# Chordates (Vertebrates Lecture Outline) for Module 3

The phylum Chordata includes three subphyla. These include vertebrates and invertebrate chordates.

### Characteristics

Notochord: the rod-shaped supporting axis found in the dorsal part of the embryos of all chordates, including vertebrates

Flexible, non-collapsible rod dorsal to the gut/coelom and below the nervous system, hydrostatic, fluid wrapped in tough connective tissue. As bone does not compact, muscles tensed on one side result in movement instead of shortening the animal. This allows much better locomotion than do cilia for larger animals in water, a crucial victory for later success.

Pharyngeal slits: Slits in the pharynx originally used to gather food, water enters the mouth, passes through pharynx and out gill-like slits, passing through a cavity called an antrium and then outside. In humans, present only in embryo.

Dorsal nerve cord: A neural tube dorsal to the notochord

Postanal tail: Elongation of the body and notochord, nerve cord and muscles past anus into tail, early locomotive function led to success.

Non-synapomorphic characteristics (not limited to chordates):

* + bisymmetrical (bilateral symmetry)
  + segmented muscles and bones

### Subphylum Urochordata

The tunicates are located in this subphylum. Along with the subphylum Cephalochordata, these two subphyla make up the invertebrate chordates. Only the tunicate larvae have notochords, nerve cords, and postanal tails. Most adult tunicates are sessile, filter-feeders which retain their pharyngeal slits. Adult tunicates also develop a sac, called a tunic, which gives tunicates their name. Cilia beating within the turnicate cause water to enter the incurrent siphon. The water enters the body, passes through the pharyngeal slits, and leaves the body through the excurrent siphon. Undigested food is removed through the anus. Tunicates are hemaphrodites and can reproduce asexually through budding.In urochordates notochord is confined to larval tail.These lack cranium. These have an open type of circulatory system.Excretion is by neural gland,nephrocytes.

### Subphylum Cephalochordata

The lancelets are located in this subphylum. Along with the subphylum Urochordata, these two subphyla make up the invertebrate chordates. Lancelets receive their name from their bladelike shape. They resemble fish but they are actually scaleless chordates only a few centimeters long. They spend most of their time buried in the sand with their mouths protruding. Fossils of lancelets have been found to be over 550 million years old.

Dropped out sessile stage, what was the larval stage is now sexually reproductive. Includes Branchiostoma (“amphioxus”).

### Subphylum Vertebrata

(Vertebra from Latin vertere, to turn). Characterized by separate bones or cartilage blocks firmly joined as a backbone. The backbone supports and protects a dorsal nerve cord. Vertebrates have tissues which are organized into organs which in turn are organized into organ systems.

All vertebrates share the following characteristics: - segmentation - a true coelom - bilateral symmetry - cephalization - a backbone - a bony skull - a closed circulatory system - chambered heart - two pairs of jointed appendages - tissues organized into organs

Vertebrate Organ Systems: - Nervous System - Circulatory System - Digestive System - Respiratory System - Reproductive System - Excretory System

* Vertebral column: Not present in higher vertebrate adults. (In humans, the gel-like, spongy core of the vertebral column is the only remainder. Ruptured or herniated disc is an injury to this.)
* Cranium: Composite structure of bone/cartilage. Two functions: 1. Supports sensory organs of head and 2. Encloses or partially encloses the brain.

What evolutionary relationship could we imagine between sessile echinoderms and the higher chordate animals?

Paedomorphic (child-form) hypothesis: basically, evolution of sexual reproduction in what had previously been a larval life stage, or the retention of at least one juvenile characteristic into the adult (adult = sexually reproducing) stage. Some scientists believe that this occurred in a proto-chordate animal lineage. Maybe chordates (and vertebrates) arose from sessile (attached) ancestors. Selection in these proto-chordates maybe began to favor more time in the larval stage, as feeding was more successful or mortality lower in this stage. As larvae got bigger physics shows that the cilia become less efficient for locomotion, favoring the undulating motion allowed by a notochord.

Is this hypothesis crazy? A similar example of this today is Epemeroptera, the mayfly, which has almost abandoned its adult stage. Its one-year lifespan is mostly larval with just a brief day of reproduce-and-die as an adult, which doesn’t even have usable mouthparts.

Tunicate (sea squirt) larva has all four chordate characteristics, although adult sessile (“attached”).

##### Class Agnatha

"jawless fish"

* + Ostracoderms: extinct Agnathans which had primitive fins and massive plates of bony tissue on their body.
  + Cyclostomes: "circle mouth" - a group of Agnathans which is still alive in the form of lampreys and hagfish.

Appeared approximately 500 million years ago and dominated the oceans for about 100 million years. The first group of fish to appear. They had neither jaws, paired fins, nor scales, but they were the first organisms with a backbone.

###### Class Acanthodia

"spiny fish" Appeared about 430 million years ago. An extinct class of fish that developed jaws with bony edges. They had internal skeletons made of cartilage and some bone.

###### Class Placodermi

Appeared about 410 million years ago, dominated the sea for about 50 million years. An extinct class of fish with massive heads.

##### Class Chondrichthyes

"cartilaginous fish" Appeared about 400 million years ago with bony fish. Includes sharks, skates and rays, and chimaeras. Their skeletons are made of cartilage strengthened by the mineral calcium carbonate.

The main characteristics and distinguishing features of this class: - gills - single-loop blood circulation - vertebral column - presence of placoid scales on their bodies - internal skeleton of cartilage - paired, fleshy pectoral and pelvic fins - asymmetrical tail fin prevents sinking - fatty liver provides neutral buoyancy - visceral clefts present as separate and distinct gills - no external ear - oviparous - internal fertilization - ectoderms - cold blooded

##### Class Osteichthyes

"bony fish" Appeared about 400 million years ago with cartilaginous fish. Includes about 95% of today's fish species.

###### Subclass Sarcopterygii

fleshy-finned fishes. Fins have bones and muscles, homologous to our limbs.

###### Order Dipnoi

lung fishes, two groups isolated when continents separated

###### Order Crossopterygii

includes coelacanths and rhipodistians, gave rise to amphibians, had lungs which evolved into a swim bladder in bony fishes, and labyrinthodont teeth, characterized by complex folding of enamel.

* Skeleton made of bone, jaws, fins, most with scales, two-chambered heart.

##### Class Amphibia

means “both lives”, aquatic larvae, terrestrial adult Amphibians: - Legs - Lungs - Double- Loop Circulation - Partially Divided Heart - Cutaneous Respiration (Breathes through Skin)

###### Order Salientia

frogs (jumping) (aka Anura)

###### Order Urodela

salamanders (tailed)

Labyrinthodont amphibians: oldest known amphibians, inherited characteristic teeth from crossopterygii ancestor, had stocky, aquatic larvae.

Amphibians have limbs instead of fins. Girdles and vertebral column now more substantial and connected, support body on legs.

Lisamphybia: no scales, “smooth”, eggs with no shell, laid in water (water-reliant).

Amphibians gave rise to cotylosaurs, from which arose dinosaurs, turtles, lizards, and therapsids.

###### Class Reptilia

amniotic egg allowed freedom from water, shelled egg. (Amnion: protection). Reptiles have four extra-embryonic membranes:

* Amnion: supports aquatic environment inside egg in fluid sac.
* Allantois: allows gas exchange and elimination of wastes.
* Chorion: gas exchange
* Yolk sac: only one of the four left over from amphibian ancestor

Reptiles cold-blooded, or ectothermic, meaning that their heat come from their environment. Sometimes defined as all amniotes that are not birds or mammals.

Reptiles can be classified by skull structure into four groups:

* Anapsid
* Synapsid
* Diapsid
* Euryasid

Refers to number of holes in the skull. Cotylosaurs had Anapsid skull Dermatocranium: from bony outer skull structure, precursor to human cranium.

###### Subclass Anapsidia

**Subclass Testudinata**

turtles1, terrapins

###### Subclass Diapsida

dinosaurs2, snakes3, most stuff

**Subclass Synapsida**

**Order Therapsids**

**Subclass Diapsida**

includes Ichthyosaurs, marine reptiles convergent on dolphins; Plesiosaurs, ancient sea monsters; Squamates, including lizards and snakes; and Thecodonts, which gave rise to

* + birds
  + dinosaurs
  + crocodilians

Dinosaurs: broken into two groups, based on hip structure

* + Saurischia: lizard hips (gave rise to birds [!]), ancestrally bipedal
  + Ornithischian: bird hips, ancestrally quadripedal

Crocodilians: come from archosaurs, the only extant (still living today) archosaur descendant. Ancestrally bipedal, secondarily quadripedal.

Synapsids: refers to joined (Greek syn-, together with) parts of skull. Led eventually to mammals. Synapsid pelycosaur >> therapsid >> mammals

Pelycosaur: Sail-backed dinosaur, legs not spread out like lizard but more pillar-like and under body, allowing greater activity and competence in motion, pendulum like rather than constant push-up. Teeth differentiated into different types, for pre-processing of food needed by higher metabolism. Skull changes, bone histology, suggestions of warm-bloodedness.

1. <http://en.wikibooks.org/wiki/turtle>
2. <http://en.wikibooks.org/wiki/dinsosaur>
3. <http://en.wikibooks.org/wiki/snake>

###### Class Aves

arose late Jurassic, early Cretaceous. Feathers, skeleton modified for flight. Feathers: epidermal derivative, made of keratin (like fingernails). Carpometacarpis: bears primary flight feathers, parallel to hand parts. Keeled sternum: breastbone, powerful one needed to support flight muscles. Strong, light, occasionally hollow bones. All birds lay eggs (as contrasted to reptiles, which have developed live birthing over 100 independent times.) Why are there no live-bearing birds? Early birds had teeth, lost them. With mammals, only exothermic animals.

Archaeopteryx: “ancient wing”, Jurassic bird-reptile, very dinosaur-like. Good fossils found in Zolenhoffen, German sandstone mine with fine sand, shows feathers clearly, found shortly after Darwin’s publication and used to support his hypothesis. Thick, heavy bones and no sternum, bony tail, not a good flyer but did have primary flight feathers.

Archaeornithes: includes archaeopteryx. Paleognathae: gave rise to Australian flightless birds. Neognathae: remaining live birds.

###### Class Mammalia

Two unique characteristics, or synapomorphies:

* Hair
* Mammary glands (don’t fossilize well)

Three skeletal characteristics (fossilize)

* Lower jaw only one bone, the dentary (several in reptiles)
* Three bones in middle ear: malleus, incus, stapes (reptiles have one or two, never three)
* Joint between upper and lower jaws between dentary and squamosal of skull (in reptiles this joint is between other bones)

Mammals basically have a synapsid skull design inherited from ancestor Non diagnostic characteristics (not unique to mammals):

* Warm-blooded
* Skin glands: sweat glands and oil-producing sebaceous glands
* Large nasal cavities (because of high metabolism) Clean, warm and humidify air
* Heterodonty (differentiated teeth)
* Diphiodonty: two sets of teeth: baby and adult (“deciduous” teeth, drop out) (reptile teeth are continually replaced)

###### Subclass Protheria

monotremes (Greek mon-, one; and trema, hole), or egg-laying mammals, have one opening for excretion and urination.

###### Subclass Theria

Metatheria: Marsupials (opossum, kangaroo. . . ) Eutheria: Placental mammals (all common mammals)

Marsupium: (from Greek marsypion, purse or pouch). Gestation period much shorter than in Eutherian mammals, but after leaving the uterus the tiny offspring crawls into a pouch where it completes development latched onto a teat.

Recent molecular (read: genetic) evidence suggests that two different mammal groups may have developed live-bearing ability separately. Instead of being a “rough draft” for placental-style live bearing, perhaps the marsupial pouch approach is another solution to the same problem. Advantage: in tough times the parent can pitch out the offspring and increase its own chance of survival.

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