

# CHORDATE ZOOLOGY

B.L. Benno

2<sup>nd</sup> Semester 2021



WEEK	UNIT	TOPIC
1-2	I	Evolution of Chordate, its characteristics and classification as exemplified by the lower chordates Salient Features, General classification of Phylum Chordata up to orders. Prochordata: General Characters and affinities of Hemichordata, Cephalochordata & urochordata
3-4	II	Fishes: Structural morphology, General characters and classification Economic importance of Pisces
5-6	III	Amphibia . Structural morphology, General characters and classification; Economic importance (Frog Adaptive features of Anura, urodela & Apoda. Parental care in Amphibia)
7-8	IV	Reptila: Structural morphology, General characters and classification; Economic importance; Study-Calotes Poisonapparatus and biting mechanism of poisonous snakes;- Identification of poisonous and non-poisonous snake
9-10	V	Aves: Structural morphology, General characters and classification;
11-13	VI	Mammalia:Structural morphology, General characters and classification; Economic importance Rabbit. FlyingMammals; - Dentition in mammals; Aquatic mammals;- Adaptive features and their economic importance

# Reference books

- **Jordan E.L. and P.S. Verma 2005. Chordata Zoology and elements of Animal Physiology. S. Chand and Co., New Delhi.**
- **Kotpal R.L. 2002. Vertebrata, Rastogi Publications, Meerut**
- **Nigam.H.C. 2003 Zoology of chordates, Vishal publications, Jalandhar.**
- **Waterman, Allyn J.et al.2001, Chordate Structure and functions. Mac.Millan and Co., New York. Karedong, K. 2006. Vertebrates 4<sup>th</sup> ed. Comparative anatomy, function and evolution, McGraw-Hill International edition**
- **Hickman, CP., 2003. Animal Diversity 3<sup>rd</sup> ed. McGraw-Hill Higher Education**
- **Pough, F.H., et al. 2004. Vertebrate Life, 7th ed. Pearson Education International.**
- **Required Laboratory Manual:**
  - **Horn, B.M. & K.W. Stewart. 2007. Introduction to Chordate Zoology - Course Information, Laboratory Manual and Essay Guidelines**
  - **Hickman, Hickman, Kats 2001Laboratory studies in Integrated Principles of Zoology, 10<sup>th</sup> ed.McGraw-Hill Higher Education**

# Meeting hours

- Everyday
- Tuesday:9-11 Batch 2 - (Lab)
- Wednesday:08-11 hrs - Lecture
- Friday:11-13 Batch 1(Lab)

# Phylum : Chordates

- Chordates are one of the most diverse and successful of all animal groups.
- They include animals with the most complex body organisation in the whole of the animal kingdom eg. the birds and mammals, which have high metabolic rates, stable body temperatures, extremely efficient blood circulation systems and highly developed nervous and hormonal systems
- However, chordates also contains many apparently simple creatures that superficially resemble worms or other higher invertebrates

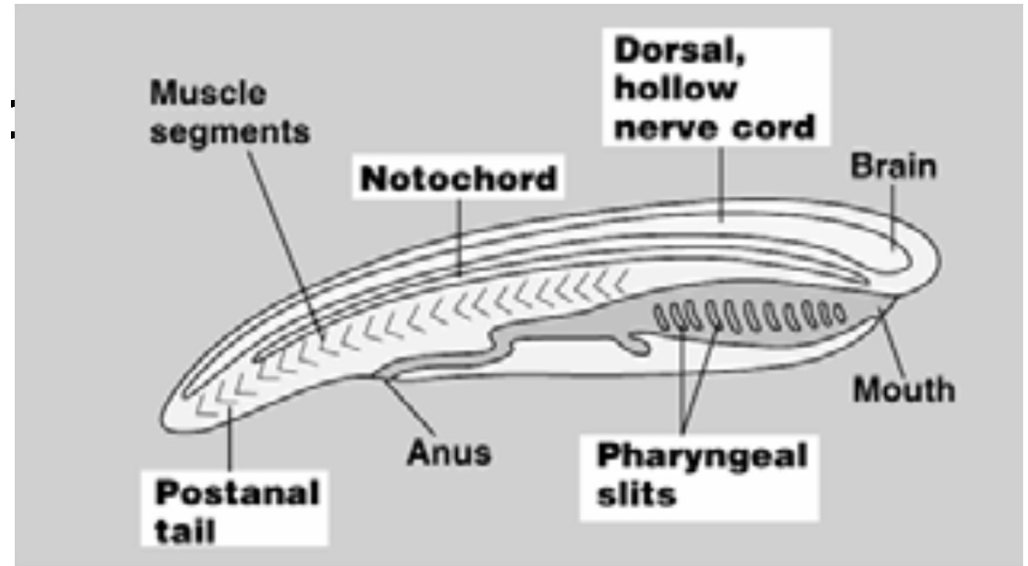
# Course Assessment:

- Final: 60 marks
- Course work: 40 marks
  - 2 Tests : 20 marks,
  - 2 assignments : 20 marks
  - lab work

# Key chordate characteristics

All animals of the phylum Chordata must have during all or part of their developmental life cycle the following:

- i. **Notochord**
- ii. **Pharyngeal gill slits**
- iii. **Dorsal tubular nerve cord.**
- iv. **Postanal tail.**



# Notochord

- (back cord) a slender rod of cartilage-like connective tissue lying near the dorsal side of the body and extending most of the length of the animal and runs beneath the the nerve cord
- It is regarded as an early endoskeleton and has the function of such in the protochordates.
- In more complex vertebrates, the notochord is present only during embryo development, not during adulthood.
- In some of the less complex vertebrates, the notochord persists throughout the life cycle and is found during embryo development and in adult stages.

# Notochord

- For those animals in which it persists into the adult form, the notochord provides support (it acts like our backbone) and increases swimming efficiency
- In most animals, bony structures called vertebrae develop near the notochord and eventually replace it during embryogenesis

## **2. Pharyngeal gill slits**

- **a series of paired, slender openings that connect the inside of the pharynx/throat to the outside of the "neck".**
- **In complex vertebrates, they appear only in the embryonic stages.**
- **The morphological equivalent of gill slits are seen briefly during human development (weeks 4-5), but they usually close or develop into other structures.**
- **Occasionally, the slits do not close, resulting in the newborn having an opening in the neck area (a cervical fistula).**
- **In many chordates, the gill slits never break through from the pharynx, but merely form pouches that have no function**

# Pharyngeal gill slits cont..

- They have been modified extensively in the course of evolution.
  - In primitive chordates, they serve as passageways for water into the gills of many aquatic chordates and facilitates filter feeding in the protochordates.
  - In fishes and some amphibians, the slits bear gills and are used for gas exchange.
  - In most land - living chordates, the "gill slits" are present only in embryonic stages; you had pharyngeal slits at one time.
  - The slits are supported by gill arches, which have also been highly modified in various groups of [vertebrates](#)

# 3. Dorsal tubular nerve cord

- a bundle of nerve fibers which runs down the "back", lying dorsal to the digestive tract in contrast to the ventral, solid nerve cord of most invertebrates
- has a fluid-filled cavity with pairs of nerves branching from it at intervals and running to the muscles.
- The anterior (forward) end of the nerve cord is often enlarged into a **brain**.
- along with the brain, forms the CNS.

## 4. Post-anal tail

- Is the extension of the notochord and nerve cord past the anus.
- This feature may or may not persist in the adult
  - Eg. is lost in the adult stages of many chordates, such as frogs and people.
- serves as a means of propulsion in water;
- In humans, the tail is short and fused (the coccyx found at the base of your spine)

# Phylum Chordata

- **Other General Chordate Characteristics**

- deuterostomate embryo development  
(deuterostomes= the anus develops before the mouth in early embryonic stages, as opposed to protostomes)
- eucoelomic body cavity
- nervous system most highly-developed of all animal phyla (consisting of central nervous system of brain and dorsal, tubular nerve cord)
- usually very well developed all other systems (organ / system level of complexity)

# Broad Classification of Chordates

- **Two groups**
  1. **Protochordata (Acrania)**
    - the invertebrate chordates
    - lack cranium and vertebral column;
      - **subphylum: Urochordata (Tunicates)** the tunicates; sea squirts, eg *Molgula* sp.
      - **Subphylum: Cephalochordata (the lancelets);** eg. sea lancelet or amphioxus

# Classification cont..

2. **Craniata** - possess a cranium and vertebral column (the vertebrates).

## **Subphylum Vertebrata**

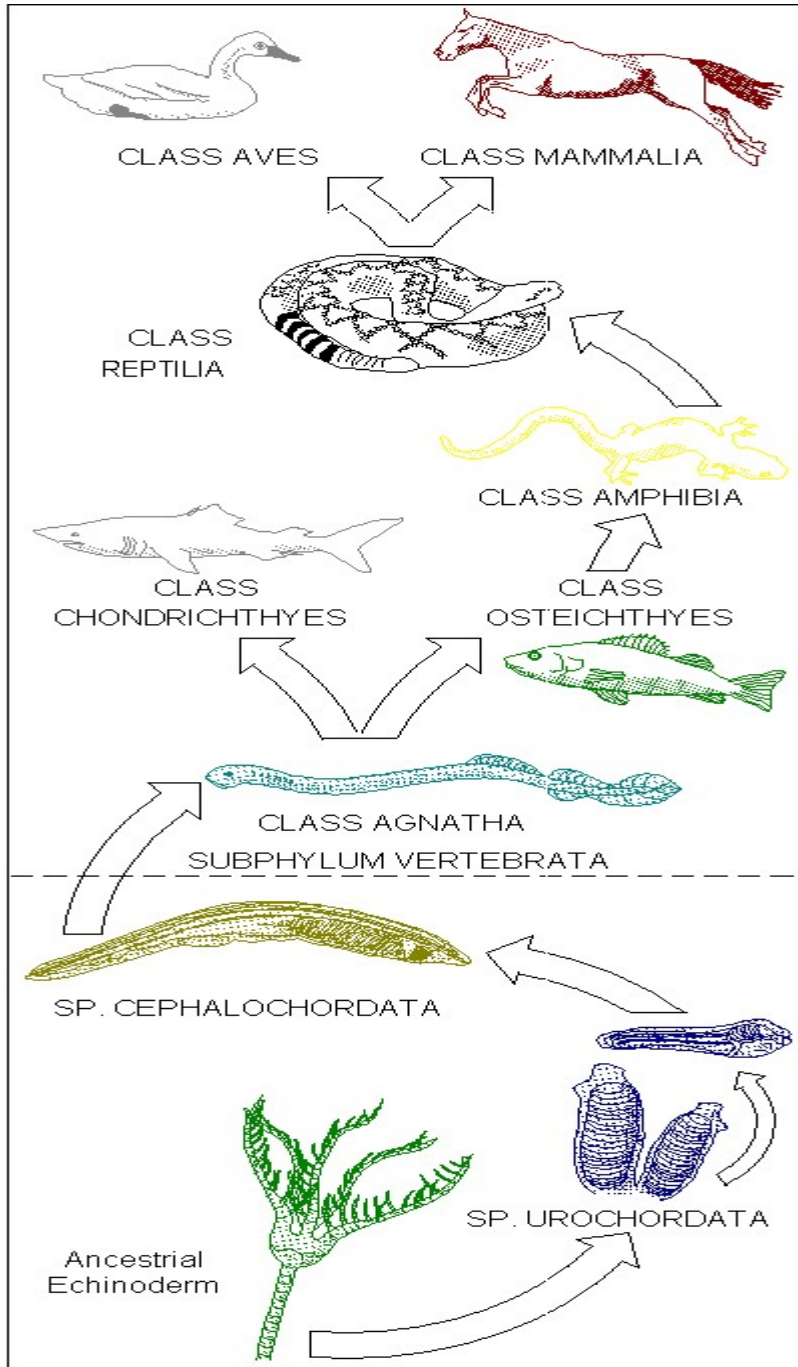
- have bony or cartilaginous vertebrae surrounding spinal cord;
- possess notochord in all embryonic stages, persisting in some of the adult fish;

# Evolution of the chordates

- **Initially hemichordates were thought to be ancestors to chordates because of some shared characteristics.**
  - eg possession of pharyngeal slits,
  - and the presence of dorsal tubular nerve cord in the collar region of some hemichordates
- **echinoderm ancestry:**
  - **Garstang's Hypothesis of chordate evolution: based on embryological affinities with echinoderms**
  - **evidence shows that they appear to be the most-likely ancestors to the early chordates**
    - **Both are deuterostomes thus sharing embryonic similarities of cleavage and mesodermal and coelomic formation.**
  - **Like chordates, echinoderm larva is bilaterally symmetrical .**

# echinoderm Chordate ancestry

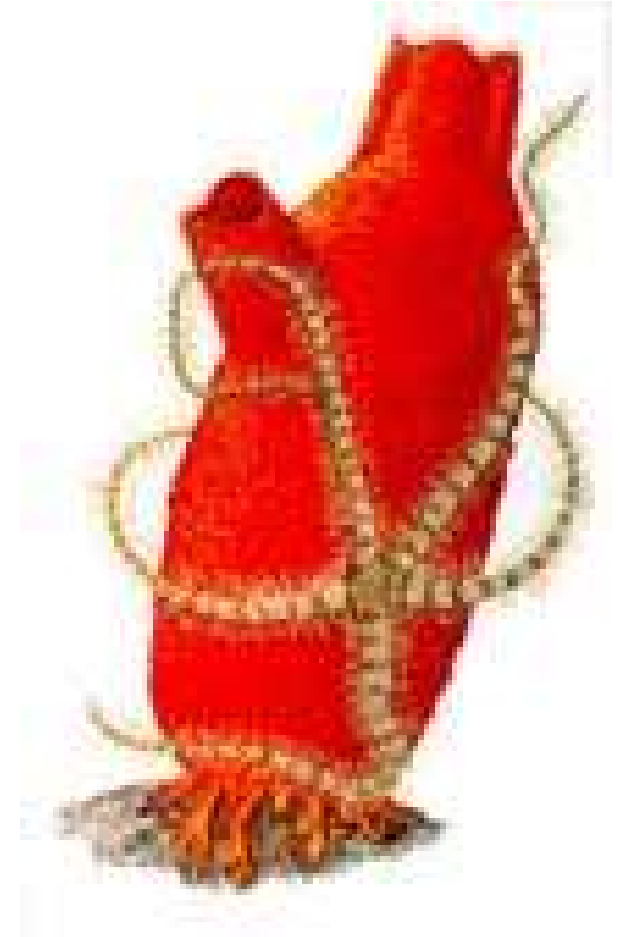
- **Primitive stemmed echinoderms are thought to have shifted from arm-feeding to filter-feeding.**
- **They then acquired a body plan similar to today's urochordates.**
- **Unfortunately, the fossil record is poor and intermediates are lacking.**
- **The similarity between present-day tunicate larvae and adult cephalochordates (amphioxus) suggests that the larvae became paedogenic (capable of reproducing while retaining larval features).**
- **Succeeding evolution and specialization of the larvae resulted in the cephalochordates.**



- Evolution of chordates

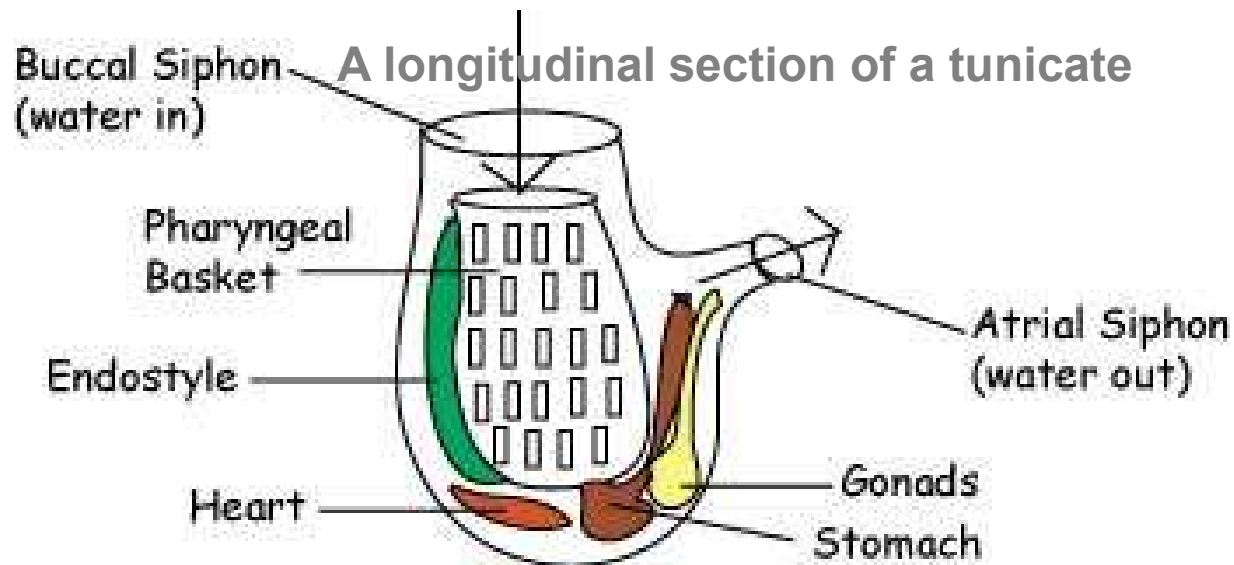
# **a. Subphylum Urochordata (Tunicata),**

- **body enclosed in a leathery covering (tunic) which contains cellulose**
- **The tunicates the notochord is restricted to the tail in larvae**
- **During adult metamorphosis the notochord and tail disappears while the dorsal nerve cord becomes reduced into a single ganglion**
- **there are about 3000 spp**



# tunicates

- Typically spherical/cylindrical in shape, attached by its base to substrate
- The mantle is the inner membrane that lines the tunic
- There are two openings: incurrent and excurrent siphons



# Tunicates

– **Three classes:**

- **Ascidiacea (the Sea squirts,)**
- **Thaliacea (The Salpians) and**
- **Larvacea (the Appendicularians)**

# 1. Ascidiacea

- Ascidians –(little bag or bottle) is the largest group
- Called sea squirts because of their habit of squirting water from excurrent siphon
- Found in all seas and at all depths
- Most are sessile as adults eg *Ciona intestinalis*,
- few species are pelagic, Solitary, colonial, compound

# Ascidiacea

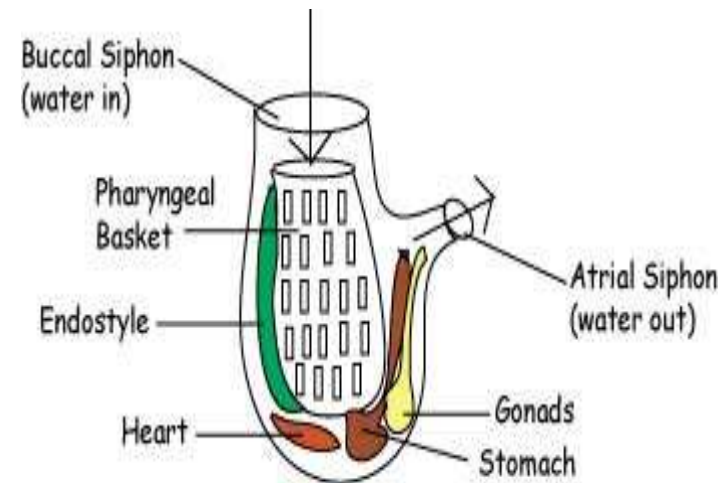
- Pelagic larval form
- only larval forms have all chordate characteristics;
- The larval form resembles an amphibian tadpole.
  - In the tail there is a well-developed notochord and a typical dorsal hollow nerve cord.
  - Anteriorly in the larva there is a rudimentary brain and sense organs.
  - Once the larva attaches and becomes a sedentary adult, the notochord and larval nervous system disappears.
- adults are sessile,

# Ascidiacea cont..

- terminal incurrent or oral siphon at the mouth and excurrent siphon on the dorsal side;
- Possess ciliated pharynx which facilitates filter feeding and movement of water through the pharyngeal gill slits and into an atrial cavity for gas exchange.
- Nervous system not well understood, but there is a cerebral ganglion between the siphons
- Probably no sensory nerves, but flexed reflexes have been observed

# Ascidiaceans

- Respiratory system consist of the branchial sac or pharynx which is perforated with many pharyngeal slits through which water passes into the atrium to be discharged through excurrent siphon
- Gas exchange takes place along the vascular wall of the pharynx



# Ascidiaceans

- Circulatory system is open
- consists of a ventral heart located near the right posterior end which empties into 2 vessels one at each side of the heart.
- Blood with numerous cells is alternately pumped into one direction and then reverses.
- Contraction initiated by two pace makers at each end of the heart

# Ascidiaceans cont..

- Digestive system consists of a ring of tentacles (between mouth and pharynx) which screen food particles from incurrent water
- The **endostyle** - a ciliated groove in the pharynx secretes mucus, then propelled posteriorly by a row of curved ciliated fingerlike processes called **languates** into the esophagus and stomach then intestine and anus which empties into the atrium near the excurrent siphon
- Nephridial excretory system exists
- The nervous system is restricted to a nerve ganglion and a few nerves that lie on the dorsal side of the pharynx
- No notochord

# Ascidiacea

## Reproduction

- Most are hermaphrodites and bears a single ovary and testis each with a gonoduct that opens into the atrium
- Eggs are shed from the excurrent siphon and cross fertilization occurs in water
- Colonial spp brood eggs in the atrium and larvae hatch, leave by excurrent siphon
- Larvae start to feed when they settle to the substrate and metamorphose
- Larvae sea squirts have all 4 key chordate characteristics but adults have one pharyngeal gill slit and no notochord

## b. Subphylum: Cephalochordata,

- the lancelets; or **amphioxus**
- all four key chordate characteristics are present in the adult form;
- notochord and nerve cord are found along entire length of body and persist throughout the life cycle;



# Cephalochordata:Amphioxus

- Slender, laterally compressed, translucent about 5-7 cm long
- The anterior tip (rostrum) with opening of the oral hood fringed by oral tentacles (**buccal cirri**) that strain large particles
- have Metapleural folds that extends ventrally
- have Continuous ( joined) Dorsal, caudal and ventral fins
- have Segmentally arranged myotomes
- Inhabit sandy bottoms of coastal waters
- live half buried in the sand, with the head projecting upwards

# Cephalochordata

- They show the beginning of a ventral heart and a metameric arrangement of muscles and nerves



# Cephalochordata, cont..

- feed by filtering water through their pharynx to extract small particles
- Ciliated tentacles, wheel organ and gills facilitate water movement into the body and aid in filter feeding;
- The endostyle (with cilia) at the floor of the pharynx secretes mucus, together with the ciliated hyperbranchial groove pushes the food towards the intestine for digestion
- Small food particles are separated from the mucus and passed into the midgut caecum (**diverticulum**) where they are phagotized and digested intracellularly
- Then filtered water passes into atrium and leaves by the atriopore

# cephalochordata

- lack a true heart;
- the colourless blood is circulated through the body by peristaltic-like contractions of the ventral aorta –branchial arteries- dorsal aorta – body tissue - veins –ventral aorta
- sexes are separate,
- gametes released into the atrium before exiting through the atriopore
- fertilization is external;

# Cephalochordata

- **Show a very primitive nervous organization.**
  - **the brain is a single enlarged region at the anterior end of the nerve cord;**
  - **Nervous system is centered around a hollow nerve cord lying above the notochord**
  - **Simple sense organs of unpaired bipolar receptors on the body.**

# Cephalochordata: The amphioxus

- **The notochord extends to the tip of the rostrum serves as a skeletal support and point of attachment of muscles**
- **a digestive tract consisting of a straight tube.**
- **The pharynx is highly specialized for food collection.**

# Amphioxus cont..

- their major development of the gill slits emphasize the animal's relationships to the vertebrates,
- they differ from the vertebrate gill apparatus both in the purpose for which they are utilized and their mode of operation.
- It appears that most of the respiration of *Amphioxus* is done through its thin skin and the gills are feeding devices.
- whereas in vertebrates, water currents through the gills are effected by muscular pumping, in *Amphioxus* is through action of cilia.

# Cephalochordata

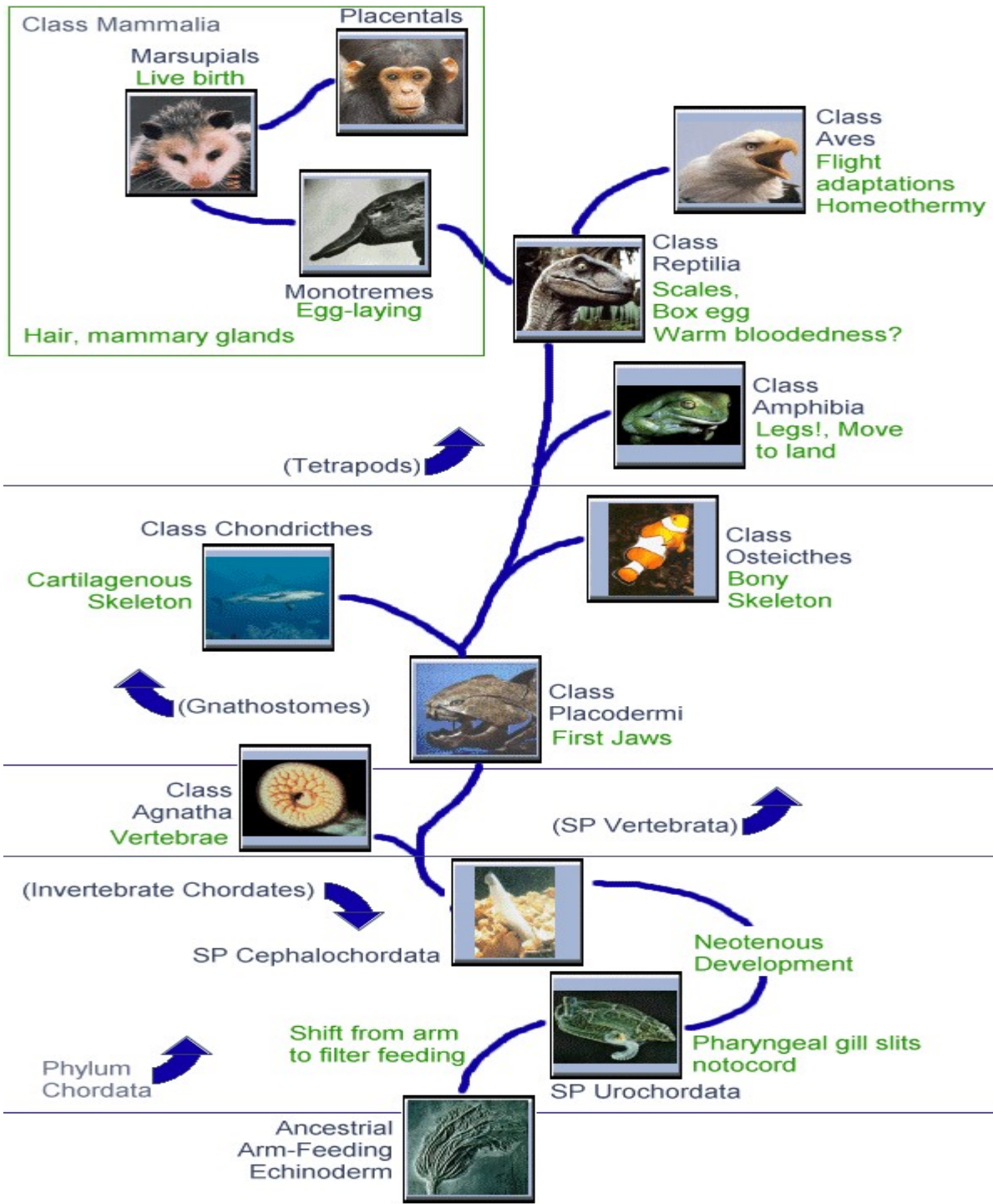
- They probably were separated from the main line of vertebrate evolution at a very early stage
- there are approx. 25 spp. in two genera of entire subphylum;
  - 1. *Branchiostoma*, "gills and mouth"; Eg. *Amphioxus* "pointed or sharp at both ends",**
  - 2. *Asymmetron* spp. - notochord and nerve cord persist throughout life; lance-shaped;**

# Cephalochordata

- Amphioxus possess some structural feature closely related to the vertebrate plan eg
  - i. midgut diverticulum which secretes digestive enzymes
  - ii. Segmented trunk musculature and
  - iii. basic circulatory pattern of advanced chordates

# CRANIATA: Subphylum:Vertebrata

- evolved about 0.5 billion years ago
- They now occupy marine, freshwater, terrestrial and aerial environments.
- Exhibit varying lifestyles
- Their success is attributed to:
  - opportunity, ie. arose at a time when there were few large predators, and
  - due to innovation of the vertebral column and the cranium



# Origin of vertebrates

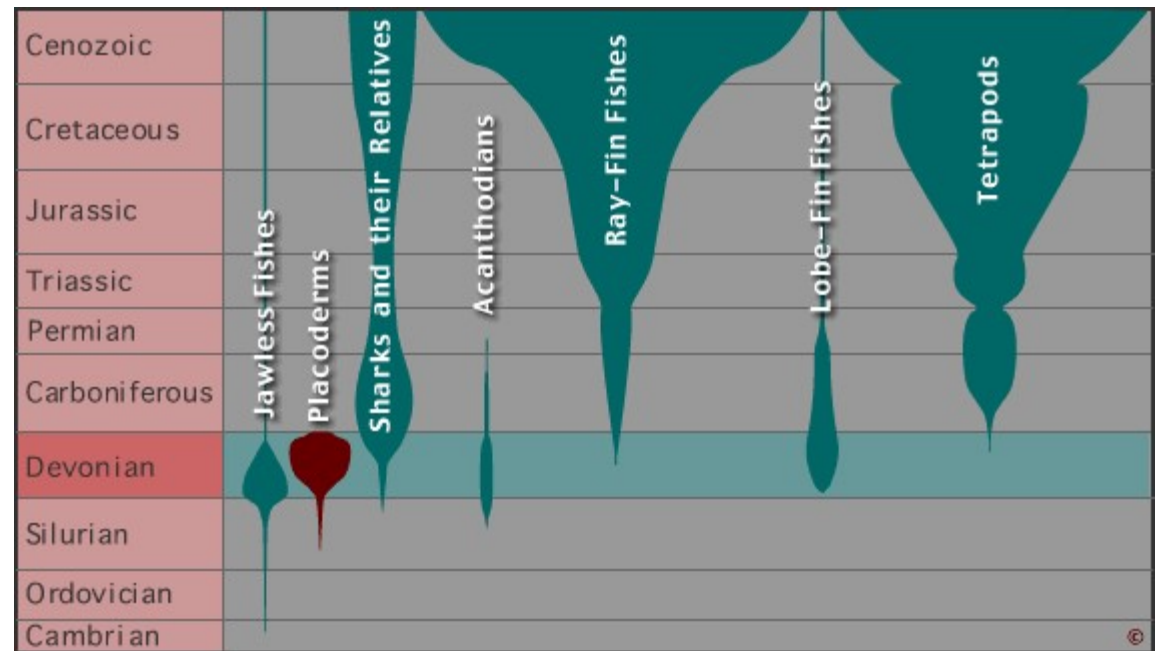
- It took place in marine waters – according to the fossils records of Cambrian period
- The pre-vertebrate was a predator and suspension feeder facilitated by ciliary movement
- For a vertebrate condition two mechanical changes eg developing an encircling band of muscles and replacement of collagen bars with cartilage occurred in the pharynx that produced a muscular pump
- This enabled constriction of the pharynx to squeeze the water out of the pharynx slits

# Evolution of vertebrates

- The relaxation of the muscle will expand the pharynx allowing water to be drawn in again
- This allowed more efficient feeding and respiratory demands following the evolution of gills which were highly vascularized
- The pharyngeal pump gave rise to evolution of the Agnathans whose feeding habits were deposit feeders, or mud grabbers by pushing their mouths into loose organic ooze or the silty mud rich in organic particles and microorganisms.

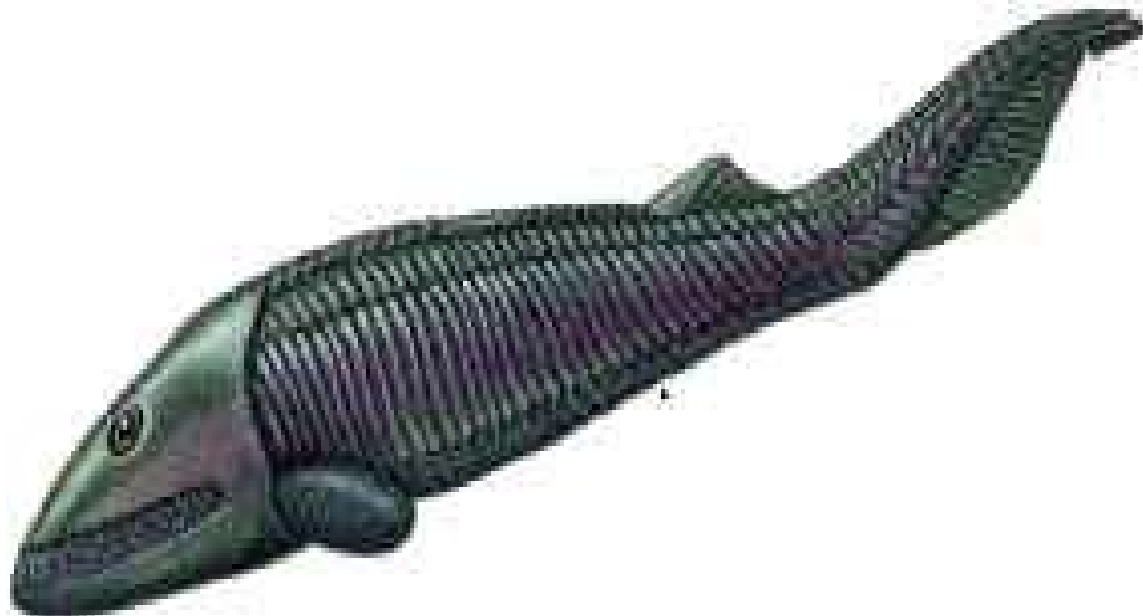
# Subphylum Vertebrata

- Vertebrate life is a complex byproduct of billions of years of evolution.
- Each organism and each individual is a unique synthesis of past and present, structure and function, nature and nurture.



# Evolution of vertebrates

- **The earliest vertebrates in the fossil record are the ostracoderms (extinct now, but within the class Agnatha).**
- **These fish had no vertebrae and some used their pharyngeal gill slits for filter feeding.**



# Evolution of vertebrates

- A comparison of an **ammocoete larva** (class Agnatha) with adult cephalochordates and tunicate larvae indicates that the relationship among the three phyla must be extremely close.

# Vertebrate evolution...

- **Agnatha-like fish continued to specialize, eventually evolving jaws.**
- **The most primitive of the jawed fish are the placoderms (named for the plate-like armor shields covering their bodies and heads).**
- **Placoderms later evolved into the cartilaginous (Chondrichthyes) and bony fish (Osteichthyes).**



# Vertebrate evolution ...

- **Although vertebrates most certainly evolved in the ocean, some primitive fish invaded freshwater habitats and adapted accordingly.**
- **It is these freshwater fish that served as the ancestral stock for the terrestrial vertebrates (Amphibians, and later the reptiles, birds, and mammals).**

# Subphylum Vertebrata

- may be divided into two groups (superclasses).
  - **Superclass: Agnatha (without jaw) -**
  - **Superclass: Gnathostomata (jawed) -**

# Superclass: Agnatha

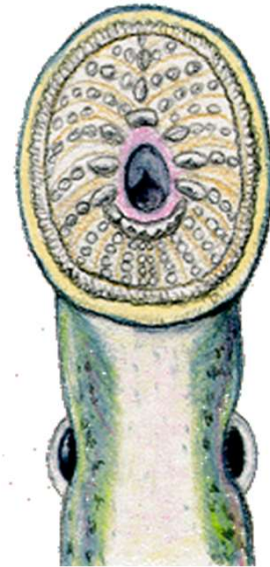
- Include Hagfishes and Lampreys;
  - lack true jaws and appendages
1. Class Myxini – the hagfishes;
    - **Hagfish and lampreys are the only living representatives of the jawless vertebrates (agnathans),**
    - **mouth with four pairs of tentacles;**
    - **5 to 15 pairs of gill slits and gill pouches;**
    - **partially hermaphroditic.**
    - **osmoconformers**

# Agnatha

## 2. Class Cephalaspidomorphi

– the lampreys;

- sucker-like mouth with teeth;
- seven pairs of gill slits and pouches.

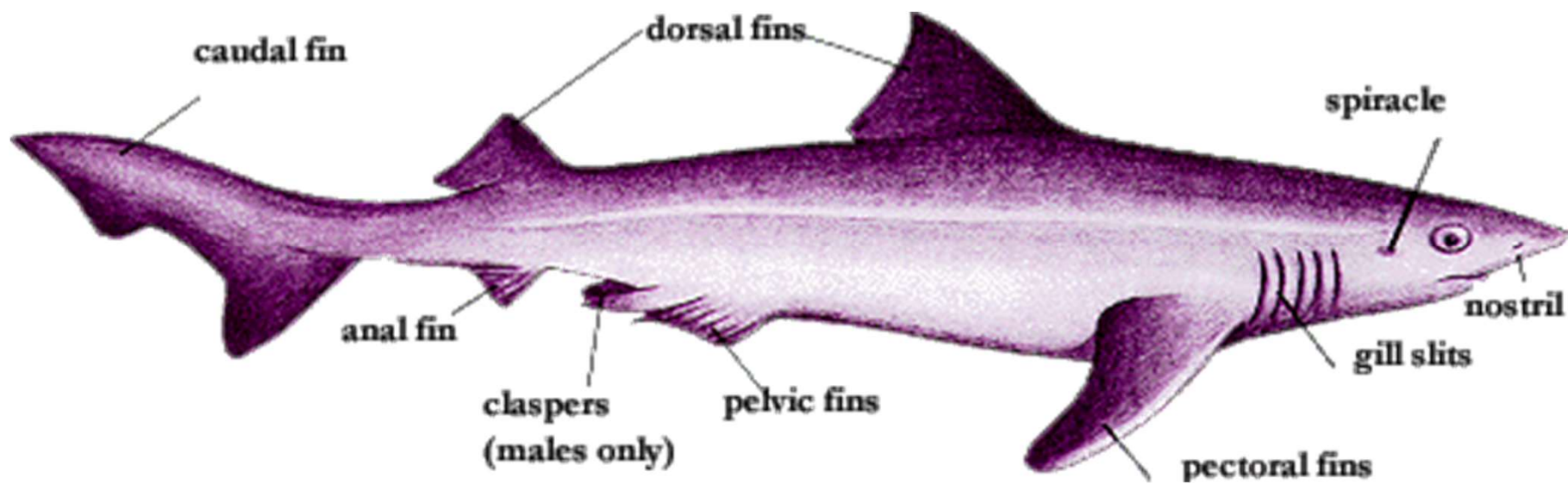


# Superclass: Gnathostomata

- jawed fishes and all tetrapods (all other vertebrates);
  - **having jaws and usually paired appendages**
- **Classes:**
  - Chondrichthyes: cartilaginous fishes such as sharks, skates and rays**
  - Osteichthyes (Teleostomi) - bony fishes**
  - Amphibia (double life) - amphibians**
  - Reptilia (to creep) - reptiles**
  - Aves (bird) - birds**
  - Mammalia - mammals**

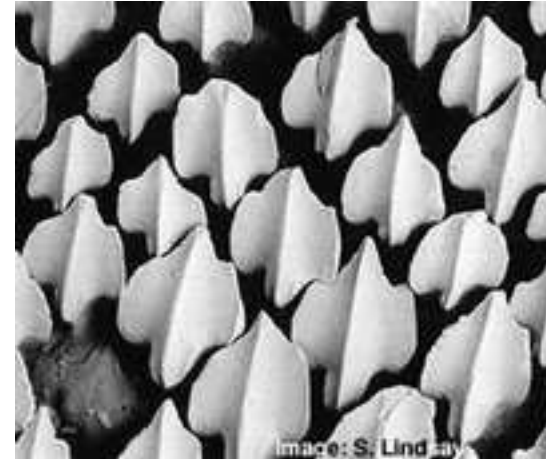
# Class: Chondrichthyes

- cartilaginous fishes such as sharks, skates and rays;
- streamlined body with heterocercal tail (asymmetrical dorsoventrally);
- Cartilaginous skeleton;
- Five to seven gills with separate openings,
- no operculum (covering);
- no swim bladder.



# Chondrichthyes

- **Mouth: ventral with jaws; olfactory sacs do not open into the oral cavity.**
- **Placoid scales on skin - scales that are composed of dentin and are covered with enamel-like substance (*denticles* sp.); modified placoid scales serve as teeth.**
- **Endoskeleton entirely cartilaginous; notochord persists in adult; vertebral column is complete and separate from the notochord.**



# Chondrichthyes

- **Digestive system of a "J"-shaped stomach, intestines, liver, gallbladder, and pancreas.**
- **Circulatory system of several pairs of aortic arches; dorsal and ventral aorta, capillary and venous systems, hepatic (liver) portal and renal (kidneys) portal systems; 2-chambered heart;**
- **high concentration of urea and trimethylamine oxide in blood (nitrogenous waste products typical of carnivorous animals which take in more nitrogen than needed):help in osmoregulation.**

# Chondrichthyes

- Gaseous respiration by means of 5 to 7 pairs of gills with separate, external gill slits.
- **NO SWIM BLADDER!**
-

# chondrichthyes

- **Brain consists of 2 olfactory lobes, 2 cerebral hemispheres, 2 optic lobes, a cerebellum, and a medulla oblongata;**
  - **Cerebellum - controls balance and coordination - small region that lies just above the medulla.**
  - **medulla - most posterior region of the brain that is really a conical continuation of the spinal cord; together with the midbrain, makes up the "brain stem" or medulla oblongata. Regulates subconscious activities such as heartbeat, respiration, etc.**
- **10 pairs of cranial (skull) nerves.**

- Classification of chondrichthyes
  - Elasmobranchii
  - Holocephali : (Chimaera)

# Sharks

## Reproduction:

- **Sexes are separate; paired gonads (sex organs: ovaries in females and testes in males); reproductive ducts open into the cloaca (excretory structure); sex organs and excretory organs.**
- **Oviparous, ovoviviparous, viviparous, direct development, internal fertilization.**
- **Sperm from the testes of the male is carried by the wolffian ducts to the cloaca and is excreted during intercourse;**



# sharks

- **The male uses specialized modifications in the pelvic fins (claspers) to deposit the sperm into the female oviduct;**
- **Well developed lateral line for detection of other organisms/objects**
- **Possess receptor organs, ampullary of Lorenzini for detection of prey even if buried in sand by detecting bioelectric field that surrounds all animals**

# sharks

- **The oviduct retains unfertilized eggs from the ovary until they are fertilized; After fertilization, the zygotes develop within a modified portion of the oviduct which becomes the uterus; Within the uterus, a primitive placenta may form and attach developing embryos to the uterus wall and to the mesonephros (coelom wall) until the shark is born;**
- **Following birth, the uterus and newborn shark are both released from the mother;**

# Sharks ....

- **The uterus may remain attached to the young shark for a short time; This type of reproduction where the embryo is attached to the mother's uterus wall is called viviparous reproduction;**
- **In some species of sharks, the mother retains the developing embryos within the uterus without attachment to the uterus wall ovoviviparous reproduction;**
- **Some other shark spp. will lay large, yolky eggs immediately after fertilization. this is called oviparous reproduction.;**
- **Finally, some sharks and rays deposit fertilized eggs in a capsule called a "mermaid's purse" which is often attached to seaweed. The young sharks or rays will later emerge from this structure.**

# Rays

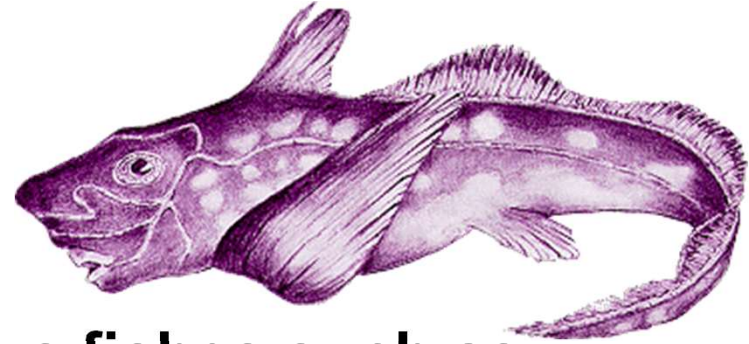
- **includes skates, electric rays, sawfishes, stingrays, eagle rays, and manta rays.**
- **All are bottom dwellers (benthic)**
- **have greatly-enforced pectoral fins that are fused to the head and used like wings for swimming;**



# rays

- external gill openings are on the ventral side of the body;
- water (for breathing) is taken through the spiracle on the dorsal side;
- feed on mollusks, crustaceans, and occasionally, fish.
- Sting rays have a slender whip-like tail that is armed with one or more saw-edged spines with venom glands. The wounds are very painful and heal very slowly.
- Electric rays produce a high-amperage current by the simultaneous discharge of electricity. The voltage output is very low, but the power output may reach several kilowatts. This is enough to stun prey or ward off predators.

# Holocephali Chimaeras



- **small subclass of cartilaginous fishes such as ratfish, spookfish, and ghostfish; 25 spp. today;**
- **anatomically appear as an odd mixture of shark-like and bony fish features;**
- **instead of a toothed mouth, their jaws bear large, flat plates;**
- **The upper jaw is completely fused to the cranium, which is very unusual in fish;**
- **eat seaweed, mollusks, echinoderms, crustaceans, and other small fish;**
- **not a commercial sp. and are seldom caught;**
- **despite their ugly appearance, they are rather colourful.**

# Bony fish origin, evolution and diversity

- **Fossils of earlier bony fishes shows structural similarities with Acanthodians (extinct Placoderms) suggesting a common ancestor**
- **By mid Devonian period they showed radiation into two major lineages the ray finned fishes and lobe finned fishes**
- **The radiation may have been contributed by adaptations such as possession of a bony operculum attached to a series of muscles – this increased the respiratory efficiency**
- **Also earlier bony fishes had a pair of lungs that provided additional means of gas exchange in oxygen poor waters and also provided neutral buoyancy**
- **Progressive specialization of jaw musculature and skeletal elements involved in feeding**

# Class Osteichthyes (Teleostomi)

**The bony fishes;**

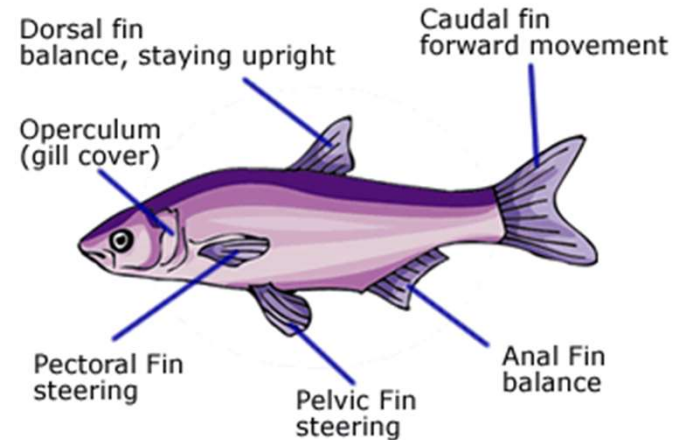
- **primarily fusiform body but form may variously be modified;**
- **Skeleton more or less ossified bony (Endochondral bone), vertebrae numerous, tail usually homocercal.**
- **Skin with mucous gland with embedded dermal scales**

**Three types**

- **Ganoid scales - diamond-shaped; simple scales with layers of silvery enamel on upper surface and bone on the lower surface.**
  - **Cycloid scales - thin, flexible scales of dermal material arranged in roughly concentric circles with smooth margins.**
  - **Ctenoid scales thin, overlapping dermal scales of advanced bony fishes; exposed posterior margins are rough with fine, tooth-like spines.**
- **No placoid scales**
  - **Some without scales**

# Osteichthyes characteristics

- **Fins: single median; also paired lateral fins with lepidotrichia (rays) of cartilage or bone.**
- **Terminal mouth with many teeth and movable jaws (some toothless fish do exist.).**
- **Olfactory sacs paired and may or may not open into the oral cavity.**



- **Respiration by gills supported by bony gill arches and covered by a common operculum –**
- **Swim bladder usually present with a duct connected to the pharynx (physostomous) or without (physoclistous).**

# Bony fishes characteristics

- **Circulation system of a 2-chambered heart, arterial and venous vessels, and usually four pairs of aortic arches; blood contains nucleated red cells.**
- **Nervous system consist of a brain with small olfactory lobes, cerebrum, large optic lobes and cerebellum; 10 pairs of cranial nerves.**
- **Sexes separate (sex reversal in some spp.); gonads are paired; fertilization usually external; few exhibit internal fertilization; larval forms may differ greatly from adults.**

# Classification of bony fishes:

Two distinct groups (Classes):

1. Sarcopterygii: **Lobe-finned fishes**
  
2. Actinopterygii: Ray finned fishes
  - Formerly divided into
    - chondrostei
    - Holostei (Lungfishes,)
    - Teleostei: Ray-finned fishes
  
3. **Current classification**
  - Palaenisciformes: primitive ray finned
  - Neopterygii (advanced ray finned fishes)

# Sarcopterygii

- Fleshy finned fishes
- Paired fins rest at end of short internal bony elements and soft muscles
- Thought to have given rise to first terrestrial vertebrate (tetrapods)
- Tetrapod limbs thought to have evolved from sarcopterygian fins

# Sarcopterygians

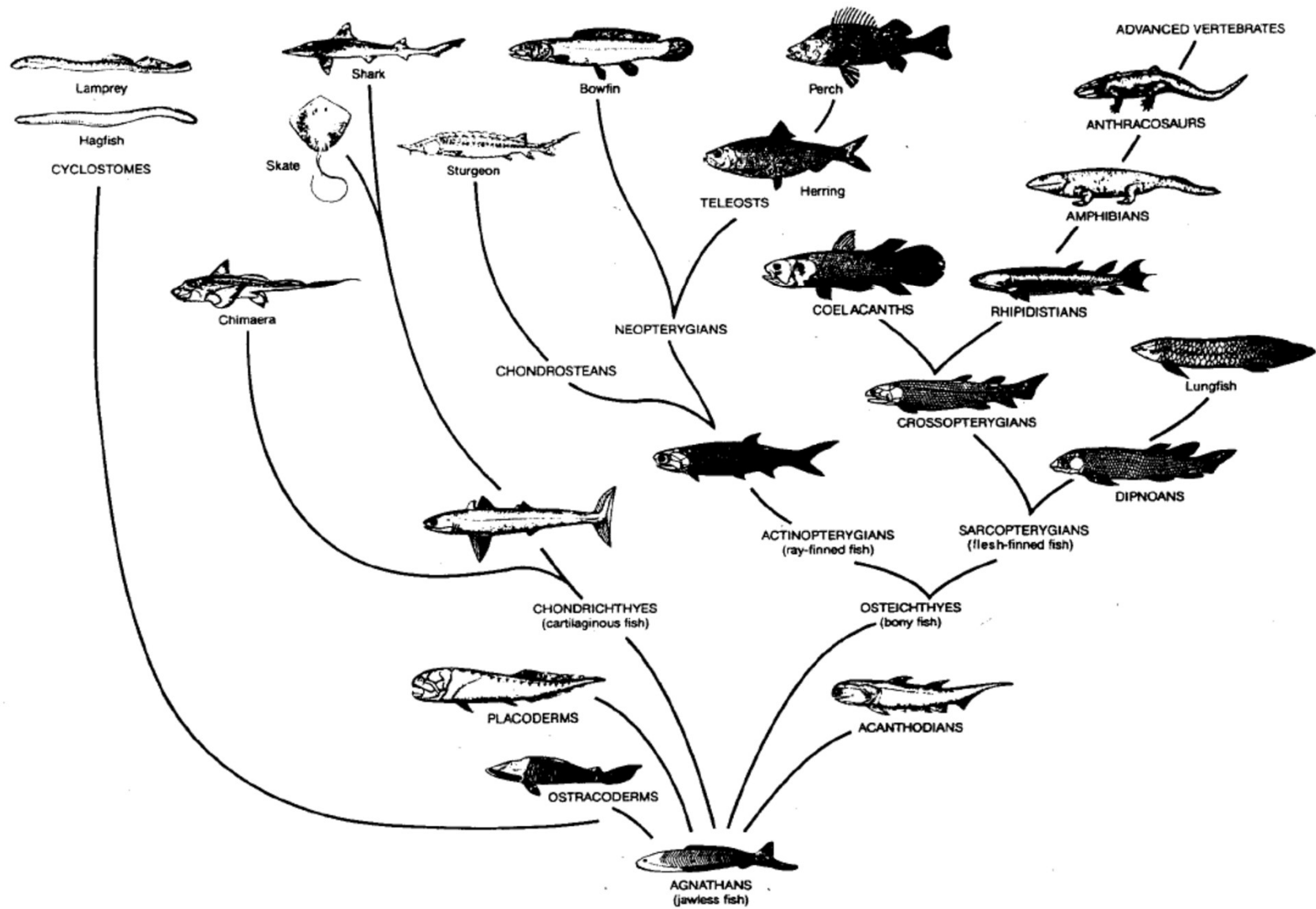
- **All early groups: Rhipidistians and Actinistia (coelacanths) had lungs, gills and strong fleshy paired lobed fins that may have been used to walk on the sea floor**
- **Powerful jaws, skin covered with heavy cosmoid scales, Diphyccercal tail**
- **Rhipidistians flourished in the late Paleozoic era and are thought to have given rise to land vertebrates**
  - **Rhipidistian jaws carried labyrinthodont teeth characterized by complex infolding around a central pulp cavity**
  - **Their braincase had a hinge like joint (cranial kinesis) that allowed flexing and allowed powerful biting**
- **Coelacanth arose in Devonian period and nearly disappeared at end of Mesozoic era but a surviving species Latimeria chalumnae was discovered in 1938 off the coast of south Africa**

# coelacanth



# Sarcopterygii

- Extant forms include Dipnoi lung fishes (The Australian lung fish *Neoceratodus* spp, The African Lung fish *Protopterus* spp, and the south American lungfish *Lipidosiren* spp)
- **The medial fins are fused to make one large, continuous fin.**
- They can survive in oxygen poor water by coming to the surface to gulp some air
- The African and S. American lungfishes can aestivate



# Geological time scale

Era	Period	Mya
Cenozoic	Neogene	24 63
	Paleogene	
Mesozoic	Cretaceous	138 205
	Jurassic	
	Triassic	
Paleozoic	Permian	240
	Carboniferous	290
		360
	Devonian	408
	Silurian	
	Ordovician	438
Cambrian	505	

# Actinopterygii

- Ray finned fishes
- Large group of about 25,000 species
- Earlier classification: **Formerly divided into**
  - chondrostei
  - Holostei (Lungfishes,)
  - Teleostei: Ray-finned fishes

## 1. Current classification

- Palaenisciformes: primitive ray finned
- Neopterygii (advanced ray finned fishes)

# Palaeonisciformes

Extinct forms among the earliest known bony fishes

- Fusiform bodies
- Ganoid (bone-dentine-ganoine) overlapping rhomboidal scales
- Heads like that of sharks and acanthodians – similar feeding style
- Occupied marine and freshwater habitat and reached great diversity during late Paleozoic before being replaced by Neopterygians in early mesozoic period

# Palaeonisciformes

- **Extant forms include members of Acipenseriformes (Acipenserids) and Polypteriformes (the bichir)**
- **Acipenserids: paddlefishes and sturgeons**
- Sturgeons unique characters**
  - **The largest freshwater fish can reach 8m, 1400kg**
  - **Toothless, bottom feeders**
  - **Can live up to 100 years, reach maturity after 20 yrs**
  - **Their roe (eggs) is the Russian caviar**
  - **First gill slit modified into spiracle**
  - **Lack ganoid scale except for a small area**
  - **Skeleton cartilaginous**
- Paddlefish occur in freshwater of N.America and china**
- **They are filter feeders of plankton**

# 1. Polypteriformes (the bichirs) eg Polypterus

- Have rhomboid ganoid scales
- Spiracle
- Live in streams and swamps in Africa
- Swim bladder functioning like a paired lung
- Flesh pectoral fins
- Formerly classified as sarcopterygians with lung fishes

# Neopterygii

- Display a great range of morphologies and show great adaptation to various habitats
- Evolutionary changes include:
  - changes in skull to increase jaw flexibility and mobility during feeding and offer for muscle attachment, therefore more swimming ability
  - Scales become thinner and rounder and more flexible although some e.g. gars (Lepisosteiformes) and bowfins (Amiiformes) still retain rhomboid scales
  - Notochord replaced by ossified vertebrae
  - Asymmetrical tail replaced by symmetrical homocercal tail

# Holostei

- Primitive neopterygians
- Homocercal tail but internally heteroceca
- No spiracle
- Reduces scales
- Living forms include gars (Lepisosteiformes), bowfin (Amiiformes)



# Teleostei

- Advanced neopterygians
- Very diverse group about 20000 spp
- Very widely distributed
- Seems to be a monophyletic group arising from a common ancestor

# Teleostei characteristics

- Homocercal tail
- Circular scales without ganoine
- Ossified vertebrate
- Swim bladder for buoyancy
- Skull with complex jaw mobility allowing capture and manipulation of food





# **Structural and Functional adaptations:**

- 1. Locomotion in water - driven by powerful trunk and tail muscle that flex and extend in a "zigzag" pattern.**
- 2. Buoyancy and the swim bladder:  
All fishes are slightly "heavier" (more dense) than water because their skeletons and other tissues therefore to keep from sinking, sharks must always keep swimming and moving forward in the water.**
  - The asymmetrical (heterocercal) tail (caudal fin) of sharks provides the necessary tail lift**
  - The broad shark head and flat pectoral fins act as angled planes to provide head lift.**

# Fish Locomotion and buoyancy

- **Sharks also have great buoyancy by having very large, fatty, livers composed of low density squalene (*Squalus* sp.) = fatty (oily) material that helps provide buoyancy.**
- **In bony fishes, buoyancy is provided by an efficient swim bladder - a gas-filled organ that regulates the buoyancy of the fish body.**

# Fish adaptations

- **Can change depth (water level by adjusting the amount of gas in swim bladder. Some fish have to "gulp" air from above the water surface to fill the swim bladder. e.g. trout.**
- **The gulped air is forced into the swim bladder through a pneumatic duct which connects the swim bladder to the esophagus (Physostomous condition).**
- **The more advanced fishes have a gas gland which secretes gas into the swim bladder (physoclistous condition). The amount of gas (oxygen diverted from gills or lungs (if present)) regulates the degree of buoyancy and the depth at which the fish remains.**
-

# Fish adaptations

## 3 Fish Respiration

- **A) Gills** are respiratory organs which are composed of t filaments covered with a thin epidermal membrane that is folded repeatedly into plate-like **gill lamellae** - tissue richly supplied with blood vessels for gas exchange.
- The gills are located inside the pharyngeal cavity and are covered by the operculum. for protection.

# Fish adaptations

## B)Lungs

- allow some fish to breathe air, but are not developed enough to provide 100% of the fish's respiratory needs.
- Most of the oxygen that fish breathe is provided by the dissolved oxygen in the water and therefore must be respired by gills.

# Fish adaptations

## 4) Osmotic regulation

- Hagfishes (Myxine) are osmoconformers
- Fresh water fishes are hyperosmotic with respect to their surroundings, Therefore, water tends to enter the cells osmotically and salt is lost due to diffusion through semi permeable membranes such as the gills.

# Fish adaptations

## 5) Reproduction and growth

- Fish are dioecious, though hermaphrodites and sex reversal occur. Fertilization is either external or internal.
- All forms of reproduction : oviparity, ovoviviparity and viviparity occur.
- all types of parental care to ensure survival of young some involving migration of species to complete the life cycle..

# Fish adaptations

## 6) Feeding habits

- The evolution of jaws and the associated feeding habits that has enabled fish to exploit a large variety of feeding from **Ramming /Filtering, Grasping, suction feeding**
- **Feeding habits range from detritivory, herbivory/planktivory, omnivory to carnivory/piscivory**