

PART 1

Phylum Annelida: General Characteristics and Classification

General characteristics of Phylum Annelida

(Annelus: little ring)

Kingdom: Animalia

Habitat: mostly aquatic, some are terrestrial

Habit: free living

Symmetry: bilateral symmetry

Coelom: coelomate (Body cavity is a true coelom, often divided by internal septa)

Body is metamerically segmented

Grade of organization: organ system grade

Germ layer: triploblastic

Body possesses 3 separate sections, a prosomium, a

trunk and a pygidium.

Digestive system: complete and developed

Respiration: by general body surface

Nervous system: nervous system with an anterior nerve ring, ganglia and a ventral nerve chord.

Circulatory system: Has a true closed circulatory system.

Excretion: by nephridia

Reproduction: Sexual and gonochoristic or hermaphroditic.

Fertilization: Internal or external

Development: direct with no larval stages

Classification of Phylum Annelida

Phylum Annelida is divided into four main classes, primarily on the basis of setae, parapodia, metamerites and other morphological features.

Class 1 Polychaeta

(Polys: many; chaite:hair)

Habitat: They are marine, terrestrial, and freshwater.

Archetypical protosome development (schizocoely).

True coelomates (schizocoelomates).

Bilaterally symmetry, segmented worms.

Complete digestive system.

Closed circulatory system.

Well-developed nervous system.

Excretory system: Both metanephridia and protonephridia.

Lateral epidermal setae with each segment.

Dioecious or hermaphroditic.

Fertilization: external

Examples: Nereis (sandworm), Syllis, Sabella

Class 2 Oligochaeta

(Oligos: few, chaite: hair)

Habitat: mostly terrestrial and few are freshwater

Body metamerically segmented

Clitellum present

Hermaphrodite but cross fertilization occur

Fertilization: external

Cocoon formation occur

**Examples: Pheretima
posthuma (Earthworm), Lumbricus, Stlaria, Tubifex**

Class 3 Hiradinea

(Hirudo: leech)

**Habitat: primarily freshwater annelids but some are
marine, terrestrial and parasitic**

The body has definite number or segments.

The tentacles, parapodia and setae are totally absent.

They are hermaphrodite.

Fertilization: internal and a larval stage is absent.

Examples: .Hirudinaria (Leech)

Class 4 Archiannelida

(Arch; first)

Habitat: They are strictly marine.

The body is long and worm like.

The setae and parapodia normally absent.

They may be unisexual or hermaphrodite.

The development: indirect forming trochophore larva.

Examples: .Protodrillus. Dinophilus, Protodrilus

ECONOMIC IMPORTANCE OF ANNELIDS

Annelids, segmented or ringed worms, are present both in soil and sea. There are more than 9000 species of annelids. They are important economically and ecologically for many reasons.

Annelids present in soil mainly come under two categories; burrowers and those live on surface. The burrowers loosen the soil making penetration

of water and oxygen easy. Thus annelids keep soil aerated and fertile. Both accelerate the process of decomposition of organic waste and minerals. This makes consumption easy for other organisms and plants. They also support production of soil by mixing minerals and organic matter. Hence, annelids play a supportive role in agricultural production.

An earthworm, the most common annelid, is food for many birds, rodents, mammals, aquarium fish and laboratory animals. Presence and conservation of earthworms has become essential for conservation some species of endangered birds. Earthworm is excellent fishing bait.

Certain varieties of annelids like, the epitokes of Eunice (Palolo worms) are used as food by the native people. They are highly nutritive. Annelids have importance in treatments. The medicinal leech was used by doctors to bleed their patients. Though this practice is not being followed now, medicinal leech is still used to heal severed appendages. They are also used in cosmetic surgeries and skin grafts because of their anesthetics and antibiotics powers. Some earthworms are used in interior parts of China, India and Japan for preparing medicines for bladder stones, jaundice, piles and rheumatism.

Earthworms and leeches are widely used for dissection and for studying comparative physiology in

colleges and universities.

Burrowing species of marine annelids supports the penetration of water and oxygen into the sea-floor sediment. These sediments support the life of aerobic bacteria and small animals alongside their burrows. Marine annelids are food for plants and animals living in sea.

Pheretima: Habit and Habitat and External Features

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Habit and Habitat of Earthworms:

The earthworms are burrowers. They are found in the soil rich in decaying organic matters usually in gardens, pastures, lawns, irrigated farm lands, near the banks of the ponds, lakes and rivers.

The do not prefer to live in sandy, clay and acid soils which are deficient in organic matters. They generally inhabit an upper layer of earth to a depth of about 30 to 45 cm and even they go down up to 3 meters or more during summer in search of moisture.

The rainy season is the most favourable time for the earthworms, during this season they live in the superficial soil of the earth and they are often seen crawling on the surface in abundance. The earthworms are nocturnal in habit; during night hours they come out of their burrows in search of food, reproduction and exploring fresh habitat.



They breed during the rainy season. They are cold-blooded or poikilothermal animals as their body temperature fluctuates with the fluctuation in the surrounding temperature.

The way of the excavation of their burrows is very interesting; as the worm eats on the soil, so it goes on eating the soil progressively downwards, the organic contents of the soil are digested and absorbed in the gut, while residual soil is discharged by its anus at the opening of the burrow as castings.

Thus, the presence of earthworms is inferred by their castings, The castings of *Pheretima* form little heaps of small round pellets lying separately near the burrows, while in *Eutyphoeus* they form large cylindrical structures of 5 cm in height. The natural life span of earthworms varies from three and a half years to ten years.

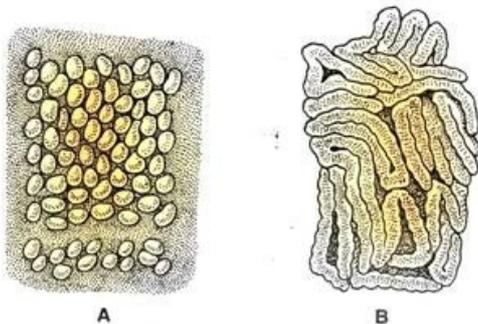


Fig. 66.1. Castings of earthworms. A—*Pheretima*; B—*Eutyphoeus*.

External Features of *Pheretima*:

Shape and Size:

Pheretima posthuma has long, elongated, cylindrical narrow body which is bilaterally symmetrical. The anterior end is tapering, while the posterior end is more or less blunt.

The dorsal surface of the body is marked by the

presence of dark median line of dorsal blood vessel which runs throughout the length of the body just below the skin, while the ventral surface is marked by the presence of genital openings and papillae in the anterior part of the body.

Size of earthworm varies from species to species and individual to individual of the same species. A mature earthworm may attain the size up to 150 mm in length and 3-5 mm in width.

Colouration:

The earthworm is slimy to touch and glistening dark-brown in colour due to the presence of a pigment porphyrin in its body wall which protects the body from otherwise effect of the bright light. The dorsal surface of its body is darker than the ventral surface.

Segmentation:

The body of earthworm consists of about 100-120 small ring-like segments or somites or metameres. It exhibits true segmentation, i.e., the external segmentation corresponds with internal segmentation. In other words, the whole surface of the body is divided into many ring-like segments by a distinct series of annular grooves or furrows representing the external segmentation.

Similarly, the interior of the body is divided by inter-segmental septa or coelosepta into small chambers representing internal segmentation. However, all the segments of the body are alike except the first and the last segments.

Setae:

In all the segments of the body except the first, last and clitellum there is a ring of chitinous setae lying embedded in the middle of each segment which project backwardly. Each seta arises from a setigerous sac of the skin and is a pale-yellow curved S-shaped pointed rod-like with a swollen middle part called nodulus.

The setae help in locomotion by holding the earth since they are directed backwards. The movement of setae is controlled by special type of muscles. With the help of these special type of muscles the setae can be moved in any direction and extended or withdrawn at the will of the earthworm.

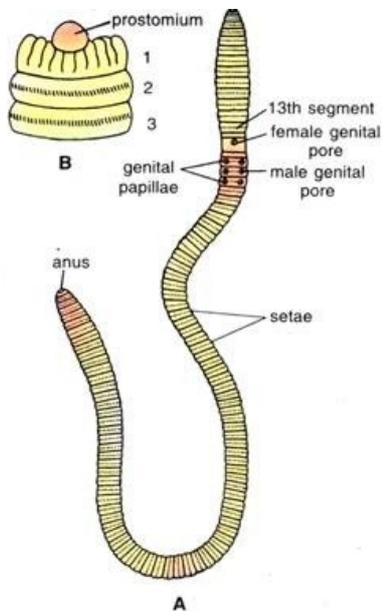


Fig. 66.2. A—*Pheretima posthuma* in ventral view; B—Anterior end in dorsal view.

Clitellum or Cingulum:

In a mature worm, there is a prominent circular band of glandular tissue known as the clitellum which completely surrounds the segments from 14th to 16th forming a girdle around these segments. The glandular cells of clitellum secrete mucus, albumen, and material for forming cocoons which assist in fertilisation as the eggs are laid in them.

Due to the presence of clitellum the body of earthworm is divided into following regions:

(i) Preclitellar Region:

This is the anterior part of the body from segment

1st to 13th. The first segment is characteristically called peristomium (peri = around + stoma = mouth) which surrounds the mouth. At the anterior end of peristomium there is a small fleshy lobe called prostomium (pro = before + stoma = mouth).

The prostomium is not a segment and remains separated from the peristomium by a groove. In fact, the prostomium is an extension of the peristomium at its dorsal side and ventral to it is a mouth.

(ii) Clitellar Region:

This region is formed by segments 14th, 15th and 16th as described earlier.

(iii) Post-clitellar Region:

This region is represented by all the segments of the body after clitellum, i.e., it starts from 17th segment up to the last segment of the body.

External Apertures of Pheretima:

1. Mouth:

It is a crescentic aperture situated just below the prostomium on the ventral side surrounded by first

segment of the body—the peristomium or buccal segment.

2. Anus:

It is the exit of the alimentary canal by which undigested wastes are removed. It is situated at the terminal end of the last body segment referred to as the anal segment.

3. Genital Openings:

Earthworm is hermaphrodite, so male and female generative apertures are found in the same individual.

(i) Male genital apertures:

A pair of male genital apertures are situated latero-ventrally in the 18th segment. These are crescentic openings through which the male reproductive bodies are discharged.

(ii) Female genital aperture:

It is a median aperture situated at the ventral side in the 14th segment through which the female reproductive bodies are discharged.

4. Spermathecal Pores:

There are four pairs of small ventrolateral spermathecal apertures lying inter-segmentally between the grooves of the segments 5/6, 6/7, 7/8 and 8/9.

5. Nephridiopores:

A large number of very minute nephridiopores are found situated throughout the body of earthworm except few anterior segments. These pores are the apertures of integumentary nephridia, through which metabolic wastes of the body are removed. These pores are found scattered all over the surface of the body.

6. Dorsal Pores:

These pores are situated along the mid-dorsal line in the inter-segmental grooves as minute openings and lead directly into the body cavity. The first dorsal pore lies in the furrow between segments 12th and 13th, while there is a pore in each of the succeeding inter-segmental furrows of the worm, except the last. Through these pores coelom communicates with the exterior.

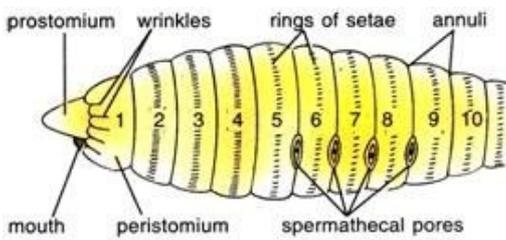


Fig. 66.3. *Pheretima*. Anterior region in lateral view

Genital or Copulatory Papillae:

In the same line, with the male pores, on the ventral side of each of the 17th and 19th segments there is a pair of circular and raised papillae; these are the genital or copulatory papillae. Each genital papilla bears a cup-like depression at the top but not any aperture. During copulation, the genital papillae function as suckers.

Body Wall of Pheretima:

The body wall of earthworm is very thin, soft, shiny and elastic which consists of the following layers:

1. Cuticle:

It is a thin, elastic, non-cellular and iridescent layer covering the body externally.

It is made of two layers of collagenous proteins forming fibres and a polysaccharide with a small amount of gelatin. It is secreted by the columnar

epithelial or supporting cells of the epidermis and remains perforated by many minute pores through which integumentary nephridia and epidermal glands open out. This layer is protective in function.

2. Epidermis:

The cuticle is followed by a single layer of tall columnar cells forming the epidermis.

The epidermis consists of the following four types of cells:

(i) Supporting cells:

These are long columnar cells constituting a major part of the epidermis and they have an oval nucleus nearly in their middle.

(ii) Gland cells:

These cells are situated between the supporting cells and are of two types

(a) Mucous gland cells:

The cells are club-shaped and are in large numbers. They secrete mucus which keeps the body moist. Thus, it prevents the animal from desiccation and helps in locomotion by lubricating the body. The

mucus secreted by these cells cements the wall of the burrows to keep them lubricated and smooth. The mucous gland cells are also known as goblet cells and they open at the surface of the cuticle by minute pores.

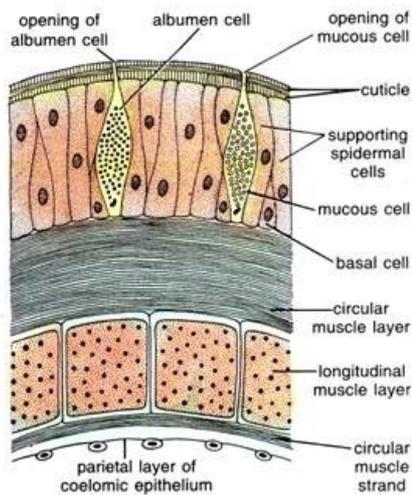


Fig. 66.4. *Pheretima*. T.S. of a portion of body wall.

(b) Albumen gland cells:

These cells are cylindrical, fewer in number and have uniformly distributed fine granules. These cells secrete albumen.

(iii) Basal cells:

These cells are small and undifferentiated which fill up the spaces between the inner ends of the other epidermal cells. The cells later differentiate to form the

supporting and gland cells, hence, they may be called replacing cells.

(iv) Sensory cell:

These cells are cylindrical and lie in groups having sensory hair-like protoplasmic processes at their outer free ends. These cells are also known as epidermal receptor cells.

3. Muscles:

The muscles of the body wall are present just below the epidermis which are of two distinct layers—the outer circular muscle layer and inner longitudinal muscle layer.

The circular muscle layer is thin and in the form of a continuous layer around the body. This muscle layer contains many granules of pigment—porphyrin. The longitudinal muscle layer is much thicker, nearly two times than the circular muscle fibres and lies in separate longitudinal bundles.

These bundles are separated together by thin connective tissue septa. The contraction of circular muscles makes the body long and narrow, while that of the longitudinal muscles makes the body short and broad. The longitudinal muscle layer is further followed by a very thin strip of circular muscle fibres.

The musculature of the body wall consists of smooth muscle fibres.

4. Coelomic epithelium:

The musculature of the body wall is lined internally by a thin layer of coelomic epithelium. It is a membranous layer consisting of thin flattened squamous cells of mesodermal origin. Since, this layer forms the outer boundary of coelom, hence, it is called parietal peritoneum or parietal layer of coelomic epithelium.

Functions of the body wall:

The body wall of earthworm performs the following functions:

- 1. It forms an outer covering of the body to protect the internal more delicate organs from injury.**
- 2. It provides definite shape to the body.**
- 3. The mucus secreted by the mucous gland cells of epidermis keeps its body smooth and moist to assist in locomotion and respiration.**
- 4. The mucus also keeps the burrow smooth and moist which assists in checking desiccation and cementing the wall of the burrow.**

5. The sensory cells of the epidermis are the only receptors to receive stimuli.
6. The setae which are locomotory structures are found lodged in it.
7. The contraction and relaxation of the muscles of the body wall, assisted by setae, bring about locomotion in this animal.
8. The thin, soft and moist body wall helps in gaseous exchange which facilitates respiration.
9. The coelomic epithelium or peritoneal layer secretes the coelomic fluid.
10. The cuticle checks excess evaporation.

Setae, setal sac and associated structures:

As referred earlier, the setae are found in every segment of the body except the first, last and clitellar segments. In *Pheretima* nearly 80-120 setae are found embedded in the middle of each segment arranged in a ring. Such an arrangement of setae is called perichaetine. In *Lumbricus*, the setae occur in two pairs on either side of a segment. This is called lumbricine arrangement. Each seta is found lodged in a setal sac.

The seta is secreted by a single large epidermal cell

situated at the bottom of the setal sac. The setae are composed of chitin and scleroprotein. The setae are pale-yellow, curved S-shaped pointed rod like structures with swollen middle part called nodulus. Two sets of muscles are found attached at the base of each setal sac the protractor and retractor muscles.

The protractor muscle radiates outwards from the base of the setal sac to join the circular muscles, while the retractor muscle runs inwards and joins the inner thin strip of circular muscle band situated just above the parietal peritoneum. These muscles serve to protrude and withdraw the setae respectively. The setae fall out of the body wall when worn out and are replaced by new ones repeatedly.

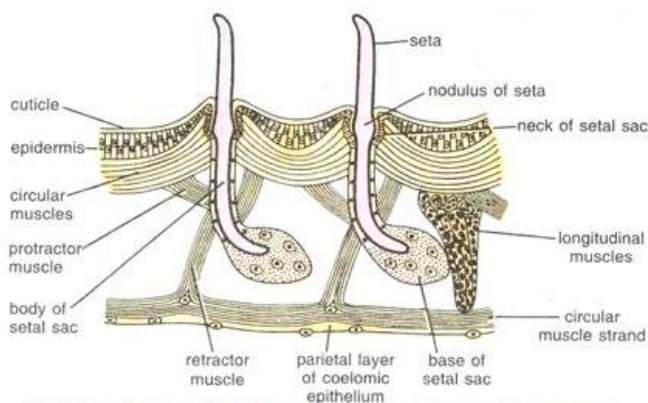


Fig. 66.5. *Pheretima*. T.S. of a part of body wall through a setal ring.

Coelom of Pheretima:

It is a large spacious cavity between the body wall

and alimentary canal and encloses all the internal or visceral organs of the body, hence, it is also called perivisceral cavity. This cavity is lined by parietal epithelium on the outer side and visceral epithelium on the inner side.

Actually, this cavity of earthworm is a true coelom derived by the splitting of embryonic mesoderm, such a coelom is called schizocoel. The outer lining of coelom, lying below the body wall, is called parietal layer or somatic layer and that around the alimentary canal is called visceral or splanchnic layer. Many cells of the splanchnic layer containing yellow granules, are called chloragogen cells.

The spacious coelom of earthworm is divided into small compartments due to the development of inter-segmental septa which grow from the inter-segmental grooves of the body wall to the alimentary canal. Each septum is a sheet in interlacing muscle fibres and surrounded from both the sides by peritoneum.

However, the first four segments are without inter-segmental septa, hence, they have a continuous coelom. The first inter-segmental septum is located between 4th and 5th segments, it is thin and membranous. The next five septa are thick, muscular and obliquely placed between segments 5/6, 6/7, 7/8, 8/9 and 10/11.

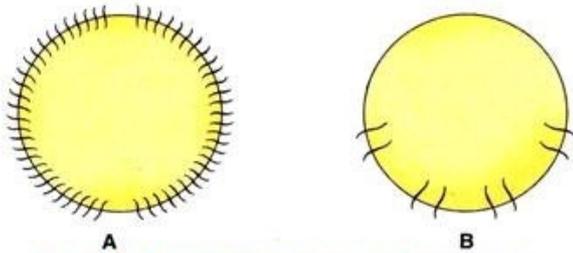


Fig. 66.6. Arrangement of setae. A—Perichaetine;
B—Lumbricine.

These are cone-shaped. Contraction of these cone-like septa increases the pressure on the coelomic fluid by which the anterior segments become turgid and are used for digging the burrow.

Inter-segmental septum between 9/10 is absent. The remaining septa from 11/12 to the posterior end are thin, membranous and transverse; the first three of them (11/12, 12/13 and 13/14) are complete with no apertures, thus, isolating their coelomic chambers.

The remaining septa from 14/15 to the posterior end are perforated by many minute apertures, these apertures are surrounded by sphincters of un-striped muscles. Such septa are characteristic of *Pheretima*. With these perforations, the coelomic chambers of these segments remain in communication. The coelom is filled with a coelomic fluid.

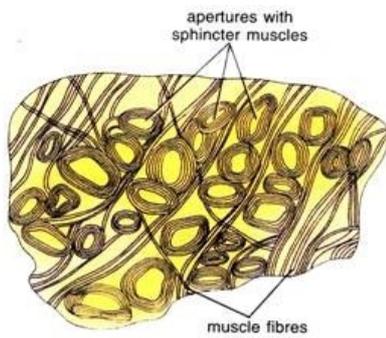


Fig. 66.7. *Pheretima*. A part of intersegmental septum.

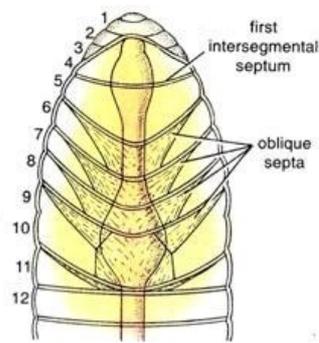


Fig. 66.8. *Pheretima*. Arrangement of septa in the anterior segments.

The coelomic fluid of earthworm is milky white and alkaline. It consists of colourless watery matrix the plasma and a large number of coelomic corpuscles.

The corpuscles are differentiated into four types:

(i) Granulocytes:

These are numerous, large-sized and spherical with a concavity having small nucleus. They have many granules of fat droplets. These corpuscles form pseudopodia-like folds to act as phagocytes. These are probably nutritive and help in removing the harmful bacteria, foreign particles and other microorganisms that happen to be in the coelomic fluid by phagocytosis. These are also called eleocytes.

(ii) Amoebocytes:

These are also numerous but much smaller having many pseudopodia-like processes. They look like

stars and nucleated. These are phagocytic, they take up excretory and foreign matter and act as defence against parasites.

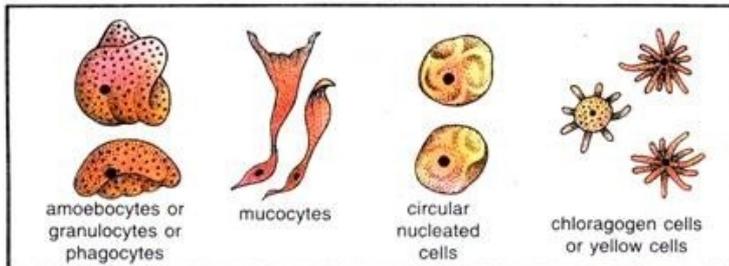


Fig. 66.9. *Pheretima*. Coelomic corpuscles.

(iii) Mucocytes:

These cells are elongated, vase-shaped with an expanded end like a fan and the other end being narrow. The narrow end bears nucleus. Their function is not definitely known.

(iv) Leucocytes:

These are small, flattened disc-shaped and nucleated cells. They are fewer in number, nearly 10 per cent of the corpuscles. They have clear cytoplasm and their functions are still uncertain.

The coelomic fluid flows from anterior to posterior on the ventral side and from posterior to anterior on the

dorsal side.

Functions of Coelomic Fluid:

The coelomic fluid performs following functions:

- 1. It oozes out through the dorsal pores and keeps the body moist which facilitates respiration.**
- 2. It kills the bacteria of the soil which come on the body surface of the worm.**
- 3. It helps in removing the excretory wastes from the body.**
- 4. It helps in the transportation of materials from one part of the body to the other.**
- 5. It helps in destroying harmful bacteria, micro-organisms and foreign materials.**
- 6. It also helps in fixing the setae into the ground during locomotion. This is achieved by making certain segments turgid and stiff by restricting coelomic fluid in them by closing sphincter apertures of the septa between them.**
- 7. The luminosity produced by some earthworms is due to the coelomic fluid.**

Lymph Glands of Pheretima:

These are small paired glandular structures present in the coelom on the sides of the dorsal vessel from 26th segment up to the last. They also contain phagocytes which ingest foreign materials and digest them.

Locomotion of Pheretima:

No specialised locomotory organs are found in earthworms, even then these are very active and they crawl rapidly when out of burrows. The process of locomotion is, in fact, a cumulative effect of contraction and relaxation of both the muscle layers of body wall aided by setae and the hydrostatic pressure created by the coelomic fluid.

The forward locomotion is brought about by an increase in the hydrostatic pressure of the anterior segments of the body (usually first nine segments) and at the same time contraction of circular muscle layer begins at the anterior end and passes backwards. This results the anterior region to extend forward and at the same time making it thinner in diameter.

The extending and thinning passes backwards as a wave of contraction at the rate of 2 to 3 cm per second; by this means the body of the worm is pushed forward. The anterior end now grips the substratum and the setae act as hooks by their posteriorly directed

points.

After the wave of contraction of circular muscles has passed down the front half of the worm, the circular muscles relax and the longitudinal muscles of the body wall of the anterior segments contract in a wave beginning from the anterior end, this shortens and thickens the anterior end, causing the posterior body of the worm to be dragged forward.

At this stage the segments in a state of longitudinal contraction do not move but remain anchored to the ground by the extended setae. The contraction of longitudinal muscles passes backwards like a wave. Again a wave of contraction of circular muscle starts from the anterior end making it thinner and extended forward.

This wave starts before the first one has reached to the posterior end. Thus, locomotion is brought about by alternate contractions of circular and longitudinal muscles causing wave of thinning and thickening to pass backward. This involves partly a pushing of the anterior end and partly a pulling of the posterior end, the setae playing only an accessory role.

The worm moves at the rate of 25 cm per minute. The nervous system coordinates the activities of circular and longitudinal muscles so the contraction of any layer brings about relaxation of the other muscle layer.

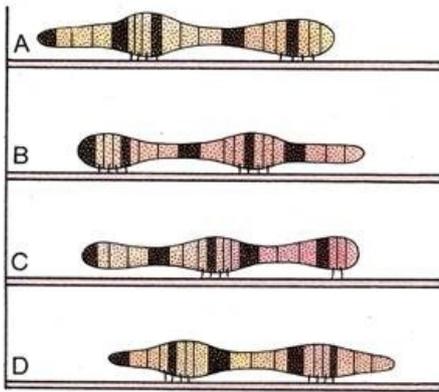


Fig. 66.10. Diagram to illustrate locomotion in an earthworm.

The earthworms can move backward also, as they usually do during their withdrawal from the burrow and also during excavating it.

The backward movement is brought about by reversing the direction of setae. The coelomic fluid serves as a hydraulic skeleton because a decrease in its pressure results in the relaxation of muscles. The earthworms can move on a smooth and hard surface like glass by using mucus for adhesion as the setae cannot anchor the substratum.

Respiratory System of Pheretima:

Although earthworm is a terrestrial animal but its mode of respiration is more like that of simple aquatic animals. The earthworm is devoid of special

respiratory organ.

The exchange of gases takes place through the body wall which is thin, semitransparent and richly supplied with blood capillaries. The tegumental glands and coelomic fluid make the surface of the skin moist with their secretions to assist in gaseous exchange. It has been observed that if its skin dries the worm dies of suffocation, i.e., asphyxia.

As mentioned earlier the blood of earthworm contains a respiratory pigment—haemoglobin in a dissolved state in its plasma. The epidermis of the body wall acts as a permeable membrane through which the atmospheric oxygen diffuses in its capillaries and combines with haemoglobin to form oxyhaemoglobin.

The oxyhaemoglobin is circulated by the blood into the tissues where oxygen tension is very less and CO₂ tension is high. The oxyhaemoglobin breaks up to release oxygen to the tissues and haemoglobin in a reduced state. This oxygen is utilised in the tissues for the oxidation of foodstuffs to release energy needed for performing the vital activities of life and carbon dioxide.

At the same time, CO₂ from the tissues diffuses into the blood due to its high tension.

The CO₂ is carried by the blood generally in a dissolved

condition and when it reaches to the epidermal capillaries the CO₂ from the blood diffuses out in the atmosphere due to low CO₂ tension at this level and again oxygen diffuses in the blood due to its high tension and combines with haemoglobin to form oxyhaemoglobin once again. Thus, respiration is affected in earthworm.

Nervous System of Pheretima:

The nervous system of Pheretima is well developed, concentrated and consists of the central, peripheral and sympathetic or autonomic divisions.

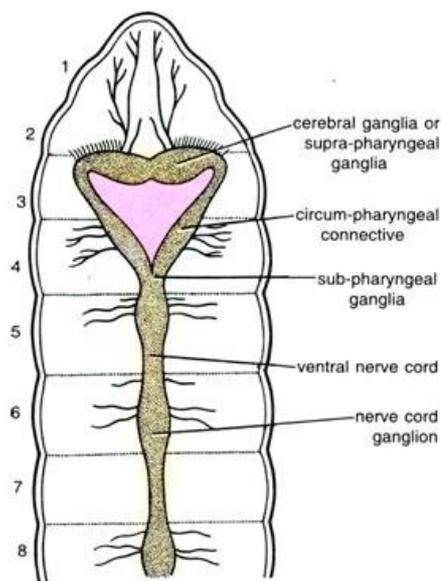


Fig. 66.25. *Pheretima*. Nervous system in dorsal view.

1. Central Nervous System:

It consists of the nerve ring or brain ring and the ventral nerve cord.

Nerve Ring:

A pair of cerebral or supra-pharyngeal ganglia is found fused together to form the so-called brain which lies dorsally in the 3rd segment in the groove between the buccal chamber and the pharynx.

From the brain a pair of circumpharyngeal connectives arise, one on each side, they encircle the pharynx and meet ventrally in the 4th segment by a pair of fused sub-pharyngeal ganglia. Thus, a nerve collar is formed around the pharynx which is called the nerve ring or brain ring.

Nerve Cord:

A nerve cord originates from the sub-pharyngeal ganglia and runs on the mid-ventral side beneath the ventral vessel but above sub-neural vessel extending up to the posterior end of the body. The nerve cord is double and is made of two longitudinal cords fused together.

In each segment from 5th to the last the nerve cord has a pair of ganglia fused together as swellings representing the segmental ganglia. The nerve cells

are distributed all over the nerve cord and are not confined to ganglionic swellings.

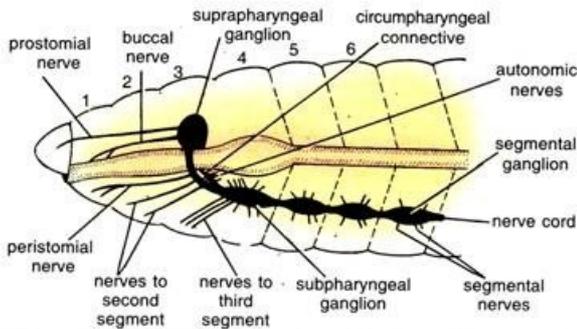


Fig. 66.26. *Pheretima*. Anterior end in lateral view to show the disposition of nerve ring and nerve cord.

Structurally, the double nerve cords of *Pheretima* are solid and enclosed in a common sheath called perineurium consisting of three layers— the outer peritoneum, middle longitudinal muscle layer and inner thick fibrous layer of epineurium. The nerve cords are solid consisting of the nerve cells and the fibres. Both the nerve cords are separated internally by a vertical epineurium.

The ventro-lateral regions of nerve cord contain bipolar and tripolar nerve cells all along the length, and the middle region has many nerve fibres with supporting neuroglia. Running longitudinally in the upper part of the nerve cord are four giant nerve fibres surrounded by epineurium, they are all tubular and filled with homogeneous plasma-like matter.

These are responsible for rapid conduction of impulses throughout the nerve cord. However, in the region of segmental ganglia the partition between the two nerve cords is absent.

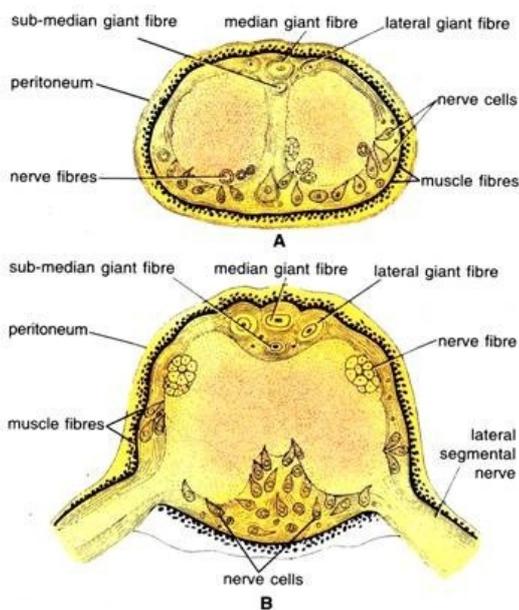


Fig. 66.27. *Pheretima*. A—Section of ventral nerve cord ;
B—Section of ventral nerve cord at the region of the origin of segmental nerves.

2. Peripheral Nervous System:

From the brain 8 to 10 pairs of nerves arise which supply to the prostomium, buccal cavity and pharynx. Two pairs of nerves arise from the circumpharyngeal connectives which supply to the first segment and buccal cavity. From the sub pharyngeal ganglia three pairs of nerves arise to supply 2nd, 3rd and 4th segments.

The nerve cord and ganglia of each segment give out three pairs of nerves which supply the various parts of the segment in which the ganglia are situated. Thus, the nerves originating from the central nervous system to supply the different parts of the body constitute the peripheral nervous system.

3. Sympathetic Nervous System:

It includes the nerve plexuses situated in the wall of the alimentary canal and some other internal organs. Such plexuses are connected with the peripharyngeal connectives by fine nervules and help in coordinating the functions of the related organs.

Working of the Nervous System:

The nervous system of Pheretima, like those of higher animals, has both sensory and motor neurons. The nerves of the nerve cord, therefore, have both sensory and motor fibres, i.e., mixed. The stimuli from the skin are transmitted by sensory fibres to the nerve cord and the stimulus is

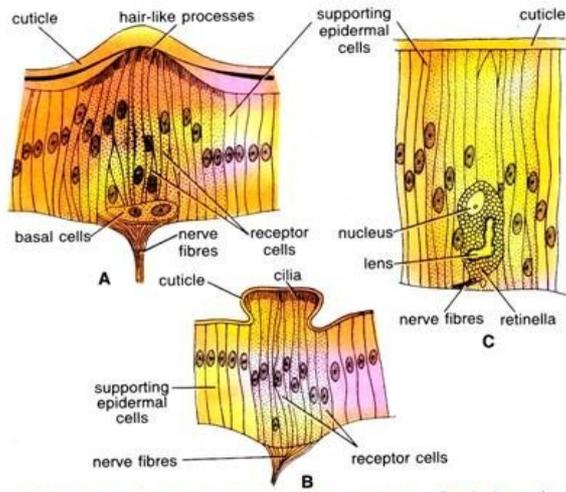


Fig. 66.28. *Pheretima*. Sense organs. A—An epidermal receptor; B—A buccal receptor; C—A photoreceptor.

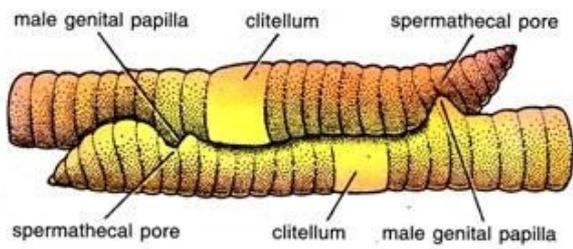


Fig. 66.36. *Pheretima*. Two earthworms in copulation.

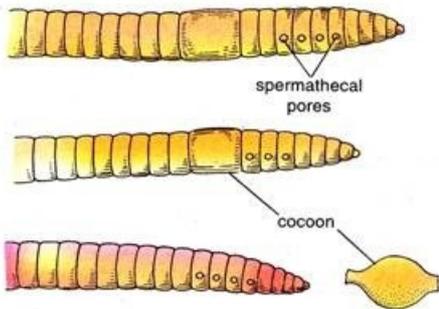


Fig. 66.37. Formation and release of a cocoon in earthworm.

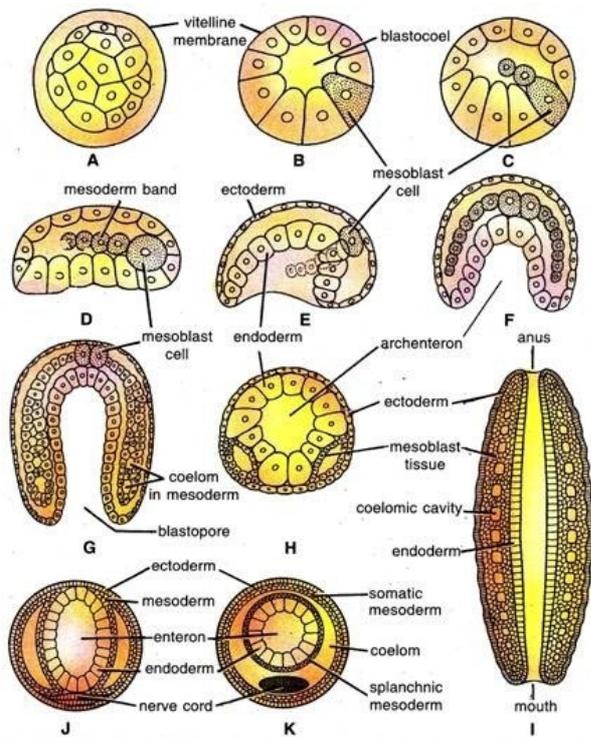


Fig. 66.38 Development of an earthworm. A—Blastula; B—T.S. blastula with mesoblast cell; C—T.S. blastula with growth of mesoblast; D—L.S. of early gastrula; E—Lateral view of gastrula showing invagination; F—T.S. gastrula; G—L.S. early embryo; H—T.S. early embryo; I—L.S. late embryo after the formation of mouth and anus; J—T.S. late embryo and K—Later embryo in T.S.

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PART 2

Trochophore Larva: Historical Retrospect, Structure and Affinities

Historical Retrospect of Trochophore Larva:

- 1. Loven (1840), a Swedish naturalist, was the first man who discovered trochophore larva. Since then the larva was known as Loven's larva.**
- 2. Semper (1859) used the name Trochosphaera, a rotifer for the organism.**
- 3. Ray Lankester (1877) gave the name 'Trochophore' to this larval form.**
- 4. Afterwards it was Hatschek (1879) who also supported the most accepted name 'Trochophore'.**
- 5. Hyman (1957) and Barnes (1980) tried to establish relationship of trochophore with other groups of animals.**

Structures of the Trochophore Larva (Loven's Larva of Polygordius):

All the archiannelids (*Polygordius* and other species) are known to pass through the larval stage—the trochophore (Fig. 17.12A-C).

1. Marine planktonic and most are lecithotrophic larvae.

2. The anterior end of the body is broader than the posterior end and it exhibits bilateral symmetry.

3. It has mouth, alimentary canal and anus.

4. The mouth is situated near the mid-ventral line of the body and leads into the sac-like stomach and proceeds as a narrow alimentary canal. Both the walls of the alimentary canal extending from mouth to anus are lined by cilia.

5. The canal ends in an anal aperture at the posterior tip of the body.

6. Two prominent bands of cilia encircle the body and in certain forms a third band may be present. These ciliary bands are used in locomotion and feeding.

7. A circlet of strong locomotor ciliary band, called the pre-oral circlet or Prototroch (Fig. 17.12A), encircle the body around the middle and lies above the mouth, and the metatroch which is a ciliary transverse ring behind the mouth.

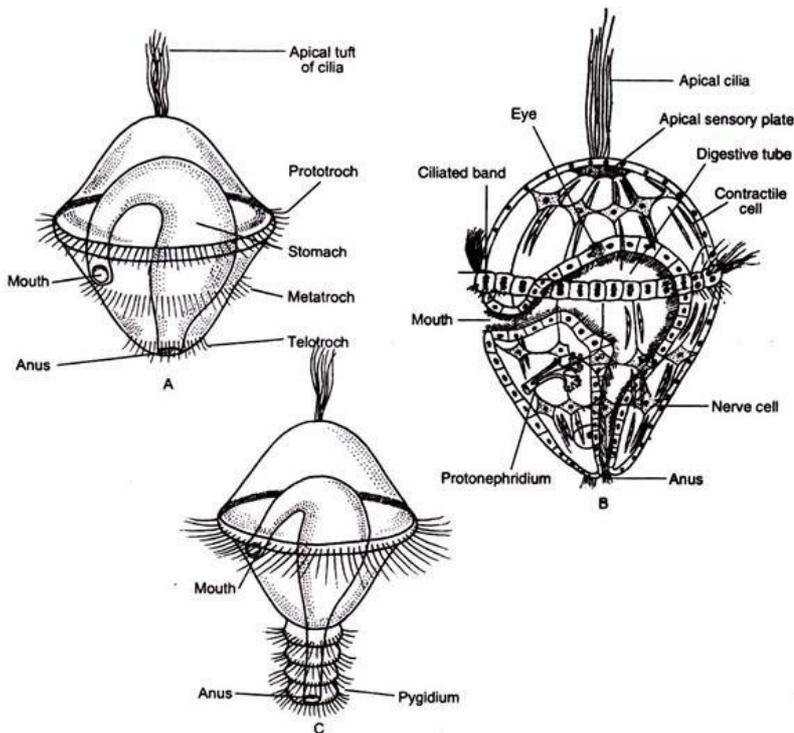


Fig. 17.12: A. External features of a trochophore larva. B. Internal organization of a trochophore larva. C. An advanced trochophore larva showing the additional ciliated segments at the posterior end.

8. The prototroch arises from special cells, called trochoblasts.

9. There is often a second circlet of cilia around the pygidium or anus, called the telotroch.

10. A longitudinal band along the mid-ventral part of the body is also present in some cases and is called a neurotroch.

11. Trochophore exhibits no metamerism and the rudiment of future adult trunk is seen as a small region

at the posterior pole.

12. There is no coelom at this stage but only a spacious blastocoel encloses the gut.

13. Within blastocoel, a pair of protonephridia, certain amount of mesenchyme and larval muscles is present.

14. The nephridia are made of two hollow cells; each contains a flame of cilia. One nephridium lies on each side of the gut.

15. The upper pole possesses an ectodermal, thickened area, called apical sensory plate which contains cells that are the primordia of the cerebral ganglia.

16. At the apical end, a number of long cilia emerge from the apical plate, called apical tuft of cilia.

17. Many trochophores bear sense organs, such as ocelli (eye spots) below the apical plate region.

18. The fully developed trochophore larva may be divided into three regions, such as the pretrochal region which includes the area above the prototroch. The posterior region of the larva is called pygidium which includes telotroch and anal area. The middle region is called growth zone which includes the area between the mouth and telotroch.

Biology and Metamorphosis of Trochophore Larva:

The free-swimming trochophore larva of some forms (e.g., Echiurans, some polychaetes, Polygordius, phyllodocids, serpulid fan worms) feeds on the plankton and other microscopic marine organisms and the trochophore is called planktotrophic larva and has long free-swimming life.

In some other groups (e.g., Sipunculans, nereids and eunicids of polychaetes), the trochophore larvae are lecithotrophic larvae. They do not take any food from external sources and mainly feed upon the yolk originally laid down in the egg. The lecithotrophic larvae lead a short planktonic life. Metamorphosis of the larvae is best seen in Polygordius.

The first sign of metamorphosis is marked by the segmentation of mesodermal bands. Later the posterior region elongates rapidly and is externally marked with segmentation. The area above the prototrochal ring becomes prostomium and the prototrochal area differentiates as peristomium.

The apical sense organ area becomes the cerebral ganglion which is joined with the ventral nerve cord. Internally the mesodermal band splits to produce coelomic sacs.

The mouth shifts forward and the anal organization changes gradually. The ciliary bands disappear and the larva grows in size and length with addition of the new segments. After metamorphosis the young worm sinks to the bottom of the sea and becomes the burrowing adult worm.

Structures of the Trochophore Larva in Different Classes:

Class Polychaeta:

1. The larva of *Neanthes* (= *Nereis*) is similar to the typical trochophore but with a pair of eye spots.
2. Larvae with no blastocoel but the ectoderm and endoderm are in contact except where they are separated by the larval mesoderm, e.g., larva of *Psugmobranchus*.
3. Cilia are either rarely distributed over the whole surface of the body or are not confined to special circlets, called atrochal larva, e.g., larva of *Lumbriconereis*.
4. In the larva of *Nephtys*, two circlets of cilia are seen, one at each end of the body, the pre-oral (anterior) and perianal (posterior), called telotroch larva.
5. The complete rings when may be present on both

dorsal and ventral surfaces, called amphitrochal larva.

6. In the larva of Chaetopterus where one or more rows of cilia surrounds the middle of the body, called mesotrochal larva. In mesotrochs the pre-oral and peri-anal rings are absent.

7. In the larva of Ophryotrocha, there are many ciliary circlets and each develops on a true mesodermal segment hence called polytrochal larva.

8. In the larva of Mitraria, long provisional setae are found which are replaced by permanent structures. The older larva of Nereis possesses parapodial-like lateral flattened structures with setae.

Class Oligochaeta:

No free larval stage is noticed.

Class Hirudinea:

There is no larval stage and the development is direct.

Affinities of Trochophore Larva:

This larval form exhibits remarkable similarities with several other larval forms. As a consequence the phylogenetic status of Trochophore warrants serious consideration.

Affinities of Ctenophora:

The aboral sense organ (Statocyst) of a ctenophore is compared with the apical sensory plate of trophophore. The sub-ectodermal radiating nerves are comparable. The prototroch is derived from fourth group of ciliated cells. Both of them have pear-shaped body.

Despite the similarities the fundamental organisation portrays many diversities. The cleavage pattern is different in both the cases. The anus is absent in ctenophores. So the trophophore larva cannot be regarded as related to ctenophores.

Affinities with Muller's larva:

The Muller's larva of Turbellarians especially that of Planocera, shows similarities with the trochophore larva. Similarity in developmental stage, similarity in the disposition of ciliated bands and presence of eye spots at the aboral end of the two larval forms led many workers on this line to draw parallelism between the two groups. But due to undernoted dissimilarities the parallelism cannot be justified.

The dissimilarities are:

(i) Absence of anus in Muller's larva,

(ii) The enteron opening into one opening in Muller's larva,

(iii) Difference in the embryonic differentiation of mesoderm and

(iv) The existence of tuft of cilia at the caudal end of Muller's larva.

Affinities with Pilidium (Nemertini) larva:

The pilidium larva of Nemertini exhibits certain similarities with the trochophore larva.

The similarities are:

(i) Both have helmet-shaped body,

(ii) The ciliated ring between aboral and oral ends of pilidium larva represents the prototroch of trochophore,

(iii) Similarities in the disposition and distribution of nerve ring,

(iv) The stomodaeum shows similarities,

(v) The schizocoelic mode of formation of coelom in both.

But the absence of anus in pilidium and the dissimilarities in the formation of mesoderm stand on the way to draw any relationship between them.

Affinities with Rotifera:

Trochosphaera, a rotifer, shows some similarities with the trochophore larva of annelid. Trochosphaera resembles trochophore in many respects, viz., ciliated girdles, disposition of nervous system ('Brain') and the sense organ, placement of anus, nephridia and curvature of intestine. But the resemblances are mostly superficial in nature and need critical examination to draw any phylogenetic relationship.

Affinities with Veliger larva:

The pre-oral ciliated ring, ciliated tuft of flagella and apical plate of the veliger larva of mollusca are similar with that of trochophore larva. The similarities between the trochophore and veliger larva are possibly due to remote phylogenetic convergence.

Phylogenetic Significance of Trochophore Larva:

In the evolutionary dynamics of invertebrates the trochophore larva occupies a prominent status. It shows similarities with many invertebrate groups. The affinities throw light on the emergence of bilateral groups from the animals having radial symmetry (Fig.

17.13).

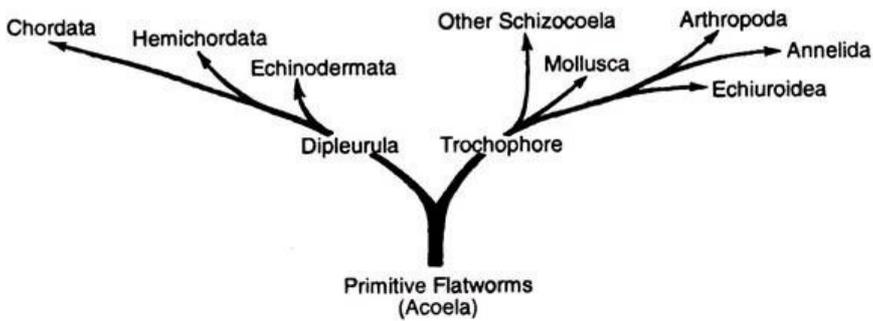
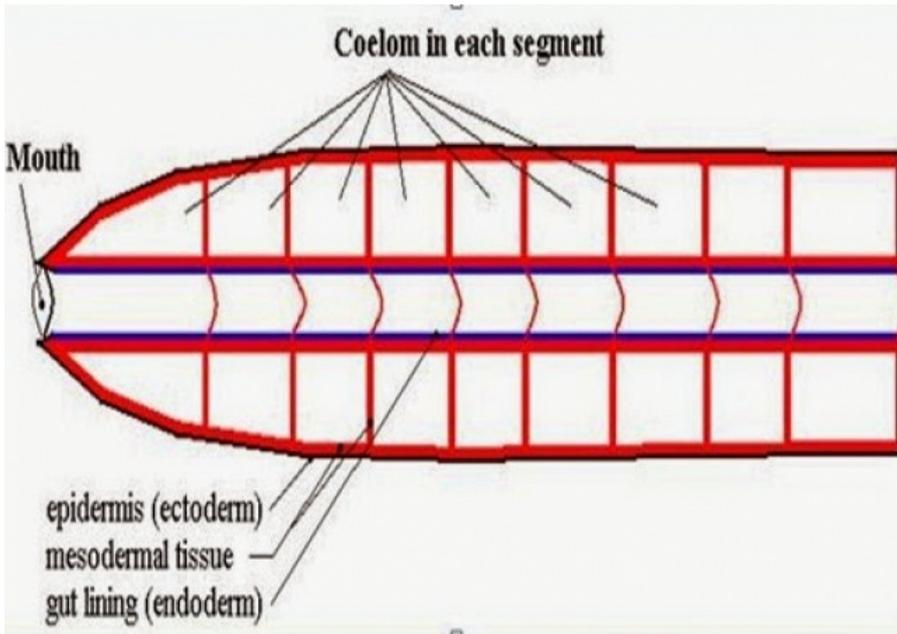


Fig. 17.13: Phylogenetic relationship of Trochophore larva.

It is claimed that the trochophore represents a transitional stage in the line of emergence of the bilateral groups (e.g., Rotifers) from the radial groups (Ctenophores). Similarities between the trochophore and the echinoderm larva (Bipinnaria and Pluteus) and Tornaria larva of Balanoglossus added more weight to this contention.

Many workers are of the opinion that the Trochophore larva serves as a bridge between radial and bilateral symmetry. They have opined that the bilateral symmetry has evolved from the radial one.

● METAMERISM IN ANNELIDS



The body of Annelids is divided into a number of segments longitudinally. All the segments look alike. They are called metameres and this is called metamerism. In these segments all systems are repeatedly arranged. Usually the metamerism is confined to the trunk region of the organisms. Cephalic and anal regions may not show metameric nature in the cephalic region sense organs are concentrated, where in the anal region new segments are produced in front of anal segment.

Metamerism first observed in Annelida in the animal

kingdom.

The most successful animals of animal kingdom like arthropoda and chordate will also show metameric segmentation.

In annelids the metameric segmentation is both external and internal. The body is divided into a number of segments which contain all body organs repeatedly but the alimentary canal is long and straight tube extending through all the segments.

In arthropods the segmentation is external.

In chordates the segmentation is internal.

Homonomous & Heteronomous metamerism:

In annelida the body is divided into a number of segments. All are usually similar. If all the metameres are similar throughout the body it is called Homonomous metamerism. But in some groups like arthropoda and chordata the anterior segments will show clear cephalisation. They are modified into head bearing specific sense organs. Such metamerism is called "Heteronomous metamerism.

(Even in annelids some anterior segments look different. Hence typical homonomous segmentation is not seen in any animal.)

In embryonic stages the metamerism is complete and uniform. But in adult condition it will change due to cephalisation.

Origin of metameric segmentation:

The origin of metamerism is not clearly known. Many theories were proposed to explain the development of metamerism.

1. Fission theory:

Metamerism is derived from non-segmented ancestor, which might have under gone transverse fissions repeatedly and gave metamerism.

This theory was improved by Perrier.

This theory infers annelids might have developed from Platyhelminthes.

Objections:

Because of fission the organism will divide into separate individuals but they will not unite to form a metameric individual.

Reproduction by fission is confined to sessile animals but not in free moving organisms.

2. Pseudometamerism theory:

This theory was supported by Hyman & Goodrich. According to this theory the body parts like coelom, blood vessels, nephridia muscles etc. will be repeatedly formed. In between them septa are formed. Thus metamerism is derived. This can be seen in some larval forms and adults of some annelids.

3. Embryological theory:

In the embryonic stage by some stress in the mesoderm fragmentation is developed which gave metameric segmentation.

4. Locomotory theory:

This theory is a combination of pseudometamerism theory and embryological theory. It is believed that metamerism is derived as an adaptation to locomotion:

In annelids the segmentation is developed as an adaptation for burrowing.

In chordates the metamerism is developed as an adaptation for swimming, undulatory movements.

Most probable annelid ancestors were long coelomate

organism. In these animals by the development of septa the liquid skeletons and muscles function will be localised and is advantageous for burrowing. Afterwards the nervous system, excretory system etc. are also undergone segmental-organization.

In chordates the metameric segmentation of body wall and musculature allow alternate waves of contraction which will help in swimming. Thus locomotion might have caused metameric segmentation in these animals.

Significance of Metamerism:

Metameric segmentation helps the animals in their locomotion.

The segments will show high structural development which gave scope for evolution.

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Phylum Arthropoda

On a pleasant evening, you decide to go to a park. However, you end up having painful itchy eruptions on the skin. Clearly, you were bitten by an insect. After all, insects are everywhere. They belong to a group of animals called the Phylum Arthropoda, which form the largest percentage of the world's organisms. They make up about 80 percent of the known species of animals! It is quite hard to escape them.

Phylum Arthropoda

Arthropods are joint-legged animals and you must have come across a few of these animals. Some prominent ones include insects, spiders, ants, bees, crabs, shrimps, millipedes, centipedes etc. Scientifically speaking, they all come under the Animal Kingdom under phylum Arthropoda.

The success of the arthropods can mainly be attributed to the presence of exoskeleton, which makes them versatile, is protective in nature and also allows flexibility and mobility. You can see arthropods living on land and in water. They are also a source of

food for many animals and human beings too!



Characteristic features of Phylum Arthropoda

The body structure shows bilateral symmetry.

They are triploblastic.

They can be found in all types of habitats – land, water and soil.

They have jointed limbs.

The body is segmented into three regions – Head, Thorax and Abdomen.

The body cavity is filled with blood and is called the haemocoel. The blood is white in colour.

The exoskeleton is hardened and is made of chitin.

They have a well-developed central nervous system.

The head is well developed and bears the sensory organs and brain.

They have compound eyes and mosaic vision.

The digestive tract is complete with the mouth and anus at opposite ends of the body.

They have an open circulatory system with dorsal heart and arteries.

Respiration is through the general body surface or by gills in aquatic forms and through trachea or book lungs in terrestrial forms.

Sexes are separate and sexual dimorphism is exhibited.

Examples

Limulus polyphemus (King Crab)

Scorpions

Spiders

Ants

Prawns

Crabs

Cockroach

Butterfly

Mosquito

Solved Questions for You

Q: Write a few lines on the exoskeleton in Arthropods.

Ans: The exoskeleton in Arthropods is hardened and is made of chitin. It can be further stiffened in a few species by calcium carbonate. In arthropods, the exoskeleton is non-expandable and hence as the organism grows, it has to shed its exoskeleton

so that it can be replaced by a new exoskeleton.
This process is called moulting.

Q: Name a few arthropod insects that are carriers of diseases.

Ans.

Insects

Disease

Housefly Typhoid, cholera, Diarrhoea Sandfly Kala-azar
Mosquito Filariasis, Dengue Fever, Malaria Rat
Flea Bubonic plague Tsetse fly African Sleeping sickness

Q: Book lung is a characteristic of which Phylum?

Ans: Phylum Arthropoda

Q: What is the process of conversion of small cockroach into an adult cockroach?

Ans: Metamorphosis

Q: The coelomic cavity in Phylum Arthropoda is filled with?

Ans: Haemocoel

Q: Which is the largest Phylum and state a few distinguishing features?

Ans: The largest phylum is Phylum Arthropoda. The distinguishing features are:

Presence of jointed legs

Body is divided into head, thorax and abdomen

Body is bilaterally symmetrical and triploblastic.

ECONOMIC IMPORTANCE OF ARTHROPODS

Arthropods are invertebrates that constitute over 90% of the animal kingdom, and their bio-ecology is closely linked with global functioning and survival. Arthropods play an important role in maintaining the health of ecosystems, provide livelihoods and nutrition to human communities, and are important indicators of environmental change. Yet the population trends of several arthropods species show them to be in decline. Arthropods constitute a dominant group with

1.2 million species influencing earth's biodiversity. Among arthropods, insects are predominant, with ca. 1 million species and having evolved some 350 million years ago. Arthropods are closely associated with living and non-living entities alike, making the ecosystem services they provide crucially important. In order to be effective, plans for the conservation of arthropods and ecosystems should include a mixture of strategies like protecting key habitats and genomic studies to formulate relevant policies for in situ and ex situ conservation. This two-volume book focuses on capturing the essentials of arthropod inventories, biology, and conservation. Further, it seeks to identify the mechanisms by which arthropod populations can be sustained in terrestrial and aquatic ecosystems, and by means of which certain problematic species be managed without producing harmful environmental side-effects. This edited compilation includes chapters contributed by over 80 biologists on a wide range of topics embracing the diversity, distribution, utility and conservation of arthropods and select groups of insect taxa. More importantly, it describes in detail the mechanisms of sustaining arthropod ecosystems, services and populations. It addresses the contribution of modern biological tools such as molecular and genetic techniques regulating gene expression, as well as conventional, indigenous practices in arthropod conservation. The contributors reiterate the importance of documenting and understanding the biology of arthropods from a holistic perspective

before addressing conservation issues at large. This book offers a valuable resource for all zoologists, entomologists, ecologists, conservation biologists, policy makers, teachers and students interested in the conservation of biological resources.

There are 1,302,809 species of arthropods described that include 45,769 fossil species. Arthropods are the most successful group found in almost all biogeographical regions and ecological zones and have a dominating influence on other elements of biodiversity. The Insecta have 1,070,781 species and it alone accounts for over 80 % of all arthropods. Another major group is Arachnida having 114,275 described species of which 55,214 species are mites and ticks. Arthropods contribute to human food supply, pollinate crops, help maintain ecosystem sustainability by biologically suppressing destructive arthropods, but cause and transmit diseases to humans and livestock and incur crop losses. Invasive arthropods can negatively impact natural resources.

Soil Biodiversity and Arthropods: Role in Soil Fertility
Healthy productive soils are essential to meet the food requirement of humans and animals. Arthropods have important role in maintaining soil fertility. The major contribution of arthropods to soil is through decomposition and humification of all organic matter. In the soil, arthropods function as litter transformers,

ecosystem engineers, and pulverizers. As much as 20 % of total animal litter input is processed by the activity of collembolans alone. Arthropods also stimulate mineralization of nutrients in soil. Soil practices in cultivated ecosystems significantly alter arthropod community which in turn has significant effect on soil productivity. Arthropods facilitate soil processes. Hence, understanding soil arthropod communities will prove useful in developing management plans for both wild and cultivated ecosystems.

Butterfly Communities of Ritchie's Archipelago in Andaman and Nicobar Islands, India: Implications for Conservation of Arthropods and Their Habitat.

The extensive distribution of butterflies in the Andaman and Nicobar islands is an important factor in the ecology of this island ecosystem. Butterflies are recognized as bioindicators and Lepidoptera are known to be susceptible to environmental changes. This work has been carried out on the islands of Ritchie's Archipelago. The Ritchie's Archipelago, a cluster of smaller islands, is situated 25–30 km east of Greater Andaman. This archipelago comprises mainly four larger islands, few smaller islands and several islets, which extends roughly as north-south chain parallel to the main great Andaman island group. The butterfly communities of Ritchie's Archipelago were investigated during 2008 and 2011, the line transect method by employing to assess the population of butterflies. A total of 84 species belonging to five

families and 58 genera were recorded during the period of the study. Highest species was recorded in Nymphalidae family followed by families of Lycaenidae, Pieridae and Papilionidae. The Havelock and Neil islands recorded the highest shared species numbers (50 spp.). The diversity index (H') ranged from 2.76 to 3.96, with the highest index of diversity observed in Havelock Island (3.96). The Ritchie's Archipelago with high representation of butterflies indicated its importance for in situ conservation.

Studies were conducted on insect fauna in Karkheh Wildlife Refuge (KWLR), southwest Iran. Insects were sampled from May to October. Species of insects were classified into morph species and allotted to the species as far as possible. A total of 2207 insects were collected deploying a combination sampling methods, e.g. netting, beating, hand-picking and trapping. Insects sampled belonged to 100 species, 47 families and 13 orders of Insecta. Based on the information gathered, Coleoptera, with 32 species, had the highest diversity index of $H' = 0.318$ and were the most diverse and abundant among sampled insects. The staphylinid beetle *Achenium debile* (Erichson) was the major species, with relative abundance of 23.9 %. The bug *Pyrrhocoris apterus* Linnaeus was categorized as the second dominant species, with abundance of 8.4 %. The Shannon-Wiener and Simpson's indices were 3.286 and 0.91, respectively. Evenness of species was

0.7, using Pielou's index. Results of studies on insects from other parts of Iran and Kuwait are also discussed in this chapter.

The use of natural resources for therapeutic purposes is as old as the humankind and continues around the world to this day. Collection of plant and animal products still prevails in different indigenous communities over the world. Ethnobiological knowledge has been passed on from generation to generation. Food habits and diet composition are adaptations to particular environmental and social conditions. Preferences given to arthropods utilized as food by humans depend on the palatability, availability, and nutritional cum medicinal values as well as on local traditions and customs. A concise compilation of arthropod use among indigenous communities in the oriental region is documented. Knowledge-based management where the benefits of biodiversity and ecosystems are acknowledged will be needed to prevent environmental degradation and ensure survival of arthropods and human communities as well.

Entomophagy, the consumption of insects by humans, is practiced in many countries around the world but predominantly in Asia, Africa, and Latin America. The practice has many environmental, health, social, and livelihood benefits. Insects are good source of protein, fat, minerals, and vitamins. Worldwide, nearly 1700

insect species are edible; four insect orders in rank sequence which predominate human consumption, viz., Coleoptera, Hymenoptera, Orthoptera, and Lepidoptera, account for 80 % of the species eaten. In Africa, ants, termites, beetle grubs, caterpillars, and grasshoppers are eaten. Eri silkworm, wasps, bamboo caterpillars, crickets, and locusts predominate insect diet of Asians. Important Latin American insect food comprises leaf-cutter ants, palm weevil larvae, bee, and wasp brood. Practicing entomophagy does carry certain risks like allergic reactions to the people consuming them. It is an age-old practice that continues to this day in many parts of the world. Science increasingly provides data corroborating the nutritional and health benefits of entomophagy, according to a broader acceptance of this practice, while giving due consideration to certain risk factors. Rewards in terms of long-term food security, income potential, pesticide reduction, and insect conservation are conceivable, and thus entomophagy has the potential of becoming an important factor in sustainable development.

Adopting monocultures of traditional cotton enhances activity of pest insects and reduces the activity of predatory insects. Cultivating cotton with other crops such as sunflower (*Helianthus annuus*) and sorghum (*Sorghum bicolor*) served as refugia for predators of pests on cotton. Thus, increased habitat diversity by strip cropping in monocultures of cotton increases the population of predators. Transgenic cotton (Bt) largely

suppressed populations of lepidopteran pests. Insecticidal sprays reduced populations of predators both on non-Bt and Bt cotton. Bt cotton alters the arthropod community by reducing the abundance of *Helicoverpa* populations. Bt cotton may also have indirect effects on the abundance of parasitoids and predators that specialize on lepidopteran pests. A 6-year research revealed that the impact of Bt cotton on minor pests and non-intended species was of less importance, particularly when compared to insecticides. Cotton ecosystem is uniquely characterized by secondary pest outbreaks, genetically engineered plants, changing arthropod communities and extrafloral (EF) nectaries. Each characteristic influences arthropod communities and crop productivity in turn in different ways. Although reduction in insecticidal use in some regions may alleviate the pest problems, much of the problems can be tackled by adopting integrated pest management (IPM) practices.

TYPE STUDY COCKROACH

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Structural Organisation in Animals

Cockroach

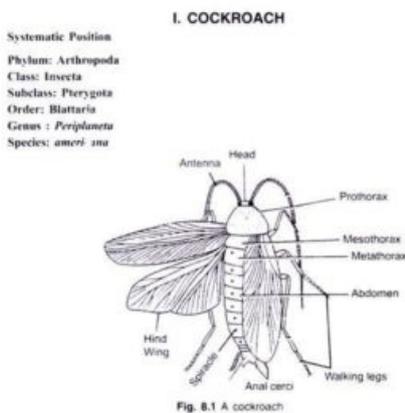
It is probably the most loathed about insect ever present. But the fact remains that cockroaches have inhabited the earth for the past 300 million years and continue to be present on earth. Read along to know more about the external morphology and internal anatomy of a cockroach which belongs to the phylum Arthropoda. The common cockroach is scientifically known by the name *Periplaneta americana*.

Epithelial and Connective Tissue



As an arthropod, the body of a cockroach is divisible

into three distinct regions. They are the head, thorax, and abdomen. There is a hard exoskeleton that is brown in color, made of chitin. The hardened plates of the exoskeleton are called the sclerites. A cockroach is a dioecious animal, with separate male and female sexes. The male species are longer in length while the females are slightly smaller than the males.



The head of the cockroach has a distinct triangular shape. It is formed by the fusion of six segments. The head shows great mobility due to the presence of a flexible neck. A pair of compound eyes is present on the head. In front of the eyes, membranous sockets are present, out of which two antennae protrude out.

The antennae monitor the surrounding environment with the help of the sensory receptors. The head also has appendages that bear similarity to the mouthparts, such as labrum, a pair of

mandibles, a pair of maxillae and a labium. There is also flexible lobe called the hypopharynx that acts as a tongue.

The thorax is further divided into prothorax, mesothorax, and metathorax. Each segment of the thorax has a pair of walking legs. The first pair of wings called the tegmina comes out from the mesothorax and the second pair comes out from the metathorax. The tegmina are dark and cover the hind wings, which are membranous, transparent and used in flight.

The abdomen is made up of 10 segments. The 7th, 8th and 9th sterna form a genital pouch in females. In males, the genital pouch is present at the hind end of the abdomen. The male cockroach has thread-like anal styles, which are missing in the female cockroach. The 10th segment has a filamentous structure called the anal cerci, in both male and female cockroach.

Body Anatomy of Cockroach

Alimentary Canal

The three parts into which the alimentary canal is divided are the foregut, midgut, and hindgut. The mouth leads into a pharynx which leads into a narrow passage called the oesophagus. The oesophagus

opens into a sac-like structure called the crop that stores food.

The gizzard is the next structure that is present after the crop. It is also called the proventriculus. It helps in grinding the food particles due to the presence of six chitinous plates called teeth. A cuticle lines the entire foregut. At the junction of the foregut and midgut, there is a ring of tubules called the gastric caecae, which secrete digestive juice.

Another ring of 100-150 yellow coloured thin filamentous Malpighian tubules is present at the junction of the midgut and hindgut. These Malpighian tubules help in the removal of excretory products.

The hindgut opens outside through the anus.

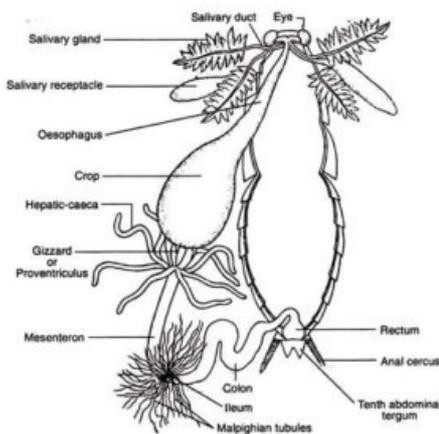


Fig. 18.54: Alimentary system of *Periplaneta americana*.

Blood Vascular System

An open blood vascular system is found in a cockroach as the blood vessels are poorly developed. There is an open space called the hemocoel into which the visceral organs are located.

These visceral organs are bathed in hemolymph which is the blood of a cockroach. The hemolymph is made of a colorless plasma and hemocytes. An elongated tube with a muscular wall regulates the blood in the hemocoel. This elongated tube which is the heart of the cockroach has many funnel-shaped chambers and lies mid-dorsally in the abdomen and thorax.

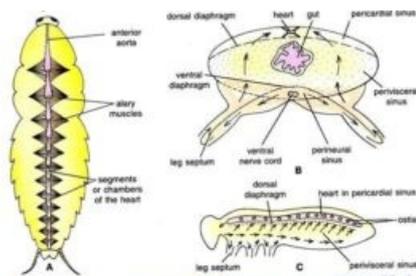


Fig. 73.18. *Periplaneta*. A—Heart in dorsal view; B—Course of circulation of blood in T.S. of thoracic segment; C—Course of circulation of blood in L.S. of body.

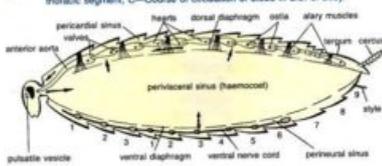


Fig. 73.19. *Periplaneta*. Blood vascular system.

Respiratory System

In cockroach, the respiratory system has a network of

the trachea. They open through 10 pairs of spiracles that are present on the lateral side of the body. Thin tubes carry oxygen from the air to all the parts of the body. The spiracles are regulated by the sphincters. Exchange of gases takes place by diffusion.

Nervous System

Fused ganglia that are segmentally arranged make up the nervous system of this insect. The thorax region has three ganglia and the abdomen has six ganglia. In a cockroach, the nervous system is spread throughout the body.

In the head region, only a little bit of the nervous system is present while the majority is situated on the ventral side of the body. The supra-oesophageal ganglion supplies the nerves to antennae and compound eyes. The sense organs in a cockroach are the antennae, eyes, maxillary palps, labial palps, anal cerci.

Excretory System

The Malpighian tubules perform the excretion in a cockroach. There are glandular and ciliated cells that are present lining each tubule, which absorb the nitrogenous waste products. These are converted into uric acid and excreted out through the hindgut. This is the reason why a cockroach is called a uricotelic.

Reproductive System

The reproductive system is well developed in both the male and female cockroaches. The male reproductive system has a pair of testes that lie on the lateral side in the 4th -6th abdominal segments. There is an accessory reproductive gland in the 6th and 7th abdominal segments that is mushroom shaped. Chitinous asymmetrical structures called the male gonapophysis or phallomere form the external genitalia.

The female reproductive system has two large ovaries that are present laterally in the 2nd to the 6th abdominal segments. A group of eight ovarian tubules forms one ovary. They contain a chain of developing ova. The fertilized eggs are encased in a casing called the oothecae. Female cockroaches produce around 9 to 10 oothecae which contain around 14 to 16 eggs each.

Solved Question For You

Q: Antennae of cockroach have

Gustatory receptors

Auditory receptors

Tactile Receptors

Tactile and olfactory receptors

Ans: The correct option is "D". The cockroach antennae have a sensory appendage that generates the olfactory, gustatory, tactile, thermal and humidity senses. Of the variety of senses, the tactile sense is thought to play a key role in perceiving physical objects.

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PART 1

Phylum Echinodermata General Characteristics and Classification

Phylum Echinodermata

General characteristics of Phylum Echinodermata

(Echinos: Spines; derma: Skin)

Kingdom: Animalia

Habitat: These are exclusively marine

Grade of organization: organ system grade

Germ layer: triploblastic

Symmetry: Adults are radially symmetrical while the larvae are bilaterally symmetrical.

Coelom: present (coelomate)

Body without segmentation

The shape of the body is flat, star like, spherical or elongated.

Head is absent

Presence of tube feet

Presence of water vascular system

Mouth is present on ventral side while anus is present on dorsal side

Respiration: by papule, gills or cloacal respiratory tree

Nervous system: absent, they are brainless organism.

Circulatory system: is reduced, heart is absent

Blood has no pigment.

Digestive system: complete

Excretory system: absent

Sexes: mostly dioecious, rarely monocious

Reproduction:

Sexual: by gamatic fusion

Asexual: regeneration

Fertilization: external

Development: indirect with characteristic larvae

Classification of phylum Echinodermata

It is divided into 5 classes:

Asteroidea

Ophiuroidea

Echinoidea

Holothuroidea

Crinoidea

Class 1 Asteroidea

Body is flattened star shaped with five arms

They possesses tube feet with a sucker

Presence of calcareous plates and movable spines.

Respiratory organ: papulae

Examples: Asterias (Star fish), Astropecten, Zoraster, Oreaster

Class 2 Ophiuroidea

Body is flat with pentamerous disc

They possess a long arm which is sharply demarcated from the central disc.

They possess tube feet without sucker

Anus and intestine are absent

Respiratory organ: Bursae

Examples: Ophiderma, ophiothrix, Astrophyton, Amphuria, etc

Class 3 Echinoidea

Body is disc-like hemi-spherical

They are devoid of arms or free-rays.

They possess tube feet with a sucker.

They possess compact skeleton and movable spines.

Examples: Echinus (Sea urchin), Cidaris, Arbacia, Echinocardium. Diadema

Class 4 Holothuroidea

Body is elongated in the oral-aboral axis and it is like cucumber.

They have no arms, spines and pedicellariae.

The tube feet are sucking type which is modified into tentacles and form a circle around mouth.

Respiratory organ: cloacal respiratory tree

Examples: Cucumaria (Sea cucumber), Holothuria, Mesothuria, etc

Class 5 Crinoidea

Body is star shaped

Some of the forms were extinct and living forms.

Arms bifurcated, with two pinnules.

They have tube feet without suckers

Examples: Neometra, Antedon, Rhizocrinus, etc

Economic Importance of Echinoderms

Echinoderms are economically important to humans due to their use in scientific research and education and also for food. Scientists have learned much about animal reproduction, fertilization and development by studying sea urchins, sea stars and other echinoderms.

Scientists have used echinoderms to study fertilization due to the fact that many species are easy to cultivate in a lab setting and also because they produce a huge amount of eggs at one time. Echinoderm eggs are also the reason these animals are economically important for food, as sea urchin roe is considered a delicacy in many places and is commonly served in sushi restaurants around the world.

There are approximately 7,000 known species of echinoderms, which can be found in every ocean on the planet. In addition, scientists have identified more than 13,000 extinct species of echinoderms through

fossil records. Nearly all known species live in seas and oceans, although there are a few species that live in brackish coastal waters. The phylum Echinodermata is the largest group to include only marine animals, as there are no known freshwater or terrestrial species.

The name echinoderm comes from the ancient Greek term for spiny skin, and many echinoderms are covered in spines. All echinoderms share the characteristic of radial symmetry, which means their limbs or appendages all grow out from one identical center point.

Asterias (Starfish): History, Habitat and Development

Contents:

History of Asterias

Habit and Habitat of Asterias

External Features of Asterias

Body Wall of Asterias

Endoskeleton of Asterias

Coelom in Asterias

Digestive System of Asterias

Water Vascular System of Asterias

Locomotion of Asterias

Circulatory System of Asterias

Respiratory and Excretory System of Asterias

Nervous System of Asterias

Sense Organs of Asterias

Reproductive System of Asterias

Life History and Development of Asterias

Regeneration and Autotomy of Asterias

1. History of Asterias:

Asterias is commonly known by the name of starfish. The name starfish is somewhat misleading suggesting an organism to be like a star and fish but as Asterias lacks in both the characteristics, therefore, recently it is renamed as sea star. There occur about 150 species of Asterias all of which have different geographical

distribution.

ADVERTISEMENTS:

Asterias rubens occurs on the English and North European coasts, **A. vulgaris** is found on the North Atlantic coast of North America, **A. forbesi** occurs on the eastern sea shore from the Maine to the Gulf of Mexico, **A. amurensis** is found in the Behring sea, Japan and Korea, and **A. tenera** occurs on the sea shore from Nova Scotia to New Jersey.

Some other common sea stars are **Pentaceros**, **Astropecten**, **Asterina**, **Heliaster**, **Solaster**, **Luidia**, etc. The following account will give a general idea about the anatomical organisation of the genus **Asterias**.

2. Habit and Habitat of Asterias:

Asterias is exclusively marine, bottom dwelling or benthonic animal, inhabiting various types of bottom, mainly in the littoral zone where they crawl about or may remain quiescent at time's, either in the open or more or less concealed. **Asterias forbesi** is found equally abundant on hard, rocky, sandy or soft bottom, while other species have been found to prefer rocky sea bottoms.

The most species of *Asterias* are generally solitary but under certain ecological conditions, such as to avoid direct sunlight or excessive drying, many individuals may gather at some place for the purpose of protection. Most of them are nocturnal, remain quiet in day time and become active during night. They move by crawling on the bottom, mostly at a rather slow rate.

All sea stars are carnivorous and feed voraciously on almost any available slow moving or sessile animals, chiefly on polychaetes, crustaceans, molluscs and other echinoderms and even corpses.

Many species of *Asterias* exhibit various types of biological relationships such as parasitism and commensalism, etc., with the members of different zoological groups. Sea stars, in general, exhibit remarkable power of autotomy and regeneration.

3. External Features of *Asterias*:

(i) Shape, Size and Colour:

Asterias has a radially symmetrical and pentamerous body. The body consists of a central, pentagonal central disc from which radiate out five elongated, tapering, symmetrical spaced projections, the rays or arms. In some genera, the number of arms may be more than five, for example, there are 7-14 arms in

Solaster and more than 40 arms in Heliaster.

The size varies from 10-20 cm in diameter though some forms may be much smaller or longer. The colour is variable having shades of yellow, orange, brown and purple. The body has two surfaces, the upper convex and much darker side is called the aboral or abactinal surface.

The lower surface is flat, less pigmented and is called the oral or actinal surface. The oral and aboral surfaces are not the ventral and dorsal surfaces but correspond to the left and right sides of the bilaterally symmetrical larva. The axes occupied by the arms are known as radii and the regions of the central disc between the arms are inter-radii. A well defined head is entirely absent.

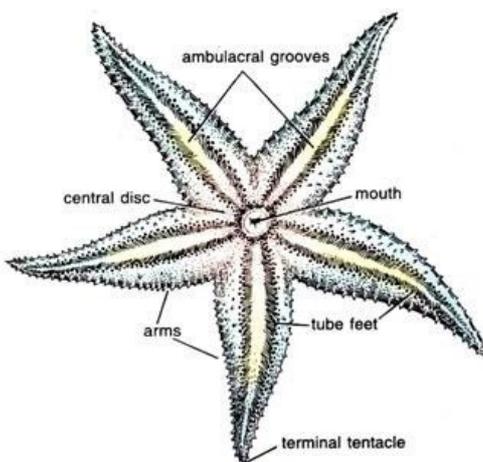


Fig. 85.1. *Asterias*. External features (Oral view).

(ii) Oral Surface:

The side of body, which in natural condition remains towards the substratum and contains the mouth or oral opening, is flat and of dark orange to purplish colour, is called oral or actinal surface.

The oral surface bears the following structures:

1. Mouth:

On the oral surface, in the centre of the pentagonal central disc is an aperture, the actinosome or mouth. It is a pentagonal aperture with five angles, each directed towards an arm. The mouth is surrounded by a soft and delicate membrane, the peristomial membrane or peristome and is guarded by five groups of oral spines or mouth papillae.

2. Ambulacral Grooves:

From each angle of the mouth radiates a narrow groove called the ambulacral groove which runs all along the middle of oral surface of each arm.

3. Tube Feet or Podia:

Each ambulacral groove contains four rows of locomotory, food capturing, respiratory and sensory organs called tube feet or podia. The tube feet are

soft, thin-walled, tubular, retractile structures provided with terminal discs or suckers. The suckers function as suction cups to afford a firm attachment on the surface to which they are applied.

4. Ambulacral Spines:

Each ambulacral groove is bordered and guarded laterally by 2 or 3 rows of movable calcareous ambulacral spines which are capable of closing over the groove. Near the mouth, these spines often become larger, stouter, assemble in five groups, one at each inter-radius of disc and are called mouth papilla.

Outside the ambulacral spines are three rows of stout immovable spines, beyond which occurs another series of marginal spines along the borders of the arms demarcating the oral from the aboral surface.

5. Sense Organs:

Sense organs include five unpaired terminal tentacles and five unpaired eye spots. The tip of each arm bears a small median, non-retractile and hollow projection, the terminal tentacle. It acts as a tactile and olfactory organ. At the base of each tentacle occurs a bright red photo-sensitive eye spot made up of several ocelli.

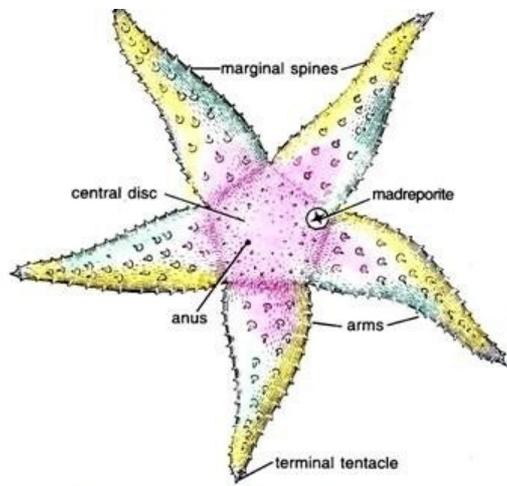


Fig. 85.2. *Asterias*. External features (Aboral view).

(iii) Aboral Surface:

The side of the body, which remains directed upward or towards the upper surface, is convex and of light orange to purplish colour, is called aboral or abactinal surface.

The aboral surface bears following structures:

1. Anus:

A minute circular aperture, called the anus, is situated close to the centre of the central disc of aboral surface.

2. Madreporite:

At the aboral surface of the central disc occurs a flat, sub-circular, asymmetrical and grooved plate called

madreporite plate or madreporite between the bases of two of the five arms. The surface of madreporite is marked by a number of radiating, narrow, straight or slightly wavy grooves with pores in them. The madreporite is, thus, a sieve-like porous plate and it leads to the stone canal of water vascular system.

The number of madreporite to an individual though remains one, but the presence of more than one madreporite in some species is due to the increase in number of arms beyond the normal number of five.

The two arms having madreporite between their bases are collectively referred to as a bivium and the other three arms as a trivium. The symmetrical position of madreporite, thus, converts the radial symmetry of *Asterias* into bilateral symmetry.

3. Spines:

The entire aboral surface is covered with numerous short, stout, blunt, calcareous spines or tubercles. The spines are variable in size and are arranged in irregular rows running parallel to the long axes of the arms. The spines are supported by the irregularly-shaped calcareous plates or ossicles which remain buried in the integument and form the endoskeleton.

4. Papulae or Gills:

Between the ossicles of integument are present a large number of minute dermal pores. Through each dermal pore projects out a very small, delicate, tubular or conical, finger-like or thread-like, thin-walled, membranous and retractile projection called the dermal branchia or gill or papula.

The papulae are hollow evaginations of the body wall and their lumen remains in continuation with the coelom. They are internally lined by coelom. They have respiratory, as well as excretory functions.

5. Pedicellariae:

Besides the spines and gills, entire aboral surface is covered by many whitish modified spine-like tiny pincers or jaws called pedicellariae. The oral surface also bears pedicellariae. Each pedicellaria consists of a long or short, stout, flexible stalk having no internal calcareous support.

The stalk bears three calcareous ossicles or plates a basilar piece or plate at the extremity of the stalk and jaws or valves which remain movably articulated with the basilar piece and serrated along their apposed edges. Pedicellariae having three calcareous pieces and a stalk are called forcipulate pedunculate pedicellariae.

Asterias possesses two types of forcipulate

pedunculate pedicellariae. viz.:

(i) Straight type and

(ii) Crossed type.

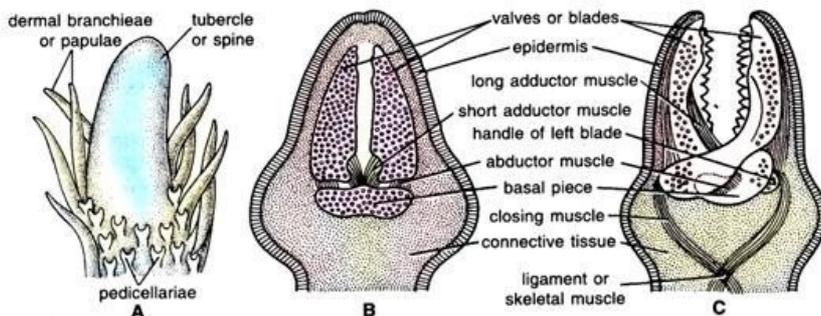


Fig. 85.3. *Asterias*. A—A cluster of pedicellariae, papulae, and tubercle; B—Straight type pedicellaria; C—Crossed type pedicellaria.

(i) Straight type Pedunculate Pedicellariae:

This type of pedicellariae are simple. Their two jaws are more or less straight and attached basally to the basal piece. When closed they remain parallel and meet throughout their length. The two jaws work against one another like the blades of a force with the help of three pairs of muscles. There are two pairs of adductor muscles for closing the jaws and a pair of abductor muscles for opening them.

(ii) Crossed type Pedunculate Pedicellariae:

In the crossed type of pedicellariae, the basal ends of

the two jaws cross each other like the mandibles of a crossbill, so that the basal piece is enclosed between their crossed portions. In this type of pedicellariae, the jaws are also operated by two pairs of adductor muscles and one pair of abductor muscles.

Certain other pedicellariae having no stalk and, thus, called sessile pedicellariae are also found on the body of Asterias. They serve as defensive and offensive organs and provide protection to gills and general body surface by keeping the body surface free from debris and organisms like sponges and coelenterates setting on the body.

4. Body Wall of Asterias:

The body wall of Asterias consists of following tissue layers:

(i) Cuticle:

The body surface is clothed with a definite cuticle consisting of two layers, an outer thick homogeneous layer and an inner delicate layer.

(ii) Epidermis:

Just beneath the cuticle lies a layer of ciliated epithelium which extends over all the external appendages of body such as spines, pedicellariae,

tube feet and gills, etc.

The epidermis is composed of a variety of cells such as ordinary flagellated or ciliated columnar cells, neurosensory cells, mucous gland cells or goblet cells having finely granular contents, muriform gland cells filled with coarse spherules and the pigment granules which provide characteristic external colouration to the animal.

(iii) Nervous Layer:

Beneath the epidermis lies a nervous layer, varying in thickness in different areas and penetrated by the attenuated bases of the epidermal cells on their elastic filaments.

(iv) Basement Membrane:

Just below the nervous layer lies a delicate basement membrane which separates the nervous layer and epidermis from the underlying dermis.

(v) Dermis:

The dermis is composed of fibrous connective tissue developed from the mesoderm. It is the thickest layer of body wall and has two regions outer and inner. The outer dermal region secretes and houses the endoskeletal ossicles and binds them together, while

the inner dermal region contains numerous blood containing spaces called perihæmal spaces.

(vi) Muscular Layer:

The muscular layer consists of smooth muscle-fibres. It is differentiated into an outer circular muscle layer and inner longitudinal muscle layer. These muscle layers are on the whole weakly developed except in the aboral wall where stronger longitudinal bundles radiate from the centre of the disc along the mid-dorsal line of each arm, to bend the arms aborally.

(vii) Coelomic Epithelium:

The innermost layer of body wall lines the coelom and is composed of flagellated cuboidal cells of mesodermal origin. The innermost layer of body wall is called coelomic epithelium or peritoneum.

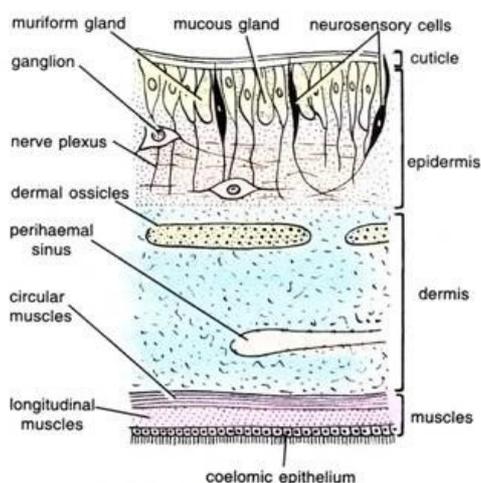


Fig. 85.4. *Asterias*. Body wall in V.S.

5. Endoskeleton of Asterias:

The rigidity of the body of Asterias is due to the presence of definite skeleton. In Asterias, the endoskeleton is unique in being mesodermal in origin instead of ectodermal as in other invertebrates. It consists of numerous calcareous ossicles. The ossicles are of various shapes and are bound together by connective tissue. They form a reticulate skeleton, leaving spaces for the emergence of groups of papulae.

The ossicles have irregular arrangement on the aboral surface but have definite and regular arrangement on the oral surface. On the oral surface, they are regularly arranged around the mouth and in the ambulacral groove. Five plate-like ossicles called oral ossicles remain arranged around the mouth. Each ambulacral groove is supported by double rows of large, transversely placed opposite rod-shaped ambulacral ossicles.

The ossicles of the two opposite rows are arranged like an inverted V, their aboral ends meeting at the apex of the V, like the rafters supporting the roof of a shed and forming a conspicuous ambulacral ridge. The ambulacral ossicles do not bear any spines, tubercles or other external appendages. Because they are movably articulated in the ambulacral groove, they

permit the opening or closing of the latter.

Further, each ambulacral ossicle has a notch on its outer as well as inner margin. The two notches of the adjacent ossicles together form an oval aperture, the ambulacral pore for the passage of tube-foot. The ambulacral pores are so arranged that they form two rows on each side of the ambulacral groove.

At its outer end, each ambulacral groove articulates with one ambulacral ossicle forming the edge of the groove and bearing two or three movable spines on small tubercles. Next to the ambulacral ossicle there are two rows of the ossicles called supra- and inframarignal ossicles.

Section of an Arm:

The arm is covered all around by a thin two-layered cuticle, a ciliated epidermis and an underlying thick dermis which has many perihæmal spaces and ossicles.

Epidermis and dermis are thinned over the projecting spines, pedicellariæ and papulae but they wear off from spines. The aboral side is a thick convex arch, and the oral side is like an inverted a, between the two limbs of the a is an ambulacral groove. The arm encloses a perivisceral coelom.

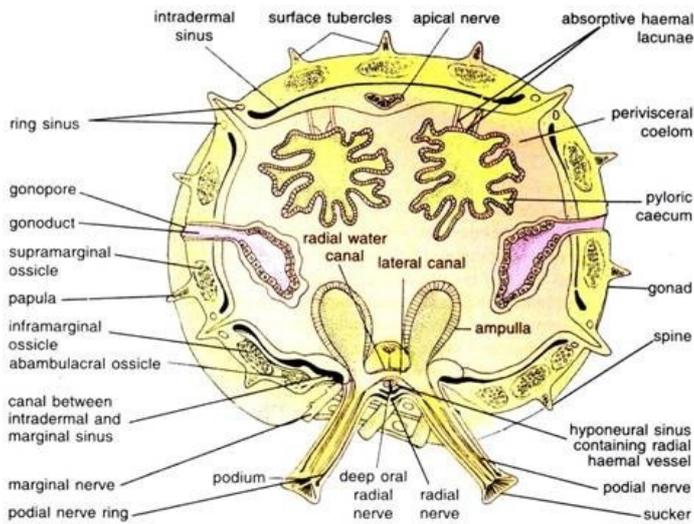


Fig. 85.5. *Asterias*. Diagrammatic transverse section of an arm.

The aboral wall has a number of irregular, fenestrated ossicles which are calcareous, on some ossicles rest projecting spines.

From the aboral side dermal papulae project out, the coelom is continued into the papulae. Between the spines and attached to them are many pedicellariae. Each lateral margin of the arm has two large spines, they are a supra marginal spines and below it an inframarignal spine. Mid-dorsally the arm has a large cardinal spine.

On the oral surface the ambulacral groove is supported by two elongated ambulacral ossicles meeting at the summit of the groove, at each end of the ambulacral groove is an adambulacral ossicles and spine. The ambulacral ossicles form two columns in the oral

surface of each arm and on each side there is a single column of adambulacrals.

The adambulacral spine can touch the substratum or bend inwards to protect the ambulacral groove. Above the ambulacral groove runs a radial canal which is joined on each side by a podial branch to two ampullae and one tube foot. Below the radial canal is a radial hyponeural sinus enclosing a radial haemal channel.

Muscles:

The median aboral side below the body wall has an apical longitudinal muscle which stretches the arm. Each pair of ambulacral ossicles has an upper and a lower transverse ambulacral muscle, the upper or superior transverse ambulacral muscle widens the ambulacral groove, and the lower or inferior transverse ambulacral muscle makes the ambulacral groove narrow.

Between the adjacent ambulacral ossicles of each side is a longitudinal ambulacral muscle which shortens the arm and the ambulacral groove. The outer end of each ambulacral ossicle is connected to the adambulacral ossicle by a lateral transverse ambulacral muscle which widens the ambulacral groove.

Nerves:

In the middle of the ambulacral groove is a radial nerve

cord in the shape of a V. Above the radial nerve cord are two Lange's nerves. Close to the outer end of each ambulacral ossicle is a marginal nerve. Each podium has a nerve ring.

Inside the perivisceral coelom of the arm is a pair of pyloric caeca, each suspended by two longitudinal mesenteries from the aboral surface. If the section passes through the base of the arm the perivisceral coelom has a pair of gonads attached to the body wall by their ducts.

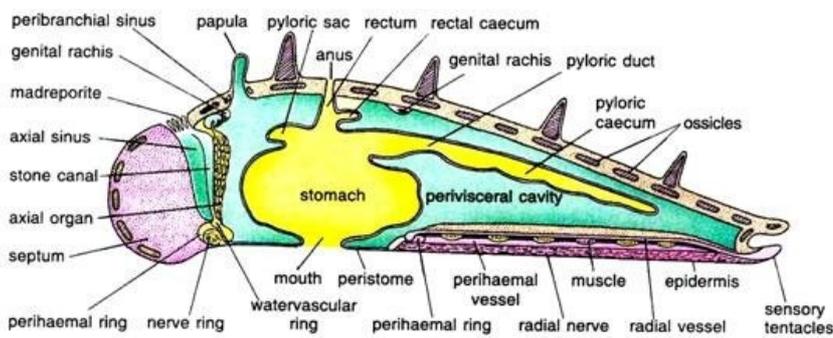


Fig. 85.6. *Asterias*. Diagrammatic longitudinal section of the disc and an arm.

6. Coelom in Asterias:

Asterias possesses a true and spacious coelom which is lined by a coelomic epithelium of ciliated cuboidal cells.

It consists of various compartments, viz.:

(i) A perivisceral coelom extending in central disc

and rays and surrounding the visceral organs such as digestive tract and the gonads,

(ii) Coelom of water vascular system,

(iii) Axial sinus,

(iv) Perihaemal sinus and canals and,

(v) Genital sinuses, etc.

The coelom is filled with a colourless, alkaline coelomic fluid which contains various dissolved nutrients such as amino acids, fatty acids, glycerol and glucoses, etc. Besides nutrients, the coelomic fluid also contains two main types of phagocytic amoeboid corpuscles, the amoebocytes or coelomocytes; coelomocytes with ordinary slender pseudopodia and coelomocytes with petaloid pseudopodia.

The coelomic fluid, like the haemolymph of Arthropoda, bathes the tissue of the body and performs the function of circulatory system. It distributes the nutrients to various body cells and also performs the respiratory as well as excretory functions.

7. Digestive System of Asterias:

Alimentary Canal of Starfish:

In *Asterias*, the alimentary canal is tubular, straight, short and extends vertically along the oral-aboral axis in the central disc.

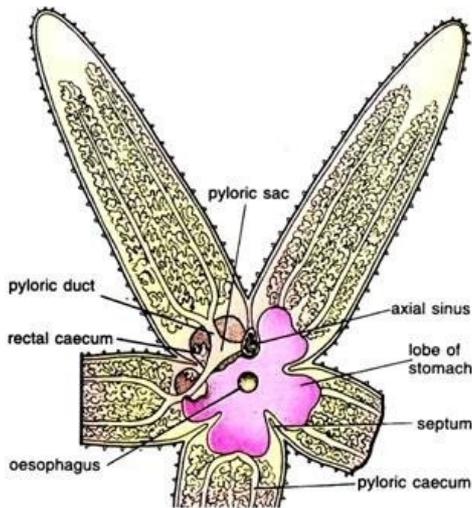


Fig. 85.7. *Asterias*. Digestive system.

It comprises the following parts:

1. Mouth:

The mouth is the anterior most aperture of alimentary canal and it is situated in the centre of the peristomial membrane of the oral surface. It is provided with a sphincter muscle and radial fibres and is capable of great expansion and retraction. The mouth leads upward into the oesophagus.

2. Oesophagus:

The oesophagus is a very short, wide and vertical tube. It opens aborally in the stomach.

3. Stomach:

The stomach is a broad sac and fills the interior of the disc. It is typically divided by a horizontal constriction into a voluminous oral part, the cardiac stomach and a flattened aboral part, the pyloric stomach. The cardiac stomach has a muscular, highly folded wall bulged out to form five lobes, one opposite each arm.

The cardiac stomach is connected to the ambulacral ridge of each arm by ligaments of muscles and connective tissues called mesenteries or gastric ligaments which serve to anchor the cardiac stomach in place. During the feeding process, the cardiac stomach can be everted through the mouth by the contraction of muscles of body wall.

The retraction of cardiac stomach is brought about by five pairs of retractor muscles which arise from the lateral sides of the ambulacral ridge. The pyloric stomach is much smaller, flat and pentagonal sac. It communicates with the intestine.

4. Intestine:

The intestine is a short, narrow, five sided tube that runs straight upward to open out at the anus. It

gives off two or three little hollow diverticula called intestinal or rectal caeca placed inter-radially. The intestinal caeca are brown in colour and each bears several short, irregularly-shaped diverticula. The actual function of intestinal caeca is well disputed. However, they are considered as excretory organs, because, they secrete a brown fluid.

5. Anus:

The intestine opens on the aboral surface by a posterior most aperture of the alimentary canal called anus. The anus is situated eccentrically on the aboral side of central disc.

Histology of Alimentary Canal:

Histologically the wall of the alimentary canal consists from within outwards of an enteric epithelium of columnar ciliated cells of endodermal origin, a sub-epidermal nervous layer, a connective tissue layer devoid of ossicles, a layer of muscles and an outermost layer of coelomic epithelium or visceral peritoneum. The thickness of the layers varies in different parts of the alimentary canal.

Digestive Glands:

To the pyloric stomach are attached ten, long brownish or greenish glandular appendages variously

called pyloric caeca, digestive glands, branchial caeca, hepatic caeca, etc. There are two pyloric caeca in each arm, each suspended from the aboral wall of the arm by two longitudinal mesenteries that enclose between them a coelomic space continuous at its central end with the general coelom of the disc.

Each pyloric caecum consists of double series of hollow lobulated sacs that open into a central tube duct. The two ducts forming a pair of caeca of each arm unite to form a main pyloric duct that opens into the pyloric stomach at one of its angles.

Histology of Digestive Gland:

Histologically the pyloric caeca are complex structures and are lined by ciliated columnar epithelium which is composed of four types of epithelial cells.

The current producer cells bear longer flagella and maintain a steady circulation of the fluids and digested food in the cavities of the caeca; the mucous cells produce mucus; the secretory or granular cells secrete digestive enzymes to convert proteins into peptones, starch into monosaccharide sugars and fats into fatty acids and glycerol, and the storage cells store reserve food such as lipids, glycogen and polysaccharide-protein complex.

The pyloric caeca function like pancreas of

vertebrates.

Physiology of Digestive System:

Food:

Asterias is a carnivorous animal and feed voraciously on worms, crustaceans, snails, bivalves, small-sized starfishes, echinoderms and fishes. Sometimes, Asterias also feed on dead animals and under hazardous conditions may live without food for several months.

Ingestion and Digestion:

The mode of feeding or ingestion in Asterias is of most unusual type. It swallows small-sized animals directly through the mouth. The prey is held by the tube feet and cardiac stomach is everted and wrapped round it. The enzymatic secretions of pyloric caeca poured out on to the prey and when digestion is completed, stomach is withdrawn along with the digested food.

To feed shelled molluscs (bivalves), Asterias adopts another interesting technique. It creeps over the clam and holding it with tube feet, orients it to bring the free margins of the shell close to its mouth. It now arches its body, assuming a characteristic humped or umbrella-like posture. The more proximal tube feet firmly grip both valves of the bivalve's shell, while the more distal ones are attached to the substratum.

The cardiac stomach is now everted through the mouth by the concentration of body wall and pressure of coelomic fluid.

The tube feet gripping the valves of the clam's shell exert a steady pull as the muscles in the arms contract. But, because the muscles of clam cannot maintain a continuous state of contraction for a long time and sooner or later, the adductors of the mussel become fatigued or exhausted and finally relax, so that the shell opens.

Asterias, now, inserts its already everted cardiac stomach into the mantle cavity of the clam and pours out its proteolytic enzymes.

The enzymes digest the visceral organs of clam, they; thus, convert the proteins of visceral organs into peptones and amino acids; polysaccharide carbohydrates and lipid contents into fatty acids and glycerol. When the digestion is partially completed the sea star withdraws its stomach along with the digested food by means of its retractor muscles and moves on leaving behind the shell of the victim.

Remaining digestion of food substances occurs in cardiac stomach from which the digested food diffuses to coelomic fluid for body wide distribution and to pyloric caeca where it may be distributed to

arms or stored in storage cells of epithelium of pyloric caeca. The undigested food is either egested out directly from the mouth or pass through intestine and egested out through the anus.

8. Water Vascular System of Asterias:

The water vascular system is a modified part of coelom and it consists of a system of sea-water filled canals having certain corpuscles. It plays most vital role in the locomotion of the animal and comprises madreporite, stone canal, ring canal, radial canal, Tiedeman's bodies, lateral canals, and tube feet.

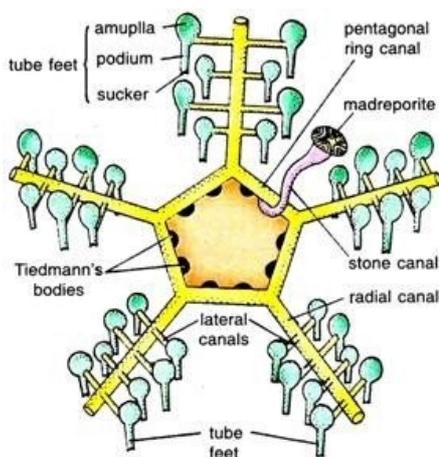


Fig. 85.8. Asterias. Water vascular system.

(i) Madreporite:

As already stated, the madreporite is a rounded

calcareous plate occurring on the aboral surface of the central disc in inter-radial position. Its surface bears a number of radiating, narrow, straight or wavy grooves or furrows. Each furrow contains many minute pores at its bottom.

Each pore leads into a very short, fine, tubular pore canal which passes inward in the substance of the madreporite. There may be about 200 pores and pore-canals. The pore-canals unite to form the collecting canals which open into an ampulla beneath the madreporite.

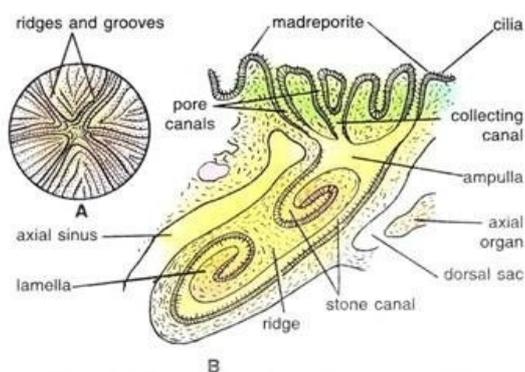


Fig. 85.9. *Asterias*. Madreporite, A—As seen from outside, B—Vertical section.

(ii) Stone Canal:

The ampulla opens into a S-shaped stone canal. The stone canal extends downwards (orally) and opens into a ring canal,

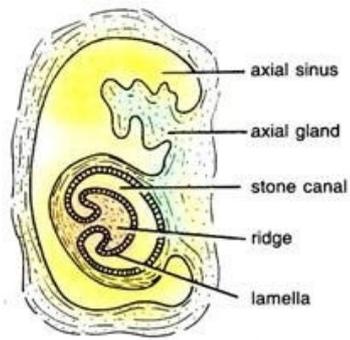


Fig. 85.10. *Asterias*. T.S. of axial complex.

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PART 2

9 Locomotion of Asterias:

Asterias lacks in head or anterior end, therefore, capable to move in any direction according to its desire. It can move on horizontal as well as on vertical surfaces by the help of tube feet.

Locomotion on a Horizontal Surface:

When an Asterias desires to move on a horizontal surface in a given direction, the arm or arms pointing in that direction is lifted.

The ampullae of raised arm contract, the valve in the lateral canals close and the water of the ampullae is forced into the podia. The podia of the tube feet become extended, elongated and enlarged in the general direction of movement due to the hydrostatic pressure produced by influx of water into them.

Subsequently, the terminal suckers of the tube feet become attached to the substratum and their central parts are withdrawn to form suction cups. Due to the vacuum so produced, the suckers acquire a firm grip over the substratum. Mucus secreted by the tips of the tube feet further aids in attachment.

The tube feet now pivot forward on their attached

suckers, assuming vertical position and thereby pushing the body forwards. The longitudinal muscles of the podia now contract and this forces their fluid back into the ampullae and releases their suckers. The ampullae then contract again and whole sequence of events is repeated.

Locomotion on a Vertical Surface:

In climbing a vertical surface, the tube feet pull the body forward. By the alternate contraction and expansion of tube feet and by adherence of suckers of tube feet on surface *Asterias* climbs on the vertical surface.

Asterias employs its tube feet, only when, it moves on hard rocky substratum. But, on soft mud or sand (substratum) the suckers of tube feet become useless, therefore, on such soft surfaces the animal literally walks on its extended tube feet which now act like small legs. Besides locomotion, tube feet serves many other functions such as clinging of animal body to substratum, tactile and respiratory function.

10. Circulatory System of *Asterias*:

The so-called circulatory system includes following two systems:

1. Perihaemal system

2. Haemal system

1. Perihaemal System:

The perihaemal system, like the water vascular system, is derived from the coelom and is composed of many tubular coelomic sinuses such as axial sinus, aboral ring sinus, genital sinuses, radial perihaemal sinuses, marginal sinuses and peribranchial sinuses.

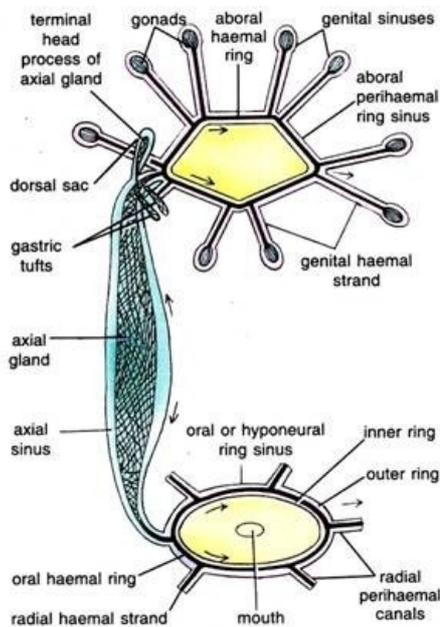


Fig. 85.11. *Asterias*. Diagrammatic representation of perihaemal and haemal systems.

(i) Axial Sinuses:

The axial sinus is a thin-walled, vertical, wide tubular coelomic cavity enclosing the stone canal and the axial gland. The three forming a well developed axial

complex.

(ii) Aboral Ring Sinus:

The aboral ring sinus is a tubular, pentagonal channel or sinus around the intestine, lying just inside the aboral wall of the central disc. It communicates with the axial sinuses.

(iii) Genital Sinuses:

The aboral ring sinus gives off five pairs of genital branches, one pair in each arm. The genital sinuses surround the gonads.

(iv) Oral Ring Sinus:

At its oral end, the axial sinus opens into the inner division of a circular channel, the oral, peribuccal, perihaemal, or hypo neural ring sinus which runs around the mouth. It is a large tubular sinus and is divisible into an inner narrow and an outer wide ring by an oblique circular septum called haemal strand.

(v) Radial Perihaemal Sinuses:

The outer division of ring sinus gives out five radial hypo neural or perihaemal sinuses, one of which extends through each arm between the radial nerve and the radial water canal. Like oral ring sinus, each

radial sinus is also divided longitudinally into two by a vertical partition or septum, continuous with the haemal strand. The radial perihemal sinuses also give out fine channels into the tube feet.

(vi) Marginal Sinuses:

In each arm, two longitudinal marginal sinuses run longitudinally on each side just aboral to the marginal nerve cord. The fine lateral channels connect the marginal channels with the radial perihemal sinuses.

(vii) Peribranchial Sinuses:

The sinuses occurring as circular spaces around the basal parts of papulae or gills are called peribranchial sinuses.

2. Haemal System:

The haemal or blood lacunar system of *Asterias* is reduced and is of open type like the haemocoel of Arthropoda and Mollusca. It includes inter-communicating spaces having no coelomic epithelium and are derived embryologically from the blastocoel. The haemal system is filled with coelomic fluid containing coelomocytes and is enclosed in the coelomic spaces of perihemal system.

The main haemal sinuses are as follows:

(i) Oral Haemal Ring:

It is the circular haemal sinus, located around the mouth just below the– ring canal of the water vascular system. Oral haemal ring is a fine channel or a ring of lacunar tissue which runs in the septum dividing the hyponeural sinus. The oral haemal ring is connected with aboral haemal ring through axial gland.

(ii) Radial Haemal Sinuses or Strands:

These arise radially from the oral haemal ring and one extends into each arm, along the floor of the ambulacral groove just below the radial canal of the water vascular system. The radial haemal sinuses also give off branches into the podia.

(iii) Axial Complex:

The perihemal and haemal systems of Asterias are intimately connected by a complicated structure called axial complex. The axial complex comprises the following three parts a thin-walled, tubular coelomic cavity called axial sinus containing the stone canal of water vascular system and axial gland, both are closely attached with the wall is of axial sinus by the mesenteries.

(iv) Axial Gland:

This is the principal part of the haemal system. The axial gland is an elongated, fusiform, brownish or purple coloured spongy body. It is covered externally by coelomic epithelium and is called variously as heart, ovoid gland, dorsal organ, septal organ, brown gland, etc. The axial gland is connected with the oral and aboral haemal sinuses at its oral and aboral ends respectively.

At its oral end the axial gland becomes thin and terminates in the septum that subdivides the hypo neural ring sinus. At its aboral end, the axial gland has an aboral extension or terminal process called head process which is lodged in a separate, closed contractile coelomic sac called dorsal sac.

The dorsal sac is situated below the madreporite, close to the ampulla of the stone canal, but has no communication with the ampulla. A pair of gastric tufts also arises from the haemal sinuses in the wall of the cardiac stomach and opens into the axial gland near its aboral end. Digested food from the stomach passes into the haemal circulation through the gastric tufts.

Histologically, the axial gland has an external lining of peritoneum and its interior is filled by connective tissue outlining numerous spaces containing irregularly arranged cells of the nature of coelomocytes. The axial

gland has an intimate relation with the circulation of blood in perihæmal and hæmal channels.

(v) Aboral Hæmal Ring:

It is a pentagonal ring canal lying beneath the aboral surface of the central disc. From the aboral hæmal ring or canal extend five pairs of genital hæmal strands to the gonads.

Function:

The hæmal system acts as a pathway for the distribution of food substances carried by the coelomocytes. The flow of fluid within it is maintained by the contractile activity of the dorsal sac. The axial gland acts as a genital stolon, producing sex-cells, which reach the gonads through the aboral hæmal ring and its branches.

11. Respiratory and Excretory System of Asterias:

The respiratory organs of Asterias are gills or papulae and tube feet. The papulae are the chief respiratory organs. They are simple, contractile, transparent, hollow outgrowths of body wall on the aboral surface having ciliated epithelium at outer and inner surfaces. They are derived from coelom and their lumen remains in direct communication with coelom.

An exchange of O₂ and CO₂ takes place between sea water and body fluid of gills. The cilia of epithelial cells have vital role in movement of coelomic fluid and in creating respiratory water currents in sea water. The other thin-walled, richly vascularized and moist body parts also act as respiratory organs.

Excretory System of Asterias:

Asterias lacks well specialised excretory organs. The nitrogenous metabolic excretory waste usually contains ammonium compounds. They pass from various tissues into the coelomic fluid and from there they diffuse through the thin walls of the rectal caeca, tube feet and gills. The coelomocytes have significant role in the excretion of excretory wastes from the coelom.

12. Nervous System of Asterias:

The nervous system of Asterias is of simple and primitive type. It is composed of nerve fibres and nerve nets which are closely associated with the epidermis. The nervous system comprises the following four units placed at different levels in the disc and arms.

(i) Oral or Ectoneural or Epidermal Nervous System:

The oral nervous system is situated just beneath the epidermis. It is the main part of the sensory nervous

system and sensory in nature.

It comprises the following parts:

(a) Nerve ring:

The nerve ring is pentagonal in shape and is circum-oral, i.e., occurs around the mouth in the peristomial membrane. It supplies nerve fibres to the peristomial membrane and the oesophagus and at each radius gives off a radial nerve.

(b) Radial nerve:

The nerve ring gives off five radial nerves, each of which runs throughout the length of the arm in the bottom of the ambulacral groove. Each radial nerve terminates as a sensory cushion on the aboral side of the terminal tentacle.

A cross section of an arm shows that the radial nerve is a thick V-shaped mass continuous on its outer side with the epidermis and separated on its inner side from the hypo neural sinus only by a thin dermis and the coelomic epithelium. The radial nerve consists of fibrillae arranged in layers and interspersed with bipolar and multipolar ganglion cells.

(c) Sub-epidermal nerve complex:

The sub-epidermal nerve complex is an extensive network of nerve cells and nerve fibres beneath the epidermis all over the body surface including the gills and pedicellariae, etc. It is connected with radial nerve cords by nerve fibres.

The sub-epidermal nerve-plexus is thickened into a cord which forms:

(i) Two marginal nerves each of which extends throughout the length of an arm on each side and gives off a longitudinal series of lateral motor nerves which supply the ossicles, muscles, coelomic epithelium of that area and

(ii) A nerve ring in the suckers of each tube foot.

The ectoneural nervous system acts as the central nervous system of *Asterias*. It has sensory and motor neurons.

(ii) Deep or Hypo Neural Nervous System:

The hypo neural nervous system occurs in the form of a nervous layer in the lateral part of the oral wall of the hypo neural sinus, beneath the coelomic epithelium lining the sinus. This nervous layer is called Lange's nerve. It is separated from the lateral part of the radial nerve only by a thin layer of dermal connective tissue.

Lange's nerve gives off a series of nerves along the arm into the adjacent lower transverse muscle extending between the ambulacral ossicles in the roof of the hypo neural sinus. Lange's nerve continues to the peristomial region, where it forms five inter-radial thickenings in the floor of the ring sinus that lies aboral to the main nerve ring.

(iii) Aboral or Coelomic Nervous System:

The aboral or coelomic nervous system is situated just outside the parietal peritoneum on the aboral side. It consists of a nerve ring in the central disc and a nerve in each arm. This system has connection with marginal nerves by nerve fibres. It innervates the body muscles of aboral side and is motor in function.

(iv) Visceral Nervous System:

The visceral nervous system occurs in wall of the gut just outside the enteric epithelium. It innervates the muscles of alimentary canal and is connected with the visceral receptors.

13. Sense Organs of Asterias:

Asterias possesses a few primitive sense organs which are as follows:

(i) Eyes:

The eyes are the most significant sensory organs of Asterias. They are simple, pigmented and occur at the base of terminal tentacles. On the oral surface, at the base of each terminal tentacle occur optic cushions which are composed of the thick epidermis with many photoreceptors or pigmented cup ocelli.

Each ocellus is a cup-shaped or funnel-like pocket of ectoderm. It is covered externally by the cuticle beneath which is found in many species a lens formed by the epidermis. The wall of cup consists of epidermal cells, altered into a shorter,- stouter shape and filled distally with red pigment granules and of retinal cells, disposed between the pigment cells.

The retinal cells are elongated cells with a distal bulbous enlargement projecting into the cavity of the cup and a proximal fibre passing into the underlying radial nerve. The number of ocelli in one optic cushion or eyes ranges from 80 to 200 in different species. A transparent gelatinous tissue fills the cavity of ocellus. The ocelli are light-perceiving organs which can detect changes in light intensity.

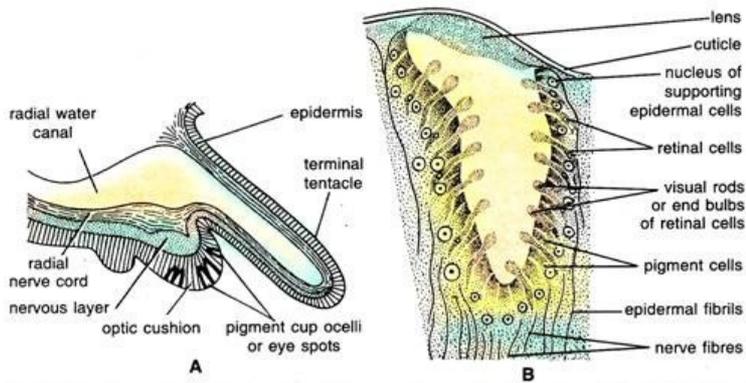


Fig. 85.12. Asterias. A—Section through a terminal tentacle and eyespot; B—V.S. of a single eye-pit or ocellus.

(ii) Terminal Tentacles:

The terminal tentacles have sensory cells which are tactile and also sensitive to food and other chemical stimuli.

(iii) Neurosensory Cells:

The entire body surface or epidermis of *Asterias* is traversed by many neurosensory cells serving as both tango- and chemoreceptors. The neurosensory cells are slender cells with a fusiform body containing the nucleus, a distal thread-like process reaching to the cuticle, and a proximal fibre entering the sub-epidermal nerve plexus.

They are especially numerous in the suckers of the podia, at the base of spines and pedicellariae and terminal tentacles.

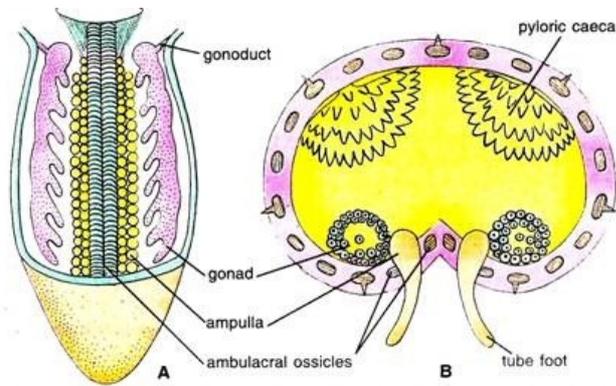


Fig. 85.13. *Asterias*. Gonads. A—An arm dissected to show gonads; B—T.S. of an arm showing gonads.

14. Reproductive System of Asterias:

Most species of *Asterias* are unisexual or dioecious, i.e., sexes are separate except a few species such as *Asterias rubens* which is hermaphrodite. There is no marked sexual dimorphism, however, during breeding season some sort of colour difference between both the sexes may occur.

The reproductive organs of *Asterias* are of primitive type and lack copulatory organs, accessory glands, receptacles for storing ova and reservoirs for storing mature sperms. There are only gonads which act as reproductive organs.

Gonads:

The male gonads are testes and female gonads

are ovaries. Each sexually mature male or female individual contains five pairs of testes or ovaries, one pair is lying free laterally in the proximal part of each arm between the pyloric caeca and the ampullae.

The testes and ovaries are morphologically similar. Each gonad appears as an elongated feathery tuft or tuft of tubules or bunch of grapes, whose size varies greatly according to the proximity of spawning time.

At maturity the gonads occupy the entire perivisceral space. The proximal end of each gonad is attached to aboral body wall near the inter-brachial septum by a very short gonoduct which is ciliated and opens laterally through a small gonopore on the aboral surface almost at the angle of two adjacent arms.

Each gonad is enclosed in a genital sac of coelomic nature with a wall of muscle and connective tissue fibres, covered externally with peritoneum. This genital sac is the outgrowth of the genital or aboral coelomic sinus. The gonad proper is lined by germinal epithelium, containing the germ cells.

The mature sperms and ova are discharged by male and female *Asterias* respectively in sea water. The release of sex cells from the gonads is regulated by neuro-hormonal secretion of radial nerve.

15. Life History and Development of *Asterias*:

(i) Fertilisation:

The most species of Asterias have only one breeding season in a year. During breeding season, both types of mature sexes shed their sex cells in the sea and union of male and female sex cells or gametes (sperms and ova) occurs in sea water. Thus, fertilisation in Asterias is external.

(ii) Embryogeny:

The embryological development of Asterias is indirect and includes various larval stages. The fertilised egg or zygote is spherical, half millimeter in diameter and contains little amount of yolk. The cleavage is holoblastic and equal and it converts the unicellular zygote into a single layered, hollow, ciliated and spherical structure called coeloblastula.

The coeloblastula possesses a fluid-filled central space, called blastocoel and it swims about freely. The blastula undergoes embolic invagination and becomes two

two layered cup-like gastrula. The gastrulation involves the inward pushing of blastomeres of one side. The in-pushing encloses a cavity called archenteron and it occupies the larger part of blastocoel which ultimately becomes obliterated.

This embryonic stage is called gastrula and it has an outer ectodermal and inner endodermal germinal layers. The archenteron or gastrocoel communicates to the exterior by a wide aperture called blastopore. The blastopore changes its relative position with the elongation of gastrula and becomes the anal opening of the larva. Two more openings appear on the surface of the larva.

On the ventral side, a tubular in-growth of ectoderm forms the larval mouth or stomodaeum. Another opening occurs on the dorsal side as the dorsal pore. The cilia of general surface of gastrula degenerate and certain definite ciliary band appears. The mesoderm is formed from two sources.

During the gastrular invagination, the advancing tip of archenteron (endoderm) buds off certain mesenchyme cells into the blastocoel. The growing archenteron is differentiated into a narrow proximal part and wide terminal part.

The narrow proximal part communicates to the exterior by the blastopore and in later stages forms the stomach, and intestine, while the wide terminal part of completed archenteron expands and cuts off on each side into a coelomic pouch, the hydroenterocoel.

These take up their position to the right and the

left sides of the archenteron and develop into coelomic pouches. The latter give rise to coelom, its mesodermal lining and water vascular system. The embryo at this stage becomes a free-swimming larva.

(iii) Larval Development:

The larval development of *Asterias* includes the following larval stages:

Bipinnaria Larva:

The bipinnaria larva develops from the zygote in about one week. It is a bilaterally symmetrical larva which possesses a preoral and a postoral ciliated band, and a preoral lobe with preoral loop of ciliated band. The various projections emerging out of its body correspond to the arms. Inside the body appears the coelomic apparatus and the alimentary canal.

The bipinnaria larva feeds on diatoms, etc., by creating food-bearing currents by ciliary tracts in the stomodaeal wall. It swims freely by forwarding its anterior end, with a clockwise rotation, after some time the bipinnaria larva transforms into the next larval stage, the brachiolaria larva.

Brachiolaria Larva:

In the brachiolaria larva the side-lobes of bipinnaria

increase in length to become long, slender and ciliated larval arms. The larval arms move and contract. The preoral arms also give out processes called the brachiolar arms. The arms of brachiolaria larva have coelomic prolongations and possess tips of adhesive cells.

The bases of these arms surround the elevated, adhesive, glandular area performing the function of a sucker or fixation disc by which the larva becomes attached at the time of metamorphosis.

Metamorphosis:

In about 6 or 7 weeks, the brachiolaria larva settles on the bottom or on some solid object and is fixed with that by its adhesive arms. Now the bilaterally symmetrical larva metamorphoses into a radially symmetrical adult. The larval mouth and anus close. A new mouth is formed on the left side of the larva and a new anus is developed on the right side.

The left and right side of the larva, thus, subsequently differentiated into oral and aboral surfaces of the adult. Five lobes called arm rudiments grow out around oral-aboral axis. In later stages, the skeletal elements appear on the arm rudiments and the radial canals grow into them.

In each arm two pairs of outgrowths from the coelom

form the first tube feet and serve for attachment. Further complex re-organisational changes result in the formation of adult Asterias. The newly detached rudiment of the body of sea star is less than 1 mm with short stubby arms.

16. Regeneration and Autotomy of Asterias:

Asterias possesses considerable power of regeneration. It is capable to regenerate its any lost part of body at any time. Moreover, if an arm is injured or held up, Asterias usually casts it off near the base at the fourth or fifth ambulacral ossicle. This is called autotomy.

The opening left in the side of the central disc by the broken off arm is immediately closed by the contraction of the adjacent body wall musculature for the protection of internal body organs and regeneration of new arm starts at that place.

A disc deprived of all its arms regenerates. In *Asterina vulgaris*, a single arm with a portion of disc regenerates an entire animal. But in *Linckia*, an arm totally devoid of disc can also regenerate complete animal . Specimens with small regenerating arms at the base of the large original arm are popularly called comets.

The Aristotle's lantern of the sea-urchin

The Aristotle's lantern, or masticatory apparatus, of regular sea-urchins is a complex musculo-skeletal system which is thought to have contributed significantly to the evolutionary success of these animals. This paper gives an account of the anatomical relationships and functional morphology of both skeletal and soft tissue components in the lantern and related structures of the sea-urchin *Stylocidaris affinis* (Cidaridae), and compares these features with their equivalent in the previously described lantern of the sea-urchin *Paracentrotus lividus* (Echinidae, Camarodonta). There are major differences in the skeletons of these lanterns which involve mostly the arrangement and morphology of elements participating in movement, i.e. joints and articular surfaces, and which highlight the generally heavier and less mobile nature of the lantern in the Cidaridae. There are remarkably few differences, however, in the microstructure of the skeletal stereom. Significant dissimilarities were found in the anatomical arrangement of muscles and ligamentous structures and in their macro- and microstructure. The implications of these morphological features for the functioning of the lantern of the Cidaridae are discussed in the context of an integrated model of lantern biomechanics.

PART 1

Phylum Mollusca: General Characteristics and Classification

General Characteristics of Phylum Mollusca

(Mollis or molluscs: soft)

Kingdom: Animalia

Habitat: Mostly aquatic and few are terrestrial

Body is soft without segmentation

Grade of organization: Organ system grade

Germ layer: Triploblastic

Symmetry: Bilaterally symmetry

The body is divided into head, muscular foot and visceral mass.

The body is covered by a mantle and a shell

**Respiration: by gills (ctinidia) in the mantle cavity.
lungs in terrestrial forms**

Digestive system: Complete and developed

Circulatory system: Closed type

Heart consists of one or two auricle and one ventricle

Excretion: pair of Metanephridia (Kidney)

**Nervous system: consists of three pair of ganglia
(cerebral, visceral and pedal)**

Sexes: Dioecious and few are hermaphrodite

Reproduction: gamatic fusion

Fertilization: external or internal

Development: direct or indirect by trochophore larvae.

Classification of Phylum Mollusca

There are six classes of which three are more prominent.

Class 1 Pelecypoda or Bivalvia

Habitat: mostly marine

They burrow in mud and sand.

Symmetry: bilateral and the body is laterally compressed.

No distinct head

Examples: Mussels, Unio, Mytilus,

Class 2 Gastropoda

Habitat: These are either aquatic or terrestrial

They possess a spiral shell.

The foot is large and flat.

Head is well developed with tentacles and eyes.

Examples: Hilex (Snail), Limax (Slug), Pila(Apple snail)

Class 3 Cephalopoda

Habitat: mostly marine.

They are adapted for swimming.

The foot is modified into eight to ten long tentacles in the head region.

The shell is either external, internal or absent.

Examples: Octopus, Loligo, Sepia, spirula, Nautilus

Class 4 Monoplacophora

Habitat: exclusively marine

Head is present without eyes and tentacles

Gills are external

Excretion: by serially arranged nephridia

Examples:

Class 5 Amphineura

Habitat: mostly marine

Body is elongated

Eye and tentacles are absent

Radula is present

Examples; Chiton, Neomenia

Class 6 Scaphopoda

Habitat: marine

Body is bilateral symmetry elongated and enclosed in tusk shell

Foot is reduced

Excretion: a pair of Kidney

Examples: Cadulus, Dentalium

Pila Globosa (TYPE STUDY)

Habit and Habitat of Pila Globosa

External Features of Pila Globosa

Coelom of Pila Globosa

Digestive System of Pila Globosa

Respiratory Organs of Pila Globosa

Blood Vascular System of Pila Globosa

Excretory System of Pila Globosa

Nervous System of Pila Globosa

Sense Organs of Pila Globosa

Reproductive System of Pila Globosa

Copulation of Pila Globosa

Fertilisation of Pila Globosa

Development of Pila Globosa

1. Habit and Habitat of Pila Globosa:

Pila globosa or the apple snail is one of the largest freshwater molluscs. It is commonly found in freshwater ponds, pools, tanks, lakes, marshes, rice fields and sometimes even in streams and rivers. They occur in those areas where there is a large amount of aquatic vegetation like Vallisneria, Pistia, for food. They are amphibious being adapted for life in water and on land.

The animal creeps very slowly by its ventral muscular foot, covering about five cm per minute.

The movement of the animal is like the gliding movement of planarian. During the rainy seasons Pila comes out of the ponds and makes long terrestrial tours, thus, respiring air directly. It can overcome long periods of drought in a dormant condition and buried

in the mud; this period of inactivity is called aestivation or summer sleep.

2. External Features of Pila Globosa:

Shell of Pila:

The shell of Pila globosa, as in other Gastropoda, is univalve but coiled around a central axis in a right-handed spiral.

The top of the shell is the apex which is formed first and growth of shell takes place from it, the apex contains the smallest and the oldest whorl. Below the apex is a spire consisting of several successively larger whorls or coils followed by penultimate whorl and the largest whorl or body whorl which encloses most of the body.

The lines between the whorls are called sutures. Internally all the whorls of the shell are freely communicated with one another; such a shell is called unilocular. The body whorl has a large mouth or opening, the margin of the mouth is called a peristome from which the head and the foot of the living animal can protrude.

When viewed from the ventral side with the peristome facing the observer, the mouth lies to the right of the columella and the shell is spiralled clockwise, then it is spoken of as being right-handed or dextral. The outer

margin of the mouth is called an outer lip, and the inner margin as inner or columellar lip.

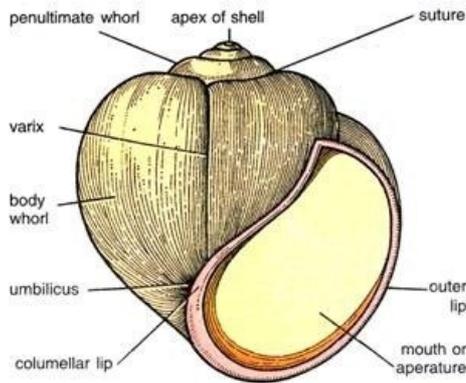


Fig. 60.1. *Pila globosa*. Shell seen from ventral surface.

In the centre of the shell runs a vertical axis or columella around which the whorls of the shell are coiled; the columella is hollow and its opening to the exterior is known as an umbilicus. Shells with an umbilicus are umbilicate or perforate. The lines of growth of shell are visible, some of them appear as ridges known as varices. The shell of *Pila globosa* varies in colour from yellowish to brown or even blackish.

Operculum of *Pila Globosa*:

Fitting into the mouth of the shell is a calcareous operculum, its outer surface shows a number of rings of growth around a nucleus; the inner surface has an elliptical boss for attachment of muscles, the boss is

cream- coloured and is surrounded by a groove. The operculum is, in fact, secreted by the glandular cells of the foot.

Microscopic Structure of Shell:

The shell of *Pila globosa* consists of an outermost pigmented layer called periostracum made of a horny organic conchiolin, below this is a prismatic layer made of crystalline calcareous plates running vertically, the innermost nacreous layer is made of calcareous plates running longitudinally.

ADVERTISEMENTS:

Shells of Gastropoda display an infinite variety of shapes, sculpturing, patterns, and colours. Inside the shell is the mantle which secretes the shell.

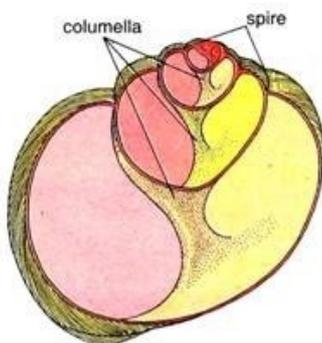


Fig. 60.2. *Pila globosa*. Shell seen from dorsal surface.

Body of Pila:

The body consists of a head, a foot and a visceral surface, mass. In an expanded animal the head and foot come out of the shell-mouth but the visceral mass lies inside the shell whorls. A collumellar muscle arises from the foot and is inserted in the columella, it attaches the body to the shell and it withdraws the animal inside and closes the operculum.

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(i) Head:

There is a distinct head produced into a snout, the head bears two pairs of tentacles. The first pair of tentacles or labial palps are small and lie in front, behind them there is a second pair of tentacles which are long. The tentacles are hollow and capable of much extension and contraction. Behind the tentacles the head has a pair of eyes borne on stalks or ommatophores.

(ii) Foot:

Below the head is a large muscular foot, its lower surface is gray and flattened sole. It is triangular with the apex pointing backwards, it is used for creeping; its upper surface is spotted and the dorsal posterior surface bears the operculum.

ADVERTISEMENTS:

When the foot is withdrawn the operculum closes the mouth of the shell. In the foot is a pedal mucous gland which forms a slime trail during locomotion. Waves of contraction which sweep from the anterior to the posterior end of the foot provide the main power for locomotion.

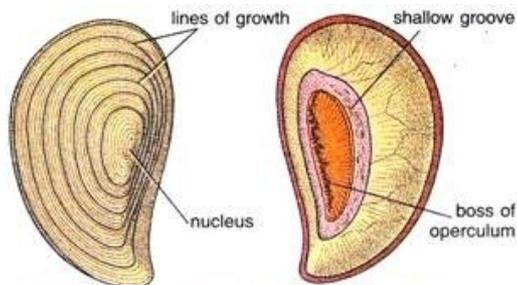


Fig. 60.3. *Pila globosa*. Operculum. A—Outer view; B—Inner view.

In fact, the head and the foot together constitute the head-foot complex which is connected to the visceral mass by an inconspicuous neck.

(iii) Visceral Mass:

ADVERTISEMENTS:

Above the head-foot complex is a visceral mass containing the main organs, it fills all the whorls of the

shell and it is spirally-coiled like the shell. The visceral mass exhibits the phenomenon of torsion which is distinct from coiling. It is soft and grey to dark brown in colour.

(iv) Mantle:

The mantle, also referred to as pallium, covers the visceral mass and it forms a hood over the animal when it is withdrawn. The edge of the mantle is thick and contains shell glands which secrete the shell, above the thickened edge there is a supra-marginal groove.

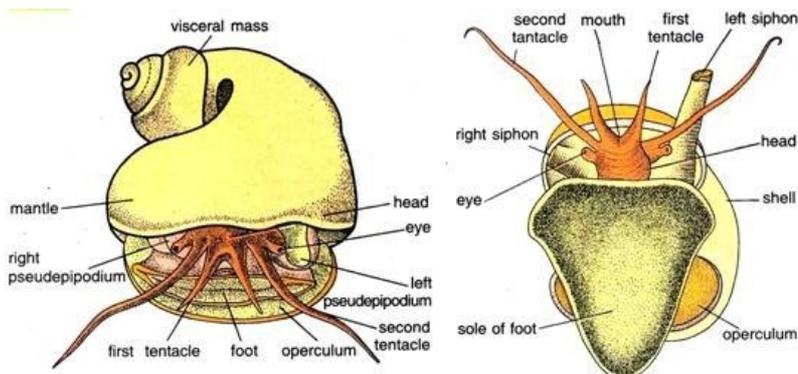


Fig. 60.4. *Pila globosa*. Front view of the animal after removal of the shell.

Fig. 60.5. *Pila globosa*. A living animal seen from the ventral side showing the elongated siphon formed by the left pseudopodium.

The mantle also has two fleshy lobes called nuchal lobes or pseudopodia which are joined on either side of the head. The left pseudopodium forms a long tubular respiratory siphon for aerial respiration and a respiratory current enters, through it, the right

pseudepipodium is less developed and not a regular tube, respiratory current passes out through it.

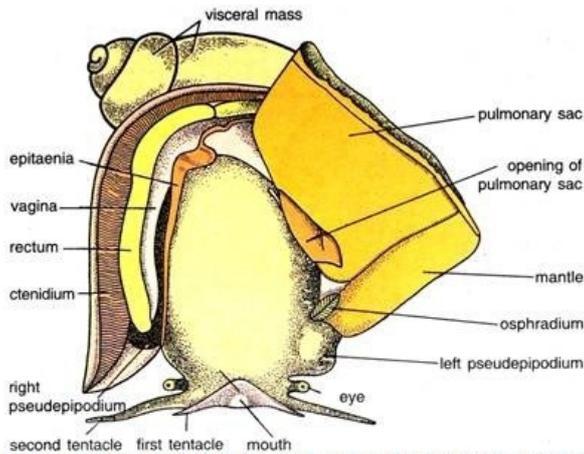


Fig. 60.6. *Pila globosa*. A female individual dissected to show the organs of the pallial cavity.

Mantle Cavity and Pallial Complex:

In the anterior part there is a large space between the mantle and the body, this is a mantle or pallial cavity which has been shifted to the front by a process of torsion. It encloses a number of organs and the head can be withdrawn into it. The mantle or pallial cavity encloses within it a number of important organs which are collectively known as pallial complex.

Near the right pseudepipodium is a prominent ridge or epitaenia which runs backwards up to the end of the mantle cavity, it divides the mantle cavity into a right branchial cavity and a left pulmonary sac.

In the branchial cavity or chamber lie a single gill or ctenidium, rectum and anus, the genital aperture and the anterior chamber of the kidney as a reddish mass near the posterior end of the epitaenia. Near the left pseudopodium is a fleshy osphradium a typical molluscan sense organ.

3. Coelom of Pila Globosa:

The coelom is reduced to unpaired cavities of pericardium, kidney and gonad. The renal and pericardial cavities communicate, but the cavity of gonad is unconnected. The visceral organs are surrounded by means of sinuses or spaces containing blood. These blood-filled spaces constitute the haemocoel.

4. Digestive System of Pila Globosa:

The digestive system of Pila Globosa comprises:

- 1. A tubular alimentary canal**
- 2. A pair of salivary glands**
- 3. A large digestive gland**

(i) Alimentary Canal:

The alimentary canal is distinguished into three regions, viz:

- 1. The foregut or stomodaeum including the buccal mass and oesophagus,**
- 2. The midgut or mesenteron consisting of stomach and intestine, and**
- 3. The hindgut or proctodaeum comprising the rectum. The midgut alone is lined by endoderm, while the other two are lined by ectoderm.**

1. Foregut:

The foregut includes the mouth, buccal mass and oesophagus.

(i) Mouth:

The mouth is a narrow vertical slit situated at the end of snout. There are no true lips but the plicate edges alone serve as secondary lips.

(ii) Buccal Mass:

The mouth leads into a large cavity of buccal mass or pharynx having thick walls with several sets of muscles. The anterior part of the cavity of buccal mass is vestibule. Behind the vestibule are two jaws hanging from the roof of the buccal mass. The jaws bear muscles and their anterior edges have teeth-like

projections for cutting up vegetable food.

Buccal Cavity:

Behind the jaws is a large buccal cavity. On the floor of the buccal cavity is a large elevation called odontophore. The front part of odontophore has a furrowed subradular organ which helps in cutting food. The odontophore has protractor and retractor muscles and two pairs of cartilages, a pair of triangular superior cartilages which project into the buccal cavity, and a pair of large S-shaped lateral cartilages.

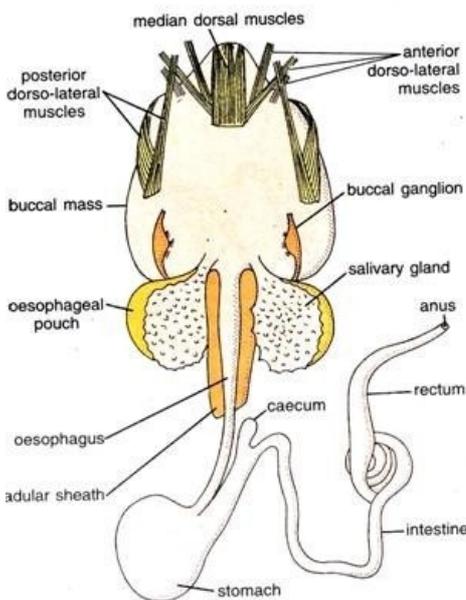


Fig. 60.7. *Pila globosa*. Alimentary canal.

Radula:

Above and behind the odontophore is a bag-like radular sac which is a diverticulum of the buccal cavity. The radular sac has transverse rows of cells called odontoblasts. Inside the radular sac is a radula which is characteristic of Mollusca. The radula is made of many transverse rows of horny teeth.

Each row has seven teeth, two marginal and one lateral tooth on each side and a central or rachidian tooth in the middle, thus, giving a formula 2, 1, 1, 1, 2. The radula moves forward and backward on the odontophore for rasping food particles; these movements of radula are called chain saw movements.

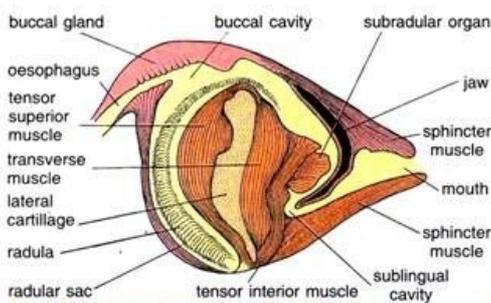


Fig. 60.8. *Pila globosa*. Vertical longitudinal section of the buccal mass about the middle.

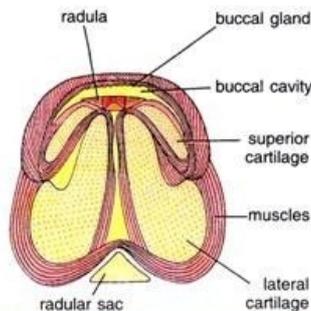


Fig. 60.9. *Pila globosa*. Buccal mass in T.S.

The teeth are made of chitin which is reinforced by hardened protein, they have sharp cutting projections which act like a file and rasp vegetable food. The teeth of the radula are worn off in front and new teeth are formed all the time by odontoblasts. On the roof of

buccal cavity, above the radula, is a pair of grooved buccal glands which are digestive.

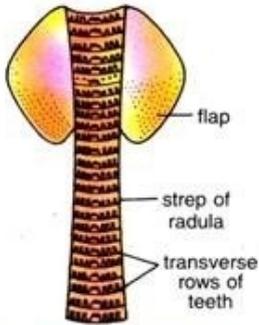


Fig. 60.10. *Pila globosa*.
The radula.

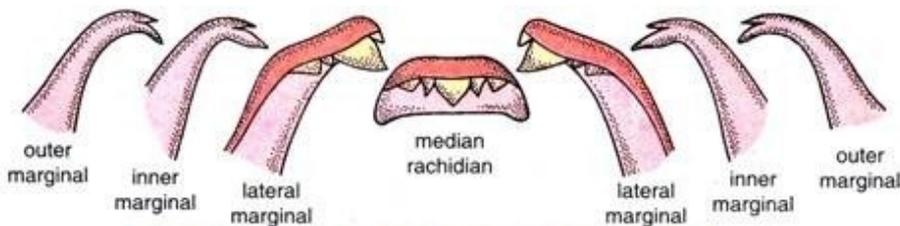


Fig. 60.11. *Pila globosa*. A single row of radular teeth.

(iii) Oesophagus:

The buccal mass leads into a long narrow oesophagus. From near the origin of the oesophagus arise a pair of round, whitish oesophageal pouches. They arise by short ducts and lie below the salivary glands. They are prolongations of the oesophagus,

they probably secrete digestive enzymes.

Oesophageal pouches serve for a temporary storage of food and digestion begins in them. Some extracellular digestion is brought about in the stomach by the enzymes produced by the salivary glands and oesophageal pouches.

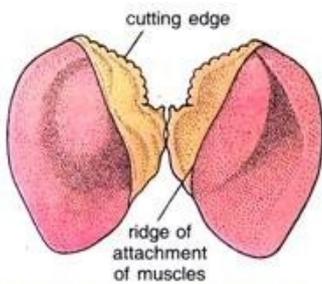


Fig. 60.12. *Pila globosa*. Jaws.

2. Midgut:

The midgut includes the stomach and intestine.

(i) Stomach:

The stomach begins on the left side just below the pericardium and runs backwards as a blind pouch on the postero-lateral sides of the main whorl of the visceral mass. It is a rectangular sac of dark red colour having a broad U-shaped internal cavity of rose-red colour. The stomach is differentiated into two

chambers—cardiac chamber and pyloric chamber.

The cardiac chamber is rounded in appearance and possesses longitudinal folds on its inner surface. The oesophagus opens into it. The pyloric chamber is tubular and has transverse folds on its inner surface. From the pyloric chamber arises a short bag-like caecum but it has no crystalline style as found in many gastropods. The duct of digestive gland opens into the stomach at the junction of its two chambers.

(ii) Intestine:

From the pyloric chamber arises an intestine which runs along its anterior edge and further along the digestive gland beneath the posterior renal chamber. It then turns upwards and backwards in the visceral mass where it forms $2\frac{1}{2}$ or 3 coils between the gonad in front and the digestive gland behind, before joining the rectum.

3. Hindgut:

The rectum or terminal part of the alimentary canal is a thick-walled tube. It enters the mantle cavity and passes downwards to open by an anus on the right of the head.

Salivary Glands:

The two salivary glands lying one on each side of the posterior limit of the buccal mass and partially cover the oesophagus. The surface and margins of each gland are greatly cut up, giving it the appearance of a somewhat branched type of gland.

The duct of each gland begins near its internal anterior corner and immediately enters the muscles of the buccal mass and opens into the buccal cavity. The secretion of salivary glands contains mucus and an enzyme which digests starch. The mucus lubricates the radula and helps in the transport of food.

Digestive Glands:

The digestive gland, often referred to as liver or hepatopancreas, of *Pila globosa* is a somewhat triangular plate or cone with a very convex outer and more or less flattened inner surface. The cone is spirally coiled from the tip inwards and downwards following the whorls of the shell.

The gland is of a brownish to dirty green colour and is quite soft when fresh. Two main ducts arise from the two main lobes of the digestive gland; these ducts unite just before reaching stomach to open into it by a common aperture.

The digestive gland is made up of a number of fine tubules bound together by connective tissue. These

tubules unite with one another to form larger tubules which terminate in two main ducts corresponding to two main lobes of the gland. The terminal part of each tubule is glandular, called the alveolus and the rest of the tubule is ciliated.

The alveoli have three kinds of cells, they are secretory, resorptive and calcareous cells or lime cells. The secretory cells produce a brown liquid containing an enzyme which dissolves cellulose of plants in the stomach converting in into pulp. The resorptive cells produce a proteolytic enzyme. This enzyme brings about intracellular digestion of cellulose pulp. The calcareous cells store phosphate of lime.

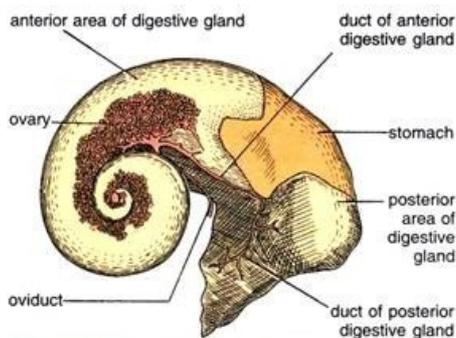


Fig. 60.13. *Pila globosa*. Digestive gland and associated structures seen from inner side.

(ii) Food and Feeding:

The food consists of aquatic plants of succulent nature like Vallisneria and Plstia which are cut by jaws

and the odontophore, then the radula moves forwards and backwards filing the food into small particles exactly like the chain-saw mechanism. Thus, the food is cut up and masticated inside the buccal cavity.

(iii) Digestion:

The salivary glands pour their secretion by means of their ducts into the buccal cavity where it mixes with the food. It helps in digesting the starch by converting it into sugar. In the stomach the food is digested by the secretion of digestive gland. Secretion of digestive gland digests various kinds of food but cellulose is digested inside the resorptive cells only.

Thus, both extracellular and intercellular digestion occur. The stomach is the site of extracellular digestion and the digestive gland is the site of intracellular digestion and absorption, this is characteristic of Mollusca. Absorption of digested food takes place mainly in the digestive gland and some in the intestine.

5. Respiratory Organs of Pila Globosa:

The respiratory organs consist of a single ctenidium or gill, a pulmonary sac or lung and a pair of nuchal lobes.

1. Ctenidium or Gill:

The ctenidium or gill is the organ of aquatic

respiration. The ctenidium is situated on the dorsolateral wall of the branchial chamber of the mantle cavity. It is composed of a long series of thin triangular leaflets or lamellae, lying parallel to each other, which are attached to the mantle wall by their broad bases but have their apices hanging free in the branchial chamber.

The line of attachment of the lamellae to the wall of the mantle forms the ctenidial axis. The ctenidial axis is provided with an afferent blood vessel (carrying deoxygenated blood) and an efferent blood vessel (carrying oxygenated blood) from gills to heart.

All the gill lamellae are not of the same size; these are largest in the middle and gradually smaller towards the two ends. Such a gill is known as monopectinate gill. Each lamella bears transverse ridges or pleats on both its anterior and posterior surfaces.

These pleats are low ridges gradually decreasing in size from the base of the lamella to its apex. Each ridge contains branches of blood vessels. Each lamella has a smaller right side, which receives blood from the afferent vessel, is called the afferent side and a longer left side, from which blood goes into the efferent vessel, is called the efferent side.

The ctenidium of *Pila*, though situated on the right side of the animal, is morphologically the gill of the left

side, which has shifted to the right on account of the development of an extensive pulmonary sac on the left side. This is shown by the blood supply and the innervation of the ctenidium and is further confirmed by the situation of the osphradium which still retains its original position on the left side of the animal.

Histologically, each lamella appears to be a hollow cavity lined on either side by the epithelium containing non-ciliated columnar cells, ciliated columnar cells and a few glandular cells. The epithelial layer is followed by a thin basement membrane below which are found connective tissue cells having scattered nuclei and oblique muscle fibres.

2. Pulmonary Sac or Lung:

The pulmonary sac or lung is a closed cavity like a bag which hangs from the dorsal wall of the mantle in the pulmonary chamber.

The dorsal wall of the pulmonary sac is densely pigmented, while the ventral wall is creamy white. The walls of the sac are highly vascular, i.e., richly supplied with blood vessels. The pulmonary sac communicates with the pulmonary chamber of the branchial cavity by an aperture known as the pneumostome.

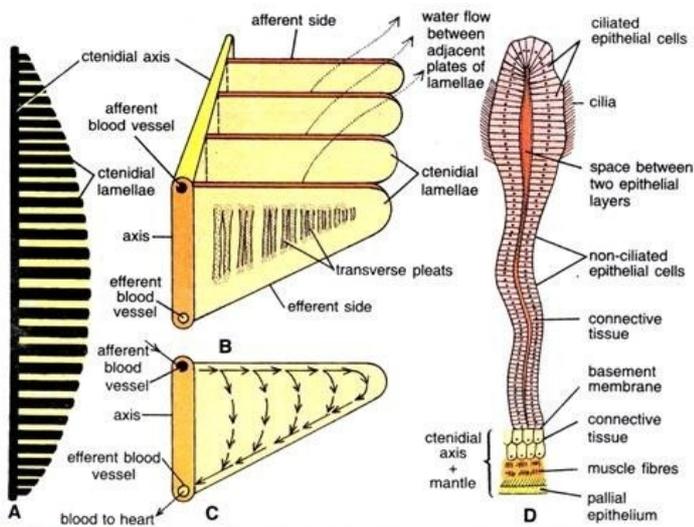


Fig. 60.14. *Pila globosa*. Respiratory organs. A—A monopectinate ctenidium; B—Stereogram to show water current through gill-lamellae; C—A single lamella to show flow of blood within it; D—A lamella in T.S.

3. Nuchal Lobes:

The right and left pseudopodia or nuchal lobes are fleshy and highly contractile processes of the mantle on either side of the head. They form elongated funnels or siphons during respiration for the entry and exit of water.

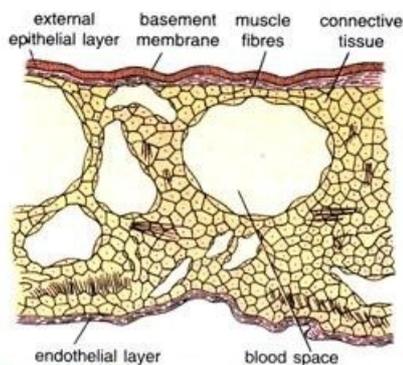


Fig. 60.15. *Pila globosa*. T.S. of a portion of the outer wall of the pulmonary sac.

Mechanism of Respiration:

There are two types of respiration in Pila which are as follows:

(i) Aquatic Respiration:

True aquatic respiration takes place when the snail lies at the bottom of a pond or aquarium, when it is floating or lying suspended in mid-water and when it is attached to plants or Weeds in water. At this time the head and foot is fully extended and the two nuchal lobes further increase in size and the left lobe takes the form of a distinct gutter in which a current of water flows.

In aquatic respiration a current of water enters the left nuchal lobe and first comes in contact with the osphradium which tests the nature of the water.

It enters the mantle cavity and passes over the epitaenia into the branchial chamber to bathe endothelial layer blood space the ctenidium, then the current passes out through the right nuchal lobe (Fig. 60.16 A). The ctenidium takes in oxygen from the current of water and gives out carbon dioxide which diffuses into water.

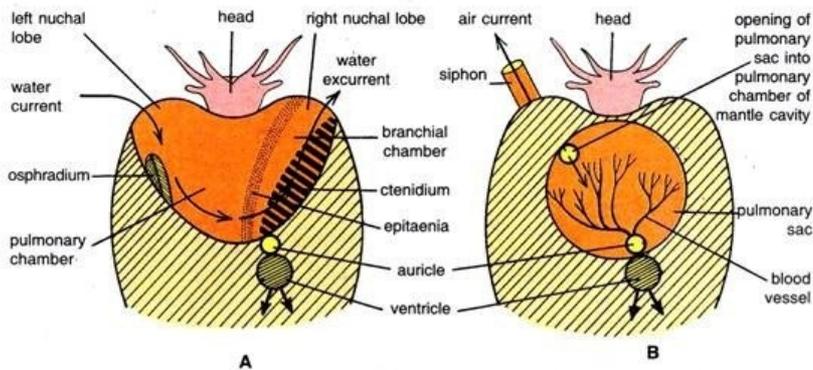


Fig. 60.16. *Pila globosa*. Diagrams showing mechanism of respiration. A—During aquatic respiration; B—During aerial respiration.

(ii) Aerial Respiration:

The pulmonary sac or lung is used in aerial respiration in two ways. When the snail comes to the surface of water its left nuchal lobe projects as a tube above the water and air is drawn into it, the air goes to the pulmonary chamber and then into the lung; the branchial chamber being shut off by the epitaenia pressing against the mantle.

When the snail comes on land it takes in air directly into its lung through the mantle cavity and no siphon is formed by the left nuchal lobe.

In both types of aerial respiration alternate contractions and relaxations of the muscles of the lung walls take place, when the muscles contract the floor of the lung gets arched increasing its cavity and air is drawn into the lung, when the muscles relax the cavity of the lung decreases and air is expelled, inward

and outward movements of the head and foot also help in the process of taking in air.

The blood vessels in the lung take in oxygen from the air and give out carbon dioxide (Fig. 60.16 B). *Pila globosa* also respire by its pulmonary sac during aestivation period by means of the air already imprisoned in the pulmonary sac.

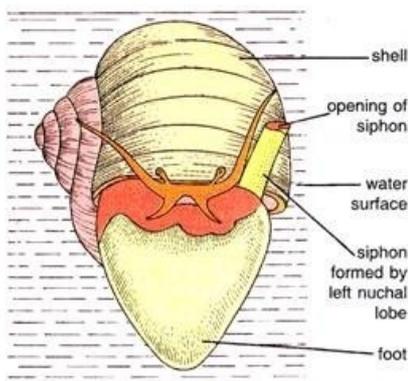


Fig. 60.17. *Pila globosa* with its siphon up for breathing air.

6. Blood Vascular System of *Pila Globosa*:

Due to double mode of respiration the blood vascular system of *Pila globosa* has become very much complicated. It is of open type.

It consists of:

(i) Pericardium

(ii) Heart

(iii) Arteries

(iv) Sinuses

(v) Veins, through which the blood flows.

(i) Pericardium:

The pericardium is a thin-walled ovoid sac lying dorsally on the left side of the body whorl behind the mantle cavity. It extends anteriorly up to the stomach and digestive gland.

It is a fairly deep cavity which communicates with that of the posterior renal chamber through a reno-pericardial aperture. The pericardium corresponds to the coelom of annelids and vertebrates. It encloses the two chambers of the heart, the main aortic arches and the aortic ampulla.

(ii) Heart:

The heart of *Pila globosa* has a single auricle and one ventricle found enclosed in the pericardium. Physiologically, the heart is said to be myogenic.

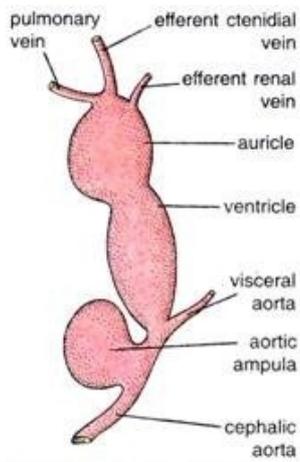


Fig. 60.18. *Pila globosa*. Heart.

(a) Auricle:

The auricle lies in the dorsal part of the pericardium, while the ventricle is situated just below it in the same vertical axis. The auricle is a thin-walled, highly contractile sac and more or less triangular in shape.

The efferent ctenidial vein from the ctenidium and the efferent renal vein from the posterior chamber of the renal organ open into the apex of the auricle, while the pulmonary vein from pulmonary sac opens at a slightly lower level at its anterior end.

The auricle communicates with the ventricle by an aperture auriculo-ventricular opening having two semi-lunar valves, so arranged as to allow the blood from the auricle to flow into the ventricle but not in the reverse direction.

(b) Ventricle:

The ventricle is ovoidal in shape and has thick spongy wall formed of a large number of muscular strands forming a meshwork which greatly reduces the cavity of the ventricle. The aortic trunk arises from the lower end of the ventricle and divides immediately into two branches, the cephalic aorta and visceral aorta. The opening between ventricle and aortic trunk is guarded by two semi-lunar valves which prevent the flow of blood from back into the ventricle.

(iii) Arteries:

From the ventricle arises an aorta or aortic-trunk which divides into two branches, a cephalic aorta and a visceral aorta.

The cephalic aorta has a bulbous outgrowth called aortic ampulla, a characteristic of the members of the family Pilidae, which aids in circulation of blood and controls blood pressure. The opening of aortic ampulla into cephalic aorta is devoid of valves. The cephalic aorta sends arteries to the head and buccal mass, the visceral aorta forms arteries going to the visceral mass.

(a) Cephalic Aorta:

The cephalic aorta, immediately beyond aortic

ampulla, gives out three arteries; first supplying to the skin, the cutaneous artery, second supplying to the oesophagus, the oesophageal artery and third being stout and thick supplies to the left side of the mantle (organs like left nuchal lobe and osphradium), the left pallial artery.

The cephalic aorta on its inner side gives out an artery supplying to the pericardium, renal chambers and to a portion of the genital organs, the pericardial artery.

The main trunk of cephalic aorta then runs ahead and crosses over the oesophagus so as to reach to its right side.

It now gives off numerous small branches to the oesophageal area and a large branch to the right side which finally gives out a right pallial artery, supplying to the right part of mantle, a right siphonal artery, supplying to the right nuchal lobe and a penial artery, supplying to the copulatory organ.

The main trunk of cephalic aorta, however, also branches to give a radular sac artery supplying to radular sac, an optic artery supplying to the eyestalks and eyes, a tentacular artery supplying to the tentacles and pedal arteries supplying to the foot.

(b) Visceral Aorta:

The visceral aorta runs into the visceral mass and supplies to its different organs by giving off many branches.

These branches are:

A pericardial artery to the pericardium, skin and digestive glands, a gastric artery to the stomach, many small intestinal arteries to the intestine, many renal arteries to the roof of the posterior renal chamber, a hepatic artery to the digestive gland and gonad, several small arteries to the tip of the genital duct and then finally the visceral aorta terminates in the rectal wall.

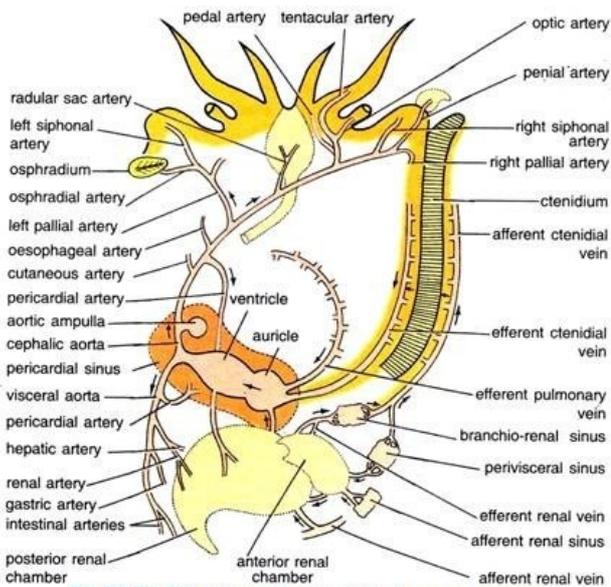


Fig. 60.19. *Pila globosa*. Heart and blood-vascular system.

(iv) Sinuses:

The blood after being distributed to the various parts of the body through the arteries and their branches passes into small lacunae, which in turn unite to form large sinuses.

There are four chief sinuses in the body:

(a) Anterior peri-visceral sinus.

(b) Anterior peri-intestinal sinus.

(c) Branchio-renal sinus and

(d) Pulmonary sinus.

(a) Anterior peri-visceral sinus:

It lies above the foot and beneath the floor of the pallial cavity surrounding the anterior part of the alimentary canal. It collects blood supplied by the cephalic aorta, except pericardial artery, and some branches of visceral aorta.

(b) Anterior peri-intestinal sinus:

It lies on the columellar axis next to the intestine and the terminal part of the genital duct and runs along the coils of the intestine up to the junction of the anterior and posterior renal chambers. It collects blood from viscera mainly distributed by visceral aorta.

(c) Branchio-renal sinus:

It lies along the right side of the anterior renal chamber. It collects blood from renal chambers.

(d) Pulmonary sinus:

It lies in the walls of the pulmonary sac. It collects blood from pulmonary sac.

(v) Veins:

The veins carry venous blood from different parts of the body to the auricle directly or through the gill, mantle and kidney.

The chief veins are as follows:

(a) Afferent ctenidial vein:

It lies above the rectum and receives branches from the rectum, terminal part of the genital duct, peri-visceral sinus and branchio-renal sinus. It sends blood through numerous branches, to the gill-lamellae for purification.

(b) Efferent ctenidial vein:

It lies along the roof of the anterior renal chamber

and carries blood from ctenidial leaflets, mantle and conveys to the auricle.

(c) Afferent renal vein:

It is situated on the roof of posterior renal chamber, and originates from the peri-intestinal sinus. It pours its blood into the posterior renal chamber.

(d) Efferent renal vein:

It carries the blood of the posterior renal chamber to the auricle.

(e) Pulmonary vein:

It collects blood from the walls of the pulmonary sac and opens into the auricle.

Blood:

The blood of gastropods contains a respiratory pigment called haemocyanin which is a compound of copper and protein, haemocyanin is dissolved in the plasma and gives a faintly blue colour to the blood.

But in a few gastropods, such as Planorbis, haemoglobin is found in place of haemocyanin. In the blood plasma are stellate amoebocytes which are phagocytic, they remove waste substances and some

of them carry on intracellular digestion.

Course of Circulation:

All parts of the body are supplied with blood from the ventricle through the cephalic and visceral aortae. The cephalic aorta carries blood to the head and its associated structures, a part of the mantle, the buccal mass, the oesophagus, the copulatory organ and the columellar muscle.

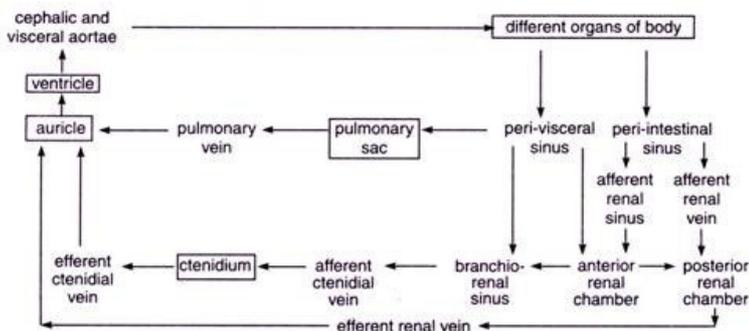


Fig. 60.20. *Pila globosa*. Diagrammatic representation of the course of circulation.

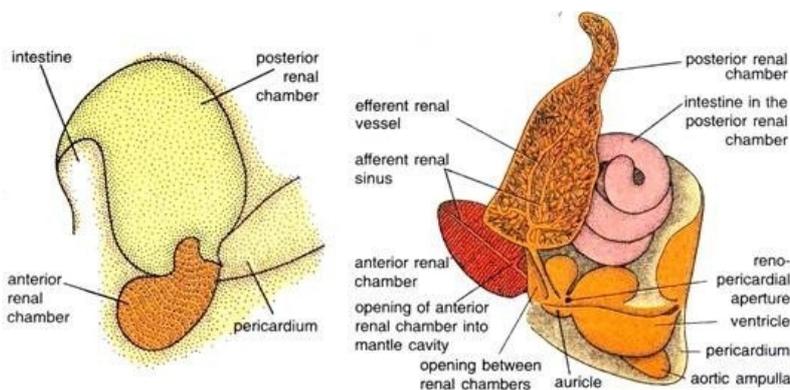


Fig. 60.21. *Pila globosa*. Renal chamber seen from above. Fig. 60.22. *Pila globosa*. Pericardium and two chambers of renal organ.

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PART 2

Torsion and Detorsion in Gastropoda

Definition:

Torsion (twisting) is the rotation of visceral organs in anticlockwise direction through an angle of 180° on the rest of the body during larval development. The phenomenon takes place in the free-swimming (veliger) larva of gastropods and converts the symmetrical larva into an asymmetrical adult.

Contraction of the larval retractor muscles and differential growth are possibly responsible for such rotation (Fig. 16.71 A, B, C). Entire rotation results within few minutes. Asymmetry is encountered at the early stage in Veliger larva where the mesodermal bands develop asymmetrically. The mesodermal band on the right side is larger than its left counterpart.

The right band is composed of five mesoderm cells which elongate to form muscle cells. With the transformation of the muscle cells the visceral hump is displaced to the left side.

These cells on the right side converge and transform into the larval retractor muscles. The muscle cells are absent on the left side. Torsion of the visceral hump

commences as soon as the larval muscle cells attain the power of contraction (Fig. 16.71 A, B, C).

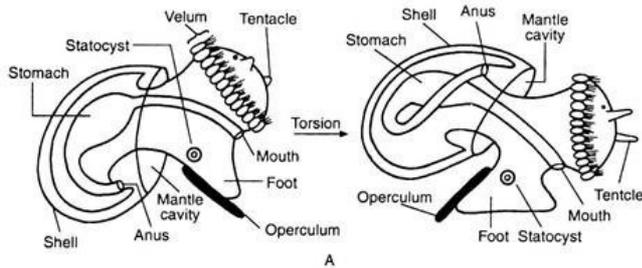


Fig. 16.71A: Figures showing the torsion of a free-swimming larva in a primitive gastropod (*Patella* sp.) (after Pechenik).

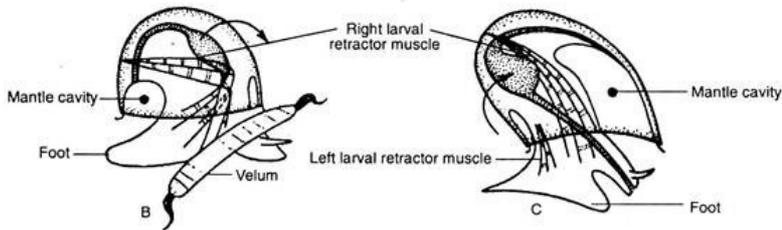


Fig. 16.71B, C: Diagrammatic representation of torsion in veliger larva of a prosobranch. B. Pre-torsional stage. C. Post-torsional stage (after Parker and Haswell).

Conditions before Torsion:

1. The mantle cavity is situated at the posterior side containing the pallial complex.
2. The ctenidia and two nephridiopores are located posteriorly.
3. The alimentary canal is straight with the mouth at the anterior side and anus at the posterior side.
4. The auricles are placed behind the ventricle.

5. The nervous system is bilaterally symmetrical.

6. Firstly, the embryo is bilaterally symmetrical in the veliger stage when foot and a planospiral shell are formed first in this stage.

Remarks:

Torsion is not the coiling of the shell and all the evidences indicate that the shell evolved before torsion.

How Torsion Occurs:

1. The morphological phenomenon of bending on the ventral side which takes place in an antero-posterior sagittal plane about a transverse axis of the animal results.

(a) Firstly, the displacement of the mantle cavity towards the right side and then to the anterior end of the body but the head and foot remain fixed (Fig, 16.72).

(b) The looping of the digestive tract and approximation of mouth and anus take place.

(c) The original saucer-shaped visceral mass and the shell become cone-shaped and finally become spirally

coiled.

2. Simultaneous coiling up of these structures results in an exogastric coil.

3. Ventral portion of the visceral mass and mantle rotate about 180° or little more.

4. Twisting of dorsal mass occurs in such a manner that organs such as right gill and right auricle remain and corresponding parts on the left side are often lost.

5. During the completion of metamorphosis there is a lateral torsion subsequent to primitive ventral plexus with the result that the original coil of the visceral sac and the shell which was originally dorsal or exogastric becomes ventral or endogastric. So the lateral torsion leads to the attainment of condition of gastropods following certain changes in original organisation.

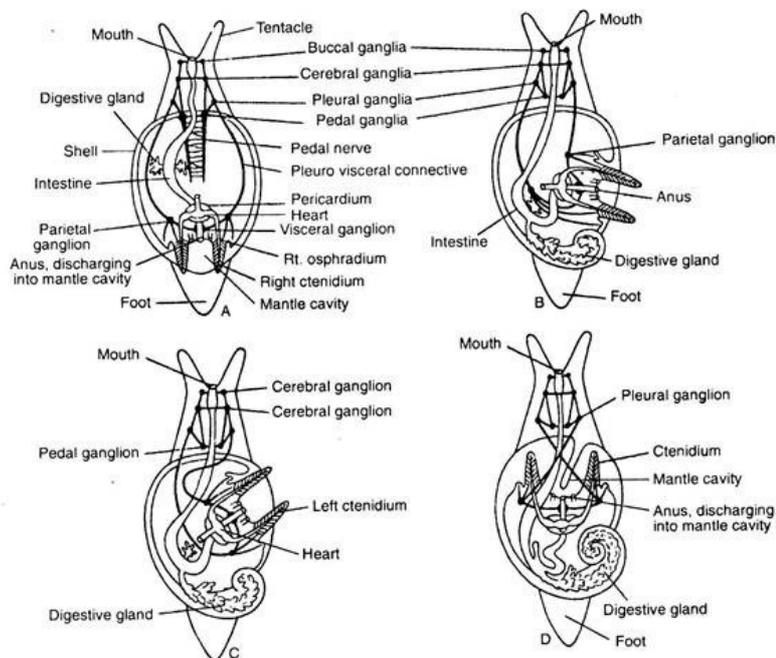


Fig. 16.72: Diagrammatic representation of torsion in Gastropod. A. Hypothetical ancestral stage with symmetrical arrangement of structures. B. Displacement of the mantle cavity to the right side. C. Showing 90° torsion. D. Showing complete torsion.

Cause and Significance of Lateral Torsion:

1. Lateral torsion is due to arrested growth of one side and active expansion of the other. Generally the growth of the right side becomes retarded so that the mantle cavity and pallial complex gradually pass down to the right side and to the anterior side on account of the better growth of visceral mass towards the left.
2. This is necessary for protection, compactness and provision for continuous growth. This is the response with necessity in life of animal for best adaptation.

Effect of Torsion and Shuttling of Pallial Complex:

ADVERTISEMENTS:

1. Displacement of mantle cavity:

The mantle cavity was originally posterior in position but after torsion the mantle cavity opens just behind the head and its associated parts shifted forward.

2. Changes in relative position:

Before torsion the anus and ctenidia are pointed backwards and auricles are situated behind the ventricle. After torsion the anus and ctenidia come forward and the auricles come to lie in front of ventricle.

3. Twisting of alimentary canal:

The alimentary canal which was primarily straight is twisted in the form of a loop and approximation of mouth and anus takes place.

4. Origin of chiastoneury:

Crossing of the pleuro-visceral connectives is due to the fact that the pallial complex must have changed its position from the posterior to the anterior part of the body and become twisted in the form of 8. The right connective with its parietal ganglion passes over the intestine called the suprainestinal and the left connective passes below the intestine called the

infraintestinal.

5. Endogastric coil:

The coil of visceral sac which was primarily dorsal or exogastric becomes ventral or endogastric after torsion. The coiling of the shell is not associated with the torsion and was a separate evolutionary event and the shell remained a symmetrical spiral.

6. Loss of symmetry:

It is due to displacement of anus towards right side of the mantle cavity and loss or reduction of paired parts of the primitively left or topographically right side.

In majority of the gastropods torsion, as already stated, is resulted in two stages, viz., Stage-I and Stage-II:

Stage-I:

The contraction of the larval retractor muscles account for 90° of the rotation of the visceral hump. This process usually lasts for only a few hours. At the end of Stage-I, the mantle cavity (which was initially situated ventrally and posteriorly) comes on the right side with the foot projecting on the left side.

Stage-II:

The rest of the torsion is the result of differential growth and is usually longer in duration. Actual mechanism of torsion in gastropods is not properly known and it is difficult to give a generalised account of torsion in gastropods.

However, Thomson (1958) distinguished five possible ways by which torsion has resulted in gastropods:

They are:

(a) 180° rotation of visceral hump is achieved by muscular contraction alone. This mechanism is seen in *Acmaea* and is regarded to be the original way of torsion.

(b) The commonest way of torsion (180°) as encountered in *Haliotis*, *Patella*, etc., is achieved in two subsequent stages.

(i) The initial 90° rotation is caused by the contraction of the larval retractor muscle and

(ii) The remaining 90° is effected by differential growth. The first phase occurs at a faster rate, while the next phase is slower.

(c) In some gastropods as exemplified by *Vivipara*, complete (180°) rotation is achieved exclusively by growth processes.

(d) In Aplysia, torsion is resulted by differential growth and the change in position of anus is halted at a region appropriate to the adult stage.

(e) In Adalaria, torsion of the visceropallium is not recognisable. The different organs appear as in the post- torsional position.

Whatever be the cause of torsion in gastropods, a post-torsional larva possesses an anteriorly placed mantle cavity and all the developing organs are severely affected.

With the completion of torsion many organ systems (e.g., Pallial organs, nervous system) become greatly affected. Formation of loop and crossing of pleuroparietal connectives are a common occurrence in the nervous system in gastropods, especially protobranchia.

Views on the Significance of Torsion in Gastropods:

Torsion is a characteristic feature of gastropods. The significance of such torsion in gastropods is not clear. Several contrasting views are extant on this issue.

They are:

(a) Garstang's view:

Garstang (1928) advocated that torsion is an adaptive feature and useful to the larvae (veliger larva) for protection of soft parts against enemies but of little direct use to the adult.

He suggested that before torsion the untwisted larva swimming the sea was subjected as an easy prey to its predators because the mantle cavity was at the posterior position and there is no place into which delicate head and velum can be withdrawn at the time of danger so it is disadvantageous to the larval life.

But after torsion the mantle cavity is brought around the anterior end of the larva which provides the space for head and velum and the larva gives the greater protection of the head and associated structures. At danger the larva is able to withdraw its head and velum into the mantle cavity. Then the beating of cilia stops and the larva falls to the sea bottom. In this way they avoid the predators.

This view is widely supported by Yonge (1947), Barnes (1980), Ruppert and Barnes (1994) and Anderson (1998). But the recent experiment by Pennigton and Chia (1985) does not support Garstang's view.

Objections:

The theory was criticised for several reasons such as:

- 1. There are many pelagic larvae of lamellidens which are not twisted but still survive in pelagic larval life.**
- 2. The cilia of some gastropods are under nervous control and these could be stopped by simpler means than withdrawing them into the mantle cavity.**
- 3. In Haliotis the shell rotates in two phases – firstly through 90° and secondly then through 180° but the animal is only pelagic at the first stage while the head is unable to retract into the mantle cavity. The larva does not complete its torsion (180°) till it has settled in the bottom.**

(b) C.M. Yonge's theory (1947):

- 1. Primitive Gastropods were not twisted and the gills were attached posteriorly inside the mantle cavity. The cilia of the gills draw the respiratory current from behind the mantle which is in opposite direction of the current produced by the locomotion of the animal and the weak current of the sea itself, thus producing disadvantage in respiration and locomotion.**
- 2. If the animal once twists all the currents would follow in the same direction, thus aid the flushing of mantle cavity with freshwater and thus torsion becomes advantageous for ventilation of mantle cavity.**

3. The twist brings the anus anterior, so there is some chance of interaction between the discharged faecal matter and respiratory current.

To avoid this, at least three adaptations are found:

(a) Shell develops a fold or series of folds. The anus retracted and respiratory currents sweep over the gills, e.g., *Haliotis*.

(b) One of the gills and its associated auricles are lost, so that the respiratory current sweeps laterally through the mantle cavity.

(c) Gills are either reduced or lost. The respiratory surface in the mantle cavity which in some cases develops pallial gills, e.g., *Patella*.

(c) Morton's view:

Morton (1958) emphasises the importance of anterior location of mantle cavity both in larval and adult molluscs. The anteriorly placed mantle cavity housing the head with sense organs, respiratory structures, etc. in adult add positive advantage to test the water and also to come in intimate contact for gaseous exchange with the oncoming water respectively.

(d) Ghiselin's view (1966):

According to him, the primitive gastropods developed a conical shell on the dorsal surface for protection instead of shield-like shell. To maintain the balance of body the shell of the gastropods prolonged anteriorly.

But for the crawling purpose it was disadvantageous bearing such anteriorly prolonged shell. The shell containing anterior- prolonged side rotated into the posterior through 180° during torsion. So it has become advantageous in the adult stage.

Stasek (1972) and Purchon (1977) have also supported that torsion is advantageous during adult stage.

Coiling:

The ability of withdrawal of the head-foot complex into the anterior mantle cavity due to torsion increases the efficiency in locomotion, feeding and sensory function in gastropods. The head-foot complex retains its bilateral symmetry. The visceral hump together with the protecting shell becomes coiled to economise the volume.

Detorsion:

Acquisition of secondary symmetry observed in some Opisthobranch Gastropod is regarded as the result of

detorsion. The distortion means the reversion to the changes that have occurred during torsion. As a result of detorsion the pallial complex travels towards the posterior end along the right side.

The ctenidia are pointed backwards and the auricles come behind the ventricle. The visceral loop becomes untwisted and symmetrical. In this way a secondary external symmetry is established again. Detorsion is always associated with the loss of shell and the liberation of gills (ctenidia) from their enclosing case.

The gills become exposed and subjected to external current. Different gradations of detorsions are encountered in the different members of opisthobranchs. In Acteon and Bulla detorsion is partial, and complete detorsion is observed in Aplysia. In some nudibranchs (e.g., Doris, Apollidia, etc.), the shell and mantle cavity are absent and the body becomes secondarily bilaterally symmetrical.

Respiratory Organs of Phylum Mollusca and Its Modification

1. Skin and mantle.

2. Molluscan gills or ctenidia or branchiae and

3. Lungs or pulmonary sac.

The outer covering of the body (skin) and mantle usually act as accessory respiratory organs.

1. Skin and Mantle – as Respiratory Organs:

Skin appears to be the simplest type of respiratory structure encountered in Molluscs. It acts as a respiratory organ in certain forms where there is no special respiratory device. Such type of respiratory organ is found in Cenia, Limapontid, parasitic Entoconcha, etc.

In most of the members of Aeolididae the dorsal surface of the body is provided with papillae. The papillae are variable in size and communicate with the heart by veins. Most of the Nudibranchia respire through skin. In some forms (e.g., Neomenia, Chaetoderma, Aplysia, Dentalium, etc.), the mantle is used for respiration.

Ctenidium – as the Respiratory Organ:

Aquatic molluscs respire through ctenidia. These are the comb-like outgrowths of the mantle and are located within the mantle cavity.

Structure:

Each ctenidium (pl. ctenidia) or molluscan gill consists of a long flattened axis hangs from the anterior wall of the mantle cavity. The ctenidium contains afferent and efferent blood vessels, muscles and nerves. A row of flattened, triangular gill filaments or lamellae are attached to each side of ctenidial axis. The surface of ctenidium is generally covered with cilia.

Mechanism of Aquatic Respiration:

The movement of water is effected through the mantle cavity by the beating of cilia. Each ctenidium contains afferent and efferent blood vessels which run through the ctenidial axis.

The body of the ctenidium receives deoxygenated blood from the body of the animal through the afferent blood vessel and after oxygenation in the gill filaments the oxygenated blood is sent back to the heart through the efferent blood vessel.

Number of Gills:

In Polyplacophora the gills vary 6-80 pairs. In Monoplacophora the gills vary 3-6 pairs. In primitive gastropods, either two bipectinate (e.g., Pleurotomaria, Haliotis) gills or single bipectinate gill (e.g., Patella, Trochus, Nerita) are present.

In Mesogastropods (e.g., Viviparus, Pila, Lambis, Cypraea, etc.) or Neogastropods (e.g., Murex, Xancus, Conus, etc.), the single monopectinate gill is present. In Bivalves, a pair of platelike gills and in Cephalopods, 4 gills in Nautilus or 2 gills in Coleoidea (e.g., Sepia, Loligo, Octopus, etc.) are present.

Based on the topography, the ctenidia present in molluscs can be divided into following categories:

1. Holobranchiate type
2. Merobranchiate type
3. Plicate type
4. Monopectinate type
5. Bipectinate type:
 - (a) Unequal,
 - (b) Equal.
6. Feathered type.
 1. Holobranchiate type:

This type of arrangement of ctenidia is found in Poly-

placophora. In this form the ctenidia extend all over the body. The number of ctenidia varies from fourteen to seventy pairs and in some cases the number may be about eighty pairs as in *Acanthopleura*.

ADVERTISEMENTS:

In *Patella* (Gastropoda) a circlet of gill lamellae extends completely around the margin of the mantle. It resembles that of *Chiton* superficially which made Cuvier to include *Patella* and *Chitons* under one class *Cyclobranchia*.

But the true nature of ctenidia differs greatly. In *Chiton* the ctenidia are present along the margin of the body excepting the head and anus, but in *Patella* the ctenidia are extended throughout the body.

2. Merobranchiate type:

When the ctenidia remain restricted to a particular area of the body, it is called the merobranchiate type. The merobranchiate type of ctenidia can be subdivided into the following types depending on the arrangement of leaflets.

3. Plicate type:

This type of gill comprises in simple flat transversely folded projecting integumentary laminae. In *Neomenia*

a tuft of filaments arises from the cloacal wall.

4. Monopectinate type:

This type of ctenidia consists of flattened gill filaments arranged in only single side of the ctenidial axis as observed in Pila, Triton.

5. Bipectinate type:

This type of ctenidium has flattened gill filaments arranged in two rows.

They may be of two types:

(a) Unequal:

When both of them are present, but right one is smaller as observed in Fissurella, Haliotis.

(b) Equal:

When both of them are of same sizes. This is the characteristic of the Bivalves. Amongst Bivalves they become variously modified (Fig. 16.66). Nucula possesses short flat leaflets (Fig. 16.66A). In some forms long filamentous leaflets are present.

These filaments may be free as in Area (Fig. 16.66B, C) or may be joined by ciliary connectives as in

**Mytilus (Fig. 16.66D). In Unio (Fig. 16.66E) the cilia
junctions are replaced by membrane. In P
16.66F) the ctenidium becomes
represented as a transverse**

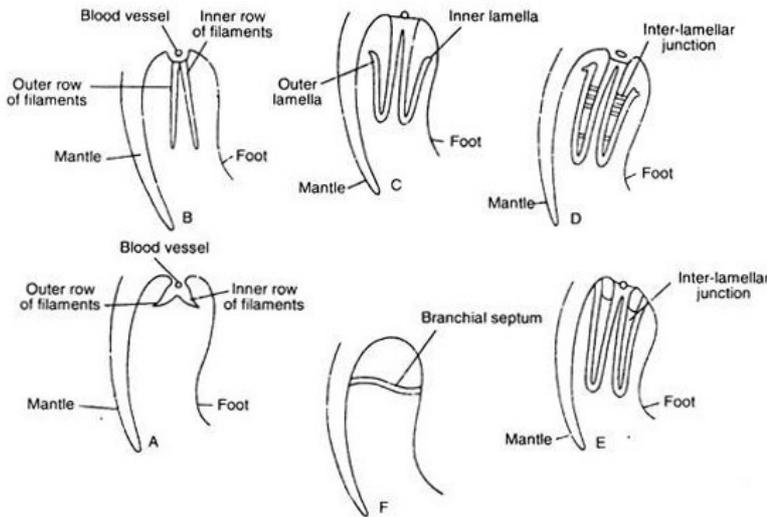


Fig. 16.66: Transverse sections showing the arrangement of gills in bivalves. A. *Nucula*. B. *Amusium*. C. *Arca*. D. *Mytilus*. E. *Unio*. F. *Poromya*.

6. Feathered type:

This type of ctenidium is characteristic of the Cephalopods. Detailed structure is described in the biology of *Sepia*.

Modifications:

The ctenidia become modified in some forms.

Anal gills:

In Doris (see Fig. 16.49B) delicate leaflets form a rosette round the anus and is designated as the anal gills. In Pterotrachea the mantle fold is absent and the filamentous branchial leaflets project freely and remain uncovered. In most cases the mantle may serve as respiratory organ.

In Solenogastres (= Subclass Neomeniomorpha) the cloacal gills are present. Gradual degradation of the cloacal gills is encountered. In Chaetoderma the gills are two in number and are symmetrically placed one on each side of the cloaca. Single distinct gill is present in Neomenia and in Proneomenia, the gills are nothing but a few folds on the cloacal wall.

Cerata:

In Aeolis, Aedida many highly vascular secondary gills (Cerata) are present on the dorsal surface of the body (see Fig. 16.49C) serving for gas exchange.

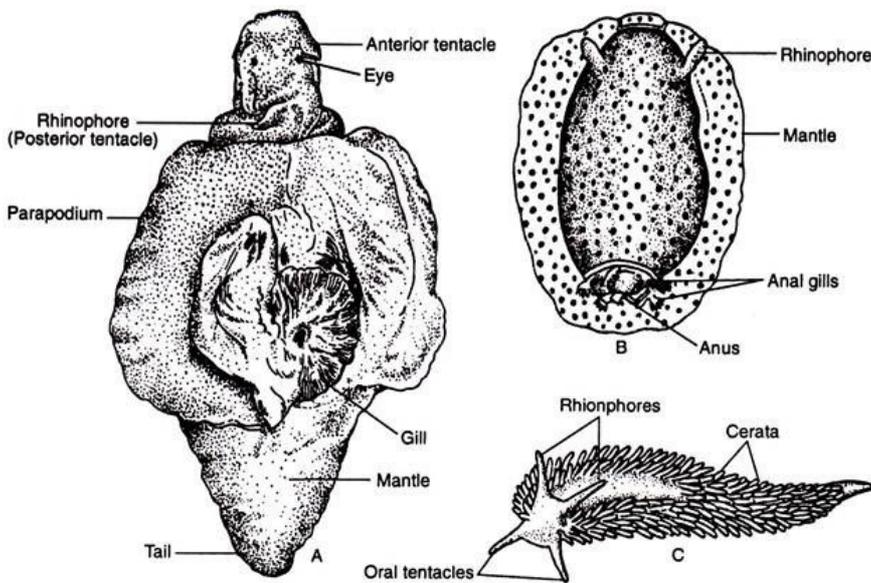


Fig. 16.49: External features of : A. *Aplysia*. B. *Doris*. C. *Aeolis*.

Relationship between heart and gills:

The heart and the gills are intimately related because the main function of the gills is to aerate blood on its way to the heart. The number of gills are directly proportional to the number of the auricles (Fig. 16.67). For example, when the gills are two in number, two auricles are present as encountered in Octopus and Loligo.

In Chiton two auricles correspond to the two sets of the multiple gills, In Nautilus there are four gills and four auricles. When the gill is unpaired, the heart has one auricle as seen in Opisthobranchs, Mesogastropods, Neogastropods, etc.

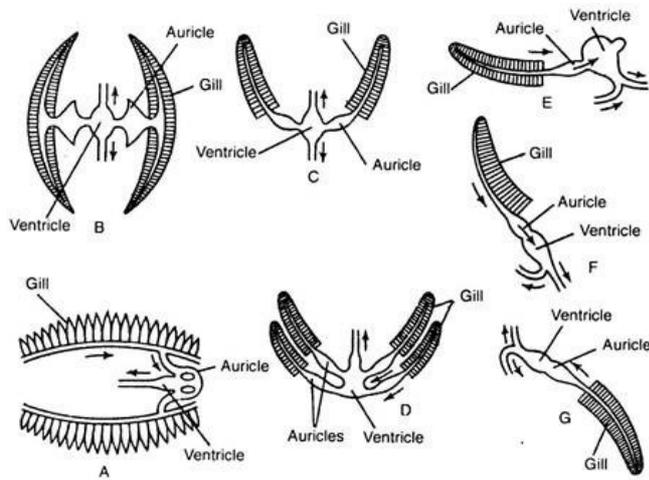


Fig. 16.67: Figures showing the relationship between gills and heart in different molluscs. A. Chitons. B. Bivalvia. C. Dibranchiate Cephalopod. D. Tetrabranchiate Cephalopod. E. Prosobranchia (Diatocardia). F. Prosobranchia (Monotocardia). G. Opisthobranchia.

Respiratory organs for terrestrial mode of living:

Terrestrial habit leads to complete loss of gills and a variety of respiratory organs develop to suit the particular environment.

They are as follows:

Pulmonary sac:

In most Pulmonata the mantle cavity forms a pulmonary chamber, the inner surface of which is highly vascularised.

Trachea:

In some Pulmonata, the pulmonary chamber gives off breathing air-tubes, called trachea.

Nuchal lobe:

In Monotocardia (Mesogastropoda) the left nuchal lobe is better developed and forms a long respiratory siphon.

Amphibious forms:

These forms are exemplified by Pila. It possesses both ctenidium as well as pulmonary sac. The genus Siphonaria is furnished with a lung- cavity and a ctenidium. Both the forms represent a transitional stage between aquatic and terrestrial life.

Circulatory System:

The circulatory system in Molluscs is quite well-developed. Almost all the members of the phylum (excepting Scaphopoda which lacks a distinct heart) have distinct heart which receives oxygenated blood from the respiratory organs and conveys it to the different parts of the body.

Blood:

The blood in Molluscs is colourless. The respiratory pigment is haemocyanin, which contains both iron and copper. Haemoglobin is also present in some rare cases, e.g., Planorbis. Special blood corpuscles with haemoglobin are present in Solen legumen, Area noae.

Heart:

The heart is composed of muscular ventricle and thin-walled auricle. The auricle gives origin to aorta which in turn divides into arteries to supply the various parts of the body.

Blood from the different parts of the body is returned to the respiratory organs. After oxygenation blood is returned to the heart from the respiratory organs to complete the circuit. The ventricle is usually single, but the number of auricle varies from one to four.

The number of auricle corresponds to the number of ctenidia present. Majority of the Molluscs possess one auricle. Double auricles are present in Chitons, Dibranchiate Cephalopods and Bivalves. Tetrabranchiate Cephalopods possess four auricles. The number of aortae originating from the ventricle varies from one to two.

Single aorta is present in Chitons, Solenogastres, Prosobranchia, etc. In some forms there are two aortae leading out of the two ends of the ventricle. In most Gastropods, a single aorta bifurcates into an anterior cephalic aorta and a posterior visceral aorta. The topography of heart also shows variation. The heart is placed within the pericardium.

In bilaterally symmetrical forms the heart lies on the median line of the body, while in asymmetrical forms the heart is shifted to one side of the body, usually on the right side.

Course of circulation:

In Molluscs the blood from the ventricle is carried through aorta/aortae into the arteries. The arteries supply blood to the different parts of the body. After making an excursion through the different organ systems, the blood is collected into irregular spaces—the lacunae which in turn open into sinuses.

Existence of capillaries is said to occur in Dibranchiate Cephalopods and in some Bivalves. The relationship between the foot-pore and the circulatory system in some Molluscs has not yet been fully established. In the opinion of many workers these foot-pores help the incoming of water into the circulatory system.

Economic Importance of Molluscs:

Some Mollusca are indirectly harmful to man but most of them are beneficial. The harmful molluscs are slugs and shipworms. Slugs are injurious in gardens and cultivations, they not only eat the leaves but also destroy plants by cutting up their roots and stems.

Teredo, the shipworm burrows into wooden structures immersed in the sea, it causes serious damage to wharves, piers and ships. But molluscs are a great source of human food in various parts of world, millions of maunds of clams, oysters, scallops and mussels are eaten in China, Japan, Malaya, Europe and America, oysters being regarded as a delicacy.

Other bivalves, octopuses and cuttlefishes furnish large quantities of food in Europe. Shells of freshwater mussels are used in the pearl button industry in all parts of the world, they are made from the nacreous layer of shells, no other material stands laundering as these buttons.

Shells of oysters are mixed with tar for making roads in America and lime from these shells is used in feeding poultry for formation of their egg shells. Lime is also used in buildings.

In many parts of the world molluscan shells are used for making ornaments and jewellery, in some parts shells of *Cypraea* (cowrie) are used as money and as ornaments.

Many freshwater clams and marine oysters produce pearls, but the most valuable natural pearls are produced by pearl oysters *Pinctada margaritifera* and *Pinctada mertensi* which inhabit the warmer parts of

Indian and Pacific Oceans along the coasts of China, India, Sri Lanka and Japan. A pearl is made when a small foreign object, such as a particle of sand or a parasite, lodges between the shell and the mantle.

The foreign object becomes a nucleus around which concentric layers of nacreous are laid by the mantle, in this manner a pearl is formed. But pearls are also produced by most pelecypods including freshwater clams.

In Japan pearl culture is practiced by artificially introducing a small solid or liquid irritant below the mantle of the oyster, the resultant one year old pearl is then transplanted to another oyster, a pearl of good size is obtained in three years after transplanting.

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HEMICHORDATA (PART1)

Balanoglossus: Habitat, Development and Affinities

Contents:

Habit and Habitat of Balanoglossus

External Morphology of Balanglossus

Body Wall of Balanglossus

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Reproductive System of Balanglossus

Development of Balanglossus

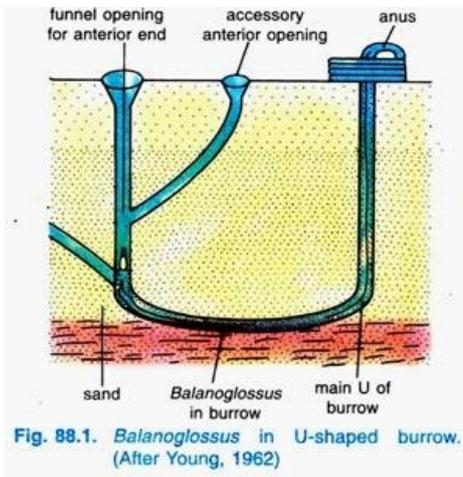
Affinities of Balanglossus

1. Habit and Habitat of Balanoglossus:

Balanoglossus is a burrowing and exclusively marine animal. It is found in shallow waters between tide marks along the coast of warm and temperate oceans. Balanoglossus is world-wide in distribution. Balanoglossus is tubicolous living in U-shaped burrows excavated in the sandy bottom. The walls of the tube are lined with mucus secreted by the mucous gland of the animal.

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The burrows are open at both ends, and spiral coils of faeces like the castings of earthworms may be seen at the posterior opening. In its burrow Balanoglossus lies in a twisted condition but its anterior and posterior extremities are straight. Knight Jones (1952) reported that the animal moves in its burrow with the help of cilia present all over the body.



2. External Morphology of Balanglossus:

The body of *Balanoglossus* is soft, elongated, cylindrical, being richly ciliated all over and covered with mucus.

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The length of animal varies from 2 cm to 2.5 meters. Most forms are drab coloured, though reddish tints are present, several species are luminescent due to mucus. They have an offensive odour. The body is bilaterally symmetrical and divided into three regions, viz., proboscis or protosome, collar or mesosome, and trunk or metasome.



Proboscis:

The proboscis forms the anterior part of the body and is either rounded or conical in shape. It is continued posteriorly into a short, narrow neck or proboscis stalk.

The proboscis is hollow and has thick muscular walls. Its cavity opens to the outside by means of a small opening called the proboscis-pore. In certain cases there are two proboscis-pores. In some species the proboscis-pore does not communicate with the proboscis-coelom, but terminate blindly, and may send off a narrow tubular diverticulum which opens into the neurocoel.

The proboscis sits in the collar somewhat like an acorn in its cup, a character that has given the name “**acorn worms**” to the group. The mouth, which is always wide open and incapable of closing completely, lies on the ventral side and its lips are the ventral edges of the collar region.

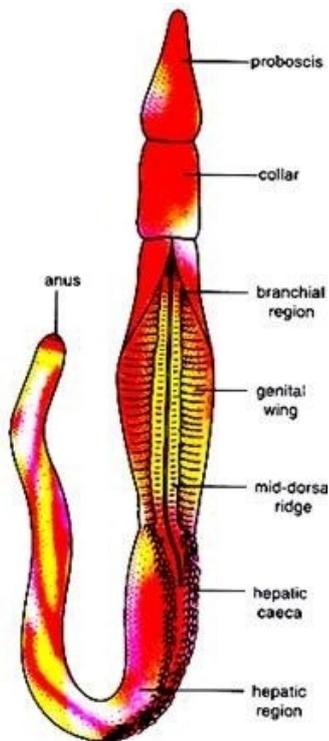


Fig. 88.2. *Balanoglossus*. External features in dorsal view.

Collar:

The collar lies posterior to the proboscis and anterior to the trunk. It is a short cylinder usually about as wide as long and mostly shorter than the proboscis although sometimes longer. The funnel-like anterior part of the collar, the collarette, embraces the proboscis stalk and usually also the posterior part of the proboscis. Posteriorly the collar is sharply demarcated from the trunk by a circular indentation.

The surface of the collar is often marked with elevations, depressions, and specially circular grooves.

The collar is also muscular and possesses two coelomic cavities. The right and left coelomic cavities are separated from one another by dorsal and ventral mesenteries. The coelomic cavities of collar are completely cut off from the proboscis cavity.

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The collar cavity as well as the proboscis cavity are crossed by numerous strands of connective tissue which give the region a spongy appearance. The collar cavity communicated with the exterior by a pair of collar-pores, and short ciliated tubes (canals) leading into the first gill pouches.

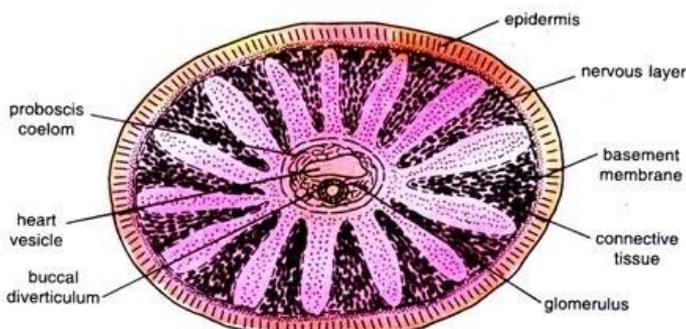


Fig. 88.3. *Balanoglossus*. T.S. of proboscis.

The functional significance of the cavities and water pores in the proboscis and collar may best be explained through a description of the burrowing habits. When on the surface of the sandy bottom

Balanoglossus pushes the tip of the proboscis into the sand, moving it around by muscular contractions until a shallow, cylindrical hole is made.

Then the proboscis empties its water content through its pore and collapses. This allows the collar to enter the hole. By taking in water through the pores the collar expands so as to fit lightly into the hole like a cork in a bottle. The well-filled collar then gives a point of resistance for further rooting movements of the refilled proboscis, which loosens sand and stows it into the scoop-shovel mouth.

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Then both proboscis and collar relax and the latter squirms deeper into the hole before tightening its hold again. Once the collar gets a firm grip, the animal makes rapid progress and soon buries itself. The tail end is left near the surface, and at intervals comes out and deposits a pile of castings somewhat after the fashion of earthworms.

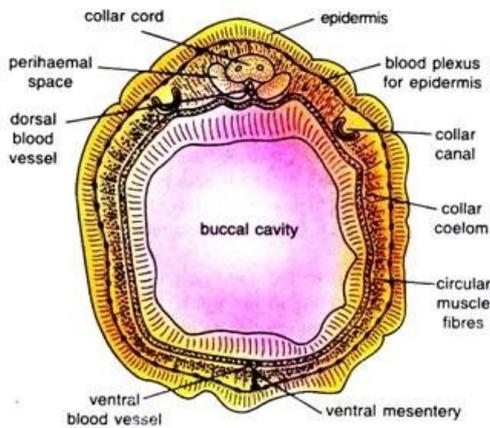


Fig. 88.4. *Balanoglossus*. T.S. of collar.

Trunk:

The trunk is the elongated posterior part of the body. It is somewhat flat and annulated on the surface. It has a mid-dorsal and a mid-ventral longitudinal ridge. The trunk is divisible into three parts, an anterior branchio-genital region, a middle hepatic region, and a posterior abdominal or post-hepatic region.

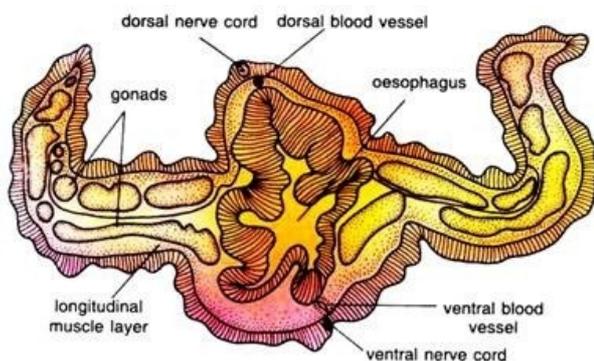


Fig. 88.5. *Balanoglossus*. C.S. through genital wings.

On the dorsal of the branchio-genital region of the trunk is a double row of small pores the branchial apertures. Each row is situated in a long furrow. These pores increase in number during growth. In some species the most anterior are overlapped by a posterior prolongation of the collar called the operculum.

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A pair of longitudinal genital ridges or genital wings extends throughout a considerable part of the body behind and in the region of the branchial apertures. In these genital ridges, gonads are situated. In some genera, the genital ridges are so prominent that they form a pair of wing-like lateral folds, the genital wings, but in other genera folds are absent.

The hepatic region is marked externally with irregular elevations due to sacculations produced by projecting hepatic caeca of the intestine. The abdominal region is longest and cylindrical. It tapers gradually and has a terminal anus. The coelom of the trunk is divided into two lateral closed cavities by vertical partition.

3. Body Wall of Balanoglossus:

The body wall of Balanoglossus is made up of an outer epidermis and an inner musculature.

1. Epidermis:

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It consists of a single layer of epithelial cells. The epithelial cells are of tall columnar type and have their nuclei near their broader bases.

These cells are mainly of two types:

(i) Ciliated epidermal cells are more numerous and each bears cilia at its free end;

(ii) Gland cells are lying interspersed between the ciliated epidermal cells and are further of three kinds

(a) Goblet cells are flask-shaped and secrete mucus;

(b) Reticulate cells are long cells with vacuolated cytoplasm which also secrete mucus;

(c) Mulberry cells are long cells containing coarse cytoplasmic granules and, hence, are also called granular gland cells.

They secrete amylase. The mucus, secreted by gland cells, covers the animal and lines its burrow. The mucus has an obnoxious smell. In addition to these cells, the body wall of proboscis and anterior part of the collar also contain neurosensory cells which take darker stain than the rest. There is no dermis.

Immediately below the epidermis is a thick nervous layer consisting of bipolar and quadripolar nerve cells and fibres which form a network lying in close contact with the epidermal cells. This layer is traversed by the filamentous bases of the epidermal cells that are connected with the basement membrane.

The fibres of sensory epidermal cells synapse with the fibres of nerve cells. Below the nervous layer is a thick basement membrane made up of two lamellae pressed together. The basement membrane supports the epidermis and serves for attachment of underlying muscles.

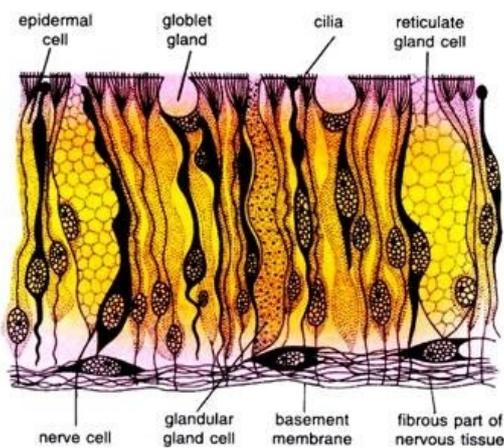


Fig. 88.6. *Balanoglossus*. V.S. of body wall.

2. Musculature:

The musculature of typical body-wall and gut-wall

is greatly reduced and more or less replaced by muscles arising from the coelomic epithelium. The muscle fibres are smooth and of circular, longitudinal and diagonal types. The muscle layer lies below the basement membrane.

The proboscis musculature comprises a thin layer of circular muscle fibres and a thick layer of longitudinal muscle fibres. The longitudinal muscle fibres obliterate the proboscis coelom and some of the fibres cross one another diagonally. The collar musculature is confined to the collarette and consists of an inconspicuous layer of circular fibres and prominent bands of longitudinal and diagonal fibres.

The longitudinal and diagonal fibres, along with connective tissue, also traverse the collar coelom in a criss-cross pattern. The trunk musculature consists mainly of moderately developed longitudinal muscle fibres which are better developed on the ventral side. The muscle layer is interrupted by the dorsal and ventral mesenteries and the lateral septa.

Several radial muscle fibres are also found in the trunk region. The radial muscle fibres extend between the digestive tract and the body wall and traverse the trunk coelom.

4. Coelom in Balanoglossus:

The coelom is enterocoelous having been formed as outgrowths of the enteron. Corresponding with the three body regions the coelom is divided into three portions which are completely separated from each other by septa. The coelom is lined with coelomic epithelium or peritoneum.

But enteropneusts are peculiar in that their coelomic epithelium has connective tissue and muscle fibres which fill much of the original coelomic cavities, and a distinct peritoneal lining has disappeared, moreover the coelomic musculature largely replaces the body wall muscles. The three parts of the coelom are an unpaired proboscis coelom, a pair of collar coeloms, and a pair of trunk coeloms.

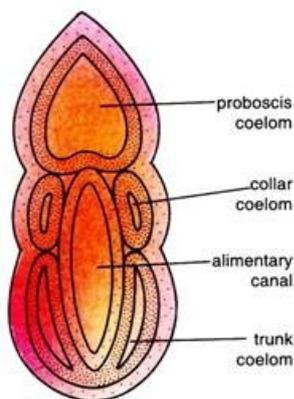


Fig. 88.7. *Balanoglossus*. Diagram of tripartite embryo showing coelomic cavities.

1. Proboscis Coelom:

The proboscis coelom or protocoel is a single space in the proboscis which is largely occupied by muscles and connective tissue and a few structures like buccal diverticulum, glomerulus and central sinus or heart.

Dorsally, towards the posterior side, the proboscis coelom is divided by a dorsal mesentery into right and left dorsolateral compartments which extend into the proboscis stalk; the left compartment is larger than the right and communicates with the exterior through the proboscis pore situated mid-dorsally at the base of the posterior stalk.

Ventrally the proboscis coelom is divided by a ventral mesentery into right and left ventrolateral compartments which are continuous behind the mesentery.

2. Collar Coelom:

The collar coelom or mesocoel has two cavities lying side by side in the collar, one on each side between the collar wall and buccal cavity. The two cavities are partitioned by incomplete mid-dorsal and mid-ventral mesenteries. The collar coelom does not communicate with the proboscis coelom, but posteriorly, its each cavity opens into the first gill sac of its side by a canal called collar canal.

Each collar coelom opens to the exterior by a collar

pore. The collar coelom is greatly obliterated by the collar musculature and connective tissue.

3. Trunk Coelom:

The trunk coelom or metacoel has two closed cavities lying between the body wall and alimentary canal. The two cavities are separated by an incomplete dorsal and a complete ventral mesentery.

In the branchiogenital region each cavity is further divided by a lateral septum into a dorsolateral and ventrolateral compartment. The trunk coelom is separated from the collar coelom by a collar-trunk septum. The trunk coelom is obliterated by the trunk musculature.

Coelomic Fluid:

The proboscis and collar coeloms communicate with the exterior and get filled with sea water through their pores, which keeps them turgid. The trunk coelom is filled with a watery coelomic fluid having amoeboid coelomocytes. The coelomocytes originate from the coelomic epithelium.

Each coelomocyte possesses a single large vacuole. According to Spengel, they behave like leucocytes by secreting a membrane around any foreign body that may invade the animal.

5. Endoskeleton in Balanoglossus:

In *Balanoglossus* there is no definite endoskeleton but there are four structures of a supporting nature, they are buccal diverticulum, proboscis skeleton, branchial skeleton, and a pygochord.

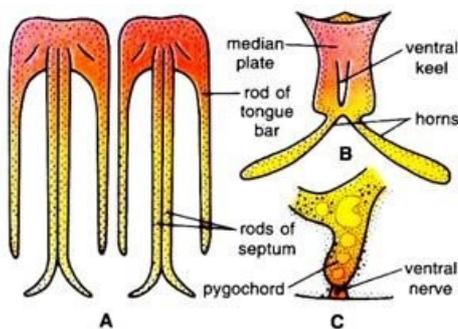


Fig. 88.8. *Balanoglossus*. Skeletal elements. A—Branchial skeleton; B—Proboscis skeleton; C—Pygochord.

(i) Buccal Diverticulum:

Buccal diverticulum is a hollow preoral outgrowth, extending from the roof of the buccal cavity into the proboscis. It was for a long time also called a notochord or a stomochord on the assumption that it represents the anterior portion of the notochord of chordates. The buccal diverticulum extends forward in some enteropneusts as a slender vermiform process or appendix.

The buccal diverticulum is neither analogous nor homologous with the chordate notochord, histologically it is identical with the wall of the buccal cavity, it is apparently nothing more than a pre-oral extension of the gut.

(ii) Proboscis Skeleton:

Proboscis skeleton or nuchal skeleton is formed by the basement membrane becoming thick to form a laminated plate from which arise two thin horns or cornua, the plate usually has a mid-ventral keel. The proboscis skeleton lies in the proboscis stalk, while its horns extend into the roof of the buccal cavity.

(iii) Branchial Skeleton:

The walls of the U-shaped gill-clefts are supported by skeletal rods called primary and secondary gill-rods formed by thickening of the basement membrane.

(iv) Pygochord:

Pygochord is longitudinal rod-like structure extending from the ventral side of the intestine to the body wall, its function is not known but it may support the soft abdominal region.

6. Digestive System of Balanoglossus:

Alimentary Canal of Balanoglossus:

In Balanoglossus, the alimentary canal is a straight tube. Its anterior opening, the mouth, is wide and circular and situated on the ventral side in a groove between the proboscis stalk and collarette. The mouth remains open constantly.

The posterior opening or the anus is a circular aperture at the extreme posterior end of the trunk. Between the mouth and anus, the alimentary canal can be distinguished into four regions buccal tube, pharynx, oesophagus, and intestine. Their walls are composed of ciliated epithelium lined externally by basement membrane and devoid of muscle fibres.

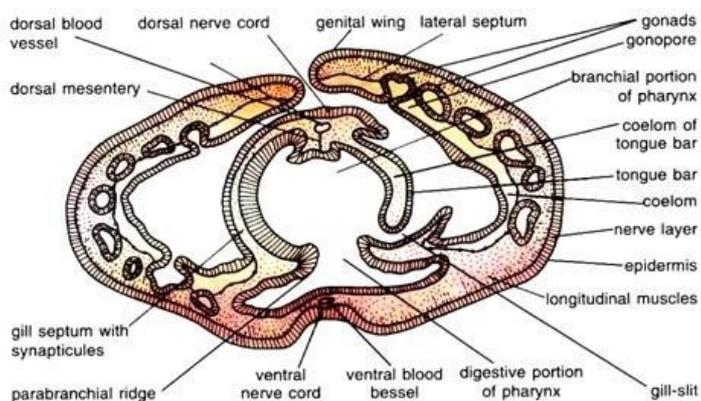


Fig. 88.9. *Balanoglossus*. T.S. through pharyngeal or branchiogenital region.

1. Buccal Tube:

The mouth leads into a buccal tube or cavity in the

collar region. Its epithelial wall contains glandular goblet cells. The dorsal wall of buccal tube forms a short, stiff and hollow buccal diverticulum that projects into the proboscis coelom. It extends up to the collar-trunk septum behind which it continues into the pharynx.

2. Pharynx:

The wall of the roof of the buccal tube opens into the pharynx lying in the branchial region of the trunk. Its wall bears a longitudinal constriction along each lateral side.

These lateral constrictions project into its lumen as ridges, called parabranial ridges consisting of tall columnar cells. These ridges and constrictions incompletely divide the pharynx into a dorsal branchial portion (pore pharynx) and a ventral digestive portion (digestive pharynx).

(i) Branchial Portion of Pharynx:

The dorsal branchial portion of pharynx is perforated dorsolaterally by two rows of U-shaped gill-slits. It is concerned with respiration.

(ii) Digestive Portion of Pharynx:

The digestive portion of pharynx is concerned with the food concentration, digestion and absorption of food.

Its ciliated epithelial wall contains gland cells.

3. Oesophagus

Behind the last pair of gill-slits the pharynx continues into the oesophagus. The dorsal and ventral divisions of the pharynx continue for some distance into the oesophagus; in this region, the dorsal part of the oesophagus is called post-branchial canal which possesses thick, folded and glandular epithelium. The posterior part of the oesophagus reduce in diameter and has deeply furrowed epithelium.

4. Intestine

Behind the oesophagus is an intestine, It occupies the hepatic and post-hepatic regions of the trunk. The hepatic region of the intestine is highly vascular. Its epithelial cells are dark green or dark brown and its dorsal wall forms numerous prominent sacculations called hepatic caeca which push the body wall outwards and are, thus, visible externally.

The post- hepatic region of the intestine is connected with the ventral body wall by the pygochord. The intestine has the form of a simple tube and bears a pair of dorsolateral grooves lined by tall epithelial cells bearing long cilia. The intestine opens out through the anus situated at the extreme hind end of the body. The anus often possesses sphincter muscles.

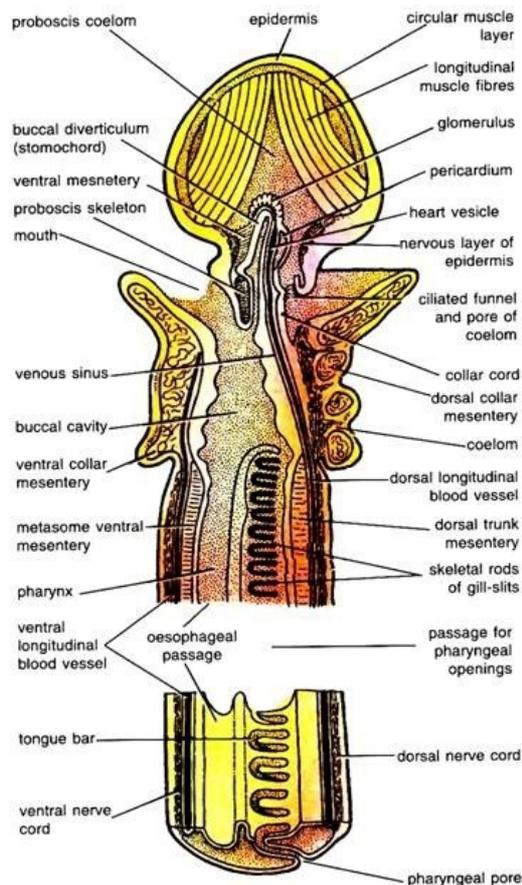


Fig. 88.10. *Balanoglossus*. M.L.S. of anterior region to show the alimentary canal.

Food, Feeding and Digestion of Balanoglossus:

Balanoglossus is a “**ciliary feeder**”. Its food comprises microscopic organisms and minute organic particles present in water and mud or bottom sand in which it makes its burrows. The lateral cilia lining the gill-slits set up a current of water directed backward which enters through the mouth, takes its course through the buccal tube, pharynx, gill-slits and branchial sacs, and leaves through gill-pores.

This is called respiratory-cum-food current. Some food particles directly enter the mouth with this current, while some come in contact with the proboscis and are entangled in the mucus that covers it.

The mucus is secreted by the gland cells of the proboscis epithelium. Cilia covering the proboscis direct the mucous string, containing food particles towards the preoral ciliary organ at the base of the proboscis.

From here the mucous string is passed back into the mouth by the action of the proboscis cilia, assisted by the main water current entering the mouth. Organic particles present in the mud or sand are ingested directly along with mud or sand at the time of burrowing.

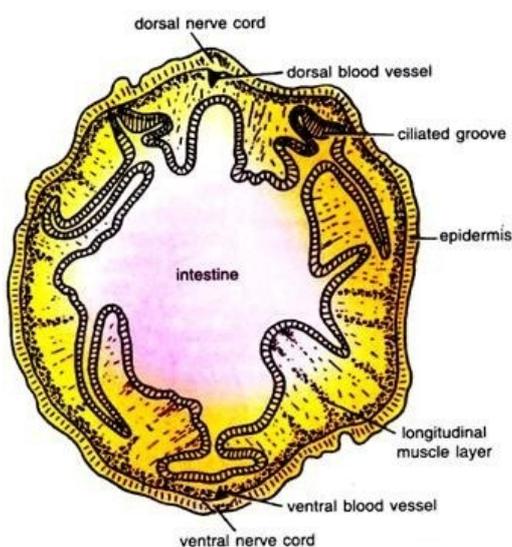


Fig. 88.11. *Balanoglossus*. T.S. through post-hepatic intestine.

At the base of the proboscis, on the ventral side, there is a U-shaped depression bordered by long epidermal cells bearing long cilia. This structure is called the pre-oral ciliary organ.

It tests the quality of food and the water entering the mouth. Undesirable substances are prevented from entering the mouth by the ventral part of the collarette which does so by covering the mouth. Thus, the rejected particles, instead of entering the mouth, pass back over the collar.

Backward movement of food through the alimentary canal is maintained by the cilia lining its walls. In the pharynx, the food passes through the ventral digestive portion.

The exact process of digestion in *Balanoglossus* is not known with certainty; however, the digestion of food is brought about by the enzymes secreted by proboscis, gland cells of the pharynx, oesophagus and hepatic region of the intestine. Proboscis secretes mucus, which contains amylase, is ingested with the food.

The gland cells of pharynx and oesophagus also secrete enzymes. It is also claimed that hepatic caeca secrete amylase, maltase, lipase and weak protease. The enzymes digest the organic particles in the mud or sand. Undigested substances, along with mud or sand,

pass out through the anus in large quantities which forms piles of “**castings**” at the posterior opening of the burrow.

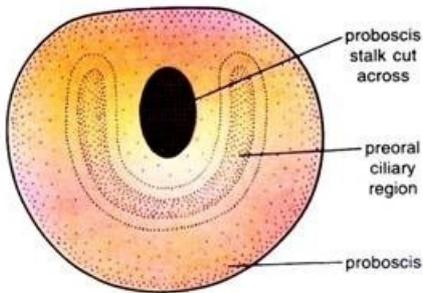


Fig. 88.12. *Balanoglossus*. Posterior view of proboscis showing the preoral ciliary organ.

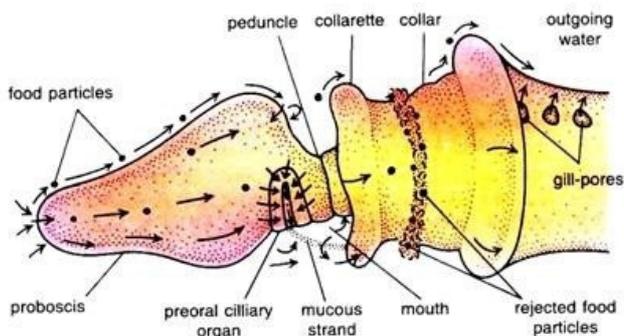


Fig. 88.13. *Balanoglossus*. Feeding current.

7. Respiratory System of Balanoglossus:

The respiratory organs of *Balanoglossus* comprise:

- (1) The branchial portion of pharynx bearing gill-slits**
- (2) The branchial sacs that open out through gill-pores**

1. Branchial Pharynx:

As already described, two lateral longitudinal parabranchial ridges divide the pharyngeal cavity into a dorsal respiratory or branchial portion and a ventral digestive portion. Dorsolaterally, on each side, the branchial portion of pharynx is perforated by a longitudinal series of numerous U-shaped openings, the gill-slits. The number of gill-slits varies and increases as the animal grows older.

Each gill-slit is a broad oval slit in the beginning, but later, a hollow projection of dorsal pharyngeal wall, called tongue bar, grows into the slit making it U-shaped. The hollow tongue bars enclose coelomic cavity and do not touch the ventral side of the gill-slits. The portions of the pharyngeal wall between two adjacent U-shaped gill-slits are called gill-septa. The gill-septa are solid and do not enclose coelom.

A tongue bar is connected with its adjacent gill-septa by longitudinal connections are called synapticula. The tongue-bars and gill-septa are supported by M-shaped skeletal rods.

The middle arm of an M-shaped rod is bifurcated at the

free end and lies in a gill-septum, while its outer arms lie in adjacent tongue bars. Thus, each tongue bar contains two arms of two adjacent skeletal rods. Each U-shaped gill-slit is richly lined by cilia, called lateral cilia.

2. Branchial Sacs:

Gill-slits do not open directly to outside. Each gill-slit opens into a gill- pouch called branchial sac which lies between the body wall and the pharynx. Each branchial sac in turn opens to the exterior by a small, independent gill-pore.

However, in *Balanoglossus misakiensis* the first four branchial sacs become united to open by a common gill-pore to outside. The collar coelom also communicates with the common branchial sac of its side through a collar canal. The gill-pores are visible externally in two longitudinal rows, one on each side of the mid-dorsal ridge in the branchiogenital region of the trunk.

Mechanism of Respiration:

The lateral cilia lining the gill-slits create a current of water (food-cum-respiratory current) that enters the

pharynx through mouth, then passes through gill-slits into the branchial sacs and finally leaves through the gill-pores. The tongue bars are richly supplied with blood capillaries and take part in respiration. The blood of their capillary networks takes up oxygen dissolved in water and diffuses carbon dioxide to it.

8. Blood Vascular System of Balanoglossus:

The blood vascular system of Balanoglossus consists of closed vessels, lacunar spaces and a definite pulsating organ, generally known as the heart. The blood is colourless and has no or very few corpuscles; it may contain a few detached endothelial cells; it has no respiratory pigment. Most of the blood vascular system is located between the lamellae of the basement membrane and the leaves of the mesentery.

There are two main longitudinal vessels, the dorsal and ventral vessels, running along the length of the body. The dorsal vessel is situated just below the dorsal nerve cord and above the alimentary canal and runs through the dorsal mesentery. The blood flows anteriorly through the dorsal vessel.

The ventral vessel is located in the ventral mesentery and the blood flows posteriorly in it. These two vessels

are highly contractile and their walls are composed of an inner endothelium surrounded by muscle layer.

The dorsal vessel extends from the anus to the collar where it occupies a median position between two perihæmal cavities. The dorsal vessel is dilated at the front of the collar, forming a venous sinus which passes anteriorly into a central sinus or heart. The central sinus is situated above the buccal diverticulum. Immediately above the central sinus there is a triangular contractile epidermal sac called heart vesicle.

Blood from the central sinus enters the glomerular sinuses of the proboscis complex. In glomerulus the blood is cleared of nitrogenous wastes. From the glomerulus, the blood is collected by four vessels. These vessels are regarded as the arteries because the blood leaving the glomerulus is considered to be purified.

These arteries are:

(i) A mid-dorsal proboscis artery,

(ii) A mid-ventral proboscis artery and two efferent glomerular arteries. The mid-dorsal and mid-ventral

proboscis arteries supply blood to the proboscis.

The efferent glomerular arteries run backward along the two sides of the buccal diverticulum. These vessels then run ventrally to encircle the buccal tube as the peribuccal arteries. The peribuccal arteries unite together ventrally to form a single longitudinal ventral vessel.

The ventral vessel runs up to the posterior end of the body through the ventral mesentery. On its way, the ventral vessel gives out a ventral collar vessel to supply the collar. The collar tissue contains two distinct lacunar networks which communicate posteriorly with a ring vessel. The ring vessel is located in the collar- trunk septum. It arises from the ventral vessel and is connected with the dorsal vessel.

A lateral pharyngeal vessel appears in the lacunar plexus at the junction of the two pharyngeal regions. The ventral vessel continues up to the anus and gives off lacunar networks all along the alimentary canal. The ventral vessel gives out an afferent branchial artery to each gill-septum which bifurcates to supply the two adjacent tongue-bars.

Thus, each tongue-bar receives two afferent branchial arteries which break up into a plexus. From this plexus an efferent branchial vein is formed. It runs dorsally up to the middle of the tongue- bar and joins with the

efferent branchial vein of the adjacent tongue-bar. The common branchial vein opens into the dorsal vessel (Fig. 88.17).

The ventral vessel supplies blood through lacunar plexus to the body wall and alimentary canal. The blood from the intestinal plexus in the trunk region is collected mostly by the dorsal vessel.

9. Excretory System of Balanoglossus:

In Balanoglossus, the excretory organ is glomerulus or proboscis gland lying in front of the central sinus and projecting into the proboscis coelom. The glomerulus is made up of several blind tubular projections formed by the peritoneum covering the buccal diverticulum, central sinus and heart vesicle. The tubular projections of glomerulus are filled with blood which is confluent with the blood of the central sinus.

The covering of the glomerulus is composed of excretory peritoneal cells. The excretory peritoneal cells of glomerulus contain yellow or brown granules, probably of excretory substances. The excretory waste substances from the glomerulus pass on into the proboscis coelom from where they finally pass out to the exterior through the proboscis pore.

10. Nervous System and Sense Organs of Balanoglossus:

The nervous system of Balanoglossus is of a very primitive type resembling that of coelenterates and echinoderms. Nervous system consists primarily of an epidermal plexus or a layer of nerve cells and nerve fibres lies just below the epidermis. Threadlike processes of the epidermal cells contribute to the network or nerve net.

The nervous layer is composed of longitudinal nerve fibres with bipolar and multipolar nerve cells at the margin.

The nervous layer becomes thickened along definite strands to form two main nerve cords, one mid-dorsal and the other mid-ventral, which run along the entire length of the trunk. Ventral cord extends up to collar-trunk septum where it is connected with the dorsal cord by a circular strand, called circumenteric nerve ring.

Dorsal cord extends anteriorly up to the base of proboscis where it is connected with another circular strand called anterior nerve ring. From the anterior nerve ring longitudinal nerve fibres are given out, these nerve fibres are called subsidiary longitudinal cords of proboscis. In the collar region, dorsal cord leaves the

epidermis and projects into the collar coelom as the collar cord.

The collar cord contains a cavity called neurocoel. The collar cord arises from the epidermis, but has sunk in to take a deeper position. Its similarity to chordate nerve cord, formed by the invagination of the nervous ectoderm at the dorsal mid-line, is evident. The collar cord and sometimes the anterior part of the dorsal cord in the trunk or nerve ring, contains giant neurons.

Each gives off a single large nerve fibre which crosses to the other side of the body and runs through the circumenteric ring to the ventral nerve cord.

The number of giant neurons varies from about 10 to 160. They are responsible for rapid conduction of stimuli leading to quick retraction of body parts. Although the collar cord is the most complex part of the nervous system, it is no more than a conduction path and the site of giant neuron formation.

Sense Organs of Balanoglossus:

In Balanoglossus, the sense organs are poorly developed. In the epidermis are numerous neurosensory cells which are connected to the nerve

net, they are more numerous on the proboscis.

It is claimed that in some species a few neurosensory cells form photoreceptors sensory to light. On the ventral side of the base of the proboscis is a U-shaped depression called a preoral ciliary organ. It has ciliated cells joined to the nerve net, it is a chemoreceptor.

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Dept of Zoology
IITM GROUP OF INSTITUTIONS**

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HEMICHORDATA (PART 2)

11. Reproductive System of Balanoglossus:

In Balanoglossus, the sexes are separate and are indistinguishable externally except in case of the colour of the ripe gonads shown through the body wall in the living animal.

The gonads occur in one or more longitudinal rows to the sides of the alimentary canal lying within the genital pleurae in the anterior part of the trunk. Gonads develop from the coelomic wall, though they have no connection with coelom in the adult.

The gonads are generally sacciform bodies but may be elongated or lobulated and secondary gonads may arise by subdivision of the primary ones through lobulation. Each gonad is a sac, it continues into a short ductule which opens to the exterior by a gonopore. The gonopores are generally located to the lateral (external) side of the gill-pores in the same branchio-genital groove.

The saccular gonads are lined with germinal epithelium which is continuous with the ectoderm. By the proliferation of cells from the germinal epithelium sperms or ova are produced. The mature sperms and ova are discharged outside through the genital pores. The sperm has a rounded head and a flagella-like tail

but the ova are of two types.

The small ovum measures about 0.06 mm in diameter and undergoes indirect development with a pelagic larva known as tornaria larva, while the larger ovum measures about 0.4 mm in diameter and undergoes direct development without larval stage. The mature sperms and ova are shed into the burrows where fertilisation takes place, i.e., the fertilisation is external.

Asexual Reproduction:

Asexual reproduction is known to occur in *Balanoglossus capensis* (Gilchrist, 1923). During summer the juvenile phase of this, at first considered a distinct species for it lacks hepatic sacculations, reproduces by cutting off small pieces from the tail end forward. These regenerate completely into the adult sexual type found in winter.

Regeneration:

Balanoglossus has great power of regeneration, small pieces are constricted from the posterior end, each of which regenerates into a complete individual. Other broken pieces of the animal also regenerate into new individuals.

A detailed study of regeneration was made by Dawydoff (1902, 1907, and 1909) for *Gloss, minutus*

and by Rao (1955) for *Ptychodera flava*. The isolated proboscis, with or without the collar, lines and moves about for some time but appears incapable of regenerating posterior structures. Pieces of trunk regenerate completely in both species.

12 Development of *Balanoglossus*:

(i) Fertilisation in *Balanoglossus*:

During breeding season (May to June) mature ova and sperms are discharged in the surrounding water where fertilisation takes place. First the ova, egg-mass, are discharged by the female from its burrow and then the sperms are discharged by the male from its burrow. The number of eggs discharged at a time varies from few dozens to more than a thousand. Normally one to three hundred eggs are shed at a time.

According to available evidences maturation starts some four hours before ovulation and that the egg is generally in the metaphase of the first meiotic division when shed. It is at this condition the egg is fertilizable.

Fertilisation of eggs within 6 to 7 hours after shedding yields a high percentage of normal development. The spermatozoon is able to enter the eggs at any point over the entire surface. After fertilisation, the cleavage starts.

(ii) Pre-Larval Development in Balanoglossus:

The zygote, produced as a result of fertilisation, undergoes cleavage. The cleavage is holoblastic, almost equal and mostly of the radial type. The first cleavage starts about two hours after fertilisation and produces two generally, but not invariably, equal cells. The second cleavage is like the first and produces usually (but not invariably) four approximately equal cells.

As a result of third and subsequent cleavages a sphere of equal blastomeres is produced, it is called morula. The morula undergoes the re-organisation of its blastomeres and takes the form of a single-layered hollow and spherical blastula or coeloblastula. Its central fluid-filled cavity is called the blastocoel. As the cells multiply the volume of blastula increases. Blastula results in about 6-15 hours after fertilisation.

Within 12-24 hours, an invagination starts in the blastula which deepens to form the archenteron. The archenteron opens to the outside through a blastopore. The blastopore marks the posterior end of the embryo. The blastopore soon closes and the embryo now called gastrula.

The gastrula elongates along the anteroposterior axis. Now the anterior tip of the archenteron is differentiated as a coelomic vesicle called the protocoel. Thus, origin of coelom is enterocoelic. The

remaining posterior part of the archenteron marks the future gut or alimentary canal.

The protocoel becomes triangular in shape. One end of the protocoel gets attached to the underside of the apical thickening and another end opens to outside through an aperture, the hydropore, towards the dorsal side of the embryo.

The protocoel and hydropore represent the future proboscis coelom and proboscis pore respectively. The collar and trunk coelom develop as solid invaginations of the hindgut, independent of the formation of protocoel.

(iii) Larval Development in Balanoglossus:

After the formation of the protocoel, the inner end of the early gut moves towards the ventral surface and opens to the outside through a mouth. The gut is now differentiated into the oesophagus, stomach and intestine. The intestine opens to outside through an anus, formed at the place of closed blastopore.

By this time (after a day or so) the embryo becomes uniformly ciliated and escapes from fertilisation membrane to lead a free swimming larval life. It is

called tornaria larva.

(iv) Tornaria Larva in Balanoglossus:

Tornaria larva was first of all discovered by J. Muller in 1850 and was considered by him as the larva of echinoderms. Later on in 1869 it was Metschnikoff who established that it is a larva of Balanoglossus clavigerus. The name tornaria is given to it because of its habit of rotating in circles. Tornaria larva is usually oval in shape and is excessively transparent.

The size of tornaria larva varies from 1 mm to 3 mm. It has a ventral mouth near the equatorial plane of the body, a posterior terminal anus and gut differentiated into an oesophagus, stomach and intestine. The cilia form two bands on the body surface. The anterior ciliary band or circumoral band takes up a winding course over the preoral surface and forms a postoral loop. Its cilia are short and serve to collect the food.

The posterior ciliated band or circumanal ring or telotroch lies as a ring in front of the anus. The cilia in this band are long, powerful and act as chief locomotor organ of tornaria. A ciliary wave passing along the telotroch causes the larva to rotate constantly in swimming. At the anterior end is an apical plate of thickened epidermal cells.

The apical plate bears a pair of eye spots or ocelli and

a tuft of sensory cilia called apical tuft or ciliary organ. The protocoel (proboscis coelom) is present in the form of a thin-walled sac and opens to the exterior through a hydropore (proboscis pore). To the right of the hydropore lies a pulsating heart vesicle which develops in the later stages of tornaria larva. The collar and trunk coeloms appear in the older larva.

(v) Metamorphosis in Balanoglossus:

The tornaria larva swims freely, leads a planktonic life feeding on minute organisms. After swimming for some time the tornaria larva sinks to the bottom and metamorphoses into an adult. During metamorphosis, the size of larva is reduced probably due to loss of water. Transparency, ciliary bands, sensory cilia and eye spots are lost.

The body elongates and is distinguished into proboscis, collar and trunk by the appearance of two constrictions, and the trunk region is elongated.

The hydropore persists as proboscis pore. Simultaneously the buccal diverticulum and gill-slits appear as outgrowth of the alimentary canal. The reproductive organs make their appearance, probably from the mesoderm. Thus, the larva gradually changes into the adult. The adult leads a benthonic life.

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13. Affinities of Balanoglossus:

The position of Hemichordata, in the scheme of classification of animals, has been controversial. In 1814, Sedgwick and Huxley suggested the affinities of Enteropneusta (Hemichordata) with the vertebrates and it was in 1885 Bateson considered this group as a subphylum of the phylum Chordata.

Metschnikoff (1865) stated that Enteropneusta had certain affinities with Echinodermata. Spengel (1893) showed the relationship of Enteropneusta with Annelida.

But on the basis of general organisation, some recent

workers, such as Van der Horst (1939), Dawydoff (1948), Marcus (1958) and Hyman (1959) have thought it proper to remove this group from phylum Chordata to give it the status of an independent invertebrate phylum.

The name “**Hemichordata**” is, however, retained for the group because it suggests that its members are related to chordates, i.e., they are “**half**” or “**part**” chordates, a fact that is undisputed.

Affinities of Balanoglossus (Enteropneusta, Hemichordata) with chordates and non-chordate phyla are as follows:

Affinities with Chordata:

Bateson (1887) included Hemichordata in phylum Chordata, since then a close relationship has been acknowledged between hemichordates and chordates. This arrangement exists even today in most books.

Resemblances:

The phylogenetic relationship of hemichordates and chordates is based on the supposed presence of the three fundamental chordate characters in both groups, viz., a notochord, central nervous system and gill-clefts.

The buccal diverticulum or stomochord of hemichordates has been regarded as the equivalent of a notochord since the time of Bateson.

Modern workers of hemichordates do not accept this idea and have raised many objections:

1. The buccal diverticulum is a hollow evagination of the anterior wall of the buccal cavity, and it is not definite whether it is endodermal or ectodermal in origin, whereas the notochord is a long solid rod formed from the roof of the archenteron.
2. The buccal diverticulum is generally made of ordinary epithelial cells, while the notochord of vertebrates consists of large vacuolated cells.
3. The buccal diverticulum has no enclosing sheath as found around the notochord.
4. The buccal diverticulum lies ventral to the dorsal blood vessel, whereas the vertebrate notochord is always dorsal to the main dorsal blood vessel.
5. The buccal diverticulum is small and confined to the proboscis, while the notochord extends far backwards. It can be safely concluded that there is no representative of the notochord in hemichordates.

There are certain resemblances between the nervous

system of hemichordates and chordates, such as its position, formation of the dorsal nerve cord from the dorsal epidermis, and the hollow collar cord which often has a neuropore and is comparable with the neural cord of vertebrates.

But there are major differences, such as its superficial position in contact with the epidermis, possession of a main ventral nerve cord, and a circumenteric nerve ring, in these features the nervous system is distinctly invertebrate. Thus, the invertebrate features of the nervous system of hemichordates outweigh its chordate characters.

The chief link between the hemichordates and chordates lies in the pharynx and its gill-clefts.

The details of the branchial apparatus having tongue bars, M-shaped skeletal rods and synaptacula are exactly like those of *Amphioxus*. But the endostyle and epibranchial groove are absent from the pharynx of hemichordates. Such similarity can be only due to common ancestry, and phylogenetic relationship of hemichordates and chordates cannot be denied.

Differences:

But the inclusion of hemichordates in phylum Chordata cannot be justified on the basis of a few similarities which are more than outweighed by

important differences.

The main differences are:

- 1. Chordates do not have the body and coelomic regions corresponding to those of hemichordates.**
- 2. The circulatory and nervous systems of hemichordates are like those of invertebrates.**
- 3. There is no post-anal tail in hemichordates.**
- 4. Chordates are metamerically segmented animals, this segmentation is clearly shown by the muscular, nervous, circulatory, and excretory systems, whereas there is a total absence of segmentation in hemichordates.**

Affinities with Annelida:

Resemblances:

The main resemblances of Hemichordata with Annelida are as follows:

- 1. The general body form and burrowing habit of tubicolous forms are alike and mud is ingested in burrowing. It is passed out from the anus as castings.**
- 2. The vascular system of most hemichordates is like**

that of annelids with blood flowing anteriorly in the dorsal vessel and posteriorly in the ventral vessels.

3. The hemichordate tornaria larva appears like a modified trochosphere larva of polychaete worms.

Differences:

The differences between two groups are so great that there can be no phylogenetic relationship between them.

The differences are as follows:

1. Gill-slits are absent in annelids.
2. Paired nerve cords are present in annelids.
3. The larva of Hemichordata and Annelida also differ in the following ways:
 - (i) Nephridia are absent in tornaria larva.
 - (ii) Pre-oral coelom is absent in trochosphere larva.
 - (iii) In trochosphere blastopore becomes the mouth, while in tornaria it becomes the anus.

Affinities with Echinodermata:

The adult hemichordate and adult echinoderm are so different that one cannot suspect any relationship between them, the only anatomical similarity between them is their nervous system which in both cases consists of nerve net lying near the surface embedded in the epidermis.

But there is a strong affinity between the two phyla on embryological evidence, the method of formation of the gastrula and the coelom is very similar in the two phyla and for years the tornaria larva was considered to be the larva of an echinoderm. The tornaria larva shows a very striking resemblance with the auricularia larva and specially with bipinnaria of Asterozoa.

Resemblances:

The resemblance extends into the following details:

1. The ciliated band is identical and follows the same course in the tornaria and the auricularia and bipinnaria, though the telotroch and eye spots of the tornaria are absent in echinoderm larvae.
2. The alimentary canal has the same shape and the same divisions into foregut, stomach, and intestine in hemichordate and echinoderm larvae.
3. In both groups the blastopore becomes larval anus.

4. The cleavage and gastrulation follow the same pattern in both.

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5. The greatest and the most convincing resemblance lies in the method of formation and arrangement of coelomic cavities.

In both the coelom is of enterocoelous origin and it divides into three antero-posterior parts, which in hemichordates are called proboscis coelom (proto-coel), collar coelom (mesocoel), and trunk coelom (metacoel), while in echinoderms the three parts of the coelom are axocoel, hydrocoel, and somatocoel.

Moreover the proboscis coelom and collar coelom of hemichordates open to the exterior by pores through short hydroporic canals, as does the hydrocoel in echinoderms.

6. The heart vesicle of hemichordates is related to the proboscis coelom and is homologous with the madreporic vesicle of echinoderm larvae, and both these structures are closely connected to the glomerulus of hemichordates and the axial gland of echinoderms which combine the vascular and excretory functions.

Differences:

There are following differences between two groups:

- 1. Eye spot is absent in bipinnaria.**
- 2. The apical plate and telotroch are absent in bipinnaria.**
- 3. The protocoel is paired in echinoderms, while unpaired in tornaria larva.**

The many embryonic resemblances between hemichordates and echinoderms cannot possibly be accidental or due to convergent evolution. The only infallible conclusion is that the two groups are closely related and that they arose from a common ancestor.

Echinoderms have deviated greatly from the ancestral type, while hemichordates are closer to it. The common ancestor gave rise to echinoderms as a blind side branch, while the main line of evolution produced the hemichordates and chordates.

Conclusion:

The above affinities have led to the conclusion that echinoderms, hemichordates and chordates have arisen from a common ancestral stock, the dipleura larva. Further, the echinoderms deviated greatly from the ancestral stock and formed blind branch in the main line of evolution. The main line of

evolution continued to give rise to hemichordates and chordates.

It appears most reasonable to place them in invertebrates as an independent phylum that has arisen from an ancestral stock that has, on the one hand, to echinoderms and to hemichordates and chordates.

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