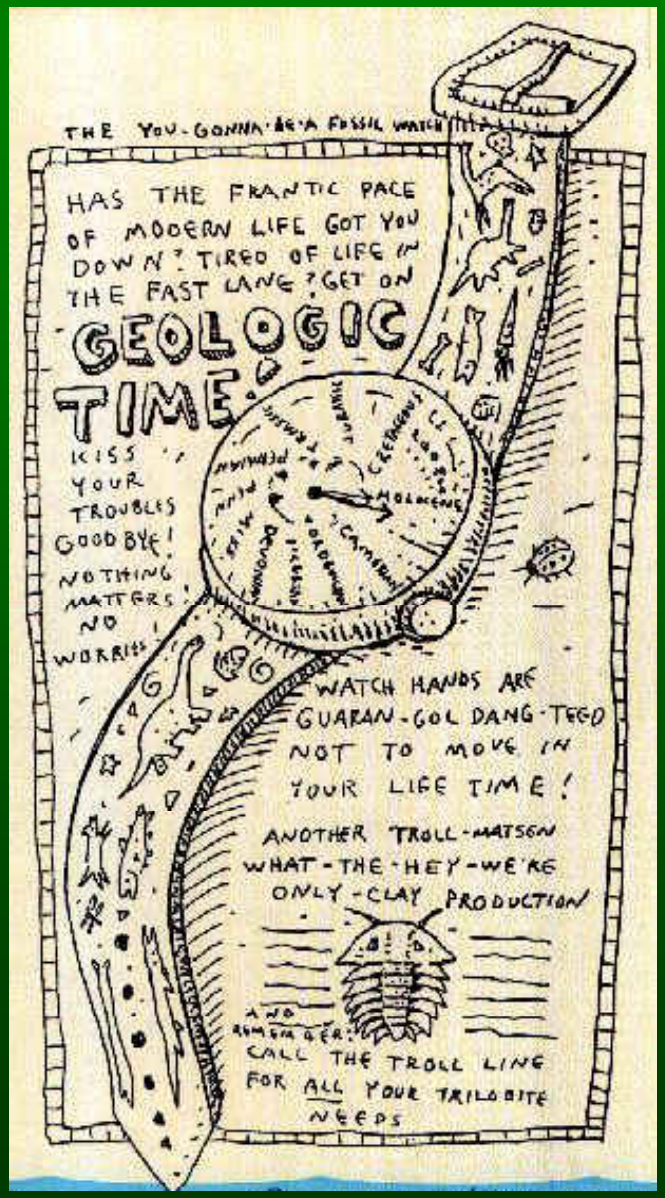
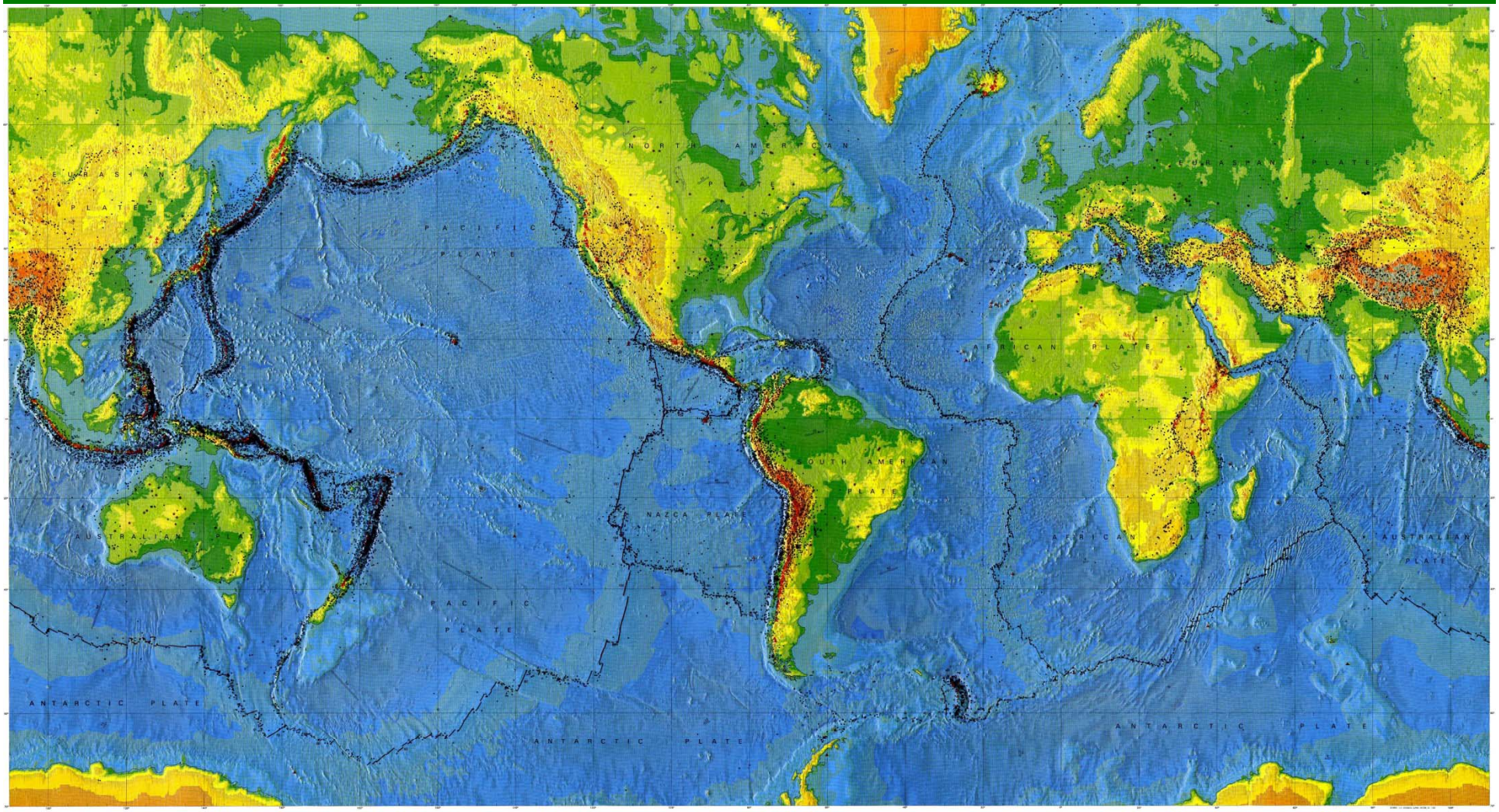
Earth History & the Fossil Record

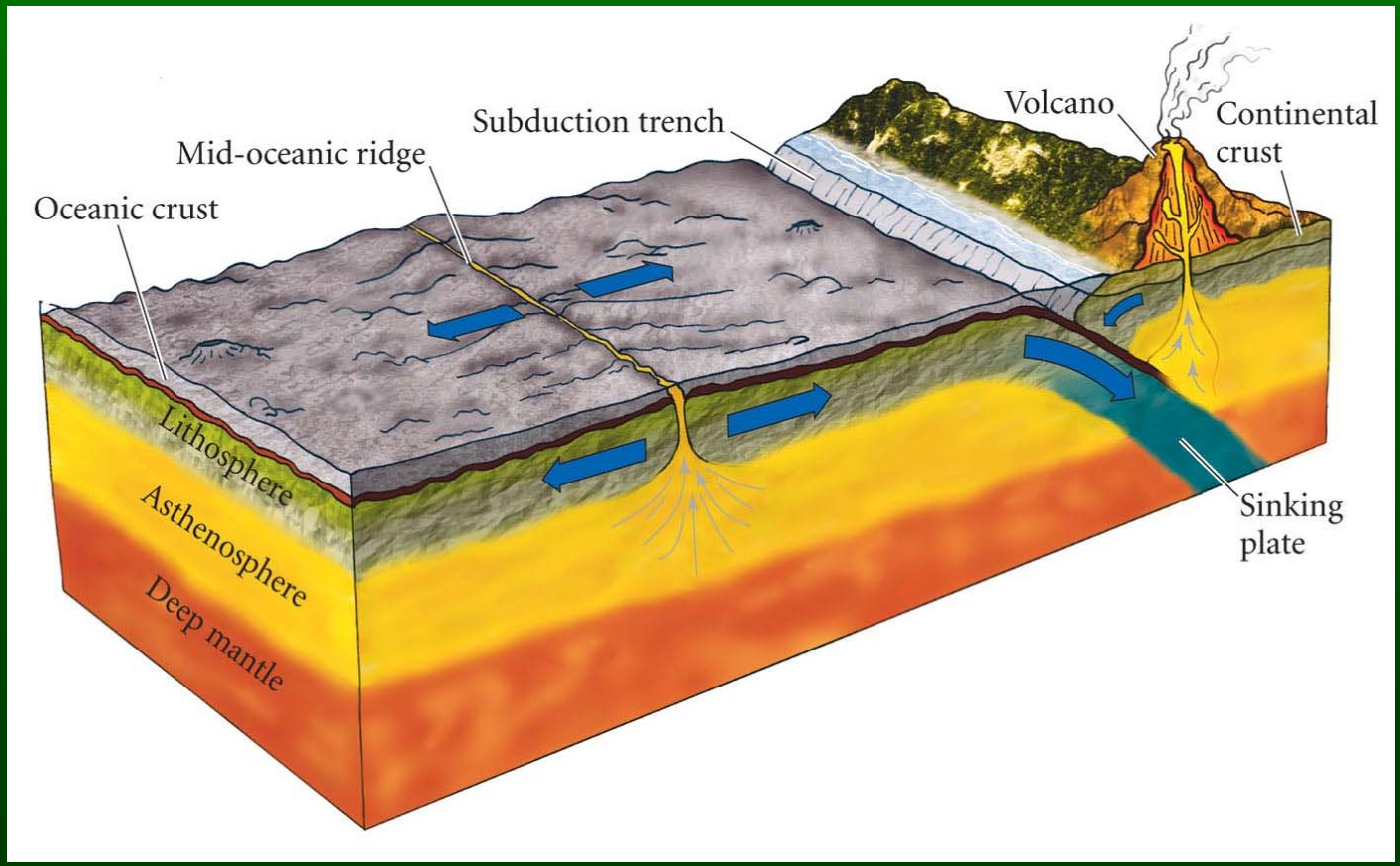


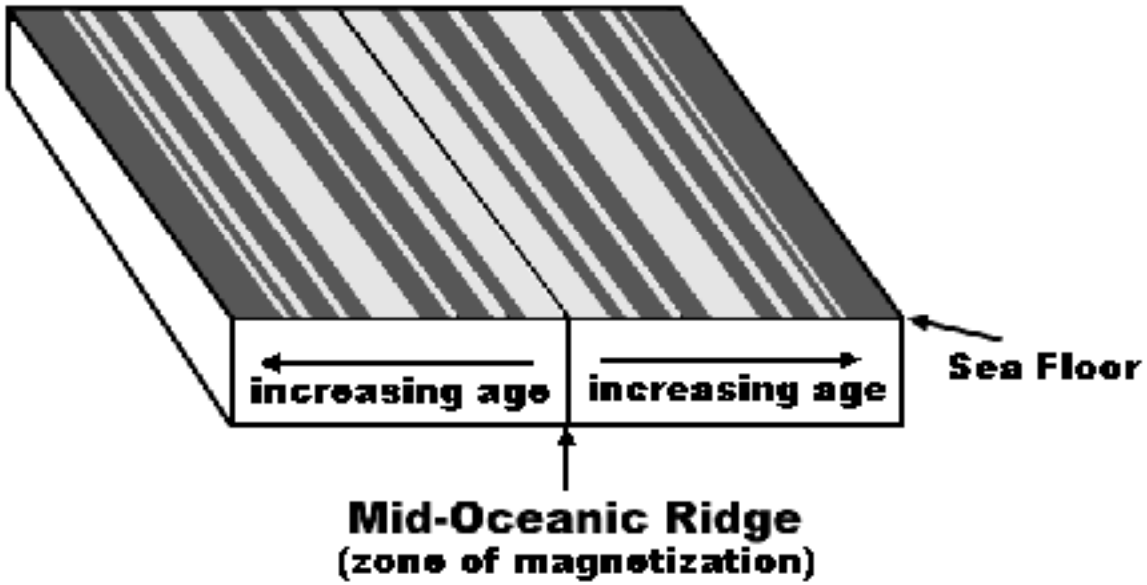
The Dynamic Earth



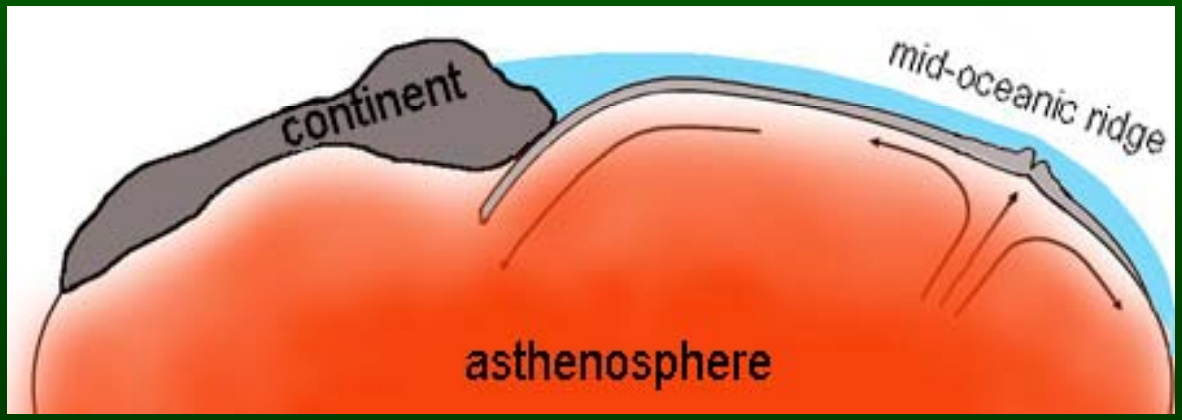
Earth's Dynamic Geology

- Earth is approx. 4.6 billion years old
- Since its formation, the surface has been unstable
- Crust and Core rotate as slightly different rates





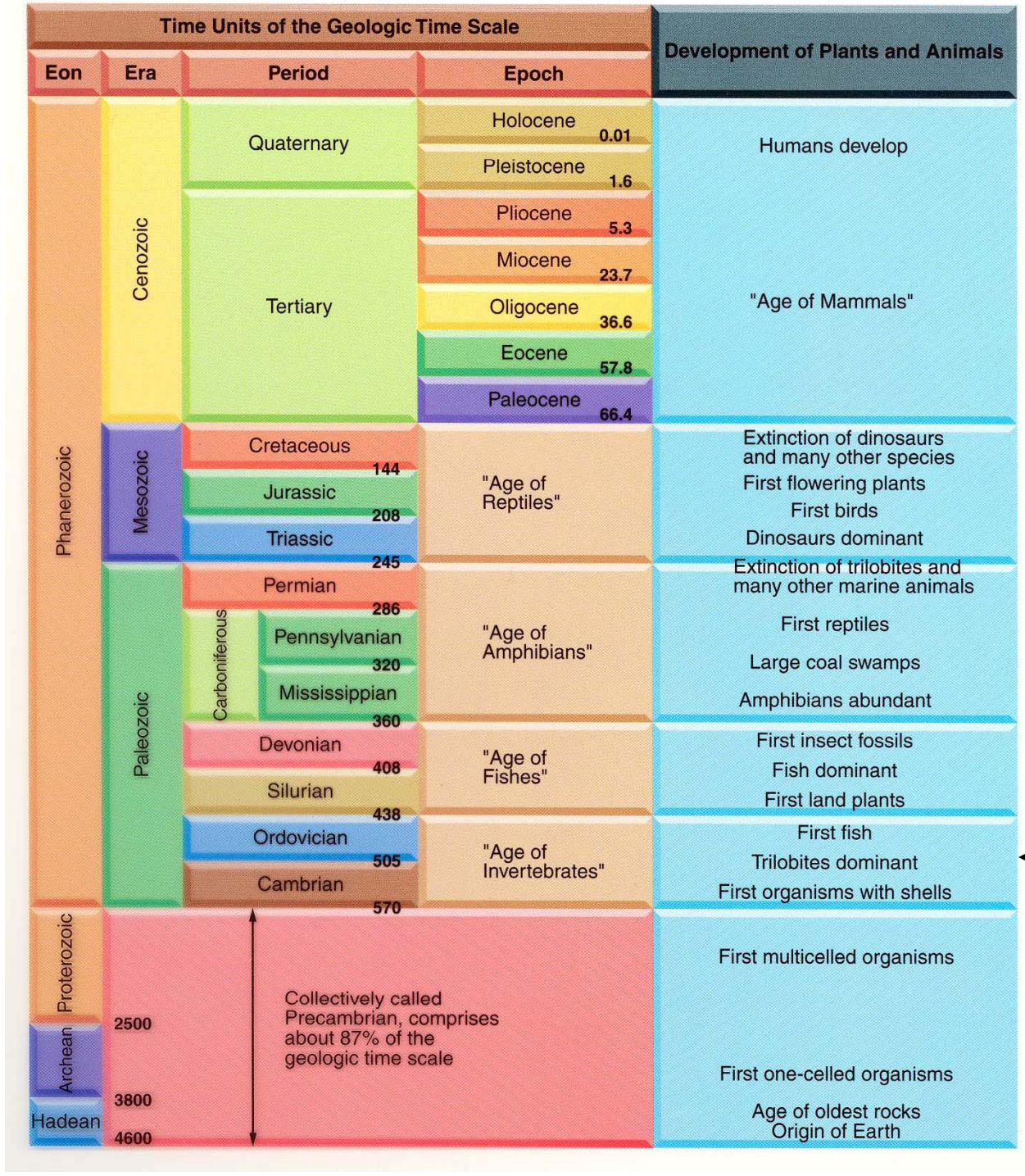
Why there are no old rocks on the bottom of the ocean.



20.1 Earth's Geological History

ERA	PERIOD	ONSET	MAJOR PHYSICAL CHANGES ON EARTH
Cenozoic	Quaternary	1.8 mya	Cold/dry climate; repeated glaciations
	Tertiary	65 mya	Continents near current positions; climate cools
Mesozoic	Cretaceous	144 mya	Northern continents attached; Gondwana begins to drift apart; meteorite strikes Yucatán Peninsula
	Jurassic	206 mya	Two large continents form: Laurasia (north) and Gondwana (south); climate warm
	Triassic	245 mya	Pangaea slowly begins to drift apart; hot/humid climate
Paleozoic	Permian	290 mya	Continents aggregate into Pangaea; large glaciers form; dry climates form in interior of Pangaea
	Carboniferous	354 mya	Climate cools; marked latitudinal climate gradients
	Devonian	409 mya	Continents collide at end of period; asteroid probably collides with Earth
	Silurian	440 mya	Sea levels rise; two large continents form; hot/humid climate
	Ordovician	510 mya	Gondwana moves over South Pole; massive glaciation, sea level drops 50 m
	Cambrian	543 mya	O_2 levels approach current levels
Precambrian		600 mya	O_2 level at >5% of current level
		2.5 bya	O_2 level at >1% of current level
		3.8 bya	O_2 first appears in atmosphere
		4.5 bya	

Geologic Time Scale



“Moss Animals”

← Newest Animal Phylum: Bryozoans

Precambrian
“Age of the Prokaryotes”

Earth's Age is Almost Inconceivable

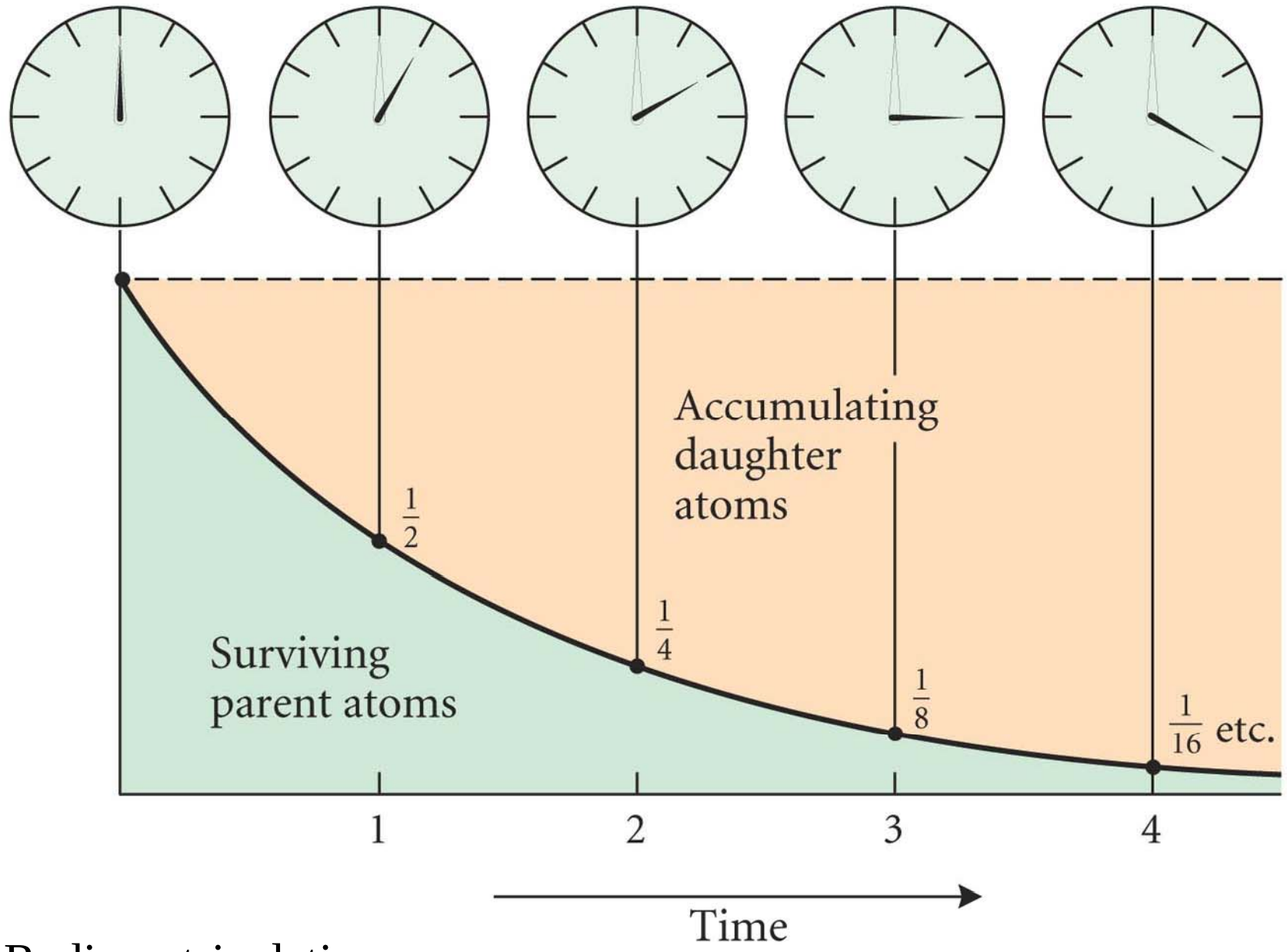
- If all of earth's history were compressed into one year:
  - Life appears in February around Valentine's day.
  - Prokaryotes rule from then till nearly Thanksgiving.
  - Dinosaurs go extinct and mammals diversify on Dec. 26.
  - Human and chimp lineages diverge at 11am on Dec. 31.
  - The Revolutionary War ends 1.5 seconds before year's end.

What does the Fossil Record tell us?

- Occurrence of phenotypic transformations
- Relative changes in diversity over time

How do we know the dates of ancient events?

- Relative time dating
- Radiometric dating



Radiometric dating

Rock types significant to the fossil record:

- Igneous
  - Formed from molten rock.
  - Not great for fossil recording.
- **Sedimentary**
  - Primarily formed from broken down rock or minerals (due to weathering and erosion processes) that form sediments in bodies of water.
  - Approx. 75% of exposed rock.
  - May contain fossils!
- Metamorphic
  - Alteration by high temperature and pressure.
  - Not good for fossil recording.

Principles of Stratigraphy

1. **Superposition –** younger rocks deposited on older rocks
2. **Original Horizontality –** lava and sedimentary rocks laid down flat
3. **Cross-cutting relationships –** dikes are younger than host rock
4. **Inclusions –** boulders & cobbles are older than host rock
5. **Faunal succession –** earlier fossils are *simpler* than recent forms.

Sedimentary rocks leave gaps

- Periods of no sedimentation: Hiatus
- Erosion of rock:
  - Unconformity has different horizontal plane.
  - Disconformity has same horizontal plane, therefore harder to see unless gaps are large.

Example of Stratigraphy

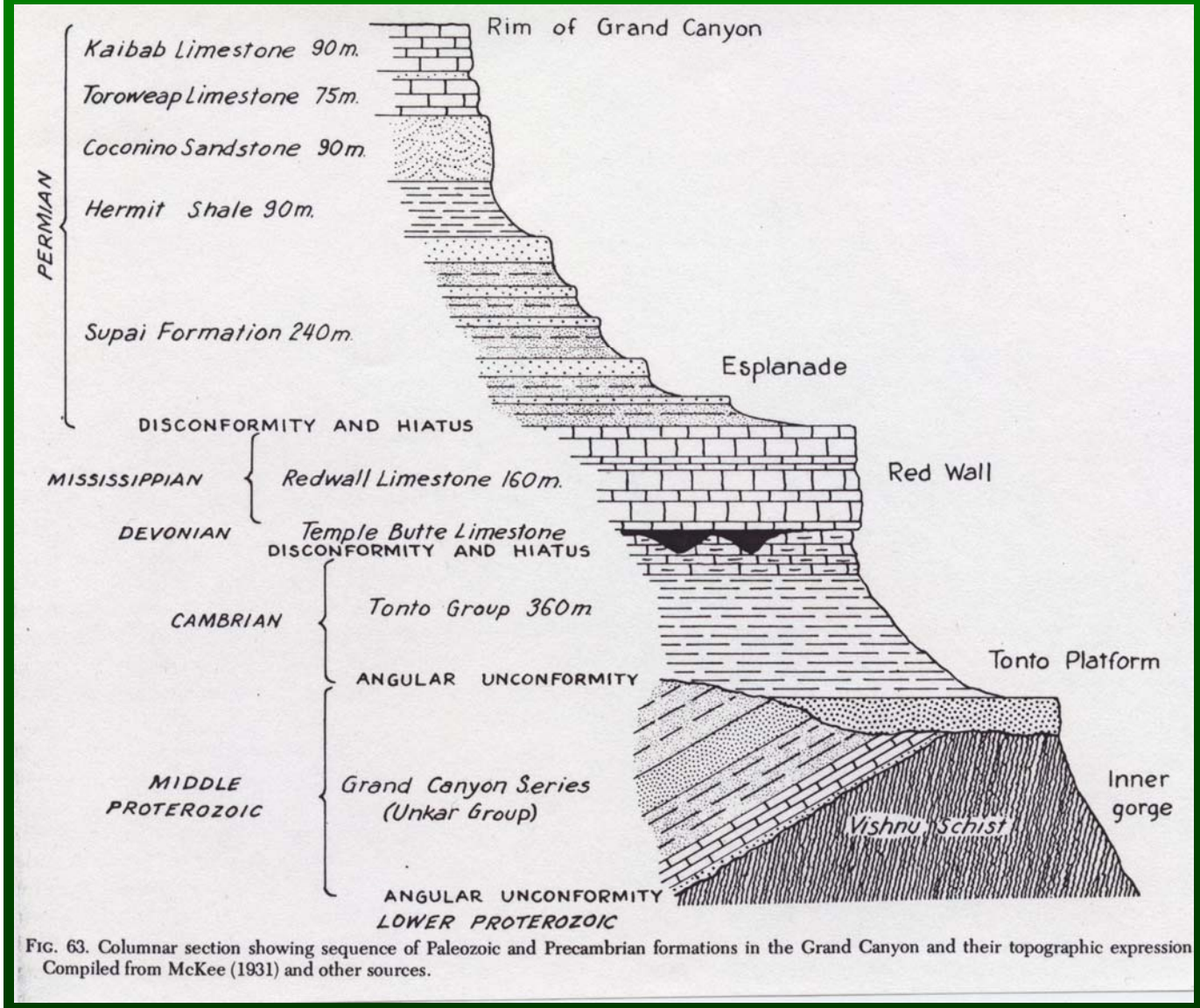


FIG. 63. Columnar section showing sequence of Paleozoic and Precambrian formations in the Grand Canyon and their topographic expression Compiled from McKee (1931) and other sources.

Marine fossils

Vertebrate tracks

Plants, reptiles

Marine fossils

Trilobites

No fossils

Sorting out the Fossil Record

- Types of Fossils
  - Compression & Impression fossils
  - Permineralization & Pertrification
  - Casts & Molds
  - Unaltered remains – mummy

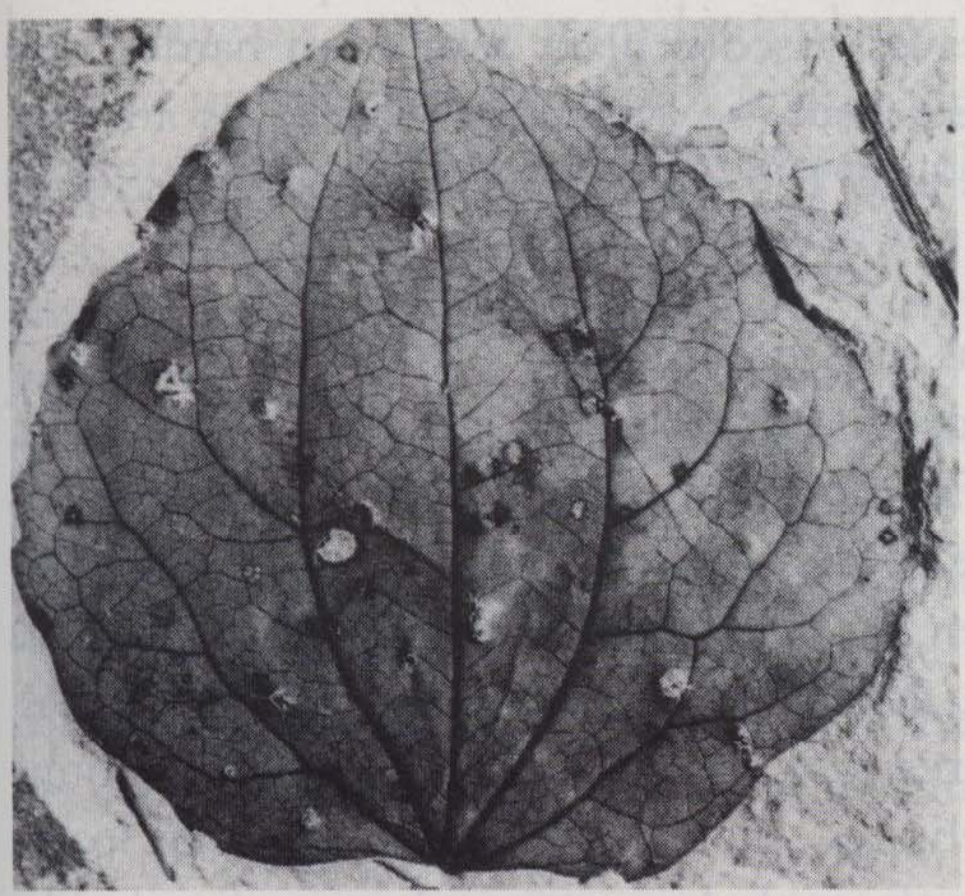
How do fossils form?

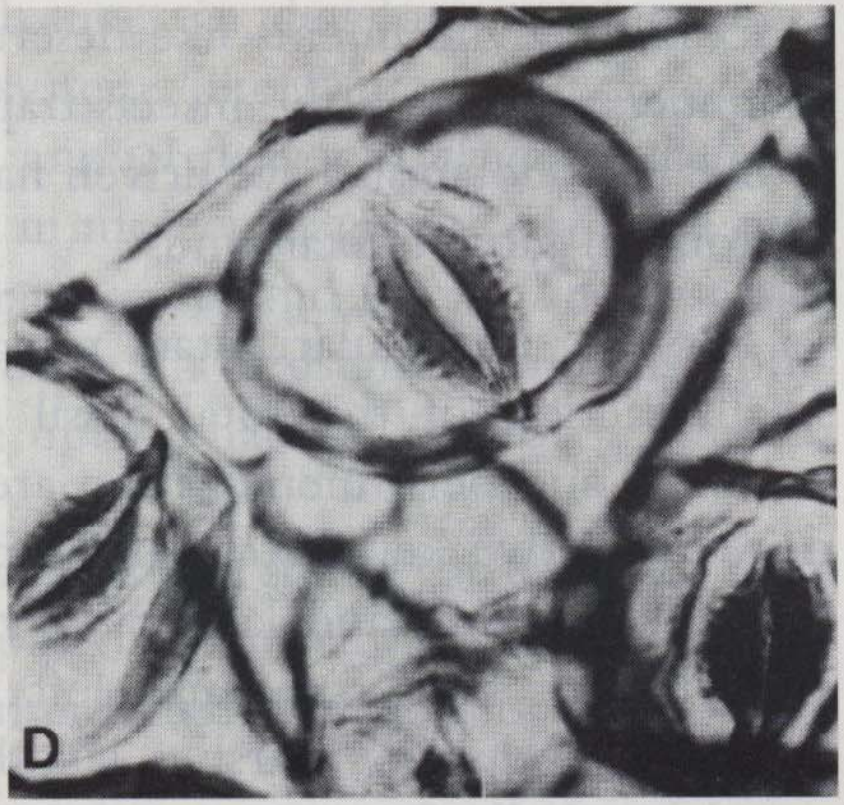
- Compression

Compression

Sediments accumulated on top of the leaf and compressed it into a thin carbon-rich film.

- Compression





2-D fossils found by splitting sedimentary rocks along bedding plane.

How do fossils form?

- Impressions

Tetrapod Tracks from the Paleozoic in fluvial standstone

FIGURE 7.4
Tracks of *Australopithecus* at Laetolil, Tanzania, in hardened volcanic ash more than three million years old.

How do fossils form?

- Permineralization and petrification

The original hard parts of the plant or animal have additional mineral material deposited in their pore spaces.

How do fossils form?

- Casts and Molds

Cast

The branch decomposed after it was buried. This left a hole that filled with dissolved minerals, faithfully creating a cast of the original.

How do fossils form?

- Unaltered remains

Scorpion found in amber.

Dinosaur mummy from Cretaceous, *Edmontosaurus annectens*, found in New Mexico, includes skeleton with preserved skin, muscles, and tendons.

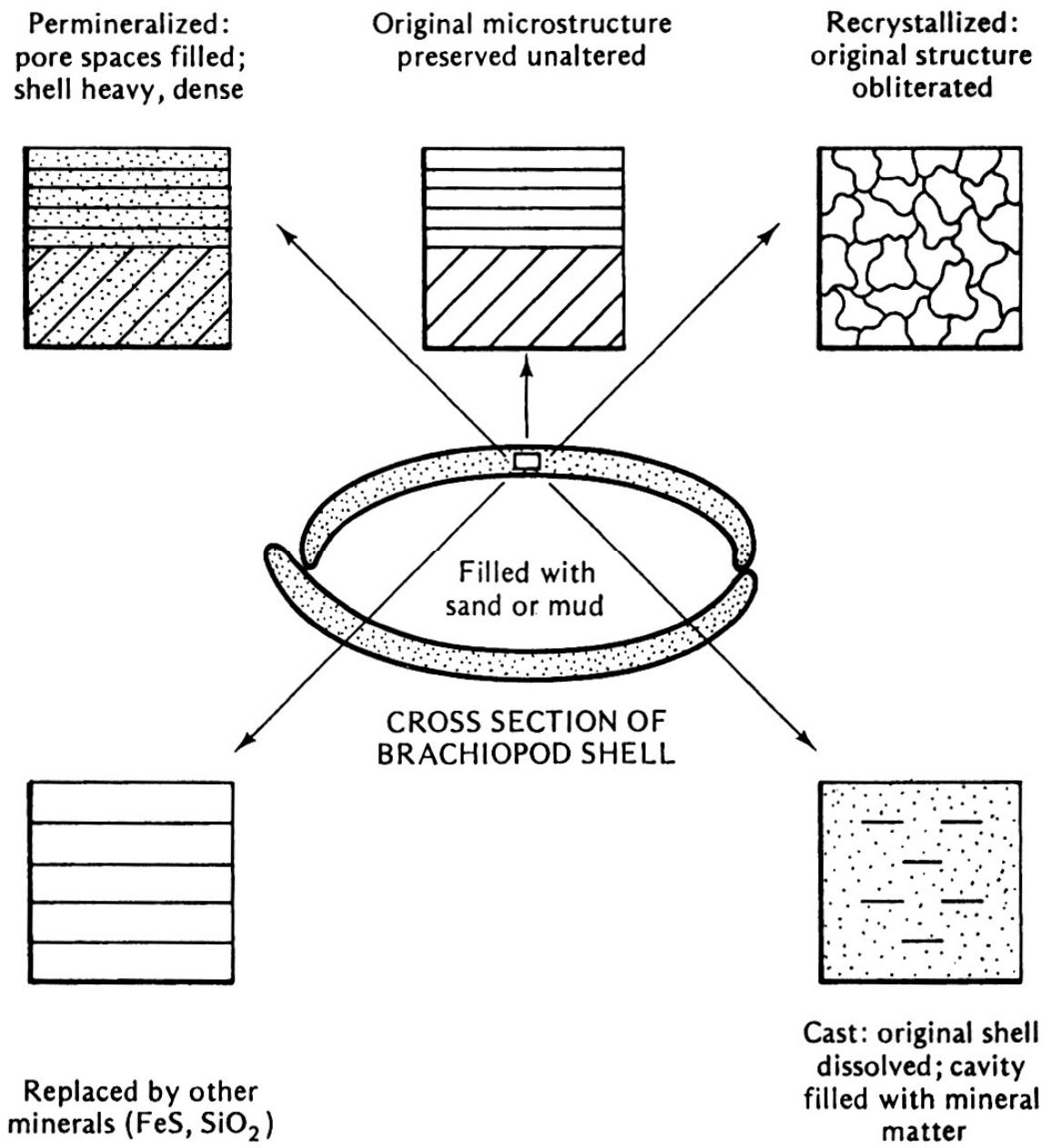


Figure 3.9 Different modes of fossil preservation of shell material. Small section of a brachiopod shell is enlarged to diagrammatically show the various ways in which hard parts may be preserved.

Where are fossils most likely to form?

- High sedimentation
- Anoxic conditions

What types of organisms are best represented in the fossil record?

- Hard-bodied organisms
- Marine organisms

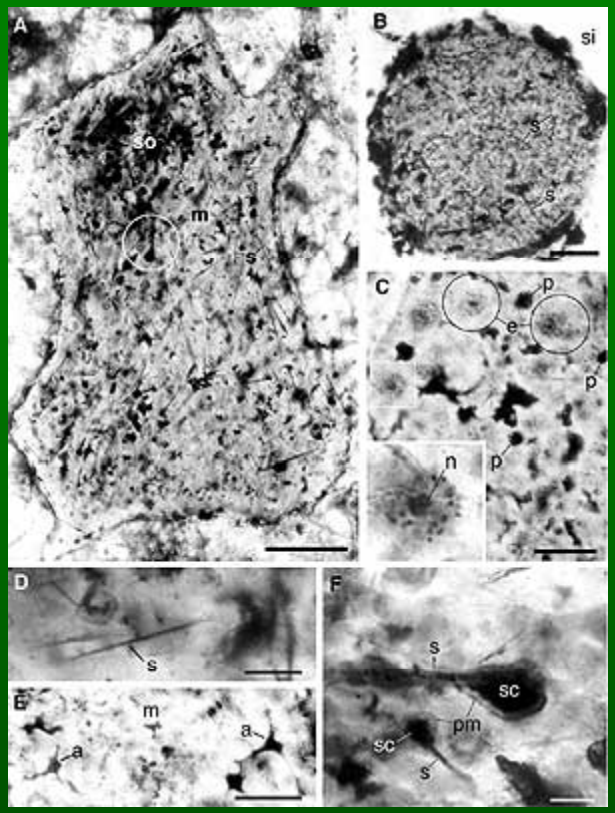
Sorting out the Fossil Record

- Strengths & Weaknesses
  - Lowland and shallow marine bias
  - Hard part bias
  - Age bias
  - Goal is to recognize the constraints and still be creative

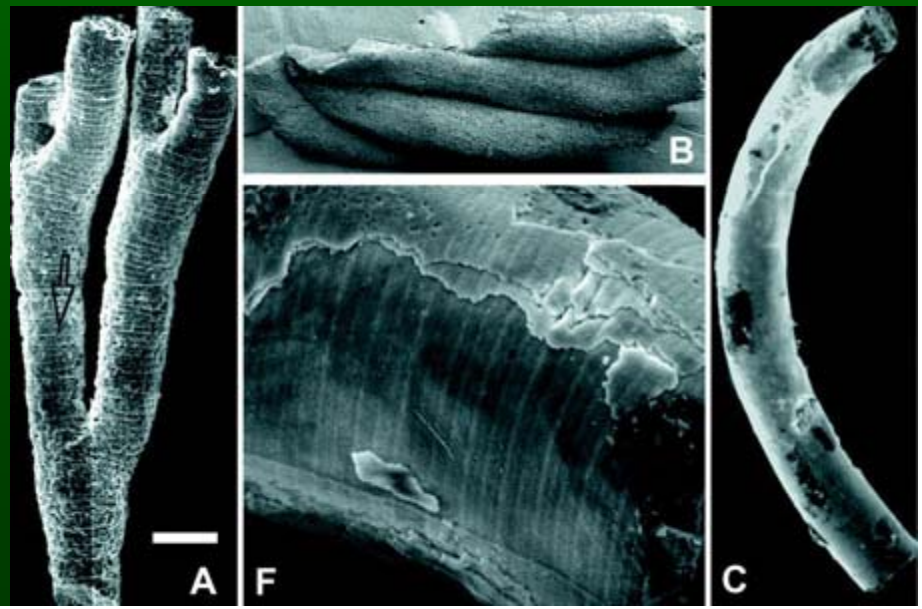
Noteworthy Fossil Assemblages

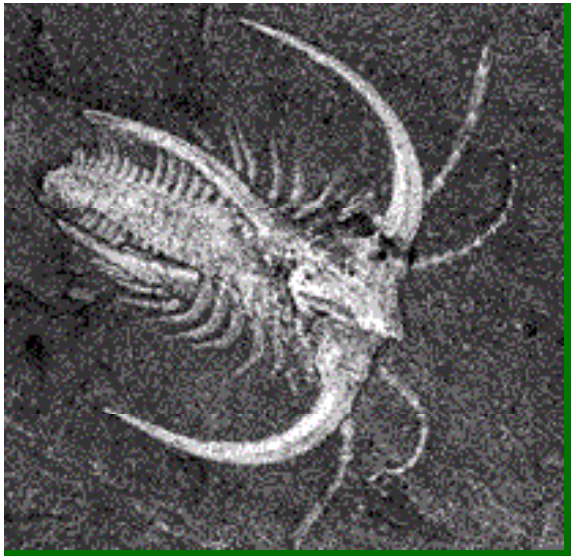
- Doushantuo Phosphorites
- Burgess Shale
- Bavarian Limestone
- Baltic Amber
- Pleistocene Megafauna

Doushantuo Phosphorites

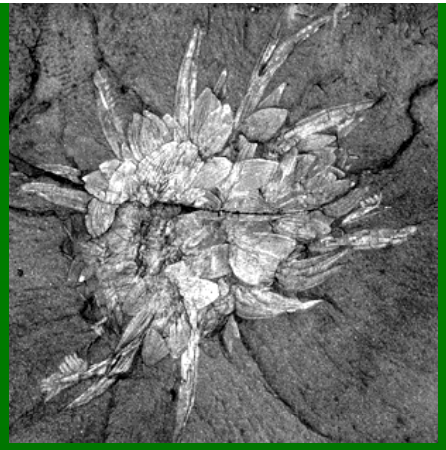


- Ancient (570 Mya)
- Features fine scale soft parts
- Sponges and Embryos!





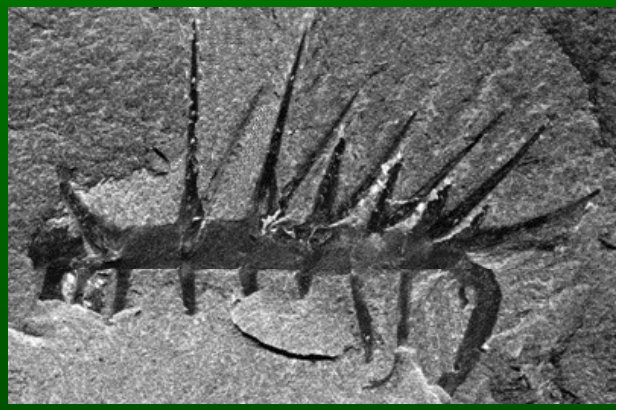
Arthropod - ***Marella***



Wiwaxia

Chordate - ***Pikaia***

Opabinia



Hallucigenia

Burgess Shale

- Ancient (520 Ma)
- Features soft-bodied marine animals
- Reveals establishment of all basic body plans (symmetries, segmentation, body cavities, exoskeletons, notochords).


CRITTERS OF THE BURGESS SHALE
THE STUFF OF NIGHTMARES

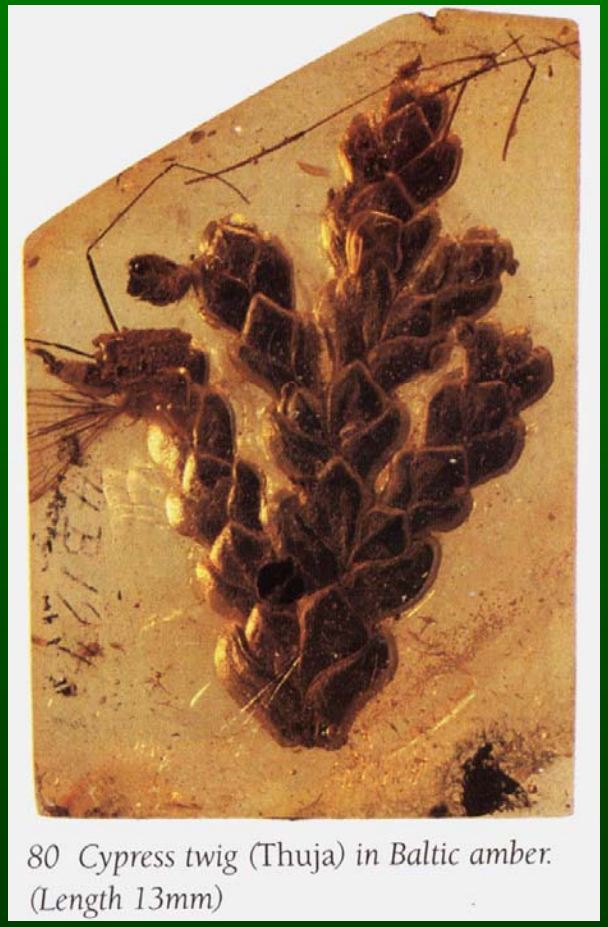
Bavarian Limestone

- Jurassic (150 Ma)
- Archaeopteryx
- Huge dragonflies

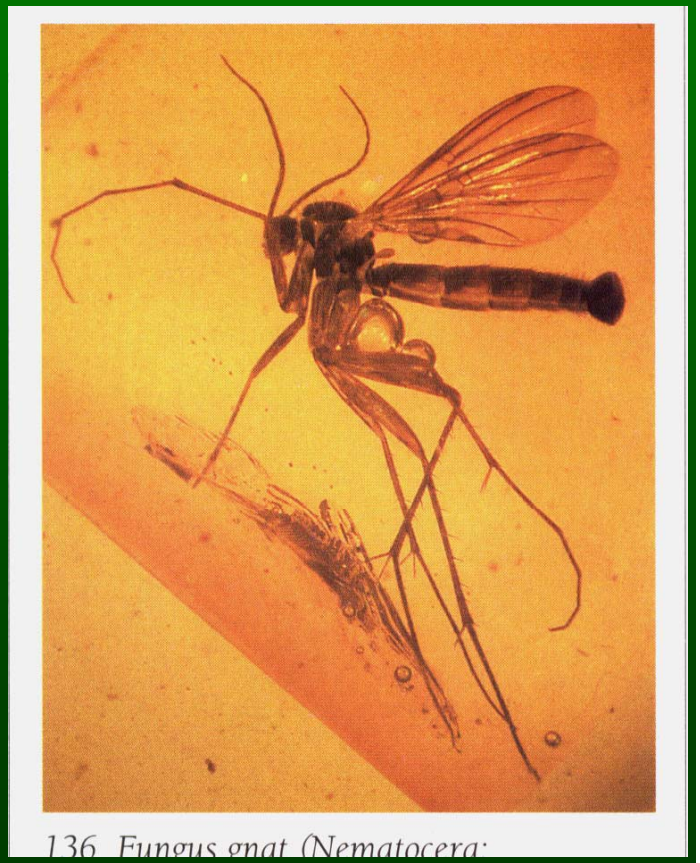
Baltic Amber

- 35-40 Ma
- Amazing detail and diversity

57 Lizard in Dominican amber. (Length 55mm)



80 Cypress twig (Thuja) in Baltic amber. (Length 13mm)



136 Fungus gnat (Nematocera:

Pleistocene Megafauna

Smilodon

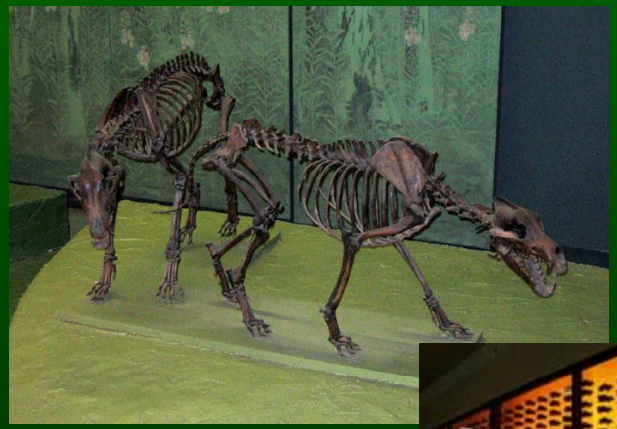
Giant (200kg) beaver

- < 1 Ma
- La Brea Tar Pit

Ground sloth

Woolly mammoth

Dire wolf



Sorting out the Fossil Record

- **Evolutionary Trends**

  - **Dollo's "Law"**: Complex features, once lost, are not regained in that lineage. No reversals…

  - **Cope's Rule**: Multiple lineages evolve through similar stages.

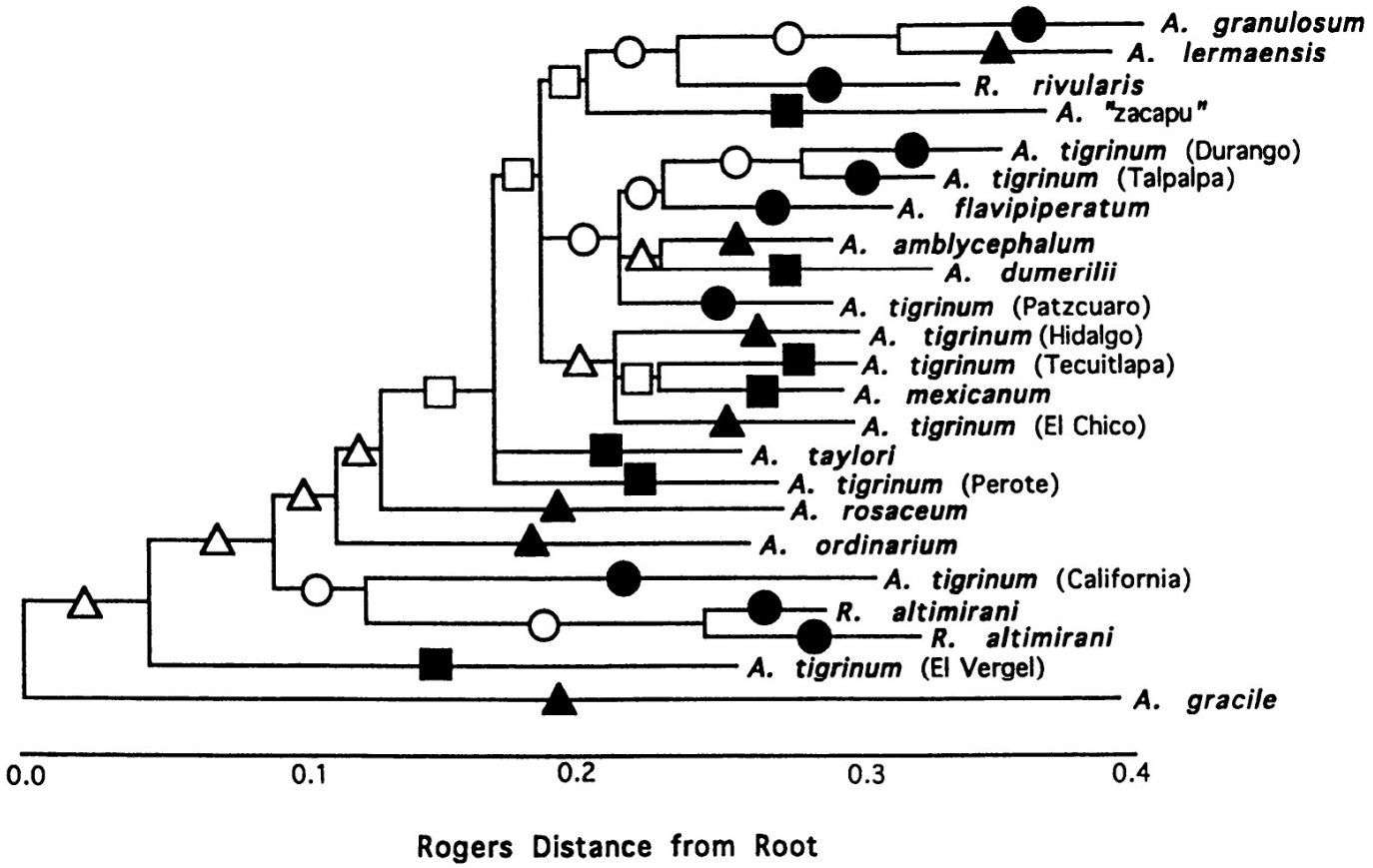
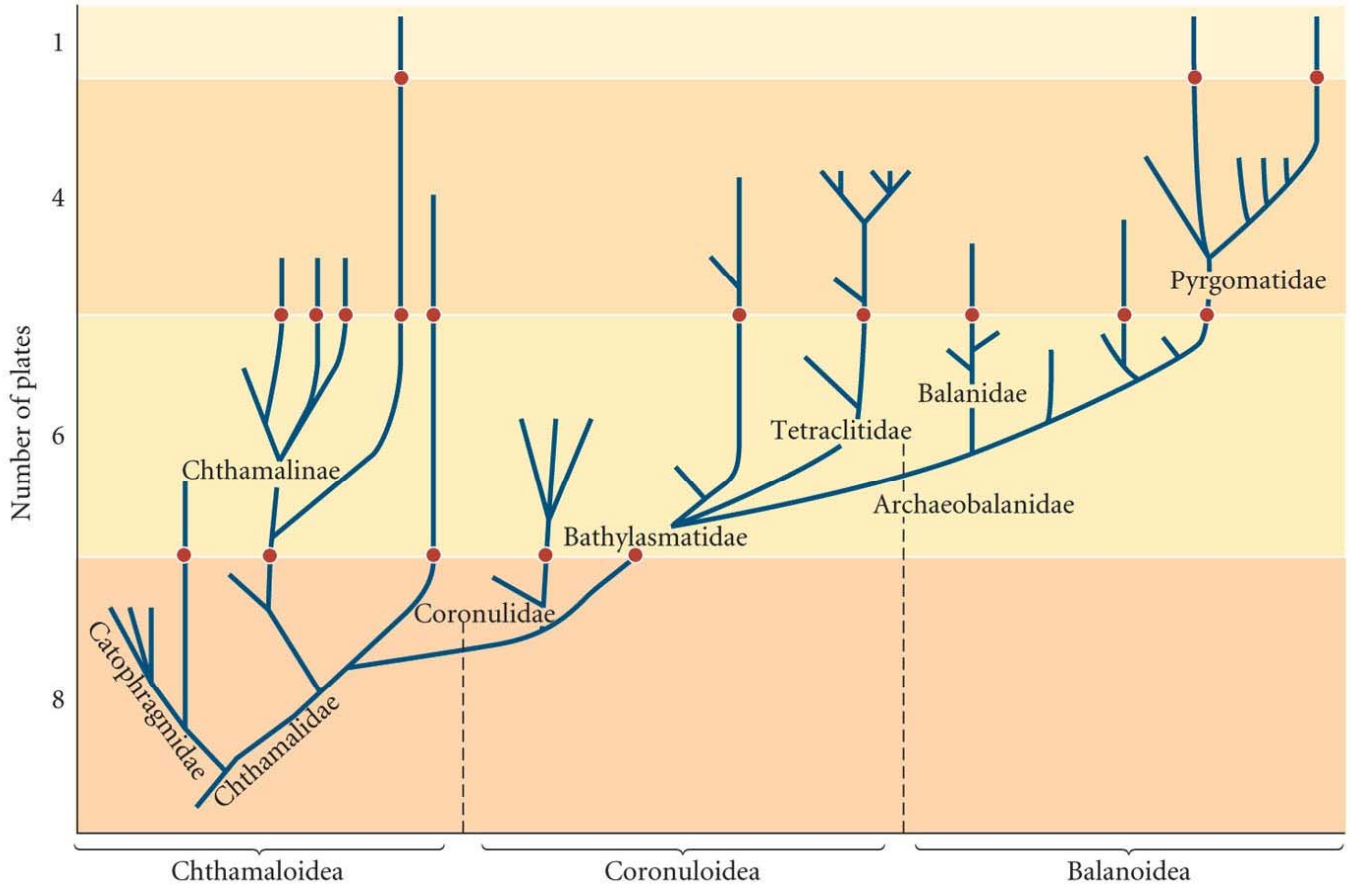
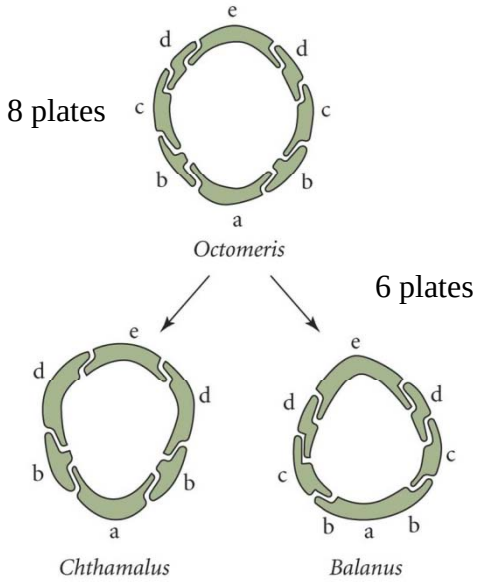
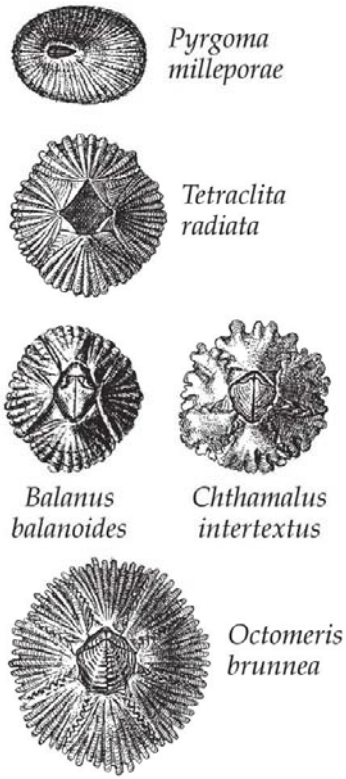


FIG. 2. Flickering of developmental traits during the radiation of Mexican ambystomatid salamanders. Developmental modes of living species are given as solid symbols: circles, metamorphosing; squares, reproduction as neotenic larvae; triangles, facultative. Open symbols represent inferred ancestral developmental modes. The ambystomatid radiation occupied 10–12 Myr ago as inferred from the age of the volcanic uplift that produced the highlands that the salamanders inhabit and from molecular clock estimates. Reversals from larval reproduction to metamorphosis are inferred at two steps in the tree, which occupy spans of <1 Myr. Reproduced from Shaffer (36), with permission (copyright 1984, Society for the Study of Evolution, Lawrence, KS).

Flickering traits show that reversals can occur and the genes controlling developmental pathways can reactivate.







A parallel trend in barnacles showing the reduction in the number of shell plates during the Cenozoic.

Sorting out the Fossil Record

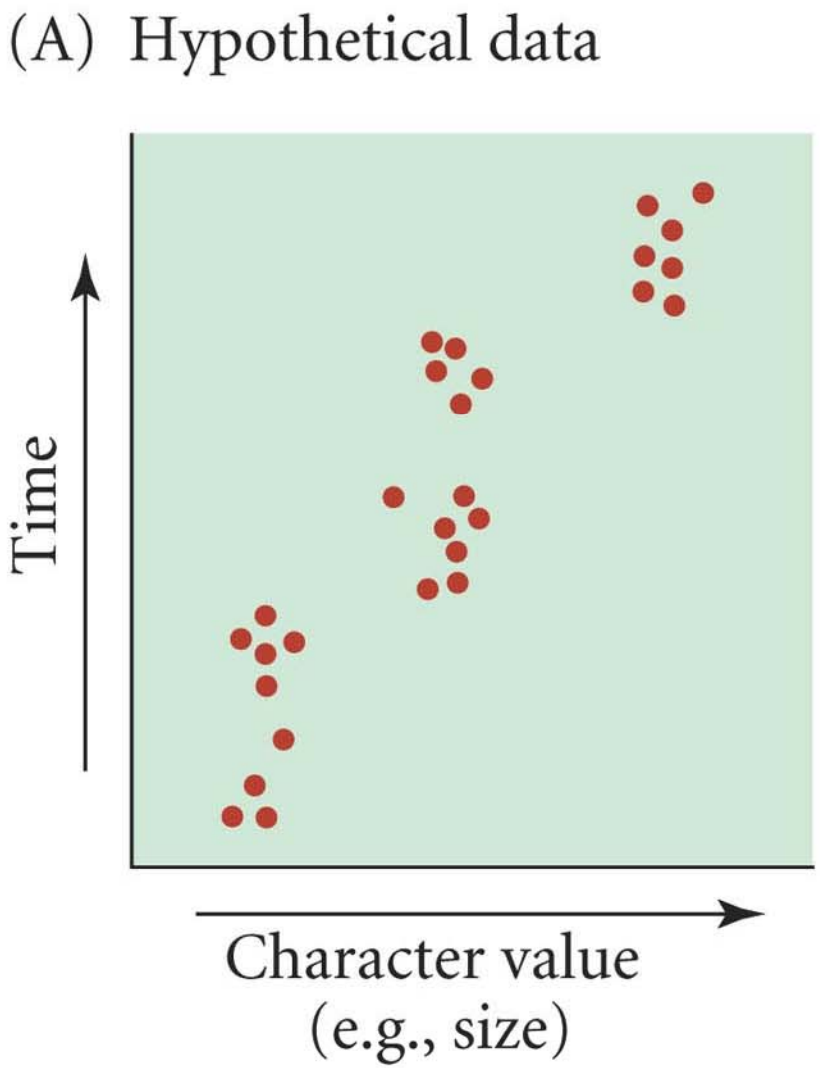
- **Evolutionary Trends**
  - **Dollo's "Law":**

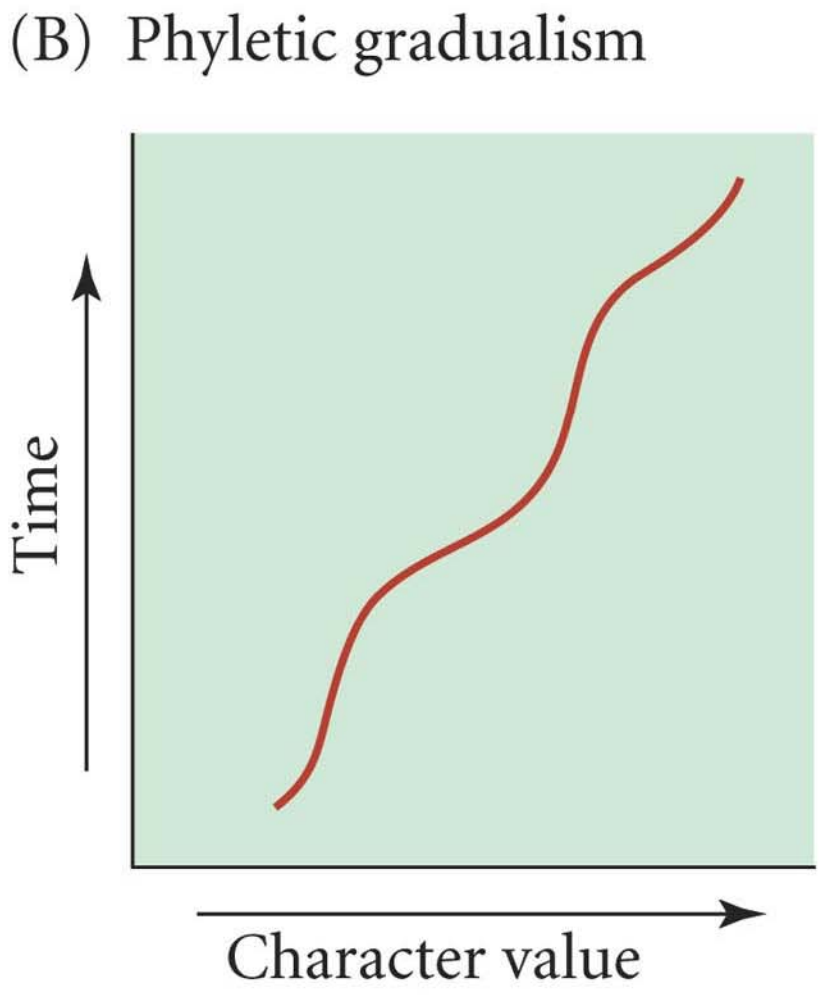
  - **Cope's Rule:**

Sorting out the Fossil Record

- Decent with Modification…..Yes!
- Punctuated or Gradual Evolution?

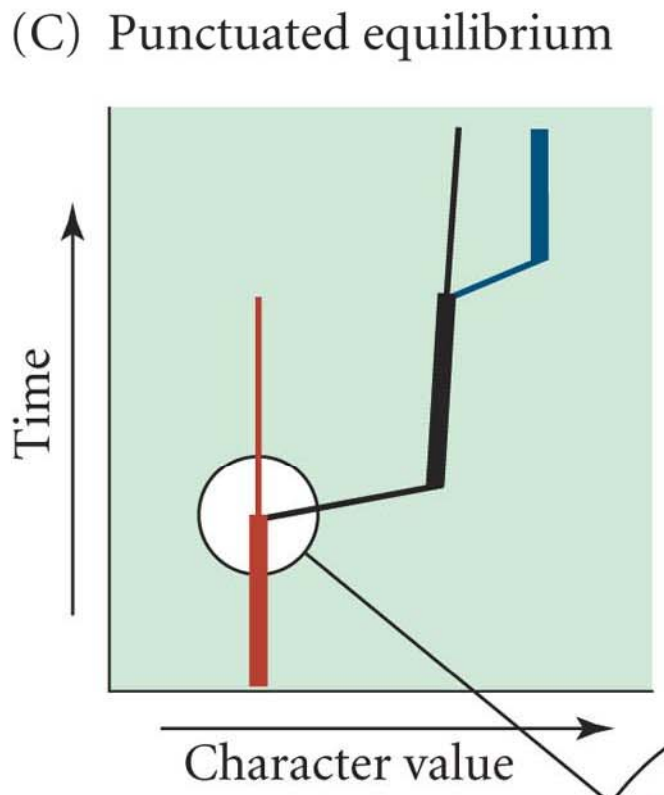
Three models of evolution, as applied to a hypothetical set of fossils.

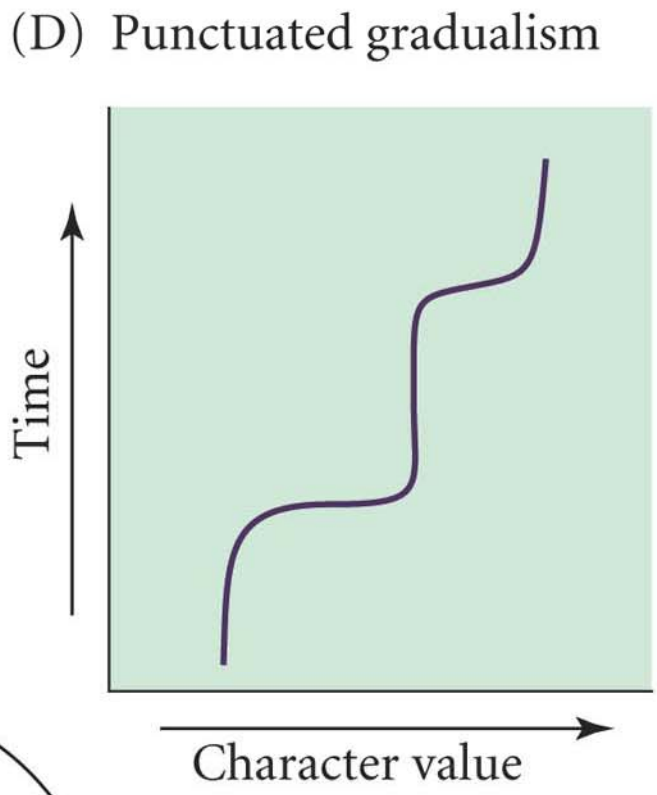


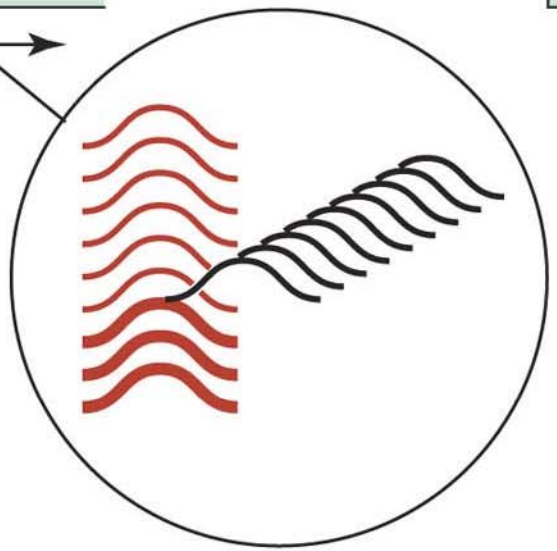


Traditional model of gradual change without any divergence.

Three models of evolution, as applied to a hypothetical set of fossils.

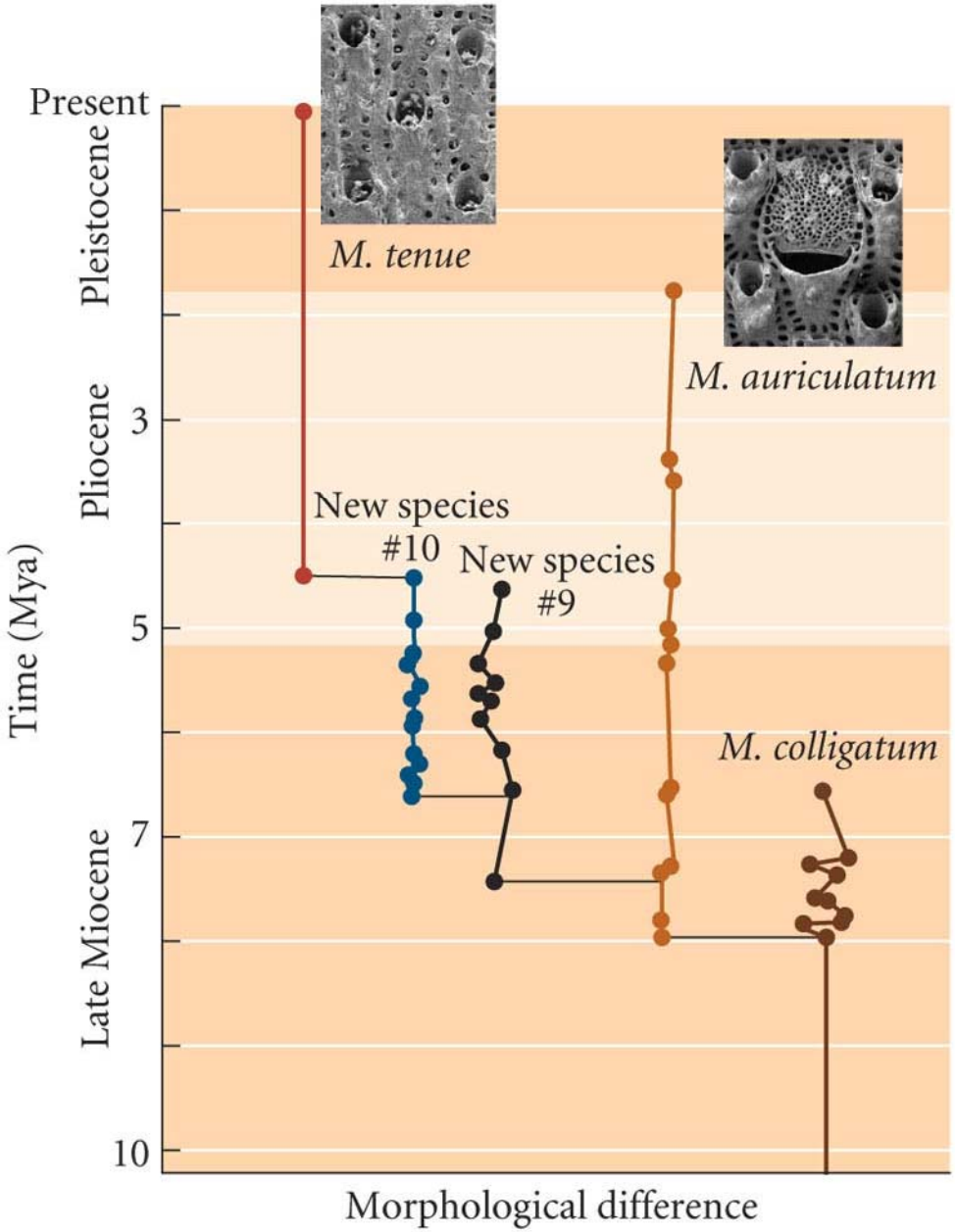






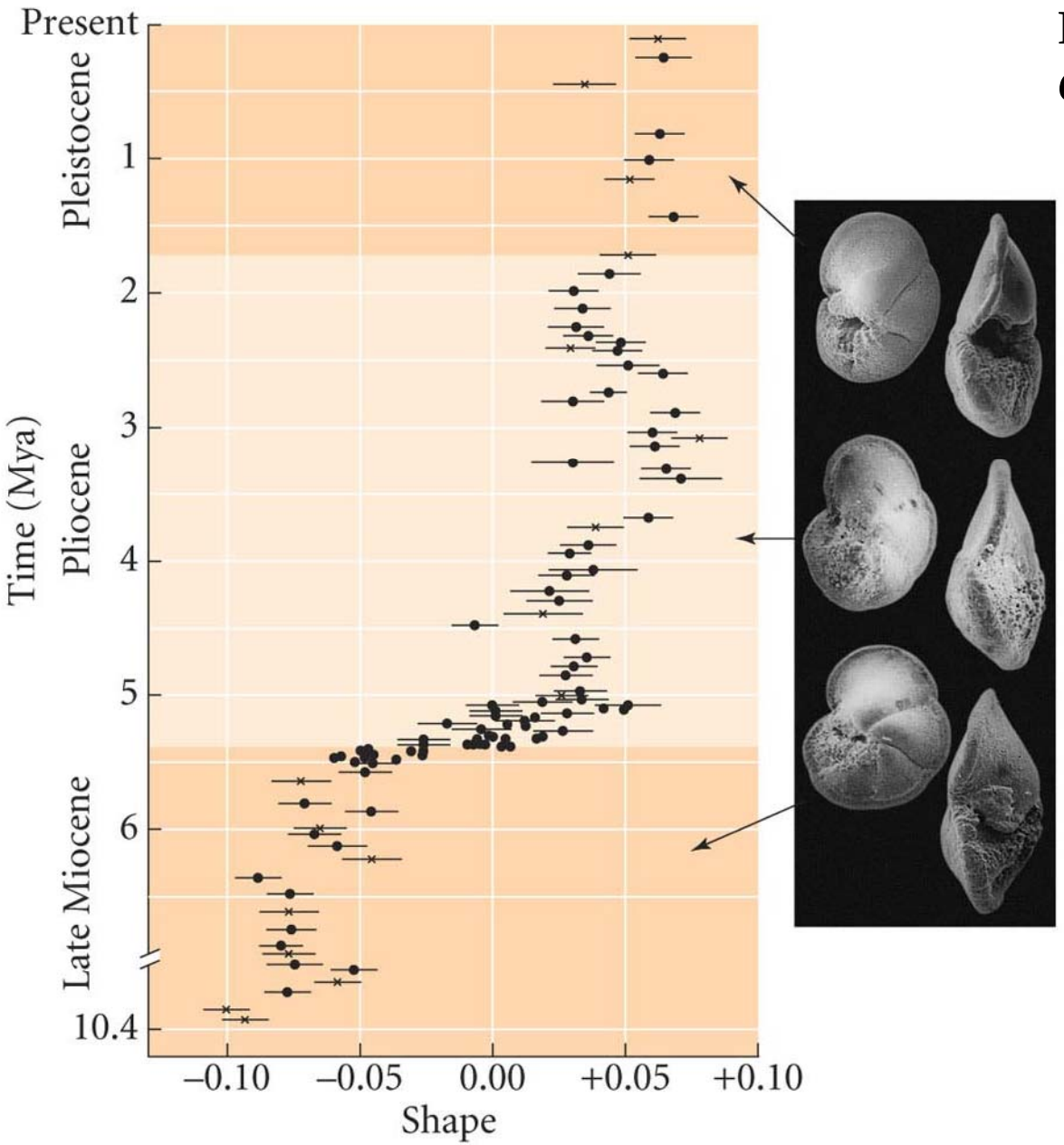
Divergence occurs rapidly then back to stasis.

A lineage passes through rapid spurts of change from one equilibrium to another.



Punctuated equilibrium of *Metrarabdotos* bryozoans.

Predicts that speciation **is** necessary for character change to occur.



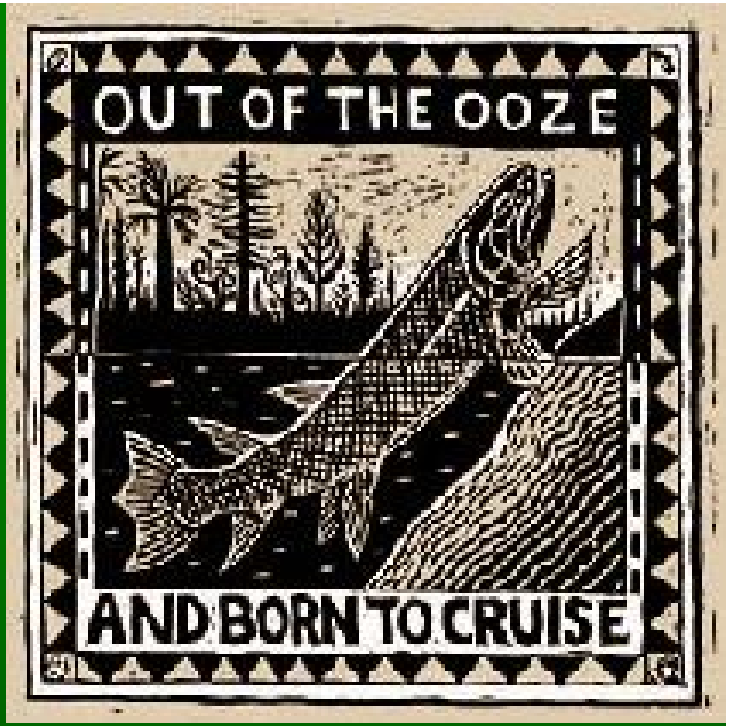
Punctuated gradualism in *Globorotalia* foraminifera.

Predicts that speciation is **not** necessary for character change to occur.

Sorting out the Fossil Record

- Decent with Modification…..Yes!
- Punctuated or Gradual Evolution…..Yes!

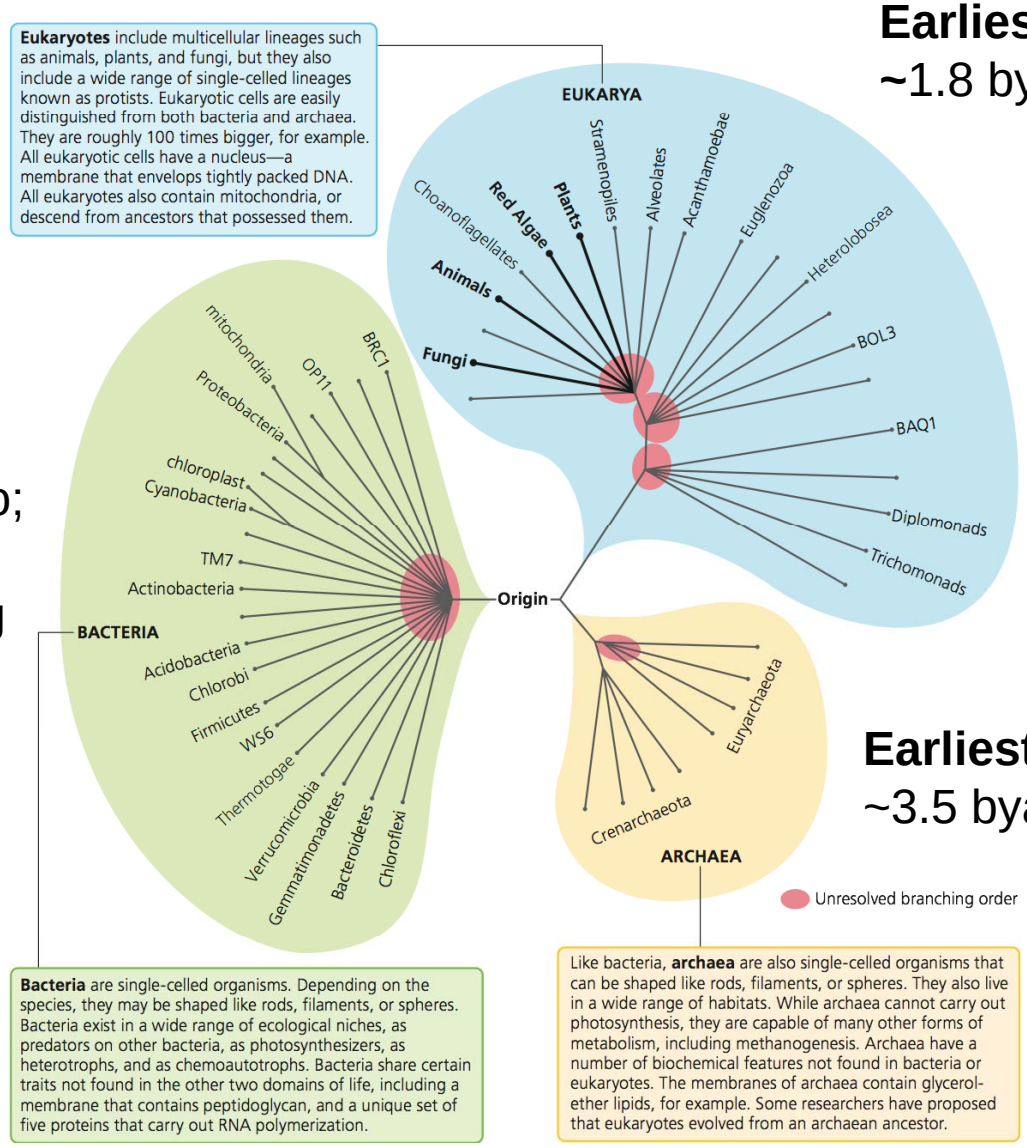
Sorting out the Fossil Record



- Origins of higher order taxa:
  - Amphibians and four-on-the-floor (Devonian)
  - Birds and flight (Jurassic)
  - Reptiles and hearing (Carboniferous)
  - Whales and back to the sea (Eocene)
  - Hominins and its-just-gotta-be-me (Miocene)

How do early organisms fit in the tree of life?

Earliest fossils:
potentially 3.45 byo; abundant by ~2.6 bya, corresponding to rise in oxygen



Earliest fossils:
~1.8 bya

Earliest fossils:
~3.5 bya