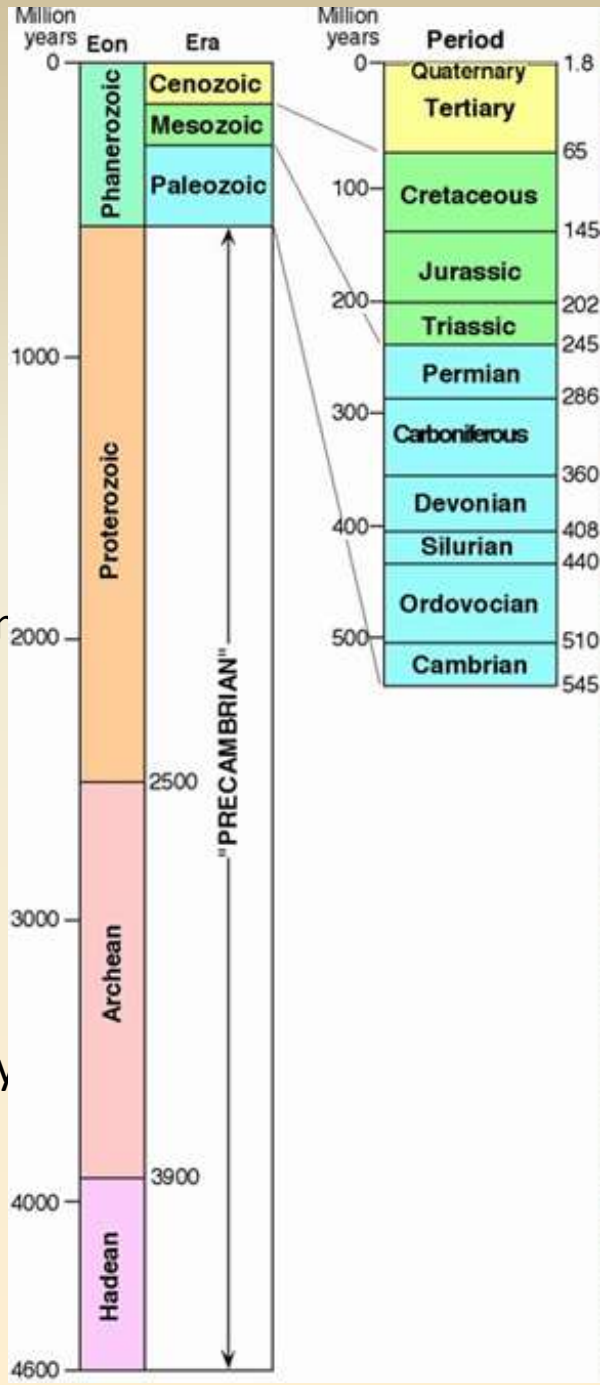
# Cambrian Explosion
# The Rise of Animals

# Geological Eras

We can divide the history of life on Earth into six main stages:

1. Hadean Era: from the formation of the Earth about 4.6 billion years ago until about 4 billion years ago. The Earth's surface is constantly bombarded by large objects which repeatedly melt the whole surface, making life impossible.
2. Archean Era: from 4 to 2 billion years ago (very roughly). Origin of life, all life is single celled bacteria. No oxygen in the atmosphere.
3. Proterozoic Era. 2 billion until 550 million years ago. Oxygen appears in the atmosphere and builds to approximately the present level of 21%. Eukaryotes appear. No hard parts: bone, teeth, shells, so very few fossils.
   - the first three eras are collectively called the Pre-Cambrian era
4. Paleozoic Era. 550 to 250 million years ago. Fossils appear, complex multicellular organisms, invasion of the land by plants and animals.
5. Mesozoic Era. 250 to 65 million years ago. Appearance of mammals and flowering plants, but the land is dominated by dinosaurs (reptiles).
6. Cenozoic Era. 65 million years ago until present. Land dominated by mammals and flowering plants.

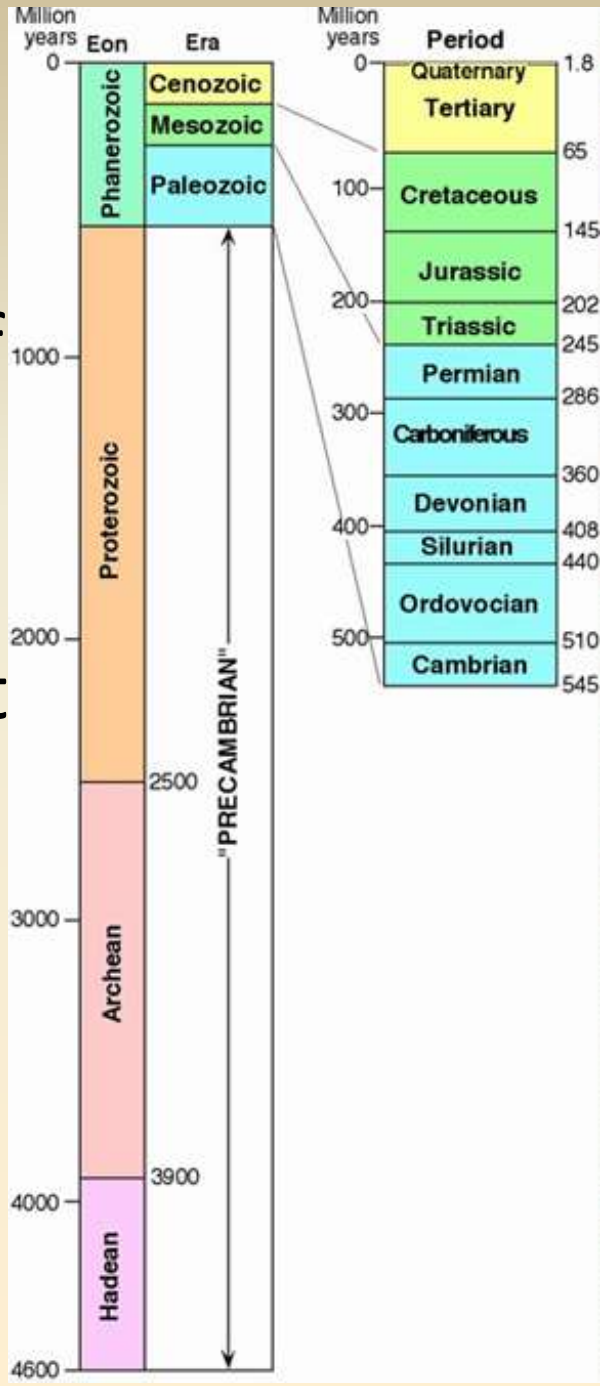


# Geological Eras

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 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.

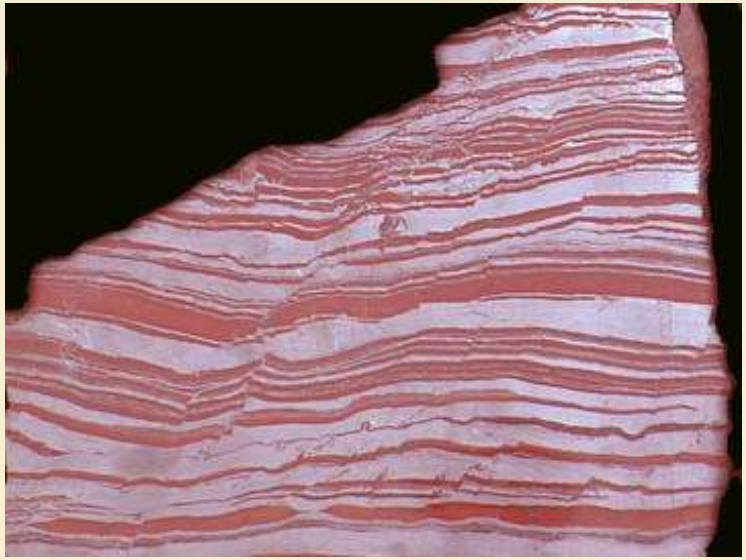


# Archaean Era: 4-2 BY

Oxygen began accumulating in the atmosphere about 2.7 billion years ago.

Cyanobacteria are photosynthetic prokaryotes that are still present today, produced the oxygen.

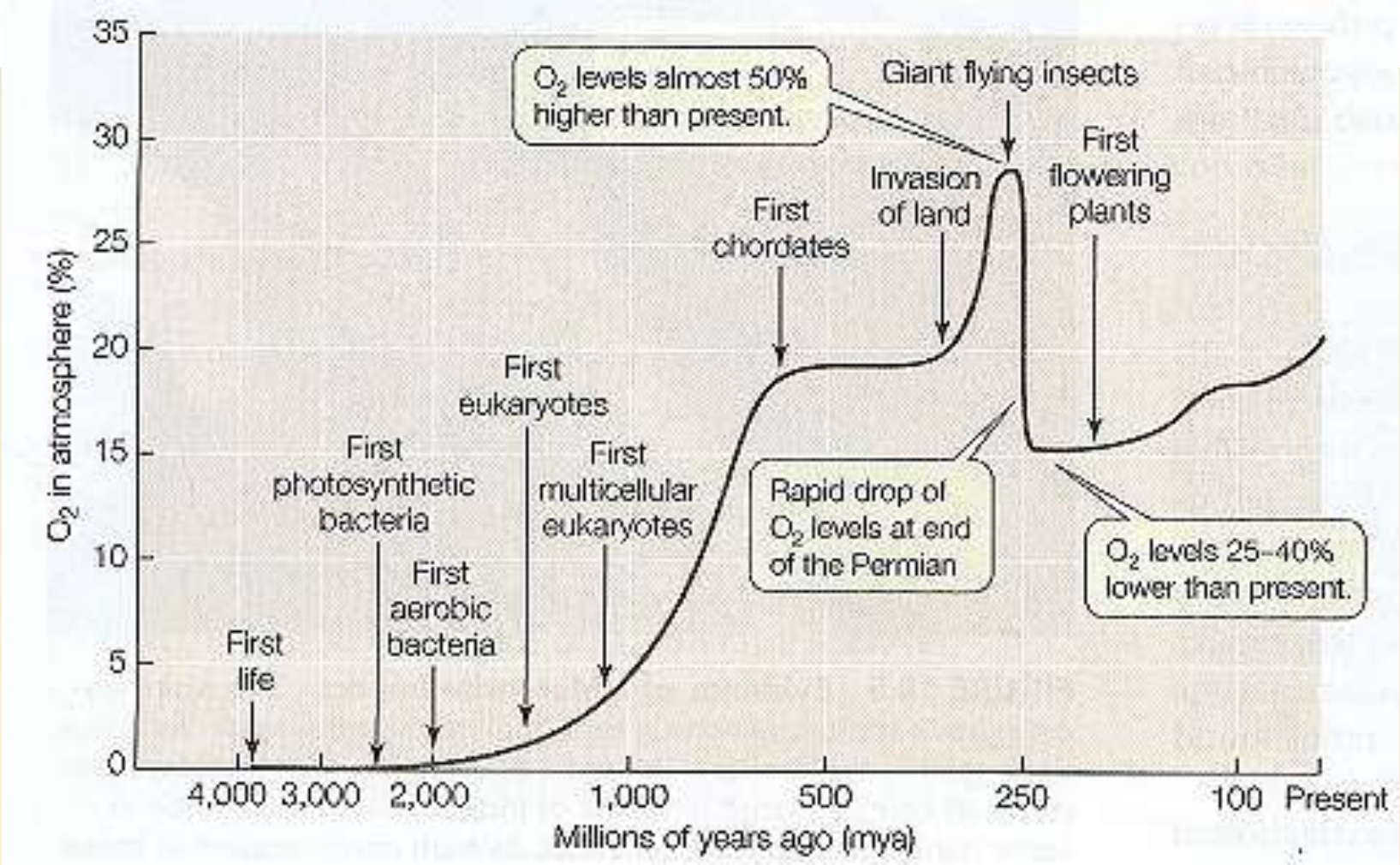
Stromatolites



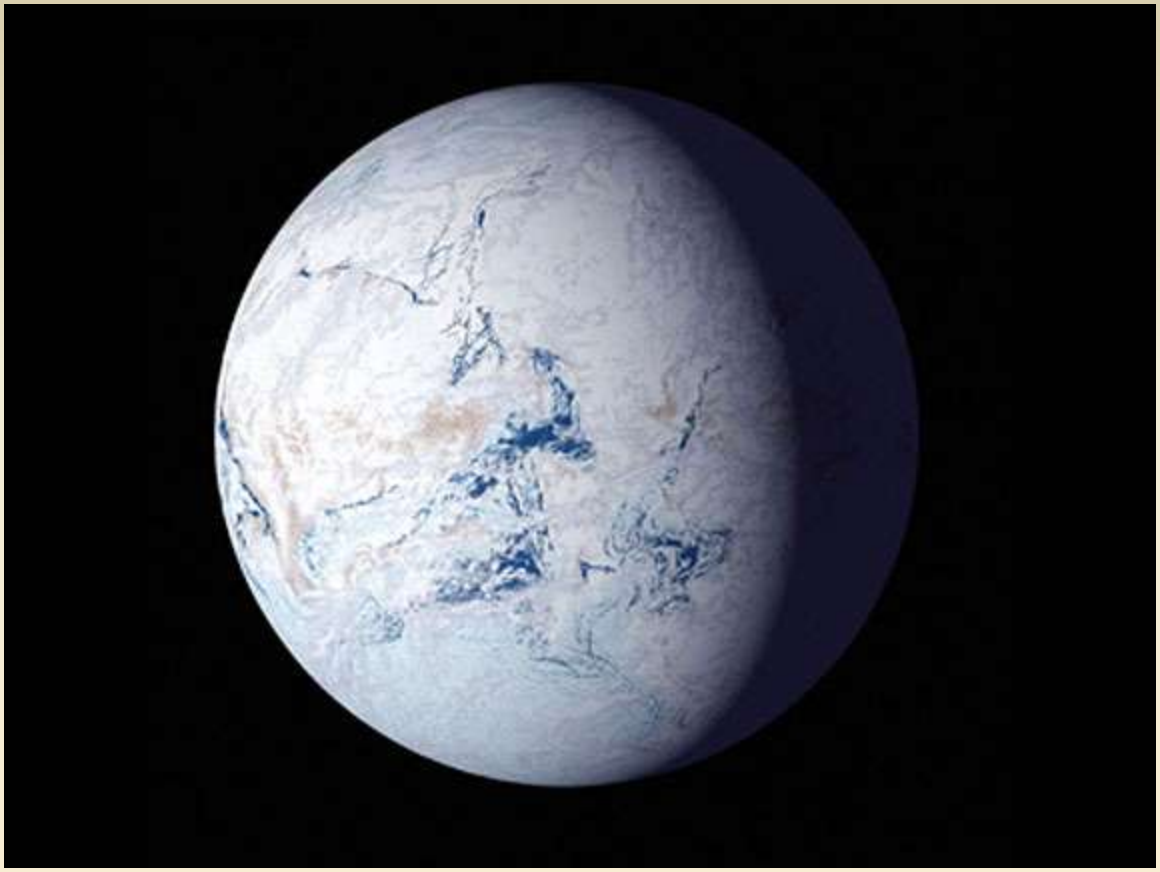
Banded Iron

# Great Oxygen Catastrophe

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



# Snowball Earth? – 716 MY ago



Sea ice extended to the equator 716.5 million years ago.

The survival of eukaryotes throughout this period suggests that sunlight and surface water remained available somewhere on Earth's surface.

The earliest animals arose at roughly the same time.

# Snowball Earth

A theory, not accepted by all scientists:

Near the end of the Proterozoic era, 550 million years ago, the Earth suffered a massive Ice Age. Glaciers covered all, or nearly all, the Earth, including tropical areas.

The freeze lasted several million years. Ice reflects sunlight, keeping the Earth cold. It ended due to the greenhouse effect: carbon dioxide from volcanoes built up in the atmosphere, trapping the Sun's warmth and slowly raising the Earth's temperature.

This caused a mass extinction, possibly killing off most Edicarian forms and leading to the Cambrian explosion of new life forms.

It's still just a theory. Many don't believe it.

But, it points out that conditions on Earth were much less stable and pleasant than they are now.

# Eukaryotes

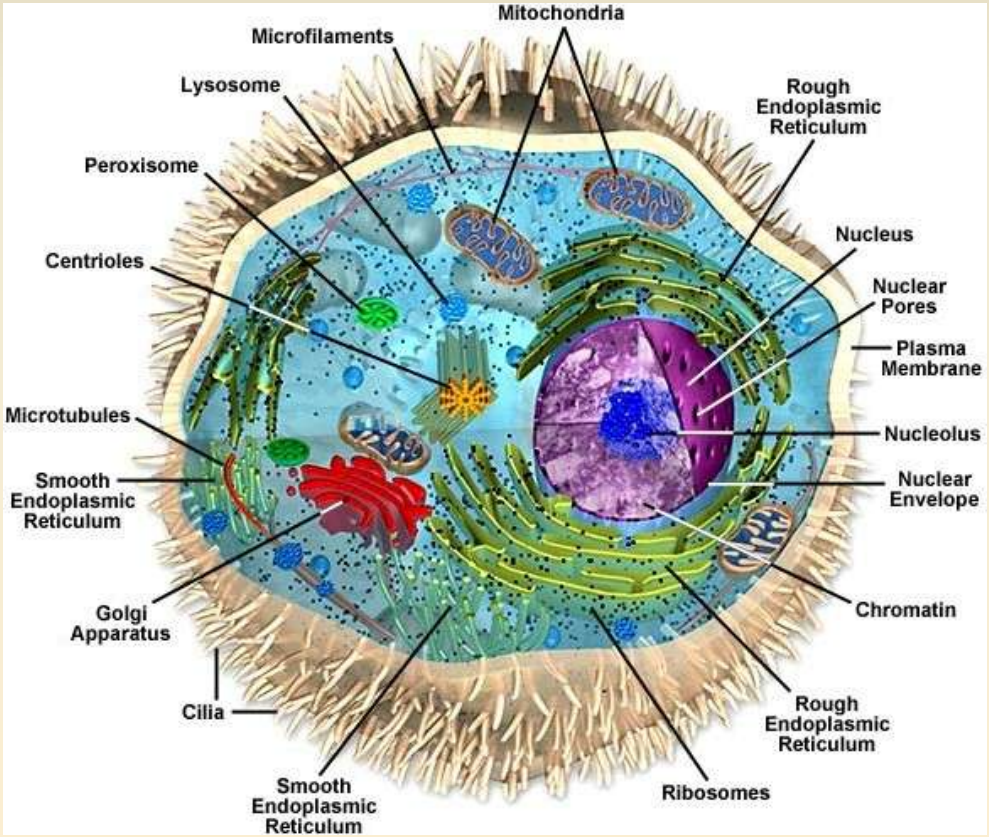
# From prokaryote to eukaryote

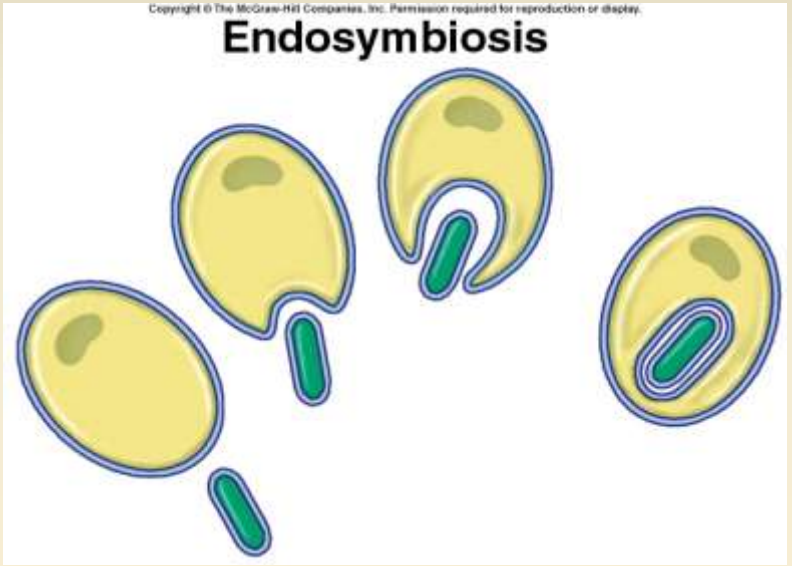
Acritarch
(algal cyst)

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 larger size.

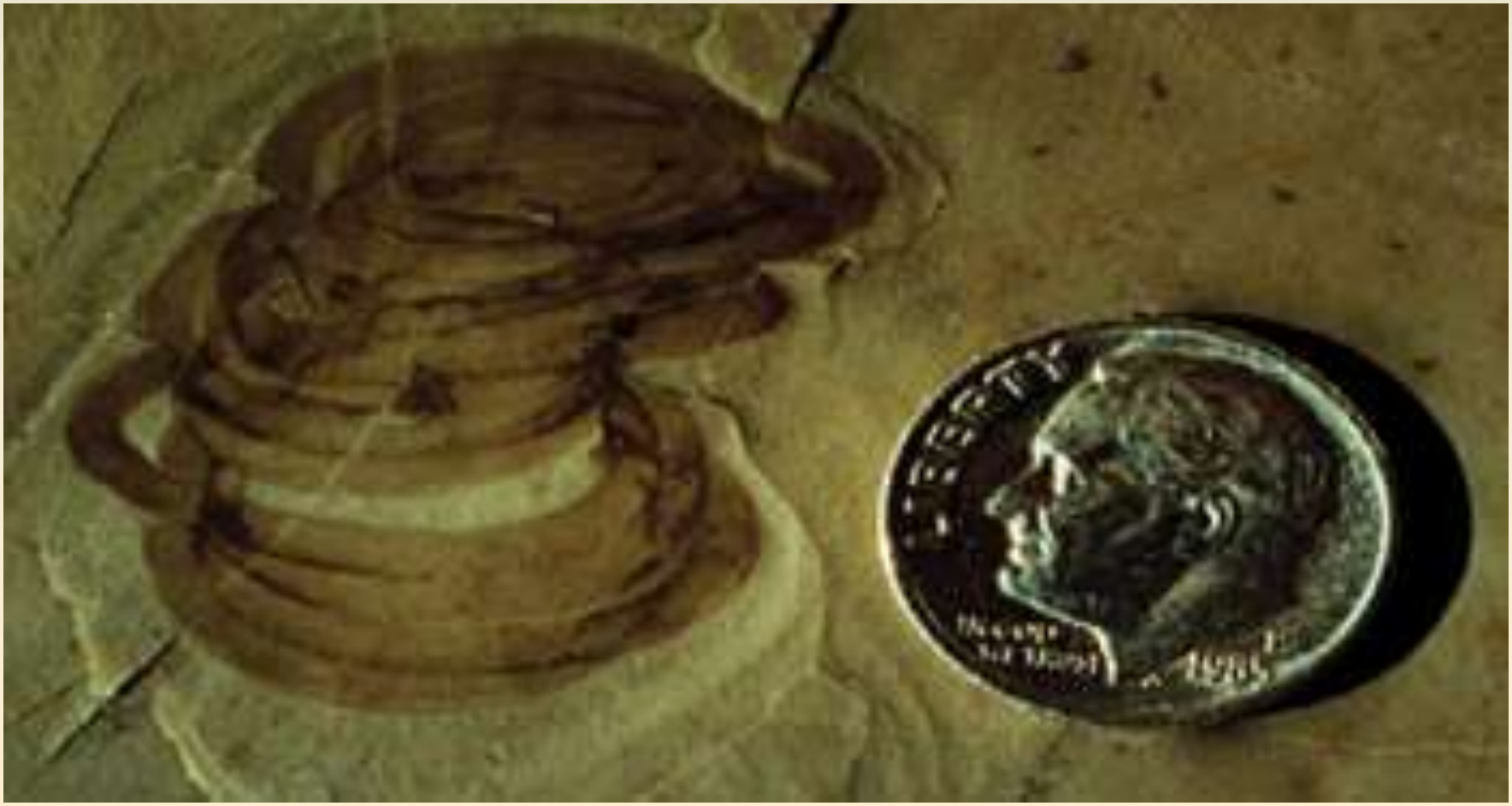
# The origin and early evolution of the eukaryotes



# Oldest known Eukaryote

2200 million years old *Grypania spiralis*, coiled thin films of carbon from the Negaunee Iron-Formation in Michigan, USA, provide the first evidence for eukaryotic life on Earth.



# The origin and early evolution of the eukaryotes

- unlike prokaryotes, eukaryotes

1. have much larger cell sizes.

2. possess nucleus and organelles.

3. are mainly aerobic.

4. have cilia and flagella with tubulin rather than flagellin protein.

# The origin and early evolution of the eukaryotes

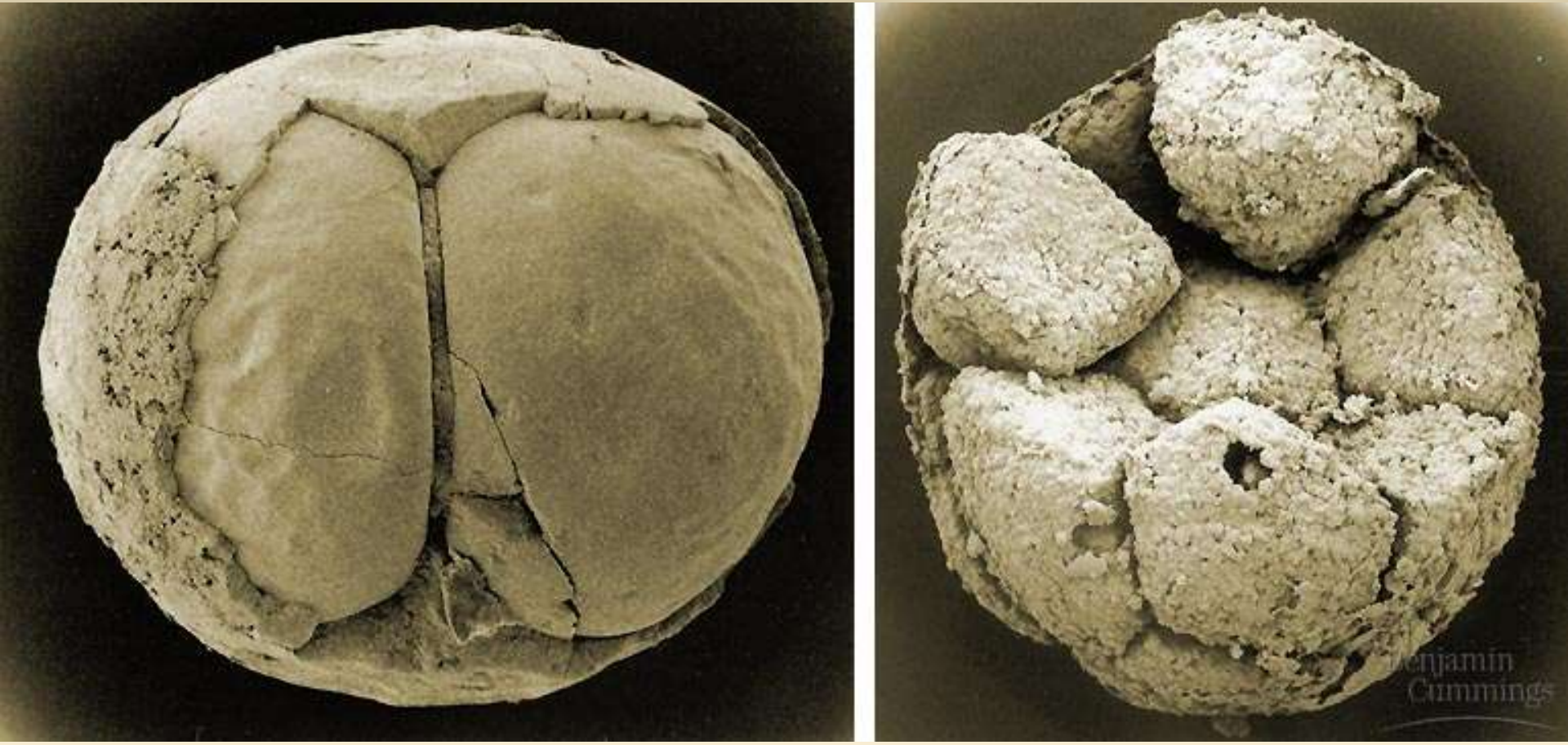
- unlike prokaryotes, eukaryotes

5. have linear DNA molecules associated with histones.

6. are usually multicellular.

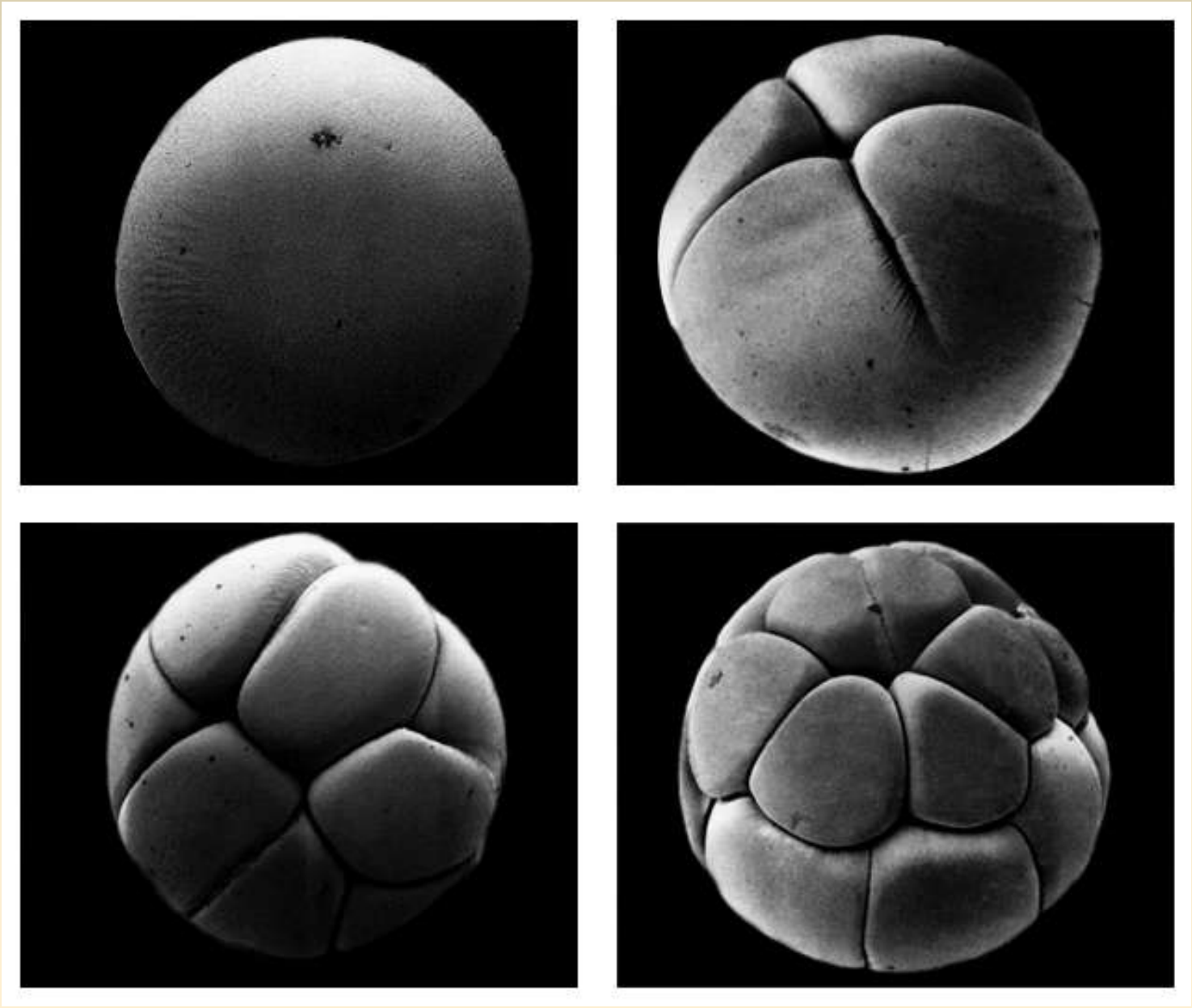
7. have both mitosis and meiosis.

8. have a cytoskeleton.

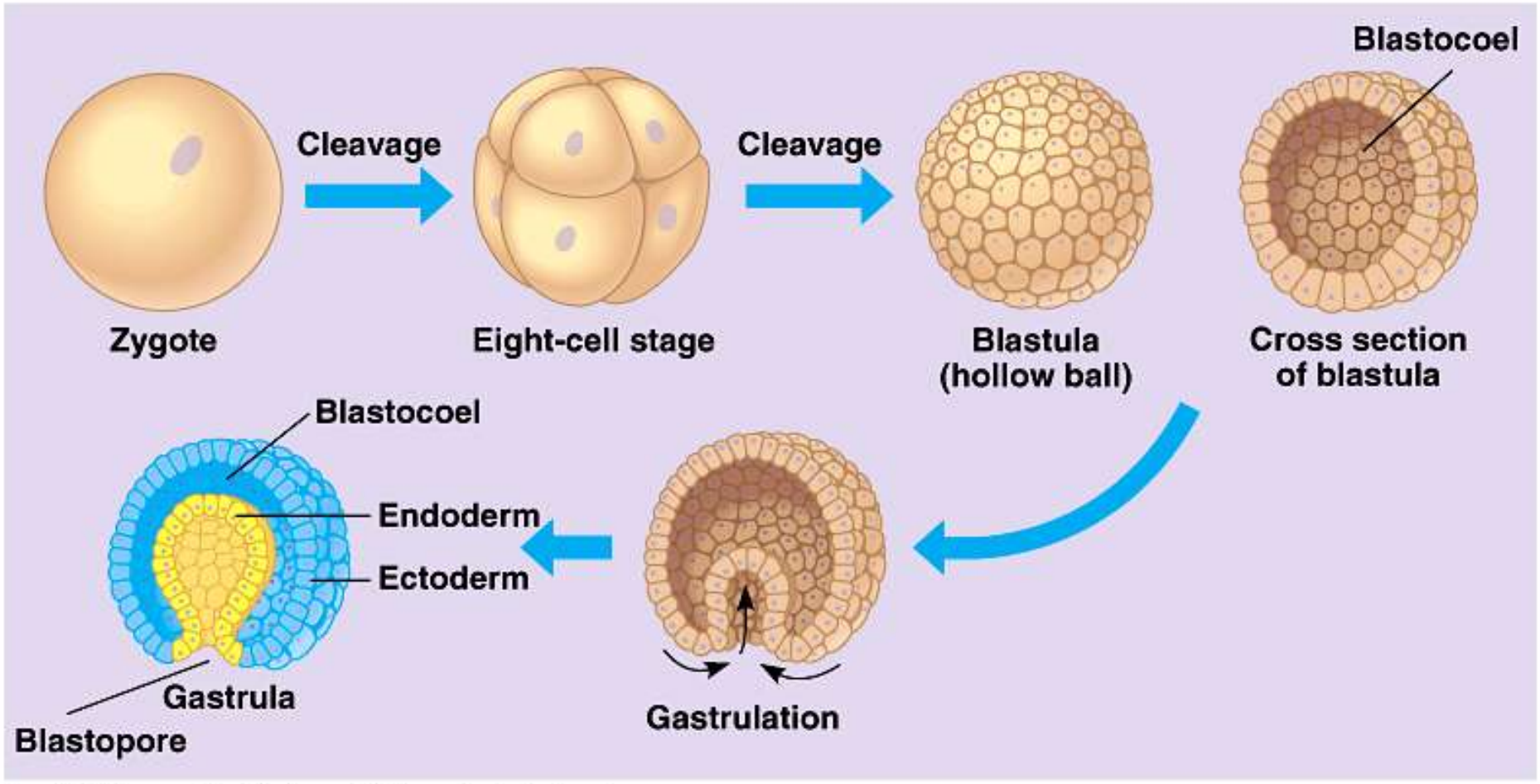



Fossilized animal embryos from Chinese sediments 570 million years ago.

# Cleavage in a frog embryo

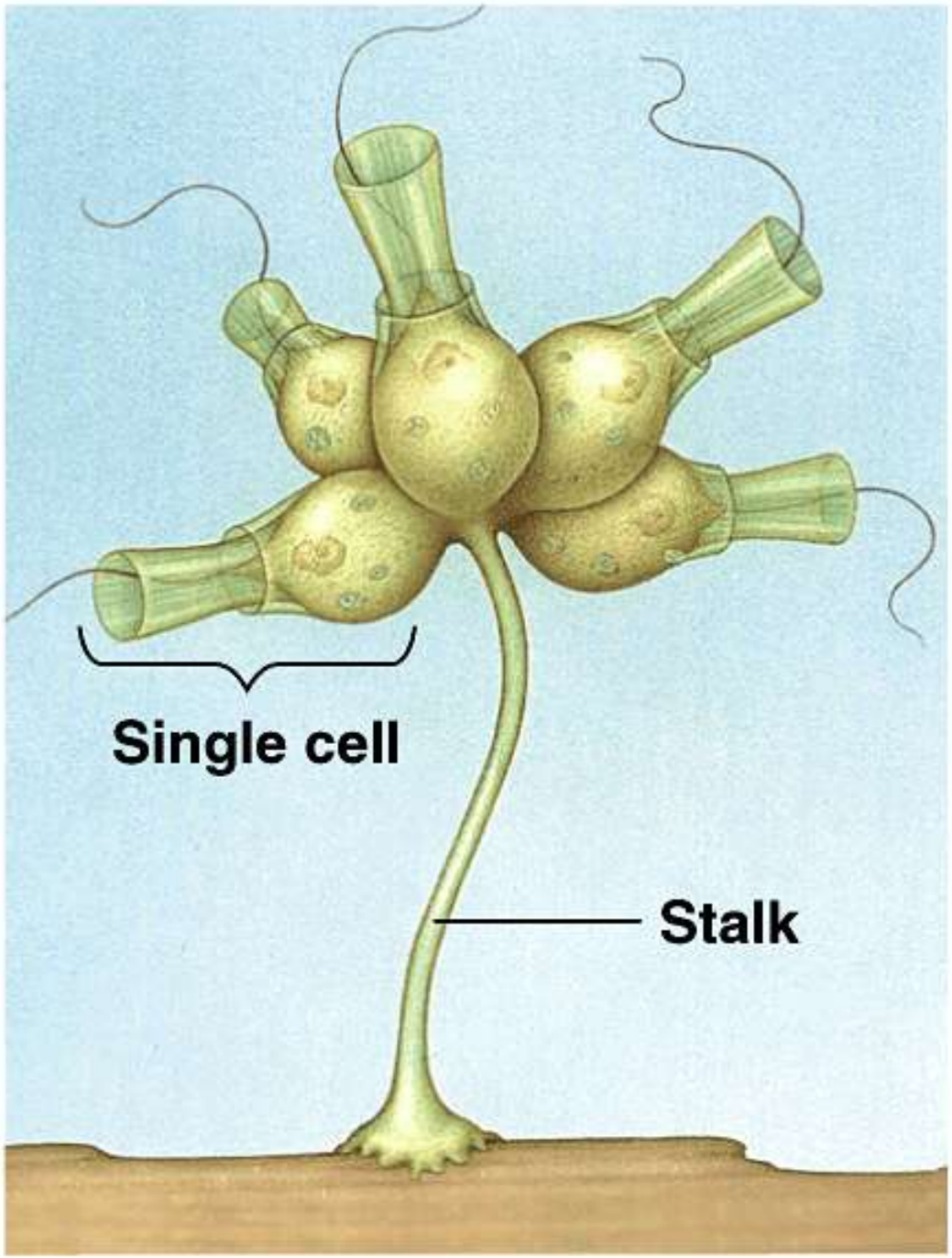


# 32.1 Early embryonic development



# Early Animals and the Cambrian Explosion

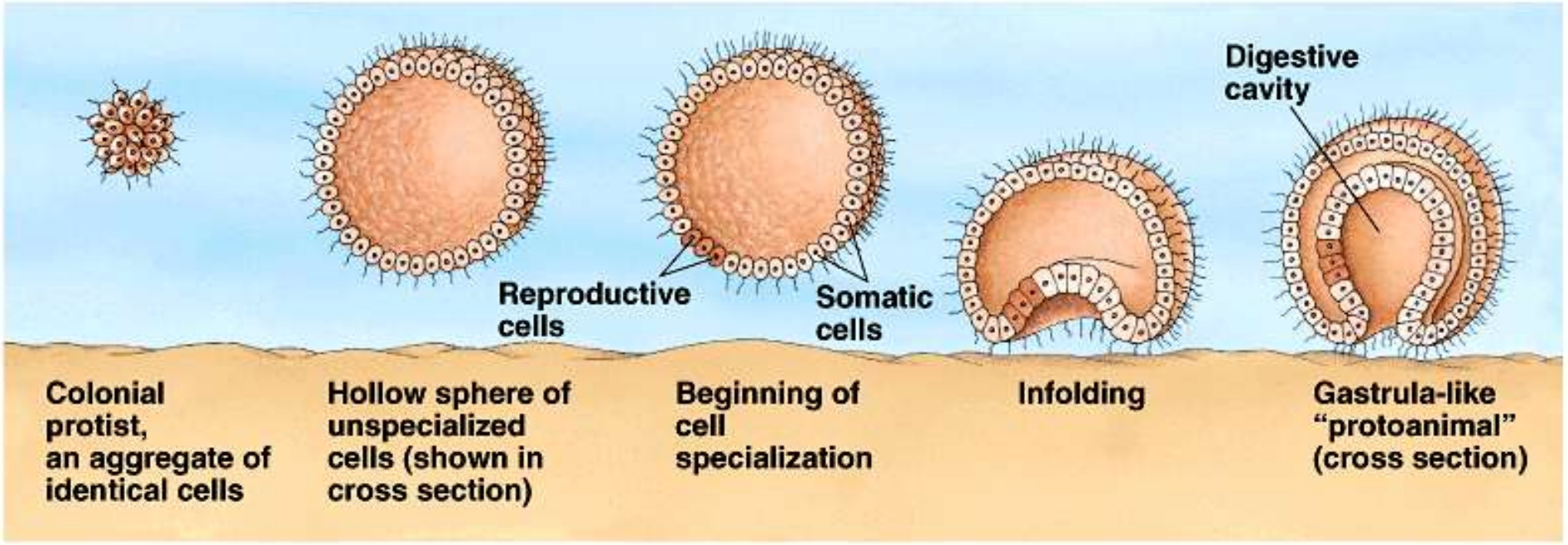
- Animals probably evolved from a colonial flagellated protist that lived in Precambrian seas about 600–700 million years ago.
- At the beginning of the Cambrian period, 542 million years ago, animals underwent a rapid diversification.
- During a span of about 15 million years:
  - All major animal body plans we see today evolved
  - Many of these animals seem bizarre






Metazoan animals probably evolved from colonial, flagellated protists, like this choanoflagellate colony.

# One hypothesis for the origin of animals from a flagellated protist.






Gastrea Hypothesis – proposed by Haeckel in 1870s

# Ediacaran

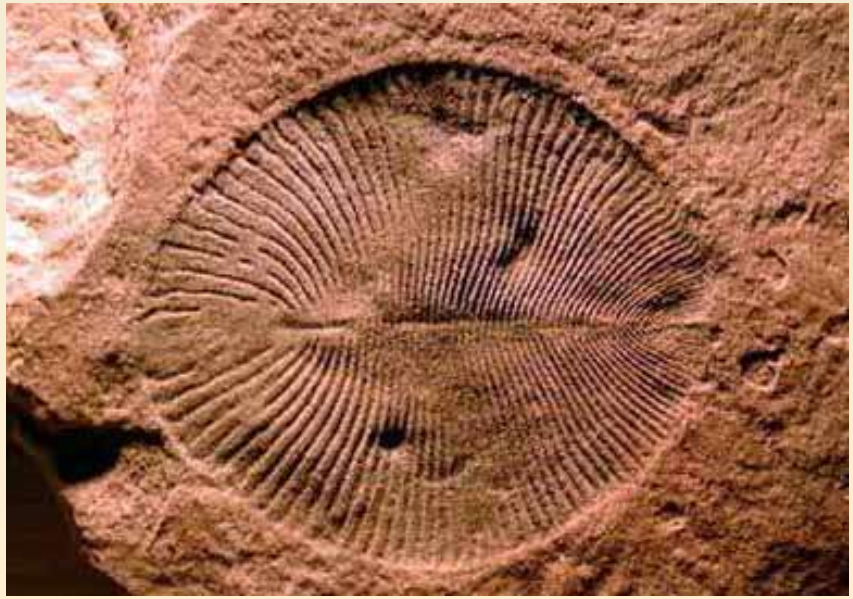
# Ediacaran Fossils

Also known as “Vendian”. A period late in the Proterozoic era, just before the Cambrian explosion. A worldwide proliferation of **multicellular organisms** whose form seems unlike anything alive after this period

Flat, segmented, soft-bodied.

Maybe ancestral to jellyfish? Or soft-bodied arthropods? Or an extinct kingdom of life?

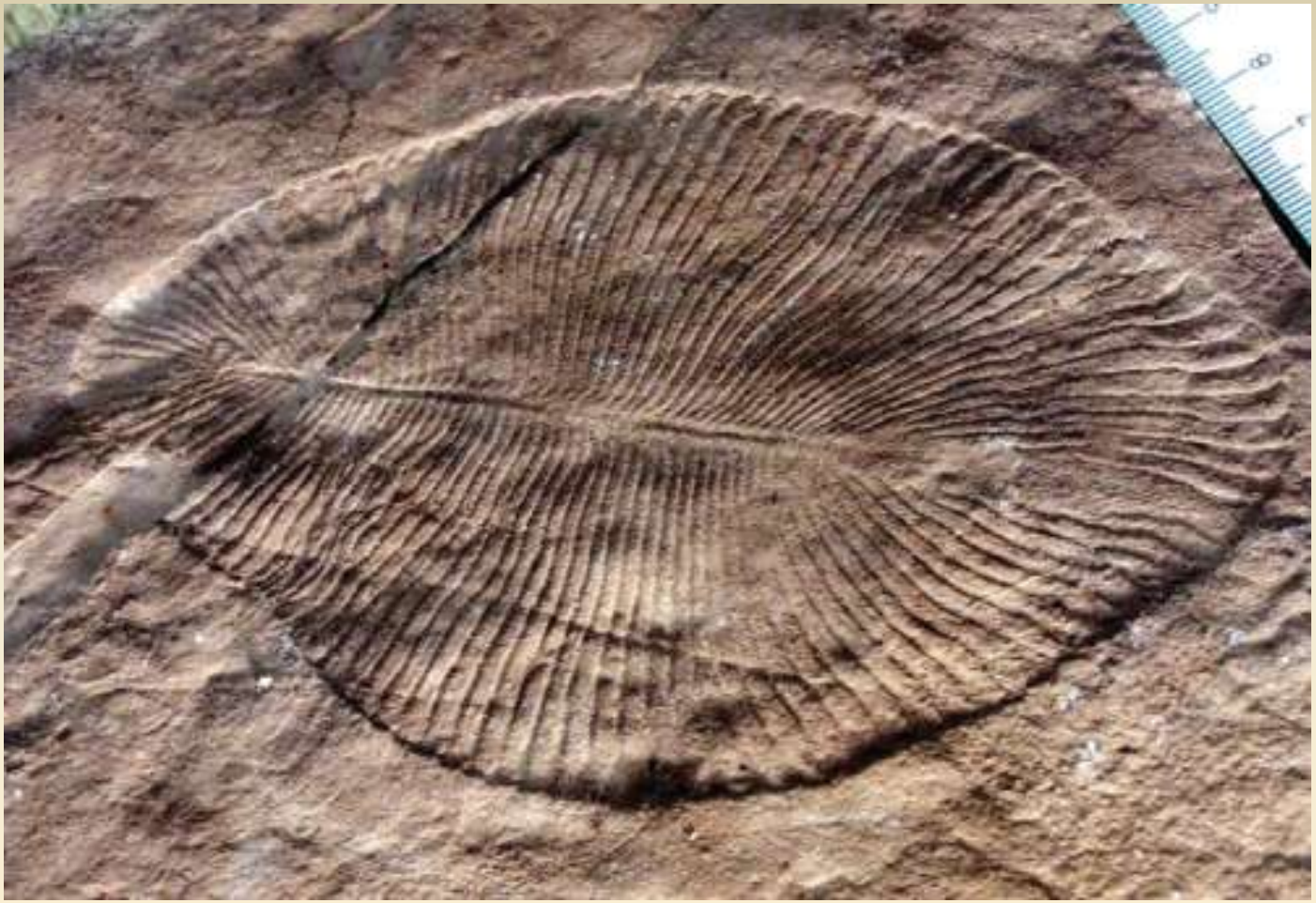
Few or none survived into the Paleozoic era.



# Ediacaran Life


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

# Ediacaran - *Dickinsonia costata* fossil



The earliest known occurrence of a rich diversity of multicellular animals is the 565 million years old Ediacaran fauna from the Ediacaran hills in South Australia. These were soft-bodied organisms which were entirely preserved as impressions, some resembling jellyfish, sponges and segmented worms found in the seas today.

# Ediacaran Fauna

- dates to about 560 MYA.
- are exclusively soft-bodied (sponges, jellyfish, comb jellies, etc) and non-burrowing.

But then, *something* happened in the “Garden of Ediacara”…

*Something* wanted to eat…

Everything !

# Cambrian Explosion

Between about 543 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

# What ignited the Cambrian explosion?

One hypothesis emphasizes increasingly complex **predator-prey relationships** that led to diverse adaptations to feed, move, and provide protection.

Another hypothesis, studying evolution and development, called **evo-devo**, focuses on the evolution of genes that control the development of animal forms.

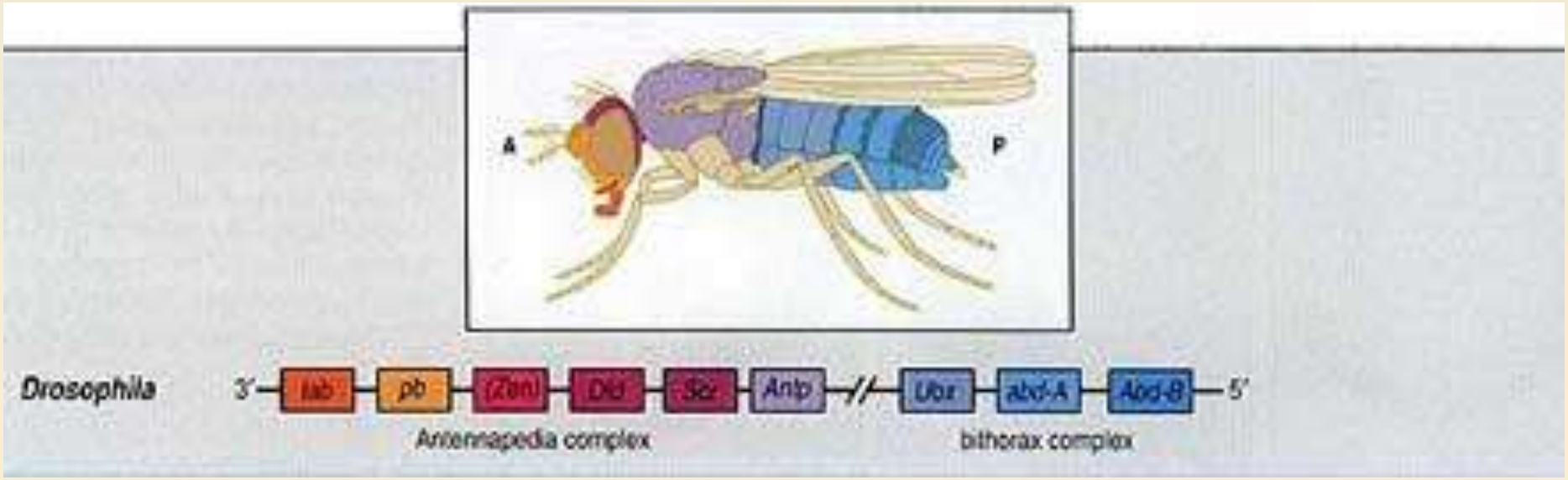
# Results of the Cambrian Arms Race

Different groups of organisms developed their weapons or defense systems in their own way, resulting in a wide array of body plans suited to various ways of life.

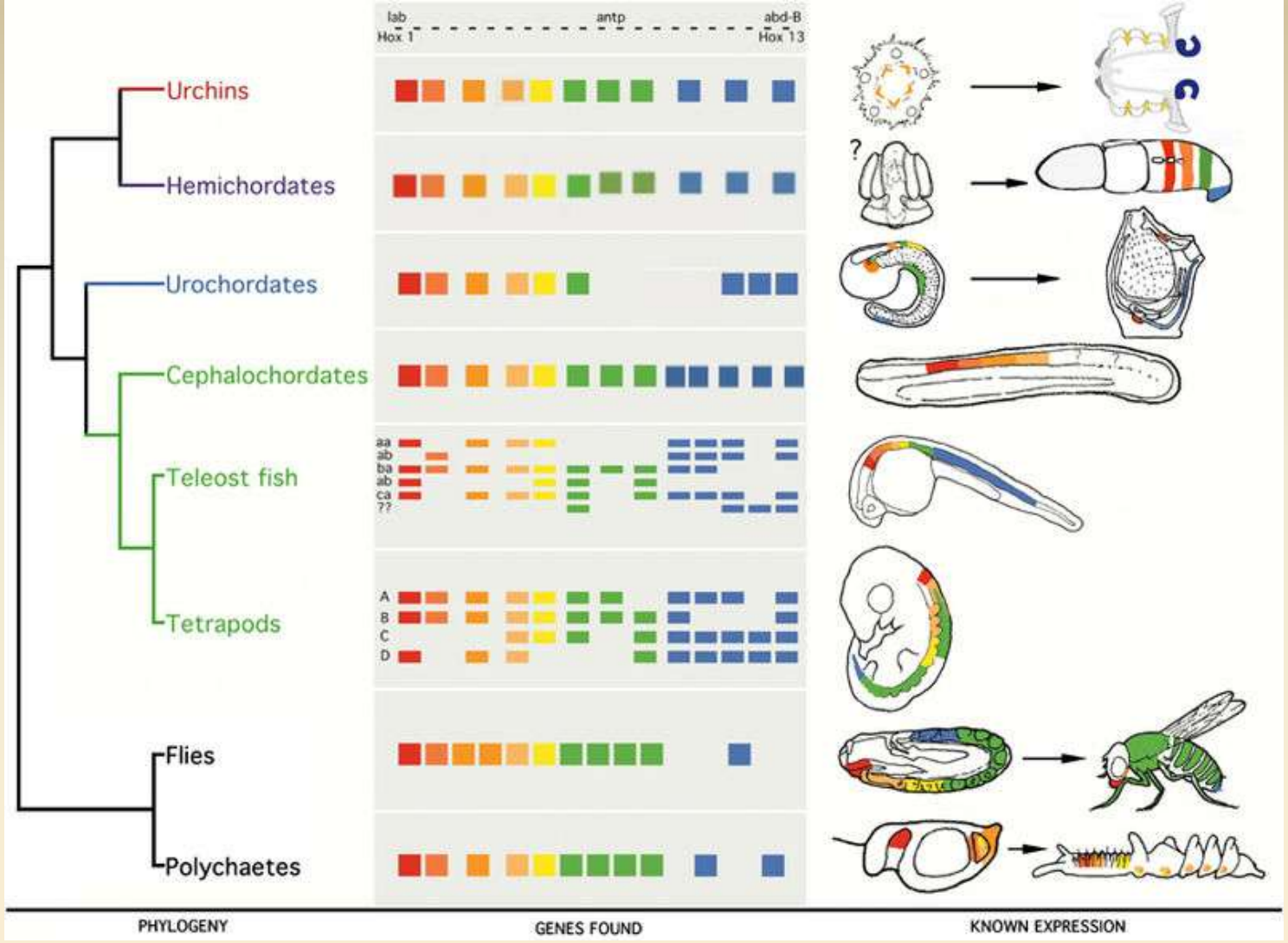
Ediacaran Period → Cambrian Period

# Evo-Devo  HOX Genes

In the diagram below, you can see an array of 9 genes in the fly, from the orange *labial* (*lab*) gene on the left, or 3′ end of the DNA, to the blue *Abdominal-B* (*Abd-B*) gene on the right, or 5′ end. What's really cool about this array is that it also corresponds to the spatial pattern of expression in the fly—the orange gene is turned on at the very front end of the fly, and the blue gene is turned on in the most posterior part.




Genes correspond with segmented body plan!



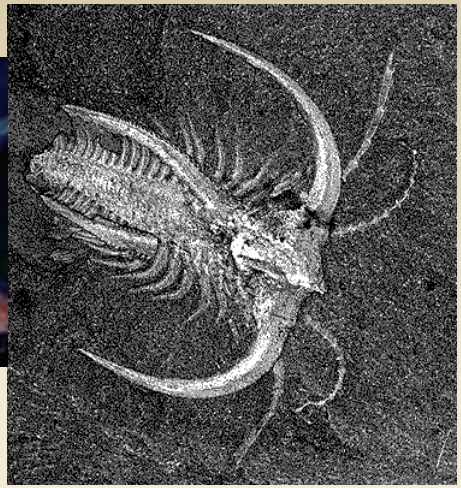

Hox gene clusters in several phyla. Each Hox gene is a colored box, and each organism has about 8 to over 40 Hox genes. The ancestral complement of Hox genes is likely similar to that in flies, polychaetes, and basal chordates, i.e. a single cluster consisting of 8-11 genes. The multiple copies of Hox genes in more derived vertebrates is due to the fact that this single cluster was duplicated as a result of successive rounds of whole genome duplication in the vertebrate lineage, with subsequent loss of some copies in various lineages

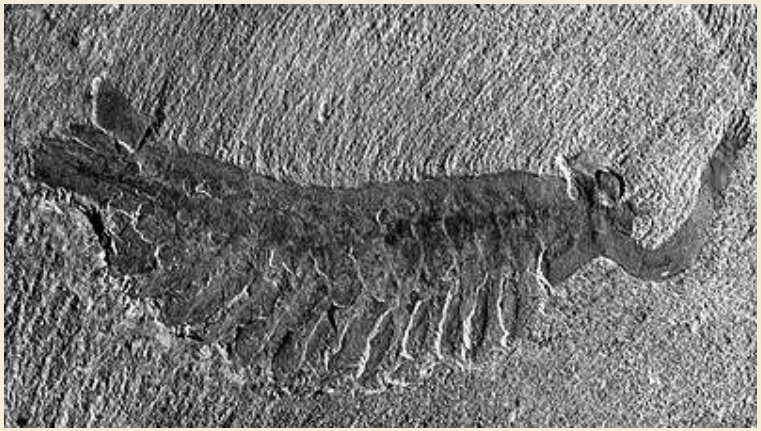
# Hox genes

- Because a single hox gene influences the expression of many other structural genes a change in when and where a hox gene is turned on may lead to major morphological changes in the phenotype such as the addition or loss of legs, arms, antennae and other structures.

# Phaenerozoic - Paleozoic - Cambrian

## Burgess shale





# Burgess Shale Fauna

Rocky Mountains, British Columbia

Discovered by Charles Walcott In 1909

Over 70,000 fossils

Soft-bodied

Cnidarians, Annelids

Hard-bodied

Arthropods, Brachiopods, Molluscs, Echinoderms

# Burgess Shale Fauna

• found near Field, B.C., dates to 520 MYA (similar to Yunnan fossils in China)

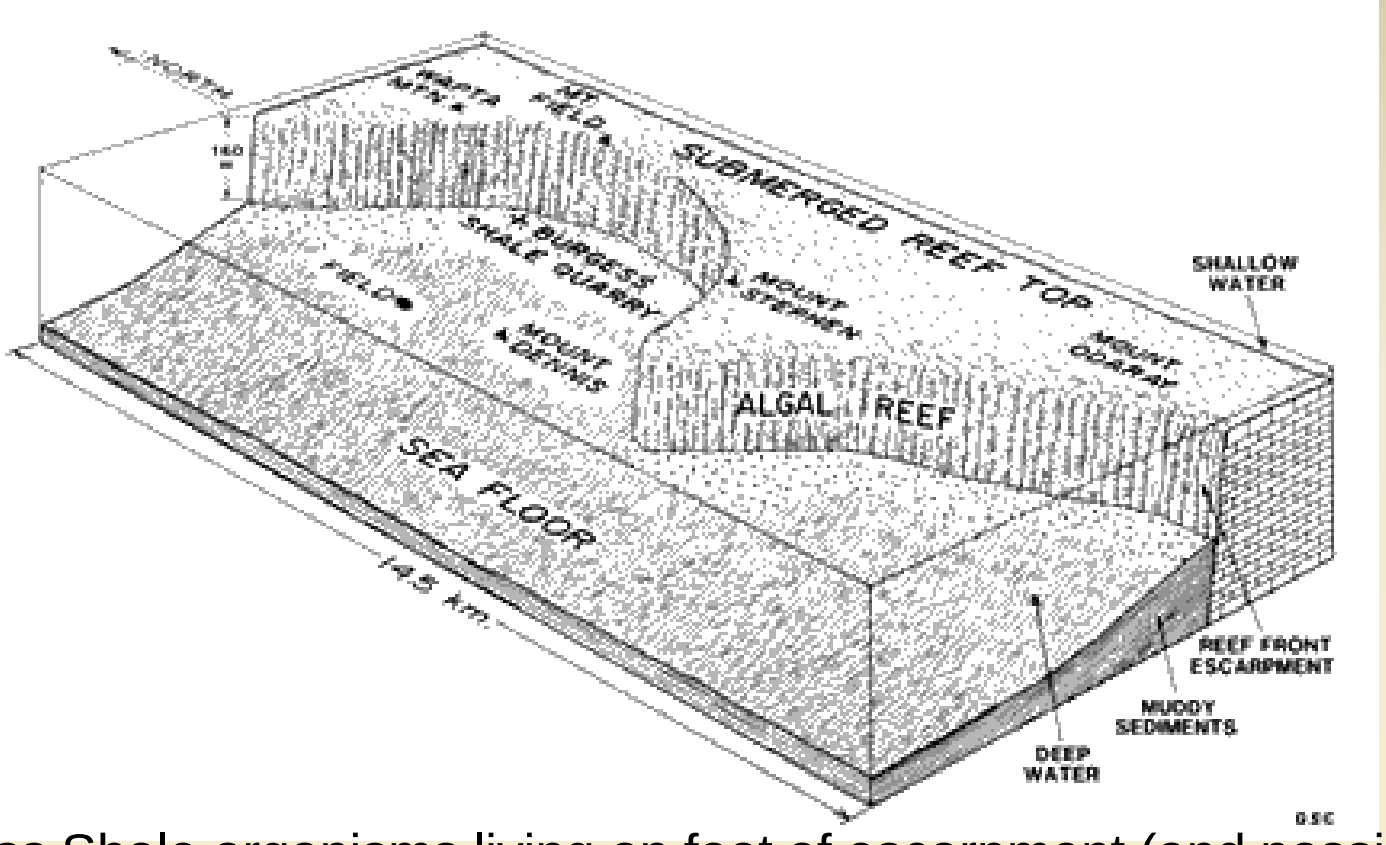
• all but one of the 35 existing phyla dramatically "appear" – this is the **Cambrian explosion**.

• entirely new modes of locomotion evolve (i.e., swimming, burrowing, climbing).

• first segmented body plans, external skeletons, appendages, and notochords

• the diversity of body plans is astonishing!

# Preservation of Burgess Shale Fauna




Burgess Shale organisms living on foot of escarpment (and possibly on edge and top of escarpment as well) smothered by due to slumping, killed and buried instantly

**Rapid burial + low oxygen** (+ possible mineralization during early decay) = exceptional preservation

Usually Fossils Look Like This


In the Burgess Shale Formation
They Look Like This!

*Lenoides serratus*

# Trilobites

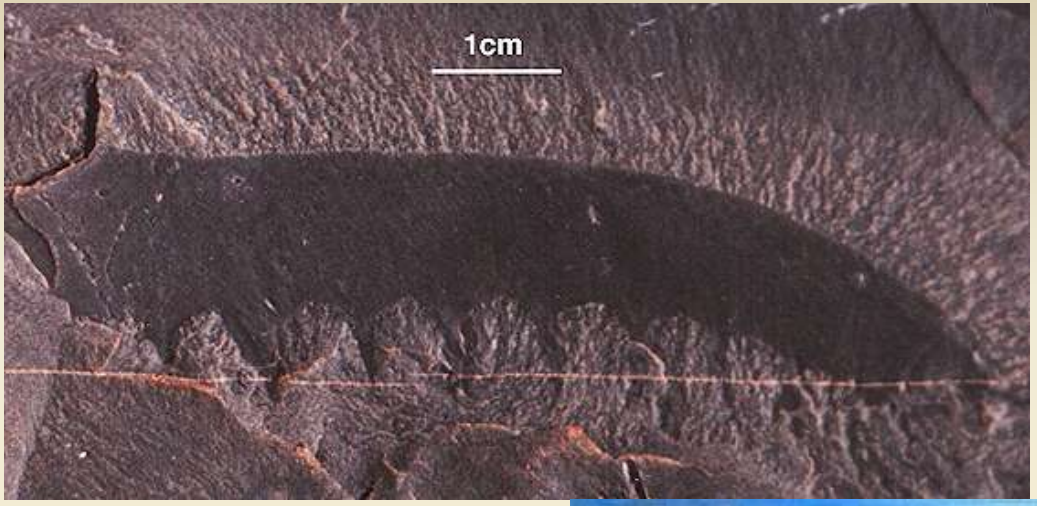
# Trilobites

**Trilobites** were among the early **arthropods**, a phylum of hard-shelled creatures with multiple **body segments** and **jointed legs** (although the legs, antennae and other finer structures of trilobites only rarely are preserved).

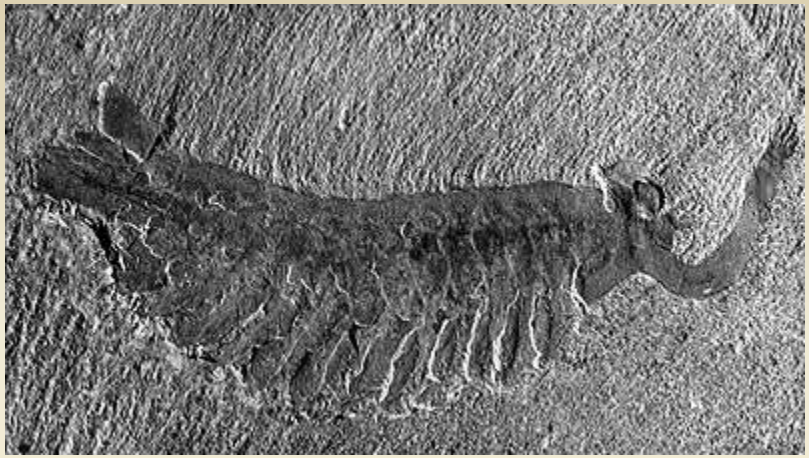
The majority of trilobites bore a pair of **compound eyes** (made up of many lensed units).

# *Anomalocaris*

**the biggest predator of the Cambrian**




# *Opabinina*



Small, resemble segmented worms.

Arm-like proboscis probably used for feeding.

Ventral lobes situated on each side of the organism; probably used to propel them through the water

# *Wiwaxia*

Small and slow
Herbivorous, ate sludge that was found on the ocean floor.
Trudged slowly around the bottom of the ocean trying to stay out of everyone else's way.
Protected by spines

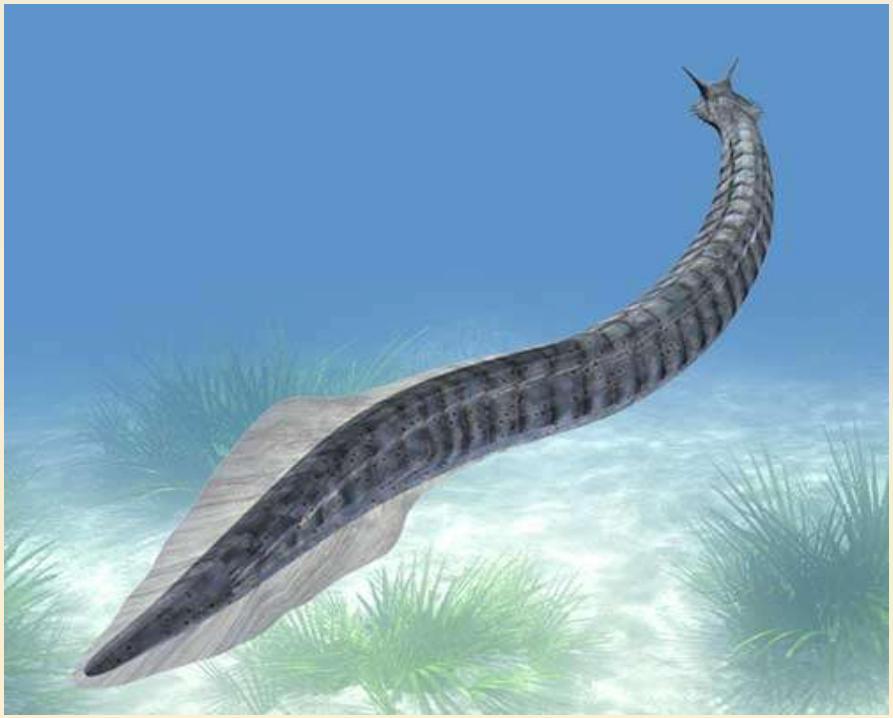
# *Hallucigenia*

Nobody knows what end of Hallucigenia was the head.

Another thing that is mysterious is that no one knows if Hallucigenia swam or crawled

Strange spines sticking out of its back

# *Pikaia*



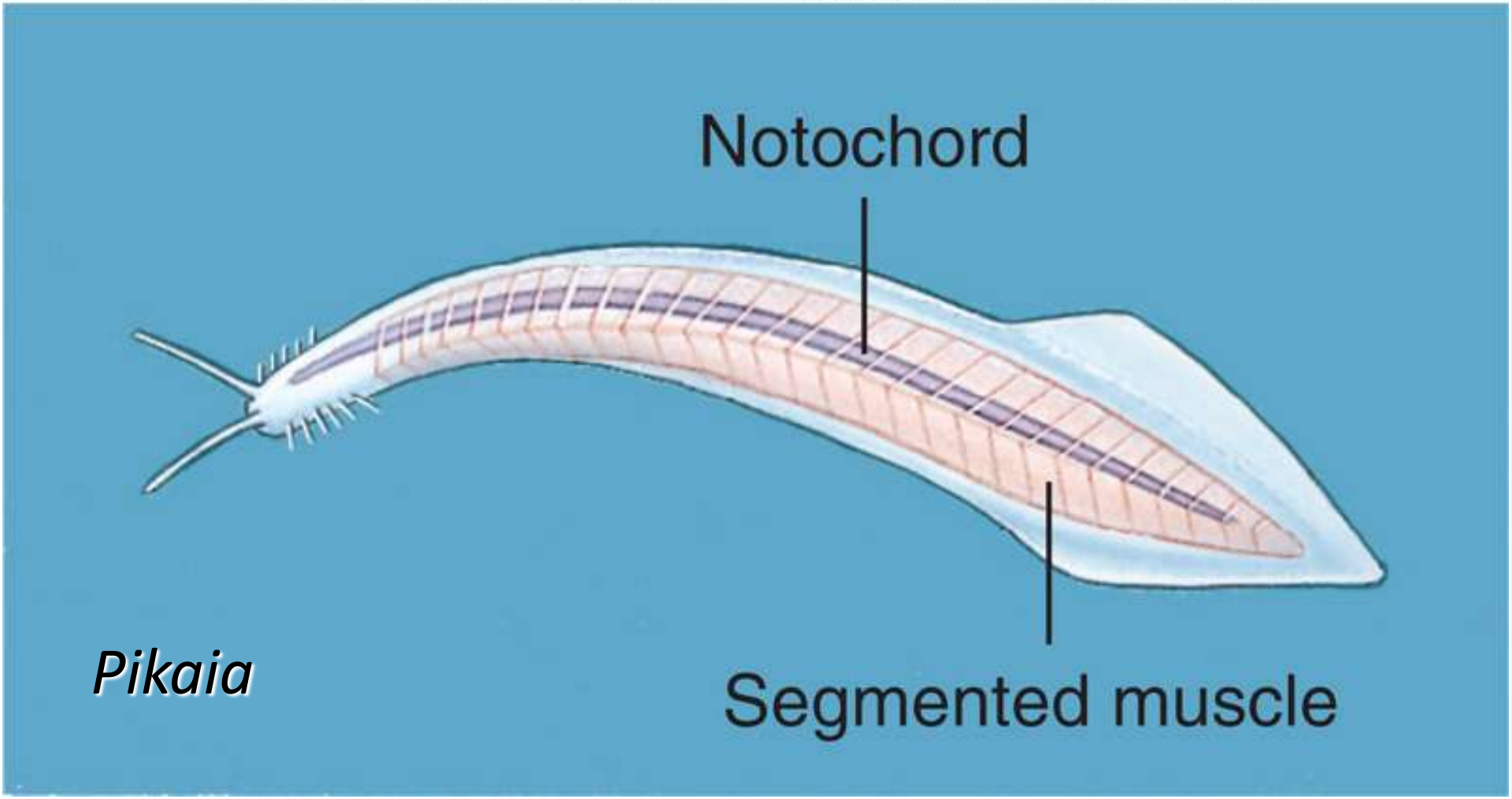
Not part of the arthropod lineage. It lacked segments, an exoskeleton, and jointed legs

Rod running along its back resembled a backbone-like structure.

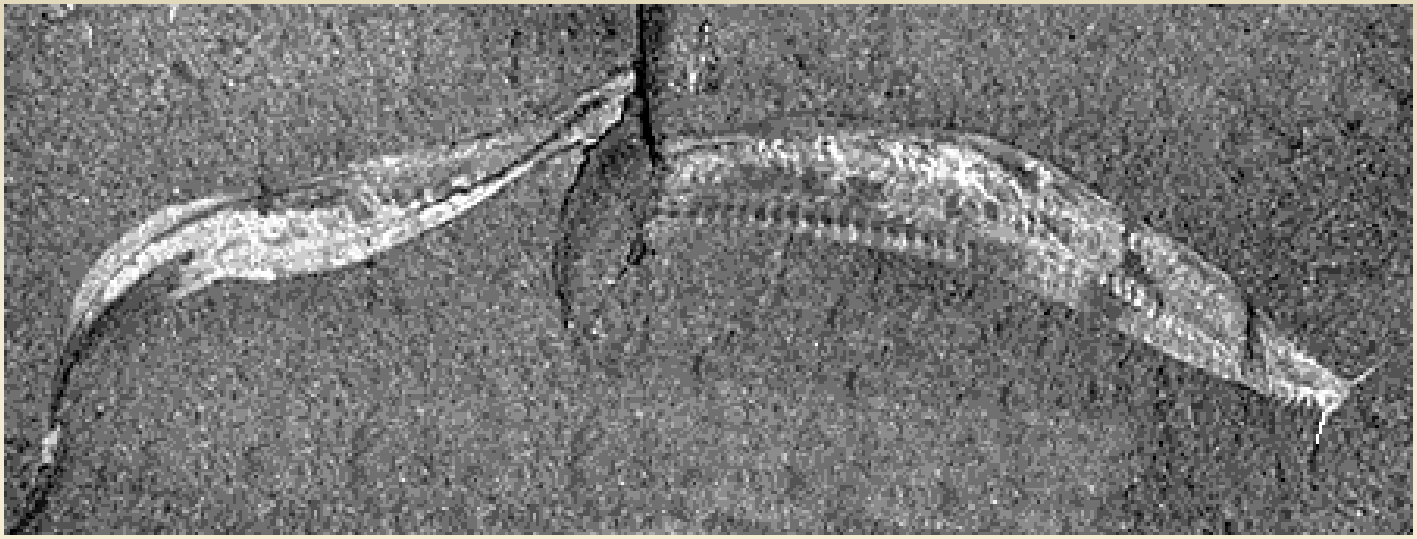
Markings on the sides of its body formed V-shapes typical shape of chordate muscle bundles

Figure 23.10





# *Pikaia*
# earliest known Chordate



**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 armour.

We ultimately evolved from an animal that looked like this !

# Cambrian Explosion

Environmental changes triggered the radiation, developmental biology and geochemistry allowed animals to diversify, and the radiation was made all the more spectacular by all-new types of ecological interactions, most importantly predation

# What caused the Cambrian explosion?

## 1. Increase in the oxygen content of seawater

• allowed organisms to achieve **increased sizes** and metabolic rates.

• large size is clearly a prerequisite for the evolution of predators.

• Increased need for speed and better sensory equipment

# What caused the Cambrian explosion?

**2. Origin of hard parts** (shells and mineralized exoskeletons).

• some of the earliest shells have holes bored through them by predators!

• strong selection pressures by presence of predators would have favored mineralized shells.

# What caused the Cambrian explosion?

## 3. The evolution of eyes

• proposed by Andrew Parker in his 2003 book, "*In the blink of an eye*".

• eyes first appear in trilobites about 543 MYA.

• large predators with eyes make for better predators!

# What caused the Cambrian explosion?

## 4. Genetic changes

• did the diversification of **homeotic genes** drive the Cambrian explosion?

• homeotic genes encode for transcription factors.

• they activate suites of genes that control body plans during early development.

• *Hox* genes evolved at that time and allowed for differential development.

# Macroevolutionary patterns

## 1. Adaptive Radiation

**Definition (Mayr 1963):** evolutionary divergence of members of a single phyletic line into a series of rather different niches or adaptive zones.

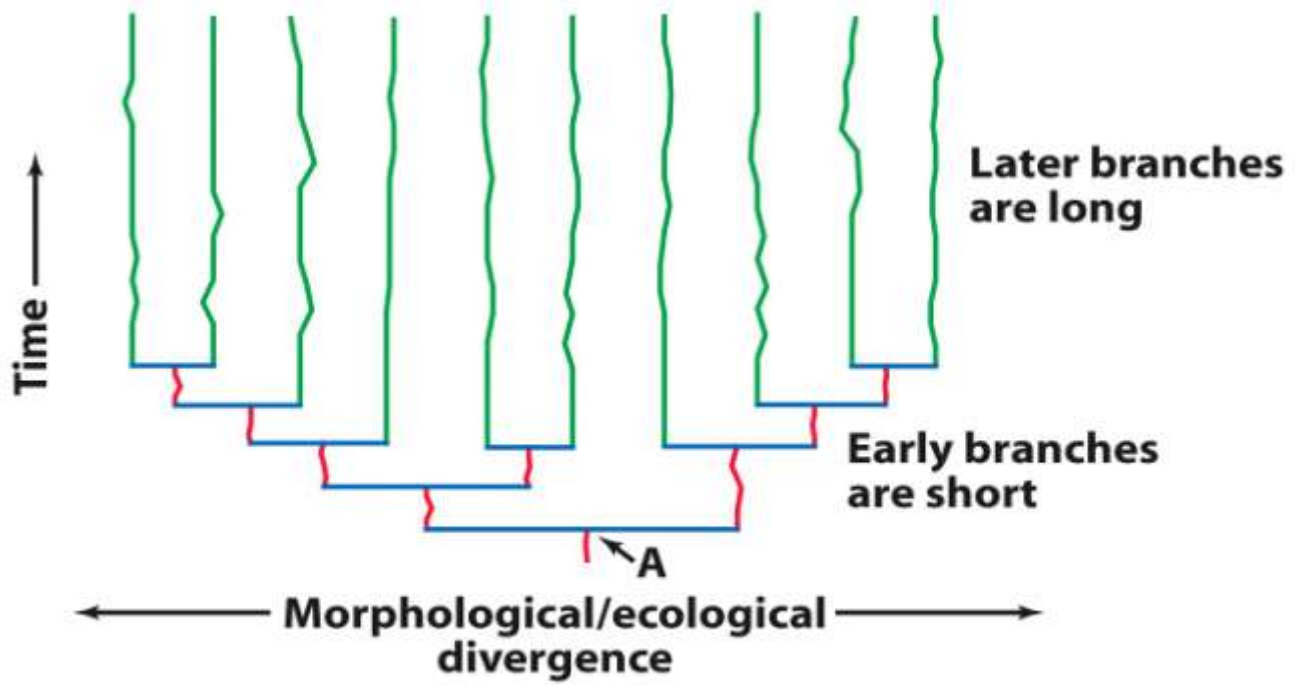



Figure 18-13 Evolutionary Analysis, 4/e

# Animal Evolution

# Animal Phylogeny

- Biologists categorize animals by:
  - General features of body structure
  - More recently, using genetic data
- One major branch point distinguishes sponges from all other animals because, unlike more complex animals, sponges lack true tissues.
- A second major evolutionary split is based on body symmetry.
  - **Radial symmetry** refers to animals that are identical all around a central axis.
  - **Bilateral symmetry** exists where there is only one way to split the animal into equal halves.

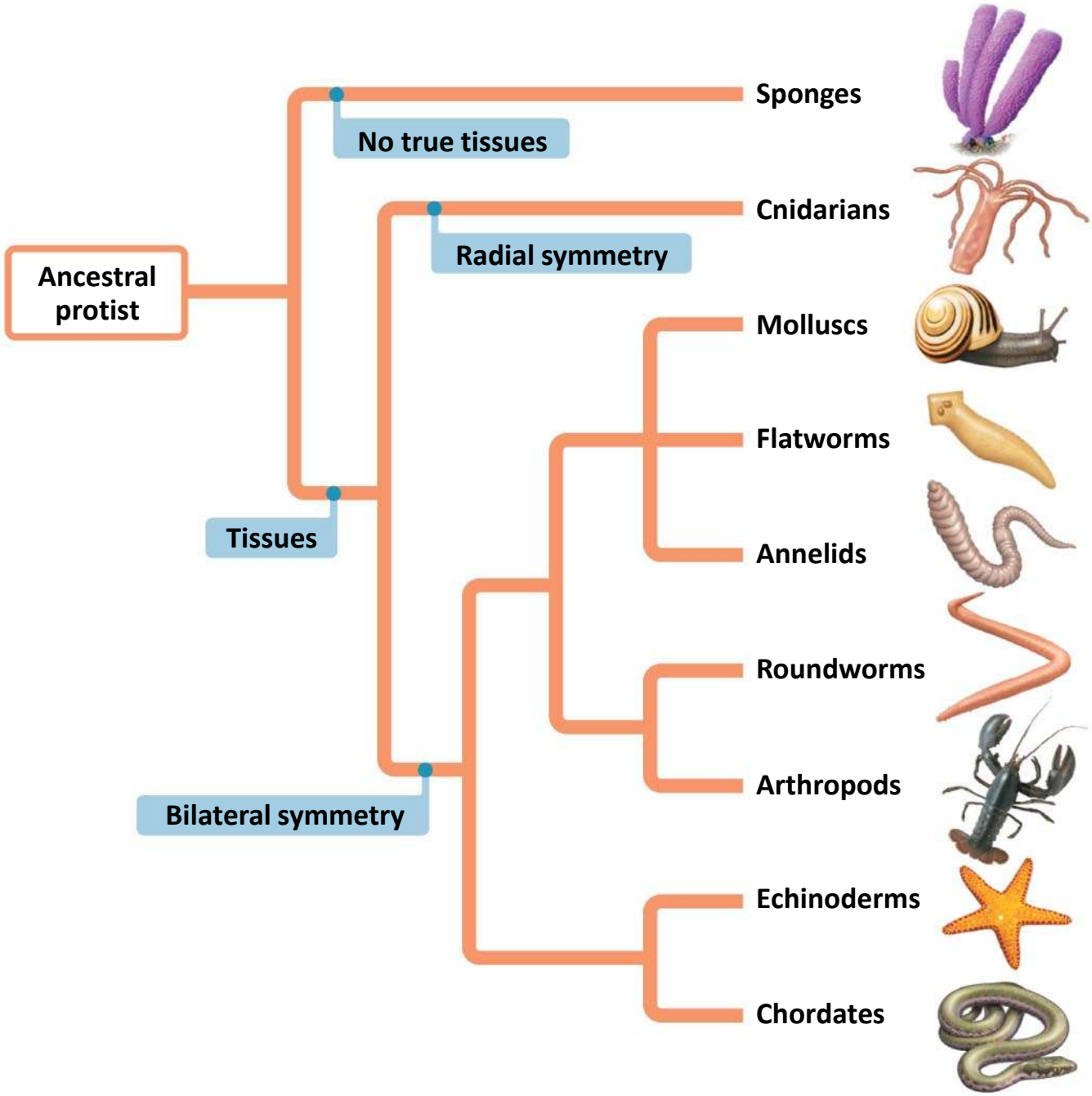
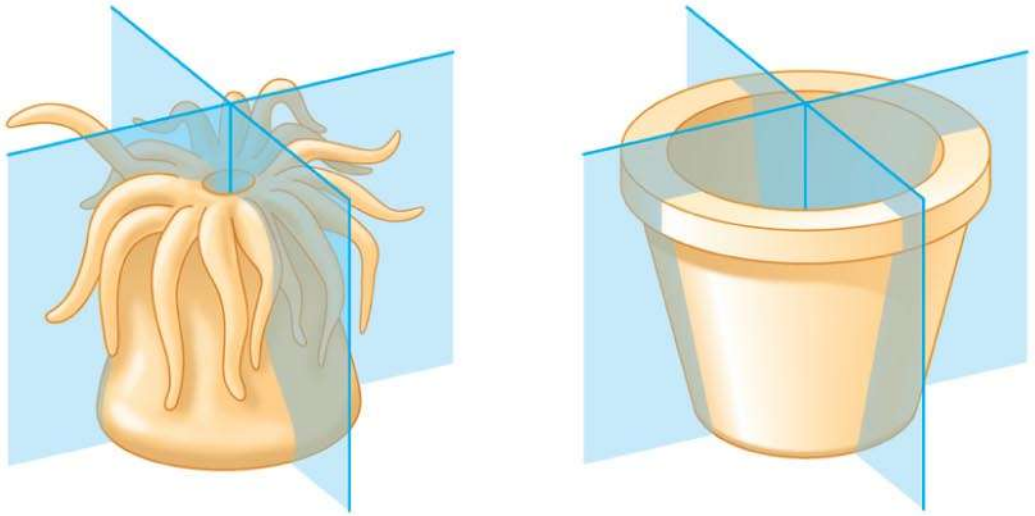
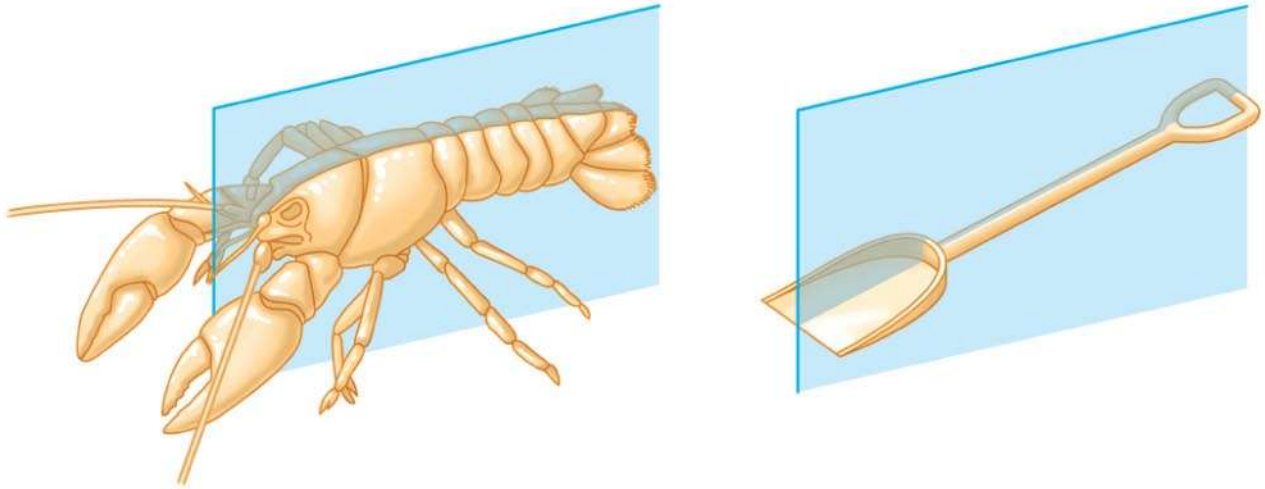





Figure 17.5



**Radial symmetry. Parts radiate from the center, so any slice through the central axis divides into mirror images.**



**Bilateral symmetry. Only one slice can divide left and right sides into mirror-image halves.**





Figure 17.6

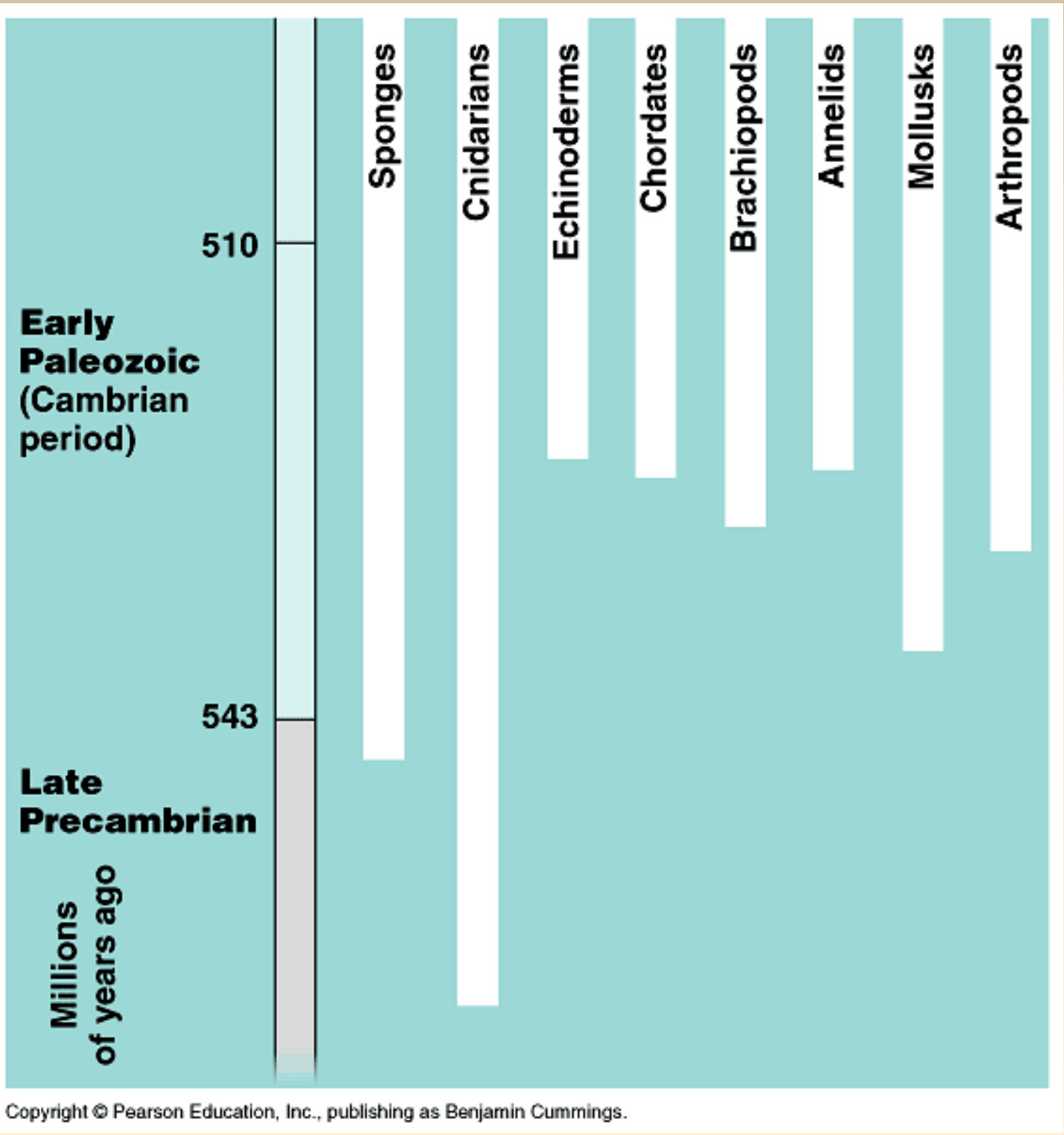
# Origins of animal diversity

Most animal phyla originated in a relatively brief span of geologic time.

1. Modern phyla developed in about 40 million years total.

2. During the Cambrian Explosion (543 to 524 million years ago), nearly all major body plans appeared.

# The Cambrian radiation of animals



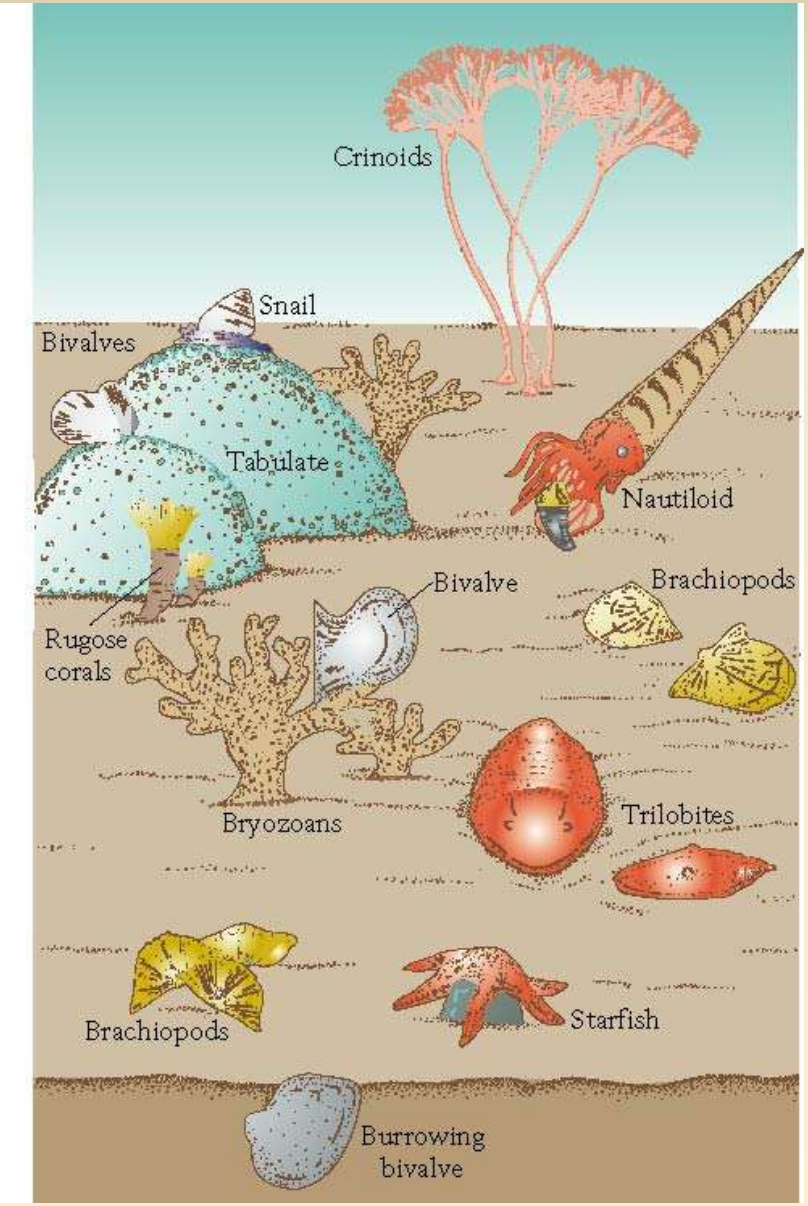
# Ordovician

# 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

# The Ordovician Sea Floor

# Ordovician Life

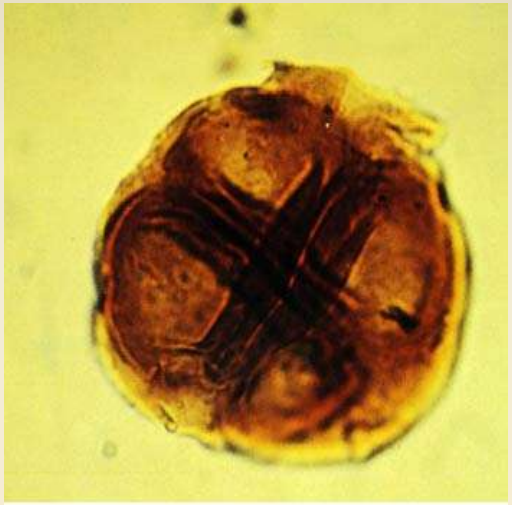



- Life on the seafloor
  - Diversity of benthic organisms increased
  - Jawless fishes
  - Grazing snails
  - Articulate brachiopods
  - Crinoids expanded
- Coral reefs
  - Rugose corals
  - Tabulate corals
  - Stromatoporoids

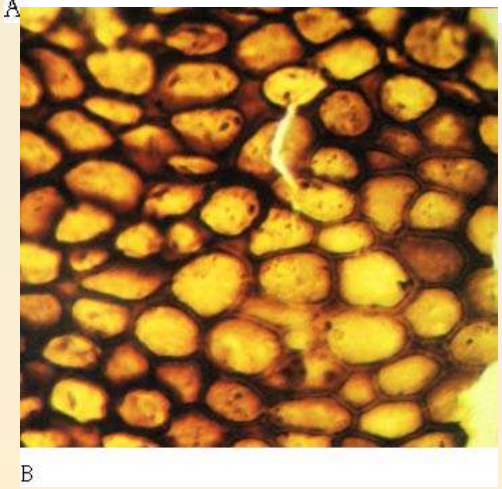
# Ordovician Fossils

## Brachiopods

# Ordovician Life



A



B

- Plants may have invaded land
  - Inconclusive evidence
  - Probably restricted to moist habitats

# Earliest Land Plants

## Bryophytes

Liverwort

Moss

Hornwort

470 Ma, Oman
Mid-Ordovician

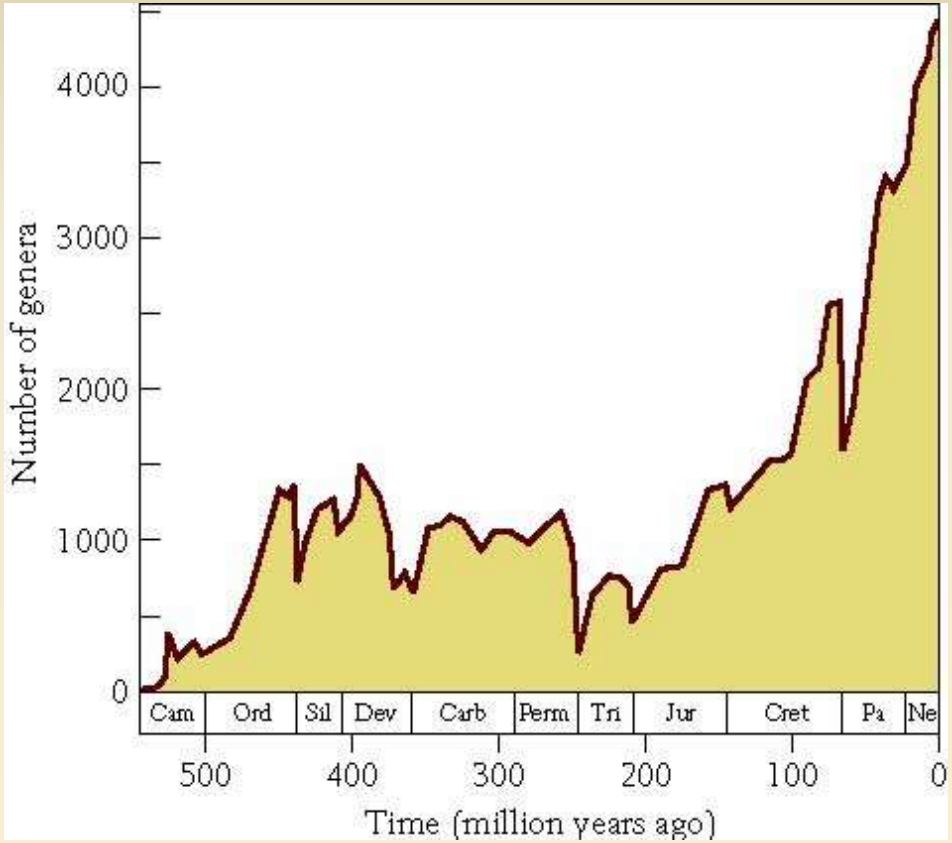
# Ordovician Extinction

- The Earth's climate became much cooler in the middle Ordovician.
  - Glaciers covered much of the continents
  - Sea level dropped
- Climate change, probably, was responsible for the Ordovician mass extinction.
- 60% of marine organisms

# Ordovician-Silurian mass extinction


The third largest extinction in Earth's history. Sea creatures such as trilobites, brachiopods and graptolites that were drastically reduced in number. In all, some 85% of sea life was wiped out.An ice age has been blamed for the extinctions - a huge ice sheet in the southern hemisphere caused climate change and a fall in sea level, and messed with the chemistry of the oceans

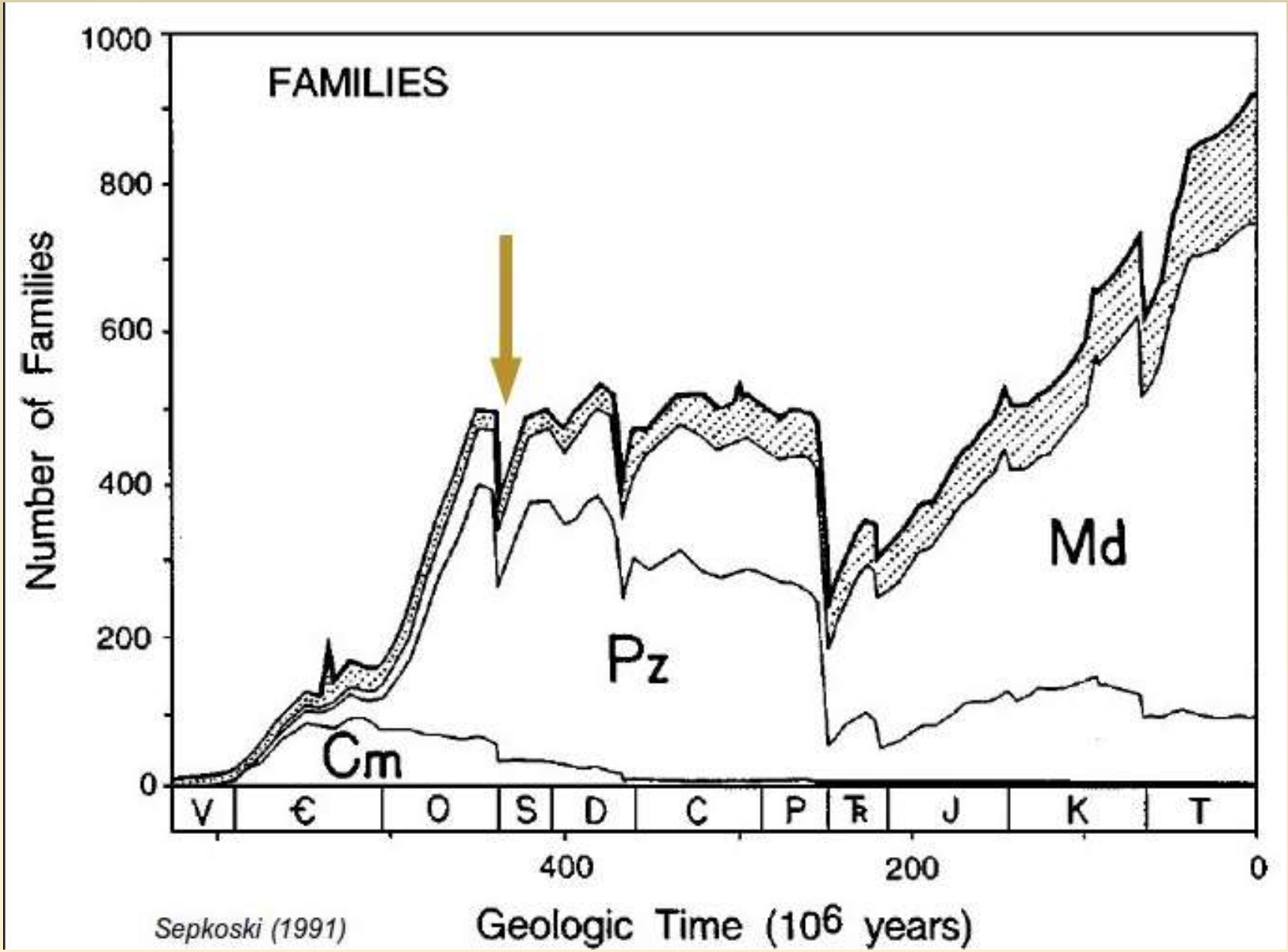
# Ordovician Life



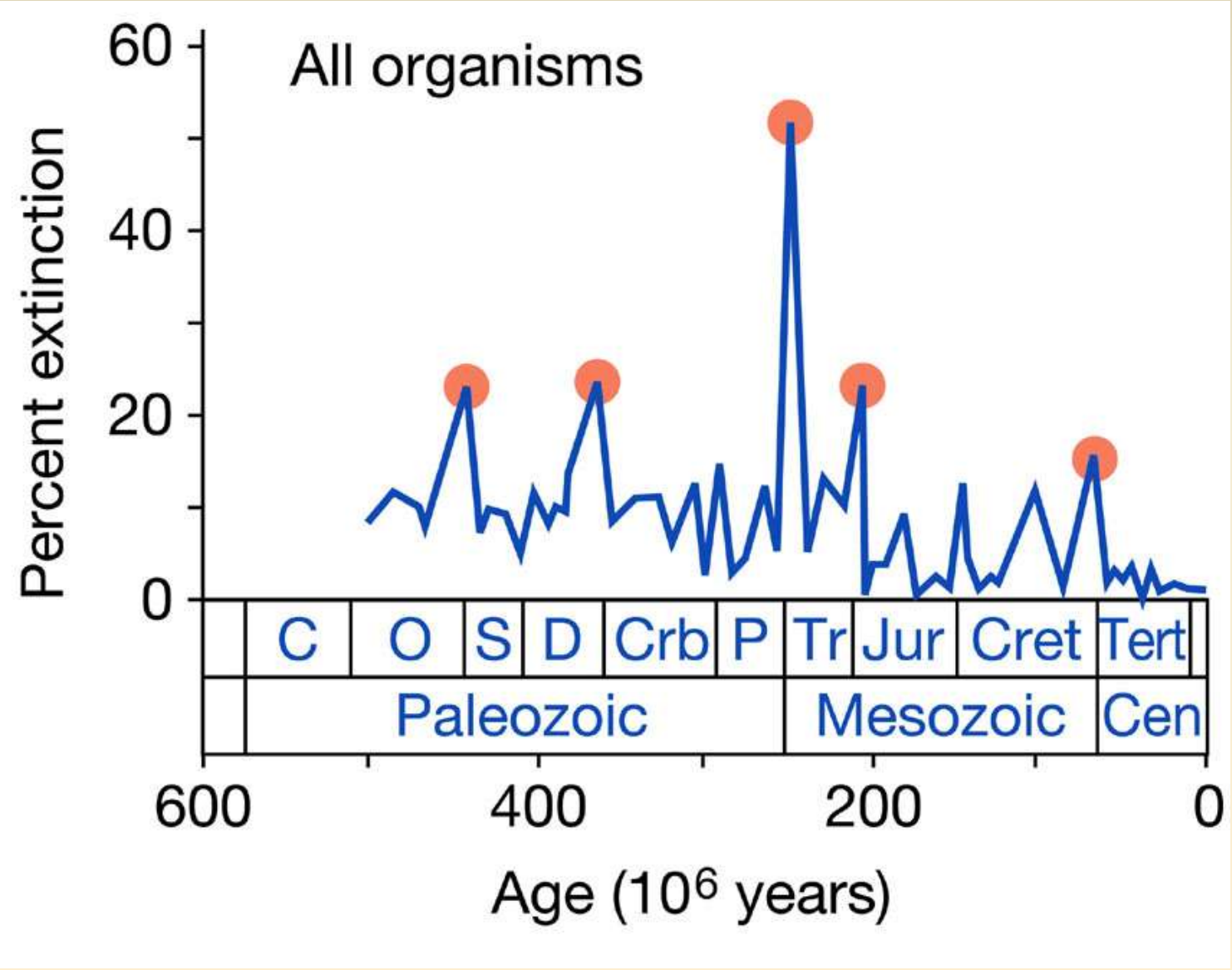

Extinctions

- Large extinction events limited diversification
- Cambrian mass extinctions
- End of Ordovician mass extinction

# End of Ordovician Extinction



# 5 Great Mass Extinctions!



# Silurian

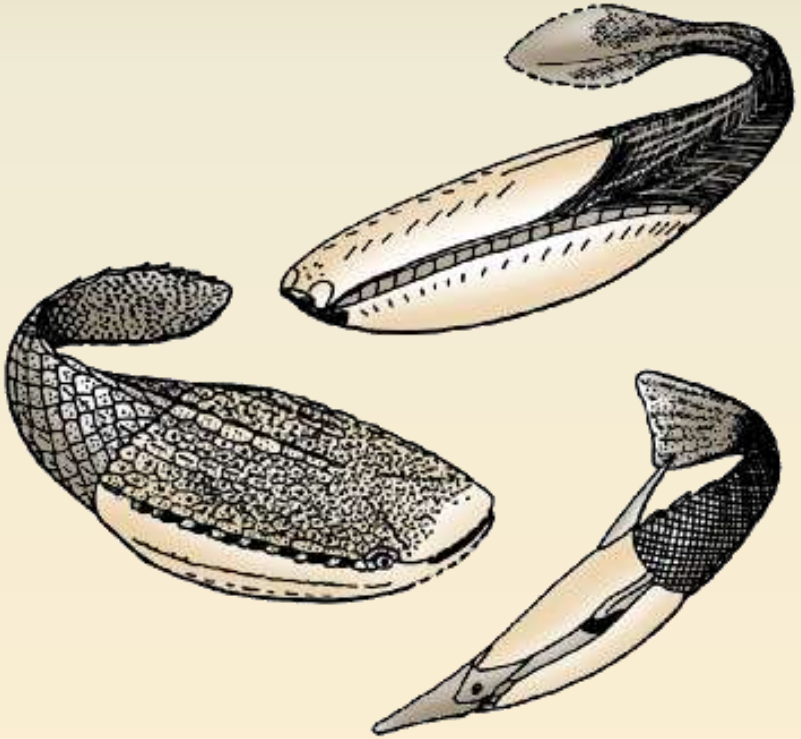
# Silurian
## (443 - 417 million years ago)

- 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 Coral Reefs

- What is coral?  An invertebrate animal related to jellyfish.
- Small marine animals that live in warm water.
- They make a “skeleton” out of calcium carbonate

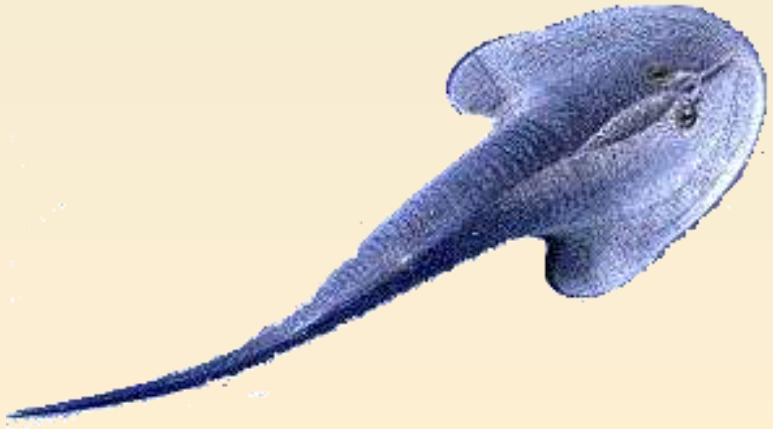
# Silurian Fish (Ostracoderms)



Vertebrates

Thought to be related to fish with jaws and sharks.

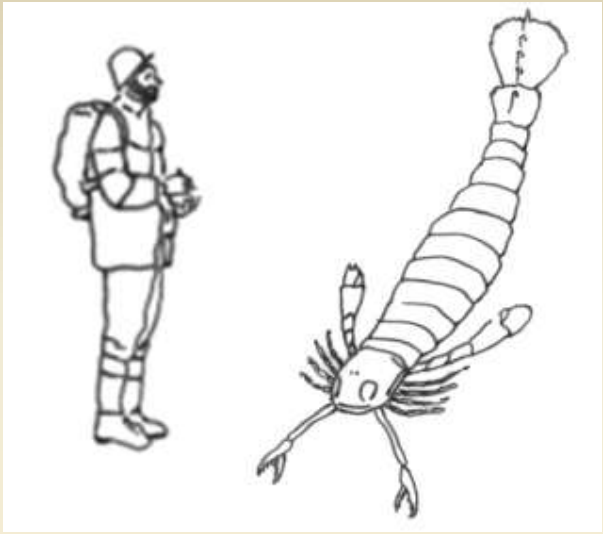
Ate through a ‘sucker’ mouth.

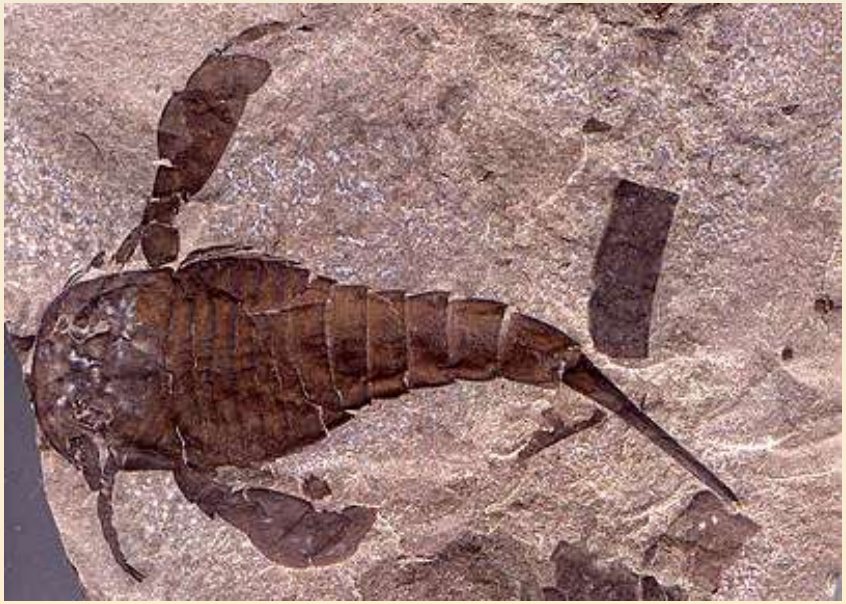


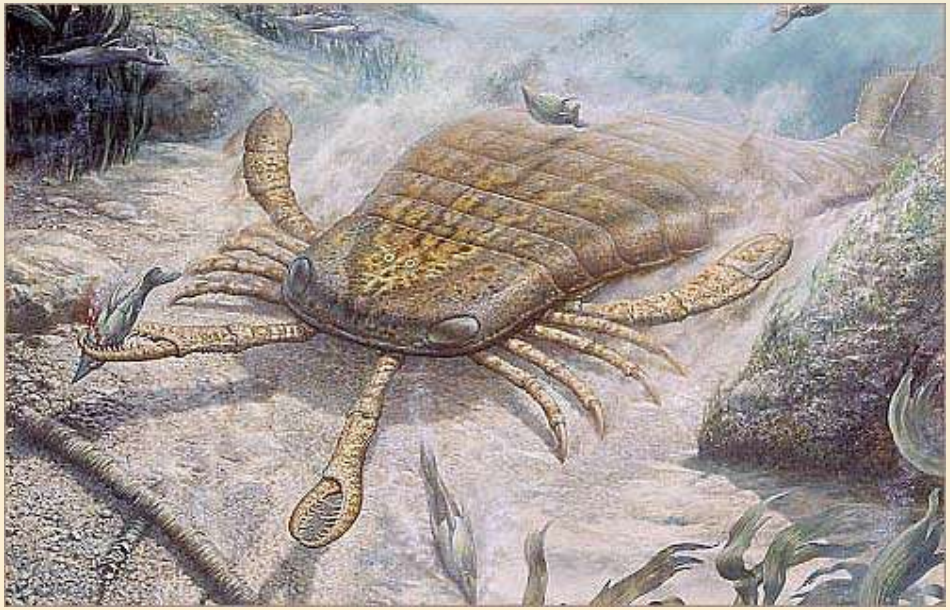
# Silurian

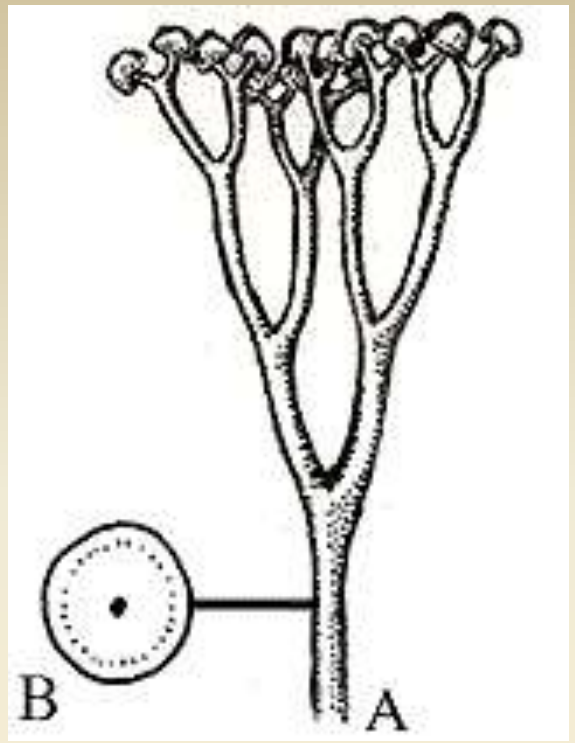
Eurypterids

- water scorpions
- Related to modern spiders and scorpions







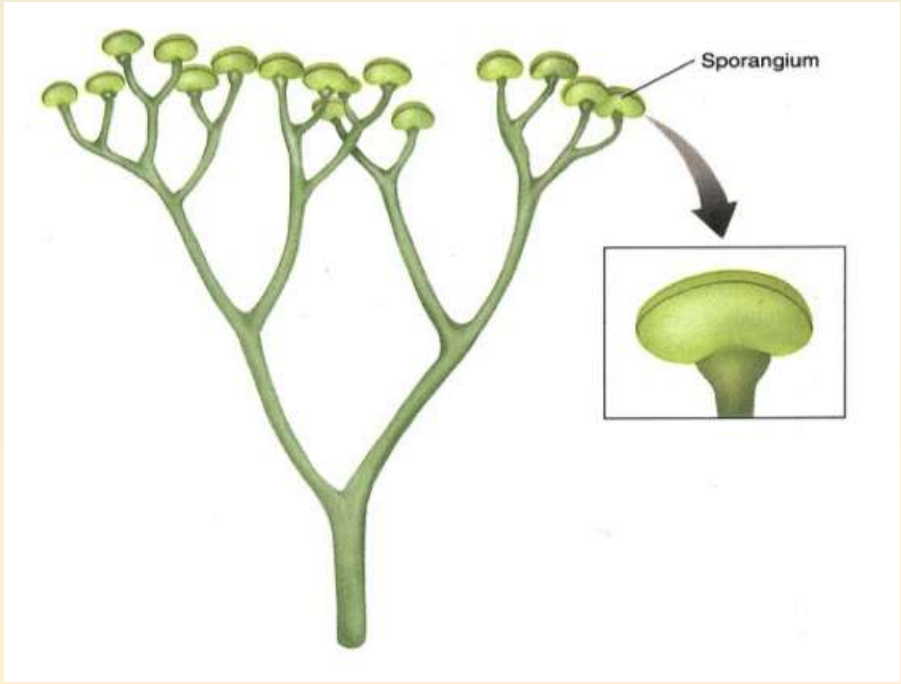


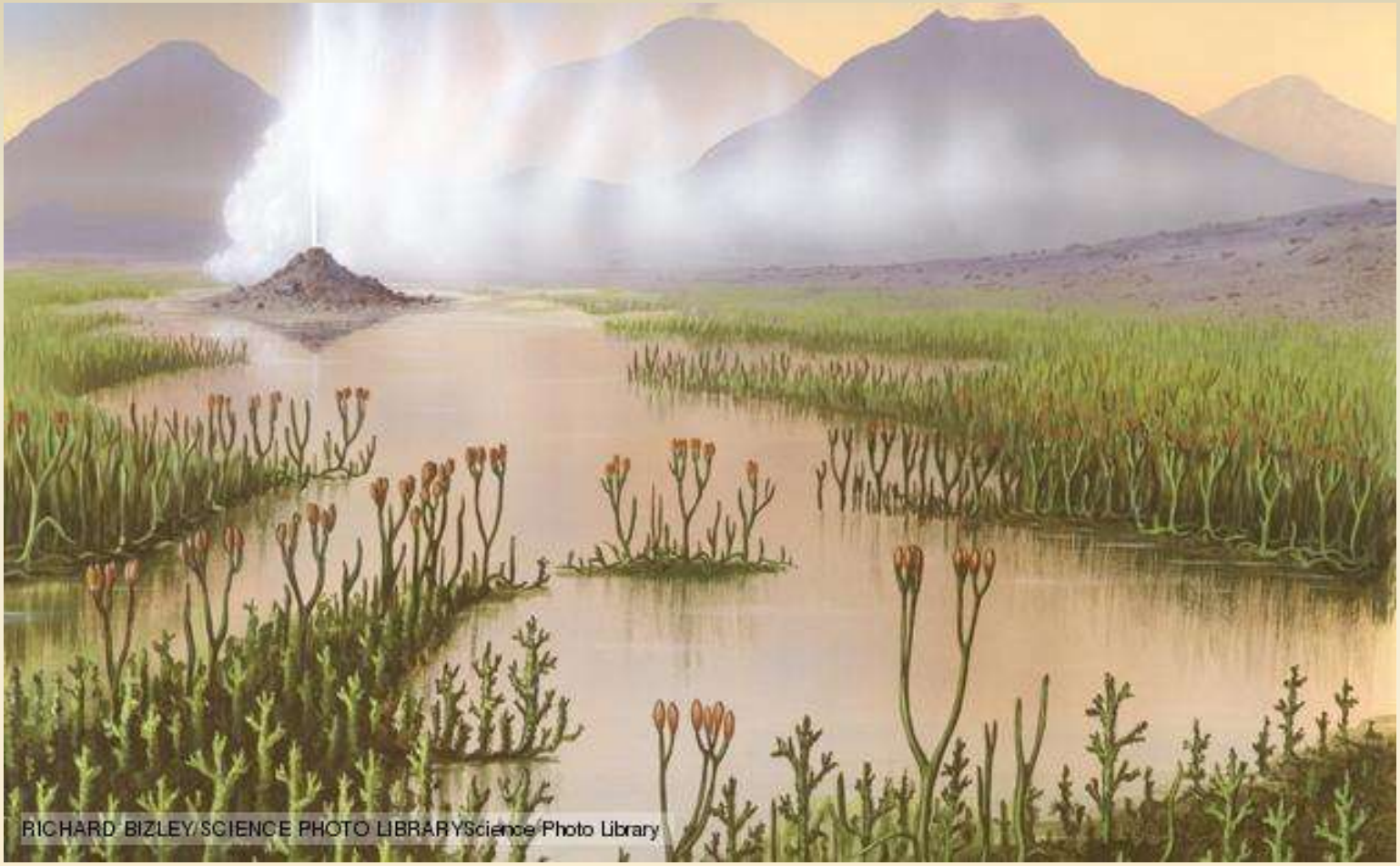

# Silurian Plants

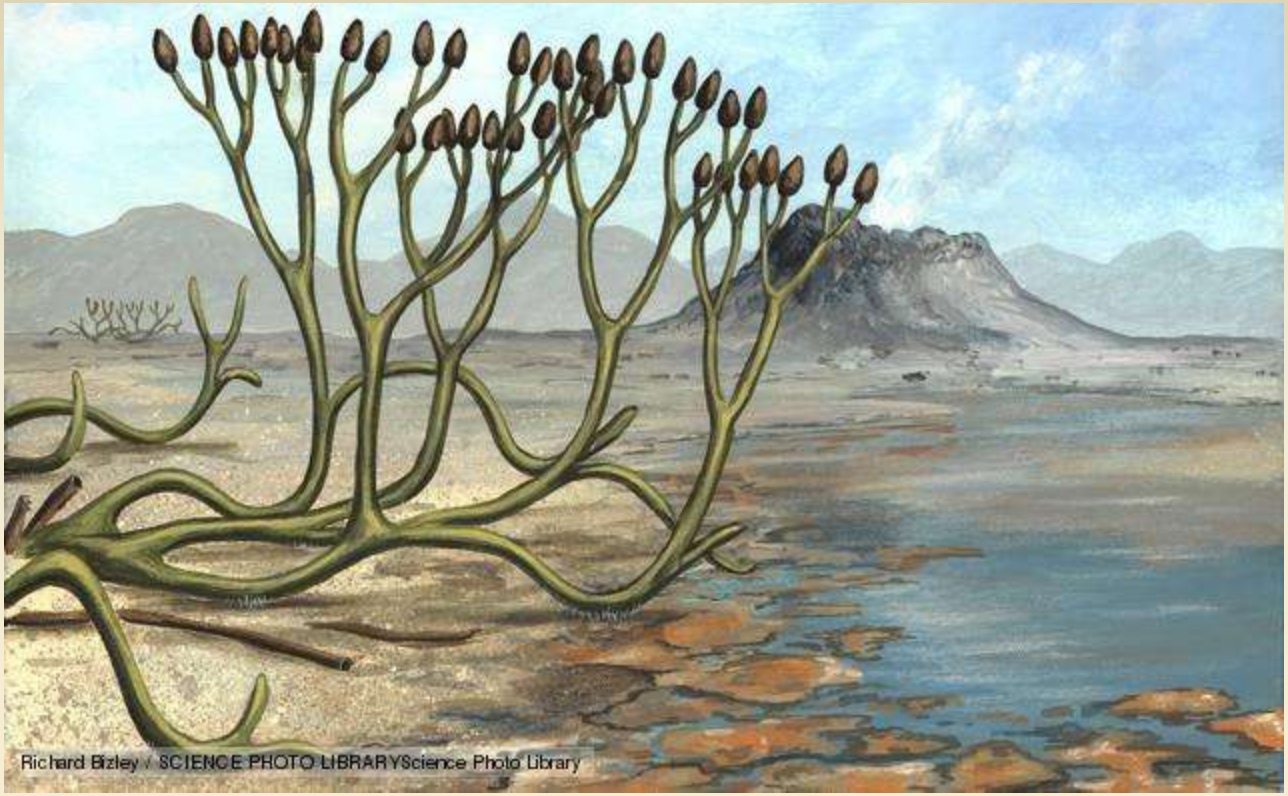
Lived near shorelines and in shallow waters

Slowly ‘invaded’ the land area by spreading in from rivers and lakes

*Cooksonia*




RICHARD BIZLEY/SCIENCE PHOTO LIBRARYScience Photo Library




Rhynie Chert in Scotland is a Devonian age deposit containing fossils of both zosterophylls and trimerophytes, some of the earliest vascular plants.

# Devonian

# Devonian
## (417 - 345 million years ago)

- The first appearances of real “trees”
  - Most vegetation was small plants
  - Tallest plants were only about 3 feet tall
- First amphibians
- First wingless insects
- Sea levels very high
- Marine life continued
  - Brachiopods, coral, echinoderms, and new fish

# Devonian Organisms

Tree Fossil

Early Amphibian Fossil

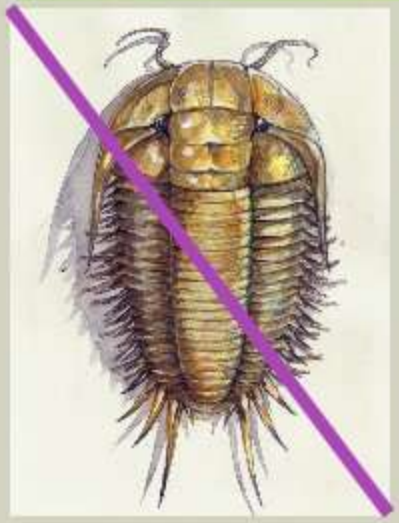
Cockroach & Tarantula **<u>similar</u>** to Devonian Arthropods

# Plants

- Early Devonian spore plants restricted to marshes
  - Required water for reproduction
  - Development of seed freed plants from water

# Early Devonian landscape

# Arthropoda



Of the five arthropod subphyla that have existed, four have managed to conquer the land.

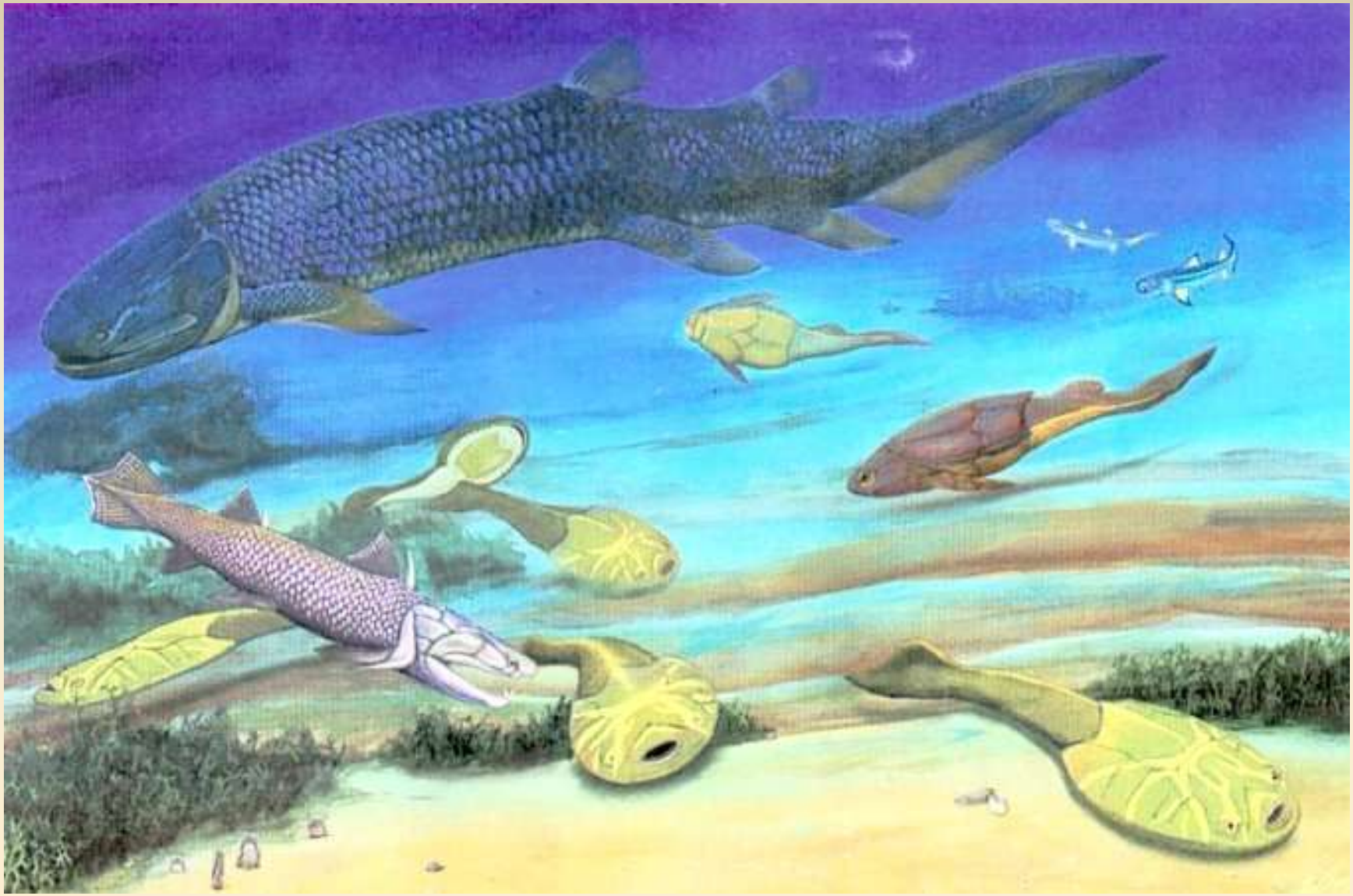
# Devonian

**-chelicerates**
**-mandibulates**

# Devonian – “Age of Fish”

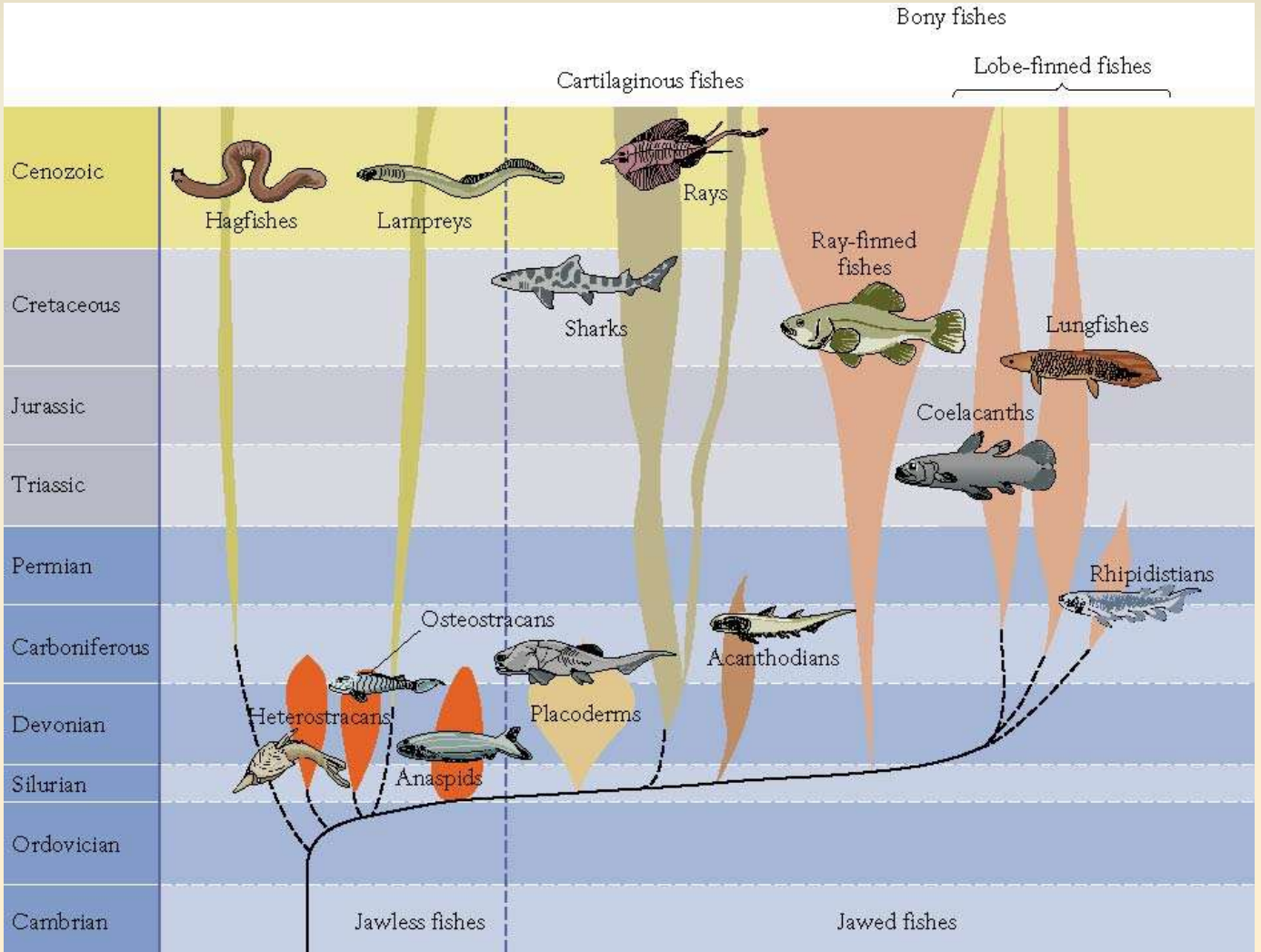
- Many fish evolved during the Devonian Period including
  - the abundant acanthodians
  - placoderms,
  - ostracoderms,
  - and other fish groups,
    - such as the cartilaginous and bony fish
- the Devonian is informally called the “Age of Fish”
  - because all major fish groups were present during this time period

# Devonian - Age of Fish

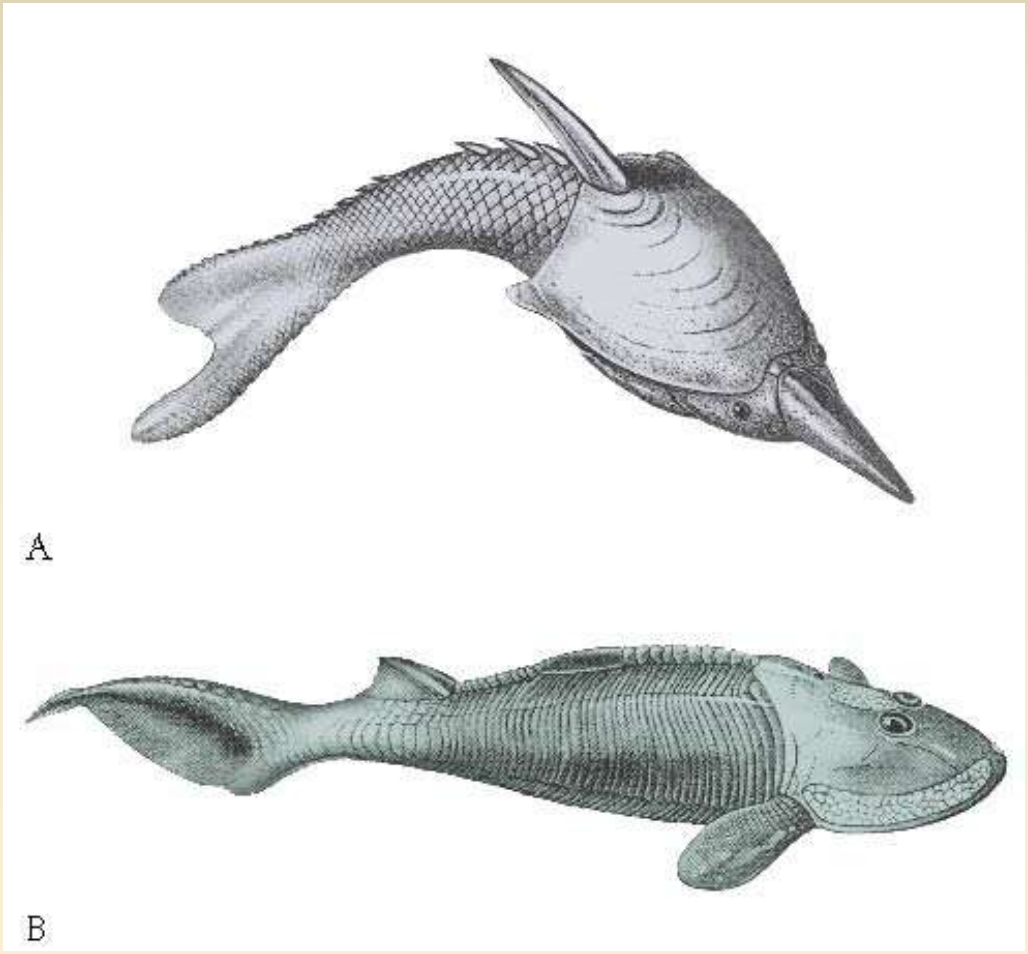


# Fishes

- Fishes evolved
  - First fully preserved specimens

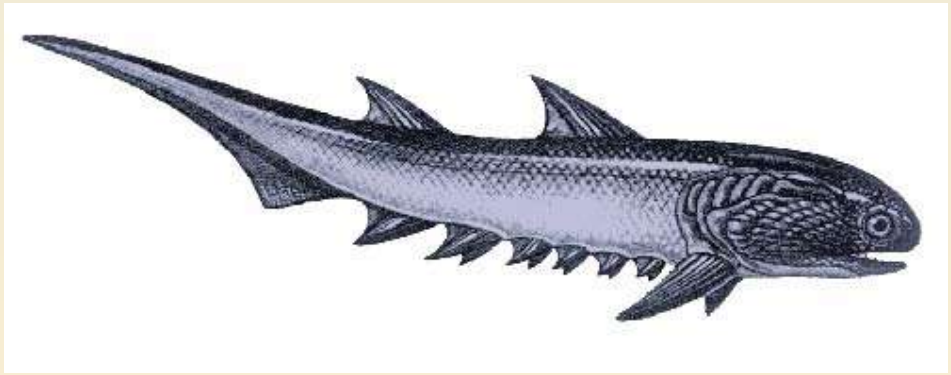


# Fish




- Jawless fish
- Ostracoderms
  - Bony skin
  - Paired eyes
  - Bony armor
  - *Pteraspis (8 - 10”)*
  - *Hemicyclaspis (4 - 6”)*

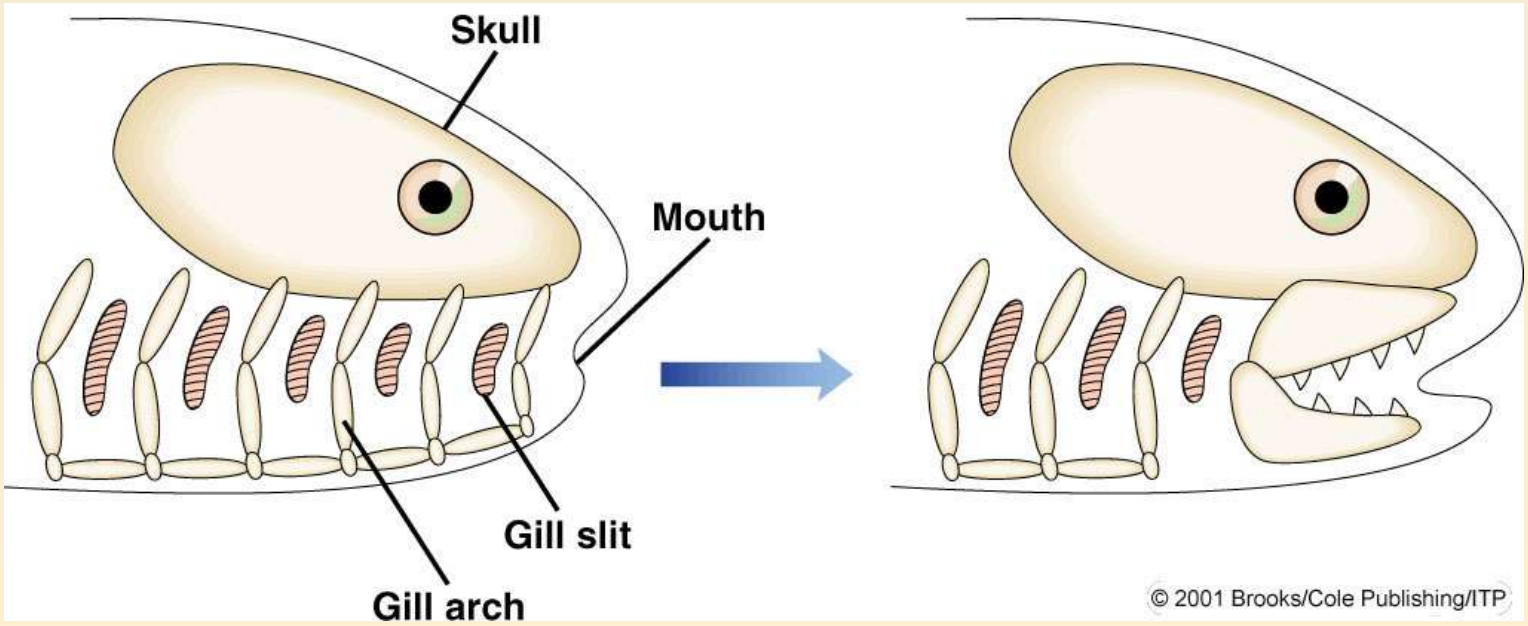
# Fish



- Jawed fish
- Acanthodians
  - Fresh and Marine
  - Fins supported by sharp spines
  - Paired fins
  - Scales cover body
  - *Climatius* (~3 inches)

# 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
- This theory is based on the comparative anatomy of living vertebrates



# Fishes

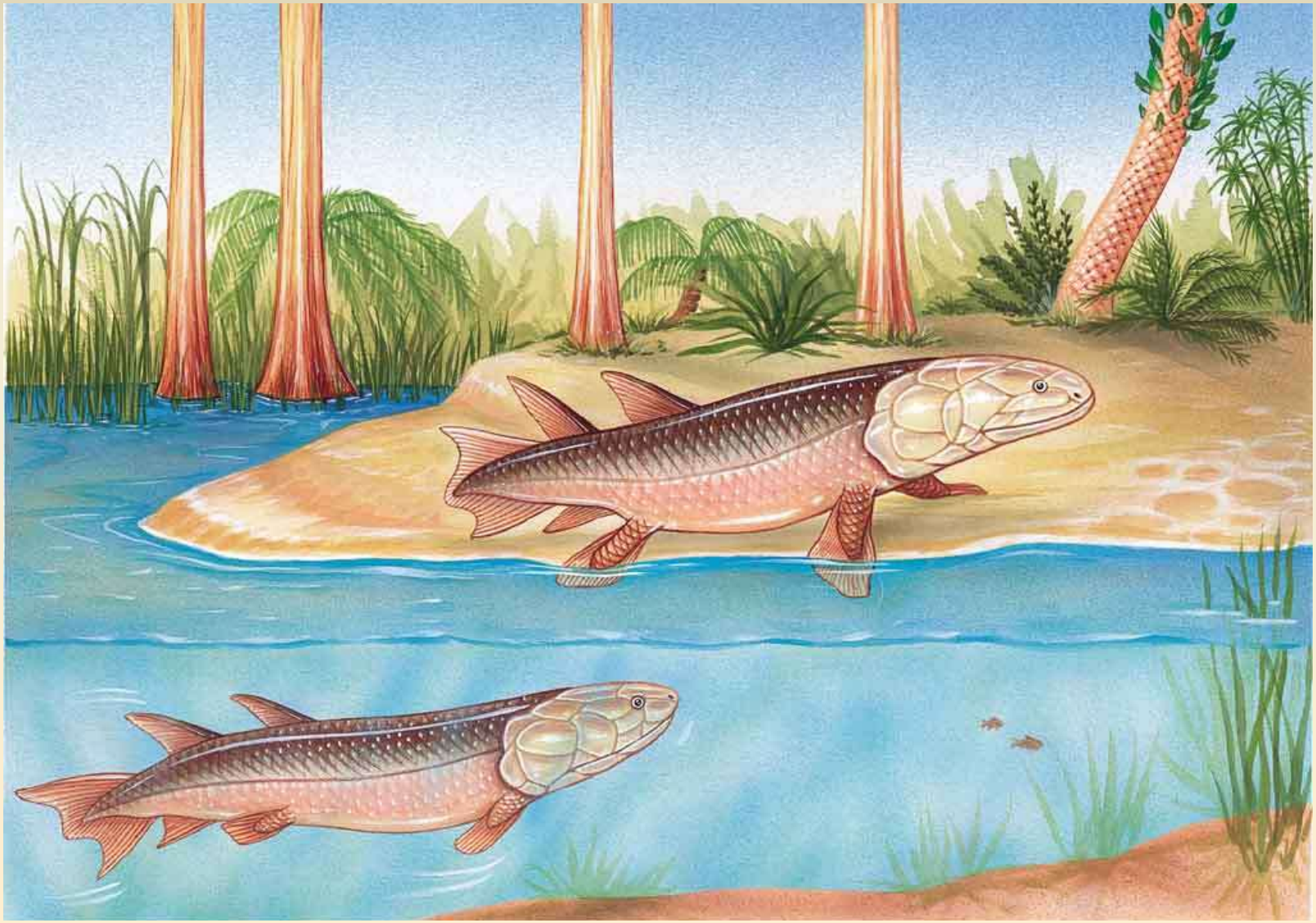
- Placoderms
  - Very large fishes
  - Predators
  - Dominated freshwater environments
    - Late Devonian, diversified in the seas
  - *Dunkleosteus*
    - 7 m long armored fish
    - Unarmored tail

# *Dunkleosteus*

# Amphibians—Vertebrates Invade the Land

- Although amphibians were the first vertebrates to live on land,
  - they were not the first land-living organisms
- Land plants, which probably evolved from green algae,
  - first evolved during the Ordovician
- Furthermore, insects, millipedes, spiders,
  - and even snails invaded the land before amphibians

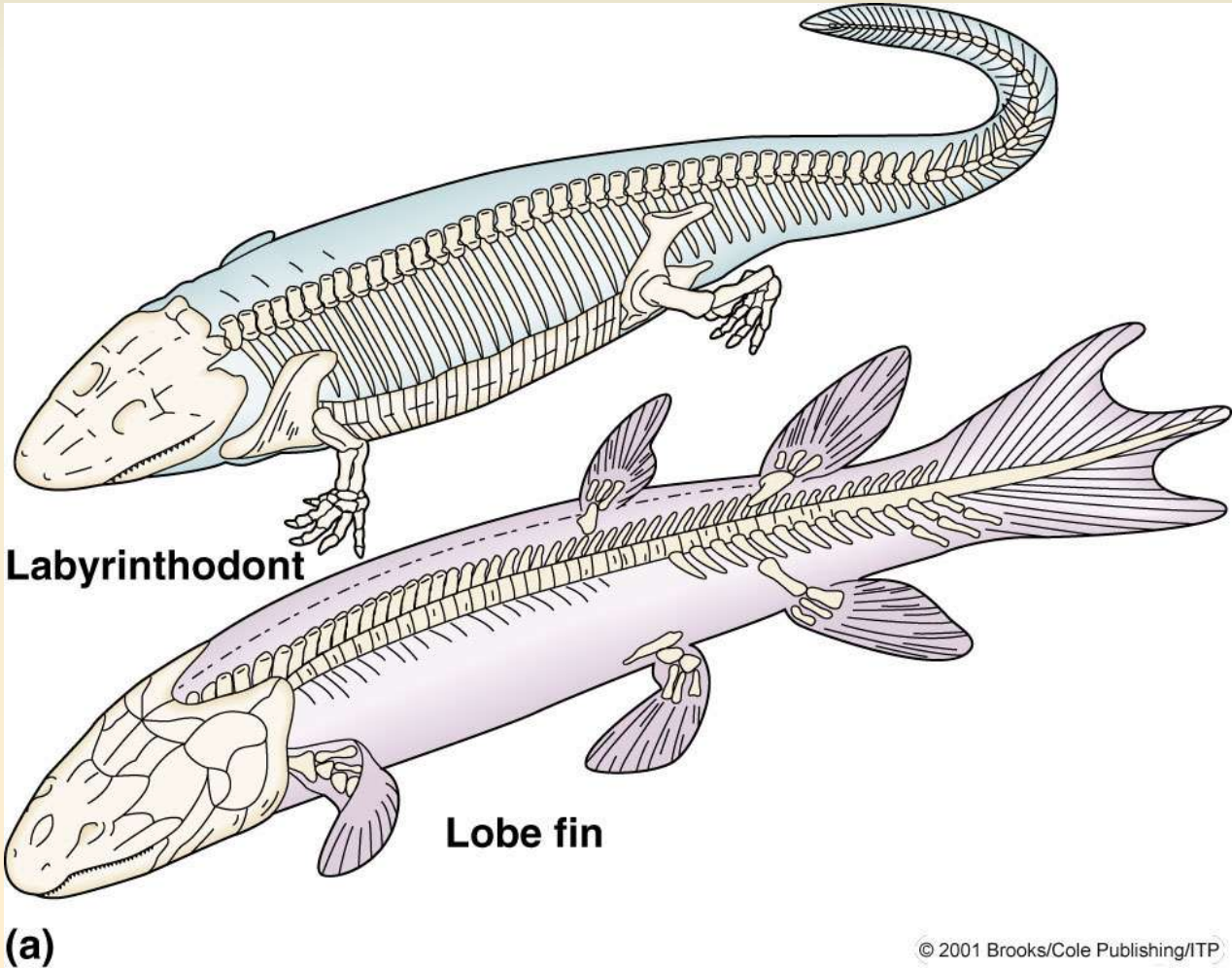
# Rhipidistian Crossopterygian and *Eusthenopteron*



# Fish/Amphibian Comparison

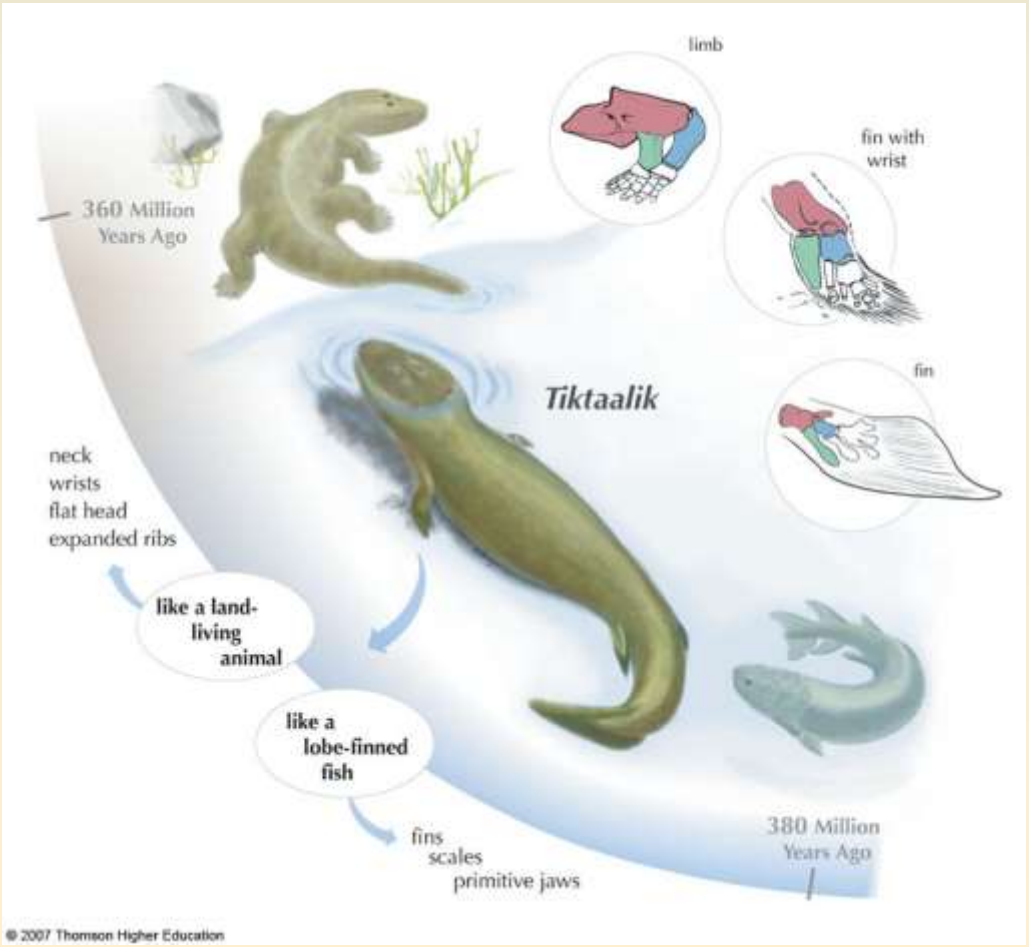
- Similarities between the crossopterygian lobe-finned fish and the labyrinthodont amphibians

- Their skeletons were similar



# *Tiktaalik roseae*

- Diagram illustrating how *Tiktaalik roseae* is a transitional species between lobe-finned fish and tetrapods

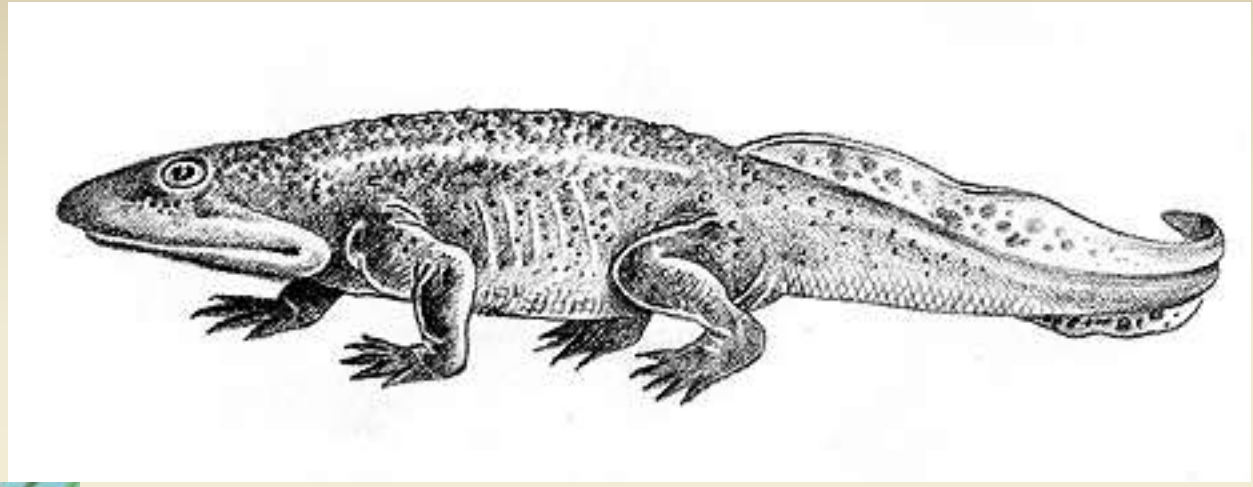


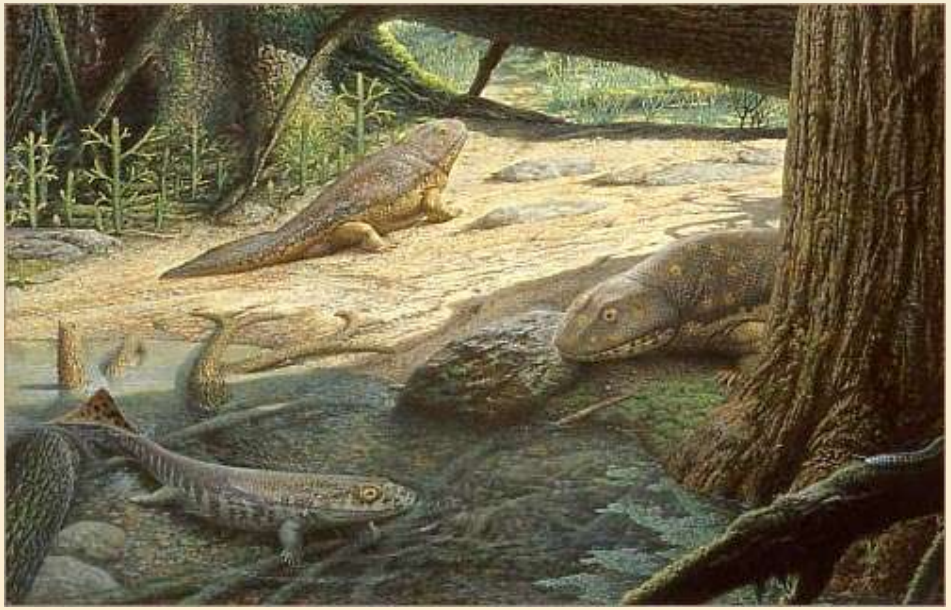
# Rapid Adaptive Radiation

- The Late Paleozoic amphibians
  - did not all resemble the familiar
    - frogs, toads, newts and salamanders
  - that make up the modern amphibian fauna
- Rather they displayed a broad spectrum of sizes, shapes, and modes of life

# Devonian

Ichthyostega

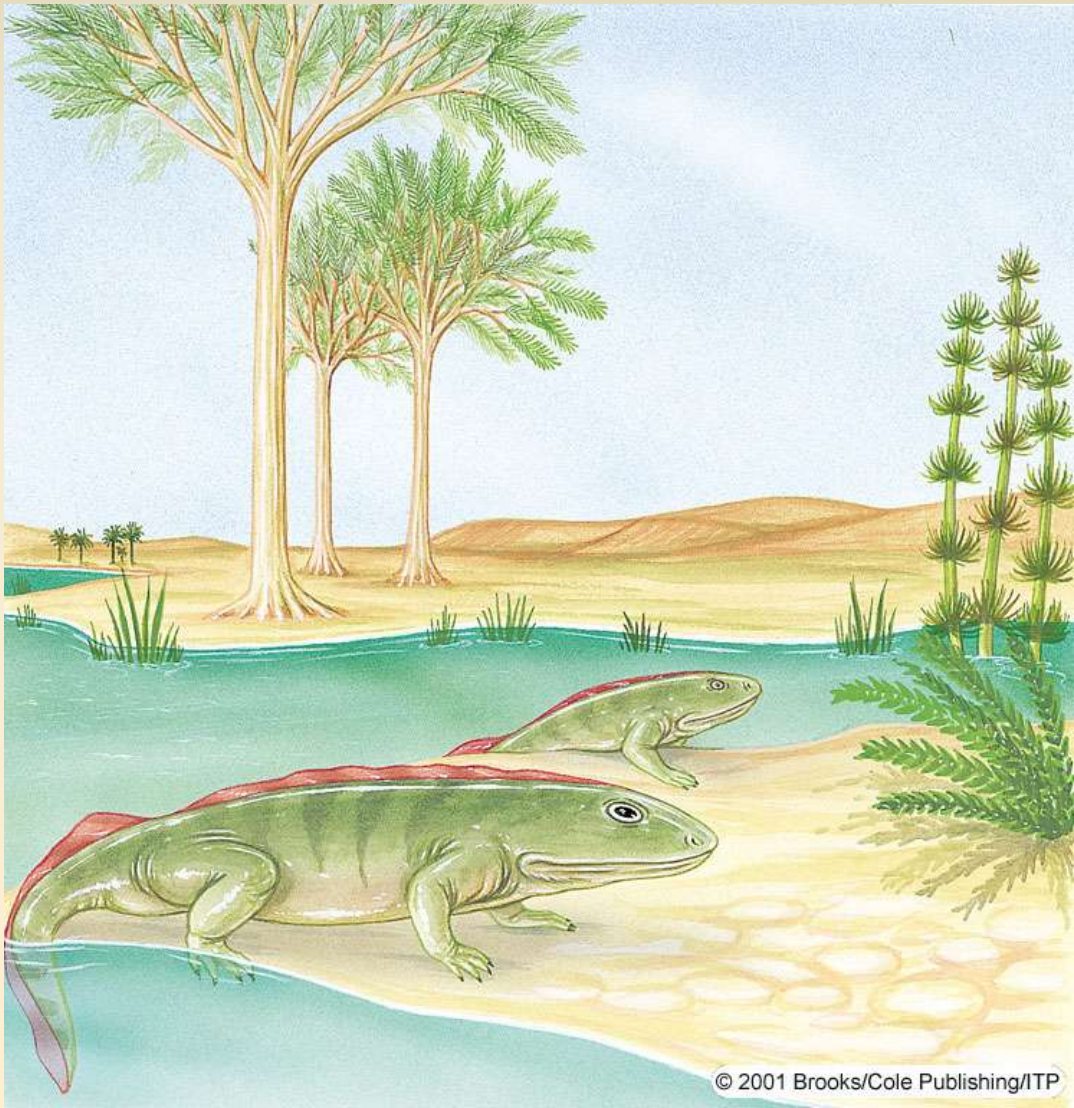




# A Late Devonian Landscape

- A Late Devonian Landscape in Eastern Greenland

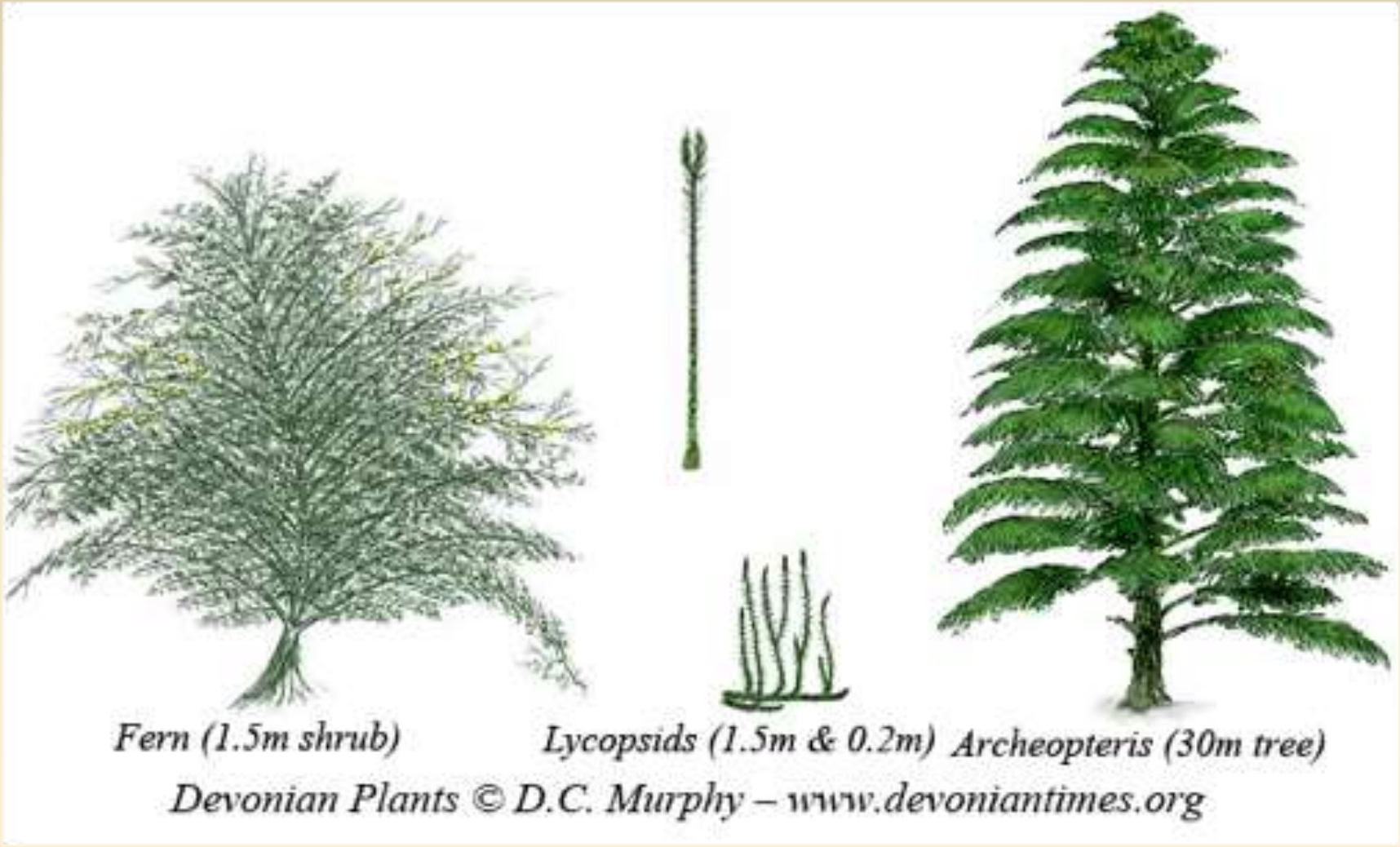
- *Ichthyostega* was an amphibian that grew to a length of about 1 m
- The flora was diverse,
  - consisting of a variety of small and large seedless vascular plants



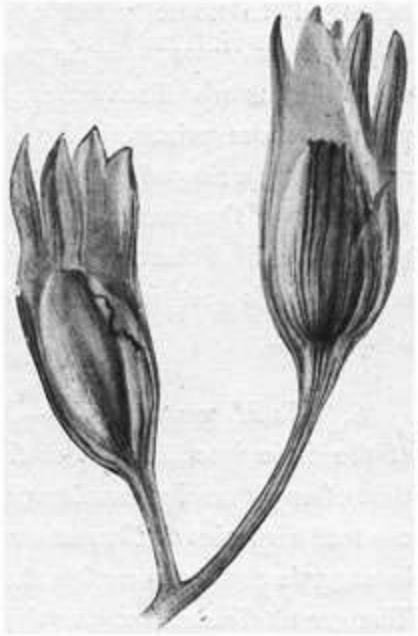
# Plants

- Lycopods
  - Club mosses
  - Early and Middle Devonian evolution
  - become very large in Carboniferous

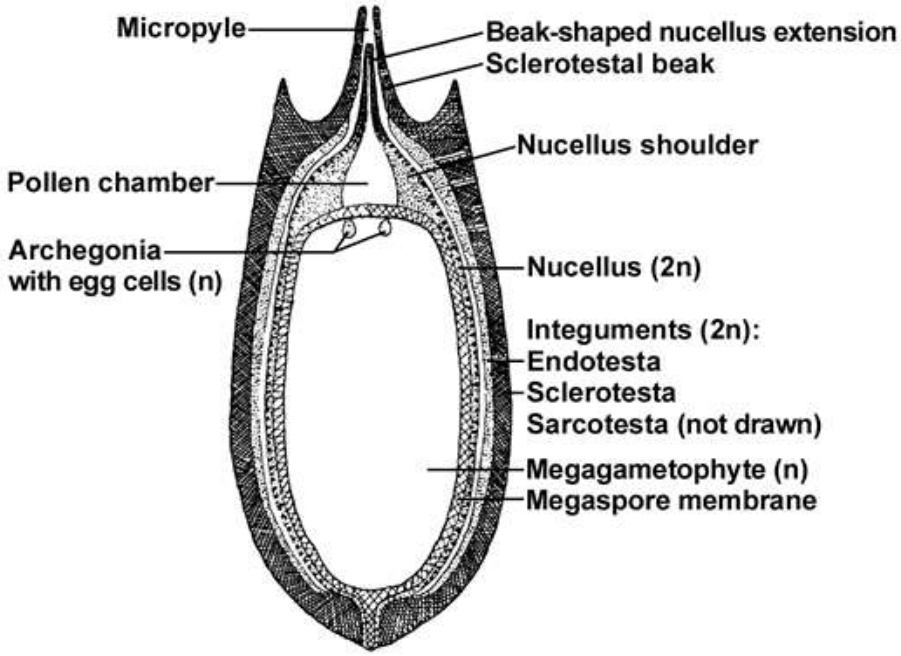
# Late Devonian Plants



# “Seed Ferns”

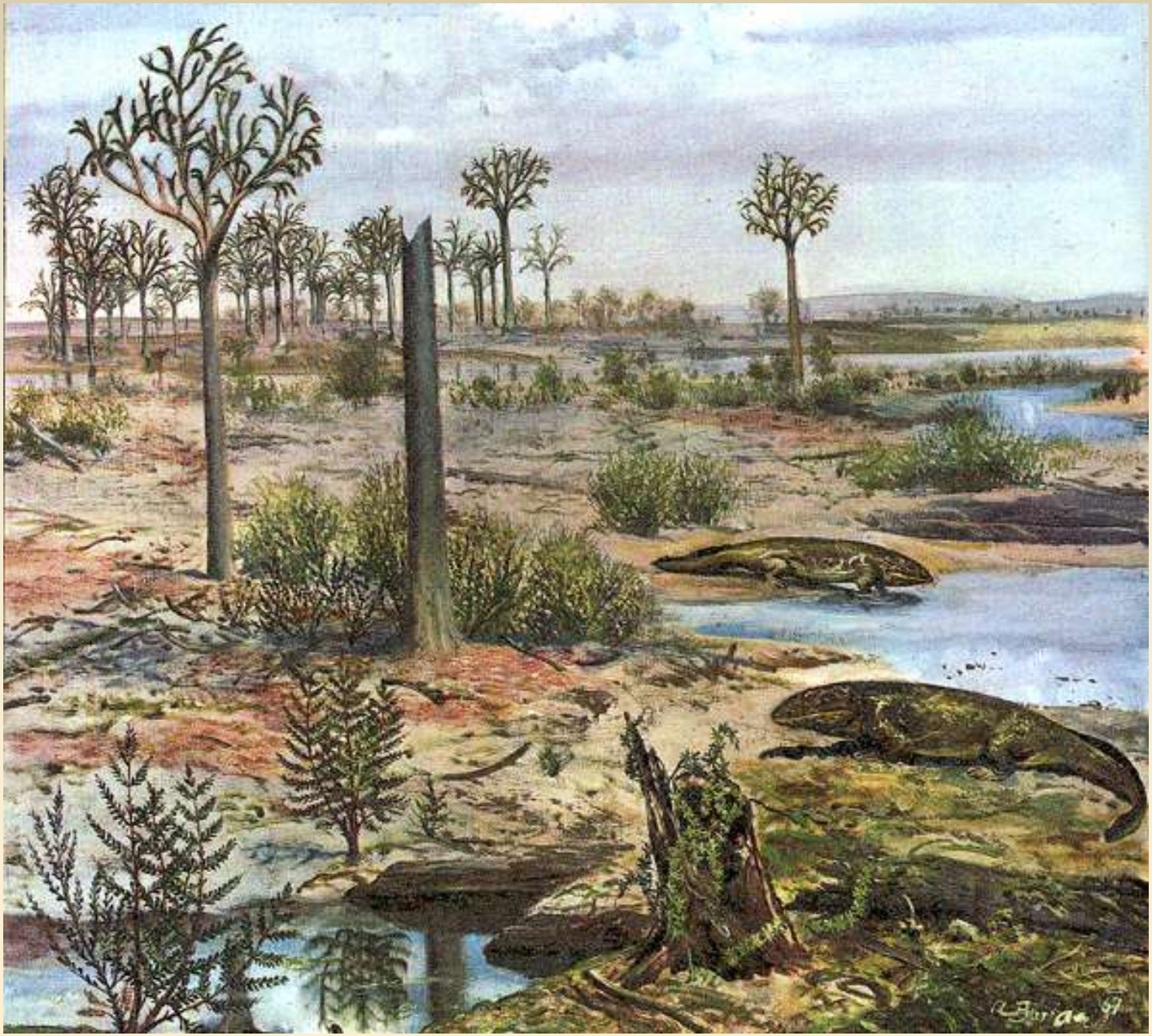



Late Devonian Lyginopterid-type seed fern ovules (*Lagenostoma*) After Arber, from Scott (1909) Studies in Fossil Botany, Vol. II, Adam and Charles Black, London

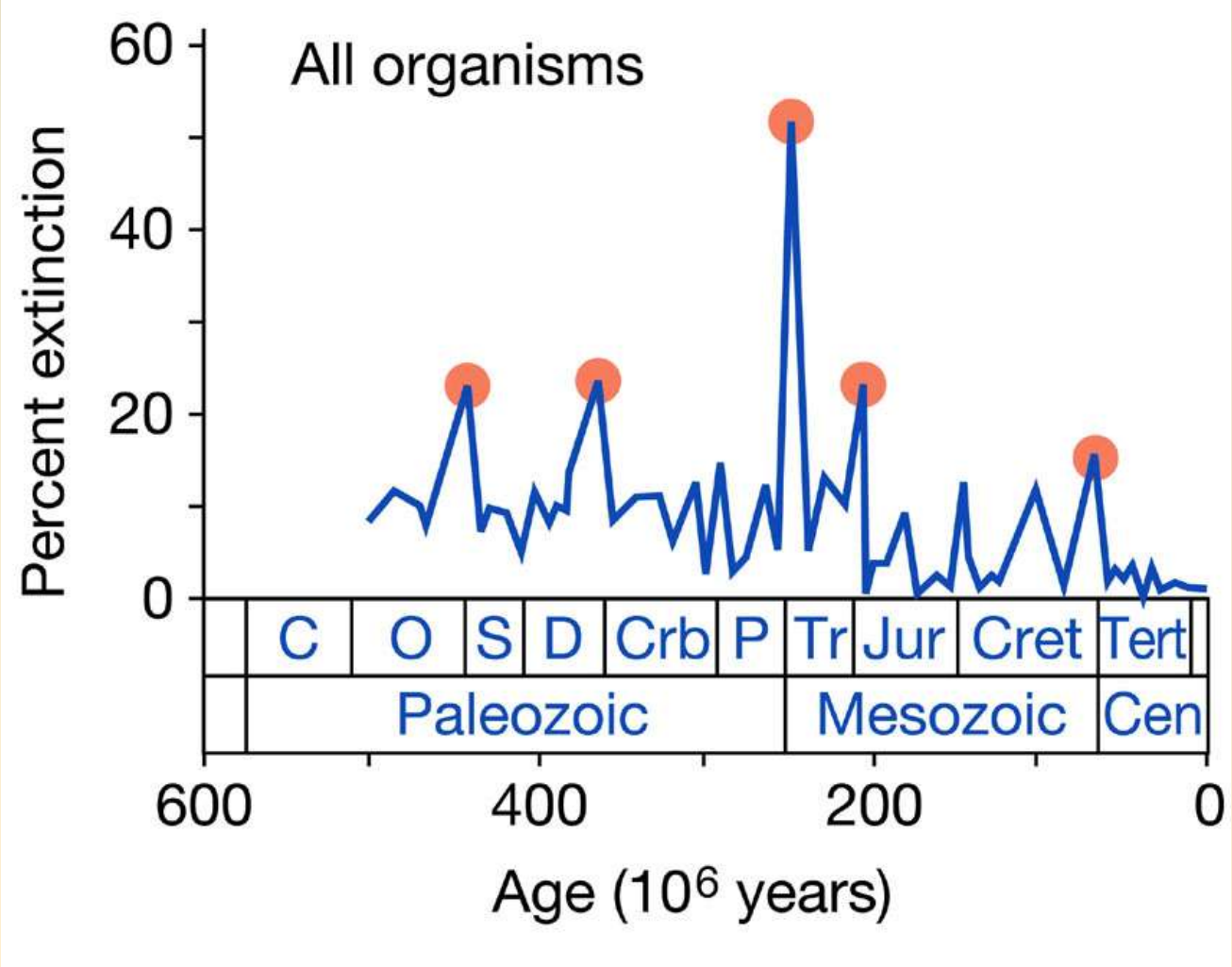



*Stephanospermum akenioides* - fossil seed of a “medullosan seed fern” (Permian-Carboniferous Lyginopteridopsida; ca. 1 cm long). Drawing of Oliver and Salisbury (1911) from K. Schnarf (1937), Anatomie der Gymnospermen-Samen, Verlag von Gebrüder Borntraeger, Berlin.

# 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, and reefs took a hammering, not returning to their former glory until new types of coral evolved over 100 million years later. In fact, much of the sea bed became devoid of oxygen, rendering it effectively out of bounds for anything except bacteria.

# Carboniferous

# Carboniferous
## (354 - 290 million years ago)

- Subdivided into the Mississippian and Pennsylvanian.
- Lots of swamps and coal formation.
- First reptiles.
  - Major biological revolution - <u>the hard shelled egg!</u>

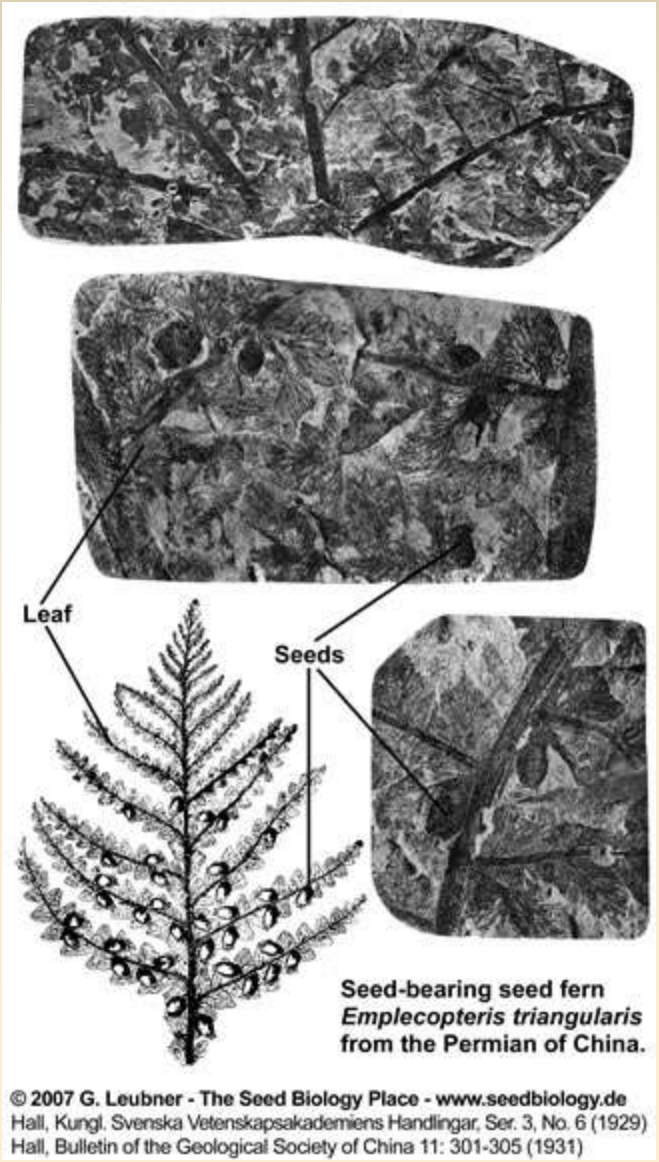
# Seedless Vascular Plants

- Vascular tissue improves sporophyte efficiency
- Dominant plants from late Devonian through early Permian
  - Equatorial coal forests

Carboniferous Forest – 300 mya (Field Museum)

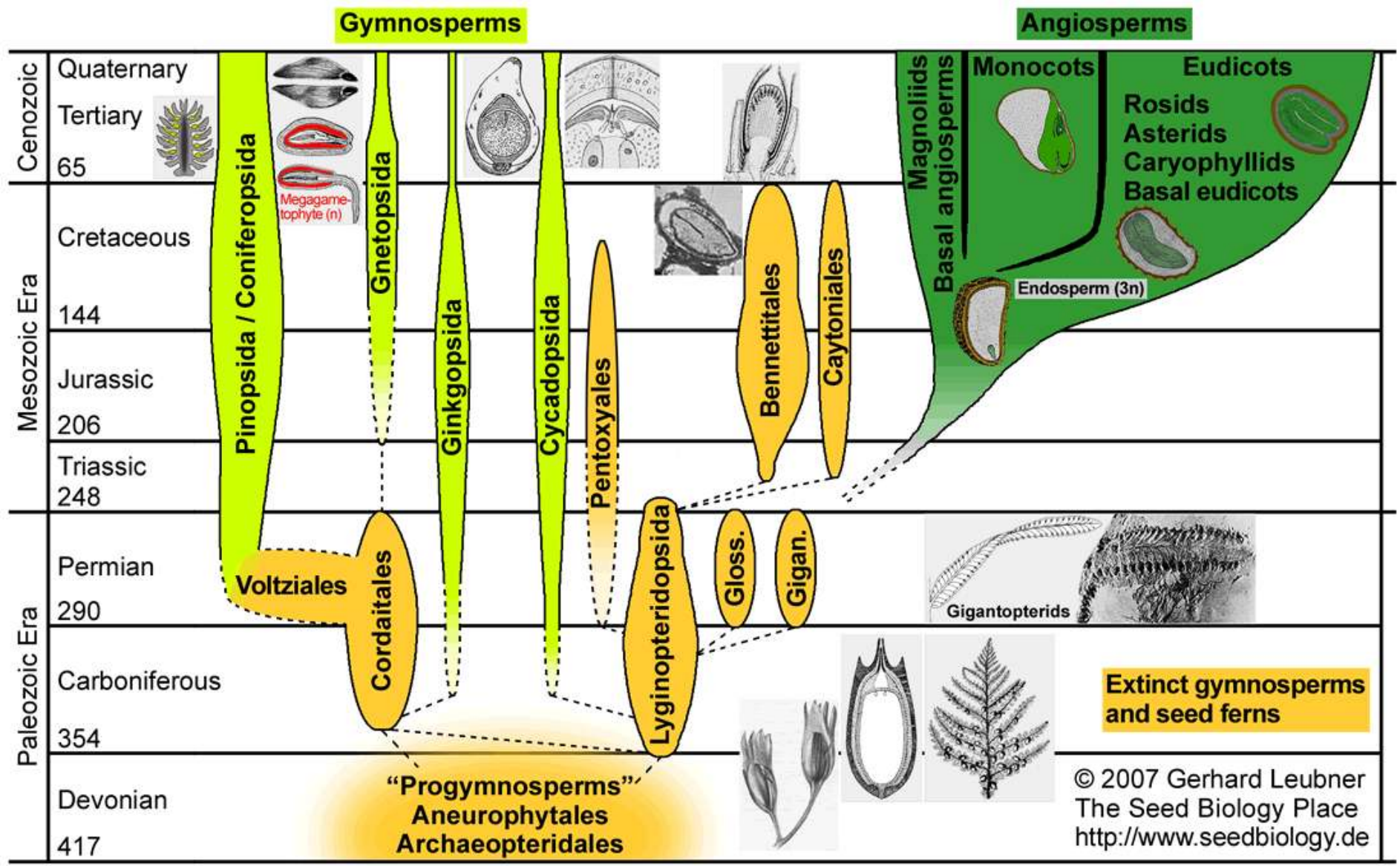
# Carboniferous Forest – 359 – 299 mya

# “Seed Ferns”





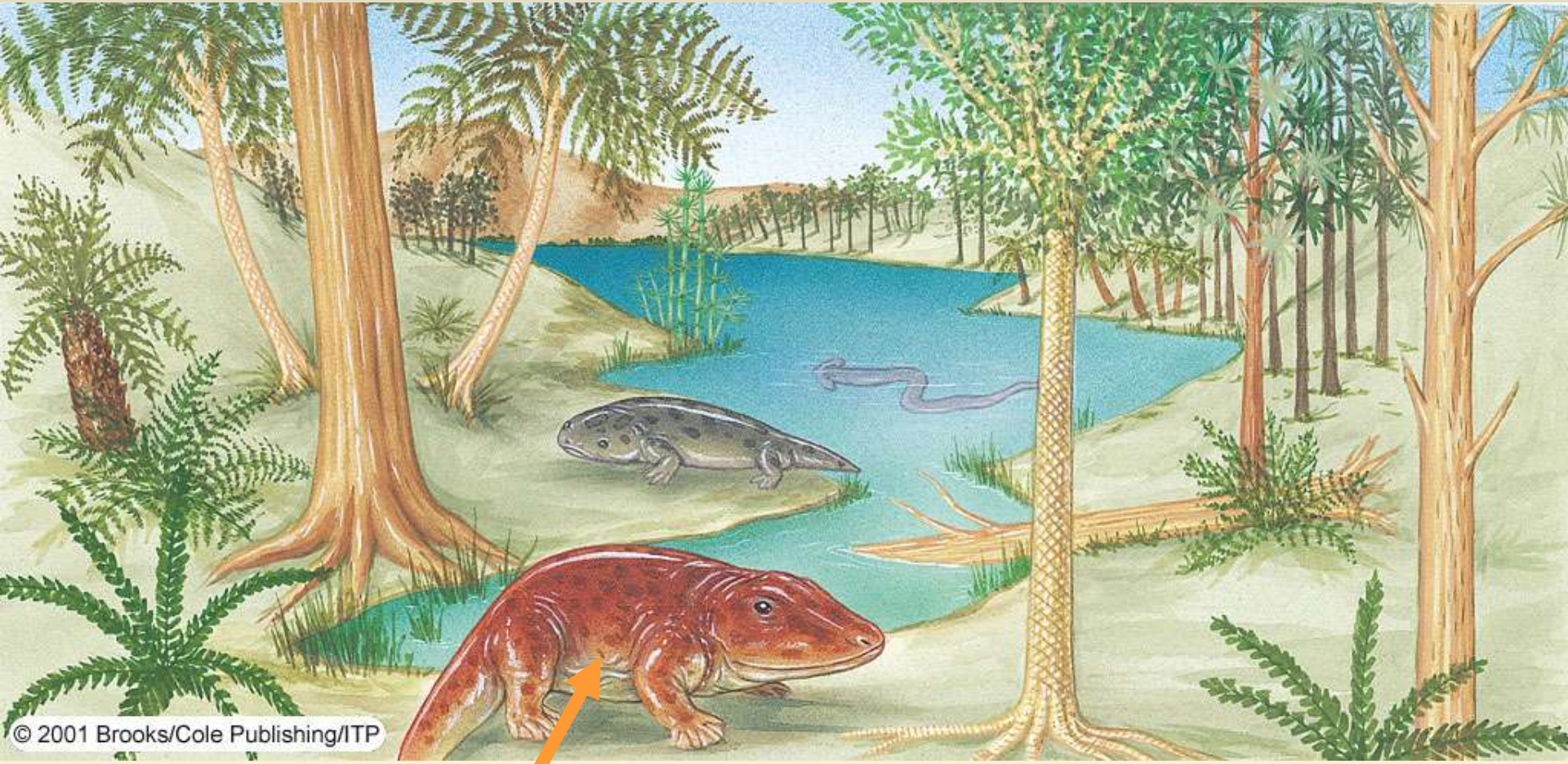
Hall, Kungl. Svenska Vetenskapsakademiens Handlingar, Ser. 3, No. 6 (1929)
Hall, Bulletin of the Geological Society of China 11: 301-305 (1931)




Seed plant phylogenetic tree considering major gymnosperm and angiosperm clades. Note that the precise evolutionary connections between the different gymnosperm groups are unknown and that the ancestors of angiosperms are unknown. Typical seed types visualize steps in the evolution of the seed. Extinct gymnosperm groups (fossils): Lyginopteridopsida (seed ferns, "Samenfarne", includes Devonian/Carboniferous Lyginopterids and Carboniferous/ Permian Medullosans and other subgroups), Cordaitales, Voltziales, Pentoxylales. Bennettitales (cycadeoids), Caytoniales, Glossopteridales (glossopterids), Gigantopteridales (gigantoperids). Extant gymnosperm groups: Pinopsida/Coniferopsida (conifers, "Nadelbäume"), Ginkgopsida (ginkgos), Cycadopsida (cycads, "Palmfarne"), Gnetopsida (gnetophytes: Ephedridae, Gnetidae, Welwitschiidae). Angiosperms (flowering plants): Most important groups depicted. Time scale: Geological eras, periods, time in MYBP (million years before present). 

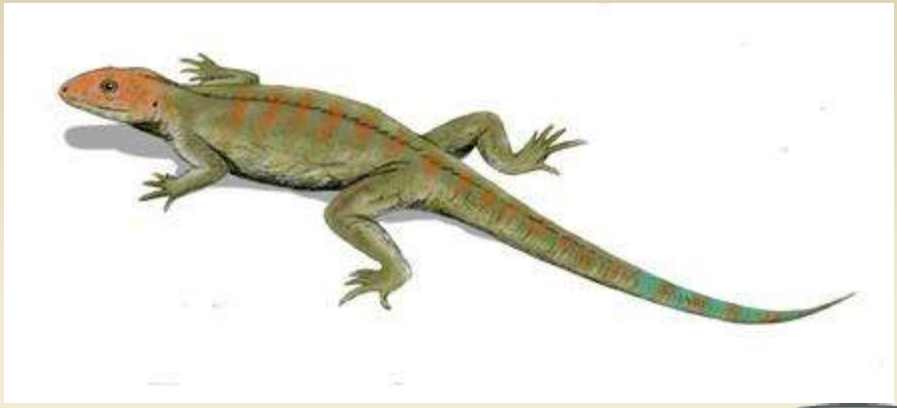
# Carboniferous Coal Swamp

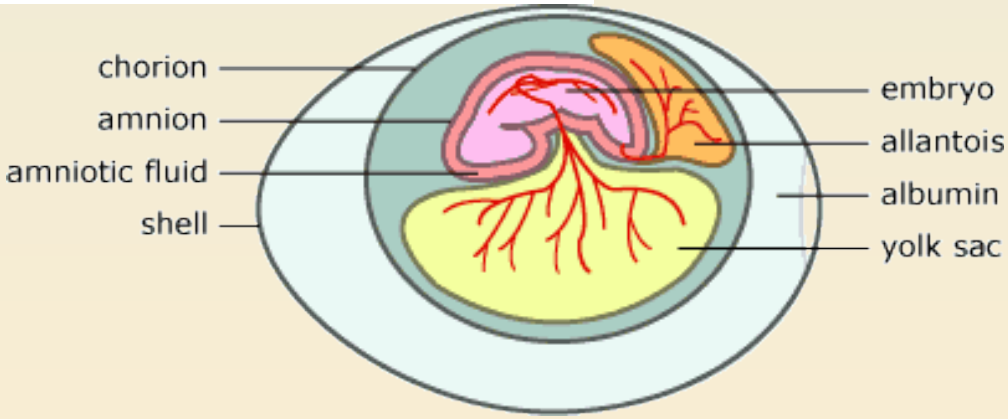
- Reconstruction of a Carboniferous coal swamp




Large labyrinthodont amphibian *Eryops*

# Amniote Egg

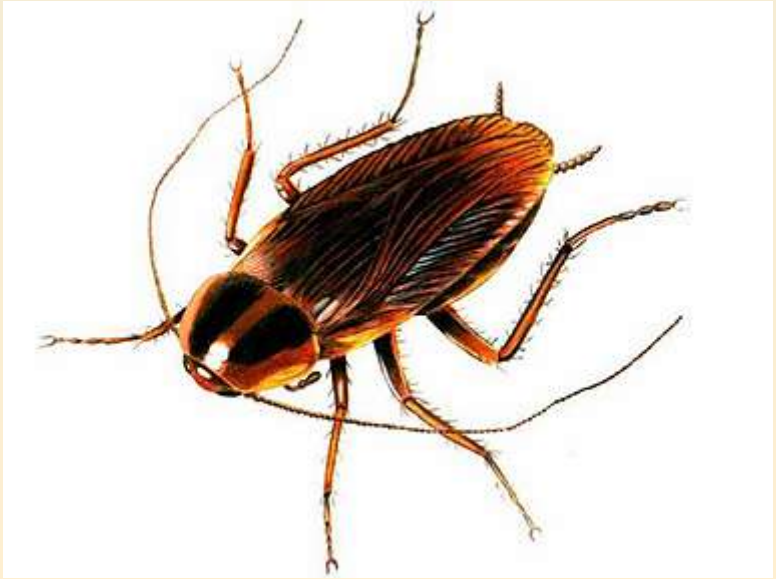





The earliest uncovered examples of Amniotes bear a superficial resemblance to insectivorous terrestrial lizards. These include fossil species like *Hylonomus* and *Paleothyris*. They have slender bodies that run a length of about 20 centimeters from nose to tail-tip. They shared their world with a wide range of small to giant primitive amphibians that together made up the bulk of vertebrate terrestrial life on earth

# Carboniferous & Permian

-winged insects

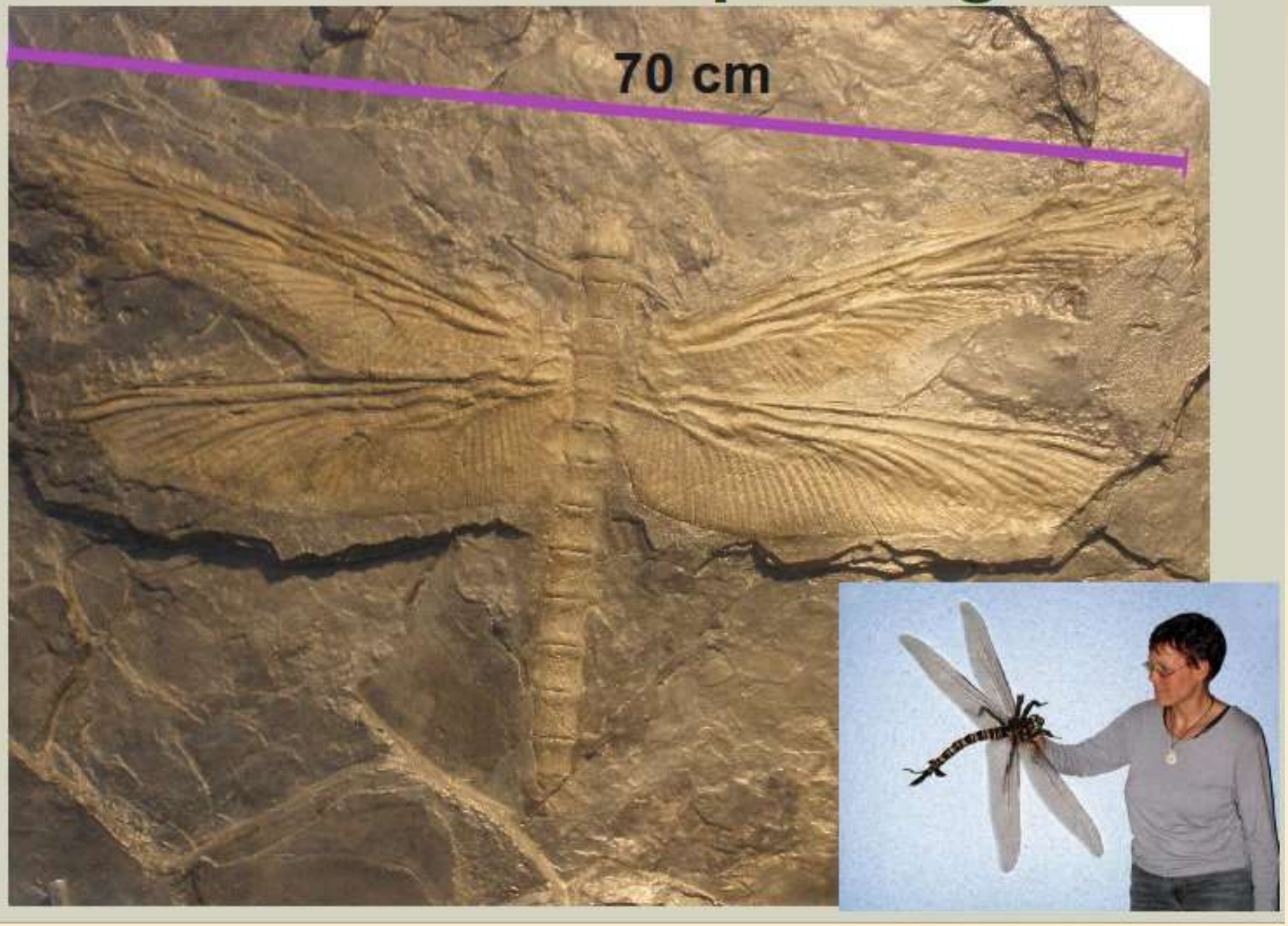


# Insects

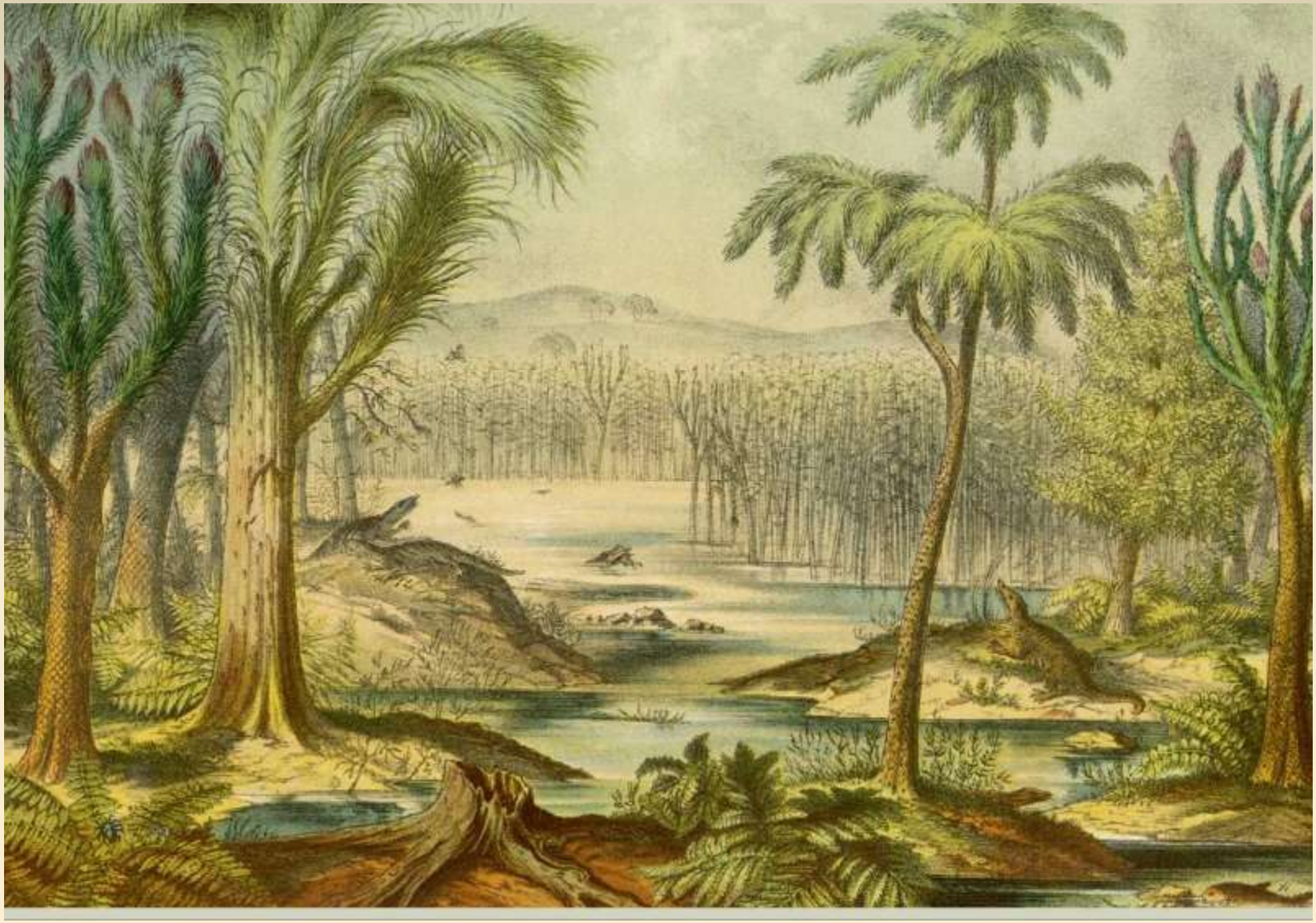
*Delitzschala bitterfeldensis*
Lower Carboniferous

*Homoioptera vorhallensis*
Mid Carboniferous

# Carboniferous Arthropod Gigantism



# Carboniferous



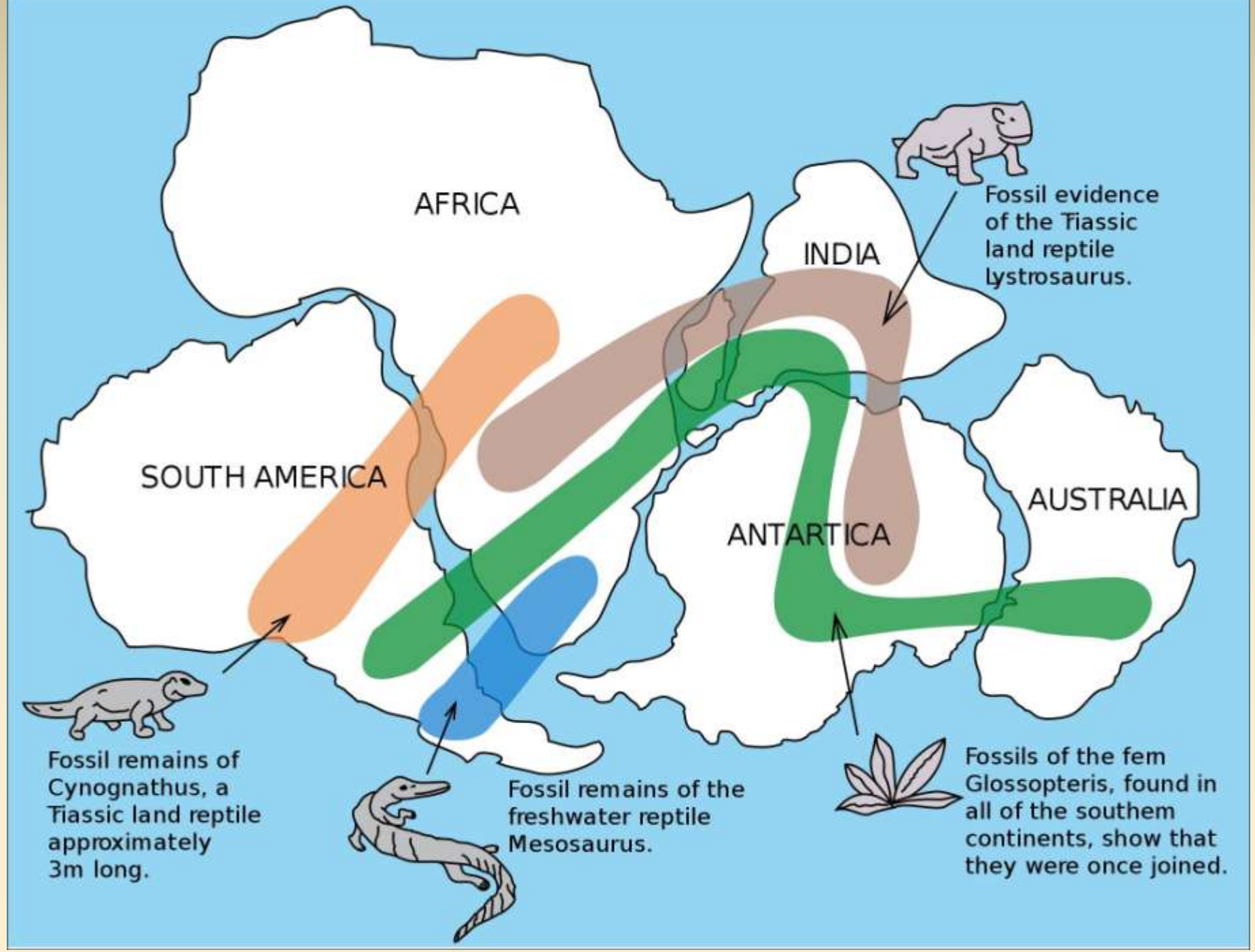
# Permian

# Permian

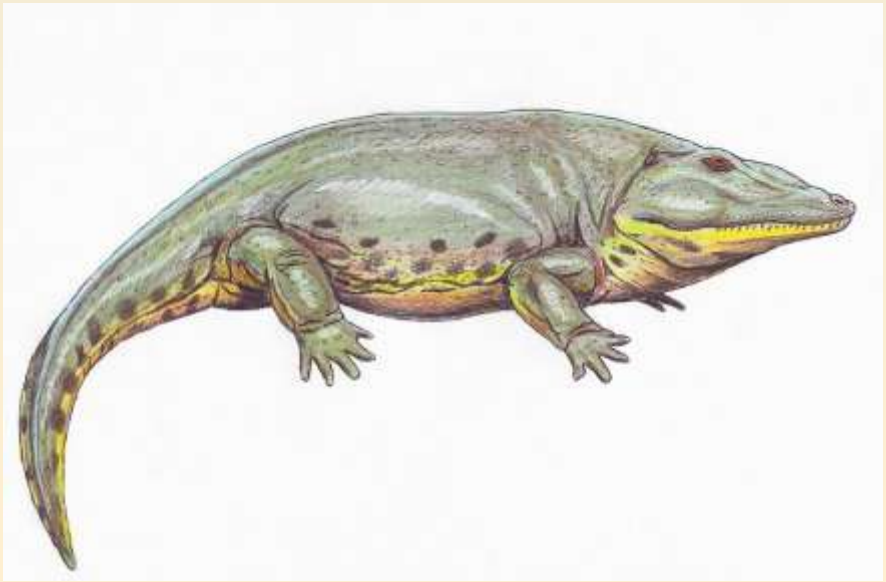
(290 - 245 million years ago)

- Last period of the Paleozoic
- Major diversification of marine fauna
- Ends with the largest mass extinction in the history of the planet
  - Mostly affected the animals in the oceans
  - 90% marine species disappeared
  - caused by volcanic eruptions? Large quantity of gas poisoned the environment

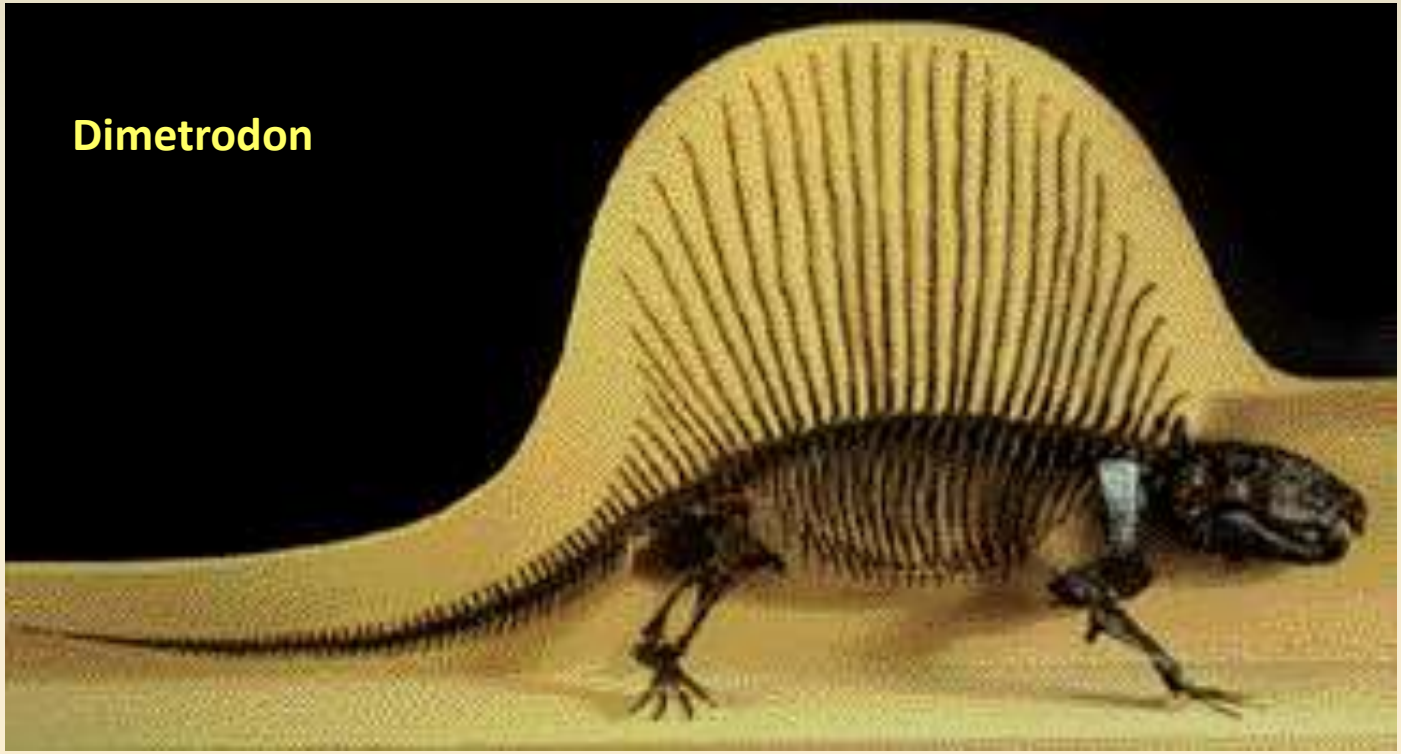
- Continents fused together – “Pangaea”


AFRICA
INDIA
Fossil evidence of the Tiassic land reptile lystrosaurus.
SOUTH AMERICA
AUSTRALIA
ANTARTICA
Fossil remains of Cynognathus, a Tiassic land reptile approximately 3m long.
Fossil remains of the freshwater reptile Mesosaurus.
Fossils of the fem Glossopteris, found in all of the southem continents, show that they were once joined.

Wide variety of amphibians
Large carnivorous *Eryops*



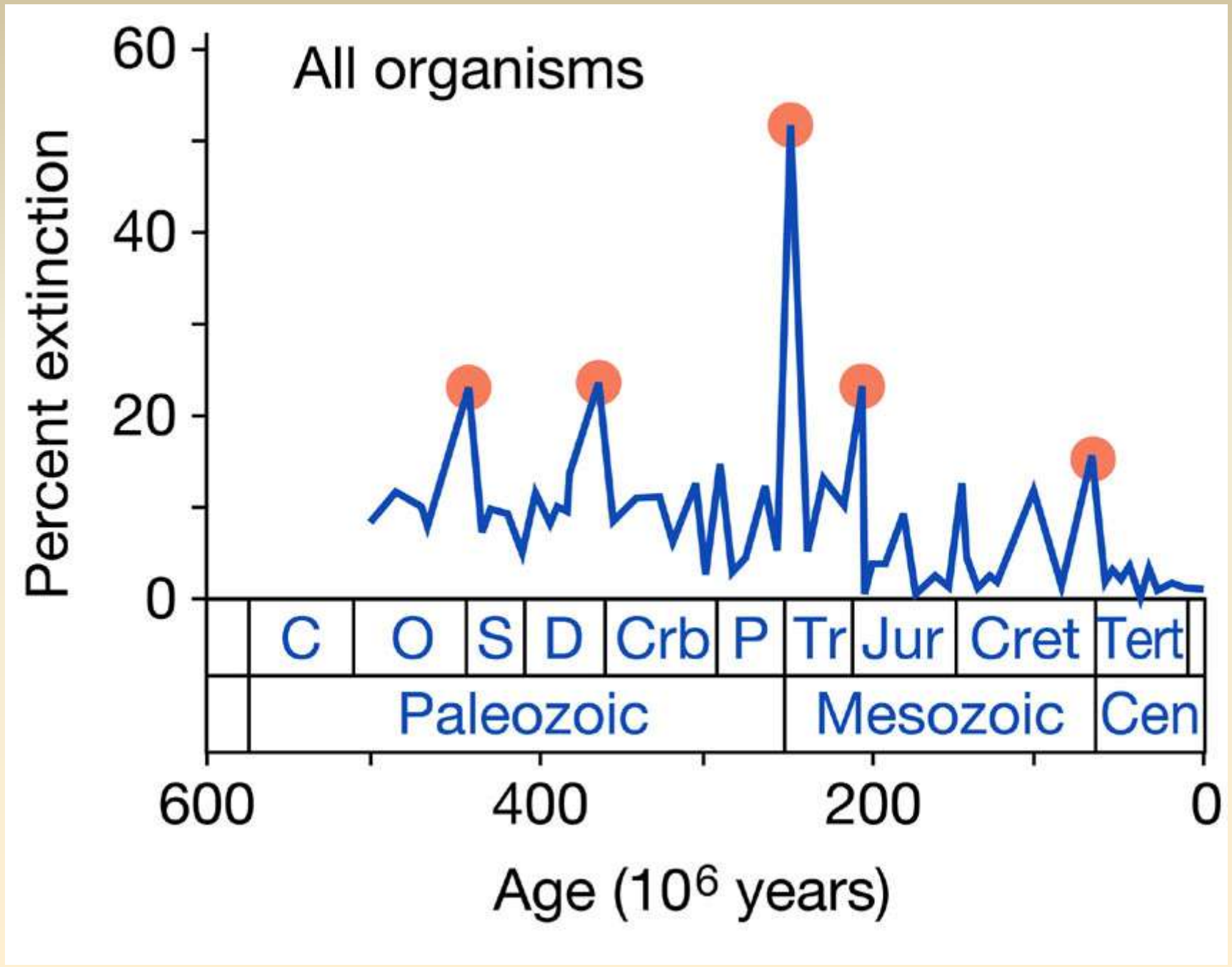
# Permian Reptile Fossils



# Permian Mammal-like Reptiles


# End of the Paleozoic

- 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 =


All organisms
Percent extinction
60
40
20
0
C
O
S
D
Crb
P
Tr
Jur
Cret
Tert
Paleozoic
Mesozoic
Cen
600
400
200
0
Age (10⁶ years)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End