Protochordata

Subject: Zoology

Lesson: Protochordata

Course Developer: Dr. Shashi C. Kant

College/ Department: Zakir Husain College, University of Delhi

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Salient features of Protochordates

The name **protochordates** literally means "the first chordates". They are members of Phylum chordata which includes a diverse group of animals ranging from ascidians to man. They all share four fundamental features: **notochord, pharyngeal slits dorsal tubular nerve cord and post-anal tail** (Fig.1.1). These features may be present only briefly during embryonic development or they may persist throughout life but all chordates exhibit them at some during their lifetime.

1.1 Characteristics shared by all chordates:

1.1.1 The notochord:

It is a slender rod that develops from mesoderm. It is the main identifying feature of the chordates and the phylum derives its name from this structure. It is an elastic rod situated above the alimentary canal and below the dorsal tubular nerve cord. The notochord persists in lower chordates but in vertebrates it is partially or wholly replaced by the vertebral column. The notochord of a generalized chordate has the mechanical properties of an elastic rod and it acts as a hydrostatic organ and helps in swimming movements of the body with the help of segmented muscles.

1.1.2 Dorsal tubular nerve cord:

All chordates possess a dorsal hollow nerve cord derived from ectoderm. It lies above the gut and is hollow along its entire length. Its cavity is called as neurocoel.

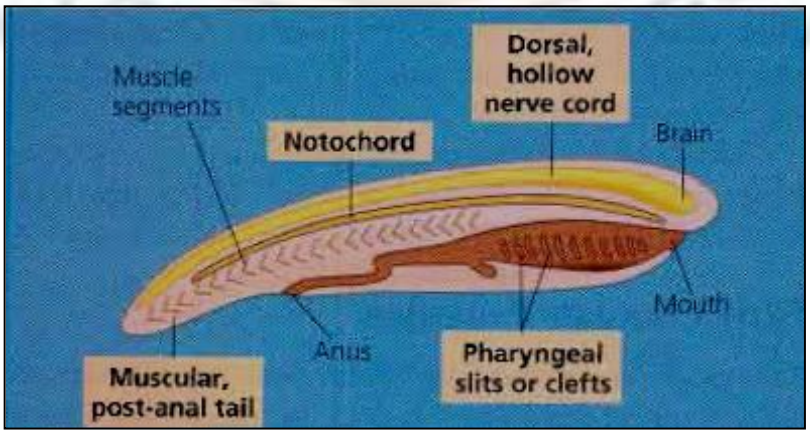


Fig.1.1 Four basic chordate characteristics

(Source: Campbell and Reece .(2008) Biology)

1.1.3 Pharyngeal gill slits:

The pharynx is a part of digestive tract located immediately posterior to the mouth. During some point in the lifetime of all chordates the walls of the pharynx are pierced by a longitudinal series of openings, the pharyngeal slits or gill slits. The pharyngeal slits may appear early in embryonic development and persist into the adult stage or may be overgrown and disappear before the young chordate is born or hatched. These slits in the pharynx allow one way flow of the water current water carrying oxygen and suspended food particles which enter through mouth and leaves through the pharyngeal slits to the outside. Later the wall between these slits becomes associated with gills and vascularized. The current of water passing through these slits can simultaneously help in feeding and respiratory activities.

1.1.4 Post anal tail:

All chordates possess a post anal tail representing the posterior elongation of the body beyond the anus. The tail helps in locomotion.

Besides these four basic characteristics chordates also show **bilateral symmetry** are **deutrostomes** and **metamerically segmented**.

We can conveniently divide the phylum chordate into four subphyla:

1. Sub phylum: **Hemichordata**
2. Sub phylum: **Urochordata (Tunicata)**
3. Sub phylum: **Cephalochordata**

} **Protochordates (Acraniates)**

4. Sub phylum: **Vertebrata (Craniata**)

1.2 Protochordates or Acraniates

Protochordates do not form a proper taxonomic group, but they are all a group of **invertebrate** and **acraniate** chordates, but showing all four features of fundamental chordate body plan. All protochordates are marine animals that feed by means of cilia and

mucus. They often live quite different lives as young larvae than they do as adult. Their larvae may be **pelagic** living in open water between the surface and the bottom. Larvae are mostly **planktonic**, moving from place to place along with currents and tides rather than by their own efforts. As adults they are usually **benthic** living on or within a bottom marine substrate. Some burrow into the substrate or are sessile and attached to it. Some adults are solitary or living alone or colonial living together in groups. Some are **dioecious** with male and female gonads in separate individuals while others are **monoecious** with both male and female gonads in same individual. The protochordates include three groups hemichordates, urochordates, and cephalochordates.

1.2.1 Subphylum hemichordata:

This includes animals of two types belonging to two classes:

1. Class **Enteropneusta** (Acorn worms) e.g., *Balanaglossus*, *Glassobalanus*, *Ptychodera* and *Saccoglossus*.

2. Class **Pterobranchia** (Feather gills) e.g., *Cephalodiscus and Rhabdopleura*

The typical Hemichordates belong to class Enteropneusta.

1.2.1.1 Class Enteropneusta

These are mostly burrowing animals like *Balanoglossus* commonly called as acorn worms(Fig.1.2) because of the shape of their proboscis. They are all marine soft-bodied bottom dwelling animals living in u-shaped burrows (Fig1.3). The body is divided into **proboscis, collar and trunk**. They have pharyngeal slits and nerve cord which may be tubular in some parts. A **buccal diverticulum** present in the proboscis region is considered as a notochord. The wall of this is thick composed of vacuolated cells. Many prefer to call it a **stomochord** and hence the name **stomochordates**. Hemichordates thus lack a proper notochord and a post anal tail and hence the name hemi- or half chordates. The coelom is **enterocoelous** present in the proboscis, collar and trunk in the form of coelomic canals. Proboscis coelom has a single proboscis pore and collar has paired collar pores through which water can enter. The skin is richly ciliated all over the body. It contains numerous gland cells whose secretion is very copious so the animals are always covered with slime. They also have an unpleasant iodoform like smell which along with mucus serves as a protective measure. Below the skin is present a diffuse network of nerve fibers. Deep to this are muscles running in various directions. The external cilia play an important part in locomotion. The animals move by alternate lengthening and shortening of the body produced by action of muscle fibers. They move first by forward protrusion of the proboscis and collar and then draw the rest of the body towards the direction of movement.

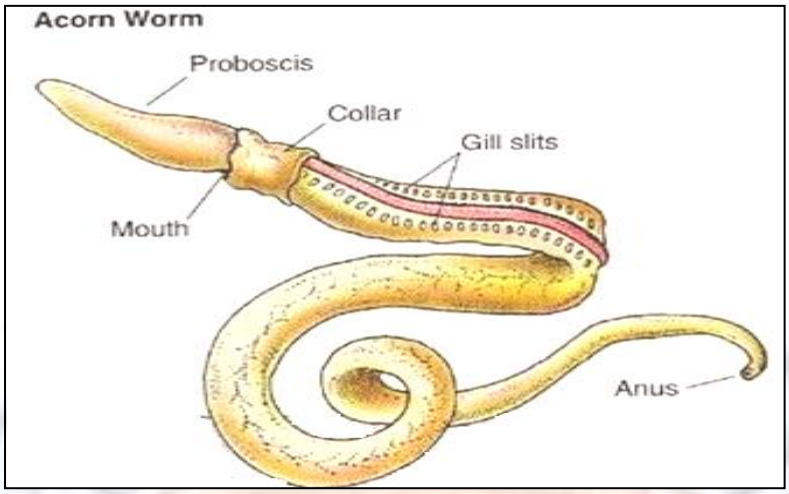


Fig.1.2. *Balanoglossus* (Acorn worm)

(Source: www.bethel.edu/~johgre/bio114d/LowerVerts.html)

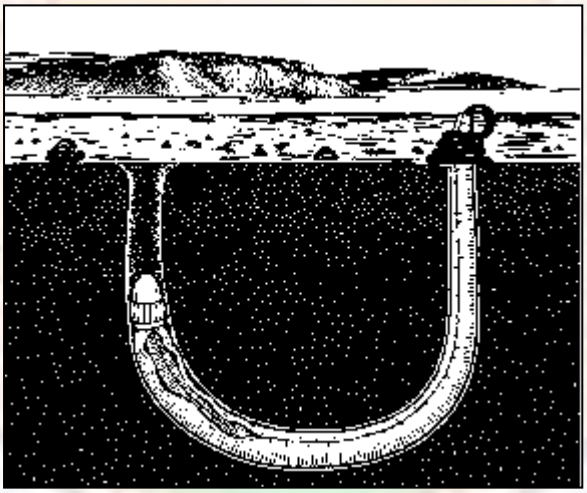


Fig.1.3. Acorn worm in a burrow

(Source: http://www.susanscott.net/Ocean_Watch2001/aug_17-01.html)

Mouth is present on the ventral side in a groove between the proboscis and collar. Proboscis contains many mucus secreting cells which help in capturing food particles. The food particles are then driven towards the mouth by ciliary currents. They feed on bacteria,microscopic algae,diatoms and nutrients they scrape from particles of sand or collect from the water. In the anterior part of the trunk is a spacious pharynx with large number of pharyngeal slits. These slits open into a spacious atrium in some species. While in others each slit opens into a gill pouch. There is no endostyle, but ventral part of the pharynx is often partly separated from the rest of the pharynx and leads to a straight

oesophagus and intestine that terminates in an anus. Numerous **hepatic caecae** can be seen in the anterior part of the intestine. The circulatory system consists of a complex set of haemocoelic spaces and large dorsal and ventral vessels. The dorsal vessel enlarges anteriorly into a **central sinus** and this is surrounded by the wall of a pericardial cavity containing muscles and may be considered as the heart. From this sinus, vessels proceed to the proboscis and round the pharynx to the ventral vessel. Direction of blood flow is forwards in the dorsal and backwards in the ventral vessel. The blood is red in some species but usually colourless. It contains a few amoebocytes. The funnel of the sinus forms a series of glomeruli covered by a region of proboscis coelom. The covering of glomeruli is composed of excretory cells called **nephrocytes**.The nervous system in enteropneusta resembles that of echinoderms. It consists of a sheet of nerve fibers and cells lying beneath the epidermis all over the body. The sheet is thick in the mid dorsal and mid ventral lines and in the collar region it is rolled up forming a hollow neural tube that opens at both ends. There is no central nervous system. Isolates from any part of the body exhibit local reflex response to touch or light stimulus**.** There are no special sense organs. Receptors cells are present all over the body which respond to tactile stimulation. The nerve fibers are present in the pharynx and **o**esophages where peristaltic movements are observed. They may represent the beginning of an **autonomic nervous system.**

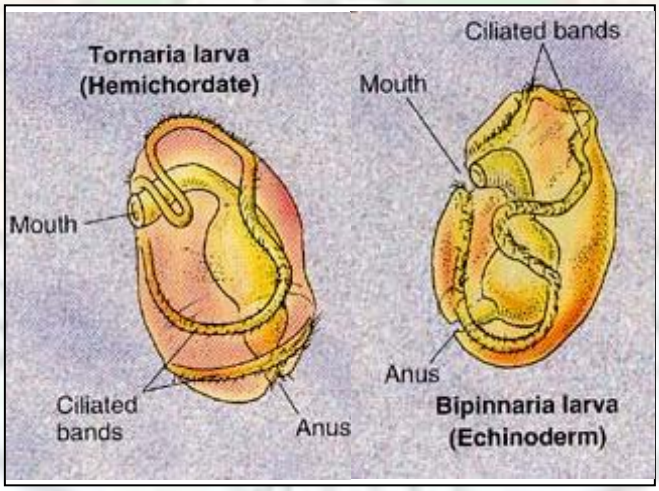


Fig.1.4. Tornaria larva of hemichordates and bipinnaria larva of echinoderms

(Source: www.bethel.edu/~johgre/bio114d/LowerVerts.html)

The sexes are separate and gonads are present in the form of a sacculated bodies arranged in longitudinal rows outside the coelom of the anterior region of the trunk known as **branchiogenital** region. Each gonad opens by a pore to exterior. Fertilization is external. The eggs are small with very little yolk. Development is indirect, cleavage is **holoblastic**, gastrulation is by invagination and the coelom is enterocoelic. A young **tornaria** larva

hatches out with a ciliated band similar to the bipinnaria larva of echinoderms (Fig.1.4). The ciliary band passes in front of the mouth, down the sides of the body and in front of the anus. It then divides into more dorsal and ventral sections, like in bipinnaria larva of a starfish. In later tornaria larva in addition to the longitudinal bands there is always a posterior ring of strong cilia (**telotroch)**. The cilia of the posterior ring are purely locmotive while those of the long bands set up feeding currents converging to the mouth.Finally the larva sinks, becomes constricted into three parts and metamorphoses into a worm like adult. These animals exhibit great power of regeneration.

1.2.1.2 Class Pterobranchia:

These are small colonial marine sedentary animals. They live in oceanic waters in tubes made of their own secretions. *Cephalodiscus* is found in the sea bottom at various depths. The colony is formed by a number of zooids held together in a many chambered gelatinous 'house'. The zooids are formed by a process of budding. Each zooid has a proboscis collar and trunk with coelom in each of these parts and proboscis and collar pores.The collar is prolonged into a number of ciliated arms, the **lophophore** by means of which the animals feeds. They have a large pharynx and only a single pair of gill silts. The intestine is U shaped so that anus opens near the mouth. An extension of the body stalk attaches it to its tube and jerks the animals safely inside when it is disturbed.A thickening in the roof of the pharynx corresponds exactly in position with the stomochord and contains vacuolated cells. *Rhabdopleura* (Fig.1.5) occurs in various parts of the world including the North Atlantic and northern parts of the North Sea. The zooids have proboscis, collar and trunk, ciliated arms, coelomic spaces with pores and stomochord, but no gill slits and no glomeruli. There is a short larval stage with the cilia not in bands. They can reproduce by budding. The zooids of a colony are connected by a basal stolon.

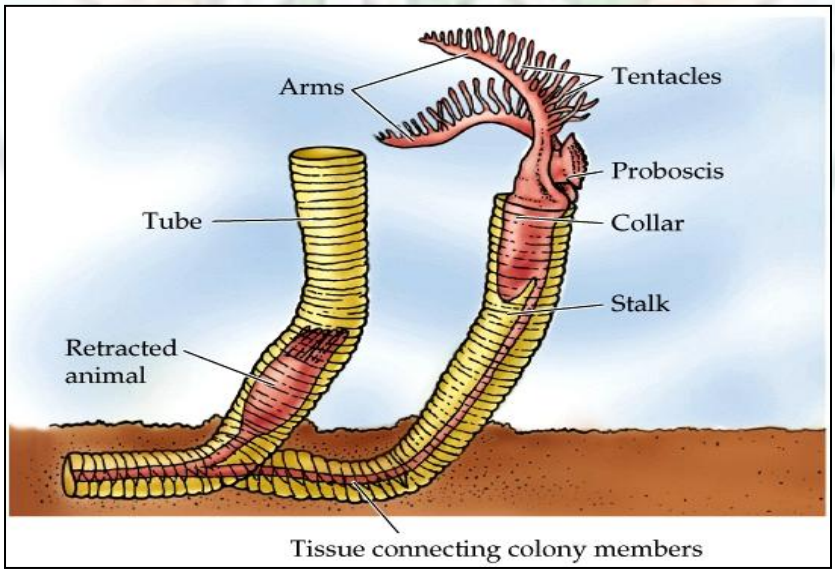


Fig.1.5. A pterobranch *Rhabdopleura* in tubes
(Source: bill.srnr.arizona.edu/classes/182/LophTer.jpg)

Value addition: Did you Know?
Hemichordates connecting link to chordate ancestors
Hemichordates are linked to chordates on one hand and echinoderms on the other hand. They connect chordates to their ancestors among non-chordates. Their stomochord is considered as a notochord but unlike a true notochord the hemichordate stomochord is hollow and lacks the fibrous sheath which gives rigidity to the notochord. Hemichordates thus share only two anatomical features with chordates, pharyngeal slits and a short length of tubular nerve cord. Their body plan composed of proboscis, collar and trunk is quite unlike the body plan of any other protochordate. Zoologist N.J.Berrill believes that the anatomical similarity of larval echinoderms and hemichordates reflects a convergence of larval types to similar pelagic marine environments.
Source: N. J. Berrill (1955) The origin of Verteberates

1.2.2 Sub Phylum Urochordata (Tunicata):

Urochordates are subdivided into three classes:
1. Class Ascidiacea (Sac animals), Ciona, Botryllus and Clavelina
2. Class Thaliacea, Salpa, Doliolum and Pyrosoma
3. Class Larvacaea, Appendicularia and Oikopleura

The typical urochordates or tunicates are sea squirts(Fig.1.6a). They are exclusively marine, bottom living, filter-feeders found in all seas at all depths. Sea-squirts are sac like creatures living on the sea floor. Some species are solitary, others colonial. Adults are sessile, but larvae are planktonic. Development is through a free swimming tailed larva known as **Ascidian tadpole**. The tadpole larva(Fig.1.6c) has all the basic chordate characters, a notochord, a dorsal hollow nerve cord and a muscular post-anal tail. The notochord is present in the tail region only hence the name **Urochordata** (tail backstring).

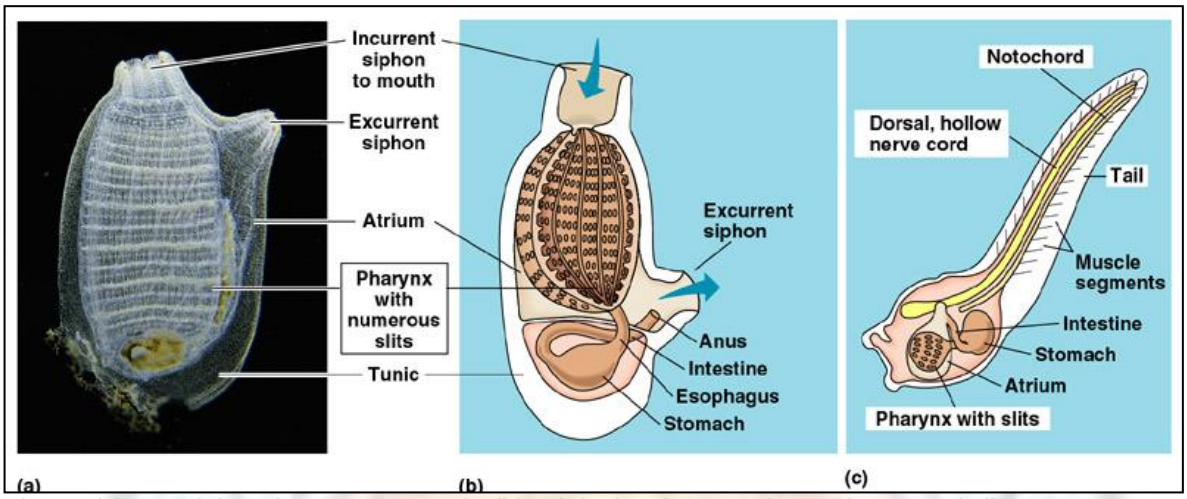


Fig.1.6 (a) An adult tunicate or sea squirt (b) Adult showing prominent pharyngeal slits
(c) Tunicate larva

(Source: http://media.pearsoncmg.com/bc/bc_campbell_biology_6/cipl/ins/34/34-03-Tunicate-L.jpg)

Body of an adult is covered by a tunic or test, hence the name **tunicates**. The tunic serves for protection and support. It is a living tissue supplied by blood vessels with blind ends. It is secreted by the epidermis and contains a few scattered cells that are mesodermal in origin. In some tunicates calcareous secretions of various shapes are found in the tunic. The tunic is composed of a protein **tunicin** and a polysaccharide similar to cellulose. Body has two openings a terminal mouth situated on an **incurrent siphon** and a more or less dorsal atriopore present on an **excurrent siphon** (Fig.1.6a&b). Below the tunic, mantle is provided with muscle fibers running in various directions but mainly longitudinally. Pharynx is large beginning below the mouth and forming a sac reaching nearly to the base. It is surrounded dorsally and laterally be a cavity the atrium. The pharynx pierced by rows of gill slits(Fig.1.6b) whose cilia set up food current entering at the mouth and leaving at the atriopore. The pharynx helps in food collection. The entrance to the pharynx is guarded by a ring of tentacles. There is an **endostyle** which has three rows of secretory cells on each side, separated by rows of ciliated cells and a single median set of cells with very long cilia. The endostyle (Fig.1.7b) is compared to the thyroid of vertebrates. The oesophagus leads to a large stomach with a folded wall containing gland cells which produce mucus and digestive enzymes. From the stomach a short intestine leads upwards to open by a rectum near the atriopore. Digestion is entirely extracellular and food is moved along the gut by cilia. The pyloric gland is present, opening into the gut near the junction of stomach and intestine. Some tunicate species shoot a jet of water (Fig.1.7a) through their excurrent siphon when disturbed hence the name "sea squirts". A small fusiform heart lies below the pharynx and is a sac surrounded by a pericardium. A hypobranchial vessel below the endostyle arises from the heart and sends branches to the pharynx. A visceral vessel joins the hind end of the heart collects blood from the body and sends it to the alimentary canal. The blood is pumped by peristaltic contractions first in one direction and then in the other. The blood plasma is colorless but contains several corpuscles, phagocytes and lymphocytes. Many of

the blood cells contain orange, green or blue pigment. The green pigment is vanadium and cells containing it are called **vanadocytes**. The blood is isotonic with sea water but has little sulphate.

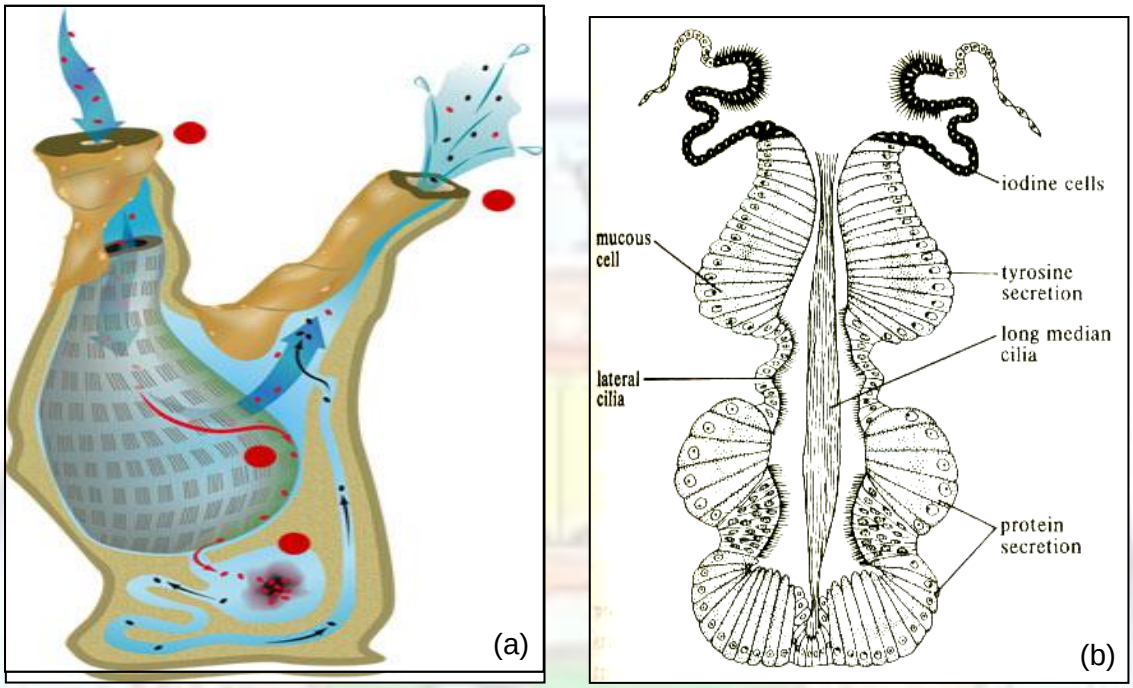


Fig.1.7. (a) A sea squirt shooting out the jet of water (Source: http://www.whoi.edu/cms/images/sea squirt_46310.jpg.)
Fig.1.7. (b) A transverse section of endostyle of *Ciona*
(Source: J.Z. Young)

They have little or no power of regulating their osmotic pressure. There are no special excretory organs. Ninety five percent of the nitrogen is excreted as ammonia. Coelom is much reduced.It is present inside in pericardial cavity and gonads. The central nervous system consists of a round solid ganglion lying above the posterior end of the pharynx. Nerves pass from this ganglion to the siphons, mantle, muscles and viscera. A subneural gland lies below this ganglion and it function is unknown. It is compared with hypophysis or pituitary gland of vertebrates. Movement consists mainly of contraction and closure of apertures. When any siphon is stimulated the other siphon closes first and then the one which is stimulated and finally body contracts, so that a jet of water sweeps out the aperture that received the stimulus. The surface of the body is sensitive to changes in light intensity. The animals show phototropic orientation of the body.

Urochordates are hermaphrodite; ovary and testis lie close to the intestine and open by ducts near the atriopore. Fertilization is external. The cleavage and gastrulation show a typical chordate pattern. The embryonic development produces the ascidian tadpole. The ascidian tadpole possesses all chordate characteristics. The larvae take no food and the gut

is not well developed. There is a pharynx with usually a pair of gill slits opening into an atrium. The larva is positively phototropic and negatively geotropic, and so proceeds to the sea surface. Within a day or two it becomes positively geotropic and negatively phototropic; it then passes to the bottom usually in a dark location attaches to a surface by its adhesive suckers. Once the larva settles on a substrate, it undergoes **retrogressive metamorphosis**, in which many of its chordate characters are lost (Fig.1.8). Its tail and notochord are resorbed. Dorsal nerve cord degenerates and is reduced to a single solid ganglion. It develops a large pharynx and gill slits increase in number and all organs rotate by 90°. The adult ascidian is thus formed as a result of retrogressive metamorphosis of the tadpole larva.

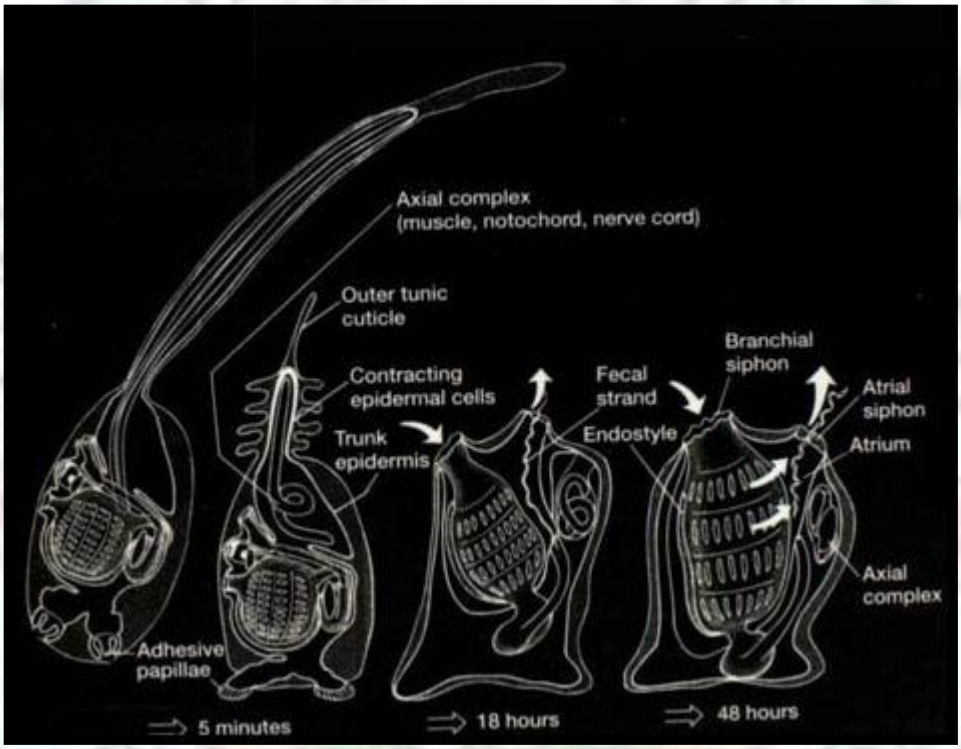


Fig.1.8. Retrogressive metamorphosis in a tunicate

(Source: http://www.biog1105-1106.org/labs/deuts/chordates.html)

Tunicates have great powers of segmentation and colonial forms reproduce asexually by budding. These have root like **stolons** at the base of the body which may fragment into pieces that produce more individuals by budding.

1.2.2.1 Class Ascidiacea:

Protochordata

This class includes the typical bottom dwelling sessile ascidians which vary greatly in size and form e.g *Ascidia*, *Clavelina*, *and Botryllus* etc. The fresh specimens may appear pink as they possess vascular ampullae in the tunic. The tunic or test has clear gelatinous matrix, interlacing fibrils, corpuscles, nerve cells and other types of cells and calcareous spicules.The calcareous spicules are of two types: large spicules, **Megascleres** and small **Microscleres**.These form the endoskeleton of tunicates. Their body can be divided into body proper and foot. The individuals may be solitary (*Ascidiae simplices*) (Fig.1.9a)or colonial (Ascidae compositae) forms with gelatinous tunic. The colonial forms (Fig.1.9b) are produced by budding. In some colonial forms like *Botryllus*, the individuals are embedded in a common gelatinous test.

Fig.1.9. Ascidians (a) Solitary form
(Source: desginmuseum.org)

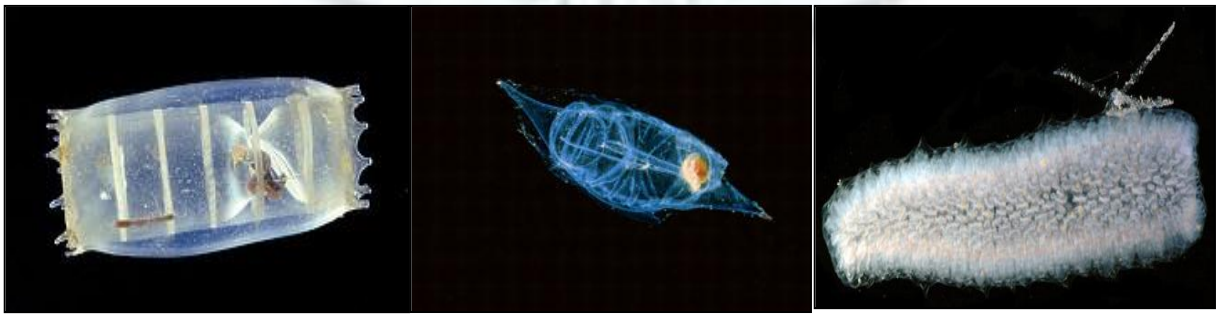
Fig. 1.9. (b) Colonial form
(Source: http://www.reefed.edu.au)

Value addition: Did you know?
Medicinal uses of Tunicates
Tunicates contain a host of potentially useful chemical compounds, including: • Didemnins, effective against various types of cancer, as antivirals and immunosuppressants • Aplidine, effective against various types of cancer • Trabectedin, effective against various types of cancer In the May 2007 issue of The *FASEB* Journal, researchers from Stanford University showed that tunicates can correct abnormalities over a series of generations, and they suggest that a similar regenerative process may be possible for humans. The mechanisms underlying the phenomenon may lead to insights about the potential of cells and tissues to be reprogrammed and regenerate compromised human organs. Gerald Weissman, editor-in-chief of the journal, said "This study is a landmark in regenerative medicine; the Stanford group has accomplished the biological equivalent of turning a sow's ear into a silk purse and back again."
Source: (Source: Sea squirt, Heal thyself. Scientists make major breakthrough in Regenerative medicine –Tunicate wikipedia)

Value addition: Did you know
Heading text: Tunicates that can filter water
Body text: video
Source: http://fins to feet.word press.com/2010/03/14/1-2

1.2.2.2 Class Thaliacea:

These are barrel shaped free swimming pelagic tunicates living in warm waters. They have circular bands of muscles which enable the animals to shoot through the water by jet propulsion. The mouth and atriopore are at opposite ends. The tunic is thin and transparent. In some like *Doliolum* (Fig.1.10a) muscle bands completely encircle the body (Cyclomyaria) whereas in *Salpa* (Fig.1.10b) the rings are incomplete (Hemimyaria). These animals show alternation of generations, *Pyrosoma* (Fig. 10c)is a colonial form.It forms a compact tubular colony. Its zooids are embedded in the wall. The muscle bands are present at the end of the body. There is no larval stage in its life history. It reproduces by budding.



(a) **(b)** **(c)**

Fig.1.10(a) *Doliolum*
(Source:http://gsite.uniprovence.fr/gsite/Local/egee/dir/neve/imagesGN/Doliolum.jpg)

(b) *Salpa* (Source: http://jellieszone.com/images/salpa_fusiformis.jpg)

(c) *Pyrosoma* (colonial) (Source: http://www.treehugger.com/pyrisome-sea-squirt-tunicate-photo.jpg)

Value addition: Did you know
Heading text -Pelagic tunicates roam the word's oceans
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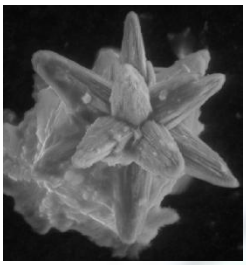
Source: http://fins to feet.word press.com/2010/03/14/1-2

1.2.2.3 Class larvacea:

These are small pelagic and planktonic tunicates. These feed by filtering minute nanoplanktonic organisms. Instead of tests, each individual builds a 'house' by secretion from a special part of the skin. Their general organization is like a typical ascidian tadpole, hence the name Larvacea. These animals are neotenous i.e., sexually mature animals have retained the larval body form, e.g., *Appendicularia* and *Oikopleura*.(Fig. 1.11)

Fig. 1.11 Oikopleura

(Source: http://jellieszone.com/oikopleura.jpg)

Value addition: Common misconception
Fossil urochordate
 Urochordates have a sparse fossil record. A Precambrian fossil known as *Yarnemia* has been referred to the Urochordata, but this assignment is doubtful. Complete body fossils of tunicates are rare, but tunicates in some families generate microscopic *spicules* that may be preserved as microfossils. Such spicules have occasionally been described from Jurassic and later rocks. Few paleontologists are familiar with them; tunicate spicules may be mistaken for sponge spicules. Shown above is a spicule from a living tunicate from Moorea, French Polynesia, photographed using an Environmental Scanning Electron Microscope.
Source: http://www.ascidians.comucmp.berkely.edu/chordata/urochordata.html.

1.2.3 Sub Phylum Cephalochordata:

These are represented by two genera *Branchiostoma lanceolatum* and Asymmetron. Asymmetron resembles Branchiostoma in general organization but has gonads only on the right side. *Branchiostoma lanceolatum* is commonly called as Amphioxus or Lancelets (pointed at both ends) (Fig1.12). These are small 5 to 8 cm long slender fish like marine animals.

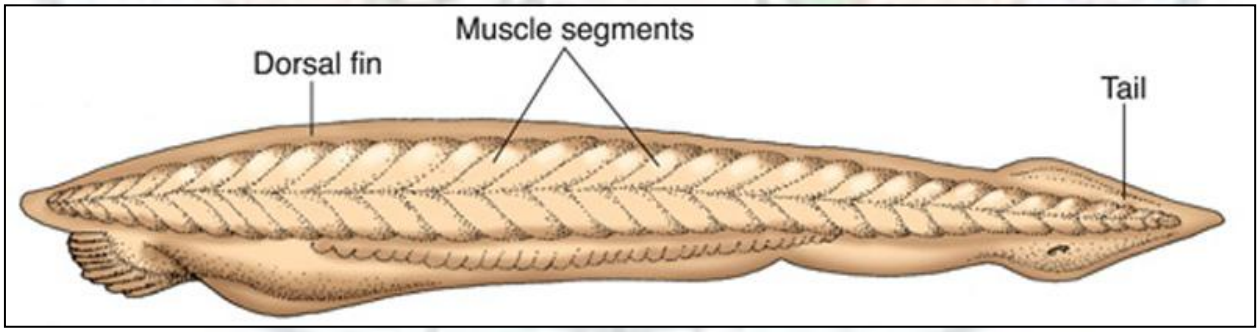


Fig.1.12 *Branchiostoma* morphological features
(Source: http://higheredbcs.wiley.com/legacy/college/levin/0471697435/chap_tut/images/nw0269-nn.jpg)

They are widely distributed in shallow water of all oceans of the world. They are mostly **sedentary** animals that remain buried in sand with their anterior end projecting out of the burrow (Fig.1.13). They have no prominent head; body has trunk and a tail. They have persistent notochord extending from rostrum to tail hence the name cephalochordates. Their body is elongated and flattened from side to side. The skin has no pigment and

muscles can be seen as series of segmental blocks, the **myotomes** helping in bending movements. The front end has a large number of **buccal cirri** which form a sieve around the opening of the oral hood and are provided with receptor cells. These animals are filter feeders. They have a large number of gill slits in their pharynx. Cilia draw sea water into the lancelet's mouth. A net of mucus secreted across the pharyngeal slits removes tiny food particles as the water passes through the slits and the trapped food enters the intestine. The pharynx and pharyngeal slits play a minor role in gas exchange which occurs mainly across the external body surface. An atrium develops around the pharynx by outgrowths of the body wall (**metapleural folds**). Pharyngeal slits open into the atrium and atrium opens to the outside through an atriopore. The alimentary canal opens posteriorly by an anus, in front of the hind end of the body, thus leaving a definite post-anal tail. Amphioxus or the lancelet can swim equally well forwards or backwards. Movements is produced by the serial contraction of muscle blocks the myotomes. They are dorso-lateral and segmentally arranged in the form of inverted v along the sides of the notochord.A posterior **caudal fin** (=tail fin) extends around the dorsal and ventral margin of the tail.There is a long **dorsal fin** along most of the dorsal margin of the body.A short **ventral fin** is located on the ventral margin of the trunk just anterior to the caudal fin.It extends from atriopore to anus.

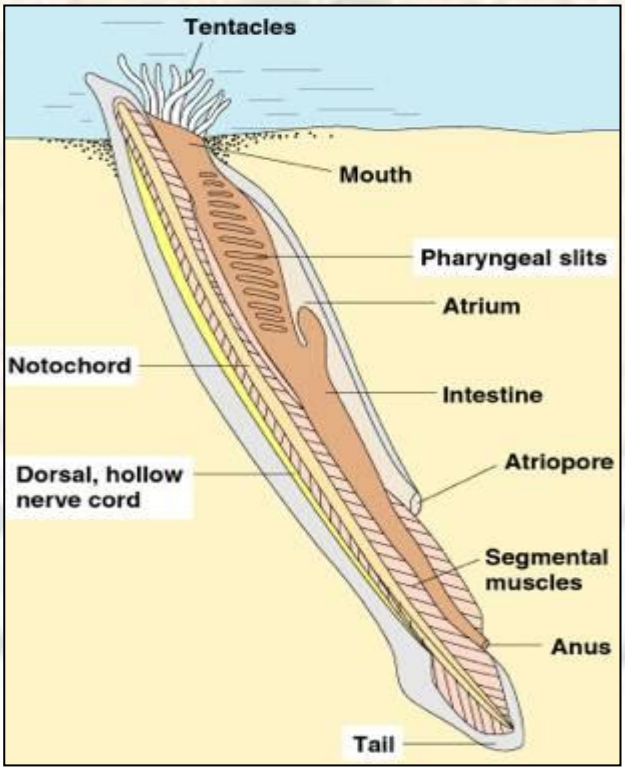


Fig.1.13 Branchiostoma

(Source: Campbell and Reece (2008) Biology)

Buccal cirri present around the mouth prevent entry of large particles into the mouth. The inside wall of the oral hood holds ciliated tracts that sweep food particles into the mouth (Fig.1.14). Coordinated movement of these cilia gives the impression of rotation and hence the name **wheel organ** is given to these tracts. One of these tracts bears a ciliated invagination that secretes mucus to help collect food particles and is known as **Hatschek's pit** or groove (Fig.1.15). This is compared with vertebrate pituitary. The posterior wall of the oral hood has a partial diaphragm **velum** that has **velar tentacles**. These tentacles once again filter the food particles entering the pharynx. Pharynx performs the main function of food collection. Its walls are perforated by nearly 200 oblique vertical slits. On the ventral floor of the pharynx is present an endostyle which has mucus secreting and ciliated cells. This endostyle is comparable to the thyroid of vertebrates. The feeding current is regulated by the rate of beating of cilia and the degree of contraction of the inhalant and exhalent apertures. The nerve fibers present in the wall of the atrium regulate the feeding and spawning. The circulatory system of cephalochordates is based on the fundamental plan of circulation of all chordates. The blood flows forward in the ventral vessels and backwards in the dorsal vessels. There is no central heart. The blood is colorless and does not contain any respiratory pigment. It contains no cells. Oxygenation probably takes place chiefly in the lacunae close to the skin. A network of blood vessels present in the **mid-gut diverticulum** is comparable to hepatic portal system.

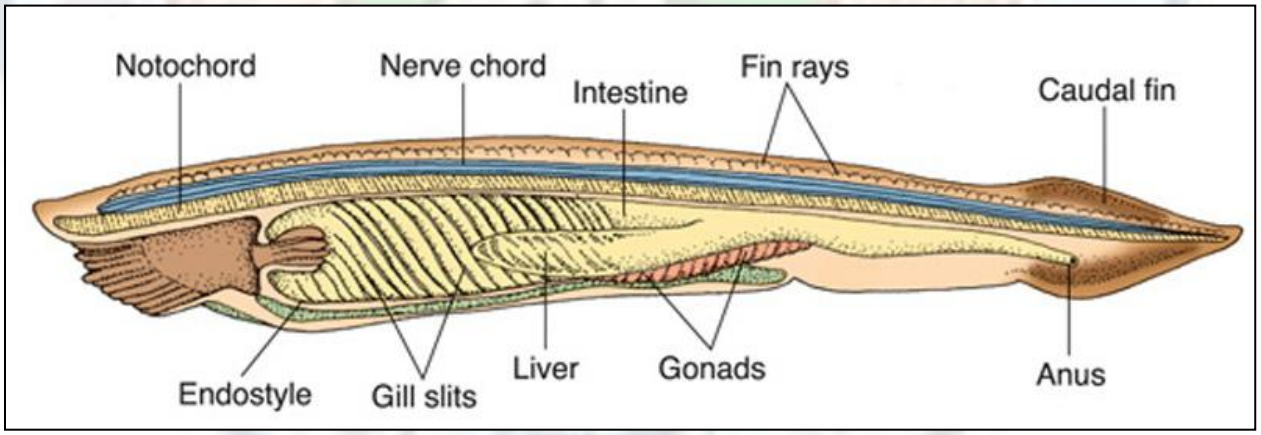


Fig. 1.14 *Branchiostoma* anatomical features

(Source: http://higheredbcs.wiley.com/legacy/college/levin/0471697435/chap_tut/images/nw0269-nn.jpg)

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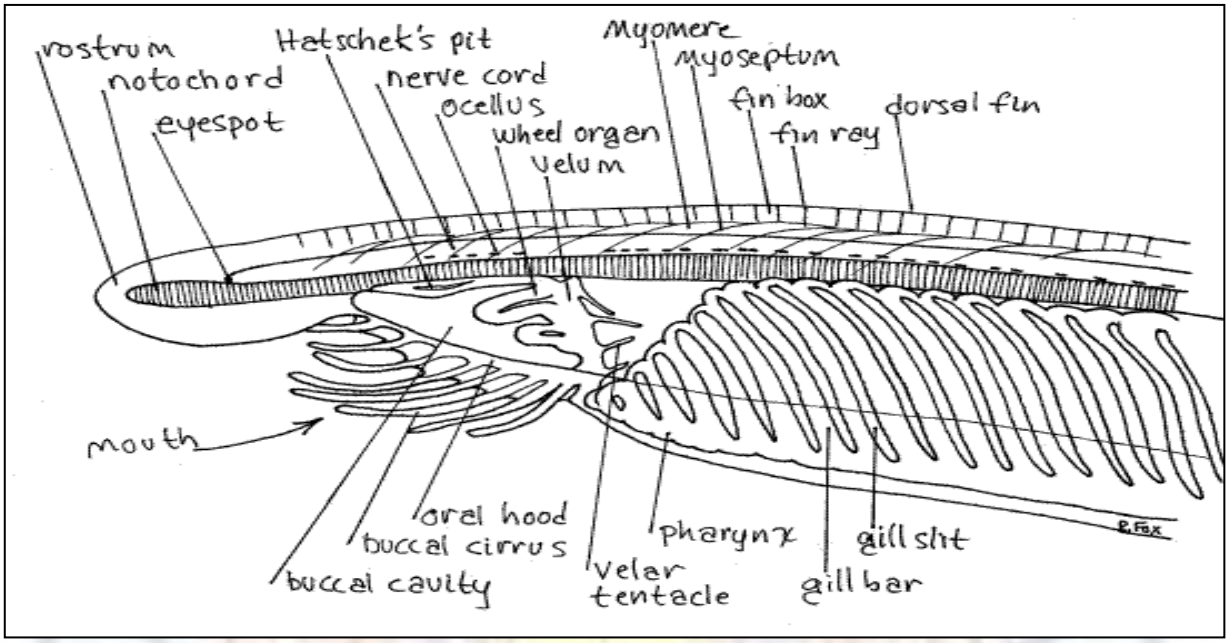


Fig.1.15 *Branchiostoma* Anterior end
(Source:http://webs.lander.edu/rsfox/invertebrates/branchiostoma.html)

Excretion is by protonephridia lying above the pharynx. These nephridia have **solenocytes** or flame cells (fig.1.16). The flame cells are comparable ith those found in platyhelminthes, mollusks and annelids.

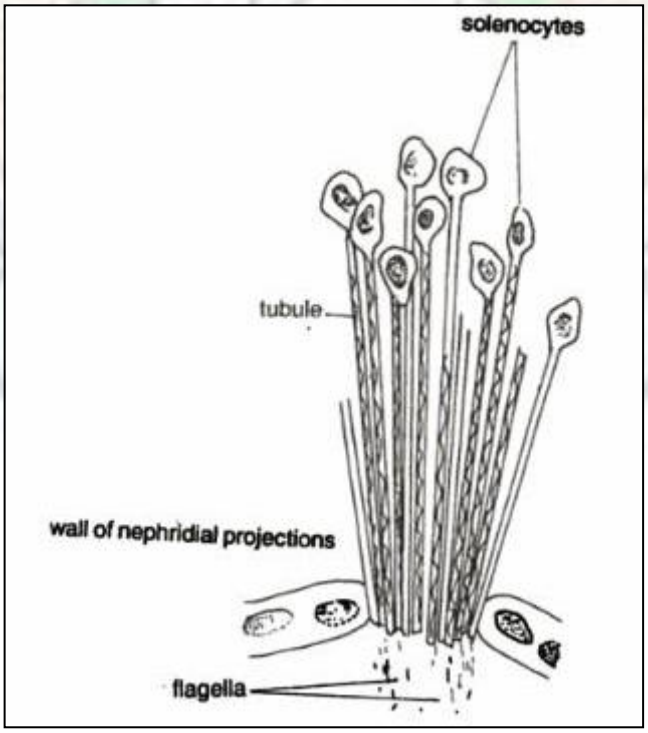


Fig.1.16 Solenocytes in protonephridia in *Branchiostoma*
(Source: http://biology-today.com/wp-content/uploads/2010/11/amphioxus-solenocytes.jpg)

A pair of **brown funnels** also play excretory role. These are blind sacs at front of the atrium. Their exact function is not known. Masses of cells in the atrial wall contain granules that may be excretory and inside the gonads especially the testes there are large yellow masses containing uric acid, which are expelled with the gametes. Cephalochordates possess a hollow dorsal nerve cord similar to that of vertebrates. The central canal of the nerve cord is enlarged at the front end to form a **cerebral vesicle**. Photoreceptor cells are distributed on the spinal cord and remain oriented in different directions. **Tactile receptors** are present on buccal cirri and chemical receptors on the velum.

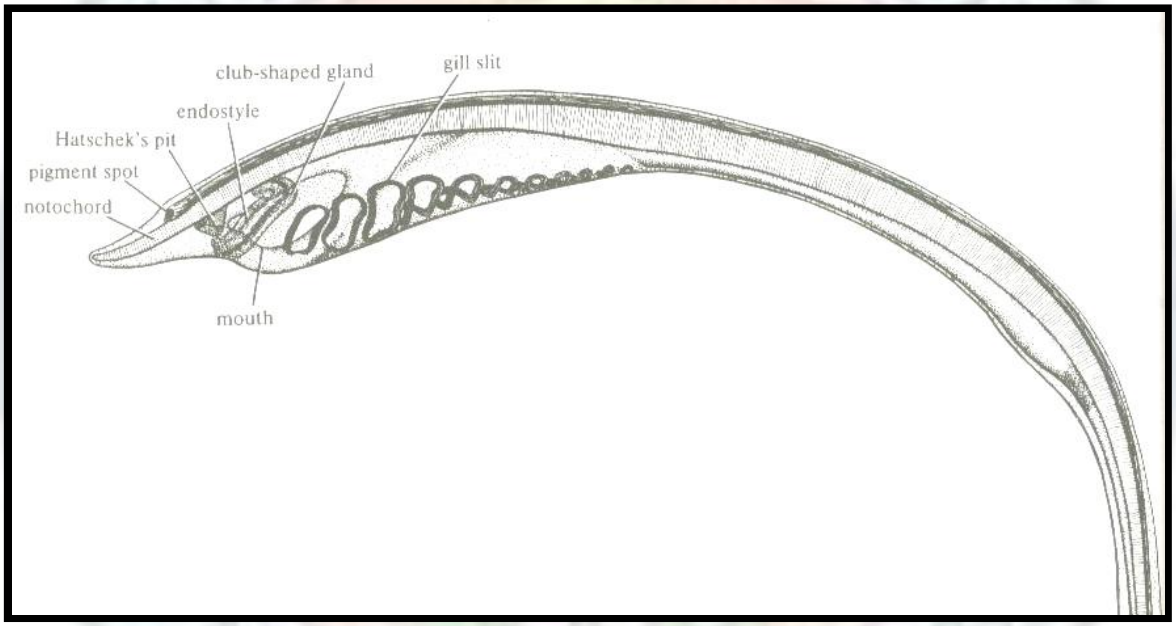


Fig.1.17 Larval *Branchiostoma* before metamorphosis

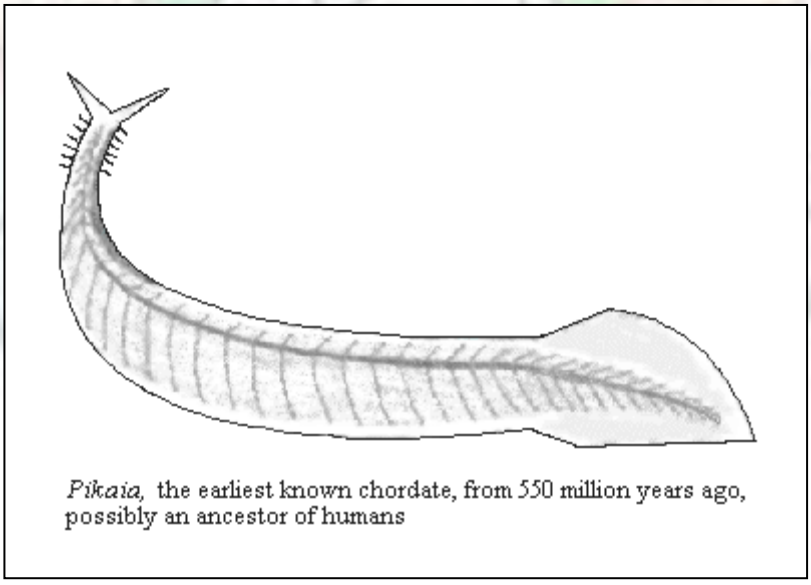
(Source:J.Z.Young (2004) The life of vertebrates.)

The sexes are separate in cephalochordates. The gonads in these animals are hollow segmented sacs. They are situated on the ventro-lateral sides of the pharyngeal region. Gonads are without gonoducts and gametes are discharged into the atrium from where they escape to the exterior through the atriopore along with the water current. Fertilization and development occur in sea water. Eggs are small but yolky. Development is indirect through a free swimming larva (Fig. 1.17). The larva lacks an atrium. The larva sinks out of the plankton to a substrate in which it will take up a burrowing residence as an adult.

Protochordata

All cephalochordates belong to a single class **Leptocordii.** There are two genera *Branchiostoma* and *Asymmetron*. *Asymmetron* has unpaired gonads only on right-side of the body.

Value addition: Did you know?
Branchiostoma or Amphioxus
When a German zoologist P.S.Pallas discovered a cephalochordate, he thought it to be a slug and called it as *Limax lanceolatus.*In 1836 William Yarrell recognized the special nature of these animals and named them as *Amphioxus lanceolatus* (meaning two-ended). Later it was discovered that actually in 1834 O.G.Costa had named them as *Branchiostoma* and according to the, rules of taxonic priority ,this official generic name was retained and amphioxus is considered as the common name, while lancelet is another common name.
Source: Kardong, K.V. (2005) Vertebrates Comparative Anatomy,Function and Evolution.

Value addition: Historical Importance
Fossil Cephalochordate
The oldest known cephalochordate is *Pikalia*.It was recovered from the Burgess Shales of Canada, dating to about the middle of the Cambrian. Unlike living forms, it had a pair of sensory tentacles. In all other features it was anatomically similar to the living *Branchiostoma* (Amphioxus) with a notochord, presumptive pharyngeal slits and chevron-shaped segmental body musculature.
 *Pikaia,* the earliest known chordate, from 550 million years ago, possibly an ancestor of humans
Source: Kardong, K.V. (2005) Vertebrates Comparative Anatomy,Function and

Evolution.

Value addition: Did you know?

Tunicate and cephalochordates linked to chordate evolution

Cephalochordates (lancelets) and tunicates occupy key positions in the history of life. They possess many but not all of the derived characters shared by vertebrates and can provide clues about the evolutionary origin of vertebrates. The ancestral chordate might have looked like a lancelet- that is it had an anterior end with a mouth, a notochord, a dorsal hollow nerve cord, pharyngeal slits and a post anal tail. The genome of tunicates has been completely sequenced and can be used to identify genes likely to have been present in early chordates. Researches have suggested that ancestral chordates had genes associated with vertebrate organs such as the heart and thyroid glands. These genes are found in tunicates and vertebrates but are absent from nonchordates. Tunicates on the other hand lack many genes that are associated with long range transmission of nerve impulses in vertebrates. This result suggests that such genes arose in an early vertebrate and are unique to the vertebrate evolutionary lineage.

Research on lancelets has revealed important clues about the evolution of chordate brain. Lancelets have a slightly swollen cerebral vesicle on the anterior end of their dorsal nerve cord instead of a brain.But, the same Hox genes that organize major regions of the forebrain, mid brain and hind brain of vertebrates express themselves in a corresponding patern in this small cluster of cells in the lancelet's nerve cord.

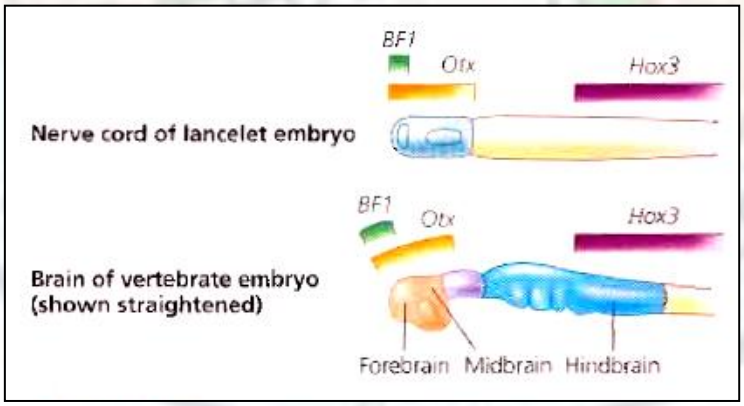


Fig. Expression of developmental genes in lancelets and vertebrates. Hox genes (including BF1, Otx, and Hox3) control the development of major regions of the verytebrate brain. These genes are expressed in some anterior-to-posterior order in lancelets and vertebrates.

This suggests that the vertebrate brain is an elaboration of an ancestral structure similar to the lancelet's simple nerve cord tip.

Protochordata

Source: Campbell and Reece.(2008) Biology 8th edition, Pearson Benjamin Cummings,San Francisco.

Summary

- All chordates have four fundamental features, dorsal notochord, Pharyngeal gill slits, dorsal tubular nervecord and post anal tail.
- They also show bilateral symmetry and metameric segmentation and are deutrostomes.
- These animals can be conveniently divided into four subphyla: Hemichordata, Urochordata, Cephalochordata and Vertebrata. First three of these subphyla are grouped together as Protochordates or Acraniates.
- **Protochordates** are all invertebrate chordates; they are marine animals feeding by means of cilia and mucus.
- **Hemichordates** are soft bodied worm like animals, having all chordate features except that they lack a true notochord.
- Their buccal diverticulum is considered as a notochord. They are found usually living in U-shaped burrows. Their body is divided into proboscis collar and coelom. Circulation of blood is through dorsal and ventral vessels. They have pharyngeal gill slits for respiration and for excretion a single glomerulus connected to blood vessels. They have subepidermal nerve plexus thickened to form dorsal and ventral nerve cord with connecting ring in the collar.
- Hemichordates belong to two classes:

1. Enteropneusta–Acorn worms living in u shaped burrows e.g. *Balanoglossus, Glossobalanus, Ptychedera* and *Saccoglossus.*

2. Pterobranchia-living in 'houses' made of their own secretions.e, g, Cephalodiscus and *Rhabdopleura.*

- Urochordates include sea squirts or Ascidians.
- They are exclusively marine, found in all seas and at all depths. They are mostly sedentary but some are pelagic or free swimming, simple (solitary) or colonial.
- Adults have degenerated bodies which are sac like unsegmented and without appendages and notochord.

- They have a single solid nerve ganglion.Body is covered by a protective tunic or test, so these animals are also known as tunicates. They have a terminal branchial aperture and a dorsal atrial aperture. An endostyle is present in the pharynx which is homologous with thyroid of vertebrates.

- Tunicates are hermophrodites. They can reproduce asexually by budding also. Development is indirect as it includes a free swimming tailed larva called Ascidian tadpole larva. The larva has all basic chordate characteristics. It undergoes retrogressive metamorphosis whereby many larval features are degenerated or lost in adults.

- Urochordates are divided into three classes:

1. Ascidiacea- sessile tunicates solitary or colonial.e. g, Ascidia, Clavelina and Botryllus etc.

2. Thaliacea-Pelagic barrel shaped tunicates with gelatinous and transparent bodies.e. g, Doliolum and *Salpa*

3.Larvacea-Pelagic and planktonic small neotenous tunicates shaped like a bent tadpole. They build a 'house' secreted by their own secretions around themselves. e.g., *Appendicularia* and *Oikopleura.*

- **Cephalochordates** are small fish like marine animals.They are widely distributed in shallow waters.

- They show all chordate features specially the persistent notochord from rostrum to tail.

- They are mostly sedentary animals that remain buried in sand with only the anterior end projecting out of the burrow. They move by help of segmentally arranged muscles. in the form of blocks called as myotomes.

- Excretion is by protonephridia having solenocytes (flame cells).

- Circualtory system is on basic chordate plan. Sexes are separate. Gonads are metamerically arranged and without gonoducts, Gametes are released into the atrium and from there go out with outgoing water current.Ferilization occurs in sea water and development is indirect with a free swimming Larva.

All cephalochordates belong to a single class Leptocardii-e,g.*Branchiostoma* (Amphioxus) and *Asymmetron.*

Exercises

1.1 Enumerate the characteristics of chordates found in protochordates.

1.2 Describe the characteristics of protochordates by which they differ from vertebrates.

1.3 Describe the special features of Hemichordates and justify their inclusion in Chordata.

1.4 Give names of classes of Hemichordates, and how do they differ from each other giving one example of each class.

1.5 Enumerate the special characteristics of Urochordates, and explain why they are called as Tunicates.

1.6 Name the two external openings of Urochordates.

1.7 Name the characteristic features in which Hemichordates differ from the other two groups of Protochordates.

1.8 Name the larval form of Urochordates and explain Retrogressive metamorphosis in them.

1.9 Discuss the habits and external features of Urochordates.

1.10 Name the classes of Tunicates bringing out differences between them and give one example of each class.

1.11 What is the common name of *Branchiostoma* and why is it so called.

1.12 Enumerate the characteristic features of Cephalochordates.

1.13 Write short notes on:Endostyle,Larval Cephalochordate , Ascidian tadpole and Tornaria larva.

Protochordata

Glossary

Bilateral symmetry- Characteristic of a body in which left and right halves are mirror images of each other.

Branchial- Pertaining to gills.

Benthic- Bottom dwelling.

Chemoreceptors- A sense organ that responds to chemical molecules.

Coelom- The body cavity in triploblastic animals which is lined by embryonic mesoderm.

Colonial- Living in colonies.Some times the buds produced as a result of asexual reproduction do not separate and thus form colonies.

Deutrosomia- organisms in which the embryonic blastopore forms the anus and mouth is formed at the opposite end.

Dioecious- Animals in which male and female gonads are present in separate individuals.

Endostyle- A mucus secreting glandular region with ciliated cells lying below the pharynx in protochordates.

Enterocoelous-Coelom which is formed by outpouching of the mesodermal sac from the archenteron.

Glomeruli- A small cluster of capillaries on the stomochord of hemichordates.

Homologous- Characteristic features having a common origin.

Lacunae- small spaces.

Metameric segmentation-division of the body where there is serial repetition of structures in the longitudinal axis of the body.

Monoecious- Animals in which male and female gonads are found in the same individual; hermaphrodite.

Nanoplankton—very small plankton.

Nephrocytes-Large phagocytic cells that accumulate waste products.

Neurocoel- A cavity inside the nerve cord.

Pelagic- Living in open water between the surface and the bottom.

Planktonic- moving with currents and tides rather than by their own efforts of long distance swimming.

Retrogressive metamorphosis- Metamorphosis in which there is degeneration of larval organs to attain adult condition.

Sessile- Pertaining to an animal attached to a fixed substratum.

Solitary- An organism living alone.

Solenocytes- Excretory cells with projecting circle of microvilli around a central flagellum;flame cells.

Tactile receptors- receptor organs that respond to touch.

Zooid- An independent organism produced by another organism asexually by budding.

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2. Suggested Readings

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Zoological Society of London, 20:36. Academic Press, New York
Berrill, N.J. (1955). The origin of Verteberates, Clarendon Press, Oxford
Pough F.H.,Janis,C.M.and Heiser,J.B.(2003) Vertebrate Life.Pearson Education.

3. Web Links (For Additional Information)

1.1 Branchiostoma and Internal anatomy. highereredbc.wiley.com
1.2 Branchiostoma by R.Fox.webs.lander.edu/rsfox/branchiostoma
1.3 Cephalochordates.cas.bellarmine.edu
1.4 Hemichordates:Hemichordata-physical characteristics,behaviour.http://animal.jrank.org
1.5 Introduction to the Cephalochordata.www.ucmp.berkeley.edu
1.6 Phylum Chordata:protochordates.www.biosciweb.net
1.7 Protochordates.http://www.reefed.edu.au
1.8 Sea squirts,urochordates,tunicates.http://www.youtube.com
1.9 The hemichordates (Phylum chordata).www.earthlife.net