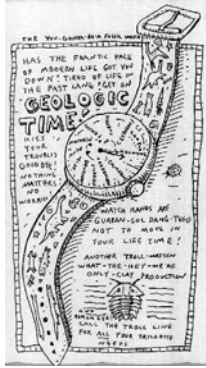


## Earth History & the Fossil Record



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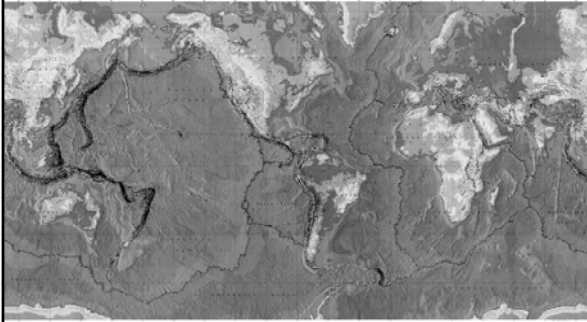
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## The Dynamic Earth



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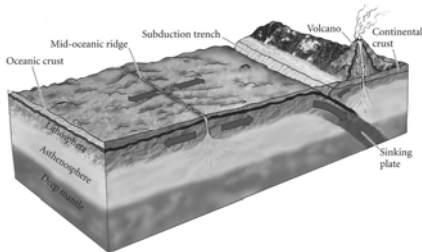
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## Earth's Dynamic Geology

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



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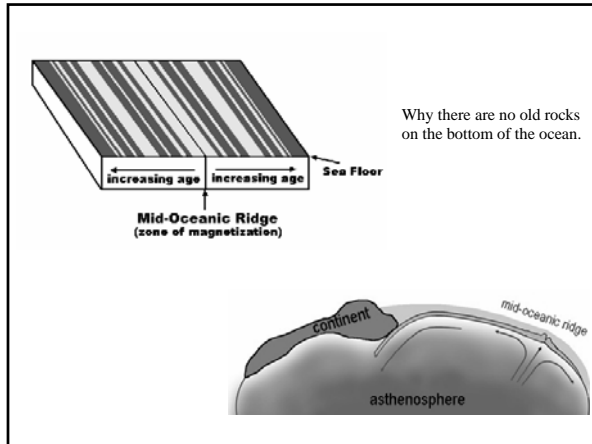
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**20.1 Earth's Geological History**

RELATIVE TIME SPAN	ERA	PERIOD	ONSET	MAJOR PHYSICAL CHANGES ON EARTH
Cenozoic	Quaternary	Quaternary	1.8 mya	Cold/dry climate; repeated glaciations
		Tertiary	65 mya	Continents near current positions; climate cools
Mesozoic	Cretaceous	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	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 <sub>2</sub> levels approach current levels
Precambrian	Precambrian	600 mya	2.5 bya	O <sub>2</sub> level at >5% of current level
		3.8 bya	4.5 bya	O <sub>2</sub> level at >1% of current level
				O <sub>2</sub> first appears in atmosphere

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**Geologic Time Scale**

Eon	Era	Period	Epoch	Development of Plants and Animals	
Phanerozoic	Cenozoic	Quaternary	Holocene	8.0	Humans develop
			Pleistocene	1.8	
		Tertiary	Pliocene	5.3	"Age of Mammals"
			Miocene	23.7	
			Oligocene	36.8	
	Mesozoic	Cretaceous	Cretaceous	66.4	Extinction of dinosaurs and many other species
			Jurassic	201	"Age of Reptiles"
			Triassic	252	First flowering plants
			Permian	252	First birds
			Triassic	252	Dinosaurs dominant
Paleozoic	Carboniferous	Permian	252	Extinction of trilobites and many other marine animals	
		Pennsylvanian	299	First reptiles	
		Mississippian	359	Large coal swamps	
	Devonian	Devonian	359	Amphibians abundant	
		Silurian	439	First insect fossils	
Precambrian	Precambrian	Ordovician	439	Fish dominant	
		Silurian	439	First land plants	
		Ordovician	439	First fish	
Proterozoic	Proterozoic	Cambrian	541	Trilobites dominant	
		Cambrian	541	First organisms with shells	
Archaean	Archaean			First multicelled organisms	
				First one-celled organisms	
Hadaean	Hadaean			Age of older rocks	
				Origin of Earth	

**"Moss Animals"**

**Newest Animal Phylum: Bryozoans**

**Precambrian "Age of the Prokaryotes"**

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### 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.

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### 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

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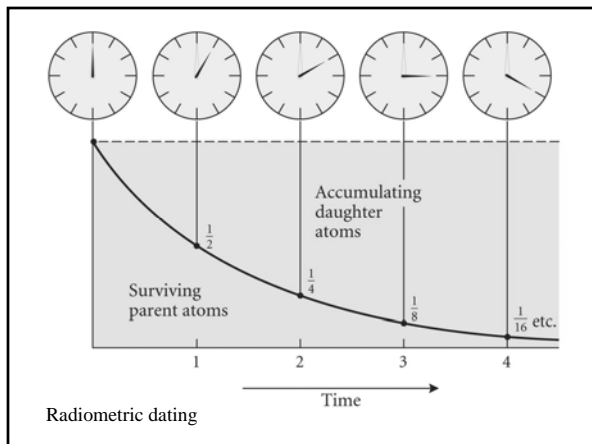
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### Rock types significant to the fossil record:

- 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.

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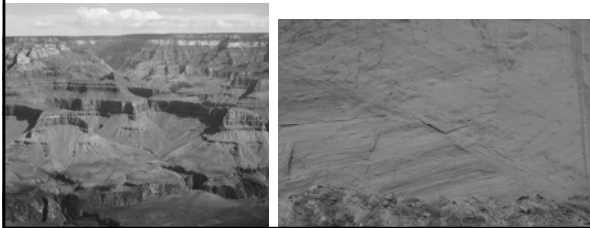
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### Principles of Stratigraphy

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.



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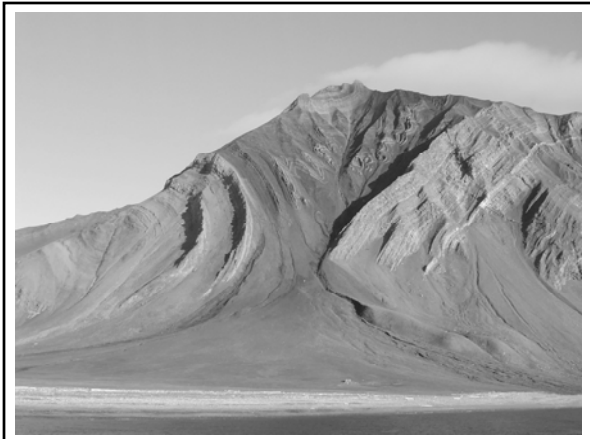
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## Sedimentary rocks leave gaps

- 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.

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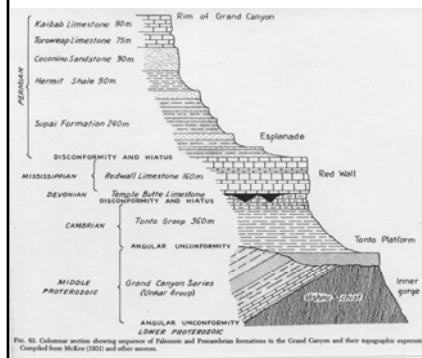
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## Example of Stratigraphy



- Marine fossils
- Vertebrate tracks
- Plants, reptiles
- Marine fossils
- Trilobites
- No fossils

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## Sorting out the Fossil Record

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

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## How do fossils form?

- Compression



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

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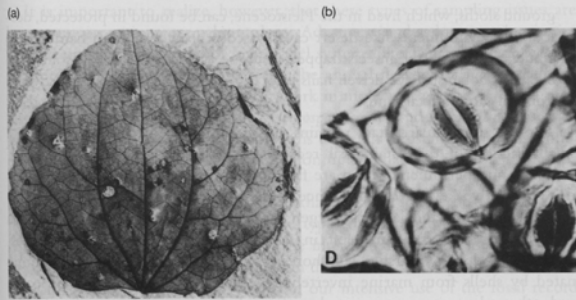
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- Compression



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

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## How do fossils form?

- Impressions



Tetrapod Tracks from the Paleozoic  
in fluvial sandstone



**FIGURE 7.4**  
Tracks of *Amphibiothis* in Lenoir, Tennessee, in bedrock volcanic ash more than three million years old.

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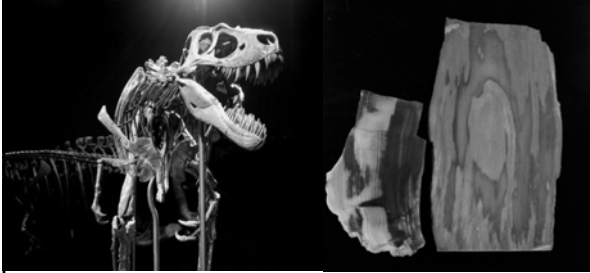
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## How do fossils form?

- Permineralization and petrification



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

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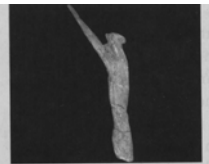
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## How do fossils form?

- 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.



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## 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.

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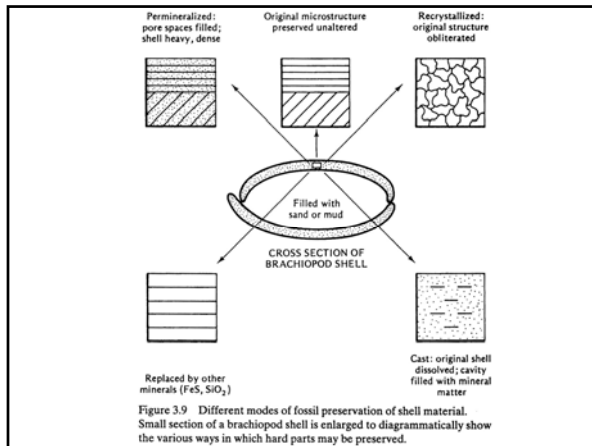
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**Where are fossils most likely to form?**

- High sedimentation
- Anoxic conditions

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

- Hard-bodied organisms
- Marine organisms

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**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

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## Noteworthy Fossil Assemblages

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

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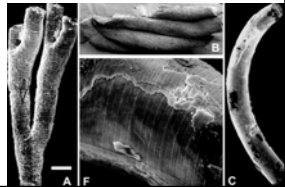
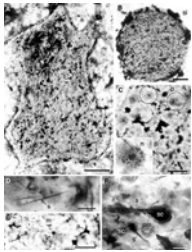


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### Doushantuo Phosphorites



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

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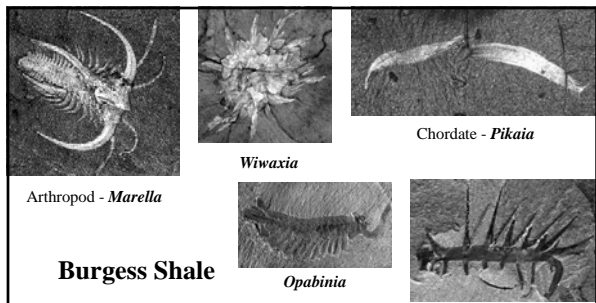
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Arthropod - *Marella*

*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).

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**Bavarian Limestone**

- Jurassic (150 Ma)
- Archaeopteryx
- Huge dragonflies

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**Baltic Amber**

- 35-40 Ma
- Amazing detail and diversity

57 Insect in Dominican amber (Length 55mm)

80 Cypress twig (Thuja) in Baltic amber (Length 1.3mm)

136 *Furcata ovalis* (Nematocera)

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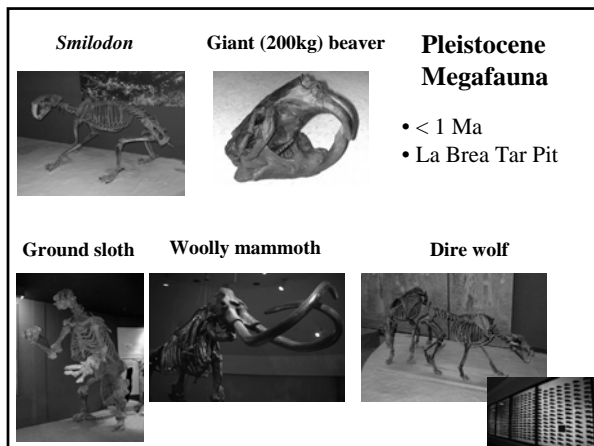
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## Sorting out the Fossil Record

- **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.

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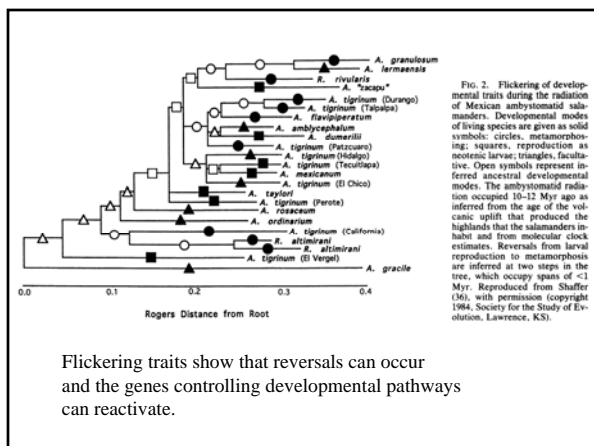
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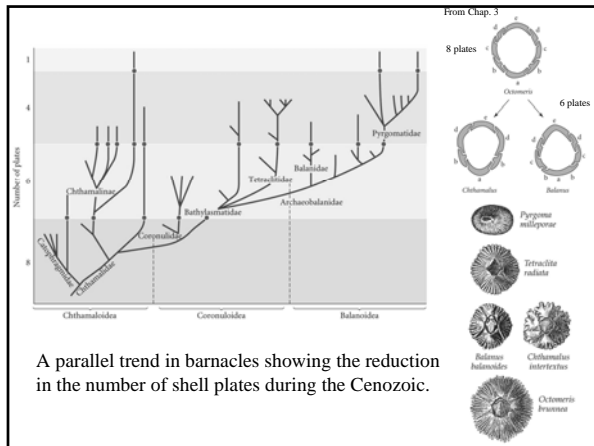
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## Sorting out the Fossil Record

### • Evolutionary Trends

• Dollo's "Law":



• Cope's Rule:




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## Sorting out the Fossil Record

• Decent with Modification..... Yes!

• Punctuated or Gradual Evolution?

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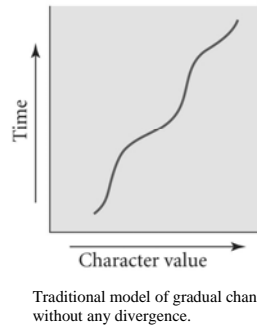
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Three models of evolution, as applied to a hypothetical set of fossils.

(A) Hypothetical data



(B) Phyletic gradualism




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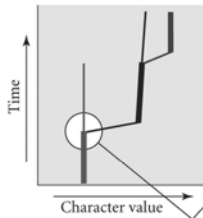
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Three models of evolution, as applied to a hypothetical set of fossils.

(C) Punctuated equilibrium



Divergence occurs rapidly then back to stasis.

(D) Punctuated gradualism



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

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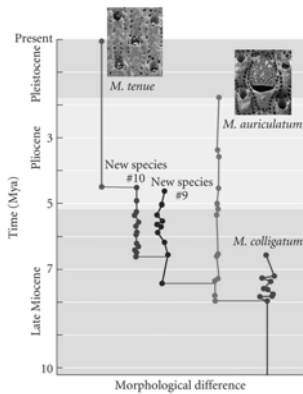
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**Punctuated equilibrium of *Metrarabdotos* bryozoans.**

Predicts that speciation is necessary for character change to occur.

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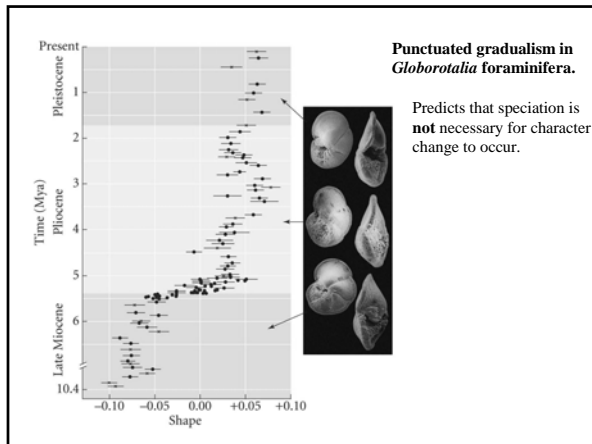
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**Sorting out the Fossil Record**

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

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**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)

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