1. The ancestral larvae were developed into the sessile degenerate adult *Ascidians* by retrogressive metamorphosis.

2. The ancestral larvae became matured and were developed into freshwater ***fish-like*** chordates by ***neoteny***.

3. The ancestral larvae re-adapted to marine conditions and gave rise to *Amphioxus*.

Conclusion

Though adult *Ascidians*, do not possess the main chordate characters, its larva develops them. Hence the inclusion of *Ascidian* in the phylum ***Chordata*** cannot be denied.

The *Ascidians* may have come from fixed ***Pterobranchs***, a group of ***Hemichordates***. The early fixed *Ascidians* developed a tailed larva. The larva after retrogressive metamorphosis became sedentary *Ascidian*. Some of the larvae became adults by ***neoteny***. These neotenous forms invaded estuaries and rivers and reached freshwater ponds where they became fishes. Some of the neotenous forms returned to the sea and became *Branchiostoma*.

Thus *Ascidian* tadpole larva is believed to be the direct ancestor of vertebrates. This conclusion is based on the ***ascidian theory of chordate origin*** proposed by ***Garstang (1928).***

3. Branchiostoma (Amphioxus)

Phylum : *Chordata*
Subphylum : *Cephalochordata*

Amphioxus is a ***protochordate***. This animal is peculiar in that the anterior end of the notochord extends into the head. Hence it is included in the subphylum ***Cephalochordata*** (cephalon=head). *Amphioxus* is commonly called ***lancet*** because of its shape. Its scientific name is *Branchiostoma lanceolatum*.

It is a ***marine, burrowing*** animal. It lives in shallow waters. In the day time, it remains in a sandy burrow with the anterior end protruding out. During night it leaves the burrow and leads a free swimming life.

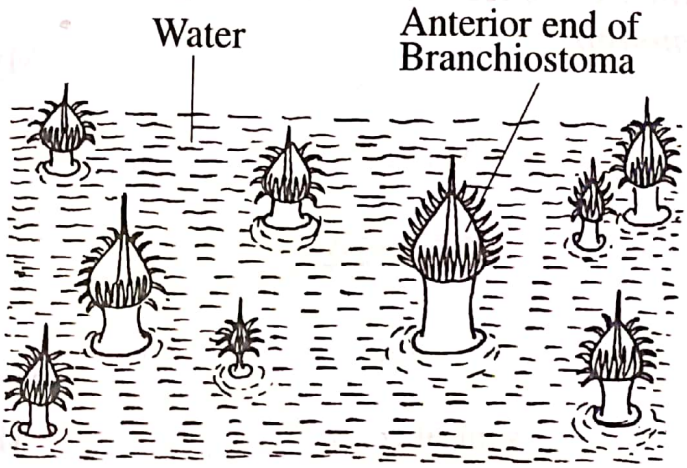

Fig.2.52: Amphioxus in its burrow.

It is ***spindle-shaped*** and laterally compressed. Both ends are pointed and *Amphioxus* looks like a ***lance*** and hence the name ***lancet***. It is about 4.5 cms long.

The body is divisible into an anterior ***trunk*** and a posterior ***tail***. It has no head. The anterior end has a pointed process called ***rostrum***. A frill-like membranous enclosure is present beneath the ***rostrum***. It is called ***oral hood***. It is formed by the forward growth of the skin. The oral hood opens to the outside at the anterior end by a large opening called ***mouth***. The cavity enclosed by the oral hood is called ***vestibule*** or ***buccal cavity***. The margin of the oral hood bears 20 or more tentacles called ***oral cirri.***

Amphioxus has three fins on the body. They are the ***dorsal fin***, the ***caudal fin*** and the ***ventral fin***. The dorsal fin is present along the mid-dorsal line throughout the entire length of the body. Posteriorly it surrounds the tail as the ***caudal fin***. Ventrally the caudal fin extends forwards about one third of the length of the body. It is called ***ventral fin***. The dorsal and ventral fins are supported by a skeletal frame work called ***fin ray boxes***. The caudal fin is without ***fin ray boxes***. Fins are used for ***locomotion***.

Body Wall

The body wall is formed of ma layers. They are ***cuticle***, the ***epiderm*** the ***basement membrane***, the ***dermis***, ***muscles*** and the ***peritoneum***. The cuti is a thin outer layer. Epidermis is form of a single layer of cells like that of t invertebrates. The epidermal cells a columnar. The dermis is formed of co nective tissue fibres. It is formed of outer compact layer and an inner thi spongy layer with a few fibres, conne

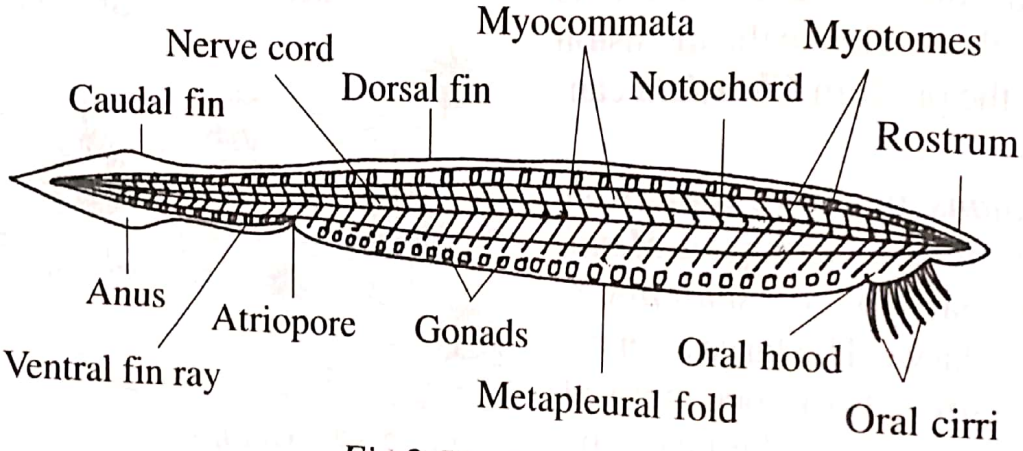

Fig.2.53: Amphioxus.

The ventral surface of the anterior two-third of the body is flat and is called ***epipleure***. The lateral margins of the epipleure are produced into two thin folds called ***metapleural folds***. The metapleural folds are continuous infront with the oral hood. Posteriorly they are joined with the anterior end of the ventral fin.

Amphioxus has three external openings. They are the ***mouth***, the ***atriopore*** and the ***anus***. The mouth is the wide opening of the oral hood. The anus is located at the anterior end of caudal fin. The atriopore is located at the anterior end of the ventral fin slightly to the left of the middle line.

tive tissue cells, blood vessels and ner fibres. The cuticle, the epidermis an the dermis together constitute the ***skin***

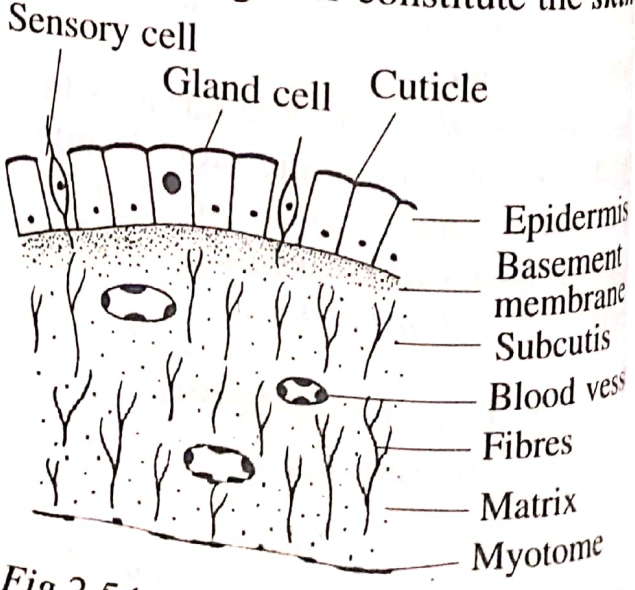

Fig.2.54: Body wall of Branchiostom

The ***muscles*** are located beneath the skin. They are metamerically segmented and are arranged in a linear series. The muscles are in the form of <–shaped blocks called ***myotomes***. There are about 62 myotomes on each side. The apex of the myotomes is directed forwards. The myotomes of the two sides do not lie opposite to each other; but they alternate with each other. Each myotome is enclosed in a fibrous connective tissue sheath called ***myocomma***. The muscles are internally lined with peritoneum.

The body wall has the following functions: ***protection, sensation, locomotion*** and ***support.***

Atrium

Atrium is a spacious cavity lying inside the body. It surrounds the pharynx, oesophagus and the intestine. It is lined with the ***ectoderm***. It opens to the outside by the ***atriopore***. The atriopore is located at the anterior end of the ventral fin. The gill slits of pharynx open into the atrium. The ventral wall of atrium is the ***epipleure***. The main function of atrium is to ***give protection to the gills*** by preventing them from being closed up with sand.

Coelom

Coelom is the body cavity lying between the body wall and the alimentary canal. It is lined with the ***coelomic epithelium***. Around the pharynx, the coelom is replaced by the atrium. In the pharyngeal region, it is reduced to three types of coelomic spaces.

1. A ***mid-ventral subendostylar coelom*** running below the endostyle.
2. Two ***dorsal longitudinal canals*** lying above the pharynx.
3. The ***vertical coelomic canals*** in the primary gill bars.

Notochord of Amphioxus

Notochord is the ***backchord***. It is a gelatinous cylindrical skeletal rod containing vacuolated notochordal cells, located on the back.

It is the ***axial skeleton.*** In vertebrates, vertebral column develops around the notochord.

The animals containing a notochord are included in the phylum ***Chordata.***

In *Amphioxus*, the notochord extends from anterior tip to posterior end. In other chordates, the notochord extends

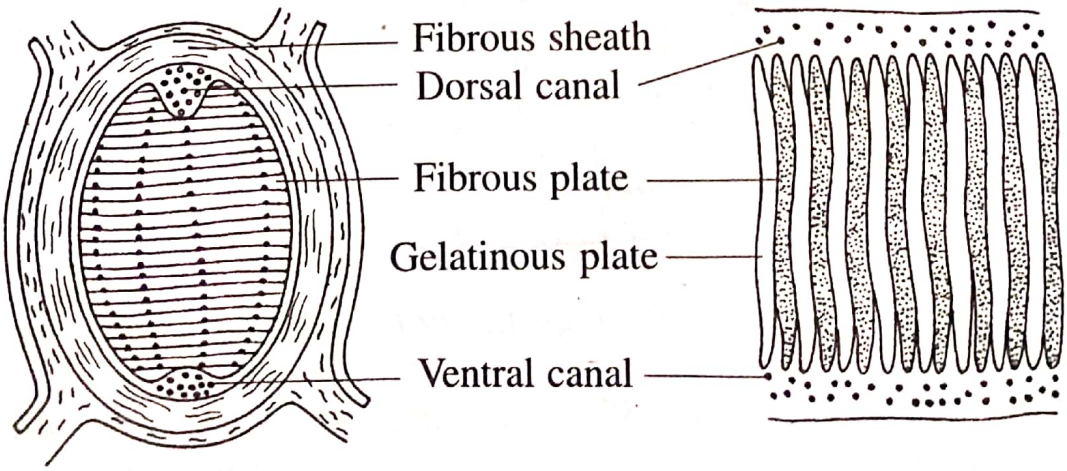

Fig.2.55: Notochord.

anteriorly upto the brain only. But in *Amphioxus*, it extends beyond the brain. As the notochord extends into the head region, *Amphioxus* is called ***cephalochordate.*** The anterior extension of notochord helps *Amphioxus* in ***burrowing***.

The notochord is situated above the alimentary canal and below the nerve cord.

It is covered by a ***notochordal sheath***. It is made up of ***fibrous connective tissue***. Inner to the notochordal sheath, there is a thin elastic membrane called ***elastica interna***.

Below the elastica interna, there are two canals called ***dorsal canal*** and ***ventral canal***. These canals are filled with chordal corpuscles.

The notochord is made up of a single row of disc-shaped cells called ***notochordal*** cells. The notochordal cells are of two types, namely ***fibrous cells*** and ***gelatinous cells***. The fibrous cells alternate with gelatinous cells. The notochordal cells are arranged in a ***longitudinal row***.

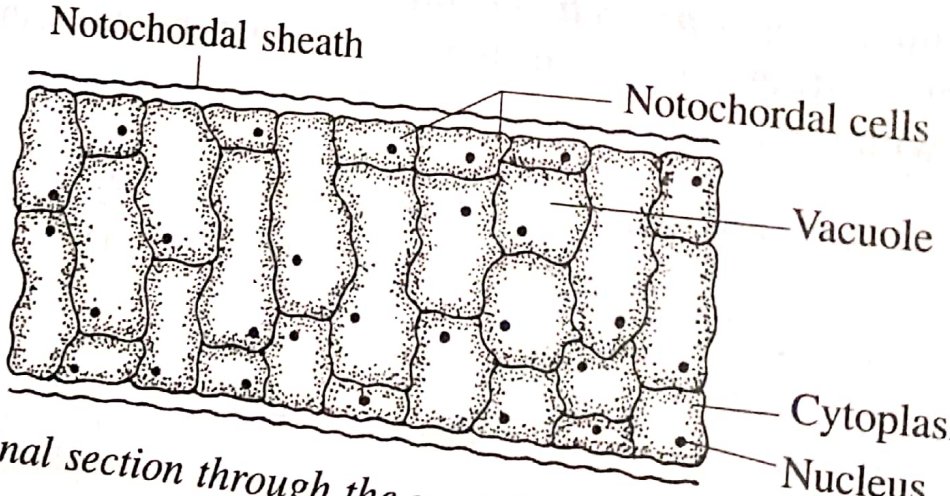

Fig.2.56: Longitudinal section through the notochord of developing chordate.

In the developing stage, the notochordal cells contain a vacuole. Hence ey are ***vacuolated cells***. The nucleus and cytoplasm are pushed towards the periphery.

In *Amphioxus* and vertebrates, the notochord develops from ***mesoderm***. But in *Balanoglossus* and *Ascidians*, it develops from ***endoderm***.

The notochord functions as the ***axial skeleton***. It gives shape and rigidity to the body. It prevents the shortening of the body during muscle contraction.

The rostrum supported by the notochord helps in burrowing.

In *Amphioxus*, the muscles are not attached to the notochord.

Digestive System

The digestive system includes the ***alimentary canal*** and the ***digestive glands***.

Alimentary Canal

The alimentary canal starts from the ***oral hood*** and ends in the ***anus.***

The ***mouth*** is a wide opening located below the rostrum. It is surrounded by a frill-like membrane called ***oral hood***. The oral hood bears about 20 finger-like processes called ***oral cirri***. The oral cirri function as a sort of sieve during feeding.

The oral hood encloses a spacious cavity called ***buccal cavity*** or ***vestibule***. The buccal cavity is lined with ectoderm.

The ectodermal lining is folded to form a number of thick, finger-like ciliated tracts. All these tracts are together called ***wheel organ*** because they create whirling water currents. The mid-dorsal tract of the wheel organ is larger. Its groove is called ***Hatschek's groove*** which ends in a glandular depression called ***Hatschek's pit***.

The posterior end of the buccal cavity has a vertical partition called ***velum***. The velum is perforated by an opening called ***enterostome***. The velum bears many ***velar tentacles***.

ynx on each side is perforated by a row of about 180 vertical slit-like openings called ***gill slits*** or ***branchial apertures***.

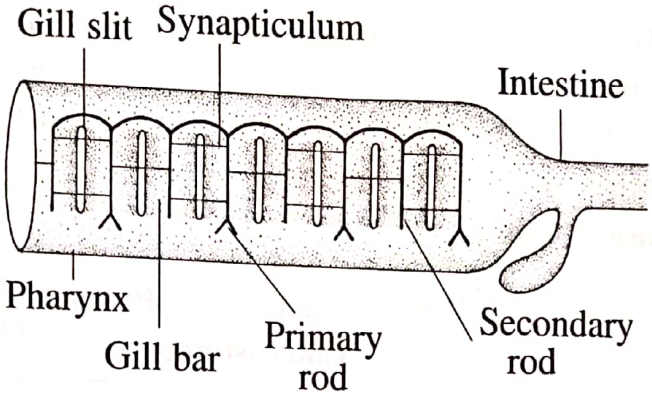

Fig.2.58: Amphioxus-A branchial apparatus.

The wall of the pharynx lying between the gill slits is called ***gill bars***.

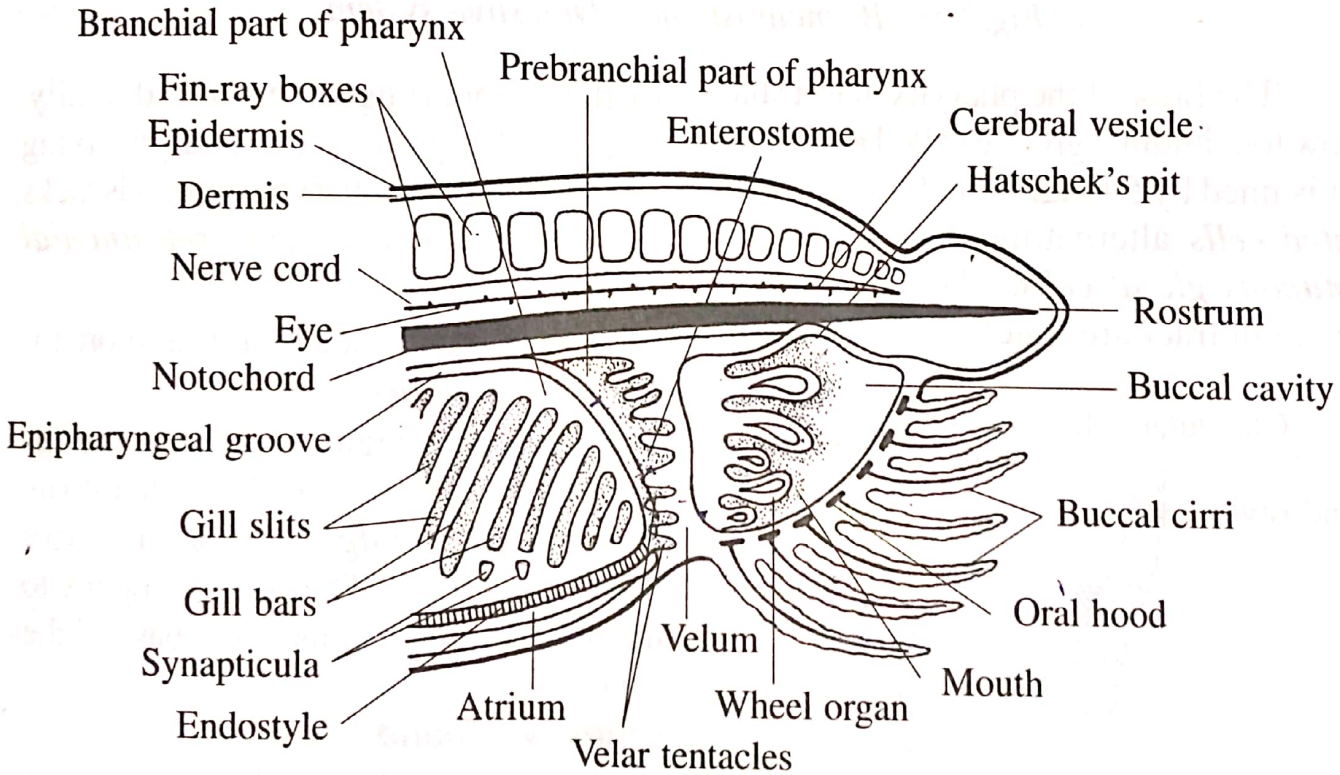

Fig.2.57: Branchiostoma; V.S of anterior region.

The enterostome leads into a sac-like structure called ***pharynx***. The pharynx is also called ***branchial basket*** because it bears gill slits. It is a laterally compressed sac. The wall of the pharynx is perforated by a row of about 180 vertical slit-like openings called ***gill slits*** or ***branchial apertures***.

The gill bars are of two types, namely ***primary gill bars*** and ***secondary gill bars***. These two bars regularly alternate with each other. The gill bars are supported internally by a skeletal rod. The

skeletal rod present in the primary gill bar is called ***primary rod***. It encloses a ***coelom*** and it is ***forked*** ventrally. The skeletal rod present in the secondary gill bar is called ***secondary rod.*** It has ***no coelom*** inside and it is ***not forked*** ventrally. The primary and secondary gill bars are interconnected by numerous horizontal partitions called ***synapticula***.

In the roof of the pharynx, there is another ciliated groove called ***epipharyngeal groove***. At the anterior end of the pharynx, there are two transverse ciliated tracts on the inner wall of the pharynx called ***peripharyngeal bands***. The peripharyngeal bands are connected to the endostyle ventrally and

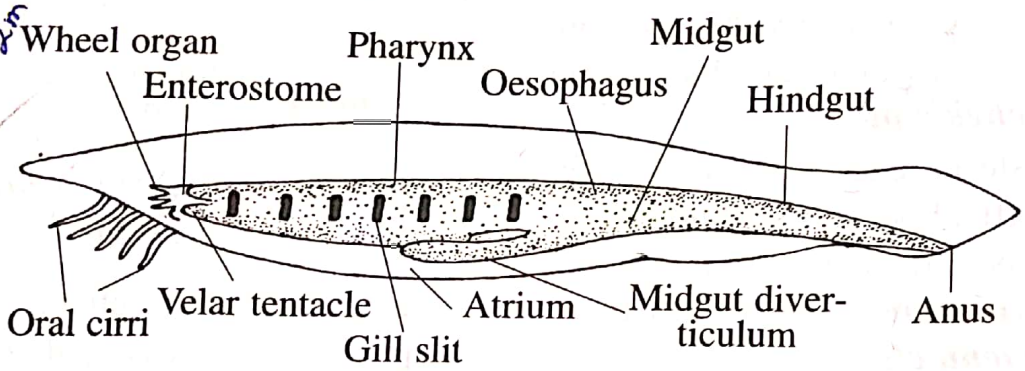

Fig.2.59: Branchiostoma - Digestive system.

The floor of the pharynx has a shallow longitudinal groove called ***endostyle***. It is lined by 5 longitudinal tracts of ***ciliated cells*** alternating with 4 tracts of ***mucous gland cells.*** The cilia of the median tract are much longer than the

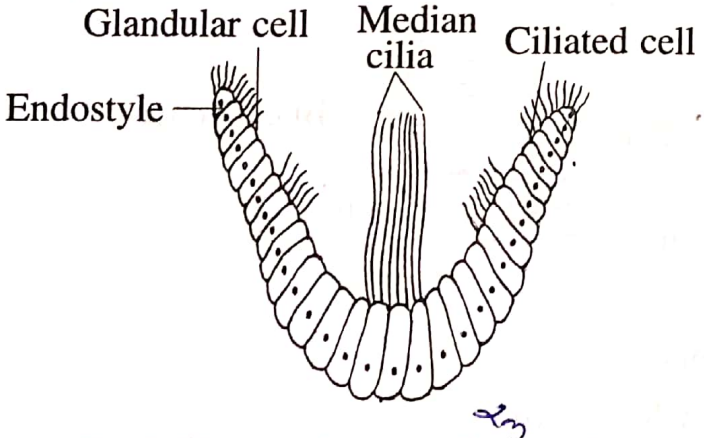

Fig.2.60: Amphioxus-Endostyle.

lateral tracts. The endostyle is supported by a pair of skeletal plates. The endostyle has two functions: 1. It secretes **mucous**. 2. It creates ***water current.***

to the epipharyngeal groove dorsally. The small region of the pharynx lying infront of the peripharyngeal bands lacks gill slits and it is called ***prebranchial region***.

The pharynx leads into a short tubular ***oesophagus***.

The oesophagus leads into the ***intestine***. The intestine is divisible into an anterior wide ***midgut*** and a posterior narrow ***hindgut***. The hindgut opens to the outside by the anus at the base of the caudal fin.

Digestive Gland

Amphioxus has a single digestive gland called ***midgut diverticulum*** or ***hepatic diverticulum***. It is in the form of a sac attached to the alimentary canal in the junction of oesophagus and midgut. It extends forward below the pharynx. The secretion of this diverticulum con-

tains enzymes like ***lipase, amylase*** and ***protease***. It helps in ***digestion***.

Feeding

Amphioxus is a ***carnivorous animal***. It feeds on microscopic organisms like plankton, protozoans, etc. *Amphioxus* feeds itself in three ways. They are ***ciliary*** feeding, ***filter*** feeding and ***mucous*** feeding.

The beating of the cilia of the gill bars creates a water current. This water current carries food materials. The water current enters the pharynx via mouth, buccal cavity and enterostome. From the pharynx, water passes into the atrium through the gill slits. From the atrium the water passes out through the atriopore. The oral cirri and the velar tentacles function as a sieve and they prevent the entry of large particles into the pharynx.

The mucous gland cells of endostyle secrete mucous. The mucous stream moves upwards along the lateral walls of the pharynx. food laden mucous stream enters the epipharyngeal groove. In the epipharyngeal groove, the mucous stream is converted into a twisted ***mucous cord*** by the beating of the cilia. The mucous cord is then passed into the oesophagus.

From the oesophagus, the mucous cord passes into the midgut. From the midgut it enters the midgut diverticulum for a short distance. From the midgut diverticulum, it returns to the midgut. Then it enters the hindgut.

Digestive enzymes are secreted by the midgut diverticulum and are poured into the midgut. Digestion occurs inside the midgut and the hepatic diverticulum. Digested food is absorbed in the hindgut. The undigested materials along with the mucous cord are eliminated through the anus.

In *Amphioxus*, digestion is both ***extracellular*** and ***intracellular***. Extracellular digestion occurs in the midgut.

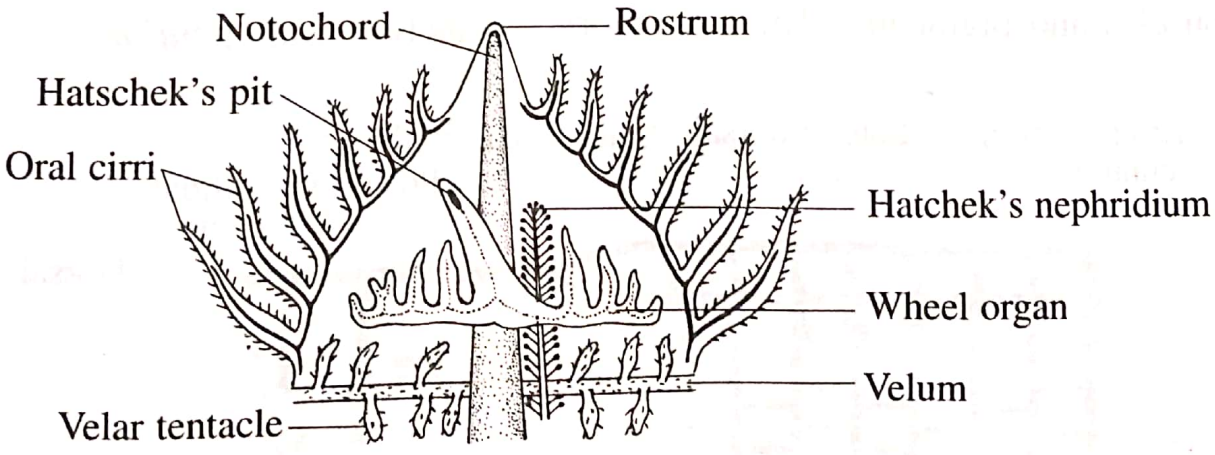

Fig.2.61: Amphioxus-Anterior end viewed from ventral side.

Food particles carried by the water current are entangled in the mucous. The

Intracellular digestion occurs in the hepatic diverticulum. Here the cells are phagocytic.

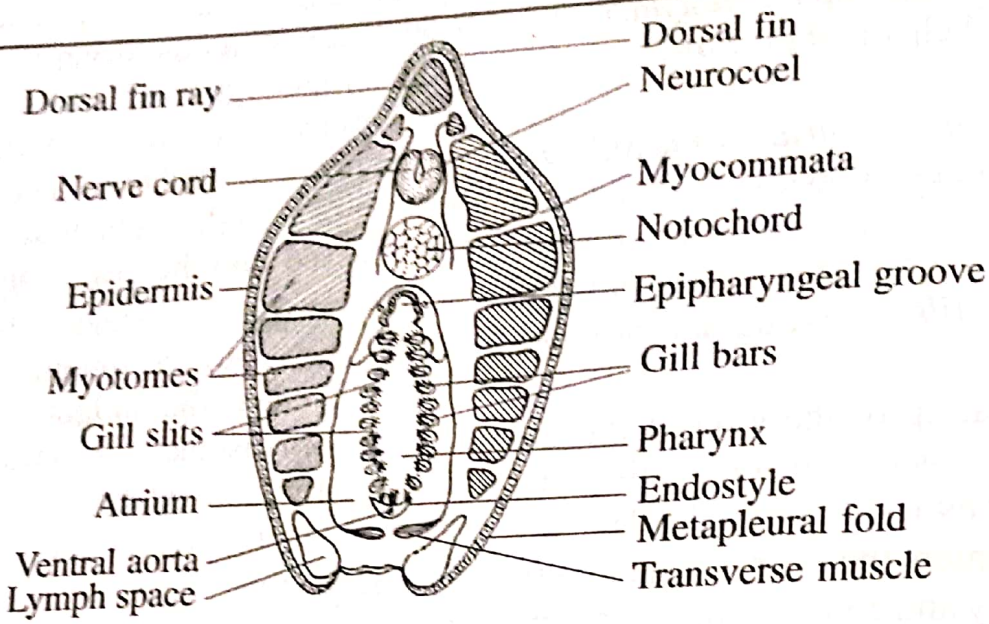

Fig.2.62: Amphioxus-T.S. through pharynx.

Respiratory System

Amphioxus has no well defined respiratory system. Respiration occurs by diffusion through the body surface. The gill slits of *Amphioxus* play a minor role in respiration.

Circulatory System

Heart is absent from *Amphioxus*. Blood is ***colourless*** and without corpuscles and pigments. The circulatory system has a ***ventral aorta*** located below the pharynx. It is contractile and it pumps the blood forwards. Anteriorly the ventral aorta divides into two branches called ***external carotid*** arteries. The ventral aorta gives off paired lateral blood vessels called ***afferent branchial vessels***. These vessels pass into the primary gill bars. Each afferent branchial vessel has a bulb-like dilation at its base, called ***bulbil***. It is contractile

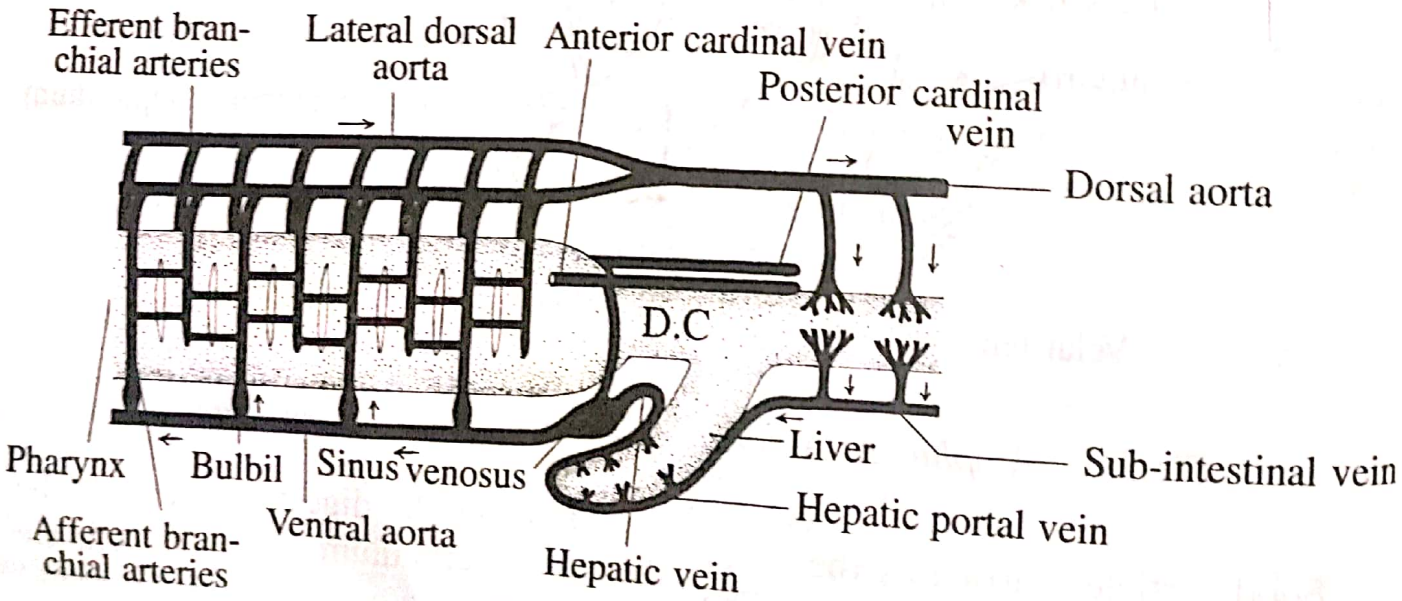

Fig.2.63: Amphioxus - Circulatory system.

and it pumps the blood into the afferent branchial vessels. The secondary gill bars receive branches from the primary gill bars through ***synapticula***. The afferent branchial vessels of the primary and secondary gill bars run upwards and leave the gill bars as ***efferent branchial vessels***. The efferent branchial vessels of each side open into a ***lateral dorsal aorta*** located above the pharynx. The two lateral aortae run forwards as the ***internal carotid arteries***. Just behind the pharynx, the two lateral aortae join together to form a ***median dorsal aorta***. Posteriorly it enters the tail and it is called ***caudal artery***. The dorsal aorta sends paired branches to the myotomes and the intestine. In the dorsal aorta, the blood flows in the backward direction.

Below the intestine there is another vessel called ***sub- intestinal vein***. It collects blood from the tail through the ***caudal vein*** and from the intestine through ***intestinal veins***. The sub-intestinal vein runs forward and forms the ***hepatic portal vein*** beneath the oesophagus. It extends forwards along the lower surface of midgut diverticulum. It gives out several minute branches to the hepatic diverticulum. These branches form a network in the wall of the hepatic diverticulum. The vessels returning blood from the midgut diverticulum join together to form the ***hepatic vein*** on its upper surface. The hepatic vein opens into a thin walled sac called ***sinus venosus***. The ventral aorta starts from the sinus venosus.

The blood from the lateral body wall, myotomes and gonads is collected by two veins on each side. They are the ***anterior cardinal vein*** and the ***posterior cardinal vein***. The two veins are joined in the middle to form ***ductus Cuvieri*** which opens into the sinus venosus.

Excretory System

The excretory system is formed of 3 types of organs, namely

1. *Segmental protonephridium*
2. *Hatschek's nephridium*
3. *Brown funnels*

1. Segmental Protonephridium

There are about ***90 pairs*** of nephridia arranged on the dorso-lateral wall of the pharynx. Each nephridium is a thin-walled ***bent tube.*** It has a ***vertical limb*** and a ***horizontal limb***. The vertical limb lies in the primary gill bar. The horizontal limb opens into the atrium by a ***nephridiopore***.

Each nephridium has about 500 ***solenocytes***. Each solenocyte is a ***round cell*** with a ***nucleus*** and a ***long tubule.*** From the cell a ***flagellum*** arises and it projects into the lumen of the tubule. It is vibratile.

The solenocyte is a ***protonephridium*** with internal opening. It is developed from ***ectoderm***. It is similar to the ***flame cell*** of annelida.

2. Hatschek's Nephridium

It is a large nephridium situated in the roof of the buccal cavity on the left side of the median line. It has a narrow thin tube. Anteriorly it ends blindly and posteriorly it opens into the ***pharynx***, just behind the velum. It bears numerous ***solenocytes***.

Mechanism of Excretion: The solenocytes extract the nitrogenous waste materials from the blood and pour into

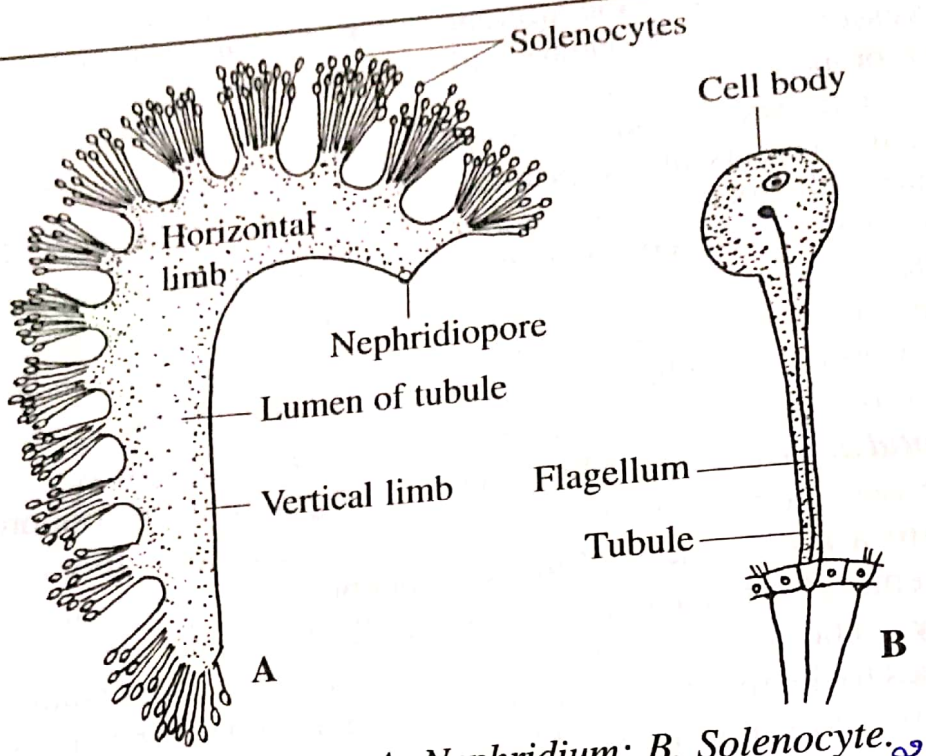

Fig.2.64: Amphioxus-A. Nephridium; B. Solenocyte.

the atrium through nephridiopore. From the atrium the wastes escape through the atriopore.

3. Brown Funnels

Brown funnels are ***excretory organs*** of *Amphioxus*. They are brown in colour and funnel-shaped. There are 2 brown funnels. They are located dorsal to the posterior end of pharynx. The narrow end of the funnel opens into the coelom and the wide end opens into the atrium.

Nervous System

Amphioxus has a hollow ***neural tube***. It extends throughout the length of the animal. It is located dorsal to the notochord. The canal situated inside the neural tube is called ***neurocoel*** or ***central canal***. Anteriorly the central canal dilates into a ***cerebral vesicle***. It gives out a dorsal diverticulum. The cerebral vesicle gives out two pairs of cerebral nerves which supply oral hood, cirri and sensory organs. The neural tube gives out paired ***spinal nerves*** which are arranged segmentally. Each spinal nerve has a dorsal root and a ventral root.

Sensory Organs

1. Eyes: *Amphioxus* has numerous eyes along the entire length of the neural tube. The eyes are photo-receptors.

2. Pigment spot: The anterior wall of the cerebral vesicle has a pigment spot. It is a thermo-receptor.

3. Infundibular organ: It is a depression in the floor of the cerebral vesicle. It is lined with ciliated cells.

4. Kolliker's pit: It is a ciliated depression located on the dorsal side of the cerebral vesicle. It is the remnant of neuropore. It is supposed to be a ***chemoreceptor.***

Reproductive System

The sexes are separate; but there is no sexual dimorphism. The gonads are