4. THE INTERNAL ANATOMY

(1) The Digestive system
(Figs. 7, 87, 88, 89, 90, 91, 92, 93, 94 and 95)

The alimentary canal of *S. mauritia*, extending from mouth to anus, is a relatively straight tube except in the region of vertriculus and intestine, where it is distinctly convoluted. It is divisible into three main regions: stomodeaum, mesenteron (ventriculus) and proctodaeum. The true mouth as discussed earlier is located high up in the head capsule and divides the sucking pump into its anteriorly placed dibarial and posteriorly placed pharyngeal region.

1. Stomodeaum

The stomodeaum consists of pharynx, oesophagus, proventriculus and crop.

*Pharynx* (Phy). The term "pharynx" is given to the region of the stomodeaum immediately behind the true mouth. In *S. mauritia*, as well as, in many other Lepidoptera, for example: Plusia gamma, Arctia caja, Hepialus humuli, H. lupulinus and Pletella maculipennis (Mortimer, 1965), the pharynx is merged with the preoral cibarium to form a complex sucking pump. This region of the pharynx as already discussed is provided with strong dilator muscles.

*Oesophagus* (Oe). The oesophagus is a straight tube which comprises greater part of the stomodeaum. It is very narrow and tubular, extending from the head to the second abdominal segment. At its posterior end, the oesophagus develops a dorsal diverticulum called crop, just before communicating with the proventriculus.

The oesophagus is provided with only circular muscle layer (cmcl). There is no trace of longitudinal muscle layer. Miller (1950) also in D. melanogaster, could not find longitudinal muscle layer. According to Mortimer (1965) both muscle layers are absent in H. humuli and
H. lupulinus. On the other hand in P. gamma, he has reported the presence of both longitudinal and circular muscle layers, though the arrangement of the two layers is different from the general pattern in the sense that the longitudinal muscle is shown to form an outer layer instead of being internal to the circular muscle layer. Next to the circular muscle layer, there is the thin basement membrane (BMb) which separates it from the epithelium. The epithelium (sEpth) of the oesophagus is more or less syncytial in nature with finely granulated cytoplasm. The nuclei (nu) are small and distributed irregularly. Henson (1931) in larva of Vanessa urticae and Grell (1938) in Panorpa communis, have also recorded syncytial epithelium in oesophagus.

Similar is the observation of Mortimer (1965) in H. lupulinus and H. humuli. Pyle (1940) in Callosomia premetheca, however, has recorded distinct cellular epithelium.

The entire oesophageal epithelium is internally lined by intima(In) and is also thrown into longitudinal folds hanging into the lumen. These folds are almost uniform throughout the length of the oesophagus, thus differing from the condition in S. deesae (Alam, 1953) where these folds get deeper and deeper in antero-posterior direction ultimately forming the oesophageal valve. Its absence in S. mauritia, may be attributed to the fact that the oesophagus and crop relationship is not so perfect as in S. deesae.

Crop (Cr). The crop is large sac-like structure forming dorsal diverticulum. When fully distended, it occupies the upper portion of the first five abdominal segments. However, under unfed
condition it is confined to the first three abdominal segments only.

Histologically, there is very little difference between the oesophagus and the crop. The intima (In) is less thick and the epithelium (sEpth) is profusely folded under unfed condition. The circular muscle layer (cMcl) is weak and the longitudinal muscle layer is absent. Mortimer (1965) also does not mention the presence of longitudinal muscles in A. caja.

Proventriculus (Prvent). It represents the posterior most region of the stomodaeum as short tube communicating with the crop (Cr) at one end and the mesenteron (Ment) at the other. Histologically it is identical to the oesophagus. As this moth is a liquid feeder, the proventriculus is not developed into a crushing centre and functions only as a passage for the descent of food. Akbar (1958) in L. varicornis, also attributes the lack of proventriculus armature to sucking habit of the bug. Mortimer (1965) in A. caja, does not find any proventriculus; whereas, in P. gamma, he reports the presence of a short proventriculus and calls it 'intermediate chamber'.

The stomodaeal valve (svlv) is formed by the posterior tip of the proventricular epithelium, which is hanging into the lumen of the ventriculus. It is in the form of a double-walled tube. The entire surface of the stomodaeal valve is covered over by an intima (In) which is continuous with that of the oesophagus. The outer wall of the stomodaeal valve ultimately merges with the epithelial lining of the mesenteron. The present writer is of the opinion that in S. mauritia,
it does function as a valve to control the flow of food in right direction. This suggestion obviously, runs counter to the opinion of Mortimer (1965) in the case of *A. caja*.

2. **Mesenteron (Ment)**

   The mesenteron is much broader than the stomodaeum and unlike the latter it is in the form of a convoluted tube. The mesenteron runs from the second abdominal segment to the fifth abdominal segment. Its size and shape is variable depending upon the quantity of the food material within it. In the unfed condition it develops wrinkles all over its surface.

   The histology of the ventriculus is different from that of the stomodaeum. The external placed longitudinal muscle layer (lmcl) is followed by a distinct circular muscle layer (cmcl). A clear basement membrane (BMB) provides support to the underlying epithelium (Epth). The latter consists of tall, columnar cells with thickly granulated cytoplasm and conspicuously large nuclei (nu) in the centre. The nuclei show distinct chromatin granules. The epithelium is thrown into distinct villi. The internal border of the epithelial cells is striated (sb). Similar epithelial cells with striated border have been observed by Mortimer (1965) in *A. caja* and Mathur (1966) in the larvae of *Achaea janata*. Pyle (1940), however, does not record the striated border in *C. premetheia*. In *Cecropia*, Anderson and Harvey (1966) have found, with electron microscope, that basal region of the columnar cells is deeply dissected by irregular foldings which may
extend two-thirds of the way to the apical border, beyond the level of the nucleus (vide; Smith, 1968). However, under light microscope no such infoldings are visible in S. mauritia.

**Peritrophic membrane.** The peritrophic membrane is wanting in S. mauritia, as also in certain other Lepidoptera (vide; Waterhouse, 1953 and Mortimer, 1965). In many other liquid feeding insects for example; L. varicornis (Akbar, 1958) the peritrophic membrane is reported to be absent. It has generally been accepted that the peritrophic membrane is a protective device for saving the midgut epithelium from being damaged by hard particles of food, thereby, serving a role which is equalent to that of the mucus in mammals (Day, 1949; Waterhouse, 1953; Wigglesworth, 1965). But Waterhouse (1953) has further recorded its absence in some insects which feed on solid food (Carabidae and Dytiscidae). He has also recorded its presence in certain other insects which feed on liquid food (adults of certain Lepidoptera and Diptera). In view of these diverse observations the present writer feels inclined to suggest that the absence or presence of peritrophic membrane in insects should not in a generalized manner be correlated with the feeding habits of insects.

**Regenerative cells (rg).** Besides the large columnar cells of the ventricular epithelium, there are also present a large number of small regenerative cells. Each cell is somewhat oval in outline. The nucleus is comparatively much smaller than that of a columnar cell. The regenerative cells are generally arranged into nidi of four to eight
cells, at the base of the villi. Alam (1953) in *S. deesae*, shows each nidus to consist of two to four cells. Pyle (1940) in *C. premethea* make no mention of the regenerative cells. The latter are also shown to be absent in *P. gamma* and *A. caja* (Mortimer, 1965). Mathur (1966) in *A. janata* calls them as 'interstitial cells'.

Mode of secretion in the ventriculus

In *S. mauritia*, the holocrine mode of secretion has been recorded. It is carried out in the following manner:

(a) Squeezing out of the epithelial cells. When the epithelial cells of the ventriculus are fully laden with digestive enzymes, their inner wall burst to provide passage for slow oozing out of the digestive enzymes into the lumen of the ventriculus. These cells later on disintegrate to be replaced by new ones which develop from the regenerative cells. Similar mode of secretion is reported by Alam (1953) in *S. deesae*.

(b) Delamination of portions of epithelium. In the event of greater requirement of enzymes, the epithelial cells which are loaded with enzymes are occasionally sloughed off in groups, thus filling the ventricular lumen with sufficient quantity of enzymes. These pieces of epithelium are replaced by new ones formed by activation of the nidi. Alam (1953) has shown a similar mode of secretion in *S. deesae*.

The opening of the ventriculus into the proctodaeum is guarded by a weak pyloric valve. The histology of the pyloric valve is basically identical with that of the mesenteron. The epithelial cells forming the
valve possess distinct striated border (sb) and lacks in intima. The presence of striated border and the absence of intima, clearly bear testimony to the ventricular nature of the valve. Thus unlike S. deesae (Alam, 1953) and the honey bee (Snodgrass, 1956) where the pyloric valve is jointly contributed by the ventricular and proctodaeal epithelia, the valve in S. mauritia, is formed by the ventricular epithelium alone.

3. Proctodaeum

The proctodaeum is the last region of the alimentary canal extending from fifth to tenth segment of the abdomen and opens to exterior by the anus (An). In S. mauritia, it may be subdivided into intestine and rectum.

Intestine (Int). The intestine is a long, narrow convoluted tube. All along its length the intestine is overlaid by the malpighian tubules (Mal). The epithelium (sEpth) of the intestine is syncytial with small but distinct nuclei. There is thin basement membrane (BMb) which supports the epithelium. Internally the epithelium is protected by a distinct intima (In). The epithelium as a whole also shows weakly developed longitudinal folds. The intestine is provided with a thick layer of circular muscle fibres (cmcl). The longitudinal muscle fibres are wanting. However, in A. gamma and A. caja (Nortimer, 1965) and also in A. proxima (Dhillon, 1966) both the circular and longitudinal muscle layers are reported to be present. Shukla and Kumar (1969) on the other hand, have reported a non-muscular 'ileum' in Odoiporus longicollis.
Rectum (Rect).—The rectum is a large sac-like chamber receiving the intestine in its proximal half and distally connecting with the exterior by the anus (An). Its anterior end is blind. The rectal epithelium (sEpth) is much flattened and is internally protected by an intimal lining (In). Like the intestine the epithelium of the rectum is syncytial. Externally the epithelium is covered over by a layer of circular muscle fibres (cmcl) which in turn is overlaid by longitudinal muscle fibres (lmcl). In the anal region the circular muscles are very strong, functioning as sphinctor. Oschman and Wall (1969) have also shown both the circular and longitudinal muscle layers in Periplaneta americana L.

The wall of the rectum is impregnated with a number of circular rectal papillae (rp). The latter are found in single and paired forms which are here named as monopapillar and dipapillar types. However, in histological details these do not differ. A typical rectal papilla (rp) is double layered with an enclosed narrow lumen called papillar lumen (lumP). The latter separates the two layers incompletely in the case of monopapillar type; whereas, in the dipapipillar type, the two layers coalesce together thus displacing the lumen completely. The epithelium (sEpth) of the rectum branches off to form two layers of the rectal papilla. The inner syncytial layer (iEpth) which is protected by a very thin intimal covering is broad with fewer large oval nuclei (nu) having thick chromatin granules scattered under no definite plan in the case of monopapillar type but these nuclei in dipapillar type are arranged centrally. The outer layer (oEpth) in both types is also
syncytial having large number of distinct nuclei (nu) scattered all over. The outer layer in the case of monopapillar type is much broader in the central region; whereas, in the dipapillar type it is almost a uniform layer.

Palm (1949) while describing the rectal papillae of insects has given two diagrams in the case of Lepidoptera, which may be taken similar to the 'monopapillar' and 'dipapillar' types of rectal papillae of S. mauritia. Pyle (1940) in C. premetheus has recorded only one type of rectal papilla which is comparable with the 'monopapillar' type of S. mauritia.

The rectal papillae may be regarded as absorptive regions of rectum. These papillae absorb watery contents from the faecal matter and pass it on to the blood for circulation, thereby, playing an important role in the conservation of water. Gupta and Berridge (1966) in Calliphora erythrocephala Meig., also regard it as water absorbing regions but are of the opinion that the papillae remove water from the rectum only as a consequence of active transport of ions from the lumen (vide; Smith, 1960). However, Oshman and Wall (1969) in Periplaneta americana, have shown that there is a net flow of water from rectal lumen to subepithelial sinus even without a proportional flow of ions. They have further suggested a system for solute recycling in which the transported ions can be returned to the cell to be re-used to generate the osmotic gradients needed to produce a flux of water.
(ii) The Salivary glands
(Figs. 7, 87 & 96)

The salivary glands (SlG1) consist of a pair of long convoluted narrow tube lying in the thorax. Each gland runs anteriorly along the side of the oesophagus. On reaching the anterior limit of the mesothorax it takes a backward turn to run up to the anterior margin of the meta thorax. It again takes up an anteriorly directed course and on reaching the prothorax communicates with the lateral salivary duct (ISID). The two lateral salivary ducts converge and unite to form the common salivary duct (SID) in the cervix region before entering the cranium. The common duct runs below the sucking pump (SP) to open at the base of the food meatus (fm). Just before its opening, the common duct expands to form the salivarium (Slv) which is provided with a pair of dilator muscles.

The epithelium (Epth) of the gland consists of distinct cuboidal cells having densely granulated cytoplasm and oval-shaped nuclei (nu). Internally the epithelium is covered over by intima (In); whereas, externally it is limited by a thin basement membrane (BMb). There is no muscular layer. Similar histological structure of the gland has been reported by Alam (1953) and Dhillon (1966) in S. deesae and A. proxima respectively. In Periplaneta americana, Kessel and Beams (1963) have shown with the help of electron microscope the secretory cells lined with 'porous material'.

There is almost no histological difference in the salivary gland and the duct. The nuclei in the cells of the duct's epithelium are smaller
but more in number.

(iii) **The excretory system**

(Figs. 87 and 97)

The excretory system consists of three pairs of malpighian tubules (Mal). The three tubules of one side unite to form a short common tube which opens at the junction between the mesenteron and proctodaeum. The tubules are very long and convoluted, lying around the mesenteron and the proctodaeum.

The malpighian tubules are of almost uniform cross section. The cells of the epithelium (Epth) are cuboidal with faint cell membrane. The cytoplasm is granulated with fairly large and rounded nuclei. Internally the epithelium is lined with a distinct brush border (sb), while externally it is covered over by a basement membrane (BMb). The 'brush border' have also been observed by Wigglesworth and Salpeter (1962) in *Rhodnius prolixus* S., under the electron microscope. Histologically the malpighian tubules resemble the ventriculus and are probably endodermal in origin. This contention of the present writer is further strengthened by the presence of the striated border. Further, it gets firm support from the embryological and postembryological observations of Henson (1931, 1932 and 1945) on *V. urticae*, *P. brassicae* and *Calliphora* respectively. The endodermal nature of the tubules has also been asserted by Trapmann (1923), Tirelli (1929), Weil (1935), Alam (1953) and Dhillon (1966). Sander (1956) in *Pyrilla perpusilla* W., and Farooqi (1963) in *Athalia proxima* K., are of the opinion that the
malpighian tubules are ectodermal in nature. Snodgrass (1956) in the honey bee admits the identity between malpighian tubules and the ventricle but make no definite commitment. He suggests that this resemblance is the result of a 'common adaptation to function', rather than an evidence of their homology.

(iv) The circulatory system

(Figs. 98, 99, 100 & 101)

The vascular system of *S. mauritia*, includes the haemocoele, median dorsal vessel, the accessory pulsatile organ, dorsal and ventral diaphragms.

The dorsal and ventral diaphragms are confined to the abdominal region, dividing the haemocoele into three longitudinal chambers, viz., pericardial sinus (DS), perineural sinus (VS) and visceral sinus (PvS). The pericardial sinus contains the heart, the visceral sinus provides space for the visceral organs while the perineural sinus possesses the ventral nerve cord.

The dorsal vessel. The dorsal vessel is the chief pulsating organ of the circulatory system lodged over the dorsal diaphragm. It extends from the seventh abdominal segment to the head and is morphologically distinguishable into the heart and aorta.

The heart (Ht). The heart is almost of uniform cross section and running under the terga along midlongitudinal line spreads between the seventh and first abdominal segment. It is laterally perforated by
seven pairs of ostia (Ost), the internal flaps of which serve as valves preventing the outward flow of blood from the heart. Due to the presence of seven pairs of ostia the heart is divided into eight chambers.

The aorta (Ao). The aorta is a narrow, tubular thin walled continuation of heart which is stretched from first abdominal segment to head. The aorta on leaving the heart, dives ventrally beneath the second phragma (2Ph). In the mesothorax, the aorta ascends to reach the scutoscutellar ridge (vr) and making a sharp loop descends to the level of oesophagus. Extending forward, the aorta runs across the prothorax and the cervix to enter the head capsule through the foramen magnum. Within the head it abruptly widens to form a sac-like structure (FS) before opening below the frontoclypeus.

The accessory pulsatile organ. In the mesothorax the aorta forms an accessory pulsatile organ for proper circulation of blood in the axillary region of the forewings. This accessory pulsatile organ consists of a vertical chamber in the form of a club-shaped sac lying in close proximity to the scutoscutellar ridge. It is connected with the ascending (pAo) and descending (aAo) aortic branches, which adhere to each other for a short distance. The chamber is provided with a pair of dorsal incident ostia (ThOst) in the manner reported by Hessel (1966, 1969) in Lepidoptera. There is a contractile muscular diaphragm (2Dph) situated beneath the mesothoracic scutellum (Scl2). This diaphragm serves to direct the flow of haemolymph anteriorly to the ostial
region of the pulsatile organ (vide: Brocher, 1919 and Gerould, 1938). The chamber itself is supported and attached to the scutellum by a thin septum (Te).

The dorsal diaphragm (dDph). The dorsal diaphragm is quite well developed in the form of a continuous sheet of membrane, stretched underneath the abdominal dorsum, thereby, forming a bed for the heart. It, incompletely separates a pericardial sinus from the visceral sinus. Laterally, the diaphragm is attached to the antero-lateral angles of eighth to second terga. The lateral margins of diaphragm are corrugated to allow communication between the pericardial and visceral sinuses. The diaphragm is provided with seven pairs of alary muscles (No. 149). Each muscle has its root fixed into the antero-lateral angle of the tergum concerned, wherefrom the muscle fibres diverge directed mesally to end by spreading on the lateral surface of the heart.

The ventral diaphragm (vDph). The ventral diaphragm is weakly developed as a narrow sheet of membrane stretched from first to seventh abdominal segments. It provides a dorsal cover to the ventral nerve cord (VNC) and encloses the perineural sinus which communicates with the visceral sinus laterally due to corrugated margins of the diaphragm. There are seven pairs of alary muscles (No. 150) in the ventral diaphragm. Richards (1963) in Lepidoptera has also shown a ventral diaphragm; whereas Gerould (1938) in Bombyx mori L., does not record it.
(v) **The respiratory system**

(Figs. 28, 57, 102, 103, 104, 105, 106 & 107)

The respiratory system of *S. mauritia* consists of nine pairs of spiracles, tracheae and air sacs. The first two pairs of spiracles (Sp2, Sp3) open in the interpleural areas between first and second and between second and third thoracic segments. The remaining seven pairs are located in the segmental pleura of the first seven abdominal segments. Ritcher (1969) in adult Scarabaeoidea, has shown up to eight pairs of functional spiracles in the abdomen.

**Spiracles** (Figs. 102, 103, 104 and 105)

**First pair of thoracic spiracles.** The first thoracic spiracle is more or less oval in shape. A distinct sclerotized spiracular rim (Spr) encloses a narrow aperture (Spap). The latter opens into a sunken atrium whose inner wall is provided with a well-developed filter apparatus (fa). The latter consists of long finger-like intimal projections densely clothed with fine hairs which prevent foreign matter from entering the respiratory system. Mathur (1967) in *U. pulchella*, has shown more or less, similar structure and arrangement of the filter apparatus. Beckel (1956) in *Hylophora cecropia* L., has reported filter apparatus at the bottom of the atrial chamber; whereas, Tomapi (1959) in *Corycera cephalonica*, shows it arising from the 'peritreme'.

Ventrally the spiracular rim (Spr) projects out in the form of a stumpy ventral process (vp) which is the seat of origin of the occlusor muscle of the spiracle. The atrium leads into the spiracular trachea.
Near their junction, is located an internal closing apparatus consisting of a non-mobile sclerotized posterior lip (pl) and a partly sclerotized movable anterior lip. Dorsally the anterior lip and the posterior lip are connected through dorsal hinge line (dh). The dorsal half of the anterior lip is sclerotized and forms the dorsal process (dp). The latter gradually tapers in the form of lever (le) which provides insertion for the occlusor muscle. The ventral half of the anterior lip is elastic and forms the valve (vlv). Mathur (1967) in *U. pulchella*, however, finds a completely sclerotized anterior lip in the first thoracic spiracle which represents the combined 'dorsal process' and the 'valve' of generalized internal closing apparatus (Snodgrass, 1935). There is no dilator muscle for first thoracic spiracle in *S. mauritia*, nor it has been recorded in *C. cephalonica* (Tonapi, 1959) or *U. pulchella* (Mathur, 1967).

**Occlusor muscle of the first thoracic spiracle** (No.151). It is a stout muscle and originates on the ventral process of the spiracular rim. Ascending obliquely forwards, the fibres are inserted on the lever of the dorsal process. On contraction, the muscle pulls the lever downwards with the result that the valve is pressed against the non-mobile posterior lip and, thereby, the passage to the trachea is closed. On relaxation of the occlusor muscle, the lever returns to its normal position by its own elasticity. It is functionally similar to the 'occlusor muscle of the first thoracic spiracle' of *U. pulchella*.

**Second pair of thoracic spiracles.** The second thoracic spiracle lies in the intersegmental membrane between the mesopleuron
and metapleuron. It is like crescent-shaped aperture enclosed by an anteriorly placed semicircular spiracular rim (Spr) which appears like a bow. The two ends of the bow are connected by a membranous valve (vlv). Ventrally, the spiracular rim is produced into a narrow ventral process (vp) which serves as a place for insertion of the occlusor muscle of the spiracle. The second thoracic spiracle lacks a filter apparatus and is the least conspicuous among all the spiracles. It is, more or less, similar to the second thoracic spiracle of *U. pulchella* (Mathur, 1967).

**Occlusor muscle of the second thoracic spiracle** (No.152). It is a small muscle arising on the mesothoracic furcal arm. Ascending obliquely in antero-dorsal direction, the fibres end on the ventral process of the spiracular rim. The contraction of this muscle straightens the 'bow', thus decreasing the curvature of the spiracular rim which ultimately abuts on the valve to close the spiracular aperture (Spap). In the absence of a dilator muscle, the spiracle automatically opens on the relaxation of the occlusor muscle. The second thoracic spiracle is, thus provided with external closing apparatus, instead of internal apparatus.

**Abdominal spiracles.** All the seven abdominal spiracles are identical in shape and structure. The abdominal spiracle is somewhat larger than the first thoracic spiracle. The anterior lip (al) of the closing apparatus is fixed, while the posterior lip is movable which is just the reverse of what had been observed in the first thoracic spiracle. The dorsal half of the posterior lip is sclerotized and forms the dorsal
process (dp); whereas, the ventral half forms the elastic valve (vlv). The lever (le) is a bit longer than that of the first thoracic spiracle, otherwise there is not much difference between the two. This shows that the internal closing apparatus of the abdominal spiracle is similar to the typical lepidopterous condition except that the dilator muscle is wanting. More or less similar structure in the abdominal spiracle has been shown to occur in _U. pulchella_ (Mathur, 1967).

**Occlusor muscle of abdominal spiracle** (No.153). A well developed occlusor muscle is present in all the seven spiracles. The fibres originate on the ventral process of the spiracular rim and running in posterio-dorsal direction get inserted on the lever of the spiracle. The contraction of this muscle closes the atrial aperture (Aap) in the manner described for the first thoracic spiracle. In the absence of dilator muscle the spiracle opens due to its own elasticity.

**Tracheal system** (Figs. 106 & 107)

The tracheation of the body is based on the arrangements of the tracheae and the air sacs. The latter are not many and moreover, there is no definite plan of their deposition. The spiracular trachea connects the spiracle with the lateral trunk in the spiracular segments. It is usually short. The lateral trunk (LT) extends along the side of the body from the first spiracle of the thorax to the seventh spiracle of the abdomen and thereafter extends up to the eighth abdominal segment, where it becomes continuous with its counterpart of the other side to form a commissure (Lcom).
1. **Tracheation of the abdomen.** The tracheation in all the spiracle bearing segments of the abdomen is more or less similar, but the first and last spiracle bearing segments show modifications. Besides these, the tracheation of fifth and sixth segments in the male also show certain modifications. The lateral trunk coming from the thorax continues into the abdomen up to the eighth abdominal segment, where it forms a commissure in combination with the lateral trunk of the other side. The lateral trunk in the region of the abdomen is very well developed and receives short spiracular tracheae in segments 1-7. In each spiracle bearing segment the trunk gives out a dorsal, a ventral and a visceral trachea from its dorsal, ventral and mesal surfaces, respectively. Besides these, the portion of the lateral trunk connecting the two spiracular tracheae, gives out dorsal and ventral branches.

**The dorsal trachea (DTra).** The dorsal trachea comes out as a broad tube from the junction of the spiracular trachea and lateral trunk. Very soon it divides into an anterior and a posterior branch. The anterior branch (Da) which is a broad and stout, almost immediately subdivides into two which ramify over the heart, dorsal diaphragm and the tergal muscles in the spiracular segments. The posterior branch (Dp) which is narrower than the anterior one, travels a short distance before supplying branches to the alimentary canal.

**The ventral trachea (VTra).** The lateral trunk in each spiracle bearing segment gives rise from its ventral surface, a well developed ventral trachea. The arrangement of the ventral trachea in segments
1-6 is almost identical. Each ventral trachea after travelling a short distance divides into an anterior and a posterior branch. The former (Va) supplies fine branches to the sternal muscles, ventral diaphragm and the ventral nerve cord. The posterior branch (Vp) which is much conspicuous, forms a definite tracheal commissure (Vcom) by meeting its counterpart of the other side. The branches coming out from the commissure go to the sternal muscles and the ventral diaphragm. In the seventh segment the anterior branch also forms a commissure, thus there are two ventral commissures in this segment. The anterior commissure (Vcom₁) sends stout branches to the terminal ganglion and the nerves coming out from it. The posterior commissure (Vcom₂), however, supplies usual branches to the sternal muscles and the ventral diaphragm.

The visceral trachea (vTra). The lateral trunk in all the spiracle bearing segments except the first, gives out a mesally directed visceral trachea. The latter travelling towards the alimentary canal soon divides into two branches which profusely ramify over the alimentary canal, reproductive organs and the malpighian tubules. The visceral tracheae of the fifth and sixth segments in the male are well developed and branch over the testes.

The dorso-lateral trachea (DLTra). The portion of the lateral trunk connecting the two spiracular tracheae gives out 2-4 branches from its dorsal surface. These tracheae branch profusely for supplying to the reproductive organs.
The ventro-lateral trachea (VLTr). Immediately anterior to the ventral trachea there arises from the ventral surface of the lateral trunk connecting the two spiracular tracheae, a short ventro-lateral trachea which sends branches to the reproductive organs. Thus, the latter are supplied both dorsally and ventrally by the dorso-lateral and ventro-lateral tracheae, besides receiving branches from the visceral trachea.

Beyond the seventh abdominal spiracle the lateral trunk extends as a narrow tube up to the eighth abdominal segment whereupon, it takes a mesally directed course to form a commissure (Lcom) by fusing with its counterpart of the other side. In the female, the lateral trunk also gives fine branches to the rectum, oviduct and the muscle of the pseudo-ovipositor. In the male, besides supplying branches to the muscles of the eighth, ninth and tenth segments, the lateral trunk gives out a stout branch called genital trachea (tg) the latter divides into two; the anterior one (tga) sends branches to the muscles of the aedeagus while the posterior (tgp) supplies fine tracheae to the parameres and their muscles.

2. Tracheation of the thorax. The tracheation in the thorax is quite elaborate. The lateral trunk on entering the thorax runs right across its length and receives the trachea of the first and second thoracic spiracles. The thorax is not only supplied by the thoracic branches of the lateral trunk coming out from the neighbourhood of the first and second thoracic spiracles but also by some fine tracheae coming
from the vicinity of the first abdominal spiracle. These branches may be broadly grouped into dorsal, ventral and wing base tracheae.

The dorsal tracheae. \( (D_2, D_3, D_4) \) All the three thoracic segments are supplied with independent dorsal tracheae, though the latter are not equally developed in all the segments. The one supplying to the mesothorax is very well developed, whereas, the remaining two going to pro-, and metathorax are not so developed.

The mesothorax is supplied by the dorsal trachea \( (D_4) \) coming from the first abdominal segment. It runs as short tube giving fine branches to the metathoracic wing muscles. The dorsal trachea \( (D_3) \) supplying to the mesothorax after coming from the lateral trunk runs in the antero-lateral direction to end near the first thoracic spiracle. It gives out peculiar types of air sacs which according to their arrangements may be grouped into dorsal, lateral and ventral air sacs.

The dorsal air sacs \( (6, 7) \). Each dorsal trachea gives out a pair of dorsal air sacs. Each sac arising as a small tracheal tube immediately gives out several finger-like air sacs which send out fine branches to the indirect and principal depressor muscle of the fore-wings and also supply to mesothoracic aorta.

The lateral air sacs \( (8) \). The lateral air sacs are innumerable, arising lateraly as a finger-like air tubes which spread out on each side of the dorsal trachea to lie between the muscle fibres. These air sacs supply minute branches to the muscles of the fore-wings.
The ventral air sacs (9). — The ventral air sacs resemble the lateral air sacs but owe their origin to the ventral surface of the dorsal trachea. These sacs also innervate the muscles of the forewings.

The dorsal trachea ($D_2$) supplying to the prothorax comes out from the lateral trunk just opposite to the insertion of the spiracular trachea of the first thoracic spiracle. This stout trachea innervates the protergal muscles and the levator muscles of the head. It also sends a branch to the patagium to form the patagial air sac (5).

The ventral trachea ($V_2$). — The ventral trachea is given out from the lateral trunk just before the latter gives out the first thoracic spiracular trachea. The ventral trachea after coming out from the lateral trunk leads towards the second thoracic ganglion, where it distributes fine branches to the latter and to the ventral nerve cord. The ventral trachea in the region of the second thoracic ganglion gives rise to a mesal branch which in combination with its counterpart of the other side, forms a horse-shoe-shaped loop ($L_1$) over the first thoracic ganglion. The loop sends fine branches to this ganglion and to the nerve connectives.

Wing base trachea. — Both the forewings and the hindwings are supplied by two tracheal branches namely anterior wing base trachea ($W_1, W_3$) and posterior wing base trachea ($W_2, W_4$). The anterior wing base trachea is formed by the union of two tracheae coming out from the first and second thoracic spiracular tracheae. They may also be called leg-cum-wing trachea which gives branches to the wing. Similarly, the
posterior wing base trachea comes out as a common stalk from the second thoracic and first abdominal spiracle.

**Anterior wing base trachea.** The lateral trunk in the region of second thoracic spiracle gives rise to an anterior wing base trachea \((W_3)\) which joins with the posterior wing base trachea \((W_4)\) coming from the neighbourhood of first abdominal spiracle and forms a transverse basal trachea \((t_2)\), which sends branches to the anterior and posterior regions of the hind wing. The two wing base tracheae give out mesal branches \((m_3, m_4)\) which join to form a common branch \((v_4)\) for supplying to the hind leg and the ventral nerve cord.

**Posterior wing base trachea.** The lateral trunk in the region of second thoracic spiracle also gives out a posterior wing base trachea \((W_2)\) which run in antero-lateral direction to become continuous with the anterior wing base trachea \((W_1)\) coming from around the first thoracic spiracle. The two thus form transverse basal trachea \((t_1)\) for supplying to the forewing. The anterior and posterior wing base tracheae give out mesal branches \((m_1, m_2)\) which run towards the mesothoracic leg and unite with each other \((V_3)\) to supply the leg muscles. The anterior wing base trachea \((W_1)\) coming from the vicinity of first thoracic spiracle gives out a small branch to the tegula where it forms a tegular air sac \((10)\) for supplying the tegula.

3. **Tracheation of the head.** The head receives four pairs of tracheae from the first thoracic spiracle.
The dorsal cranial trachea (D1). — The dorsal cranial tracheae of the two sides come close to each other before entering the neck region. Therefrom these take up divergent course to enter into cranium to form an unpaired, large dorsal cranial air sac (1). The latter is located just above the brain and almost covers it dorsally. The air sac gives out a number of fine branches which supply to the brain and the optic lobes.

The dorso-lateral cranial trachea (DL1). — It runs along the side of the oesophagus to enter into the head. Each trachea ends into a pyriform dorso-lateral cranial air sac (2), lying lateral to the dorsal cranial air sac. This pair of sacs send minute branches to the eyes and the muscles of stipites.

The ventro-lateral trachea (VL1). — The ventro-lateral cranial trachea running lateral to the dorso-lateral cranial trachea, enters the cranium to end into the ventro-lateral cranial air sac (3) lying just beneath the brain. It supplies branches to the sucking pump.

The ventral cranial trachea (V1). — The ventral cranial trachea soon after emerging from the first thoracic spiracle, ends into a sub-triangular air sac (4) lying in the prothorax. Each ventral prothoracic air sac sends out a narrow but stout branch to the cranium, which running below the pharynx and the sucking pump extends into the lumen of the galea.
(vi) The male reproductive system

(Figs. 83, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117 and 118)

The male reproductive system of *S. mauritia*, consists of two completely fused testes, a pair of vasa deferentia, a pair of seminal vesicles, a pair of accessory glands and unpaired ejaculatory ducts.

**Testes (Tes).** In a freshly killed insect the two testes in fused condition form a spherical body which is pink in colour. It is enclosed in a peritoneal sheath (PSh) and lies dorsally on the alimentary canal in the fifth abdominal segment.

The testes consist of eight testicular follicles which are separated from each other by incomplete septa (sm). The enclosing peritoneal sheath is structureless and transparent. Ruckes (1919) in Lepidoptera has shown a similar layer which he calls as the 'tracheal membrane' considering it to have formed from the fused wall of the tracheae. Srivastava (1960) in *L. orbonalis*, does not record any such layer. The peritoneum is followed by two distinct cytoplasmic layers which are called (i) inner (iEpth), and (ii) outer (oEpth) epithelium. Similar double layered epithelium has been reported by Alam (1953) in *S. deesae*, and Mathur (1966) in *Utetheisa pulchella* L. The outer epithelium of *S. mauritia*, is a thin syncytial layer with oval nuclei having thick chromatin granules. The nuclei (nu) are scattered under no definite plan. The inner epithelium is also syncytial and more or less, as thick as the outer epithelium. Its oval and granulated nuclei are less numerous. Alam (1953), and Akbar (1958) in *S. deesae*, and *L. varicornis* respectively, have also recorded syncytial nature in the inner
epithelium. The inner epithelium is continued for short distance into the testicular lumen in the form of septa (sm) which divide the testes into eight testicular follicles (Fol). Each septum is fairly thick at the base and gradually thins out apically.

The lumen of the testes contains the germ cells at various stages of development. The spermatogonia (Spg) which are the primary germ cells are more numerous towards the periphery. The spermatogonium subdivides and the daughter spermatogonia are encysted to form the sperm cysts (Cst). The latter, develop into spermatids (Spd) which are transformed into bundles of mature spermatozoa (Spz).

**Vas deferens and seminal vesicle.** The two vasa deferentia (Vd) arise separately by broad base from the ventral surface of the testes and gradually become narrow. Each vas deferens descends dorso-ventrally, thus flanking the midgut from sides. These open separately into the seminal vesicle (Vsm). The latter is nothing but a destended form of the vas deferens. The seminal vesicle opens into the reservoir of the accessory gland (ResAcGl) by a narrow tubular duct (dVsm) as demonstrated by Alam (1953) in S. deesae.

The vas deferens is externally bounded by the peritoneal layer (PSh). Its epithelium (Epth) is composed of very tall, columnar and densely granulated cells with nuclei lying towards the periphery. The entire epithelium is thrown into folds. Musgrave (1937) in E. kühniella, records the 'brush border' condition of the epithelium. Mathur (1966) has also shown prominent 'striated border' in U. pulchella. The present
writer, however, could not find any such border in _S. mauritia_. The vas deferens is devoid of any muscular layer as is also the case in _L. orbinalis_ (Srivastava, 1960). Ruckes (1919), however, records the circular muscle layer in Saturnidae. The seminal vesicle, histologically resembles the vasa deferentia in broad outline, only differing from the latter in having centrally placed nuclei. The duct of the seminal vesicle is regular in cross section. The epithelium is externally bounded by the peritoneum (PSh). Beneath the peritoneum is a basement membrane (BMb) which supports the tall columnar cells (Epth), having basally located nuclei (nu).

**Accessory gland (AcGl).** There is a pair of long, highly convoluted tubular accessory glands. The two glands adhere to each other through connecting tracheae. Each gland is somewhat broad at the base and gradually tapers to end blindly. The gland opens into a wide tubular reservoir (ResAcGl). The latter converge posteriorly to open into the common duct of the accessory gland (cdAcGl) which is a long, highly convoluted tube opening into the ejaculatory duct (Dej).

The accessory gland is having a syncytial epithelium (sEpth). The large, oval nuclei (nu) are scattered under no definite plan. These are heavily ladden with chromatin granules; whereas, the cytoplasm is poorly granulated. The epithelium of the gland has a distinct basement membrane (BMb) which is externally bounded by a very thin layer of circular muscle fibres (cmcl). Ruckes (1919), has recorded columnar epithelium, covered by longitudinal muscle layer in the accessory gland.

The epithelium of the reservoir is also syncytial in nature.
The spacious lumen of the reservoir contains a fluid (Secr) which is secreted by the reservoir and its gland. This fluid serves as a medium for sperm. The epithelium (sEpth) contains small, oval nuclei arranged in a regular manner. The epithelium rests on a basement membrane (BMb) which is externally covered over by a thin layer of circular muscles (cmcl). Srivastava (1960) in *L. orbonalis*, shows no muscle layer in the reservoir.

The reservoir of accessory gland (ResAcGl) has been called 'ductus ejaculatorius duplex' by Ruckes (1919) in Lepidoptera; Callahan and Chapin (1960) in Noctuidae; Tedders and Calcote (1967) in *Laspeyresia caryana* F. It has been taken as 'paired ejaculatory duct' by Srivastava (1960) and Mathur (1966) in *L. orbonalis* and *U. pulchella*, respectively. This seems to be incorrect because there is no intimal lining. Norris (1932) in *E. kühniella* and *P. interpunctella*, as well as, Musgrave (1937) in *E. kühniella*, call it as 'paired glands'.

The common duct of the accessory gland (cdAcGl) functions as a passage for the descent of sperms and is also secretory in nature. On the basis of different types of secretion it may be subdivided into four regions which are externally demarcated from each other by distinct constrictions.

The first portion of the common duct (1) is very long whose epithelium is columnar with oval nuclei. The chromatin granules are present in the nuclei, as well as, in cytoplasm. The epithelium is externally bounded by a weak circular muscle layer (cmcl). The epithelial secretion (Secr) forms triangular lumps scattered in spacious lumen.
The second portion of the common duct (2) is slightly larger in diameter than the first portion; but its epithelial lining (Epth) is a little narrower than the latter. The cytoplasm is finely granulated with centrally placed nuclei having thick granulation. A weak circular muscle layer (cmcl) forms the outer covering of the epithelium. The lumen is filled with the secretion (Secr) which consists of homogenous rounded globules.

The third portion (3) is the shortest portion of the common duct. The epithelium (Epth) is narrower than that of the second portion. It consists of short columnar cells with fairly granulated cytoplasm. The rounded nuclei are centrally located. The circular muscle layer (cmcl) is weak. The lumen is filled with secretion (Secr) which are in the form of rounded globules.

The fourth portion (4) is longer than the third portion and opens into the ejaculatory duct (Dej). Its epithelial lining (Epth) is much narrower than that of the third portion. The small columnar cells are granulated with rounded nuclei placed in the centre. The circular muscle layer forming the outer covering is weakly developed. The spacious lumen contains secretions (Secr) having fine granulations.

Ruckes (1919) in Lepidoptera, following the terminology of Schroeder (1900), calls the common duct of the accessory glands plus the ejaculatory duct as 'ductus ejaculatorius simplex'. Callahan and Chapin (1960) in Noctuidae; Callahan and Cascio (1963) in H. zea, as well as, Tedders and Calcote (1967) in L. caryana, have also used the same.
terminology. Further, Ruckes (1919) does not consider any portion of 'ductus ejaculatorius simplex' as secretory, whereas, Callahan and Chapin (1960) divide it into a proximal secretory and a distal non-secretory region. Norris (1932) in *E. kühniella* and *P. interpunctella*, calling the common duct of the accessory gland of *S. mauritia* as 'unpaired gland' has divided it into four secretory regions. Musgrave (1937) in *E. kühniella*, suggests eight subdivisions; four of them being distinctly secretory in nature. Mathur (1966) in *U. pulchella*, divides the 'common ejaculatory duct' (common duct of the accessory gland of *S. mauritia*) into a 'glandular region' and 'chitinous region'.

**Ejaculatory duct** (Dej). The short unpaired ejaculatory duct communicates anteriorly with the fourth portion of common duct of the accessory gland, while posteriorly it opens into the aedeagus through the gonopore. The entire ejaculatory duct is enveloped by a thin peritoneum (PSh) which is fairly loose in the region of aedeagus.

The epithelial lining (sEpth) of the ejaculatory duct is highly folded. It is syncytial in nature having rounded nuclei with thick chromatin granules. The cytoplasm is also granulated. The epithelium is externally covered over by a distinct basement membrane (BMB) while internally it is lined by a thick intima (In). In between the peritoneum and the basement membrane, there is a thick coat of circular muscle layer (cmcl). A small proximal portion of the ejaculator duct (Bej) is conspicuously wider and highly muscular. This portion can be compared with the 'bulbus ejaculatorius' of *E. kühniella* and *P. interpunctella*. 
(Norris, 1932).

(vii) **The female reproductive system**
(Figs. 74, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129 & 130)

*Spodoptera mauritia* is a distinct example of Dytrisia possessing independent openings of bursa copulatrix and of the vagina. The latter communicates with the exterior in the fused ninth and tenth segment through the oviporous, whereas, the bursa copulatrix opens in the intersternal membrane of the seventh and eighth sternum. The other components of the female reproductive organs are paired ovaries, paired lateral oviduct, unpaired common oviduct, unpaired spermatheca, and a pair of accessory glands.

**Ovary.** The two ovaries are placed dorso-lateral to the digestive tract from seventh to second abdominal segments. When mature, these occupy the major portion of the visceral sinus. Each ovary consists of four very long and coiled ovarioles which are held together by fine branches of tracheae. Each ovariole is divisible into an apical germarium (Grm) and a basal vitellarium (Vtl).

**Ovariole (Ovl).** The whole length of the ovariole is externally covered over by a non-nucleated thin peritoneal layer (PSh). There is no suspensory ligament, though Williams (1948) reports its presence in *Agrotis ypsilon*. However, Callahan and Chapin (1960) reported its absence in the same species (*Agrotis ypsilon*) and also in ninety other Noctuids. Williams (1948) perhaps mistook the closely fused terminal germarium for the suspensory ligament.
The germarium (Grm) possesses a mass of undifferentiated germ cells. These develop into oocytes, nurse cells and follicular cells. The germarium is followed by the conspicuously beaded vitellarium (Vtl). The follicles (egg chambers) become bigger and bigger in apico-basal direction. Each follicle contains a posteriorly placed oocyte (Ooc) and anteriorly placed nurse cells (NrCl) which are three to five in number. This type of arrangement gives 'polytrophic' condition to the ovary (Wigglesworth, 1965).

In the vitellarium the peritoneal layer (PSh) is followed by a distinct cyncytial epithelium (sEpth) having finely granulated cytoplasm and small nuclei. It resembles the 'syncytial epithelium' of ovariole of S. deesae (Alam, 1953) comparable with the 'inner tunica propria' of Nezara viridula (Malouf, 1933). The follicular epithelium is demarcated from the syncytial epithelium by a basement membrane (BMb). The follicular epithelium (Epth₁) enclosing the oocyte (Ooc) consists of distinct columnar cells having large nuclei and granulated cytoplasm. The epithelium (Epth₂) around the nurse cells (NrCl), however, undergoes gradual disintegration and ultimately loses its cellular nature. The epithelium of the follicle extends in the form of incomplete septum between the oocyte and the nurse cells leaving a conspicuous communicating passage between the two chambers. Musgrave (1937) in E. kühniella, has also recorded more or less, similar incomplete septum.

Each oocyte (Ooc) is more or less spherical in shape and filled with yolk (ylk). Its rounded nucleus (nu) is least granulated. A structureless chorion (Cho) is secreted by the follicular epithelium
around the fully developed oocyte. The nutritive cells (NrCl) are large and irregular in shape having densely granulated and large nuclei.

Norris (1932) in E. kühniella, and P. interpunctella, as well as Musgrave (1937) in E. kühniella, report the presence of lobate nuclei in the nurse cells. With the development of the oocyte, the cells are gradually utilised by them.

**Lateral oviduct (Od1).** The four ovarioles of each side unite basally to form the short lateral oviduct. The epithelium (Epth) of the lateral oviduct consists of somewhat cuboidal cells having very faint boundaries. The nuclei and the cytoplasm are densely granulated. Externally the epithelium is based in a basement membrane (BMb). In C. pomonella (Allman, 1930) and L. orbonalis (Srivastava, 1960) the epithelium of lateral oviduct is similar to that of S. mauritia. External to the basement membrane is a layer of circular muscle fibres (cmcl) which is overlaid by a longitudinal muscle layer (lmc1). A similar arrangement of muscularis is present in C. erythrocephala (Graham-Smith, 1938) and L. varicornis (Akbar, 1958) while a reverse condition is met within L. orbonalis (Srivastava, 1960). Allman (1930) in C. pomonella and Norris (1932) in E. kühniella and P. interpunctella, recorded the presence of only circular muscle layer. Snodgrass (1956) in the honey bee, has shown the longitudinal muscle layer only.

**Common oviduct (Odc).** The common oviduct is a short, straight tube connecting the lateral oviducts with the anterior end of the vagina. The histological details of the common oviduct is almost similar to that of the lateral oviduct. Srivastava (1960) in L. orbonalis, shows that
the circular muscles are external to the longitudinal muscles, a condition just the reverse of what is present in *S. mauritia*.

**Vagina (Vag).** The common oviduct opens through the gonopore into the tubular vagina, which communicates with the exterior through the oviporous (opr). Its anterior limit is automatically marked by the opening of the spermatheca (Spt). Similarly the posterior limit is externally represented by the opening of the accessory glands (Gl). The vagina of *S. mauritia*, may be compared with the 'genital chamber' of the horsefly (Bonhag, 1951) and *L. varicornis* (Akbar, 1958).

The epithelium (sEpth) of the vagina is thrown into several folds. It is syncytial in nature having oval shaped nuclei, scattered under no definite plan. Internally it is lined by an intima (In) and externally by a basement membrane (BMb). External to the latter is a thick layer of circular muscle fibres (cmcl), which is followed by a thick longitudinal muscle layer (lmcl). Allman (1930) in *C. pomonella*, attributes distinct cellular nature to the vaginal epithelium. Musgrave (1937) and Srivastava (1960) has shown syncytial nature of the epithelium in *E. kühniella* and *L. orbonalis*, respectively. But these authors have not shown any definite plan of disposition of the circular and longitudinal muscles.

**Spermatheca (Spt).** The spermatheca is tubular in shape. It is distinguished into a spermathecal gland (SptGl), reservoir (SptR) and a spermathecal duct (SptD), the latter opening into the vagina (Vag). The spermathecal gland lies coiled among the female reproductive organs. The broad epithelium of this gland consists of large columnar secretory cells
(Epth) whose nuclei (nu) are large and rounded. There is no muscle layer in the gland. Norris (1932) in _E. kühniella_, Srivastava (1960) in _L. orbonalis_ and Callahan and Cascio (1963) in _H. zea_ have also recorded large epithelial cells in the gland having no muscularis.

The reservoir of the spermatheca (SptR) is somewhat oval and sac-like structure. Its narrow epithelium (Epth) is thrown into small folds. The cellular demarcation in the epithelium is not very clear but the rounded nuclei are arranged in more or less, a regular manner. Internally it is protected by a very weak intimal lining (In), while externally covered by a basement membrane (BMb). The outer most covering, however, is a circular muscle layer (cmcl). Norris (1932) in _E. kühniella_, has shown a distinct cellular condition of the epithelium, whereas Musgrave (1937) has recorded syncytial nature of the epithelium in the same species. Allman (1930) in _C. pomonella_, has not shown the muscular coat, whereas Callahan and Cascio (1963) in _H. zea_, have recorded circular as well as longitudinal muscle layers.

The reservoir (SptR) is connected with vagina (Vag) through a coiled spermathecal duct (SptD). The epithelial lining of the spermathecal duct is of variable thickness. The cells are granulated with basally located rounded nuclei (nu) and are supported on the basement membrane (BMb) which is overlaid by several layers of circular muscle fibres (cmcl). The epithelium is internally lined by a thick intima (In). One of the epithelial folds is conspicuously deep and is lined by strongly developed intima (In). This makes the duct look like bi-luminal in form. Musgrave (1937) in _E. kühniella_, shows the presence of two distinct lumina in the
spermathecal duct. The latter has been shown by him to open on a papilla-like structure called 'infundibulum'. The present writer, however, fails to record any such structure in S. mauritia.

**Bursa copulatrix (Bcpx).** The bursa copulatrix is a fairly large structure lying under the digestive tract and extending up to the fourth abdominal segment. It is distinguished into a bursal sac (bs) and a bursal duct (bd) through which it opens to the exterior at the bursal orifice (bo). A narrow highly convoluted ductus seminalis (sd) connects the bursal duct with the vagina.

The epithelium of the bursal sac is composed of small cuboidal cells supported on a basement membrane (BMb). The cells are finely granulated having centrally located rounded nuclei (nu). The epithelial layer (Epth) is internally lined by an intima (In). The latter is, however, poorly developed in the apical region but gradually becomes thicker towards basal region. In a portion of the side wall of the bursal sac, the intima is greatly thickened so as to form two small 'W'-shaped plate-like structure, which bear stout spines. These plates (OP) are comparable with 'lamina dentata' of Norris (1932), Musgrave (1937) and Klots (1956). However, Callahan and Cascio (1963) call it as 'signa'. The bursal sac is externally surrounded by circular muscle fibres which are strongest in the basal region.

The bursal duct (bd) is curved and dorso-ventrally flattened. It opens at one end into the bursal sac while at the other end it communicates with the exterior through the bursal orifice (bo). The
epithelium (Epth) of the bursal duct is composed of small but distinct cuboidal cells with centrally placed rounded nuclei. The cells are supported on the basement membrane (BMb) which is overlaid by a thick layer of circular muscle fibres (cmcl). Internally, the epithelium is lined by a thick intima (In) bearing small spines.

**Ductus seminalis (sd).** The narrow ductus seminalis is spirally coiled connecting the bursal duct with the vagina. Its epithelium is syncytial (sEpth) with rounded nuclei (nu) sparsely distributed. The epithelial lining is internally protected by a thick intima (In) bearing small spines. As the duct reaches the vagina, its intimal lining becomes conspicuously thicker. The duct is surrounded by 5-6 strong bands of circular muscles (cmcl). Callahan & Cascio (1963) also report the syncytial nature of the epithelium in H. zea. Srivastava (1960) in L. orbonalis, on the other hand has recorded distinct cellular epithelium. Musgrave (1937) in E. kühniella, finds both circular and longitudinal muscle fibres in the ductus seminalis.

**Accessory gland (Gl).** The paired accessory glands are long, tubular and convoluted structure. Each gland opens into a pear-shaped reservoir (ResGl). The duct of the accessory gland which is much broader than the gland, unites with its counter part to form a small common reservoir. The latter opens into the vagina through a short and narrow common duct (dGl).

The epithelium (Epth) of the accessory gland consists of collumnar cells. Externally the epithelium rests on a basement membrane (BMb).
The basally located rounded nuclei are granulated. The cytoplasm is highly vacuolated. More or less, similar histological details of the accessory glands have been given by Callahan and Cascio (1963) in *H. zea*. Allman (1930) in *C. pomonella*, reports the presence of multinucleated condition of the cells of the epithelium.

The reservoir of the accessory gland encloses a spacious lumen. The epithelium of the reservoir is syncytial in nature with scattered nuclei. It is externally bounded by a layer of circular muscle fibres (cmcl). The lumen of the reservoir is filled with thick secretion (Secr) which have a collateral function. The accessory gland's duct also possesses syncytial epithelium which is internally protected by an intimal lining. The circular muscle fibres (cmcl) are well developed.

(viii) The nervous system
(Figs. 6, 131, 132, 133 and 134)

The study of the nervous system in *S. mauritia*, is confined to the central nervous system and the stomodaeal (sympathetic) nervous system. Further at the moment only the anatomy of the system has been taken into consideration.

Central nervous system

The central nervous system consists of the brain, the suboesophageal ganglion and the ventral nerve cord.

Brain (Br). The brain of *S. mauritia*, is a compact body without conspicuous prominences. It consists of the usual three parts viz.,
protocerebrum, deutocerebrum and tritocerebrum. However, these three subdivisions of the brain are not easily demarcated externally but are actually differentiated on the basis of the nerves originating in them.

**Protocerebrum (IBr).** The dorsally situated protocerebrum is the largest subdivision of the brain. Its two lobes have undergone fusion which is externally visible by a shallow mid-longitudinal groove (gr). The protocerebrum dorso-laterally gives out a pair of short stout ocellar nerves (ONv) going to the lateral ocelli. From each lobe of the protocerebrum extends laterally a large pyriform optic lobe (OpL) which innervates the compound eye (E). Each optic lobe is demarcated from the protocerebrum along a distinct external constriction. The optic lobes according to Chauthani and Callahan (1967b) in *H. zea*, begin to distinguish itself in the prepupal stage.

**Deutocerebrum (IIBr).** This middle part of the brain is much smaller and lies ventral to the protocerebrum from which it is not clearly demarcated. It can, however, be identified by the antennal lobes (AntL) which are borne by it. Each antennal lobe gives out anteriorly a long and stout antennal nerve (AntNv) which innervates the antenna of its side. Bahadur and Srivastava (1968) in *Prodenia littura*, have shown large sized deutocerebrum.

**Tritocerebrum (IIIBr).** The tritocerebrum is the smallest portion of the brain lying ventral to the antennal lobe, from which it is faintly demarcated. Its postero-lateral portions are drawn downwards to meet the suboesophageal ganglion (SoeGng). These drawn out structures
may be taken as very short circum-oesophageal connectives (CoeCon) enclosing a circular passage for the pharynx and the aorta to pass through. The tritocerebrum gives out a pair of labro-frontal nerves which later on bifurcates into two branches, the inner branch goes to the frontal ganglion (frGng) and may, therefore, be called as frontal ganglion connectives (frCon). The outer branch (LmNv) is homologous to the labral nerve of the generalized insects and innervates the labrum.

**Sub-oesophageal ganglion.** The sub-oesophageal ganglionic mass lying below the pharynx is formed by the fusion of the paired mandibular, maxillary and the labial ganglia. The sub-oesophageal ganglion gives out three pairs of nerves, namely mandibular (MdNv), maxillary (MxNv) and labial (LbNv). The paired mandibular nerves innervate the area of the head capsule which normally possess the mandibles. This nerve seems to represent the generalized mandibular nerve which is still retained, in spite of the fact that in *S. mauritia* the mandibles are wanting. Eastham and Eassa (1955) in *P. brassicae*, have shown that because of the withdrawal of the mandibles from active use, the mandibular nerves have completely disappeared. Similarly, Ehrlich and Davidson (1961) in *D. plexippus*, have recorded absence of the mandibular nerves. The maxillary nerves enter the lumina of the stipites to continue into the galeae. The labial nerve supplies to the labium.

**Ventral nerve cord (VNC).** The ventral nerve cord bears six dull white coloured ganglionic centres arranged in linear manner along the mid-ventral longitudinal line of the trunk. Each ganglionic mass represents the paired segmental ganglia completely fused together. The
The prothoracic ganglion is the first ganglion of the ventral nerve chain (1Gng). It is somewhat oval in shape lying on the pro-endosternum. Chauthani and Callahan (1967a) in H. zea, have shown it 'somewhat displaced from its original position in the mesothorax'. Two short but very stout connectives extend posteriorly from the prothoracic ganglion to connect it with the second thoracic ganglionic mass. This is the only place in the nerve chain of the adult where the paired ganglionic connectives maintain their separate entity otherwise they are completely fused with each other. However, the paired nature of interganglionic connectives is maintained in the larval stages as shown by Chauthani and Callahan (1967b) in H. zea. The prothoracic ganglion gives rise to a pair of stout nerves (N₁) that arise from its antero-ventral surface. This nerve soon after emerging from the prothoracic ganglion divides into two. The anterior one (N₁a) subdivides into several branches which ramify over the extrinsic muscles of the head and prothorax. The posterior branch (N₁p) also divides to innervate the muscles of the forelegs. The paired stout connectives between the first and second thoracic ganglia gives out in its middle a lateral nerve (N₂) which extends towards the first thoracic spiracle and gives branches to the latter. Chauthani and Callahan (1967a) have shown two pairs of such nerves in H. zea, which are called 'anterior and posterior median nerves', respectively.

The second thoracic ganglionic mass is a composite structure formed by the fusion of the meso- and meta-thoracic ganglia together.
with the first two abdominal ganglia. The mesothoracic ganglion, however, can be differentiated due to the presence of a clear constriction in the otherwise fused ganglionic mass. But there is no distinction between its metathoracic component and the first and second abdominal components, which are completely fused. Three pairs of nerves arise from the mesothoracic ganglion. The first nerve (N₃) arising antero-laterally, leads towards the base of the forewing where it undergoes sub-branching to innervate the forewing and its muscles. The second nerve (N₄) arising posterior to the first one runs in postero-lateral direction to supply branches to the wing muscles. The third nerve (N₅) arises from the ventro-lateral surface of the mesothoracic ganglion and extends postero-laterally to supply branches to the extrinsic muscles of the middle legs.

Two pairs of nerves originate from the posterior part of the second thoracic ganglion representing the composite metathoracic, first and second abdominal ganglia. The first nerve (N₆) arising laterally gives out branches to the intrinsic and extrinsic muscles of the hind legs. It also gives out stout branches to the second thoracic spiracles. The second nerve (N₇) arises from the postero-lateral margin and extends ventro-laterally to innervate the hind wings as well as, their muscles. It also sends a branch each to the first and second abdominal segments, which do not possess segmental ganglia of their own. The innervation of the first and second abdominal segments suggest, the merger of the first and second abdominal ganglia with the second thoracic ganglion. Besides, the portion of the ventral nerve cord connecting the second thoracic ganglionic mass with the third abdominal ganglion gives out two pairs of
accessory nerves (N₈, N₉) for supplying to the first and second abdominal segments.

The third, fourth and fifth abdominal ganglia represent 3-5 segmental ganglionic centres and are thus simple ganglia. These are located in the anterior half of 3-5 abdominal segments. Each segmental abdominal ganglion which is small, more or less, oval in shape gives out two pairs of lateral nerves to the segment concerned. The first pair which is called anterior lateral nerve (aLN) runs laterally and ascending along the segmental pleuron ends by several branches which innervate the dorsal diaphragm and the heart. On its way, the anterior lateral nerve sends branches to the muscles of its segment. In the pleural region, it innervates the segmental abdominal spiracles through a fine nerve branch. The second pair of nerves is called the posterior lateral nerve (pLN). The latter is a short nerve arising immediately posterior to the anterior lateral nerve. It travels in the postero-lateral direction to send branches to the intersternal, as well as, sternal muscles. Just anterior to each abdominal ganglion including the sixth ganglion, an unpaired median nerve (MN) is given out from the dorsal surface of the ventral nerve cord. The median nerve soon divides into two diaphral nerves (DphN) which go to the ventral diaphragm. The diaphral nerves are connected by a short connective (Con) with the segmental anterior lateral nerves of the following ganglion. Beckel (1956) in H. cecropia, shows three pairs of nerves coming out from an abdominal ganglion and calls them 'antero-lateral', and 'postero-lateral' nerves. Libby (1961) in the same insect calls these nerves as 'transverse', 'dorsal' (antero-
lateral) and 'ventral' (postero-lateral) nerves respectively.

The terminal ganglion is a composite structure made of the sixth, seventh and eighth abdominal ganglia of the larva. It gives out five paired and one unpaired nerve in the male and six paired nerves in the female to innervate the structures in the sixth segment and beyond.

In the male, the terminal ganglion (6 Gng) gives out five paired and one unpaired nerve. The first pair which represent the typical segmental anterior lateral nerve (aLN₄) innervates dorsal diaphragm, heart, segmental muscles and spiracles. Similarly, second pair is the typical posterior lateral nerve (pLN₄) supplying to the intersternal and sternal muscles of the sixth segment. The third pair of nerves (LN₅) arising posterior to the second pair travel in the postero-lateral direction to enter the seventh segment, where it divides into two branches for supplying to this segment. The fourth pair (LN₆) also travels in postero-lateral direction and sends branches to the eighth abdominal segment. The fifth pair (LN₇) comes out from the postero-lateral angle of the terminal ganglion as stout nerves. The latter divide and redivide to supply to the anal pouch, vasa differentia, muscles of the ninth and tenth segments and muscles of the aedeagus and parameres. The last nerve (UN) is the unpaired one which arises from the posterior surface of the terminal ganglion, to innervate the ejaculatory duct and the aedeagus. Libby (1961) in H. cercropia, shows ten pairs of nerves arising from the terminal ganglion, three pairs each for sixth, seventh and eighth segments and one pair for the reproductive organs and the genitalia.
In the case of the female the terminal ganglion gives out six pairs of nerves. The first pair which arises from the antero-lateral angle of the terminal ganglion represent the anterior lateral nerve (aLN₄). It is fairly thick nerve whose branches innervate the sixth segment. The small second pair (pLN₄) which is the typical posterior lateral nerve supplies to the sternal, as well as, intersternal muscles. The third pair of nerves (LN₅) arising posterior to the posterior lateral nerve innervate the seventh segment. The fourth pair (LN₆) sends branches to the eighth segment. The fifth pair (LN₇) ramifies over the accessory glands, bursa copulatrix and muscles of the pseudo-ovipositor. The last pair of nerves (LN₈) give branches to the vagina and the muscles of the pseudo-ovipositor.

Stomodaeal nervous system

The frontal ganglion (frGng) of the stomodaeal nervous system is subtriangular in shape. It is placed dorsally over the sucking pump at the junction of the cibarium and the pharynx and is connected with the tritocerebrum by a pair of frontal ganglion connectives (frCon) which encircle the pharyngeal dilators of the sucking pump. The frontal ganglion anteriorly gives out an unpaired frontal nerve (fNv) whose branches go to the cibarium and the food meatus. Likewise, it posteriorly gives out an unpaired recurrent nerve (rNv) the latter running backwards along the mid-dorsal line of the pharynx and underneath the aorta, terminates at the anterior end of the hypocerebral ganglion (hGng). The latter is placed on the dorsal wall of the pharynx, lying within the limits of
the head capsule and just anterior to the foramen magnum. Bickley (1942) in *P. eridania*, calls it 'occipital ganglion' and attributes its formation to the fusion of the median parts of the corpora cardiaca and the recurrent nerve. The posterior end of the hypocerebral ganglion gives out an unpaired recurrent nerve (rNv). The latter runs backwards on the dorsal surface of the stomodaeum upto the end of oesophagus (Oe) where it ends by ramification. The fine branches extend over the crop (Cr) as well. There is, however, no trace of stomachic ganglion. Bickley (1942) in *P. eridania*, has shown paired oesophageal nerves without stomachic ganglion.

The paired corpora cardiaca (oesophageal ganglia) are oval in shape and dorso-lateral to the hypocerebral ganglion. The latter is connected with the corpora cardiaca by short lateral connectives. Their close proximity with the hypocerebral ganglion normally conceals the connectives. The corpora cardiaca (Cc) are closely appressed against the walls of the aorta. According to Hanström (1942) in insecta, the corpora cardiaca governs the function of the dorsal vessel. These are anteriorly connected with the protocerebrum through a pair of nerves called 'paracardiac nerves' (PcNv).

The paired corpora allata (Ca) are very small lying ventral to and in close association with the corpora cardiaca with which it is connected by means of very short connecting duct which are not normally visible. Bickeley (1942) in *P. eridania* recorded the dorsal part of the corpora allata connected with each other. According to Ehnbom (1948) in Insecta, the corpora allata are in intimate contact with both, the wall
of the aorta, and posterior surface of the protocerebrum. Chauthani and Callahan (1967b) in H. zea, describe the corpora cardiaca and the corpora allata lying in wall to wall condition without any visible interconnecting duct.