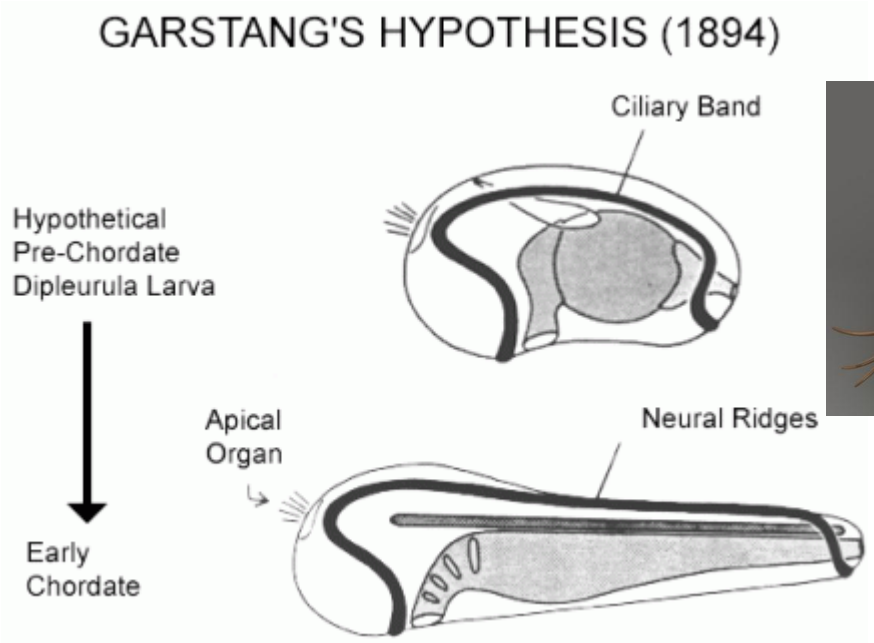
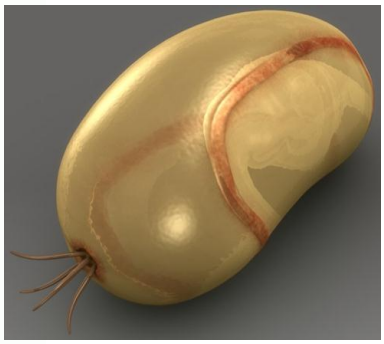
Chordata and Comparative anatomy **L_2C_1**

Phylum chordates

Phylogeny of Chordata

The most accepted theory to explain the origin of chordates, which resulted in Craniata and vertebrates. This is **the Garstang's theory**. It proposes that the origin of chordates, which took place about 570 million years ago during the Precambrian, must be from some deuterostomes (that includes echinoderms, hemichordates and chordates). The larvae of these animals have some similarities with a chordate body plan: bilateral symmetry, unidirectional digestive tract and an adoral and circumoral ciliated band. Thus, it is believed that a deuterostome larva, perhaps the auricularia larvae of echinoderms, would have resulted in the evolutionary line of chordates.





- **Echinoderm Origin.** The theory was given by Johannes Muller (1860) and is based on the comparative studies of larval stages of echinoderms and hemichordates. Tornaria larva of hemichordates resembles echinoderm larvae such as Bipinnaria, Auricularia, Dipleurula and Doliolaria, which all possess ciliary bands and apical tuft of cilia. Johannes Muller, W. Garstang and DeBeers proposed that echinoderm larvae gave rise to chordates by neoteny (neoteny is the condition in which an organism reaches maturity without losing all of its juvenile characteristics or meaning when larval life is extended and with sexual maturity. Neoteny also called juvenilization.

1. . Typical examples would include becoming sexually viable while still in a larvae stage or retention of gills in an adult).

The discovery of fossil echinoderms called **Calcichordata** from Ordovician period (450 mya) further confirms echinoderm ancestry of chordates. Calcichordates were asymmetrical animals which demonstrate affinities with both echinoderms and chordates but their skeleton is made of $CaCO_3$ whereas in vertebrates the bones are made of hydrated Ca and phosphate. They had large pharynx with a series of gill slits, each covered with flaps for filter feeding, a small segmented body and a postanal tail. A

perforated pharynx for filter feeding appears to have evolved in diverse groups of animals during Cambrian-Orodovician periods when planktons were abundant in water.

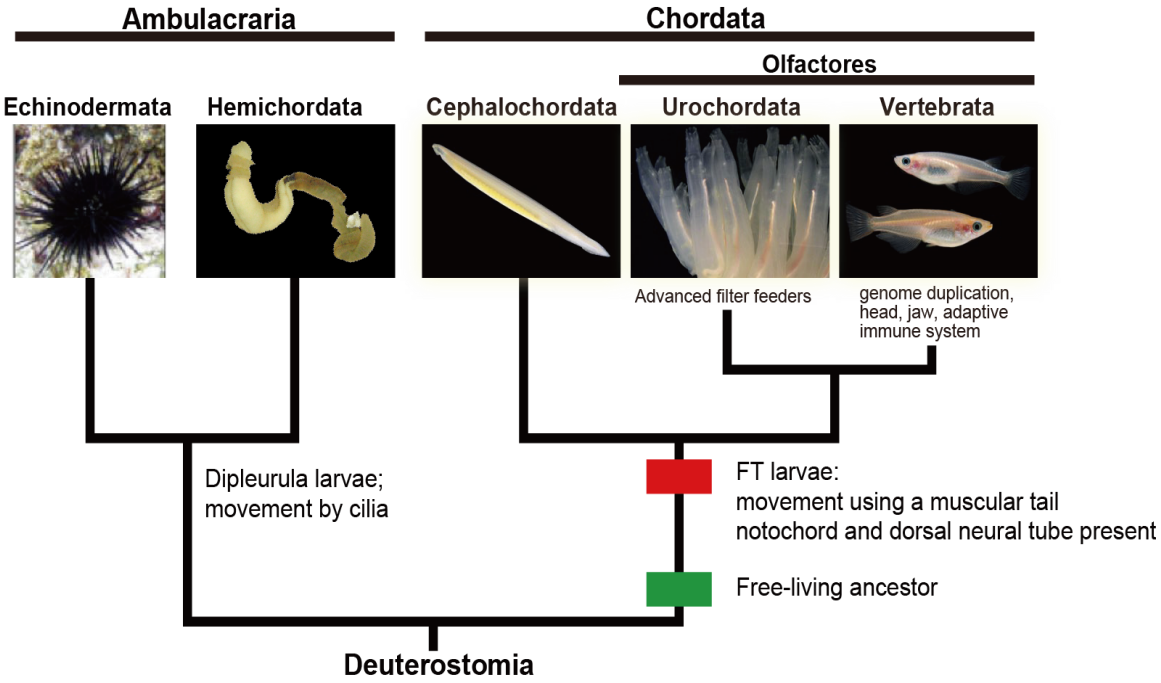
2. Hemichordate Origin. Romer (1959) suggested that ancestral deuterostomes were sedentary tentacle feeders whose mucous-laden ciliated tentacles served to trap planktons as they were waved in water as do the modern lophophorates and pterobranch hemichordates. By some mutation pharyngeal gill slits evolved in these ancestors, who made the pharynx sieve-like to trap planktons as the water current passed through it. Extant pterobranchs possess both ciliated arms and pharyngeal gill slits. Tornaria larva of hemichordates shows phylogenetic relationship with echinoderm larvae and hemichordates also show affinities with chordates.

3. Urochordate Origin. W. Garstang (1928) and N.J. Berrill (1955) gave importance to the tadpole-like larva of urochordates which carries typical chordate characters, namely, a notochord in tail along with segmented myotomes, dorsal hollow nerve cord, sense organs and pharyngeal gill slits. Garstang (1928) suggested that chordates evolved from some sessile filter feeding urochordate by the larval stage evolving into adult by neoteny and by losing the sedentary adult stage.

4. Cephalochordate Origin. Chamberlain (1900) studied the primitive and advanced characters of cephalochordates and proposed that while extant cephalochordates possess all chordate characters in typical state, they also show some primitive features of non-chordates, such as, absence of heart, head, sense organs, respiratory pigment, filter-feeding mode of food capture and excretion by solenocytes.

5. **Combined theory**. E.J.W. Barrington (1965) combined all the above theories and proposed that the common ancestor of echinoderms and chordates was a sessile ciliary arm feeder that lived in the plankton-rich environment of the Cambrian. Modern Crinoidea (Echinodermata), Pogonophora and Pterobranch hemichordates evolved from a similar ancestor by retaining the original mode of feeding, perhaps because they continued to inhabit the same environment as occurred in ancestral days.

6- Recent studies of **deuterostome** molecular phylogeny, nuclear and mitochondrial genomics, and evolutionary developmental biology, have unambiguously demonstrated that echinoderms and hemichordates form a clade, and those urochordates, cephalochordates and vertebrates form another distinct clade. The former is called the Ambulacraria, with similarities in coelomic systems and larvae, and the latter Chordata. In addition, within the chordate clade, cephalochordates diverged first, and urochordates and vertebrates form a sister group (sometimes called Olfactores, with similarities in extensive pharyngeal re-modification leading to the formation of new structures, which are not found in cephalochordates).

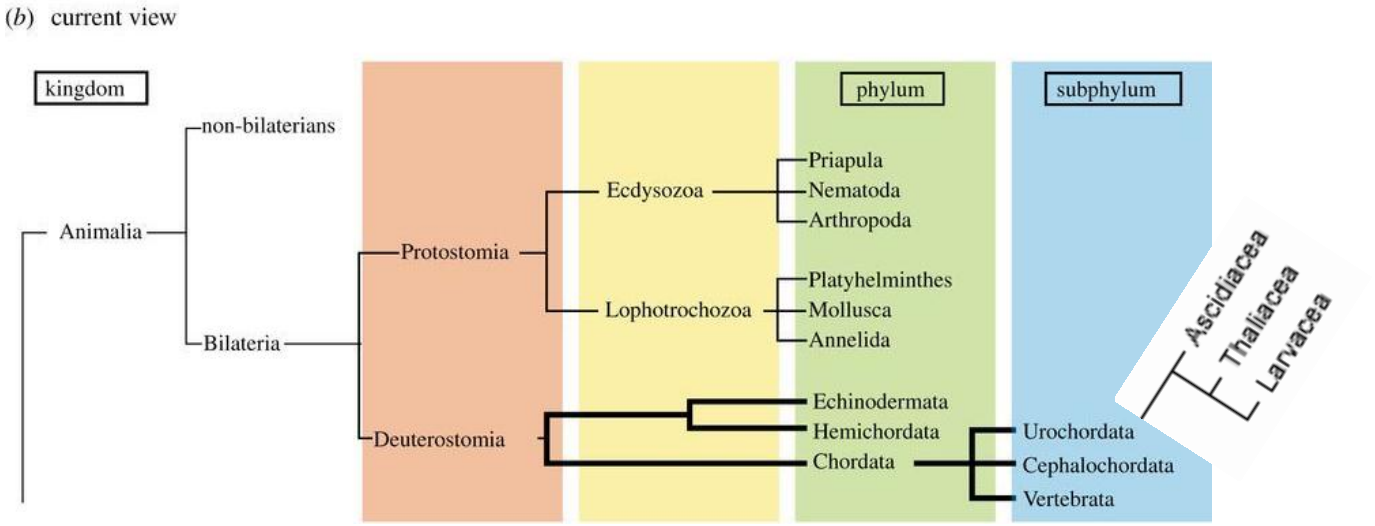

Ambulacraria
Chordata
Olfactores
Echinodermata
Hemichordata
Cephalochordata
Urochordata
Vertebrata
Advanced filter feeders
genome duplication, head, jaw, adaptive immune system
Dipleurula larvae; movement by cilia
FT larvae: movement using a muscular tail notochord and dorsal neural tube present
Free-living ancestor
Deuterostomia

Phylum chordates

Characteristics of chordate

Chordates made their first appearance in fossils dating back approximately 550 million years ago. Chordates are organisms that possess a notochord, at least during some part of their development.

1- Notochord is first (primitive) supporting, a road-like, skeletal structure of the chordate body that extends along the body, originates from the mesoderm, lying dorsal to the gut tube but ventral to the CNS, they persist or altered or disappear in the adults.
2- A single dorsal, hollow Nerve cord, found above the notochord, differentiates into the brain anteriorly and spinal cord that runs through the trunk and tail region.
3- Pharyngeal pouches (gill slits or gill arches) present in the pharyngeal part of the digestive tract, thus the slits are continuous passages connecting the pharynx to the exterior, for the exit of water current and for respiration. Gills slits functioned as a mechanism for filter-feeding in primitive vertebrates.
4- Muscular post-anal tail.
5- Circulatory sys. Is closed; include ventral heart, with dorsal and ventral blood vessels and haemoglobine found in RBC.
6- Complete digestive sys.
7- Body has true coelom, two chambers in protochordata, while four in vertebrata.
8- Endostyle secretes mucus & traps food; can also bind proteins with iodine, may be homologous with thyroid.
9- Bilateral symmetry, axiate organization, Triploblastic condition and Segmentation of muscles (Metamerism)
10- Majority of chordates are dioecious (sexes are separate).Tadpole larva present.
10- Loss of mesodermal tentacles



Phylum chordates

Protochordata (A craniata) — Vertebrates (Craniata)

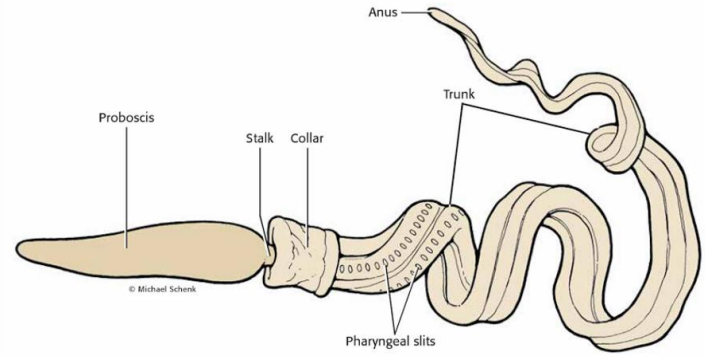
This group subdivided into three subphylum according to location & length of notochord

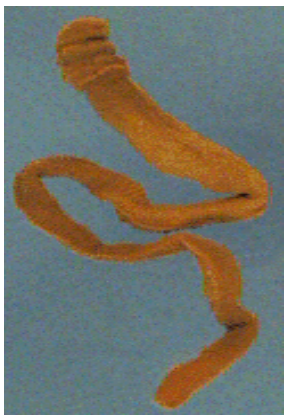
1- Subphylum; **Hemichordata (e.g *Balanoglosus*).**

Notochord is found on anterior (to phrynx) half of the body. Bateson added acorn worms to the phylum Chordata in 1884 because they have: a dorsal, hollow nervous system only in the collar zone, gill slits, and a short, hollow, thick walled buccal diverticulum of the gut called the stomochord. (The stomochord is not homologous with the notochord and originates from the endoderm; it help in locomotion; therefore Hemichordates are placed in a separate phylum).

Hemichordates considered an invertebrate because

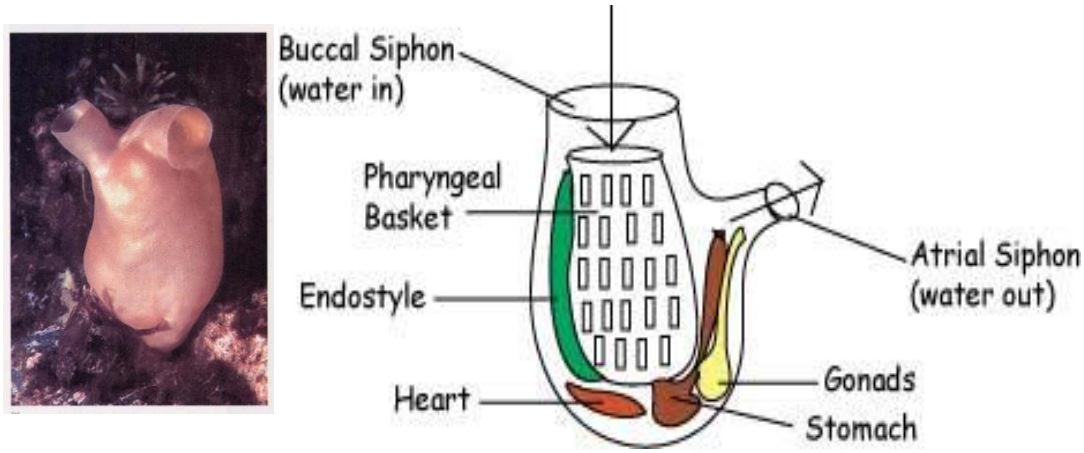
1- Tornaria larva similar to auricularia larva of echinoderms.
2- Blood flow from anterior to posterior by ventral b.v and blood return by dorsal b.v from posterior to anterior, so that similar to invertebrates.
3- Intra-epidermal N.S & Double solid (dorsal & ventral) nerve cord is present.
4- Annelid-like body
5- The presence of arginine phosphate.





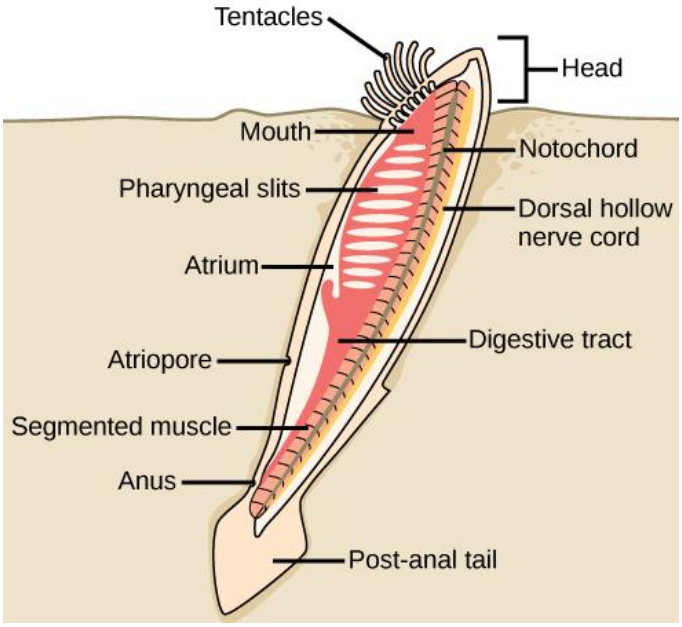
2- Subphylum; Urochordata (e.g *Ciona* and *Molgula*)

The notochord is persisting in the tail region only during the larval stages but disappear in adult stages. Marine, Sessile Adults - attached to rocks or other hard surfaces, solitary or colonial, larvae (Bilateral, Free-swimming - fish-like motion, Notochord), filter-feeder, pharyngeal slits remain in adults, undergoes metamorphosis and surrounded by a mucous tunic, Water taken into the incurrent siphon enters the pharynx and passes out through the gill slits, leaving food particles trapped in the pharynx, endostyle secretes mucus that traps the particles and conveys them into the digestive tract; the movement of the mucus is caused by the action of cilia. Water leaves the atrium, a sac surrounding the pharynx, by way of the excurrent siphon. Thus the gill slits in tunicates serve a feeding function, not a respiratory function.



3- Subphylum; Cephalochordata (e.g *Amphioxus lanceolatus*)

The notochord & nerve chord extends along the body and persists throughout life. Marine, fish-like appearance, bury into sand and sediment, filter-feeder, larvae - similar to the tunicates. The muscles (V-shaped myomeres) as in fishes, this is the most primitive occurrence of the segmental body wall structure characteristic of lower vertebrates and have dorsal & ventral aorta. Numerous (50) pharyngeal slits, use cilia to pump water.



4- Sub phylum: **<u>Vertebrata (Craniata)</u>**

1- Organism having cartilaginous or bony skull (cranium), which encloses the brain and sensory capsules
2- Sense organs include one pair eyes, olfactory organs and inner ears.
3- Notochord is replaced by vertebral column. The vertebral column allows the body to flex and provides attachment sites for muscles. In addition, it surrounds and protects the nerve cord
4- Excretory system achieved by a pair of kidneys.
5- The sexes are usually separate and reproduction usually sexual, achieved by pair of gonads.

Differences between protochordates and vertebrates

1. Almost no cephalization (no concentration of sense organs in a head and brain).
2. No paired sense organs.
3. No cranium or vertebral column. Notochord persists throughout life.
4. High number of gill slits persists throughout life. Atrium siphon is present
5. Segmented musculature extends to anterior tip of head.
6. No paired appendages.
7. Outer layer of skin (epidermis) one-cell thick.
8. No muscular heart (chamber less).
9. Excretory protonephridia resemble those on non-chordates.

Evidence for relationships between protochordates and vertebrates

- Both they are deuterostomes, resemble echinoderms and hemichordates.
- The most primitive living vertebrates are jawless fishes (cyclostomes).
- The free-swimming, filter-feeding larval stage of lampreys closely resembles protochordate larvae--this provides us with further evidence for a close relationship between vertebrates and protochordates.

Ammocoete larvae (filter feeders) have;-

I. Seven (7) pair's gill slits (respiratory in function).
II. Notochord extending from head region into tail (no vertebral column).
III. Dorsal, hollow nerve tube; typical embryonic vertebrate brain with three primary vesicles.
IV. A stratified epidermis.
V. Typical embryonic vertebrate kidney.
VI. Typical closed, embryonic vertebrate circulatory system with two-chambered heart and red blood cells.
VII. Tadpole-like morphology typical of vertebrate larvae (such as frogs).
VIII. Sense organs more numerous than lancelets--median naris that leads to an olfactory sac, two mid-dorsal eyes on head, otic vesicles that develop into inner ears.

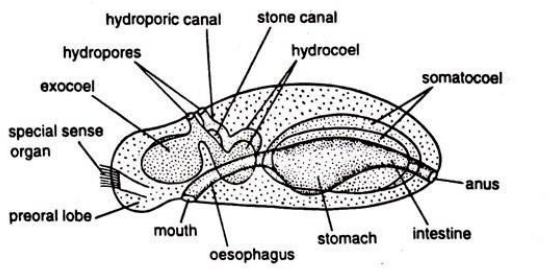


Fig. 27.14. Dipleurula larva. Diagrammatic reconstruction of hypothetical ancestor