CC5: **Unit 2: Protochordata**

Group A. Acrania (Protochordata):

(Greek, ‘a’ = absent; ‘kranion’ = head / or Greek, ‘protos’ = first; ‘chorde’ = cord).

General characters:

They are all marine, small, primitive or lower chordates.

They have no cranium, jaws, vertebral column, and paired appendages.

About 2,000 species.

The Acrania is divided into two subphyla-**Urochordata** and **Cephalochordata.**

Subphylum Urochordata or Tunicata:

- (Gr., ‘oura’ = a tail; L., ‘chorda’ = cord).
- Notochord and nerve cord in tail only in minute free-swimming tadpole larva. Adult sac-like, covered with tunic (test) often transparent; usually no notochord, nerve cord is reduced to ganglion; no coelom, segmentation or nephridia.
- **Class 1. Ascidiacea:** Sessile tunicates with scattered muscles in tunic. Solitary, colonial or compound. Gill-slits many; tunic well developed, permanent. Ascidians or sea squirts. Include 3 orders, 12 families, 37 genera and 1,200 species. Examples- *Herdmania*, *Ciona* and *Molgula*.
- **Class 2. Thaliacea:** Free-swimming or pelagic tunicates with circular muscle bands in tunic. Salpa like tunicates and chain tunicates. Include 3 orders, 5 families, 9 genera and 30 species. Examples- *Salpa, Doliolum, Pyrosoma*.
- **Class 3. Larvacea or Appendicularia:** Tiny transparent, free-floating. Adults retain many larval features including tail. Only two gill-slits. Tunic not persistent. Include 2 orders, 2 families, 5 genera and 3 species.
- Examples- *Oikopleura, Appendicularia*.
- The **Urochordata**, also known as **Tunicates** and **Ascidians**, are more commonly known as "**sea squirts**." They belong to the same phylum as the vertebrates although adults do not have a backbone.
- During development the free-swimming larvae possess a tail, a dorsal nerve cord, a dorsal stiffening structure (not composed of bone) called the **notochord,** and gill slits in the throat (pharynx) region.

- Tunicates are among the most common marine invertebrates with around 3,000 species.
- Most tunicates live attached to a hard surface on the ocean floor and are commonly known as **sea squirts** (or cunjevois) and **sea pork**. They are found at all depths of the ocean. Other tunicates – such as **salps**, **doliolids** and **pyrosomes** – live in the pelagic zone as adults and are free-swimming or drifters.
- The name tunicates come from the tunic surrounding their body.
- The name sea squirt comes from the way water is pushed out through the exhalant siphon.
- The **Subphylum Urochordata** includes a large number of species which exhibit *high degree* of biological diversities. The members are classified under three classes: **Ascidiacea**, **Thaliacea** and **Larvacea** or **Appendicularia**.
- **Class Ascidiacea / sea squirts / Structure, function:**
- **Class Ascidiacea** [Gk. askidion, diminutive of askos, a bag or bladder], Approx. 2,000 species.
- i. Ascidians are marine and benthic forms which vary greatly in size and form.
- ii. The individuals are solitary or colonial. The colonial animals are social and compound, and colonies are formed comprising a few to hundreds zooids.
- iii. Adults become usually sessile after retrogressive metamorphosis of the larval stage, when the notochord, nerve cord and tail are lost.
- iv. The outer surface of the body is covered by a permanent, thick cuticular covering called **test** or **tunic**, composed of a special protein, the tunicin and polysaccharides related to plant cellulose.
- v. Animals are fixed to the substratum by one end, and the other free end bears two openings — **oral** or **branchial aperture** at the top and the **atrial aperture** at the side. The stream of water *enters* through the oral or branchial opening and *exits* through the atrial siphon.
- vi. The pharynx or **branchial basket** is unusually large with a persistent few to numerous ciliated slits, called stigmata. The pharynx is used for *filter feeding*.
- vii. The **intestine** is U-shaped. **Digestion** is extracellular.
- viii. There is well-developed **blood vascular system** including a tubular heart, covered by pericardium. Circulation is through a system of channels, called ***haemocoel.*** The

blood contains various pigments but these pigments are *non-respiratory* in nature. The system is most peculiar for the *periodic reversal of the flow* through the circuit.

- ix. **Nervous system** is simple consisting of a cerebral ganglion or 'brain' which is situated in the connective tissue between the two siphons.
- x. Special **sensory organs** are lacking.
- xi. Mostly **hermaphrodite** but in a species of some genera (e.g. *Distaplia*, *Holozoa, Sycozoa*), the uni-sexuality is observed.
- xii. **Fertilization** takes place externally in sea water or within the atrium.
- xiii. Mostly *solitary* ascidians. are **oviparous** and *most compound* ascidians are **ovoviviparous** and a few species of the families of Molgulidae and Styelidae **develop directly**.
- xiv. **Eggs** are yolky and develop into lecithotrophic, planktonic larvae.
- xv. The **larva** is free-swimming with a bulging trunk and long tail, resembles the shape of a tadpole, hence, called tadpole larva.
- xvi. Colonial ascidians are produced by *asexual budding*.
- They are commonly called "sea squirts", because the solitary forms spray water when they are disturbed mechanically.
- The **inhalant siphon** is used to take in food and water, and the **exhalant siphon** expels waste and water.
- The **tunic** is a thick, usually opaque, covering protecting their barrel-shaped bodies from predators. It is made from a material very similar to cellulose. On the inner surface of the tunic is a thin epidermis, it is this which secretes the tunic. On the inside of the epidermis is a thicker dermis (**body wall**) and bands of muscles which can squeeze the tunic forcing a jet of water from the exhalant siphon.
- Most of the space within the tunicate body is taken up by the **atrium** (a large cavity). This contains the enlarged **pharynx**, which has large numbers of small pores or slits in its walls through which water can pass. It is connected to the digestive system at one end and to the inhalant siphon at the other, this is effectively the animal's mouth.
- The tunicate's pharynx is covered by tiny hairs (**ciliate cells**) which allow the consumed food to pass down through to the oesophagus. The digestive system is U-shaped, the anus emptying directly to the outside.

- Tunicates are filter feeders, feeding by drawing often hundreds of liters of water each day through the inhalant siphon. This water passes through the pharynx where small particles are filtered out before the water is expelled through the exhalent siphon. The water current is caused by beating cilia. Water can also be pushed out of the atrial cavity by muscular contractions of the tunic if the tunicate is threatened. The small particles of plankton, etc., are trapped on a continually moving layer of mucous. This mucous is released by special cells and is moved across the surface of the pharynx by the beating of many small cilia, until it is passes into the digestive system where the food particles and mucous are digested.

- Most tunicates are hermaphrodites. They avoid self fertilization by either having the eggs and sperm reject each other, or by having the eggs and sperm mature at different times. Sperm are released into the sea but the eggs are retained within the body where they are fertilized by sperm brought in with incoming water. The eggs are brooded within the body until they hatch.

- The larvae look like tadpoles and are far more obviously members of the phylum Chordata than the adults. Tunicate larvae do not feed but search for a suitable location on the sea floor and then settle in a head down position. They attach themselves to the sea floor using special adhesive glands in the front of their head. Once settled they undergo metamorphosis during which they lose their tail and their ability to swim. The remainder of the body twists through 180 degrees in order to become a small tunicate. Most tunicates live about one year as adults.

- They are eaten by sharks, skates, and other bottom-dwelling animals including periwinkles. Many have poisonous flesh to deter predators.

- Sea squirts have shown promise as sources of chemicals which may be used to treat cancers and other medical conditions.

- **Fossil history of Subphylum Urochordata:**

- Jaekelocarpus oklahomensis recorded from the upper Carboniferous, Gene Autry Shale Formation near Ardmore of Oklahoma, U.S.A. is considered as fossil tunicate, belonged to the stem group of Urochordata, because it possessed calcite skeleton, ciliated pharyngeal slits and a downward flexing tail.

- **Habit and Habitat:**

- Urochordates are all marine, found in all seas from the intertidal zone to deep waters.

- About most of the urochordates (95%) lead a free moving larval stage but in adults they lead to sessile (attached) and sedentary life. This type of life cycle is seen among ascidians, but larvaceans and thaliaceans lead throughout planktonic life. Most of the

urochordates are sac-like creatures inhabiting the sea-bottom and are popularly called ‘sea-squirts’.

- **Scheme of Classification of Subphylum Urochordata:**

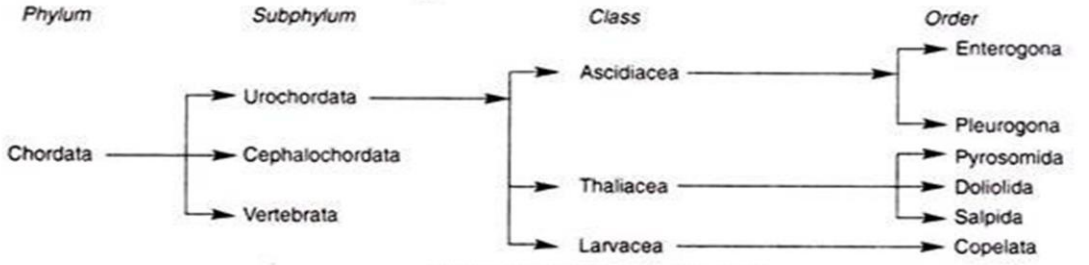
- Berrill (1950), Marshall and Williams (1964), Ruppert and Barres (1994), Anderson (1998) and Pechenik (2000) have divided the Urochordata into different Classes and orders. Barrington (1967, 1979), Young (1981), Kent and Miller (1997) and Kardong (1998, 2002) have divided the Urochordata into three classes only (Ascidiacea, Thaliacea and Larvacea) and these classes do not pertain any order.

- The outline classification of Urochordata according to Berrill (1950), Young (1981), Ruppert and Barnes (1994), Anderson (1998) and Pechenik (2000) has been given here in summarized form.

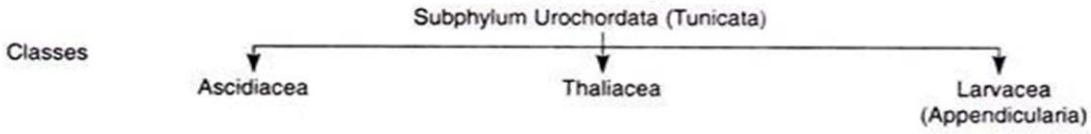
- **Classification in Outline:**

- Subphylum. Urochordata Herdman, 1910 or Tunicata Lamarck, 1816 [Gk. Oura, the tail, or L. Tunicatus, clothed with the tunic]. Approx. – 1400 species.

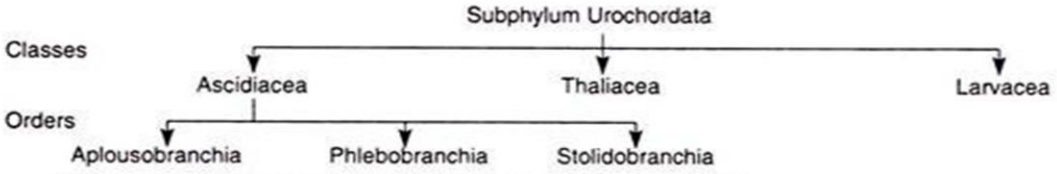
According to Berrill's Scheme of Classification



According to Young (1981)

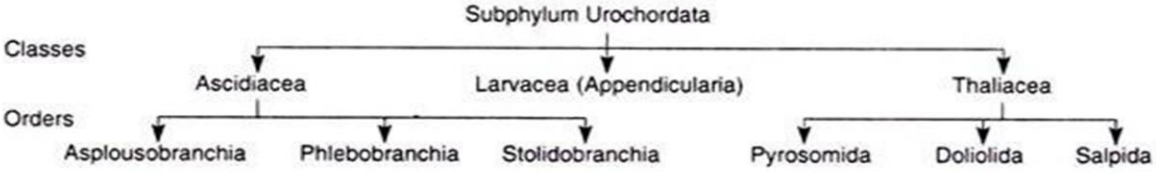


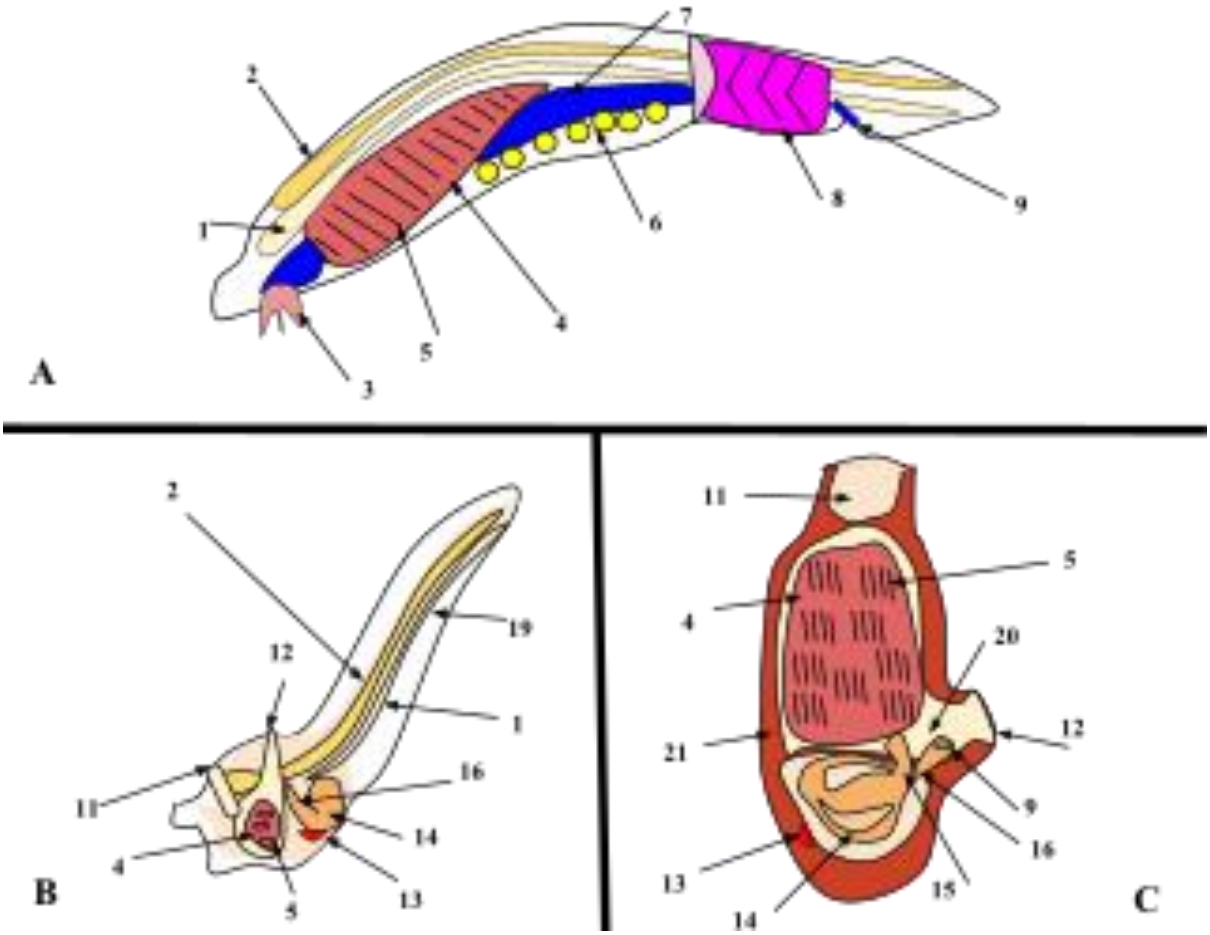
According to Ruppert and Barnes (1994)



Anderson's scheme is same as Ruppert and Barnes (1994).

According to Pechenik (2000)





Subphylum Cephalochordata :

- Historical Resume :
- The first individual of this group was described by Pallas in 1778. He regarded the specimen as a slug and named it *Umax lanceolatus*. Yarrell (1836) studied the animal in detail and gave the name *Amphioxus lanceolatus*. Costa (1834) suggested the name of the genus as Branchiostoma. Since then the biological name of the genus has been established as Branchiostoma according to the law of priority.
- **Salient Features of the Subphylum Cephalochordata Lankester, 1877**:
- [Gk. Kephale, a head], Approx. 23 species.
- a. Cephalochordates are small, fish-like translucent marine chordates.

- b. The body is laterally compressed and tapered at both ends with a post-anal tail. They are commonly called "*lancelets*" for the shape of the body.
- c. There is a low continuous dorsal and caudal fin; no paired fins.
- d. Body muscles are arranged as a series of V-shaped blocks of striated muscles fibres running throughout the body, called the myotomes (myomeres) and are separated by sheets of connective tissue, the myosepta or called myocommas.
- e. Epidermis is single layered.
- f. The persistent notochord extends from the tip of the tail to the region beyond the brain, hence called Cephalochordata.
- g. Ventral mouth surrounded by small tentacles, leads into large pharynx with numerous gill-slits open into the atrium.
- h. Blood vascular system is closed type and lacking of a specialized heart. The blood is colourless and without any respiratory pigment.
- i. The dorsal hollow nerve cord runs immediately dorsal to the notochord and opens to the exterior through an anterior neuropore.
- j. The excretory organs are protonephridia with solenocytes, derived from ectoderm.
- k. Ductless gonads are metamerically arranged.
- l. Sexes are separate (dioecious). Fertilization takes place in sea-water.
- m. Radial cleavage.
- n. Development with a transparent asymmetrical planktotrophic larva is similar to the shape of an adult.

Fossil History:

The oldest known cephalochordates is *Pikaia*, recorded from the Burges Shales of Canada, about the middle Cambrian period. The anatomical characteristic features are more or less same as *Branchiostoma* except a pair of sensory tentacles that are found at the end of the body.

Geographical Distribution:

Cephalochordates are found near shore areas (sub-tidal areas) of the seas of temperate and tropical regions.

Size: 50 to 70 mm.

Habit and Habitat:

They are the inhabitants of coarse sands, shell gravels and fine sands of the seas. In coarse sand and gravel they will bury completely, but in finer sandy areas the anterior end protrudes into the water column.

Marshall and Williams (1964) pertain a single class Cephalochordate under the subphylum Cephalochordata, but without any order under the class Cephalochordate. Godeaux (1974) comprises a single order Amphioxi under the subphylum Cephalochordata but without any class.

Berrill (1950), Barrington (1979), Young (1981), Romer and Parson (1986), Ruppert and Barnes (1994), Kent and Miller (1997), Anderson (1998), Pechenik (2000) and Kardong (2002) do not mention any class and order under Cephalochordata. We follow in this text book Young's (1981) scheme, adopted from the book "**The Life of Vertebrates (3rd ed.)".**

DIVERSITY

Table 17 : Families, genera and species known from India

Taxa	World	India
Subphylum cephalochordata		
Family Branchiostomatidae	1	1
Genera	1	1
Species	15	6
Family Epigonichthyidae or Asymmetrontidae	1	—
Genera	1	—
Species	6	—

Systematic Resume:

The subphylum Cephalochordata comprises a single family Brachiostomatidae with two genera ***Branchiostoma*** (Costa, 1834) and ***Asymmetron*** (Andrews, 1893). Other genera as

Epigonichthys is now synonym with Asymmetron and *Amphioxides*, once considered as member of the family Amphioxididae, now considered as giant larval individuals of the genus Asymmetron.

Genus 1. *Branchiostoma* [Approx. 16 species]

Gonads lie on each side of the body.

They inhabit the tropical and sub-tropical seas.

Examples: *B. lanceolatum* (Sri Lanka, India, Mediterranean, N. W. Europe, eastern part of U.S.A.); *B. belcheri* (Sri Lanka, India, Torres Strait, Singapore, Borneo); *B. capense* (S. Africa); *B. indicum* (India, Sri Lanka);

- *B. pelagicum* (India); *B. elongatum* (Peru); *B. nakagawae* (Japan); *B. caribbaeum* (N. and S. America and West Indies); *B. californiense* (California, U.S.A.); *B. tattersali* (India).

Genus 2. *Asymmetron* [Approx. 7 species]

- Gonads lie only on the right side. They inhabit the tropical seas.
- **Example:** *A. cingalense* (Sri Lanka); *A. cultellum* (Sri Lanka, Australia); *A. lucayanum* (Maldives, Bahamas, Zanzibar); *A. caudatum* (Louisiade Archipelago); *A. bassanum* (Australia); *A. maldivense* (Maldives, Zanzibar); *A. hectori* (New Zealand).

Indian Cephalochordates

Collection and Research

Gray (1847), Thurston (1890), Foster-cooper (1903), Tattersall (1903) and **Prosad (1934)** described several species of cephalo-chordates, collected from different parts of Indian coasts. **Kurian (1953)** recorded *Branchiostoma lanceolatum* from the west coast of Travancore (part of Kerala state at pre-sent). **Azariah (1953, '65, '71)** several species from the Tamilnadu coast and studied the habit and habitat of *Branchiostoma*.

The author (**Badal Chandra Bharati Goswami**) collected *Branchiostoma lanceo-latum* from the Okha coast (Gujarat).

Branchiostoma lanceolatum, B. indicum, B. tattersali and *B. belcheri* (Tamilnadu coast), *B. lanceolatum* (Okha coast, Gujarat), *B. indicum, B. pelagicum,* and *B. lanceolatum* (Gulf of Mannar) have been recorded from the Indian coasts.

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- **Feeding Mechanism:**

- Most of the animals move from one place to another in search of food. But in partial or complete sessile animals, this particular function of locomotion is compensated by the development of special structures.

- Majority of the invertebrate chordates are either sedentary or sessile and they have developed specialized devices to strain off micro-organisms from water. Isolation of food materials from water is done by the ciliary and glandular tracts. So the method of feeding is called ciliary mode of feeding.

- The pharynx is modified in the invertebrate chordates to perform dual functions:

- (1) Respiration and

- (2) Food collection.

- In all of them, a constant flow of water current passes into the pharyngeal cavity and goes out through the atriopore.

- **Structural elements associated:** The pharynx in the invertebrate chordates plays the most spectacular role in straining off the food materials from the incoming water current. For this physiological function, the pharynx and its associated structures become greatly altered.

- The pharynx includes the portion of the gut from the posterior part of the mouth cavity to the beginning of oesophagus. Although the pharyngeal apparatus is basically similar in all these forms, some minor differences exist which depend on the degree of sessile habits.

- **Mechanism of food concentration:**

- The food of invertebrate chordates comprises of micro-organisms which are suspended in sea- water in a very dilute condition. The food particles need to be filtered out by removing the excess of water from the pharyngeal cavity. This phenomenon is effectively done by an efficient mechanism of food concentration.

- The cilia of gill-bars in the pharynx beat synchronously and by their powerful movement a current of water is produced which, after entering the mouth, passes towards the pharynx. The velar tentacles in urochordates resist the entry of big particles which are undigestible.

- The same function is performed by the **buccal cirri in the cephalochordates**. In cephalochordates the wheel-organ creates a vortex of water and focuses it towards the mouth.

- Before entering the pharyngeal cavity the velar tentacles sieve-off sand grains and other unwanted particles. Enormous quantity of water containing food enters into the pharyngeal cavity and most of the water goes out to the atrium in urochordates and cephalochordates.

- [and directly to the outside in hemi-chordates through the gill-slits or their derivatives.]

In hemichordates, the food particles along with the sand grains are entangled by the mucus secreted from the glands present in the mouth cavity and pass through the pharynx into the intestinal cavity. The mucus secreted by the proboscis entangles the sand and other food particles.

- The mucus-coated food particles are pushed directly into the mouth by ciliary action. This transit is assisted by the ciliary beatings of the ciliated strips so that the food matters are driven towards the intestine. Digestion occurs in the intestine and the sand grains are eliminated in the form of castings.

- In urochordates and **cephalochordates** the ***endostyle*** entangles the food by its viscous secretion of mucus. The cilia of the endostyle transform the food into a ***mucous rope***

which is driven forward towards the peripharyngeal groove wherefrom it travels backwards through the hyper pharyngeal groove in **cephalochordates** and the dorsal lamina in case of urochordates into the intestine by ciliary action.

- In the intestine the food is digested and the undigested products are discharged through the anus.
- The most important feature of the ciliary feeding in invertebrate chordates is that selection and filtration of food are done by physical means. This method of feeding is a variant of the general process observed in other forms where the sorting of the food particles is done inside the pharyngeal cavity.
- The presence of numerous gill-slits is an adaptive feature which facilitates the elimination of excess of water from the pharyngeal cavity and also helps in the process of gaseous exchange.
- The pharynx of the invertebrate chordates has been specialised and elaborated as a food-concentrating apparatus in addition to its normal respiratory function. This apparatus shows close similarity in different invertebrate chordates.
- The degree of specialisation of the pharynx in these forms bears a distinct ratio to their sedentary habits. The close similarities in the structure and function of the pharyngeal apparatus are suggestive of the original habit of the earliest ancestral chordates from which they have evolved.
