

## Phylum Chordata

1. Deuterostomes (like the echinoderms)
2. All share four features:
  - Notochord supports body
  - Nervous system develops from dorsal nerve cord
  - Embryos have pharynx with slits
  - Embryos have tail that extends past anus

## Three Subphyla

Two invertebrate subphyla

1. Urochordata (tunicates)
2. Cephalochordata (lancelets)

3. Subphylum Vertebrata (the vertebrates)

Have backbone of cartilage or bone

Brain is encased in protective skull

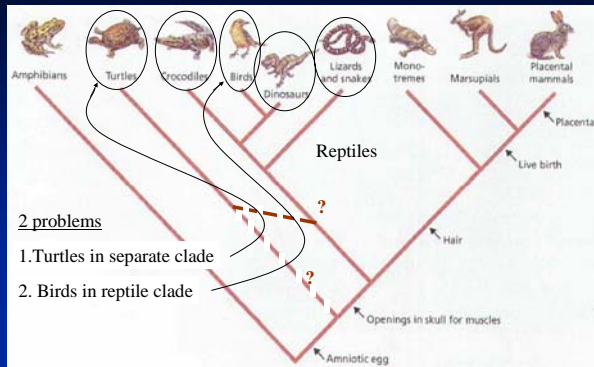
## Eight Vertebrate Classes

1. Agnatha - jawless fishes
2. Placodermi - jawed armored fishes (extinct)
3. Chondrichthyes - cartilaginous fishes
4. Osteichthyes - bony fishes

## Eight Vertebrate Classes

5. Amphibia - Amphibians
6. Reptilia - Reptiles
7. Aves - Birds
8. Mammalia - Mammals

## Recent Findings Suggest:

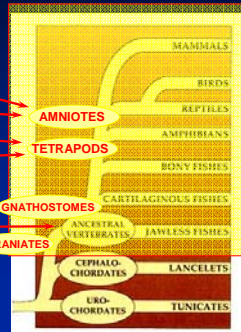


## Trends in the Evolution of Vertebrates

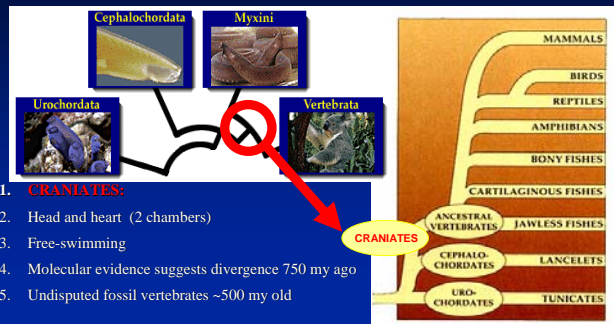
1. Shift from notochord to vertebral column
2. Nerve cord expanded into brain
3. Evolution of jaws
4. Paired fins evolved, gave rise to limbs
5. Gills evolved, gave rise to lungs

## Evolutionary Trends in Vertebrates

7. Diversity of Adaptations for land, air, and water
6. Amniotic Egg
5. Terrestrial Locomotion
4. Lungs
3. Jaws
2. Gills
1. Paired Fins



## Divergence of Cephalochordates and Vertebrates



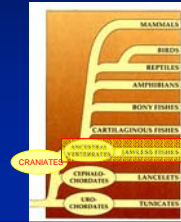
## Earliest Craniates

530 million year old *Haikouella*: transition between invertebrate and vertebrate?

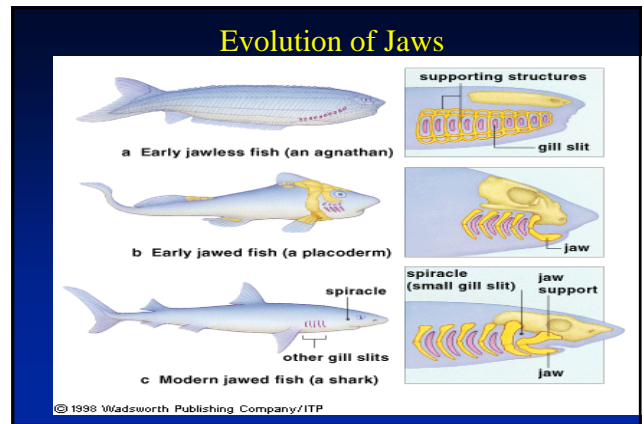
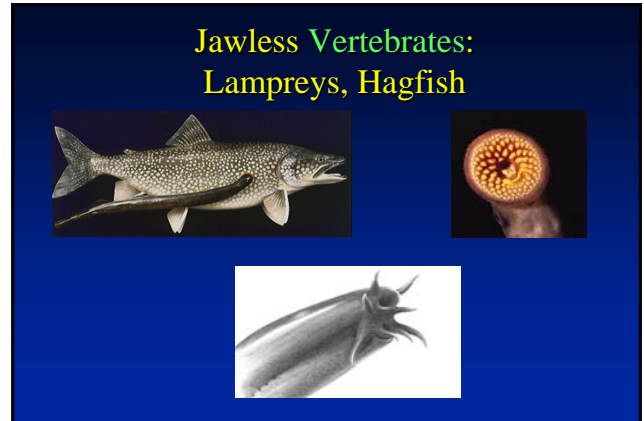
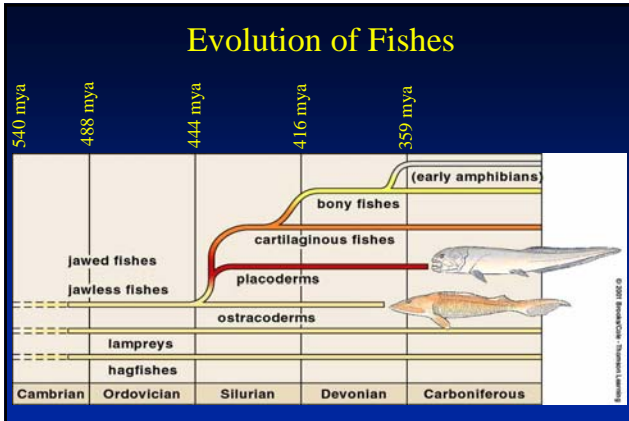


## Characteristics of Earliest Vertebrates

1. Small jawless fish
2. Bony skeleton, including vertebrae
3. Bodies completely covered with bony armor plates
4. Ate sea-floor invertebrates
5. Brain imprints reveal many "modern" brain features: forebrain, midbrain, hindbrain



Extinct "agnathan"



### Jawed Fishes

1. Most diverse and numerous group of vertebrates
2. Two classes:
  - Chondrichthyes (cartilaginous fishes)
  - Osteichthyes (bony fishes)

### Cartilaginous Fishes: Class Chondrichthyes

1. Most are marine predators
2. Cartilaginous skeleton
3. Main groups:
  - Skates and rays
  - Sharks
  - Chimaeras (ratfishes)

Subphylum Vertebrata  
Chondrichthyes

Cartilaginous fishes  
Sharks and Rays



*Carcharodon carcharias*  
white shark

Subphylum Vertebrata  
Cartilaginous fishes



*Rhinobatos productus*  
shovelnose guitarfish

Subphylum Vertebrata  
Cartilaginous fishes



**MANTA RAY**  
*Manta birostris*

**Bony Fishes:**  
**Class Osteichthyes**

1. Includes 96 percent of living fish species
2. Three subclasses:
  - Ray-finned fishes
  - Lobe-finned fishes
  - Lung fishes

Subphylum Vertebrata  
Osteichthyes

Bony fishes  
Ray-finned fishes  
"Common fishes"



*Sebastes atrovirens*  
kelp rockfish

Subphylum Vertebrata



*Amphiprion melanopus*  
red and black anemonefish

Subphylum Vertebrata



*Sebastes chrysomelas*  
black and yellow rockfish

Subphylum Vertebrata



*Sebastes miniatus*  
vermillion rockfish

Subphylum Vertebrata



*Plectorhynchus goldmani*  
sweet lips

Subphylum Vertebrata



Lutjanid  
snapper

Subphylum Vertebrata



*Sebastes serranoides*  
olive rockfish

Subphylum Vertebrata



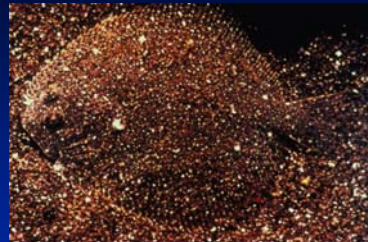
*Epinephelus tukula*  
potato cod

Subphylum Vertebrata



flatfish

Subphylum Vertebrata



camouflaged  
flatfish

Subphylum Vertebrata



porcupinefish

Subphylum Vertebrata



seahorse

Subphylum Vertebrata



*Lophius piscatorius*  
anglerfish

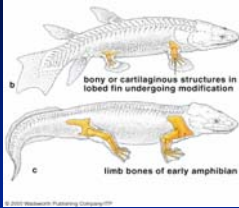
Subphylum Vertebrata



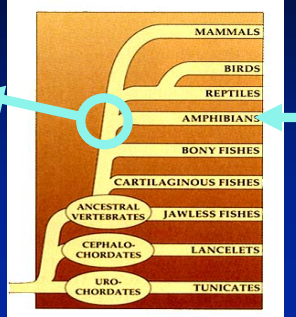
*Chauliodus sloani*  
viperfish

## TETRAPODA

### Invasion of the Land: Amphibians



- Body plan and reproductive mode between fishes and reptiles
- Eggs need water



## Evolution of Amphibians

1. Lobe-finned fishes arose during the early Devonian
2. Used their fins to travel over land from pool to pool

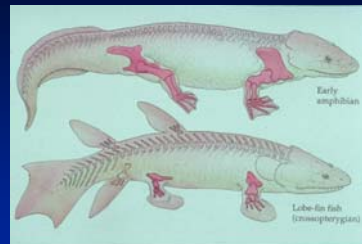


## Subphylum Vertebrata



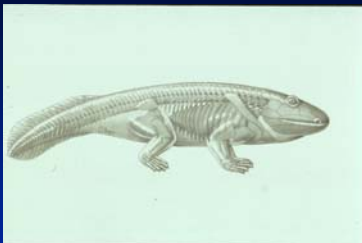
*Latimeria menadoensis*  
coelacanth

## Subphylum Vertebrata



from fish to tetrapod

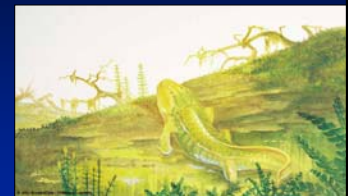
## Subphylum Vertebrata



Ichthyostega - early amphibious tetrapod

## Early Amphibians

1. Lungs became more effective
2. Chambers of the heart became partially separated, making circulation more efficient



## Modern Amphibians

1. All require water at some stage in the life cycle; most lay eggs in water
2. Lungs are less efficient than those of other vertebrates
3. Skin serves as respiratory organ

## Living Amphibian Groups

1. Frogs & Toads
2. Salamanders
3. Ceacilians



## Subphylum Vertebrata



*Ambystoma mexicanum*  
Mexican axolotl

## Subphylum Vertebrata



salamander

## Subphylum Vertebrata



frog

## Subphylum Vertebrata



frogs



## Subphylum Vertebrata



frog tadpoles

## Subphylum Vertebrata

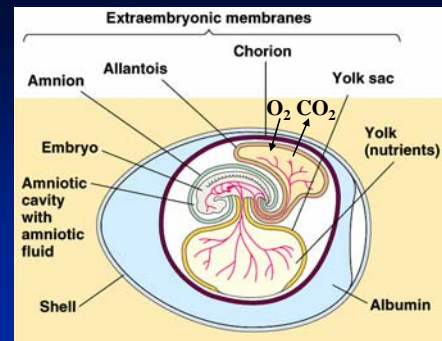


*Bufo marinus*  
cane toad

## Evolution of Reptiles

1. Reptiles arose from amphibians in the Carboniferous
2. Adaptations to life on land
  - Tough, scaly skin
  - Internal fertilization
  - Amniote eggs
  - Water-conserving kidneys

## Subphylum Vertebrata



amniotic egg

## Reptilian Radiation

1. Adaptive radiation produced numerous lineages
2. Extinct groups include:
  - Therapsids (ancestors of mammals)
  - Marine plesiosaurs & ichthyosaurs
  - Dinosaurs and pterosaurs

## Therapsids

Possess many characteristics of both reptiles and mammals



## Plesiosaurs

Up to 40 feet long



## Ichthyosaurs

Fish-like reptiles  
250 – 90 million years ago



## Living Reptiles

Four orders made it to the present day

- Crocodylians
- Turtles
- Tuataras
- Snakes and lizards

## Crocodile



## Turtles and Tortises

1. Armorlike shell
2. Horny plates instead of teeth
3. Lay eggs on land



## Lizards and Snakes

1. Largest order (95 percent of living reptiles)
2. Most lizards are insectivores with small peglike teeth
3. All snakes are carnivores with highly movable jaws



## Tuataras

1. Only two living species
2. Live on islands off the coast of New Zealand
3. Look like lizards, but resemble amphibians in some aspects of their brain and in their way of walking

## Tuatarara



*Sphenodon guentheri*

## Subphylum Vertebrata



*Varanus goanna*

## Subphylum Vertebrata



*Varanus goanna*

## Subphylum Vertebrata



blood python with  
amniotic eggs

*Python curtus brongersmai*

## Subphylum Vertebrata



*Aipysurus laevis*  
olive sea snake

## Subphylum Vertebrata



*Alligator mississippiensis*  
American alligator

## Birds: Phylum Aves

1. Only birds have feathers
2. Arose from reptilian ancestors
  - Feathers are highly modified reptilian scales



## Amniote Eggs

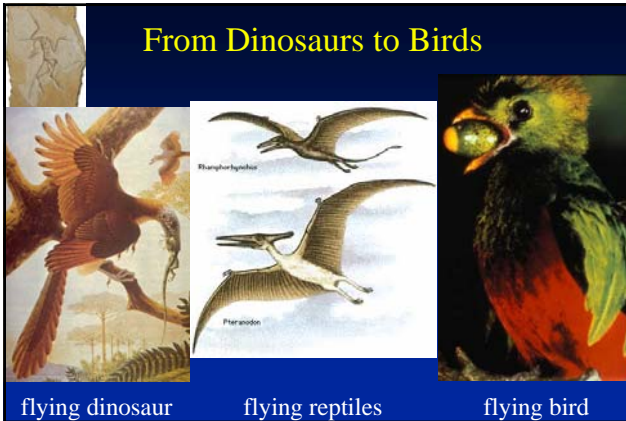
1. Like reptiles, birds produce amniote eggs
2. Inside the egg, the embryo is enclosed in a membrane called the amnion
3. Amnion protects the embryo from drying out

## Adapted for Flight

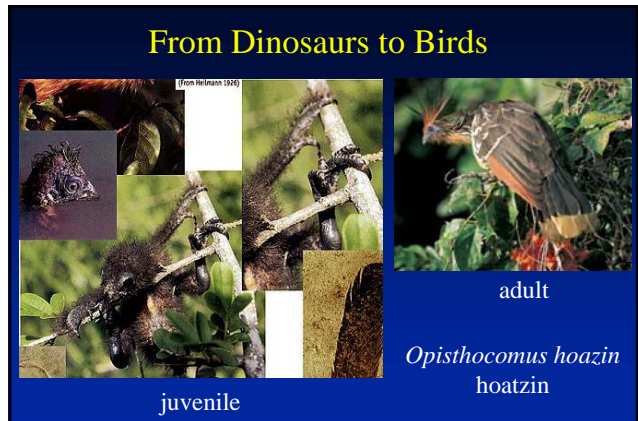
1. Four-chambered heart
2. Highly efficient respiratory system
3. Lightweight bones with air spaces
4. Powerful muscles attach to the keel



## From Dinosaurs to Birds



## From Dinosaurs to Birds



## From Dinosaurs to Birds



feathers



Scales and Feathers are Similar

scales

## Evidence that Birds are Dinosaurs

- Birds and Reptiles have scales
- Birds and Reptiles lay eggs
- Birds and Reptiles have many similar bones including hips, feet and toes

## Bird and Reptile Scales



Bird leg



Snake skin

## Bird and Reptile Feet



Owl talons

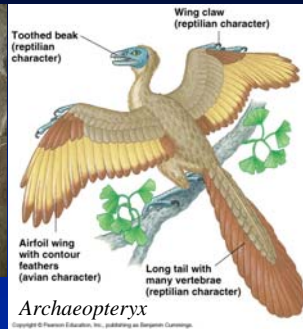


*Deinonychus*

## Dinosaurs are NOT extinct!



They are birds!



## Subphylum Vertebrata



*Alisterus scapularis*  
Australian King Parrot

## Subphylum Vertebrata



*Casuarius casuarius*  
cassowary

## Subphylum Vertebrata



*Aptenodytes patagonicus*  
King Penguin

## Subphylum Vertebrata



*Ninox boobook*  
Southern Boobook  
(Australian owl)

## Mammals: Phylum Mammalia

1. Hair
2. Mammary glands
3. Distinctive teeth
4. Highly developed brain
5. Extended care for the young



## Mammalian Origins

1. 200 million years ago, during the Triassic, synapsids gave rise to therapsids
2. Therapsids were the reptilian ancestors of mammals
3. The first mammals had evolved by the Jurassic

## The first Mammal!



*Scratchus mammalus*

## Three Mammalian Lineages

1. Monotremes
  - Egg-laying mammals
2. Marsupials
  - Pouched mammals
3. Eutherians
  - Placental mammals

## Living Monotremes

1. Three species
  - Duck-billed platypus
  - Two kinds of spiny anteater
2. All lay eggs

## Living Marsupials

1. Most of the 260 species are native to Australia and nearby islands
2. Only the opossums are found in North America
3. Young are born in an undeveloped state and complete development in a permanent pouch on mother

## Living Placental Mammals

1. Most diverse mammalian group
2. Young develop in mother's uterus
3. Placenta composed of maternal and fetal tissues; nourishes fetus, delivers oxygen, and removes wastes
4. Placental mammals develop more quickly than marsupials

## Subphylum Vertebrata



mammal

## Subphylum Vertebrata

Monotremes Marsupials Placentals



Three groupings of mammals

Subphylum Vertebrata



*Dasyus novemcinctus*  
armadillo

Subphylum Vertebrata



*Dasyus novemcinctus*  
armadillo

Subphylum Vertebrata



*Manis sp.*  
pangolin

Subphylum Vertebrata



*Loxodonta africana*  
African elephant

Subphylum Vertebrata



*Giraffa camelopardalis*  
giraffe

Subphylum Vertebrata



*Trichechus manatus latirostris*  
manatee



Subphylum Vertebrata



*Zalophus californianus*  
California sea lion



Subphylum Vertebrata



*Ailuropoda melanoleuca*  
Giant Panda

Subphylum Vertebrata



*Ursus arctos*  
brown bear

Subphylum Vertebrata



*Ursus arctos*  
grizzly bear

Subphylum Vertebrata



ocelot

Subphylum Vertebrata



jaguar

## Subphylum Vertebrata



*Trichosurus vulpecula*  
common brushtail possum

## Subphylum Vertebrata



Kangaroo and joey

## Behavior



## Subphylum Vertebrata



bat

## Subphylum Vertebrata



baby orangutan

## Earliest Primates

1. Primates evolved more than 60 million years ago during the Paleocene
2. First primates resemble tree shrews
  - Long snouts
  - Poor daytime vision

## From Primates to Humans

“Uniquely” human traits evolved through modification of traits that evolved earlier, in ancestral forms

## Hominoids

1. Apes, humans, and extinct species of their lineages
2. In biochemistry and body form, humans are closer to apes than to monkeys
3. Hominoids
  - Subgroup that includes humans and extinct humanlike species

## Trends in Lineage Leading to Humans

1. Less reliance on smell, more on vision
2. Skeletal changes to allow bipedalism
3. Modifications of hand to allow refined hand movements
4. Bow-shaped jaw and smaller teeth
5. Longer lifespan and longer period of dependency

## Adaptations to an Arboreal Lifestyle

1. During the Eocene, certain primates became adapted to life in trees
  - Better daytime vision
  - Shorter snout
  - Larger brain
  - Forward-directed eyes
  - Capacity for grasping motions

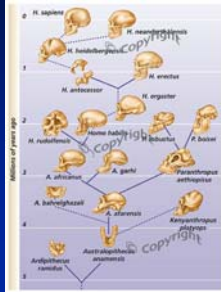
## First Hominids

1. Earliest known is *Ardipithecus ramidus*
  - Lived 4.4 million years ago in Africa
  - More apelike than humanlike
2. Numerous australopiths evolved during the next 2 million years
  - Large face, protruding jaw, small skull
  - Walked upright

## Australopiths

1. Earliest known is *A. anamensis*
2. *A. afarensis* and *A. africanus* arose next
3. All three were slightly built (gracile)
4. Species that arose later, *A. boisei* and *A. robustus*, had heavier builds
5. Exact family tree is not known

## Hominid phylogeny



## Humans Arise

1. First member of the genus *Homo* is *H. habilis*
2. Lived in woodlands during late Miocene



## *Homo erectus*

1. Evolved in Africa
2. Migrated into Europe and Asia about 1.5 million - 2 million years ago
3. Had a larger brain than *H. habilis*
4. Was a creative toolmaker
5. Built fires and used furs for clothing

## *Homo sapiens*

1. Modern man evolved by 100,000 years ago
2. Had smaller teeth and jaws than *H. erectus*
3. Facial bones were smaller, skull was larger

## *Homo Neanderthalensis*

1. Early humans that lived in Europe and Near East
2. Massively built, with large brains
3. Disappeared when *H. sapiens* appeared
4. DNA evidence suggests that they did not contribute to modern European populations

## Earliest Fossils Are African

1. Africa appears to be the cradle of human evolution
2. No human fossils older than 1.8 million years exist anywhere but Africa
3. *Homo erectus* left Africa in waves from 2 million to 500,000 years ago

## Where Did *H. sapiens* Arise?

1. Two hypotheses:
  - **Multiregional model**
  - **African emergence model**
2. Both attempt to address both biochemical and fossil evidence

## Multiregional Model

1. Argues that *H. erectus* migrated to many locations by about 1 million years ago
2. Geographically separated populations gave rise to phenotypically different races of *H. sapiens* in different locations
3. Gene flow prevented races from becoming species

## African Emergence Model

1. Argues that *H. sapiens* arose in sub-Saharan Africa
2. *H. sapiens* migrated out of Africa and into regions where *H. erectus* had preceded them
3. Only after leaving Africa did phenotypic differences between races arise

## Genetic Distance Data

