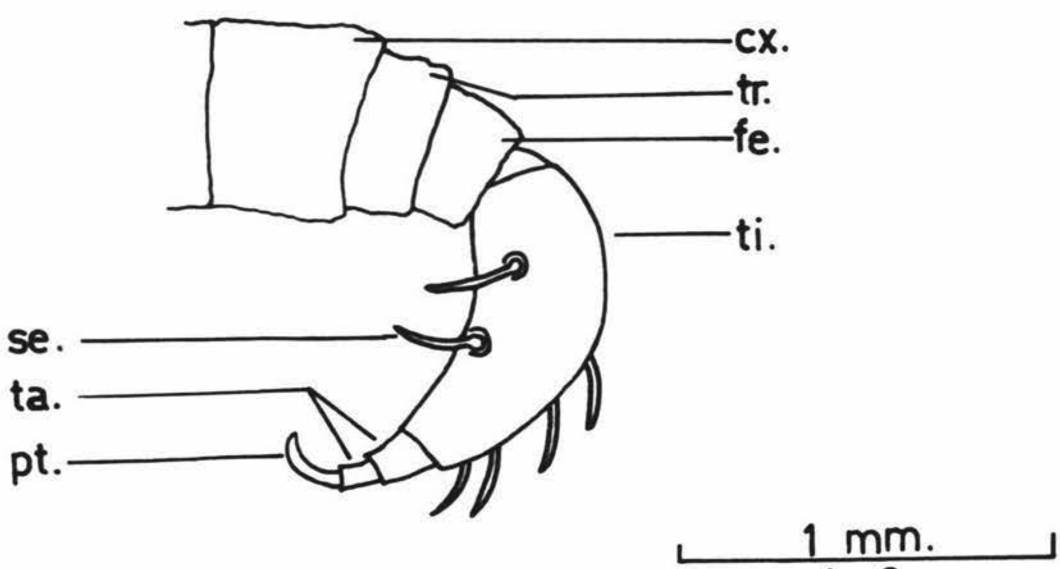


FIG. 49. GENITALIA OF ADULT FEMALE, VENTRAL ASPECT.

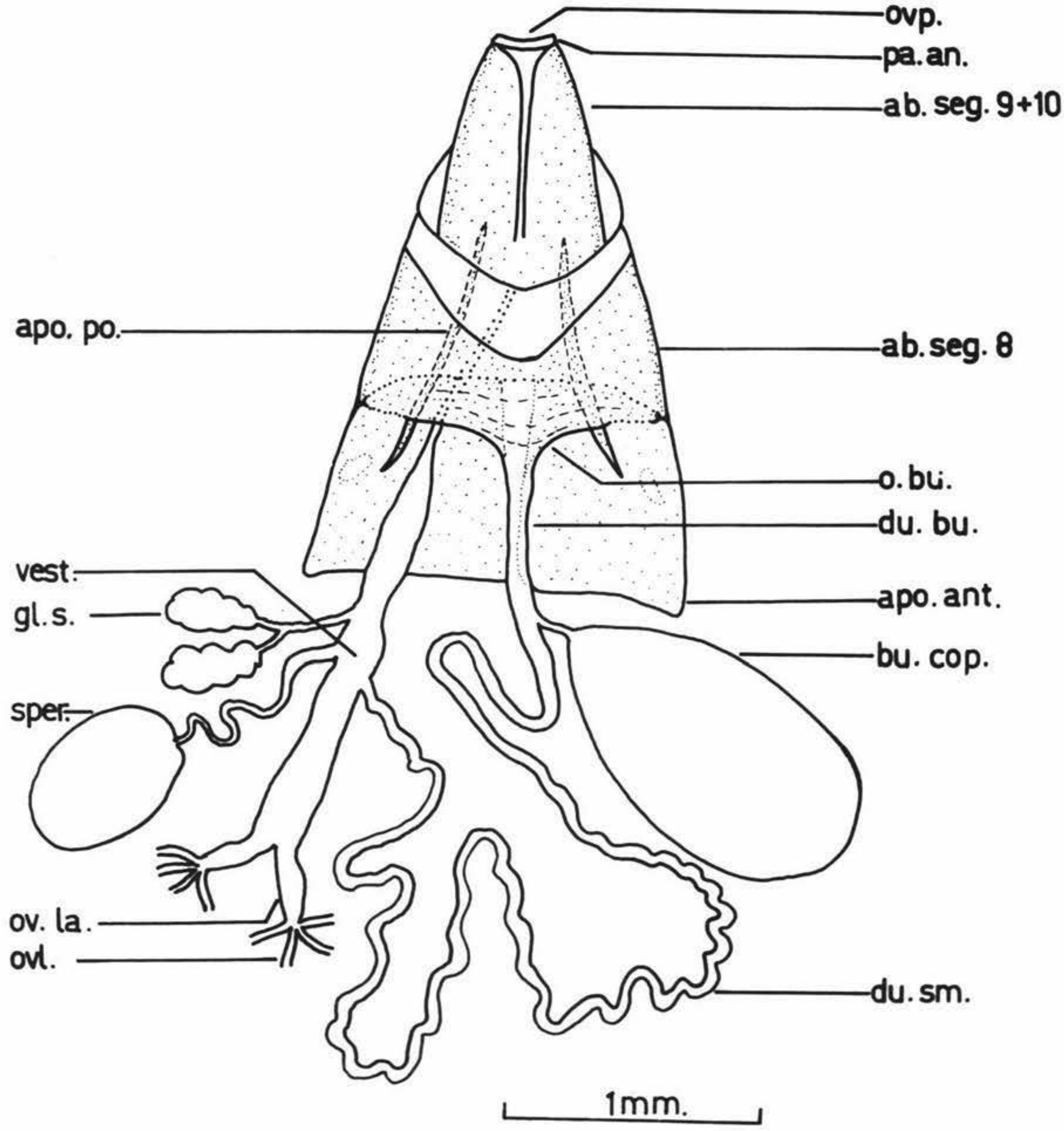


FIG. 50. INTERNAL ANATOMY OF MALE 7TH INSTAR LARVA, LATERAL ASPECT.

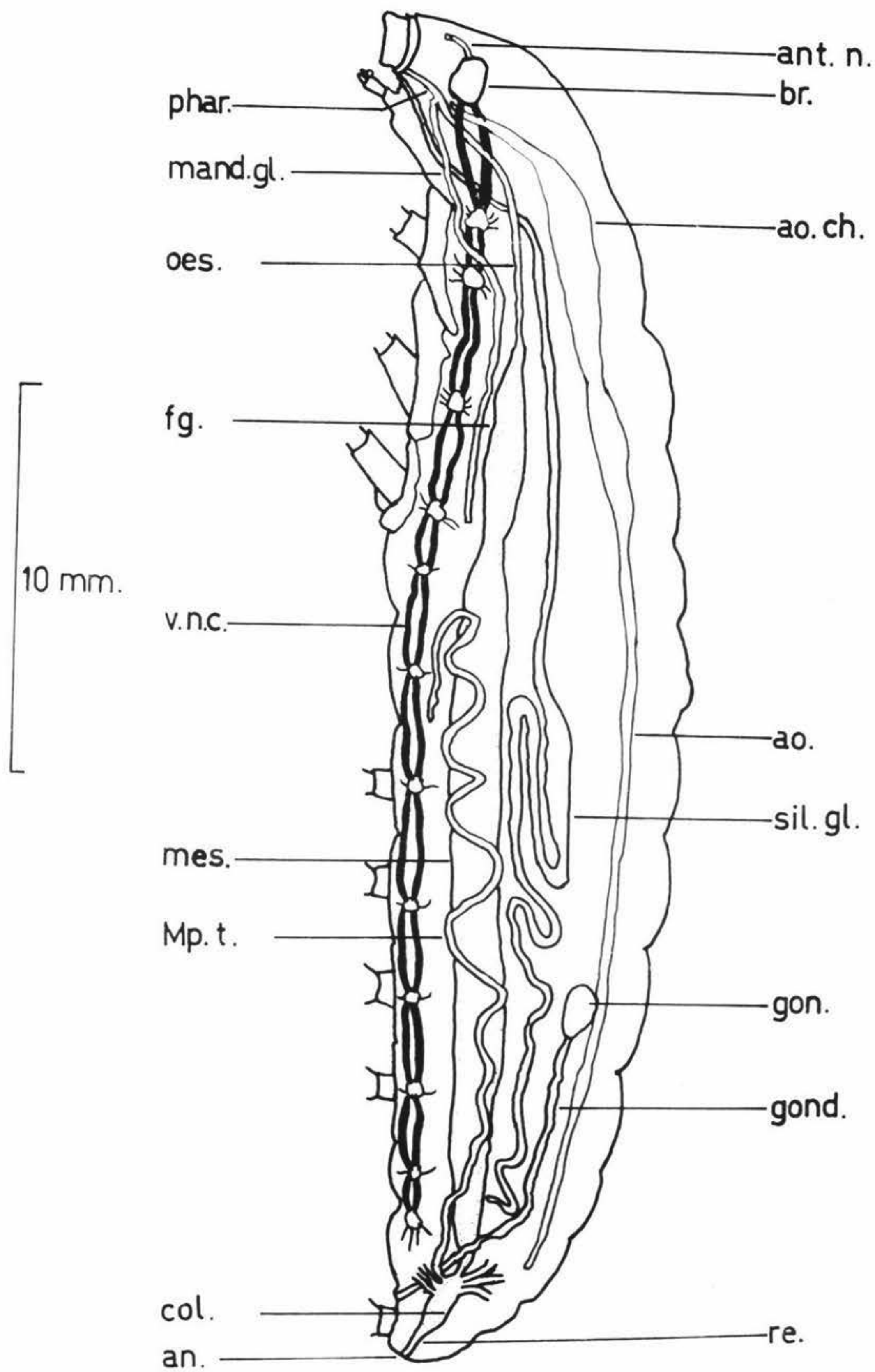


FIG. 51. INTERNAL ANATOMY OF FEMALE 7TH INSTAR LARVA, LATERAL ASPECT.

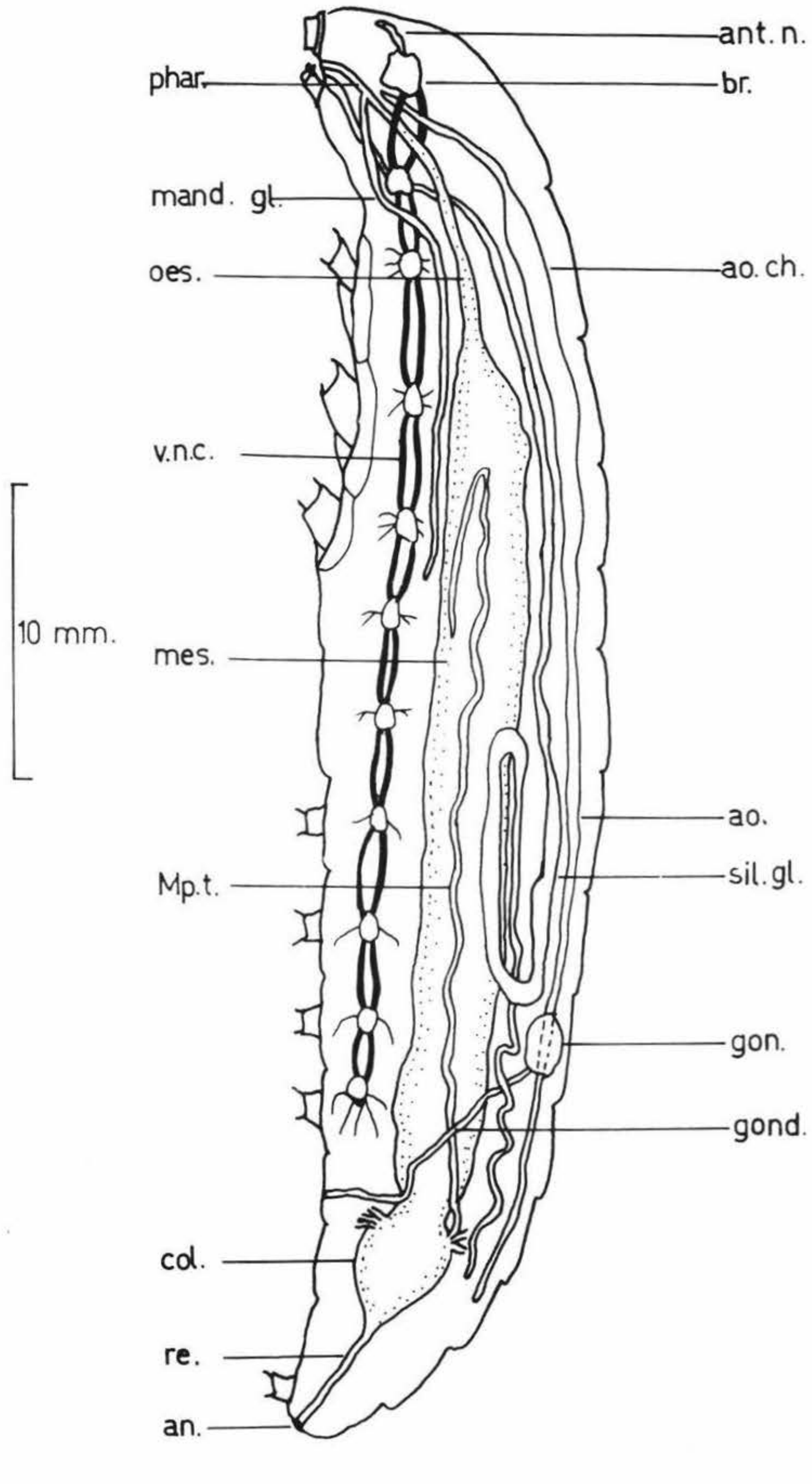


FIG. 52. INTERNAL ANATOMY OF MALE PUPA AT SEVEN DAYS, LATERAL ASPECT.

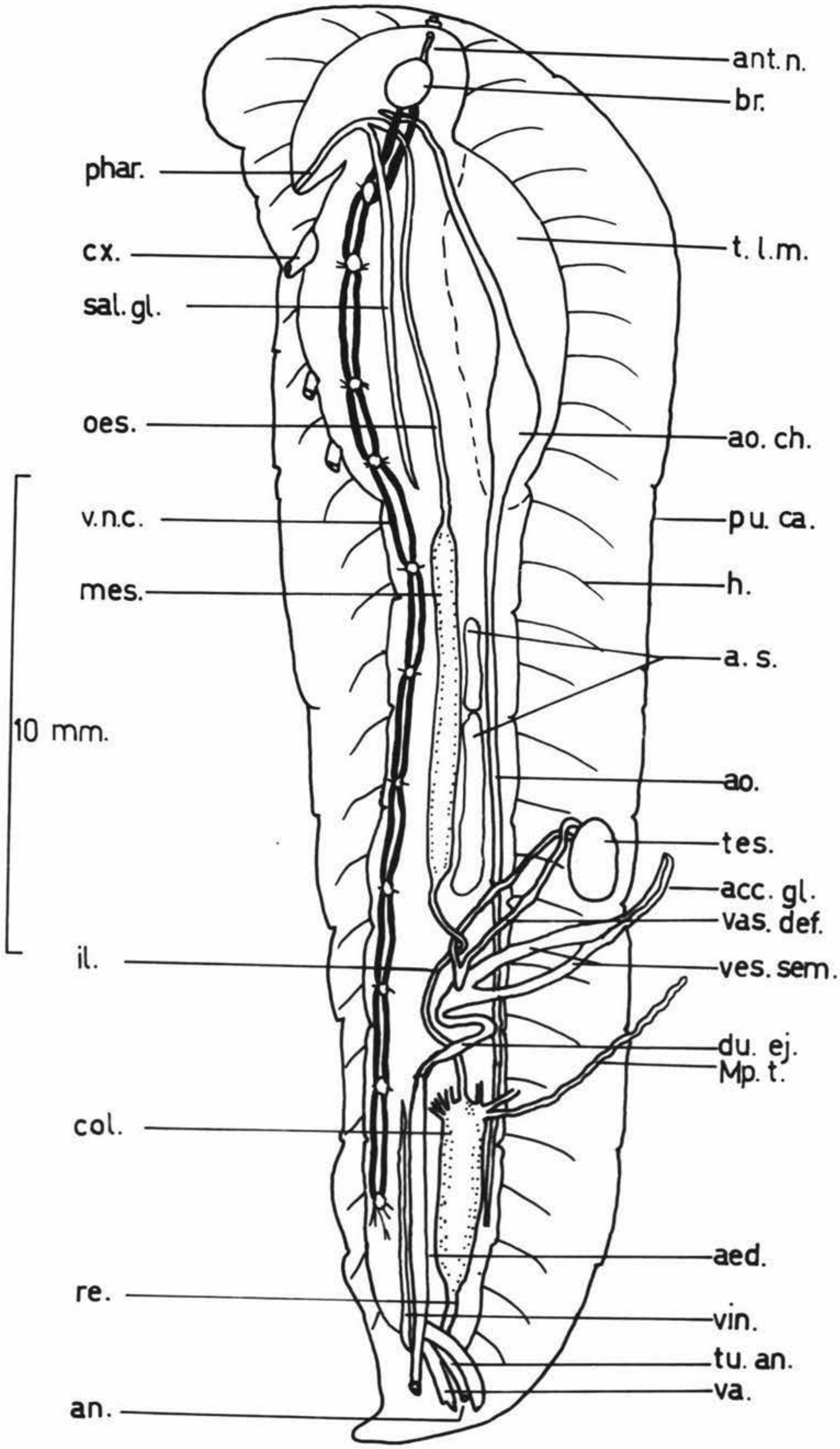


FIG. 53. INTERNAL ANATOMY OF FEMALE PUPA AT SEVEN DAYS, LATERAL ASPECT.

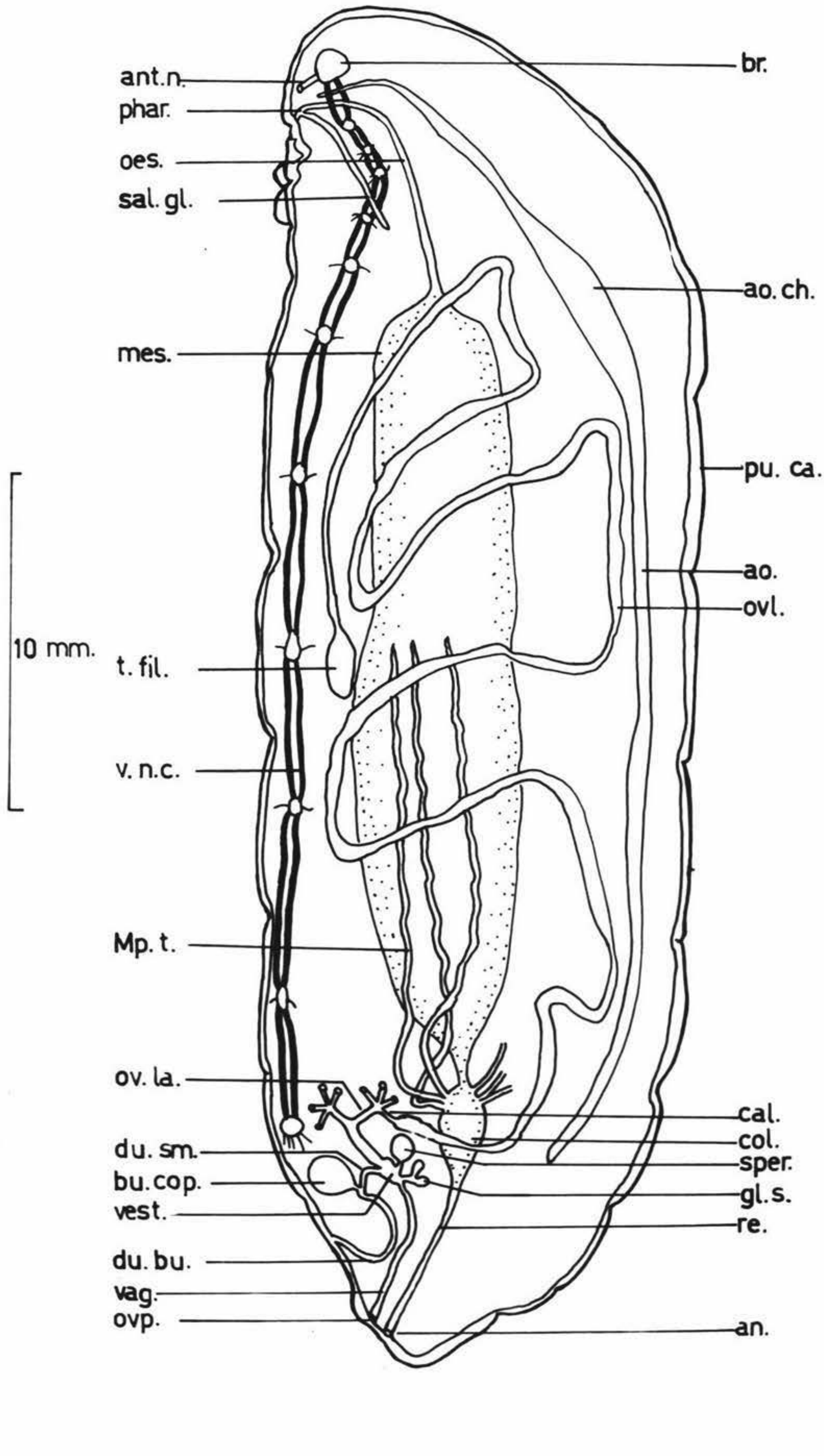


FIG. 54. PROTHORAX OF ADULT MALE, POSTERIOR INTERNAL ASPECT.

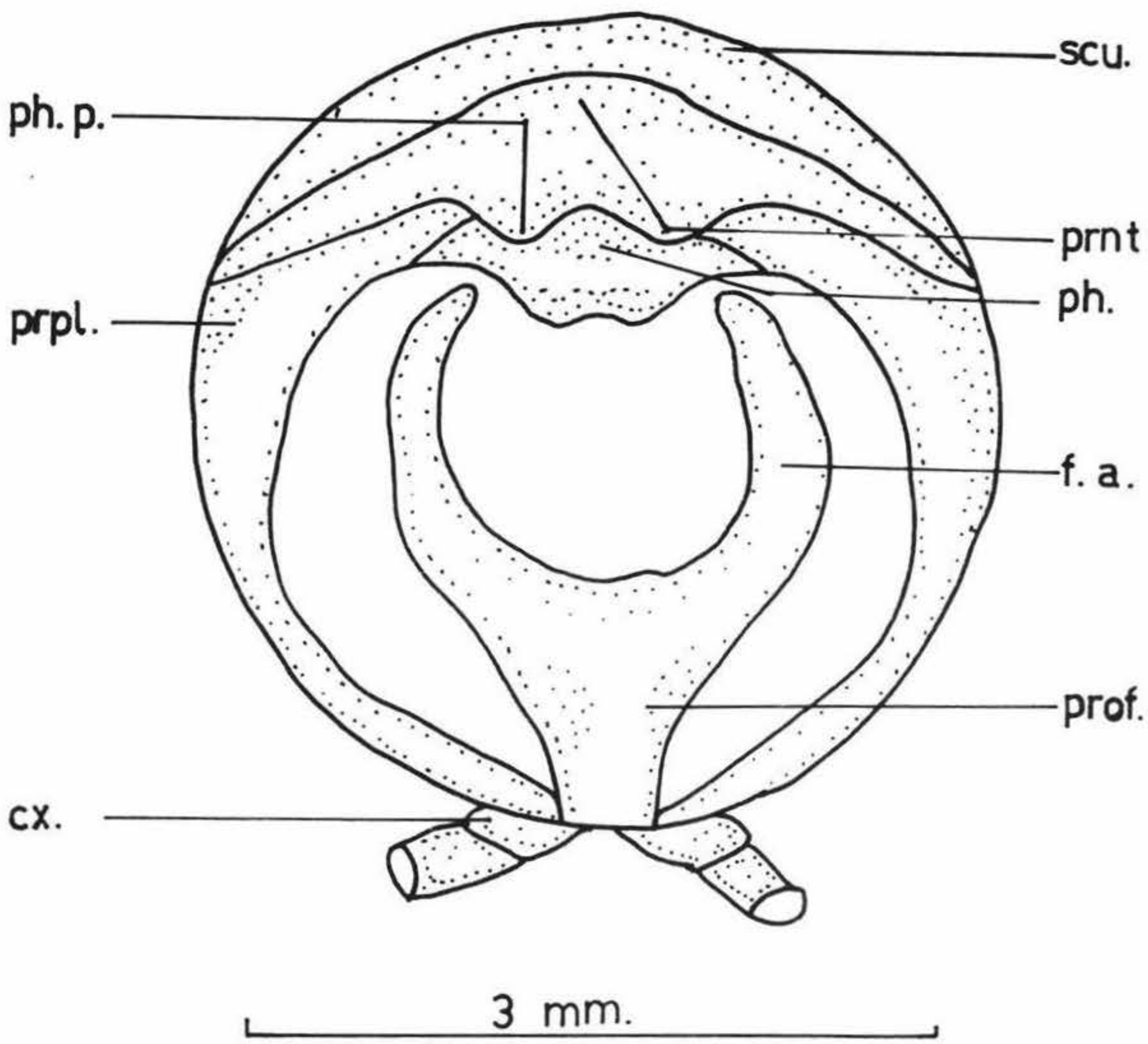


FIG. 55. MESOTHORAX OF ADULT MALE, POSTERIOR INTERNAL ASPECT.

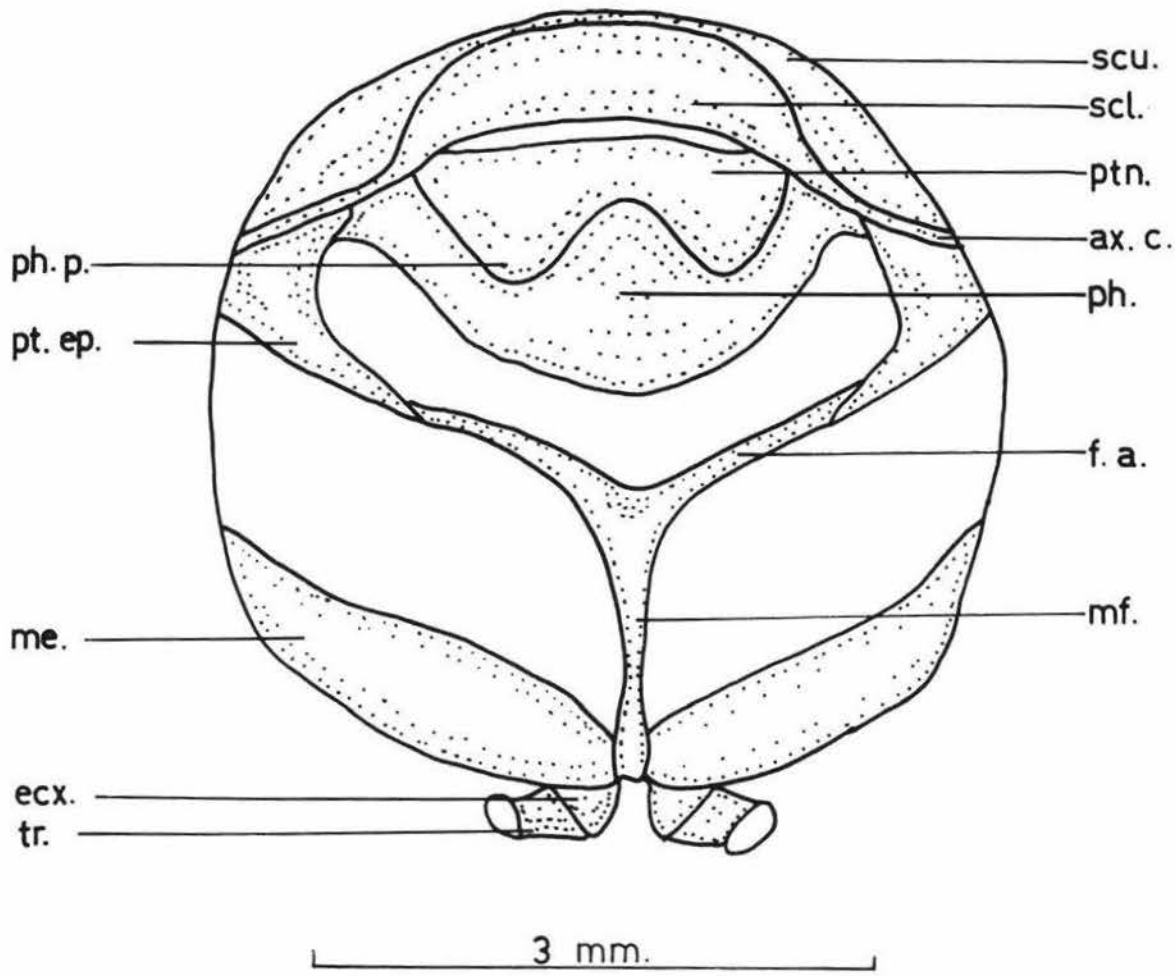


FIG. 56. METATHORAX OF ADULT MALE, POSTERIOR INTERNAL ASPECT.

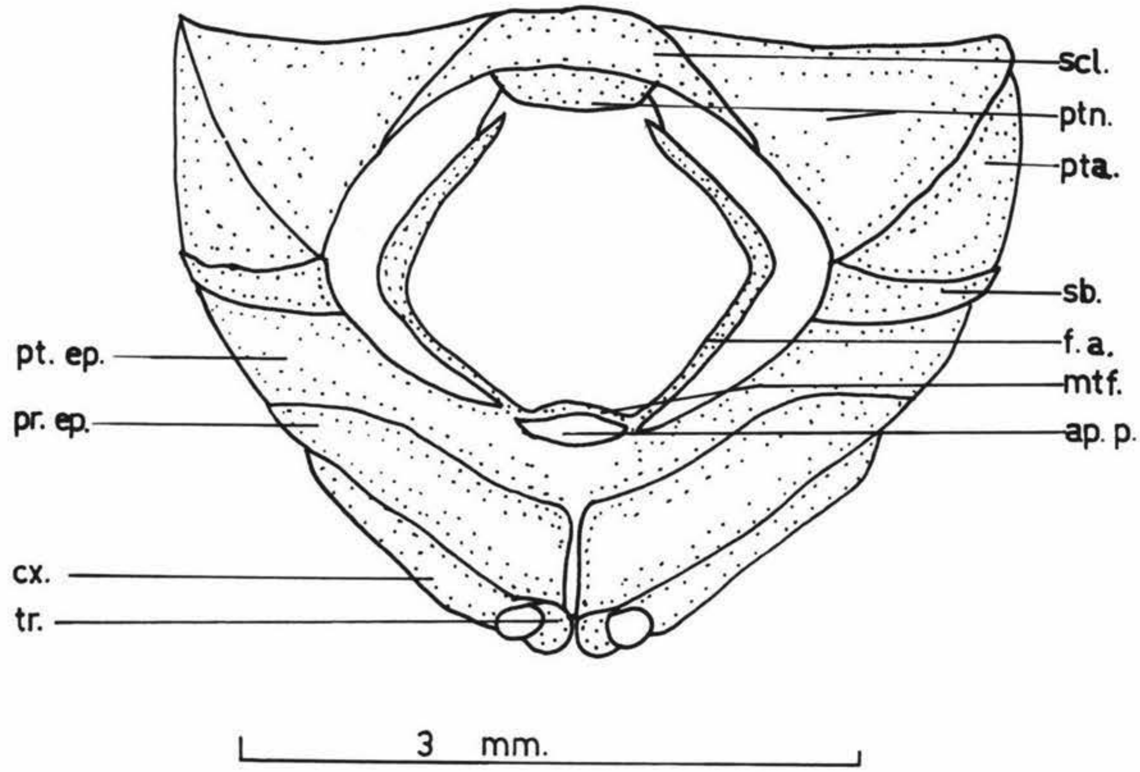


FIG. 57. INTERNAL ANATOMY OF ADULT MALE, LATERAL ASPECT.

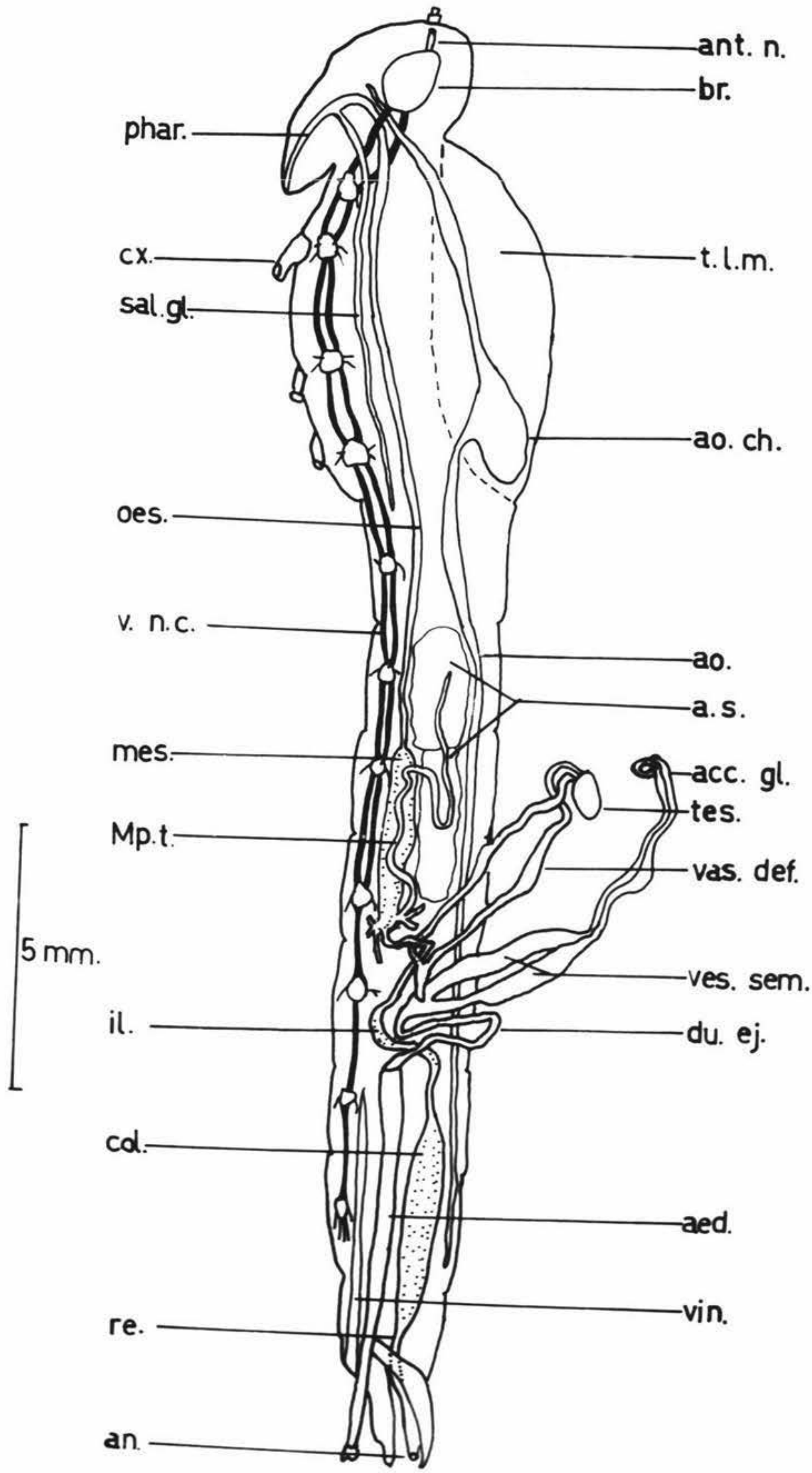


FIG. 58. CENTRAL NERVOUS SYSTEM OF ADULT MALE, DORSAL ASPECT.

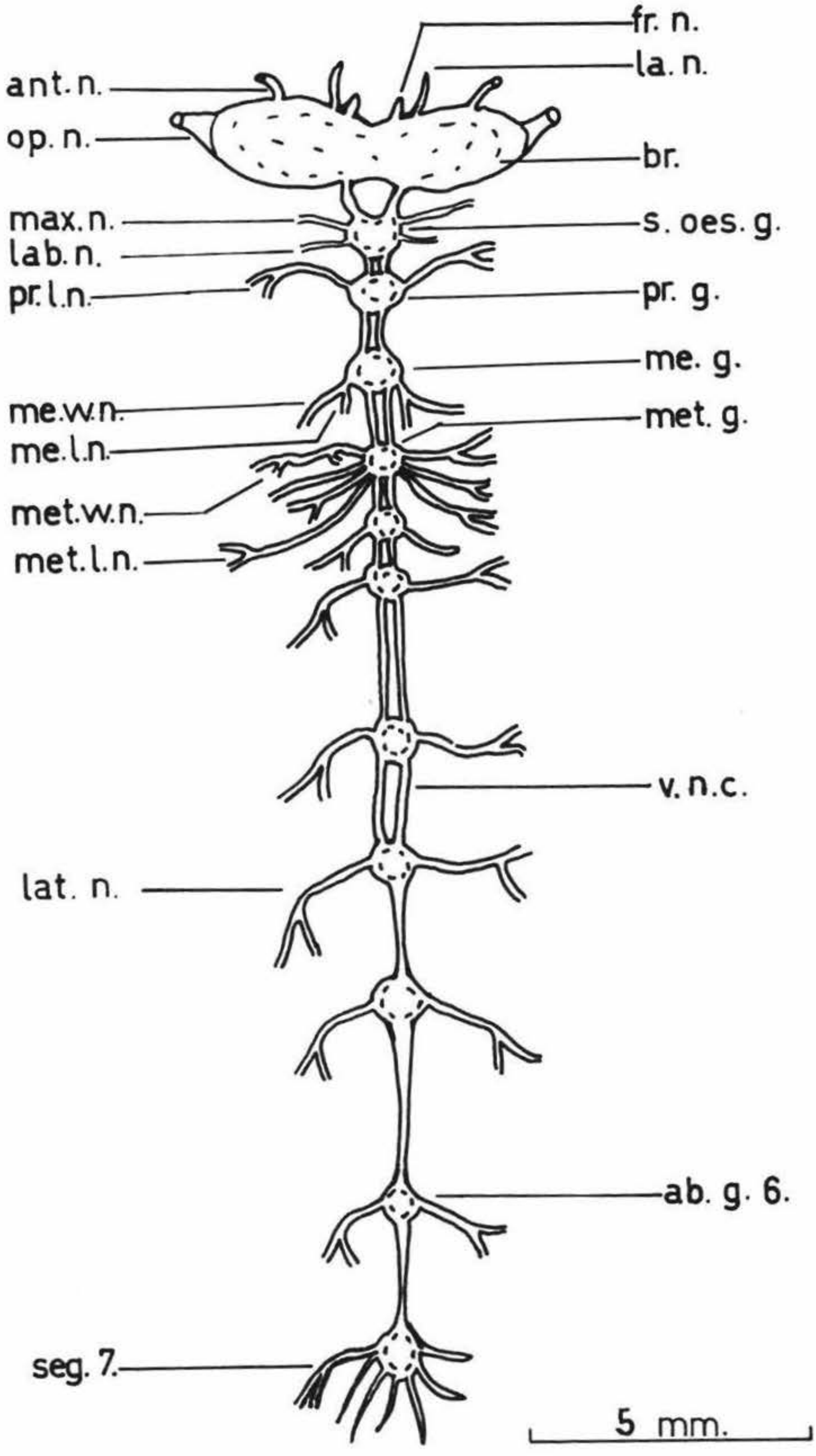
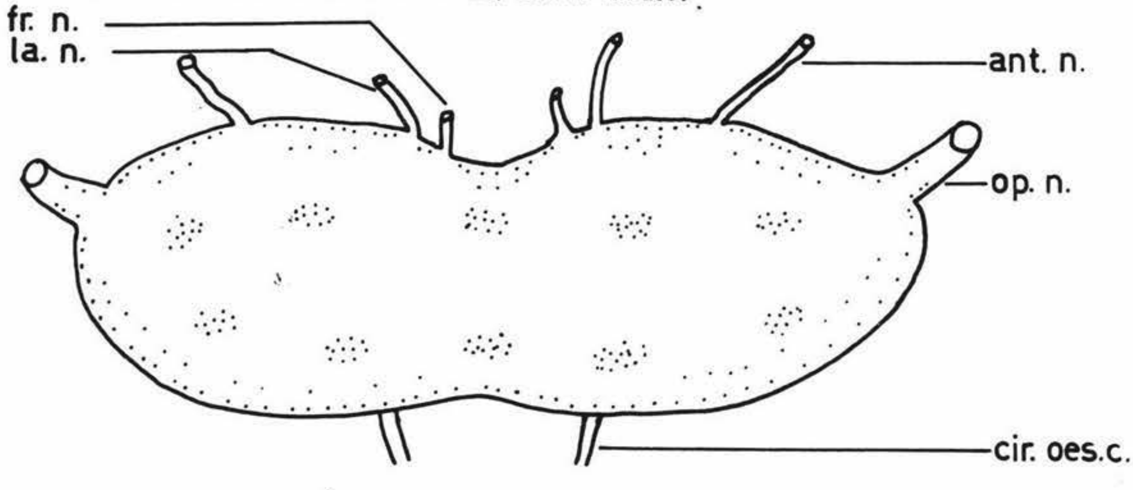
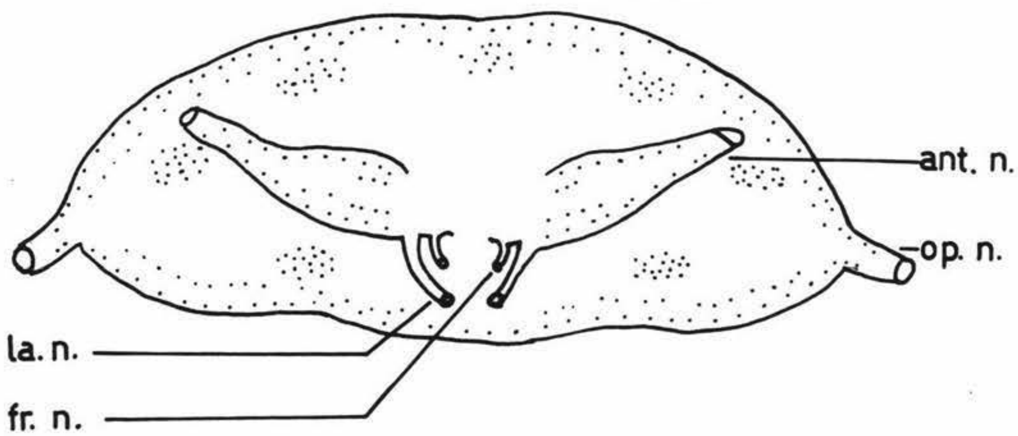


FIG. 59. A. BRAIN OF ADULT MALE, DORSAL ASPECT.



B. BRAIN OF ADULT MALE, ANTERIOR ASPECT.



C. BRAIN OF ADULT MALE, LATERAL ASPECT.

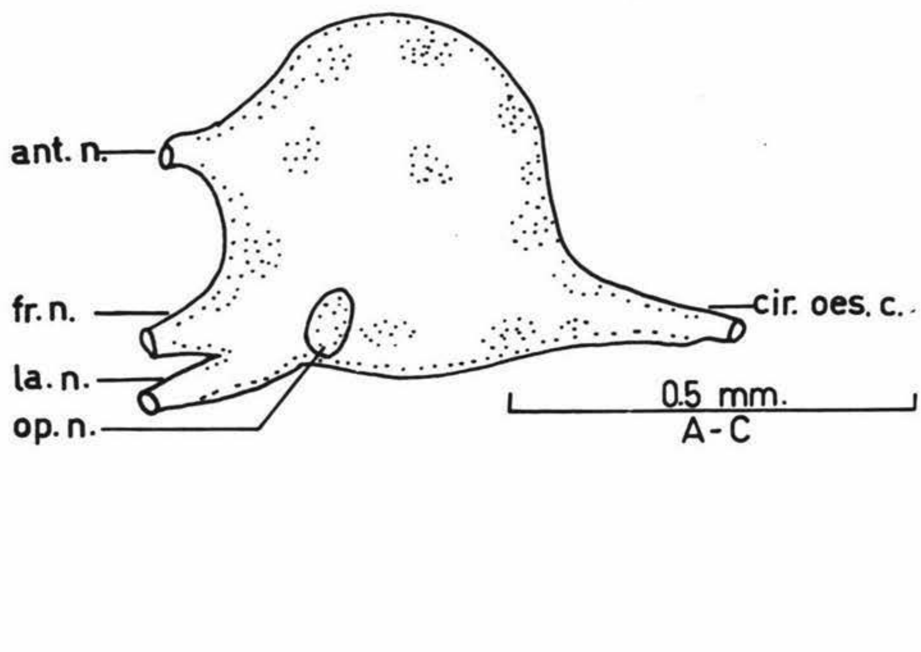
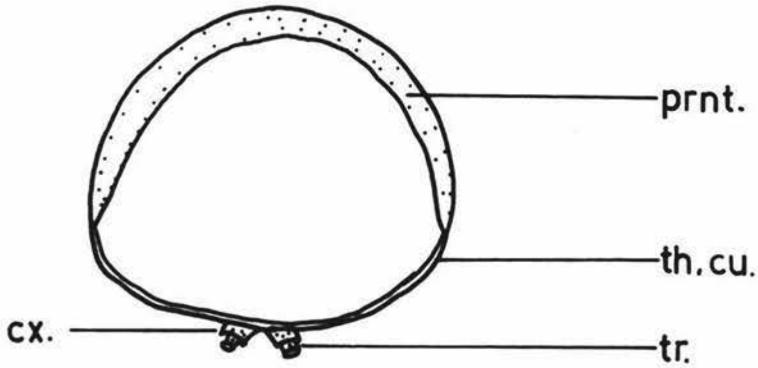
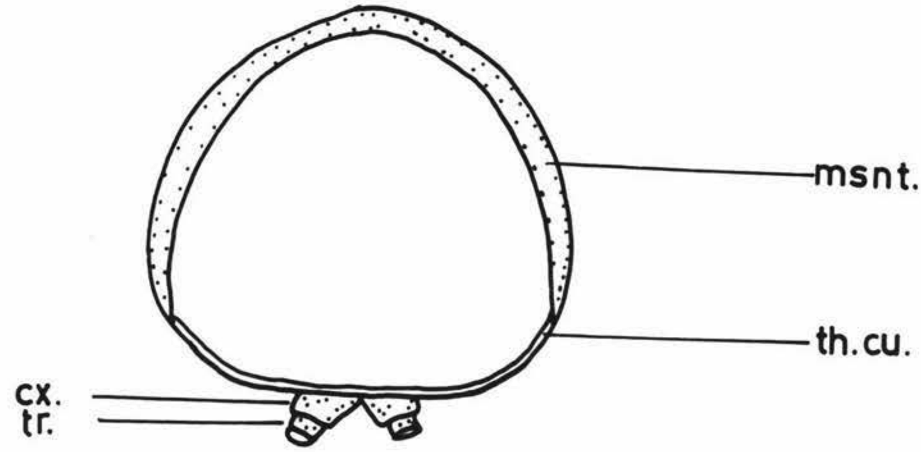


FIG. 60. A. PROTHORAX OF ADULT FEMALE, POSTERIOR INTERNAL ASPECT.



B. MESOTHORAX OF ADULT FEMALE, POSTERIOR INTERNAL ASPECT.



C. METATHORAX OF ADULT FEMALE, POSTERIOR INTERNAL ASPECT.

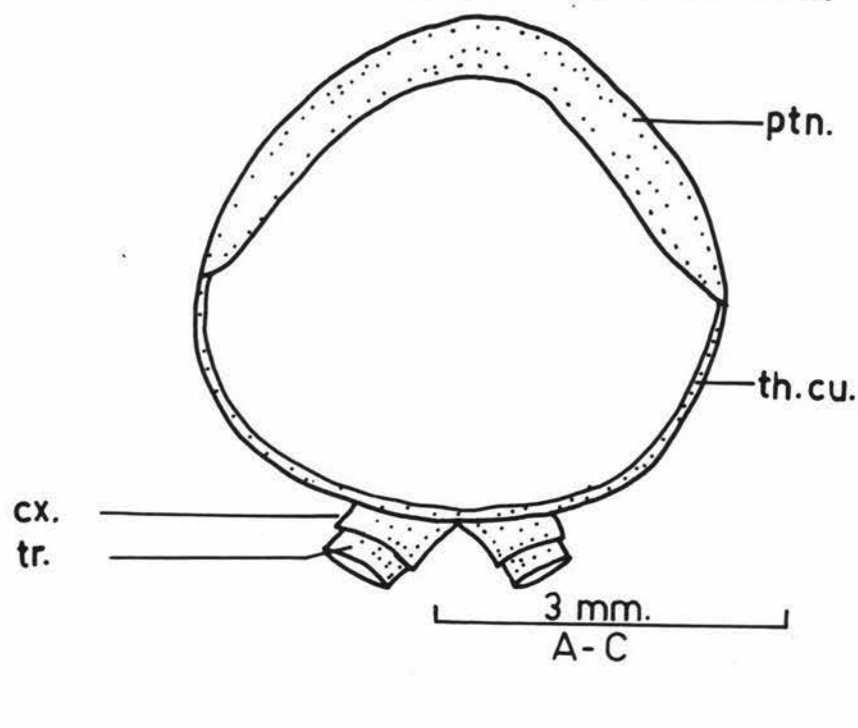


FIG. 61. INTERNAL ANATOMY OF ADULT FEMALE, LATERAL ASPECT.

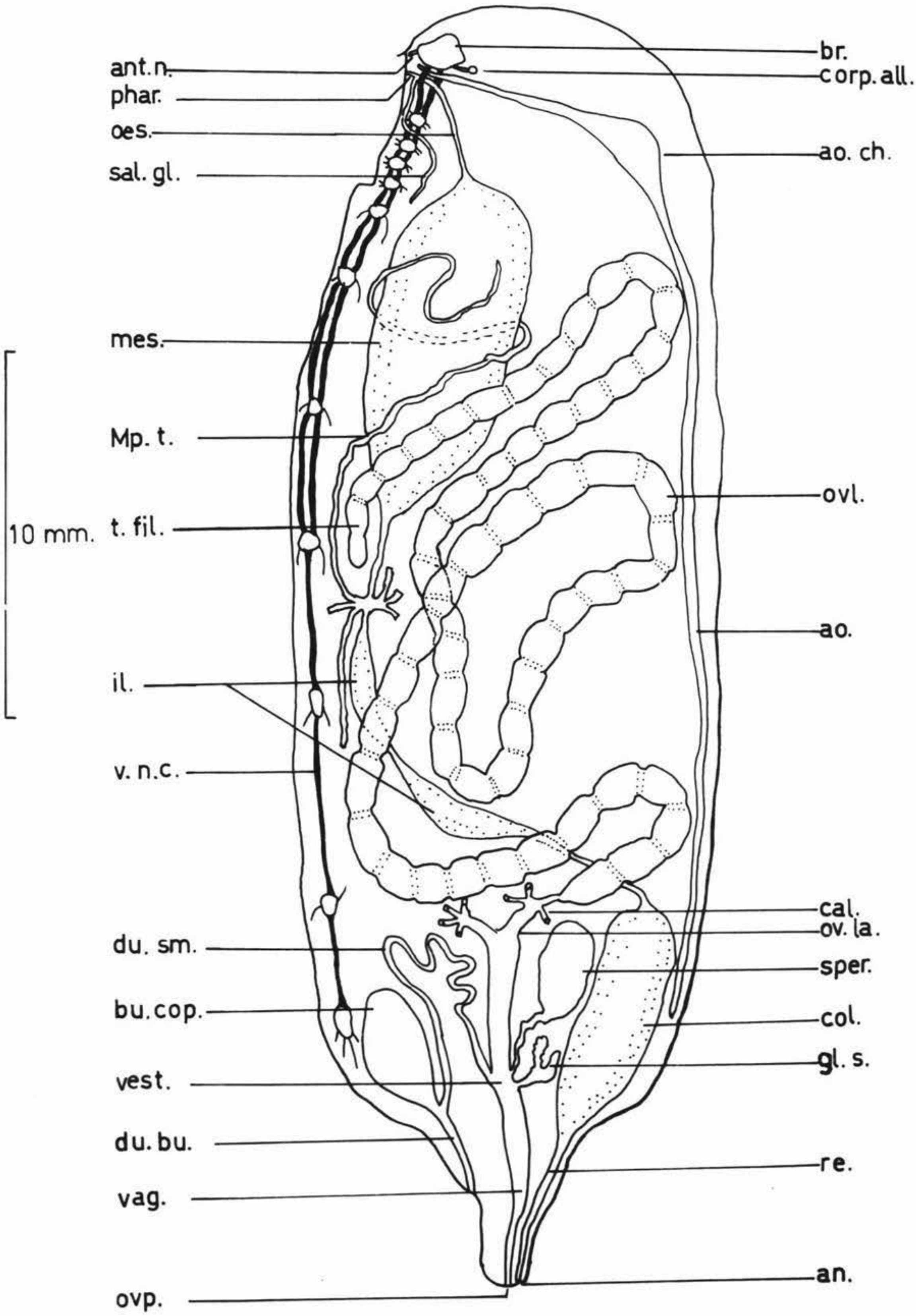


FIG. 62. LEFT LONGITUDINAL TRACHEAL TRUNK OF ADULT FEMALE, LATERAL ASPECT.

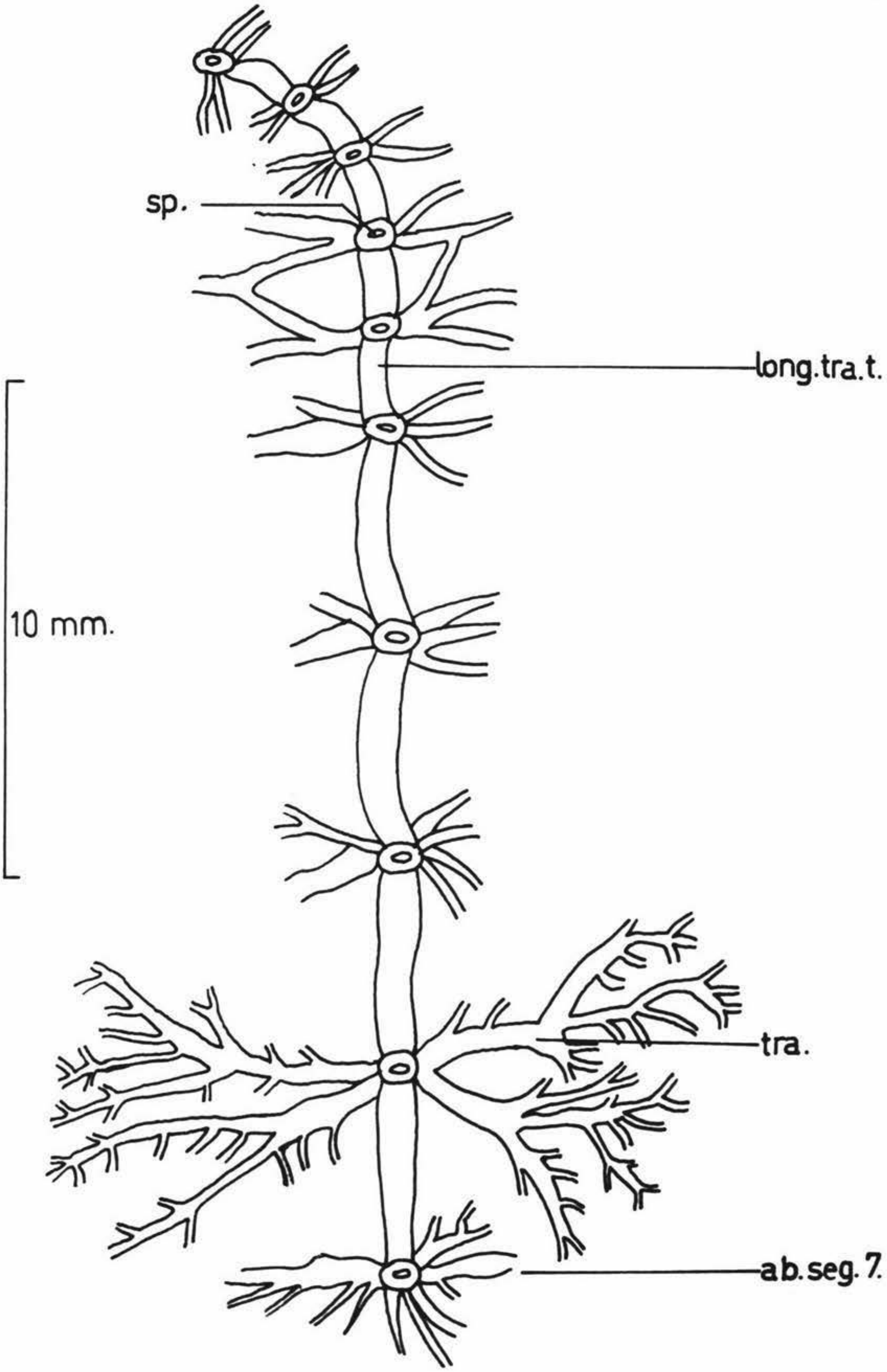


FIG. 63. CENTRAL NERVOUS SYSTEM OF ADULT FEMALE, DORSAL ASPECT.

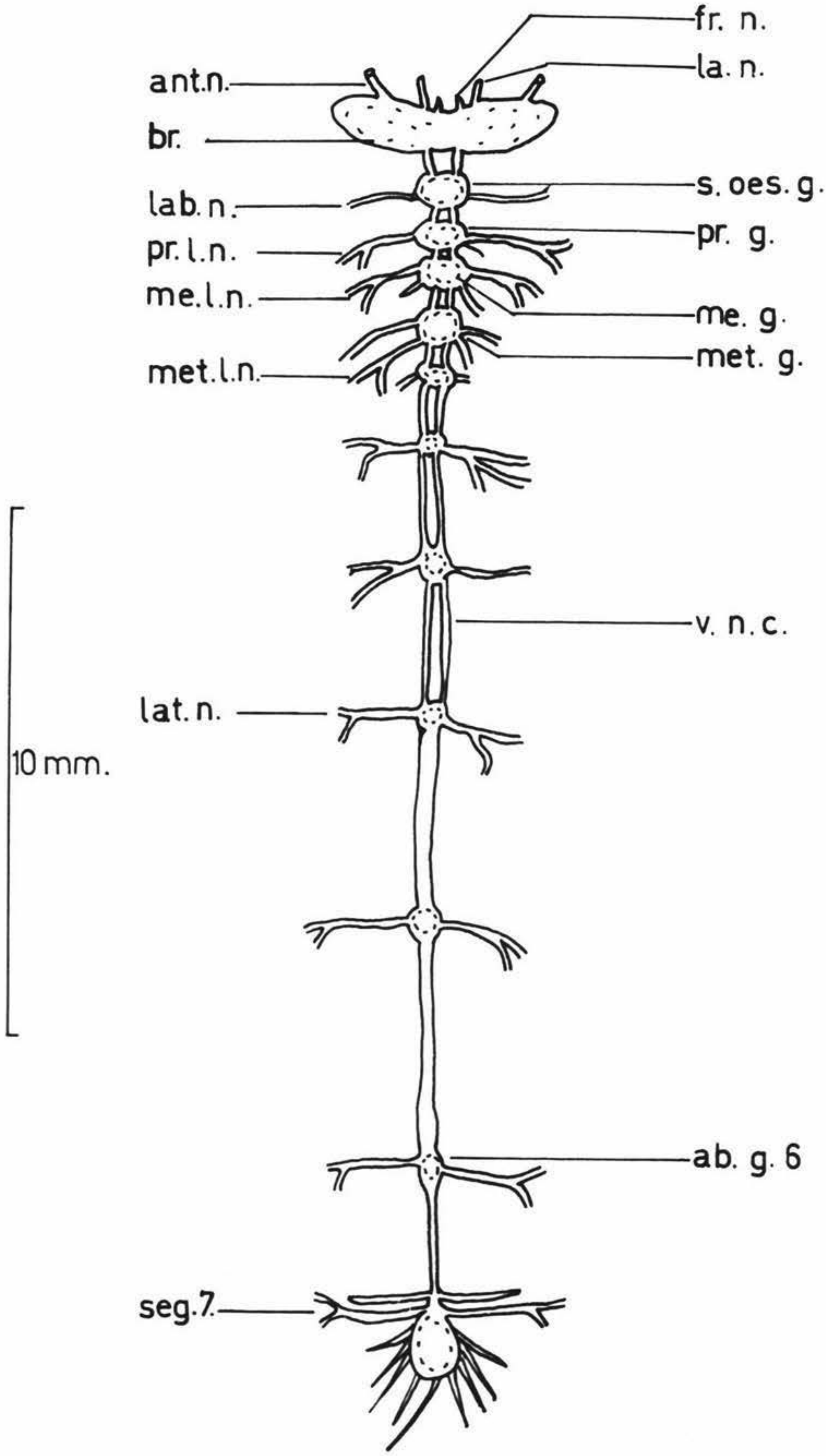
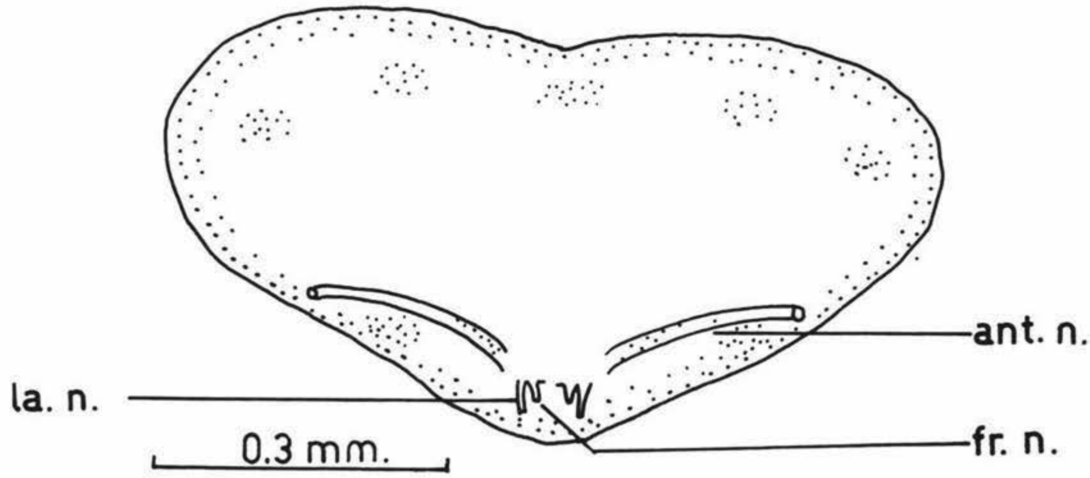
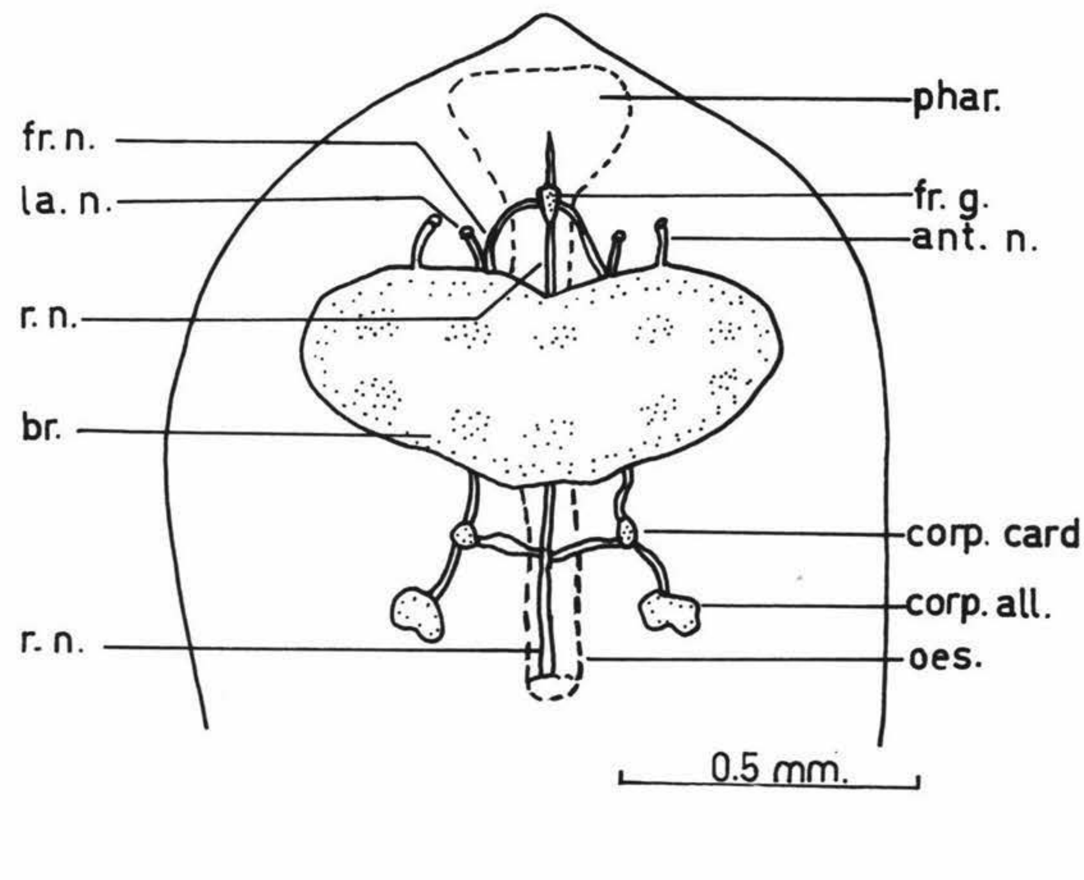


FIG. 64. A. BRAIN OF ADULT FEMALE, ANTERIOR ASPECT.



B. ANTERIOR SYMPATHETIC NERVOUS SYSTEM OF ADULT FEMALE, DORSAL ASPECT.



CHAPTER III

LIFE HISTORY AND BIOLOGY

INTRODUCTION

In this study the following aspects of the life history and biology of *L. omnivora* have been considered : -

A. THE EGG,
   1. DEPOSITION
   2. NUMBER
   3. DEVELOPMENT
   4. INCUBATION PERIOD
   5. ECLOSION

B. THE LARVA
   1. NUMBER OF INSTARS
   2. ECDYSIS
   3. GROWTH

C. PUPATION

D. EMERGENCE OF ADULT MALES AND FEMALES

E. HOST PLANTS

F. NOTES ON BEHAVIOUR

MATERIALS AND METHODS

A. THE EGG

Mature females were collected in the field and kept until their eggs hatched. Dates of egg laying and hatching were recorded. Cases containing eggs were also collected in the field, counts and measurements were made of some eggs and others were kept in cases in petri dishes for development studies. Measurements were also made of pupal cases containing eggs.

B. THE LARVA

Five larvae which hatched on 15 January 1967 were placed on twigs of the host plant, Cupressus lusitanica, placed in small labelled bottles containing water. The bottles were placed in beakers covered with nylon netting and kept in the laboratory. Other larvae which emerged on the same day were kept in a large cage containing twigs of the host plant. At three-day intervals, case length was measured under a stereoscopic binocular microscope fitted with a linear eye-piece micrometer. Body plus case weights were measured on a Sartorius balance. Cases of larger larvae with larger cases were measured with a Vernier calliper, and weight of body plus case was measured on a Mettler balance. Food was renewed at six-day intervals. The times at which each larva attached firmly to the host plant and ceased feeding temporarily before moulting were noted. In the laboratory, temperature and relative humidity were recorded continuously by using a hydrograph recorder placed in a breeding cage; and duration of light was also noted.

Larvae which emerged from 894 eggs in a single case on 24 January 1967 were used to infest a host plant, Juniperus squamata in the field. At three-day intervals, four larvae of different sizes (selected to include extreme large and small larvae present) were taken and removed from their cases. Head width, body length, and body weight of each larva as well as case length and case weight were measured.

Colour of larvae and moulting exuviae were also noted.

Observations on ecdysis and morphological changes of the larvae, behaviour of larvae, pupae, and imagoes were also made. Numbers and percentages of potential host plants infested were recorded.

RESULTS

A. THE EGG

Eggs are deposited inside the pupal case of the female, filling its posterior end as far forward as the second abdominal segment. Large numbers of eggs are laid by a single female. Numbers laid be 11 females examined ranged from 364 to 2,583, with a mean of 1474.

EGG DEVELOPMENT - As the egg grows older it changes from a fresh cream colour to a dirty yellowish white, later to greyish white and ultimately to dark grey. The head and thorax of the developing larva are visible externally as a dark spot, and the larvae can be seen moving about inside the eggs shortly before hatching. The mean length of the incubation period of eggs (in the field at a mean temperature of 15.6°C. [range 4.6 - 27.6°C.]) was found to be sixty one days (range 58 - 64 days).

B. THE LARVA

1. NUMBER OF INSTARS - *L. omnivora* has seven larval instars. Measurements and some structural characters of the instars are

presented in table 4 and the head capsule width increase factor is shown in table 5. Maximum numbers of final instar larvae were found in July. The number of crochets per proleg varies between legs of any one individual and between individuals (table 6).

Other differences between the instars are : -

(1) The frontal suture appears first in the third instar larvae when the head capsule has reached a width of 1.10 mm.

(2) The mandibular teeth and antennae do not show external changes but only increase in size as the larvae grow.

(3) The spiracles are circular in the first three instars but become oval in the fourth to seventh instars.

An excellent example of sexual dimorphism between male and female final instar larvae is shown by width of the anteclypeus. The mean width of seven male anteclypeus is 1.33 mm., range 1.10 - 1.55; and that of nineteen female anteclypeus is 1.85 mm., range 1.45 - 2.25. The mean ratio of width of female anteclypeus to width of male anteclypeus is 1.39. Figure 65 shows percentages of larval instars present in monthly samples taken in Palmerston North between November 1966 and August 1967.

2. ECDYSIS - Before moulting the larva spins a ring of silk (0.5' - 6.00 mm., wide) around a twig of the host plant, closes the anterior end of the case and ceases feeding. During moulting the old head capsule is pushed forward by the development of a new capsule beneath it. The anterior part of the larva from the head capsule to the third abdominal segment elongates. The weak connection between

TABLE 4. MEASUREMENTS OF THE 7 INSTARS REARED IN THE FIELD AT PALMERSTON NORTH, 1967.

Measurements		Number of specimens in each instar examined.	Instars						
			1st	2nd	3rd	4th	5th	6th	7th
Head height / Head width		4	1.21	1.12	1.00	0.96	0.85	0.78	0.71
Height of fronto clypeus / Length of mid-cranial suture		4	1.30	1.24	1.20	1.11	0.99	0.92	0.90
Setal number		4	130	148	163	164	164	167	177
Total number of crochets of sinistral row of 5 prolegs		4	111	154	178	187	194	201	206
Range of number of crochets per proleg		4	10-12	14-18	15-18	16-19	17-20	18-21	19-22
Head width (mm)	Mean	20	0.54	0.75	1.12	1.50	1.93	2.53	3.68
	Range		0.47-0.60	0.65-0.85	1.03-1.20	1.30-1.70	1.55-2.30	1.80-3.25	2.60-4.75
Body length (mm.)	Mean	20	1.85	2.95	6.03	8.55	9.56	15.36	23.80
	Range		1.40-2.30	1.70-4.20	5.60-6.45	6.60-10.5	8.80-10.31	9.52-21.20	14.61-33.00
Body weight (mg.)	Mean	20	0.75	2.00	8.00	23.50	35.50	163.75	367.5
	Range		0.5-1.0	1.0-3.0	6.0-10.0	14.0-33.0	23.0-48.0	37.5-290.0	68.0-667.0
Case length (mm.)	Mean	20	2.0	5.20	10.71	15.5	17.30	25.6	47.1
	Range		1.50-3.50	3.60-6.80	9.91-11.50	14.0-17.0	14.60-20.0	19.2-32.0	28.2-66.0
Case weight (mg.)	Mean	20	0.75	1.50	5.0	11.0	25.5	5.68	93.5
	Range		0.5-1.0	1.0-2.0	4.0-6.0	8.0-14.0	22.0-29.0	17.5-96.0	43.0-144.0
Head width / Case length		20	0.18	0.14	0.11	0.097	0.11	0.10	0.06
Head width / Body length		20	0.29	0.25	0.19	0.20	0.20	0.17	0.16
Larval length / Case length		20	0.67	0.57	0.52	0.55	0.55	0.60	0.51
Larval weight / Case weight		20	1.00	1.33	1.78	2.14	1.39	2.89	3.93

TABLE 5. HEAD CAPSULE INCREASE FACTOR OF LARVAE REARED IN THE FIELD.

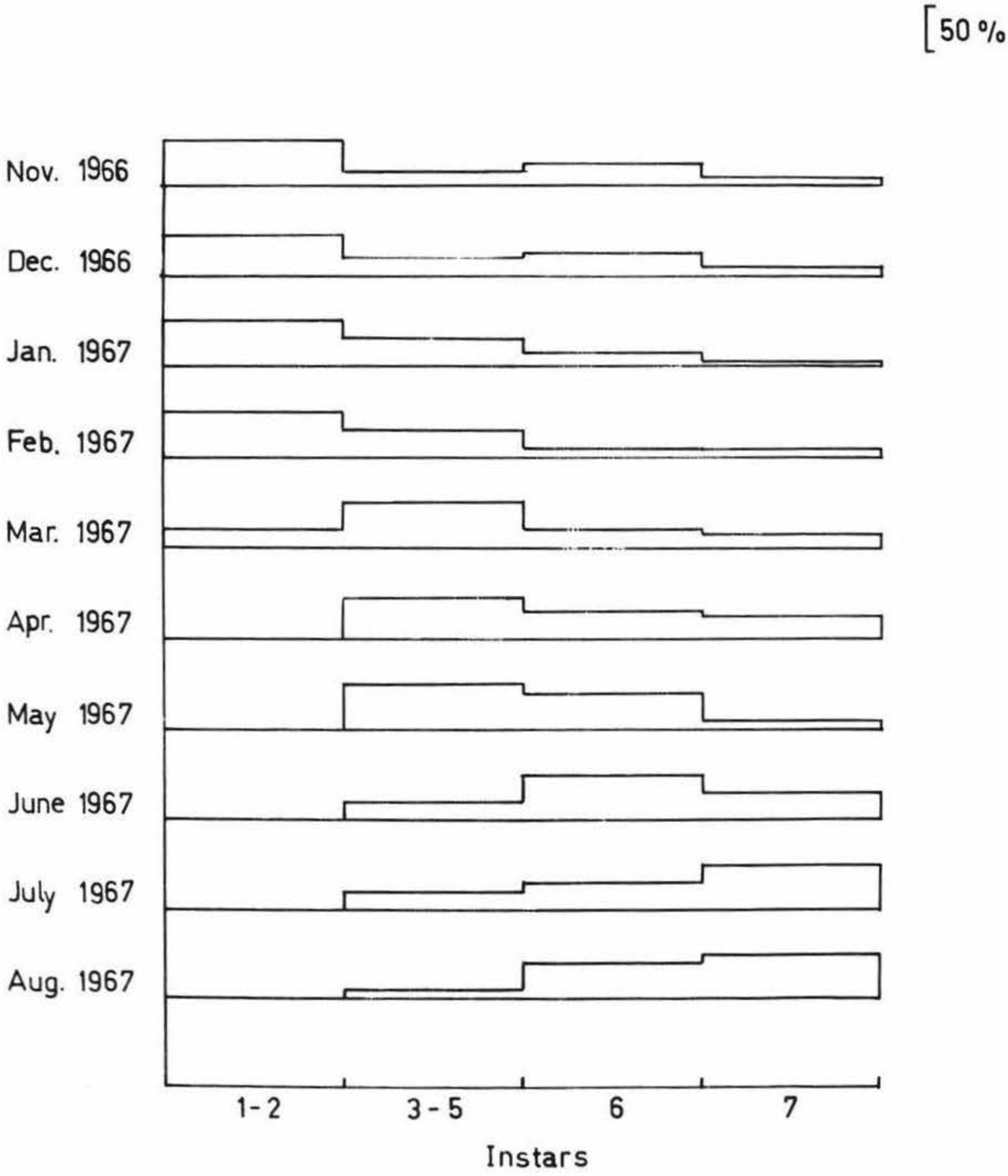
Instar	Head width increase ratio
2nd : 1st	1.39 (20) 1.38 - 1.42
3rd : 2nd	1.49 (20) 1.59 - 1.41
4th : 3rd	1.34 (20) 1.26 - 1.42
5th : 4th	1.29 (20) 1.19 - 1.35
6th : 5th	1.31 (20) 1.16 - 1.41
7th : 6th	1.46 (20) 1.44 - 1.46

N.B. Numbers in parentheses indicate numbers of larvae used. Lower readings are ranges of values.

TABLE 6. NUMBER OF CROCHETS PER PROLEG IN FOUR LARVAE OF 1st AND 7th INSTARS COLLECTED AT PALMERSTON NORTH, 1967.

Instar	Abdominal segments	1		2		3		4	
		Right proleg	Left proleg	Right proleg	Left proleg	Right proleg	Left proleg	Right proleg	Left proleg
1st	3	12	11	11	11	12	11	10	10
	4	11	11	10	12	11	11	11	11
	5	11	11	11	11	10	12	11	10
	6	10	10	12	10	11	11	10	11
	Anal	12	12	11	12	11	12	12	12
7th	3	22	21	22	20	19	20	19	19
	4	21	22	20	19	20	20	19	20
	5	19	20	20	22	20	21	20	21
	6	20	21	21	21	21	20	20	22
	Anal	19	21	20	21	22	22	21	22

FIG. 65 PERCENTAGES OF LARVAL INSTARS COLLECTED MONTHLY AT PALMERSTON NORTH FROM NOVEMBER 1966 TO AUGUST 1967.



the head capsule and the prothorax splits. Thus the head capsule together with the prothoracic legs are separated from the remaining part of the body. A wave of contraction occurs and the metathoracic legs are drawn free. Contraction of the body frees the head from the old head capsule. Then the larva moves out from the posterior half of the exuvia. Immediately after moulting, the larvae are pale yellow and usually darken after three days.

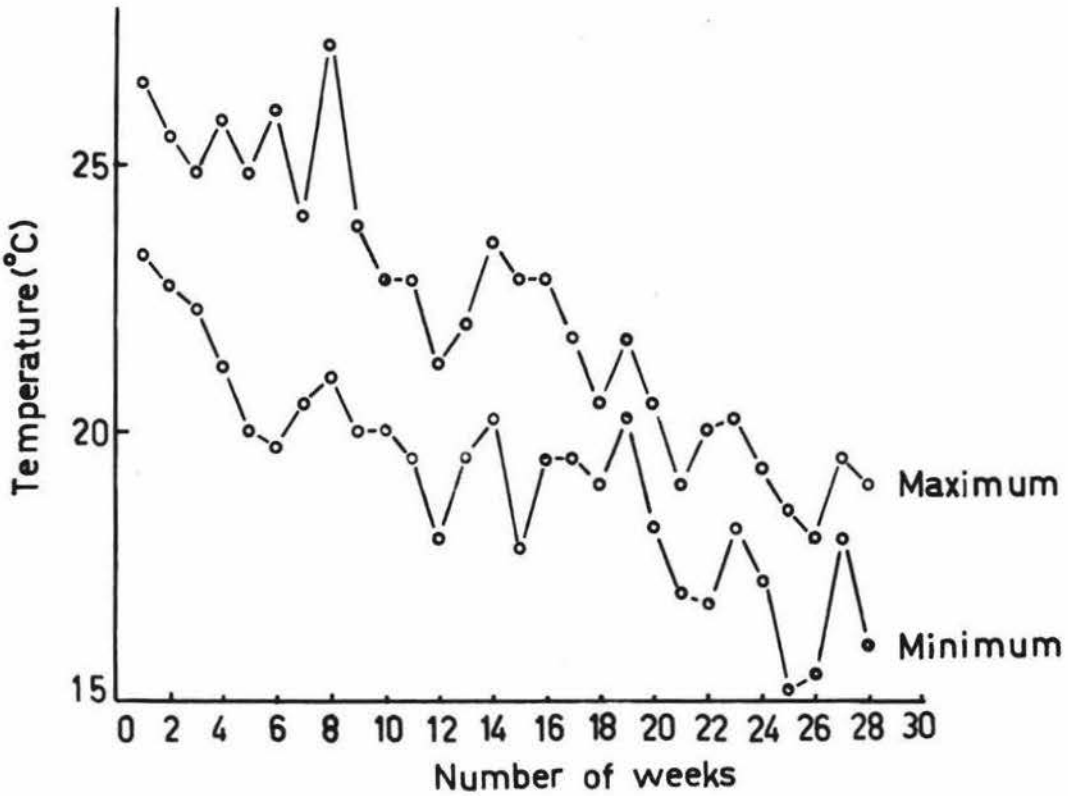
3. <u>GROWTH</u> - (a) Figures 66 - 69 show the climatic conditions under which the casemoth larvae developed in the laboratory and in the field.

In the laboratory, the weekly mean maximum temperature decreased from 26.5°C. in January to 19.0°C. in August, and the weekly mean minimum temperature decreased from 23.3°C. in January to 16.0°C. in August. The weekly mean relative humidity decreased from 91.5% in January to 80.0% in August. The duration of light including electric light decreased from a weekly mean duration of 14.5 hours per day in January to 8.5 hours per day in August (the light was turned off for a longer period in winter).

In the field, the weekly mean maximum temperature ranged from 23.0°C. in January to 12°C. in August. The weekly mean daily relative humidity ranged from 76.0% in January to 90% in June and the daily duration of bright sunlight ranged from 6.9 hours in January to 3.2 hours in August. Monthly rainfall ranged between 3.11 inches in January to 7.20 inches in August.

Temperatures recorded in the field were lower than those in the

FIG. 66. A. WEEKLY MEAN TEMPERATURES RECORDED IN THE LABORATORY DURING LARVAL GROWTH.



B. WEEKLY MEAN TEMPERATURES IN THE FIELD DURING LARVAL GROWTH.

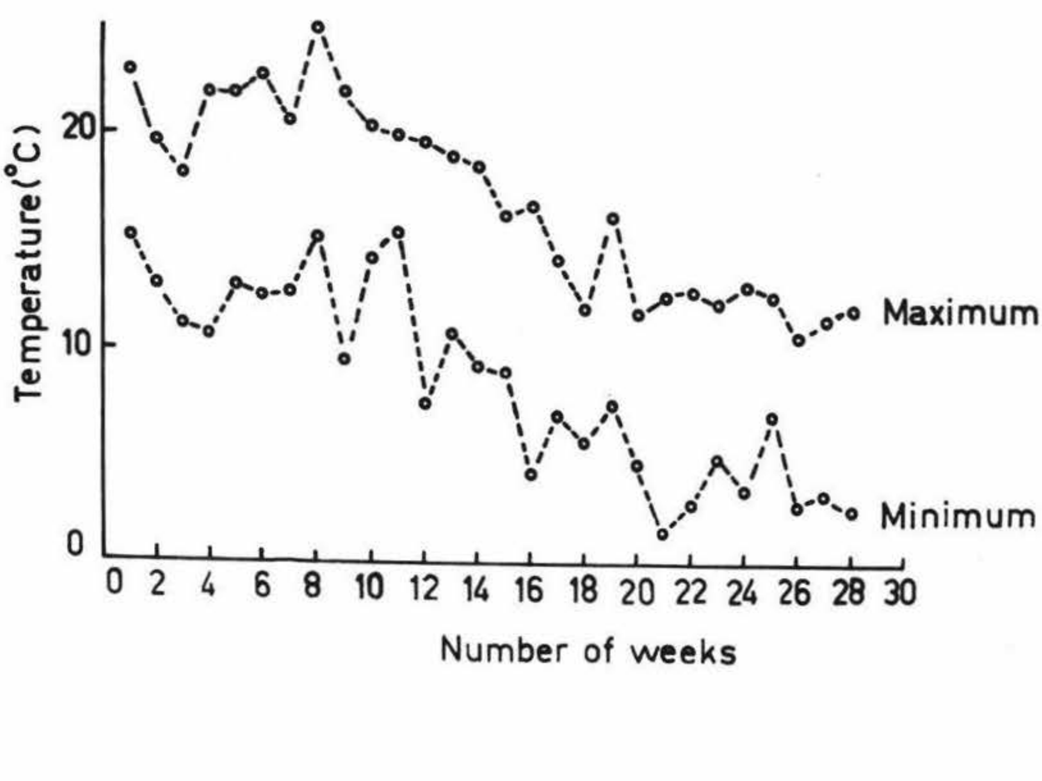


FIG. 67 WEEKLY MEAN RELATIVE HUMIDITY RECORDED IN THE LABORATORY (CONTINUOUS LINE) AND IN THE FIELD (BROKEN LINE) DURING LARVAL GROWTH.

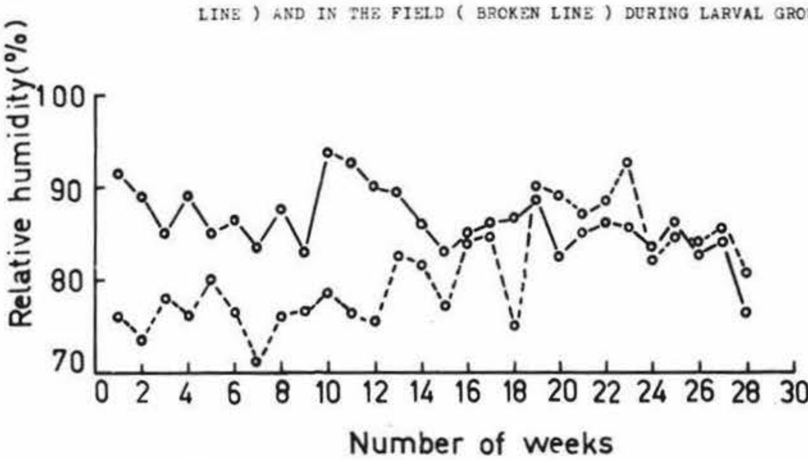


FIG. 68. WEEKLY MEAN DURATION OF BRIGHT LIGHT (INCLUDING ELECTRIC LIGHT) IN THE LABORATORY (CONTINUOUS LINE) AND WEEKLY MEAN DURATION OF BRIGHT SUNSHINE IN THE FIELD (BROKEN LINE) DURING LARVAL GROWTH.

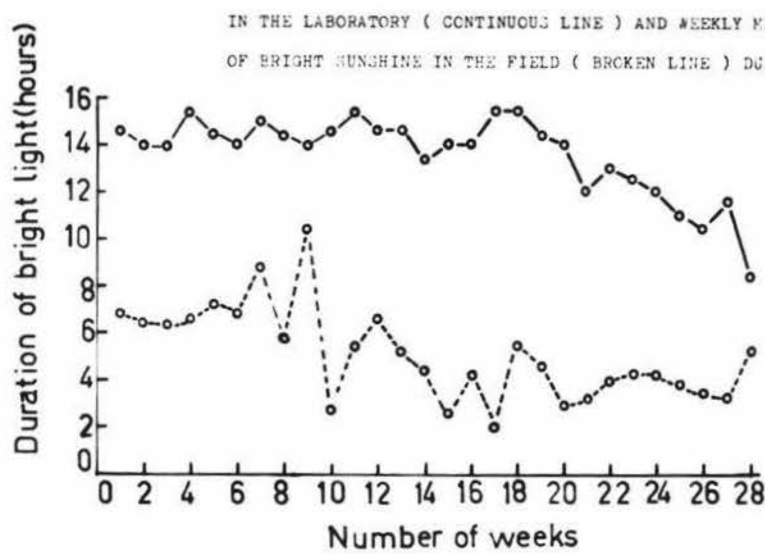
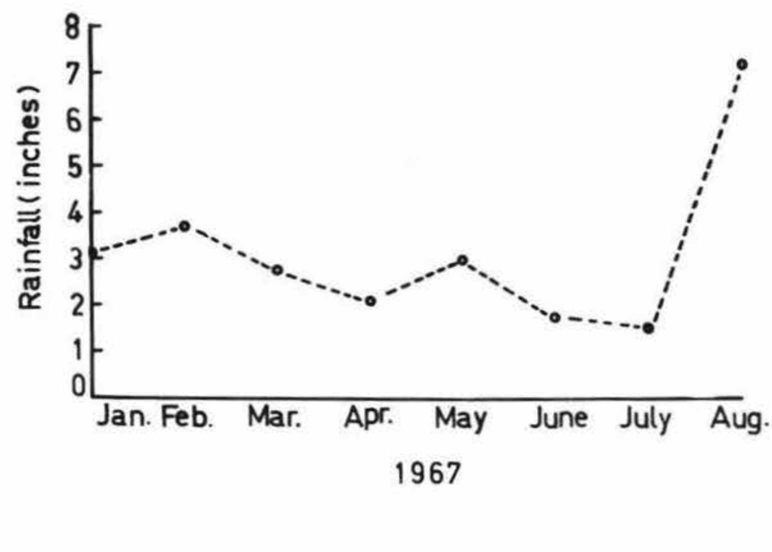


FIG. 69. MONTHLY RAINFALL DURING LARVAL GROWTH.



laboratory by an average of 6°C. and the duration of light hours in the field was shorter than that in the laboratory by an average of 5.5 hours.

(b) Figure 70 compares the growth of larvae and their cases reared in the laboratory and in the field. Lengths of stadia are shown in table 7. The length of larval life in the laboratory was found to be at least 191 days and in the field at least 194 days. As the larval instars overlap, many larvae had reached only the fifth instar when other larvae were pupating, i.e., the larvae from the same brood do not moult and pupate at the same time throughout their life. In the laboratory the length of the larval stadia observed varied from 20 - 34 days. In the field, the larval stadia observed varied from 19.5 - 35 days. A progressive increase in body weight occurs after each ecdysis, but at the time the larvae moult, they lose a little of their body weight temporarily, probably due to a cessation of feeding (the anterior end of the case being closed and attached firmly to the host plant). Larvae reared in the laboratory grew slightly faster than those in the field, probably due to the higher temperature favouring more rapid growth. The increase in body weights of female larvae was greater than that of the male larvae. There was a relatively greater increase in case length towards the end of 6th instar. This increase in case length parallels the increase in body weight of the larvae.

4. <u>PUPATION</u> - Pupae were found in the field from January to July. The mean duration of the male pupal stage was 92 days, range 87 - 97, and that of the female pupa 26.5 days,range 21 - 32 (table 8). Of 97 pupae collected in the field only 30 were female, giving a male

FIG. 70. GROWTH CURVES OF MALE AND FEMALE LARVAE AND THEIR CASES IN THE LABORATORY AND IN THE FIELD AT MASSEY UNIVERSITY, 1967.

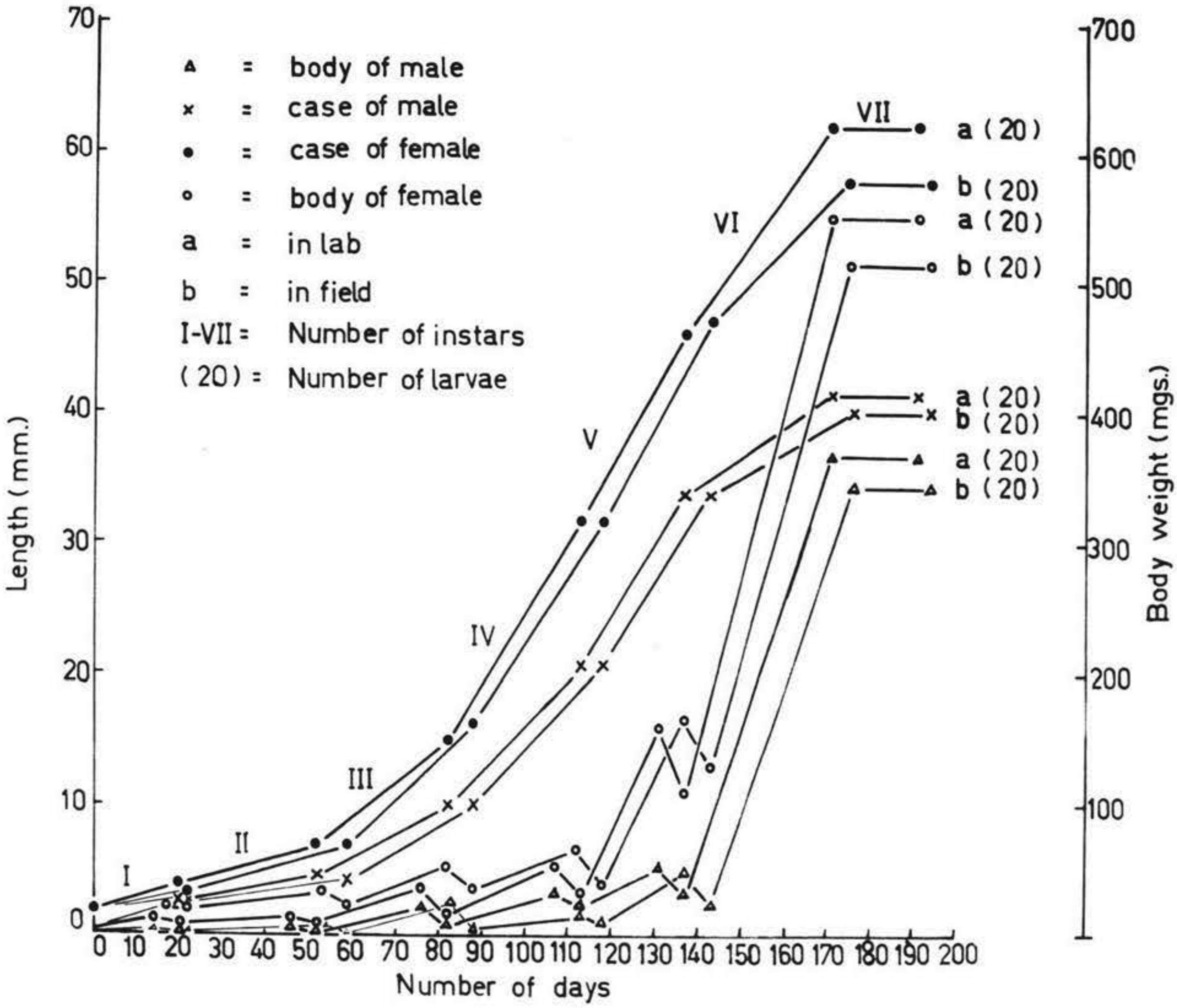


TABLE 7. STADIA OF LARVAE REARED IN THE LABORATORY AND IN THE FIELD AT PALMERSTON NORTH, 1967.

Instar	Laboratory		Field	
	Days	Mean days	Days	Mean days
1st	18 - 22 (5)	20	20 - 24 (20)	22
2nd	31 - 33 (5)	32	32 - 38 (20)	35
3rd	28 - 32 (5)	30	28 - 34 (20)	31
4th	28 - 34 (5)	31	28 - 32 (20)	30
5th	23 - 25 (5)	24	22 - 28 (20)	25
6th	31 - 37 (5)	34	30 - 34 (20)	32
7th	18 - 22 (5)	20	16 - 23 (20)	19.5

N.B. Numbers in parentheses indicate numbers of larvae observed.

to female ratio of 97 : 30 or approximately 3 : 1.

5. EMERGENCE OF MALE IMAGO - The adult male within the pupa makes jerky movements until the junction between the pronotum and the mesonotum and that between the mesonotum and the metanotum break-down. The adult male then pulls itself out from the head capsule, mouth parts and thoracic appendages of the pupal case, and the mesonotum becomes detached from the pupal case and falls apart. After leaving the posterior end of the pupal case, the male clings to the lower end of the case and expands its wings. When the wings are fully expanded, the adult male vibrates them for 1 - 2 minutes before taking off. The whole process has been observed to take twenty six minutes and is summarized in figure 71.

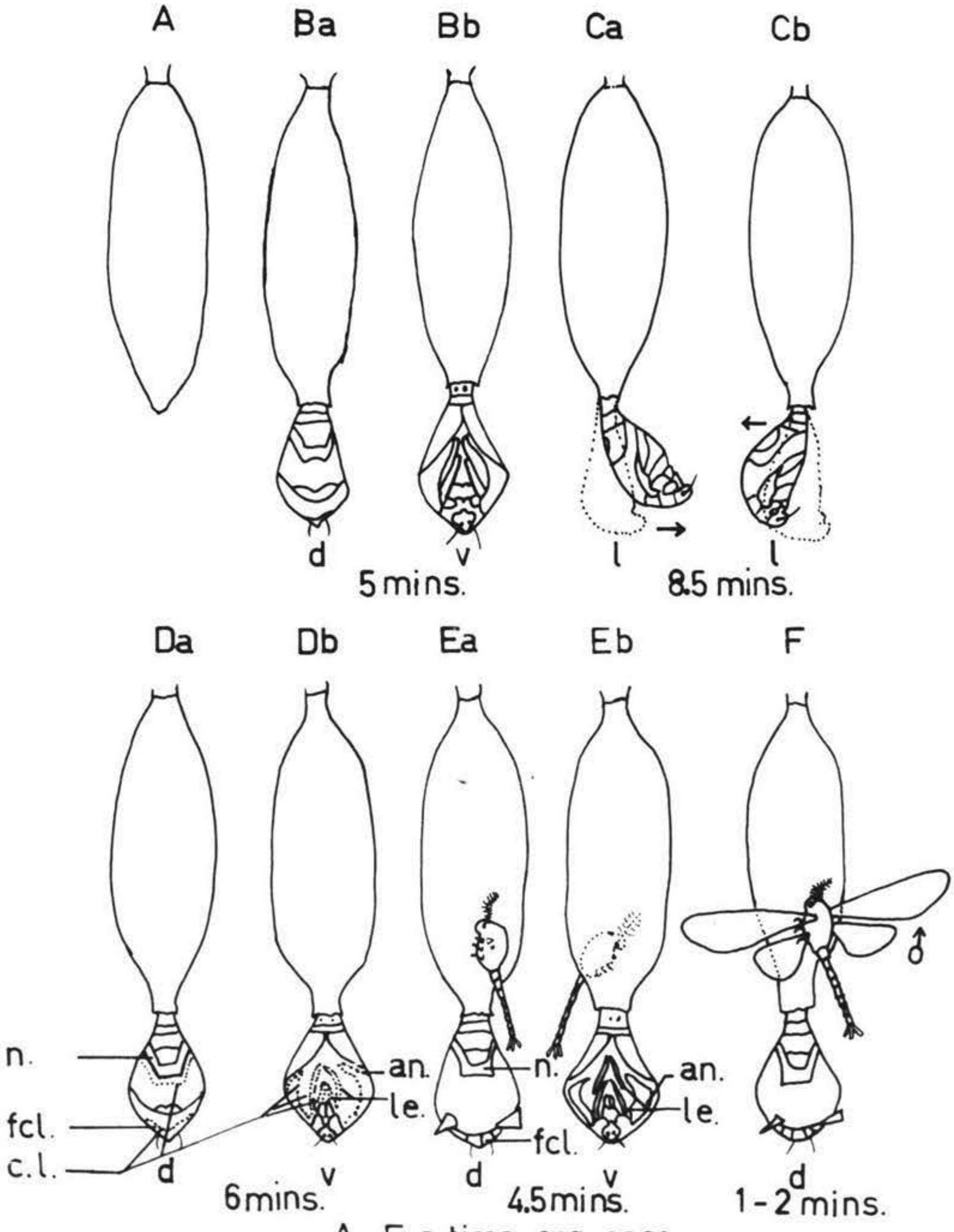
EMERGENCE OF FEMALE IMAGO - The female pupa wriggles until it pushes the pupal head parts off, while the median dorsal line from the prothorax to the posterior margin of the first abdominal segment splits posteriorly. The whole process takes about eight minutes and is shown in figure 72. After emergence has been completed the adult female remains within the pupal case although its head, thorax and the dorsal portion of the first abdominal segment are exposed outside it.

a. COPULATION AND OVIPOSITION (Fig. 73) - In a cage the male was seen to alight on the lower end of the female case, and with its wings and antennae vibrating continuously it began to probe its genitalia into the aperture of the case. Through the transparent adhesive tape closing the case, the abdomen of the male was seen to pass into the ruptured anterior end of the female pupal case. The

TABLE 8. DURATION OF PUPAL STAGE DETERMINED FROM LARVAE COLLECTED IN THE FIELD AT PALMERSTON NORTH IN 1967.

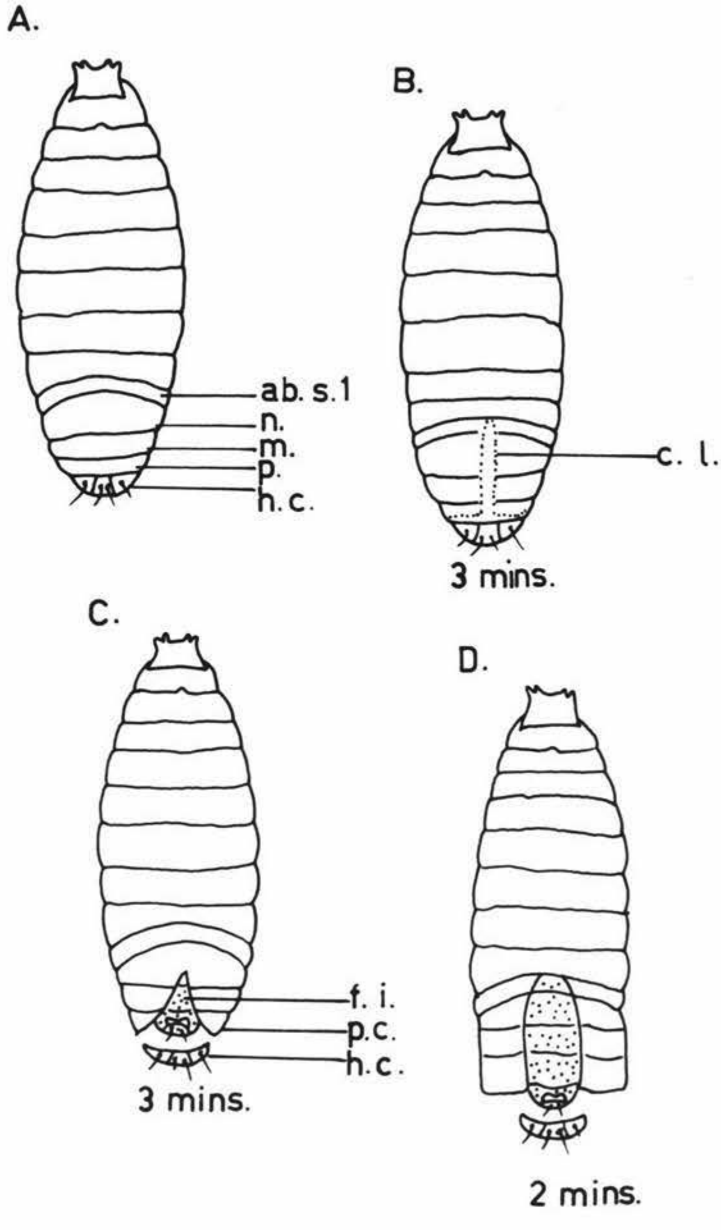
Sex	Pupation date	Number	Date of emergence of imago	Duration of pupal stage (days)
	24 V 1967	1	29 VIII 1967	97
Male	29 V 1967	1	24 VIII 1967	87
	30 V 1967	1	27 VIII 1967	89
	27 V 1967	1	24 VI 1967	28
	29 V 1967	1	29 VI 1967	31
	31 V 1967	1	2 VII 1967	32
FEMALE	13 VI 1967	1	4 VII 1967	21
	19 VI 1967	1	16 VII 1967	27
	20 VI 1967	1	19 VII 1967	29

FIG. 71. EMERGENCE OF MALE IMAGO.



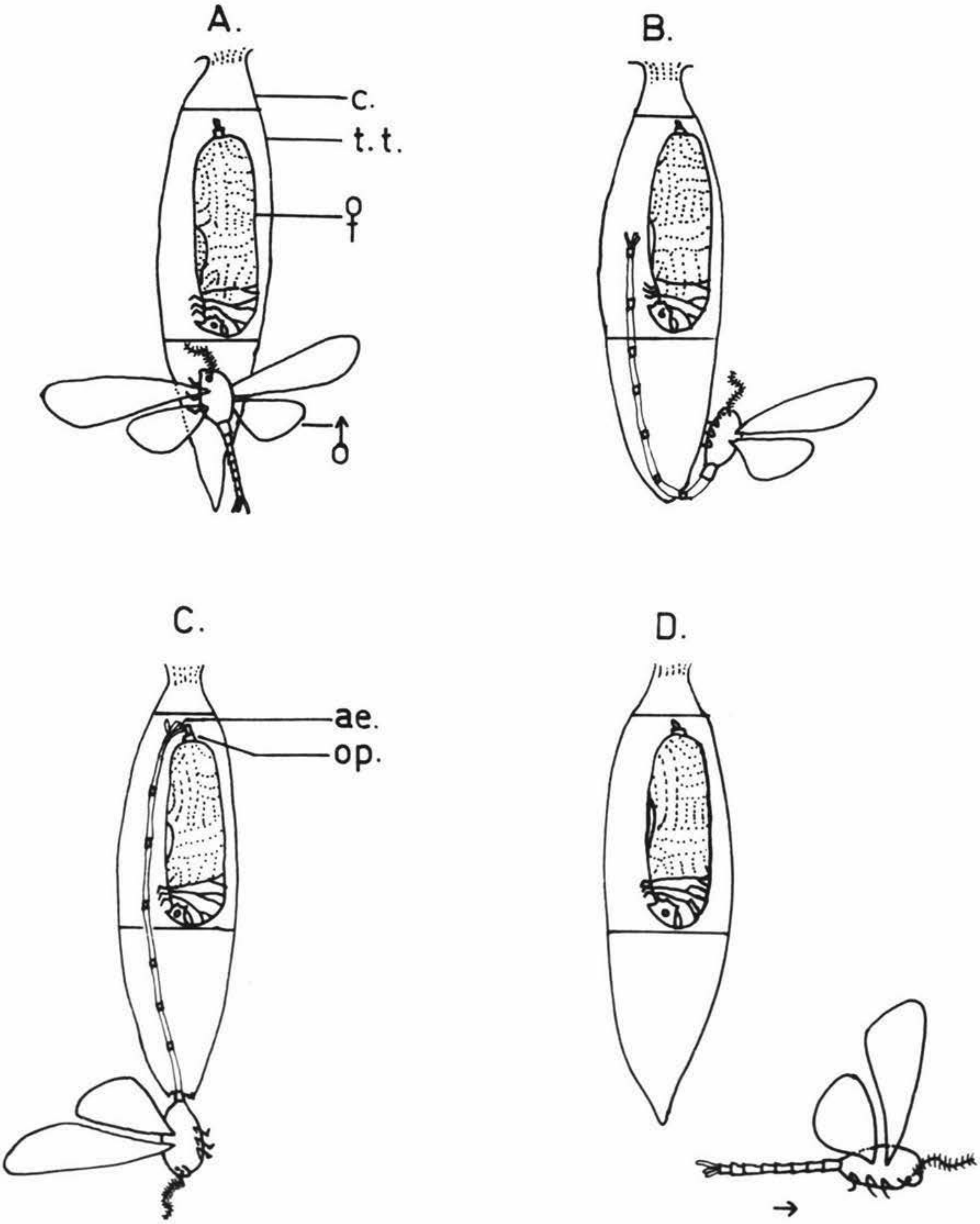
A - F = time sequence
d = dorsal aspect, l = lateral aspect, v = ventral aspect
an. = antenna
c. l. = cleavage lines
fcl. = frontoclypeus
le. = thoracic legs
n. = metanotum

FIG. 72. EMERGENCE OF FEMALE IMAGO, DORSAL ASPECT.



A–D = time sequence
ab. s. = abdominal segment
c. l. = cleavage line
f. i. = female imago
h. c. = head capsule
m. = mesonotum
n. = metanotum
p. = pronotum
p. c. = pupal case

FIG. 73. COPULATION OF IMAGOES AS OBSERVED IN THE BREEDING CAGE.



A - D = copulation sequence
ae. = aedeagus
c. = case
op. = ovipositor
t.t. = transparent tape

intersegmental membranes of the male abdomen allowed it to extend the entire length of the female's body before coming into contact with the female genitalia. This process took three minutes. The male became quiescent and was suspended with its head downwards. After five and a half minutes, the abdomen was withdrawn and the male flew away.

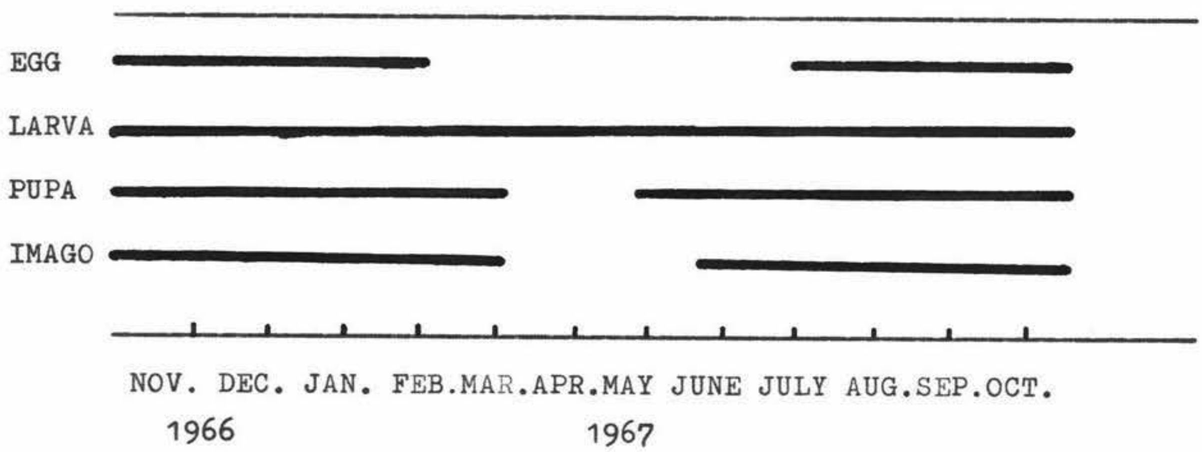
After copulation , the female crawled gradually out of the pupal case. The eggs were released from its ovipositor and gradually filled the upper cavity of the case until after four days the female abdomen became shrivelled up. The female finally dropped out of the pupal case and died in the external larval case. The eggs were closely packed together and were mixed with hairs from the abdomen of the female and with silk of unknown origin.

b. LONGEVITY - The adult male died in the cage forty two hours after its emergence. Females observed enjoyed a longer life and in the breeding cage one female died twenty six days after emergence.

SUMMARY OF THE LIFE HISTORY

The life-cycle of the species may be briefly represented by the accompanying diagram (fig. 74).

FIGURE 74. LIFE CYCLE OBSERVED AT PALMERSTON NORTH, 1966/67.



6. HOST PLANTS - The larvae have a wide host range. Cottier (1956) recorded seven host plants for the casemoth : manuka, willow, broom, *Cupressus macrocarpa*, *Pinus radiata*, *Cassinia*, and *Dracophyllum longifolium*, and a list of fifty host plants recorded during this investigation is given in table 9. Major hosts are considered to be those of which 60 - 100% of the plants observed were infested, and the minor hosts those in which only 1 - 29% of the plants were infested. Further observations will undoubtedly bring more host plants to light. Of the hosts recorded 86% were exotic and 14% indigenous, 88% evergreen, and 12% decidous. As such a high percentage of the host plants recorded are exotic, it is clear that *L. omnivora* has rapidly and successfully adapted to the introduced plants and has not developed specific attachments to limited numbers of indigenous plants.

In order to examine the distribution pattern of larvae on their host plants, numbers of larval cases collected in 10 minutes from the upper, middle, and lower thirds, and on the north and south sides of sixteen Scotch brooms on the Massey University campus were counted (table 10 A). Chi-squared tests were used to calculate probability values (tables 10 B - E) which indicate that there is no significant deviation in the distribution of larval cases between (1) north and south sides, (2) upper and middle thirds, (3) lower and middle thirds, and (4) upper and lower thirds of the host plants.

7. NOTES ON BEHAVIOUR

FIRST INSTAR LARVAE - The abdominal and anal prolegs of the larvae are provided with hooks which hook into the silken linings of the cases. The abdomens of the newly-hatched larvae are carried elevated at almost right angles to the thorax (fig. 75A). After construction of a completed case, the abdomens are still carried upright, but as the larvae grow, the cases are enlarged correspondingly, and because of the increased weight, are carried in a pendant manner with the larvae clinging to a support by means of their well-developed thoracic legs, (fig. 75B).

PROTECTIVE BEHAVIOUR - When disturbed, larvae quickly withdraw into their cases whose anterior ends are then grasped by the thoracic legs and mandibles and closed, so providing the larva with greater protection.

CASE REPAIRING - The younger the larvae, the shorter the length of

TABLE 9. HOST PLANTS RECORDED AT PALMERSTON NORTH IN 1966/67.

Scientific name	Common name	Significance	Indigenous or Exotic	Evergreen or Deciduous
1. Cupressus lusitanica Benthami	Cedar of Goa	Major Host	Exotic	Evergreen
2. Thuja plicata D. Don	Western red cedar of North America	" "	"	"
3. Cedrus deodara Laws.	Indian cedar	" "	"	"
4. Cupressus macrocarpa Hartw.	Monterey cypress	" "	"	"
5. Quercus robur L.	English oak	" "	"	Deciduous
6. Chamaecyparis lawsonianea Ellwoodi	Lawson's cypress	" "	"	Evergreen
7. Juniperus squamata 'Meyeri'	-	" "	"	"
8. Juniperus communis L.	Common juniper	" "	"	"
9. Erica vagans L.	Cornish heath	" "	"	"
10. Erica darleyensis Bean	-	" "	"	"
11. Podocarpus hallii Kirk	Mountain-totara	" "	Indigenous	"
12. Cytisus scoparius Link	Scotch broom	" "	Exotic	"
13. Berberis vulgaris L.	Barberry	" "	"	"
14. Acacia dealbata Link	Silver wattle	" "	"	"
15. Salix babylonica L.	Weeping willow	Intermediate Host	"	Deciduous
16. Pinus radiata D. Don	Monterey pine	" "	"	Evergreen
17. Juniperus chinensis L.	Chinese juniper	" "	"	"
18. Hypericum calycinum L.	Rose of Sharon or Aaron's beard	" "	"	"
19. Cupressus sempervirens L.	Italian cypress	" "	"	"
20. Cupressus arizonia Greene	Arizona cypress	" "	"	"
21. Chamaecyparis pisifera Endl	Sawara cypress	" "	"	"
22. Chamaecyparis lawsoniana v. Duncanii	Lawson's cypress	" "	"	"
23. Cryptomeria japonica 'Elegans Aurea'	-	" "	"	"

24. Santolina chamaecyparissus L.	Lavendar cottan	" "	"	"
25. Leptospermum scoparium J.R. et G. Forst	Tea tree	" "	Indigenous	"
26. Dodonaena viscosa L.	Akeake	" "	"	"
27. Cupressus torulosa D. Don	Himalayan cypress	" "	Exotic	"
28. Cedrus atlantica 'Glauca'	Atlas Mountain cedar	Minor host	"	"
29. Thuja occidentalis 'Rheingold'	Northern white cedar	" "	"	"
30. Chamaecyparis obtusa 'Nana Aurea'	Hinoki cypress	" "	"	"
31. Taxus baccata 'Fastigiata'	Irish yew	" "	"	"
32. Kunzea baxteri	Kunzea	" "	"	"
33. Cassinia fulvida Hook. f.	Golden bush	" "	Indigenous	"
34. Escallonia macrantha Hook. & Arn	-	" "	Exotic	"
35. Podocarpus dacrydioides A. Rick	New Zealand white pine	" "	Indigenous	"
36. Adenandra fragrans	-	" "	Exotic	"
37. Lophomyrtus obcordata (Raoul) Burret	-	" "	Indigenous	"
38. Myrtus ralphii Hook. f. Lophomyrtus bullata (Sol. ex A. Cumm) Burret L. obcordata	-	" "	"	"
39. Mahonia aquifolium	Oregon grape	" "	Exotic	"
40. Beaufortia sparsa	Swamp bush myrtle	" "	"	"
41. Rosa Moyesii Hemsl. & Wils.	-	" "	"	"
42. Rosa damascena Mill.	Damask rose	" "	"	"
43. Chamaecyparis obtusa 'Crippii'	Hinoki cypress	" "	"	"
44. Cassia corymbosa Lam.	-	" "	"	"
45. Phebalium squameum	Satinwood	" "	"	"
46. Cydonia sp.	Quince	" "	"	Deciduous
47. Pyrus malus L.	Apple	" "	"	"
48. Prunus persica Stokes	Peach	" "	"	"
49. Citrus sp.	Orange	" "	"	Evergreen
50. Prunus armeniaca L.	Apricot	" "	"	Deciduous

TABLE 10A. DISTRIBUTION OF LARVAL CASES IN <u>CYTISUS SCOPARIUS</u> (SCOTCH BROOMS).

Plants				Number of larval cases counted in 10 minutes					
				North			South		
Number	Height (ft.)	Diameter (ft.)	Height at which foliage begins (ft.)	Lower third	Middle third	Upper third	Lower third	Middle third	Upper third
1	6	5	3	6	12	5	6	4	3
2	5	4	2	2	2	3	7	6	4
3	14	6	2	6	12	4	3	8	6
4	4	3	3	4	3	1	2	6	2
5	8	4	1	11	8	13	5	4	1
6	10	8	2	2	10	5	7	6	0
7	7	6	2	2	1	2	3	4	1
8	9	6	1.5	5	3	12	4	2	6
9	14	8	2	9	20	6	5	1	2
10	6	2	2	1	3	2	2	4	0
11	16	7	1	5	7	3	3	8	2
12	15	6	1	3	6	5	6	8	5
13	7	4	0	10	2	6	8	2	5
14	8	8	0	4	6	2	2	8	3
15	16	8	1	6	9	4	2	5	6
16	15	7	0	3	5	6	2	7	4
	Total			79	109	79	67	83	50

TABLE 10B. COMPARISON OF DISTRIBUTION OF LARVAL CASES BETWEEN NORTH AND SOUTH SIDES OF HOST PLANTS.

		Divisions of host plants		
	Lower	Middle	Upper	Total
Observed (O) = South	89	111	67	267
Expected (E) = North	79	109	79	267
Deviation (D)	+ 10	+ 2	- 12	
$\frac{D^2}{E}$	$\frac{100}{79}$	$\frac{4}{109}$	$\frac{144}{79}$	
χ^2	1.2650	0.0367	1.8230	
P	0.25-0.50	0.10-0.25	0.75-0.90	

Probability values = 0.10 - 0.90, $\therefore$ no significant deviation in the distribution of larval cases between north and south sides was observed.

TABLE 10C : COMPARISON OF DISTRIBUTION OF LARVAL CASES BETWEEN UPPER AND MIDDLE THIRDS OF HOST PLANTS.

	Aspect of host plants		
	North	South	Total
Observed (O) = Middle third	73	56	129
Expected (E) = Upper third	79	50	129
Deviation (D)	- 6	+ 6	
$\frac{D^2}{E}$	$\frac{36}{79}$	$\frac{36}{50}$	
χ^2	0.4557	0.7200	
P	0.30 - 0.50	0.30 - 0.50	

Probability values = 0.30 - 0.50, $\therefore$ no significant deviation in the distribution of larval cases between upper and middle thirds was observed.

TABLE 10D : COMPARISON OF DISTRIBUTION OF LARVAL CASES BETWEEN LOWER AND MIDDLE THIRDS OF HOST PLANTS.

	Aspect of host plants		
	North	South	Total
Observed (O) = Middle third	83	63	146
Expected (E) = Lower third	79	67	146
Deviation (D)	4	- 4	
$\frac{D^2}{E}$	$\frac{16}{79}$	$\frac{16}{67}$	
χ^2	0.2025	0.2388	
P	0.50 - 0.70	0.50 - 0.70	

Probability values = 0.50 - 0.70, ∴ no significant deviation in the distribution of larval cases between lower and middle thirds was observed.

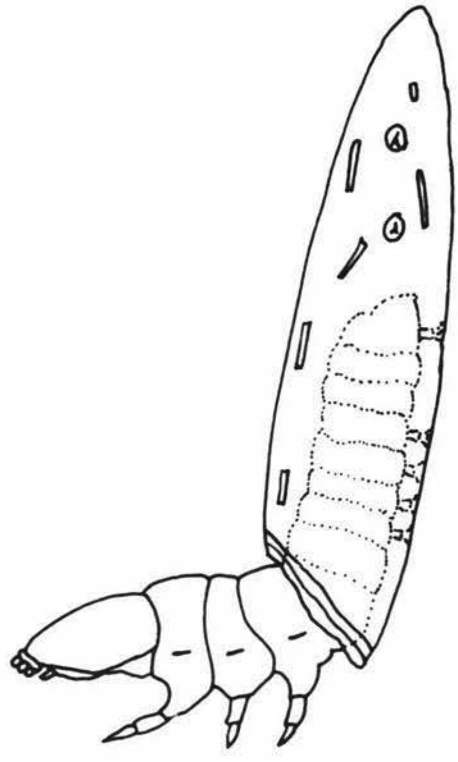
TABLE 1OE : COMPARISON OF DISTRIBUTION OF LARVAL CASES BETWEEN UPPER AND LOWER THIRDS OF HOST PLANT.

	Aspect of host plants		
	North	South	Total
Observed (O) = Lower third	70	59	129
Expected (E) = Upper third	79	50	129
Deviation (D)	- 9	+ 9	
$\frac{D^2}{E}$	$\frac{81}{79}$	$\frac{81}{50}$	
χ^2	1.0253	1.6200	
P	0.30 - 0.50	0.20 - 0.30	

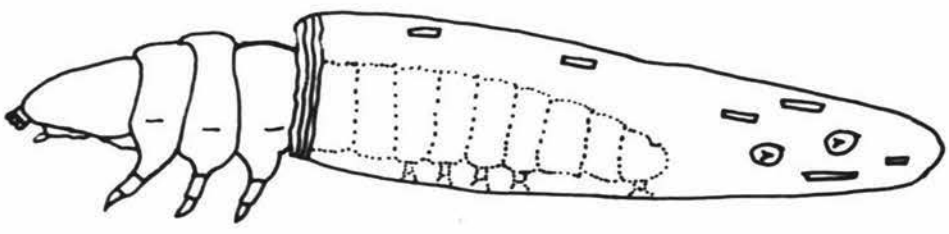
Probability values = 0.20 - 0.50, $\therefore$ no significant deviation in the distribution of larval cases between upper and lower thirds was observed.

FIG. 75 ATTITUDE OF FIRST INSTAR LARVA.

A. WITH TAIL ELEVATED.



B. WITH TAIL PENDANT.



time required for repairing cases which were cut throughout the length on one side (table 11).

TABLE 11 : TIME REQUIRED BY LARVAE TO REPAIR CASES WHICH WERE CUT THROUGHOUT THE LENGTH ON ONE SIDE.

Time required for case repairing.	Experimental groups		
	3rd instar (20)	5th instar (20)	7th instar (20)
Mean hours	6.5	16	30
Range hours	1 - 12	6 - 26	12 - 48

N.B. Numbers in parentheses indicate numbers of larvae used.

<u>LATE INSTAR LARVAE</u> - Generally penultimate instar larvae move with their cases from tree tops or edges of lines of trees to less conspicuous places, such as tree trunks and the proximal ends of branches. In these places they spin a tight band of silk (0.5 - 6.5 mm. wide) around a twig or apply the necks of the cases to tree trunks by firmly fastening all around. The anterior ends of the cases are filled with silk and form strong cords that prevent the cases from being swayed by strong winds. Feeding of the larvae ceases, and the larvae then turn round so that they face the lower ends of the cases. The larvae then moult into the final instar larvae.

The male final instar larvae are yellow in colour throughout the prepupal stage but female final instar larvae become yellow only for 2 - 3 days after pupation. The larvae secrete a loose irregular webbing of silk between the posterior aperture of the case and the head of the larva. This allows the male moth to escape, or the abdomen of the male to enter the female case for copulation. No true cocoon is constructed inside the case. However, an additional layer of silk is spun and attached to the inside of the case, giving it added strength.

PUPA - The male and female pupae exhibit jerky wave-like dorso-ventral movements when their cases are cut open. These movements also occur when wind is blown across the pupae or when their bodies are touched by a probe.

ADULT - At rest the adult male folds its front wings over the hind wings in a posterolateral direction. Often the abdomen is held vertically as in the early larva. When held horizontally, the abdomen aften actively elongates and contracts. When at rest the adult female contracts its thorax at intervals causing a wave of movement to pass from the thorax down the abdomen. The adults have vestigial mouthparts and do not feed.

CHAPTER IV

EXPERIMENTAL STUDIES ON CASE BUILDING AND CASE FUNCTION

INTRODUCTION

Experiments were designed to discover :

A. 1. How larvae construct their cases.

2. How long larvae take to construct their cases.

3. Whether or not larvae of different size groups differ in their ability to construct their cases.

4. Whether or not the original and later constructed cases differ.

5. Whether or not larvae have preferences for particular building materials.

B. 1. What effects removal of the case has on living larvae, including any effects on maintaining water relations of the larvae.

MATERIALS AND METHODS

CASE BUILDING AND FUNCTIONS

(a) Forty larvae of each of three size (age) groups, small (3rd instar), medium (5th instar), and large (ultimate, 7th instar), were collected from the host plant Cupressus lusitanica Benthami on the Massey University campus between 10th and 14th March, 1967.

Cases were removed from 20 larvae in each size group whereas the cases of another twenty larvae in each group were not removed. Larvae within their cases acted as control groups. Each larva was weighed before experimentation to 0.001 gram on a Mettler balance and its weight was recorded.

Each larva was placed on a small twig of the host plant, C. lusitanica placed in a small labelled bottle containing water. The bottle was placed in a beaker covered with nylon netting.

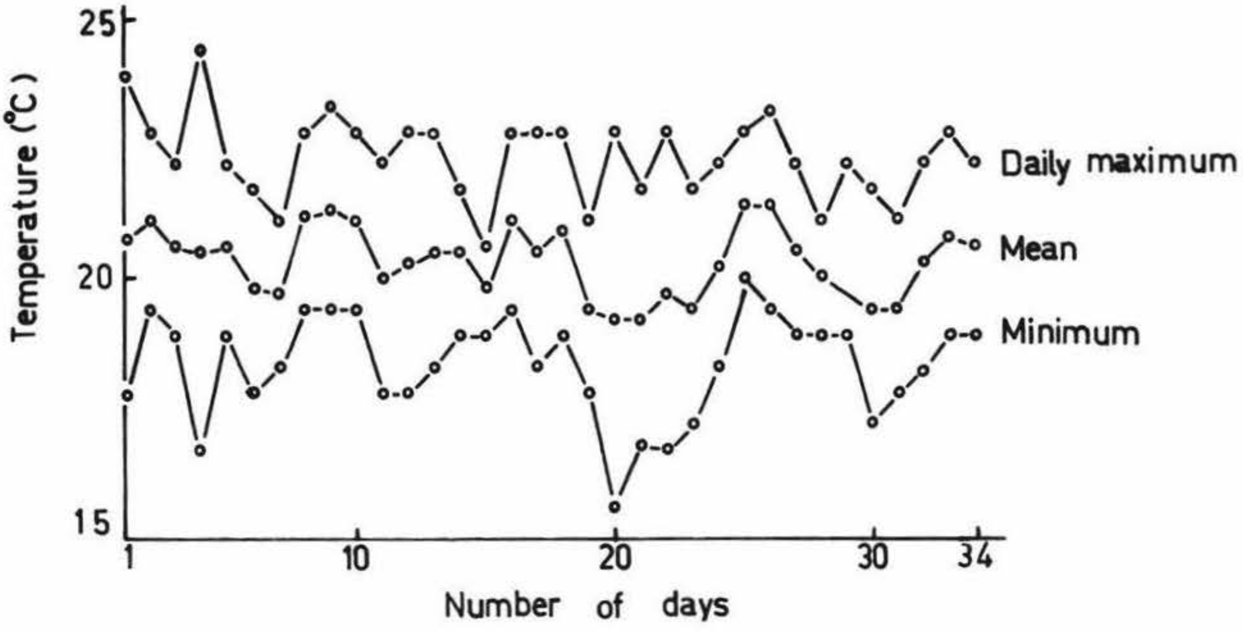
Larvae were removed from the beakers and weighed every 24 hours for a period of almost 5 weeks by which time almost all of the caseless larvae had died. During this period, twigs of host plants were replaced weekly.

Mean, maximum and minimum daily temperatures recorded in breeding cages in the laboratory during the period of experimentation are shown in figure 76. Maximum and minimum temperatures recorded were 24.4 and 15.6°C.

Direct observations on the process of case building were carried out in conjunction with this experimental programme. An Olympus stereoscopic microscope fitted with a ten times squared eyepiece was used in making all observations and drawings.

(b) Larvae representing the same 3 size groups used above were also used in a series of experiments designed to measure the effect of cases on water balance in the larvae. Before commencing an experiment, larvae were kept for 2 days at 92.5% relative humidity and at a constant temperature of 22.5°C. This was done by placing a

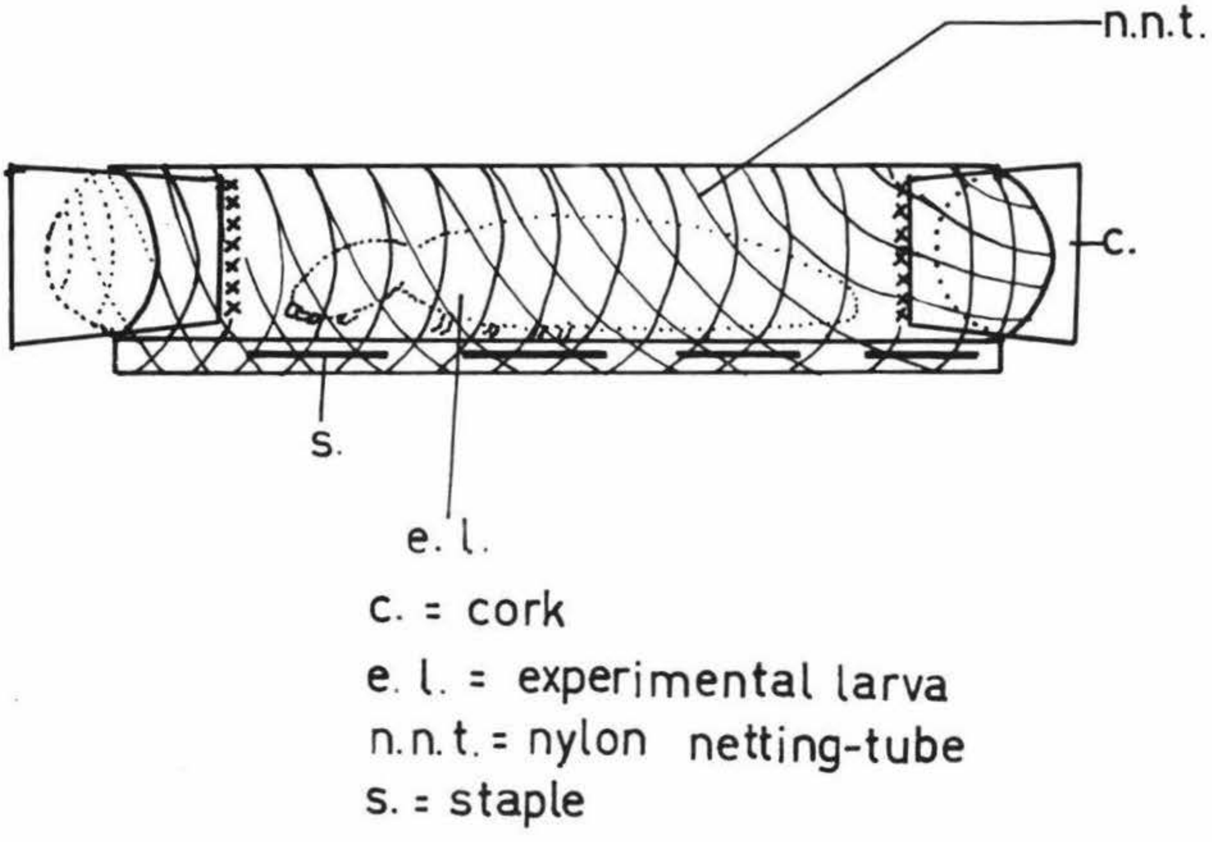
FIG. 76. TEMPERATURES RECORDED IN BREEDING CAGES DURING CASE BUILDING EXPERIMENTS.



glycerine-water mixture (1 : 1, V : V) in a breeding cage which was itself placed in an incubator. The glycerine mixture maintains a constant relative humidity in the cage. Continuous records of relative humidity and temperature were made on a hydrograph and temperature recorder placed inside the incubator. Larvae were starved for 24 hours before beginning experimentation. Starvation of the larvae should eliminate any unwanted variables introduced by feeding and the production of waste products. Immediately prior to the commencement of an experiment, cases were removed from 20 larvae belonging to the same age group. Small or medium-sized larvae could be removed from their cases with forceps, but with large larvae, the case had first to be cut open before the larva could be removed. Larvae and cases were weighed separately to the nearest 0.01 mg. on a Sartorius balance.

Half the larvae were then replaced in their cases, the slits in large cases being closed with transparent adhesive tape. Larvae without cases were placed in nylon netting-tubes (fig. 77) whose ends were stopped by small corks (protected from being chewed by the larvae, by a covering of nylon netting). The main function of the nylon netting-tubes was to prevent excessive activity of the larvae. When not in use corks and nylon were kept in a desiccator at 0% relative humidity. On commencing the experiment, larvae in cases and nylon netting-tubes, as well as empty cases, were transferred to a dessicator, in an atmosphere of 0% R.H., maintained by calcium chloride and potassium hydroxide pellets. Dessicators were placed in a cool incubator for 13 hours at a constant temperature of 16.5°C. As the incubator was dark inside, the effect

FIG. 77. LARVA IN NYLON NETTING-TUBE.



of changes of light on activity of the larvae are avoided. At the end of the experiment, larvae and cases were removed from the desiccators, larvae were removed rapidly from their cases or netting tubes and weighed. Empty cases were also weighed. Since the process of weighing takes only 40 seconds, loss or gain of water from the air by larvae or cases should be negligible. The difference in weights of larvae and cases before and after the experiments was then calculated.

All experiments, on each size group of larvae were carried out in triplicate. The same experiments were repeated at 100% R.H., maintained by placing the lower half of a sheet of saturated filter paper in a layer of distilled water around the inside of the desiccator. All other factors were identical to those at 0% R.H.

In the above experiment with living larvae, a considerable amount of water uptake and loss by the tracheal system would be controlled by the spiracles closing mechanisms. In order to determine the effect of spiracular activity on water loss, further experiments were carried out at 0% R.H., with relaxed specimens, freshly killed with ethyl acetate and having the spiracular openings fully open (Bursell, 1959). Before experimentation they were kept for 10 hours in air of 92.5% R.H. at 22.5°C. to allow full relaxation of spiracular muscles.

RESULTS AND DISCUSSION

THE CASE - The cases are smooth, cylindrical, greyish-brown, and ornamented longitudinally with pieces of host plant. The diameters of the cases increase towards the mouth ends. Both extremities of the cases are open and usually very flexible for a short distance from either end, thereby facilitating the closing of the two apertures by the larvae inside.

The cases of different instar larvae are shown in figure 78. In general, the larger the cases, the larger the size of ornamental materials used in constructing them. Adornment of cases is normally a gradual process. Occasionally fully grown cases may not be ornamented.

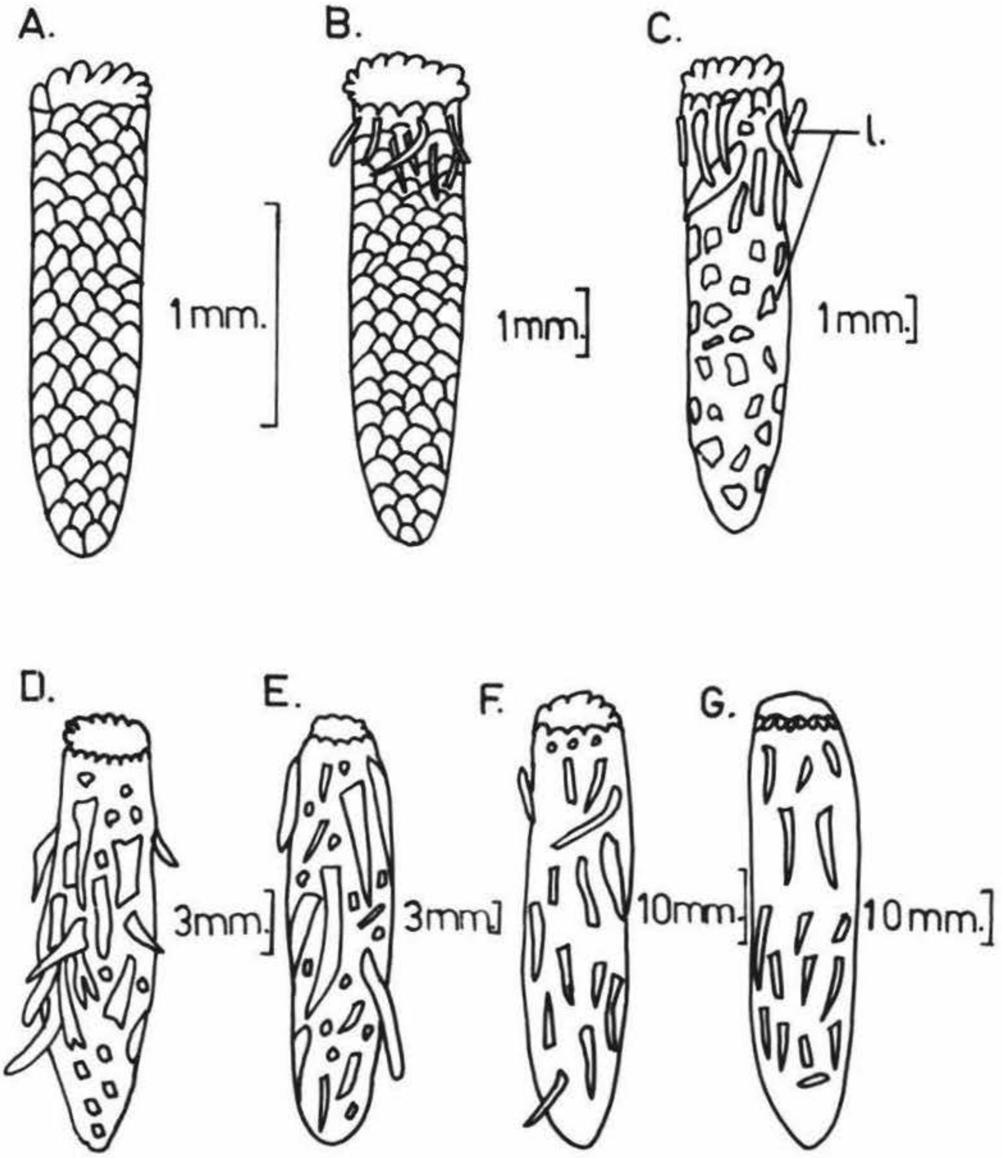
Forty three of the 3,565 cases collected were compound cases - cases each comprising a main case with one or more than one empty cases attached (fig. 79). Five cases examined had three small cases attached to the main case, fifteen had two smaller cases attached to the main one, and the remaining twenty three cases had single small cases attached to them. In all cases observed, only the main case was inhabited. These smaller, empty, attached cases have apparently been abandoned by other larvae.

CASE BUILDING

During the 5 week experimental growth programme, observations were made on the method of case construction, the time taken for case construction, and the ability of different instars to make cases. Comparisons between the structure and construction of original and later cases were also made and information on choice of building materials gained.

FIG. 78. CASES OF DIFFERENT INSTAR LARVAE COLLECTED FROM HOST PLANT, _J. SQUAMATA_.

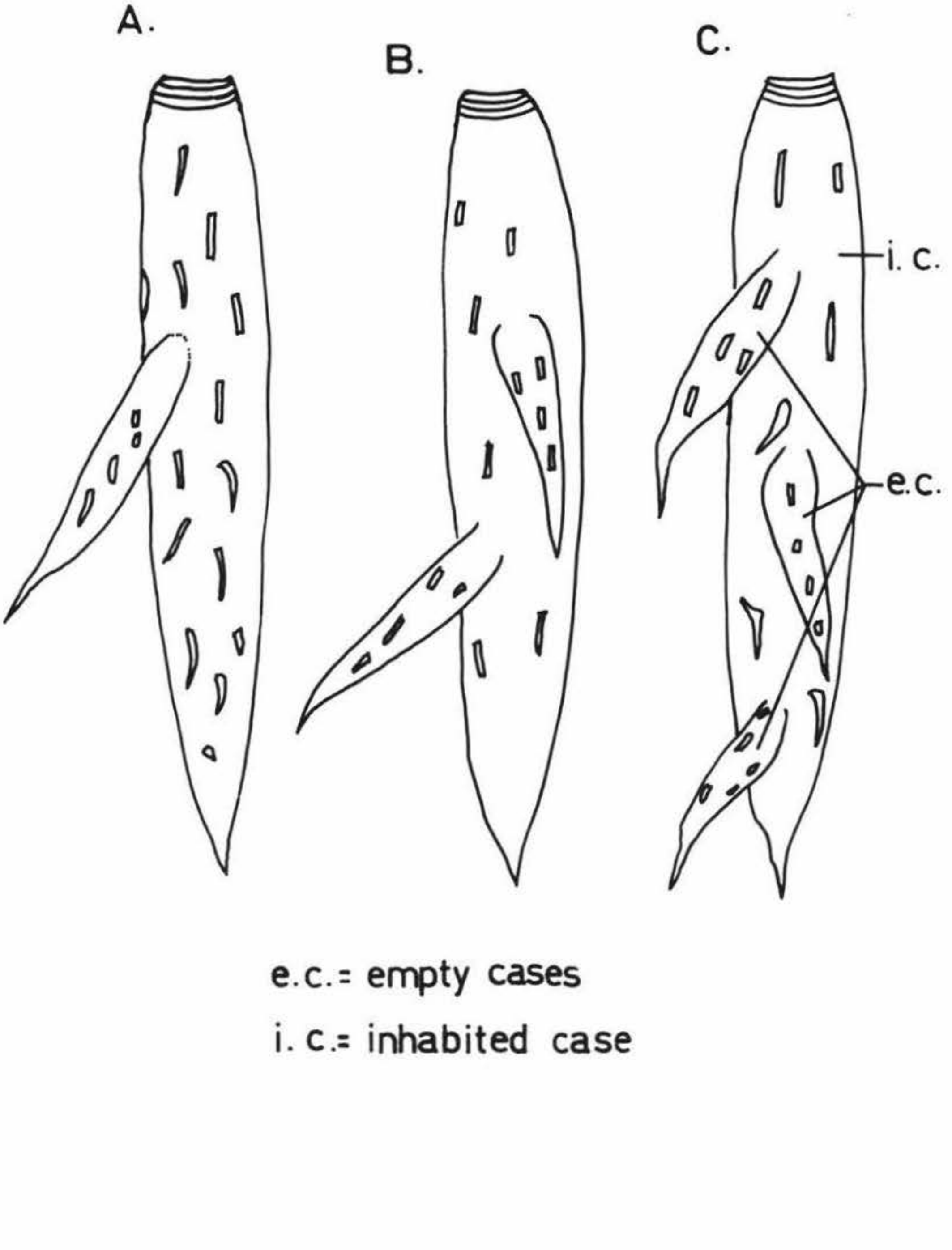
A. FIRST INSTAR CASE, B. SECOND INSTAR CASE, C. THIRD INSTAR CASE, D. FOURTH INSTAR CASE, E. FIFTH INSTAR CASE, F. SIXTH INSTAR CASE, AND G. SEVENTH INSTAR CASE.



l.= leaf fragments

FIG. 79. COMPOUND CASES OF LARVAE.

A. SINGLE CASE ATTACHED, B. TWO CASES ATTACHED, C. THREE CASES ATTACHED.



(a) METHOD OF CASE BUILDING

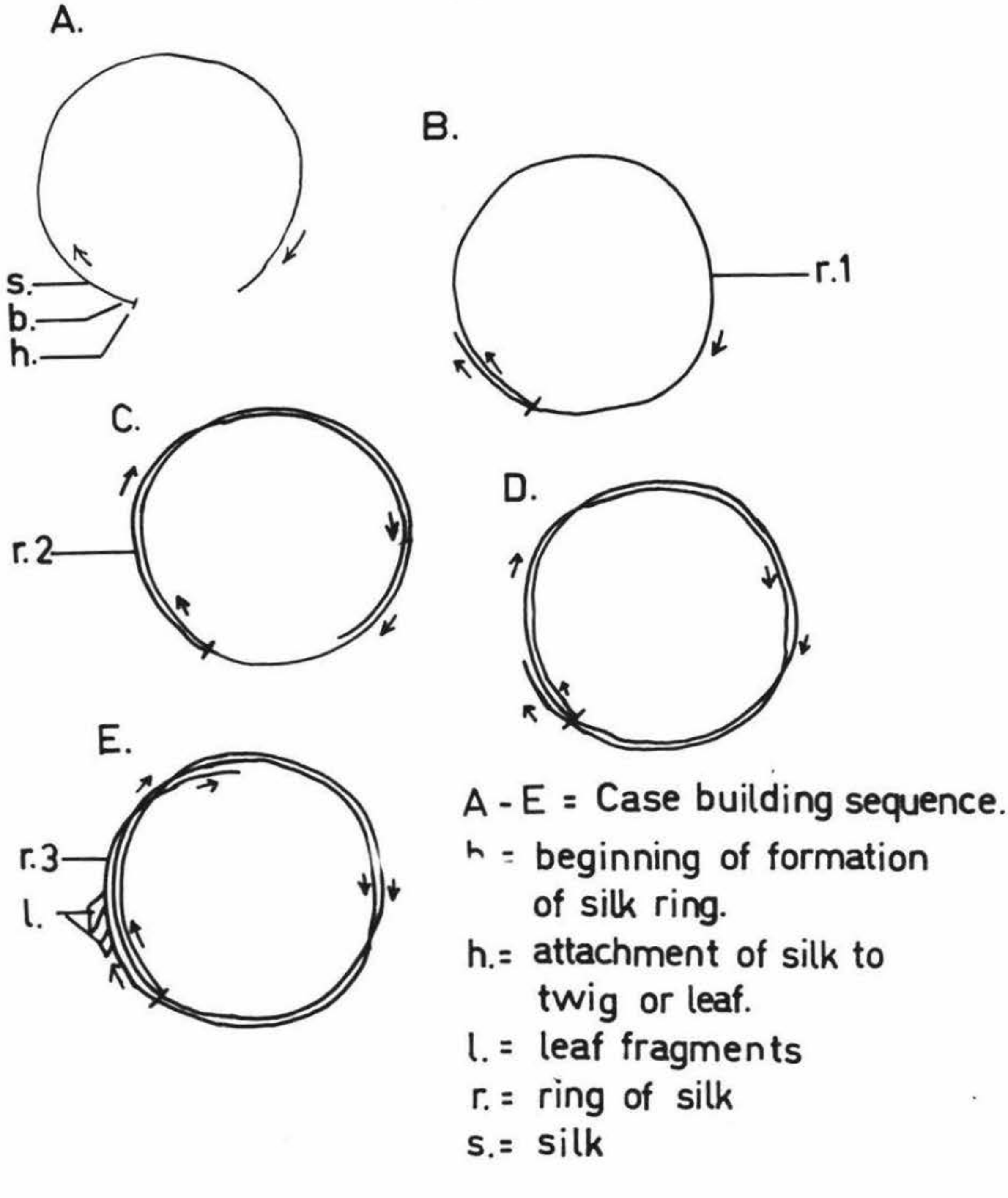
One hour after the experiment had started, 12 out of the 20 3rd instar caseless larvae began to cut off pieces of leaves (0.5 - 1.0 mm. long) with their mandibles, and each larva weaved pieces of leaves together with silk spun from the labial glands to form a ring around its neck. Successive rings were then added to the anterior end of the first ring until a conical case was formed (fig. 80).

As the experiment was set up in the evening, the time for only two small larvae to complete case construction was recorded. These two larvae took 3 and 4 hours respectively. All remaining larvae took more than 4 hours to complete their cases and when observations were made 12 hours after the experiment had been begun all had completed case construction.

Two fifth instar caseless larvae started case building 24 hours after experimentation commenced. One died after 25 days and had constructed only a quarter of its new case, whereas the other completed its case after 7 hours. During the third day after beginning the experiment, two further 5th instar larvae started case building. One made a complete case within 8 hours, but the other died after 19 days its case being made of a ring of silk only. The two 5th instar larvae, which made complete cases used identical methods to those employed by 3rd instar larvae.

Of the 7th instar caseless larvae, two started case building 24 hours after the experiment began, another three began 24 hours later, and another two after 72 hours. None completed case construction and all eventually died. The incomplete cases made by 7th instar larvae were similar to those made by the unsuccessful

FIG. 80. THE METHOD OF CASE BUILDING BY LARVA ILLUSTRATED DIAGRAMMATICALLY.



5th instar larvae.

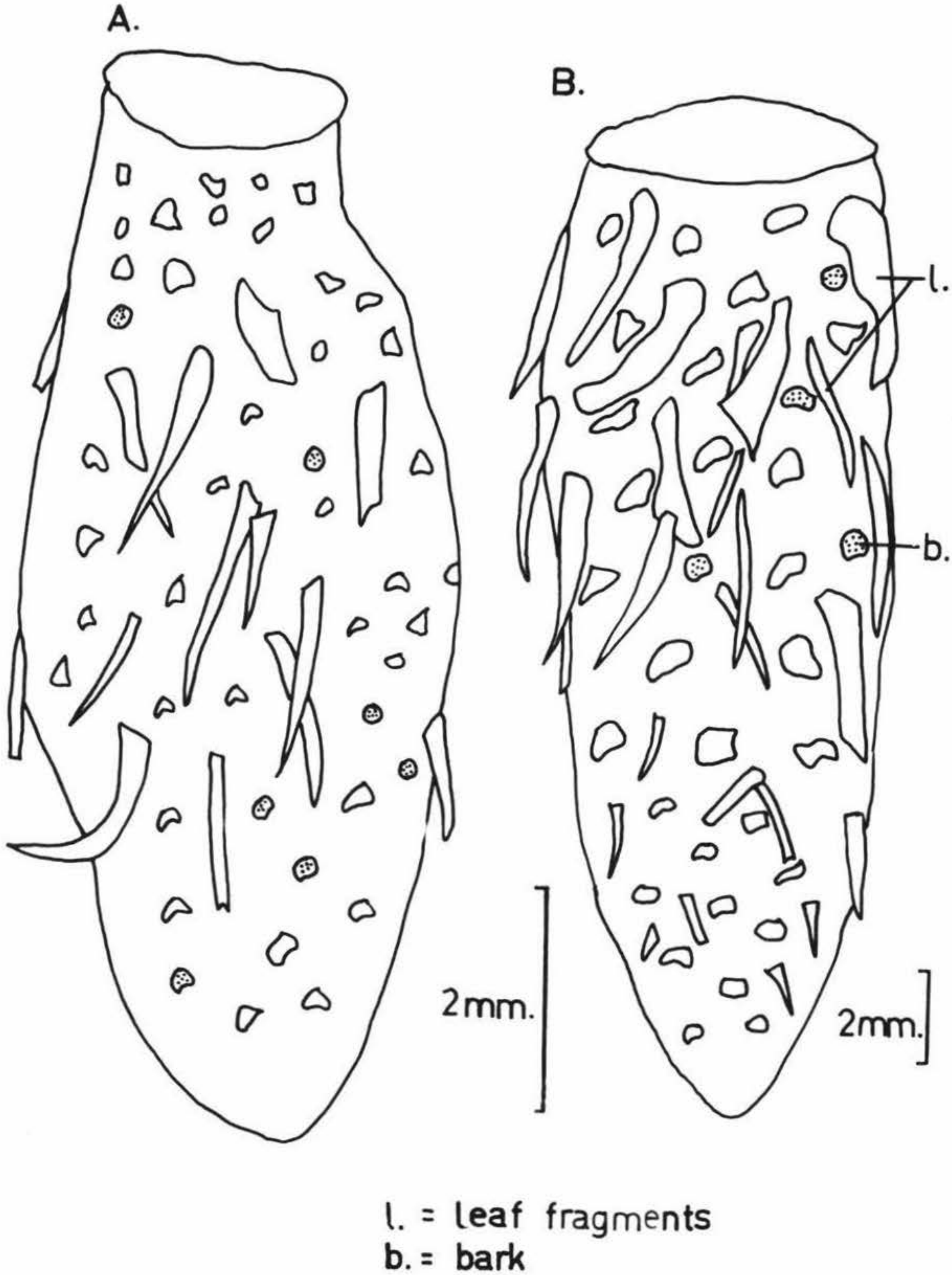
Percentages of small, medium, and large experimental larvae that made complete new cases were 60, 10 and 0 respectively. This seems to indicate that the younger the larvae, the greater is their case-building capacity.

Unlike original cases, secondarily developed cases are very soft, and their anterior ends have a relatively larger diameter. Because of their softness the anterior and posterior ends of these cases can be pressed together more easily than the ends of original cases.

In the laboratory, pieces of leaves and occasionally the bark of twigs were the main items used in case construction (Fig. 81), and grass is also used when supplied. Small irregular pieces of leaves or bark were used by both 3rd and 5th instar larvae. These pieces ranged in size from 0.14 - 0.56 mm. for the small larvae to 0.70 - 1.60 mm. for the larger ones. The smallest experimental larvae attached mainly lanceolate pieces of leaves ranging from 1.20 - 3.12 mm. in length to their cases in a longitudinal manner (fig. 81A). The number of pieces of building material used by each 3rd instar larva for a completed case during the 5-week experimental period ranged from 16 to 36. Fifth instar experimental larvae also mainly utilized lanceolate pieces of leaves ranging from 2.22 - 6.25 mm. in length, again attaching them longitudinally to their cases. The number of pieces of building materials used by each 5th instar larva during the 5-week experimental period ranged from 20 to 47 for complete cases.

(b) EFFECTS OF CASE REMOVAL ON LIVING LARVAE

FIG. 81. A. SECONDARY CASE OF THIRD INSTAR LARVA, B. SECONDARY CASE OF FIFTH INSTAR LARVA.



Mean weights of 3rd, 5th and 7th instar larvae were recorded daily throughout the experimental period and the life span of the larvae after case removal was determined.

Mean weights of the larvae of the different size groups during the experimental growth period are shown in figure 82. Since the experiment lasted 33 days, a slight growth increase would be expected to occur although of minor importance as no ecdyses occurred during this time. The life span of larvae of the 3 size groups after case removal is shown in table 12.

TABLE 12. DURATION OF LIFE OF LARVAE AFTER CASE REMOVAL.

	Experimental groups		
Life span	3rd instar (20)	5th instar (20)	7th instar (20)
Mean days	19.5	17.5	23
S.D. days	11.04	8.75	12.89
Range	6 - 33	3 - 32	2 - 44

N.B. Numbers in parentheses show the numbers of animals used.

For the duration of the experiment the mean weights of all larvae decreased, caseless larvae showing a slightly greater weight loss than those with cases. There is no apparent difference in survival time of larvae of different sizes.

(c) CASE FUNCTION

As larvae deprived of cases lost a little more weight than

FIG. 82. WEIGHT LOSS OF LARVAE IN CASE BUILDING EXPERIMENTS.

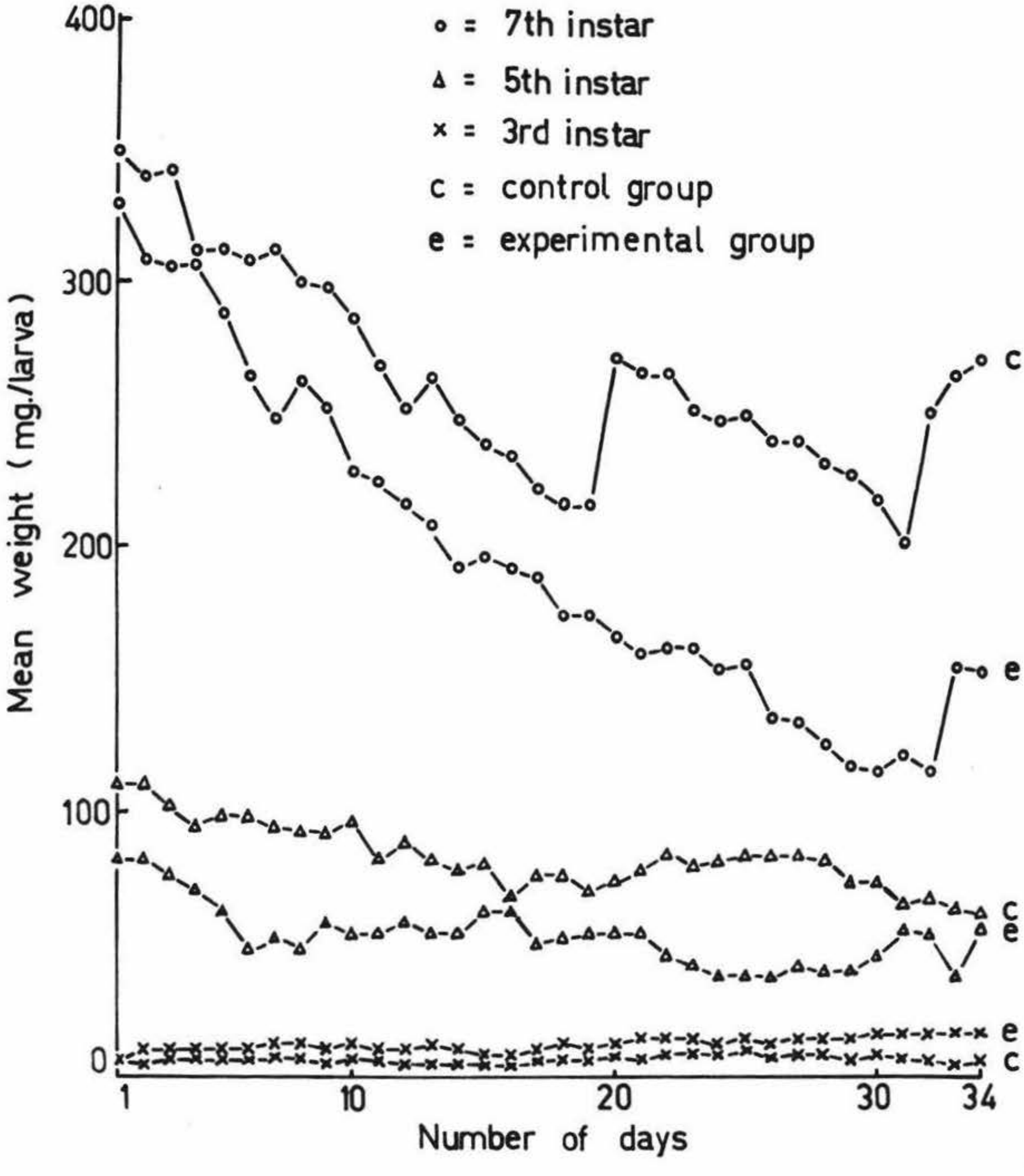


TABLE 13. EFFECT OF THE CASE ON THE WATER LOSS OF LARVAE.

Temp.	Relative humidity	Exptl. groups	State of larvae	Larval size groups	Numbers of larvae	Mean water loss (mg/larva/hr.)	S D mg/larva/hr.	Range mg/larva/hr.
16.5°C.	0%	Without cases	Living	3rd instar	60	0.104	0.010	0.093-0.110
				5th instar	60	0.581	0.193	0.371-0.757
				7th instar	60	2.177	0.759	1.333-2.803
			Recently killed	3rd instar	60	0.349	0.080	0.278-0.436
				5th instar	60	1.189	0.620	0.732-1.895
				7th instar	60	2.555	1.070	1.380-3.473
		With Cases	Living	3rd instar	60	0.096	0.035	0.066-0.135
				5th instar	60	0.466	0.301	0.232-0.805
				7th instar	60	1.885	0.656	1.134-2.347
			Recently killed	3rd instar	60	0.286	0.026	0.268-0.316
				5th instar	60	0.976	0.230	0.668-0.998
				7th instar	60	2.386	0.421	2.029-2.850
	100%	Without cases	Living	3rd instar	60	0.025	0.008	0.018-0.034
				5th instar	60	0.272	0.013	0.262-0.287
				7th instar	60	1.721	0.616	1.102-2.334
		With cases	Living	3rd instar	60	0.018	0.003	0.015-0.020
				5th instar	60	0.239	0.159	0.128-0.421
				7th instar	60	1.406	0.124	1.283-1.530

larvae retaining their cases it was postulated that this additional weight loss may result from greater desiccation facilitated by removal of the case. Experiments were thus carried out to examine this hypothesis.

Results of these water loss experiments are shown in table 13 and figure 83 and summarized in table 14.

TABLE 14. COMPARISON OF AMOUNTS OF WEIGHT LOSS BY LARVAE UNDER DIFFERENT CONDITIONS.

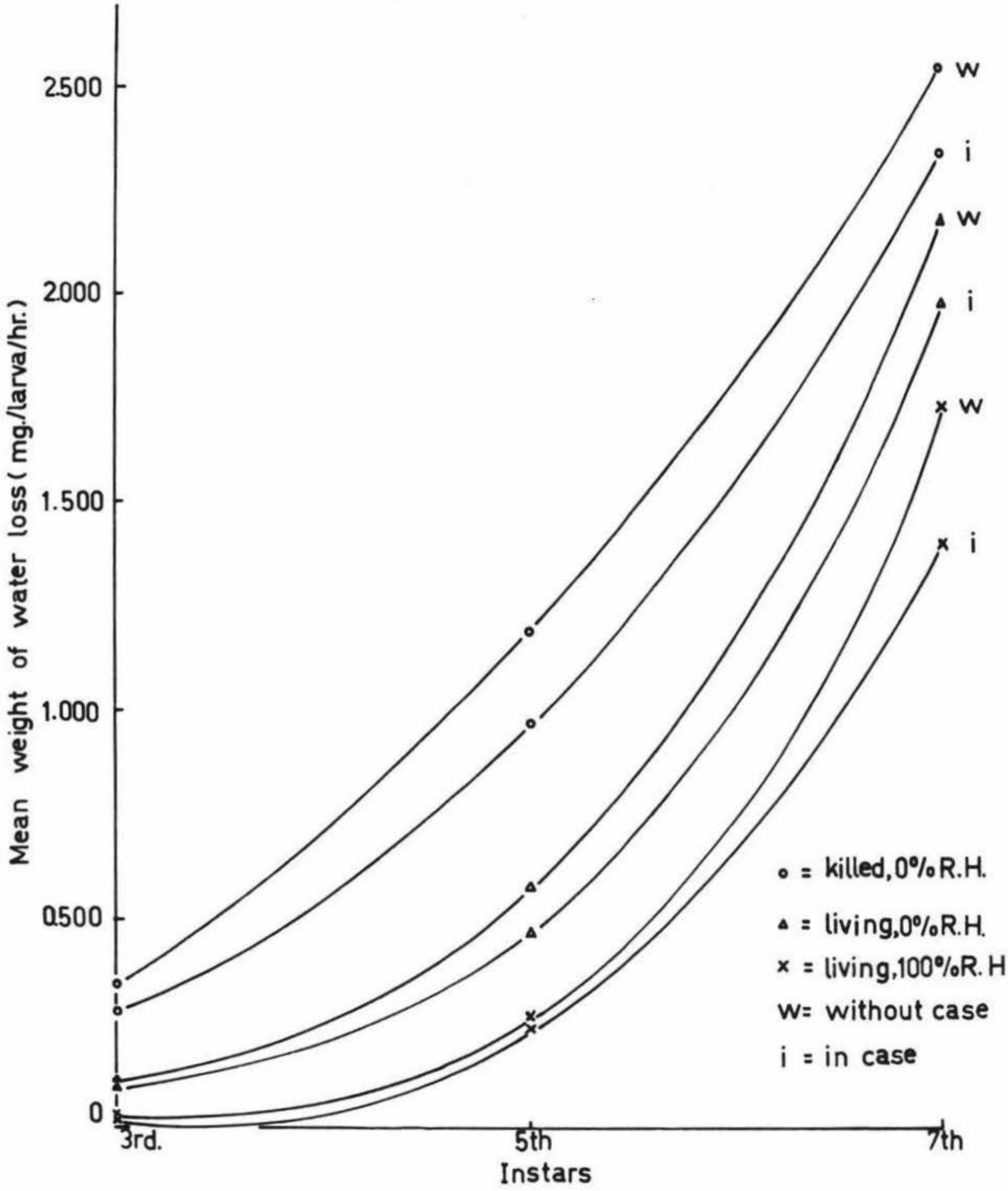
Increase in weight loss	Group of larvae	Condition
↓	100% RH with cases ↓	Living
	100% RH without cases ↓	Living
	0% RH with cases ↓	Living
	0% RH without cases ↓	Living
	0% RH with cases ↓	Freshly killed
	0% RH without cases ↓	Freshly killed

1. The larger the larvae the greater the weight loss.
2. More weight was lost with cases removed than with cases present when all other factors were identical.
3. More weight was lost in dry air than in saturated

4. More weight was lost in dead larvae than in living ones.

Using this information we may now infer : -

FIG. 83. EFFECT OF THE CASE ON THE MEAN WATER LOSS OF LARVAE.



1. Presence or absence of case affects weight loss.
2. Humidity of outside environment affects weight loss.
3. Spiracular activity controls water balance to a marked degree (from 4 above) and that a high percentage of water loss is from the tracheae.

A possible explanation of the importance of the case in water loss could be that water vapour is evaporated from the insect body and retained in the case so that the R.H. of the air in the case is always near saturation and normally greater than that in the outside air. In this way, the case may function to maintain a constant layer of moist air around the larva and so act as an important mechanism reducing the likelihood of desiccation. This could be of considerable importance in an insect which inhabits relatively exposed situations open to the wind as the larvae of casemoths often do.

CHAPTER V

PARASITES

The known parasites of casemoths include (1) Ichneumonidae, of which several species are larval parasites (2) parasitic Hymenoptera of the families Bethylidae, Braconidae, and Chalcidae, (3) parasitic Diptera of the families Sarcophagidae and Tachinidae, (4) a fungus Beauvaris bassiana Balsamo, and (5) a protozoan, Nosemo sp. (Davis, 1965). Zondag (1957) recorded the following parasites of L. omnivora.

Cerosomyia (Pharocera) feredayi (Hutton) (Diptera, Tachinidae),
C. marginata (") (" "),
C. nefaria (") (" "),
Echthromorpha intricatoria Fabr. (Hymenoptera, Ichneumonidae) and
Beauvaria sp. (fungus), and in this investigation the following parasites were recorded :

Pales marginata (Hutton) (Diptera, Tachinidae),
two Eupteromalus species (Hymenoptera, Pteromalidae),
E. intricatoria Fabr. (" Ichneumonidae),
an unidentified Ichneumon fly (" "), and
Beauvaria sp. (fungus).

OCCURRENCE OF PARASITES - Pales marginata, Eupteromalus spp., E. intricatoria, the unidentified Ichneumon fly and Beauvaria fungus attack the larval stage of L. omnivora. In addition, E. intricatoria and the Beauvaria fungus also attack the pupal stage.

Table 15 shows the percentages of larvae of L. omnivora examined, parasitised by P. marginata, Beauvaria fungus, unidentified Ichneumon fly, Eupteromalus spp. and E. intricatoria.

The percentage of parasitised pupae of L. omnivora in the same period was 19.61 (table 16), considerably lower than the larval figure.

(a) P. Marginata is the most common and abundant parasite. How the adults initially infect the larvae of L. omnivora was not found. Their larvae break through the hosts and after 4 - 9 days, pupate in the case of L. omnivora. From 1 - 18 of these parasites may be found in a single case. The pupa of E. marginata is enclosed in a brown barrel like puparium. The pupal stage lasts 2 - 3 weeks before the adults emerge and find their way out of the case through its posterior aperture.

(b). The Eupteromalus spp. are the smallest known parasites of L. omnivora (1.72 - 2.55 mm. long, maximum width 0.70 - 0.75 mm). Their larvae pupate either within or in close proximity to the remains of their hosts. The pupae change from white to black before emergence of the adults. Frequently they also parasitise pupae of the primary Dipteran parasite, P. marginata.

(c) The Ichneumon flies are longer than the Eupteromalus spp., the males being 3.35 - 3.50 mm., long and the females 4.05 - 4.20 mm., long. The adult females oviposit in the larval stage of the host by passing their ovipositors through the walls of the cases and into the host's larvae with their long (1.12 - 1.32 mm.) ovipositors.

TABLE 15 : PERCENTAGE OF PARASITISED LARVAE RECORDED AT PALMERSTON NORTH FROM 26 NOVEMBER, 1966 TO 26 JUNE, 1967.

Date of Collection.	Living larvae unparasitised.	Parasitised larvae							Dead larvae (unknown cause).
		By *Pales marginata*.	By *Eupteromalus* spp.	By Unidentified Ichneumon	By *E. intricatoria*.	By Multiple parasites	By Hyper-parasites	By Fungus *Beauvaria* sp.	
26 XI 1966	22	2	0	0	0	0	0	1	4
26 XII 1966	21	1	0	0	0	0	0	10	0
26 I 1967	14	39	0	0	0	2 Pm Ui	1 P m	10	36
26 II 1967	22	27	4	2	0	0	1 P m	11	25
26 III 1967	13	15	0	2	1	0	0	2	1
26 IV 1967	9	1	1	2	0	0	1 P m	0	8
26 V 1967	18	12	2	4	0	0	0	5	5
26 VI 1967	21	8	2	8	0	0	0	9	12
Total	140	105	9	18	1	2	3	48	91
% Parasitised		25.18	2.16	4.32	0.24	0.48	0.72	11.51	
Total % of parasitised larvae = 44.60%									

N.B. P m - *P. marginata* acted as a primary parasite. Ui - Unidentified Ichneumon acted as a primary parasite.

TABLE 16 : PERCENTAGE OF PARASITISED PUPAE RECORDED AT PALMERSTON NORTH FROM 26 NOVEMBER 1966 TO 26 JUNE 1967.

Date of collection	Living pupae unparasitised		Parasitised pupae: By *E. intricatoria*		Parasitised pupae: By *Beauvaria* sp. (fungus)		Empty pupal cases		Dead pupae (unknown cause).	
26 XI 1966	0	2	0	1	0	1	0	0	0	0
26 XII 1966	0	2	0	6	2	0	0	0	0	0
26 I 1967	3	0	0	0	0	0	5	7	0	0
26 II 1967	4	2	0	1	0	0	1	3	1	0
26 III 1967	3	0	0	5	0	0	1	6	0	0
26 IV 1967	0	0	0	3	0	0	0	1	2	0
26 V 1967	28	3	2	3	0	0	6	3	1	2
26 VI 1967	4	9	0	5	0	1	4	14	6	0
Total	42	18	2	24	2	2	17	34	10	2
% parasitised			1.31	15.69	1.31	1.31				
Total % parasitised = 19.61										

The parasitic larvae break through the body wall of the host larvae and after 1 - 2 weeks pupate in the case. Pupae are enclosed in yellowish, barrel like cases. These pupal cases are usually found in aggregates bound together by white silk, and up to 41 parasites have been found in one case of L. omnivora. The pupal stage lasts 2 - 3 weeks before the adults emerge.

(d) E. intricatoria usually parasitises the pupal stage of L. omnivora (Gourlay, 1926) by ovipositing through the case (Zondag, 1957). But in this study it was also found attacking the larval stage of L. omnivora (table 15). The parasite completes its life history within the pupal or larval stage of the host before its emergence and in all cases observed only one adult E. intricatoria emerged from each pupa of L. omnivora. E. intricatoria is also known to parasitise the pupae of other lepidoptera (Gourlay, 1930).

(e) MULTIPLE PARASITES. Not infrequently, more than one species of parasite may occur in the case of L. omnivora. For example, a P. marginata puparium and 32 pupal cases of the unidentified Ichneumon fly were found in the same case.

(f) HYPERPARASITES. Eupteromalus spp. have been found parasitising the important primary parasite P. marginata and on 26 January 1967, 129 adult chalcids emerged from twelve P. marginata puparia which had been removed from a case of L. omnivora. Each P. marginata puparium was punctured at either one or several places as a result of emergence of the adult chalcids. On another occasion, three P. marginata and seven chalcids emerged from five P. marginata puparia in a case of *L. omnivora*. Two out of the five parasitic *P. marginata* puparia were hyperparasitised by *Eupteromalus* spp.

CHAPTER VI

SUMMARY

1. The family Psychidae contains two species endemic to N.Z., *Liothula omnivora* and *Orophora concolor*. The former was the subject of this thesis. All studies were made at Palmerston North where the species was observed both in the field and in the laboratory.

2. A literature review has been made and the taxonomic history and economic importance of the insect briefly discussed.

3. The external anatomy of the egg, larva (including chaetotaxy), pupa, and imago and the internal anatomy of five selected systems (alimentary, circulatory, respiratory, nervous and reproductive systems) of the larva, the 7-day pupa and the imago have been described and figured.

4. The external anatomy and some features of the internal anatomy exhibit remarkable differences between the sexes, the adult female being greatly simplified in all its features except the reproductive system. Externally wings are absent, the notal plates of the thorax are partly membranous, legs and antenna are short, but the abdomen is swollen and has lost its sclerotisation. The chief advantages gained by this sedentary type of flightless female, are possibly increased capacity for egg production and protection of eggs in the case.

5. The species is univoltine, having only one generation per year. In spring, summer and winter the eggs are deposited loosely in the pupal case which is retained within the external larval case. After oviposition, adult females leave the pupal cases and die within the

external larval cases before the eggs hatch. The mean length of the incubation period of eggs was found to be 61 days and over 90% of the eggs observed were fertile.

6. From September to February, the newly-hatched larvae leave the pupal case and original external larval case and feed on a wide range of host plants. The larva can be found throughout the year and represent the sole means of dispersal available to the species. There are seven larval instars and the length of larval life was found to be at least 191 days in the laboratory and 194 days in the field. Over-lapping of instars occurs from the fourth instar on and therefore size measurements become unreliable for determining individual instars.

7. Before pupation larvae reverse their positions in the cases so that they face the lower ends. The mean duration of male pupal period was 92 days and that of the female 26.5 days. Male and female pupae can be distinguished by the maggot-like appearance and absence of wings in the female.

8. Imagoes appear in spring, summer, early autumn and winter. Male imagoes emerge through the posterior openings of the external larval cases, but females remain within the pupal cases before and during copulation. Eggs were laid immediately after copulation. Length of adult life observed in captivity was 42 hours in the male and 26 days in the female.

9. When case building, the larvae first make a ring of silk around the neck. Successive rings of silk are then added to the anterior end of the first ring until a conical case is formed. Construction of cases in third instar larvae takes 3 - 4 hours and in fifth instar larvae at least 7 hours. There is greater probability that secondarily developed cases will be completed successfully, the

younger the larva. Secondarily developed cases are relatively softer than the original ones and their anterior ends have a relatively larger diameter. In the laboratory, larvae used mainly leaf fragments and occassionally bark of twigs in case construction although grass is also used when supplied.

10. Experiments on case function reveal that the presence of a case may play an important role in the maintenance of water relations of the larvae and so prevention of desiccation.

11. Five insects (Pales marginata, two Eupteromalus species, Echthromorpha intricatoria, and an unidentified Ichneumon fly) as well as a fungal parasite, Beauvaria sp. were found parasitizing L. omnivora. Total percentages of parasitized larvae (4th instar and larger) and pupae found during the study were 44.60 and 19.61 respectively.

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APPENDICES

APPENDIX I. EGGS COLLECTED IN THE FIELD AT PALMERSTON NORTH IN 1966/67.

Date	Larval case length (mm.)	Pupal case length (mm.)	Maximum width of pupa (mm.)	Number of eggs in pupal case	No. of eggs per mm. pupal case length	No. of eggs per mm. pupal case width.
28.11.66	48.7	21.3	4.8	803	37.7	167.3
29.11.66	39.7	17.5	4.5	631	36.1	140.2
30.11.66	51.3	19.5	6.5	1326	68.0	204.0
6.12.66	61.2	22.4	7.6	1926	86.0	253.4
16.12.66	50.0	22.2	5.1	1202	54.1	235.7
19.12.66	41.9	18.0	4.0	736	40.9	184.0
31.12.66	46.0	16.0	5.0	441	27.6	88. 2
2. 1.67	45.0	19.0	4.1	894	47.1	218.1
4. 1.67	52.0	20.0	7.1	1636	81.8	230.4
15. 1.67	71.2	28.2	8.9	2583	91.6	315.0
24. 1.67	34.1	16.4	5.0	364	22.2	72. 8
Range	34.1-71.2	16.0-28.2	4.0-8.2	364-2583	22.2-91.6	72.8-315.0
Mean	52.65	22.1	6.1	1473.5	56.9	193.9

APPENDIX II. LARVAE FROM EGGS LAID BY AN ADULT FEMALE COLLECTED FROM THE HOST PLANT, *JUNIPERUS SQUAMATA*.

	Egg width (mm.)	Egg length (mm.)	Head width (mm.)	Body length (mm.)	Larval case length (24 hours after hatching). (mm.)	Case colour.
1	0.60	0.95	0.45	1.45	1.70	White
2	0.55	1.00	"	1.45	1.80	Brown
3	0.55	1.00	"	1.45	1.60	Greenish brown
4	0.60	1.05	"	1.45	1.70	White
5	0.50	0.95	"	1.40	1.70	Light brown
6	0.50	0.95	"	1.40	1.70	Dark brown
7	0.60	0.95	"	1.45	1.40	Green
8	0.60	0.90	"	1.40	1.40	Orange red
9	0.60	0.95	"	1.45	1.40	Greenish brown
10	0.60	1.00	"	1.45	2.00	Light brown
11	0.60	1.00	"	1.45	1.50	Greenish brown
12	0.60	0.95	"	1.40	1.80	Light brown
13	0.60	0.85	"	1.40	1.70	Orange red
14	0.60	0.95	"	1.45	1.80	Light brown
15	0.60	1.00	"	1.45	1.60	Orange red
16	0.60	0.95	"	1.45	1.70	Orange red
17	0.55	1.00	"	1.45	1.70	Orange red
18	0.60	0.90	"	1.40	1.70	Greenish brown
19	0.65	0.95	"	1.45	1.70	Greenish red
20	0.60	0.95	"	1.45	1.50	White