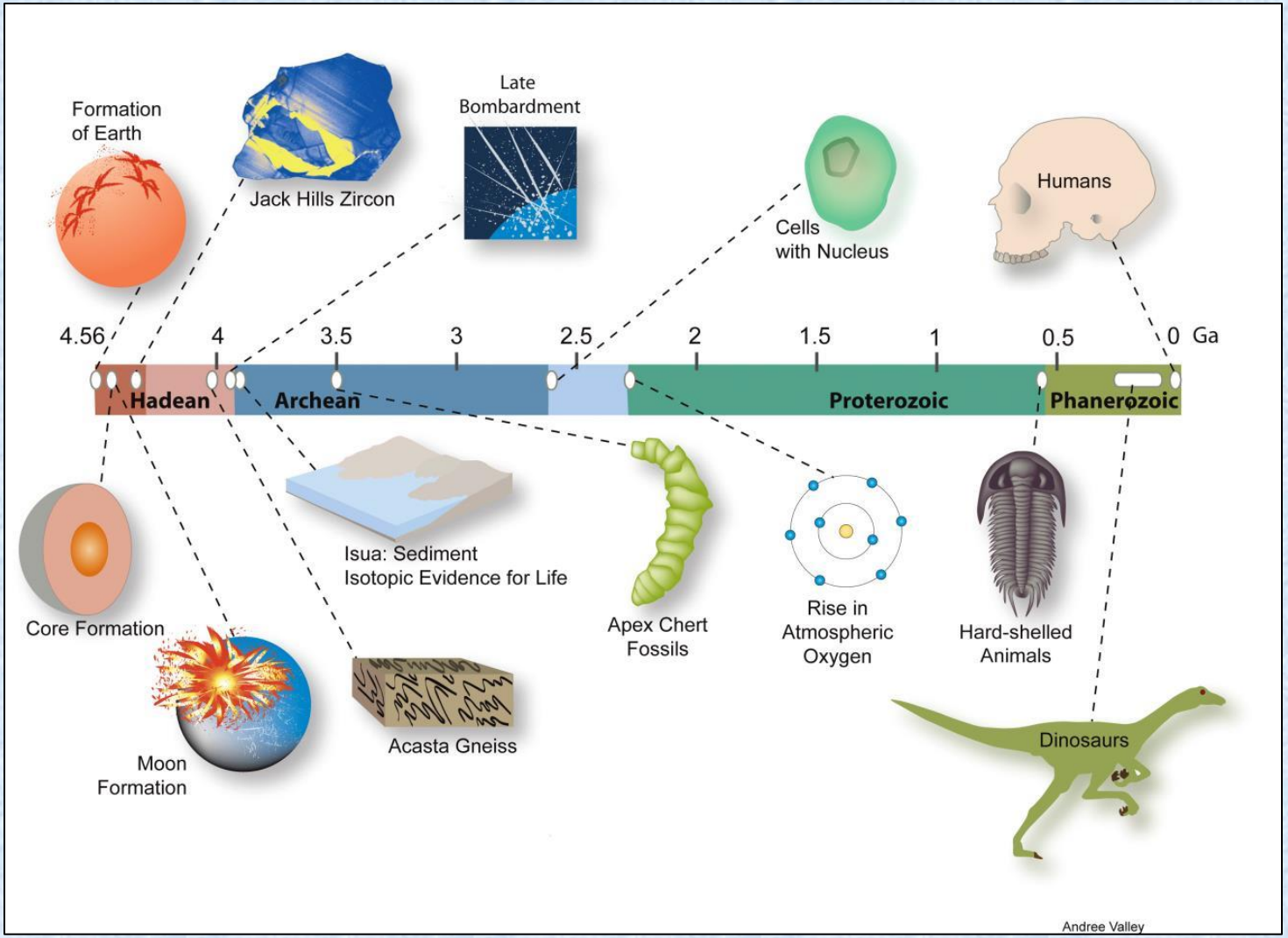
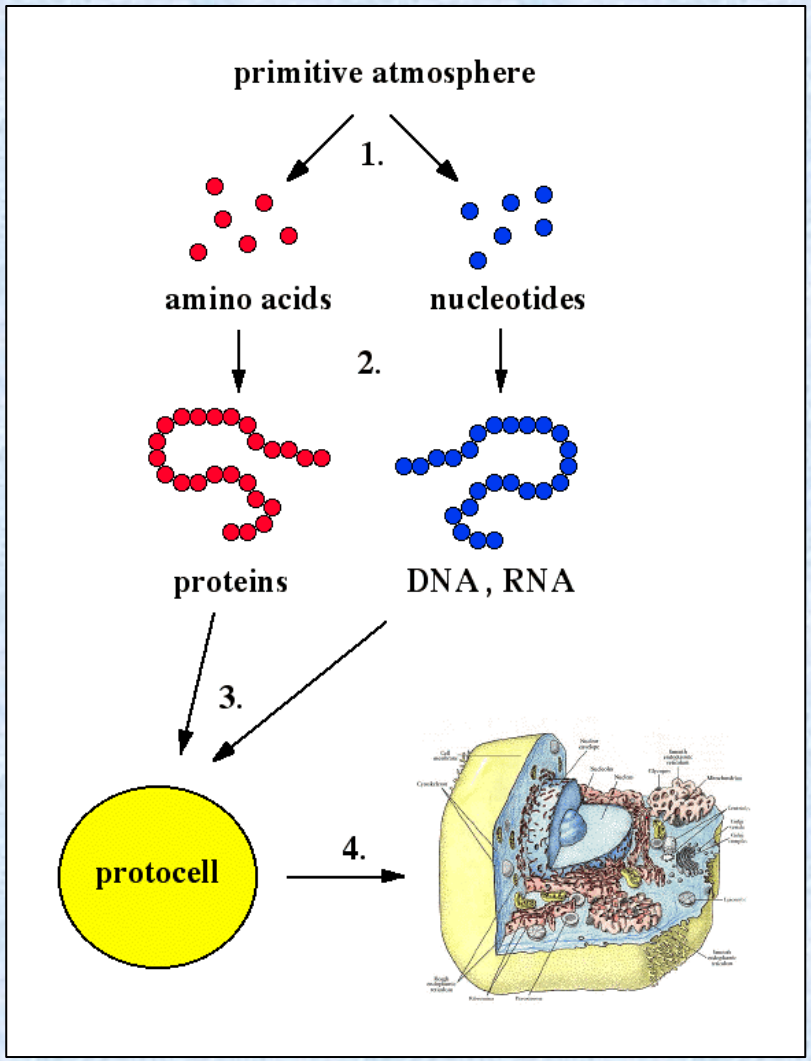
Brief History of Life on Earth
Major Steps in Evolution



Chemical Evolution of Life on Earth

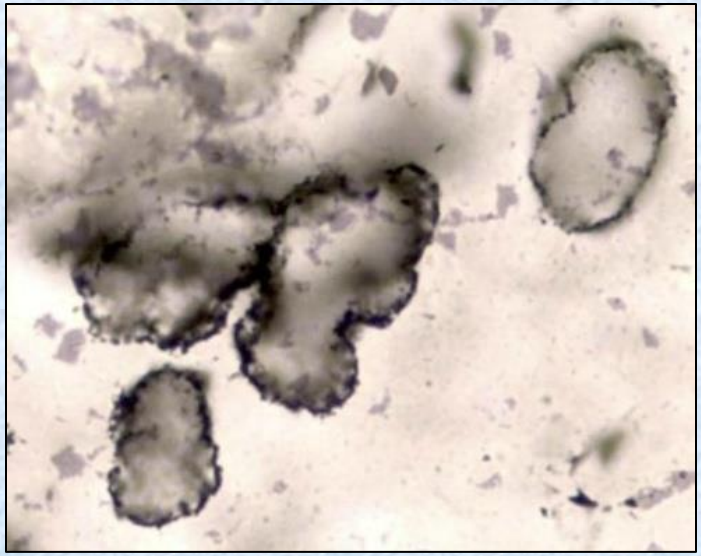
Consider the following sequence:

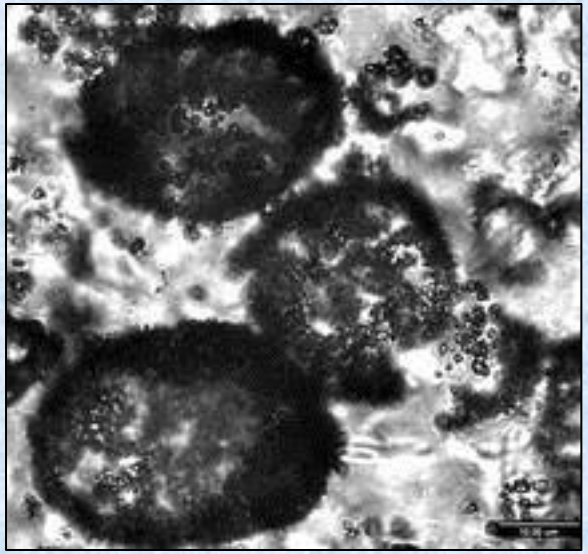
1. Synthesis and accumulation of small organic molecules
2. Joining of these monomers into polymers
3. Aggregation of these molecules into protocells to form microenvironments
4. Origin of heredity molecules and reproduction
5. Origin of metabolism



Oldest definite fossils 3.4 BY

Older fossil evidence questionable





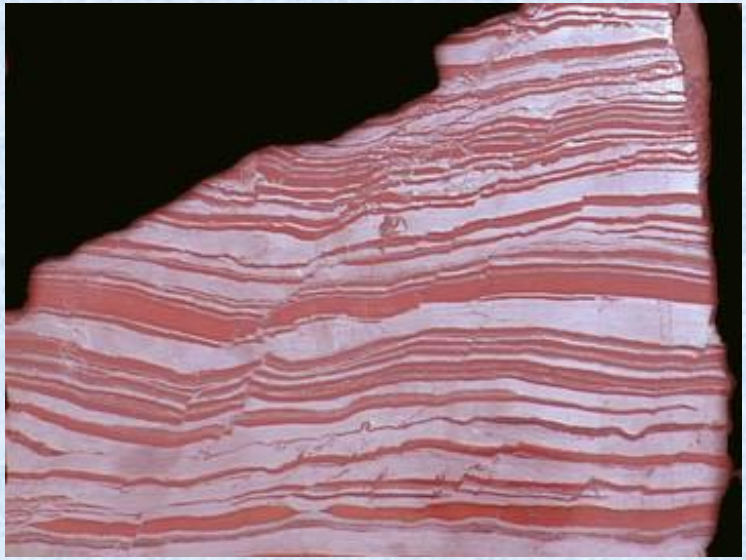
- Found in a remote part of Western Australia (Strelley Pool)
- Well preserved between the quartz sand grains of the oldest beach known on Earth, in some of the oldest sedimentary rocks that can be found anywhere.

Archean Eon: 4-2 BYA
Great Age of Bacteria

Rise of O2 Photosynthesis

- Oxygen began accumulating in the atmosphere about 2.7 billion years ago.
- Cyanobacteria are photosynthetic prokaryotes, produced the oxygen.
- Eukaryotes appear shortly after

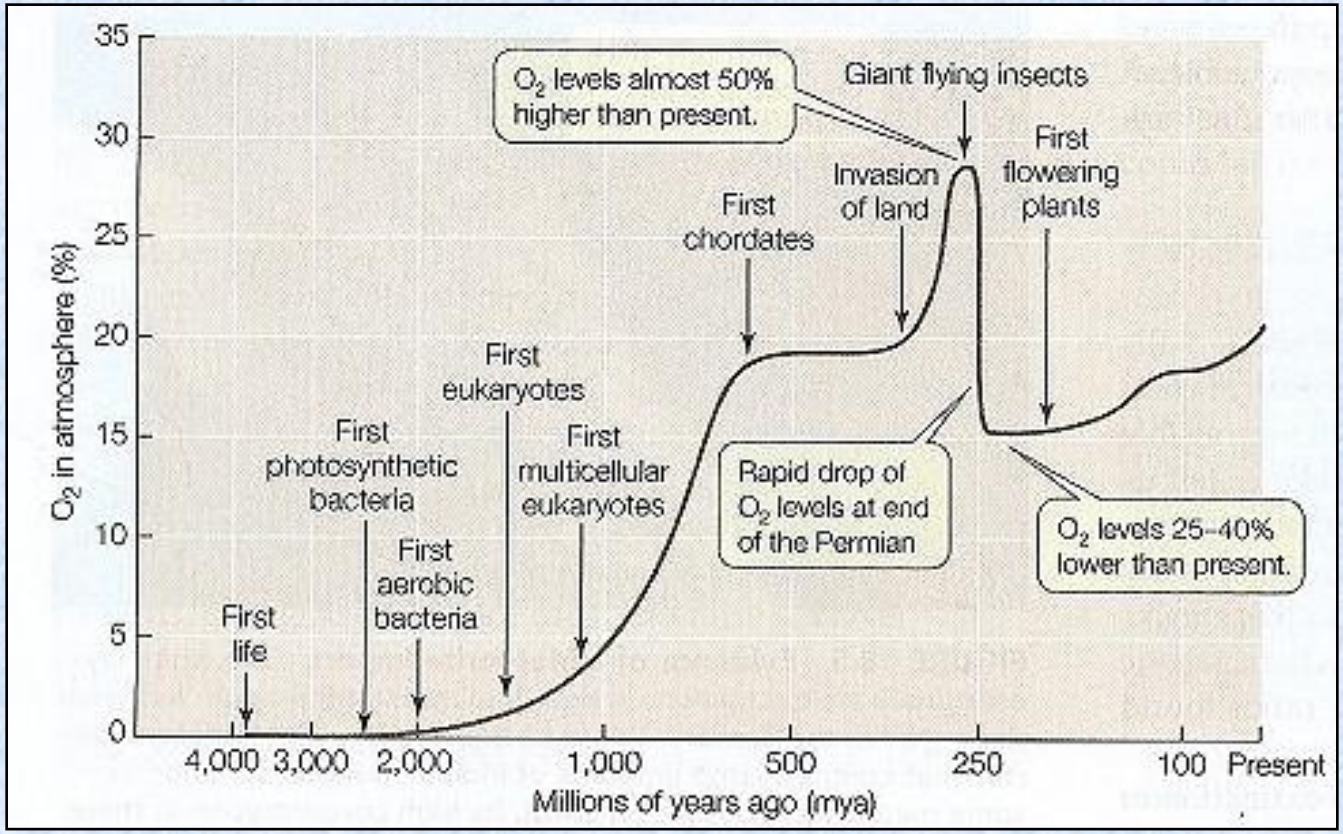
Stromatolites



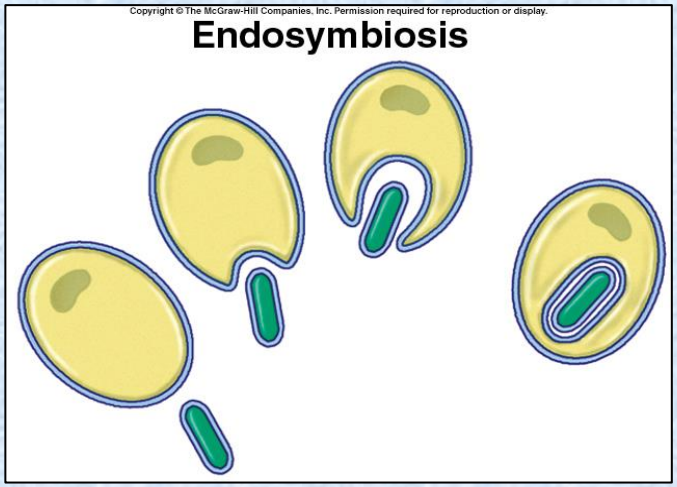
Banded Iron

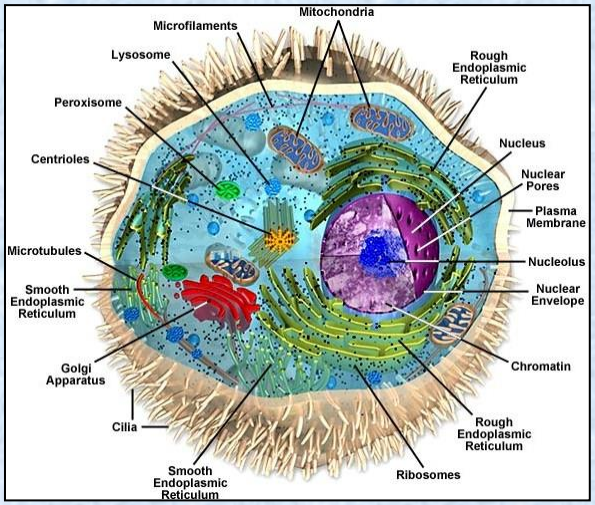
“Great Oxygen Catastrophe” – 2 BYA

- Increases in oxygen levels led to a mass extinction of obligate anaerobes that could not tolerate oxygen.
- Maximum oxygen levels reached 250 million years ago.



From Prokaryote to Eukaryote





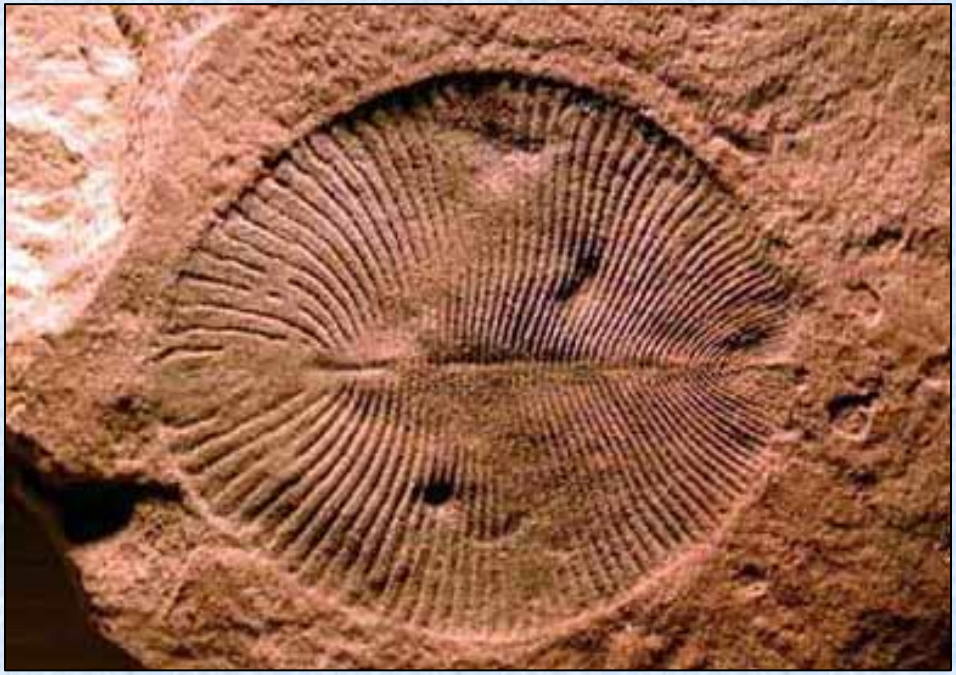
Acritarch
(algal cyst)

By about 2 to 1.5 billion years ago (Proterozoic Eon) the first eukaryotes appeared (organisms will a well-defined nucleus and organelles).

These are distinguished in the fossil record by their <u>larger size</u>.

Ediacaran Fossils – 600-542 MYA

- Just before the Cambrian explosion, worldwide proliferation of multicellular organisms
- Flat, segmented, soft-bodied.
- Ancestral to jellyfish or soft-bodied arthropods? Or an extinct kingdom of life?
- Few or none survived into the Paleozoic era.

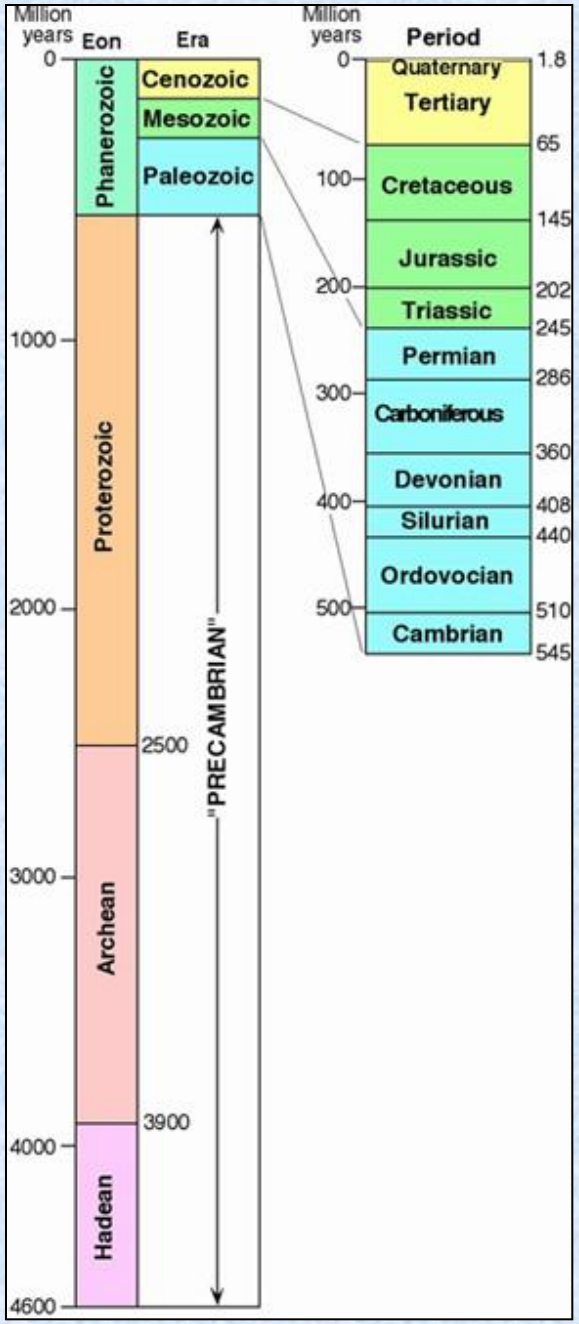


Ediacaran Life - 600-542 MYA

All of these were soft-bodied, and are known only from impressions
Became extinct in early Cambrian

Our Story So Far

- We have come 5/6 of the way through the history of the Earth.
- Earth forms 4.6 billion years ago
- Solid surface forms 4 billion years ago
- Life starts (?) 3.8 billion years ago
- Precambrian - Age of Bacteria
- Oxygen atmosphere develops 2 billion years ago.
- Eukaryotes develop.
- Ediacaran life: 600 million years ago. First multicellular life, forms unknown today



Between about 542 and 510 million years ago, skeletonized organisms appeared in a huge explosion of diversity.

This event is called *The Cambrian Explosion*.

Seascapes changed…

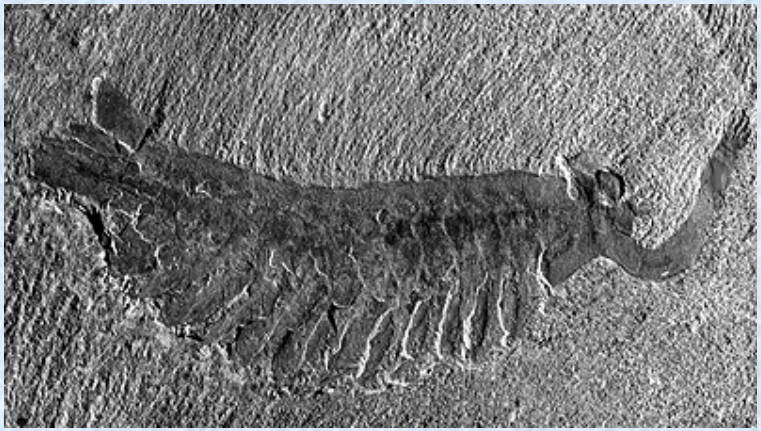
From peaceful oasis…

…to war zone with weapons and armor

Cambrian Explosion

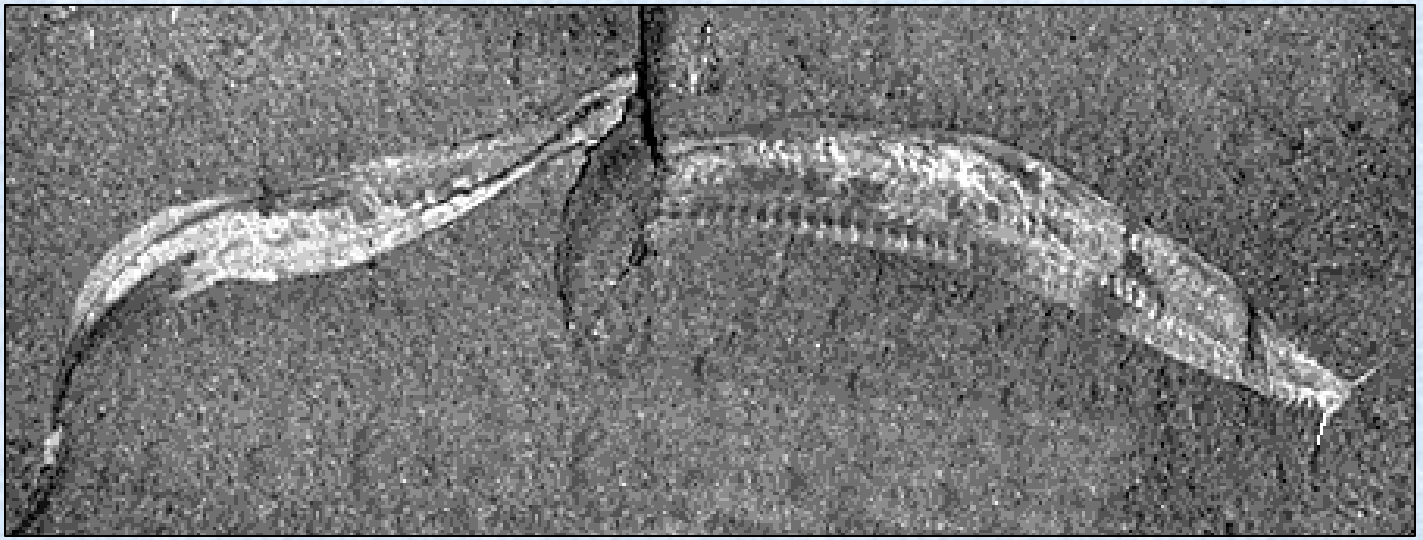
Cambrian Seas – trilobites

Burgess shale



Pikaia

One of earliest known Chordates



A notochord (an internal band of elastic tissue that could be flexed by muscle packs down its length) allowed early chordates to swim without the burden of heavy external armor.

We ultimately evolved from an animal that looked like this !

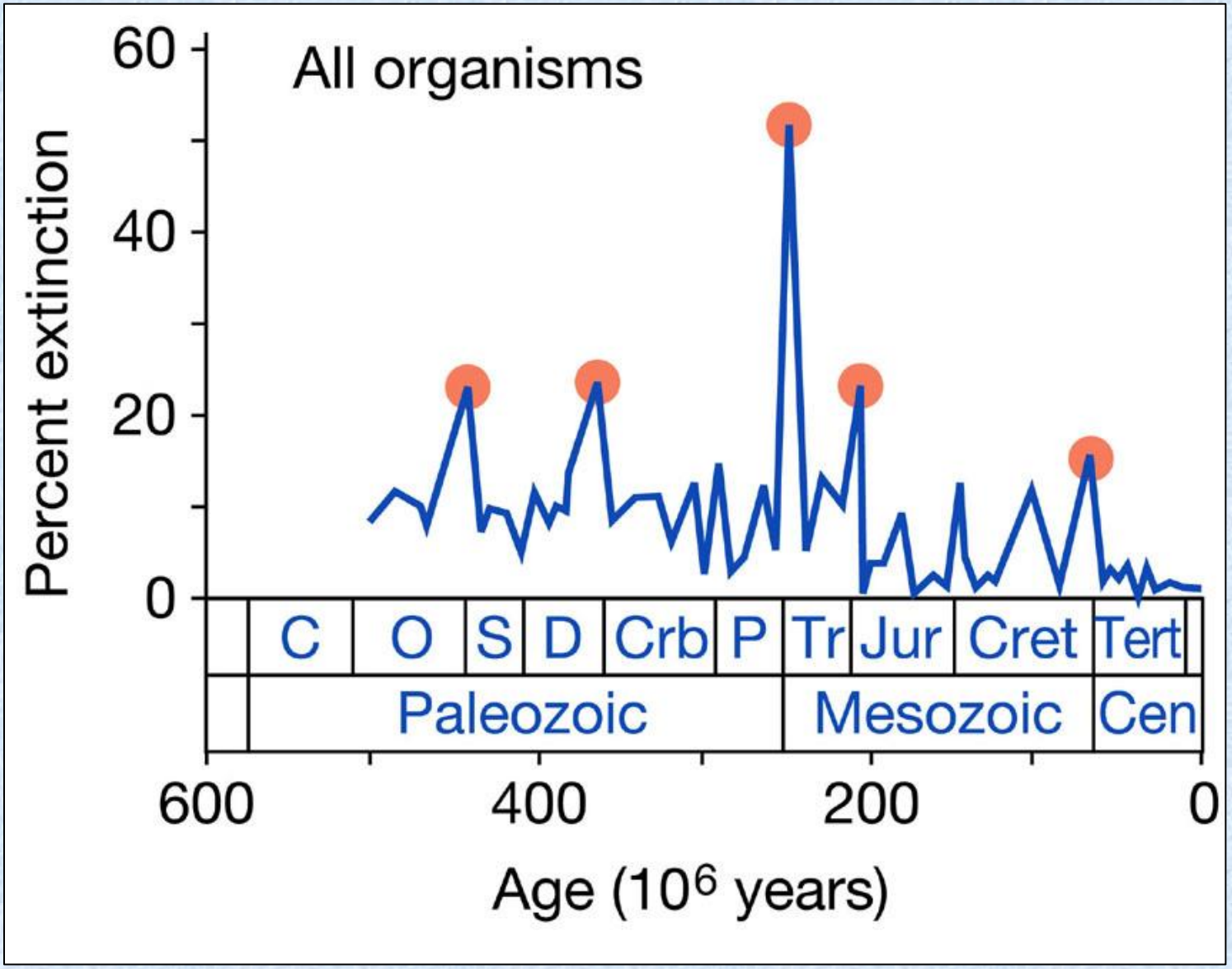
Ordovician - (490 - 443 million years ago)

- Most animals alive in the Ordovician were similar to those alive in the Cambrian.
- Introduction of animals similar to squid.
  - Cephalopods

Ordovician-Silurian Mass Extinction

- The third largest extinction in Earth's history.
- Trilobites, brachiopods and graptolites drastically reduced in number.
- 85% of sea life was wiped out.
- Ice age has been blamed for the extinctions, messed with the chemistry of the oceans

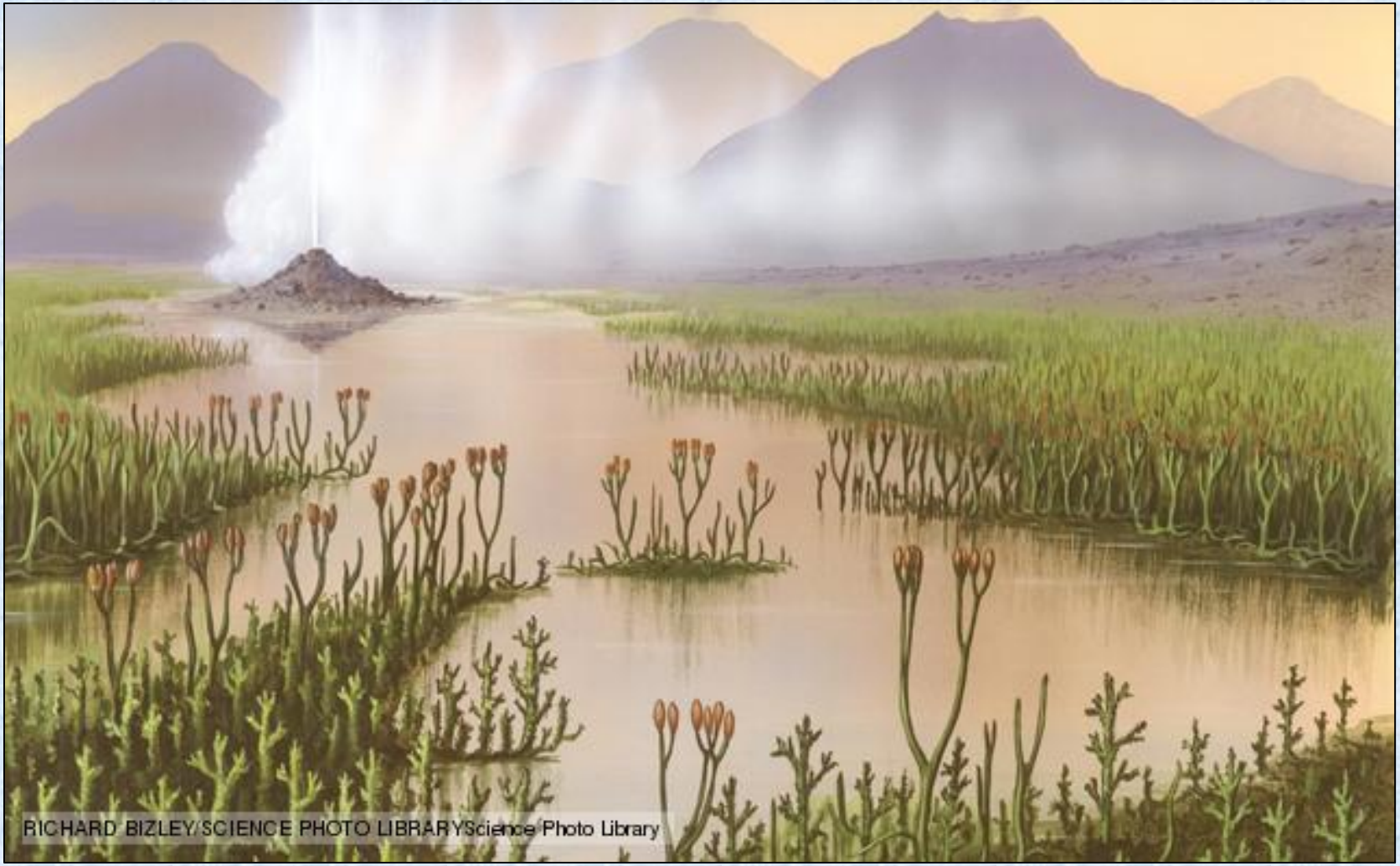
5 Great Mass Extinctions!



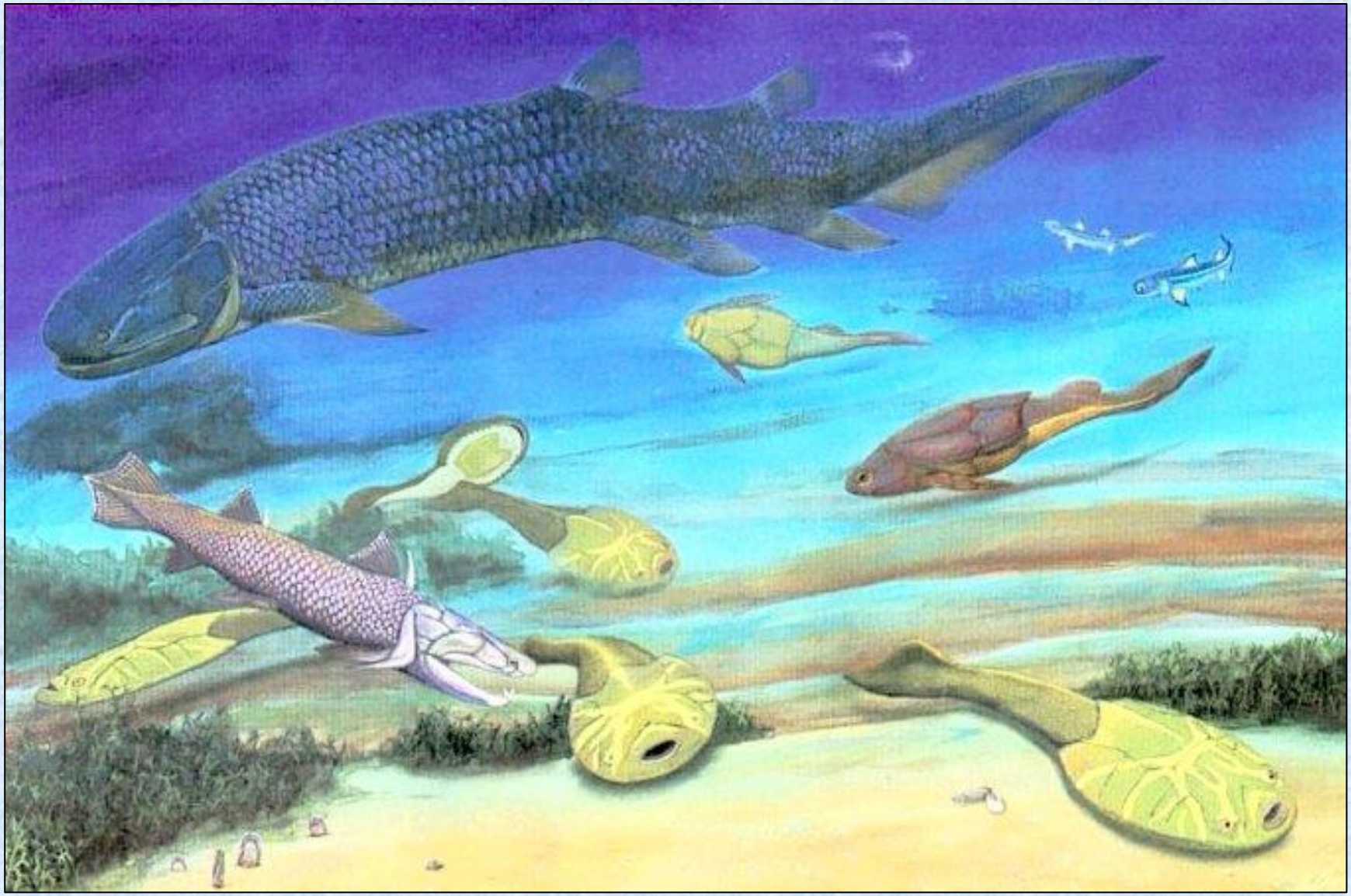
Silurian (443 - 417 million years ago)

- The Earth's climate became stable and a bit warmer during the Silurian.
- This allowed many new animals to appear for the first time.
  - Coral Reefs
  - First (Jawless) Fish
  - Land plants

Silurian Plants

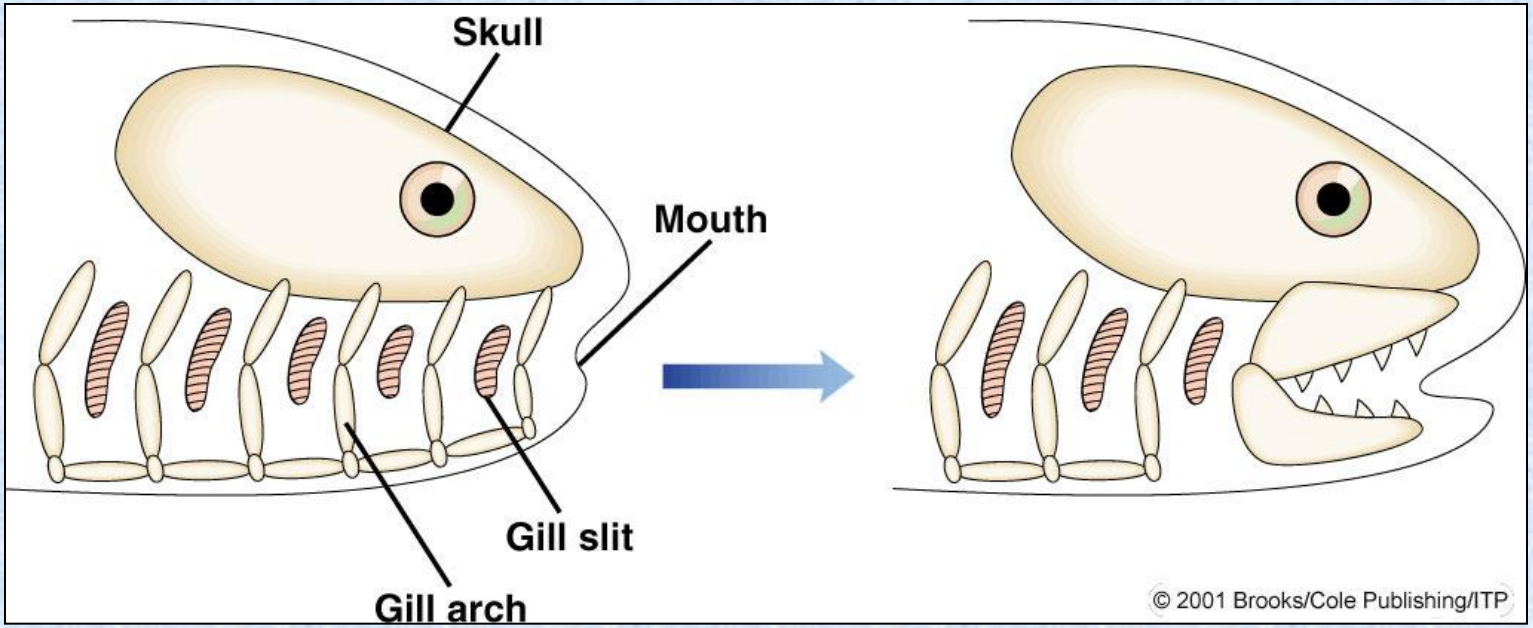


Devonian - Age of Fish

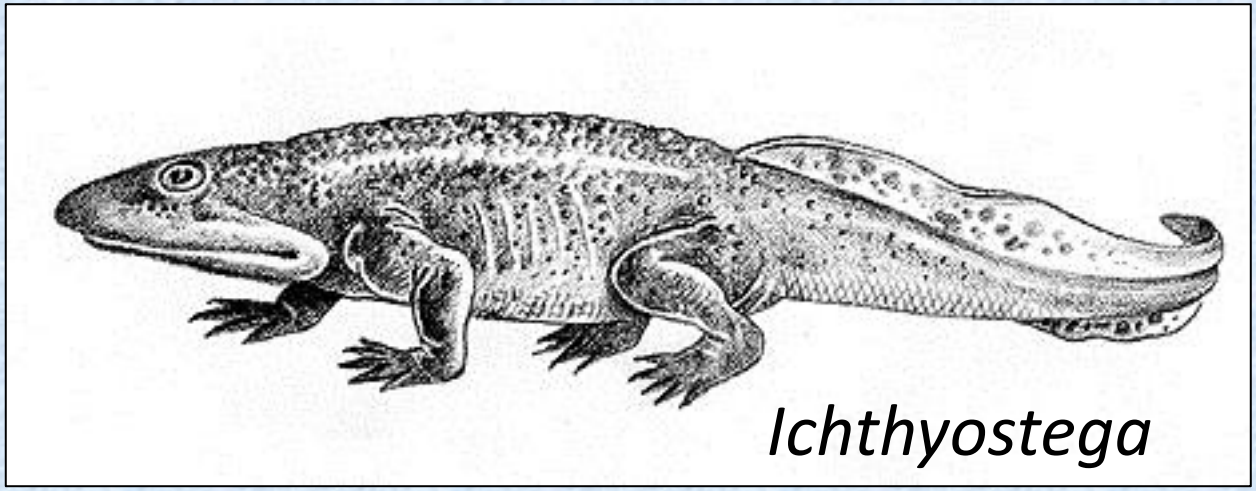


Evolution of Jaws

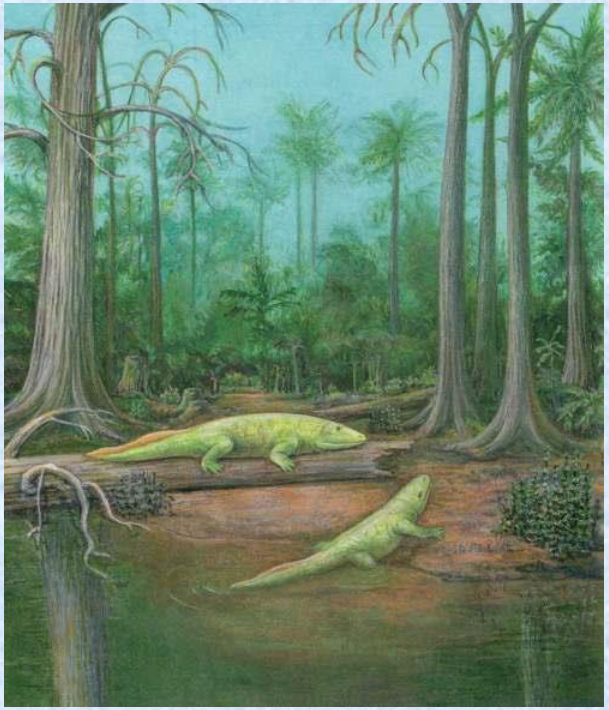
- The evolution of the vertebrate jaw
  - is thought to have occurred
  - from the modification of the first two or three anterior gill arches

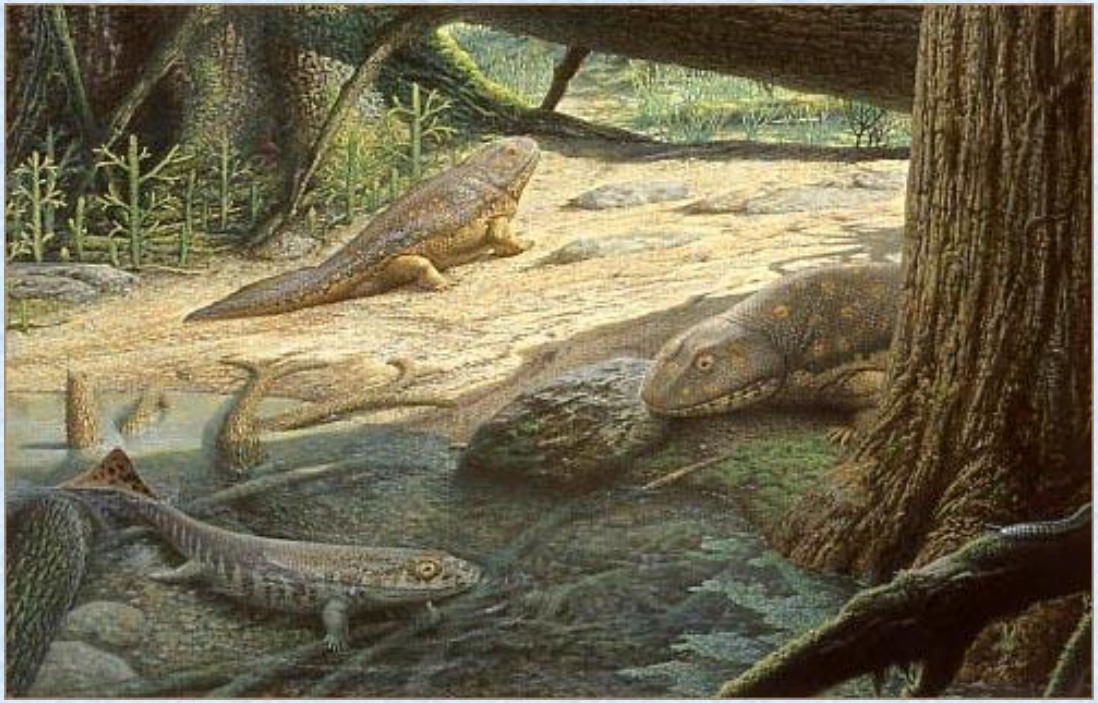


Devonian - Vertebrates Invade the Land

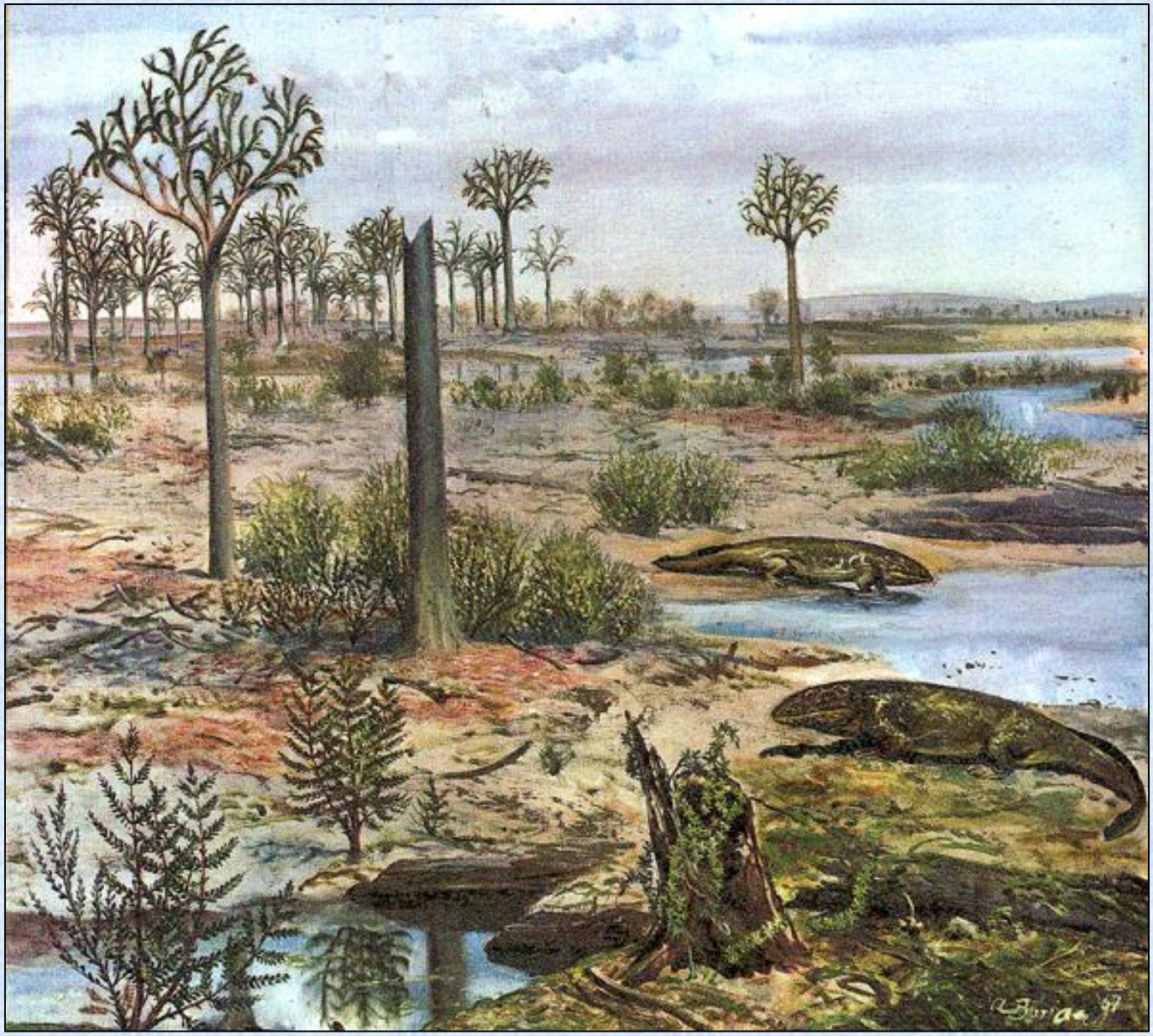


Ichthyostega



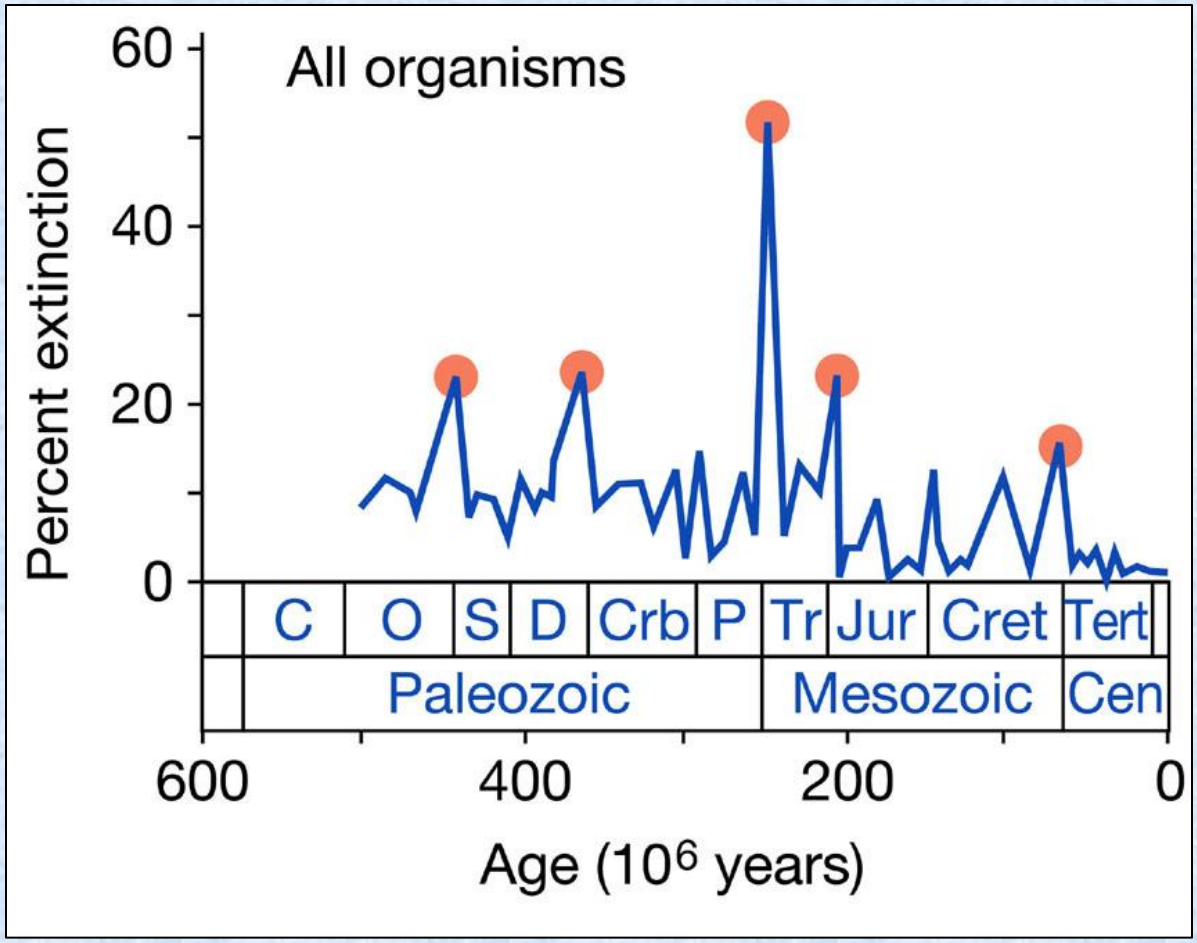


Devonian Forest Landscape



End of Devonian - Prolonged Mass Extinction

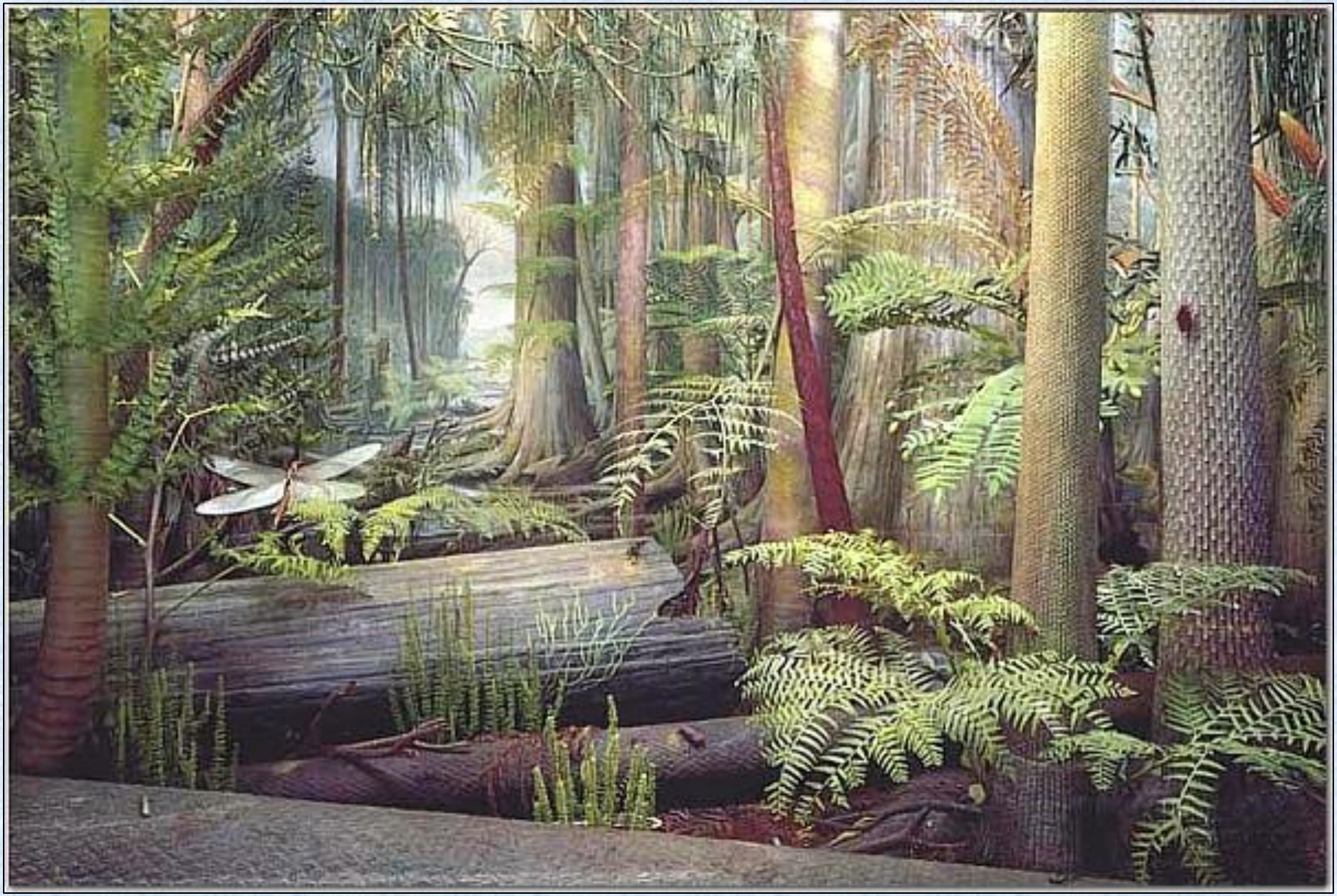
- Global cooling, glaciation?
- Link to land vegetation, carbon deposition in ocean?
- 20% all families, 75% all species



Late Devonian Mass Extinction

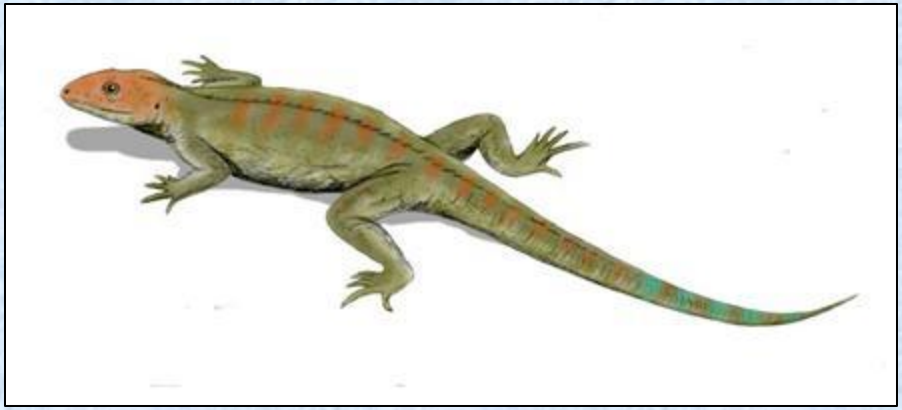
- Three quarters of all species on Earth died out.
- Life in the shallow seas were the worst affected.
- Much of the sea became devoid of oxygen.

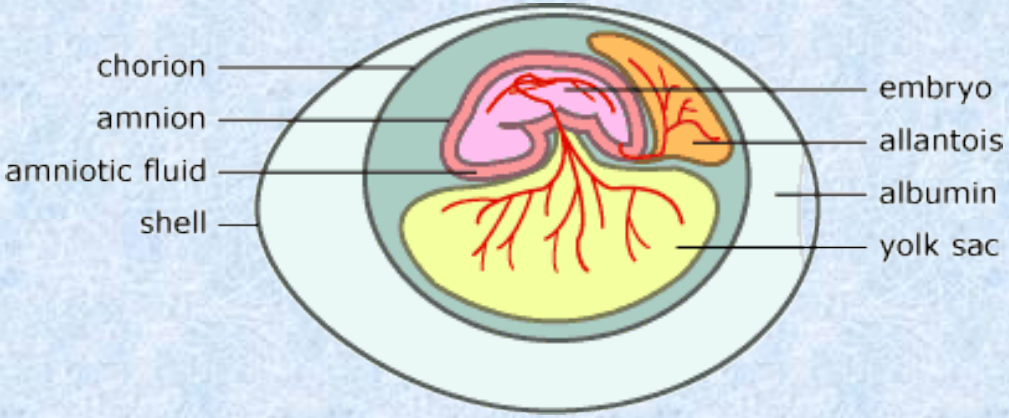
Carboniferous Forest – 300 mya (Field Museum)



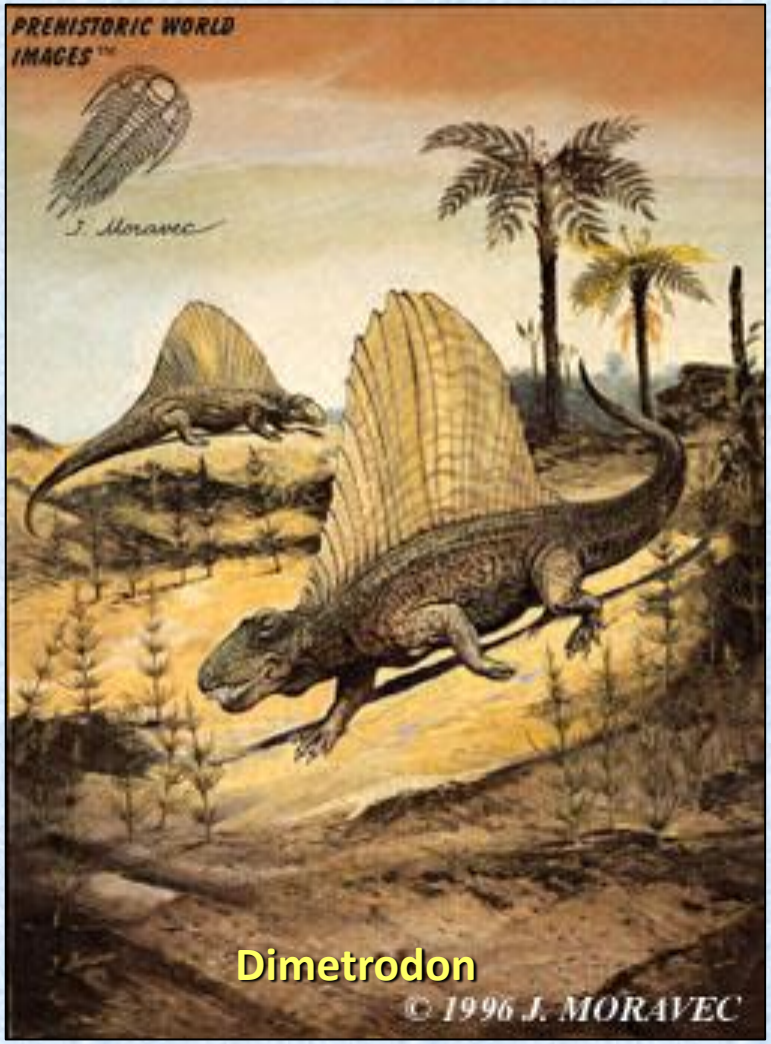
Amniote Egg

Reptiles cut ties to the water





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.

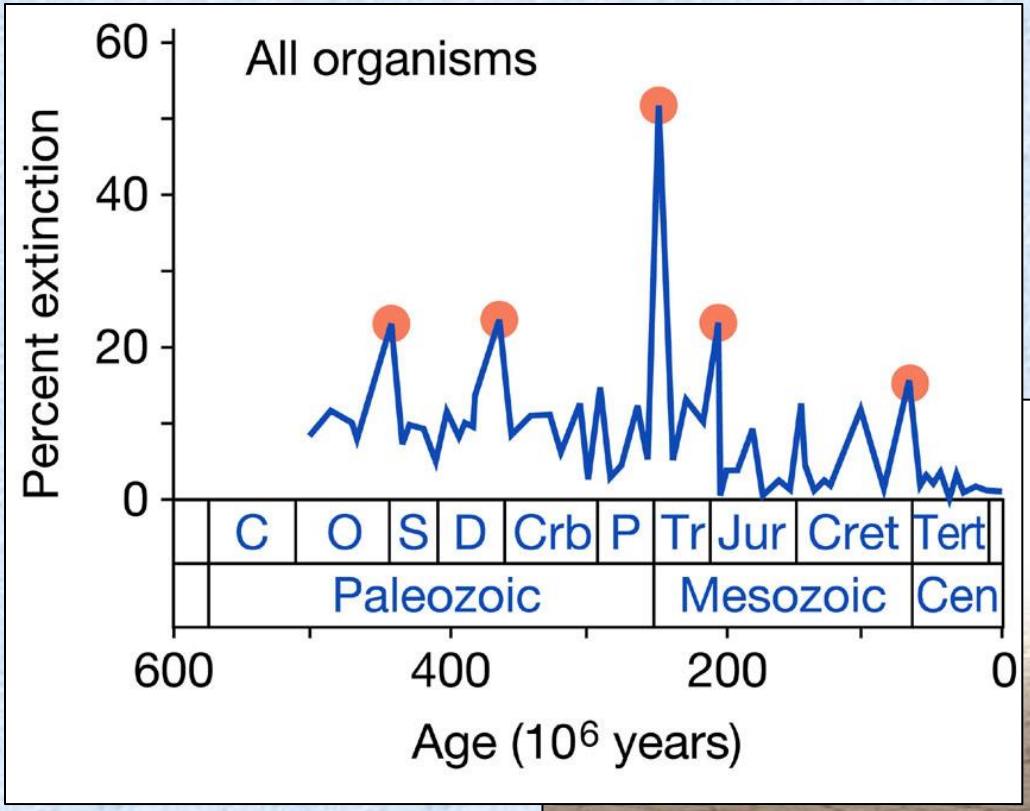
Cynodonts – late Permian mammals

- 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.

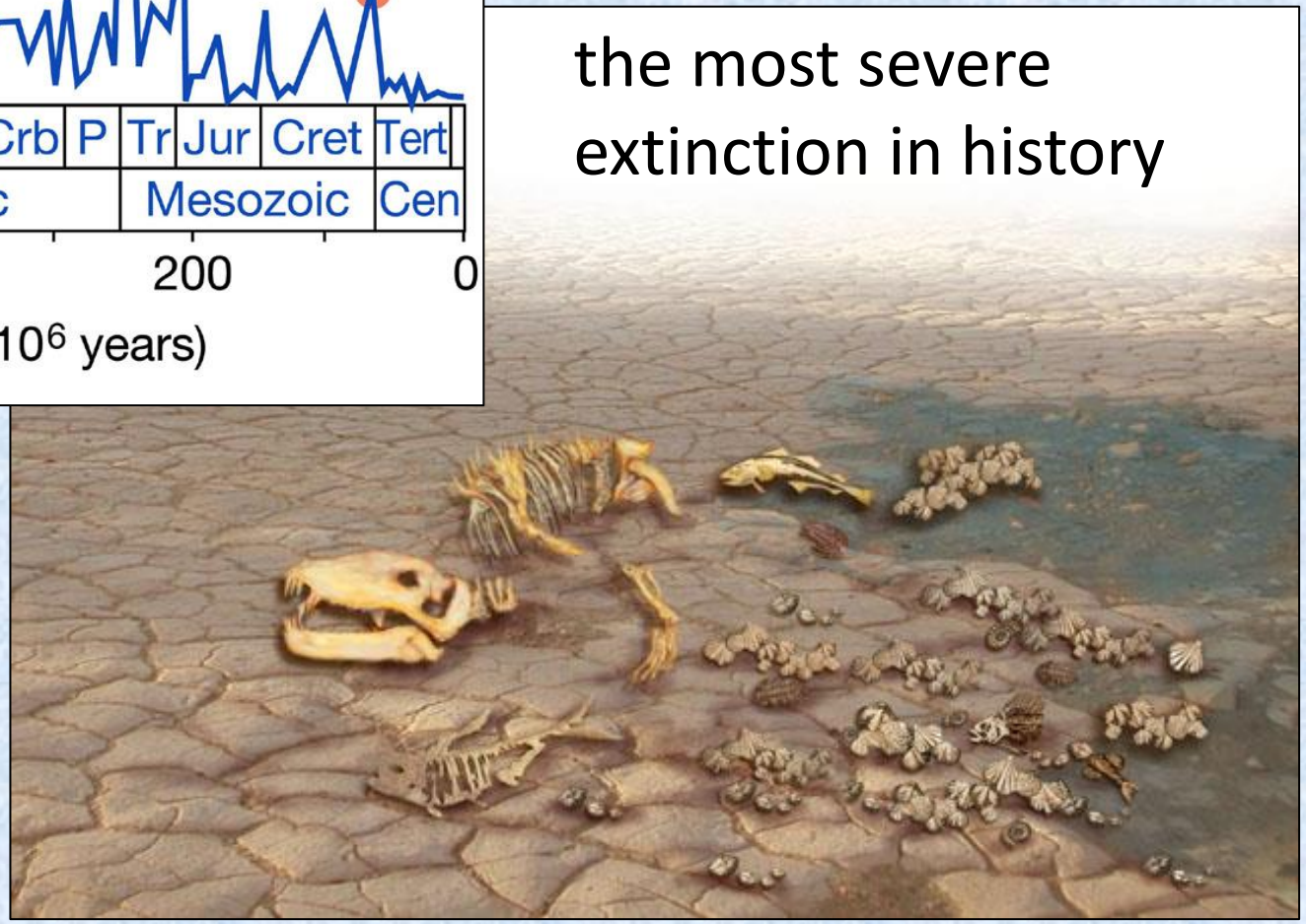
End of the Paleozoic - Mass Extinction

- Largest mass extinction in Earth's history
  - 90% - 95% of all marine species became extinct
  - Likely due to changes in the environment and competition for living space.
  - Colder climate
  - Volcanic eruptions
  - Ocean ecosystems collapse

Permian Extinction
"Great Dying"



the most severe extinction in history

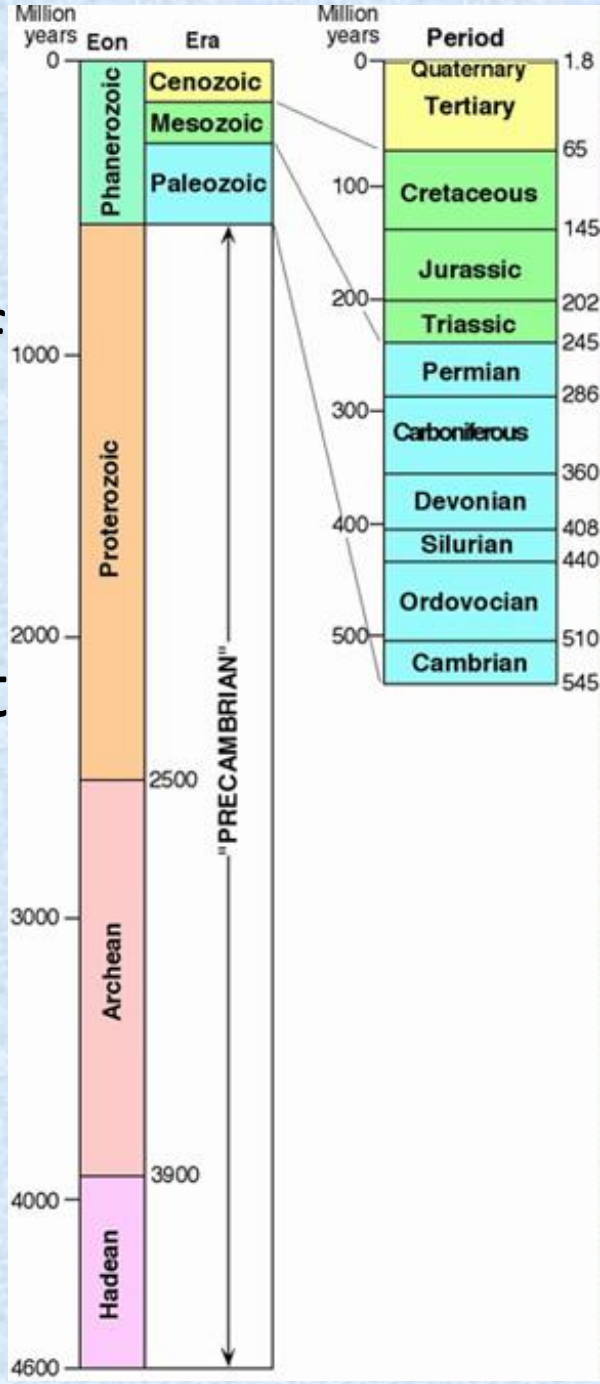


Geological Eras

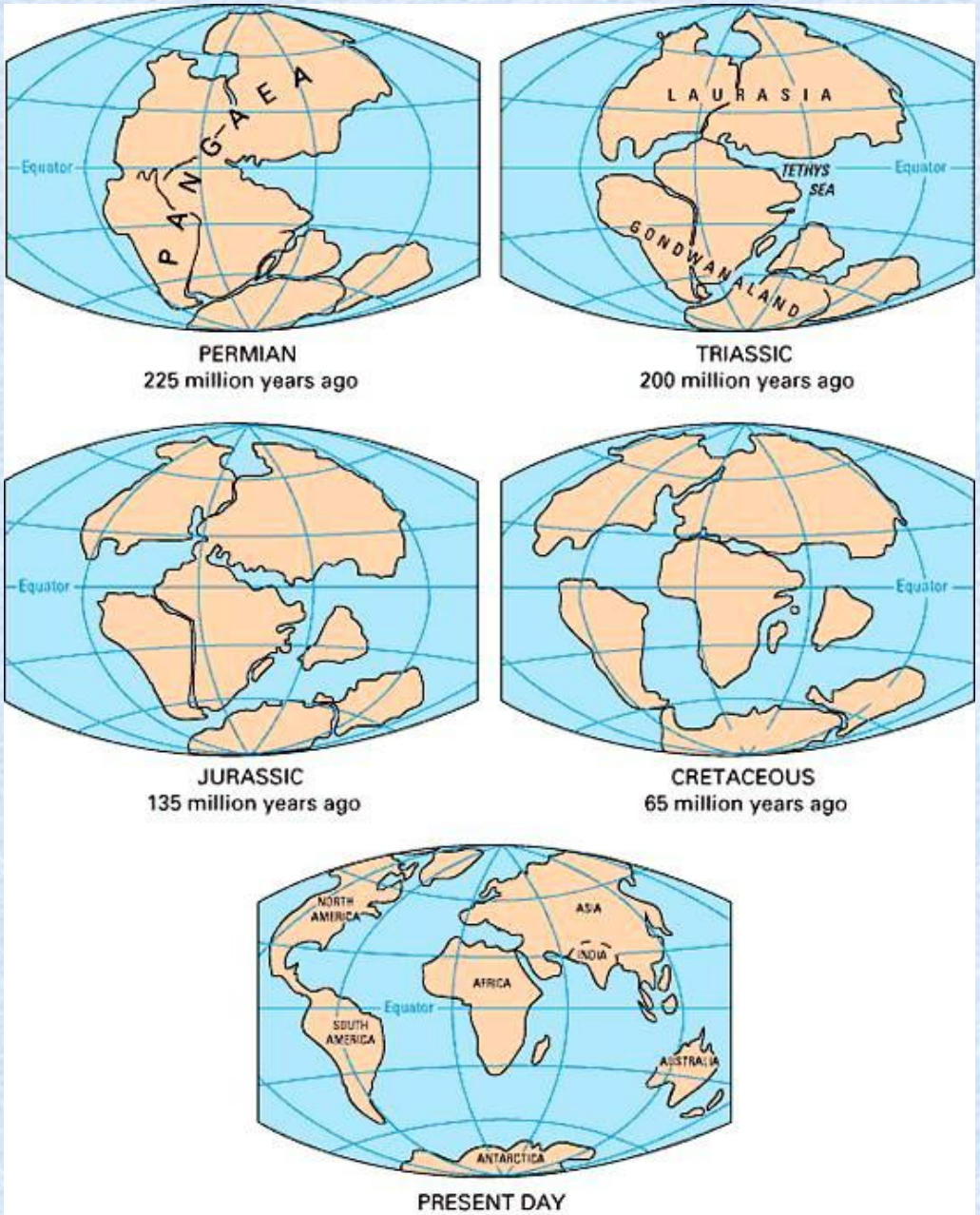
Paleozoic Era. 550 to 250 million years ago. Fossils appear, complex multicellular organisms, invasion of the land by plants and animals.

Mesozoic Era. 250 to 65 million years ago. Appearance of true mammals and flowering plants, but the land is dominated by dinosaurs (reptiles).

Cenozoic Era. 65 million years ago until present. Land dominated by mammals and flowering plants.

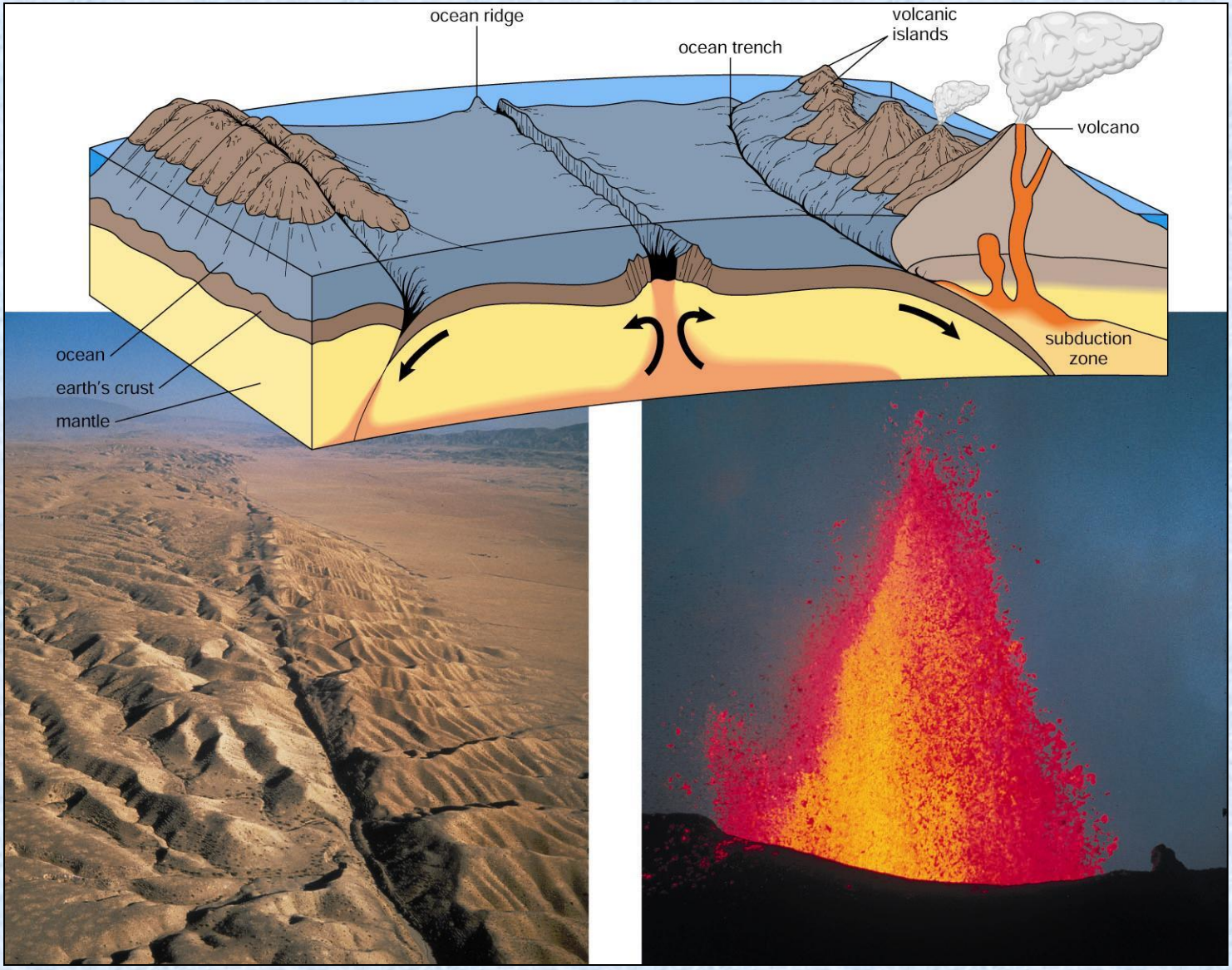


Mesozoic Key theme: Pangea breaks up



- Process will take 150 my and will extend into the Cenozoic
- Laurasia – northern
- Gondwanaland - southern
- Laurentia/Baltica and Australia/Antarctica are still joined at the end of the Mesozoic

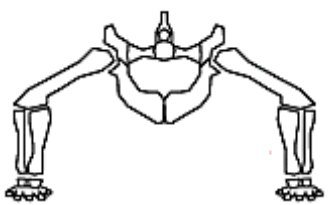
Plate Tectonics



Mesozoic – Age of Dinosaurs

- **Dinosaurs appeared in the Late Triassic**, about 225 MY ago.
- The name "dinosaur" comes from the Greek *deinos* = "terrifying" and *sauros* = "lizard".
- The earliest dinosaurs were small. Many were less than 3 ft long.
- By the end of the Triassic, dinosaurs were up to 20 feet long.
- They became much larger later in the Jurassic and Cretaceous.

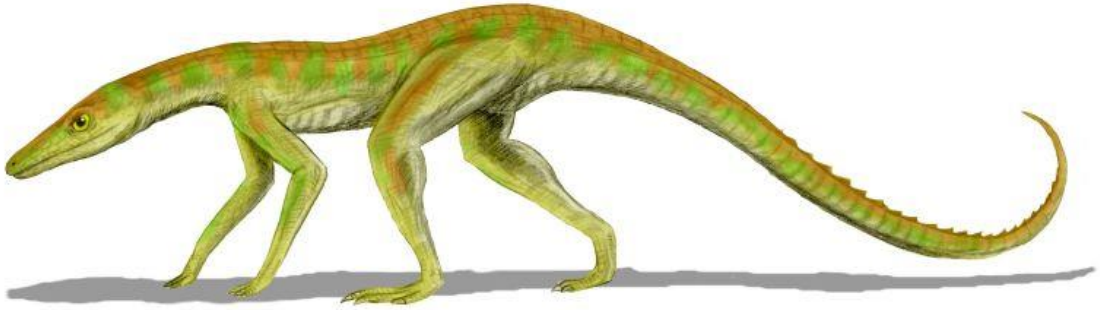
Dinosaur Locomotion



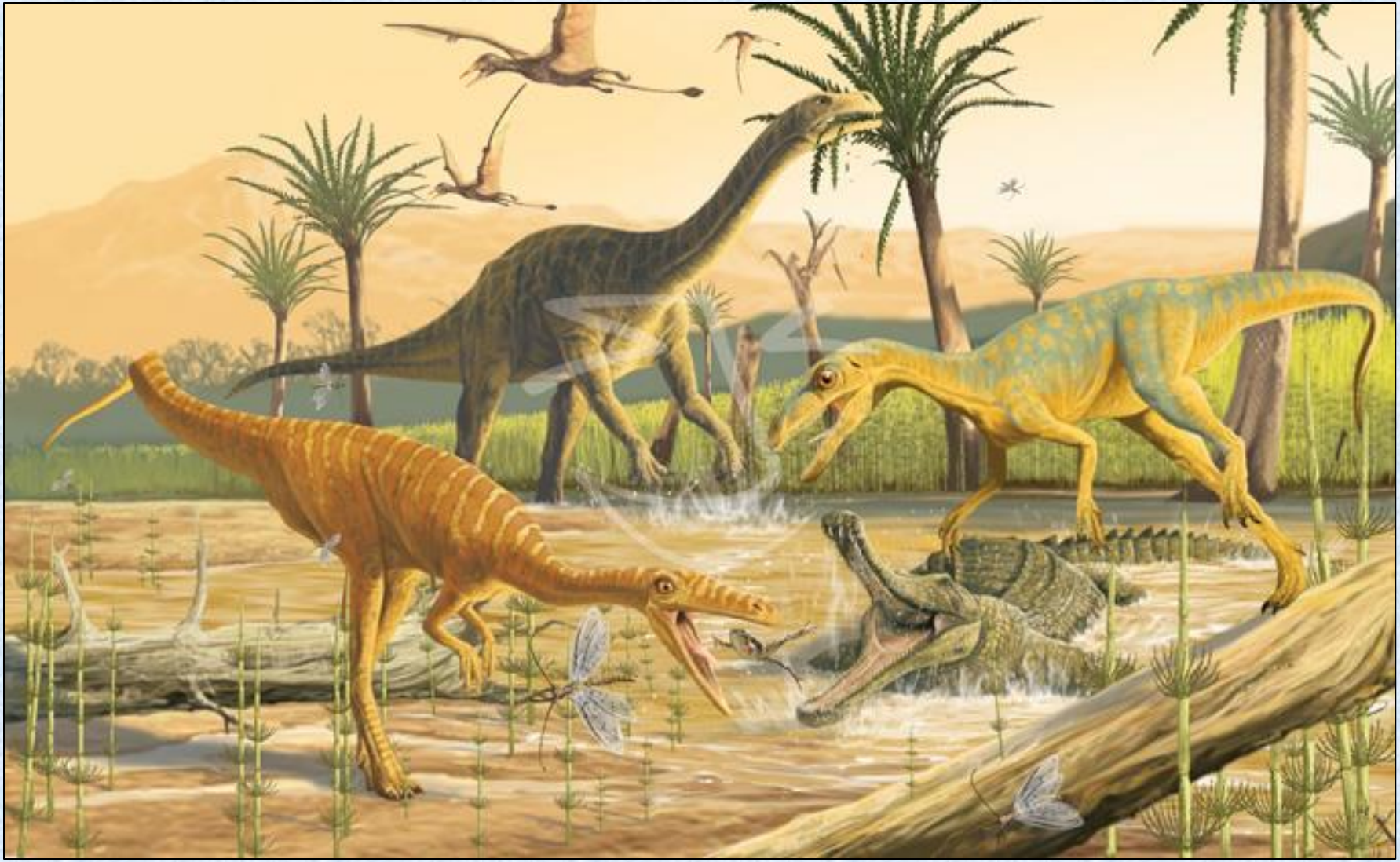
Sprawling

Erect
(dinosaurs, mammals)

Pillar-erect
(rauisuchians)



Triassic Dinosaurs

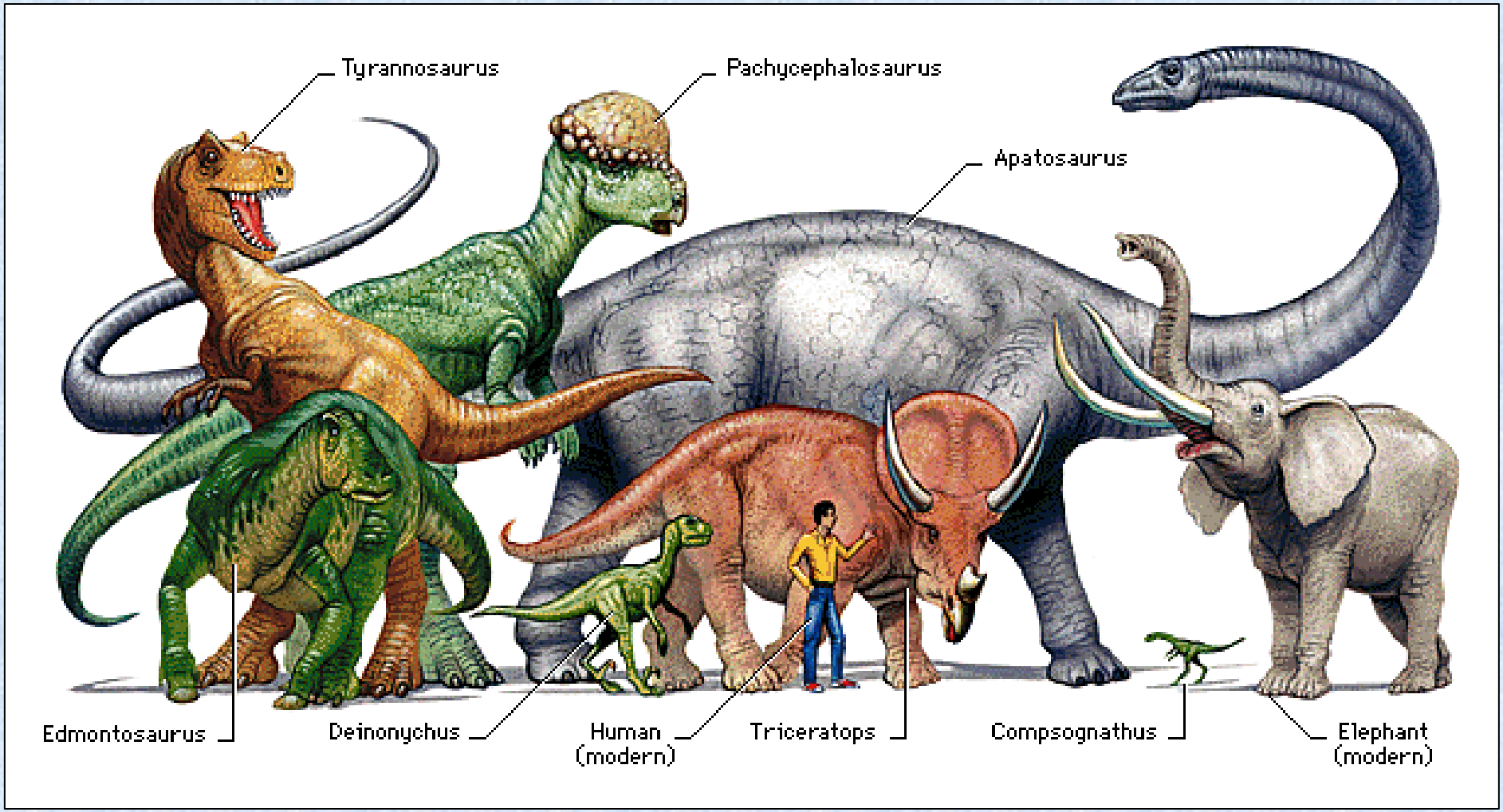


Mammals Too

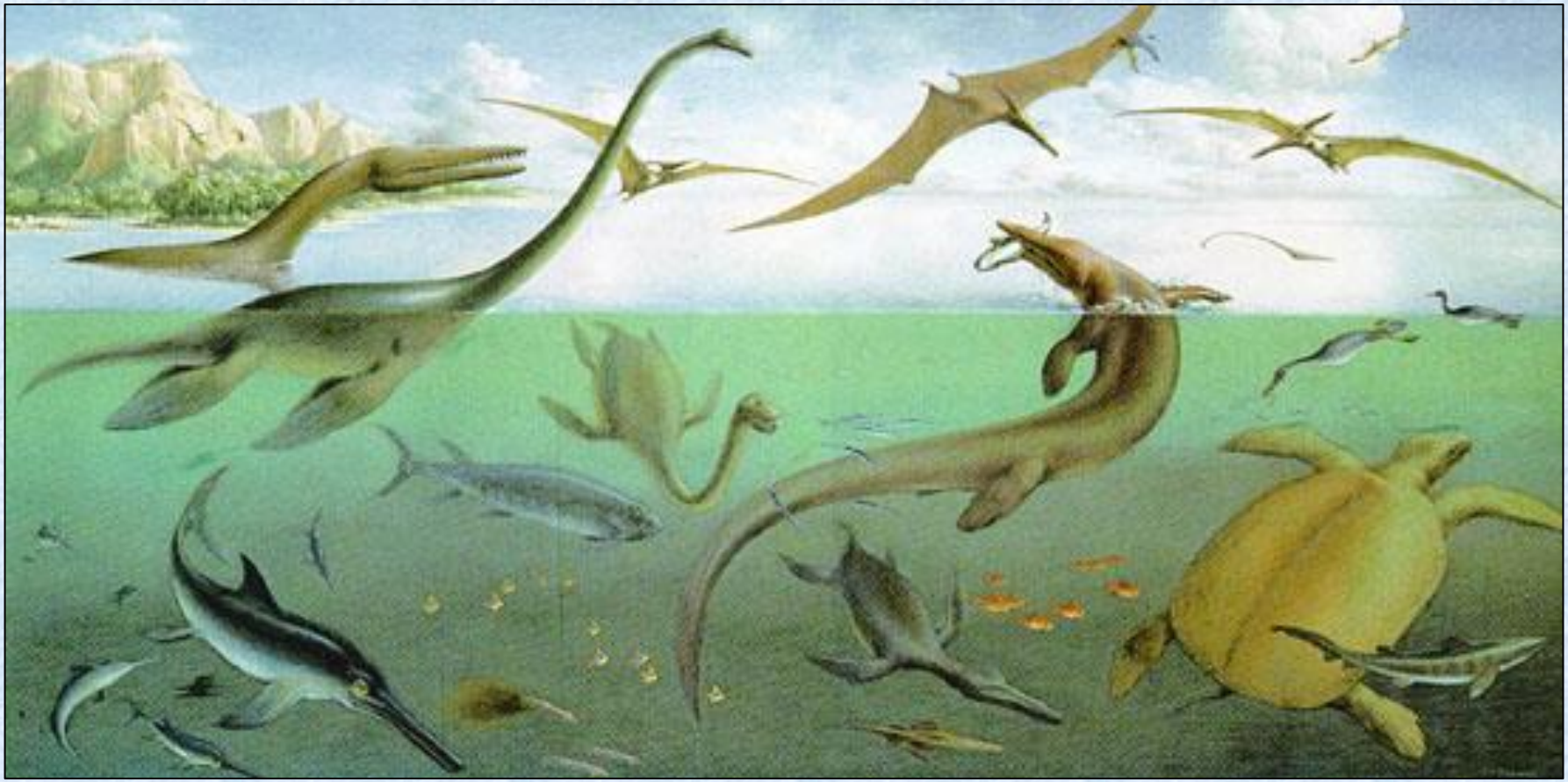
Mammals and dinosaurs were contemporaries

- Hairy, warm-blooded
- but mammals were not particularly diverse
- and none were very large

Dinosaur Size and Diversity



Cretaceous - Marine and Flying Reptiles



Theropod dinosaurs

- Top predators in the Jurassic and Cretaceous periods.
- Tyrannosaurus, Velociraptor and Spinosaurus.
- However, not all theropods were predators.

Earliest Birds - *Archaeopteryx*

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

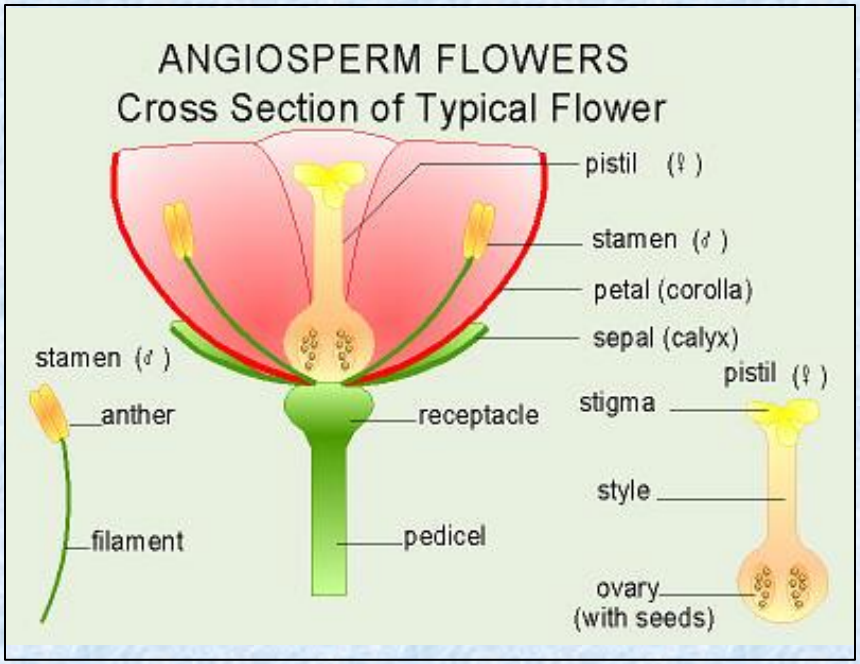
Mesozoic Gymnosperms, “naked seed” plants

Cycads, Conifers

Jurassic Gymnosperm Conifer Forests

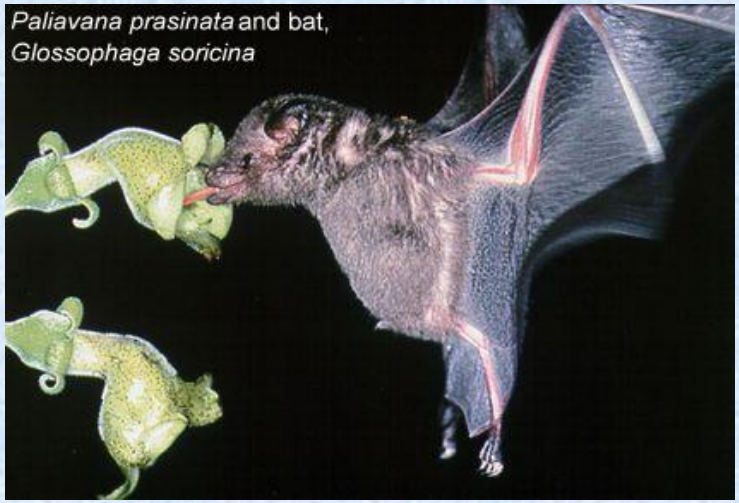
Painting of a late Jurassic Scene on one of the large island in the Lower Saxony basin in northern Germany. It shows an adult and a juvenile specimen of the sauropod *Europasaurus holgeri* and iguanodons passing by. There are two *Compsognathus* in the foreground and an *Archaeopteryx* at the right.

Angiosperms present in the Cretaceous, probably appeared earlier in Triassic



- Angiosperm plants are those that have flowers
- Major change in plant life – insects are now the pollinators
- Sets the stage for grasses to appear in Cenozoic

Angiosperms - Pollination mechanisms



Flowering Plants
Angiosperms
Fruit and seed dispersal

K/T Boundary Mass Extinction

- 65 MY ago
- Dinosaurs, pterosaurs, many marsupial mammals became extinct
- Extinction for terrestrial organisms 15%
- Marine extinctions at the generic level 70%
- All ammonites, rudists (bivalves), marine reptiles

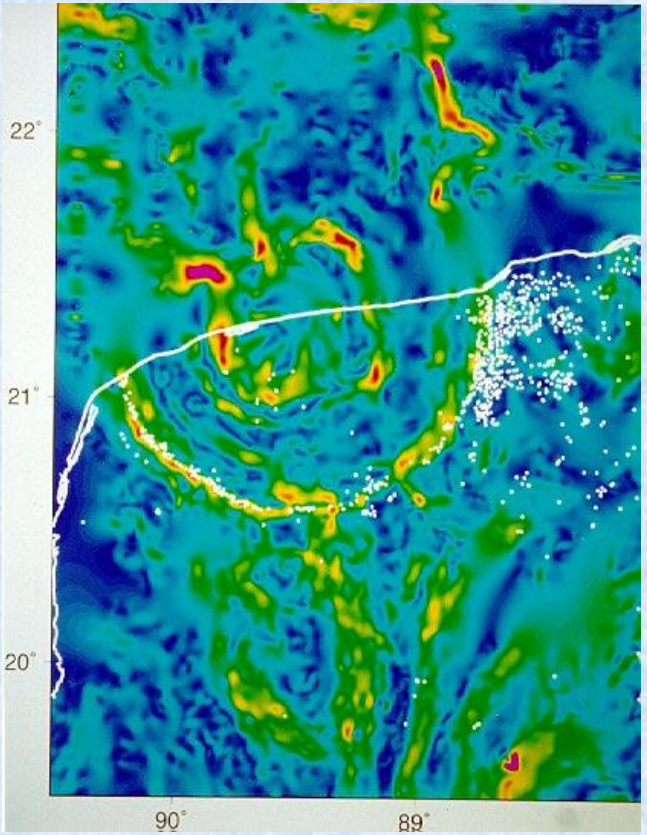
K/T Extinction
Cretaceous Asteroid Impact

K/T Extinction – End of Cretaceous

Luis and Walter Alvarez stand by the rock layers near Gubbio, Italy, where unusually high traces of **iridium** were found at the Cretaceous-Tertiary boundary.

Where is the impact crater?

The most likely location of an impact structure of the proper age is the **Chicxulub structure**, a buried circular crater-like structure on the Yucatan Peninsula of Mexico.

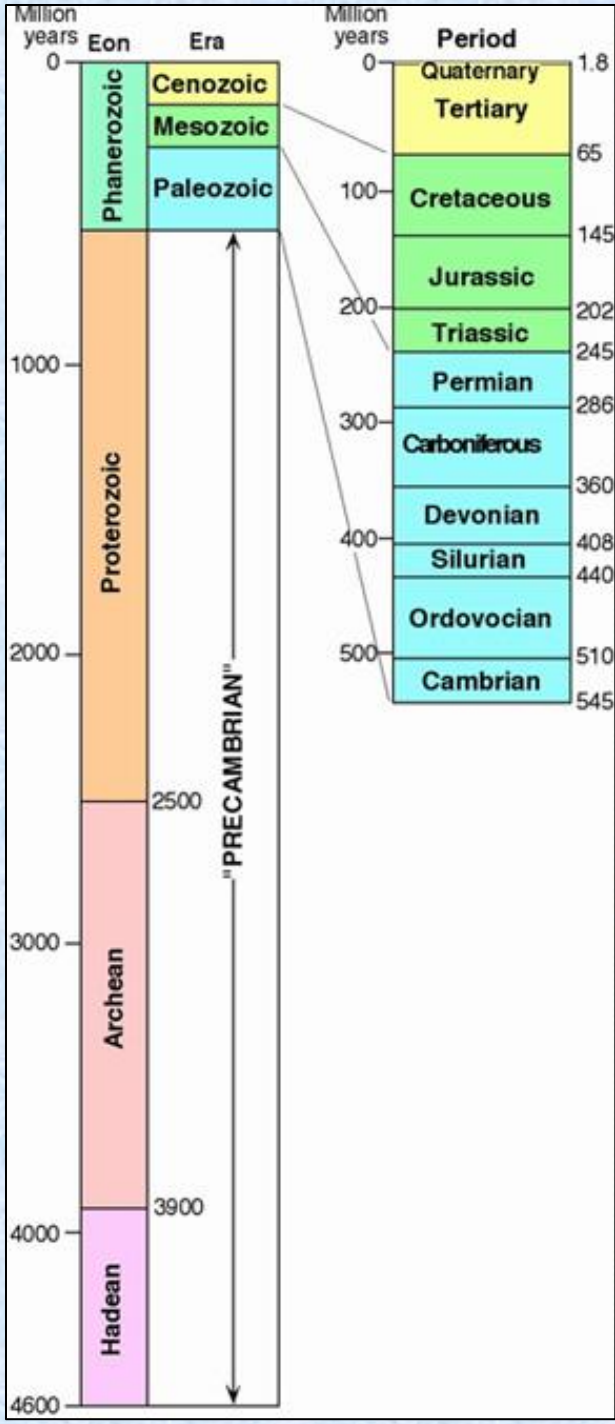


Geological Eons and Eras

Paleozoic Era. 550 to 250 million years ago. Fossils appear, complex multicellular organisms, invasion of the land by plants and animals.

Mesozoic Era. 250 to 65 million years ago. Appearance of mammals and flowering plants, but the land is dominated by dinosaurs (reptiles).

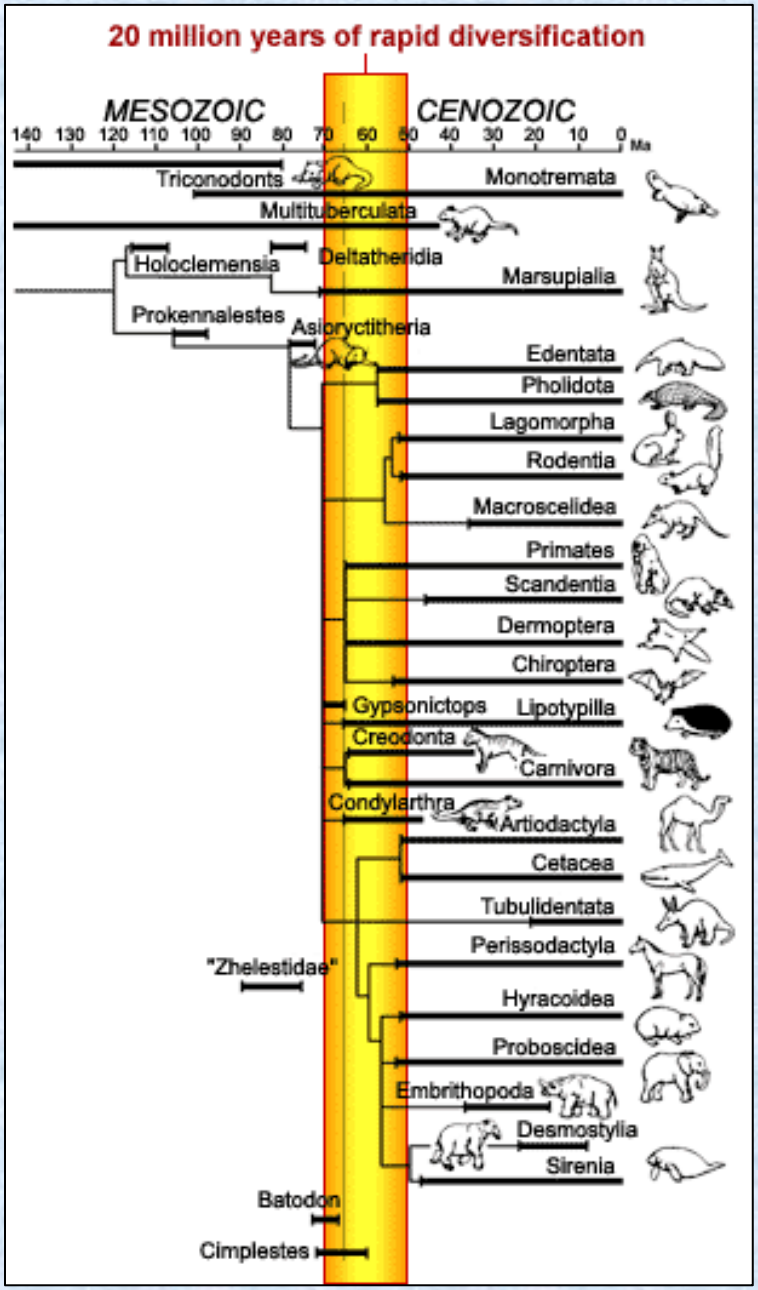
Cenozoic Era. 65 million years ago until present. Land dominated by mammals and flowering plants.

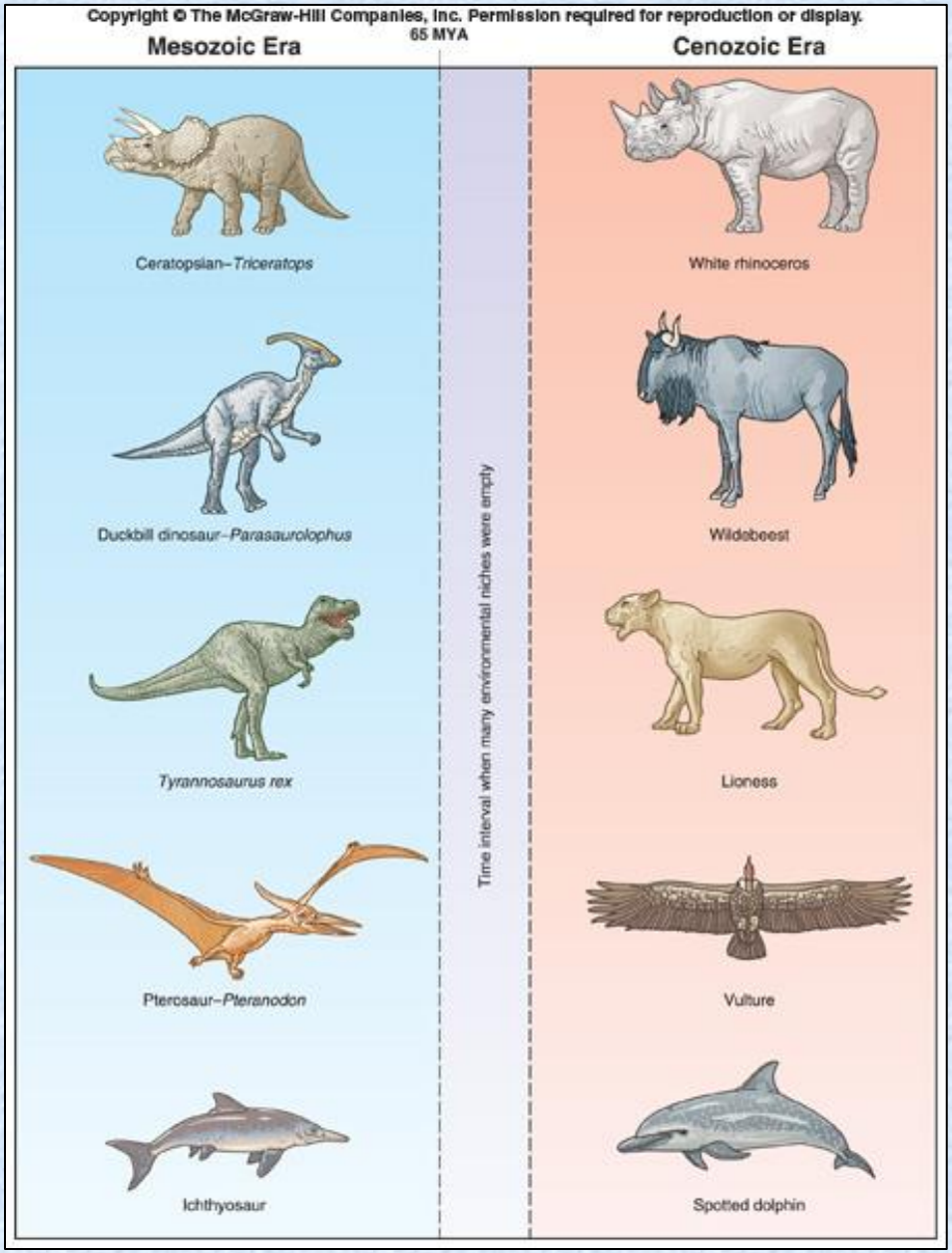


Cenozoic - Age of Mammals

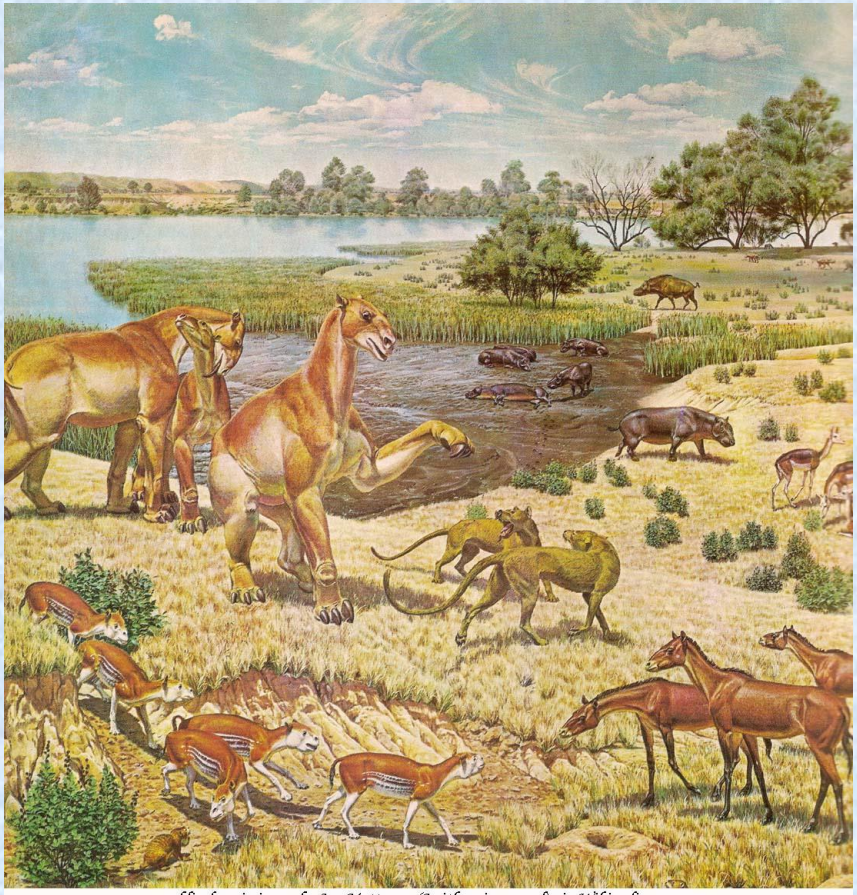
- Mammals evolved during the Late Triassic,
  - and some Mesozoic mammals retained characteristics of their ancestors,
    - the cynodonts.
- Cenozoic time,
  - Earth's flora and fauna became increasingly familiar
  - mammals clearly differentiated from their ancestors
  - grazing mammals appeared
  - first hominids

Mammals took over the role of the Dinosaurs





Cenozoic Era



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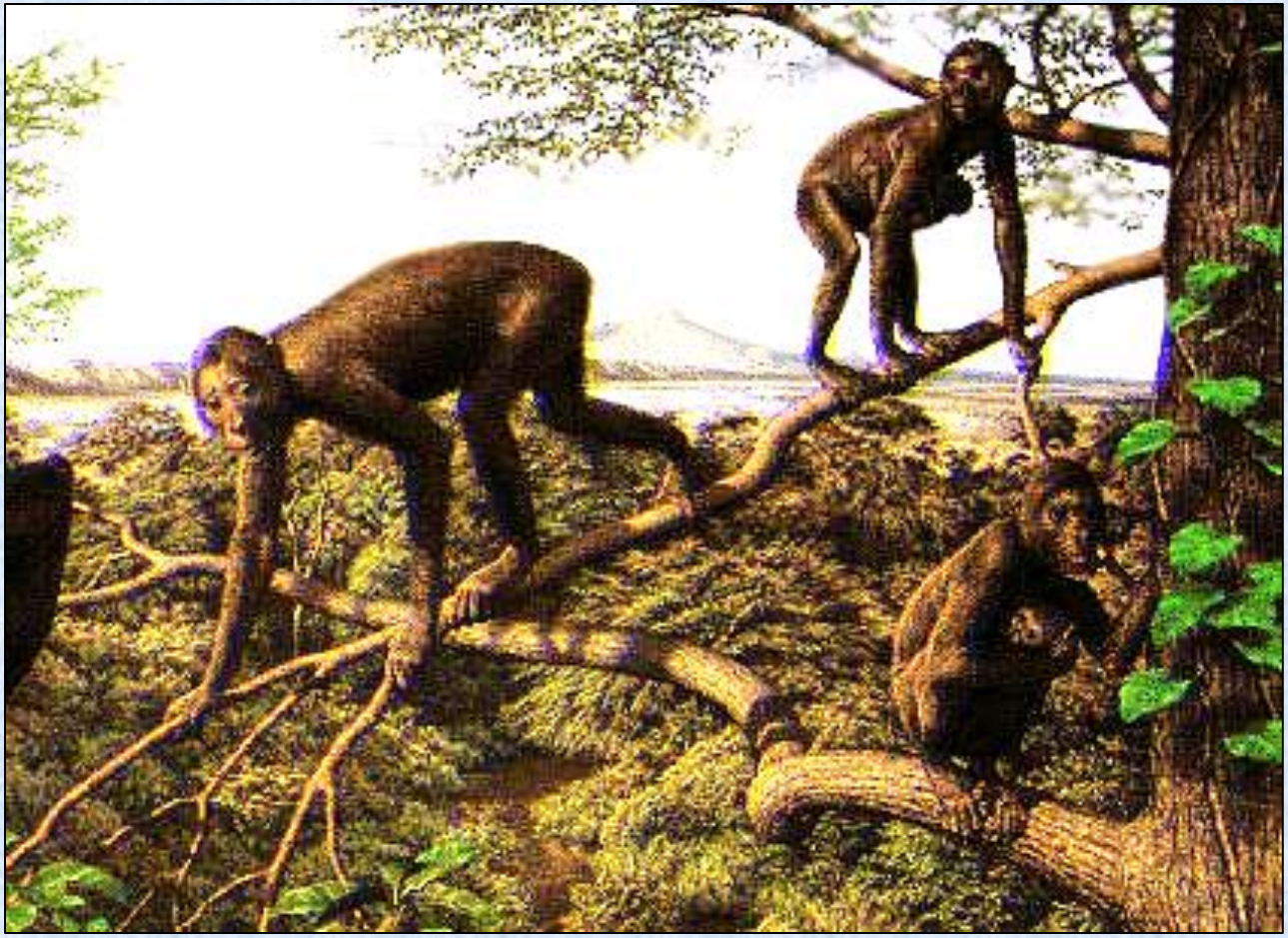
Cenozoic – Age of Mammals

Cenozoic - Oligocene – Grasslands and Horses

Mesohippus bairdi, a browsing, short-necked, three-toed Oligocene horse (Perissodactyla, Equidae). It fed on leaves (not grass) stood about 55 cm tall.

Miocene Ape – Proconsul, 25-15 MYA



Proconsul africanus is one of the very first primates that can be classified as an ape. It lived 25-15 million years ago in the forests of Eastern Africa, but had cousins spread all over the old world. Since it is such a basal hominoid, it shares certain features with both monkeys (catarrhines) and apes.

Primates







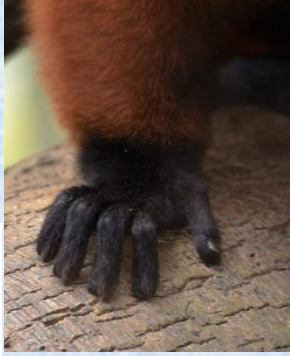




Primate Hands

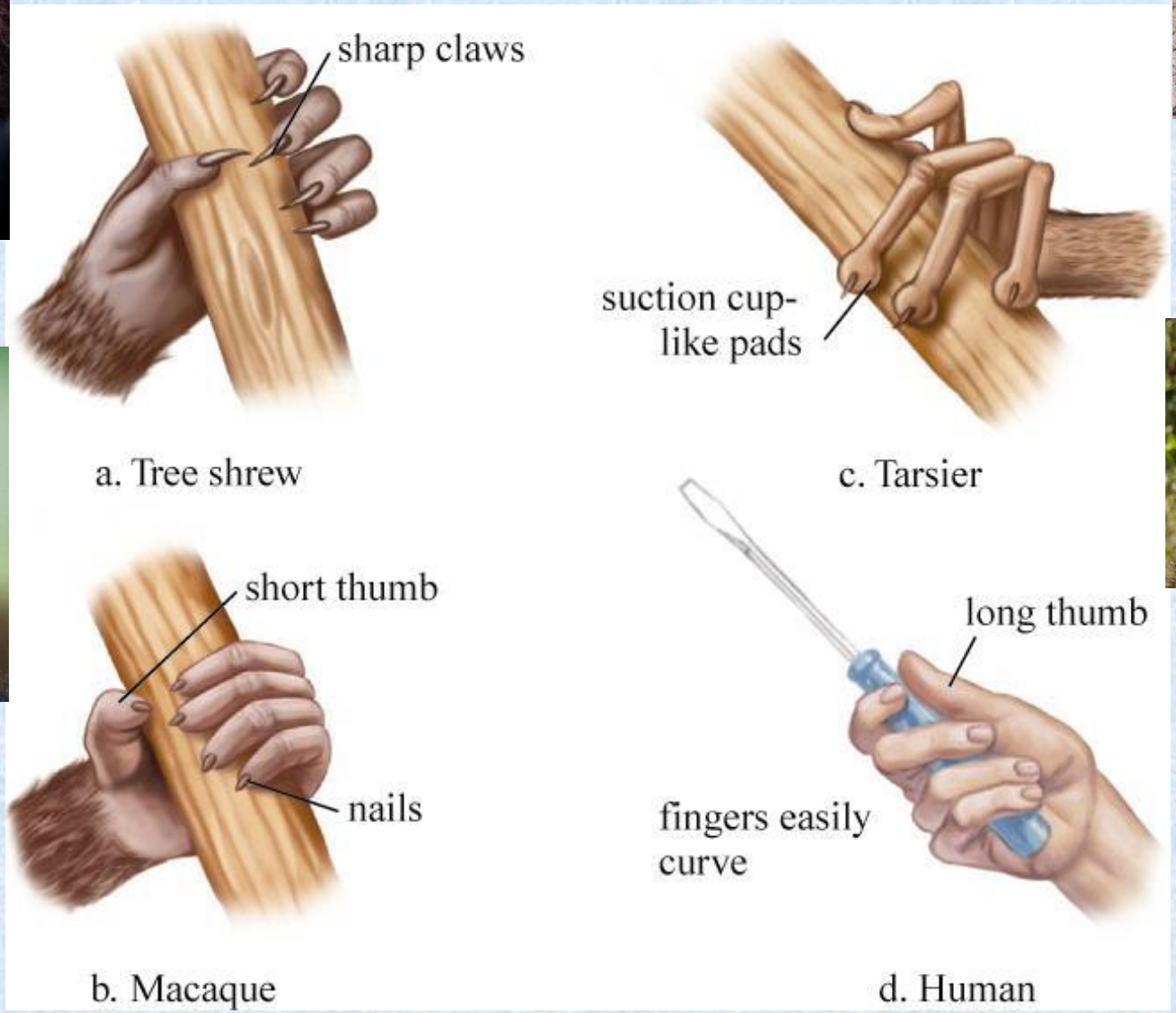
orangutan

gorilla



lemur

chimpanzee



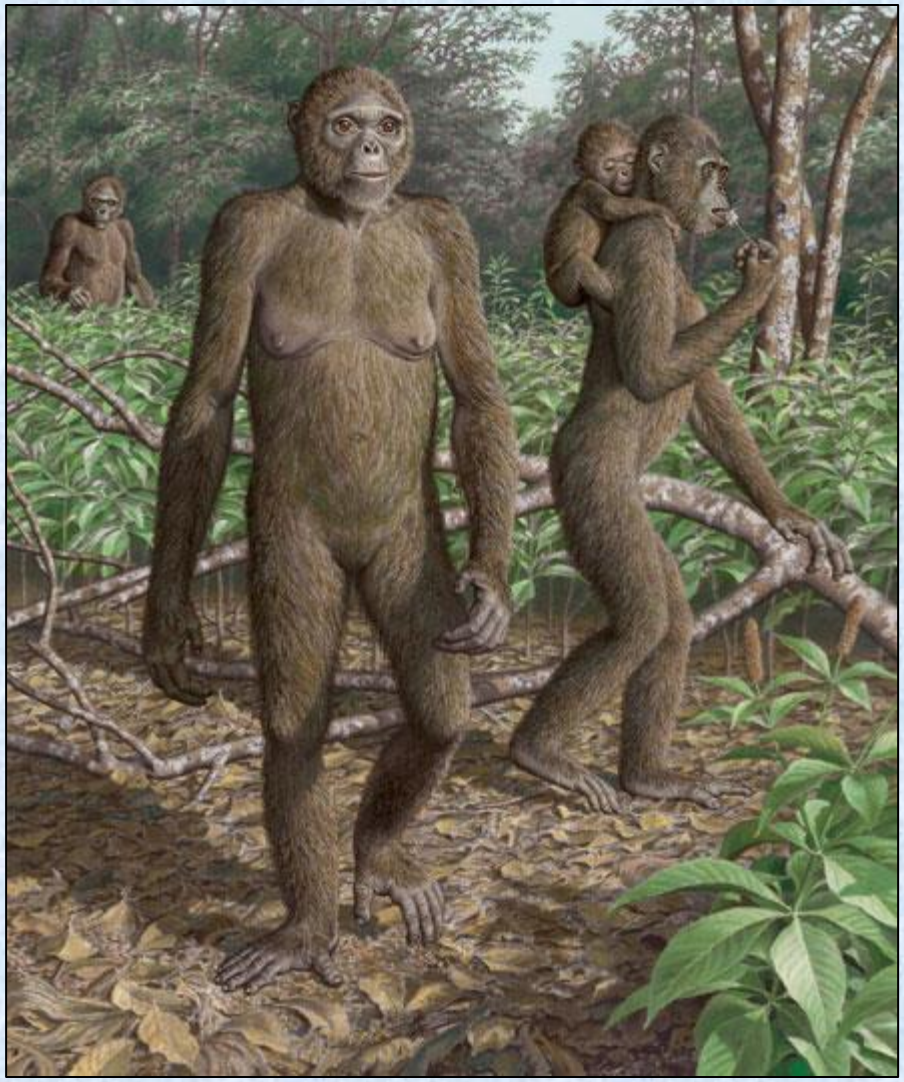
Human Evolution Overview

- The first bipedal hominins diverged from the apes in Africa some 5-7 Mya
- An increase in brain size *followed* the origin of bipedalism
- Earliest fossils of the genus *Homo* are 2.4 Mya old, and genus *Homo* eventually expanded throughout the Old World

Ardipithecus ramidus – 4.4 MYA

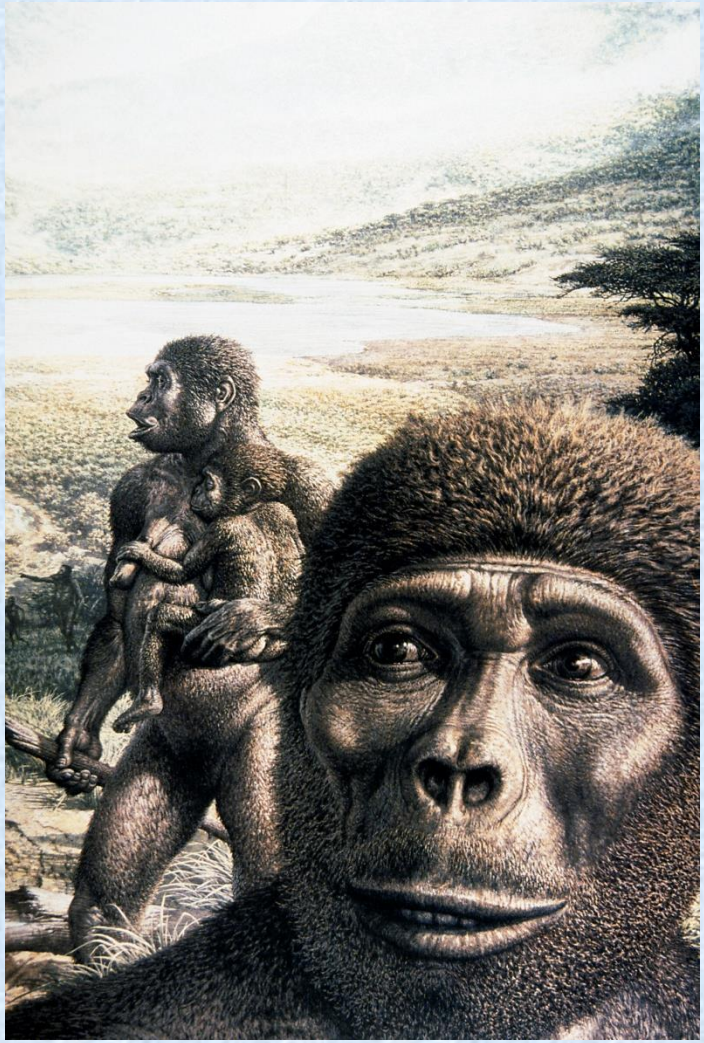
- left the trees part-time, walked around

“It's not a chimp. It's not a human. It shows us what we used to be”
Tim White



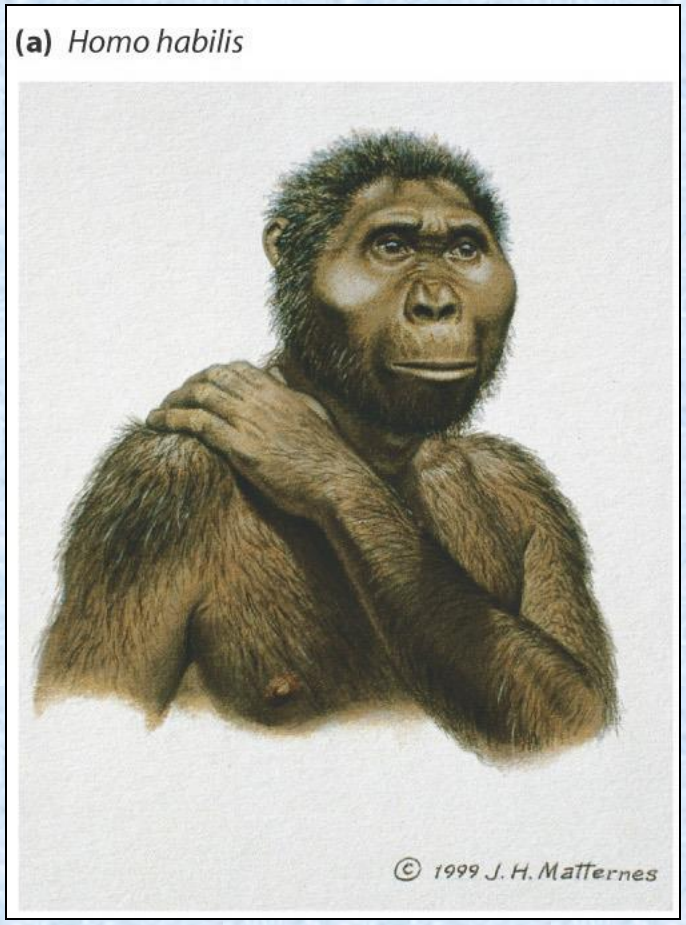
The first bipeds: Australopithecines

Hominids appeared in the Africa savannas, the Australopithecines.



3.9 mya: Appearance of *Australopithecus*, genus of hominids.

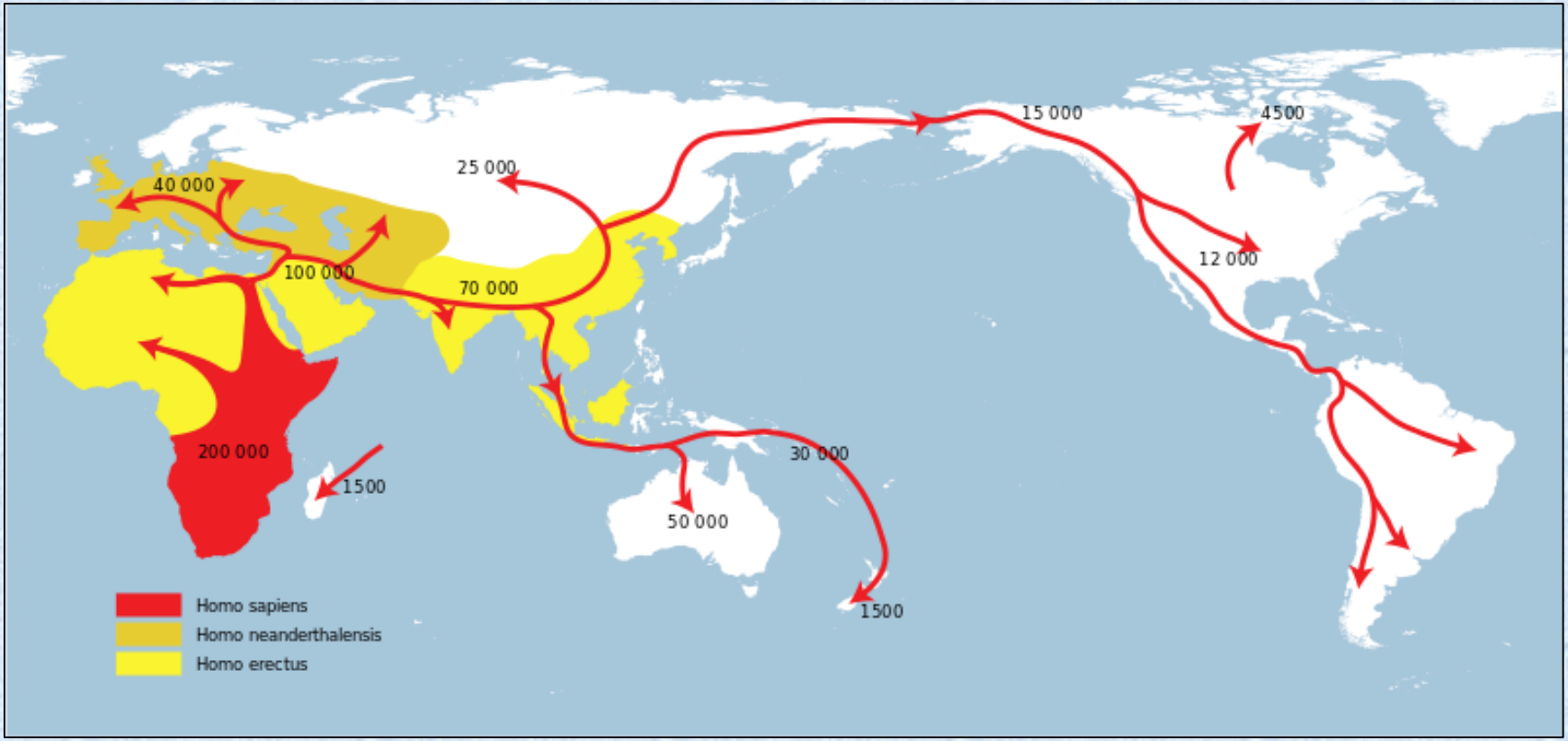
Artist's Conception of the Two Hominin Species



Homo habilis stayed close to home (Africa)

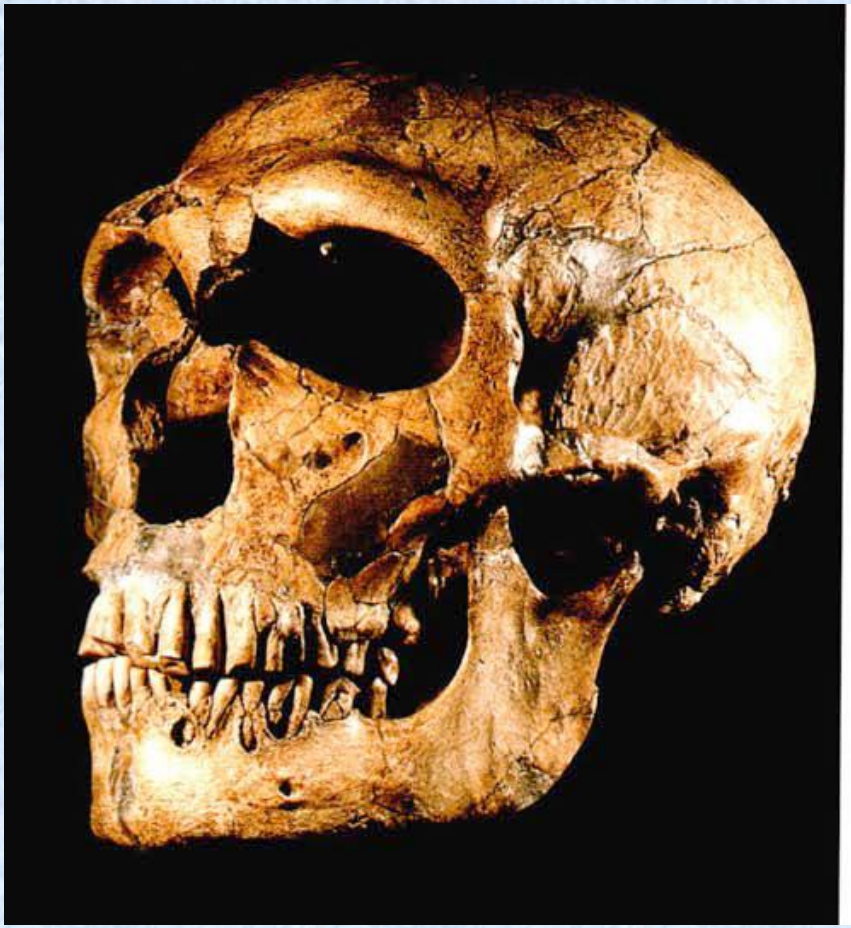
Homo erectus migrated widely from Africa into Asia.

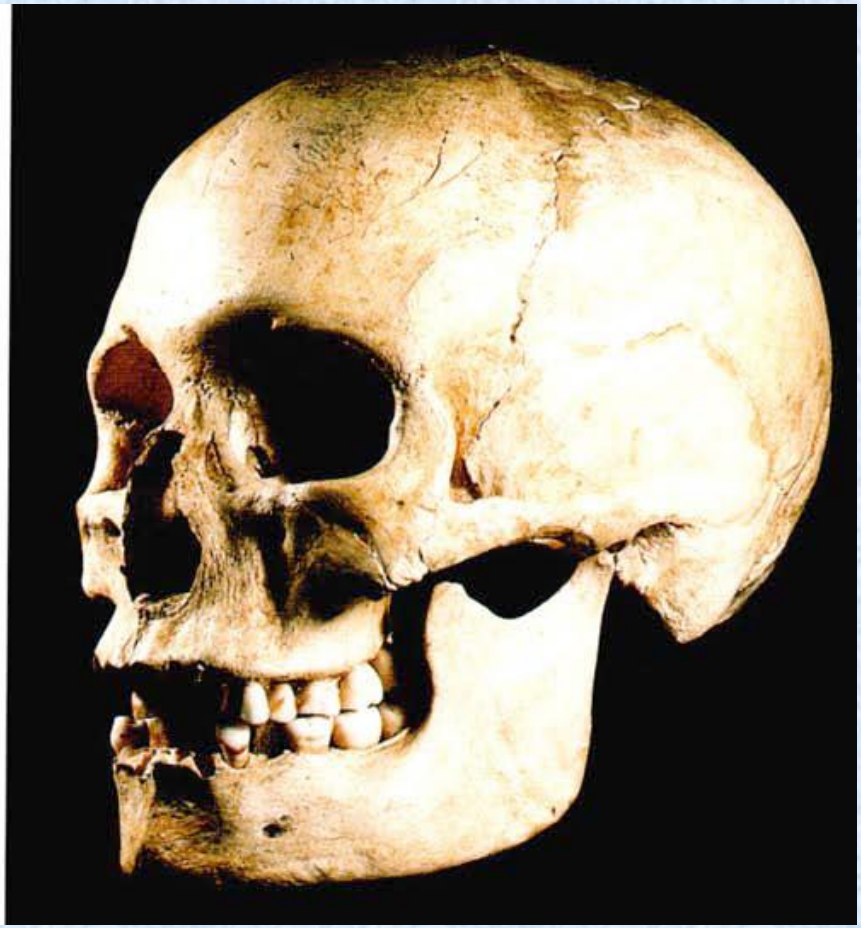
Homo - Out of Africa



- About 130,000 years ago, the first anatomically modern *Homo sapiens* evolved in East Africa (probably from *H. erectus*), then migrated out of Africa to Europe, Asia, and the rest of the world.
- At this point, *H. sapiens* may have interbred with *and* out-competed other existing species, such as *H. erectus* and *H. neanderthalensis*

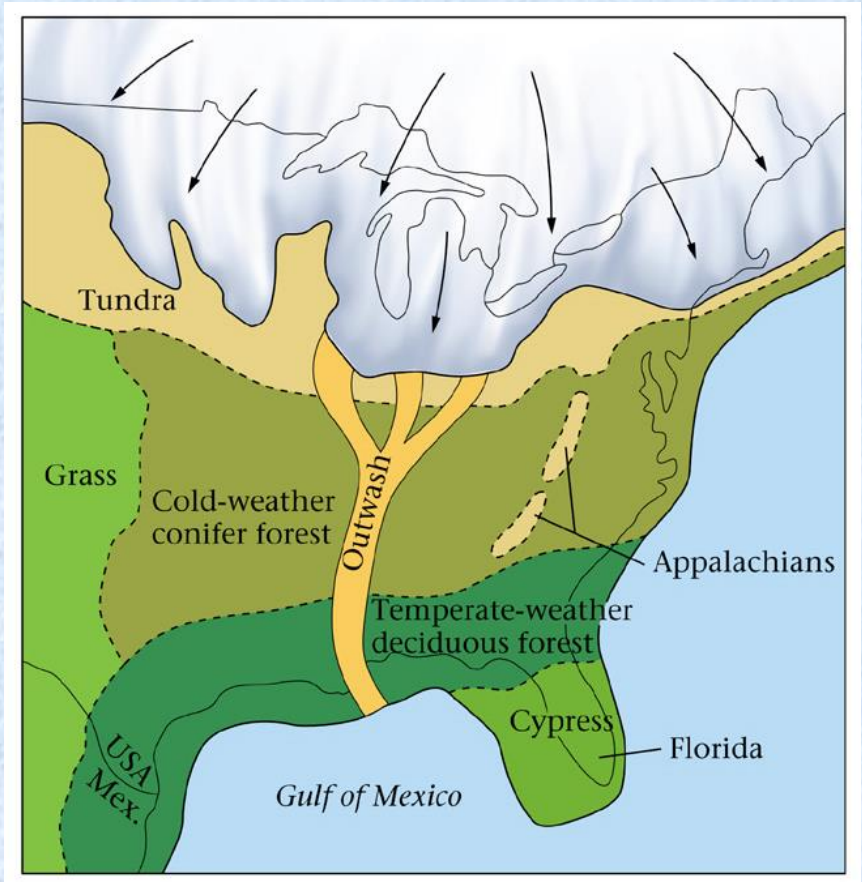
*Homo neanderthal*ensis vs. *Homo sapiens*





Pleistocene Glaciation of the Northern Hemisphere

Maximum Extent of glaciation in the Northern Hemisphere



Climate Belts

The ice age was at its most extreme - and the climate at its most severe - 18,000 years ago.

Spain – horses, wooly mammoth, lions, wooly rhinoceros

Pleistocene Extinctions

- During the Pleistocene,
  - the continental interior of North America
  - was teeming with horses, rhinoceroses, camels,
  - mammoths, mastodons, bison, giant ground sloths,
  - glyptodonts, saber-tooth cats, dire wolves,
  - rodents, and rabbits
- Beginning about 14,000 years ago,
  - many of these animals become extinct,
  - especially the larger ones.

Pleistocene Mass extinction
Over-kill Hypothesis

Is There a Sixth Major Mass Extinction?

Why are species becoming extinct so rapidly?

- Human population growth
- Human impact on the environment
  - Deforestation and Desertification
  - Fragmentation and Destruction of Natural Habitats
  - Contamination of Habitats
    - Pollution, mining wastes, chemicals
    - salts from irrigation and aquifer depletions
  - Global Warming

End