

Vertebrates

- Humans and their closest relatives are **vertebrates**.
 - This group includes other mammals, birds, lizards, snakes, turtles, amphibians, and the various classes of fishes.
- They share several unique features including a backbone, a series of vertebrae.
- The vertebrates belong to one of the two major phyla in the Deuterostomia, the **chordates** (the other major phyla being the Echinoderms).
- The phylum Chordata includes three subphyla, the vertebrates and two phyla of invertebrates, the urochordates and the cephalochordates.

Chordate Characteristics

- Although chordates vary widely in appearance, all share the presence of four anatomical structures at some point in their lifetime.
 - These chordate characteristics are **a notochord**; **a dorsal, hollow nerve cord**; **pharyngeal slits**; and **a muscular, postanal tail**.
1. The **notochord**, present in all chordate embryos, is a longitudinal, flexible rod located between the digestive tube and the nerve cord.
 - It is composed of large, fluid-filled cells encased in fairly stiff, fibrous tissue.
 - It provides skeletal support throughout most of the length of the animal.
 - While the notochord persists in the adult stage of some invertebrate chordates and primitive vertebrates, it remains as only a remnant in vertebrates with a more complex, jointed skeleton.
 - For example, it is the gelatinous material of the disks between vertebrae in humans.
 2. The **dorsal hollow nerve cord** develops in the vertebrate embryo from a plate of ectoderm that rolls into a tube dorsal to the notochord.
 - Other animal phyla have solid nerve cord, usually located ventrally.
 - The nerve cord of the chordate embryo develops into the central nervous system: the brain and spinal cord.
 3. **Pharyngeal gill slits** connect the pharynx, just posterior to the mouth, to the outside of the animal.
 - These slits allow water that enters the mouth to exit without continuing through the entire digestive tract.
 - In many invertebrate chordates, the pharyngeal gill slits function as suspension-feeding devices.
 - The slits and the structures that support them have become modified for gas exchange (in aquatic vertebrates), jaw support, hearing, and other functions during vertebrate evolution.
 4. Most chordates have a **muscular tail** extending posterior to the anus.
 - In contrast, nonchordates have a digestive tract that extends nearly the whole length of the body.
 - The chordate tail contains skeletal elements and muscles.
 - It provides much of the propulsive force in many aquatic species.

Invertebrate chordates provide clues to the origin of vertebrates

- Most **urochordates**, commonly called **tunicates** (sea squirts), are sessile marine animals that adhere to rocks, docks, and boats.
- Tunicates are suspension-feeders.
- While the pharyngeal slits of the adult are the only link to the chordate characteristics, all four chordate trademarks are present in the larval forms of some tunicate groups.
- **Cephalochordates**, also known as **lancelets**, closely resemble the idealized chordate.
 - The notochord, dorsal nerve cord, numerous gill slits, and post- anal tail all persist in the adult stage.
- Lancelets are suspension feeders, feeding by trapping tiny particles on mucus nets secreted across the pharyngeal slits.
- Though feeble swimmers, their swimming mechanism resembles that of fishes through the coordinated contraction of serial muscle blocks.
- Molecular evidence suggests that the vertebrates' closest relatives are the cephalochordates, and the urochordates are their next closest relatives.

Subphylum Vertebrata

- Neural crest
- Pronounced cephalization with sense organs
- Vertebral column replaces notochord
- Endoskeleton of cartilage or bone
- Ventral heart with closed circulatory system
 - In vertebrates, a group of embryonic cells, called the **neural crest**, forms near the dorsal margins of the closing neural tube.
- Neural crest contributes to the formation of certain skeletal elements, such as some of the bones and cartilages of the cranium, and other structures.
- The cranium and vertebral column are parts of the vertebrate axial skeleton.
 - This provides the main support structure for the central trunk of the body and makes large body size and fast movements possible.
 - Also included in the axial skeleton are ribs, which anchor muscles and protect internal organs.
- Most vertebrates also have an appendicular skeleton, supporting two pairs of appendages (fins, legs, or arms).
- The vertebrate endoskeleton is made of bone, cartilage, or some combination of the two materials.
 - The vertebrate endoskeleton can grow continuously, unlike the exoskeleton of arthropods.
- Active movement by vertebrates is supported by ATP generated through aerobic respiration.
 - These movements may be to acquire prey or to escape predators.
 - Adaptations to the respiratory and circulatory systems support mitochondria in muscle cells and other active tissues.
 - These include a closed circulatory system, with a ventral, chambered heart that pumps blood through arteries and capillaries to provide nutrients and oxygen to every tissue in the body.
 - The blood is oxygenated as it passes through capillaries in gills or lungs.

- An active lifestyle requires a large supply of organic fuel.
 - Vertebrate adaptations for feeding, digestion, and nutrient absorption help support active behavior.
- These multiple adaptations in form and function to a variety of systems have supported the transition from a relatively sedentary lifestyle in pre-vertebrates to a more active one pursued by most vertebrates.

An overview of vertebrate diversity

- Our current understanding of vertebrate phylogeny is based on anatomical, molecular, and fossil evidence.
 - At the base are hagfishes and lampreys which lack hinged jaws.
 - All other vertebrates, the ***gnathostomes***, have true jaws and also two sets of paired appendages.
 - In “fishes,” including the cartilaginous fishes and three classes of bony fish, these paired appendages function in swimming.
 - In **tetrapods**, the appendages are modified as legs to support movements on land.
- Among tetrapods, most amphibians lay eggs in water or an otherwise moist environment.
- The other terrestrial tetrapods are **amniotes**, producing shelled, water-retaining eggs which allow these organisms to complete their life cycles entirely on land.
 - While most modern mammals do not lay eggs, they retain many of other key features of the amniotic mode of reproduction.
- The traditional vertebrate group known as “reptiles” (turtles, snakes, lizards, crocodiles, and alligators) does not form a monophyletic group *unless* birds are included.

Jawless Vertebrates

- The two extant classes of jawless vertebrates, the **agnathans**, are the ***hagfishes*** and the ***lampreys*** – *classes Myxini (hagfishes) and Cephalaspidomorphi (lampreys)*.
- All of the 30 or so species of hagfishes are marine scavengers, feeding on worms and sick or dead fish.
- The skeleton of hagfish is made entirely of cartilage, a rubbery connective tissue – they lack vertebrae!
 - Hagfishes diverged from ancestors that produced the vertebrate lineage about 530 million years ago, during the early Cambrian.
- There are about 35 species of lampreys inhabiting both marine and freshwater environments.
- Sea lampreys live as suspension-feeding larvae for years in streams before migrating to the sea or lakes as predaceous/parasitic adults.

Clade Gnathostomes: “jawed mouth”

- During the late Silurian and early Devonian periods, gnathostomes largely replaced the agnathans.
- These organisms have a hinged jaw, and 2 pairs of paired appendages (such as fins for fish).
- Jaws and paired fins were major evolutionary breakthroughs.
 - Jaws, with the help of teeth, enable the animal to grip food items firmly and slice them up.
 - A jawed fish can exploit food supplies that were unavailable to earlier agnathans.
 - Paired fins, along with the tail, enable fishes to maneuver accurately while swimming.
- With these adaptations, many fish species were active predators, allowing for the diversification of both lifestyles and nutrient sources.

Class Chondrichthyes: Sharks and rays

- The class Chondrichthyes, sharks and their relatives, have relatively flexible endoskeletons of cartilage rather than bone.
- The intestine of shark is a **spiral valve**, a corkscrew-shaped ridge that increases surface area and prolongs the passage of food along the short digestive tract.
- Shark eggs are fertilized internally.
 - **Oviparous** sharks encase their eggs in protective cases and lay them outside the mother's body.
 - These hatch months later as juveniles.
 - **Ovoviviparous** sharks retain fertilized eggs in the oviduct.
 - The embryo completes development in the uterus, nourished by the egg yolk.
 - A few sharks are **viviparous**, providing nutrients through a placenta to the developing offspring.

Class Osteichthyes: Bony fishes

- Nearly all bony fishes have an ossified endoskeleton (skeleton of bone) with a hard matrix of calcium phosphate.
- Bony fishes breathe by drawing water over four or five pairs of gills located in chambers covered by a protective flap, the **operculum**.
- The reproductive modes of fishes vary extensively, with most being oviparous (external fertilization).
- Most fishes have an internal, air-filled sac, the **swim bladder**, which enables them to be neutrally buoyant and remain suspended in the water.

Class Amphibia: Salamanders and frogs

- *Amphibian* means “two lives,” a reference to the metamorphosis of many frogs from an aquatic stage, the tadpole, to the terrestrial adult.
 - Tadpoles are usually aquatic herbivores with gills, a lateral line system, and swim by undulating its tail.
 - During metamorphosis, the tadpole develops legs, the lateral line disappears, and gills are replaced by lungs.
 - Adult frogs are carnivorous hunters.
- Many amphibians do not live a dualistic - aquatic and terrestrial - life.
 - There are some strictly aquatic, and some strictly terrestrial frogs, and salamanders.
- Paedomorphosis, the retention of some larval features in a sexually mature adult, is common among some groups of salamanders.
 - For example, the mudpuppy (*Necturus*) retains gills and other larval features when sexually mature.
- Most amphibians retain close ties with water and are most abundant in damp habitats.
 - Most amphibians rely heavily on their moist skin to carry out gas exchange with the environment.
 - Some terrestrial species lack lungs entirely and breathe exclusively through their skin and oral cavity.
- Amphibian eggs lack a shell and dehydrate quickly in dry air.
 - Most species have external fertilization, with eggs shed in ponds or swamps or at least in moist environments.

Evolution of the amniotic egg expanded the success of vertebrates on land

- The amniote clade consists of the mammals, the birds, and the vertebrates commonly called reptiles, including turtles, lizards, snakes, and crocodiles.
- The evolution of amniotes from an amphibian ancestor involved many adaptations for terrestrial living including
 - the amniotic egg
 - waterproof skin
 - increasing use of the rib cage to ventilate the lungs.
- The amniotic eggs enabled terrestrial vertebrates to complete their life cycles entirely on land.
 - In contrast to the shell-less eggs of amphibians, the amniotic eggs of most amniotes have a shell that retains water and can be laid in a dry place.
 - The calcareous shells of bird eggs are inflexible, while the leathery eggs of many reptiles are flexible.
 - Most mammals have dispensed (done away) with the shell.
 - The embryo implants in the wall of the uterus and obtains its nutrition from the mother.
- Inside the shell of the amniotic egg are several **extraembryonic membranes** that function in gas exchange, waste storage, and the transfer of stored nutrients to the embryo.
 - These develop from tissues layers that grow out from the embryo.

A reptilian heritage is evident in all amniotes

- Reptiles have several adaptations for terrestrial life not generally found in amphibians.
 - Scales containing the protein keratin waterproof the skin, preventing dehydration in dry air.
 - Reptiles obtain all their oxygen with lungs, not through their dry skin.
- Most reptiles lay shelled amniotic eggs on land.
 - Fertilization occurs internally, before the shell is secreted as the egg passes through the female's reproductive tract.
- Many reptiles regulate their body temperature by basking in the sun when cool and seeking shade when hot.
- Because they absorb external heat rather than generating much of their own, reptiles are more appropriately called **ectotherms**.

Birds began as feathered reptiles

- In addition to amniotic eggs (internal fertilization), modern birds have feathers and other distinctive flight equipment.
- Almost every part of a typical bird's anatomy is modified in some way to enhance flight – hollow bones, feathers, wings.
- The skeletons of birds have several adaptations that make them light, flexible, but strong.
 - The bones are honeycombed to reduce weight without sacrificing much strength.
- Modern birds are toothless and grind their food in a muscular gizzard near the stomach.
- Birds are endothermic, using their own metabolic heat to maintain a constant body temperature.
- Birds have excellent vision and excellent coordination, supported by well-developed areas of the brain.
- The large brains of birds (proportionately larger than those of reptiles or amphibians) support very complex behavior.

Class Mammalia

- Vertebrates of the **class Mammalia** were first defined by Linnaeus by the presence of mammary glands.
 - All mammalian mothers possess mammary glands and nourish their babies with milk.
 - All mammals also have hair, made of the keratin.
 - All mammals are endothermic.
- Most mammals are born rather than hatched.
 - Fertilization is internal, and the embryo develops in the mother's uterus.
- Mammals generally have larger brains than other vertebrates of equivalent size.
 - Many species are capable of learning.
 - The relatively long period of parental care extends the time for offspring to learn important survival skills by observing their parents.
- Feeding adaptations of the jaws and teeth are other important mammalian traits.
 - Unlike the uniform conical teeth of most reptiles, the teeth of mammals come in a variety of shapes and sizes adapted for processing many kinds of foods.
- **Monotremes** - the platypuses and the echinids - are the only living mammals that lay eggs.
 - The reptile-like egg contains enough yolk to nourish the developing embryo.
- Monotremes have hair and females produce milk in specialized glands.
 - After hatching, the baby sucks milk from the mother's fur because they lack nipples.
- **Marsupials** include opossums, kangaroos, bandicoots, and koalas.
- A marsupial is born very early in development and in most species completes its embryonic development while nursing within a maternal pouch, the marsupium.
 - In most species, the tiny offspring climbs from the exit of the female's reproductive tract to the mother's pouch.