MORPHOLOGY
MATERIALS AND METHODS

The specimens for the laboratory work were collected from the Veli lake. Collections were made during night hours using a $\frac{1}{2}$ m. diameter conical net made of organde. Live specimens were brought to the laboratory in large containers.

The gross morphology of the different organ systems was studied by microdissections. Animals preserved in lactic acid were found very suitable for studying the external morphology.

Histology was studied from serial sections. The fixatives used included, Bouin's fluid, Zenker's fluid, Carnoy's fluid and Heidenhain's susa. Of these Bouin's fluid and Heidehaien's susa gave excellent results. The sections were cut at 6-8 $\mu$ thickness and stained with Harris haematoxylin-eosine, chromalum haematoxylin-phloxine (CHP) and Heidehains azan stains.

The methods adopted for ecological studies are described at appropriate places.
TAXONOMIC DESCRIPTION

Order Mysidacea
Suborder Mysida
Family Mysidae
Subfamily Mysinae
Tribe Mysini
Genus Mesopodopsis Czerniavsky, 1882

Mesopodopsis zeylanica Nouvel

Mesopodopsis zeylanica Nouvel, 1954, p. 33, figs. 1-16;
Pillai, 1961, p. 28, figs. 1968, p. 21, figs.

Male (Fig. 1)

Body is rather slender and elongated. Post-cephalothoracic portion is nearly cylindrical and not narrowing backwards as usual among mysids. Carapace rather elongated and postero-laterally expanded into moderately large lobes. Anteriorly it has a shallow but prominent lateral concavity. The carapace is produced forwards into a large rostral lobe more or less shaped like a gothic window and posteriorly bounded on either side by a pair of sharp anteriorly directed spines. A well marked groove, the cervical sulcus runs across its surface a little behind the rostral lobe. The carapace leaves the seventh, and eighth thoracic segments and about half of the 6th segment exposed. Abdomen rather long, clearly longer than cephalothorax, segments one to five subequal in
length and width, sixth segment is elongated, one and a half times as long as fifth and slightly narrowing backwards. Eyes with long cylindrical stalk which are rather stout. Cornea broader than the stalk. Telson is longer than broad, with four pairs of lateral spines (Fig. 2). Beyond the fourth lateral spine the telson is produced into an apically rounded conical lobe bordered with a row of closely arranged spines, this telsonic lobe closely resembles the rostral lobe in shape.

Colour of live specimens is greyish due to the presence of several large highly branched dark chromatophores distributed as follows: one on the antennal peduncle, one on the basis of each of the eighth thoracic limbs, a large one on the posterior brood lamella, a very large one on the ventral side of each abdominal segment and one on the peduncles of the uropod.

**Antennule** (Fig. 3)

The peduncle of the antennule is three-segmented. It slightly over reaches the antennal scale and is over 14% of the total length of the body. First peduncular segment is long, roughly equal in length to the rest of the peduncle, with a bunch of about 5 short dorsal distal setae and an outer
distal bunch of about four setae one of which is stout. Second segment has two outer distal and five dorsal distal setae. Third segment steadily broadens distalwards and carries a dorso-distal semicircular lobe carrying small spinules and an outer seta. The inner distal part of the third segment is drawn out into a stout elongated process steadily narrowing distalwards. This process fails to reach the tip of the male lobe. Apically it is rounded and armed with a long spine-like process as long as the process itself and apically drawn out into a filament. Inner to this process are three identical but very small filaments which are apically curved in a cork screw fashion. The male lobe is unusually large, fleshy and profusely hairy. It starts from the ventral side and is distally suddenly narrowed. Its outer part is free of hairs. The antennule carries the usual two flagella, inner short and outer long. Basal segment of the outer flagellum is long and carries about 11-13, olfactory setae (aesthætæs).

**Antenna (Fig. 4)**

Peduncle of the antenna carries a sharp dorsal spine. The scale just reaches the tip of the antennular peduncle. It steadily narrows towards its tip. There is a distinct distal partition. The whole margin of the scale is setose.
The peduncle of the flagellum is three-segmented and is much shorter than the scale. The basal segment is the shortest and the middle segment twice as long as the distal. The middle segment bears a few setae at its inner distal end. A bunch of setae is present at the distal dorsal end of the last segment.

Labrum (Fig. 5)

The labrum is irregularly circular. Its distal border and distal part of its dorsal border are armed with two types of spines, marginal ones spiniform, and submarginal ones dagger-like.

Mandibles (Fig. 6)

Mandibles are asymmetrical, heavily chitinised bodies. Both have remotely similar stout conical incisor process somewhat hollowed and not divided into distinct teeth. The left mandible has a small lacinia mobilis and the right a large one, both carrying several subsidiary teeth. The lacinia mobilis according to Calman (1909) is a distinguishing character of peracarida. The left mandible has a spine row composed of two small spines while the right has a stout spine. The molar of the left mandible is cut into several sharp teeth followed by two setae, the right has no marginal teeth or setae.
Various authors have discussed the origin and evolution of the lacinia mobilis. According to Calman (1909) it is apparently formed by the enlargement of the spines of the spine row. But Gordon (1964) does not agree with this view. She quotes Manton (1928b) to show that the lacinia mobilis has a different origin. Manton has shown that in Meganectiphanes norvegica, it develops from an area between the incisor and molar process which she calls cusp 'b'. The cusp 'b' is better developed on the left side than on the right side. Hence the lacinia mobilis of the left side which develops from cusp 'b' of that side will naturally be better developed. Gordon feels that Manton's explanation of the origin and homology of the lacinia mobilis is obvious.

In M. zeylanica the lacinia mobilis of the left side is less prominent and hence Gordon's opinion does not seem to apply at least to this species. The lacinia mobilis might have developed at the expense of the spine row as the latter is poorly developed. This is in agreement with Calman's view.

The palp is 3-jointed, basal segment short and unarmed, second long with a few plumose setae along its inner margin and a bunch of setae at its inner distal end, third segment
with a marginal row of long pectinate setae and a short submarginal row of barbed setae, apical seta is very long (Fig. 7).

According to Hansen the mandible proper is the enlarged precoxa or possibly the precoxal and coxal segments combined. The first segment of the palp represents the basis or fused coxa and basis. The second and third segments represent a two-segmented endopod.

The incisor and molar processes of the mandible lodged inside the buccal cavity, apart from mincing the food, serve to prevent the loss of food, from the latter.

Labium (Fig. 8)

The labium is symmetrical with large roughly rounded outer lobes internally armed with stiff hairs. The inner lobes are rather indistinct. They remain fused leaving a median suture.

Maxillule (Fig. 9)

The maxillule has a fairly large base. The inner lobe is rather small and carries two small proximal outer spines and three long strongly barbed distal spines. The outer lobe is fairly large and distally carries about eight to ten
comparatively short but strong teeth arranged in two irregular rows. Its dorsal side carries two pectinate setae and inner distal border a few stiff hairs.

All the spines of the maxillule point towards the oral aperture. These function as aids in manipulating food or masticating it.

**Maxilla (Fig. 10)**

The Maxilla is a thin, flat, many-lobed structure. Because of its larger size it covers the maxillule. The coxal segment is fused with the basis. The latter is internally expanded into a large endite which is proximally hairy and distally armed with strong pectinate spine-like setae. The other two endites are small and roughly oblong, outer longer and both with an apical row of spine-like setae. Endopod is two-jointed, the stout basal segment is unarmed but the distal segment is armed on the inner and distal borders. Exopod is narrow, with a comparatively broad base, its outer border with well spaced setae.

**First thoracic appendage (Fig. 11)**

The basis is produced at the inner distal part into a conical gnathobasic lobe armed with a row of fine setae. Endopod is five-jointed and weakly armed. Dactylus does not
carry a nail. Basal segment of the exopod is distally rounded and does not have a spine. The epipod has a stout basal part and an elongate oblong thin lamina about twice as long as the base.

Second thoracic appendage (Fig. 12)

The basis is comparatively broad and armed with about seven long setae. Endopod is five-jointed and the dactylus has no nail. The proximal segment is the shortest of the five. The 2nd leg is very much like the first leg.

Thoracic limbs three to eight (Figs. 13, 14 & 15)

These six pairs of appendages differ from the anterior two pairs mainly in the extreme elongation of the endopods which are well armed with different types of setae. But the main difference is that the carpus and propodus have undergone fusion and got divided into a few identical segments. Hence beyond the merus there are five to seven short segments including the dactylus. Each carpopropodal segment has an inner bunch of slender setae and a stout outer seta which is proximally stout and pectinate and distally narrowed. The eighth leg is however different in that each carpopropodal segment carries two dissimilar outer setae, the shorter one is similar to the setae on the previous legs but the longer
one has its proximal part carrying a comb of stiff hairs (Fig. 15). The distal half is curved-like a sickle and internally armed with a row of basally directed small spines. This limb carries a stout oblong male appendix or penis. The penis bears a pair of median apical setae and four plumose setae near its distal end.

**Pleopods**

Pleopods one, two and five are unsegmented setose plates carrying a small lobe-like pseudendopod (Figs. 16, 17 & 18). But the third (Fig. 19) and fourth (Fig. 20) are modified. The third pleopod has a stout indistinctly two-jointed basipod a short stumpy endopod and a setose exopod. The distal segment of the basipod is bulged at its outer distal part and bears small spines, its inner distal end has a row of submarginal setae. The fourth pleopod is elaborately modified. The basipod is elongated. Second segment of the basiopod is internally spiny. The endopod is small and apparently two-jointed and carries a small pseudobranchial lobe. The exopod consists of a short basal segment and a long distal segment which shows three indistinct septa so that the ramus appears to be five-jointed. The last segment carries a short barbed spine and a peculiarly sculptured outer spine which has a moniliform appearance.
Uropods (Fig. 21)

Both rami of the uropod are setose all round. Exopod is much longer than the endopod. Basal part of the endopod housing the statocyst is highly swollen. On the outer margin of the endopod interspersed between the setae are a few slender spine-like setae.

Average length 6.5 mm.

Female (Fig. 22)

The female differs from the male in the following characters. The rostral lobe is slightly more produced so that it overreaches the base of the eye-stalks. The eyes are comparatively longer and stouter. The antennule is more slender and longer and without the accessory flagellum or male lobe. The antennal scale is longer reaching the tip of the antennular peduncle.

The thoracic limbs have a smaller number of carpopropodal segments and the setae on their outer side are of the type found in the third endopod of the male. The last two pairs of limbs carry a pair of large brood lamella (Figs. 23 & 24) and the sixth a pair of rudimentary ones. All the pleopods are small unsegmented plates, like the first two pleopods of the male (Figs. 25, 26 & 27).
Average length 6.8 mm.

Remarks

Members of the genus *Mesopodopsis* can be easily distinguished by the broad rostral lobe which exactly resembles a gothic window in shape. The telson is also unique in its apical prolongation which is bordered with a row of closely packed spines. In addition to these the male lobe of the antennule is unusually large and the fourth pleopod has a very characteristic armature.

A very unique character of *Mesopodopsis* is the presence of a third flagellum, accessory flagellum, on the antennule of the male. This structure is totally absent in the female. But in the female antennule the inner distal part of the third antennular segment carries four setae. These are absent in the male. Curiously the accessory flagellum of the male has on its tip four peculiarly shaped spines. Therefore Pillai's (1968) assumption that the accessory flagellum of the male is only a prolongation of the third peduncular segment appears to be reasonable. The elaboration and peculiar armature of this structure indicates that it is not merely a "male ornament". It may serve some useful function in propagation. A similar prolongation of the third antennular segment is present in a few other mysids also. But they are
comparatively small and lack any special armature. This structure makes Mesopodopsis rather unique.

The distribution of Mesopodopsis sp. is unique. M. slabberi the type species is found all over the Mediterranean but it has got itself adapted to live in estuaries where it occurs in large colonies. The other three species M. orientalis M. africana and M. zeylanica are exclusively estuarine. Estuarine mysids are very few in the number of species and hence there is very little competition. Hence in the nutrient rich estuarine waters Mesopodopsis found a very suitable habitat. They are indeed very abundant in all the brackish water localities from where they have so far been collected.

Mesopodopsis is confined to the Indian ocean and the Mediterranean. The waters around the tip of Africa are too cold for free swimming animals like Mesopodopsis to cross. Hence the possibility is that Mesopodopsis enjoyed a continuous distribution in the remote part when the Mediterranean was in contact with the Indian ocean.
DEVELOPMENT OF THE SECONDARY SEXUAL CHARACTERS

Among the members of the family Mysidacea sexual difference is evident in the shape of the rostral lobe and the comparative length of the antennular peduncle and the antennal scale. But sexual dimorphism is particularly prominent in the antennule and the pleopods. The antennular characters of the male of Mesopodopsis are in many ways unique and hence their development is traced.

Individuals of M. zeylanica below 4 mm in length are sexually indistinguishable. The antennular peduncle is rather slender, with normally developed inner and outer flagella. In individuals above 3.5 mm - 4 mm long the third segment of the antennular peduncle shows changes (Fig. 28). In the males this segment becomes rather swollen and its inner distal part gets produced into a small conical process carrying a single seta. The latter is stiff and non-plumose. From the median distal part of the ventral side originates a short flattened linguiform extension which is destined to develop into the male lobe. In the female neither is visible. The inner distal part carries four stout plumose setae.

In individuals 4.5 mm long the accessory flagellum is fairly well developed, cylindrical and about four times as long as broad (Fig. 29). The apical filament is about one and a
half times as long as the flagellum proper and near the base of the filament appears a pair of slightly unequal short filaments. The male lobe is still linguiform but very large, exceeding the tip of the accessory flagellum.

In individuals nearly 5 mm long the accessory flagellum progressively narrows towards the tip and there are three subapical filaments which show the beginning of the curvature seen in the adult (Fig. 30). The male lobe gets constricted at its distal inner part and acquires a few sparsely distributed hairs. The shape of both structures is almost as in the adult.

The next moult brings forth an individual which shows all the characteristics of the adult. It should be mentioned in this connection that the growth of the accessory flagellum and the male lobe is very fast compared to that of the animal. This is bound to be so because as will be shown later the androgenic gland which is responsible for initiating the development of the secondary sexual characters of the male is very active in juveniles.

The development of the pleopods also shows a similar growth pattern. In individuals about 3.5 mm. long the third pleopod is a more or less bilobed lamina (Fig. 31). The lobe destined to develop into the endopod is short, and
without setae. The future exopod is about three times as long as endopod and sparsely setose. The fourth pleopod is similarly a bilobed lamina but both lobes are comparatively long and curiously the endopod carries setae and the exopod is without any armature but longer than the endopod (Fig. 32).

In individuals 4.5 mm long the third pleopod does not show much change except that the protopod has elongated much and the exopod is narrower and longer and demarcated from the protopod by an indistinct septum (Fig. 33). The fourth pleopod shows much change (Fig. 34). The rami are separated from the protopod by a partition and the exopod is very long and stout showing three distinct constrictions. Distally it carries two stout spines of which the outer is slightly longer.

During the next moult which liberates the sexually mature males the pleopods take on the adult structures.

Thus the three main secondary sexual characters appear simultaneously and show synchronised development.

In the Mysidacea members of the suborder Lophogastrida have 7 pairs of brood lamellae on appendages 2 to 8. In Mysida there are generally 3 pairs on legs 7 and 8 and occasionally a rudimentary pair on the sixth. The presence of the
third pair obviously shows that *Mesopodopsis* is a more primitive member of the Mysida.

In individuals 3.8 mm long the brood lamellae are small lamellar plates not extending beyond the coxal segment (Figs. 35 & 36). The second pair is slightly larger than the first but similar in shape, one and a half times as long as broad. Both are devoid of setae.

In animals 5 mm long the brood lamellae are larger and reach the sixth thoracic segment, nearly double the size in the previous stage (Figs. 37 & 38). The posterior pair acquires a few setae distributed on the outer margin. In this stage the ovary is clearly visible and extends from the 2nd to the 5th thoracic segment.

In individuals 5.5 mm long the brood lamellae show further development (Figs. 39 & 40). The posterior pair is very large, reaching the 5th thoracic segment and the carpopropodal segments of the 8th leg. The margin is fully bordered with plumose setae. The first pair also increases in size and is sparsely setose. This pair has an accessory lobe bearing 2-3 setae. The ovary extends up to the 7th thoracic segment.
The moult preceding copulation releases the adult with the completely formed brood pouch. All the setae become plumose.

The coxal segment of the 6th leg of the adult has a small rudimentary lamella bearing a few long distal setae.

The brood lamellae grow fast till the precopulatory moult. Their development closely parallel that of the ovary.
DIGESTIVE SYSTEM

Gelderd (1909) made a comparative study of the alimentary canal of a few representative mysids. His observations helped to confirm the validity of the separation of Mysidacea from Euphausiacea proposed by Boas (1882) and Hansen (1893). Mainly based on the findings of Gelderd, Zimmer (1927) briefly described the foregut of Mysida. Siewing (1954, 1956) studied the structure and histology of the foregut and digestive glands of lophogastrids. The structure and histophysiology of the alimentary canal of mysids were thoroughly investigated by Molloy (1958, unpublished). In view of the peculiarities noticed in the foregut of Mesopodopsis slabberi she suggested a reconsideration of its systematic position. Recently Nath and Pillai (1972, 1973) have described the alimentary system of Spelaemysis longipes and Gastrosaccus simulans.

Many early workers have studied the food and feeding habits of mysids. Cannon and Manton (1927) studied the mode of feeding, feeding currents and food of Hemimysis lamornae in detail. Manton (1928a) studied some aspects of the anatomy and habits of lophogastrids. Others who studied the feeding habits are Rauschenplat (1901), Apstein (1906), Depdolla (1916), Elmhirst (1923), Blevgad (1922) Lucas (1936) and Benko (1962).
Gross morphology

The alimentary canal is divisible into 3 main regions (Fig. 41) on the basis of their origin, the fore-gut (FG), the mid-gut (MG) and the hind-gut (HG). The fore-gut includes the buccal cavity (BC), oesophagus (OES) and the stomach and extends from the mouth situated antero-ventrally in the mandibular segment to the distal end of the stomach lying in the first thoracic segment. The mid-gut consists of a long tubular intestine having a small median dorsal diverticulum and four pairs of laterally placed digestive gland tubules originating at its junction with the fore-gut. The mid-gut terminates in the penultimate abdominal segment. The hind-gut is confined to the last abdominal segment.

The fore-gut:

The buccal cavity situated ventrally in the mandibular segment opens to the exterior through the slit-like mouth. Anteriorly the mouth is bounded by the labrum and posteriorly by the labium. The molar processes of the mandibles project into the buccal cavity from the lateral sides. The buccal cavity is spacious and provides space for the movements of the masticatory appendages. It is lined by a thick cuticle bearing spines at certain places (Fig. 42, SP). Molloy (1958) has also noticed the presence of spines in the buccal cavity of all the mysids she studied.
The buccal cavity merges with the proximal part of the oesophagus which runs upwards and backwards to enter the anterior face of the stomach. The oesophagus is 75 µ long and has a maximum diameter of 35 µ. The wall of the oesophagus is thrown into four longitudinal ridges which project prominently into its lumen. Due to the presence of these ridges the lumen appears X-shaped in sections (Fig. 43). These ridges are named, following the terminology adopted in the study of decapods, the labral (LBR), lateral (LTR) and metastomial (MSR) ridges. The labral ridge, which is a continuation of the upper lip has an average height of 15 µ, whereas the ventral or metastomial ridge is rather flat and only 8 µ tall. The lateral ridges are triangular in cross section and 7 µ high. All the ridges except the ventral have the same contour throughout their length, with a broad base and a tapering apex. The ventral ridge is more or less rectangular in cross section (Fig. 43, MSR) with a flat summit.

While the epithelium of the oesophagus merges imperceptibly with that of the cardiac stomach, the ridges protrude into the cavity of the stomach for a short distance (Fig. 42, EOR). This might be for preventing the reentry of food from the cardiac stomach into the oesophagus. The diameter of the lumen of the oesophagus is uniform except at the beginning where it is broader and funnel-shaped (Fig. 42).
The epithelial cells of the wall of the oesophagus are lined by a thin layer of cuticle (Fig. 43, CL) which is a continuation of the cuticular covering of the body. This layer is devoid of bristles and hairs as observed by Gelderd (1909) in P. flexuosus and by Nath and Pillai (1972) in S. longipes. At the region of the longitudinal ridges the epithelial cells are tightly packed and taller than those of the other regions. The cytoplasm is homogeneous and the nuclei round or oval. The epithelial layer is surrounded by a thin structureless basement membrane (Fig. 43, BM). Outer to this is a layer of circular muscles followed by a serosa formed of loosely packed cells (Fig. 43, CT). Apart from these circular muscles, the oesophagus is supplied with a number of powerful extrinsic muscles which will be described along with the gastric muscles.

Rosette-shaped glandular bodies are present at the base of the labrum, mandibles and maxillae (Fig. 44). These are homologous with similar glandular structures found in other crustaceans. Gelderd (1909) has described salivary glands in P. flexuosus and other mysids. According to Yonge (1932) the tegumental glands in Homarus are homologous with similar glands found in other malacostracans including mysids. But in P. flexuosus the tegumental glands are confined to the oesophageal region (Molloy 1958).
The glandular bodies consist of a number of conical cells, their apices converging towards the centre of a sphere from where arises a short canal going outside the gland (Fig. 44, TGLC). The nuclei (N) of these cells are large and occupy the broad outer halves. The cytoplasm is vacuolated and highly granular and takes basic stains.

Early workers like Huet (1882) claimed that these cells function as salivary glands. Gelderd (1909) emphasised the glandular and vacuolated nature of these cells. Ide (1892) assigned a salivary function to the rosette glands in isopods. Yonge (1924, 1932) suggested that these glands are concerned with the secretion of the cuticle. According to Gorvett (1946) the activity of these glands in land isopods is closely connected with the moulting cycle and their function is mainly secreting the cuticle. But Schmitz (1967) observed that the rosette glands in *Gammarus lacustris lacustris* might play some part in the secretion of chitin and digestive enzymes. However no one has conclusively proved that the rosette glands secrete any enzymes. In *M. zeylanica* the rosette glands do not have any connection with the alimentary canal and hence cannot have anything to do with digestion at least in this animal. In their structure and function the rosette glands of *M. zeylanica* closely resemble those of the land isopod *Porcellio scaber* described by Gorvett (1946).
The oesophagus enters the much wider stomach which extends up to the first thoracic segment. The stomach of *M. zeylanica* is much different from that of other mysids hitherto studied. Generally among mysids the stomach is clearly demarcated into cardiac and pyloric portions. In *M. zeylanica* it is tubular and undifferentiated. Nevertheless based on internal structure an anterior and a posterior portion can be distinguished. Pearson (1908) observed that the terms cardiac and pyloric are not very appropriate. But they have gained acceptance and hence are adopted here also. Otherwise comparison would be very difficult or even impossible.

The inner wall of the stomach is thrown into folds and ridges bearing spines, setae and bristles. Various terms have been employed by different workers to describe these structures. In the present work the terminology adopted by Molloy (1958) is followed.

The cardiac stomach is much reduced in size and lacks the anterior prolongation into the head which is a characteristic feature of the fore-gut of most mysids. It is tubular, with a lumen thrice the width of the oesophagus (Figs. 45, CST). The more important internal structures of the cardiac stomach are two pairs of lateral cardiac folds and a ventre-median cardiac ridge. These structures are typical of the stomach of most
malacostracans. The lateral cardiac folds starting just behind the entrance of the oesophagus into the stomach run backwards along the lateral walls of the cardiac stomach up to its junction with the pyloric stomach (Figs. 46, ICF & SCF). The inferior cardiac folds placed on a level with the ventral cardiac ridge are more prominent and are continued as the infero-lateral pyloric folds. The inferior cardiac folds carry on their inner margin 16–17 spines which curve inwards and upwards (Figs. 46, SP). The two inferior cardiac folds are oriented in such a way that they converge along the median line over the ventral cardiac ridge (Fig. 47). The upper folds called superior lateral cardiac folds are median lateral in position and hence widely separated from the ventrolateral. They proceed backwards and terminate just in front of the posterior dorsal cardiac projection (Figs. 46 & 48, SCF). The free margins of these folds are beset with feeble setae directed backwards. The two cardiac folds are continuous at the anterior end.

Considerable variation in the arrangement of spines and teeth on the lateral folds of the cardiac stomach of mysids has been noticed by several workers. According to Molloy (1958) these variations are specific and reflect the variations in the feeding habits. *M. zeylanica* does not possess either the dorso-lateral toothed projections bearing spines of various kinds
or any teeth on the lateral cardiac folds as in P. flexuosus, N. integer, L. mediterraneus and G. spinifer (Molloy 1958) and G. simulans (Nath and Pillai 1973).

The mid-ventral wall of the cardiac stomach is raised to form the ventro-median cardiac ridge (Fig. 47, VCR). This ridge appears to be somewhat semicircular in transverse sections. Posteriorly it gets more flattened and merges with a prominence situated just in front of the ventral pyloric ridge. The ventral cardiac ridge bears numerous hairs directed backwards (Fig. 48). This ridge is present in almost all malacostracans and is homologous with the "ventral ampulla" plus filter I of isopods (Nicholls 1931) "inferior cardiac piece" of Cumacea (Stappers 1909) and the "cardiacaules ventral stucke of Decapoda, Nebaliacea and Tanaidacea (Siewing 1953, 1956). The antero-dorsal wall of the cardiac chamber is thickened to form a plate-like projection which represents the "anterior dorsal cardiac fold" (Fig. 47, ADCF).

At the junction of the cardiac and pyloric chambers the dorsal wall of the cardiac chamber bears a mid-dorsal invagination which is semicircular in outline and directed backwards (Fig. 48, PDCP). Its free margin bears 16 long spines, 15 μ long and projecting downwards and upwards (Fig. 48, SP). This structure is the counterpart of the posterior dorsal cardiac
projection described by Molloy (1958) and superior median piece (PSM) described by Gelderd (1909) in P. flexuosus and M. flexuosus*. But unlike as in P. flexuosus, it is a single piece and its spines are not barbed. The dorso-median cardiac prominence in G. simulans (Nath and Pillai, 1973) bears 2 pairs of anteriorly directed barbed setae, in addition to the usual complement of 12-16 setae. The posterior dorsal cardiac projection of M. zeylanica corresponds to the mid-dorsal ridge of Spelaeomysis longipes (Nath and Pillai 1972).

This mid-dorsal ridge plays an important role in the working of the cardiac chamber because of its position in the cavity and the presence of powerful spines on it. It prevents the entrance of food particles, that have not been sufficiently masticated, into the pyloric chamber. According to Gelderd (1909) the spines on this ridge help to force the main food mass into the upper cavity of the pyloric chamber.

The posterior dorsal cardiac projection is homologous with the "P.S.M" (superior median piece) of the cumacean, Diastylis (Stappers 1909). Siewing (1954) described a similar piece in the cardiac stomach of Eucopia under the name "dorsal hakenplatte" (DH). According to Siewing the "DH" is also homologous with the cardiopyloric valve of

*Macropsis flexuosa later became Praunus flexuosus
Euphausiacea. In Anaspides (Siewing 1956) there are two median dorsal filaments on the roof of the cardiac chamber which can be treated as the homologues of "PSM". A typical posterior cardiac projection is found in Nabalia (Siewing 1956) and also in Decapoda eg. Nephrops (Yonge 1924). It may be emphasised that the armature of the cardiac stomach is extremely simplified in M. zeylanica. Nath and Pillai (1972) have correlated the reduction in the gastric armature of S. longipes with the type of food consumed by the animal. Gelderd (1909) has stated that the simple nature of the cardiac stomach in M. slabberi is compensated by the development of powerful mouth parts and large buccal cavity. Molloy (1958) pointed out that many of the mysids examined by her have both powerful masticatory oral appendages and a well developed cardiac stomach as well. Since M. zeylanica retains the food in the cardiac stomach only for a short period and digests it rapidly it may not require a complicated triturating mechanism. In other mysids the dorsal part of the cardiac chamber behind the entrance of the oesophagus and above the ventral cardiac ridge where all the armed projections converge functions as a powerful masticatory region.

The pyloric chamber which is a continuation of the cardiac chamber has a wider lumen. It is also provided with
two pairs of folds on its lateral walls and a ventral median ridge arising from its floor. This chamber is similar to that of *M. slabberi* in which it is indistinctly divided into an upper and a lower chamber. The lower or the inferior fold which is a continuation of the lower cardiac fold runs on a level with the summit of the ventral pyloric ridge (Fig. 48, IPF). The free inner margins of the two folds of this pair converge over the ventral pyloric ridge forming an incomplete transverse partition. These folds bear on their lower surface a number of minute spines. The upper or superior pyloric fold originates from behind the posterior extremity of the posterior dorsal cardiac ridge (Fig. 48, SPF). In *M. zeylanica* this fold is rather inconspicuous and bears minute setae on its inner edge. It runs parallel to the lower fold up to the posterior end of the ventral pyloric ridge where it dips downwards (Fig. 46, SPF). This downward extension bears long bristles projecting into the region where the stomach meets the mid-gut. The posterior lateral extension of the lower lateral pyloric folds along with the spines present on their lower surface prevents the entry of food into the lower pyloric chamber.

The lateral ridges, called br1 and br2 by Gelderd (1909) connecting the inferior and superior lateral folds of both the chambers in *P. flexuosus* are not found in this animal.
Unlike in *P. flexuosus*, the lower folds are continuous in *M. zeylanica*. The superior folds, though discontinuous are not connected by any ridge. An identical condition has been reported in *M. slabberi* (Molloy 1958). But Molloy (1958) failed to locate the lateral ridge, br2 in *P. flexuosus*. In most mysids these two folds are continuous and hence can be considered as a single fold of the epithelial wall. Its anterior part is modified for the mastication of food and the posterior part for filtering the same. In *M. zeylanica* the lower cardiac and pyloric folds are continuous forming a single fold. The existence of single lateral folds in the epithelial wall of the stomach is consistent with the condition found in related peracarida. In Isopoda there is a single pair of plates which is continuous both in the cardiac and pyloric regions of the stomach (Nicholls 1931) i.e. the anterior ventral lamellae together with the lateral ampullae. Siewing (1954, 1956) recognised two pairs of lateral ridges in Lophogastrida, referred to as Ls, Li, which are similar to the upper (Dorsal Wulst) and lower (Pylorikale seitenstucke) pairs of projections on the lateral pyloric folds. According to Martin (1964) the lateral cardiac fold in *M. obtusatus* is an anterior extension of the lateral superior pyloric fold.

The lower cavity of the pyloric chamber is encroached upon by an unpaired median ridge in the form of a column rising
from the floor of the chamber (Figs. 48 & 51, VPR). In transverse sections this ridge is triangular, its broad base forming the entire floor of the pyloric chamber. Anteriorly its summit is rather flat, but becomes progressively taller and narrower backwards. The posterior end of this ridge is produced into a narrow extension bearing long setae (Fig. 49, SE), which together with the bristles of the inferiQ lateral folds forms an efficient sieve which prevents larger food particles going into the ventral chamber. This median ridge almost occludes the entire lumen of the lower chamber leaving only a narrow space on either side between it and the lateral pyloric folds. The lateral wall of the median ridge is provided with a pair of lateral grooves or gutters (Fig. 50, LG) placed obliquely on its lower half. These grooves are bordered with narrow ridges which carry a series of closely set setae arching over the grooves. The lateral sides of the median ridge as well as its summit are beset with closely set hairs (Fig. 50, HR). The lateral walls of the pyloric chamber facing the lower half of the median ridge also accommodate a pair of grooves or filter channels (Figs. 46 & 48, FCH). The epithelial wall bordering these grooves is thickened to form ridge-like prominences bearing stiff setae (Fig. 46, SE) which curve over the grooves producing filter channels. These grooves are also slanting, going backwards and downwards and terminate far behind the grooves of the mid-ventral ridge.
The filter channels are connected to the mid-gut where the digestive glands open into the alimentary canal. The lateral wall of the pyloric chamber above the filter channels and facing the mid-ventral ridge is covered with fine hairs. These hairs lying in close proximity to the free surface of the median ventral ridge prevent food from falling into the channel below where the digestive glands discharge their secretions. The roof of the pyloric chamber is also provided with fine hairs throughout. The obliquely set spines on the ventral face of the lower pyloric folds are directed opposite to that of the long setae on the grooves of the median ventral ridge. These spines are characteristic of the entire surface of the pyloric folds. The semicircle of bristles borne by the upper folds observed by Molloy (1958) in *P. flexuosus* is lacking in *M. zeylanica*. Gelderd (1909) has also failed to locate these bristles in *P. flexuosus*. Siewing (1956) has mentioned the presence of similar structure in lophogastrids and designated them "Pylorikaler Porstenkorb".

The number of lateral grooves or gutters borne by the ventral pyloric ridge varies considerably in different groups of Malacostraca. Wherever the median ridge is high there is a corresponding increase in the number of lateral grooves. In isopods there are one to two pairs, one to three pairs in mysids, seven to eight in lophogastrids, two pairs in
amphipods and several in decapods. This correlation was first suggested by Stappers (1909). But it has been observed that the number of lateral grooves varies in the same order. Molloy (1958) found two pairs in *S. armata* and three in *S. jaltensis*. On the other hand Gelderd (1909) and Siewing (1956) failed to find any groove in Euphausiacea while in the closely related Decapoda there are several grooves. Clearly the difference in the number of grooves is adaptational and has no phylogenetic significance.

Molloy (1958) found a correlation between the complexity of the ventral pyloric ridge and the increase in the number of the digestive gland tubules. "Thus Mysidacea forms an intermediate group having four to six pairs of tubules whereas Cumacea and Isopoda have two to three pairs and decapods and euphausids have numerous".

The filter channels present on the lateral wall of the pyloric chamber form a unique feature of the suborder Mysida. Gelderd (1909) and Molloy (1958) have described these structures in *M. slabberi*. In *G. simulans* Nath and Pillai (1973) have observed five or six pairs of shallow grooves on the lateral wall of the ventral chamber. No other malacostracan so far studied has these. These filter channels are reminiscent of the condition found in decapods, in which the filter channels
on the mid-ventral ridge encroach upon the lateral pyloric folds though they are much reduced in size.

Posterily in the mid-dorsal region the epithelial wall of the pyloric stomach just in front of the anterior wall of the dorsal diverticulum is thickened to form a crescentic plate (Fig. 45, PDPF). This plate is the homologue of the 'posterior dorsal pyloric fold' described by Molloy (1958) in P. flexuosus and the "lamelles annulair" of Ide (1892). Posterily this plate stands detached from the wall of the stomach and its chitinous extension reaches far beyond the opening of the dorsal diverticulum into the mid-gut. This structure is the pyloric valve (Fig. 52, PV) which prevents food materials from entering the dorsal diverticulum. The pyloric valve however does not extend on to the ventral side as in P. flexuosus.

The posterior dorsal pyloric fold is apparently the homologue of the decapod "trichter". Yonge (1924), Balss (1927) and Siewing (1954, 1956) used the term "trichter" for the complex of structures extending into the mid-gut. The posterior dorsal pyloric fold in mysids is homologous with Siewing's "Dorsal spange" or "Reststucke". The pyloric valve appears to be both analogous and homologous with the "Entonnoir" found in certain insects (Molloy, 1958).
The cuticular lining of the stomach is thicker than that of the oesophagus. The dorsal wall of both cardiac and pyloric stomachs possesses a thin layer of epithelial cells (Figs. 47 & 51, E). The lateral walls at the region of the ridges are 7-10 μ thick. The epithelium is syncytial at certain areas with a large number of nuclei. In the mid-ventral ridge the cells are thickly packed and are widely separated from the overlying cuticular layer. Surrounding the epithelial layer are the circular muscle bands which are poorly represented in the dorsal aspect of the chamber. The wall of the stomach has a connective tissue coating outer to the muscular layer. The longitudinal muscles are absent.

The cuticular lining of the stomach is found to be detached from the underlying epithelium wherever it is thick as in the mid-ventral ridge of the pyloric and the cardiac stomachs (Figs. 47 & 53, A). Many workers have noticed this feature in other crustaceans, Gelderd (1909) and Molloy (1958) in mysids, Rehorst (1914) in Asellus, Nicholls (1931) in Ligia and Martin (1964) in Marinogammarus. According to Gelderd this is brought about by the fixative, an artifact. But Molloy suggests that the epithelial cells contract and recede to provide space for a new cuticle. Martin suggested a compromise namely that it may be an artifact together with the separation of the old cuticle from the new one being formed in the early
premoult stage. This observation seems to be the most acceptable. Fixation can certainly accentuate the natural condition.

Gastric musculature

The muscles controlling the working of the stomach constitute the gastric musculature. Mocquard (1883) has classified the gastric musculature of Crustacea into two types, the extrinsic and intrinsic, the former having their origin in the exoskeleton and insertion on the wall of the stomach and the latter originating and getting inserted on the wall of the stomach itself. This procedure is accepted in the present work.

The anterior oesophageal dilator muscles consist of muscle bands arising from the sternal plates of the cephalic segments and the dorso-median aspect of the cephalic shield and get inserted on the oesophagus at the region of the labral ridge (Fig. 54, AODM). A median unpaired muscle originating from the inner wall of the cephalic shield gets inserted on the proximal part of the labral ridge. A pair of muscles arising from the junction of the oesophagus and buccal cavity runs outwards and downwards to get inserted on the outer wall of the labrum. There is yet another pair of muscles extending between the ventral body wall and the oesophagus.
Extending between the endoskeletal plate (Fig. 55, ESP) and the metastomal ridge of the oesophagus are the posterior oesophageal dilators. These are concerned with increasing the lumen of the oesophagus (Fig. 54, PODM).

The lateral oesophageal dilators are attached to the lateral body wall and the lateral ridges of the oesophagus. These muscles work in conjunction with the other muscles (Fig. 54, LODM).

The muscles found attached to the lateral cardiac folds are the anterior lateral cardiac dilators (Fig. 54, ALCDM). These muscles have their origin on the lateral wall of the cephalic shield, and are concerned with the movements of the cardiac folds.

The posterior ventral cardiac dilator muscles emerge from the ventral wall of the cardiac stomach and get attached to the maxillary sternum. They help to increase the lumen of the cardiac stomach in the dorso-ventral direction (Fig. 54, PVCDM).

The anterior gastric muscles extend between the anterior wall of the cardiac chamber and the mid-ventral part of the cephalic shield (Fig. 54, AGM). Expansion of the cardiac chamber is brought about by the contraction of these muscles.
The ventral pyloric dilator muscles are three pairs of muscles, an anterior, a posterior and a median. They are attached to the ventral wall of the pyloric chamber and have their origin on the endoskeletal plate and the sternal plate of the maxillary segment (Fig. 54, VPDM). The ventral pyloric dilators are concerned with the movements of the median ventral pyloric ridge.

The posterior gastric muscles are formed of 3 median muscle bands. The anterior one emerges dorsally at the junction of the cardiac and pyloric chambers (Fig. 54, PGM). This muscle is responsible for the working of the posterior dorsal cardiac projection. The remaining two muscle bundles are inserted posteriorly on the mid-dorsal wall of the stomach just in front of the anterior end of the dorsal diverticulum. These muscles run backwards and upwards to attach themselves to the median part of the inner wall of the cephalic shield. The posterior gastric muscles serve to drive the posterior dorsal cardiac projection into the food mass by pulling on the wall of the stomach.

Apart from those described above a pair of large muscles originates from the cephalic shield and going straight downwards on either side of the stomach gets attached to the endoskeletal plate (Fig. 55, MEC).
The intrinsic muscles are poorly developed, probably due to the absence of well developed gastric armature.

The lateral cardiac muscles lie laterally on the wall of the cardiac chamber between the insertion of the anterior gastric muscle and the origin of the ventral pyloric muscle (Fig. 54, LCM).

The lateral pyloric muscle consists of several muscle bands spread on the lateral wall of the pyloric chamber. They are placed obliquely between the anterior lateral part of the mid-ventral ridge just below the insertion of the posterior gastric muscle (Fig. 54, LPM).

Connecting the cardiac and pyloric stomach, on the ventral side is a sheet of intrinsic muscles (Fig. 56, ICP).

**Functions**

Food is transported from the mouth to the cardiac stomach by the peristaltic movements of the wall of the oesophagus. The spines and hairs in the buccal cavity help in pushing the food into the oesophagus. The food particles entering the cardiac stomach are acted upon by the spines of the inferior cardiac folds before they are transferred to the much complicated pyloric region where they are strained through the filter channels. The finely divided food mixed
with fluid passing through these channels enters the digestive gland tubules. Larger particles are carried away to the exterior through the anus via the mid-gut.

As already stated the fore-gut of *M. zeylanica* is simple compared to that of other malacostracans. The simple gastric armature is evidently a secondary development. Siewing (1956) has traced the evolution of the gastric mill of Crustacea. According to him the fundamental type is tubular, the oesophagus having four longitudinal ridges followed by a simple gizzard (cardiac stomach) ending posteriorly in a pyloric chamber. The division into cardiac and pyloric portions is hardly evident. The fore-gut of most malacostracans is a modification of this fundamental pattern. In mysids the stomach is nearly always differentiated into cardiac and pyloric portions. The cardiac portion is provided with strong cuticular structures and is masticatory in function and the pyloric mainly provided with hairs is an efficient filtering apparatus. Early workers considered the posterior dorsal cardiac projection armed with strong spines as the chief masticatory organ. Tait (vide Nicholls 1931) working on isopods observed that the term stomach is inappropriate since it implies that food is masticated here. He is of opinion that the stomach simply conveys the food to
the hind portion. Nicholls (1931) agreed with this view but observed that the fore-gut actually does something more than merely conveying food.

The function of the cardiac stomach varies widely among mysids. *P. flexuosus* and *N. integer* retain food in the cardiac stomach for a long period to be churned by various cardiac pieces (Molloy 1958) whereas in *Seriella* and *M. slabberi* the food is passed through the stomach fairly rapidly, especially in the latter. In this species the food is actually bolted through the cardiac chamber. In this respect *M. zeylanica* closely resembles *M. slabberi*.

Gelderd (1909) and Nicholls (1931) observed that the pyloric chamber is mainly concerned with the separation of fine particles of food from coarse ones and mixing them with the secretions of the digestive glands. Yonge (1924) also attributed a filtering function to the stomach of decapods, but added that the pyloric portion possesses filters which prevent coarse material from passing through the stomach. Though this is largely true of the stomach of *M. zeylanica*, the presence of larger particles, in the digestive tubules indicates that the filtering mechanism of this animal is not very efficient. According to Gelderd (1909) mixing of food with digestive enzymes takes place solely in the pyloric
stomach. Nath and Pillai (1973) have supported this view. But Molloy (1958) contented that the entire digestion and absorption takes place in the digestive tubules and that the pyloric stomach has no part in this.

Opinions differ regarding the precise function of the stomach. According to Ide (1892) the stomach is mainly a triturating organ. Gelderd observed that the stomach supplements the masticatory activity of the oral appendages. On the other hand Hewit (1907) found that the stomach of Ligia is an efficient masticating apparatus capable of tackling the wide variety of food the animal consumes. But Tait (1917) disputes Hewit's finding and suggests that the only function of the fore-gut is propelling the food backwards. Nicholls (1931) generally agreed with Tait, but observed that the fore-gut is not merely an organ for propelling food.

M. zeylanica exclusively feeds on animal matter. What little mastication there is, is done by the oral appendages. Therefore the main function of the stomach appears to be extracting the most readily absorbable nourishment. This will not require an efficient triturating mechanism and the food need be retained in the stomach only for a short time. This explains the comparative simplicity of the stomach. Nath and Pillai (1972) found that S. longipes, feeding on detritus, has
a very simple stomach devoid of spines.

The mid-gut.

The mid-gut is a long tubular structure extending up to the beginning of the 6th abdominal segment. At the anterior end of the mid-gut is a small curved, finger-shaped dorso-median diverticulum and four pairs of laterally placed digestive gland tubules communicating with the mid-gut ventro-laterally through a pair of common ducts.

The mid-gut is not a straight tube. While proceeding backwards from the maxillary segment it follows a slightly downward course for a while and then runs parallel to the nerve cord, surrounded by the digestive gland tubules and sex organs. On reaching the fifth thoracic segment it bends obliquely upwards till it reaches the 8th thoracic segment. Beyond this point it continues as a straight tube close to the dorsal integument up to the hind-gut. The terminal portion of the mid-gut is somewhat enlarged (Fig. 41).

Histology

The mid-gut or the intestine proper has an outer connective tissue layer followed by circular and longitudinal muscle layers. The circular muscle bands are of uniform
thickness and width. Nath and Pillai (1972) have described narrow and broad muscle bands alternating in *S. longipes* but have not explained the significance of such an arrangement. The longitudinal muscle bands are placed 1.5 μ apart and are 1 μ thick (Fig. 57, CM & LM). These muscles cause peristaltic movement which can be easily seen in live animals. Inner to the muscles is a thin structureless membrane (Fig. 57, BM) followed by the epithelium formed of cubical cells (Fig. 57, E). The lumen of the mid-gut often appears triangular in sections probably due to the effect of fixatives.

The epithelial cells are not uniform throughout. They are shorter and in T.S. rectangular in the anterior region. The cytoplasm with basally placed round or oval nucleus is faintly stainable and is devoid of vacuoles. The free ends of the epithelial cells are not striated. Molloy (1958) has found small vacuoles in the cytoplasm of the epithelial cells of *P. flexuosus*. She has also observed a conspicuous striated border in the same species. Nath and Pillai (1973) also have observed the striated nature of the mid-gut epithelium in *G. simulans*.

Beyond the proximal region the epithelial cells are somewhat detached from one another as if contracted (Fig. 58, E). The apices of these cells are irregular in shape. The cytoplasm
is homogeneous containing no vacuoles. Further posteriorly the cells are more flattened increasing the size of the lumen. The cells at this region are closely packed, their nuclei are ventral or dorsal (Fig. 59, E). These cells undergo division and hence form an embryonic zone (Fig. 60, EZ) from where new cells migrate anteriorwards to replace the seniscent cells. These elongated cells form an annular ridge marking the posterior limit of the mid-gut (Figs. 61 & 121, AR). The termination of the mid-gut at the junction of the fifth and sixth abdominal segments confirms the observation of Manton (1928b) that the endoderm extends up to the 6th abdominal segment. Molloy (1958) has also made a similar observation in P. flexuosus. Gelderd has observed an increase in the size of the lumen of the mid-gut at its terminal part and also stated that the epithelial wall is formed of loosely packed small cells.

In sections of the gut entire cells or portions of cells are often found. These cells are extruded from the wall of the gut (Fig. 62, EC). By this process the seniscent cells are removed and replaced by new ones formed at the embryonic zone. All these cannot be regarded as seniscent cells of the gut epithelium because there is every possibility of some digestive gland cells entering the lumen of the gut.
Since the latter are much larger than the intestinal cells they can be easily identified.

Holocrine secretion has been reported in the mid-gut epithelium of Astacus (Hirsch 1929), Caridina (Pillai 1958) and Spelaeomysis (Nath and Pillai 1972). This observation was based on the presence of cells similar to those of the epithelium within the lumen. Nath and Pillai (1972) have assigned a secretory function to the epithelial cells of the mid-gut of S. longipes. Chandy (1939) has demonstrated the presence of "blisters" in the mid-gut of Ligia which according to her is proof of holocrine secretion. The present study is not detailed enough to support or oppose the above observation. I could not observe eroded cells in the mid-gut or blisters on the epithelium. In view of this and also from the nature of the cells, there is no reason to believe that the epithelial cells of the mid-gut of M. zeylanica have any secretory activities. Molloy (1958) has presented evidence to show that the mid-gut epithelium of N. integer is absorptive in nature.

Balss (1927) remarked that the mid-gut varies considerably in length among the malacostracans. In M. zeylanica it forms 90% of the entire length of the intestine. The same is true of other mysids also. Manton (1928b) has
shown that in *H. lamornae* it is the longest part of the alimentary canal. *M. orientalis* (Nair 1939) also possesses a long mid-gut. The mid-gut of all the mysids examined by Molloy (1958) is long. Other crustaceans like *Caridina* (Pillai 1958), *Squilla* (Nair 1941), *Nephrops* (Yonge 1924), *Palaemon* (Patwardhan 1937), *Marinogammarus* (Martin 1964) and *Alpheus* (Calman 1909) also have long mid-gut. But in Cumacea and Isopoda, the mid-gut is very short or nearly absent. As observed by Martin (1964) this is because in these animals the mid-gut is proctodael in origin while in the others it is mesodermal.

**Dorsal diverticulum**

This is a median outgrowth bifid distally, projecting forwards over the posterior part of the pyloric stomach (Fig. 41, DD). This paired tubular organ has a median proximal stem connecting it with the anterior part of the mid-gut (Figs. 52 & 63, STM). The lumen of the anterior portion is circular whereas that of the posterior part is crescentic as the cells lining these regions differ in size and shape. In general the epithelial cells are tall and closely packed. They stain more intensely than those of the mid-gut (Fig. 63, E). The nuclei of these cells are situated away from the tip and are more or less oval in shape with scattered chromatin granules.
and one or two nucleoli. The ventral wall of the diverticulum lying in close proximity to the dorsal wall of the pyloric stomach is formed of thinner cells having a centrally placed nucleus and a faintly stainable cytoplasm (Fig. 56, E).

The epithelial cells forming the antero-ventral wall of the diverticulum are peculiar in that they undergo nuclear division and mitotic figures are commonly observed. This region showing active nuclear division is homologous with the anterior wall of the dorsal diverticulum of P. flexuosus (Molloy 1958).

The dorsal diverticulum is moderately well developed in mysids, but is large in amphipods, and small in isopods (Martin 1964). It is present in all mysids so far studied, though in structure and disposition it shows specific variation. In Siriella jaltensis it is reduced to a small projection, but it attains maximum size in N. integer (Molloy 1958). It is single, large and backwardly directed in P. flexuosus (Gelderd 1909). M. slabberi, L. mediterrania and G. spinifer possess a short, paired organ (Molloy 1958). In S. longipes (Nath and Pillai 1972) it reaches the anterior end of the cardiac stomach. The dorsal diverticulum in G. simulans is short and directed forwards (Nath and Pillai 1973).
Though the gut diverticula are present in a number of crustaceans their true function has not so far been clearly understood. Molloy (1958) and Beechermoore (1959) have considered this organ as glandular in mysids and isopods. Molloy has even assigned a digestive function to this organ. But she has not given any evidence in support of this. However both Molloy and Beechermoore have found that the dorsal diverticulum is responsible for the formation of the peritrophic membrane. Molloy's observations show that this organ is not concerned with absorption. Nath and Pillai (1972) have also assigned a digestive function to the dorsal diverticulum of S. longipes. Dall (1967) has concluded that the gut diverticulum of Metapenaeus bennettae is concerned with the secretion of enzymes as well as excretion of salts. He supports Martin's (1964) observation on Marinogammarus that the peritrophic membrane is secreted by the anterior part of the mid-gut and not the mid-gut caecum.

As the dorsal diverticulum is a formative region showing great activity it cannot be considered as a vestigial organ. But how far it is involved in the formation of the peritrophic membrane is not yet clearly known. Nevertheless the wide variation in the dorsal diverticulum showing specific differences shows that it is playing a vital role and that the variations are adaptive.
Peritrophic membrane

This is a thin sheet of chitin found in the lumen of the intestine enclosing the faecal matter (Fig. 57, PM). It takes the aniline blue component of Heiden hain's azan. In order to prove the chitinous nature of this membrane the intestines of several starved animals were subjected to "chitosan test". The positive results obtained indicated the presence of chitin in the mid-gut of the animal.

The presence of peritrophic membrane has been demonstrated by many workers in members of most crustacean orders. Dall (1967) asserted that this membrane is characteristic of malacostracans with a long mid-gut. Siewing denied the existence of a peritrophic membrane in mysids and amphipods. Forster (1953) found it in Caridea, Molloy (1958) in mysids, Beechermoore (1959) in isopods and Martin (1964) in amphipods. Molloy and Beechermoore have stated that it is secreted by the dorsal diverticulum whereas according to Martin (1964) and Dall (1967) it is derived from the anterior part of the mid-gut epithelium. It has not been possible to locate the exact origin of this membrane in M. zeylanica though its presence cannot be disputed.

The peritrophic membrane is protective in function. Gauld (1957) working on calanoids observed that apart from its
protective function, the peritrophic membrane binds the food into a solid mass. In *M. zeylanica* this membrane breaks into bits at the hind end of the intestine and along with the faeces they enclose pass out of the anus.

**Digestive gland tubules**

These glandular tubules have been given several names, mid-gut caeca, digestive diverticula and hepatopancreas. Vonk (1960) has stated that the hepatopancreas of crustaceans has the same role as the liver in vertebrates, but is also an enzyme secreting organ like the pancreas. It also absorbs food. Hence the hepatopancreas of Crustacea is a more versatile organ than the liver of vertebrates.

Though the digestive gland tubules are treated along with the mid-gut, they have a different origin from that of the intestine and dorsal diverticulum. Siewing (1956) observed that the dorsal diverticulum and hepatopancreas are homologous structures. Molloy (1958) has questioned this statement citing Manton's (1928b) work on *H. lamornae*. In *H. lamornae* the yolk sacs give rise only to the intestine and the anterior endodermal plate develops into the dorsal diverticulum. The liver or the digestive gland rudiment is derived from the posterior part of the mandibular mesoderm. But in *N. integer* (Needham 1937) the liver rudiment is not derived from the mandibular mesoderm.
Nair (1939) supported Manton's observation. I did not study the embryology of *M. zeylanica*, but it is bound to be identical to that of *M. orientalis* studied by Nair. It may in this connection be mentioned that Pillai (1968) observed that the species inhabiting the estuarine waters near Madras is *M. zeylanica* and that *M. orientalis* is not found there. If this is true Nair must have actually worked on *M. zeylanica*.

There are four pairs of digestive gland tubules (Fig. 41, DG) of which the anteriormost is the shortest and is vertically placed. The second pair about twice as long as the first is slightly oblique running in a postero-dorsal direction. The third pair goes backwards between the sex gland and the fourth pair is placed immediately below the third. The 4th pair is slightly longer than the 3rd. These glands are surrounded by connective tissue. The terminal portions of the last two pairs of glands are deflected upwards at the region of the 5th thoracic segment. The fourth pair is the longest reaching the 6th thoracic segment.

The digestive gland tubules open into the posterior part of the pyloric chamber ventro-laterally through a common duct (Fig. 64, CD). These tubules are covered by a thin layer of filamentous connective tissue, beneath which is a layer of fine striated circular muscles broken into isolated bundles (Fig. 65, CM). Food is drawn into the digestive glands by the
rhythmic contraction of these muscles. The epithelial lining of the tubules has an outer thin basement membrane (Fig. 65, BM).

Each tubule is divided into different zones based on the nature of the epithelium. Martin (1964) has recognised 4 different zones in the amphipod, *M. obtusatus*. Molloy (1958) has divided the digestive tubule of *N. integer* into 3 zones, embryonic zone, region of glandular ridges and region of cell extrusion. In *M. zeylanica* there are 3 zones, the embryonic zone, mature zone and the proximal zone.

The embryonic zone is the distal blind end of the tubule. It is composed of closely packed undifferentiated cells. Each cell has a large basal nucleus and 2 or 3 nucleoli. The cells occupying the luminal portions undergo mitotic division (Figs. 65 & 123, MF). This region from where new cells are added to the epithelium is hence considered to be the embryonic zone. The cytoplasm of these cells is devoid of vacuoles. Gelderd (1909) failed to observe such a region in *P. flexuosus*. Molloy (1958) has located an embryonic zone at the extreme tip of the digestive tubules of *N. integer*.

The cells proximal to the embryonic zone increase in size and get differentiated into two distinct types arranged in a definite pattern along the length of the tubules. The next zone following this transitory zone is lined with mature
cells. The epithelial lining of this region is produced into four ridges which are more prominent in the last pair of tubules (Fig. 66, R). The cells that are involved in the formation of ridges are tall and elongated and project into the lumen of the gland and those between the ridges are triangular or wedge-shaped (Fig. 66, WC). The columnar cells of the ridges have basally placed nuclei with granular chromatin. The cytoplasm is provided with a few vacuoles filled with granular material (Fig. 66, V) which takes the aniline blue of Heidenhain's azan. Owing to the presence of secretory material inside the vacuole these cells are designated as secretory cells. The small vacuoles gradually increase in size and ultimately occupy a large part of the cell displacing the cytoplasm to the basal part. From this basal cytoplasm strands extend to the free border of the cells supporting the vacuoles between them. At this stage the ridges project prominently reducing the lumen considerably.

The presence of glandular ridges is universal among mysids and Molloy considered it as a unique characteristic. But Siewing failed to observe them in lophogastrids. Martin (1964) reported their presence in the amphipod *M. obtusatus*.

The pyramidal or wedge-shaped cells possess centrally placed spherical or oval nuclei. The nucleolus also
is centrally placed, the chromatin material is less dense. These cells appear to be less active and their cytoplasm does not enclose vacuoles.

The proximal zone has shorter cells with faintly stainable cytoplasm (Fig. 67). The glandular ridges are very much reduced in this region. The nucleus is situated in the basal part. In this region the cytoplasm of certain cells along with the nucleus bulges into the lumen of the gland. They are later on pinched off into the cavity and find their way out (Figs. 68 & 122, EC). These cells correspond to the "effete" cells described by Martin (1964) in M. obtusatus.

Molloy (1958) has noticed this type of extrusion of cells in N. integer. According to her these cells are replaced by embryonic cells which migrate from behind forwards as in the case of the crayfish (Hirsch 1931, Hirsch and Jacobs 1928, 1930). She also adds that embryonic cells are continuously produced to replace secretory, absorptive and storage cells. Some of these mature cells are eventually eliminated either because their effectiveness has diminished with age or that their fatty reserves are needed by other zones of the body.

The phenomenon of cell extrusion and budding of vesicles from the epithelial layer has often been taken as
evidence of holocrine or merocrine secretion. Nath and Pillai (1972) have described that the tips of the secretory cells laden with secretion are pinched off into the lumen. They call it merocrine secretion. Pillai (1958) has observed the same phenomenon in Caridina, whereas in Astacus, the method of secretion is holocrine (Hirsch and Jacobs 1928, 1930). But according to Molloy (1958) the phenomenon of cell extrusion is intended to eliminate the unwanted cells and cell contents. In *N. integer* (Molloy 1958) the secretory products are diffused into the gland through the pore canals present on the striated border of the cells. Gelderd (1909) has suggested that the enzymes are liberated from the vacuolar cells by the bursting of the cell border facing the lumen. In *M. zeylanica*, the method of secretion appears to be merocrine as seen from the fact that the inner border of the secretory cells laden with granular secretory material is found broken at several points. Further these cells do not have pore canals at their luminal edge. The phenomenon of cell extrusion observed in the proximal part of the gland is for eliminating the seniscent cells.

Hirsch and Jacobs (1928, 1930) have demonstrated cyclic secretory activity in Astacus and Hirsch (1931) found this coinciding with a rhythmical cycle of secretion. Since *M. zeylanica* consumes food continuously cyclic secretion as
found in *Astacus* which takes food in definite large meals is not evident. Further in this animal mitotic division is found to occur continuously.

The digestive gland tubules have been assigned both absorptive and secretory function by various authors. Gelderd (1909) has stated that in *P. flexuosus* these tubules function as secretory and absorptive organs. Molloy (1958) holds that the glandular ridges are the main sites of secretion in *N. integer* and the ordinary gland cells are concerned with absorption of foods. According to her, apart from secretion and absorption the digestive gland tubules are the chief sites of digestion and storage and to some extent function as excretory organs, eliminating worn out cells. Nath and Pillai (1973) have observed both absorptive and secretory cells in the hepatopancreas of *G. simulans*. Martin (1964) has revealed that the digestive gland is primarily a structure for producing a copious supply of digestive enzymes, but also absorb and store food. He concludes that secretion absorption and food storage are not confined to one type of cell. Davis and Burnett (1964) have presented evidence to show that in crayfish all cells arise from the embryonic cells of the apex and go through absorptive, and secretory stages and then atrophy.

Yonge (1937) traced the evolution of the sites of absorption in Crustacea. In simple lower forms the intestine
performs both digestive and absorptive functions because of the absence of separate digestive diverticula. With the development of the hepatopancreas, as in isopods, these two functions came to be shared by the mid-gut cells and the liver cells. This condition seems to be prevalent in mysids. In fact this condition might have developed even in the ancestral peracarids. In higher forms like decapods both digestion and absorption have been taken up by the hepatopancreas.

The Hind-gut.

The hind-gut occupying a small part of the 6th abdominal segment opens out by the anus (Fig. 41, HG). The epithelium of the hind-gut is formed of small cells. Their cytoplasm appears to be transparent and thin (Fig. 69, E). The lumen of the distal parts of the hind-gut looses its cylindrical shape due to the presence of four ridges which project into it so as to transform it into an X-shaped cavity. The cells of the gut wall are loosely packed. The hind-gut is lined by a thin layer of cuticle which is continuous with the exoskeleton. The contraction of the extrinsic muscles extending between the hind-gut and the external integument brings about the distention of the lumen of the gut. The lateral ridges serve to keep the anus closed. The muscles attached to them pull them apart to open the anus. The anus possesses valvules that can be opened
or shut at will by means of powerful circular and extrinsic muscles. The valvules help to evacuate the excrement intermittently.
CIRCULATORY SYSTEM

The comparatively few available works on the circulatory system of mysids deal with the heart and the more prominent blood vessels. The first important publication on the subject is that of Van Beneden (1861) which is unsatisfactory in many respects. But Delage (1883) gave a satisfactory description of the respiratory and circulatory systems of mysids. G.O. Sars (1867) and Claus (1884) gave fairly accurate descriptions of both systems. More recently Mayrat (1956 b) compared the circulatory system of $P. \text{flexuosus}$ with that of decapods. Alexandrowicz (1955) studied the innervation of the heart of $P. \text{flexuosus}$.

During the present study the morphology and histology of the heart and blood vessels were studied with the help of gross dissections and serial sections. The course of the flow of blood was studied by observing live animals under a cover glass. To study the distribution of the vessels Indian ink and carmine solution were injected into the pericardial sinus. But both failed to give satisfactory results.

Different workers have used different terminology in describing the circulatory system. As that given by Delage appeared to be most satisfactory it was adopted here.
Like other malacostracans *M. zeylanica* has an open circulatory system. It includes a heart, an accessory heart, arteries and venous sinuses. The heart is the main pumping organ. From the heart the blood is conveyed through definite arteries to the various tissues. The de-oxygenated blood from the tissues gets collected in sinuses and lacunae. From the sinuses the blood is sent to the pericardial sinus directly or indirectly through afferent vessels and ultimately to the heart.

**Heart**

The heart is situated in the cephalothorax immediately below the carapace. It is a single chambered tube extending from the second thoracic segment to the sixth, thus occupying nearly half the length of the cephalothorax. Delage has observed that with regard to size and shape the heart shows variation among mysids. The heart in *M. zeylanica* resembles that of the mysids described by Sars and Delage. But in *Spelaeomysis* (Nath, 1969) the heart is very short and confined to the 6th segment. Such extreme shortening of the heart, according to Gordon (vide Nath, 1969) is characteristic of cavernicolous crustaceans. According to Claus (1884) lengthening of the heart indicates primitiveness. *Spelaeomysis* is obviously more primitive than *Mesopodopsis* but has a
shorter heart. But it is subterranean in habit. Hence both the above observations might be valid.

The heart is not of uniform width. The widest part is at the posterior third (Fig. 70). At both ends the heart is drawn out into vessels. At the widest part and situated laterally (more precisely submarginal dorsal) is a pair of small openings, the cardio-pericardial orifices or ostia (Figs. 70 & 125, OS).

In *Mysis* (Delage 1883) there are two pairs of ostia, and according to Claus (1884) there are two pairs in *Siriella*, a dorsal and a ventral. In *Spelaeomysis* there is only a single pair, but it differs from that of *M. zeylanica* in position.

The heart is kept in position inside the pericardium by suspensory ligaments (Fig. 71, SL). These ligaments exhibit a regular arrangement and each originates from the wall of the pericardium as a compact bundle but gets rather diffused before attaching itself on to the wall of the heart. There is a pair of dorso-lateral and a pair of ventro-lateral ligaments arising from the wall of the pericardium and getting attached to the corresponding areas of the heart.

**Histology**

The wall of the heart is formed of a single layer
of cells forming the myothelium (Fig. 71, MTH). As the cell boundaries are indistinguishable, the wall appears as a syncytium. The nuclei are large and spherical containing chromatin granules staining deep red with azocarmine of Heidenhain's azan (Fig. 71, N). The cytoplasm is clear and stains only slightly. Surrounding this syncytial layer is the muscularis layer (Fig. 71, ML) composed of striated muscle fibres. The fibres are grouped into distinct bundles which form complete rings disposed at right angles to the long axis of the heart. The muscular layer is invested by a thin layer of connective tissue which at four areas gets prolonged into the suspensory ligaments described above.

The ostia, as already indicated, are situated at the widest part of the heart almost sub-dorsally. They are oval or nearly rounded openings guarded by thin flaps projecting into the lumen of the heart (Fig. 125, OF). These ostial flaps are thin extensions of the muscular rim of the ostial openings. Maynard (1960) observed that the contraction of the muscle fibres attached to the ends of the ostia brings the lips of the ostia closer bringing the flaps in contact, thereby closing the opening. But unlike as in Galathea (Pike 1947) and Caridina (Pillai 1958) there are no muscles connected to the ostia in M. zeylanica. Herrick (1909) observed that in Homarus the
ostia close automatically due to the pressure exerted by the blood inside on the ostial flaps during the contraction of the heart. Obviously this is the mechanism operating in the case of *M. zeylanica* also. The ostia serve to prevent the flow of blood from the heart into the pericardium facilitating its free flow into the arteries.

**Pericardium**

The heart is enclosed in a pericardium which extends from the first thoracic segment to the beginning of the 6th thoracic segment (Fig. 71, PC). It is situated above the gonads and behind the stomach and is flanked by the dorsal digestive gland tubules. The pericardial wall is rather tough and rigid and provides a firm surface for the attachment of the suspensory ligaments. The floor of the pericardium is formed of elastic connective tissue which is thin and membranous and is usually referred to as the pericardial septum.

Passing through the pericardial wall are a few blood vessels, the most important of which are the anterior and posterior aortae which are actually continuations of the heart. Six pairs of blood vessels coming out of the thoracic limbs (2–7) run upwards and form a common sinus. This sinus opens into the pericardium ventrally on a level with the ostia. These ascending vessels are termed curopericardial vessels (Fig. 72, CPV), Opening into the pericardium on the dorsal
side opposite to the entry of the europericardial vessels are two larger vessels, the branchiopericardial vessels, bringing blood from the respiratory surface of the carapace.

In M. zeylanica the pericardium almost closely invests the heart and hence there is not much space around the heart. The blood from the different lacunae and sinuses instead of collecting in the pericardium is almost directly sent into the heart through the ostia. The histology of the pericardial wall appears to indicate that it is not capable of contracting rhythmically.

At either end the heart wall is drawn out into the anterior and posterior aortae. At the beginning of the aortae the wall of the heart is produced into a pair of flaps projecting into the aortae, the cardio-aortic valves (Fig. 124, CAV). The free ends of these flaps converge and hang freely in the direction of the flow of the blood. Normally the flaps remain apart. But when the pressure of blood in the aortae increases they contact each other and close the cardio-aortic openings.

These aortic valves maintain the flow of blood in a definite direction, namely towards the aortae. Similar valves have been described in Galathea, (Pike 1947), Caridina (Pillai 1958) and Parhyale hawaiensis (Divakaran & Pillai 1975). However in Spelaeomysis (Nath 1969) these valves are poorly
developed, and are mere thickenings of the ostial lips and do not project into the aortae.

Valvular structures guard the opening of the heart into the other arteries emanating from the heart, but compared to those of the anterior and posterior aortae they are poorly developed.

Arterial system

The heart gives rise to the cephalic aorta in front and the abdominal aorta behind. From its ventral side the heart gives off a prominent descending artery in addition to several small arteries going to the various visceral organs. In *Mysidopsis* Claus (1884) observed two lateral arteries arising from either side of the median cephalic aorta. I could not observe the counterparts of these vessels in *M. zeylanica*. A peculiar feature observed by Nath (1969) in *Spelaeomysis* is that the descending artery arises from the abdominal aorta. This is obviously the result of the extreme shortening of the heart characteristic of cavernicolous crustaceans.

The cephalic aorta (Fig. 73, CA) proceeds forwards parallel to the dorsal side of the carapace up to the region of the stomach. Here it descends slightly and enlarges into
a bulbous structure resting on the cardiac stomach. This bulge corresponds to the 'cor frontale' described in many crustaceans (Figs. 73 & 128, BS). Delage (1883) has described a similar structure in *Mysis* but according to Bouvier (1891) a similar dilatation is present on the ophthalmic artery of all the decapods except *Inachus* he studied. It is not on the cephalic aorta. In *Ligia* Hewit (1907) has described what is obviously the cor frontale as "cephalic heart". Baumann (1917) has described the cor frontale in decapods and according to Schmitz (1967) a similar structure is visible in *G. lacustris lacustris*. The cor frontale has attained a high degree of development in *Praunus flexuosus* (Mayrat 1956 b). The cor frontale of *M. zeylanica* is rather poorly developed. It is supposed to function as an accessory organ for pumping blood. But in *M. zeylanica* no dilator muscles are associated with the cor frontale. But a few muscles having both their origin and insertion on the stomach wall go around the cor frontale. Their contraction and relaxation, if any, may bring about a slight pulsating movement of the cor frontale. The cor frontale in most of the malacostracans functions as an accessory organ for pumping blood (Maynard 1960).

Beyond the cor frontale the cephalic aorta continues as a median vessel and anteriorly sends off branches to the
brain, eyes, antennules and antennae. Just beyond the stomach it gives off a median branch which running backwards and slightly downwards reaches the anterior part of the oesophagus and breaks up into fine branches most of which enter the labrum.

On nearing the brain the cephalic aorta gives rise to a dorso-median vessel, the common ophthalmic artery (Fig. 128, COA). This artery takes an ascending course up to the tip of the head, passing through a median furrow between the protocerebral lobes of the brain and finally bifurcates. The two ophthalmic arteries thus formed enter the two eyes (Fig. 73, OA) along the inner face of their stalk and divide into a highly developed capillary net-work.

Soon after entering the brain the cephalic aorta gives off a slender dorsal branch, the cerebral artery (Fig. 73, CBA). This artery travels dorsalwards and gets distributed in the brain.

In the middle of the brain the cephalic aorta bifurcates (Fig. 127, CA). The two branches go outwards and forwards and get united by a transverse vessel at the anterior part of the brain (Fig. 127). Each of the above lateral vessels gives off a proximal vessel, the antennal vessel (Fig. 73 & 127 AV)
and a distal vessel, the antennular (Fig. 73 & 127, ANV). The anterior parts of the brain receive several small vessels from the lateral arteries as well as their transverse connectives.

In all the mysids hitherto investigated the cephalic aorta bends downwards and runs in between the stomach and the brain after it has given off the ophthalmic artery. The antennal and antennular arteries arise from a common artery originating from the terminal part of the cephalic aorta. John (1968) reported a more or less identical condition in *Sphaeroma terebrans*. On the other hand in decapods the heart gives off anteriorly three arteries, the median cephalic and lateral antennal arteries. In *Galathea* (Pike 1947) the ophthalmic artery is a branch of the antennal artery. But in *Caridina* and *Palaemonetes* the ophthalmic arises from the cephalic aorta itself.

Surprisingly the distribution of the arteries in *M. zeylanica* is slightly different from that of other mysids.

**Hepatic artery:** Of the several arteries originating from the ventral side of the heart the hepatic is the anteriormost. It arises medially just behind the base of the cephalic aorta (Fig. 73, HA) and runs forwards and downwards to the junction
of the digestive glands with the intestine. Here it divides into two branches an inferior and a superior branch. These branches go in between the digestive gland tubules of the corresponding side (lower and upper pairs of tubules) and give off a number of transverse branches which go round the tubules giving them the appearance of being transversely striated. The transverse branches have between them longitudinal connections so that the tubules are invested in a network of fine arterial branches.

The hepatic artery of Mysis is identical to that of M. zeylanica but in others there is some variation. But according to Delage (1883) the lateral arteries described by Claus in Mysidopsis are actually hepatic arteries. However Nath (1969) reported that in Spelaeomysis the hepatic artery originates from the cephalic aorta itself, obviously the effect of the shortening of the heart.

**Abdominal artery:** Further posteriorly, from the mid-ventral part of the heart arises a small vessel, the abdominal artery (Fig. 73, AA) which supplies the alimentary canal.

**Gonadial artery:** This artery originates from the ventro-median line almost at the posterior one-third of the heart (Fig. 73, GA). This gonadial artery which gets bifurcated on
reaching the vicinity of the gonads feeds the latter with blood.

**Descending artery:** Of all the ventral arteries this is the most prominent. It originates from the hind end of the heart (Fig. 73, DA) and goes downwards along the left side of the intestine and on reaching the 6th thoracic ganglion divides into anterior and posterior branches, the anterior branch is the sternal artery. The sternal artery goes through the space between the connectives of the fifth and sixth thoracic ganglia and proceeds up to the oral aperture. Since it occupies the space between the nerve cord and the underlying integument it is difficult to trace its course. The sternal artery gives off several branches to the ventral body wall, thoracic appendages and the ganglia of the ventral nerve cord. The blood vessels which go into the thoracic appendages continue up to the basal segment of each leg where they end up without proceeding further. After giving rise to moderately prominent branches to the maxillae and mandibles the sternal artery apparently terminates in the labium.

The posterior branch of the descending artery proceeds backwards above the ventral nerve cord and gives off an artery to the seventh thoracic segment and another to the eighth.
Further back this artery, takes up a course above the nerve cord to end in the eighth segment. The brood lamellae on the last two thoracic segments of the female receive branches from the posterior branch.

The descending artery of *M. zeylanica* is identical to that of other crustaceans studied, namely *Mysis* (Delage 1883) *Palaemonetes* (Brody and Perkins 1930) *Caridina* (Pillai 1958) and *Galathea* (Pike 1947). But in *Spelaeomysis* (Nath 1969) the descending artery originates from the abdominal artery and not the heart. According to Mayrat (1956 b) the trifid nature of the descending artery in *P. flexuosus* indicates that originally there were 3 separate arteries and that consequent on the fusion of their basal parts, a single distally trifid artery was produced. Defretin (1934) (vide Mayrat 1956) expressed the opinion that originally there was a pair of descending arteries in each of the last three thoracic segments. Subsequently one branch from each pair was lost resulting in the rather curious asymmetry seen in the present day mysids. However in *M. zeylanica* the descending artery is not trifid distally. It bifurcates into an anterior and a posterior branch, the latter further divides leading to the trifid condition.

**Abdominal aorta**: The abdominal aorta originates from the hind end of the heart, traverses the seventh and
eighth thoracic segments and enters the abdomen (Fig. 73, ABA). In the abdomen it takes a dorso-median position above the intestine and goes straight up to the tip of the sixth abdominal segment. Here it divides into a dorsal and a ventral branch. The dorsal branch which appears as a continuation of the aorta enters the telson and splits up into small vessels. The ventral branch goes downwards and backwards to the base of the telson and divides into two branches. The dorsal of these divides and enters the uropods. The ventral vessel bends forwards and empties itself into the ventral venous sinus.

In each of the first five abdominal segments the abdominal aorta gives off a pair of vessels which travelling close to the body wall terminate in the pleopods. As the pleopods except the fourth pair in males are vestigeal, the arterial vessels entering them are comparatively small.

The abdominal aorta sends small branches to the abdominal wall and the nerve cord.

Venous system: The venous system of M. zeylanica is not composed of distinct vessels. The blood flows through spaces between the various internal organs except at certain regions where there are definite vessels like the europericardial. The blood brought by arteries to the different organs and tissues,
collects in sinuses from where it is sent into the pericardium. By the time the blood reaches the sinuses it is divested of the oxygen it contains. The de-oxygenated blood from the anterior region is sent to the branchial apparatus of the carapace where it picks up oxygen from the steady flow of water through the branchial cavity. The oxygenated blood is conveyed to the pericardium through a pair of branchiopericardial apertures and ultimately to the heart through the ostia. The blood coming from the posterior region passes through the basal part of the thoracic appendages for purification before it enters the pericardium through the e uropericardial vessels.

In the thorax and the abdomen the blood is circulated through definite sinuses which occupy all the available space. The thorax is occupied by a large thoracic sinus and the abdomen by two sinuses, a dorsal and a ventral. There is also a cephalic sinus in the head.

The thoracic sinus receives blood from the anterior and posterior parts of the thorax (Fig. 72, TS). The ventral abdominal sinus (Fig. 74, VAS) encloses that part of the ventral nerve cord and the hind gut situated in the sixth abdominal segment, and extends forwards close to the ventral side. Part of the blood coming from the mid-gut, the nerve cord and the appendages gets collected in this sinus. The
The dorsal abdominal sinus encloses the abdominal aorta and the mid-gut. The blood coming from the abdominal muscles and part of the mid-gut is received into this (Fig. 74, DAS). The dorsal sinus opens directly into the pericardium in front. The dorsal and ventral sinuses are connected by narrow channels running close to the body wall (Fig. 74, LC). The blood flows from the ventral to the dorsal sinus.

The blood that collects in the dorsal abdominal sinus is sent directly to the pericardium while from the ventral sinus the blood goes to the thoracic sinus.

The cephalic sinus (Fig. 75, DCS) is situated in the head just behind the brain. It receives the blood coming from the brain, eyes, antennules and oral appendages. Part of the blood from the oral appendages enters the thoracic sinus at the region where the cervical sulcus is situated via two channels placed on either side of the stomach. But most of the blood goes to the blood channels in the carapace (Fig. 76, BCC). From the lacunae of the carapace the blood is sent back to the pericardium through the branchiopericardial orifice (Figs. 76 & 126, BPA).

From the thoracic sinus some of the blood enters the thoracic appendages. The space inside the rami is longitudinally divided into an afferent and efferent channel by a
distinct system. This can be easily seen by the flow of the blood in live animals. From the basal segment of these appendages the blood (afferent) is conveyed dorsalwards through a set of unique vessels which traverse the whole depth of the body above. These are the europericardial vessels (Fig. 77, CPV) which open directly into the pericardium beneath the branchiopericardial aperture. Each of the thoracic appendages except the first has a europericardial vessel.

The first six vessels coming from thoracic segments 2-7 open directly into the pericardium while the last enters the dorsal abdominal sinus. Van Beneden (vide Delage 1883) erroneously described these vessels as originating from the "median thoracic current".

As in Mysis (Delage 1883) the ventral abdominal sinus encloses the entire nerve cord in the present case also. But in Spelaeomysis only a part of the nerve cord is enclosed. The dorsal abdominal sinus is identical in Mysis and Mesopodopsis, but this sinus is absent in Spelaeomysis.

According to Delage (1883) a superior current brings blood from the cephalic region into the thoracic sinus. But this is obviously absent in M. zeylanica. On the other hand the blood from the oral appendages is received into a lateral
vessel which is visible in *Spelaeomysis* also. This vessel has not been described in *Mysis*.

From the heart the blood flows out through the anterior and posterior aortae and gets distributed all over the body through a more or less definite system of efferent vessels or arteries. The de-oxygenated blood collects in lacunae and sinuses and finally reaches a few permanent sinuses with definite location. Part of the blood from these lacunae enters directly into the pericardium while the other part is sent to the pericardium via the europericardial vessels. A third part enters the blood spaces of the carapace and gets oxygenated and returns to the pericardium via the branchio-pericardial openings. The circulation is therefore partly vascular and partly lacunar and only a part of the blood is oxygenated before being returned to the pericardium. Presumably cutaneous respiration takes place and that part of the blood not passing through the carapace must receive some oxygen on their way to the pericardium. This must be so since thin lamellar structures like the epipod of the first thoracic appendage and the brood lamellae show thin areas exactly as on the carapace.
RESPIRATORY SYSTEM

Respiratory function has been assigned to diverse organs. Thompson (1840) considered the exopods of the thoracic limbs as respiratory. Part of the blood received into the thoracic sinus is sent into the thoracic limbs. Inside the limbs there is a distinct afferent flow and an efferent flow and this circulation is comparatively slow. The epithelial and exoskeletal covering of the limbs is rather thin and can permit some gaseous exchange. Above all the exopods bring about removal of the water surrounding them. Hence Thompson's surmise is reasonable. It is significant that part of the de-oxygenated blood in the thoracic sinus takes a circuitous course through the limbs to the pericardial sinus.

According to Milne Edwards (1837) the epipodite of the first thoracic limb is the sole respiratory organ. The chitinous covering of the epipodite is extremely thin and there is a spacious blood sinus inside. There is a constant flow of water over it. Obviously the epipodite must act as an efficient respiratory organ.

Frey and Leuckart (1847) suggested that the carapace is a respiratory organ. Van Beneden (1861) also observed likewise. According to him the "blood comes out from heart
and after having run through the place which is occupied by the gills in other decapods and always receiving a venous connection from the cephalic appendage returns rapidly to the heart to repeat the course anew" (vide Delage 1883). Van Benden was not aware of the structure of the carapace and hence could not correctly interpret the circulation inside the wall of the carapace.

The channels he described as bringing blood to the heart are the europericardial vessels which are totally unconnected with the circulation within the carapace. These vessels lie actually outside the carapace.

The exopod of the second maxilla is a highly flattened structure with a very thin chitinous covering. Like the epipodite of the first thoracic limb this structure is also kept in constant motion as it is the chief organ concerned with the pumping of the water out of the subcarapacial space. This structure must obviously do the same function as the epipodite of the first thoracic limb.

In entomostracans and the lower malacostracans a lot of cutaneous respiration takes place. Any appendage or part of appendage which is constantly in motion and contains a blood space must permit gaseous exchange provided the cutaneous covering is permeable. This is certainly so in mysids.
The carapace is however the primary respiratory organ of *M. zeylanica*. The carapace is fused with the cephalic segments and the first thoracic segment, but is dorsally prolonged backwards covering thoracic segments one to five. Laterally it extends downwards enclosing between it and the body two fairly spacious branchial cavities, rather subcarapacial spaces (Fig. 72, SCS).

That part of the carapace which surrounds this space is covered by a thin membrane. This thin membrane is detached from the fairly thick outer wall more or less at regular intervals to produce a number of lacunae which superficially appear as oblong transparent spaces giving the carapace a pitted appearance (Fig. 76, LCN). These lacunae receive blood from the anterior part of the body through a vessel running along the ventro-lateral edge of the carapace. The blood which enters the lacunae takes a winding course and hence remains in contact with the water circulation in the subcarapacial space for sufficiently long to get oxygenated. The oxygenated blood is finally conveyed to the pericardium through a large vessel running up the hind end of the pericardium to the branchio-pericardial aperture (Fig. 76 & 126, BPA).

The blood that enters the lacunae of the carapace wall spreads out as a thin film kept in constant motion. This
blood is separated from the water which fills the subcarapacial space by a thin membrane only and thus the blood gets enough time to take up oxygen and discard carbon dioxide. By the bailing action of the epipodite of the first thoracic limb and the exopod of the maxillae, a steady flow of water is maintained in the subcarapacial space. Thus before the blood that is pumped into the lacunae of the carapace reaches the pericardium, it is aerated.

Among malacostracans especially those with a well developed carapace, enclosing the respiratory structures, there is always a mechanism for the continuous removal of the water which passes over the respiratory surface. In mysids also the water in the subcarapacial space is constantly renewed. This is done by the constant forward and backward movement of the epipod of the first thoracic limb and to a lesser extent by the exopod of the maxillae which correspond to the scaphognathite of decapods. These two structures produce a suction pump action sending water out in front and drawing it in from behind. This respiratory current enters at the dorso-median part of the hind end of the carapace, bifurcates and enters the subcarapacial spaces. They move forwards and are sent out in front.

By the rotatory movement of the exopods of the thoracic limbs two currents directed backwards are created
on either side of the animal. These currents leave a restricted area of still water that supplies water for the respiratory current.

The epipodite of the first thoracic limb is a thin elongated lamina progressively narrowing to its tip. It is normally kept pointing upwards, perpendicular to the long axis of the body. During its forward movement which is the more active one, the water column in front of it is pushed forwards and out of the subcarapacial space. This facilitates the automatic entry of water from behind. During its recovery stroke the epipodite rotates in such a way that it is held parallel to the long axis of the body offering no resistance to the entry of water into the subcarapacial space. These strokes forward and backward take place successively. The effective or forward stroke takes a longer time than the recovery stroke which is rather quick.
REPRODUCTIVE SYSTEM - FEMALE

The earliest work on the female reproductive organs of mysids is that of G.O. Sars (1870-1879). He gave a detailed description of the anatomy of the reproductive organs of *Mysis oculata relicta*. Nair (1939) made a thorough study of the female reproductive system of *M. orientalis*. Subsequently Siewing (1953, 1956) furnished some information on the genital ducts of *Eucopia*.

Secondary sexual characters

The coxae of the 7th and 8th thoracic limbs bear two pairs of thin brood lamellae fringed with short setae which form a large marsupium. The posterior pair is concave and larger than the anterior (Fig. 23 & 24). A rudimentary pair of lamellae is present at the base of the 6th thoracic appendage (Fig. 80).

Breeding dress

According to Antheunisse et al (1968) a few crustaceans acquire what is called a breeding dress. The breeding dress consists mainly of extra setae or hairs the female acquires during the moult preceding copulation. This is invariably lost during the moult succeeding the release of young ones. In *M. zeylanica* the breeding dress is rather insignificant since the embryos undergo development inside the brood pouch. But
before breeding begins the brood lamellae are comparatively small and carry non-plumose setae. During the moult preceding copulation the brood lamellae enlarge in size and become highly concave. They get bordered with long plumose setae.

Structure of the ovary

The ovary consists of two pairs of tubes situated parallel on either side of the median line between the alimentary canal and the floor of the pericardium. In the adults the ovary extends from the 2nd to the 7th thoracic segment and is easily visible as two rows of eggs through the semitransparent dorsal body wall. As already stated each ovary consists of a dorsal and a ventral part (Fig. 78, VOVT, DOVT) the two communicating anteriorly through a small opening (Fig. 79, OVT). The dorsal part is comparatively larger than the ventral. The two ovaries are interconnected by a transverse bar situated in the middle of the two ventral parts of the ovaries.

The oviducts are mere extensions of the ovarian (Fig. 78, OVD) tubes and originate from the hind end of the upper parts of the two ovaries. The ducts proceed outwards and then downwards between the integument and the musculature of the body wall. At this region the oviducts are much
compressed. Further on they curve towards the median line and open on a small prominence situated at the base of the 6th pair of legs (Fig. 80, 00) into the brood pouch. An artery runs between the ovaries and sends branches to the different parts of the ovary.

The ovary is enveloped in a thin delicate membrane of uniform thickness. The membrane is formed of a single layer of highly flattened cells (Fig. 79, EOY) having small nuclei with finely granular material. The cells take very little stain. As the ova within increase in size the membrane is stretched further making the nuclei appear very sparsely distributed.

The wall of the oviduct is formed of a single layer of epithelial cells similar to those of the membrane covering the ovaries. This is to be expected since the oviducts are formed as simple extensions of the ovaries. However the distal part of the oviducts has an additional inner layer of cells. These cells are highly glandular and their nuclei take deep stain (Figs. 81 & 129, GLC). It has been observed that during the breeding time these glandular cells become very active and produce a secretion which in sections appears as long threads within the oviducts (Figs. 81 & 129, TSO).
The median bridge connecting the ventral parts of the two ovaries has an anteriorly directed triangular extension which is the formative zone. The formative zone can be distinguished (Fig. 78, FZ) due to the presence of a large number of undifferentiated cells bounded by a thin epithelium. The cells have small nuclei enclosing a few clumps of chromatin. Slightly behind the apex of this lobe these formative cells get differentiated into oogonia. The oogonia are in a state of active division and have large nuclei with a prominent reticulum (Fig. 78, OG). The oogonia later develop into oocytes (Figs. 78 & 82, OC) which are found in the middle of the triangular extension of the connecting bridge. The posterior part of the bridge is packed with elongated cells. Similar cells are found around developing oocytes also. These cells differ from the more anteriorly placed cells in many respects, especially in their oval nuclei.

The oocytes soon outgrow the surrounding cells and get arranged in a linear manner beginning from the middle of the triangular extension of the median bridge (Fig. 82, DOC). On reaching the posterior part of the bridge or the hind part of the triangular extension, the oocytes move outwards along the anterior face of the bridge and enter the ventral ovarian tubes.
The oocytes exhibit a progressive increase in size towards the outer side (Fig. 82, OC).

At this stage the oocytes are round or somewhat oval with large nuclei measuring 30 μ (Fig. 83, NDOC). Each nucleus has a prominent nucleolus. The chromatin appears as sparsely distributed granules. The cytoplasm is restricted to the periphery as a narrow band and is devoid of vacuoles but takes very deep stain. Before the oocytes enter the ventral part of the ovary their nuclei enlarge further and the nuclear material condenses. At this stage vitellogenesis starts and the oocytes grow to 80 μ in diameter.

The nucleoplasm no more takes stain and the nucleolus takes up an eccentric position. While these developments are taking place in the nucleus the cytoplasm gets demarcated into a granular perinuclear zone and a homogeneous cortical zone (Fig. 84, PZ, CZ). Having undergone the above changes the oocytes enter the ventral part of the ovary and remain there.

During further growth the cytoplasm increases in bulk and displaces the nucleus to the dorsal side of the oocyte. At the opposite side small vacuoles appear in the cortical part of the cytoplasm. These developing oocytes migrate into the upper tube through a common opening as soon as the latter becomes
empty and get arranged in two rows. These oocytes which undergo secondary growth (vitellogenesis) attain a diameter of 60 μ. This is mainly the result of the development of yolk platelets (Fig. 85, YPL). The oocytes as soon as they enter the dorsal ovarian tubes get covered by a layer of cells (Figs. 85 & 130, FC) which grow in size simultaneous with the growth of the oocyte. The vacuoles increase in size due to the accumulation of yolk within and also in number. This results in the accumulation of yolk at one side of the oocytes and the nucleus which can now be designated as the "germinal vesicle" is shifted to the periphery at the opposite end (Figs. 86 & 131, GV). The cytoplasm gets stretched at the periphery of the oocyte forming a thin layer except where the germinal vesicle is situated. The germinal vesicle is circular with prominent nucleus having dense minute chromatin granules.

The vacuoles in the cytoplasm coalesce and the yolk forms a large mass at the lower part of the oocyte. This oocyte with a thin peripheral layer of protoplasm and a germinal vesicle at the dorsal region has the appearance of a "signet ring" (Figs. 86 & 131). Meanwhile the outer cellular layer investing the developing ovum becomes indistinguishable and eventually disintegrates. The dorsal ovarian tube swells up due to the presence of fully developed ova within.
Consequently these tubes project beyond the ventral ovarian tubes. Each upper tube holds up to six ripe ova.

The accumulation of yolk at one end of the egg and the consequent shifting of the germinal vesicle to the opposite end is a unique characteristic in the development of the oocytes of Mesopodopsis. Nair (1939) observed the same in M. orientalis. This type of telolecithal development of the eggs in Mesopodopsis is very significant since in other crustaceans including mysids the eggs are centrolecithal.

Crustaceans exhibit considerable variation in the structure of the germogen area of the ovary. In Mysidacea this area lies outside the ovarian tubes. In the simplest condition there is no definite germogen (Calman 1909) and the oocytes are budded off from the inner area of the ovary. The entire ovarian wall acts as a formative zone or germogen. But such a simple condition is very rare in present day crustaceans. Generally the germogen is confined to a definite area of the ovary. In Xiphocaridina the ventral wall of the ovary projects as a longitudinal ridge which buds off oogonia. In Homarus (Bampus, 1891) the ovarian wall forms shelf-like invaginations at regular intervals. In Mysis (Sars 1879) the bridge connecting the two ovarian tubes contains a transverse band of actively dividing cells. In M. orientalis
the germogen is confined to the apex of the triangular extension of the median bridge. In *S. longipes* (Nath 1969) the germogen is situated at the outerside of the ovary and it is connected to the ovary by a transverse bridge. Jackson (1913) and Kamalaveni (1949) have noticed thickenings similar to those in *Xyphocaridina* in *Eupagarus* and *Clibanarius* respectively. Pillai (1958) described the germogen of *Caridina Levis*, as superficial appearing as a thickened region of the inner epithelium. In *Sphaeroma terebrans* (John 1968) the germogen is restricted to a longitudinal ridge along the inner dorsal side of the ovary.

The ovary of mysids varies in shape. In *Mysis* (Sars 1879) it consists of a single pair of tubes with a transverse bridge connecting the two. In *Spelaeomysis* also there is only a single pair of tubes, but in this genus the bridge is absent.

The female reproductive system of *M. zeylanica* is essentially similar to that of *M. orientalis* described by Nair (1939). In both the ovary consists of two identical halves each half composed of a smaller ventral tube and a larger dorsal tube. The two halves are connected by a ventral transverse bridge which lodges the germogen. But in *M. orientalis* the oviducts originate from slightly in front of
the hind end of the dorsal ovarian tubes while they originate from the hind end in *M. zeylanica*. Further in *M. zeylanica* the distal part of the oviduct has a two cell thick epithelium.
REPRODUCTIVE SYSTEM - MALE

The earliest work on the male reproductive system of Mysidacea is that of Frey and Leuckart (1847) who studied the genital organs and spermatogenesis of *P. flexuosus*. G.O. Sars (1867) studied the spermatogenesis and male reproductive organs of *M. oculata relicta*. Siewing (1953, 1956) gave a detailed account of the histology of the generative organs of *Eucopia*. In 1959 Holmquist published his observations on the genital apparatus of *Mysis relicta*. Somalainer (1954) has described the chromosomes in *Neomysis vulgaris*. Labat's (1961) account of the structure of the reproductive organs of *P. flexuosus* seems to be the most recent. He has also attempted a description of the spermatogenesis of the same species. From the above resume it is evident that the knowledge on the male reproductive system is somewhat inadequate.

Secondary sexual characters

As in other members of the suborder Mysida sexual dimorphism is confined to the antennules and the pleopods. The third segment of the antennular peduncle has a conspicuous profusely hairy male lobe. In addition species of *Mesopodopsis* have a third flagellum, an unsegmented slender rod distally armed with a long slender stiff filament. At the base of this
filament there are slender processes, straight basally but distally bent outwards and coiled around the main filament. As in the members of the family Mysidae the fourth pleopod of the male has its exopod modified into an armed structure which helps in pairing and in the transference of the sperms.

Structure of the reproductive organs

The genital apparatus lies between the heart and the digestive tubules and extends from the hind part of the stomach to the 4th thoracic segment. It is composed of a pair of testes, vas deferens and penis (Fig. 87, PNS), latter occupying a submedian position. Each testes is composed of three testicular lobes and a corresponding number of saccular pouches. The blind ends of these lobes lying at the mid ventral side represent the germagen or the germinative zone. The cells which fill up this part get differentiated into germ cells. The distal part of the testicular lobes merges with the testicular pouches lying in close proximity to the former (Fig. 87, TL). The first pair of pouches is situated anterior to the seminal vesicle and the second and third pair are located posterior to it (Fig. 87, TP). They communicate with the seminal vesicles through fine canals (Fig. 88, C). The seminal vesicles are merely the swollen anterior ends of the
vas deferens extending downwards (Fig. 87, SV). The vasa deferentia are continued backwards as narrow tubular structures placed close to each other medially up to the 8th thoracic segment (Fig. 87, VD). In the 8th segment the two vasa deferentia diverge and curve downwards describing a semicircle and reaching the ventro-median part open into the penis situated between the 8th thoracic limbs. At the base of the penis the vas deferens is slightly swollen and carries a small lobe-like glandular structure the androgenic gland situated slightly in front of the swollen tips (Fig. 87, AG).

The wall of the testes is thin and syncytial. The nuclei are compressed and elongated, with granular chromatin. The testicular pouches and lobes which contain the germ cells in different stages of growth are invested by this syncytial layer. The formative zone of the testicular lobes is filled with a large number of nuclei scattered in a homogeneous cytoplasmic layer (Fig. 89, FR). These nuclei are large and prominent. The chromatin is reticulated, with small clumps attached to the inner surface of the nuclear membrane. Each nucleus possesses two or three nucleoli. These nuclei develop into the primary spermatogonia (Fig. 89, PSG). Apart from these spermatogonial cells, the formative zone contains small irregular nuclei which take only light stain. A clear cytoplasmic boundary
is not visible around these nuclei. These are supposed to be nutritive cells found in association with spermatogonia as in Squilla (Komai 1920), Clibanarius olivaceus (Rathnavati 1941), Caridina laevis (Pillai 1958) and Sphaeroma terebrans (John 1968).

The transformation of the spermatogonia into spermatocytes and spermatozoans takes place in the testicular lobes and pouches. The different zones are characterised by the presence of germ cells at a particular stage of growth. The primary spermatogonia migrate into the proximal part of the testicular lobes and divide actively to form secondary spermatogonia (Fig. 89, SSG). Before this division commences, the chromatin assumes the form of spheres. Some of these spherules are found attached to the inner surface of the nucleolar membrane. Various transformations also take place in the cytoplasmic elements. The secondary spermatogonia are smaller than the primary ones and the chromatin in their nuclei stains much more deeply. These secondary spermatogonia undergo division to form primary spermatocytes (Fig. 88, PSC 1) which are located in the middle region of the testicular lobes. The primary spermatocytes are larger cells with prominent nuclei. In a later stage the nucleolus disappears and the granular chromatin gets transformed into fine filaments which later form a disorderly mass occupying the centre of the nucleus.
The cytoplasmic elements are restricted to a narrow band around the nucleus. These cells undergo further growth before dividing to produce secondary spermatocytes. These maturing spermatocytes are found close to the testicular pouches and are polygonal cells, with highly granular cytoplasm taking the aniline blue component of Azan stain (Figs. 88 & 133, PSC 2). The chromatin of the nucleus breaks up into small fragments which further elongate into definite threads. This is followed by the division of the primary spermatocyte into secondary spermatocytes (Figs. 88 & 134, SSC). These enter the testicular pouches. They are half the size of the primary spermatocytes. The secondary spermatocytes give rise to the spermatids. These are small cells (Fig. 90, SPT) which appear as spherical or ovoid bits of cytoplasm containing a nucleus at one pole. Large blocks of chromatin are found adhering to the nuclear membrane. The nucleolus occupies the centre of the nucleus.

The spermatids anchored on the nutritive cells of the testicular pouches are confined to the periphery of the pouch. Each of these nutritive cells is surrounded by 6–8 spermatids (Figs. 90 & 134, NC). The nutritive cells have large spherical nuclei with fine chromatin granules distributed around a centrally placed nucleolus.
The spermatids undergo several transformations before developing into spermatozoans (Figs. 88 & 134, SPZ). Spermatozoans are elongated bodies comprising of 3 parts, the acrosome, the nucleus and an intermediate piece carrying the flagella. The spermatozoa are emptied into the seminal vesicles in bundles. These bundles are surrounded by a mucilaginous substance secreted by the epithelial cells lining the seminal vesicles.

The wall of the seminal vesicle (Figs. 89 & 132, SV), is formed of cells with round or ovoid nuclei. The wall is not of uniform thickness. The median inner part of its lateral wall is multi-layered and formed of tall cells with a narrow base and a broad apex. The remainder of its wall is single-layered. The multi-layered median wall is a region of intense proliferation of cells. The cytoplasm of these cells is highly granular and vacuolated (Fig. 89, V). This part functions as a veritable gland. The secretions of these cells are collected in vacuoles which gradually grow in size and migrate towards the lumen to expel their contents into the lumen of the seminal vesicle. The secretions apart from binding the spermatozoans are concerned with nourishing the spermatozoans. Labat (1961) has reported the existence of such a region in the seminal vesicle of P. flexuosus.
The vasa deferentia are tubular structures concerned with the conveyance of spermatozoa. Their wall is formed of an epithelial layer which is syncytial (Fig. 91, E). The large nuclei having a spherical or ovoid shape, are found scattered in a homogeneous protoplasmic sheet. This layer is surrounded by a thin layer of connective tissue (Fig. 91, C). The wall of the vas deferens is highly distensible and becomes very thin when filled with spermatozoa. Often the diameter of the two tubes shows difference. The distal or the terminal part of the vas deferens is enlarged before opening into the penis. The spermatozoa accumulated at this region are ejected with the help of the lateral musculature of the thorax closely adhering to the outer wall of the vas deferens. The penis is essentially a chitinous swelling devoid of muscles. The cells lining the penial wall do not appear to be glandular though Labat (1961) observed them to be so in P. flexuosus. The penis does not function as a copulatory organ.

The male genital apparatus of M. zeylanica differs from that of other mysids in structure. Frey and Leuckart (1847) observed that the testes in P. flexuosus is solely formed of a few "cysts" which have connections with the seminal vesicle. G.O. Sars (1867) has made a similar observation in M. oculata relict a. But Labat (1961) found that the testes in P. flexuosus consists of two fine elongated parallel cordons and six pairs
of cysts. The latter communicate with the seminal vesicle through small tubes. According to him the spermatogonia in *P. flexuosus* are produced in small pouches which are mere outpushings of the cordons. The 'cysts' are the regions where maturation and spermatogenesis take place. The testicular lobes and pouches of *M. zeylanica* are homologous with the cordons and cysts of *P. flexuosus*. But the testicular pouches are characterised by the presence of a peripheral layer of cells which Labat has not described in *P. flexuosus*.

The seminal vesicle of *M. zeylanica* is similar to that of *P. flexuosus*. According to Siewing in *Eucopea*, (1953, 1956) the anterior part of the vas deferens is glandular. Nath (1969) makes no mention of a seminal vesicle in *S. longipes*.

The vas deferens in *M. zeylanica*, unlike as in *P. flexuosus* (Labat 1961), is non-muscular.

Labat has shown that there is no glycogen in the glandular part of the seminal vesicle. On the other hand he observed that the cells bordering the seminal vesicle are nutritive. This is true of *M. zeylanica*. 
**EXCRETORY SYSTEM**

Organs concerned with osmoregulation in crustaceans are the gills, antennal or maxillary glands and the integument. *M. zeeylanica* does not possess gills. Of the other two the antennal gland is more important.

Vogt (1932, 1933) studied the morphology and histology of the antennal glands of *M. relicta*, *G. spinifer*, *P. flexuosus*, *P. inermis* and *M. slabberi*. Wilson (1951 unpublished) briefly described the antennal gland of *N. mercedes*.

The antennal gland of *M. zeeylanica* consists of a pair of structures lying laterally in the cephalic region. Each gland is composed of three parts, an end-sac (Fig. 92, ES), a U-shaped excretory duct (ED) and an exit duct (EXD). The end-sac is a hollow structure lodged in a bottle-shaped appendix of the precoxal segment of the antenna. The excretory canal originates from the anterior end of the end-sac and proceeds backwards and upwards along the inner lateral side of the carapace. On reaching the antero-lateral face of the cardiac stomach it turns upwards and goes forward forming a loop. This forwardly directed dorsal limb of the excretory canal runs in close contact with the carapace. It dips down at the region of the basal segment of the antenna and becomes the exit duct which opens to the exterior through a pore on
The ventral aspect of the coxal plate.

The cells of the wall of the end-sac are long, with distinct nuclei and finely granulated cytoplasm (Fig. 93, E[SW]). The nuclei stain red with azocarmine of Azan. Cell boundaries are discernible and are not striated on their inner margins. The wall does not present infoldings or invaginations and hence the lumen of the sac is cylindrical. Wilson (1951) and Vogt (1933) have also described this structure. But Wilson has noticed some impushings in the wall of the end-sac. Pillai (1958) reported the presence of ridge-like projections in the end-sac of Caridina. But in M. zeylanica the lumen of the end-sac is uninterrupted. A similar condition is reported in G. lacustris lacustris (Schmitz 1967). Wilson (1951) could not find cell boundaries in the wall of the end sac. They are distinct in M. zeylanica.

Several workers have assigned a filtering function to the end-sac as its lumen contains an ultrafiltrate of the blood. According to Schmitz (1967) the end-sac in G. lacustris lacustris is a filtering apparatus. Pillai (1958) observed that the end-sac epithelium is cytolytic in function. According to him worn out corpuscles brought to the blood spaces around the end-sac are taken in by the cells of the wall of the
end-sac. The exact function of the end-sac cells of
M. zeylanica is not clearly understood. However the lumen
of the end-sac contained fragments of cells or nuclei. This
indicates that disintegrated cells are discarded via the
end-sac.

The wall of the excretory canal is syncytial.
Nuclei are large and found distributed throughout the cytoplasm
(Fig. 94, N). The nuclei contain a very prominent nucleolus
and finely granular chromatin material. They stain deep with
azocarmine of Azan. The cytoplasm, basophilic in reaction,
is densely granular. It encloses a few vacuoles (Fig. 94, V).
The lumen of the canal is not of uniform diameter throughout
its length.

Wilson (1951) has also noticed the syncytial nature
of the epithelial wall of the excretory canal of N. mercedes.
Schmitz (1967) and Schorstein (1941) have also made similar
observations. Hynes (1954) assigned a resorptive function to
the antennal gland cells. The densely granular nature as well
as the basophilic reaction of the cytoplasm according to
Schmitz (1967) are indirect evidence of the resorptive ability
of the cells. Since the cells of the excretory canal of
M. zeylanica also showed these characters it is presumed that
these cells are concerned with the resorption of salts.
The excretory canal of *M. zeylanica* is short and simple. It is U-shaped as in all other mysids. According to Vogt (1932) the short and uniform canal represents a primitive condition. Grobben (1880) found that the excretory canals of fresh water crustaceans are longer than those of marine forms. But Vogt (1933) disproved this hypothesis at least in the case of mysids. He found that the fresh water mysid, *M. relicta*, possessed a short excretory canal whereas the marine species, *Gastrosaccus spinifer*, had a long and convoluted excretory canal. Though *M. zeylanica* is a brackish water form, its antennal gland is short. This appears to support Vogt's opinion. But Wilson (1951) found a convoluted, well developed, nephridial canal in the brackish water species *N. mercedes* which he considered as an adaptation to live in dilute water.

The antennal gland of *M. zeylanica* is more or less similar to that of *M. relicta* studied by Vogt (1933). But the dorsal limb of the excretory duct in this animal is not vesicular as described by him. In *M. relicta* the loop of the excretory canal is transformed into an end-bladder. The excretory canal of *M. zeylanica* is not differentiated into a bladder. Also this gland in *M. zeylanica* is not confined to the basal segment of the antenna as in *M. relicta*. Vogt has observed a branch of the canal going to the upper lip. Such a branch is not present in *M. zeylanica*. 
Wilson (1951) observed some cells similar to those of the antennal gland under the carapace of *N. mceodes* which he believed to be excretory in function. In *M. zeylanica* there were a few cells at the base of the legs which resembled the cells of the excretory canal of the antennal gland. These cells may have an excretory function. Vogt (1932) also made an identical observation.

Several authors have speculated on the phylogenetic significance of the excretory glands of crustaceans. The antennal gland was considered as homologous with the nephridia of annelids (Waite 1899). Vejdovsky (1901) regards the secretory tubules (excretory duct) of *G. pulex* as homologous with the nephridium proper of the Annelida. Goodrich (1945) supports the concept that the antennal gland of Crustacea is derived from the annelid type. The structural variations in the different parts of the gland obviously are due to change in the method of discharge of the waste products in crustaceans.
NERVOUS SYSTEM

The gross structure of the nervous system of mysids was studied by G.O. Sars (1870-1879). Koechler (1887) published a detailed description of the brain of *Mysis flexuosa* (= *Praunus flexuosus*). Hanstrom (1947) described the brain of *Eucopia* and *Boreomysis* and compared it with those of other malacostracans. Grenacher (1879), Parker (1891), Chun (1896) and Mayrat (1956a) described the eye of mysids.

The nervous system includes the brain or the supraoesophageal ganglion (SOG or BR) the suboesophageal ganglion (SBOG), the optic ganglia (OGL) and the ventral ganglia together with the ventral ganglionic chain and the nerves arising from it (Fig. 106).

The brain of *M. zeylanica* is of the Carcinus type described by Hanstrom (1947). Encased in a membranous sheath, the brain is situated on the antero-ventral aspect of the cephalic shield on a level with the cardiac stomach. It is composed of three main neuropiles viz. the protocerebrum, the duetocerebrum and the tritocerebrum (Figs. 95 & 96, PRC, DC and TRC). Among mysids due to the flexion of the brain between the protocerebrum and duetocerebrum, the former is pushed dorsalwards lying above the latter (Dahl 1956).
In *M. zeylanica* also the protocerebrum occupies the antero-dorsal aspect of the brain. The tritocerebrum forms the posterior ventral part and the duetocerebrum is placed anterior to the tritocerebrum and below the protocerebrum.

**Protocerebrum.** It is composed of the protocerebral lobes, the medulla terminalis of the optic peduncle, the central body and the pons cerebri or protocerebral bridge.

The protocerebral lobes consist of an antero-dorsal lobe, and a pair of postero-ventral lobes. The antero-dorsal lobe (Fig. 97, ADPRL) is large and tapers towards the tip. Dorso-medially it has a furrow (Fig. 97, MFP) which accommodates the anterior extension of the common ophthalmic artery (Fig. 97, COA). Antero-laterally on a level with the median furrow the protocerebral lobes bulge to form rounded prominences (Fig. 98, RP) which are interconnected by a thick transverse bundle of fibres. The dorso-lateral prolongations of the anterior protocerebral lobes send fibres to the pedunculus lobus opticus (Fig. 99, PLO). The antero-ventral part of the anterior protocerebral lobes merges imperceptibly into the lobus paracentralis or the postero-ventral protocerebral lobes.

The posterior protocerebral lobes or lobus paracentralis consists of a pair of large glomeruli situated just below
and behind the anterior extension of the anterior protocerebral lobes (Fig. 97, P PRL). These two pairs of glomeruli are connected by a stout commissure.

The lobus paracentralis has been described as the 2nd lobe of the protocerebrum (Walker 1935). But because of its position near the central body it has been designated as lobus paracentralis following the term employed by Hanstrom (1947).

Central body. The central body is situated between the protocerebral lobes. As in other mysids it is well developed in M. zeylanica. The median part of this neuropile disposed across the centre of the protocerebrum is arched forwards forming a crescent (Figs. 99 & 135, CB). The central body is the meeting place of axons from diverse parts of the brain. It acts as an association centre as described by Hanstrom (1947) and Nicoles (1966) in Eucopia and Niphargus respectively.

Pons cerebri. The pons cerebri is composed of eight (four pairs) glomeruli placed between the lateral prominences of the anterior protocerebral lobes (Fig. 98, PCR). These glomeruli are connected to the underlying central body by distinct fibre bundles. A transverse commissure running across the median line provides a connection between the glomeruli. The number of glomeruli involved in the formation of the pons-
cerebri varies among mysids. Hanstrom (1947) has observed 7–8 pairs in Callomysis. In M. zeylanica there are only four pairs. According to Hanstrom this wide variation in the nature of the pons cerebri is very characteristic of Mysida. On the other hand there is much homogeneity in Lophogastrida.

**Duetocerebrum.** The major part of the duetocerebrum is situated below the lobus paracentralis of the protocerebrum. Posteriorly it is bounded by the anterior edge of the tritocerebrum. The duetocerebrum occupies the entire antero-ventral surface of the brain and is the region where the antennular sensory nerves end. The principal parts of the duetocerebrum are the lobi olfactorius, lobi parolfactorius and the nerve tract, tractus olfactorius globularis.

**Lobi olfactorius** are a pair of spherical lobes located lateral and posterior to the posterior protocerebral lobes (Fig. 100, OL). Each lobe is formed of a large number of regularly arranged individual glomeruli and receives a lateral fibre bundle from the antennule. Unlike in lophogastrids where the lobus olfactorius is large and well developed (Hanstrom 1947), in M. zeylanica as in other mysids these lobes are comparatively small and ill developed.
The tractus olfactorius globularis originates from the cells of the lobus olfactorius. This nerve tract goes inwards for a while and then curves dorsalwards and crosses the commissure between the lobi paracentralis (Figs. 100 & 136, TOG). Further dorsally it traverses the central body and the antero-dorsal protocerebral lobes to reach the medulla terminalis along with the pedunculus lobus opticus. Hanstrom (1947) considered this tract as the mightiest nervous pathway of the brain. In lophogastrids this tract is connected to a small unpaired glomerulus and a large paired glomerulus. In Spelaeomysis (Nath 1969) this tract is in contact with a large glomerulus situated mid-dorsally.

Lobi parolfactorius are a pair of U-shaped neuropiles lying postero-ventral to the lobus paracentralis (Fig. 101, LP0). Postero-laterally these neuropiles are bounded by the lobi olfactorius. The two arms of this neuropile are not of the same length. They merge posteriorly in such a way that their concavity faces anteriors. The antennular nerve of each side starts from the outer side of the lobus parolfactorius (Fig. 101, ANN). It is composed of fibres arising from the cells of the lobus olfactorius and also of fibres of cells in the postero-ventral lobes of the protocerebrum. The lobus parolfactorius has been described as Neuropilum Antennarii I laterali (Helm 1928) and lobus parolfactorius (Hanstrom 1947).
Tritocerebrum. This forms the postero-ventral part of the brain (Fig. 100 TRC). It consists of a dorsal tegumentary neuropile (TN) a lateral antennal neuropile (AN) and the fibres of the circumoesophageal connectives. The two halves of the tritocerebrum are connected by many transverse fibres. The tegumentary neuropile (Fig. 100, TN) and the antennal neuropile (Fig. 100, AN) are the centres of the tegumentary nerve and the nervous antennarius respectively. The circumoesophageal connectives are joined together by a post-oral commissure (Fig. 106, POC) behind the oesophagus. The post-oral commissure as in all lower crustaceans is post-oesophageal in position and functions as a commissure between the tritocerebral ganglia.

The tritocerebrum innervates the antennae. It receives sensory tracts from the tactile hairs of the antennae. The ventro-lateral sides of the tritocerebrum are drawn out as the circumoesophageal connectives which run backward around the oesophagus to meet the suboesophageal ganglion (Fig. 106, SBOG).

Distribution of neurons. The neurons enveloping individual neuropiles are concentrated at definite areas. These groups of neurons are designated as A1, A2, A3, A4, A5 and A6.
**Group A1.** This is the largest aggregation of nerve cells and covers the entire dorsal surface of the brain (Fig. 97, GA1) from the anterior tip of the protocerebrum to the posterior extremity of the tritocerebrum. The anteriormost cells form a pair of hemispherical aggregations (Fig. 97) on either side of the descending part of the common ophthalmic artery. A thin sheet of cells connects this with the ventral A5 cell groups.

**Group A2.** These masses of cells are located mid-laterally behind the olfactory lobes (Fig. 102, GA2). Posteriorly these cells are bounded by the antennary neuropile. The axons of the A2 group of cells form the olfactorio globularis tract.

**Group A3.** The neurons of this group are accommodated in the space between the olfactory lobes and the lobus paracentralis (Fig. 102, GA3). These cells extend laterally along the outer boundary of the lobus paracentralis.

**Group A4.** This group of cells occupies the median ventral aspect of the tritocerebral lobes (Fig. 102, GA4). The lobus parolfactorius forms the anterior boundary of this group. These cells send axons to the tritocerebrum.

**Group A5.** This is a median group of cells situated at the antero-ventral part of the lobus paracentralis (Fig. 102, GA5)
The basal part of the antennal nerve forms the ventral limit of these neurons. Narrow lateral extensions of this group extend along the outer anterior margin of the glomeruli of the posterior protocerebral lobes.

**Group A6.** These cells are distributed all along the outer margin of the lobus parolfactorius (Fig. 139, GA6). Anteriorly this sheet of cells extends upto the basal region of the antennular nerves. The cells of the posterior region merge with the A3 cells.

**Connective tissue of the brain**

As in other crustaceans the brain of *M. zeylanica* has two types of connective tissue viz, the perineurium or perilemma (Fig. 100, PN) and endoneurium or glia cells (Fig. 100, GL). The perineurium forms a thin continuous layer surrounding the whole of the central nervous system and also envelops the individual neuropiles. The cells of the perilemma are thin and elongated and are found in between the different neuropiles. The glia cells are found disbursed among the neurons and also within the neuropiles. They are found abundantly between the lobi paracentralis and the tritocerebrum.

**Optic ganglia.** The optic neuropiles consists of four masses of nerve fibres arising from the neurons which surround
them (Figs. 103 & 137). Besides these the ocular peduncle encloses a few sinuses and muscles. These neuropiles are called lamina ganglionaris (LGN) medulla externa (ME), medulla interna (MI) and medulla terminalis (MT).

In describing the eye-stalk the terminology proposed by Mayrat (1956a) is followed. The part which is in contact with the head is called the proximal and the corneal portion the distal. The sides which face each other when the eyes are directed forwards from the internal and the opposite the external.

Lamina ganglionaris is the distal neuropile which corresponds to the periopticum of insects. The medulla externa and medulla interna are the homologues of the epiopticum and the optic lobe of insects. The medulla terminalis which is connected to the protocerebrum by the pedunculus lobus opticus forms the proximal neuropile. Hanstrom (1928) considers the distal three of the four neuropiles as true optic lobes and the proximal as a part of the protocerebrum which has secondarily got shifted into the optic peduncle.

Lamina ganglionaris. This neuropile is situated behind the basement membrane of the cornea. The lamina ganglionaris consists of a distal fibrous portion and a proximal non-nucleated dense neuropile. The distal portion is further divisible into
a multilayered aggregation of loosely arranged cells (Fig. 103, MLLG) the space between which is occupied by retinal fibres and capillaries. The other unilayered (Fig. 103, ULLG) portion consists of closely packed cells with centrally placed nucleus and sparse chromatin.

The dense neuropile is formed of axons of unipolar association cells. These axons have a characteristic rectangular outline in frontal view (Fig. 103, BA) and squarish outline in sagittal sections. Each axon has a clearly visible central axis covered by a dense layer of fibrous matter. The lamina ganglionaris of *M. zeylanica* is similar to that of *P. flexuosus* (Mayrat 1956a) in having two layers of batonets (Fig. 103, BA). In decapods the lamina contains only a single layer of batonets.

In medial frontal sections the layers of batonets constituting the neuropile mass of the lamina is crescentic the convexity facing the optic cup. In sagittal sections it appears as a more prominently convex arc contacting the outer and inner walls of the eye-stalk.

The lamina and the medulla externa are connected by the "external chiasma" (Fig. 103, ECH) composed of fibres originating from both neuropiles. The fibres originating from the proximal outer part of the lamina enter the inner distal part of the
medulla and vice versa creating a chiasma.

The fibres originating from the centre of the lamina go straight to the medulla externa. The various bundles of fibres are held together by connective tissue containing stray nuclei.

The lamina of mysids varies in the structure and disposition of its various layers. In Mysis vulgaris there are two layers of ganglion cells where as in P. flexuosus Mayrat (1956a) observed five distinct layers. M. zeylanica has four distinct layers including fibrous and palisade layers. Horridge (1965) concluded that in many pelagic and deep sea forms only the palisade layer is clear. It may be pointed out that M. zeylanica is neither pelagic nor a deep sea form.

Medulla externa. This neuropile is reniform in frontal view (Fig. 103, ME). Externally it remains in contact with the lamina but internally they remain wide apart, the interspace being filled with the external chiasma.

The neuropile mass of the medulla is composed of rhabdom-shaped batonets arranged in transverse bands which appear light. These bands alternate with dark bands producing a banded appearance.

There is a distal dark layer (Fig. 103, DL) followed by two light layers of batonets. This is followed by a narrow
dark layer followed by two broad layers of batonets (Fig. 103, LLL).

The medulla externa and medulla interna are connected by a stout internal chiasma formed of loosely arranged fibres (Fig. 103, ICH). A few stout fibres arising from the mid-dorsal part of the medulla externa go to the medulla terminalis directly and ultimately to the brain through the pedunculus lobi optici (Fig. 104, MEN). Hanstrom (vide Mayrat 1956) has described a similar condition in Pachygrapsus in which these fibres travel to the brain through the medulla terminalis and the optic tract. The neurons which form these fibres are situated at the proximal dorsal part of the medulla externa. These cells have large nuclei with fine granules.

**Medulla interna.** This is more or less an oval ganglionic mass which lies closer to the medulla externa on the inner side than the outer (Fig. 103, MI). The medulla interna also shows dark and light transverse bands as the medulla externa.

The medulla interna is connected to the terminalis through a stout connective arising from the middle of the proximal part of the medulla interna (Fig. 103, CN). While some of the fibres of this connection terminate in the medulla terminalis others go to the brain through the medulla terminalis.

**Accessory medulla interna.** This is an oval minute neuropile occupying the space between the outer end of the
medulla externa and interna (Fig. 105, AMI). This homogeneous mass receives fibres from the internal chiasma and sends them to the medulla terminalis.

Mayrat (1956a) observed accessory medulla interna in *P. flexuosus*. But it differs from that of *M. zeylanica* in the presence of dark and light bands.

**Medulla terminalis.** This roughly conical ganglionic mass is situated behind the medulla interna (Fig. 103, MT) and tapers to form the pedunculus lobus opticus. Unlike the other neuropiles of the optic peduncle this is not fully covered by neurons. The nerve cells are mostly confined to the distal dorsal and mid-ventral parts. Laterally it is covered by a thin sheet of cells which is the extension of the dorsal cells. Apart from these neurons, there are some larger cells filled with cytoplasm in the proximal region.

Hanstrom (vide Horridge 1965) described hemiellipsoid bodies in many Crustacea including mysids. These neuropile masses situated normally in the medulla terminalis of the eye stalk are homologous to the corpora pedunculata of insects (Horridge 1965). But these structures are not found in the eye-stalk of *M. zeylanica*. Mayrat (1956a) also could not observe this neuropile in *P. flexuosus*. 

Connective tissue. Two types of connective tissue are distinguishable in the optic peduncle. They are similar to the connective tissue of the brain described earlier.

Ventral nerve cord. The nerve connections between the ganglia of the ventral nerve cord of crustaceans are described as commissures or connectives according to the liking of individual workers. The longitudinal connectives between successive ganglia and the transverse connections between members of a pair have both been described as commissures by Patwardhan (1937) and Schmitz (1967). Pearson (1908) and George et al. (1955) used the term connectives for the transverse connections. Calman (1909), Pike (1947), John (1968) and Horridge (1965) have used the term connective for the longitudinal connection and commissure for the transverse connections. This has the advantage of uniformity and the same is followed here.

The ventral nerve cord lying in close proximity to the underlying integument throughout its length is composed of a double row of ganglia and connectives. The suboesophageal ganglion which forms the proximal part of the ventral nerve cord is connected to the tritocerebrum by the circumoesophageal connectives (Fig. 106, COC). These connectives arising from the postero-lateral corners of the brain run obliquely in a
postero-ventral direction around the oesophagus. Behind the oesophagus these connectives are joined together by the postoral commissure (Fig. 106, POC). The posterior continuations of these connectives merge with the anterolateral corners of the suboesophageal ganglion (Fig. 106, SBOG). The nerves arising from the circumoesophageal connectives innervate the oesophagus and the labrum. The suboesophageal ganglion located behind the post-oral commissure is formed by the incomplete fusion of 3 pairs of ganglia belonging to the mandibular, maxillular and maxillar segments. This elongated more or less rectangular mass is narrower than the succeeding thoracic ganglia. The connectives between the mandibular and maxillular ganglia enclose a foramen (Fig. 106, P) through which passes a pair of muscles extending between the labium and the endoskeletal plate (Fig. 107, MEL). Though the connectives between the maxillar and the succeeding thoracic ganglia are fused dorsally they can be clearly recognised in the ventral aspect. The three pairs of nerves (Figs. 106, MDN, MXLN, & MXN) given out from the sides of the suboesophageal ganglion innervate the mandibles, maxillules and the maxillae respectively.

The number of ganglia involved in the formation of the suboesophageal ganglion is not the same in all mysids.
In Boreomysis (Sars 1867) all the ganglia are separate. In Mysis (Illig 1913) the ganglia of the cephalothoracic region are coalesced to form a continuous mass. The suboesophageal ganglion in Gnathophausia (Calman 1909) and in Spelaeomysis (Nath 1969) is formed by the fusion of the first three ganglia and in the former the fourth ganglion is closely approximated to the suboesophageal ganglion. The condition observed in M. zeylanica is similar to that of Gnathophausia.

The incorporation of more ganglia into the suboesophageal ganglion has been reported in other peracaridans also. In Gammarus lacustris lacustris (Schmitz 1967) it is formed by the fusion of four ganglia. A similar condition is observed in the isopod Asellus militaris (Rosine 1954). According to Rosenstadt (1889) the incorporation of more ganglia into the suboesophageal ganglionic mass takes place with the progress of cephalisation.

The thoracic part of the chain is formed of eight pairs of ganglia and their connectives (Fig. 106, THGL). The individual ganglia and their connectives are found fused dorsally into a single mass. However their separate identity is clear on the ventral side. The ganglia of the same segment as well as those of the succeeding segments are linked by
distinct commissures (Fig. 108, CMT) and connectives (Fig. 108, CNT) respectively. The anteriormost thoracic ganglia remain separated from the succeeding ganglia by a longer interval and hence their connectives are longer than those between the posterior ones. The remaining seven ganglia are closely held together and they are wider than the anterior ones. A pair of nerves (Fig. 106, NTG) given off from the sides of each ganglion innervates the appendages, body muscles and other organs of the respective segments. The ventral branch of this nerve which goes to the appendage is stout and more prominent. The dorsal branch is rather thin and less obvious. The ganglia of the last thoracic segment and their nerves unlike their counterparts are directed posterowards.

The abdominal ganglia (Fig. 106, ABGL) are small swellings connected by long and slender separate connectives. The ganglia are completely fused. The abdominal ganglia of all the segments except the last appear alike. The last or the sixth is the largest of all and it is more or less triangular in shape. Each ganglion gives off a pair of nerves (Fig. 106, NAG) which innervates the abdominal muscles, the pleopods of the respective segments and the alimentary canal. The last abdominal ganglion gives out a pair of nerves from its postero-lateral parts which go to the statocyst (Fig. 106, NST). This ganglion
is concerned with the innervation of the uropod and the rectal muscles.

The ganglia and connectives of the ventral nerve cord are enveloped by a connective tissue sheath formed of elongated flat cells with small nuclei (Fig. 107, PNC). Besides these, interspersed among the ganglionic cells and the connectives, is yet another type of connective tissue cells termed the endoneurial cells (Fig. 107, ENC). Along with the ordinary neurons are present some secretory cells (Fig. 107, SCNC).

The pattern of distribution of the neurons is different in the thoracic and abdominal regions. In the former the neurons are evenly distributed along the ventral surface of the nerve chain (Fig. 138, NNC). They are also found to occupy the space between the connectives as well as the ganglia (Fig. 108, NNC). The neurons of the abdominal nerve chain are comparatively small and sparsely distributed. They are restricted to the anterior face of each ganglion. The connectives of the abdominal ganglia are free of neurons.

The ventral nerve cord of *M. zeylanica* exhibits a primitive condition in having paired longitudinal connections between the thoracic and abdominal ganglia and transverse connections between thoracic ganglia. Almost a similar condition is retained in *Gammarus lacustris lacustris* (Schmitz 1967). But in this animal the thoracic ganglia are
fully fused. In M. zeylanica also the thoracic ganglion appears as a fused mass in the dorsal aspect due to the presence of neurons all along the surface of the ganglia.
ENDOCRINE SYSTEM

The existence of neurosecretory cells which produce active substances controlling the various life activities of animals has been proved only comparatively recently. These cells are located in different parts of the nervous system. Hanstrom (1931) described the presence of neuroglandular cells in the eye-stalk of Squilla mantis and several species of decapod crustaceans. Since then several investigators described the neurosecretory cells and endocrine system of diverse groups of crustaceans (Hanstrom 1931, 1933, 1934, 1937 and 1947; Bliss 1951 and 1953; Bliss Durand and Welsh 1954; Carlisle 1953, Bliss and Welsh 1952; Carlisle and Passano 1953; Enami 1951; Passano 1951, 1952 and 1953; Carlisle 1959; Durand 1956; Miyawaki 1960; Matsumoto 1954, 1958 and 1962; Potter 1954, 1956 and 1958; Parameswaran 1956; Johanson and Shreiner 1965; Gabe 1966; Lake 1970; Nath et al., 1972; Hogstad 1969; Kulakovskii 1969, and Setsuji Hisano 1976).

The neurosecretory complex in crustacea in general is composed of groups of neurosecretory cells designated as X-organs and the sinus gland formed by the terminal endings of the X-organ cells.
Bellonci (1882a, 1882b) observed, in *Sphaeroma serratum* and *Squilla mantis*, an organ associated with a neurosecretory pathway, but failed to interpret it correctly. Hanstrom (1931, 1933, 1937) described a similar organ in various crustaceans, which he termed X-organ. Later Welsh (1941) described a formation he found in the medulla terminalis of *Cambarus* as X-organ. The same structure has been described in various brachyura by Bliss and Welsh (1952) Bliss, Durand and Welsh (1954) and Potter (1954, 1956 and 1958).

Carlisle and Passano (1953) observed that the above mentioned workers were using the same term to describe very different structures. They designated the structure described by Welsh and colleagues as pars ganglionaris X-organ and the one described by Hanstrom as pars distalis X-organ. Later Knowles and Carlisle (1956) and Carlisle and Knowles (1959) replaced these terms by medulla terminalis X-organ and sensory pore X-organ to designate pars ganglionaris X-organ and pars distalis X-organ respectively.

Gabe (1966) redesignated medulla terminalis X-organ as Hanstrom's organ and the sensory pore X-organ as Bellonci's organ. According to him it was Hanstrom who stressed the significance of the X-organ in neurosecretion and suggested
that these formations had no contact with the sensory pore. Hanstrom should therefore be regarded as the original discoverer of the X-organ (medulla terminalis X-organ or pars ganglionaris X-organ). Since Bellonci (1882a, 1882b) had described the main features of the sensory pore X-organ, it is quite appropriate to name this organ as organ of Bellonci.

Carlisle and Knowles (1959) described the neurosecretory cells in the medulla interna and the medulla externa as Medulla interna X-organ and Medulla externa X-organ respectively.

Koller (1928) discovered the presence of the blood gland, now known as the sinus gland in crustaceans. But endocrinological studies started only after the description of this gland by Hanstrom (1931). This organ is considered to be the reservoir of neurosecretory products produced by the neurosecretory cells of the brain and the optic regions. Hanstrom and his colleagues (1931, 1933) identified the secretory products in the sinus gland and also established the relationship of the gland with the medulla terminalis. Using specific stains like chrome haematoxylin&phloxine they demonstrated that secretory materials processed by the neurosecretory cells of the medulla terminalis are actually transported through axons to the sinus gland and stored there.
Carlisle (1953a) Bliss and Welsh (1952) Bliss et al. (1954) and Hubschman (1963) have shown that the sinus gland is supplied by axons from neurosecretory cells, individual cells or aggregations in the various neuropiles. The largest group lies in the medulla terminalis. Thus the sinus gland is considered to be a congregation of the swollen nerve terminations loaded with neurosecretory products. A few early workers however held that the sinus gland is an organ of autochthonous secretion. Pyle (1943) and Panouse (1947a) pointed out the absence of clearly distinguishable secretory material in it. Gabe (1966) maintains that the sinus gland itself is a secretory organ. Quoting Hodge and Chapman (1958) and Fingerman and Aoto (1959) who employed infrastructural cytological techniques Gabe (1966) showed that the sinus gland contains autochthonous cells as well as nerve terminations. This was confirmed by the ultrastructural study of the sinus gland of *Carcinus maenas* by Meusey (1968).

"In Mysidacea, the perikaryons giving origin to the protocephalic neurosecretory pathway have not yet been described" (Gabe 1966). Gabe (1966) located the "organ of Hanstrom" in the dorsal cellular cortex of the medulla terminalis in *P. flexuosus*, *Siriella* sp. and in 2 species of *Paramysis*. But he found that migration of neurosecretory
material through the axons is not as distinct as in higher crustaceans. Kulakovskii (1969) demonstrated that axons of the X-organ cells penetrate the sinus gland. The organ of Bellonci or the sensory pore X-organ (SPX) which has a very unusual shape in Mysidacea was known since the investigations of Dohrn (1905) Hanstrom (1934, 1937, 1947) and Stammer (1936). Dahl and Mecklenberg (1969) also made a thorough study of this organ in *Boreomysis arctica*. The SPX organ of *Mysis relicta* was described by Hogstad (1969).

The position and nature of the sinus gland of *Eucopia* sp. *Gnathophausia zoea* and *Boreomysis arctica* have been described by Hanstrom (1931). Gabe (1966) while confirming Hanstrom's findings indicated the existence of a nervous connection between the sinus gland and the medulla terminalis X-organ (MTGX). Hogstad (1969) and Kulakovskii (1969) have described the sinus gland of *Mysis relicta* and *Mysis oculata* respectively.

During the present study examination of serial sections of the eyes, brain and ventral nerve cord stained with Heidenhain's azan and chrome haematoxyline phloxine (CHP) revealed the presence of many groups of special cells which appeared histologically different from ordinary neurons that abound around the optic ganglia and the neuropiles of the
brain and ventral nerve cord. These cells are characterised by their large size, large nuclei, vacuolated cytoplasm containing granules staining deep blue with aniline blue of Azan or red with azocarmine of Azan or blue with haemotoxylène and pink with phloxine of CHP. They were not of uniform size and shape and their nuclei and cytoplasmic inclusions showed marked differences. They closely resemble the neurosecretory cells described in a great variety of crustaceans (Gabe 1954, Scharrer and Scharrer 1954, Miyawaki 1960 and Matsumoto 1958).

The neurosecretory cells of *M. zeylanica* are found at definite areas in the brain, optic ganglia and the ventral nerve cord. In addition to these there are scattered neurosecretory cells between the neuropiles of the brain and the optic peduncle.

**Neurosecretory cells and neuroendocrine organs of the eye stalk:**

Three types of cells designated as A, B, and C have been recognised in the optic ganglia. They are classified according to size, general appearance of the cell body, presence or absence of vacuoles in the cytoplasm and the nature of their secretory products.
A cells. These are large polygonal cells with comparatively large spherical nuclei (Fig. 109). The nuclei (N) are prominent and centrally placed. The nucleoplasm contains scattered chromatin granules staining red with azocarmine of Azan. The cytoplasm contains densely distributed fine granules staining light blue with aniline blue and deep blue with chrome haematoxylin. Their axon is not very prominent. The A cells are very few in number and are confined to the mid-ventral part of the medulla terminalis.

B cells. The neurosecretory cells of the eye-stalk are mostly of this type (Fig. 110). They are spherical or elongated. The nuclei (N) are large with one or two nucleoli (NU). The nuclear material appears to be phloxino-philic. The cytoplasm contains secretory granules and a few small vacuoles. These cells are found at the inner dorsal and ventral aspects of the medulla terminalis and also between the medulla terminalis, medulla externa and medulla interna.

C cells. These are ellipsoid or tear drop-shaped cells lying on the dorsal and ventral side of the medulla terminalis and also mid-laterally between the medulla interna and externa (Fig. 111). Their nuclei are spherical or oval containing
one or two nucleoli. The cytoplasm is homogeneous, staining deep blue with chromogehmatoxylin. Secretory granules are seldom found. Vacuoles, when present, are restricted to the periphery of the cell. The axons are not very conspicuous.

Sensory papilla X-organ (Pars distalis X-organ or organ of Bellonci)

This organ is situated medio-laterally on the inner aspect of the eye-stalk (Fig. 112), just opposite the junction between the medulla interna and medulla terminalis. It consists of a spherical vesicle enclosed in a connective tissue sheath (Figs. 112 & 142, $SV$). Anterior to this vesicle is a bunch of bipolar cells which lies in contact with the adjoining epidermis (Fig. 112, BPC), forming the sensory papilla. The axons of these cells form a sensory nerve which runs towards the medulla interna. The vesicle is filled with concretions of different dimensions staining bluish pink with azocarmine of Heidenhain's azan and dark blue with chrome haematoxylin of CHP. These concretions are mingled with vacuoles which are vesicular in appearance. The vesicle is not always filled with secretory materials and are often found free of inclusions. The vesicle appears to have a comparatively small amount of secretory material during the intermoult period (Fig. 142, $SV$).
Postero-laterally the vesicle is associated with a group of cells which lies dorsally at the inner distal corner of the medulla terminalis. These cells termed SPX cells (Fig. 112, SPXC) are larger than ordinary neurons. The cytoplasm is limited to a narrow band around a large nucleus. The secretory material in the cytoplasm stains blue with aniline blue of Azan stain. The nucleus contains scattered chromatin granules which stain red with Azan stain. However the cytoplasm was devoid of any vacuoles. The high degree of activity and the accumulation of fine secretory material in the cytoplasm suggest that these cells are the sites of formation of secretory material. Even though actual transport of secretory material from these cells to the vesicle has not been clearly observed, the accumulations in the vesicle appear to be secretory products of the SPX tissue from the nature of their staining reactions. The vesicle is regarded as a site for storing and releasing secretory material directly into the sinus.

Hanstrom (1933, 1937 and 1947) studied the SPX of several species of mysids. It is in the form of a vesicle with a wall formed of cuboid epithelial cells. Its lumen is filled with a secretory product. In *P. flexuosus* Gabe (1966) showed that the vesicle is divided into a series of compartments.
which represent the so-called "onion bodies" described in the SPX of several decapods. These onion bodies have been interpreted as coiled or twisted nerve endings of the enlarged axons originating in the neurosecretory cell bodies of MGTX or elsewhere. They are hence considered as storage and release sites of neurosecretory products. Rogstad (1969) observed the presence of onion bodies in the SPX vesicle of *M. relicta*. The SPX or the sensory pore X-organ of *M. zeylanica* is as Hanstrom described in other mysids. Dahl and Mecklenberg (1969) has made similar observations regarding the structure of this organ in *B. arctica*. However the SPX of *M. zeylanica* lacks the onion bodies which are said to be present in some mysids (Gabe 1966, Hogstad 1969) and in decapods (Carlisle 1953a, Knowles and Carlisle 1956; Carlisle and Knowles 1959).

Different views have been expressed regarding the source of the secretory product of the SPX. Hanstrom (1947) observed that the secretory products in the SPX vesicle are solely the secretions of the neurosecretory cells of the SPX. But Chiagneeu (1971) contradicted this view on the basis of ultrastructural studies on *Palaemon elegans*.

Carlisle (1953a & 1959) and Carlisle and Knowles (1959) observed that the onion concretions in *Lysmata seticaudata*
and Pandalus borealis are swollen nerve terminations. These swollen nerve endings (Carlisle 1959) showed a secretory cycle. More recently Drach and Gabe (1960 & 1961) after studying in detail the SPX of certain crustaceans suggested that the secretion consists sometimes of vesicular or tubular formations derived from the epineurium.

According to Dahl and Mecklenberg (1969) the 'SPX' represents the only neurosecretory system in Boreomysis arctica. The neurosecretory materials synthesised in the SPX cells are transported to the vesicle which is the site of storage and release of neurosecretory material.

The SPX vesicle in M. zeylanica appears to have a neurosecretory function. This is evident from its position and the staining reaction shown by the secretory material inside the vesicle.

Gersch (1964) is of the view that the SPX organ in mysids should be looked upon as not only a neurosecretory organ but also as a neurohaemal organ. Because of the absence of a separate sinus gland it is reasonable to conclude that this organ in M. zeylanica functions as a neurosecretory as well as a neurohaemal organ.
Neurosecretory cells of the brain

Three types of neurosecretory cells are observed in the brain of M. zeylanica. These are designated as A\textsuperscript{i}, B\textsuperscript{i}, and C\textsuperscript{i} cells.

\textbf{A\textsuperscript{i} cells.} These are very few in number, found antero-lateral to the parolfactory lobes (Figs. 113 & 140, NSC). The cells are large and their cytoplasm contains dense granular structures. The cytoplasm may enclose vacuoles (V). The axon (AX) is prominent and stains pink with chrome haematoxyline phloxine. Secretory granules (SG) staining dark with CHP are found attached to the inner margin of the cell membrane. These cells correspond to the A cells described by Matsumoto (1958). The nucleus is round and comparatively small, the nucleolus is eccentric.

\textbf{B\textsuperscript{i} cells.} These are tear drop-shaped cells located antero-dorsal to the parolfactory lobes (Fig. 114), larger than identical cells found in the eye-stalk. The nucleus (N) is fairly large and encloses two to three nucleoli (NU). The secretory granules are uniformly distributed in the cytoplasm. A few large vacuoles are also encountered. The cytoplasm stains deep blue with Azan stain. The chromatin material is in the form of diffuse granules. These cells are restricted to the basal part of the antennular nerve.
C^1_ cells. These are round or polygonal and widely distributed (Fig. 115). They are found all along the lateral surface of the parolfactory lobes. The nucleus (N) is spherical or oval with a single nucleolus (NU). It stains red with CHP, and Azan stains. The secretory granules in the cytoplasm appear dense and are found at the inner margin of the cell membrane. The axons are not very prominent. The cytoplasm does not contain vacuoles. The chromatin appears in the form of a loose net work.

Neurosecretory cells of the ventral nerve cord:

There are no published reports on the neurosecretory cell types of the ventral nerve cord of Mysidacea. In M. zeylanica cells which appear to be secretory occur among the ordinary neurons. These occupy the space between adjacent thoracic ganglia. Secretory cells are absent in the abdominal ganglia. The cells of the thoracic ganglia largely resemble those of the brain and are designated as A^2^ B^2^ and C^2^ cells.

A^2^ cells. These are large cells confined to the posterior region of the thoracic ganglia nearer to the median line (Figs. 116 & 141, NSC). A^2^ cells, more or less spherical in shape, are larger than A^1^ cells of the brain. The nuclei (N), round and centrally placed, have two nucleoli (NU).
The nuclear material is sparsely distributed. The cytoplasm is homogeneous staining pink with Heidenhains Azan. Vacuoles are absent in the cytoplasm.

**B² cells.** (Fig. 117). These cells are found distributed on the lateral parts of the nerve cord and are similar to the B¹ cells of the brain. The axon (AX) is prominent. The cytoplasm encloses a few vacuoles (V) and is limited in quantity. Nuclei are large with more than one nucleolus. The variable staining reaction of the nucleus reveals that it takes an active part in the elaboration of the secretory products.

**C² cells** (Fig. 118). These are oval or round cells found uniformly distributed along the thoracic ganglia. The nuclei (N) are round with a single nucleolus (NU). Chromatin granules are found attached to the nuclear membrane. The cytoplasm is devoid of vacuoles, stains blue with CHP and Azan stain. The axons of these cells are inconspicuous. It is not clear whether these cells produce any secretory material.

**Y-organ**

The Y-organ has been described in a large number of malacostracans and was shown to influence the moulting process.
of crustaceans. The Y-organ was first discovered by Gabe (1953). Echalier's (1954, 1955, 1956 and 1959) experiments on Carcinus maenas revealed that this organ is responsible for the secretion of the moult hormone. In malacostracans with active maxillary gland the Y-organ is situated in the antennal segment. Those with active antennal gland have this organ in the maxillary segment. The appearance of the Y-organ varies from group to group. In brachyurans it is conical, lenticular in Natantia and foliaceous in Isopoda and Amphipoda.

The Y-organ appears to be quite similar to the ecdysial gland of insects producing ecdysone, the insect moulting hormone (Tombes 1970).

In crustaceans the moult hormone may comprise of different molecules like crustecdysone (Hampshire and Horn 1966) and deoxy crustecdysone (Galbraith et al., 1968). The findings of King and Siddal (1969) and Moriyama et al. (1970) that in a particular arthropod there will be more than one form of ecdysone and that in insects and crustaceans α ecdysone is converted into β ecdysone revolutionised the concept of the moulting hormone.

Though the moult hormone is primarily responsible for initiating the premoult changes, it can influence hardening
of the cuticle (Faux et al. 1969), colour change, (Adiyodi and Adiyodi 1969) regeneration (Passano 1960, Adiyodi 1967) and also reproduction. According to Tombs (1970) the juvenile Y-organ produces a hormone which is essential for the development of the gonads. The moulting hormone has been found to be necessary during the initial stages of gonad maturation, namely, of oogonia (Arvy et al. 1954). During the intermoult period the Y-organ does not store the moulting hormone in decapods (Karlson and Skinner 1960) and histological studies have shown that the gland is almost inactive (Matsumoto 1962). In Maja the Y-organ regresses simultaneously with the puberal moult which is the final one. Carlisle (1957) Arvy et al. (1954) and Passano (1960) have shown that Carcinus ovulates and carries embryos in the absence of the Y-organ which indicates that the moulting hormone is not essential for reproduction.

The Y-organ in M. zeylanica consists of a pair of conical structures situated laterally in the maxillary segment (Fig. 119). Each is composed of a group of cells without distinct cell boundary. The nuclei (N) are densely crowded and arranged in several layers in a plasm. They are clear and round with dense chromatin staining deep with azocarmine of Azan stain. The cytoplasm is homogeneous and takes basic stains very feebly. The nucleolus is very distinct occupying
a central position. The whole organ is encased in a thin membrane. The Y-organ is bathed in the haemocoelic fluid. The nerve fibres detected in the vicinity of the gland have their origin in the suboesophageal ganglion. The gland does not have any duct leading out of it.

The Y-organ in *M. zeylanica* resembles the lateral organs described by Vogt (1936 vide Gabe 1956) in *Gastrosaccus* and *Praunus*. Silen (1954) has observed similar structures in isopods. But as described by Vogt and Silen there is no centralised zone close to the cuticle devoid of nuclei, in *M. zeylanica*. The Y-organ in *M. zeylanica* is conical as in brachyurans (Gabe 1966). Gabe detected definite cell boundaries while Vogt (1936) Siewing (1953) and Silen (1954) failed to find them. Cell limits are not clear in *M. zeylanica*.

**Androgenic gland**

Courrier (1921) and Brinkmann (1936) reported the existence of male hormones controlling the development of the male sex characters. But these authors did not investigate the source and nature of this hormone. The androgenic gland was first discovered by Charniaux Cotton (1954) in the amphipod *Orchestia gammarella*. Since then this gland has been discovered in all groups of malacostracans (Charniaux Cotton 1966 et al). The androgenic hormone secreted by this
gland controls the development of the primary and secondary sex characters in male malacostracans (Charniaux Cotton 1960, 1962 and Zerbib 1967). The gland shows great diversity even among closely related groups. Except for a majority of isopods and tanaids, the androgenic gland occurs on the subterminal portion of the vas deferens. In certain isopods it extends up to the testicular utricles. Variations in the morphology and histology of the androgenic gland among isopods have been reported by many workers (Charniaux Cotton 1956, 1958, Demeusy 1960, Carlisle 1959, Hoffman 1969, Carpenter and De roos 1970 and Thampy and John 1970 & 1972).

Among mysids this gland has already been described in Paramysis nouveli by Juchault (1963) and Meusy (1963). Juchault (1963) and Nath et al. (1970) have described this gland in Praunus flexuosus and Spelaeomysis longipes respectively.

In M. zeylanica this gland is attached to the outer wall of the distal part of the vas deferens at the region where the latter bends mesiad to reach the ventral side. It is pyramidal in shape with a basal width of 120 μ and a height of 50 μ in an animal 4.5 mm long (Fig. 120). Extensions of the basal part of this gland reach the muscles
attached to the 8th thoracic appendage. The gland consists of a group of cells covered by a thin membrane. The boundaries of the constituent cells are indistinct. The cytoplasm is dense and homogeneous. It is basophilic in reaction and fully stainable. But for the presence of a few vacuoles (Fig. 120, V) in the cytoplasm of certain cells, the cells are free of inclusions. Two types of nuclei are distinguishable, small, round or spherical ones (Fig. 120, SC) and large roughly oval ones (Fig. 120, BCAG). These nuclei possess a centrally placed nucleolus (Fig. 120, NU). The nucleoplasm is denser and takes more stain. The finely granular chromatin is evenly distributed.

The androgenic gland in _M. zeylanica_ seems to be more active in juveniles than in the adults. These animals attain sexual maturity within a short period after their release from the brood pouch. Hence the high secretory activity of this gland coincides with the development of the secondary sexual characters. This indicates that this gland plays a very active role in the maturation of the individuals. The above observation agrees with the statement of Husson and Graf (1961) that the low activity of the androgenic gland will lead to prolonged prematurity period. In _S. longipes_ (Nath et al, 1972) where the androgenic gland is less active, secondary sexual characters appear only after a lapse of six months.
FOOD AND FEEDING HABITS


*M. zeylanica* exhibits two different methods of feeding like many other mysids. The more common method is the creation of a food current containing small particles of food which is directed towards the mouth by the movements of the exopods of the thoracic limbs. The alternate method involves the catching of relatively large items of food with the thoracic endopods and the mandibular palps. The food is then cut into smaller pieces by the incisor process of the mandibles and the distal endites of the maxillules and ground down to fine particles by the molar process of the mandibles.

The filter feeding mechanism is the more primitive and the only type exhibited by the most primitive of the known mysids, *Gnathophausia* (Manton 1928a). In this animal filter feeding is facilitated by the suction pump action of the maxillae.
According to Manton Gnathopausia is more primitive than Lophogaster. The modification of the mouth parts in the latter for feeding on large food particles was accompanied by the loss of the filter feeding mechanism. In Lophogaster the pleopods function as the main organs of locomotion and the exopods of the thoracic limbs are mainly concerned with the maintenance of the respiratory current. The exopods do not produce a subsidiary food current as it is likely to clog the gills. In Mysida in addition to the ventral food current produced by the suction pump action of the maxillae, there is a subsidiary food current produced by the exopods of the thoracic legs. This according to Manton (1928a) is a secondary development.

The ancestral Mysidacean must have closely resembled Gnathophausia and must have entirely depended on the maxillary filtering apparatus. Dennel (1936) suggested the possible lines of evolution of the present day Mysida from such ancestral forms.

The filter feeding mechanism in M. zeylanica is similar to that described by Cannon and Manton (1927) for H. lamouinae. Observations on the general movements of the appendages and the course of the currents produced in the water were made by keeping the animals in a small container
with suspended carmine particles. The fine particles of carmine are carried to the mouth in a ventral food stream created by the movements of the exopods of the thoracic appendages and the suction pump action of the maxilla.

During locomotion an area of still water is produced in the mid-ventral area. This water drawn in by the suction pump action of the maxilla into the food groove forms the main food current. This forward moving stream also receives subsidiary food currents produced by the rotatory movements of the thoracic exopods. The ventral food groove is enclosed by the ventral body wall dorsally, the bases of the thoracic appendages laterally and the overlapping setae on the basal joints of the endopods ventrally.

The food current which reaches the food basin at the region of the mouth is filtered by the setae on the proximal endite of the maxillae. The food stream after being filtered passes out between the maxillary exite, maxillule and the body wall. The minute particles retained by the maxillary setae are pushed on to the mandibles by the long setae on the proximal endite of the maxilla and the comb-like setae on the proximal endite of the first thoracic limb. The mandibles are asymmetrical and their incisor processes interlock. Lateral movements of the mandibles transfer the food to the molar
processes where it is ground and then sucked into the oesophagus.

**M. zeylanica** feeds mainly on suspended matter and organic detritus by filter feeding. Majority of the animals examined immediately after collection had an empty stomach. The gut contents mainly consisted of organic detritus and parts of small crustaceans like calanoid copepods, daphnids, and copepod eggs, rotifers, algal filaments and peridinians like *Ceratium*. This indicates that **M. zeylanica** takes a wide variety of food, anything suspended in the surrounding water.

There is no reference to selective feeding among mysids. Being typical suspension feeders they cannot be particular about what they take in. Apstein (1906) found that **Mysis mixta** in the Baltic fed on copepods and their eggs, diatoms, peridinians and other small organisms. Blegvad (1915) concluded that **M. mixta** and **Gastrosaccus spinifer** fed entirely on bottom detritus and animal matter. Rauschenplat (1901) stated that **P. flexuosus** feeds on diatoms, algal remains, copepod and other crustacean remains. According to Kinne (1955) **N. vulgaris** is an omnivore but prefers to eat animal food. Wilson (1951) found both plant and animal food in the stomach of **N. mercedes**. Tattersall and Tattersall (1951) indicate that most of the mysidaceans
filter out microscopic plants and animals and detritus. Mauchline (1967) stated that *S. spiritus* extracts suspended matter indiscriminately from the water. Raymont et al. (1964) indicated that detritus is important in the nutrition of *N. integer* especially in estuarine conditions where there is normally a constant supply of suspended organic matter. *Neomysis vulgaris* utilises whatever food is available at any particular place or time.

Molloy (1958) observed that *M. slabberi*, an estuarine mysid, had empty stomach when examined soon after catching during night hours. According to her this may be due to complete utilisation of the food during its upward migration for breeding purposes. Another explanation is that the animals being carnivorous take food only occasionally and the intestine becomes empty as soon as the digestion of the food is completed. Krogh (1931) noted that in transparent animals like larval fish digestion is rapid and the stomach appears empty most of the time. These facts according to Molloy (1958) account for the apparent emptiness of the alimentary canal of *M. slabberi* in which digestion is extremely rapid and probably inefficient.

The vertical migration undertaken by *M. zeylanica* is in no way connected with its breeding activity. Moreover
the depth of the water in the lake is not so great as to exhaust the food before the animal reaches the surface waters. The apparent lack of food in the stomach of *M. zeylanica* must be due to rapid digestion.

As already stated *M. zeylanica* also feeds on large pieces of food, living or dead. It is found to capture live copepods and *Artemia* nauplii. Occasionally the animal dives to the bottom and comes up carrying the corpse of another mysid. These are held by the thoracic endopodites and tackled by the oral appendages. The thoracic region of the victim is eaten first and often the abdominal part is discarded. This is obviously because the area where the abdomen meets the thorax which is often uncovered by the carapace is the weakest part. The food mass is held below the mouth parts and manipulated by the multiarticulated carpopropodite of the thoracic limbs. When the food mass is caught and held by these endopodites, it is suitably oriented and brought close to the mandibles. The mandibular palps grip the food mass. The animal further reduces the size of the caught food with the help of the incisor process of the mandibles and the distal endites of the maxillules. The food bitten off by the incisor processes of the mandibles is passed on to the lacinia mobilis and then to the molar processes where it is ground down to finer particles and finally sent into the oesophagus.
Raptatory feeding habit has been observed in *Hemimysis lamornae* (Cannon and Manton 1927), *Neomysis vulgaris* (*N. integer*) especially when suspended food was not available (Lucas 1936), in *P. flexuosus* (Depdolla 1916, 1922), in *M. slabberi* (Molloy 1958) and in *Gastrosaccus simulans* (Nath and Pillai 1973). Molloy (1958) and Zimmer (1932) have found *P. neglectus* and *P. inermis* respectively browsing on sea-weeds.

In small containers when the food material in suspension becomes insufficient for filter feeding, *H. lamornae* swims down to the bottom and takes up a vertical position resting on the antennal scales and the inner flagella of the antennule. The thoracic exopods create the usual currents and large quantities of fine particles of detritus are drawn off the bottom, thus bringing about an increase in the suspended matter.

*M. zeylanica* was never found resorting to such a type of feeding. It swims freely at all levels of the water and does not cling to weeds or the wall of the vessel as many other species. It usually remains at a level just below the surface of the water where copepods and other small animals congregate.

**Observations on the passage of food through the alimentary canal**

The method of feeding mysids on carmine particles in suspension (Cannon and Manton, 1927) was used to observe the
movement of food particles within the alimentary canal. Since *M. zeylanica* is extremely transparent the course taken by the carmine particles can be seen in live animals. Further the use of Carmine has the advantage that the animals need not be starved before beginning the observation, as its red colour distinguishes it from other matter in the digestive tract.

Animals were introduced into a cavity block containing a fine suspension of carmine. They were observed under a binocular microscope. The animal took in these red particles rapidly and in about five minutes the stomach which was contracting regularly was full of carmine. This was followed by the rhythmic contraction of the digestive gland tubules which made the digestive fluid flow into the lower chamber of the pyloric stomach. Meanwhile the rocking action of the ventral pyloric ridge facilitated the mixing up of the food further with the digestive fluid. The carmine particles in the form of red faecal pellets appeared in the anterior part of the mid-gut in 15 minutes after the beginning of feeding. The faecal matter passed rapidly through the mid-gut. When the faeces reached the hind-gut vigorous muscular contractions were set up. The faeces was shot out of the anus rapidly. The muscular contractions of the anus are continued until the pellet is freed by a sudden jump of the animal. Once
the faecal string is broken away from the main food mass in the midregion it is usually eliminated within a few seconds.

The interval between the onset of feeding and the elimination of the first faecal string containing carmine was normally 22 to 25 minutes. The faecal matter is ejected out in the form of elongated cylindrical rods which are normally 0.50 mm to 1.00 mm long. Under normal conditions only one piece is extruded at a time.

**Feeding with Artemia nauplii**

Individual animals were placed in filtered water into which was introduced a few *Artemia* nauplii. The animal never attempted to catch the nauplii unless the latter chanced to move near the ventral part of its head. In that case the animal pounced on the prey which it held close to the mouth and chewed with its mandibles. The operation lasted for less than five minutes. After about ten minutes the undigested food material was evacuated. The animal continued to eat the nauplii no matter whether the stomach is full of food or not. One individual was found to eat 10 *Artemia* nauplii within a period of 2 hours. This showed that *M. zeylanica* is a continuous feeder and that it takes less time to feed on animal matter than inert substances like
carmine particles. The usual emptiness of the alimentary canal of *M. zeylanica* when freshly caught may be due to the fact that this species normally feeds on zooplankton which passes rapidly out through the gut.

The mode of entry of the masticated food into the cardiac stomach is described differently by various authors. Berradaile (1901) holds that the muscles of the oesophagus help to carry the food into the stomach. Parker and Mocquard (vide Berradaile 1917) suggest that a sucking action by the stomach is responsible for the passage of food up the gullet. In *Mesopodopsis* there is an oral intake of water. This is initiated by the dilator muscles of the oesophagus. The masticated food ascends the stomach along with this water. Fox (1952) holds that oral gulps are not primarily for swallowing food. However this ascend of water helps the transportation of food in this animal. This also prevents the particles of food from being thrown out during the movements of the mouth parts. Pillai (1958) has also reported oral intake of water in *Caridina*. Such intake of water according to him is quite indispensable in those crustaceans in which external trituration is more marked than internal trituration. It should be emphasized in this connection that in *M. zeylanica* the food particles are thoroughly masticated by the oral appendages before they reach the stomach which is poorly armed.
"The usual type of muscle contraction in mysids is antiperistaltic and is more or less continuous throughout the whole length of the intestine" (Molloy 1958).

Antiperistalsis occurs along the entire length of the intestine of *M. zeylanica* also. It is a continuous process, the waves of contraction being short and rapid. The contractions are initiated in the hind-gut region and pass forwards to the mid-gut. They occur whether or not the intestine contains faecal matter. But in *P. integer*, *P. flexuosus* and *S. armata* (Molloy 1958) antiperistalsis is not continuous, but initiated in the intestinal wall when the faecal string passes into the posterior region of the mid-gut. Zimmer (1932) observed a continuous antiperistaltic action in the alimentary tract of *M. slabberi*. He thought that this might be a method by which the excess of water taken in with the food is ejected through mouth. Fox (1952) contradicting this view, correlated the phenomenon of antiperistalsis with anal intake of water. This he proved by demonstrating that cells of *Chlorella* suspended in water were taken in by *H. lamornae* through the rectum. He found that in the absence of faecal matter these cells pass forwards as far as the stomach by the antiperistaltic contractions of the intestinal wall.

The rectal swallowing of water has been observed as early as 1850 by Lerebouillet (Fox 1952) in *Limnadia* and *Daphnia*. 
Weismann (1874) and Siedentop (1930) interpreted this as anal respiration. Fox (1952) disproved this finding as he could not observe an increased rate of rectal swollowing in any of the forms, studied by these workers, when put in oxygen deficient water. According to him the intake of water through the anus acts as some sort of natural enema as it increases following defecation. Pillai (1958) observed that anal intake of water might supplement the oral intake in maintaining turgidity inside the intestine.

Experiments with *M. zeylanica* did not reveal the occurrence of anal intake of water. Neither the particles of fine charcoal nor carmine entered into the intestine through the anus when the animal was kept in a suspension of both. Further the faecal matter travels posteriorly or remains stationary but has never been observed passing forward in the same direction as the waves of contraction associated with the antiperistaltic movements of the intestine. Molloy (1958) also could not observe this phenomenon in any of the mysids she studied.
MESOPODOPSIS ZEYLANICA AS FOOD OF FISH

That mysids form an important constituent of the diet of fishes has been proved by many workers. It is necessary to have an understanding of the actual consumers of a particular species in order to assess its importance in the trophic relationship within the habitat.

Records of mysids from the stomach of marine fishes are many. Tattersall and Tattersall (1951) have given a list of the various fishes that feed on different species of mysids. As early as 1835, Ross reported that M. flexuosa formed the chief food of salmon. Smith (1879) found N. americana in the stomach of flounder, shad, herring and mackerel. In Delaware bay (Stevenson 1958) Neomysis ranked high in the diet of the common anchovy. Hopkins (1965) also stressed the importance of this species as food for the fishes in Delaware bay. According to him this species plays an important role both in the temperate and inshore waters of North America.

Lasenby (1971) stated that Mysis relicta could be of economic value in fisheries work since it provides a staple diet for many species of fish. Furst (1965) introduced Mysis in lakes previously uninhabited by this species. The
increased growth of the fish kokanee (Onchorhyncus) in Kootenay lake, British columbia, according to Stringer (1967) was due to the presence of Mysis introduced into the lake.

Of the estuarine species Neomysis awatschensis is the most intensively studied species. It occurs in brackish water bays, estuaries and in fresh water (Light 1954). Heubach et al. (1963) have shown that it forms an important food of one-year old striped bass (Roccus sexatilis) over 2.5 cm long. According to Heubach the distribution of young bass and N. awatschensis is interrelated and bass feeds exclusively on this mysid resulting in a decrease in its abundance.

From our waters there is no report regarding the part played by mysids in the food needs of fishes. Kaliamoorthy (1972) found that M. orientalis is an important item in the food of fishes. Devaraj et al. (1975) reported the presence of mysids in the stomach of pearl spot, Etroplus suratensis. But they have not identified the species.

During the course of the present study random collections of fishes was made and their gut contents examined. The fishes examined were Mugil cephalus, Chanos chanos, Channa striatus, Ambassis, Megalops filamentosus,
Glossogobius giurea, Arius, Etroplus suratensis and
E. maculatus. But none of these fishes except Etroplus
suratensis had mysids in their stomach. Further no mysid
was found in fishes above 5 cm in length. Small fishes
measuring 2.5 cm in length contained 12–27 mysids. Apart
from mysids there were also a good number of copepods. These
fishes were observed following swarms of mysids. The stomach
of E. suratensis was full of M. zeylanica during the months
of February, and March 1973 when the peak in the abundance
of this mysid occurred.

The above observations indicate that M. zeylanica
forms a preferred item in the food of Etroplus particularly
juveniles ranging from 2.0 to 5.0 cm. Those above 5 cm show
no preference probably because they feed on larger organisms.
The intensity of feeding is directly proportional to their
abundance in their habitat. This suggests the importance of
this mysid in fish culture.

Under natural conditions an important factor controlling
the multiplication of any species is the availability of nutrients,
which sustain the growth of the organisms forming the food of
mysids. If artificial manuring is resorted to this continuous
breeder can be made available in large numbers throughout the
year ensuring a steady supply of fish food. As early as 1950,
artificial manuring of fish ponds in the estuarine areas of Kayamkulam was tried and a phenomenal growth of *M. zeylanica* was actually observed. The availability of this mysid in adequate quantities can be ensured by artificial manuring of brackish water fish culture ponds.
DISCUSSION

The morphology of *M. zeylanica* presents an intriguing picture in that primitive features exist along with specialised ones. The only explanation is that this contradiction is the result of adaptational modifications.

Compared to other mysids *M. zeylanica* has a simple fore-gut. It is tubular and of uniform diameter. This is definitely a primitive condition and closely resembles the fundamental malacostracan type envisaged by Siewing (1956). According to Siewing Mysidacea forms the basic stock of Peracarida, which gave rise on the one hand to the Amphipoda and on the other to the Isopoda via Tanaidacea and Cumacea.

The cardiac stomach of *M. zeylanica* differs from that of other mysids in the absence of an anterior prolongation. The cardiac armature is much simplified, lacking dorso-lateral toothed projections carrying teeth and spines. In other mysids the posterio-dorsal cardiac projection is a very complicated structure. But in *M. zeylanica* it is very simple bearing small weak spines.

In mysids the cardiac stomach has an efficient trituration apparatus and is hence supplied with powerful intrinsic muscles. *M. zeylanica* has a simple cardiac stomach
and appropriately the intrinsic muscles are poorly developed.

The simplicity of the cardiac stomach cannot be easily explained. *M. zeylanica* is a continuous feeder and my observations have shown that the food is simply passed through the stomach and never retained there for mastication. It may be that this has resulted from the fact that estuaries contain a lot of suspended matter and hence food is available in plenty, especially for a suspension feeder like *M. zeylanica*.

Among malacostracans the pyloric chamber exhibits conservatism in its internal structure. But *M. zeylanica* shows a significant peculiarity in that the lateral walls of the pyloric chamber carry filter channels recalling the condition in decapods. In decapods the channels always present on ventral pyloric ridge extend on to the side walls.

Manton has shown that the paired nature of the dorsal diverticulum is a primitive feature. In *M. zeylanica* it is bifid and directed forwards. However this organ in *M. zeylanica* is a formative region showing intense activity. This goes against its supposed primitive nature.

Other members of the tribe like *Praunus, Neomysis* and *Hemimysis* have a capacious well armed stomach. Their pyloric stomach does not have filter channels on the lateral walls.
The dorsal diverticulum is unpaired and directed backwards. It would appear that on the strength of the peculiarities of the alimentary system *Mesopodopsis* can be excluded from the tribe Mysini as suggested by Molloy (1958).

In lower crustaceans the mid-gut epithelium is concerned with digestion and absorption of food. As soon as the hepatopancreas got developed the mid-gut epithelium and hepatopancreas shared these function. In decapods the hepatopancreas is solely responsible for digestion as well as absorption. In all the mysids hitherto studied it has been stated that the mid-gut epithelium is both secretory and absorptive to some extent. In *M. zeylanica* the mid-gut takes no part in this. On the other hand the digestive glands do the entire secretory and absorptive functions and also act as an excretory organ aiding in the elimination of worn out cells. The present study has shown that the cells of the hepatopancreas are both secretory and absorptive in nature. The fact that the food is retained in the hepatopancreatic tubules for a long period and also kept in constant motion supports the histological evidence. This obviously is a specialisation.

The heart of *M. zeylanica* is long and tubular. According to Claus this is a primitive character. The cor frontale is
poorly developed and no muscles are attached to this. The cephalic aorta in *M. zeylanica* goes direct to the brain and there is perhaps no necessity for any additional pumping organ. The cor frontale is well developed in other mysids and in them the cephalic aorta after giving off the common ophthalmic artery, bends downwards and runs in between the stomach and the brain. The brain is supplied with blood by the cerebral artery originating from the cephalic aorta.

The cephalic arterial system of *M. zeylanica* is again peculiar. The aorta enters the brain at its hind region and bifurcates in the middle of the brain. The antennular and antennal arteries originate from the lateral branches of the cephalic aorta. In no other mysid has such a distribution of vessels been reported.

Contrary to the conditions reported in other mysids the descending aorta is not trifid. According to Mayrat the trifid condition has resulted from the fusion of the basal part of 3 separate arteries. In *M. zeylanica* the descending artery bifurcates into an anterior and posterior branch, the latter devides leading to the trifid condition.

Unlike in typically marine mysids, the antennary gland of *M. zeylanica* is simple showing primitiveness.
The brain of *M. zeylanica* is of the carcinus type. All the neuropiles typical of the malacostracan brain are well developed. The parolfactory lobes of the duetocerebrum innervating the antennules are large and well developed. This is obviously because the basal part of the outer flagellum of the antennules is supplied with a large number of sensory structures. The pons cerebri is formed of four pairs of glomeruli which is characteristic of this species. The number of glomeruli involved in the formation of the pons cerebri varies among mysids.

The absence of the additional mid-dorsal glomerulus seen in lophogastrids and *Spelaeomysis* shows that the brain of *M. zeylanica* is highly developed. On the other hand the existence of paired longitudinal connectives between the ganglia of the ventral nerve chain is a primitive condition.

Different types of neurosecretory cells were located throughout the central nervous system excluding the abdominal ganglia. The sinus gland or the actual transport of neurosecretory material could not be detected. As moulting takes place once in 3 days it is quite probable that this animal lacks an elaborate arrangement for the storage and release of secretory material which controls the moulting process. The SPX organ is well developed and is apparently the only neurosecretory organ present.
The androgenic gland is well developed. Its greater activity in juveniles synchronises with the short prematurity period. *M. zeylanica* attains maturity within two months after its emergence from the brood pouch.

The reproductive organs are highly developed and show a high degree of specialisation. The germogen is confined to a definite area and differentiation of the germ cells takes place at definite regions. The eggs are telolecithal which is unusual among arthropods. The oviducts originate from the hind end of the ovary and the distal end of the former is double-layered. This again is a distinguishing feature of *M. zeylanica*. The developing ovum is covered by a layer of follicular cells. The follicular layer characteristic of decapods has not previously been observed in mysids.

The male reproductive system differs from that of other mysids in structural details. The testicular lobes and pouches of each testes remain separate and the testicular pouches have a peripheral layer of cells. The vas deferens is non muscular. Spermatozoa are ejected with the help of the lateral musculature of the thorax.

The vas deferens and the ovary are always found filled with spermatozoa and eggs indicating that breeding is continuous in this animal.