# Vertebrata Taxonomy

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# About the Book

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# CHORDATA

## INTRODUCTION:

The Phylum Chordata includes the well-known vertebrates (fishes, amphibians, reptiles, birds, mammals). The vertebrates and hagfishes together comprise the taxon Craniata. The remaining chordates are the tunicates (Urochordata), lancelets (Cephalochordata), and, possibly, some odd extinct groups. With few exceptions, chordates are active animals with bilaterally symmetric bodies that are longitudinally differentiated into head, trunk and tail. The most distinctive morphological features of chordates are the notochord, nerve cord, and visceral clefts and arches.

Chordates are well represented in marine, freshwater and terrestrial habitats from the Equator to the high northern and southern latitudes. The oldest fossil chordates are of Cambrian age. The earliest is Yunnanozoon lividum from the Early Cambrian, 525 Ma (= million years ago), of China. This was just recently described and placed with the cephalochordates (Chen et al., 1995). Another possible cephalochordate is Pikaia (Nelson, 1994) from the Middle Cambrian. These fossils are highly significant because they imply the contemporary existence of the tunicates and craniates in the Early Cambrian during the so-called Cambrian Explosion of animal life. Two other extinct Cambrian taxa, the calcichordates and conodonts, are uncertainly related to other Chordata (Nelson, 1994). In the Tree of Life project, conodonts are placed as a subgroup of vertebrates.

Chordates other than craniates include entirely aquatic forms. The strictly marine Urochordata or Tunicata are commonly known as tunicates, sea squirts, and salps. There are roughly 1,600 species of urochordates; most are small solitary animals but some are colonial, organisms. Nearly all are sessile as adults but they have free-swimming, active larval forms. Urochordates are unknown as fossils. Cephalochordata are also known as amphioxus and lancelets. The group contains only about 20 species of sand-burrowing marine creatures. The Cambrian fossils Yunnanozoon and Pikaia are likely related to modern cephalochordates.

During the Ordovician Period (510 - 439 Ma) jawless or agnathan fishes appeared and diversified. These are the earliest known members of Vertebrata, the chordate subgroup that is most familiar to us. Fossils representing most major lineages of fish-like vertebrates and the earliest tetrapods (Amphibia) were in existence before the end of the Devonian Period (363 Ma). Reptile-like tetrapods originated during the Carboniferous (363 - 290 Ma), mammals differentiated before the end of the Triassic (208 Ma) and birds before the end of the Jurassic (146 Ma).

The smallest chordates (e.g. some of the tunicates and gobioid fishes) are mature at a length of about 1 cm, whereas the largest animals that have ever existed are chordates: some sourwood dinosaurs reached more than 20 m and living blue whales grow to about 30 m.

## GENERAL CHARACTERS OF PHYLUM CHORDATA:

All chordates have the following features at some point in their life (in the case of humans and many other vertebrates, these features may only be present in the embryo):

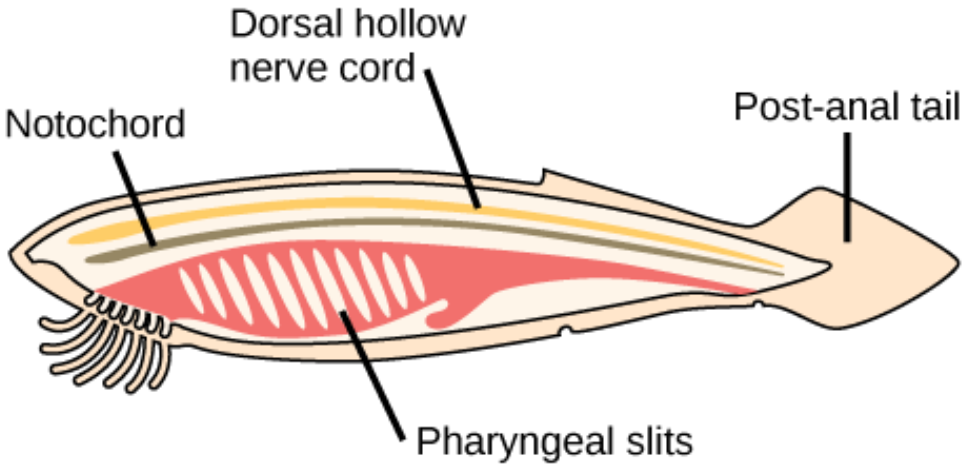
**Key Points:**

- These characteristics are only present during embryonic development in some chordates.
- The notochord provides skeletal support, gives the phylum its name, and develops into the vertebral column in vertebrates.
- The dorsal hollow nerve cord develops into the central nervous system: the brain and spine.
- Pharyngeal slits are openings in the pharynx that develop into gill arches in bony fish and into the jaw and inner ear in terrestrial animals.
- The post-anal tail is a skeletal extension of the posterior end of the body, being absent in humans and apes, although present during embryonic development.

**Key Terms:**

- **notochord**: a flexible rod like structure that forms the main support of the body in the lowest chordates; a primitive spine
- **nerve cord**: a dorsal tubular cord of nervous tissue above the notochord of a chordate
- **pharyngeal slit**: filter-feeding organs found in non-vertebrate chordates (lancelets and tunicates) and hemichordates living in aquatic environments

Animals in the phylum Chordata share four key features that appear at some stage during their development (often, only during embryogenesis) (:




In chordates, four common features appear at some point during development: a notochord, a dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail.

1. a notochord
2. a dorsal hollow nerve cord
3. pharyngeal slits
4. post-anal tail

## NOTOCHORD

The chordates are named for the notochord: a flexible, rod-shaped structure that is found in the embryonic stage of all chordates and also in the adult stage of some chordate species. It is located between the digestive tube and the nerve cord, providing skeletal support through the length of the body. In some chordates, the notochord acts as the primary axial support of the body throughout the animal's lifetime.

In vertebrates, the notochord is present during embryonic development, at which time it induces the development of the neural tube which serves as a support for the developing

embryonic body. The notochord, however, is replaced by the vertebral column (spine) in most adult vertebrates.

## DORSAL HOLLOW NERVE CORD

The dorsal hollow nerve cord derives from ectoderm that rolls into a hollow tube during development. In chordates, it is located dorsally (at the top of the animal) to the notochord. In contrast to the chordates, other animal phyla are characterized by solid nerve cords that are located either ventrally or laterally. The nerve cord found in most chordate embryos develops into the brain and spinal cord, which comprise the central nervous system.

## PHARYNGEAL SLITS

Pharyngeal slits are openings in the pharynx (the region just posterior to the mouth) that extend to the outside environment. In organisms that live in aquatic environments, pharyngeal slits allow for the exit of water that enters the mouth during feeding. Some invertebrate chordates use the pharyngeal slits to filter food out of the water that enters the mouth. In vertebrate fishes, the pharyngeal slits develop into gill arches, the bony or cartilaginous gill supports.

In most terrestrial animals, including mammals and birds, pharyngeal slits are present only during embryonic development. In these animals, the pharyngeal slits develop into the jaw and inner ear bones.

## POST-ANAL TAIL

The post-anal tail is a posterior elongation of the body, extending beyond the anus. The tail contains skeletal elements and muscles, which provide a source of locomotion in aquatic

species. In some terrestrial vertebrates, the tail also helps with balance, courting, and signaling when danger is near. In humans and other apes, the post-anal tail is present during embryonic development, but is vestigial as an adult.

## Reproduction and life cycle:

The chordate life cycle begins with fertilization (the union of sperm and egg). In its primitive form, fertilization occurs externally, in the water. Asexual reproduction takes place in tunicates and in some vertebrates (females of some fish and lizards can reproduce without fertilization). Hermaphroditism (possessing both male and female reproductive organs) is found in tunicates and some fishes, but otherwise the sexes are separate. Larvae (very young forms that differ considerably from the juveniles and adults), when they do occur, differ in structure from the larvae of nonchordates. Internal fertilization, viviparity (giving birth to young that have undergone embryological development), and parental care are common in tunicates and vertebrates.

## Ecology and habitats

Chordates are common in all major habitats. Tunicate larvae either seek out a place where they can attach and metamorphose into an adult or develop into adults that float in the open water. Cephalochordates develop in the open water, but as adults they lie partially or entirely buried in sand and gravel. In either case, they are filter feeders with simple behaviour. Vertebrates are much more complex and, in keeping with their more active manner of obtaining food, highly varied in their ecology and habits.

## Locomotion

Chordates are capable of locomotion by means of muscular movements at some stage in life. In tunicate larvae, this is accomplished using a tail; in cephalochordates, by undulations of the body; and in vertebrates, by general body movements (as in eels and snakes) and by the action of fins and limbs, which in birds and some mammals are modified into wings.

## Associations

Chordates enter into a wide variety of symbiotic relationships and are especially noteworthy as hosts for parasites. Family groups and societal relationships, in both a broad and narrow sense, are particularly well developed in vertebrates, due primarily to their elaborate nervous systems. This phenomenon is seen in schools of fish, flocks of birds, and herds of mammals, as well as in the primate associations that suggest the beginnings of human society.

## Form and Function

Chordates have many distinctive features, suggesting that there has been extensive modification from simple beginnings. The early stages of chordate development show features shared with some invertebrate phyla, especially the mouth that forms separately from the anus, as it does in the phyla Hemichordata, Echinodermata, and Chaetognatha. Likewise, as in these phyla, the coelom, or secondary body cavity around the viscera, develops as outpouchings of the gut. A coelom also is present in some more distantly related phyla, including Annelida, Arthropoda, and Mollusca, but the main organs of the body are arranged differently in these phyla. In chordates the main nerve cord is single and lies above the alimentary tract, while in other phyla it is paired and lies

below the gut. Cephalochordates and vertebrates are segmented, as are the annelids and their relatives; however, segmentation in the two groups probably evolved independently. The gill slits and some other features that are common among the hemichordates and the chordates originated before the chordates became a separate group. Hemichordates have no tail above the gut and no mucus-secreting endostyle between the gill slits.

## External features

An ancestral chordate, as suggested by the adult lancelet and the tadpole larva of tunicates, had a distinct front and hind end, an anterior mouth, a posterior tail above an anus, unpaired fins, and gill slits that opened directly to the exterior. A free-swimming tunicate larva metamorphoses into an attached, sessile adult with an atrium that surrounds the gills. The atrium of lancelets probably evolved independently.

## Skeleton and support

The chordate notochord is a stiff rod with a turgid core and fibrous sheath. It keeps the animal from shortening when locomotors waves are produced through muscular contraction. The chordate body is supported by fluid in the body cavities. In tunicates, added support is provided by the tunic. Cartilaginous material supports the gills and other body parts of tunicates and cephalochordates. Immature vertebrate skeletons generally consist largely of cartilage, which becomes increasingly bony with age. The cartilaginous skeletons of sharks and some other vertebrates are thought to have evolved from more highly mineralized ones.

## Tissues and muscles

In both cephalochordates and vertebrates, muscles used in locomotion are well developed and organized segmentally. The tail musculature of tunicates is simpler and without clear indications of segmentation. There is at least a small amount of musculature throughout the body of all chordates. As jaws, limbs, and other body parts have evolved in vertebrates, so have the muscles that operate them.

## Nervous system and sense organs

The anterior end of the main nerve cord in chordates is enlarged to form at least the suggestion of a brain, but a brain is well developed only in vertebrates. Tunicate larvae have visual organs sensitive to light and sense organs responsive to the direction of gravity. Pigment spots and light receptors in the nerve cord of lancelets detect sudden changes in light intensity. The eyes and other sense organs of vertebrates are more elaborate and complex.

The presence in cephalochordates and vertebrates of a nervous system with segmentally repeated nerves arising from the dorsal hollow nerve cord is suggestive of a common ancestry. The tunicate nervous system does not have the segmentally repeated nerves. The brains of all vertebrates are greatly enlarged and subdivided into functionally specialized regions.

## Digestion and nutrition

Both tunicates and cephalochordates are filter feeders of small particles of food suspended in the water. Beating cilia (hairlike cellular extensions) on the gill slits draw a current of water into the mouth and through the pharynx, where a sheet of mucus, secreted by the endostyle (a glandular organ lying below the two rows of gill slits), filters suspended food particles from the

water. Cilia lining the pharynx move the food-rich sheet of mucus upward over the gill slits, and it is then rolled up and transported to the posterior part of the gut. The water current passes into the atrium and exits through the atrial opening.

Something similar to this arrangement occurs in the vertebrates in the "ammocoetes" larva stage of the primitive jawless fish called the lamprey. The difference is that the food consists of somewhat larger particles that have been deposited on the bottom (detritus), and, instead of the feeding current being driven by cilia; the pharyngeal musculature pumps water and food particles across the gill slits. The earliest fishes probably fed on detritus, and a sucking action is retained by their extant representatives (lampreys and hagfishes). With the development of jaws, it became possible for the vertebrates to capture and seize larger food items.

The lower digestive tract of the primitive chordate is a simple tube with a saclike stomach. There are only indications of the specialized areas and of glandlike structures, such as the liver and pancreas that occur in vertebrates.

## Excretion

The excretion of wastes and the control of the chemical composition of the internal environment are largely effected by kidneys, although other parts of the body, including the gills, may play an important role. Tunicates and cephalochordates have a salt content essentially the same as seawater, but vertebrates, even marine species, have body fluids of low salt content, with the exception of hagfishes. A possible explanation is that the vertebrates evolved in fresh water, but it

seems reasonable that hagfishes branched off while still marine and that the freshwater form evolved later.

## Respiration

A primitive chordate gill is present in tunicates and cephalochordates, where it serves in both respiration and feeding. The vertebrate gill may retain some role in feeding, although the current is now produced by the action of muscles, not cilia. The gills became reduced in number in various lineages, and they were strengthened by supporting elements, some of which evolved into jaws. Lungs, already present in fishes, became the main respiratory organs of terrestrial vertebrates.

## Circulatory system

The circulatory system in chordates has a characteristic pattern. In tunicates and vertebrates the blood is propelled by a distinct heart; in cephalochordates, by contraction of the blood vessels. Unoxygenated blood is driven forward via a vessel called the ventral aorta. It then passes through a series of branchial arteries in the gills, where gas exchange takes place, and the oxygenated blood flows to the body, much of it returning to its origin via a dorsal aorta. The blood of vertebrates passes through the tissues via tiny vessels called capillaries. In tunicates and cephalochordates, capillaries are absent and the blood passes through spaces in the tissues instead.

## Hormones

In vertebrates, endocrine glands (those of internal secretion) produce hormones that regulate many physiological activities. In tunicates and cephalochordates, organs have been identified that correspond in anatomical position to the pituitary gland of

vertebrates, but which hormones, if any, they secrete is uncertain. In vertebrates, the thyroid gland produces thyroxine, an iodine-containing hormone that helps regulate metabolism. The thyroid is a modified endostyle, as can be illustrated by larval lampreys in which the thyroid still secretes mucus for use in feeding. The endostyles of lancelets take up iodine and form thyroxine, but the thyroxine formed may not function as a hormone in the lancelets themselves.

## Features of defense and aggression

Tunicates largely rely upon the passive defense afforded by their heavy tunic. Lancelets move rapidly through the substrate, and their well-developed locomotory apparatus evolved largely to provide a means of escaping predators. Vertebrates have ceased to feed on detritus brought to them by water currents. They have shifted to consuming larger foodstuffs and to actively locating, pursuing, and subduing what they eat.

## Evolution and Paleontology

Many scientists maintain that chordates originated sometime earlier than 590 million years ago; that is, they predate the fossil record. Such early representatives were soft-bodied and therefore left a poor fossil record. The oldest known fossil chordate is Pikaia gracilens, a primitive cephalochordate dated to approximately 505 million years ago. There is disagreement over whether older animals such as Yunnanozoon lividum and Haikouella (both of which date to 530 million years ago and possess several chordate features)—should be considered chordates. An extensive vertebrate fossil record begins about 400 million years ago.

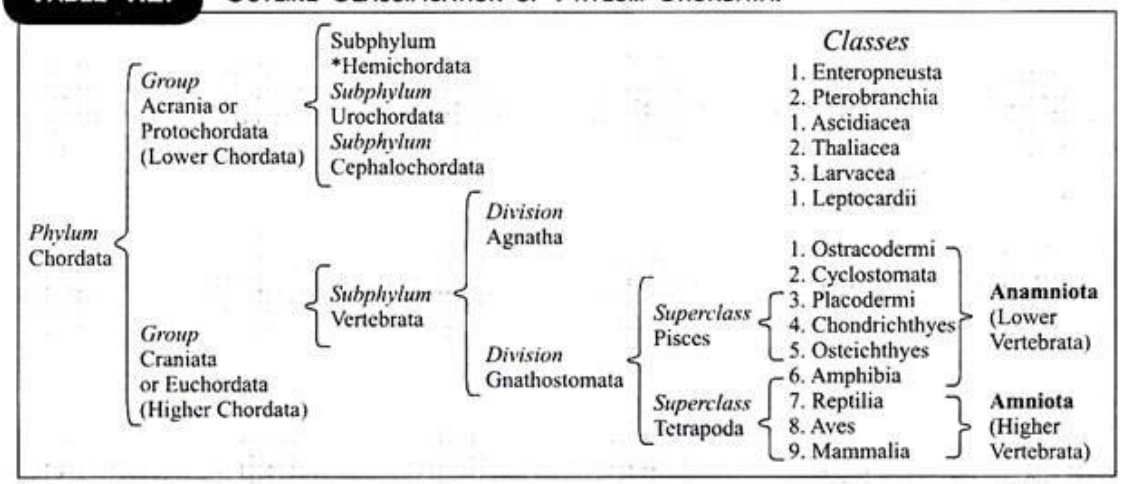
Embryological evidence places the phylum Chordata within the deuterostomes (bilaterally symmetrical animals with undeterminate cleavage and whose mouth does not arise from the blastopore), which also includes the phyla Hemichordata, Echinodermata, and Chaetognatha. The closest relatives of the chordates are probably the hemichordates, since these animals possess gill slits and other features not found in other animal phyla. A slightly more remote relationship to the echinoderms is inferred on the basis of resemblances between the larvae in some groups of hemichordates and echinoderms. The derivation of chordates from certain fossil echinoderms has been argued on the basis of features such as what appear to be gill slits. Theories that derive them from other phyla (e.g., Annelida, Nemertea, Arthropoda) have been proposed, but such theories have few contemporary advocates.

Whether the first ancestral chordate was more like a tunicate or a cephalochordate has been extensively debated. The classical theory is that the ancestor was like a cephalochordate and that one lineage became attached to hard surfaces and evolved into tunicates, whereas another remained unattached and evolved into vertebrates. An alternative theory is that the ancestor was like a tunicate and that the other two subphyla arose by modification of the tadpole larva. There is some preference for the classical theory because it provides the most satisfactory way of accounting for the similarities between chordates and hemichordates of the subphylum Enteropneusta. Within the chordates, the tunicates probably branched off before the common ancestor of cephalochordates and vertebrates arose, for

the latter resemble each other in some details of neuroanatomy and biochemistry.

## Classification of Phylum Chordata into four Sub-Phyla

**TABLE 1.2.** OUTLINE CLASSIFICATION OF PHYLUM CHORDATA.




**Subphylum Hemichordata is now considered to be an invertebrate group.*

### Subphylum I. Hemichordata:

(Gr., hemi = half; chorde = cord). Body divided into 3 regions- proboscis, collar and trunk. Notochord doubtful, short confined to proboscis and non-homologous with that of chordates.

**Class 1. Enteropneusta:**

(Gr., enteron = gut; pneustos = breathed). Body large and worm-like. Gill-slits numerous and paired. Alimentary canal straight. Acorn or tongue worms. Enteropneusts include 3 families, 15 genera and 70 species.

Examples- Balanoglossus, Saccoglossus, Ptychodera.

**Class 2. Pterobranchia:**

(Gr.,pteron = feather; branchion = gill). Body small and compact. Gill-slits one pair or none, never U-shaped.

Alimentary canal U-shaped. Pterobranchs include 2 orders, 3 genera and 20 species.

Examples- Cephalodiscus, Rhabdopleura.

**Class 3. Planctosphaeroidea:**

Transparent, round and specialised tornaria larva possessing extensively branched ciliary bands. Alimentary canal L-shaped. Planctosphaera pelagica is a representative of this class. This form is supposed to be specialised tomaria larva of some unknown hemichordate.

**Class4: Graptoli**

The fossil graptolites (e.g., Dendrograpture) were abundant in Ordovician and Siurian periods. These are often considered as an extinct colonial class of Hemichordata. Their tubular chitinous skeleton and colonial habits shown an affinity with Rhandopleura

***Subphylum2: Urochordata** (Gr., oura = a tail; L., chorda = cord).

- The adults are fixed to the substratum.
- It is also known as tunicate because the body of an adult is enclosed within a tunic made up of cellulose -like substance known as tunicin.
- Notochord can be seen only in the larval stage and disappears in the adults.
- The nerve cord present in larva is replaced by a dorsal ganglion in adults.
- The larva can move and undergoes a metamorphosis.
- **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.

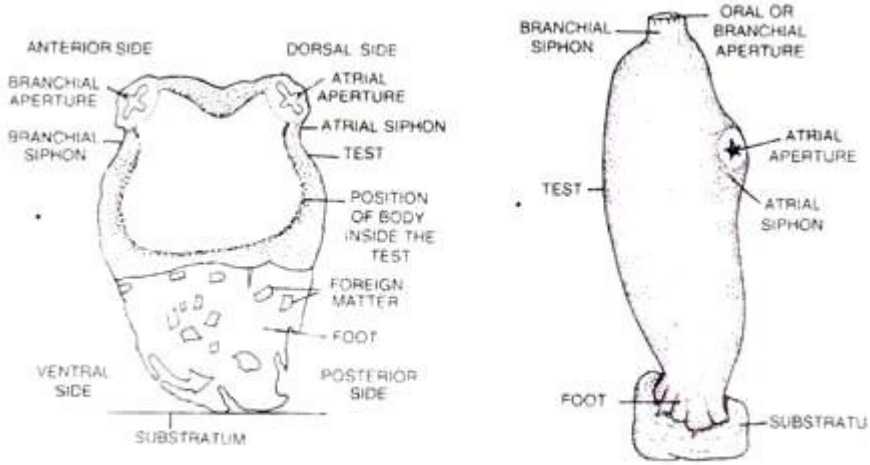



Fig. 4.42. Two Urochordates. *Left Herdmania, Right Ascidia.*

- **Class 2. Thaliacea:**
- Free-swimming or pelagic tunicates with circular muscle bands in tunic. Salpians 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.

***Subphylum3: Cephalochordata** (Gr., kephale = head; L., chorda = cord). Notocho

- The atrium is present.
- Motile adult and larval stage.

- The tail is present throughout life.
- They show progressive metamorphosis.
- The notochord is found throughout life.
- Numerous well-developed pharyngeal gill slits are present.

For e.g., Lancelets possess the notochord and nerve cord throughout their life. However, they lack the brain and bony vertebral column like Branchiostoma.

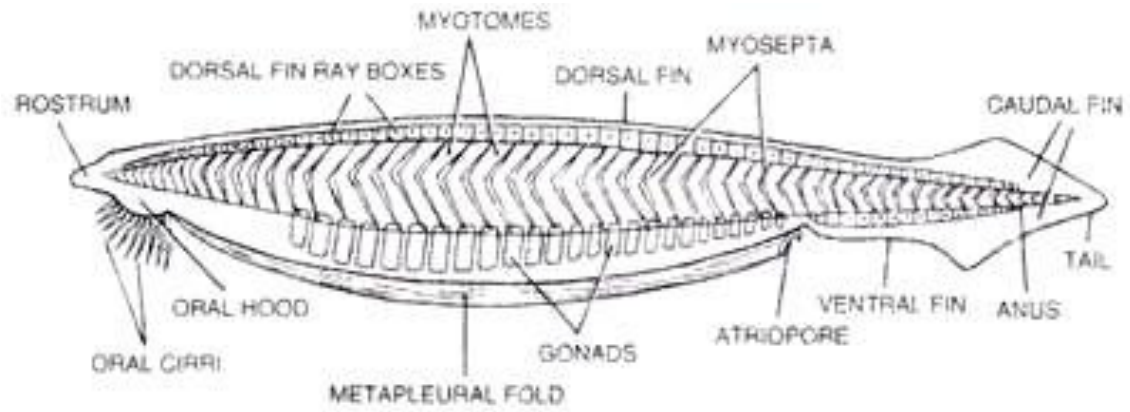



Fig. 4.43. *Amphioxus*.

## Subphylum4: Vertebrata

(1) These are advanced chordates that have cranium (brain box) around brain.

(2) Notochord is only present in the embryonic stage; it is replaced by a cartilaginous or bony vertebral column in the adult forms.

(3) There is very high degree of cephalization (formation of head).

(4) The epidermis consists of many layers of cells. Epidermis may bear an exoskeleton of scales, feathers or hair.

(5) Three types of muscles, striped, un-striped and cardiac, are present.

(6) Coelom is well developed.

(7) Digestive tract is complete.

(8) The endoskeleton is formed of cartilage or of cartilage and bone.

(9) Heart is ventrally situated with two, three or four chambers. There is present hepatic portal system.

(10) There is closed circulatory system consisting of blood vascular and lymphatic systems. RBCs are present.

(11) Respiratory organs may be gills, skin, buccopharyngeal cavity and lungs.

(12) A pair of kidneys is present for excretion and osmoregulation.

(13) Nervous system consists of central nervous system (brain and spinal cord), peripheral nervous system (cranial and spinal nerves) and autonomic nervous system (sympathetic and para-sympathetic nervous systems).

(14) Sense organs are eyes, ears, tongue, nasal chambers, and skin. In some vertebrates lateral line system is present.

(15) Cranial nerves are 8, 10 or 12 pairs.

(16) Endocrine glands are found in all vertebrates.

(17) Sexes are separating (unisexual) except hag fish, which is bisexual. There is no asexual reproduction.

**The Subphylum Vertebrata is divided into two divisions:**

**1. Agnatha**

| Division I. Agnatha | Division II. Gnathostomata |
|---|---|
| 1. True jaws absent. | 1. True jaws present. |
| 2. Paired appendages absent. | 2. Paired appendages (pectoral and pelvic) present. |
| 3. Internal ear with 2 semicircular canals. | 3. Internal ear with 3 semicircular canals. |
| 4. Notochord persistent in adults. | 4. Notochord persists or replaced by vertebrae. |

**2. Gnathostomata**

**Division I. Agnatha (The lawless Vertebrates):**

(Gr., a = not; gnathos = jaw). Jawless fish-like vertebrates without true jaws and paired limbs.

The mouth does not possess jaws hence named Agnatha. Notochord persists throughout life. Vertebral column is represented only by small imperfect neural arches over the notochord. They do not have paired appendages. They have single nostril. Internal ear has one or two semi-circular canals. They are cold blooded. Agnatha has two classes: Ostracodermi and Cyclostomata.

**Class 1. Ostracodermi):**

(Gr., ostrakon = shell; derma = skin).

They are earliest known vertebrates which appeared in Ordovician period. They had well developed dermal scales which led to their names "Ostracoderms"— bony skin. They are also called "armoured fishes". All are extinct.

Examples: Cephalaspis, Pteraspis, Birkenia, Thelodus.

**Class 2. Cyclostomata:**

(Gr., cyclos = circular; stoma = mouth). Body eel-like, long, cylindrical, skin smooth; without scales, jaws and lateral fins. Mouth rounded and suctorial. Gills 5 to 16 pairs. Heart 2-chambered. Parasites and scavangers. About 50 species.

Examples- Lampreys (Petromyzon) and hagfishes (Myxine).

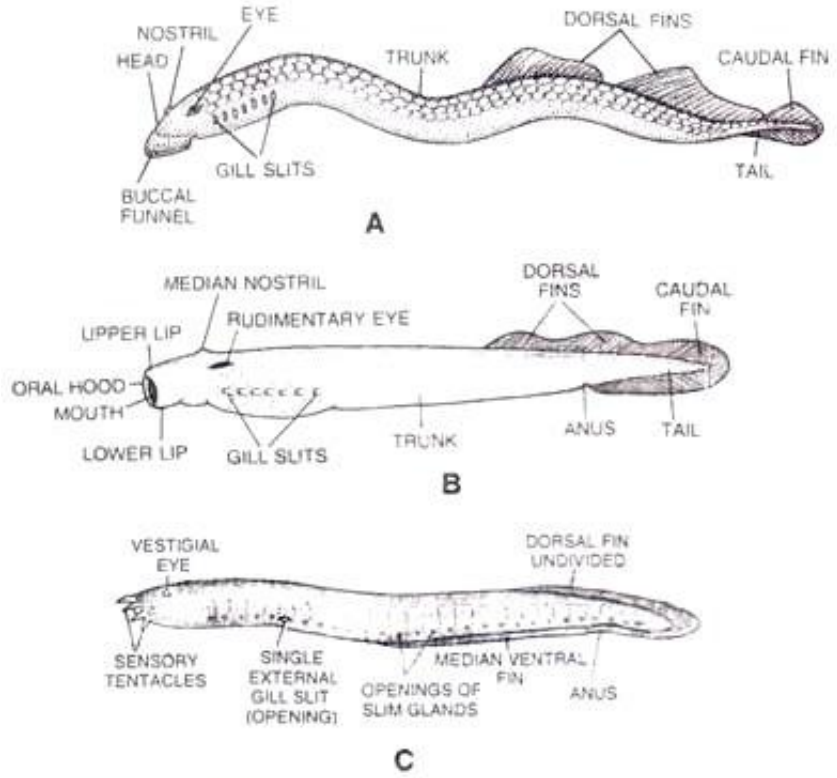



Fig. 4.44. *A, Petromyzon.* B. Ammocoete (Larva). C. *Myxine.*

**Division II. Gnathostomata:**

(Gr., gnathos = jaw; stoma = mouth). Jawed vertebrates having true jaws and paired limbs.

**Class 2. Cyclostomata (The Circular mouthed fishes):**

Gr. cyklos-circularal; stome-mouth).

(1) They occur in the seas and large rivers.

(2) The mouth is circular and jawless. They are also called jawless fishes (not true fishes).

(3) They have 1-16 pairs of gill slits.

(4) Head and brain are poorly developed.

(5) Unpaired fins are present.

(6) Endoskeleton is cartilaginous.

(7) Kidneys are mesonephric.

(8) Stomach is absent.

(9) Respiratory organs are gills.

(10) Heart is two chambered (one auricle and one ventricle).

(11) There are 10 or 8 pairs of cranial nerves.

(12) Lateral line sense organs are present.

(13) Fertilization is external. Life history may include a larva named ammocoete.

**Example:**

petromyzon (lampr), myxine (hagfish)

**Gnathostomata has been further divided into two superclasses:**

**1. Pisces**

**2. Tetrapoda.**

| Superclass 1. Pisces | Superclass 2. Tetrapoda |
|---|---|
| 1. Exclusively aquatic gnathostome vertebrates. | 1. Aquatic or terrestrial. Some arboreal and aerial. |
| 2. Paired limbs, if present, as fins. | 2. Paired pentadactyle limbs present. |
| 3. Median fins present. | 3. Median fins absent. |
| 4. Skin usually moist and scaly. | 4. Skin usually dry not cornified (without scales). |
| 5. Respiration aquatic, by gills. | 5. Respiration aerial, by lungs. |
| 6. Sense organs functional in water. | 6. Sense organs function in air. |

All the fishes and fish-like aquatic gnathostomes in the superclass Pisces, whereas all the four-footed terrestrial gnathostomes in the superclass Tetrapoda.

**Superclass 1. Pisces:**

(L., piscis = fish). Fishes or fish-like aquatic forms with paired as well as median fins, gills and scaly skin. It includes true fishes and divided into three classes:

**Class 1. Placodermi:**

Several extinct orders of primitive earliest jawed fishes of Palaeozoic with bony head shield. Placoderms. A full-sized functional gill-arch precedes hyoid arch.

Examples – Climatius, Dinichthys.

**Class 2. Chondrichthyes:**

(Gr., chondros = cartilage; ichthys = fish). Mostly marine. Cartilaginous endoskeleton. Skin with minute placoid scales. Gill-slits not covered with operculum. Mouth and 2 nostrils ventral. Males with claspers. Cartilaginous fishes. Approximately 600 species.

Examples-: Scoliodon (dogfish), Chimaera (ratfish).

**Class 3. Osteichthyes:**

(Gr., osteon = bone; ichthys = fish). Freshwater and marine. Bony endoskeleton. Skin having various types of scales (cycloid, ctenoid) other than placoid. Gill-slits covered with operculum. Males without claspers. Bony fishes. Approximately 20,000 species.

Examples – Labeo (rohu), Protopterus (lungfish), Hippocampus (sea horse).

**Superclass 2. Tetrapoda:**

(Gr., tetra = four; podos = foot). Land vertebrates with two pairs of pentadactyle limbs, comified skin with lungs. It is divided into 4 classes:

**Class 1. Amphibia:**

(Gr., amphi = both; bios = life). Larval stage usually aquatic and breathes by gills. Adults typically terrestrial and respires by lungs. Living forms with moist glandular skin, no external scales. Typically 2 pairs of limbs, nostrils connecting mouth cavity. Heart 3-chambered. Amphibians. Approximately 2,500 species. Examples- Rana (frog), Bufo (toad), Ambystoma (salamander).

**Class 2. Reptilia:**

(L., reptilis = covering). Terrestrial and aquatic tetrapods. Skin dry covered by ectodermal horny scales or scutes. Limbs typically 4, each with 5 clawed toes. Skeleton bony. Heart incompletely 4-chambered. Cold blooded. Respiration by lungs. Approximately 7,000 species.

Examples- Hemidactylus (wall lizard), Uromastix (spiny-tailed lizard), Naja (cobra), Sphenodon (tuatara), Crocodilus (crocodile).

**Class 3. Aves:**

(L., avis = bird). Body covered with feathers. Forelimbs modified as wings usually adapted for flight. Hindlimbs for walking, perching or swimming. No teeth in beak. Heart 4-chambered. Lungs compact, with air-sacs. Warm blooded. Birds. About 9,000 species.

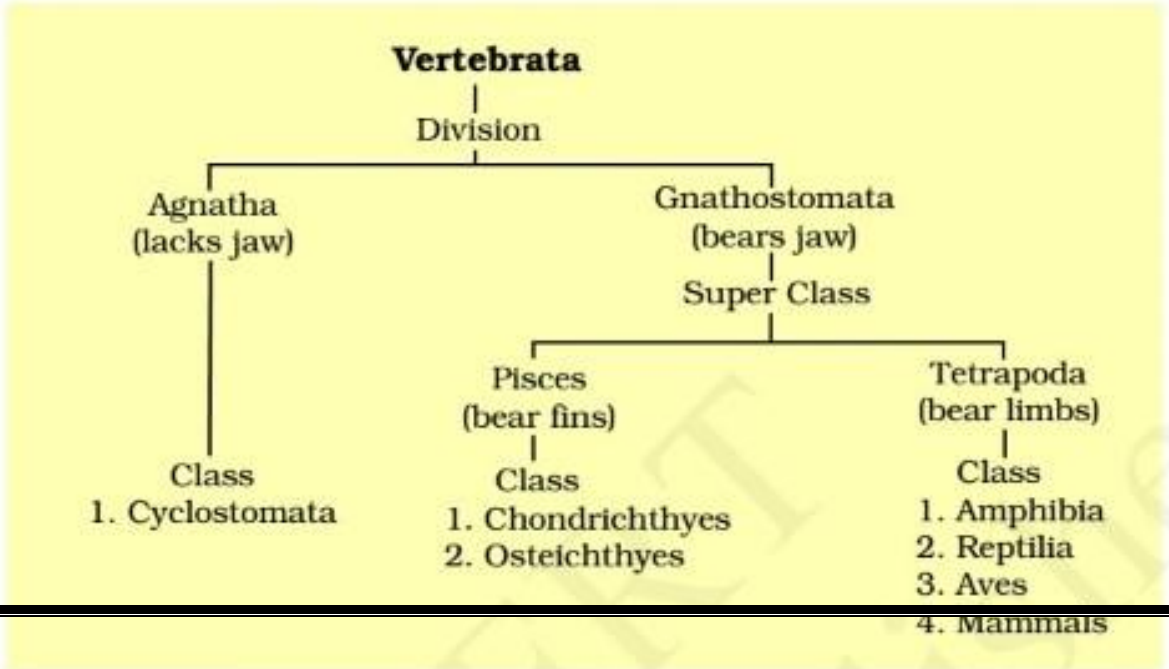
Examples- Struthio (African ostrich), Columba (pigeon), Gallus (fowl).

**Class 4. Mammalia:**

(L., mamma = breast). Body usually covered with hair. Skin with various glands. Female with mammary glands which secrete milk for suckling the young. Heart 4-chambered. Warm blooded, air breathing vertebrates. Mammals. Approximately 4,500 species.

Examples- Echidna (spiny anteater), Macropus (kangaroo),

The subphylum Vertebrata is further divided as follows:



Rattus (rat). Homo (man).

**Class. Cyclostomata**

**Orde: *Petromyzontiformes***

- Members of this order are called lampreys.
- Lampreys are both marine and freshwater forms.
- fluviatilis is the common freshwater lamprey. They are usually used for laboratory studies because of their large size.
- Phylum: Chordata
- SubPhylum: Vertebrata
- Superclass: Agnatha
- Class: Cyclostomata
- order: Petromyzontiformes
- Family: petromyzonidae
- e.g.: *Petromyzon fluviatilis*

*** Parasitic

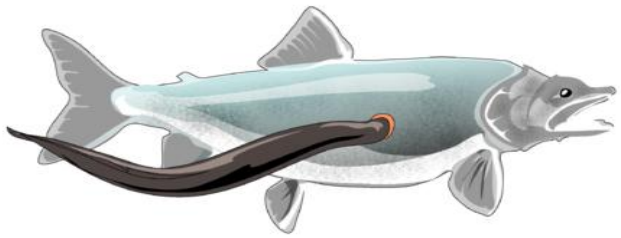
*** Rounded mouth, sucker-like with papillae and horny teeth

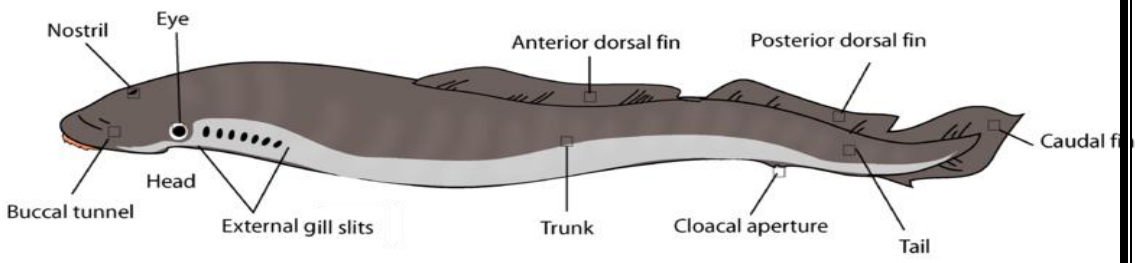
**External features of lambry**

✓ Shape and size. The adult lamprey has an elongated eel-like body made of three regions: head, trunk, tail, which are not clearly demarcated.

✓ Head and trunk are cylindrical. Tail is laterally compressed.

- ✓ It is without exoskeleton
- ✓ Attains a length of 90 cm.
- ✓ Eyes. Large eye on each lateral side of the head, lack eyelids
- ✓ Mouth is a narrow aperture lying at the apex of the buccal funnel.
- ✓ Nostril is a single small mid-dorsal between the eyes.
- ✓ Gill slits are seven small rounded opening in a row on each lateral side of the head, just behind each eye.
- ✓ Fins: two unequal dorsal fins are located near the posterior end. Caudal fin around the tail, the upper lobe of which is continuous with the second dorsal fin. The fins are supported by cartilaginous fin rays.
- ✓ The cloaca is a slit-like depression on the ventral side, at the junction of trunk and tail.
- ✓ Lateral line is numerous small sensory pores extend along each lateral side of the body and below the head.





## ECONOMIC IMPORTANCE

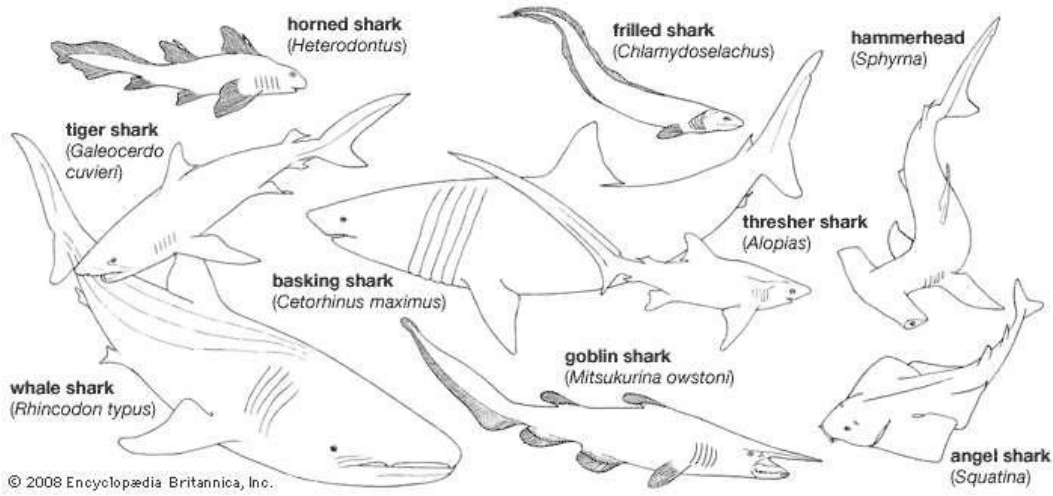
1. Lampreys have posed a great economic problem to the fisheries. They destroy valuable fish by feeding on their blood and body fluids.

2. Fertilization is external; the female lays up to 200,000 eggs. The eggs hatch in about 3 weeks into minute transparent larva called ammocoetes.

# CLASS CHONDRICHYTHES

Chondrichthyan**,** (class Chondrichthyes), also called **chondrichthian**, any member of the diverse group of cartilaginous fishes that includes the sharks, skates, rays, and chimaeras. The class is one of the two great groups of living fishes, the other being the osteichthians, or bony fishes. The name Selachii is also sometimes used for the group containing the sharks.

The name Selachii refers to a category of fishlike vertebrates characterized by a skeleton primarily composed of cartilage. Selachii are given a variety of treatments by ichthyologists. Some authorities consider Selachii to be a class or subclass that contains all the modern sharks and rays; other authorities restrict the use of the name to an order of modern sharks and certain extinct ancestral forms. Under the latter system, the rays (including the sawfishes, guitarfishes, electric rays, mantas, skates, and stingrays) are ranked separately.




The chimaeras (Holocephali) bear many similarities to sharks and rays in skeletal structure, internal organs, and physiology. Ichthyologists commonly although not unanimously emphasize these similarities by grouping the modern and ancient sharks, rays, and chimaeras in the class Chondrichthyes, the cartilaginous fishes. Under this system, which is used in the present article, the sharks, skates, and rays are further grouped into one subclass, Elasmobranchii, and the chimaeras into another, Holocephali. Some authorities classify the elasmobranchs into one class (Selachii) and classify the chimaeras into another (Holocephali); however, assigning the two groups class rank implies a degree of distinctness equal to that of the amphibians (Amphibia), reptiles (Reptilia), birds (Aves), and mammals (Mammalia).

## GENERAL CHARACTERISTICS OF CHONDRICHTHYES

Their digestive systems have spiral valves and, with the exception of Holocephali, a cloaca.

As they do not have bone marrow, red blood cells are produced in the spleen and special tissue around the gonads. They are also produced in an organ called Leydig's Organ which is only found in cartilaginous fishes (although some have lost it). Another unique organ is the epigone organ which probably has a role in the immune system. The subclass Holocephali, which is a very specialized group, lacks both of these organs. Originally the pectoral and pelvic girdles, which do not contain any dermal elements, did not connect. In later forms, each pair of fins became ventrally connected in the middle when scapulocoracoid and pubioischiadic bars evolved. In rays, the pectoral fins have connected to the head and are very flexible.

A spiracle is found behind each eye on most species.

Their tough skin is covered with dermal teeth also called placoid scales or dermal denticles which feel like sandpaper (again, the Holocephali is an exception as the teeth are lost in adults, only kept on the clasping organ seen on the front of the male's head). In most species, all dermal denticles are oriented in one direction, making the skin feel very smooth if rubbed in one direction and very rough if rubbed in the other. It is assumed that their oral teeth evolved from dermal denticles which migrated into the mouth. But it could be the other way around as the teleost bony fish *Denticeps clupeoides* has most of its head covered by dermal teeth (as do *Atherion elymus*, another bony fish). This is most probably a secondary evolved characteristic which means there is not necessarily a connection between the teeth and the original dermal scales. The old placoderms did not have teeth at all but had sharp bony plates in their mouth. Thus, it is unknown which of the dermal or oral teeth evolved first. It has even been suggested that the original bony plates of all the

vertebrates are gone and that the present scales are just modified teeth, even if both teeth and the body armor have a common origin from long ago. But for the moment there is no evidence of this.

## Distribution and abundance

The majority of sharks and rays are marine fishes, but many enter estuaries; some travel far up rivers, and a few are permanent residents of fresh water. Most species live in the relatively shallow waters of continental margins or around offshore islands; a few roam far out in the vast spaces of the oceans. Some live at great depths, in midwaters or on the bottom; others are surface swimmers or inhabit the bottom in shallow waters.

Once regarded as "trash" fish, sharks and rays are increasingly represented in the fisheries of most countries. With numbers of more highly valued bony fishes decreasingly rapidly, many fisheries are specifically targeting elasmobranchs as a primary commercial resource. Annual yields are as much as 750,000 metric tons (roughly 827,000 short tons), and most of this is sold fresh, dried, salted, or processed. This intense harvest is causing the reduction of many shark and ray populations and, in some cases, causing the commercial extinction of some species. One consequence of this depletion of these top-level predators may be a disruption of the food chain in marine ecosystems.

## ECONOMIC USES OF ELASMOBRANCHS

The meat of sharks is marketed for food in all maritime countries. It may be prepared in various ways—fresh, salted, smoked, or pickled—offered in such forms as steaks, fillets, or flakes and under such misleading names as whitefish, grayfish,

swordfish, sea bass, and halibut. The flesh is often rather strong tasting; however, this quality is one that can be removed by cleaning and washing and soaking the flesh in brine.

Since ancient times, Chinese people have used the fins of certain sharks and rays as the basis of an epicurean soup

Shark liver oil is used in various regions for tanning leather; for preserving wood; as a lubricant; as a folk medicine against rheumatism, burns, and coughs; as a general tonic; as a laxative; and as an ingredient of cosmetics

The hard scales provide an abrasive surface to the skin of sharks and some rays, giving it a special value, as leather called shagreen, for polishing hard wood. When heated and polished, shagreen is used for decorating ornaments and, in Japan, for covering sword hilts.

Shark leather is made in several countries, including the United States, from the skin of certain shark species after removal of the scales by a chemical process. A luxury product, much more durable than cowhide, shark leather is used for footwear, belts, wallets, and other accessories.

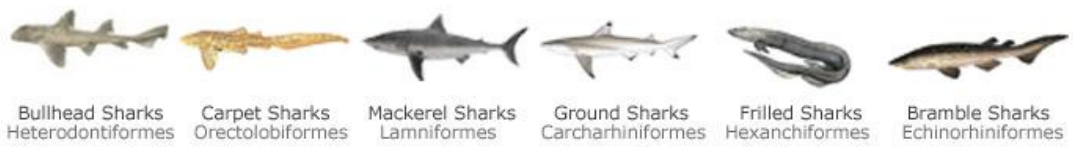
In Greenland, some Inuit make rope from strips of the skin of the sleeper shark (*Somniosus microcephalus*). Polynesians once added to the effectiveness of their war clubs with sharks' teeth. Sharks' teeth have some commercial value as curios. Traditionally the Maori of New Zealand prized the teeth of the mako shark (*Isurus*), which they wore as earrings.

About 126,000 short tons (roughly 114,000,000 kilograms) of rays are marketed for food in various countries about the world, principally in Europe and Asia. By-products in local demand are skins of scaleless species for drumheads; those of scaly species

are used for shagreen. Livers are used for oil, fins for gelatin. People of many tropical regions—Polynesia, Oceania, Malaysia, Central America, and Africa—have used the spines of stingrays for such items as needles and awls, spear tips and daggers, and for the poison they contain. The entire tail of stingrays, complete with spines, has been used as a whip in various tropical areas.

The electric rays, or numb fish, have little commercial value. The ancient Greeks and Romans used the electric shock of *Torpedo* to relieve diseases of the spleen, chronic headaches, and gout. From the Greek word for electric ray, *narke*, comes the word *narcotic*. Today these fishes are worrisome to bathers who step on them and to fishers who may be shocked when hauling in their wet nets.

Among the more than 400 known shark species, about 30 have been authoritatively implicated in unprovoked attacks on persons or boats; of these only about 15 species are considered dangerous, however. Hospital and other records attest to many attacks on bathers, divers, and people awash in the sea following sea or air disasters




## TAXONOMY OF CLASS: CHONDRICHTHYES

| Subclass: Elasmobranchae (Selachii) | |
|---|---|
| • Order: Pleurotremata | • Order: Hypotremata |
| Includes sharks and dogfishes. | Includes rays, skates, and saw fishes. |
| Body is spindle shaped. | Body is dorsoventrally flattened. |
| Gill slits are lateral (5-7 pairs). | Gill slits are ventrally (5 pairs). |
| Spiracles, when present, are small behind eyes. | Spiracle is present, large on the dorsal side. |
| Pectoral fins of moderate size with narrow bases. | Pectoral fins are of enormous size and fused with the sides of head and trunk. |
| Teeth are sharp and conical. | Teeth are blunt. |
| Tail is well developed, used in swimming. | Tail is slender and sharply marked from the trunk. |
| Inhibit open waters. | They are bottom dwellers. |
| Examples: Heptranchias (Seven gilled shark). Scyliorhinus (European spotted dogfish) | Examples:Rhinobatus(Guitar fish or Beaked Ray), Raja(Raia), Torpedo (Electric Ray), Myliobatis( Eagle Ray),Trygon(Sting Ray) |

**Order: Pleurotremata**

**Family 1: Scyliorhinidae**

**e. g.: *Scyliorhinus canicula*** **(The spotted dogfish)**

*Scyliorhinus canicula*

- ✓ The body is slender-shaped with a blunt head.
- ✓ Body colour is grey with brown spots.
- ✓ The head with short blunt snout
- ✓ Large crescentric ventrally mouth
- ✓ A pair of rounded nostrils connected to the mouth.
- ✓ Lateral oval eyes without nictitating membrane.
- ✓ Spiracles behind eyes
- ✓ Pairs of lateral gill slits.
- ✓ The trunk is short
- ✓ A pair of pectoral fins, a pair of smaller pelvic fins and the anal fin is present.
- ✓ Tail is heterocercal, bear two dorsal fins
- ✓ Lateral line is in the form of a groove
- ✓ Lives in shallow waters near the bottom.
- ✓ Feeds on Crustacea, worms and molluscs.
- ✓ It is oviparous, lays eggs in rectangular chitinous capsules having curling tendrils to twine round weeds for fixation.
- ✓ Family 2: Squatinidae

e.g.: Squatina sp. (Angel shark)

- ✓ This species with a flattened body and large, wing-like pectoral fins whose anterior lobes are not fused to the head.
- ✓ The color is gray to reddish or greenish brown above, with many small black and white spots, and white below.

✓ The head and body are very broad and stocky, with small eyes positioned dorsally and followed by a pair of larger spiracles.

✓ There is a pair of barbells in front of the nares. Folds of skin with single triangular lobe are present on the sides of the head.

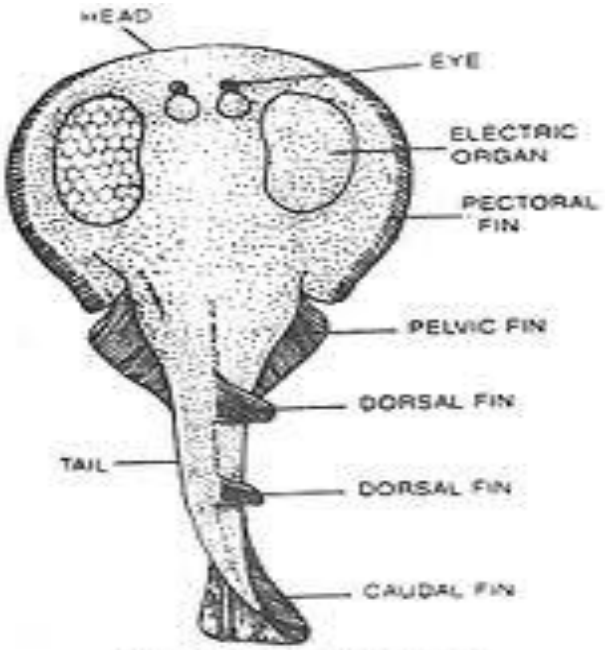
✓ The pectoral and pelvic fins are wide with rounded tips; the two dorsal fins are positioned on the muscular tail behind the pelvic fins. The anal fin is absent, and the caudal fin has a larger lower lobe than upper.

✓ It is a benthic shark feeds on bony fishes and generally unaggressive.

**Order: Hypotremata**

**Family 1: Torpedinidae**

**e.g.: Torpedo sp. (The electric ray)**




*Electric ray–Torpedo*

✓ Body is subcircular disc-like.

✓ Skin is smooth.

- ✓ Head with blunt rounded snout
- ✓ Ventral mouth connected to small nares.
- ✓ 5 pairs of gill slits.
- ✓ Large spiracles close behind eyes.
- ✓ Trunk:
- ✓ Pectoral fins extending along the head and trunk.
- ✓ Pelvic fins lie close behind pectoral fins and bear claspers in male.
- ✓ Tail is short and thick, bears two small dorsal fins and small caudal fin.
- ✓ Possesses a pair of large electric organs between eyes and pectoral fins generate electric current to stun the prey and defend.
- ✓ It is a benthic fish feeds on bony fishes and crustacea.

# CLASS OSTEICHYTHES

**Bony fish**, any member of the superclass Osteichthyes, a group made up of the classes Sarcopterygii (lobe-finned fishes) and Actinopterygii (ray-finned fishes) in the subphylum Vertebrata, including the great majority of living fishes and virtually all the world's sport and commercial fishes.

The scientific term Pisces has also been used to identify this group of fishes. Osteichthyes excludes the jawless fishes of the class Agnatha (hagfishes and lampreys) and the cartilaginous fishes constituting the class Chondrichthyes (sharks, skates, and rays) but includes the 20,000 species and more than 400 families of modern bony fishes (infraclass Teleostei) of the world, as well as a few primitive forms.

The primary characteristic of bony fishes is a skeleton at least partly composed of true bone (as opposed to cartilage). Other features include, in most forms, the presence of a swim bladder (an air-filled sac to give buoyancy), gill covers over the gill chamber, bony platelike scales, a skull with sutures, and external fertilization of eggs.

Bony fishes occur in all freshwater and ocean environments, including caves, deep-sea habitats, and thermal springs and vents. The variety of shapes and behavioral habits is remarkable. Their body sizes range from tiny species such as the pygmy goby (*Pandaka pygmaea;* 12 mm [0.5 inch]) to the enormous marlins and swordfishes (family Istiophoridae) with lengths up to 4.5 m (15 feet) and the ocean sunfish (*Mola mola*), which may weigh over 900 kg (1 ton).

## General characters:

- Appeared ~420 million years ago
- The largest class of vertebrates with ~28,000 species (96% of all fishes)
- Stronger and more rigid than cartilage.
- Made of collagen and calcium.
- The operculum (bony plate that protects the gills). Typically, gill slits cannot be seen.
- Have a jaw and skeleton of bone with operculum
- Paired fins
- Homocercal tail (symmetrical)
- Swim bladder

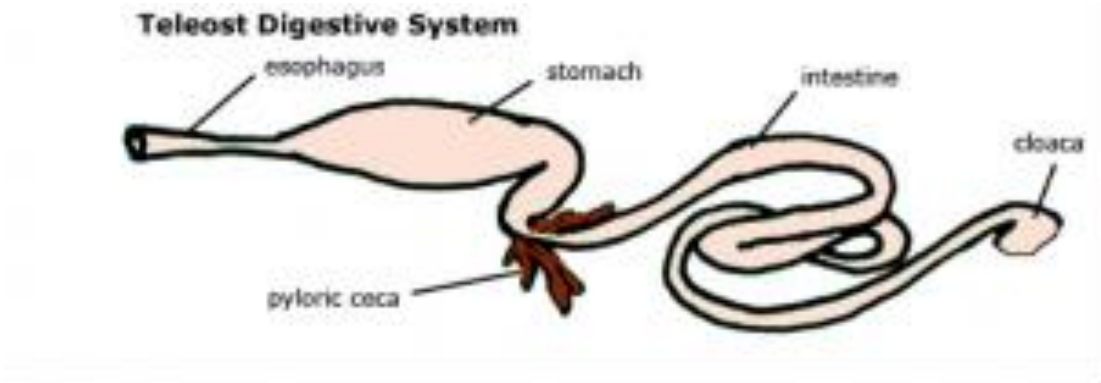
Mucus glands embedded in dermal scales

- Formed from the deeper skin layer
- Large air sac within the fish
- Acts as a buoyancy organ – it helps the fish maintain buoyancy in the water (so it doesn't sink to the bottom)

- Increases in size when the fish wants to go up and decreases in size when the fish wants to go down.
- Neutrally buoyant fishes can hover in the water and swim with much less energy. However, there is only one depth at which a fish has neutral buoyancy, so it is important for the fish to be able to regulate the amount of gas in the swim bladder to maintain neutral buoyancy at different depths." (Liem 1998:17)
- This allows for easier neutral buoyance – more energy efficient (bony fish don't need to swim to stay in the water column).

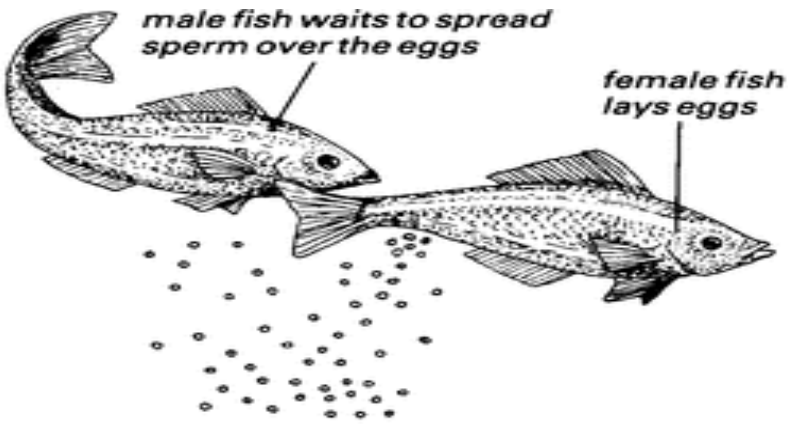
## DIGESTIVE SYSTEM

- Similar to chondrichthyes, however no enlarged liver.
- Have a U-shaped stomach
- Have **pyloric ceca** which increases gut area and aids in digestion by secreting digestive enzymes.
- No true cloaca (Separate opening for digestive system)




## REPRODUCTION

- External and internal fertilization (depends on species)
- Ovoparous (egg laying), Viviparous (live bearing), ovoviviparous (Aplacental yolk sac viviparous) all seen in bony fish.
- Some are **hermaphrodites** (both male and female reproductive organs at same time, or can change)




**FUN FACT:**

Seahorses (Family Syngnathidae) are ovoviviparous (nutrients from yolk sac inside a parent) but it is the male seahorse that holds the eggs.

- The female seahorse deposits eggs into a pouch on the male.
- The male releases sperm into the pouch, fertilizing the eggs.
- After the embryos have developed, the male gives birth to tiny seahorses.

**Subclasses of Osteichthyes**

**Subclass Actinopterygii**

- Ray-finned fishes
- Fins are webs of skin supported by bony spines or "rays"

- 99% of all bony fish species
- Salmon, eels, angler fish, seahorses, cod, halibut

**Infraclass: Teleostei**

- Skeleton is fully ossified.
- Paired fins have a narrow base attachment.
- Scales are cycloid or ctenoid.
- Mouth is small.
- Spiracle is absent.
- Caudal fin is homocercal.

Order: Anguillifome
Order: Siluriformes
Order: Osteoglossiformes
Order: Scorpaeniformes
Order: Perciformes
Order: Pleuronectiformes

**Order: Siluriformes**

(Head bears long sensory barbels, scales are usually absent).

**Family: Malapteruridae**

e.g.: *Malapterurus electricus* (The electric catfish) * Freshwater fish


✓ *Malapterurus species* have an elongate and cylindrical body.

✓ Species in *Malapterurus* are generally grayish-brown on the back and sides. There are irregular black spots or blotches randomly distributed on the sides of the body.

✓ The eyes are small, the lips are rather thick, and the snout is rounded with widely separated nostrils. The gill openings are narrow and restricted to the sides. There are three pairs of barbells, and small adipose dorsal fin. The pectoral, pelvic, and caudal fins are rounded.

✓ Lives in shallow waters with muddy and sandy bottom.

✓ Feeds on worms, plants and animal debris.

✓ The electric organ is derived from anterior body muscles. A fish that is 50 cm in length can discharge up to 350 V.

✓ The electrical discharge of *M. electricus* is not known to be fatal to humans. *M. electricus* is eaten as food in certain parts of Africa.

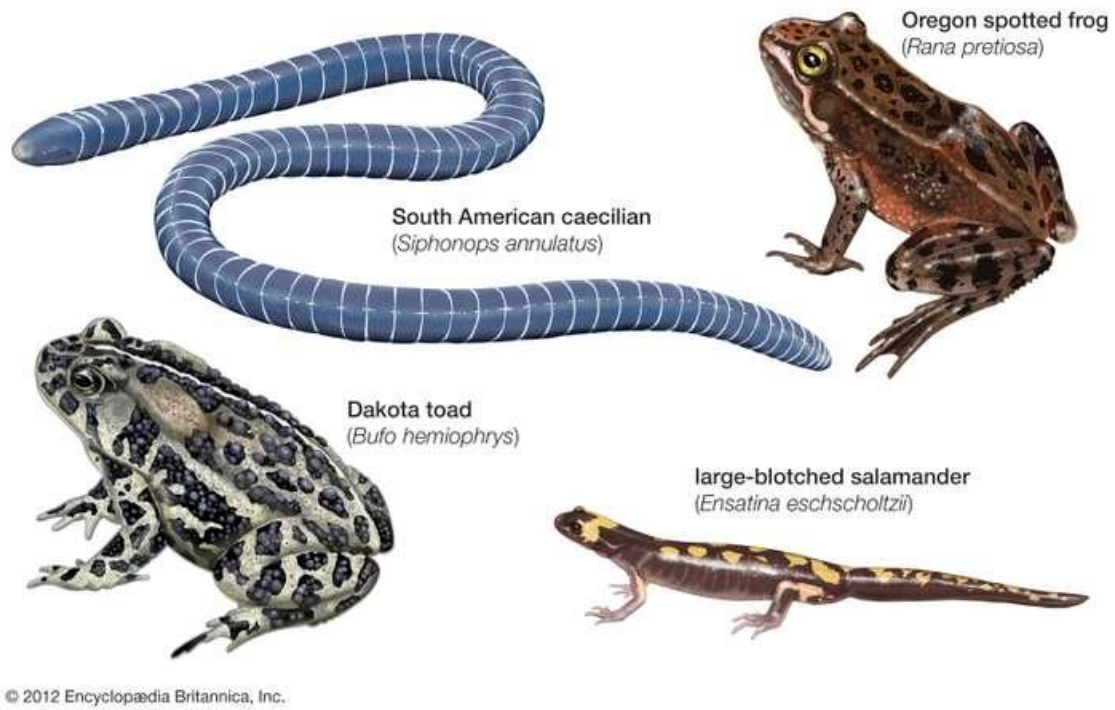
## Subclass Sarcopterygii

- Lobe-finned fishes
- Fins are fleshy and joined to the body by a bone (able to support weight)

- Limbed animals are thought to have evolved from lobe-finned fishes
- Only 7 species are living today
- Coelacanth -> thought extinct, rediscovered in 1938
- Lungfish -> Have lungs and gills

# CLASS AMPHIBIA

**Amphibian** (class Amphibia), any member of the group of vertebrate animals characterized by their ability to exploit both aquatic and terrestrial habitats. The name amphibian, derived from the Greek amphibios meaning "living a double life," reflects this dual life strategy—though some species are permanent land dwellers, while other species have a completely aquatic mode of existence. These are multicellular vertebrates that live both on land and water. This class includes about 3000 species. They are the first cold-blooded animals to have appeared on land.




## Characteristics of Class Amphibia

The characteristics of the organisms present in class amphibia are as follows:

1. These can live both on land and in water.
2. They are ectothermic animals, found in a warm environment.
3. Their body is divided into head and trunk. The tail may or may not be present.
4. The skin is smooth and rough without any scales, but with glands that make it moist.
5. They have no paired fins. Unpaired fins might be present.
6. They have two pairs of limbs for locomotion.
7. They respire through the lungs and skin. Gills might be present externally in some adults.
8. The heart is three chambered.

9. The kidneys are mesonephric. The excretory material includes ammonia and urea.
10. They possess ten pairs of cranial nerves.
11. The lateral line is present during their development.
12. The sexes are separate and fertilization is usually external. However, in salamanders, the fertilization is internal.
13. Development is indirect with metamorphosis.
14. Breeding occurs in water. The copulatory organs are absent in males.
15. E.g. Frogs, Salamanders.

**Generalized amphibian integument**

- earliest amphibians probably covered with scales - still apparent in some caecilians
- epidermal layers highly glandular although glands actually located in dermis
- mucus secretions for reduction of water loss
- venom glands - poisonous or toxic substances
- hedonic glands - male head or chin - pheromonally stimulates female to clasp and reproduce
- cornified layers shed in pieces
- males usually lacking claws, some with cornified extensions similar in appearance
- colors variable, produced by lipophores (lipid-soluble, yellow-red), melanophores (melanin, tawny-black), guanophores (guanine crystals, clear-white), ameboid (change shape and location to produce color variation)

**The circulatory and respiratory systems** work with the integument to provide cutaneous respiration. A broad network of cutaneous capillaries facilitates gas exchange and the diffusion of water and ions between the animal and the environment. Several species of salamanders and at least one species of frog (*Barbourula*

*kalimantanensis*) are lungless. Amphibians also employ various combinations of branchial and pulmonary strategies to breathe. The buccal pump mechanism, which involves the pushing of air between the lungs and the closed mouth, is present in amphibians and some groups of fishes.

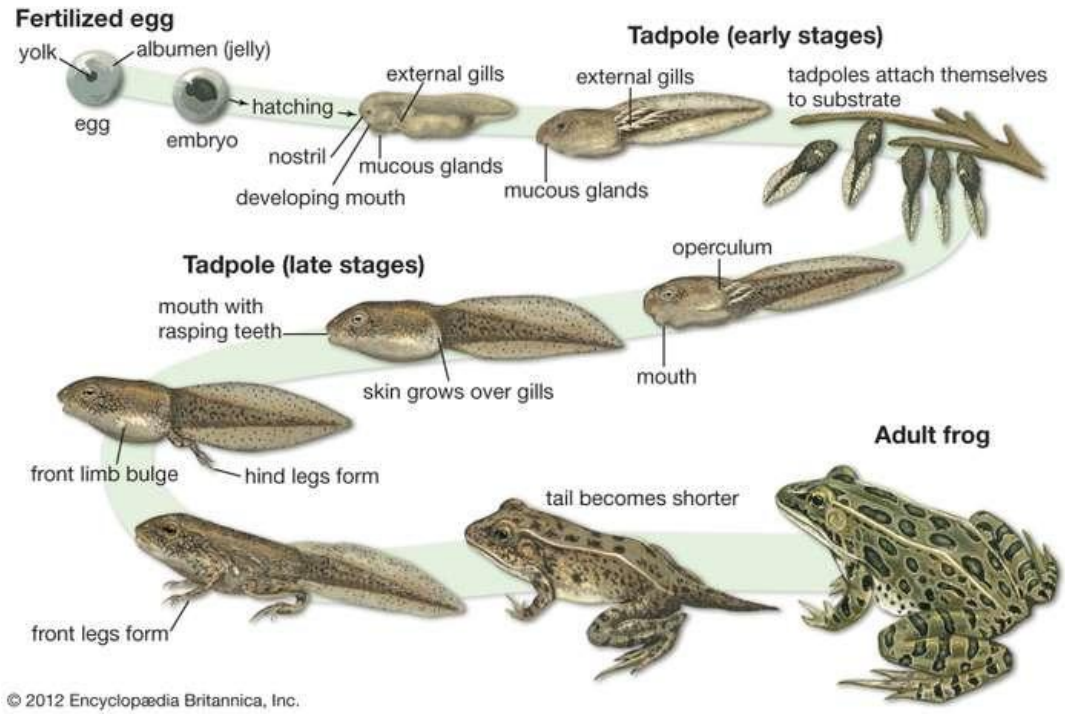
In addition to its roles in respiration and maintaining water balance, the integument of amphibians contains poison glands that release toxins. Specific toxins are found only in amphibians and are used to defend against predators.

The eye of the modern amphibian (or lissamphibian) has a lid, associated glands, and ducts. It also has muscles that allow its accommodation within or on top of the head, depth perception, and true colour vision. These adaptations are regarded as the first evolutionary improvements in vertebrate terrestrial vision. Green rods in the retina, which permit the perception of a wide range of wavelengths, are found only in lissamphibians.

The amphibian auditory system is also specially adapted. One modification is the papilla amphibiorum, a patch of sensory tissues that is sensitive to low-frequency sound. Also unique to lissamphibians is the columella-opercular complex, a pair of elements associated with the auditory capsule that transmits airborne (columella) or seismic (operculum) signals.

## Amphibian reproduction variable

- fertilization may be internal or external
- egg-layers (oviparous) but may have modifications associated with development
- egg anamniotic - doesn't have a shell but covered with a series of gelatinous layers
- hatchling in aquatic larval form which breath by gills
- most larvae herbivorous, some omnivorous to carnivorous
- larval stage may last from 10 days to 20+ years




## Classification of Amphibia

The Amphibians are divided into three orders within the Subclass Lissamphibia. Three primary orders of Amphibia are

- Caudata (Urodela) - Salamanders
- Anura (Salientia) - Frogs and toads
- Apoda (Gymnophiona) - Caecilians

### 1- Order Caudata - Salamanders

- "bearing a tail"
- ~340 species worldwide, 9 Nearctic families, 6 in US - most holarctic (N. hemisphere)
- have four limbs usually of equal size, a tail, and elongated body
- skin is smooth and glandular with mucus and poison glands
- found primarily under leaf litter, in soils, or may be fully aquatic
- most have internal fertilization by way of a spematophore (packet of sperm deposited by the male which is picked up by the

female following courtship; gelatinous coating dissolves to release sperm

- all predaceous - none herbivorous: feed on insects, worms, etc.

In southern US reproduction occurs primarily in the winter

- come out of burrows, mate, and return to burrows
- eggs develop in ponds
- increased rainfall seems to stimulate breeding
- most species breed annually although some breen only every two years

Sexual dimorphism limited - little differences between males and females

- cloacal glands enlarge during reproductive activity to contribute mucus layers to spermatophore
- male skin slightly rougher and caudal fins become longer
- hedonic glands in male

90% of all salamanders utilize spermatophores for internal fertilization

Egg and larval development may follow one of five general pathways

- Both egg and larval stages aquatic
- Necturidae, Amphiumidae, most Ambystomatidae permanently aquatic
- Eggs terrestrial, larvae aquatic
- *Ambystoma opacum* (marbled salamander) lay eggs in depressions which fill with rainfall; eggs hatch as aquatic larvae
- eggs terrestrial, larvae terrestrial
- Plethodontid *Desmognathus aeneus* - larval form does not feed before developing into adult
- eggs terrestrial with direct development
- Plethodontids which develop from egg directly through larval stage to adult
- eggs retained in the oviduct and fully develop, followed by live birth

Reproductive strategies based on site of oviposition

- in open static water (lentic systems) - sirens and salamandrids
- in running water (lotic systems) - some plethodontids
- eggs deposited under rocks, debris
- terrestrial sites - Plethodontids
- deposited away from water under logs, rocks, leaf litter
- eggs of salamanders typical for amphibians
- mesolecithal (~50% yolk) surrounded by vitelline membrane and gelatinous capsule
- sperm typically have acrosome, headpiece, and tail
- acrosome contains some golgi and important for fertilization
- headpiece contains the nuclear material
- tail consists of flagella for locomotion and mitochondria in midpiece
- sperm delivered by spermatophore - stalk supporting sperm cap 2-10mm above substrate
- stalk secreted by cloacal glands; sperm cap by pelvic glands

**Family Cryptobranchidae - hellbenders**

- "hidden gill"
- contain the largest living salamanders
- distributed in eastern US, Japan, one species in China to 9
- *Cryptobranchis alleganiensis* found in Appalachians of Kentucky/Tennessee

**Family Ambystomatidae - mole salamanders**

- restricted to US and Canada
- represented by marbled, tiger, and small-mouthed salamanders

**Family Amphiumidae - congo eels**

- only three species in the world
- named for the number of toes
- *Amphiuma tridactylum* in Walker County

**Family Plethodontidae - lungless salamanders**

- breath entirely through the skin and floor of the mouth
- many New World species which may breed on land

**Family Necturidae (Proteidae) - mudpuppies**

- represented by five species in the US all in the genus *Necturus*
- permanently aquatic salamanders which retain functional gills as adults

**Family Salamandridae - newts**

- US and European distribution
- rough-skinned with no costal grooves

**Family Sirenidae - sirens**

- 3 species restricted to the eastern US - lesser, greater, and dwarf sirens
- *Siren intermedia* (lesser siren) in Walker Co.)
- permanently aquatic with front legs and no back legs, external gills

## 2- Order Anura - frogs and toads

- ~3,400 species
- have four limbs usually of unequal size - hind limbs are elongated and modified for jumping
- head and trunk fused, tail in larval form lost as adult
- more widespread than the salamanders
- vocalizations are restricted primarily to the male for courtship, establishing territories - may be resonated by a vocal pouch
- most have external fertilization where eggs and sperm are shed directly into the water - general reproduction patterns follow that of salamanders

Generalized reproductive pattern
males vocalize to attract females
amplexus (clasping of the female by the male for mating) brings the cloacas of the male and female together
external fertilization of eggs by sperm; both deposited in the water
tadpoles develop - length of development depends on the species
metamorphosis
adults predaceous - insectivorous/carnivorous

Two primary reproductive positions:
Axillary - male grasps the female just behind the forelimbs
Inguinal - male grasps the female around the waist just in front of the hind limbs
remain in position until eggs and sperm are released for fertilization

**Family Ascaphidae - tailed frog**

- represented only by Ascaphus truei in mountainous Pacific NW
- male retains its tail as an intromittent organ as an adaptation for mating in fast-flowing streams - copulation may last for 24-30 hours, sperm viable for up to 2 years

**Family Pelobatidae - spadefoot toads**

- eye with an elliptical pupil; expanded horny digger on hind feet
- primarily live underground and come out at night
- breed in temporary pools and young may develop from egg and larval stage in 12 days

**Family Leptodactylidae - narrow-toed toads**

- SW US and Rio Grande River valley
- most species tropical laying eggs on land
- frog-like in appearance with prominent tubercles on underside of toes near joints

**Family Bufonidae - true toads**

- ~350 species worldwide - all 17 US species in the genus *Bufo*
- skins very warty with partid glands behind the eyes - secretes bad tasting poisonous substance as a protection against predators
- shorter legs designed for hopping rather than leaping
- typically burrow at night

**Family Hylidae - tree frogs**

- ~700 species worldwide; *Acris*, *Hyla*, and *Pseudacris* in Walker Co.
- *Hyla* are the true tree frogs with large adhesive toe pads and very little webbing between the toes - arboreal
- *Pseudacris* mostly ground dwellers with almost webless toes and very small or no toe pads

**Family Ranidae - true frogs**

- small to large frogs with long legs and slim waist
- large, distinct eardrum
- broadly webbed hind feet and usually with a prominent ridge down each side of the back
- aquatic to terrestrial with aquatic larvae
- represented by the genus *Rana*

**Family Myrohylidae - narrow-mouthed toads**

- small, chunky anurans with a smooth skin, a small head with a pointed snout, and short limbs
- arboreal, terrestrial, or burrowing
- terrestrial larvae may be nonfeeding
- Primary skeletal modifications in Anurans
- a general reduction in skull and girdle elements
- pelvic girdle attackes to a single sacral vertebra
- single cervical vertebra (atlas) articulates with two occipital condyles - no second differentiated axis
- no differentiation in the thoracic and lumbar vertebrae anterior to the urostyle followed by a single sacral vertebra
- ribs if present never articulate with the sternum
- distal limb bones fused - tibiofibula and radio-ulna
- increased joints in pelvic limbs to increase jumping ability

**Order Apoda (Gymnophiona) - Caecilians**

- name means ‘without legs’ - a worm-like animal
- subterranean diggers
- ~160 species restricted to tropics and subtropics
- eyes may be covered by skin or even bone
- tentacle of head may serve as a chemosensory organ to detect underground prey
- vivipary common - young 30-60% of female’s body size when born
- initial growth of fetus supported by yolk sac, embryos feed on uterine milk secreted from the epithelial wall of oviduct

## Economic importance

Amphibians, especially anurans, are economically useful in reducing the number of insects that destroy crops or transmit diseases. Frogs are exploited as food, both for local consumption and commercially for export, with thousands of tons of frog legs harvested annually. The skin secretions of various tropical anurans are known to have hallucinogenic effects and effects on the central nervous and respiratory systems in humans. Some secretions have been found to contain magainin, a substance that provides a natural antibiotic effect. Other skin secretions, especially toxins, have potential use as anesthetics and painkillers. Biochemists are currently investigating these substances for medicinal use.

# CLASS REPTILIA

The Class Reptilia includes the snakes, lizards, crocodiles, and turtles of the world. There are almost 10,000 species of reptiles on the planet lumped into a single class known as Reptilia.

These were the first class of organisms to adapt to life on land. They are believed to have evolved from the amphibians millions of years ago. There are about 10000 different species of reptiles on earth. They are cold-blooded animals belonging to the phylum Chordata of Animal kingdom.

The skull of the reptiles is modified that gives the reptiles an efficient and powerful jaw action. The modification also makes the skull light.

## Characteristics of Reptilia

1. These are creeping and burrowing terrestrial animals with scales on their body.
2. They are cold-blooded animals found in most of the warmer regions of the world.
3. Their skin is dry, and rough, without any glands.
4. The body is divided into head, neck, trunk, and tail.
5. Few of these shed the scales on their skin as skin cast.
6. The respiration takes place with the help of the lungs.
7. The skull is monocondylic.
8. They have two pairs of pentadactyl limbs, each bearing claws. Snakes are an exception.
9. The heart is 3 chambered. However, crocodiles have a 4-chambered heart.
10. The nervous system comprises of 12 pairs of cranial nerves.
11. The lateral line system is absent in reptiles.
12. Except for snakes, all the reptiles have well-developed ears.
13. They possess a typical cloaca.
14. Reptiles are ureotelic, uricotelic, and ammonotelic.

15. Fertilization is internal.
16. They exhibit a meroblastic segmentation.
17. They are oviparous and the eggs are very yolky.
18. Eg., Snakes, Turtles, Lizards, Crocodiles

## Life cycle and life history

The diversity of reptile life histories is amazingly wide and often reveals nearly unimaginable reproductive adaptations. Some reptiles are annual species that hatch, mature, reproduce, and die in one year or, at most, two years (as in side-blotched lizards [Uta stansburiana]). Others, such as loggerhead sea turtles (Caretta caretta), are long-lived species that require 25 or more years to mature and have life spans that exceed 50 years. Numerous other species fall between these extremes. Some reptiles lay eggs, whereas others are live-bearers. Some species lay 1 or 2 eggs, whereas others lay 100 or more eggs in each nesting event. Some reptiles nest year round, whereas others may nest once each year or allow two or more years between breeding cycles.

## Courtship and fertilization

The evolution of amniotic development and the shelled egg enabled vertebrates to become fully terrestrial. These two evolutionary advances required the previous development of internal fertilization. In other words, the deposition of sperm by the male into the female's reproductive tract and the sperm's subsequent penetration of the egg cell were necessary before the shelled egg could exist.

## Digestive systems

The digestive system of modern reptiles is similar in general plan to that of all higher vertebrates. It includes the mouth and its salivary glands, the esophagus, the stomach, and the intestine and ends in a cloaca. Of the few specializations of the reptilian digestive system, the evolution of one pair of salivary glands into poison glands in the venomous snakes is the most remarkable.

## Importance

In the agriculture industry as a whole, reptiles do not have a great commercial value compared with fowl and hoofed mammals; nonetheless, they have a significant economic value for food and ecological services (such as insect control) at the local level, and they are valued nationally and internationally for food, medicinal products, leather goods, and the pet trade.

Reptiles have their greatest economic impact in some temperate and many tropical areas, although this impact is often overlooked because their contribution is entirely local

The reptile groups also show a diversity of morphologies. Some groups, such as most lizards and all crocodiles, possess strongly developed limbs, whereas other groups, such as the worm lizards and snakes, are limbless.

Reptilian body flexibility ranges from the highly flexible forms found in snakes to the inflexible armoured bodies of turtles. In addition, the tails of most turtles tend to be short, especially when compared with the long heavy tails of crocodiles.

## Classification of Reptilia

The class Reptilia is differentiated into two major sub-classes:

- Anapsida
- Parapsida

- Diapsida

**Anapsida**

- The dermal bones form a complete roof over the skull with no temporal fossae.
- These are sub-divided into Cotylosauria and Chelonia.
- Modern chelonians are classified according to the method of retracting the head in the shell.
- Turtles, tortoises, and terrapins belong to this group.

**Parapsida**

- These reptiles possess one temporal fossa present high up on the skull.
- Protosaurs, Nothosaurs, Placodonts showed this type of skull.
- The two largest groups among these were- Ichthyosaurs and Plesiosaurus. These became extinct at the end of the Cretaceous period when several other reptiles including dinosaurs died.

**Diapsida**

- There are two temporal vacuities in the skull.
- They are diverse of all reptiles.
- The dinosaurs and pterosaurs are included in this group.
- These are divided into two major groups- Archosauria and Lepidosauria.
- Eg., Crocodilus, Chameleon

Groups of Reptiles

The class Reptilia is further divided into different groups known as orders:

| Order | Examples |
|---|---|
| Order Squamata | Lizards, Snakes |
| Order Testudines | Turtles, Tortoises, Terrapins |
| Order Crocodilia | Crocodiles, Alligators |

| | |
|---|---|
| Order Sphenodontia | Tuataras |

Extinct groups of class Reptilia

- Ichthyopterygia
- Lepidosauria
- Archosauria
- Synapsida

**Ichthyopterygia**

- This group had one temporal fossa place high up on the skull.
- The two largest groups belonging to this sub-class are Ichthyosaurs and Plesiosaurs.
- Eg., Ichthyosaurus

**Lepidosauria**

- These were all the lizard-like reptiles.
- They had two temporal vacuities in the skull.
- Eg., Youngina,

**Archosauria**

- The skulls were diapsid.
- Some were bipedal which gave rise to birds.
- They also gave rise to dinosaurs.
- Eg., Brontosaurus

**Synapsida**

- They had one temporal fossa on the lower side of the skull.
- These were the most dominant group of reptiles during the Permian period.
- The surviving Lepidosaurs in the Mesozoic era gave rise to mammals. The rest were replaced by dinosaurs.
- Eg. Plesiosaurus.
-

# CLASS AVES

The Aves belong to the phylum Chordata of the animal kingdom. It has about 9,000 species. Aves are adapted to fly. All the birds come in the class Aves. They show courtship, parental care, nest building, and territorial behaviour.


**General Characteristics of Class Aves:**

Some of the general characters of class Aves the birds are listed below:

1. Birds are bipedal feathered and warm blooded (homoiothermous) animals i.e., they are able to maintain a constant body temperature. Their fore-limbs are modified into wings. Most of them can fly except flightless birds (e.g., Ostrich). Class Aves has about 9000 species.

2. The hind-limbs are adapted for perching, walking or swimming, etc., and usually bear four, sometimes three and rarely two toes.

3. Except uropygium gland (preen gland or oil gland), at the base of the tail, no skin gland is present. Ostrich and parrot lack oil gland.

4. The upper and lower jaws are modified into beak, which lacks teeth. Beaks are adapted to many ways of feeding; seed-crushing, fruit-scooping, flesh-tearing, nector-sip- ping, wood-chiselling and so on.

5. Legs are modified for walking, hopping, grasping, perching, wading and swimming. Legs bear homy epidermal scales.

6. The alimentary canal has additional chambers, the crop and gizzard. The crop stores and softens the food; however, the gizzard helps in crushing and churning the food. There is a cloacal aperture. Gall bladder is absent in some seed-eating birds (graminivorous) such as pigeons.

7. Respiration is by lungs. The lungs are spongy and inelastic. Air sacs are connected to lungs for supplement respiration. The larynx does not act as a voice box. Voice is produced by a special organ, the syrinx.

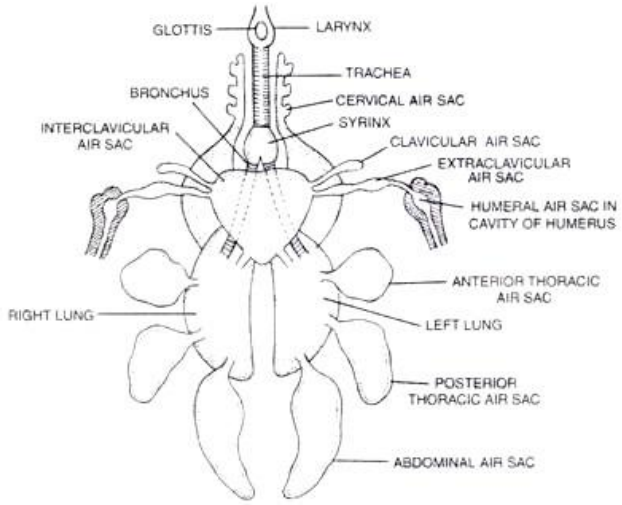



Fig. 4.65. Respiratory System of a bird.

8. The heart is four-chambered. Sinus venosus is absent. Renal portal system is very much reduced. Red blood corpuscles are nucleated, oval and biconvex.

9. The kidneys are metanephric which drain the nitrogenous waste matter (chiefly uric acid) into cloaca through the ureters. Urinary bladder is absent except Rhea Americana (American Rhea— also called "South American Ostrich". This is the only bird that has urinary bladder).

10. Brain is better developed than that of reptiles, of which cerebrum, cerebellum and optic lobes are quite large.

11. Birds have 12 pairs of cranial nerves.

12. Birds have a keen sense of sight but poor sense of smell but kiwi has good sense of smell. Pecten is present in the eyes of birds. Ear openings are present. Each ear consists of three parts: external, middle and internal.

13. Endoskeleton is fully ossified (bony) and the long bones are hollow with air cavities (pneumatic) to reduce weight. There is no bone marrow. The skull is monocondyllc, i.e., with one occipital

condyle. Sternum with a median keel for the attachment of flight muscles.

14. Female has usually well-developed single left ovary and oviduct. If right ovary and oviduct are present, they are vestigial (nonfunctional).

15. Many birds show sexual dimorphism. All birds are oviparous. Like reptiles birds lay cleidoic eggs which are macrolecithal and calcareous. Four embryonic membranes (e.g., chorion, amnion, allantois and yolk sac) are formed.

16. The birds are the most beautiful among the animals. They show courtship, nest building, parental care, migration and territorial behaviour.

**Flight Adaptations in Class Aves:**

**1. Spindle-Shaped Body:**

It is designed to offer minimum resistance to the wind.

**2. Feathers:**

They provide the passage for air and reduce friction to minimum. They also prevent loss of heat and help to maintain a constant temperature.

**3. Wings:**

Fore-limbs are modified into wings, which help during flight.

**4. Beak:**

Besides procurement of food, the beak is also used for nest-building.

**5. Neck and Head:**

Mobile neck and head are very useful for feeding, nest building, offence and defense.

**6. Flight Muscles:**

The flight muscles on the breast are greatly developed which help in flight.

**7. Hind Limbs (Legs):**

They are well suited for perching.

**8. Endoskeleton:**

Most of bones are pneumatic and filled with air instead of bone marrow. It makes the body light. Most of bones are firmly fused together, which help in flight.

**9. Air Sacs:**

These are attached to lungs which serve as reservoirs of air. They may also aid as cooling devices in regulation of the temperature of the body.

**10. Warm-Bloodedness:**

Birds are warm-blooded animals which is necessary for flight.

**11. Circulatory System:**

A large oxygen supply is required for rapid metabolism and warm-bloodedness. It is done by an efficient circulatory system.

**12. Absence of Urinary Bladder:**

Except Rhea, urinary bladder is absent in birds. Excreta are passed out at once. This helps in reducing the weight of the body.

**13. Brain and Eyes:**

Brain and eyes are well developed. Equilibrium is maintained by well developed cerebellum of the brain.

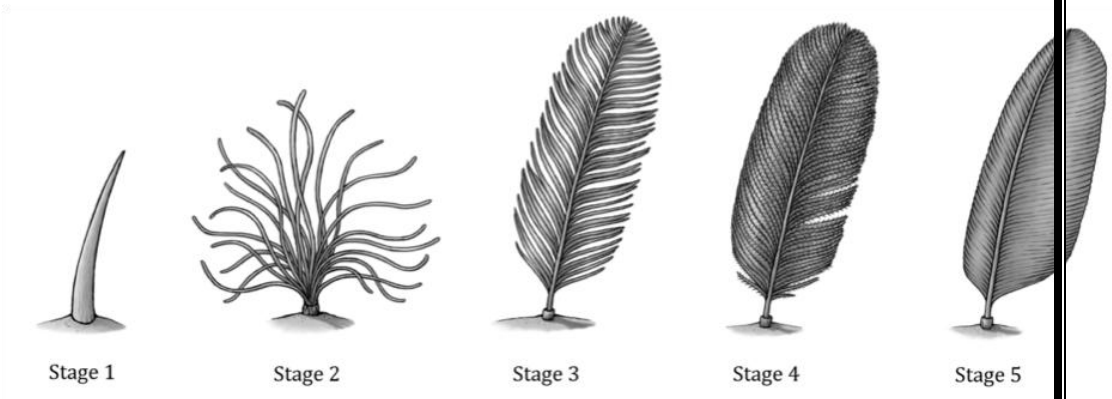
**14. Single Ovary:**

Presence of a single functional ovary on the left side in the female bird also leads to reduction of weight which is so essential for flight.

## Major Evolutionary Advancement #1 – Feathers

Feathers (integument)

- Evolved for insulation/thermoregulation, displays, or water proofing.
- Initial feathers could not have provided lift – secondary function of feather evolution was flight




- Potentially evolved from scales (debatable) however a 2006 study confirmed feather keratin in crocodile scales during early development.
- Proposed evolution of feathers. Notice how stage 2 resembles down feathers we see today
- Feathers are involved in sexual displays – males are often more colourful than females, which tend to be brown/plain.

- Brighter colours/completeness of feathers indicate fittest mate as that male has access to territory capable of facilitating the colour production.

**Major Types of Feathers**

## 1- Contour feathers

- Largest and most important
- Give bird its shape and colouring, while protecting the bird from physical objects, wind, rain, etc.


Flight and Tail feathers – notice the difference Includes flight and tail feathers

## 2- Down Feathers

- Soft and fluffy!
- Not neatly arranged like contour feathers
- Found underneath the tough contour feathers
- Provide insulation for the bird

## 3- Filoplume

- Much smaller – have only a few barbs at their tips.

- Believed to have a sensory function, allowing birds to keep their feathers in order.


## Types of feathers

It is important to note that while feathers are a major evolutionary advancement (i.e. derived character) that will be (potentially) reflected in evolutionary divergences in the future – birds are the youngest class of vertebrates and on a lineage separate from mammals, therefore feathers are unique to Class Aves (unlike our past major evolutionary advancements from previous classes). Even endothermy (below) evolved twice – once in mammals and one in birds!

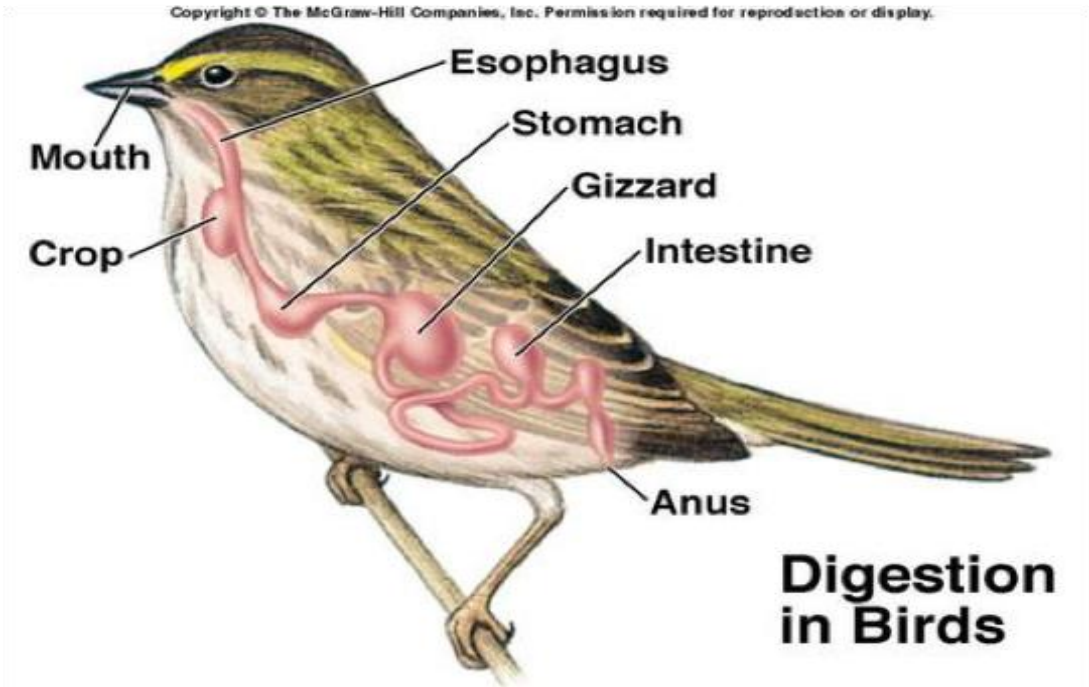
## Major Evolutionary Advancement #2 – Endotherms

- Endothermy ("Warm blooded")
- Regulate their body temperature internally. By maintaining a constant internal body temperature bodily functions occur at optimum levels of efficiency (this is known as homeostasis – more on this in bio 12 J)

- Allowed for decreased vulnerability to external temp. and be more active during night time (i.e. avoid higher predation times)
- More food required – most energy goes into maintaining temperature rather than growth.

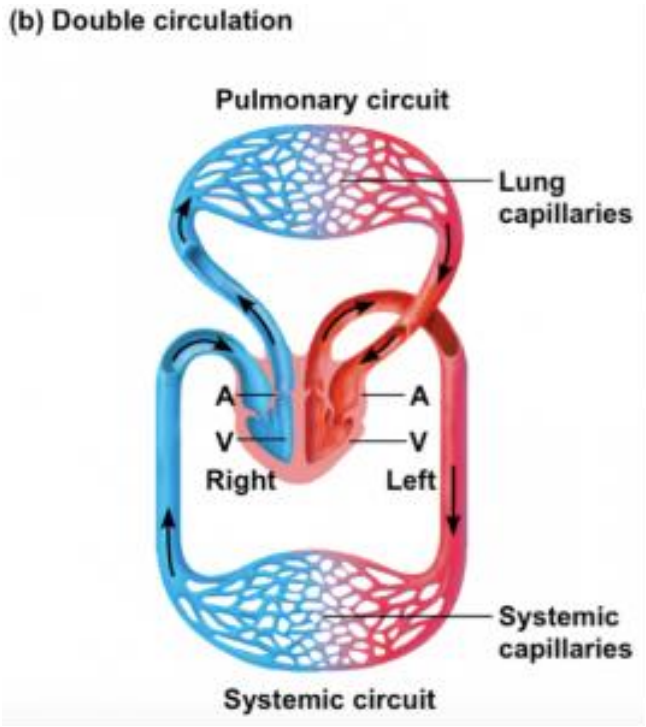
## Digestive System

- Birds face special challenges when it comes to obtaining nutrition from food. They do not have teeth, so their digestive system must be able to process whole food.
- Many have organs called the crop and gizzard.
- Crop = enlarged area of the esophagus where food can be stored/moistened before it enters the stomach or is reguritated for young.
- Gizzard = Specialized part of stomach that contains small bits of gravel that help grind food down through muscle contractions.
- Most have true cloaca.
- Birds have evolved a variety of beak types that reflect the vast variety in their diet, ranging from seeds and insects to fruits and nuts. The complexity of their digestive system (along with enzymes) allows for many different food sources to be consumed and digested. Because most birds fly, their metabolic rates are high (5-20x the resting metabolic rate of a running mammal) in order to efficiently process food.



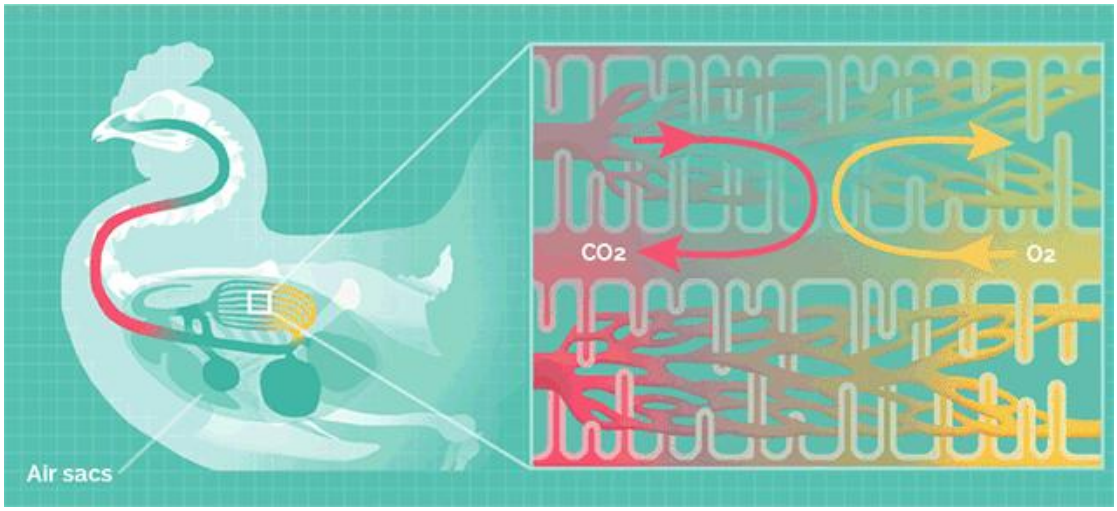

## Circulatory System

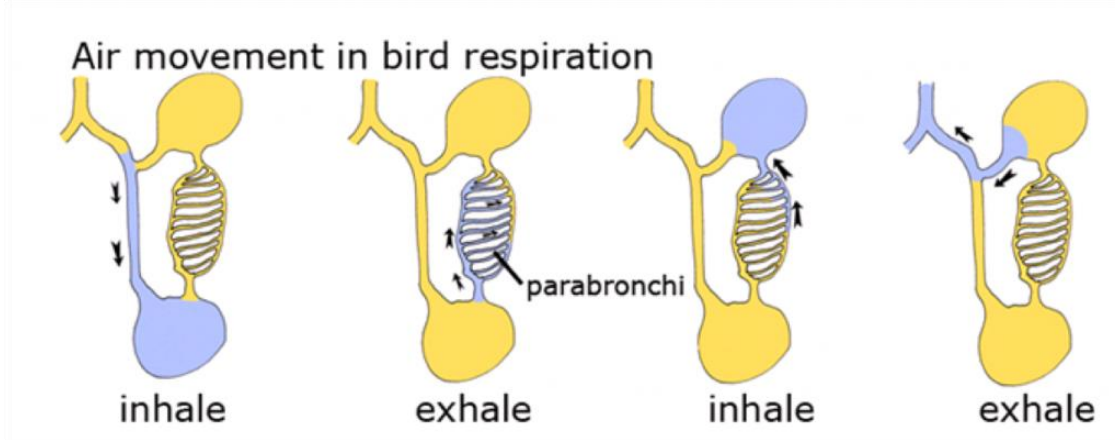
- Four chambered heart with double loop circulation
- Complete separation of deoxygenated/oxygenated blood
- Complete separation of oxygenated and deoxygenated blood – more efficient as blood that is circulated to the body is richer in $O_2$ content.
- Birds tend to have larger hearts than mammals (relative to body size and mass). The relatively large hearts of birds may be necessary to meet the high metabolic demands of flight.
- Avian hearts also pump more blood per unit time than mammalian hearts (cardiac output – blood pumped per minute is the highest of the vertebrates.
- Fun fact: A hummingbird's heart can beat up to 1200 times a minute and takes up approximately 2.5% of the total weight of the animal – human hearts are around 0.5%!




# Respiration

- Extremely efficient – this is needed due to the high demand of flight.
- Respirations through lungs – however, bird lungs are connected to large air sacs.
- When a bird inhales, air travels into lungs and the posterior air sacs.
- When the bird exhales, the air stored in the posterior air sacs moves into the lungs for gas exchange.
- This means that birds have a one way respiratory system and gas exchange occurs during inhalation and exhalation.




## Reproduction

- Internal fertilization and oviparous (hard-shelled amniotic egg)
- Since birds have cloaca, birds "cloacal kiss" to transfer sperm to the female.
- 90-95% of birds are socially monogamous, meaning they have only one partner (although the key word is social rather than sexual).
- Most birds incubate their eggs –a form a parental care.
- Bi-parental care is common – both males and females look after their eggs/young equally
- Keep sex organs small during most of the year. Why?
- 3% of bird species' have penises. In the other 97%, the production of a protein kills off what would develop into a penis.

## Classifications of Class Aves:

Class Aves is divided into two subclasses:

### Subclass I. Archaeornithes:

Extinct, toothed beak, tail long lizard-like e.g., Archaeop-teryx (Fig. 4.66).

### Subclass II. Neornithes:

Modern as well as extinct birds, teeth absent, tail short, e.g., Struthio, Aptenodytes (Penguin), Ardea (Grey heron), AIcedo (Kingfisher), Anas (duck), Columba, Psittacula, Gallus, Tyto, Bubo (Great homed owl), Phonicopterus (Flamingo), Aquila (Eagle), Neophron (Vulture, Gidh), Milvus (Kite, Cheel), Pavo, Corvus (Crow), Passer domesticus (House sparrow

Gauriyya), Crane (‘Saras’), Cuckoo (Papiha), Eagle (Baz), wild goose (Hans), hawk (Basha), hornbill (Dhanesh), Par-tridge (Teetar), quail (‘Bater’), myna, swift (Babila), tailor-bird (Durzee), weaver-bird (Baya), wood pecker (Kathphorwa). Dar-win Finches; Dodo was pigeon-like bird which became extinct during 17th century in Mauritius.

# CLASS MAMMALIA

Animals belonging to class Mammalia are referred to as mammals. Mammals are one of the most evolved species in the animal kingdom categorized under vertebrata.

They exhibit advanced characteristics which set them apart from all other animals. They are characterized by the presence of mammary glands through which they feed their younger ones.

They are distributed worldwide and have adapted well to their surroundings – from oceans, deserts and Polar Regions to rainforests and rivers etc.

There are several features that help define what a mammal is. These include the following:

- ✓ The presence of sweat glands (this includes sweat glands modified for milk production).
- ✓ Three middle ear bones that are used in hearing(malleus, incus and stapes.
- ✓ A neocortex region of the brain

## Characteristics of Mammals:-

Following are a list of distinct characteristics of mammals that separates them from other classes:

1. Mammals are warm-blooded animals who give birth to their younger ones.

2. They are the most dominant form of animals found in almost all types of habitats.

3. They have mammary glands that help them produce milk to feed their younger ones

4. Presence of region of the brain known as Neocortex

5. Their skin possesses oil glands (sebaceous glands) and sweat glands (sudoriferous glands).

6. The fur of hair throughout the body which helps animals adapt to their environment.

7. They are heterodont, i.e., possess different types of teeth.

8. Mammals also possess cervical vertebrae.

9. The skull is dicondylic.

10. The trunk is divided into thorax and abdomen.

11. The mammals respire through lungs.

12. Good sense of hearing as mammals are aided with 3 middle ear bones

13. Mammals have a four-chambered heart. The sinus venous and renal portal system is absent.

14. Presence of single-boned lower jaws.

15. The brain is well developed divided into cerebrum, cerebellum and medulla.

16. They possess 12 pairs of cranial nerves.

17. Exhibit one of the most advanced forms of Diaphragms.

18. The mammals can lay eggs also. They are known as viviparous.

**Habitat and Distribution:-**

Mammals are distributed worldwide, in a variety of habitats. Marine mammals range from coastal areas (e.g., the manatee) to the pelagic zone (e.g., whales), with some, such as sea turtles and seals, even venturing into the deep sea to feed.

**Feeding:-**

Most mammals have teeth, although some, like the baleen whales, do not. Since mammals range widely in habitat and food preferences, they have a wide range in feeding styles and preferences.

In marine mammals, whales feed using teeth or baleen, and on a variety of prey, including small fish, crustaceans and sometimes other marine mammals. Pinnipeds feed using teeth, usually eating fish and crustaceans. Sirenians also have teeth, although they also use the power of their strong lips when grasping and ripping aquatic vegetation.

**Reproduction:-**

Mammals reproduce sexually and have internal fertilization. All marine mammals are placental mammals, meaning they give birth to live young, and the unborn young are nourished in the mother's uterus by an organ called the placenta.

**Adaptation:-**

One of the most amazing things about mammals is the different evolutionary niches they've managed spread into over the last 50 million years. There are swimming mammals (whales and dolphins), flying mammals (bats), tree-climbing mammals (monkeys and squirrels), burrowing mammals (gophers and rabbits), and countless other varieties. As a class, in fact, mammals have conquered more habitats than any other family of vertebrates; by contrast, during their 165 million years on earth, dinosaurs never became fully aquatic or learned how to fly.

**Economic Importance for Humans: Positive**

Mammals are a vital economic resource for humans. Many mammals have been domesticated to provide products such as meat and milk (e.g., cows and goats) or fiber (sheep and alpacas). Many mammals are kept as service animals or pets (e.g., dogs, cats, ferrets). Mammals are important for the ecotourism industry as well. Consider the many people who travel to zoos or to all corners of the world to see animals like elephants, lions, or whales. Mammals (e.g., bats) often help control populations of crop pests. Some species like Norway rats and domestic mice are vitally important in medical and other scientific research; because humans are mammals, other mammals can serve as models in human medicine and research.), which can summaries in:-

- Pet trade
- Food
- Body parts are source of valuable material
- Ecotourism
- Research and education
- produces fertilizer
- controls pest population

**Economic Importance for Humans: Negative**

Some mammal species are considered to have a detrimental impact on human interests. Many mammals that eat fruit, seeds, and other types of vegetation are crop pests. Carnivores are often considered to be a threat to livestock or even to human lives. Mammals that are common in urban or suburban areas can become a problem if they cause damage to automobiles when they are struck on the road, or can become household pests. A few species coexist exceptionally well with people, including some feral domesticated mammals (e.g., rats, house mice, pigs, cats, and dogs). As a result of either intentional or unintentional introductions near human habitation, these animals have had considerable negative impacts on the local biota of many regions of the world, especially the endemic biota of oceanic islands.

Many mammals can transmit diseases to humans or livestock. The bubonic plague is perhaps the most well-known example. Plague is spread via fleas that are carried by rodents. Rabies, which can be transmitted among mammalian species, is also a significant threat to livestock and can kill humans as well, which can summaries in:-

- Injures humans
- Bites or stings
- Causes disease in humans
- Carries human disease crop pest
- Causes or carries domestic animal disease
- Household pest

## Classifications of Class Mammalia:

Living mammals are divided into two sub-classes.

**1. Sub-classI. Prototheria:**

Prototherians are considered to be the most primitive mammals which are only restricted in Australia and its neighbouring islands (Tasmania New Guinea). Besides egg-laying habit, they have several reptilian characters including a cloaca. They lay eggs containing ample amount of yolk. Subclass prototheria includes one order Monotremata e.g., Omithorhynchus, Tachyglossus- (Echidna).

**2. Sub-ClassII. Theria:**

They produce young ones. Subclass theria is divided into two infraclasses; Metatheria and Eutheria.

**I. Infra-Class Metatheria:**

Now they are found mainly in Australia, New Guinea and S. America. Females have a marsupium or brood-pouch for rearing young ones. Infraclass metatheria includes one Order Marsupialia. Mammals of this order are called marsupials or pouched mammals, e.g., Macropus, Didelphis (Opossum) and Phascolarctos (Koala).

**II. Infra-class Eutheria:**

They are provided with true placenta, hence called placenta Mammals. The embryos are retained in the uterus (womb) till an advanced stage.

Some of the principal orders of placental mammals are briefly described here.

**(1) Insectivora (L. insectum- insect, vorare- to eat).**

Testes are abdominal. The water shrew is the tiniest mammal which is as large as a human thumb e.g., shrews, moles and hedgehogs.

**(2) Dermoptera (Gr. derm- skin, pteron- wing):**

A hairy skin fold called patagium extends like a parachute from neck to tail for gliding, e.g., flying lemours. Actually, flying lemurs are neither true lemur nor do they fly.

**(3) Chiroptera (Gk. Cheiros- hand pteron- wing):**

They are flying mammals. The forelimbs are modified into wings, e g bats and flying foxes. The vampire bats feed on the blood of mammals including man

**(4) Edentata (L edentatus- toothless):**

They are toothless. This order includes the armadillos and sloths of South America.

**(5) Phoiidota (Gk. pholis- a homy scale):**

The body of these mammals is covered with overlapping horny scales with sparse hair in between. Teeth are absent, e.g. Manis (scaly ant eater or pangolin).

**(6) Primates (L. primus- of the first rank):**

Primates have highly developed brain. The living primates include prosimians (meaning before monkeys) and simians. The prosimians include lemurs, lorises and tarsiers the simians include monkeys, apes and men.

**(7) Rodentia (L. rodo- gnaw):**

They have one pair of sharp chisel-like incisors in each jaw. The canines are absent, leaving a toothless space, the diastema in the jaw no canines, e.g., rats, mice, squirrels, guinea-pigs and porcupines!

**(8) Lagomorpha (Gk. logos- hare, morphe- form):**

They have two pairs of incisors in the upper jaw and one pair of incisors in the lower jaw and no canines, e.g., rabbits and hares.

**(9) Cetacea (L. cetus- whale):**

They have fish-like body, well adapted for aquatic life. They have fin-like fore limbs, but no hind limbs. Testes are abdominal. The skin has a thick layer of fat called blubber serving as reserve food, an insulator for reducing the specific gravity.

Pinnae are reduced or absent. Hair is only on lips. They do not have sweat and oil glands, e g whales, dolphins and porpoises. Blue whale is the largest living animal. Whales normally lack pelvic girdle and hind limbs.

The Green land whales, however, possess vestiges of pelvic girdles and bones of hind limbs inside the body

**(10) Carnivora (L. Caro- flesh, vorare- to eat):**

They are flesh eating mammals. These animals have sharp pointed canines, strong jaws and well developed claws, e.g., dog, cat, wolf, jackal, fox, cheetah, lion, tiger, hyaena, mongoose, bear, panda, otter, seal, walrus, sea lion. Cheetah is the fastest runner. It can cover a distance of 120 Km in one hour.

**(11) Proboscidea (Gk. pro- in front, boskein- to eat):**

They have a long muscular trunk. They are thick skinned animals hence called pachyderms (Gk. pachys – thick, derm – Skin). They are the largest land animals, e.g., elephants.

**(12) Sirenia (Gk. siren- sea nymph):**

They are herbivorous aquatic mammals with fin-like forelimbs and no hind limbs. They have few hairs and do not have external ears.

They have thick blubber. Testes are abdominal. The males have tusks, e.g., Manatee, Seacows.

**(13) Perissodactyla (Gk. perissos- odd, dactylos- toes):**

They are herbivorous odd-toed hoofed mammals or ungulates (L. ungula- hoof) or hoofed which have an odd number of toes (1 or 3). True horns with a bony core are never present.

The stomach is of nonruminating type (these are not cud chewing animals) e.g., horses, asses, mules, zebras, tapirs and rhinoceros.

**(14) Artiodactyla (Gk. artios- even, dactylos- digit):**

They are herbivorous even toed hoofed mammals or ungulates (hoofed) which have even number of toes (2 or 4). True horns or antlers are present in many animals of this order. Many even toed hoofed mammals like cow and camel are ruminants or cud-chewing.

The four chambered stomach of cow (Fig. 4.80) is capable of digesting cellulose of plant materials by micro-organisms present in the rumen (first part of their stomach) e.g., cows, buffaloes, sheep, goats, deer, antelopes, yaks, camels, giraffes, pigs and hippopotamuses.

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**Question: Mark the right sentence with (√) and the wrong sentence with (×):**

**……**

**1-** Order Dipnoi belonges to Class Chondrichthyes.

2- Prototheria includes animals having placenta.

3- Both eyes are in the same sides in *Solea* sp.

4- Cyclostomata animals characterized by internal fertilization.

5- Super Class Agnatha has Inner ear with 3 semi-circular canals.

6- Aves are fully ossified skeleton with air cavities. Presence of air sacs

7- There are air sacs connected to the lungs in reptilian animals.

8- The Aves are worm-blooded with an exoskeleton of feather.

9- *Amphioxis lanceolatus* belongs to Class Cyclostomata.

10- Lizards eyes usually have movable eyelids.

11- The head of *Upupa epops major* is large and rounded and crowned with small ear tufts.

12- The endoskeleton of Reptilian animals is completely ossified.

13- The tunicates are a group of freshwater animals with a (tunic) sac.

14- The tetrapod's animals include birds and mammals only.

15- Both median and paired fins present in cartilaginous fishes.

16- Anapsida reptiles without temporal fossae.

17- The shell in aquatic turtles is domed.

18- Three large parotid glands in Toads are behind the head.

19- *Anguilla Anguilla* is a small bird found in most parts of the world

20- *Testudo* sp. has an ovoid shell covered by well-developed horny scutes.

21- *Falco tinnunculus* has beak with strong and hooked at the tip and has a cere at the base.

22- The feet of cats have thick pads underneath.

23- Class Osteichthyes including sharks, rays and skate.

24- Lampreys are parasitic both marine and freshwater forms.

25- In Eutheria animals; Teeth present in young and absent in adults.

26- Skin is usually covered with fur and sometimes spines are present in Order Insectivora

27- Most of Long-eared Hedgehog body is armed with short hard erectile spines and the rest with fur

28- Females have one pair of teats located in the thorax in order Primata