

ORIGIN AND EVOLUTION OF CHORDATE (PART 1) (PG SEMESTER 1 Paper 2)

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Chordates are bilaterian (bilaterally symmetrical) animals, and within Bilateria, they belong to the clade of animals known as Deuterostomia.

Chordate evolution is a history of innovations that is built upon major invertebrate traits.

ORIGIN

- ▣ Chordates evolved sometime during Cambrian period, 500 million years ago during Cambrian explosion, almost at the same time when invertebrates were beginning to evolve.
- ▣ They may have evolved from some freshwater forms as Chamberlain (1900) pointed out that all modern chordates possess glomerular kidneys that are designed to remove excess water from body.

- ▣ However, early fossils of chordates have all been recovered from marine sediments and even modern protochordates are all marine forms.
- ▣ Also glomerular kidneys are also found in some marine forms such as myxinooids and sharks. That makes the marine origin of chordates more plausible.

- ▣ Chordates evolved from some deuterostome ancestor (echinoderms, hemichordates, pogonophorans etc.) as they have similarities in embryonic development, type of coelom and larval stages. Fossils of the earliest vertebrates are known from the Silurian-Devonian period, about 400 million years ago.
- ▣ The following theories have been given to explain the origin 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.
- ▣ Also like chordates, echinoderms are also deuterostomes and possess mesodermal skeletal elements.

- ▣ 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.

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, *Cephalodiscus* and *Rhabdopleura*.

- ▣ By some mutation pharyngeal gill slits evolved in these ancestors, which 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.

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.

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.

- ▣ Fossils of 60 specimens from mid-Cambrian of the earliest chordate, *Pikaia gracilens* have been discovered from Burgess Shale in British Columbia, Canada.
- ▣ The Amphioxus-like fossils show streamlined, ribbon-shaped, 5 cm long body having notochord in the posterior two-third of body and myomeres
- ▣ It has a small head with two tentacles and gill slits in the neck region. Other chordate-like fossils are: *Cathaymyrus* from early Cambrian sediments in China and *Palaeobranchiostomata* from early Permian from South Africa that appears to be more similar to Amphioxus.

Combined theory

- ▣ 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.

- ▣ However, pharyngotomy (perforation of pharynx with gill slits) must have evolved in a large number of groups at that time, which must have been much more superior method of food gathering by filtering water through pharynx as compared to ciliated arm feeding. Hence, the sedentary Protoascidians of that time lost ciliated arm feeding and adopted pharyngeal filter feeding as the only method of food gathering.

- ▣ Sometime later, when the plankton population in water declined, free-swimming tailed larva of these urochordates did not metamorphose and became a neotenic adult, since free-swimming mode was superior in food searching at a time of food scarcity..

- ▣ Cephalochordate-like ancestors evolved by perfection and expansion of chordate characters that were already present in the ascidian tadpole larva. We already have fossils of such primitive chordates, e.g. *Pikaia gracilens* from mid-Cambrian.

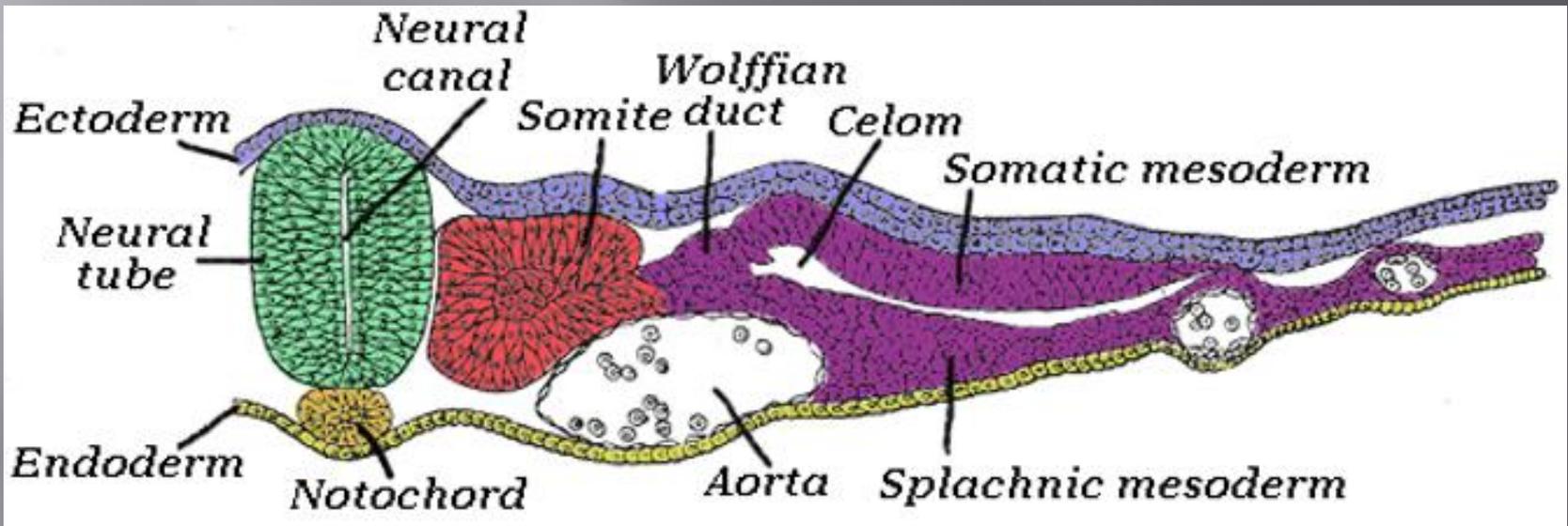
Derived Characters of Chordates

- ▣ All chordates share a set of derived characters, though many species possess some of these traits only during embryonic development.
- ▣ Illustrates four key characters of chordates: a notochord; a dorsal, hollow nerve cord; pharyngeal slits or clefts; and a muscular, post-anal tail.

- ▣ Notochord is a long supporting rod that runs through the body just below the nerve cord. Most chordates have a notochord only when they are embryos
- ▣ Pharyngeal pouches are paired structures in the throat region. In some chordates – such as fishes and amphibians – slits develop that connect the pharyngeal pouches to the outside of the body

These slits may then develop into gills that are used for gas exchange.

At some point in their lives, all chordates have a tail that extends beyond the anus. The tail can contain bone and muscle and is used in swimming by aquatic species.

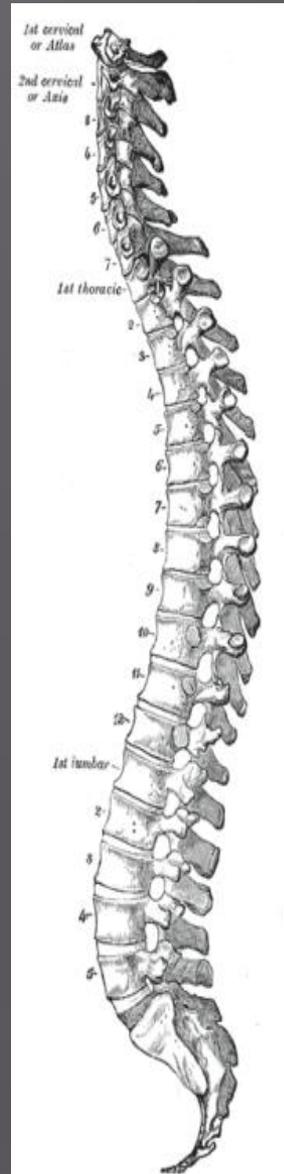


Transverse section of a chick embryo of forty-five hours' incubation.

Most Chordates are Vertebrates

- ▣ More than 99% of all chordates are placed in the subphylum Vertebrata and are called vertebrates. A vertebrate is a chordate that has a strong supporting structure known as a vertebral column or backbone

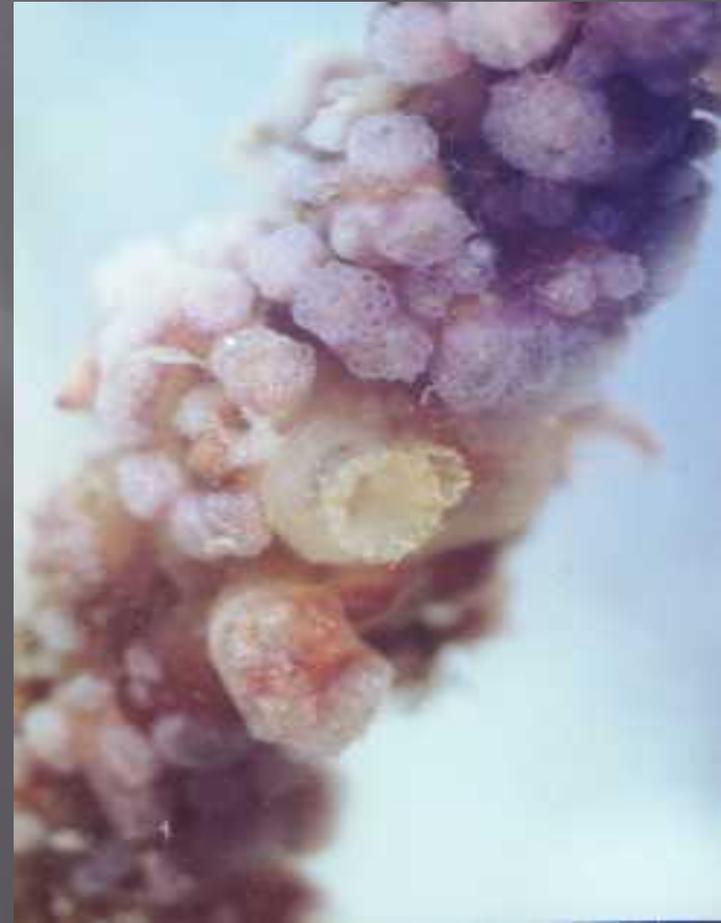
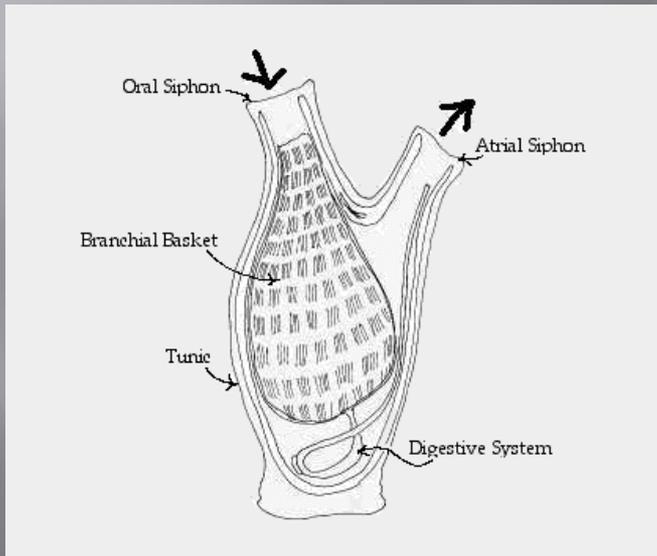
- ▣ In vertebrates, the dorsal, hollow nerve cord is called the spinal cord. As a vertebrate embryo develops, the front end of the spinal cord grows into a brain. The backbone, which replaces the notochord in most developing vertebrates, is made of individual segments called vertebrae that enclose and protect the spinal cord.



- ▣ A vertebrate's backbone is part of an endoskeleton, or internal skeleton. Like an arthropod's exoskeleton, a vertebrates, endoskeleton supports and protects the animal's body and gives muscles a place to attach.
- ▣ A vertebrate's skeleton grows as the animal grows and does not need to be shed. A vertebrate's skeleton is made of living cells as well as nonliving material.

Nonvertebrate Chordates

- Tunicates are one of two groups of nonvertebrate chordates



Nonvertebrate Chordates

- ▣ Both are soft-bodied marine organisms. Like all chordates, these animals have a hollow nerve cord, a notochord, pharyngeal pouches and a tail.

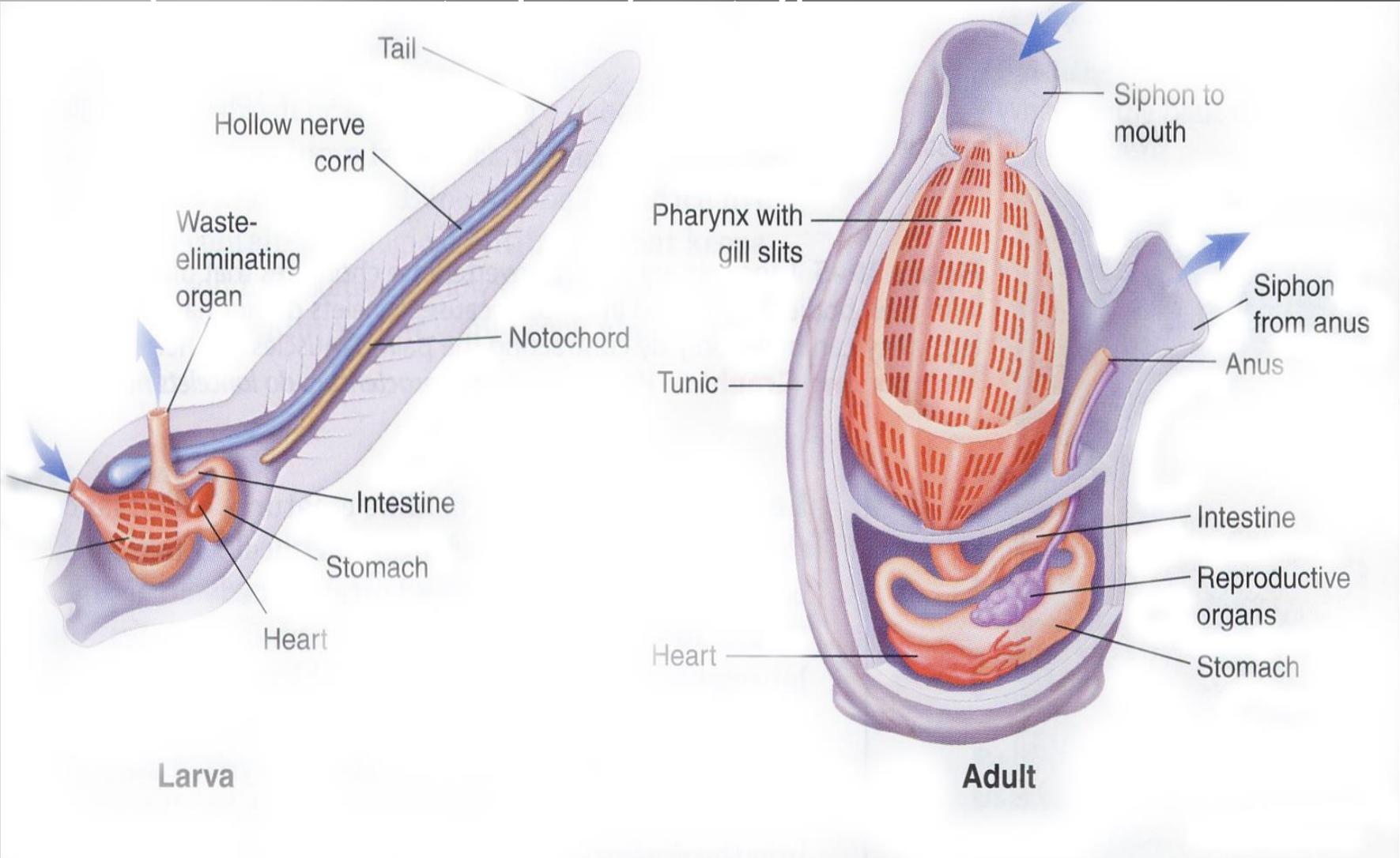


Most Chordates are Vertebrates

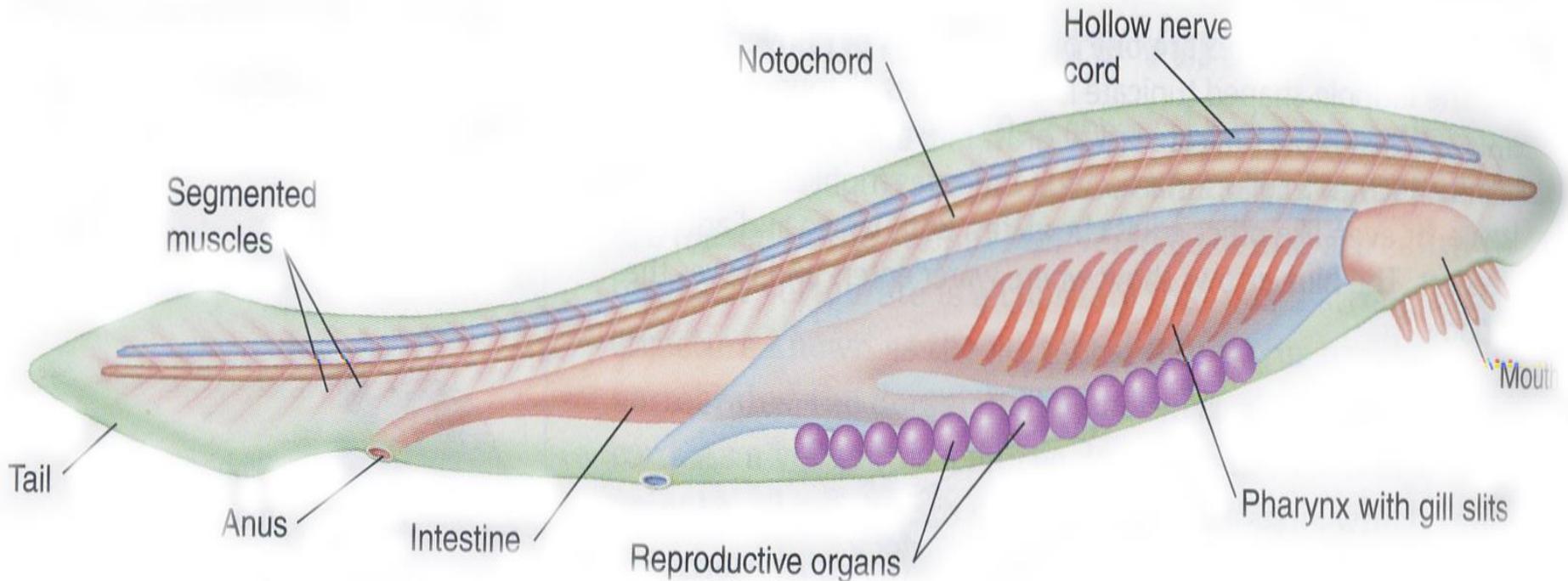
- ▣ The two groups of nonvertebrate chordates are tunicates and lancelets.



- ▣ Tunicates – Filter-feeding tunicate larva have all the chordate characteristics. Adult tunicates



Lancelets – small, fishlike creatures. Live on sandy ocean bottoms. Adult has definite head with mouth. Closed circulatory system. No true heart.



Fishes

- ▣ Fishes are aquatic vertebrates that are characterized by paired fins, scales, and gills.
- ▣ Fishes are so varied that for almost every general statement there is an exception. Fins are for movement, scales for protection, and gills for exchanging gases

Evolution of Fish

- ▣ The evolution of jaws and the evolution of paired fins were important developments during the rise of fishes.



Geologic Timetable

- ▣ The earth is estimated to be millions of years old. To help us understand the order in which life “evolved” we need to look at the Geologic Timetable. This timetable outlines the periods and major events that occurred during each.

The first fish

- ▣ The earliest fishes to appear in the fossil record were odd-looking jawless creatures whose bodies were armored with bony plates. They lived in the oceans during the Cambrian Period, about 510 million years ago.

The Age of Fishes

- ▣ During the Ordovician and Silurian Periods, about 505 to 410 million years ago, fishes underwent a major adaptive radiation. The species emerged during the Devonian Period, which is often called the Age of Fishes

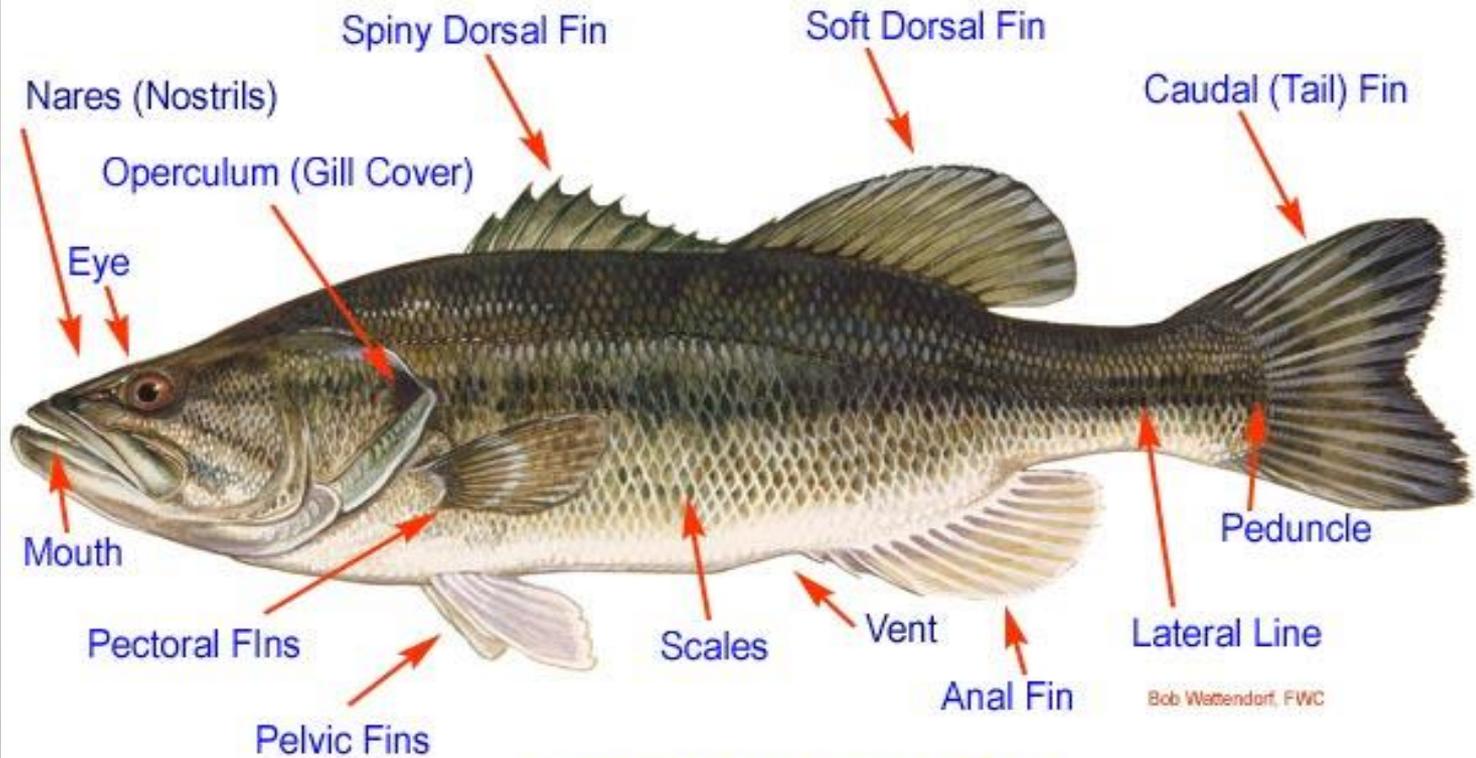
Jawless and Paired Fins

- ▣ Some ancient fishes kept their bony armor and had a deeding adaptation that changed everything. These fishes had jaws. Jaws are an extremely useful adaptation. Jawless fish were limited to small soft food that that they filtered from the water.



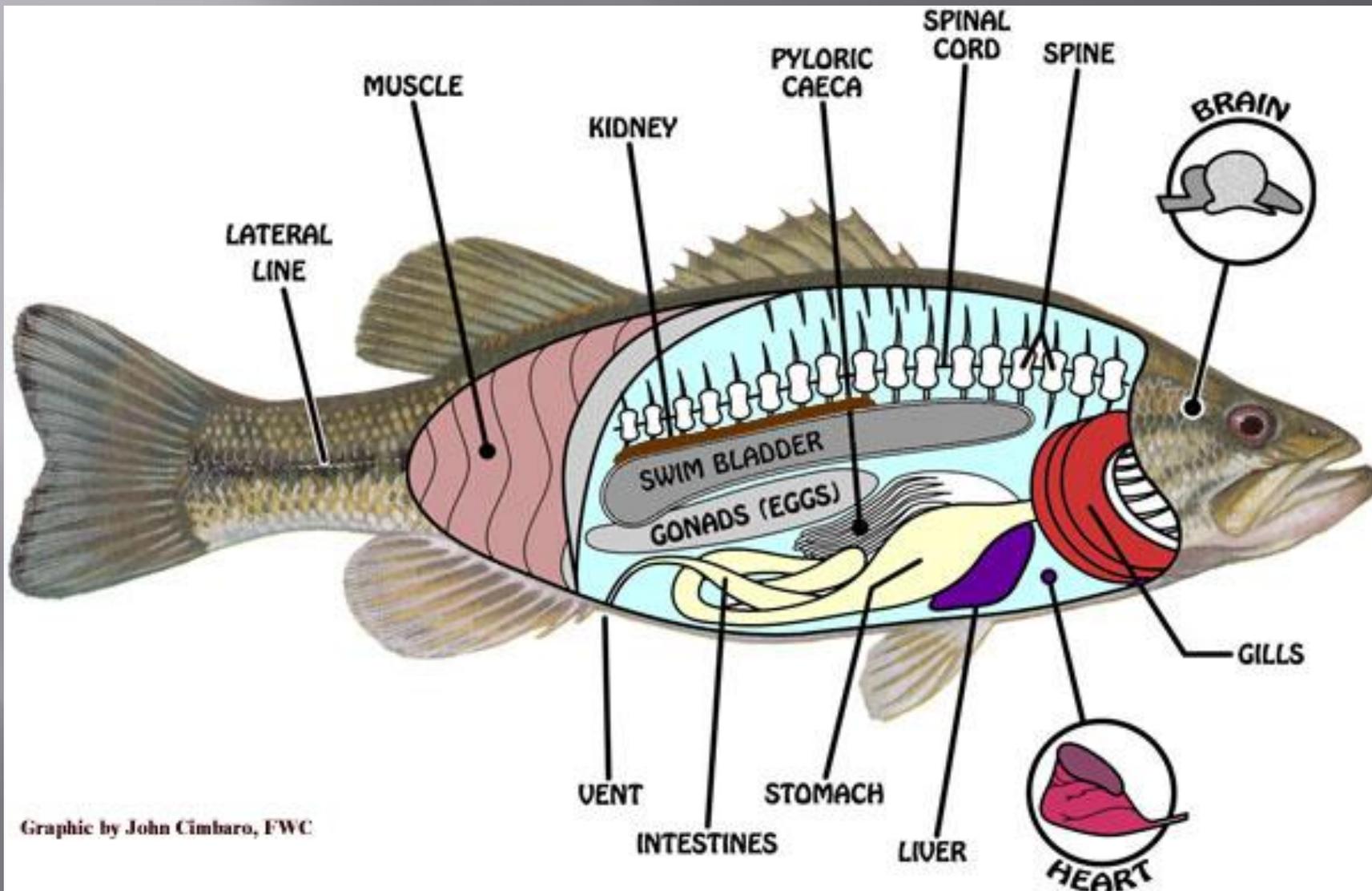
- ▣ Jaws allowed fish to eat a much wider variety of foods. Their fins were attached to girdles – structures of cartilage or bones that supports the fins.
- ▣ Cartilage is a strong tissue that supports the body and is softer and more flexible than bone.
- ▣ Paired fins gave fishes more control of their body movement. Tail fins and powerful muscles gave fishes greater thrust when swimming. This gave accuracy and speed. They had the ability to turn and use jaws in complex ways.

Modern Fishes



Bob Wetendorf, FWC

EXTERNAL ANATOMY



Graphic by John Cimbaro, FWC

Modern Fishes

Two groups:

- ▣ Modern sharks and rays — had an evolved skeleton made of strong, resilient cartilage.
- ▣ Bony fish — evolved skeletons — true bones. Lobe-finned fishes — had fleshy fins.

- ▣ A fish must overcome inertia, or the resistance to motion, to move through water. Most of this resistance is in the form of drag, which is caused by the friction of water as it flows over the body of the fish. Drag is also caused by the backward pull of the eddies of water that form behind the fish's tail.

- ▣ If the fish is streamlined, the water flowing past both sides of the fish meets and blends together, producing less turbulence and less drag.
- ▣ Primitive fishes had asymmetrical tails in which the vertebral column either pointed upward or downward as it extended from the body. When the fins pushed against the water to propel the fish forward, the movement was inefficient.

- ▣ Modern fishes have tails in which two symmetrical lobes extend from the end of the vertebral column. The forward thrust provided by this tail is greater and more evenly distributed along the length of the body. They can swim faster and have more control over their movement.

Form and Function in Fishes

- ▣ The oceans of the earth are extensive and the fishes found in the them have had to adapt to survive in the tremendous range of environments.
- ▣ Adaptations to aquatic life include various modes of feeding, specialized structures for gas exchange and paired fins for locomotion.

Feeding

- ▣ There are fish who are herbivores, carnivores, parasites, filter feeders and detritus feeders.
- ▣ (detritivore – organisms that feeds on dead plants and animals.)
- ▣ From the mouth, food passes through a short tube called the esophagus to the stomach where food is broken down. Then it travels to the pyloric ceca

Respiration

- ▣ Most fishes exchange gases using gills located on either side of the pharynx. The gills are made up of feathery threadlike structures called filaments. The filaments contain a network of fine capillaries that provide a large surface area for the exchange of oxygen and carbon dioxide.

- ▣ Fish pull the oxygen-rich water through their mouth, over the gills and then pushing the oxygen-depleted water out through openings in the sides of the pharynx.
- ▣ Some fishes such as lampreys and sharks have several gill openings. Most fish only have a single gill on each side. This opening is hidden beneath a protective bony cover called the operculum.

Reproduction

- ▣ The eggs of fishes are fertilized either externally or internally, depending upon the species. The female lays the eggs and the embryos in the eggs develop and hatch outside her body. Fishes whose eggs hatch outside the mother's body are oviparous. As the embryos develop, they obtain food from the yolk in the egg.

Groups of Fishes

All living fishes can be classified into three groups:

1. Jawless fishes
2. Cartilaginous fishes
3. Bony fish

Jawless Fishes

- ▣ Jawless fish have no true teeth or jaws. Their skeletons are made of fibers and cartilage
- ▣ They lack vertebrae and instead keep their notochords as adults. There are two classes: **hagfishes** and lampreys

Sharks and Their Relatives

- ▣ The class Chondrichthyes contains sharks, rays, skates and sawfishes
- ▣ There are 350 species of sharks. They have an enormous number of teeth

Amphibians

- ▣ An amphibian is a vertebrate that lives in water as a larva and on land as an adult, breathes with lungs as a adult, has moist skin that contains mucus glands, and lacks scales and claws.

- ▣ The first amphibian is guessed to have come to land during the late Devonian Period, about 360 million years ago.
- ▣ Early amphibians evolved several adaptations that helped them live at least part of their lives out of water. Bones in the limbs and limb girdles of amphibians became stronger, permitting better movement.

- ▣ Lungs and breathing tubes enable amphibians to breath air. The sternum or breastbone formed a bony shield to support and protect internal organs.
- ▣ (EVOLUTION OF REPTILIANS ,AVES AND MAMMALS WILL BE DISCUSSED IN PART 2 OF THIS COURSE MATERIAL)

THANK YOU