

PHYLUM CHORDATA

I. Characteristic

A. Divided into 3 subphyla:

1. Urochordata (tunicates) invertebrates.
2. Cephalochordata (lancelets) invertebrates.
3. Vertebrata (vertebrates).

* B. All subphyla share 3 important characteristics: all three form in the early embryo (or larva) of a chordate and they persist, are altered, or may disappear in the adult.

1. Stiff, rod-like notochord (ventral to the nerve cord) at some stage of life: serves as an internal skeleton (first supporting and stiffening structure of the chordate body) and prevents the body from shortening when the body muscles contract; in the vertebrate embryo it acts as a skeletal axis and is surrounded or replaced by a column of vertebrae (cartilaginous or bony) formed from a connective tissue sheath that surrounds the notochord during embryonic development (this does not occur in the invertebrate chordates, which make up the other two subphyla)
2. Pharyngeal gill slits to pharyngeal pouches: connects the pharynx (a muscular tube linking the mouth cavity and the esophagus) with the outside
 - a. in most vertebrates, however, the slits do not actually connect to the outside and are termed pharyngeal pouches
 - b. these pouches are present in the embryos of all vertebrates, but are lost later in terrestrial vertebrate development
3. Dorsal, tubular, nerve cord that is hollow, single and dorsal to the alimentary canal (digestive tube); anterior end becomes enlarged to form the brain; the nerve cord distinguishes the chordates from most invertebrates (e.g. annelids, molluscs, arthropods, echinoderms) whose main nerve cord is solid, ventral, usually paired and ventral to the alimentary canal; the cord lies in neural arches of the vertebrae while the brain is enclosed in a bony or cartilaginous cranium.

C. Other features:

1. Bilaterally symmetrical.
2. Triploblastic.
3. Complete digestive tract.
4. Well-developed coelom; tube within a tube.
5. Segmentation of at least part of the body in most groups (internal).
6. Post-anal tail at some stage in the life history combined with somatic musculature and a stiff notochord that continues behind the digestive tract; allows for a free swimming existence in lower invertebrate chordates for propulsion in water.
7. Ventral heart with dorsal and ventral blood vessels; CLOSED system.
8. Endoskeleton: cartilaginous or bony in the majority of its members (vertebrates).
9. Occupy all kinds of habitats in salt and freshwaters and on land.

D. The collection of chordate characteristics comprises a particularly successful set of adaptations:

1. Combination of an internal notochord with segmented blocks of chordate muscles (myotomes), allowed early chordates to swim quickly and efficiently by a side-to-side wiggle of the body, permitting them to swim further and faster than other animals.
2. Swimming forward allows for food and water to be taken in through the mouths and permits extra water escape through the gill slits.
3. Sense organs in the head detected direction and found food; brain and nervous system became well developed.

II. Subphyla.

A. Urochordata (tunicates)

1. Members include the sea squirts, which are quite common around the sea coasts, and other planktonic forms that are common, but rarely seen; fragile and transparent; filter planktonic food.
2. Exclusively marine and sessile as adults (attached at its base to rocks, seaweed, ship hulls, etc.); body covered by a nonliving "tunic" of cellulose; incurrent and excurrent siphons.
3. As adults, they look nothing like any other chordate; have a tadpole-like larva stage with a notochord, a hollow dorsal nerve cord, segmented musculature and post-anal tail which are lost in the sedentary adult; adult retains only the pharyngeal gill slits (found internal of tunic).
4. Tadpole larva metamorphoses into an adult; larvae does not feed but swims for hours, then fastens vertically to object to become an adult.
5. Possesses a primitive circulatory system.
6. The vertebrates could have evolved from an animal closely related to the tunicate tadpole; only problem is that the tadpole metamorphoses into an adult that looks nothing like any vertebrate.

B. Cephalochordata (lancelets).

1. Contains only amphioxus, the lancelet, which is a small, fishlike animal found in shallow marine waters in many parts of the world; it can swim with lateral, undulating body movements, although it spends most of the time buried in the sandy bottom with its anterior end projected.
2. It swims poorly because most of the body is occupied by an enormous pharyngeal basket, leaving little room for swimming muscles.
3. It lacks a distinct head; has an oral hood, which projects beyond the mouth entrance that bears tentacles
4. Has the three distinctive characteristics in simple form plus a post-anal tail and secondary characteristics of a liver diverticulum, hepatic portal system and the beginnings of a ventral heart.
5. Has a well-developed coelom, a circulatory system without a discrete heart, and has prominent muscle segments.
6. The notochord, that lies ventral to the nerve cord, extends the length of the body and serves as an internal skeleton; extends to the tip of the snout; small brain development.
7. Lancelets retain all three chordate characteristics through adulthood.

C. Vertebrata (vertebrates).

1. Members include lampreys, sharks, bony ray fishes, toad, frogs, salamanders, turtles, lizards, snakes, monkeys, rodents, whales, cows, human beings, etc.
2. Large in size, motile, distinct body plan: embodies distinguishing features that have led to eminent evolutionary success
3. Differ from the other chordates in having a vertebral column, which replaces the notochord to a greater or lesser extent (cartilaginous and fibrous in lower forms and bony in higher forms); spinal column forms chief skeletal axis of the body; also a brain case or cranium.
4. A well-developed coelom largely filled with visceral systems.
5. Many muscles attached to the skeleton to provide for movement.
6. Complete digestive system ventral to the spinal column provided with large digestive glands, liver, pancreas; endocrine organs (ductless glands) for chemical regulation (hormones); kidneys that differ completely from the various invertebrate excretory organs (paired with ducts that drain to the cloaca or anal region); cloaca may receive from the digestive, excretory and reproduction systems (not found in mammals).
7. Integument of two divisions:
 - a. Outer epidermis: stratified epithelium from ectoderm.
 - b. Inner dermis: connective tissue from the mesoderm.
 - c. Many modifications of the skin among the various classes: glands, scales, feathers, claws, horns, hair, nails.
8. A tail that extends beyond the anus is common.
9. A ventral heart and closed blood vessels; 2-4 chambers; arteries, veins, and capillaries; RBC with hemoglobin and WBC.
10. Pronounced cephalization so that vertebrates have very obvious heads with specialized sense organs; 10-12 pairs of cranial nerves with both motor and sensory functions; pair of spinal nerve for each myotome; autonomic system (reflex) in control of involuntary organ functioning.
11. Terminology relating to organism's metabolism:
 - a. Poikilothermous: an organism whose body temperature varies.
 - b. Ectothermic: relating to the majority of animals, whose heat gain depends on that from the environment because it can produce very little metabolic heat.
 - c. Homeothermous: organisms maintain a constant body temperature.
 - d. Endothermous: maintenance of a relative. constant body temperature by internal controls over metabolic activity and heat-conserving mechanisms independent of the environment; using metabolic heat.
12. Representative classes:
 - a. Agnatha (cyclostomes = "round mouths")
 - 1) Lowest forms with vertebrate features (retaining the three chordate features into adulthood) including a differentiated brain and paired cranial nerves, eyes, internal ears, both red and white blood cells, and organ systems on the vertebrate pattern.
 - 2) Includes the hagfishes and lampreys; all hagfishes are marine, whereas lampreys inhabit both marine and fresh waters; retain chordate characteristics into adulthood.
 - a) Are long, narrow, scaleless, cylindrical animals without paired fins (only median fins) and without jaws; eel-like; fibrous and cartilaginous skeleton.
 - b) The adult lamprey is a semi-parasite, and hagfishes are scavengers.
 - c) Lampreys have a sucking mouth and a rasping tongue covered with teeth, which are used to break the skin and suck the blood (use an anti-coagulant) of bony fish; they do not usually kill their prey; sucker is also used to attach the adult to stones when at rest.

- (1) The larval form, an **ammocoete** (blind and toothless); lives for as long as seven years as an ammocoete- like-filter-feeder buried in the mud of a river or stream, whereas the adult lives for only a few years and dies after migrating to spawn (3-7 years as larva; then metamorphoses into an adult).
 - (2) Lampreys are considered a scourge to freshwater fisheries; parasitic lampreys either migrate to the sea, if marine, or else remain in freshwater.
 - (3) Are **Poikilothermous**.
 - (4) Persistent notochord and cartilaginous skull; "branchial basket": gill region supported by cartilage; nerve cord is **dorsal** to the notochord; vertebrae is represented by small, imperfect neural arches over the notochord (consists of bits of segmented cartilage).
 - (5) Two kidneys with excretory ducts.
 - (6) Heart with one auricle and one ventricle (two chambered).
 - (7) Dioecious; internal fertilization.
 - d) The hagfishes have no larval stage and apparently attack only dead, diseased, or disabled fish and also feed on various invertebrates; they do not suck and rasp at their prey as do lampreys.
- b. **Chondrichthyes** (cartilaginous fish; chondros: "cartilage"; ichthys = "fish")
- 1) Members include sharks, skates, and rays: *lowest living vertebrates with complete and separate vertebrae, movable jaws, and paired appendages (pectoral and pelvic fins).
 - 2) All are predaceous, mostly marine.
 - 3) Tough skin, with minute **placoid scales** (conical and toothlike) or dermal **denticles** (dentine covered by enamel that also comprise the teeth) and many mucous glands; median and paired fins, all supported by fin rays; pelvic fins with claspers in males; scales, collectively form an **exoskeleton**.
 - 4) **Ventral** mouth, with many teeth (unlike those of bony fish and higher vertebrates in that the teeth are not attached to the jaw, but are embedded in the flesh; continuously formed and move forward for replacement); Olfactory (smell) sacs 2 (or 1), not connected to mouth cavity; with lower and upper jaws; intestine with **spiral valve** (spirally arranged partition that delays the passage of food and offers increased area for absorption); vision less acute than bony.
 - 5) Entirely **cartilaginous** skeleton, no true bone; cranium joined by paired sense capsules; notochord persistent ventral to the cord in spaces between the vertebrae with dorsal **neural arch** to hold and support the nerve cord.
 - 6) **Two-chambered heart** (1 auricle, 1 ventricle), with **sinus venosus** (receives blood from veins) and **conus arteriosus** (receives blood from ventricle and passes on to the arterial system to be oxygenated in the gills; heart contains **only venous blood** which is unoxygenated); red blood cells nucleated and oval.
 - 7) Respiration by 5 to 7 pairs of gills; external gill openings or slits; no operculum; **spiracles** on top of the head for taking in water for respiration to prevent gill clogging if the mouth is buried in sand.
 - 8) Ten pairs of cranial nerves; each auditory organ with three semicircular canals (equilibrium).
 - 9) Poikilothermous.
 - 10) Dioecious; typically paired gonads; reproductive ducts discharging into **cloaca** (a common passage from the digestive, excretory and reproductive organs in various vertebrates); internal fertilization usually, but no copulatory organ; eggs large with much yolk; direct development with no metamorphosis; **ovoviviparous** embryo develops within the mother receiving nourishment from the yolk of its egg and then hatches within the mother and is born alive (sharks) or immediately after laying; a few are **viviparous** = nourished internally by the mother, with close contact between the blood vessels of the oviduct and those that grow out of the embryo; offspring born as juveniles; **oviparous** types as well.
 - 11) **Lateral line systems**: composed of pressure receptors arranged along the sides of the body for vibration or sound wave detection (detecting and locating objects and moving animals).
 - 12) Shark's nutrition typically of fish, squid and small crustaceans; some eat sea lions and seals; some man-eaters; rays and skates consume a principal diet of small invertebrates.
 - 13) **No** swim bladder.
 - 14) **Heterocercal** tail: vertebral column turns upward and extends to the dorsal tail lobe
 - 15) Devonian Period (405 million years ago): "Age of Fishes;" lasted 60 million years.
- c. **Osteichthyes** (bony fish)
- 1) Most typical fishes are those with bony skeletons, embedded **dermal** scales (thin, flexible and arranged in overlapping rows), jaws, gills covered by an **operculum**, streamlined in shape, with a wide variety of forms to assure success in given habitats; highly successful and adaptable group inhabiting all types of water: fresh, brackish, salt, and either warm or cold
 - 2) Represents a staple protein food (13-20%) of mankind as well as a sporting recreation.

- 3) Members range from perch, bass, catfish to the flying fish, sea horse, and lungfish.
- 4) Skin contains many mucous glands, usually with dermal scales (exoskeleton); some scaleless; both median and paired fins present usually, supported by fin rays of cartilage or bone; homocercal tail (upper and lower lobes of equal size).
- 5) Usually a terminal mouth with teeth embedded in bone; jaws well-developed, articulated to the skull, two dorsal Olfactory sacs; large eyes with no lids.
- 6) Chiefly bony skeleton (cartilage in sturgeons); many distinct vertebrae, *relics of a notochord often persist; adult skull is closely affixed to the vertebral column so that a fish cannot "turn its head"; neural arch for the cord.
- 7) Two-chambered heart (1 auricle, 1 ventricle) within a pericardial cavity containing only venous blood; ventricle pumps the blood; red blood cells nucleated and oval; blood is pale and scanty.
- 8) Respiration by gill pairs on bony gill arches in a common chamber at each side of the pharynx, covered by the operculum; usually with an air bladder (in dorsal body cavity, connects to the pharynx; fills with gases to act as a hydrostatic organ to adjust the specific gravity of the fish to that of the water at different depths); some species have perforate nostrils and accessory structures that enable them to breath air in shallow, mucky water; no spiracles; flow of the water over the gills is opposite in direction to the blood flow (countercurrent) which is the best arrangement for extracting the greatest amount of oxygen (85%).
- 9) Ten pairs of cranial nerves.
- 10) Poikilothermous.
- 11) Typically paired gonads; usually oviparous (producing eggs that hatch outside the body); usually external fertilization; yolk amounts vary; early young sometimes quite unlike adults.
- 12) Lateral line system (row of small pores connected to lengthwise tubular canal under scales, in which are sensory organs responsive to slow vibrations in the water and pressure changes.
- 13) Nutrition varies from filter feeders (like herrings), parrotfishes which crunch up coral, to insectivores (like trout) and predaceous carnivores (like piranhas and barracuda); most fishes are predaceous.
- 14) Paleontologists believe that bony fishes and chondrichthyes evolved from placoderm ancestors (heavily armored) at about the same time, but independently: the Devonian period; 405 million years ago was the "Age of Fishes" lasting 60 million years.
 - a) The bony fishes diverged into two major groups: ray-finned fishes, which gave rise to the modern osteichthytes, and the fleshy-finned fishes, which include the lung fishes and lobe-finned fishes.
 - (1) The lobe-finned fishes (Crossopterygii) have since become almost extinct; a few surviving species, the coelacanths, have continued to survive (flourished some 350 million years ago); they have been caught off the east coast of Africa (thought to be extinct for over 70 million years).
 - * (2) They represent an important position in vertebrate evolution as it is believed their ancestors used their fleshy based fins to pull themselves across land from pond to pond and utilized a kind of lung that developed as a pharynx outgrowth; could have led to the first tetrapods (amphibians) for the initial transition to a land existence.
 - (a) The Devonian period was a time of mild temperatures and alternating droughts and floods, where streams progressively dried up, water became foul, and the dissolved oxygen disappeared.
 - (b) When pools dried up, fishes were forced to move to another pool of water: the pectoral fins of lobe-finned fishes were especially well developed, containing a series of skeletal elements in the fins and a pectoral girdle that is believed to foreshadow the pentadactyl (with five digits) limb of tetrapods.
 - (c) The development of strong fins did not happen so that fish could colonize land, but rather as a necessary adaptation to find water and a continued fish existence.

D. Amphibia (salamanders, toads, frogs, newts, mud puppy).

1. Name means "dual life" in that most of the species live partly in fresh water and partly on land.
2. Were the first group among the chordates to live out of water, being derived from a fish-like ancestor (possibly the lobe-finned fishes).
3. Approximately 380 million years ago amphibians moved to land and flourished during the Carboniferous Period (350 to 280 million years ago); "Age of Amphibians".
4. Adaptations for terrestrial life: (*although amphibians are NOT fully adapted).
 - a. Legs instead of fins: tetrapods.
 - b. Nostrils connecting to the mouth cavity (2 open into anterior end of mouth cavity).
 - c. Lungs for breathing air (small and relatively inefficient); amphibians are still more dependent on moist skin for gas exchange (some salamanders have no gills or lungs).

- d. Sense organs functioning in both water and air.
 - e. Vasopressin (ADH): a hormone that increases the amount of water reabsorbed into the body from the urine to conserve in a terrestrial existence.
 - f. Double circulation: lungs as an efficient, air filled cavity that is highly vascularized; provided with a pulmonary circuit, supplying the lungs, and a systemic circulation, serving the body for efficient gas transfer; through evolutionary advancement oxygenated blood will eventually be completely separated from deoxygenated.
5. Amphibians along with reptiles, birds, and mammals are known as **tetrapods** "four feet".
6. Characteristics:
- a. Common in moist, temperate and tropical regions; live in damp places or in water; **none** in marine environment (salt waters).
 - b. Poikilothermous: must avoid extreme temperatures and drought (can lose water easily from the soft skin); **hibernation** in winter in the soft mud of the bottom of pools, streams or under logs and stumps in the forest; derives energy from glycogen and fat stored in their bodies during spring and summer (frogs, terrestrial and aquatic salamanders, toads), **aestivate** in summer in hot, dry areas; some active at all seasons.
 - c. Skin moist and glandular; poison glands in warts on toad produce acrid secretions for protection; no external scales.
 - d. Two pairs of limbs for walking or swimming (no paired fins); toes 4 to 5 or fewer; hind toes webbed.
 - e. Two nostrils with valves to exclude water; eyes often with movable lids; eardrums external on toads and frogs; mouth usually with fine teeth; tongue often protrusible.
 - f. Nutrition of live, moving animals as insects, crustaceans, worms, small molluscs; also small fishes, birds or mammals (bullfrog).
 - g. Skeleton largely bony; ribs, if present, not attached to sternum.
 - h. Heart **3-chambered**, with 2 auricles and a ventricle; red blood cells nucleated and oval; double circulation to the heart (pulmonary and systemic circuits); oxygenated and deoxygenated blood may still mix due to the one ventricle.
 - * i. Reflecting their transitional place between aquatic and land habitats, amphibians have more means for respiration than any other animal: gills, lungs, skin, and the mouth lining (buccopharynx), separately or in combination; gills present at some stage in life history; **vocal cords** in toads and frogs for distinctive mating calls for each species.
 - j. Brain with 10 pairs of cranial nerves.
 - * k. Amphibians are **not totally** emancipated from water because of water's significance to amphibian reproduction: amphibian eggs are without the membranes and shell that protect the higher chordates from desiccation on land; skin is not protected from desiccation either.
 - 1) External or internal fertilization, no copulatory organ; **mostly** oviparous.
 - 2) Eggs with some yolk and enclosed in gelatinous coverings; toad eggs in long strings, tapioca-like masses in frogs, and small clumps in aquatic salamanders.
 - 3) **Usually** an aquatic larval stage (tadpole) with metamorphosis to adult form.
 - 4) Each species has a characteristic type of breeding place where both sexes gather in the breeding season.
 - 5) Aquatic and terrestrial salamanders have characteristic courting performances.
 - * l. Contributions of Amphibians to Vertebrate Evolution:
 - 1) Change from gill to lung breathing.
 - 2) Links for locomotion on land (tetrapods).
 - 3) Strengthening skeletal changes.
 - 4) Shift of senses from the lateral line system of fishes to smell and hearing.
 - 5) Double circulation.
- E. **Reptilia** (lizards, snakes, turtles, tortoises, crocodiles and alligators); lizards and snakes comprise nearly 95%; modern crocodiles are the largest today.
- 1. Were the first group among vertebrates adapted for life in dry places on land with the following modifications:
 - a. Support own weight (since no longer could depend on the surrounding water medium as aquatics do).
 - b. Resist drying and rapid temperature changes.
 - c. Efficient extraction of oxygen from the air.
 - d. Reproduction more appropriate for land
 - 2. Adaptations
 - a. Skin and scales (exoskeleton) resist loss of moisture from the body and facilitate living on rough surfaces (thick **Keratin**, a protein in the outer skin cells is impermeable to water); the thin epidermis is shed periodically with an underlying thick dermis that results in coloration.

- b. Reproduction appropriate for land: eggs with membranes and shells to protect the embryo and free the dependence on water (leathery and contains some calcium carbonate); copulatory organ for internal fertilization.
 - 1) **Extra embryonic membranes** (accessory structures developed beyond the embryonic body and are discarded when the embryo hatches):
 - a) **Amnion**: sac that fills with fluid to provide a "private pond" for the developing embryo; immediately surrounds the embryo
 - b) **Yolk sac**: food supply; contributes to the umbilical cord in viviparous mammals
 - c) **Allantois**: gas exchange through the shell and storing toxic wastes; contributes to the umbilical cord in viviparous mammals
 - d) **Chorion**: outermost surrounding membrane giving rise to the placenta in viviparous types
 - c. More efficient lungs; **no** need for exchange across the skin.
- 3. Their class name refers to the mode of travel (reptilis = creeping), and the study of reptiles is called "herpetology".
- 4. This group flourished during the **Mesozoic Era (Age of Reptiles)**: 65 to 225 million years ago); dinosaurs dominated for more than 100 million years then suddenly become extinct.
- * 5. Their **major disadvantages** compared with their mammalian and avian (bird) descendants is that they have **less ability** to maintain a high body temperature independently of the environment.
 - a. Considered poikilothermous and ectothermic although they maintain a body temperature higher than their surroundings; this feature is mainly **behavioral** rather than **physiological (metabolism)** as in birds and mammals; reptiles lie in the sun for a period before they become active; hibernation in winter months (**Behavioral thermoregulation**).
- 6. Characteristics:
 - a. Dry, cornified skin (**not** slimy) with scales made of **keratin** (protein also present in feathers, horns, hair, nails); few surface glands.
 - b. Two pairs of limbs, each typically with 5 toes ending in horny claws suited for running, crawling, or climbing; limbs paddle-like in marine turtles, reduced in some lizards, and absent in a few other lizards and in all snakes (**vestigis** in boas and pythons).
 - c. Skeleton completely ossified; lower jaw of more than one bone; ribs with sternum forming a complete thoracic basket.
 - d. Heart **imperfectly** 4-chambered (2 auricles and a partly divided ventricle; a 3-chambered heart in actuality although crocodiles are the first vertebrate to show 4 true chambers) which allows for greater separation of the oxygenated and unoxygenated blood over the amphibians due to flow patterns within the heart; red blood cells nucleated, **biconvex**, and oval; efficient circulatory system and higher blood pressure as there are two functionally separate circulations (Pulmonary and systemic) with the right atrium receiving unoxygenated blood from the body and the left atrium receiving oxygenated blood from the lungs to be sent back out to the body parts and mixing basically prevented between the two as in lower forms.
 - e. Respiration **always by lungs**; except for cloacal respiration in aquatic turtles (thin-walled vascular sacs in cloaca that serve as "cloacal gills" when submerged; **no** gills nor integument exchange).
 - f. Twelve pairs of cranial nerves; **taste buds** on the tongue; **olfactory organs** in nasal cavity, **lacrimal glands** with the eyes; **eustachian tube** (ear to throat); cerebrum increased in size; crocodilians have **cerebral cortex** that is true (outer layer of gray matter).
 - g. Internal fertilization, usually by copulatory organs (penis-like structures in cloaca); eggs large with much yolk in leathery or limy shells; **oviparous** mostly *(internal development among land vertebrates may have begun as a regular phenomenon among reptiles since some strictly oviparous turtles and snakes can retain their eggs temporarily when conditions for deposition are unfavorable); some **ovoviparous** types (rattlesnakes, vipers, water, sea and garter snakes); calcareous **egg tooth** develops on tip of upper mandible, as in birds, for young to hatch (in oviparous types).
 - h. No metamorphosis.
 - i. Excretion by paired Kidneys; urine is a semisolid paste with uric acid being the main nitrogenous waste; very efficient in conserving water.
 - j. Regeneration (lizard's tail).
 - k. Distribution includes tropical and subtropical regions, humid regions; swamps and rivers, ocean, oceanic islands, trees, open floor of forests; numbers decline rapidly toward the poles and in high altitudes.
 - l. Feed chiefly on animals; some eat vegetation (land tortoises, some turtles and a few lizards).

7. Poisonous reptiles in North America:
 - a. Gila monster of the American southwest (poorly developed mechanism for venom transfer; injury to humans rare).
 - b. Venomous snakes occur on all the continents and on many large islands.
 - 1) In North America, north of Mexico: two coral snake types, the moccasin, the copperhead and 20 kinds of rattlesnakes.
 - 2) The "pitvipers" (moccasins, copperheads, rattlers) have **wide heads**, **vertically elliptical pupils**, and a **pit** between the nostril and eye on each side of the head; pit is a sensory organ for detecting body heat of warm-blooded prey at some distance.
 - 3) **Venom** is secreted by a pair of poison glands, one on either side of the upper jaw, each connected by a duct to a **fang** (tooth); venom of the cobra and related snakes affects the respiratory center resulting in asphyxiation (neurotoxin); that of rattlers and other vipers affects the heart and circulatory system more severely (hemotoxin).
- F. **Aves:** (birds).
1. Best known and most easily recognized of all vertebrates because they have **feathers**.
 2. Their coloration and voices appeal to the eye and ear of mankind.
 3. They occupy all continents, the seas, and most islands; they penetrate both the Arctic and Antarctic and occur from sea level to above timber line on mountains.
 4. Fossil remains are meager because bird bones are light, hollow and quickly disintegrate
 5. Considered to have reptilian ancestry:
 - a. Early embryonic development parallels that of reptiles
 - b. Scales, persist on the legs of birds and feet; claws at end of toes.
 - c. Fossil remains of some of the earliest birds indicate they had reptile-like teeth (no teeth in living birds of today).
 - 1) **Archaeopteryx** (150 million year old ancestor) fossilized remains: reptilian skeleton with long bony tail, clawed fingers, abdominal ribs, and feathers.
 6. Characteristics:
 - a. Four body divisions: head, neck, trunk, and tail.
 - b. Body covered with feathers (probably evolved from reptilian scales); an exoskeleton of sort produced by epidermis; involve an orderly replacement (molt) in which the feathers drop out in symmetrical pairs so that flight is not hindered.
 - 1) Strong by weight; flexible.
 - 2) Excellent insulation.
 - 3) Oil gland above tail base keeps beak from getting brittle and aids in dressing the feathers.
 - c. Fore limbs modified as wings for flight allowing the legs to be free for running, swimming (webbed) or perching; toes usually 4; shanks and toes covered with horny skin; wings shaped like "air foils" to supply lift, wings degenerated in ostrich and kiwi.
 - d. Birds share with mammals the highest organ development.
 - e. Birds share with mammals complete separation of respiratory and systemic circulations: very efficient in supplying oxygen to active tissues for a higher rate of metabolism; homeothermic and endothermic.
 - f. Well developed nerve system with 12 pair of cranial nerves.
 - g. Mouth a projecting **beak** or **bill** with horny sheath for multipurposes and **no teeth**:
 - 1) Functions both as a mouth and as hands; preen feathers, obtain and arrange nesting materials, defense and feeding.
 - h. Pelvis fused to many vertebrae and open ventrally (permit laying large eggs); sternum large with small ribs; tail vertebrae few and compressed.
 - i. Heart **4-chambered** (2 auricles, 2 separate ventricles) which allows for complete separation of oxygenated and unoxygenated blood (significant to maintaining a regulated body temperature), red blood cells oval, nucleated and biconvex; WBC.
 - j. Lungs compact, attached to ribs and joined to thin-walled **air sacs** between the internal organs and into some bones; lungs are inexpandible with air capillaries instead of alveoli; air sacs serve as reservoirs for fresh air; the bird's respiratory system is the **most efficient** of all vertebrates; **voice box** at base of the windpipe.
 - k. **Endothermic** characteristic of using metabolic heat to maintain body temperature at a high level and **homeothermic**: maintaining a stable internal temperature to allow biological processes and nerve function to proceed at steady high levels of activity; allows birds to be active whatever the external temperature (down feathers and a layer of fat under the skin for insulation); **no sweat glands**: use dilating vessels to skin, panting, and air sacs; shivering in winter.

- 1) Air sacs allow heat to be lost rapidly, particularly during flight, when the flight muscles and heart generate large quantities of metabolic heat.
- l. No bladder; excretions of semisolid wastes from kidney pass to the cloaca (uric acid); paired kidneys each with thousands of nephrons.
- m. **Usually** only a left ovary and oviduct (right remains rudimentary unless left is removed; two testes in male and vas deferens; internal fertilization although in most species male has no penis; instead cloacal surfaces are brought into contact as the male stands on back of the female and sperm in seminal vesicles are inserted into the female cloaca. **Oviparous** eggs with large yolk and limy shell, laid and incubated; young at hatching either (a) fully formed, feathered, and able to get about; or (b) naked and helpless, requiring further growth in nest; **always** fed and cared for by parents (**brooding**: protection against chilling and wetting; shielding against undue heat of sun)
7. Are active at all seasons; none hibernate.
8. **Migration**: many species shift regularly with the change of the seasons from one region to another; most is north and south (**latitudinally**) using established routes; more or less on schedule, arriving and disappearing regularly; 20 to 50 miles per hour stopping to feed averaging 25 miles per day.
9. Nutrition chiefly of seeds or fruits together with worms, arthropods, molluscs, and vertebrates; others are insects, fish, snakes, lizards, rodents and some eat dead animals; digestive tract contains a gizzard for grinding.
- * a. Limited fat storage, therefore a bird cannot long survive without food and must literally "eat to live"
- G. **Mammalia**: (rodents, monkeys, bats, horses, whales, cows, deer, human beings, etc.)
 1. Most advanced group of animals.
 2. Class name refers to the **mammary glands** that supply milk for suckling the young.
 3. Are covered with hair or fur to varying degrees combined with and the underlying fat layer for insulation (subcutaneous).
 4. Integument of outer epidermis supported by thick dermis; contains sweat, scent, sebaceous and mammary glands.
 5. Endothermic (using metabolic heat) and homeothermic (uniform body temperature; "warm-blooded"); allows for quick responses or actions as during dangerous situations; active when external temperature is unfavorable.
 6. **Parental care** is highly developed.
 - a. Primitive mammals (such as the duckbill platypus and spiny anteater) resemble reptiles in that they are egg layers; called **monotremes**; young are still reared on mother's milk that they obtain by licking and not sucking.
 - b. More advanced mammals (**marsupials**: opossum and kangaroo) have limited uterine development of the young; they are born in a very immature condition and transferred to a pouch where they are suckled until they are more mature
 - c. Young of most advanced are retained in the uterus until they are in an advanced stage (**viviparous**); mother can be active while carrying
 7. Believed to have originated from early reptiles some 200 million years ago (mammal-like reptiles). Dinosaurs vanished near the beginning of the Cenozoic era (70 million years ago). The mammals suddenly expanded filling ecological niches vacated by the reptiles. The "**Age of Mammals**" then reached a peak in the **Tertiary Period** (55 to 30 million years ago) declining in numbers especially within last million years; man's influence has accelerated the extinction rate.
 8. Live in all kinds of habitats from the tropics to the poles and from the oceans to the driest deserts.
 9. Secrets of mammalian success: perfection of **quadrupedal** locomotion (4 legs) and adaptations to carnivory (flesh-eaters).
 10. Characteristics:
 - a. Hair molted periodically with many glands (sebaceous, sweat, and mammary).
 - b. Lower jaw of one bone; neck vertebrae usually 7; tail usually long and mobile.
 - c. Nasal region commonly long; jaws usually with teeth of several types, differentiated in relation to food habits; tongue usually mobile; eyes with movable lids; ears with external fleshy lobes.
 - d. Four limbs, each foot with 5 (or fewer) toes and variously adapted for walking, running, climbing, burrowing, swimming, or flying; toes with horny claws, nails, or hoofs and often fleshy pads.
 - e. Heart completely **four-chambered** (2 auricles, 2 distinct ventricles) red blood cells **unnuclated**, usually circular and biconcave; WBC.
 - f. Respiration **only** by lungs (microscopic alveoli surrounded by capillaries); larynx with vocal cords; a complete muscular **diaphragm** separating lungs and heart from abdominal cavity.
 - g. A urinary bladder; excretions (urine) are fluid with **urea** the chief nitrogenous waste; kidneys with **nephrons** and ureters that open into bladder; external opening separate; ADH
 - h. Twelve pairs of cranial nerves; **brain** highly developed, both cerebrum and cerebellum large; sight, hearing and smell well developed; high degree of coordination, learning and retentive memory.

- i. Male with copulatory organ (**penis**); internal fertilization; eggs usually minute, **without** shells, and retained in uterus of female for development; **placental** membrane significant to development of embryo and fetus (**viviparous**: embryo enclosed in extra embryonic membranes with nutritional aid internally from mother); young nourished after birth by milk secreted from mammary glands by female; fetal membranes: amnion, chorion and the allantois; yolk **not** as significant for embryonic nourishment as in lower forms of animals.
 - 1) All mammals except **monotremes** (egg layers: duck-billed platypus, spiny anteater) are viviparous.
11. Nutrition: **herbivores** (plant feeders), **carnivores** (flesh eaters), **omnivores** (both plant and animal materials), **insectivores** (insect eaters) and **scavengers**.