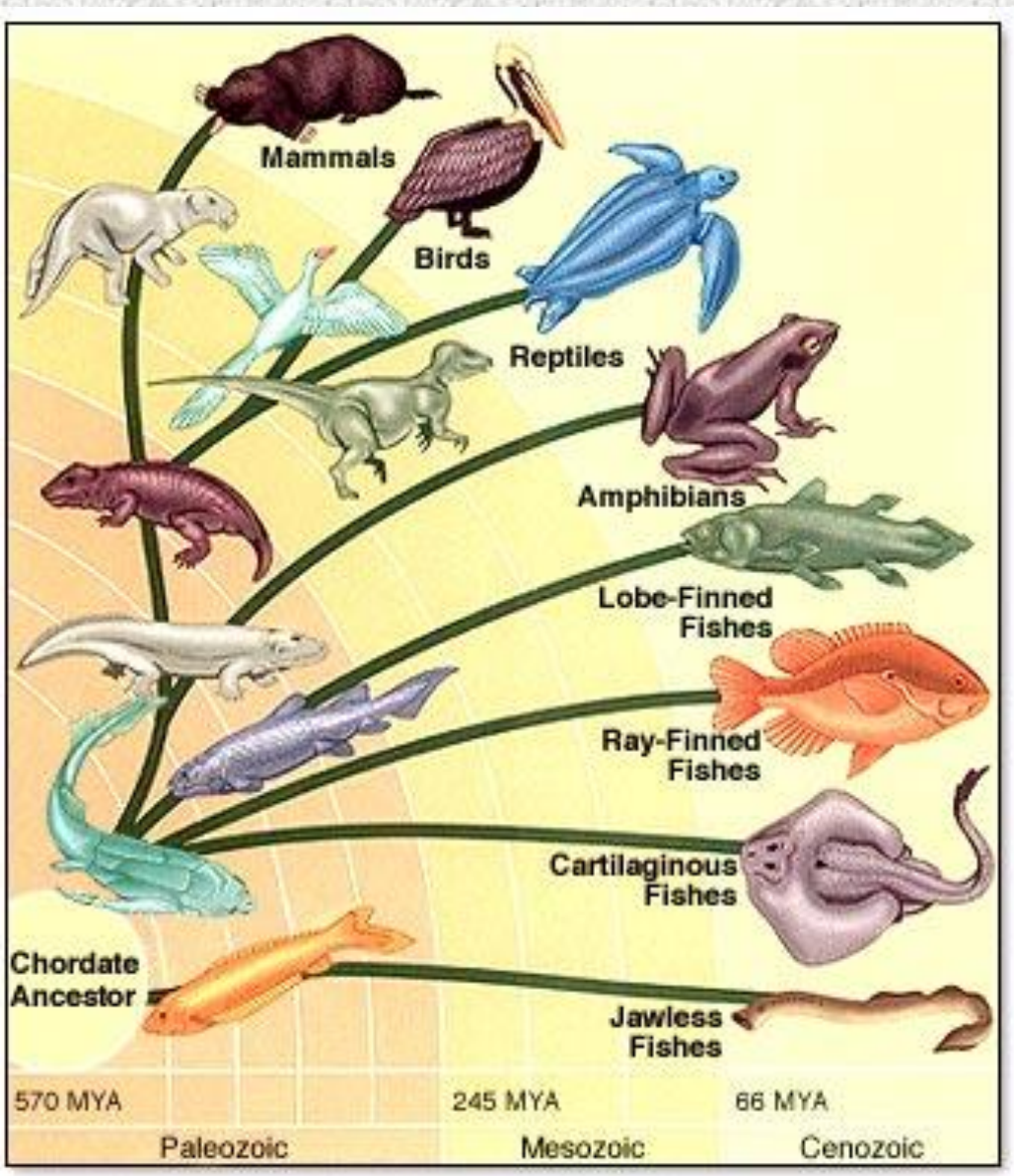
Vertebrate Diversity



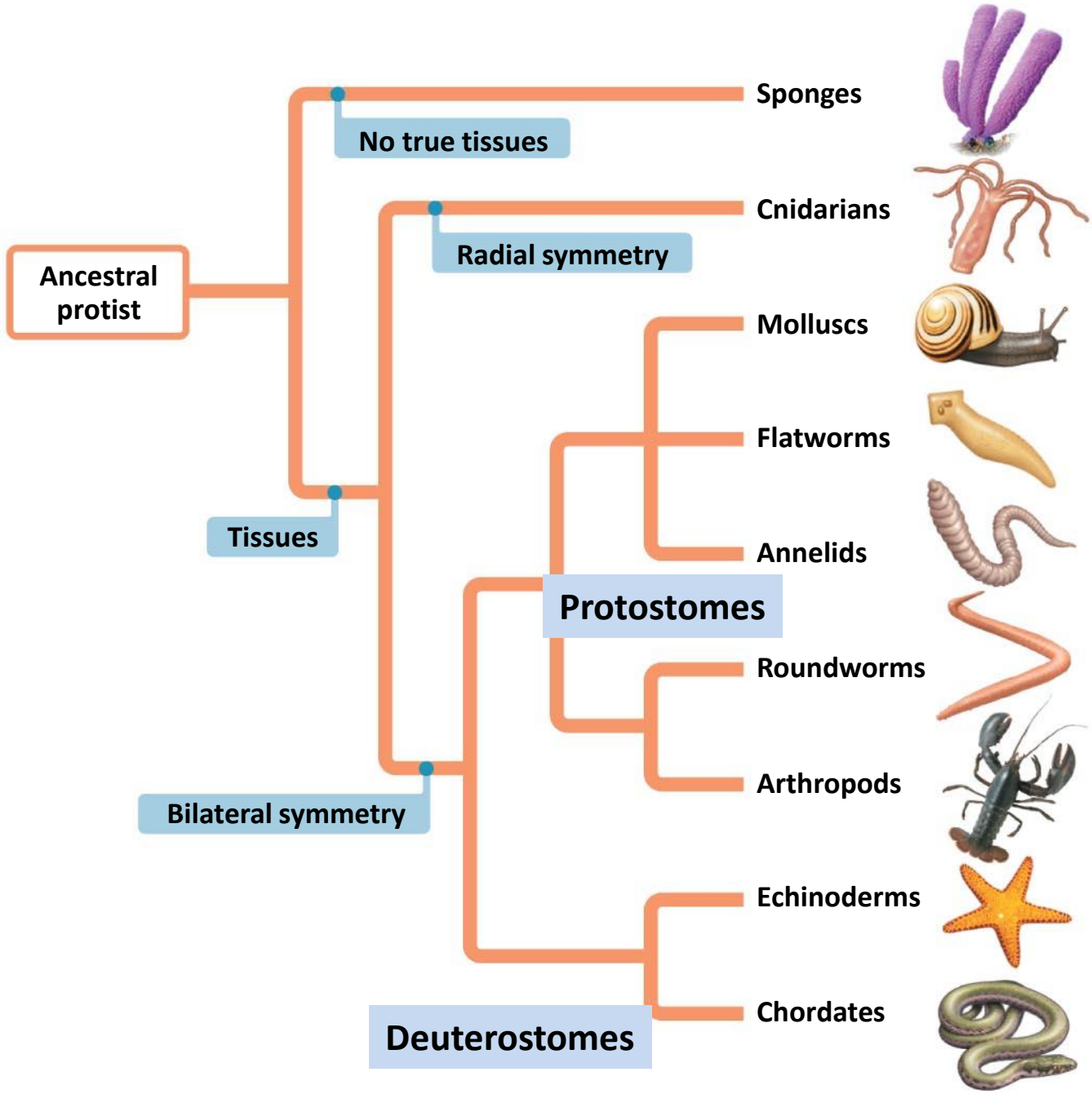


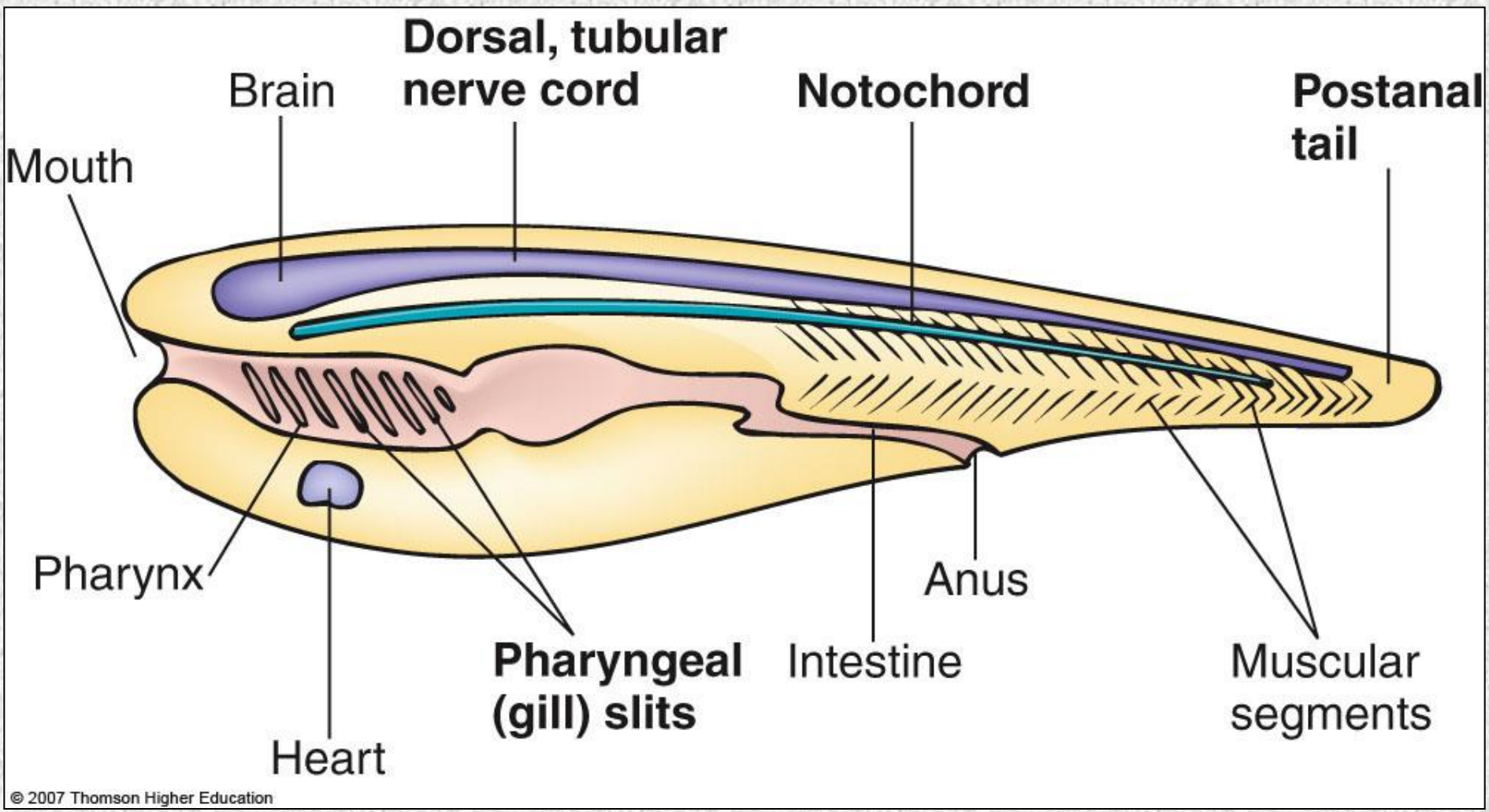
Figure 17.5

Phylum Chordata

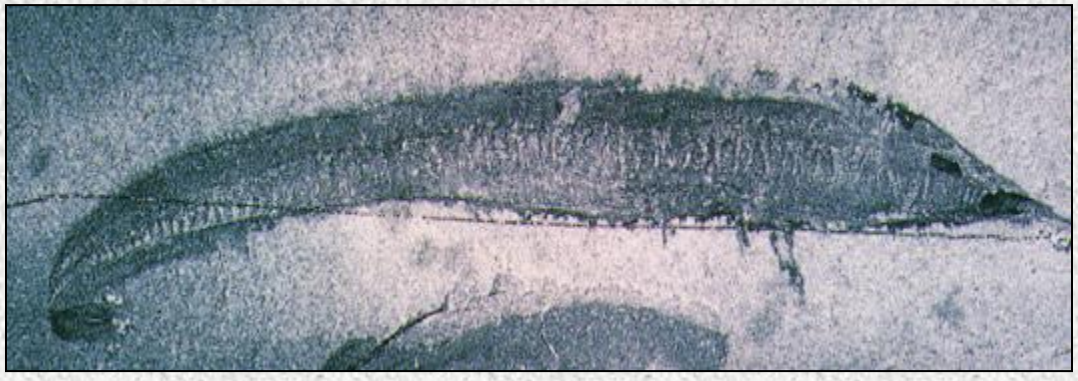
~45,000 species, 97% of them are vertebrates

1. Subphylum Urochordata (Tunicates)
2. Subphylum Cephalochordata (Lancelet)
3. Subphylum Vertebrata

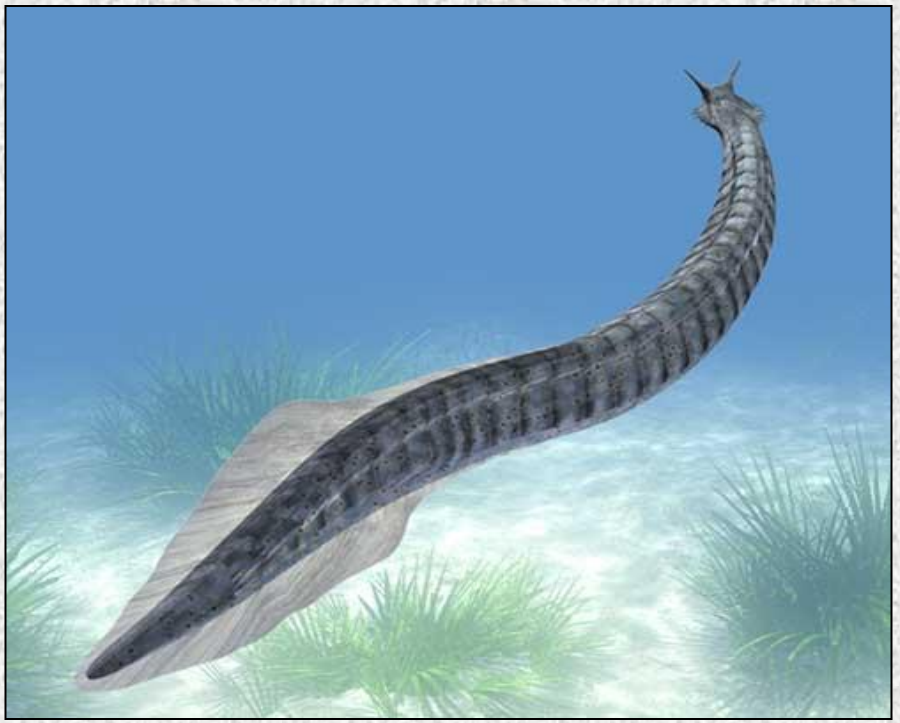
Chordate Body Plan

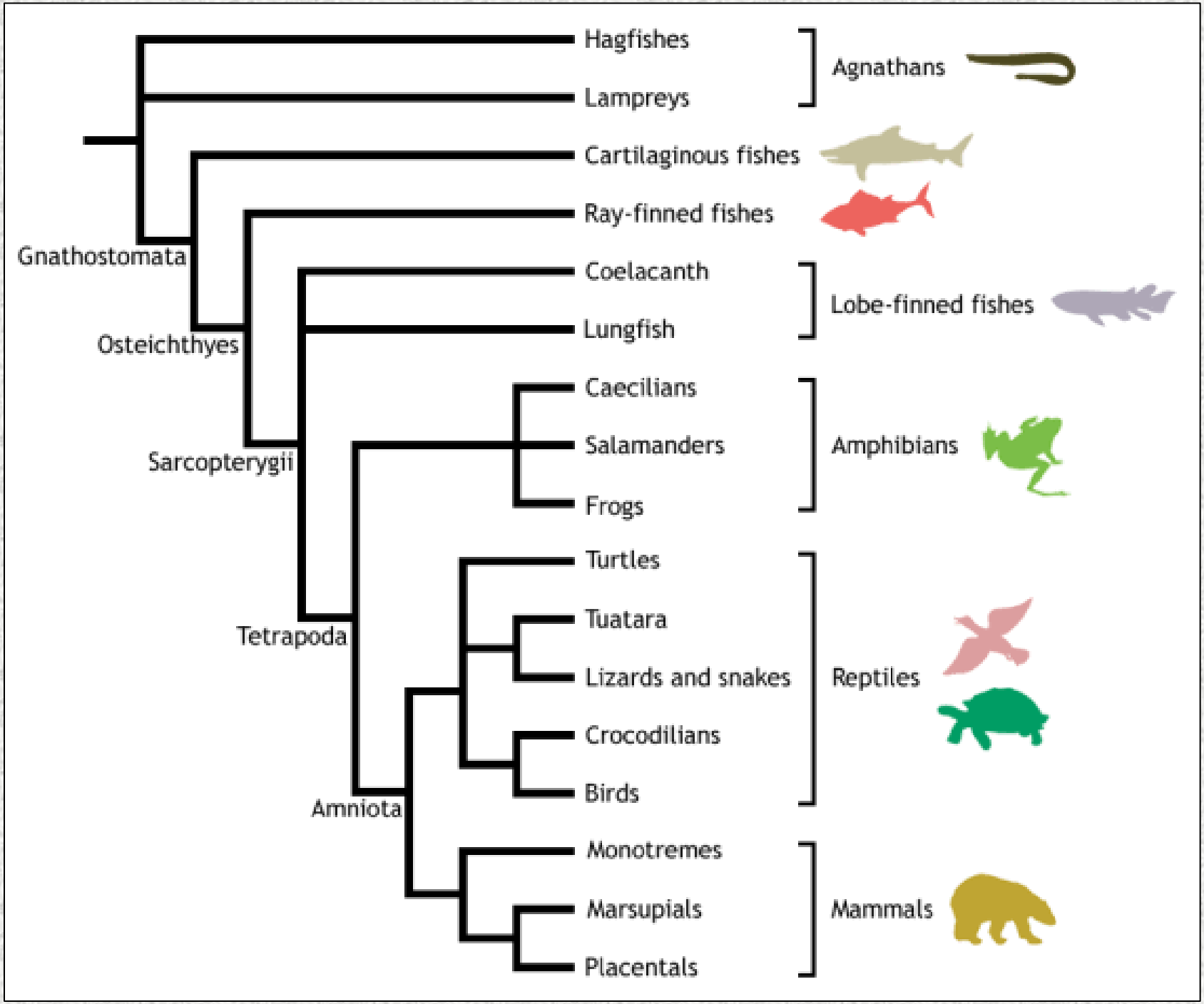


Cambrian Chordates – *Pikaia* – 550 MYA



- Not part of the arthropod lineage. Lacked segments, exoskeleton, jointed legs
- Rod running along its back resembles a backbone-like structure.
- Markings on the sides of its body formed V-shaped muscle bundles




Hagfishes
Lampreys
Agnathans
Cartilaginous fishes
Ray-finned fishes
Gnathostomata
Coelacanth
Lungfish
Lobe-finned fishes
Osteichthyes
Caecilians
Salamanders
Frogs
Amphibians
Sarcopterygii
Turtles
Tuatara
Lizards and snakes
Crocodilians
Birds
Reptiles
Tetrapoda
Amniota
Monotremes
Marsupials
Placentals
Mammals

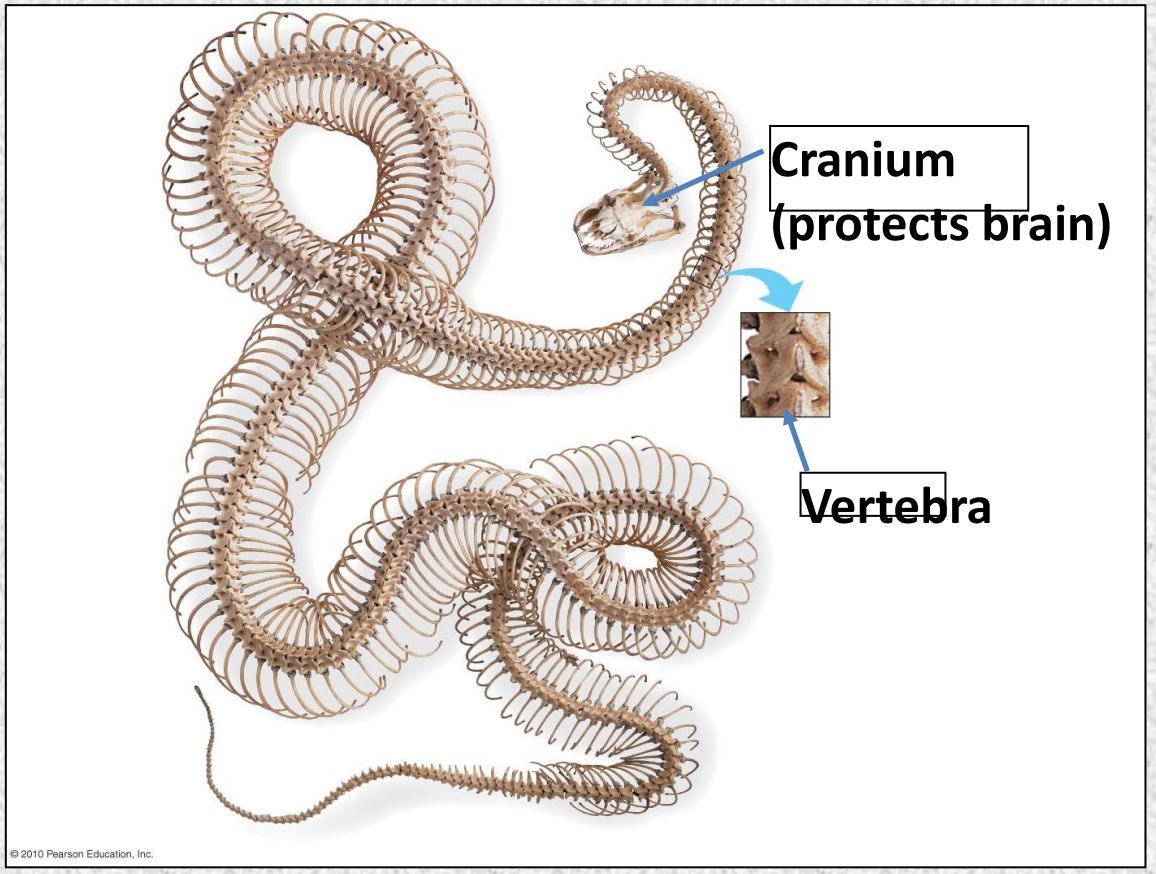
Evolutionary trends in Vertebrates

- **Internal skeleton** - skull, backbone, vertebral column.
- **Brain** - Nerve chord expanded, became better at processing information.
- **Jaws** - first jaws evolved from modified gill-supporting structures.
- **Fins** - paired, fleshy fins were starting point for arms and legs.
- **Lungs** and more efficient respiratory systems.
- **Heart** - improved circulatory system.

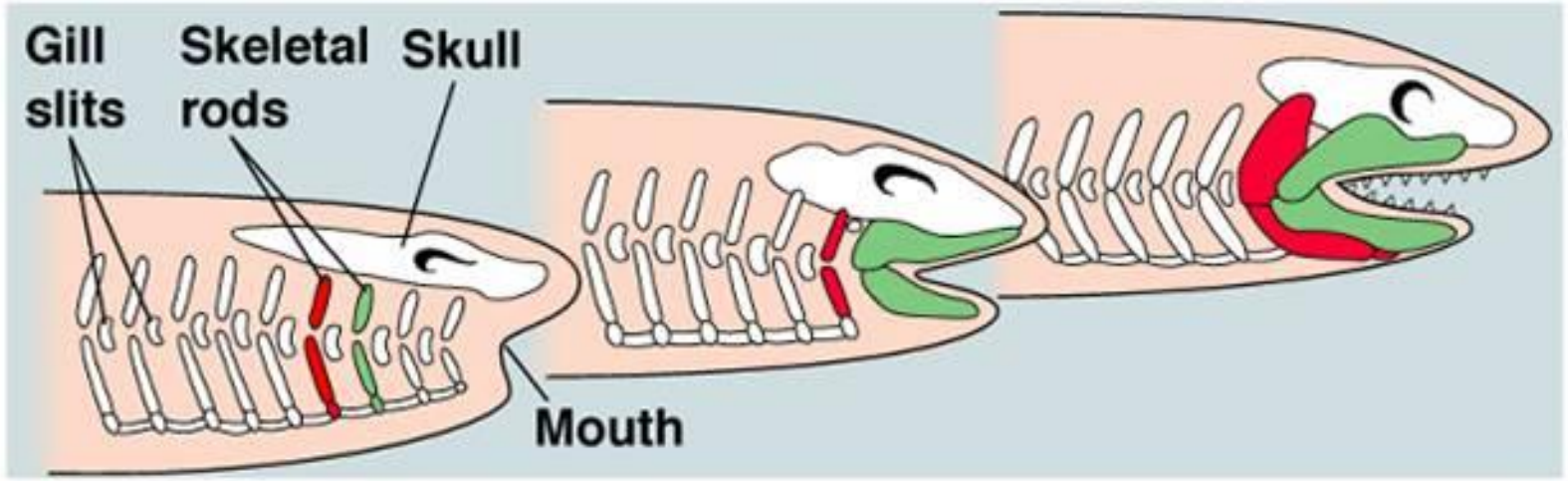
Internal Skeleton, Cranium, Vertebrae

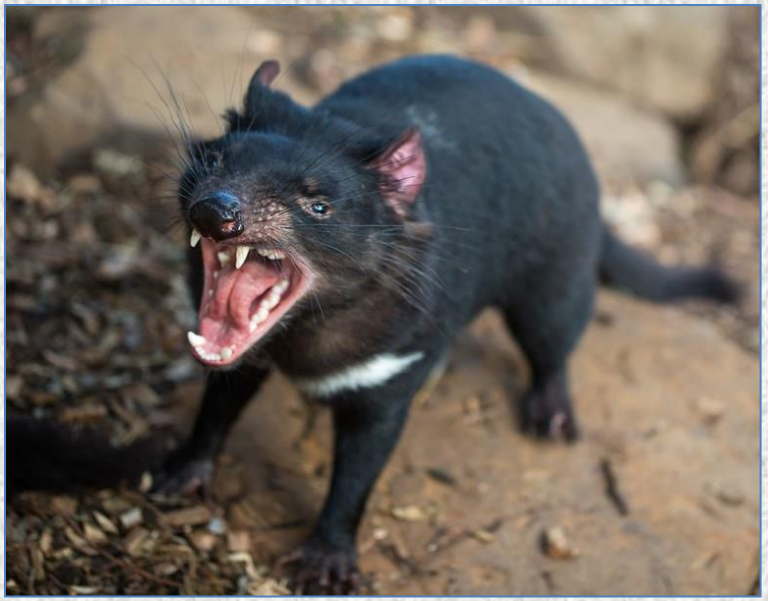
Vertebrates have unique **endoskeletons** composed of:

- A cranium (skull)
- A backbone made of a series of bones called vertebrae

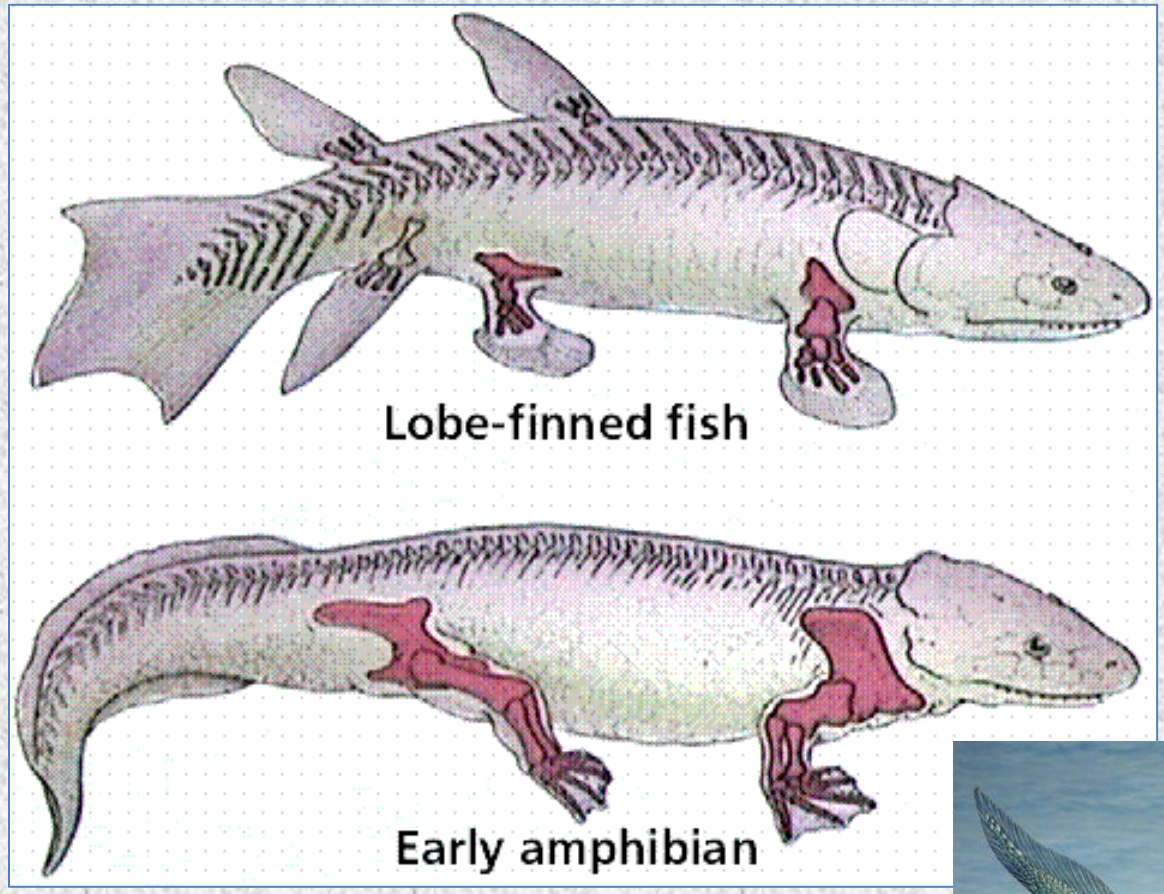


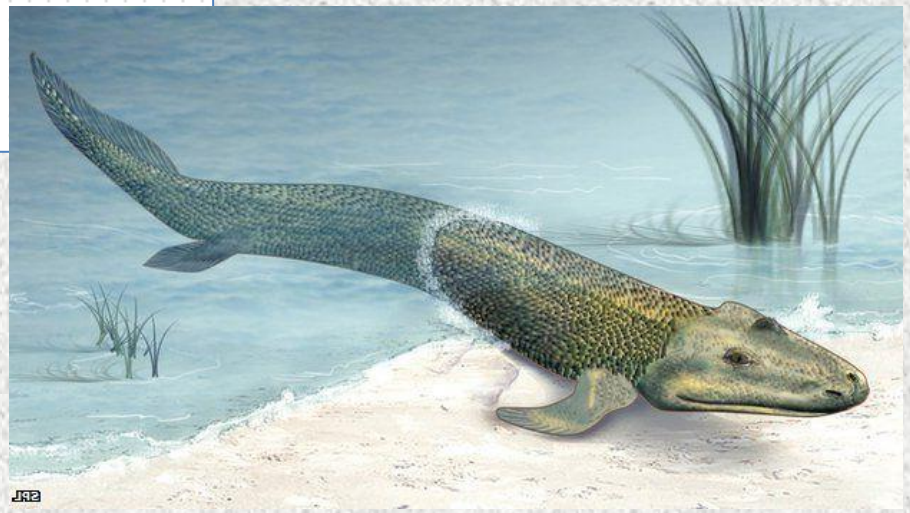
Evolution of Jaws



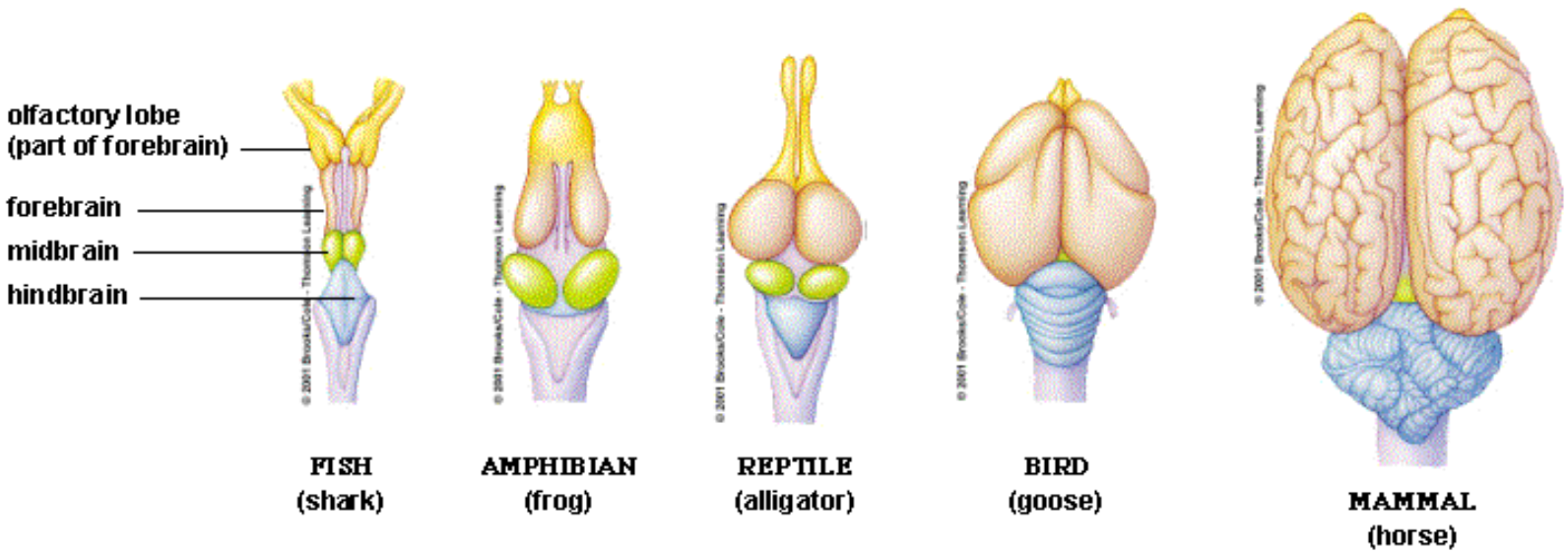


Evolution of Fins to Limbs

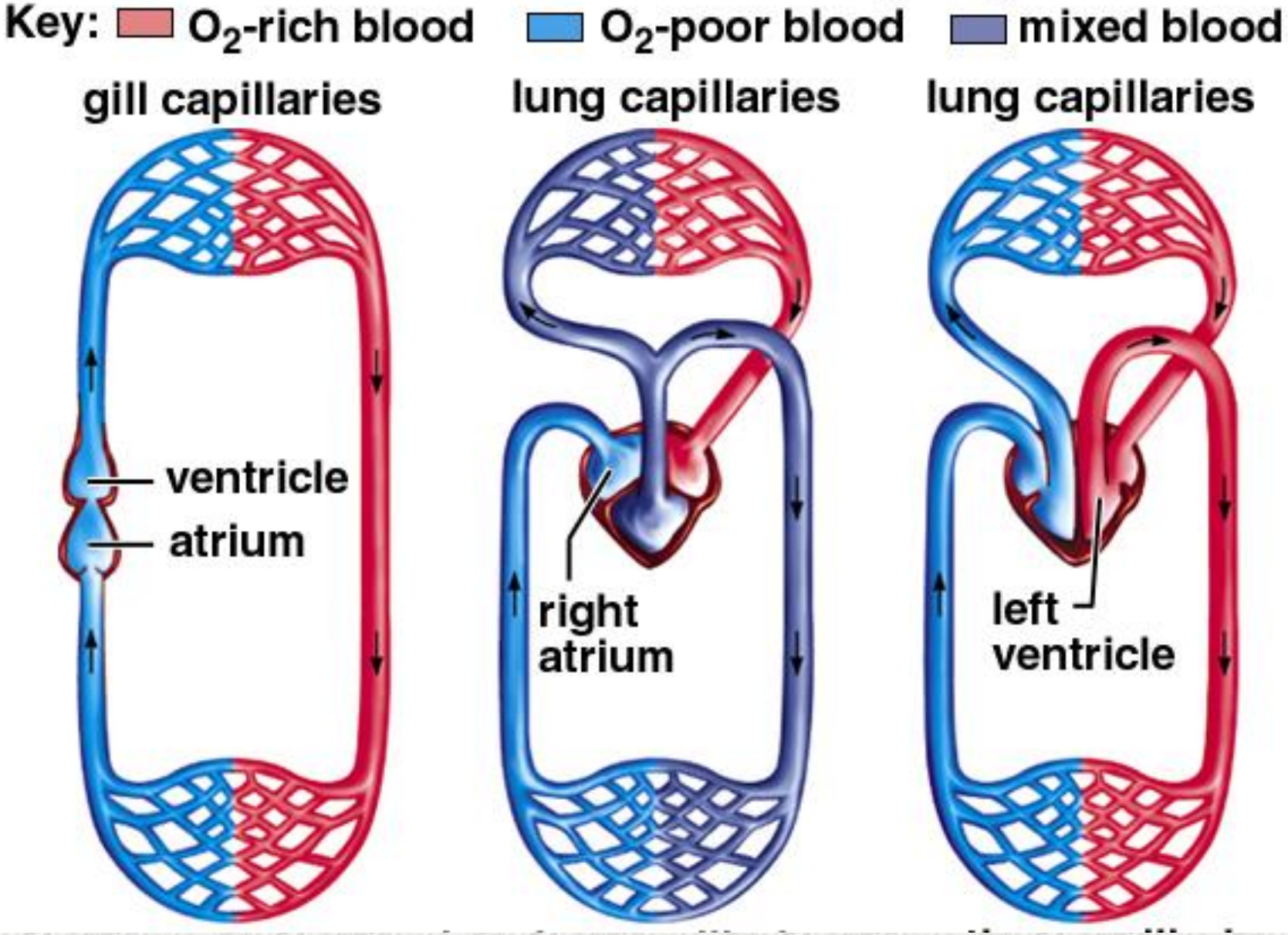




Brain Evolution



Vertebrate circulatory systems



Fish Reptiles Birds, Mammals

Major Groups of Vertebrates

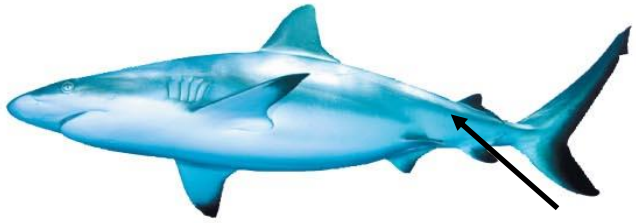
Two major groups

- Jawless vertebrates (**Agnatha**)
- Jawed vertebrates (**Gnathostomata**)

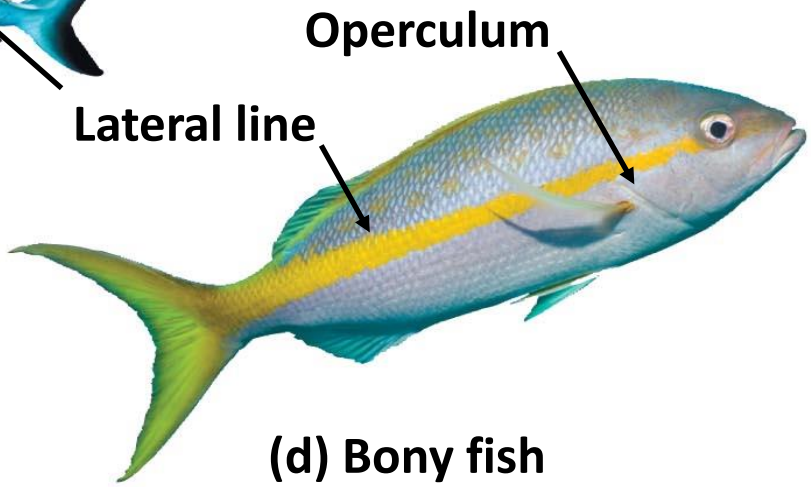
“Fish” – major groups

(a) Hagfish
(inset: slime)

(b) Lamprey
(inset: mouth)



(c) Shark, a cartilaginous fish

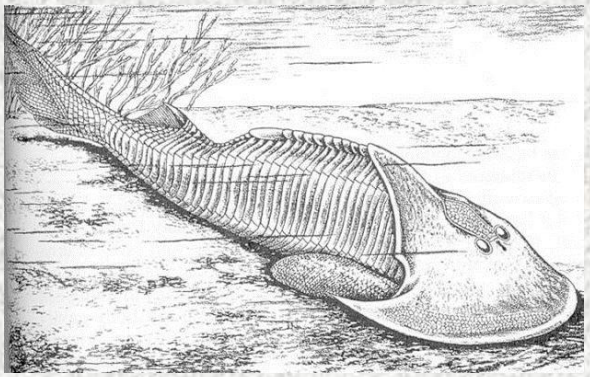


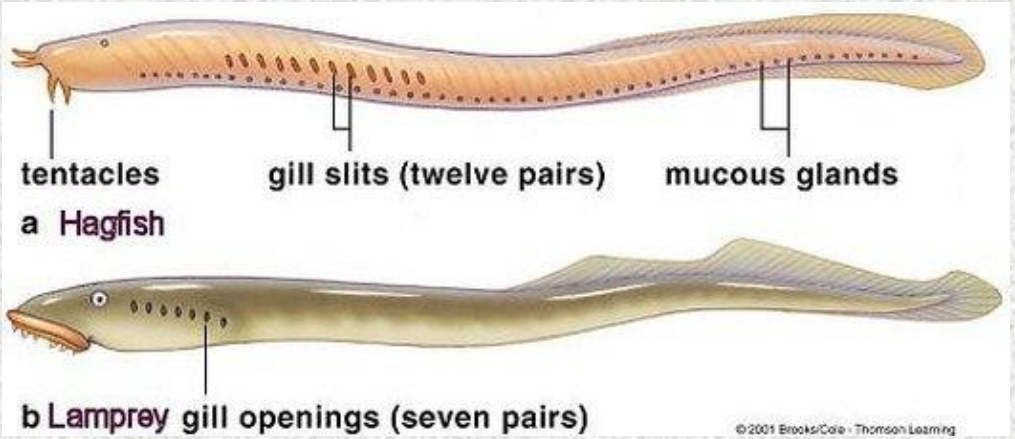
(d) Bony fish

Jawless Fishes

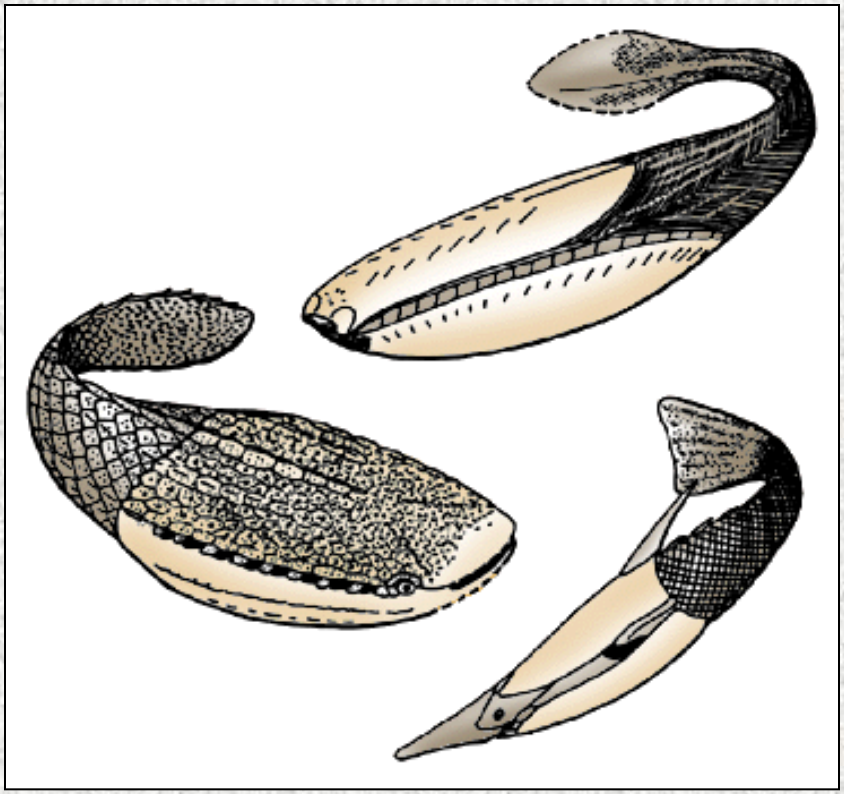
These are the most primitive vertebrates.

- Ostracoderms (extinct)
  - among earliest known vertebrates
- Hagfishes
  - class Myxini
- Lampreys
  - class Cephalaspidomorphi

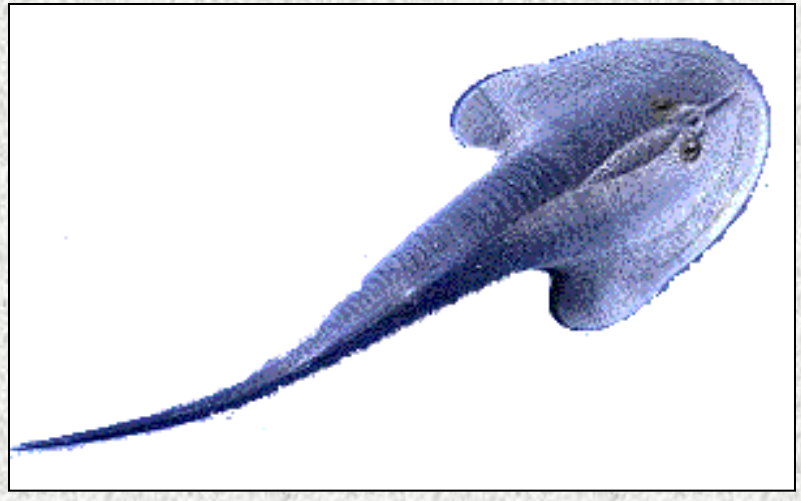




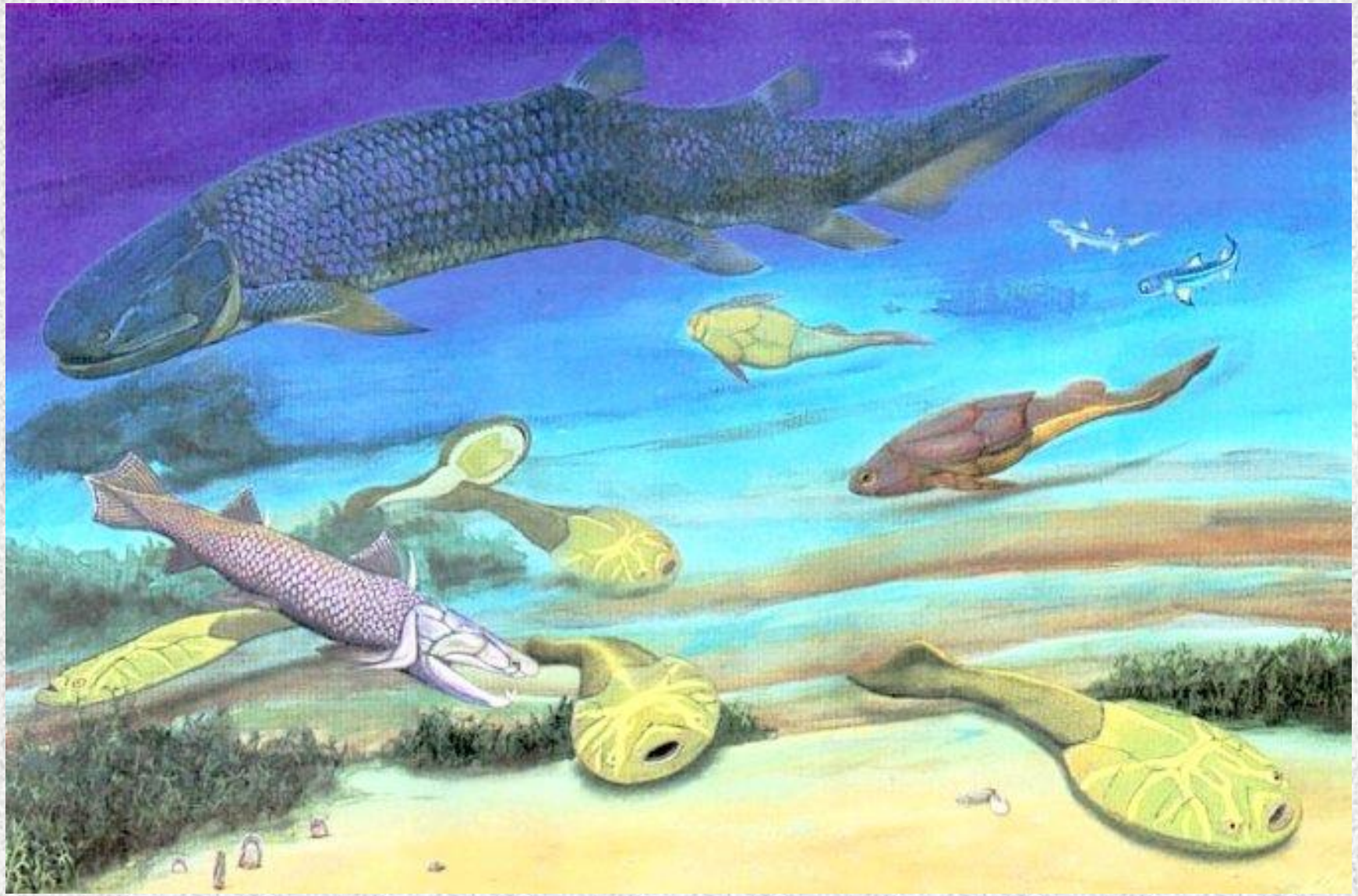
Jawless Fish (Ostracoderms)



- No paired fins
- Ate through a ‘sucker’ mouth
- Thought to be related to fish with jaws and sharks.



Devonian – “Age of Fish”



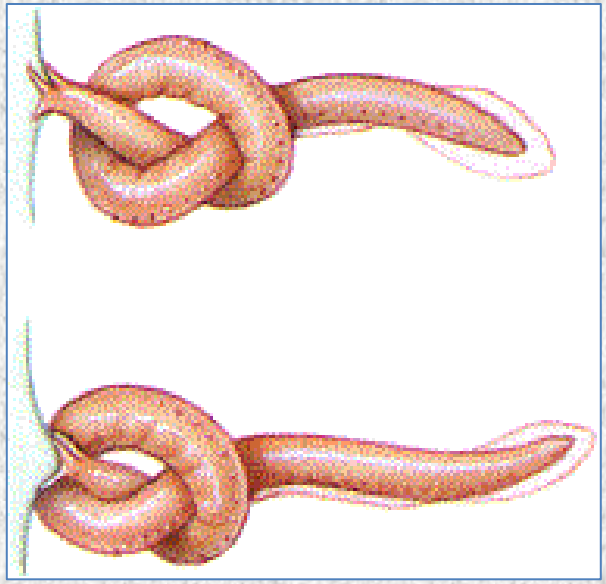
Hagfish and Lampreys

- Primitive vertebrates, least changed from the first vertebrates.
- Lacking jaws
- No paired pectoral (shoulder) or pelvic (hip) fins.
- Notochord persists for life, never being completely replaced by a backbone even in the lampreys.
- No scales.
- The axons of their neurons are unmyelinated (like those of all invertebrates).

Hagfish

Hagfishes

- Marine group, primarily scavengers.
- No trace of vertebrae
- Use keen sense of smell to find dead or dying fish, rasp off flesh using their toothed tongue.
- Gain leverage by knotting themselves and bracing themselves against whatever they're pulling.



Hagfishes

- Hagfishes have a remarkable (and revolting) ability to generate enormous quantities of slime, which they do to defend themselves from predators.
- A single individual can fill a bucket with slime.

Hagfish) feeding
https://www.youtube.com/watch?v=tKTRv3hx1s0

Very slimy hagfish
https://www.youtube.com/watch?v=BcsG8DYWx5M

Eaten alive from the inside (Ugly hagfish Pt 1)
https://www.youtube.com/watch?v=6DlWftios0s

Lamprey - The Forgotten Fish
https://www.youtube.com/watch?v=_tTaWJdOPzk

Lampreys

Figure 24.04

Lampreys

Lampreys

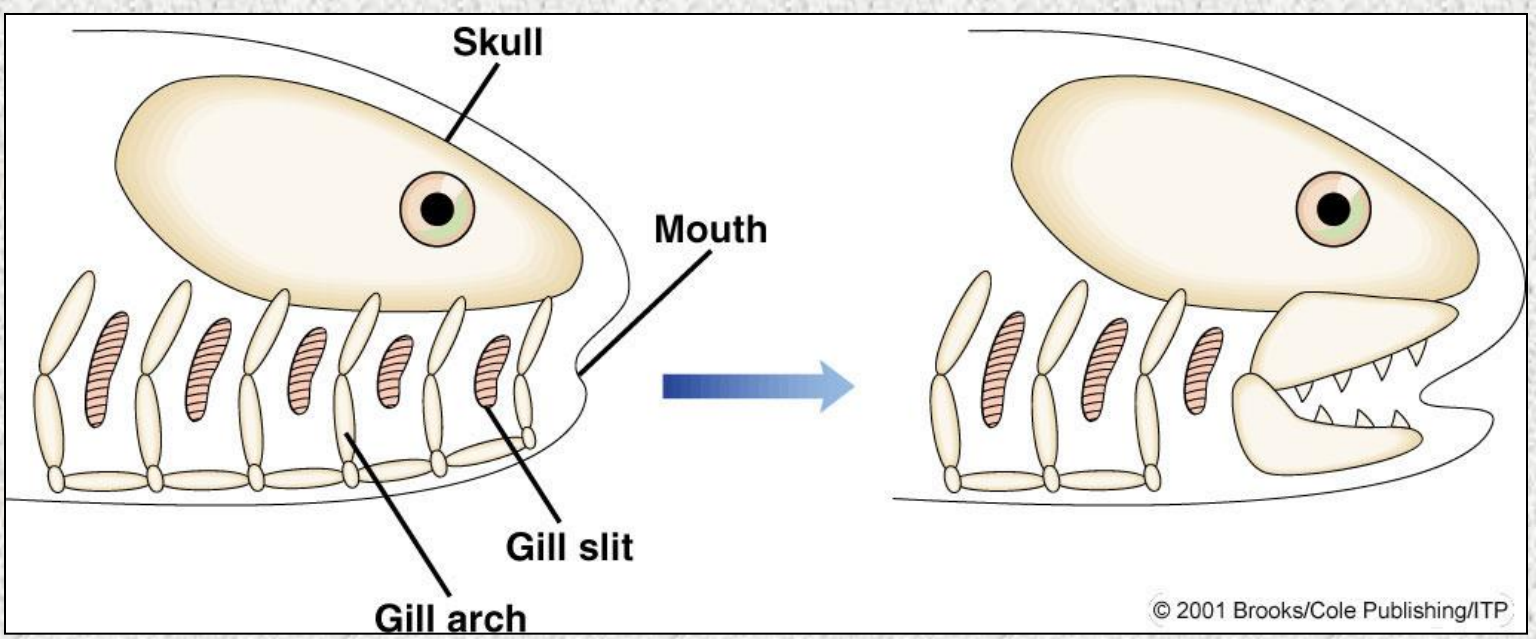
- Parasitic lampreys have a sucker-like mouth, attach to fish and rasp away at them with their keratinized teeth.

- The lamprey produces an anticoagulant as it feeds to maintain blood flow. When it is full the lamprey detaches, but the open wound on the fish may kill it. At best the wound is unsightly and largely destroys the fish's commercial value.

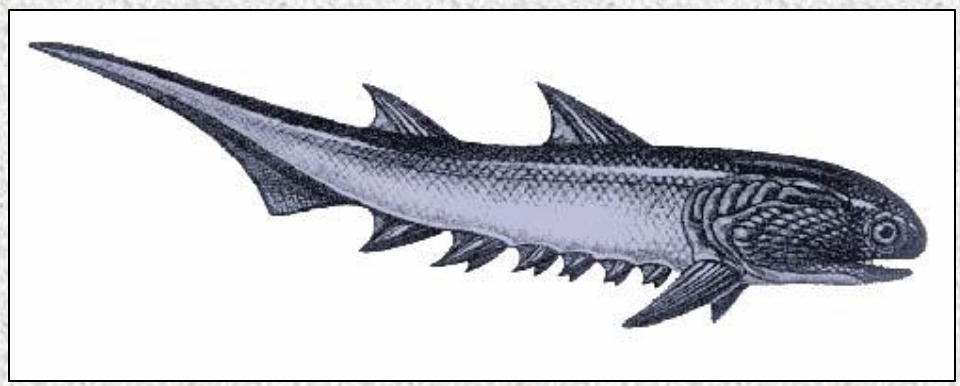
Lampreys

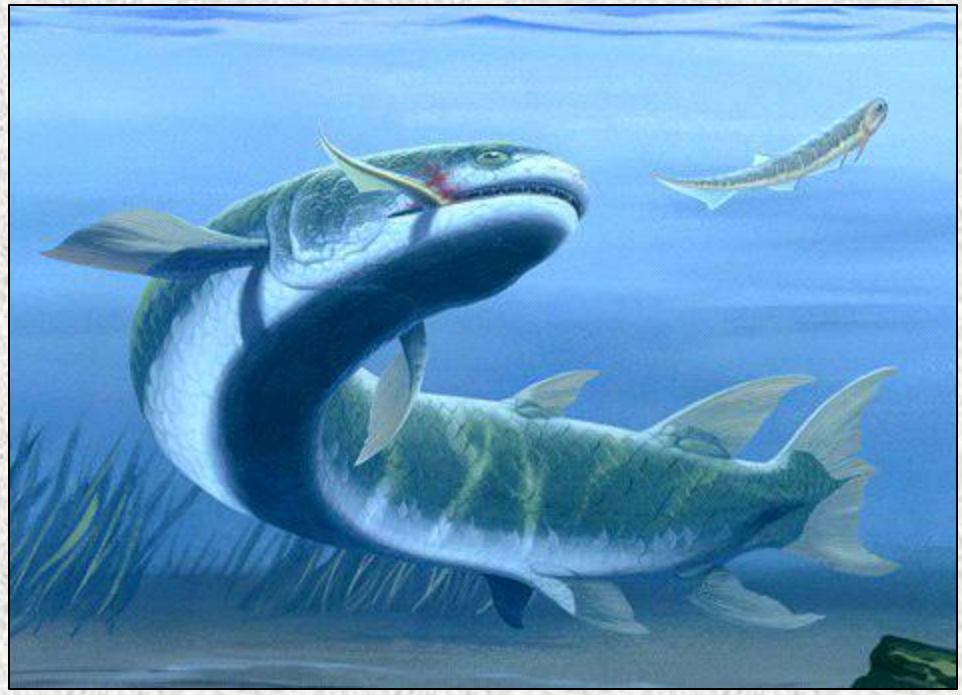
Evolution of Jaws

- The evolution of the vertebrate jaw
  - 410 MYA, close of Silurian
  - modification of the first two or three anterior gill arches
- Made fish more efficient predators



Early Jawed Fish – “Spiny Sharks”



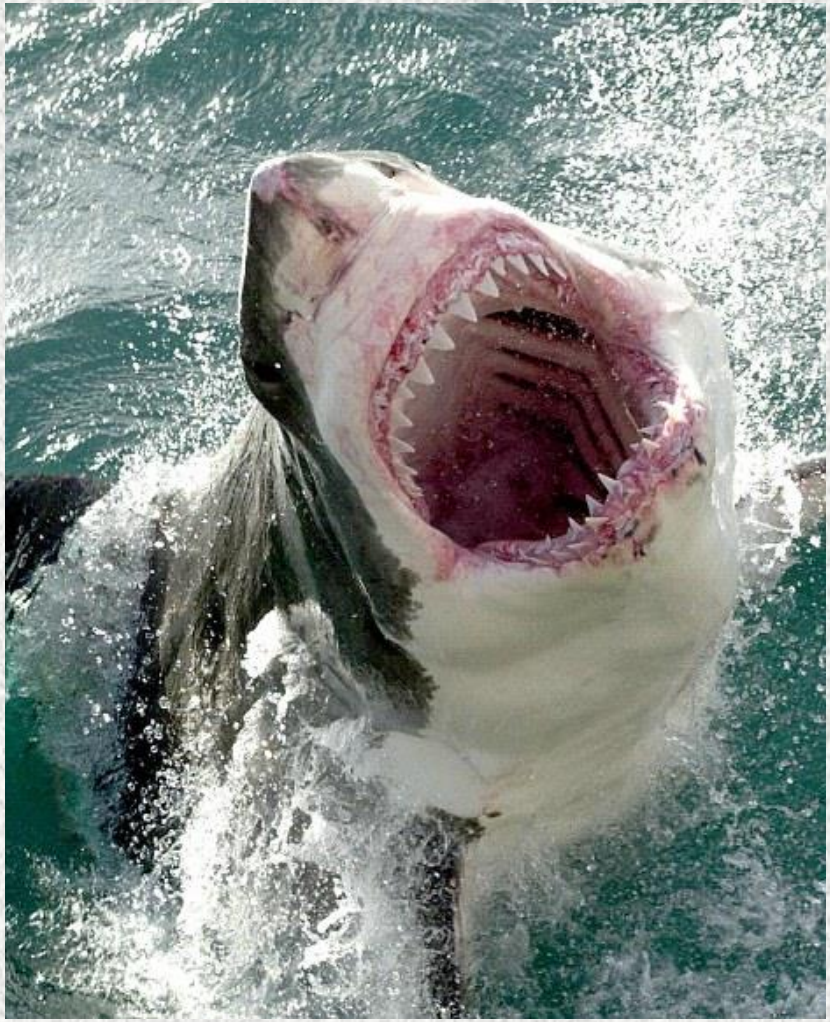


- Fresh and Marine
- Fins supported by sharp spines
- Jaws with teeth
- Paired fins
- Scales cover body
- Died out in Permian

Dunkleosteus

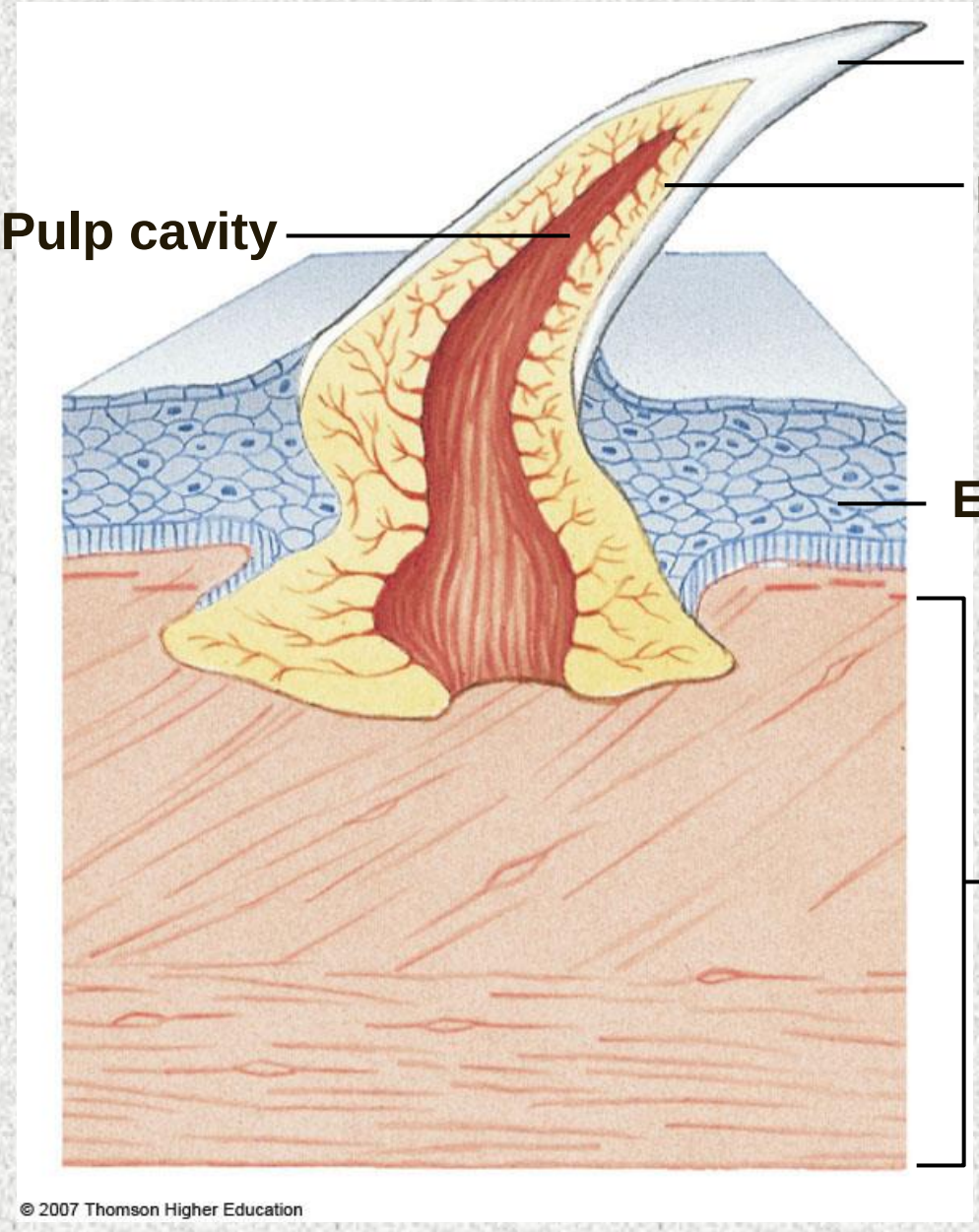
7 m long armored fish (Placoderms)

Teeth in sharks originate from modified placoid scales



Teeth in Sharks

Teeth in Sharks - Structure of a placoid scale

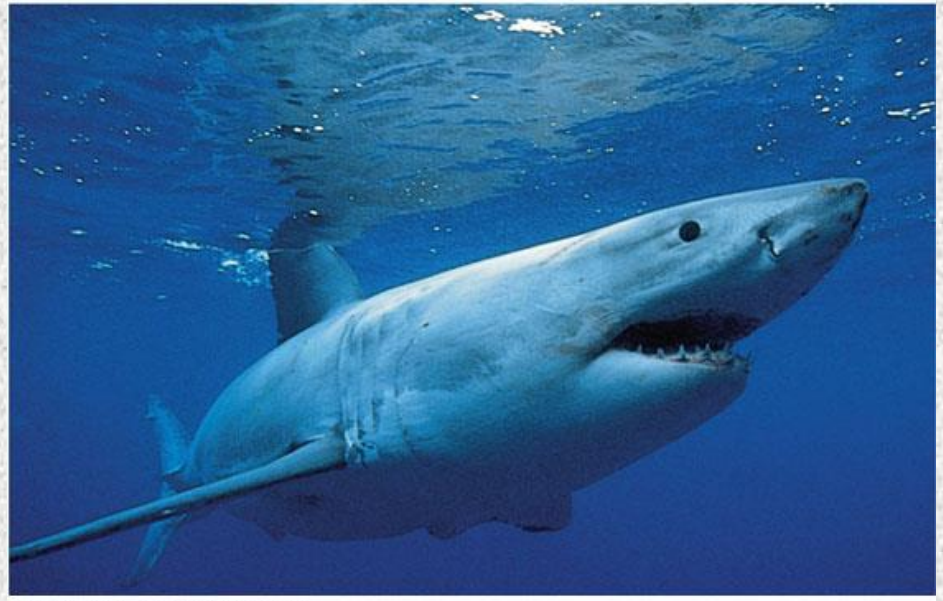


Two major groups of living fishes:

- **Cartilaginous fishes** (sharks and rays) with a flexible skeleton made of cartilage
- **Bony fishes** with a skeleton reinforced by hard calcium salts
  - **Ray-finned fishes**
  - **Lungfishes**
  - **Lobe-finned fishes**

Cartilaginous Fishes

- Skates
- Rays
- Sharks

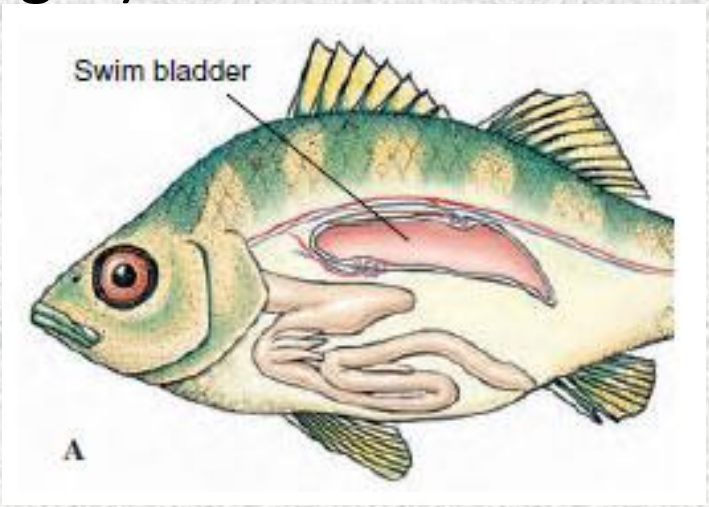


Cartilaginous fishes have:

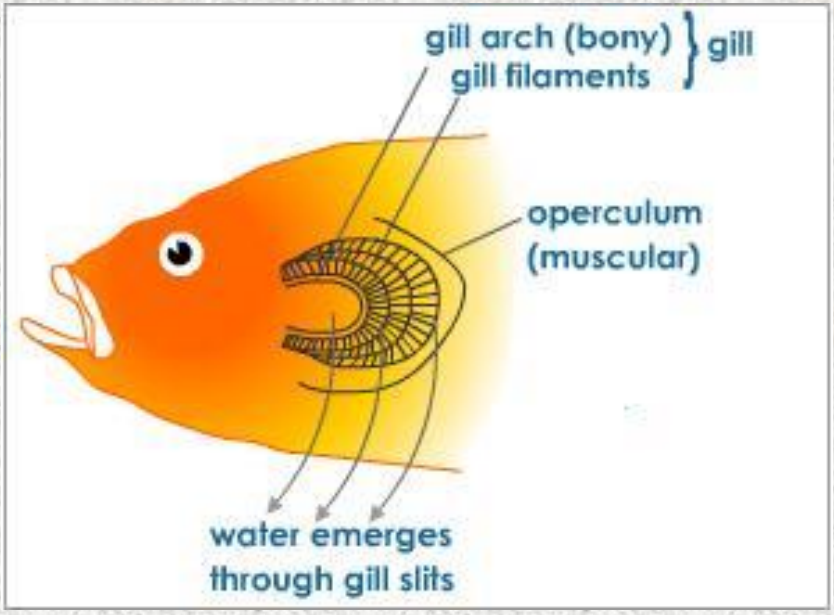
- Skeleton made of cartilage (but probably derived from boney ancestors)
- Two pairs of fins
- Jaws
- Placoid scales, derived from dermis
- No operculum to breathe, must keep moving

Ray Finned Bony Fish

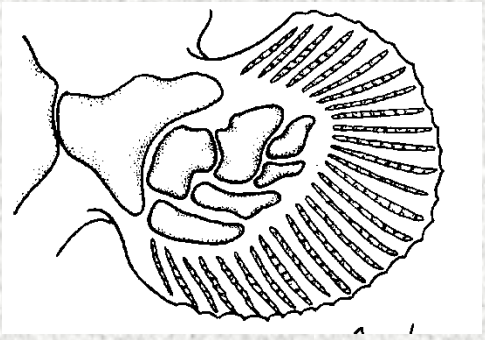
- Recent radiation - 65 million years ago
- By far most diverse class
- Skeleton of calcium fortified bones
- Swim bladder in most species (detached from gut)



Operculum covering gills - bony covering overlying gill slits



Lobe-fin Fish

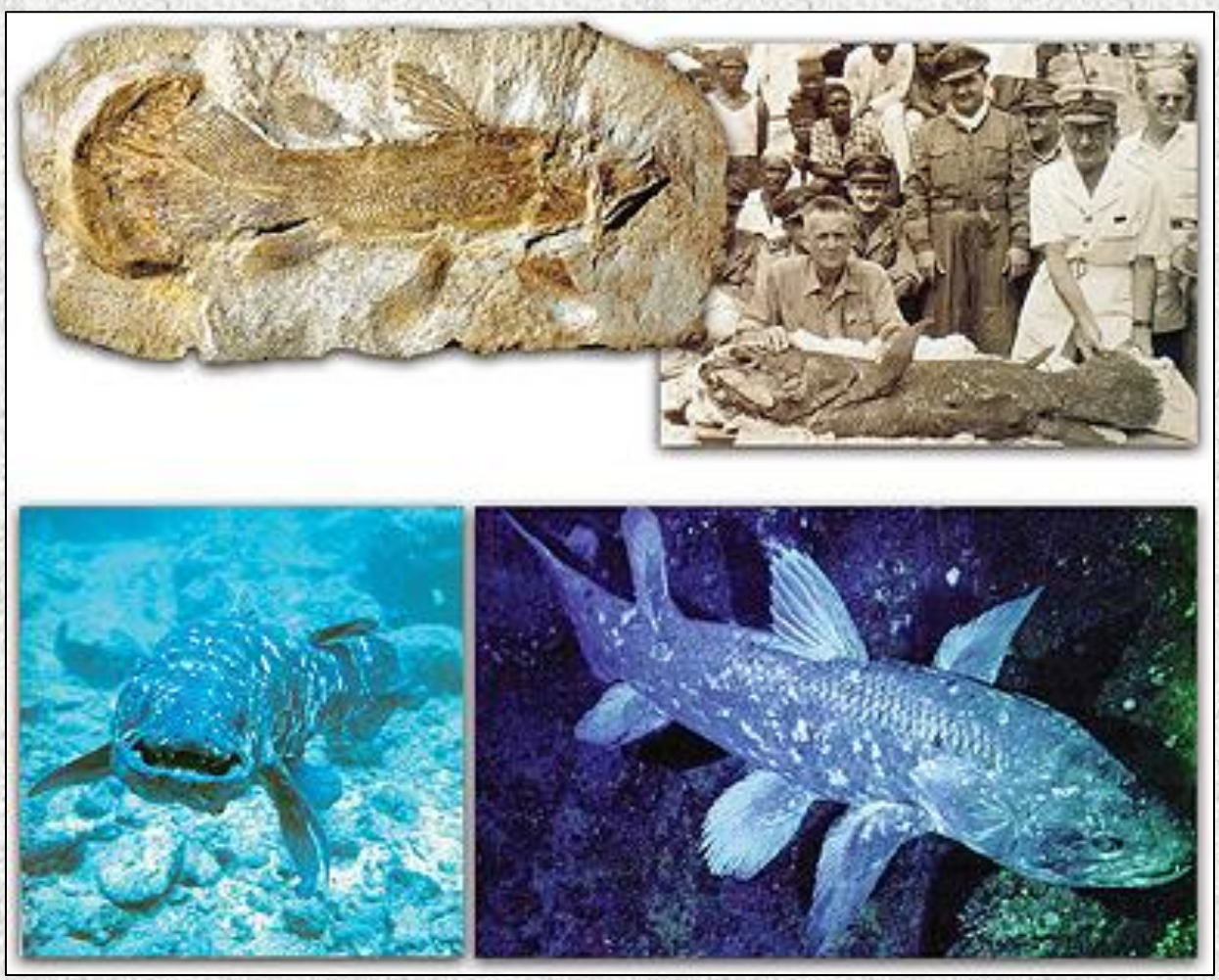


Paired, lobed fins
Swim bladders used as “lungs”

African Lung Fish
Fossil Coelacanth, but still living

Living Fossils – Transitional Forms

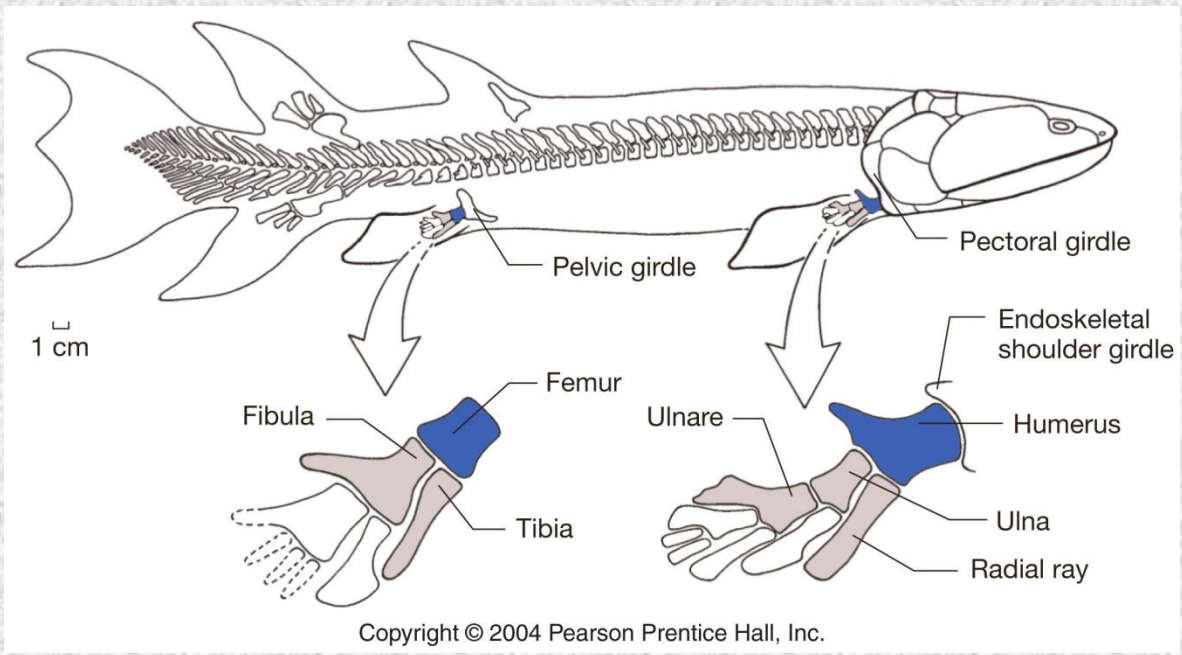
Coelacanth - a rare type of lobe-finned fish that closely resembles fossils from 400 Million years ago was discovered in 1938 off Madagascar, Comoros, and later in Indonesia. Transitional to tetrapods.

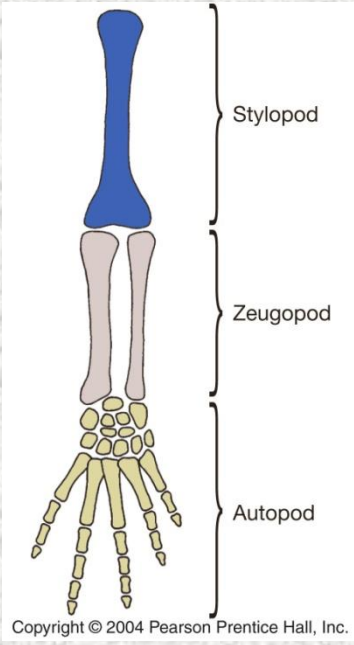


Lungfish

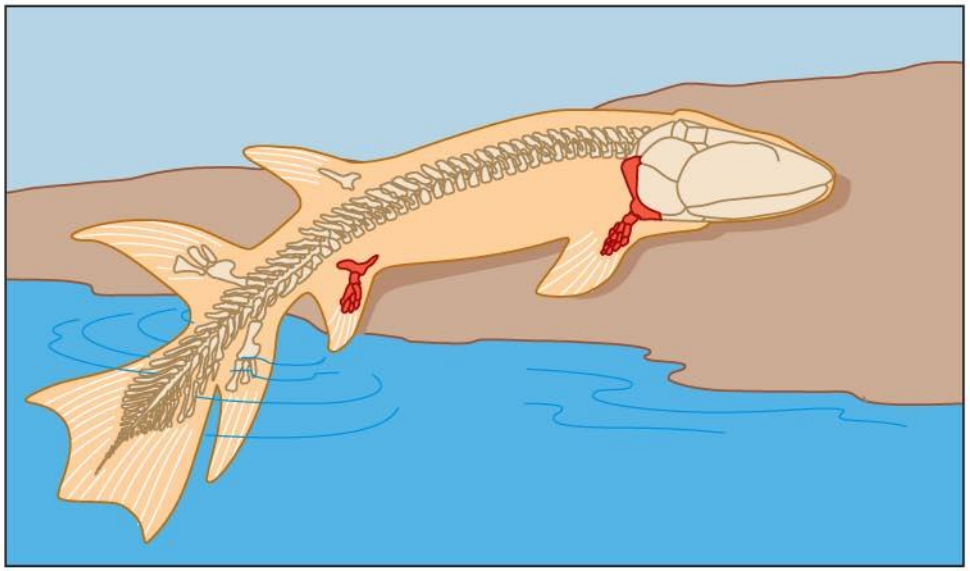
- Lateral fins, fleshy lobes
- Paired lungs, breathe air
- In warm waters - not as much dissolved oxygen
- During droughts they make cocoon, can survive 2 years

Lobe-finned fish and the tetrapod limb

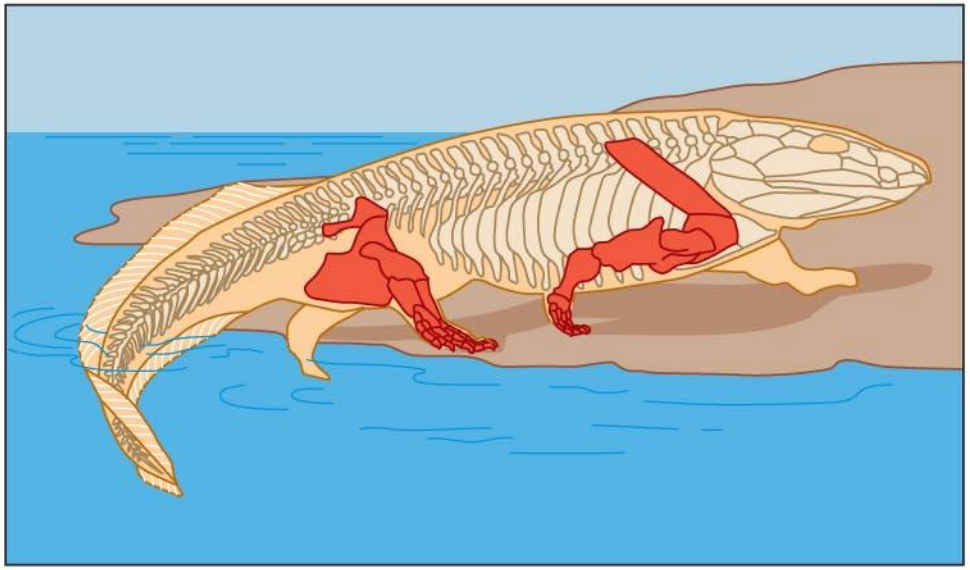




- *Eusthenopteron,* a lobe-finned fish from the Devonian (409-354 mya)



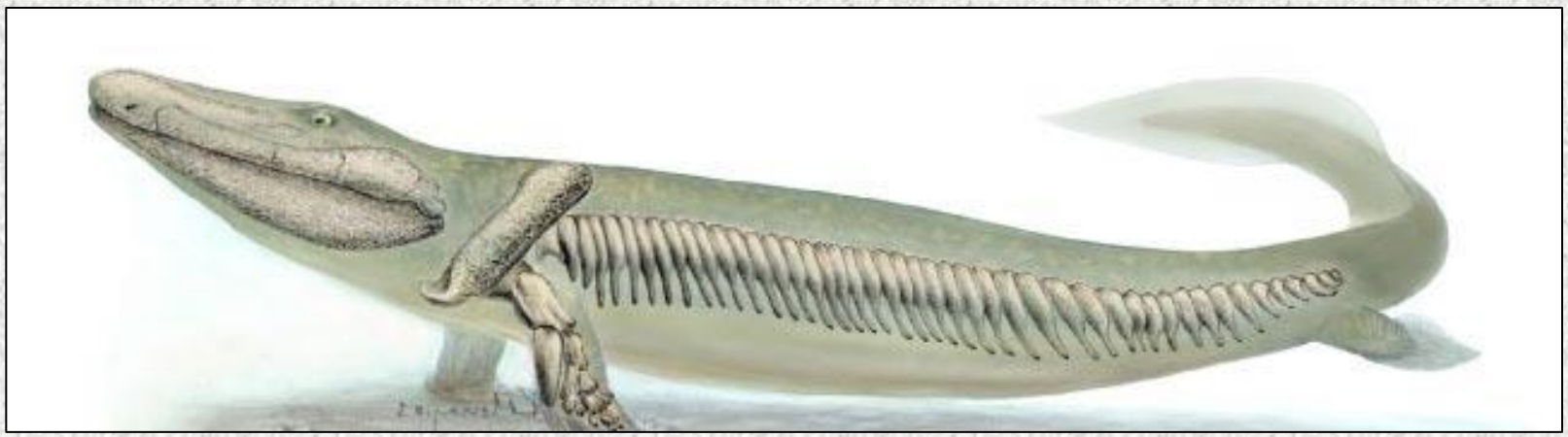
Lobe-finned fish

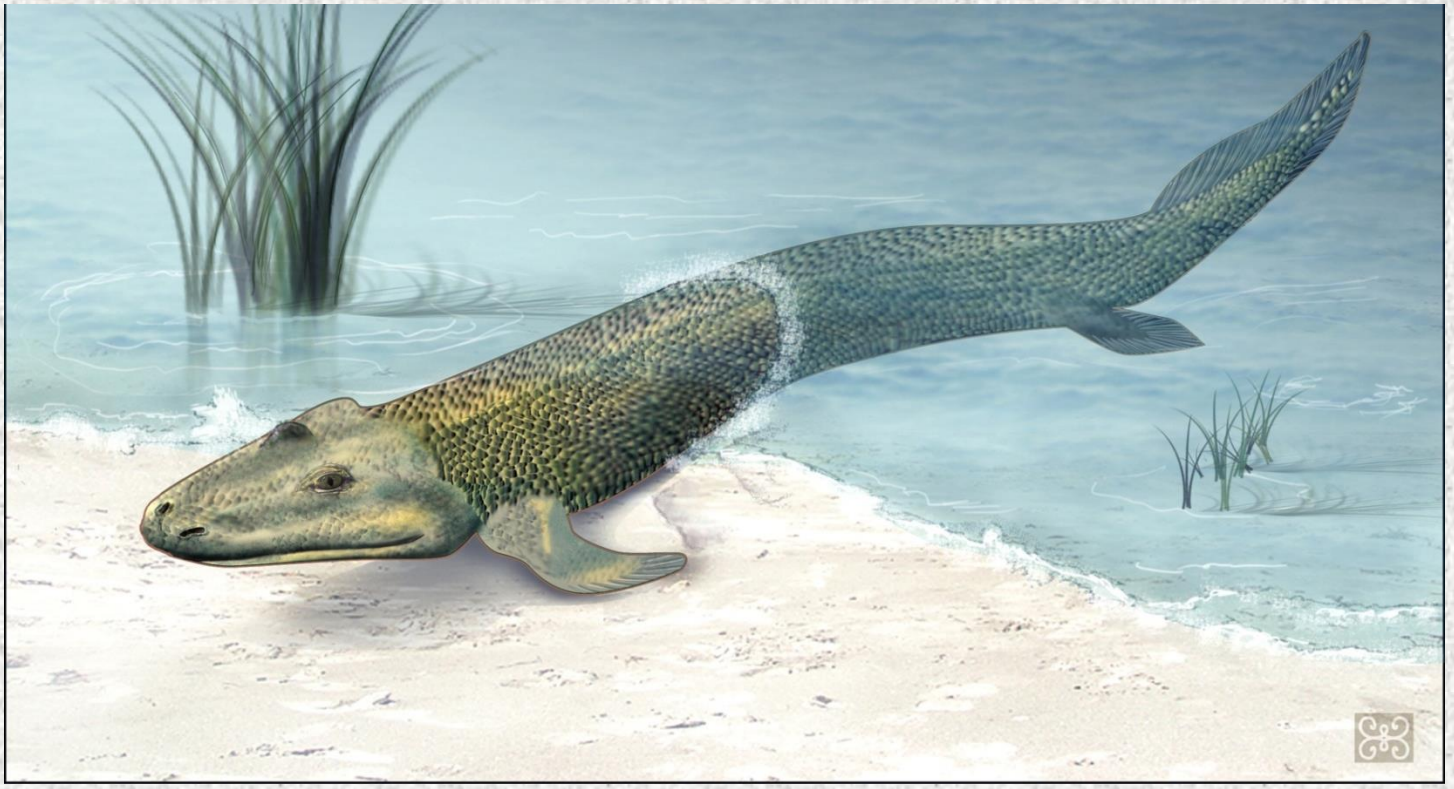


Early amphibian

Figure 17.32

Tiktaalik – discovered in 2004



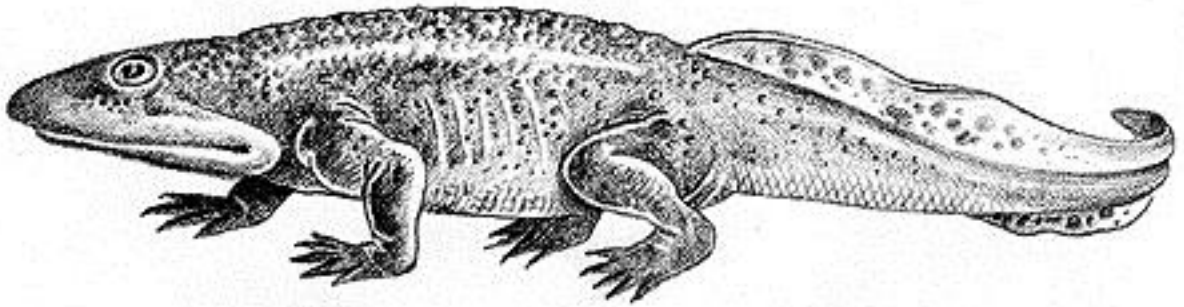


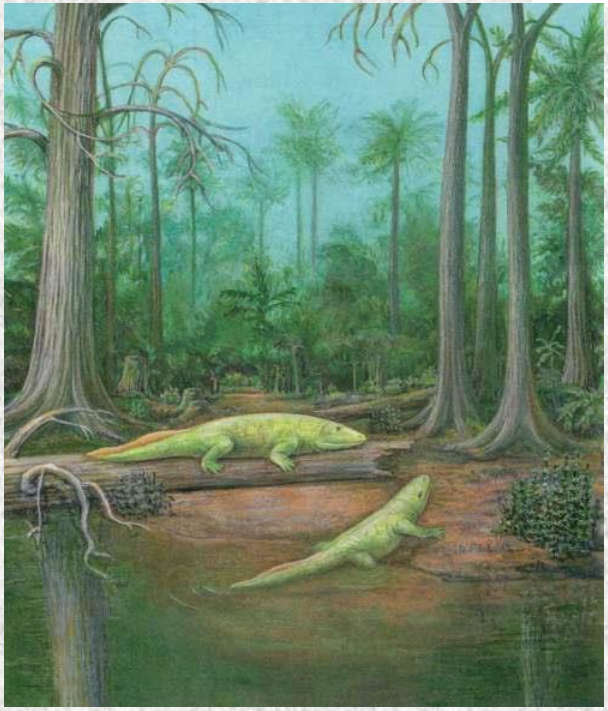
Terrestrial Vertebrates

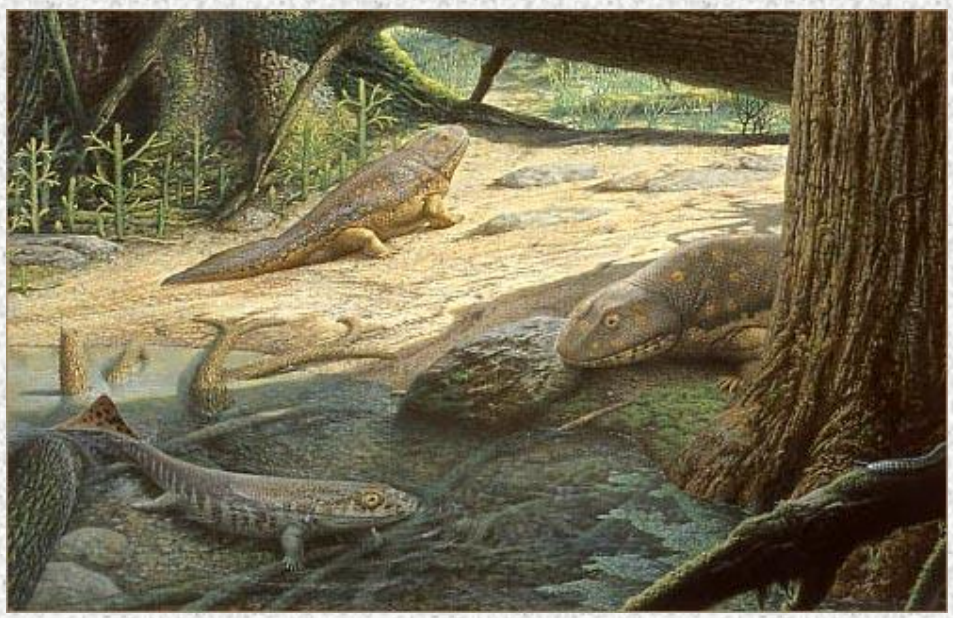
- Terrestrial vertebrates are collectively called **tetrapods**, which means “four feet.”
- Tetrapods include:
  - Amphibians
  - Reptiles
  - Mammals

Devonian - Amphibians

Ichthyostega

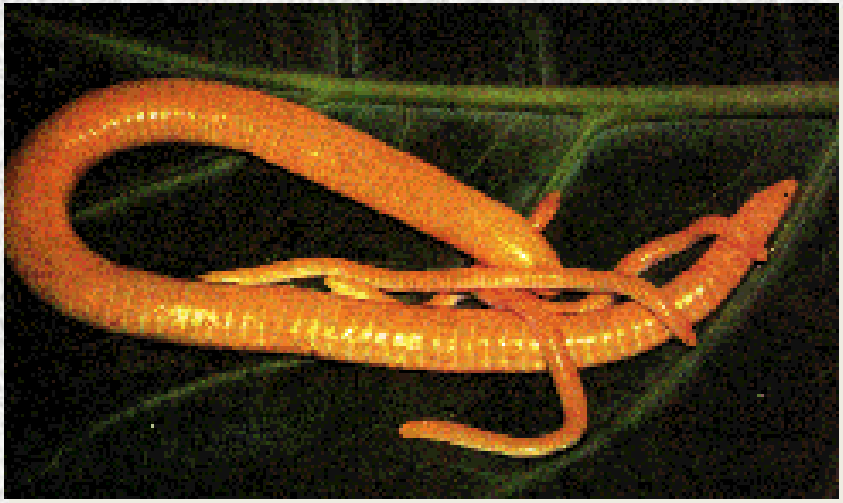






Amphibians - have aquatic larval stage

- Toads and Frogs (Anura)
- Salmanders (Urodela)
- Caecilians (Gymnophiona)



Amphibians

- Exhibit a mixture of aquatic and terrestrial adaptations
- Usually need water to reproduce
- Typically undergo **metamorphosis** from an aquatic **larva** to a terrestrial adult
- Were the first vertebrates to colonize land
- Descended from fishes that had lungs and fins with muscles

Frogs

Frogs lay eggs in water, aquatic tadpole larval stage with gills

Toad –frog adapted for drier conditions

Salamanders

- Possess tails
- Mostly aquatic, some have gills
- Resemble earliest amphibians

Hellbender – giant salamander, in Ozarks, endangered

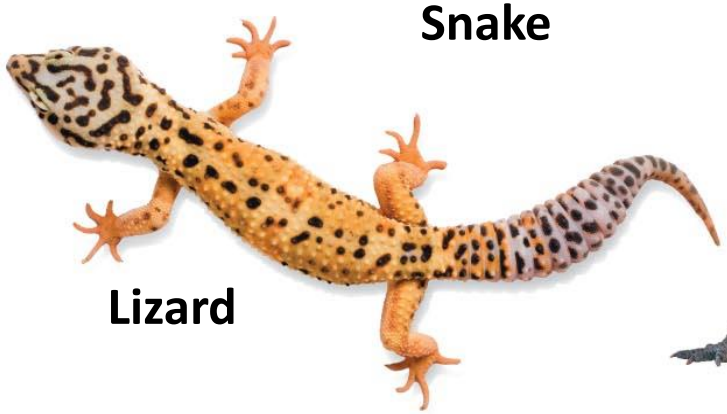
Caecilians

- Limbless amphibians
- Live hidden underground
- Lost their limbs, resemble worms

Reptiles

Snake

Dinosaur



Lizard

Crocodile

Turtle

Birds

Reptiles

Reptile adaptations to living on land include:

- Amniotic eggs
- Scaled, waterproof skin

Reptiles include:

- Snakes
- Lizards
- Turtles
- Crocodiles
- Alligators
- Birds

Reptile Characteristics

- Dry skin with horny scales
- Lungs with many chambers, large folds
- Three-chambered heart
  - some separation of oxygen-rich and oxygen-poor blood
- Well developed kidneys, urine thick white paste

Reptile Characteristics

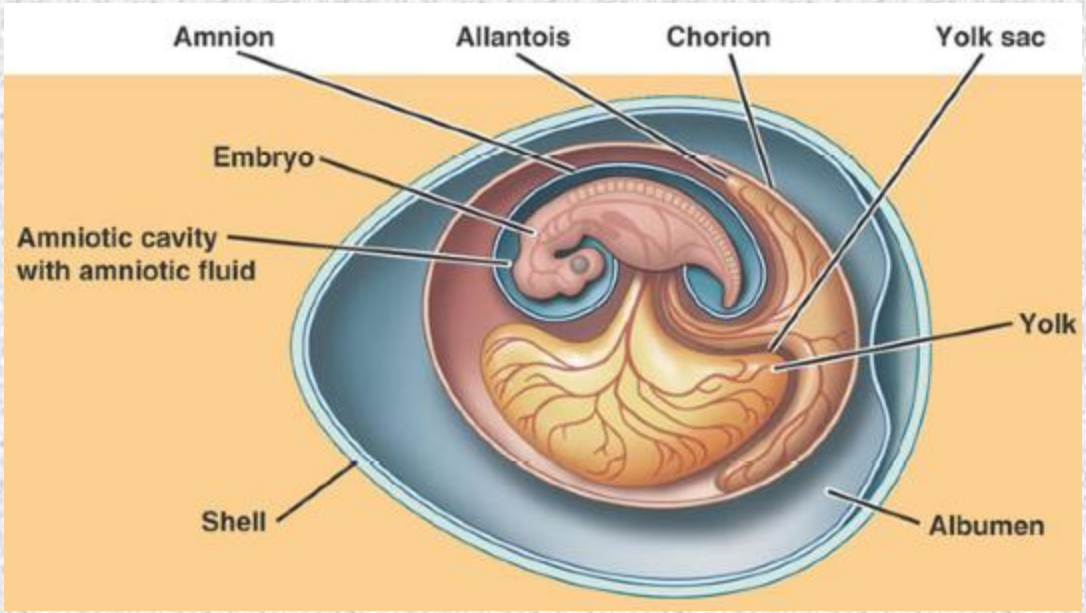
Reproduction

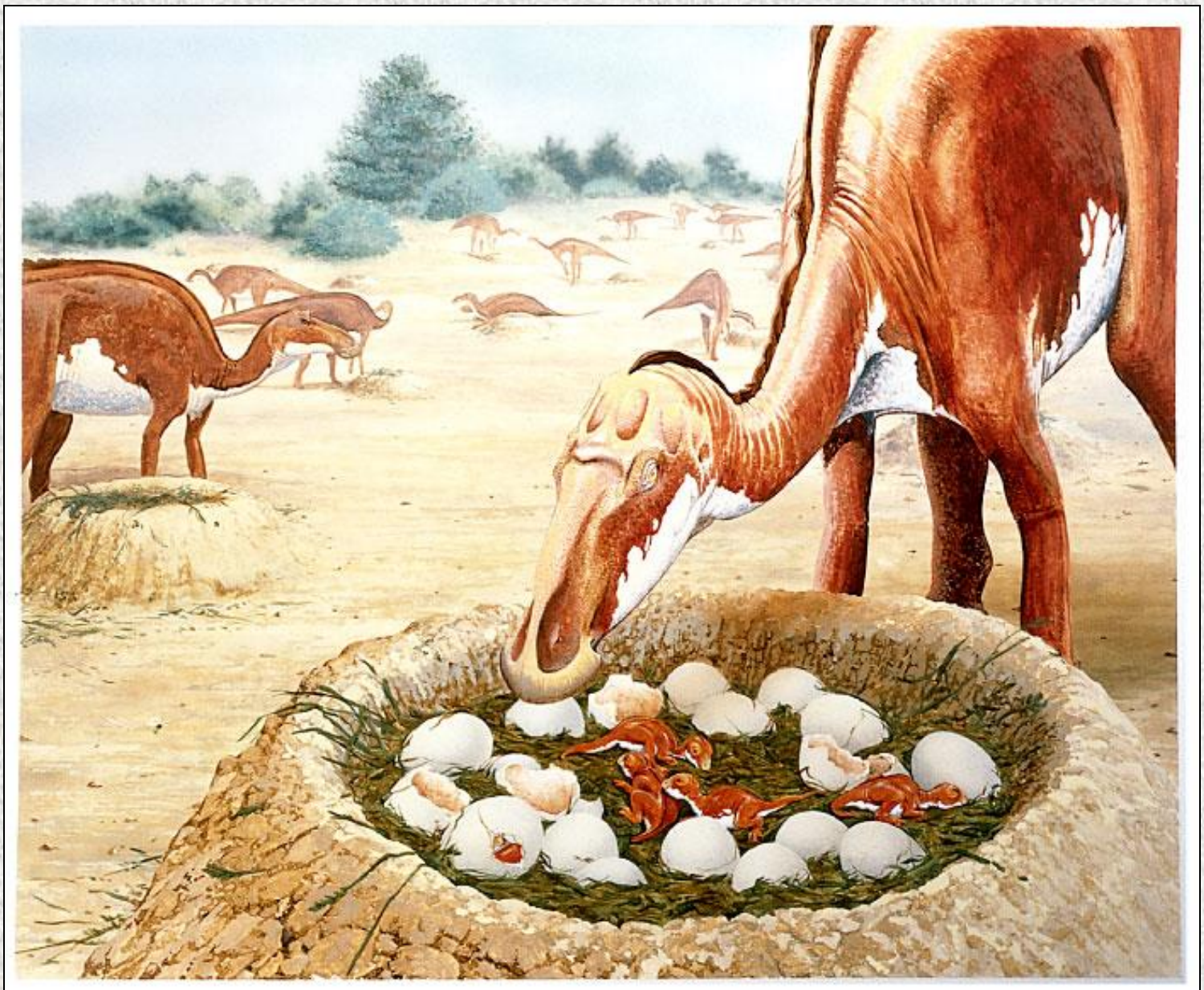
- internal fertilization
- leathery protective shell around egg
- embryo develops protective membranes (including amnion)

Amniotes

Amniotes - have embryos with extra-embryonic membranes

- amnion keeps water from leaving the egg or developing young.



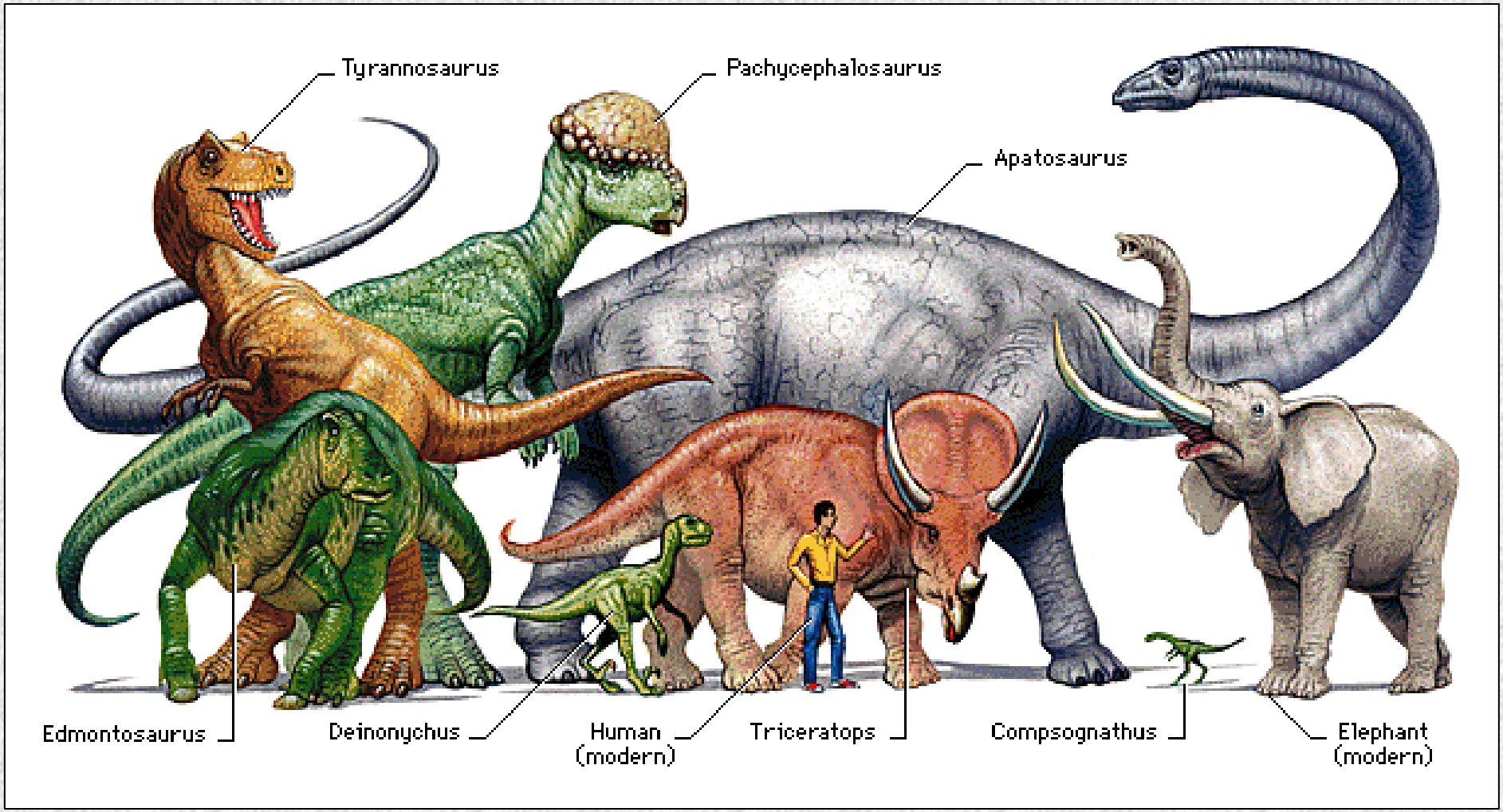


Non-bird Reptiles

- **Ectotherms**, sometimes referred to as “cold-blooded,” obtain their body heat from the environment.
- Can survive on less than 10% of the calories required by a bird or mammal of equivalent size.
- Diversified extensively during the Mesozoic era.
- Dinosaurs were the largest animals ever to live on land.

Triassic Dinosaurs

Dinosaur Size and Diversity



Major living ‘reptile’ groups:

- Lizards and snakes (Squamata)
- Crocodiles and alligators (Crocodilia)
- Turtles (Testudinata)

Turtles, terrapins, tortoises

- Have hard shell which consists of pieces of dermal bone attached to the skeleton
- Most occur mainly on land, all lay eggs on land

Lizards, snakes

- Snakes are closely related to lizards and evolved from them through the loss of their limbs

Tuataras

- More ancient lineage than lizards.
- Descended from a group that dates back more than 200 MY.
- Have a pineal eye in the middle of the skull

Crocodiles, alligators, caimans, gavials

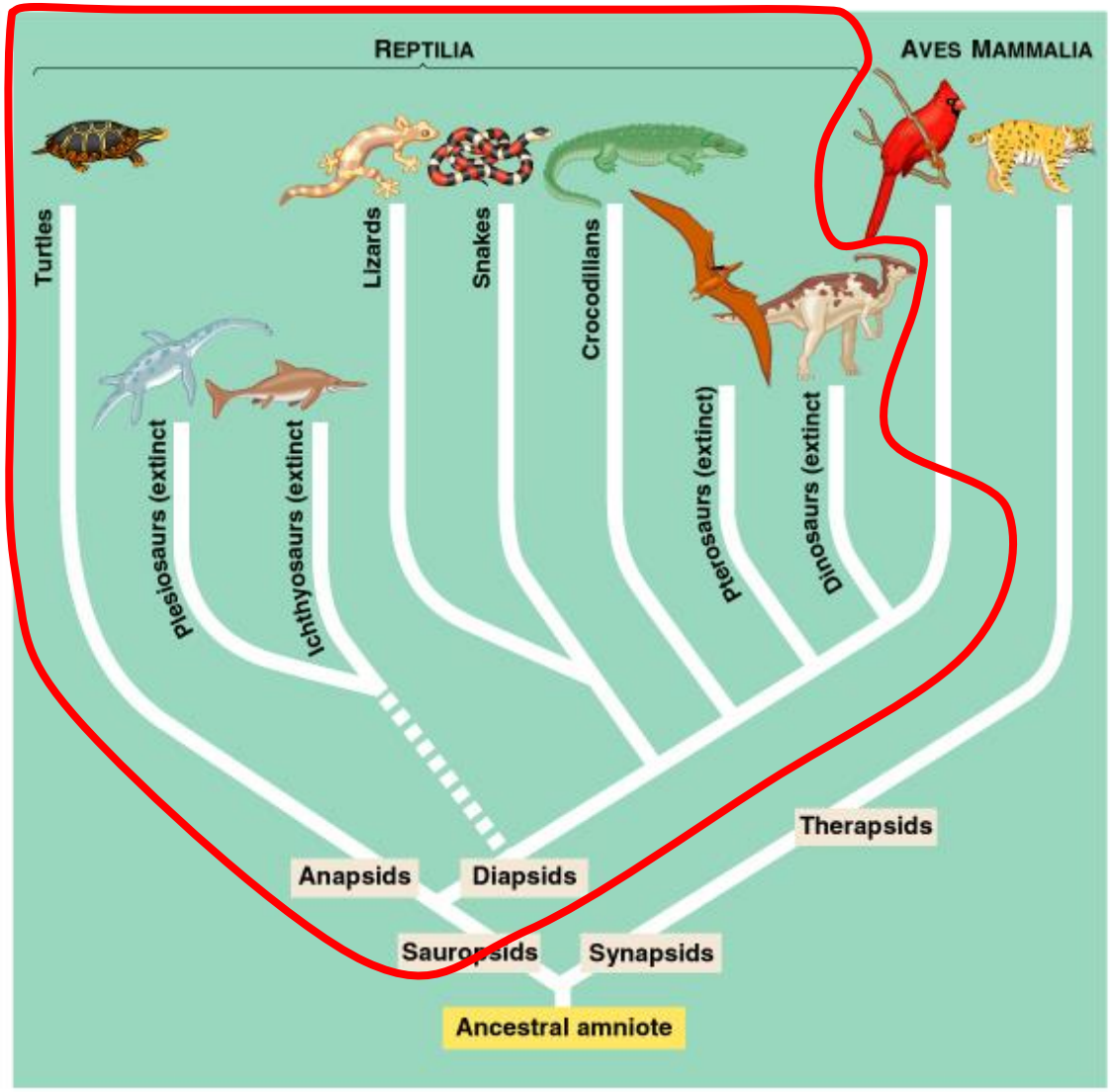
- Have 4-chambered heart.
- More closely related to birds than to other living reptiles.
- Show **parental care**, build nest

Birds

Birds - Aves

Monophyly vs Paraphyly: Reptiles/Birds

Reptilia



Paraphyly

Birds are more closely related to crocodilians than to other extant vertebrates

Archosauria = Birds + Crocs

We think of reptiles as turtles, lizards, snakes, and crocodiles

But Reptilia is a paraphyletic group unless it includes Aves

Birds - Aves

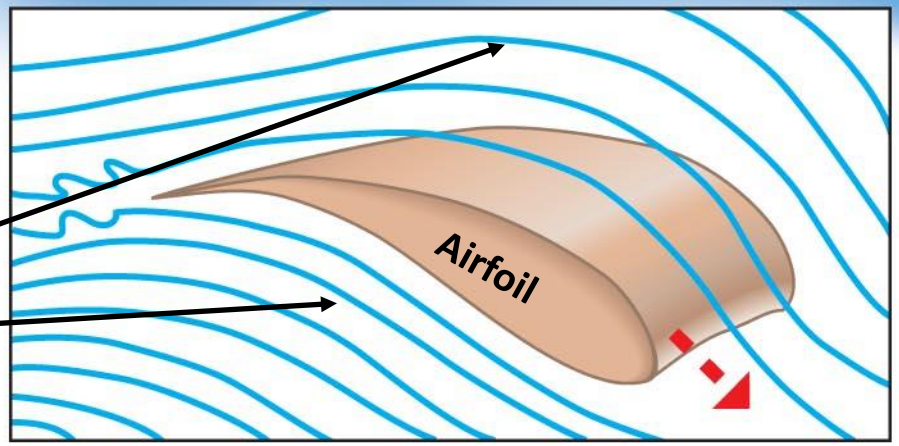
- Most diverse class of tetrapods
- Feathers
  - modification of skin
  - thermoregulation, flight

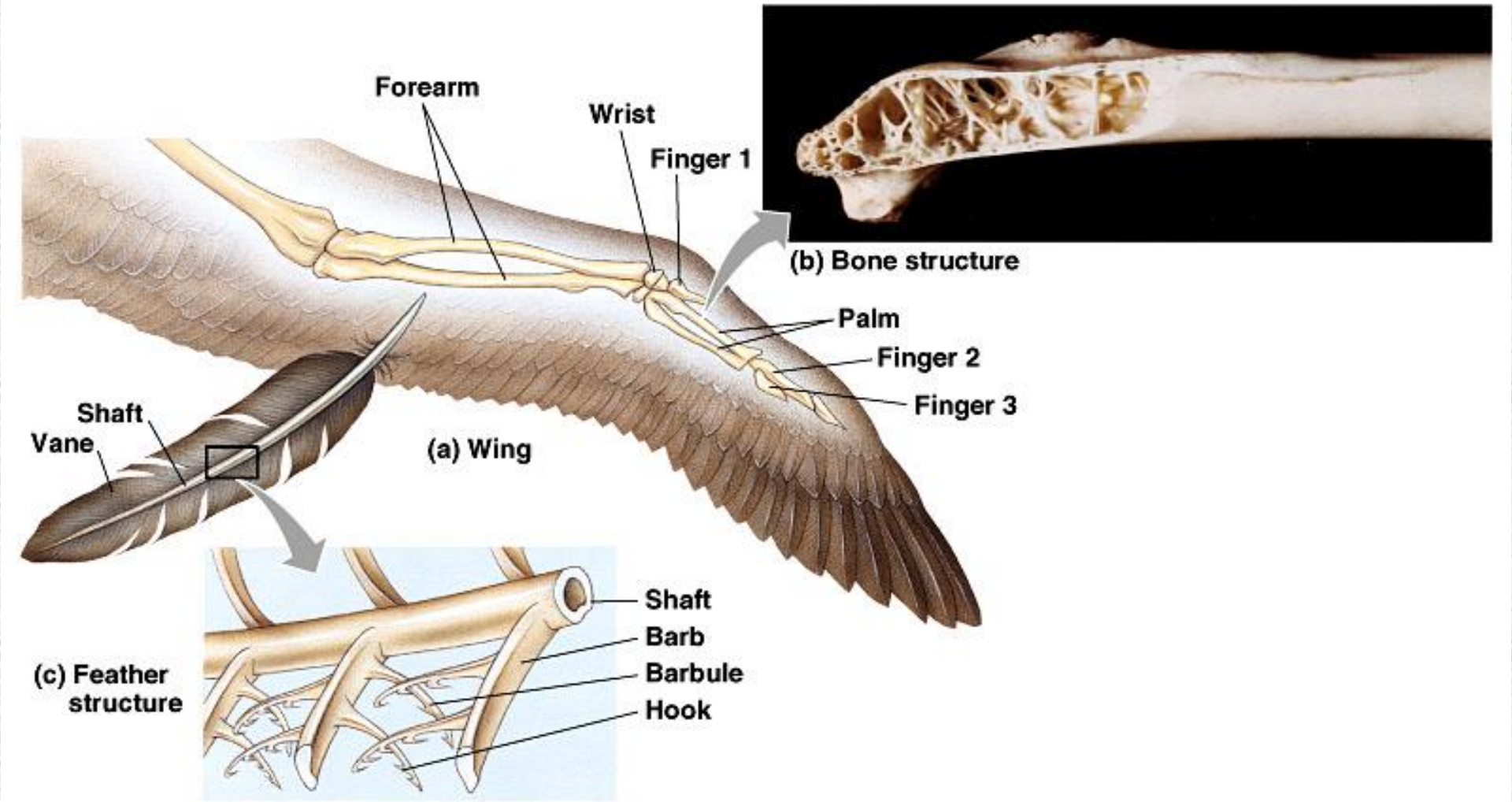
Bird Characters

- Evolved from a lineage of small, two-legged dinosaurs during Mesozoic era.
- Adaptations that make them lighter in flight:
  - Light honeycombed bones
  - One instead of two ovaries
  - A beak instead of teeth
- **Endotherms**, maintaining warm body temperature.
- Wings adapted for flight are airfoils, powered by breast muscles anchored to a keel-like breastbone.

Lower air pressure

Higher air pressure



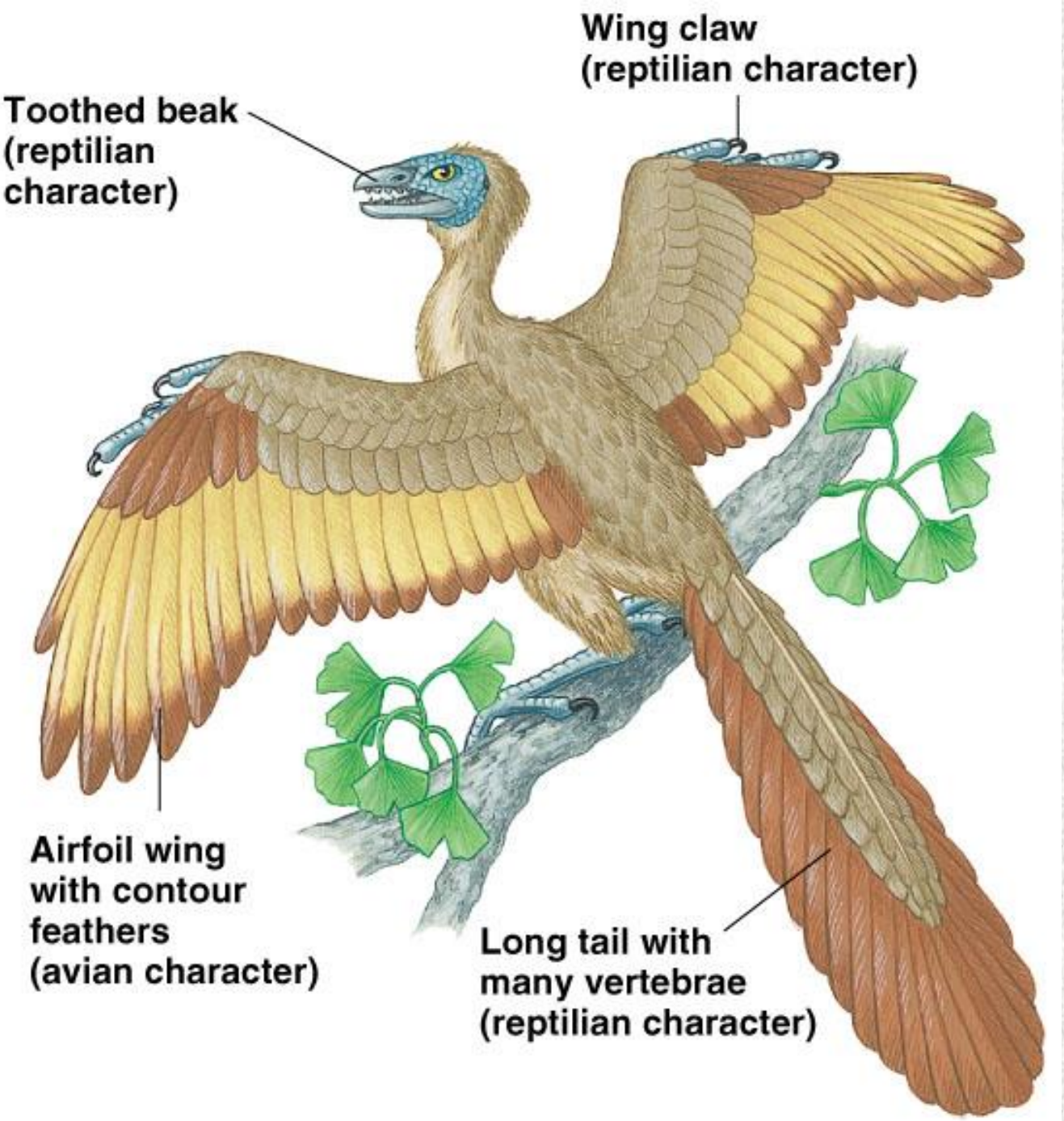


Bird Characters

- Four-chambered heart
- Very efficient lungs
- Excrete solid metabolic wastes (uric acid)
- Well-developed nervous system
- Excellent vision and hearing

Earliest Birds - *Archaeopteryx*

- Earliest known flying birds, 150 MYA.
- Missing link, share sharp teeth and a long bony tail with small theropod dinosaurs, and a wishbone and feathers with the birds



Modern birds include about 8,600 species

Mammals



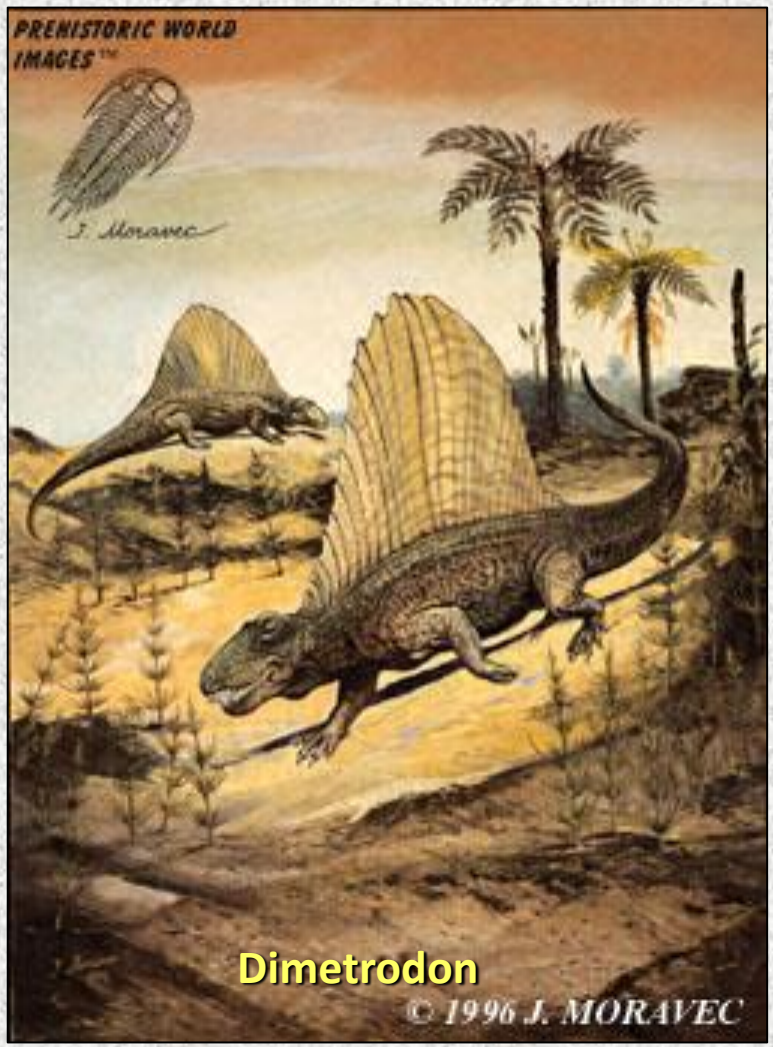





Mammals

- The first true **mammals**:
  - Arose about 200 million years ago
  - Were probably small, nocturnal insect-eaters
- Most mammals are terrestrial although dolphins, porpoises, and whales are totally aquatic.
- Mammalian hallmarks are:
  - Hair
  - Mammary glands that produce milk, which nourishes the young
- There are three major groups of mammals:
  - **Monotremes**, egg-laying mammals
  - **Marsupials**, pouched mammals with a **placenta**
  - **Eutherians**, **placental mammals** provide more intimate and long-lasting association between the mother and her developing young than do marsupial placentas.

Permian Mammal-like Reptiles

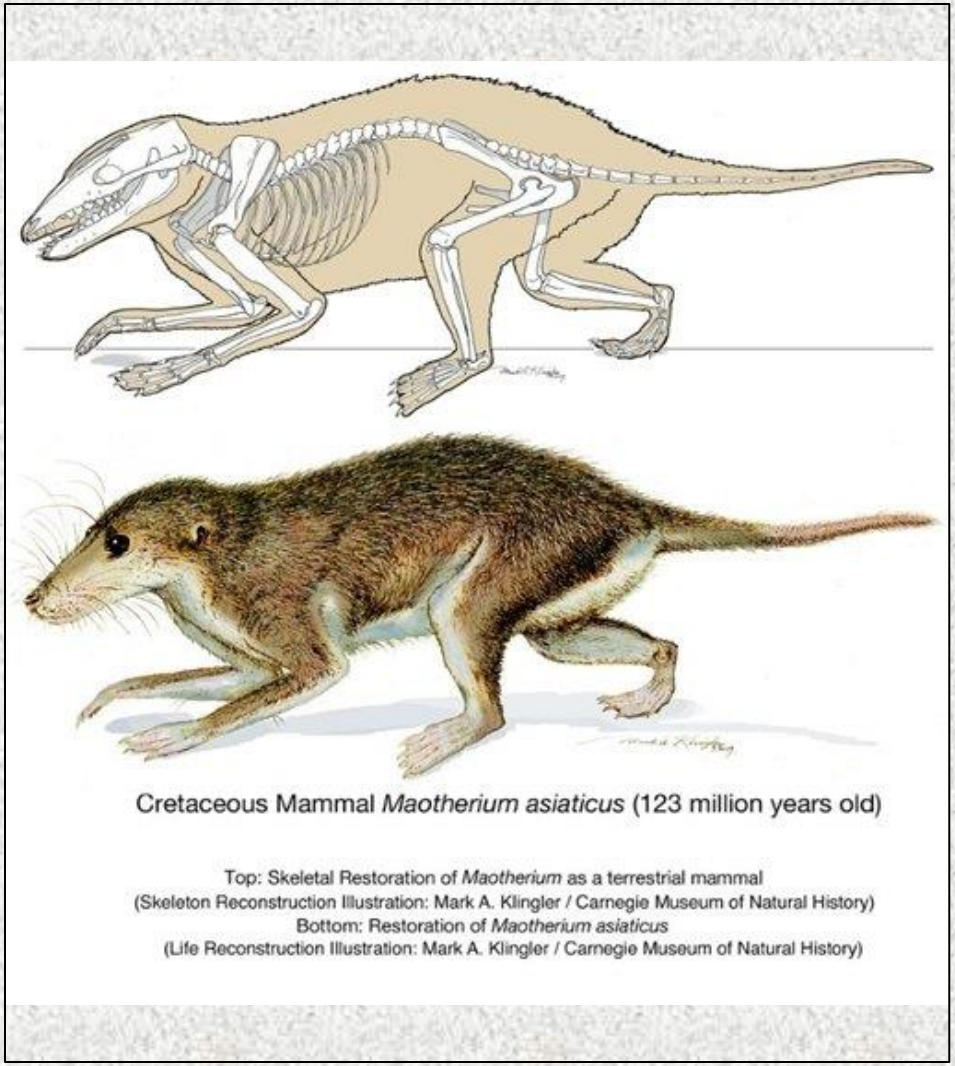


Dominated the land vertebrate fauna of the Permian and early Triassic before losing ground to the diversifying dinosaurs and other archosaurs.

Cynodonts – late Permian mammals

- Jaw structure, the hammer, anvil and stirrup bones of their inner ear, and - the secret of their success - their efficient chewing teeth.
- Things which don't fossilize so easily, such as warm-bloodedness, furry bodies and milk production also probably arose in the pre-mammalian cynodonts.

True mammals appear in the Triassic



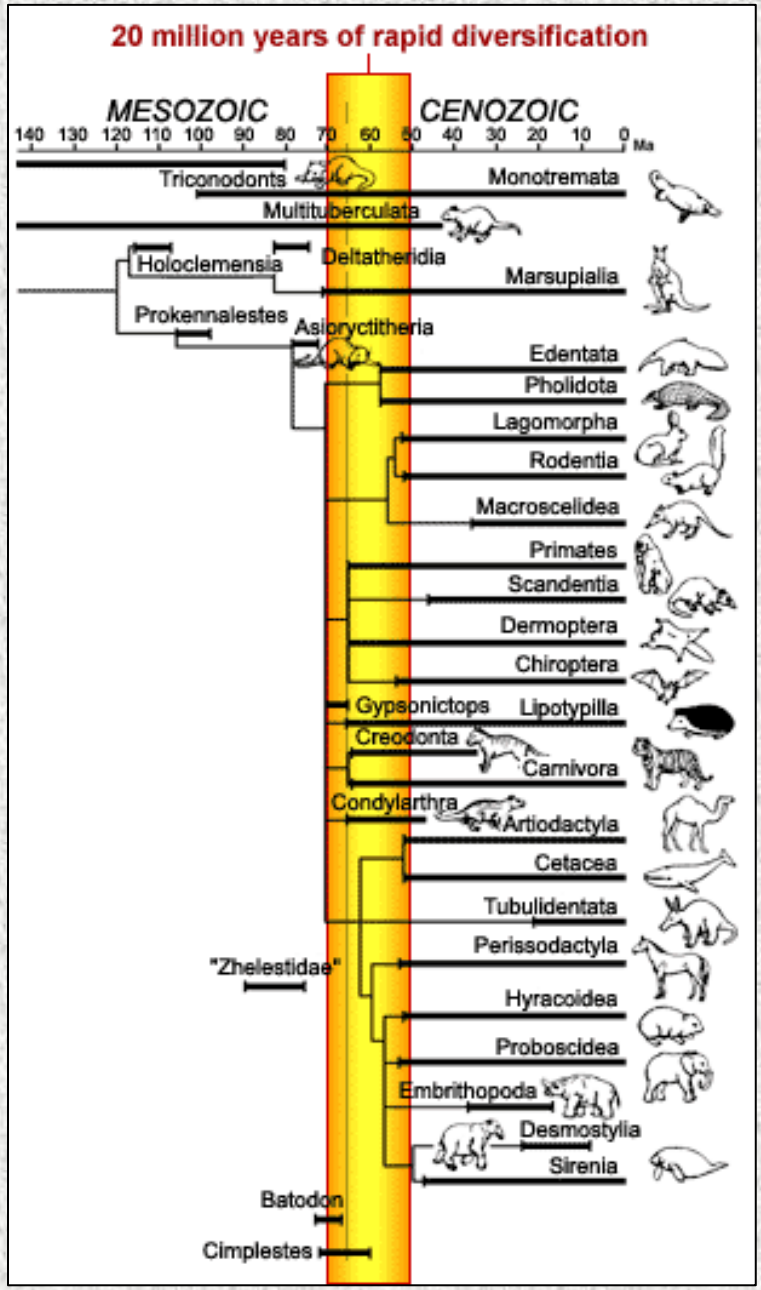
Cretaceous Mammal *Maotherium asiaticus* (123 million years old)

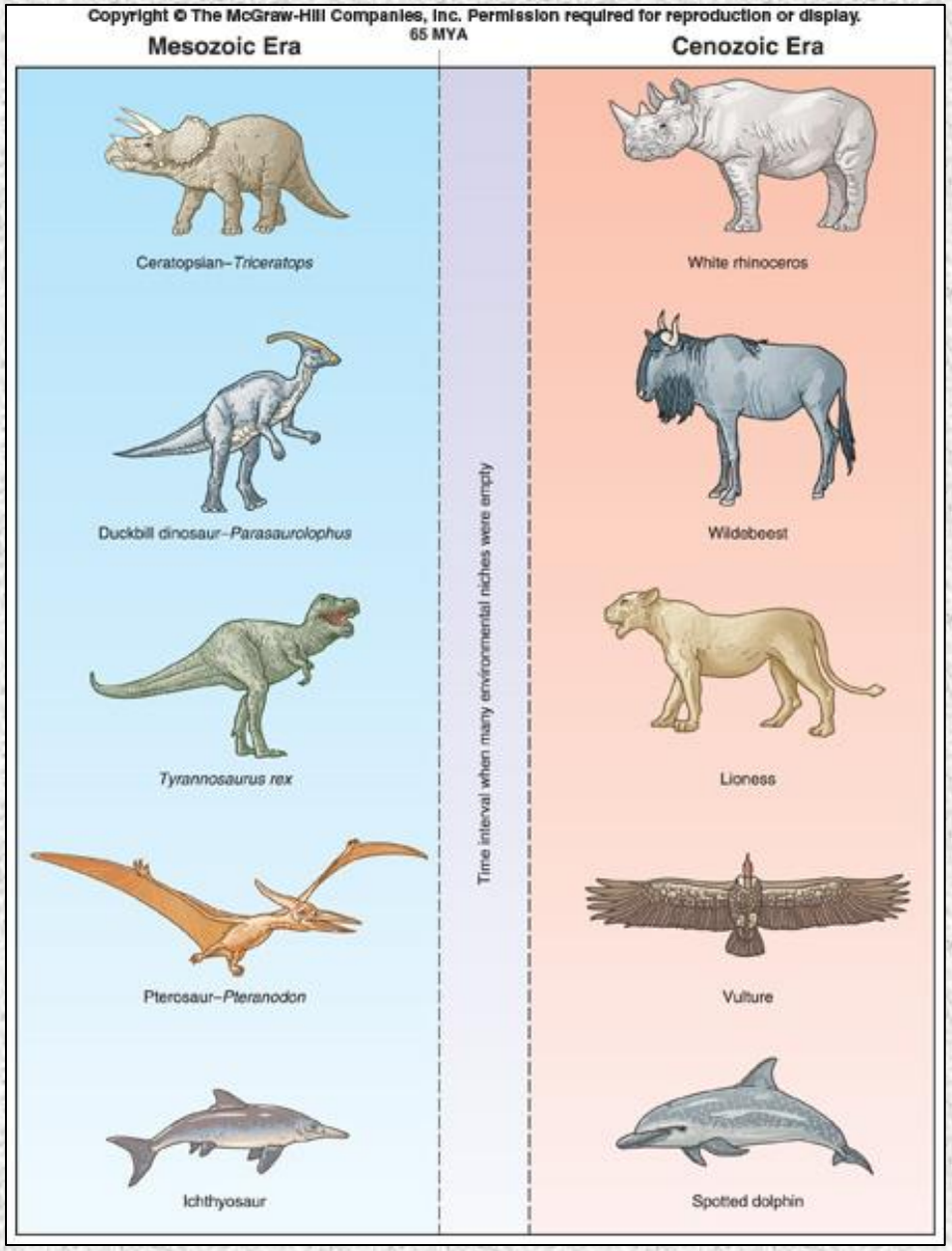
Top: Skeletal Restoration of *Maotherium* as a terrestrial mammal
(Skeleton Reconstruction Illustration: Mark A. Klingler / Carnegie Museum of Natural History)
Bottom: Restoration of *Maotherium asiaticus*
(Life Reconstruction Illustration: Mark A. Klingler / Carnegie Museum of Natural History)

- Evolved from a lineage of mammal-like reptiles
- Hair, mammary glands homeostasis (= “warm-blooded”, though some of the dinosaurs may have been)

Asteroid 65 MYA – Extinction of the Dinosaurs

Mammals took over the role of the Dinosaurs





Cenozoic – Age of Mammals

Mammal Characters

- Hair
- Mammary glands
- Differentiated teeth
- Three middle-ear bones
- Have highly developed nervous system and muscular diaphragm
- Are endotherms

Monotremes (Subclass Holotheria)

- Duck-billed platypus, spiny anteaters
  - Monotremes lay eggs

- Monotremes - oviparous

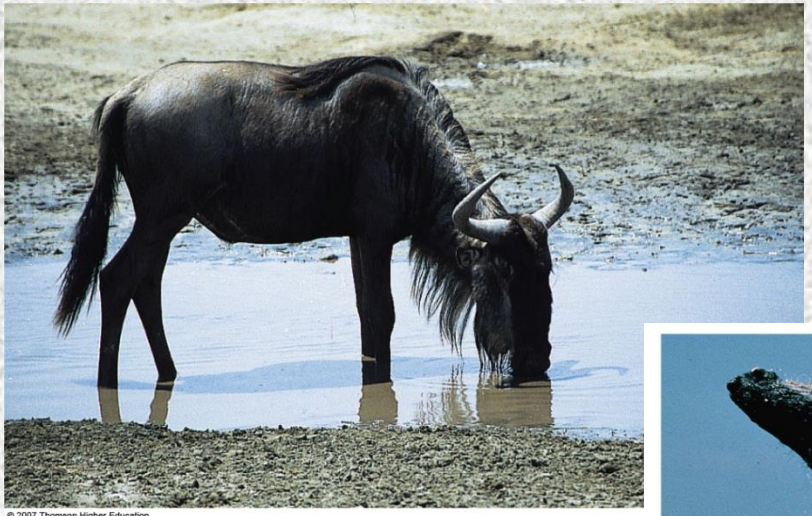
Marsupials (Subclass Metatheria)

- Include pouched mammals
  - kangaroos, opossums
- Young are born in embryonic stage
- Complete development in mother's marsupium
  - nourished with milk from mammary glands

- Marsupials - partial internal - external development

Placental Mammals (Subclass Eutheria)

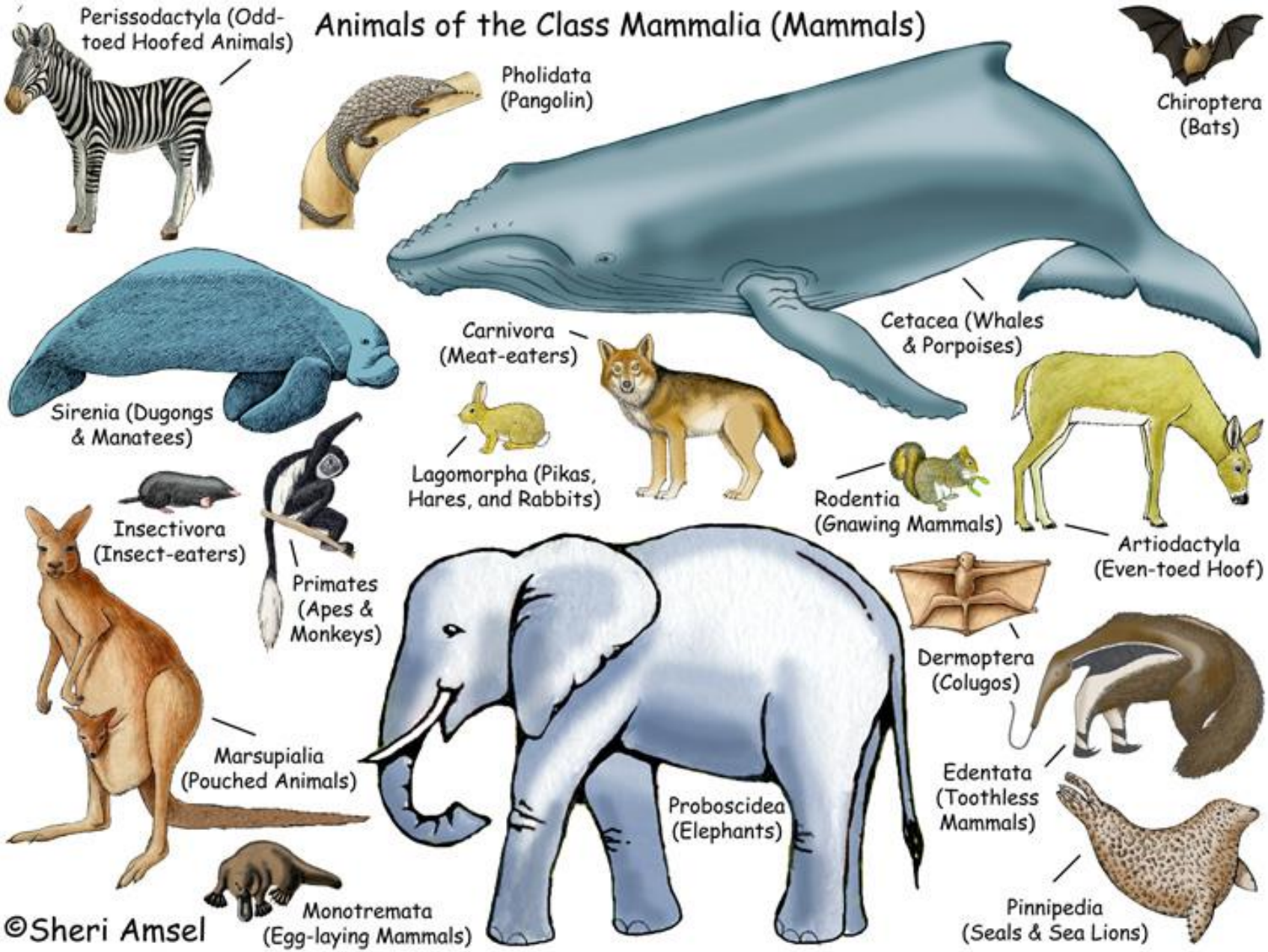
- Characterized by placenta
  - for exchange between embryo and mother



- Placentals (eutherians) - completely internal development - Most diverse





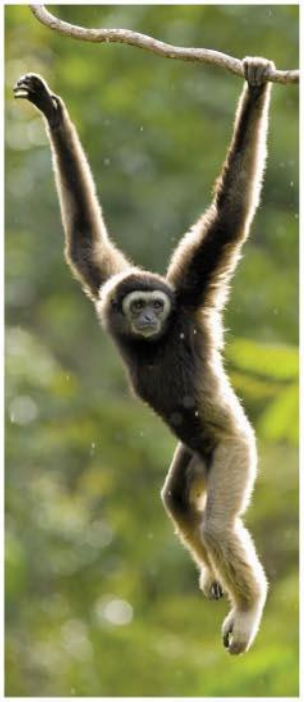


Animals of the Class Mammalia (Mammals)
Perissodactyla (Odd-toed Hoofed Animals)
Pholidata (Pangolin)
Chiroptera (Bats)
Cetacea (Whales & Porpoises)
Sirenia (Dugongs & Manatees)
Carnivora (Meat-eaters)
Lagomorpha (Pikas, Hares, and Rabbits)
Rodentia (Gnawing Mammals)
Artiodactyla (Even-toed Hoof)
Insectivora (Insect-eaters)
Primates (Apes & Monkeys)
Dermoptera (Colugos)
Marsupialia (Pouched Animals)
Proboscidea (Elephants)
Edentata (Toothless Mammals)
Monotremata (Egg-laying Mammals)
Pinnipedia (Seals & Sea Lions)
©Sheri Amsel

Ring-tailed lemur

Tarsier

Black spider monkey (New World monkey)

Patas monkey (Old World monkey)



Gibbon (ape)

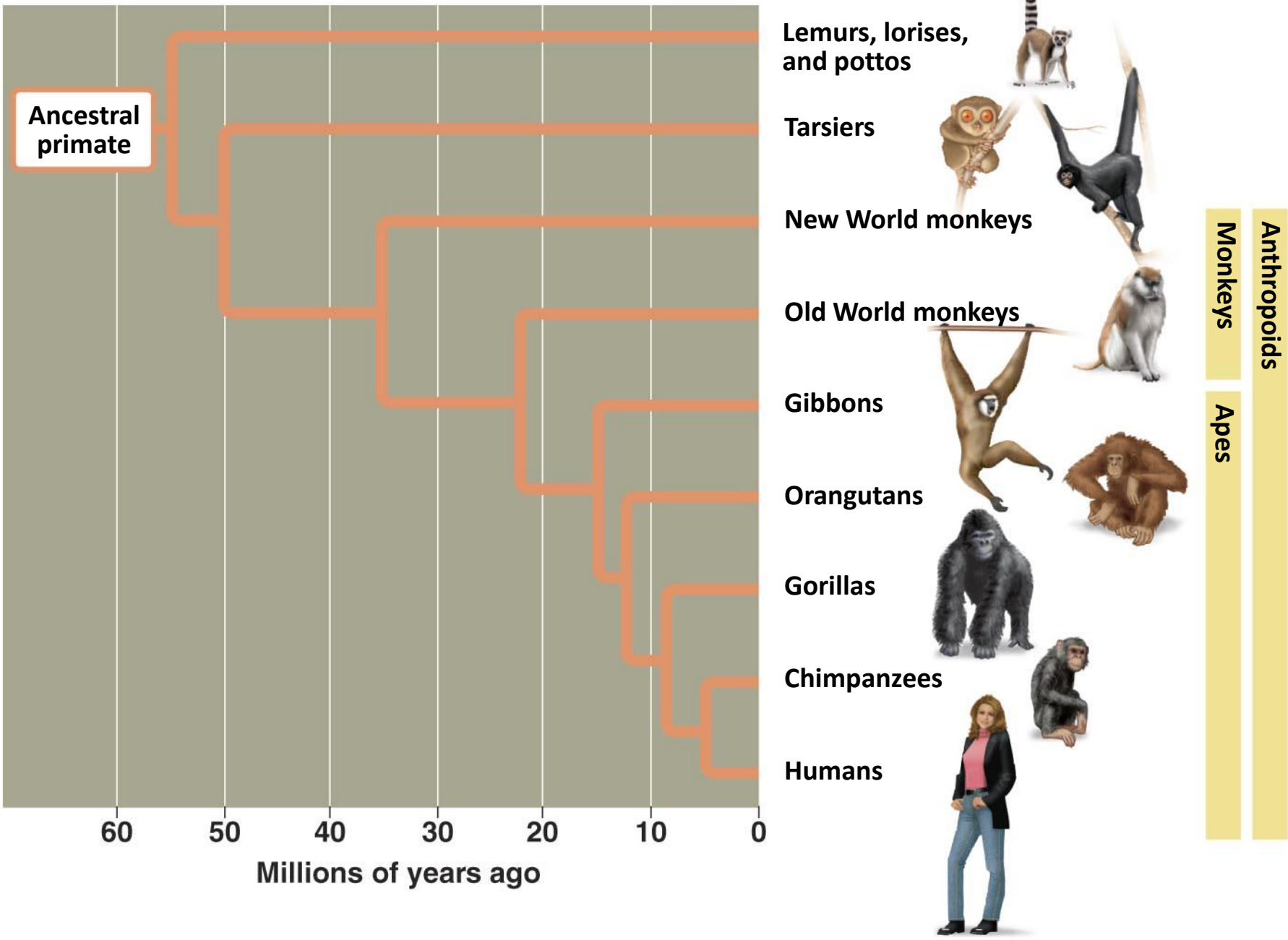
Orangutan (ape)

Gorilla (ape)

Chimpanzee (ape)

Human

Figure 17.37

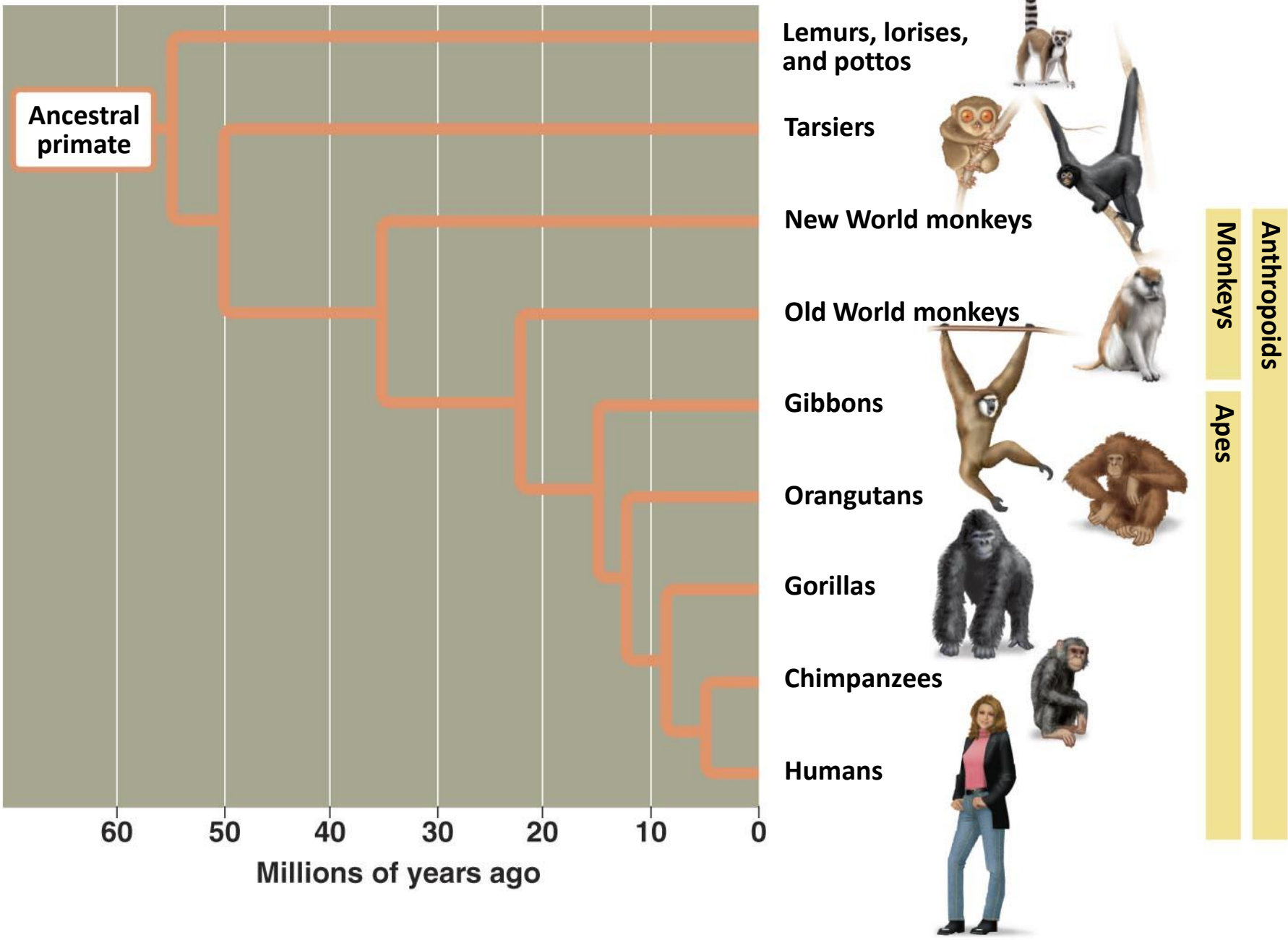


End

Primates

THE HUMAN ANCESTRY

- Humans are **primates**, the mammalian group that also includes:
  - Lorises
  - Pottos
  - Lemurs
  - Tarsiers
  - Monkeys
  - Apes
- **Primates** evolved from insect-eating mammals during the late Cretaceous period.



Primate Characteristics

- Primates are distinguished by characteristics that were shaped by the demands of living in trees. These characteristics include:
  - Limber shoulder joints
  - Eyes in front of the face
  - Excellent eye-hand coordination
  - Extensive parental care
- Taxonomists divide the primates into three main groups.

Three Groups of Primates

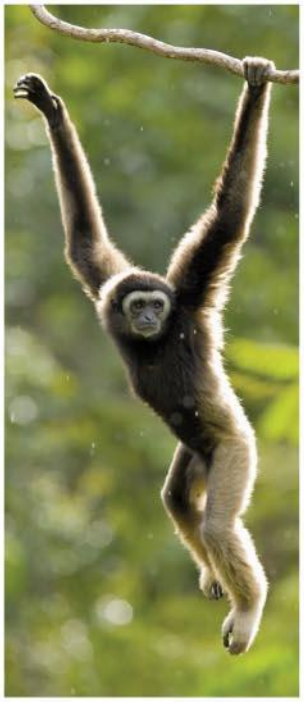
- The first group of primates includes:
  - Lorises
  - Pottos
  - Lemurs
- Tarsiers form the second group.
- The third group, **anthropoids**, includes:
  - Monkeys
  - **Hominoids**, the ape relatives of humans
  - And humans

Ring-tailed lemur

Tarsier

Black spider monkey (New World monkey)

Patas monkey (Old World monkey)



Gibbon (ape)

Orangutan (ape)

Gorilla (ape)

Chimpanzee (ape)

Human

Figure 17.37

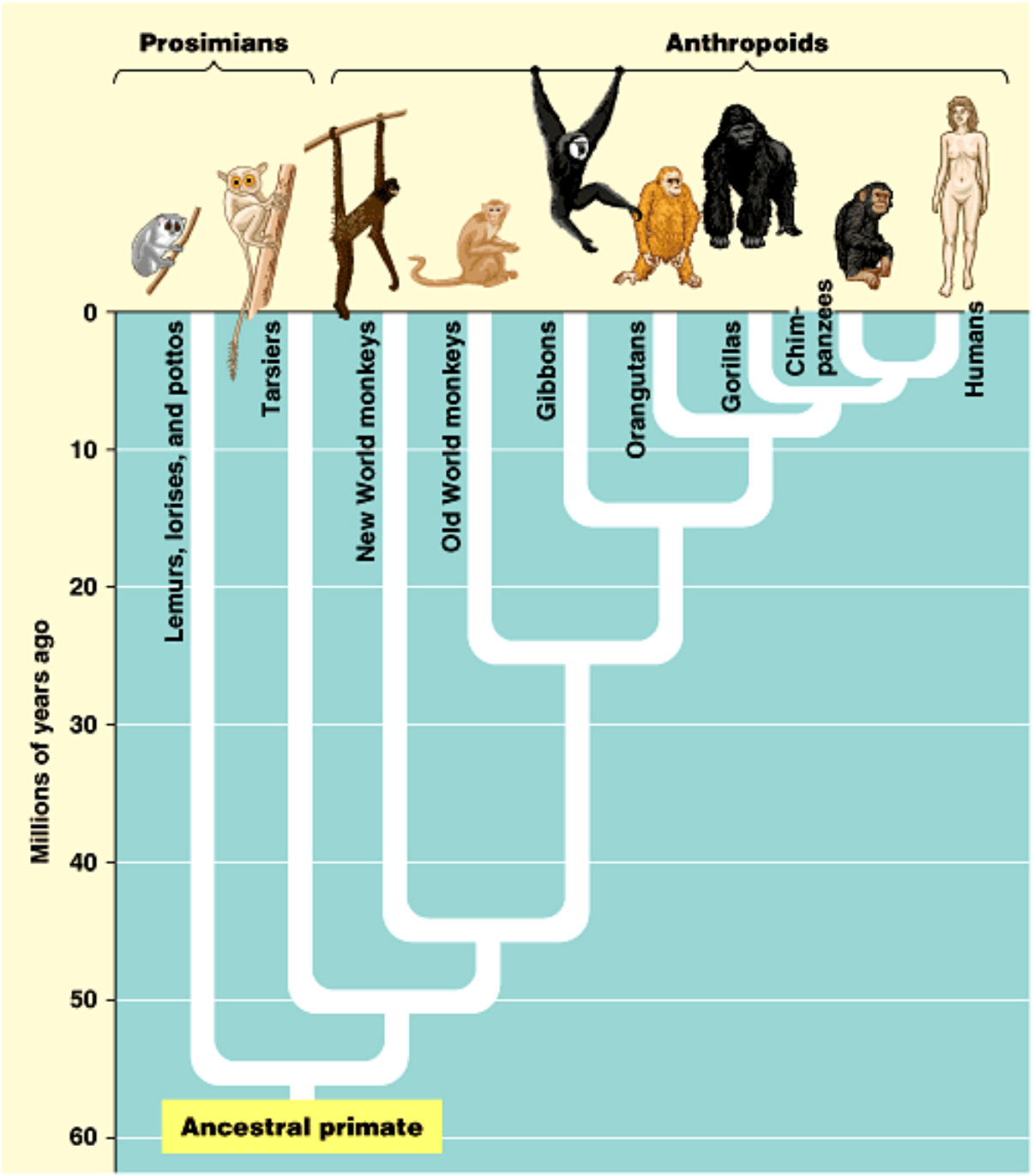
VI. Primates and the evolution of *Homo sapiens*

A. Primate evolution provides context for understanding human origins

1. Hands and feet adapted for grasping. Possess opposable thumb.

2. Large brains allow complex social behavior.

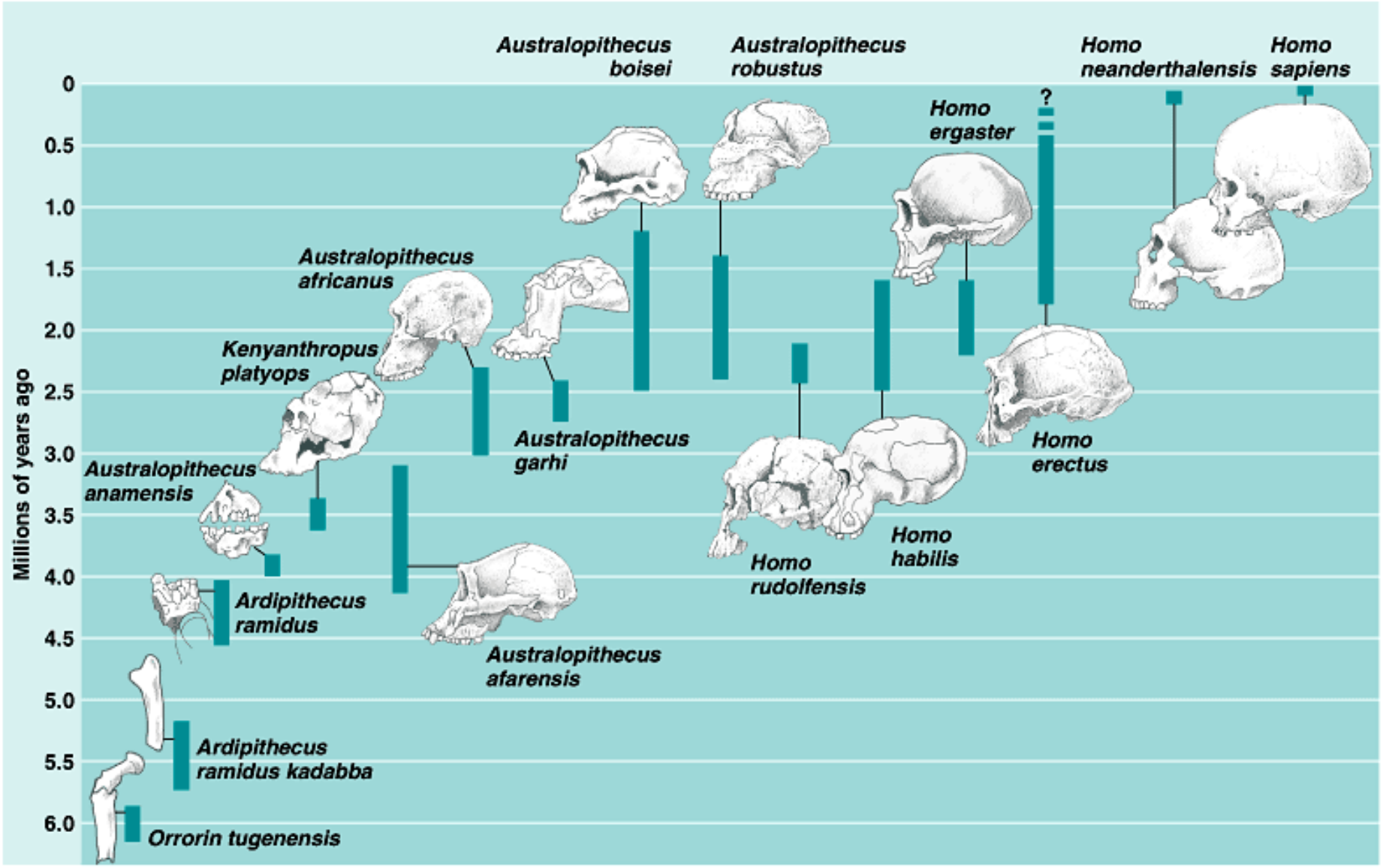
Figure 34.35 (p. 708) – A phylogenetic tree of primates.



B. Hominid lineage diverged from other primates about 7 million years ago. Humans compared to other hominids:

a. Brain size – large size allows development of language and social behavior.

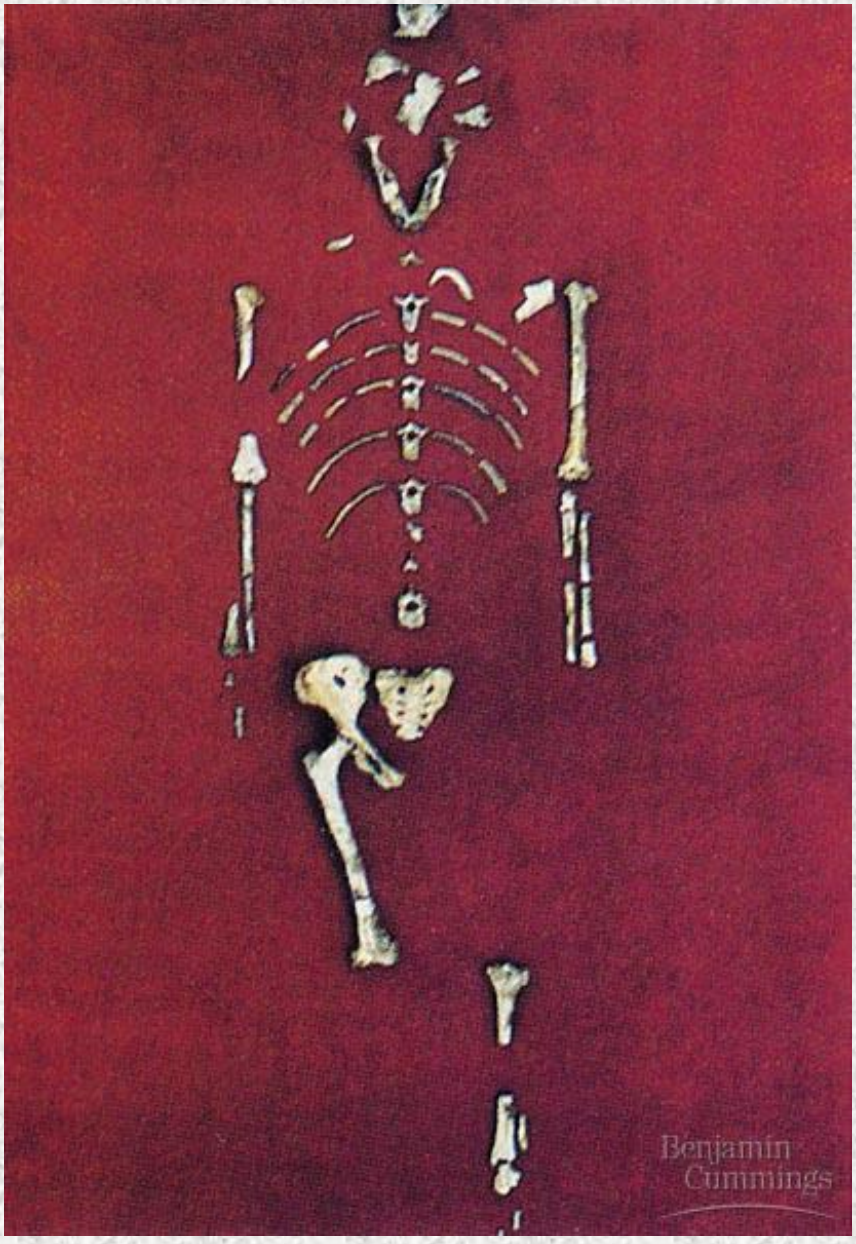
b. Jaw shape – shortened to give a flatter face.

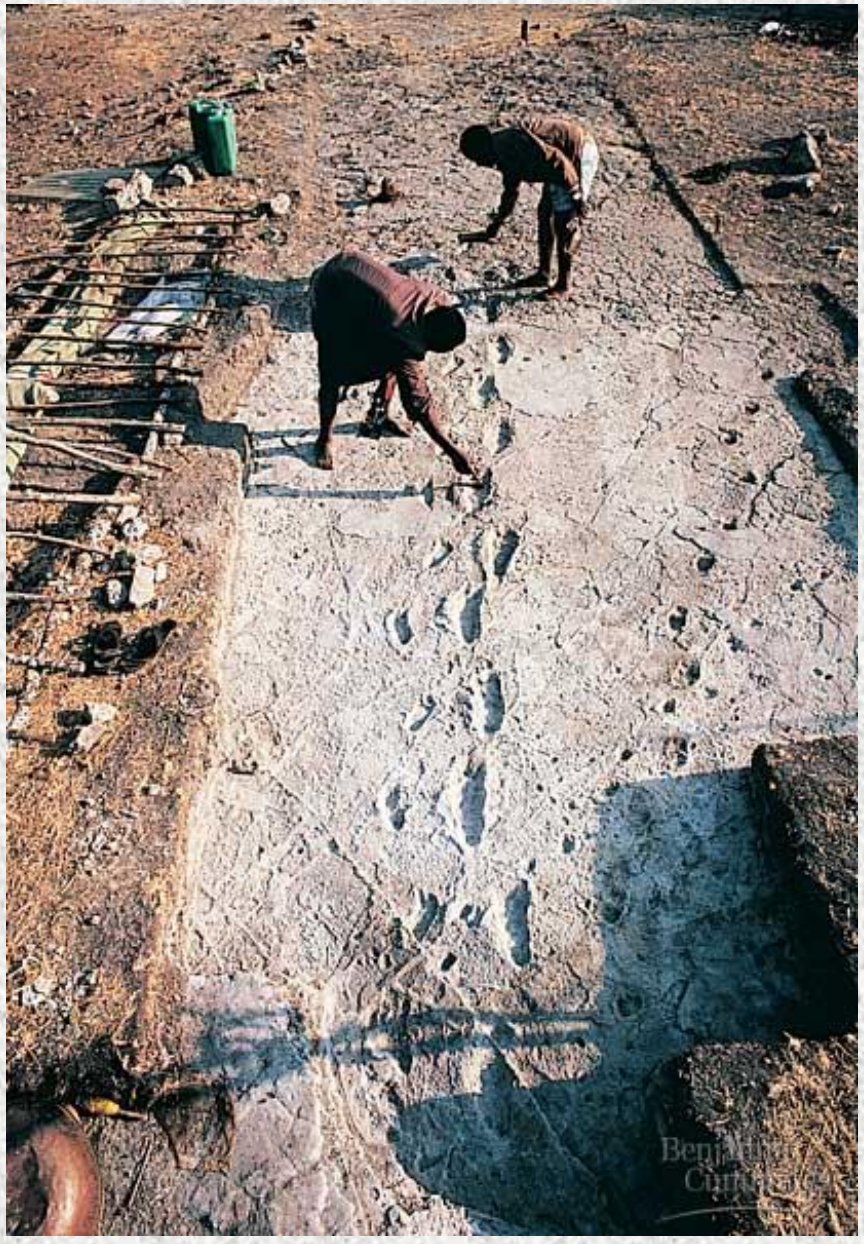


c. Bipedalism = walking on two legs.

- Frees hands to do other things.

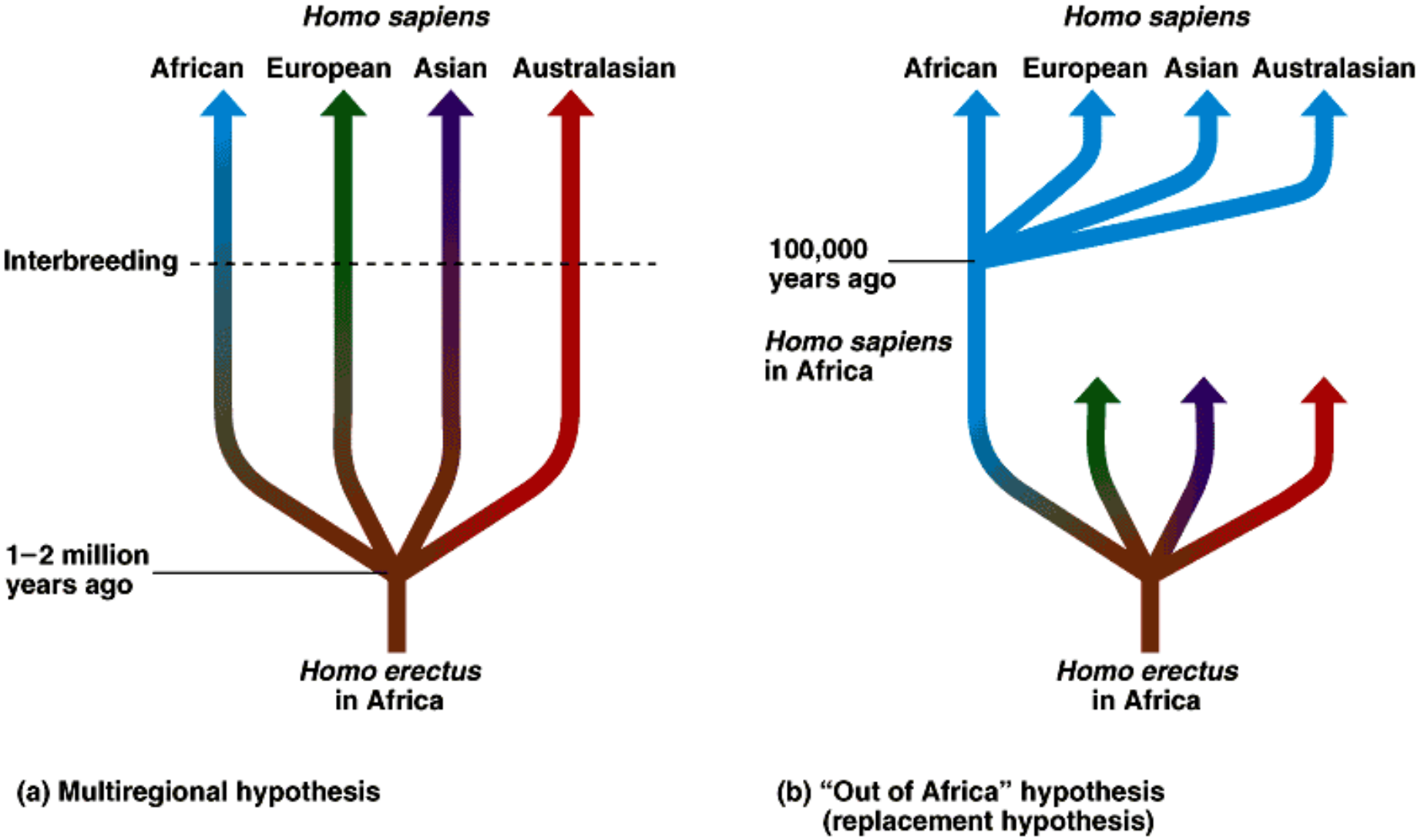
- Eyes set higher; can see farther.


Benjamin
Cummings



d. Females smaller than males

e. Extended parental care changes family structure and enhances learning and social behavior.



End