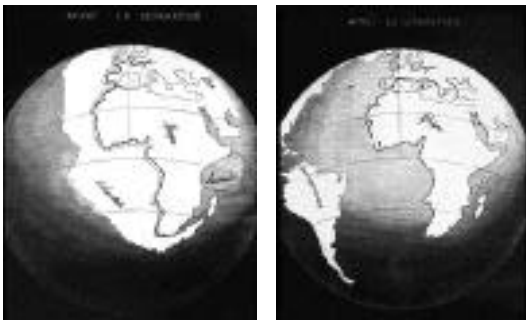


Plate Tectonics

- Relatively new theory - introduced about 30 years ago
- Unifies several branches of the Earth Sciences
- <http://pubs.usgs.gov/publications/text/dynamic.html>

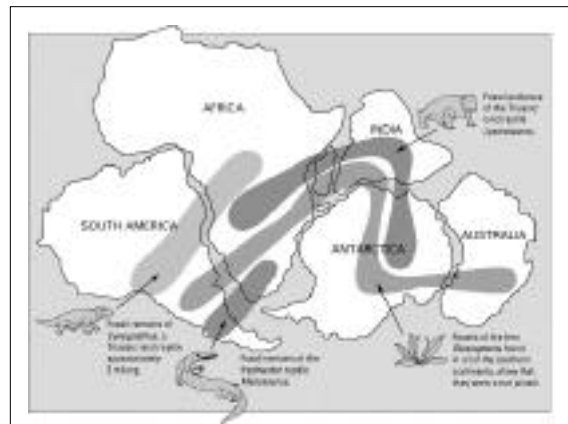


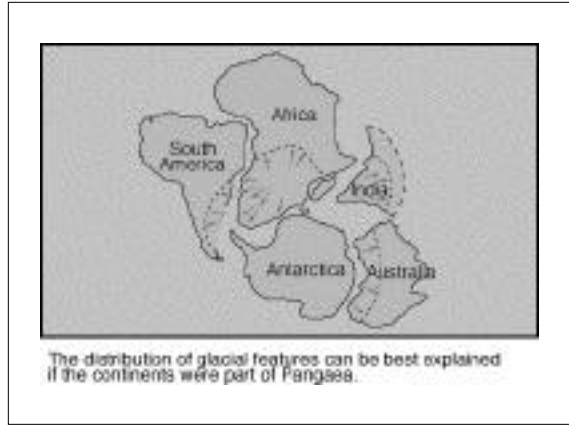
In 1858, geographer Antonio Snider-Pellegrini made these two maps showing his version of how the American and African continents may once have fit together, then later separated.

Alfred Lothar Wegener



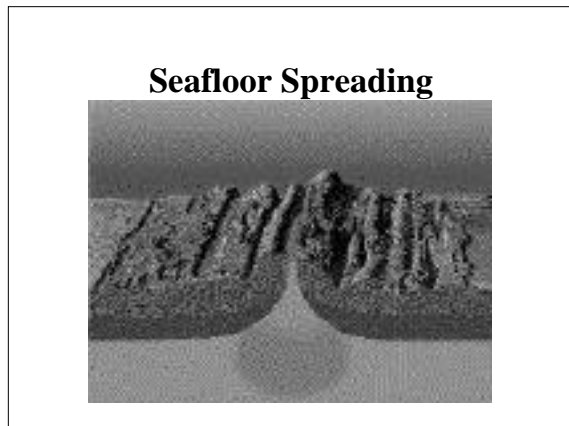
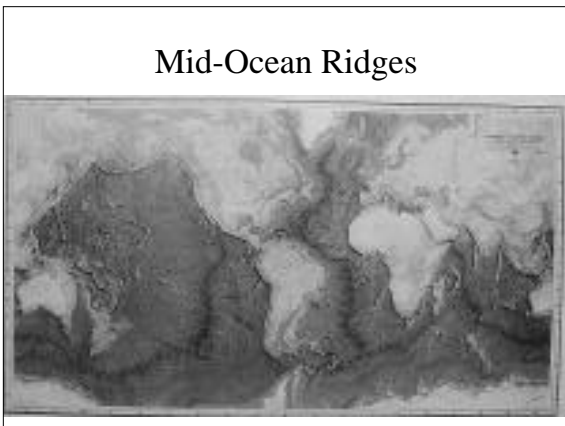
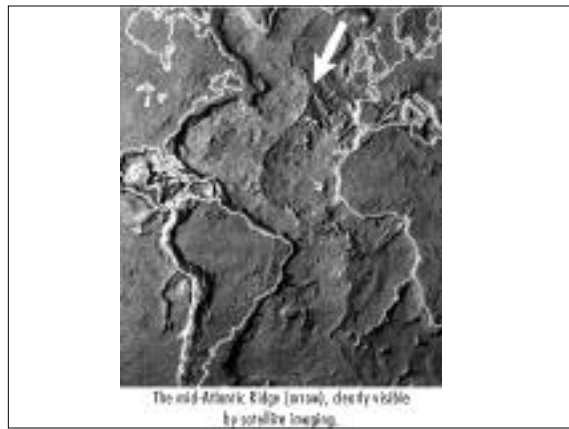
- Developed the Theory of Continental Drift
- Published "Die Entstehung der Kontinente und Ozeane" in 1915





BUT -

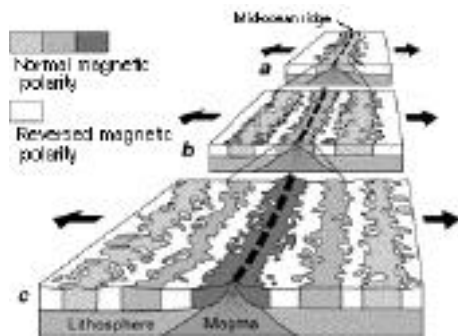
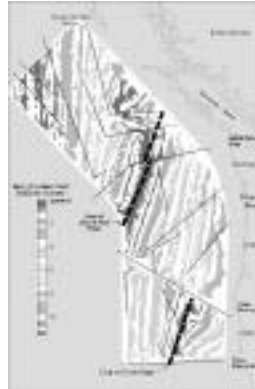
- NO MECHANISM !!!



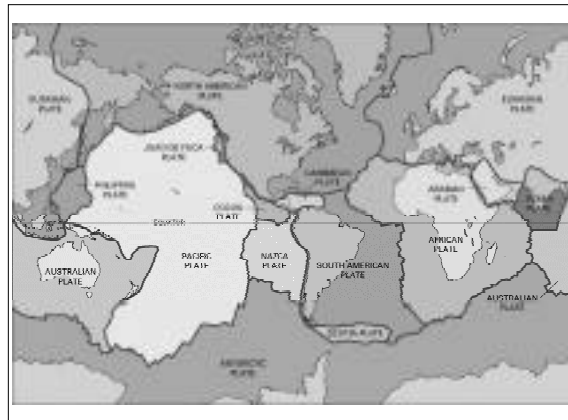
Paleomagnetism



Magnetic Striping

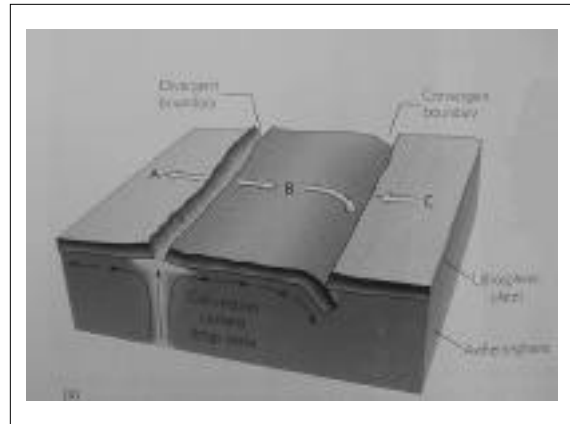


Continental Drift +
Seafloor Spreading +
A few refinements =
PLATE TECTONICS



All Plates are surrounded by a combination of three different types of boundaries

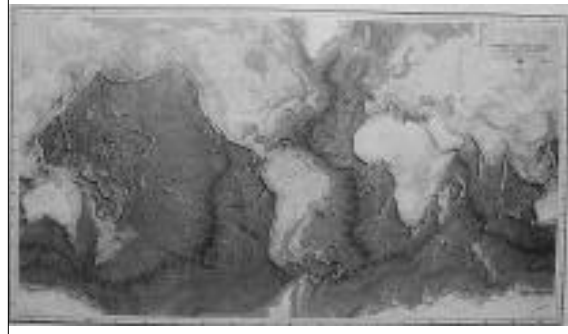
- Divergent
- Convergent
- Transform



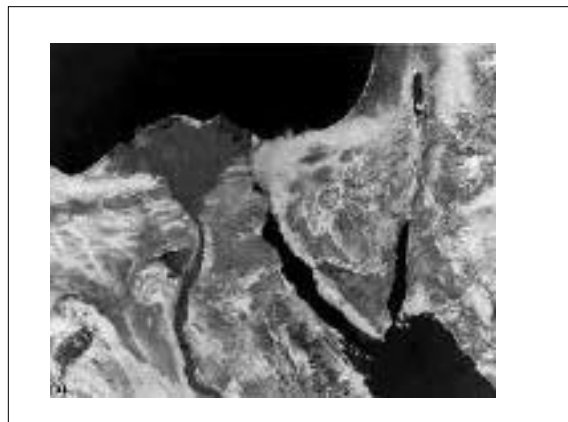
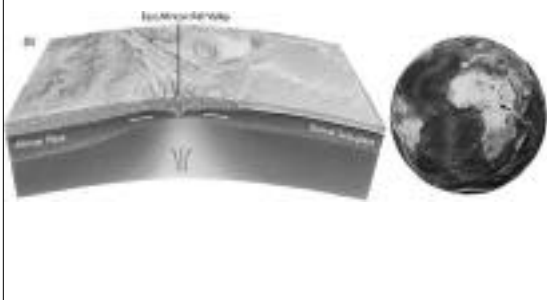
Divergent Boundary

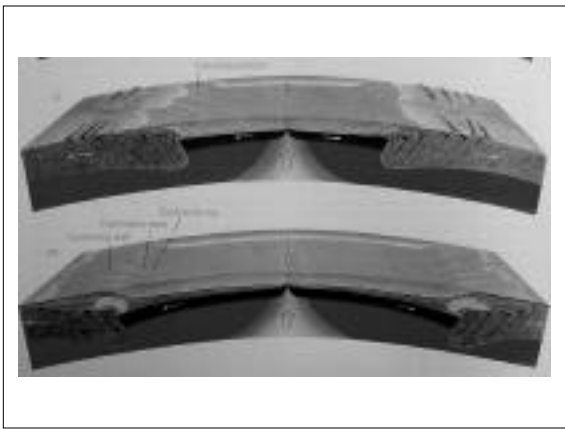
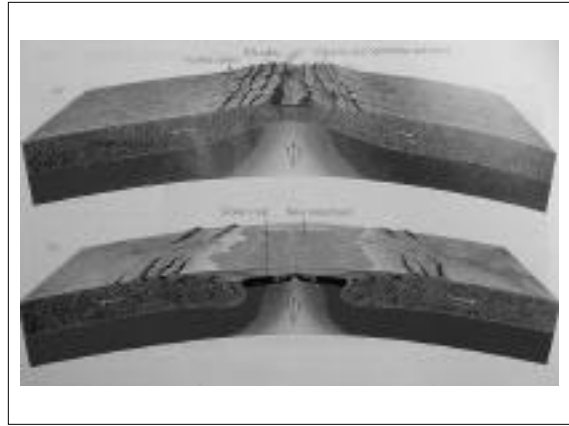
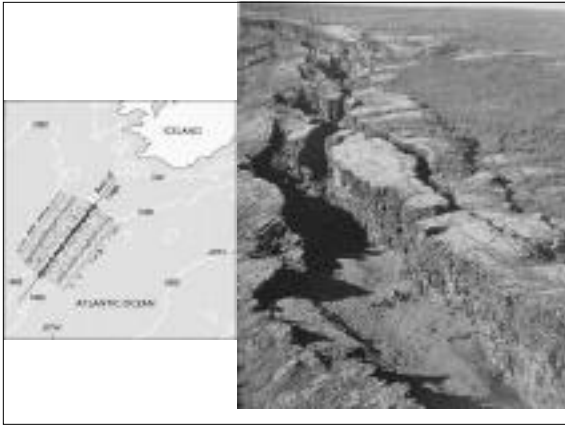


Mid-Ocean Ridges



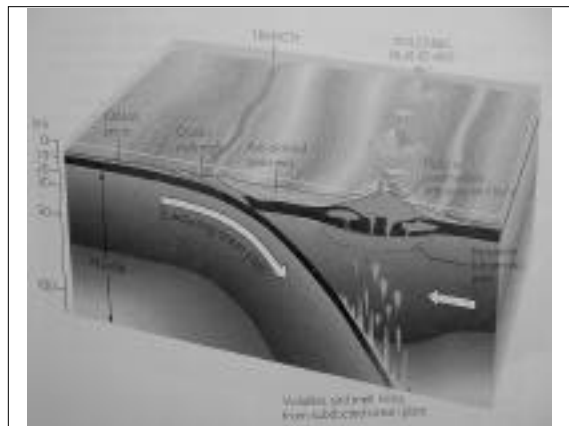
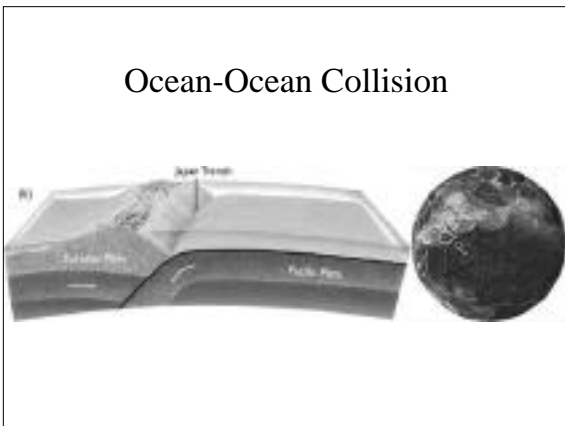
Continental Rift Systems



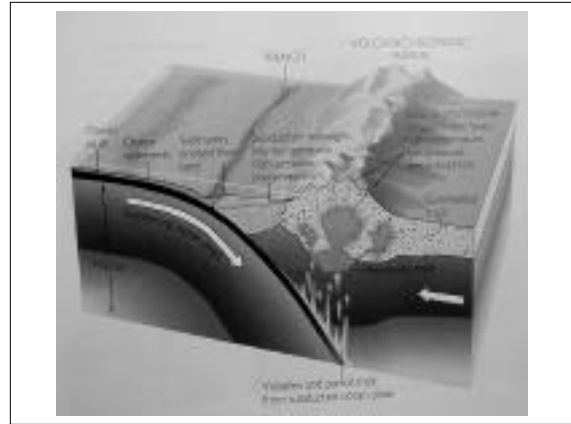
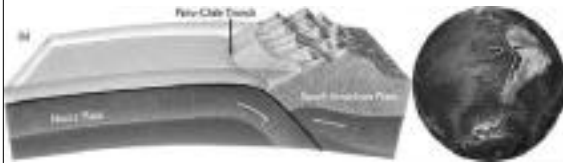


Convergent Boundary

- Three Types
 - Ocean-Ocean Collision
 - Continent-Ocean Collision
 - Continent-Continent Collision



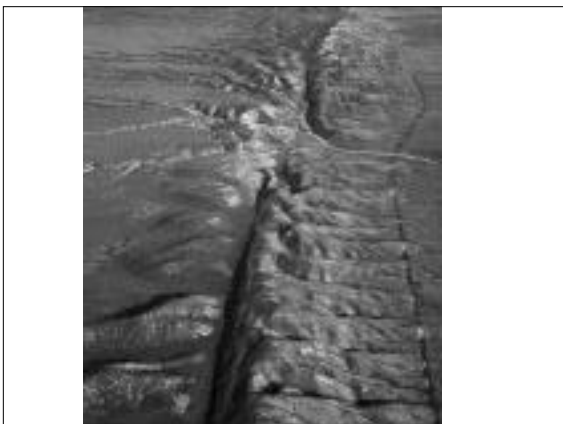
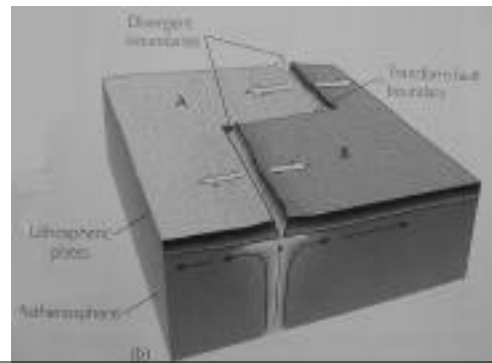
Ocean-Continent Collision

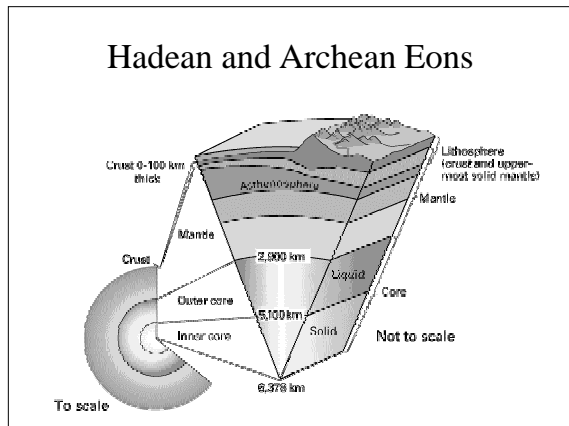
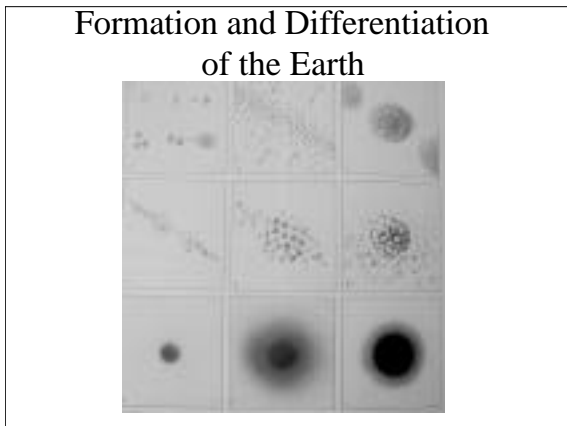
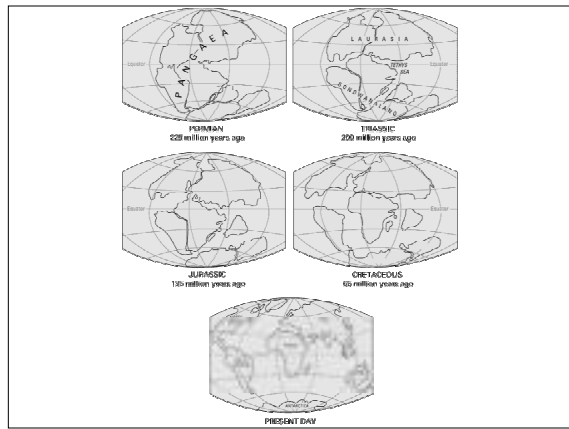
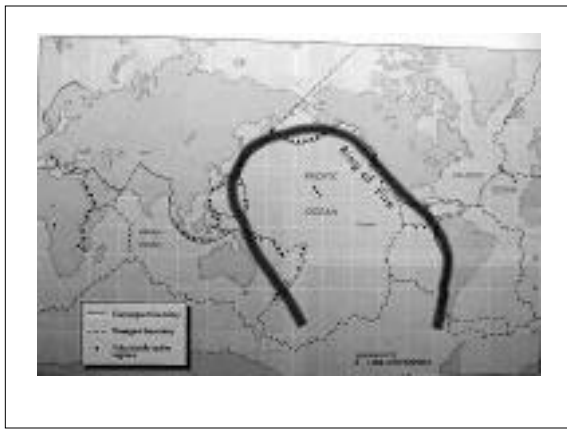
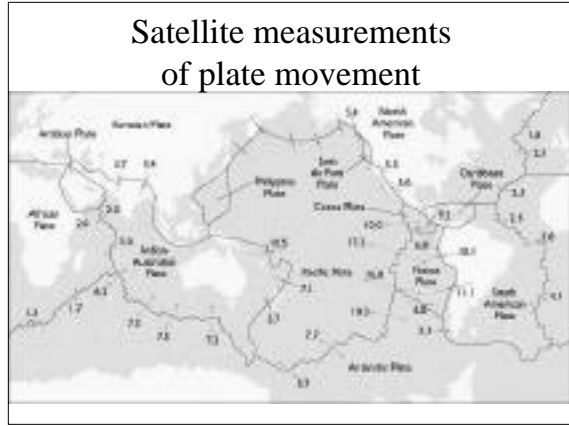
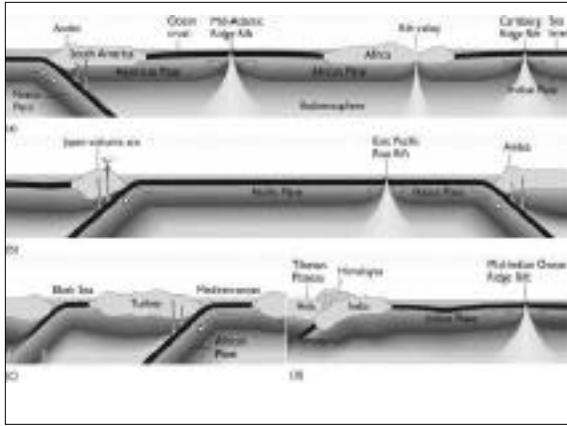


Continent-Continent Collision



Transform Boundary





Archean (until 2.5 BYA)

- Atmosphere composed of methane, ammonia, hydrogen and very little oxygen
- Very primitive life – bacteria and stromatolites (3.4 –3.5 billion years ago) – prokaryotes
- Cratons of significant size begin to form approximately 3 billion years ago

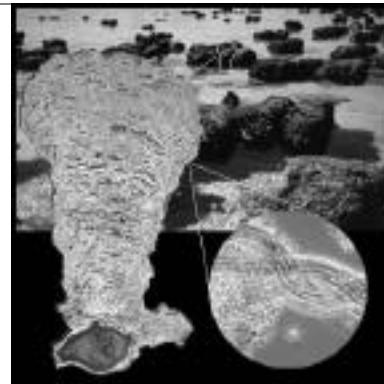


Prokaryotes

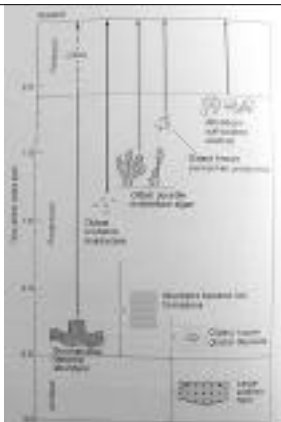
- individuals (not colonial)
- single celled
- no nucleus
- no partitions
- Originally heterotrophic (ate others)



- **Autotrophs** (organisms capable of creating their own food i.e. photosynthesis) appeared about 2 bya.
- Originally referred to as blue-green algae they are actually closer to bacteria and are photosynthetic prokaryotes



stromatolites



Proterozoic EON

- Moderate levels of oxygen in the atmosphere were reached about 2 billion years ago
- Oldest multicellular life ~1.3 bya
- Stable continents form

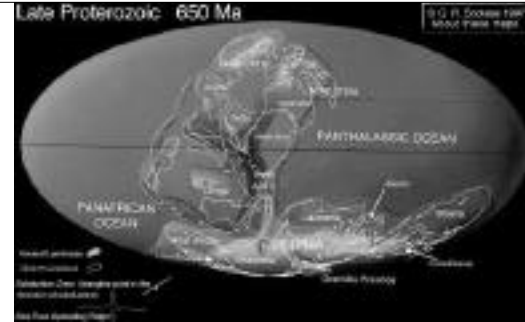
Eukaryotic Organisms

- evolved ~1.7 bya
- have nucleus and internal chambers called organelles w/ specific functions
- unicellular, colonial or multicellular
 - Introduction of Sexual Reproduction !
 - Multicellular “animal” life evolved ~670 Mya

Pangaea I ??

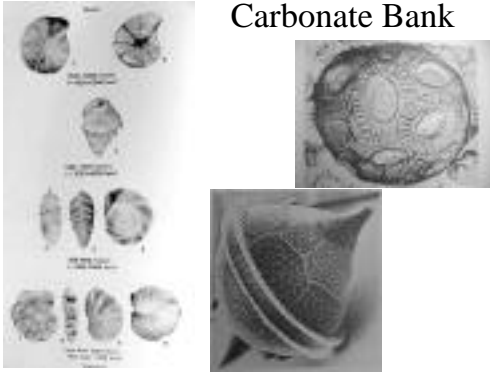


Rodinia was a supercontinent formed about 1100 million years ago (that's 1,100,000,000 years) situated about the South Pole. 750 million years ago, Rodinia broke into three pieces that drifted apart as a new ocean formed between the pieces.



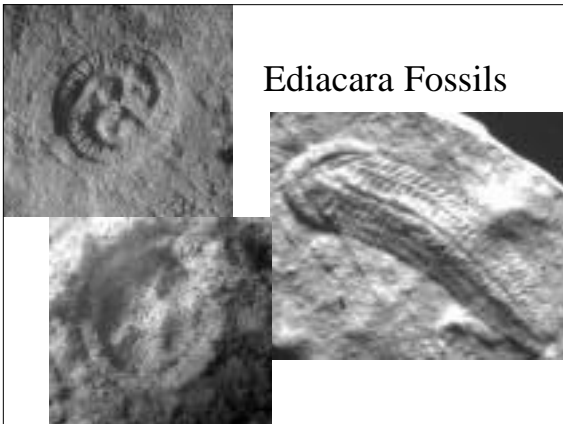
The landmasses would collide again 650 Ma to form Pannotia which would remain a supercontinent until the very end of the Precambrian when it started to break apart.

Carbonate Bank



- Most famous examples of early animal life are the Ediacara Hills Fossils - actually impressions in sandstone with no hardparts
- 670 Mya
- All softbodied organisms
 - segmented worms
 - pre-arthropods
 - jellyfish
 - shell-less mollusks

Ediacara Fossils

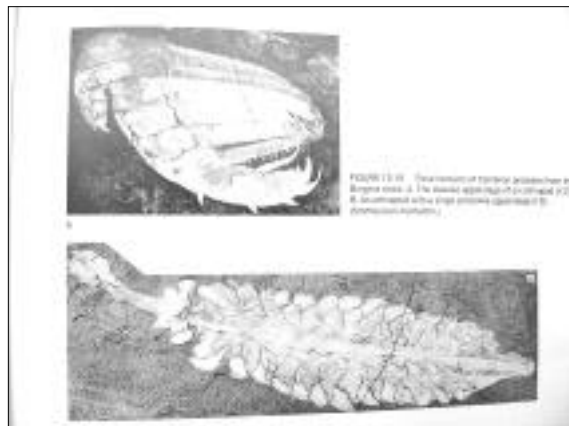
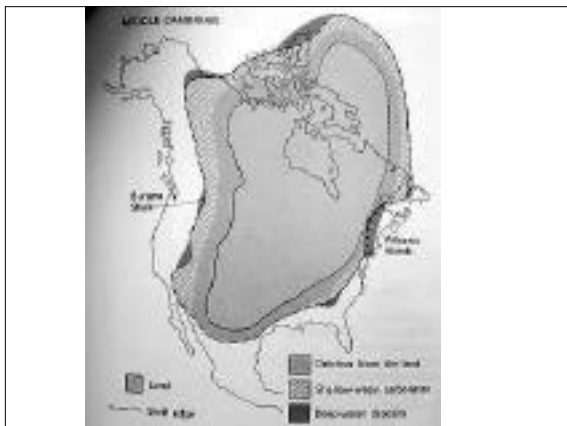
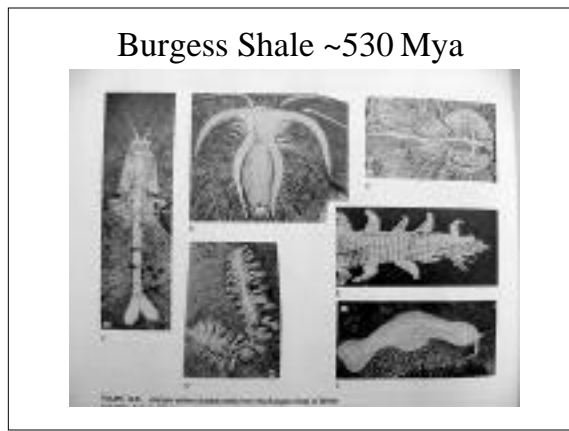
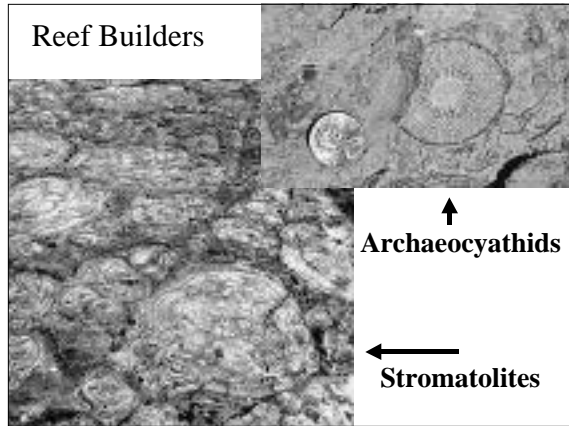


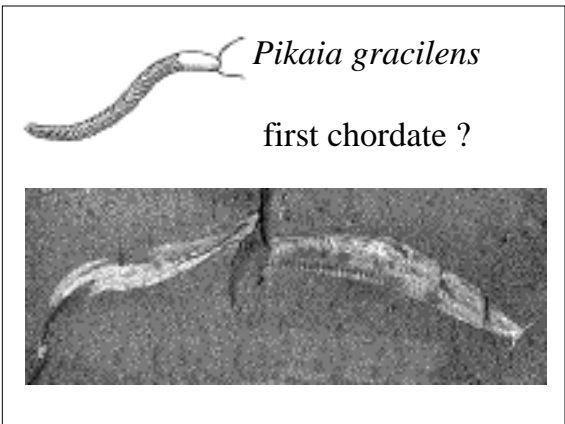
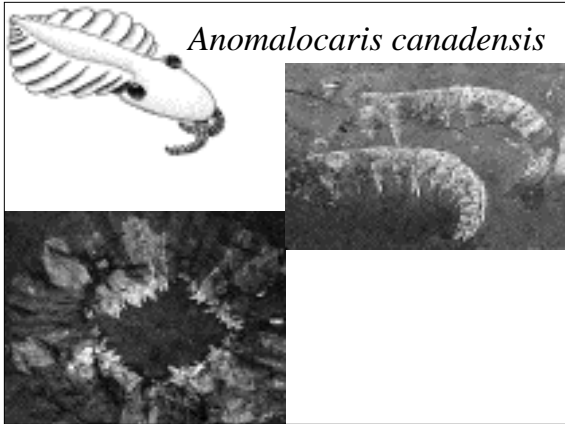
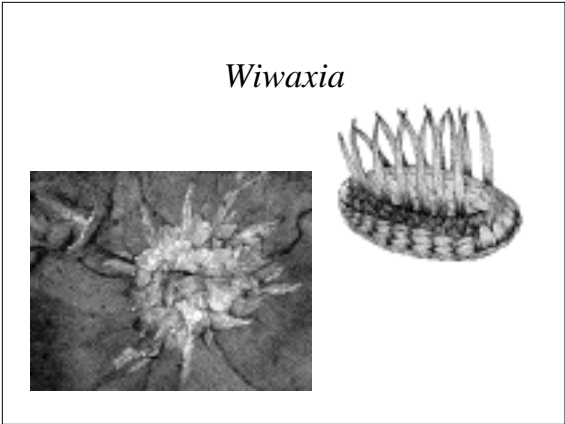
Phanerozoic Eon - Palozoic Era

- Cambrian Period - 570 million years ago
 - "Explosion of life" in the sea
 - No life on land or in the deep sea
 - Exoskeletons develop



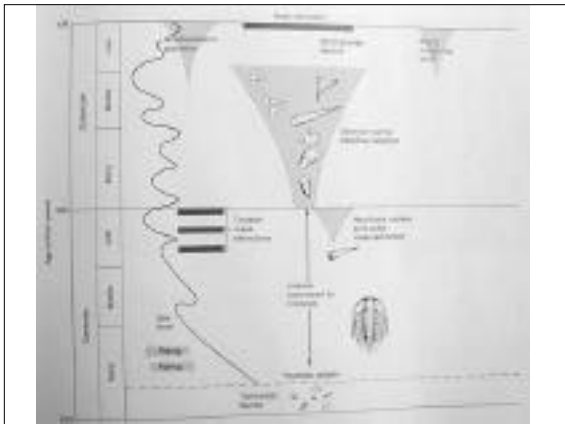
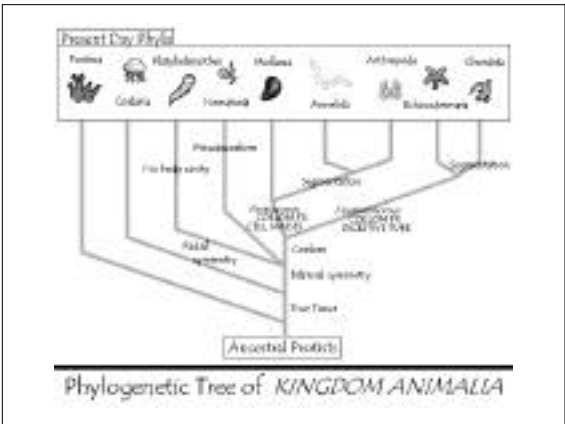
550 million years ago





- ### Chordates
- Notochord - a stiff rod or chord
 - Dorsal hollow nerve cord

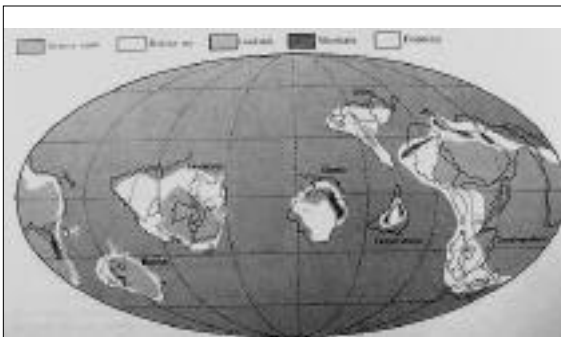
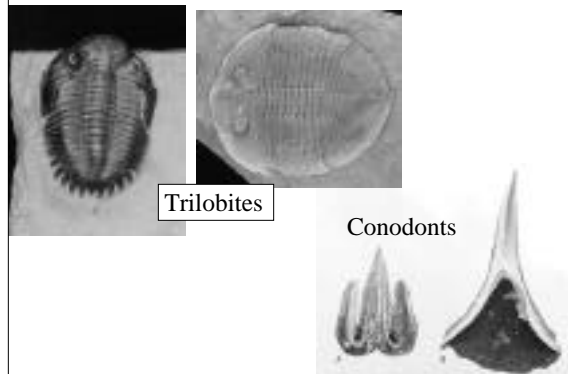
 - bilateral symmetry
 - encephalization - complex central nervous and neural material structure = brain



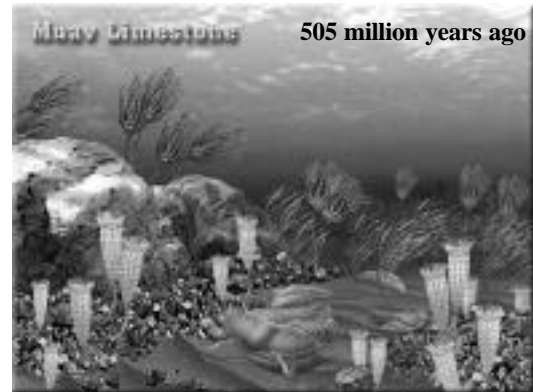
Vertebrates

- characterized chiefly by a vertebral column
- Earliest known was the conodont
- Fish also evolved during the Cambrian

Life



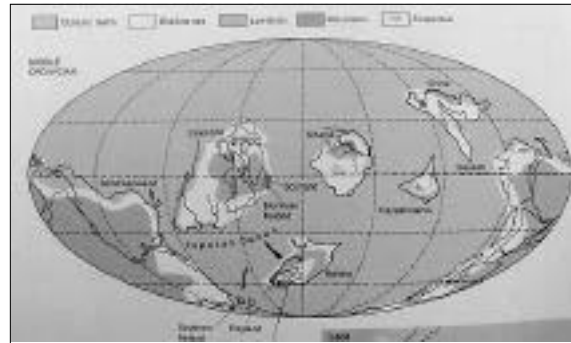
Virtually all of the major landmasses lie on or near the equator, warm temperatures, lots of evaporation



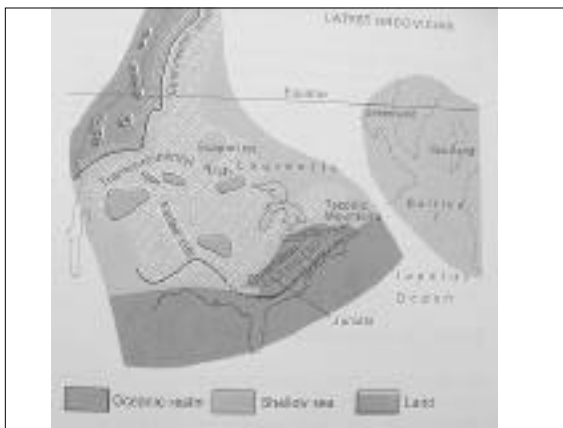
Cambrian Ended with a Mass Extinction

505 million years ago

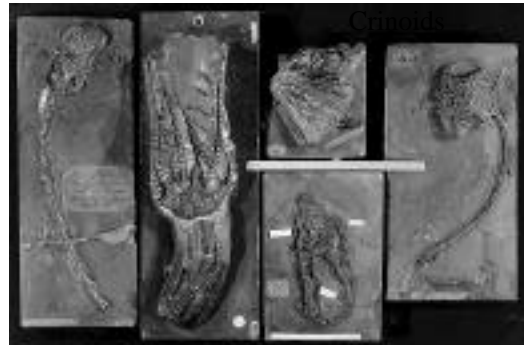
Ordovician started



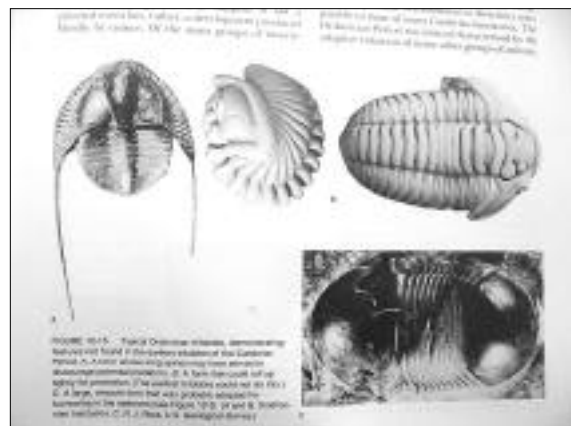
Laurentia (still missing Europe) located on the equator in tropical to sub-tropical zone - **widespread flooding of cratons**



Ordovician Life



Brachiopods

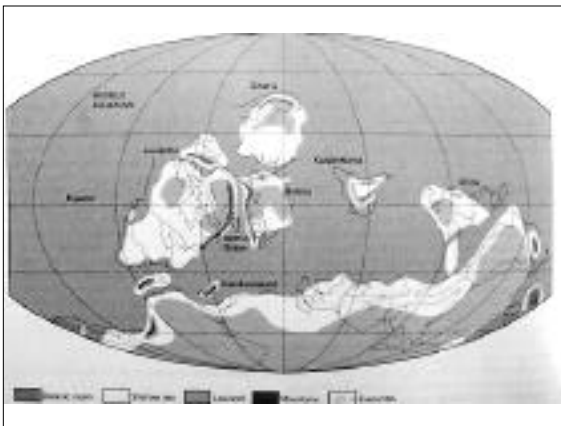


Predators

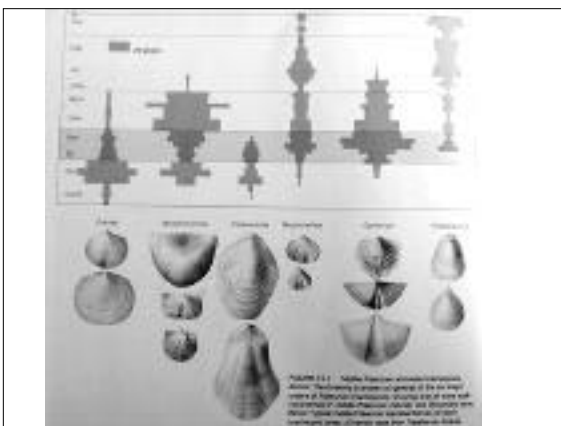
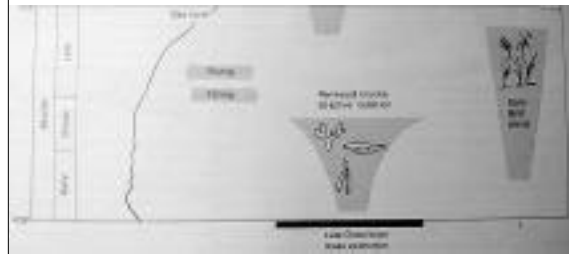


Ordovician ends with
another mass
extinction
climate gets much colder

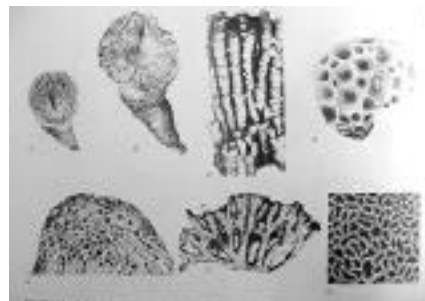
438 million years ago
Silurian Starts

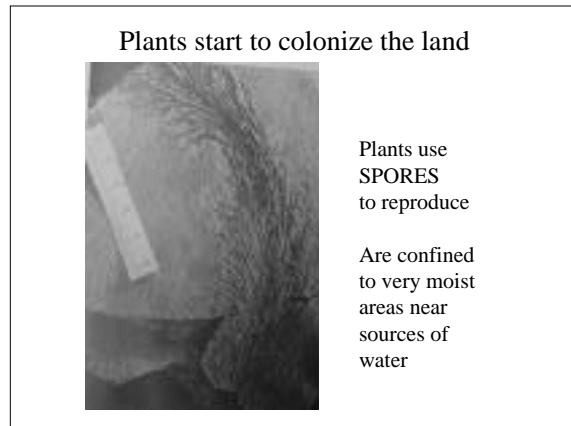
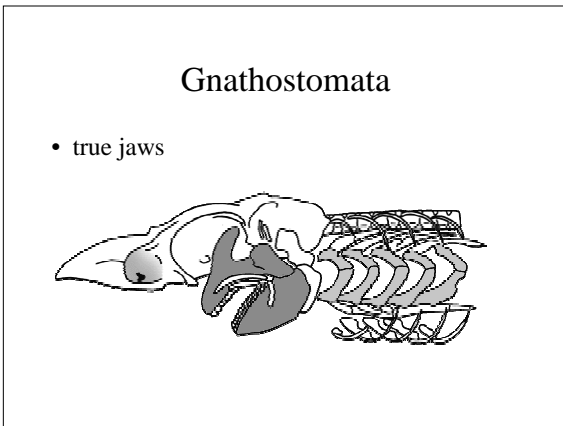
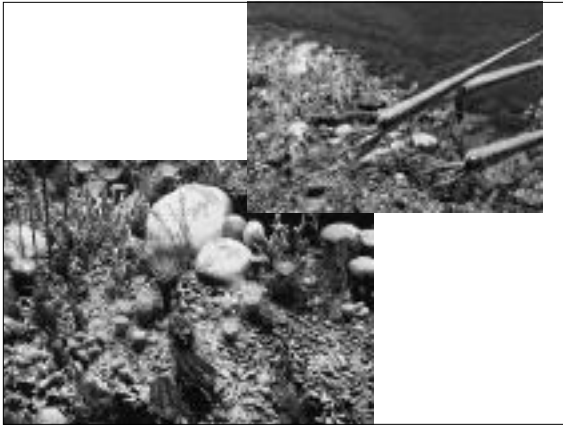


Silurian Life



Rugose Corals and Bryozoans new reef builders



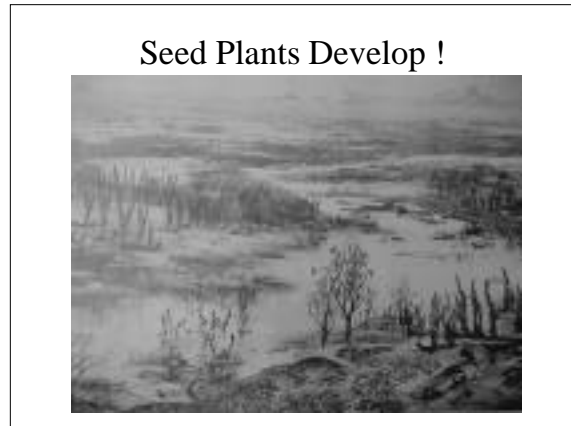
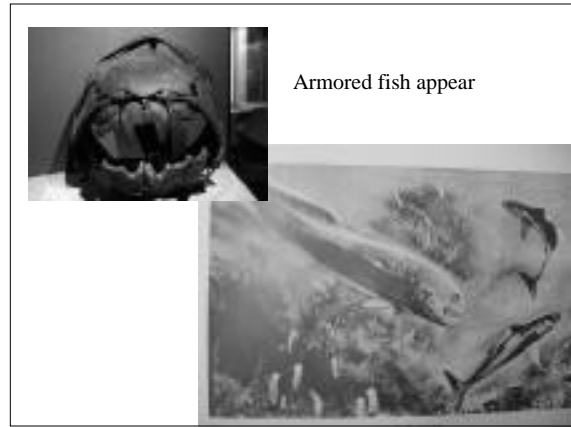
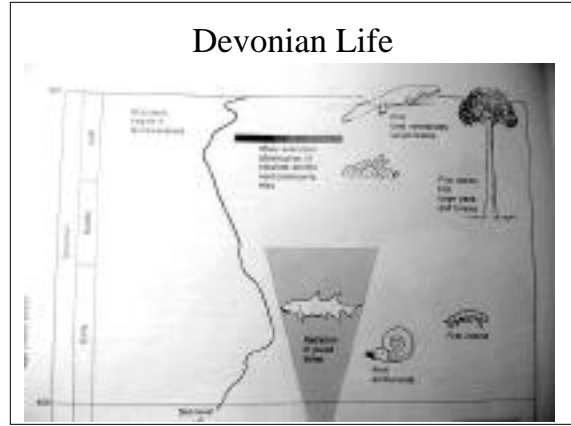
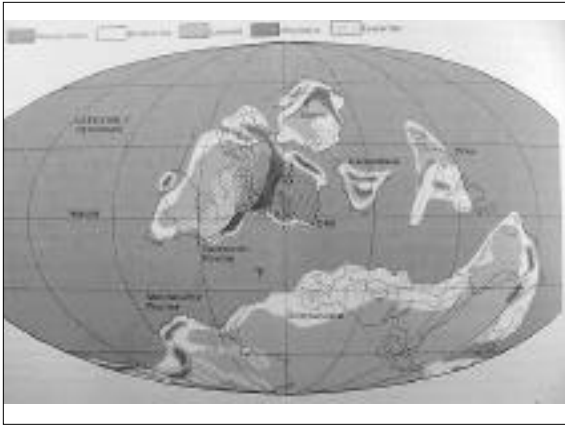


Silurian Period

- Oceans high - most land flooded - partial glacial melting in Gondwanaland

Silurian ends without a
big mass extinction
and 408 million years ago

Devonian Starts



Fish

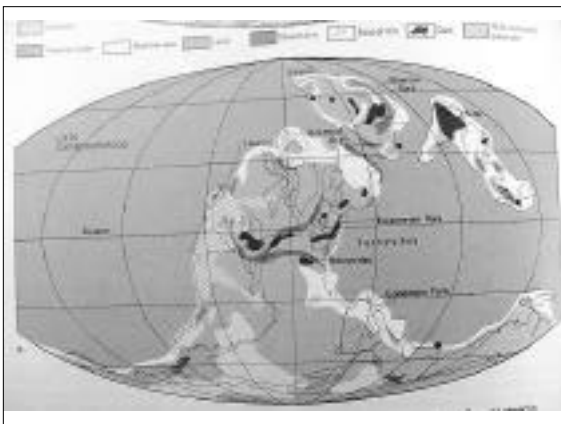
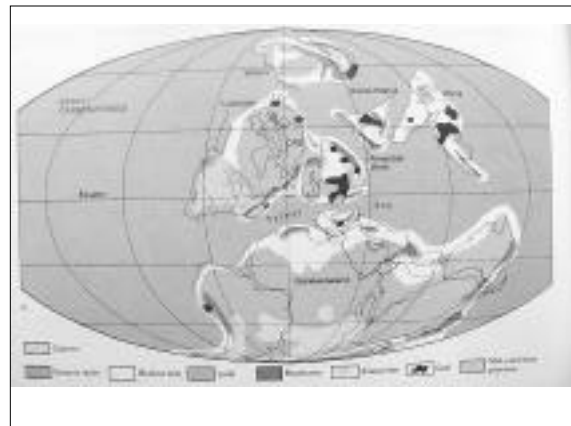
- Chondrichthyes - cartilage fish (sharks)
- Osteichthyes - bone fish
 - Actinopterygii - ray finned fish (look in a fish tank)
 - ☆ – Sarcopterygii - lobe-finned fish (lungfish, coelocanths and eventually tetrapods !)

- The oldest known skeletal remains of terrestrial vertebrates were found in the Upper/Late Devonian

Devonian Ends with Laurentia
attached to Baltica

360 million years ago

Carboniferous Starts



- **Tetrapods** originated no later than the Mississippian (about 350 million years ago), the period from which the oldest known relatives of living amphibians are known.
- The oldest **Amniotes** currently known date from the Middle Pennsylvanian

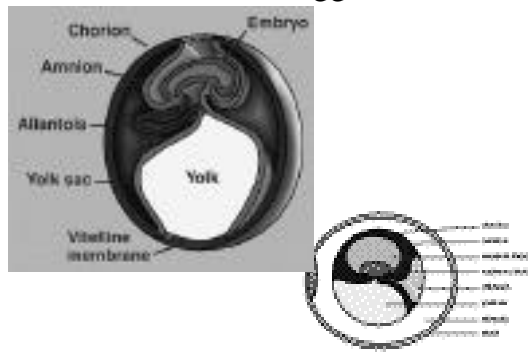
Tetrapods

- four feet
- modified vertebrae (processes etc)
- limbs all have single upper bone and lower paired bones
- the general body plan that we discussed last week

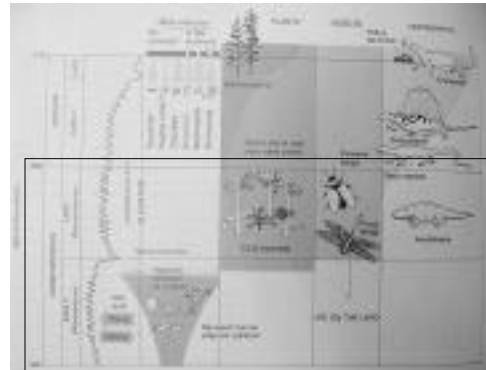
Amniota

- The amniotic egg possesses a unique set of membranes: amnion, chorion, and allantois. The amnion surrounds the embryo and creates a fluid-filled cavity in which the embryo develops. The chorion forms a protective membrane around the egg. The allantois is closely applied against the chorion, where it performs gas exchange and stores metabolic wastes (and becomes the urinary bladder in the adult). As in other vertebrates, nutrients for the developing embryo are stored in the yolk sac, which is much larger in amniotes than in vertebrates generally.

Amniotic egg



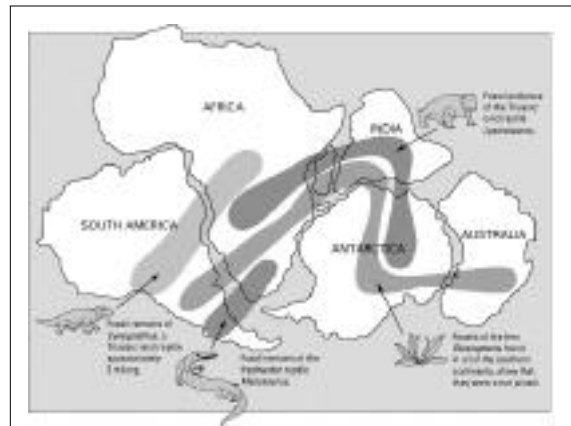
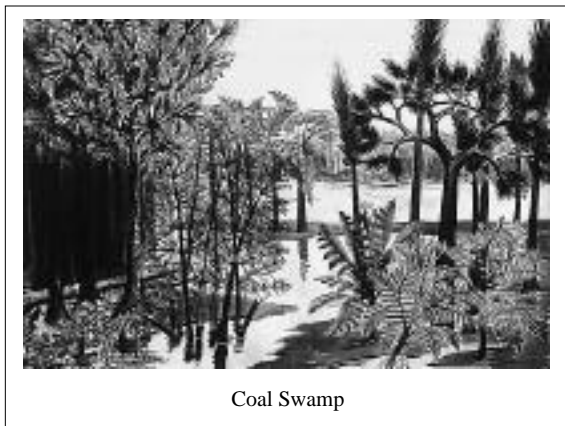
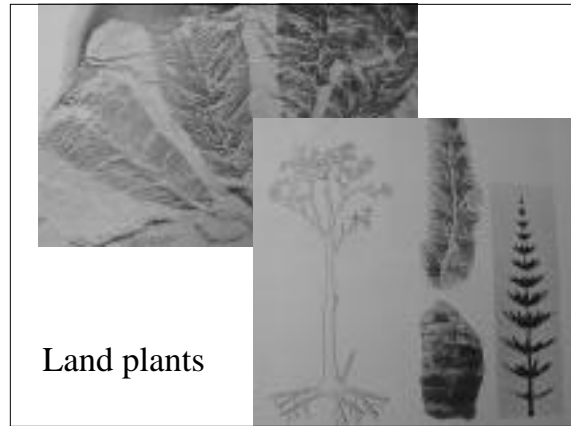
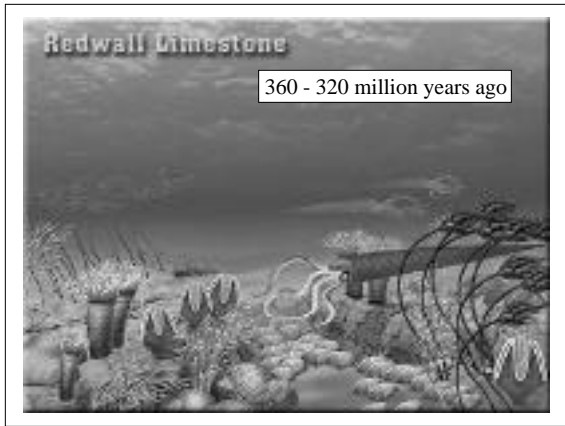
Carboniferous Life



The move onto land !

Amphibians



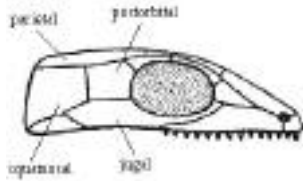


Great Split

- Between 310 and 320 million years ago the Amniotes split into two groups characterized by skull morphology
 - Synapsida
 - Reptillia

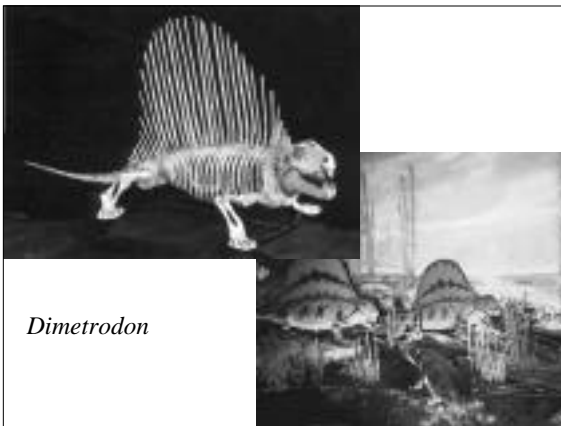
Anapsida

primitive condition - solid cheek bones



Synapsida

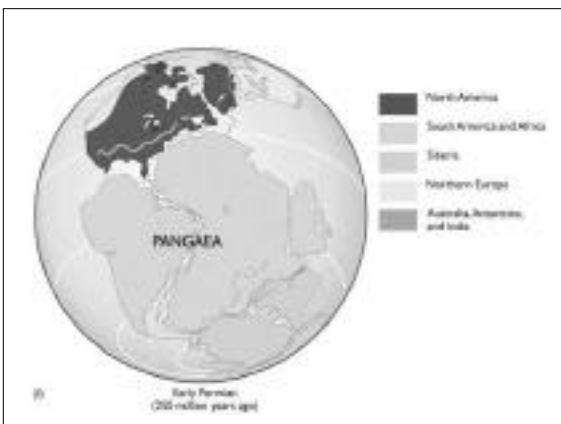
- skull roof has developed a low opening (fenestra) behind the eye - the lower temporal fenestra

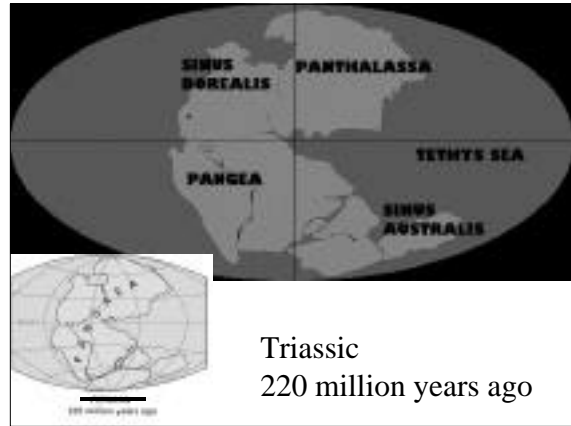
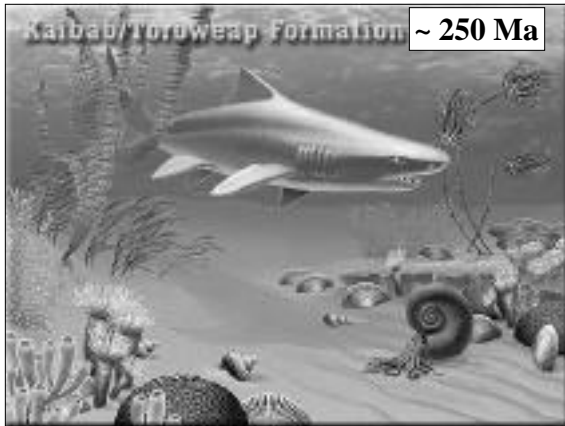


Dimetrodon

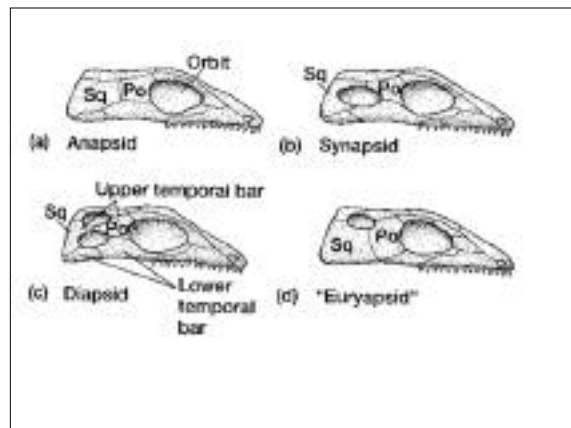
Permian 286 - 245 mya

- Pangaea fully formed - southeast Asia attached too
- World wide sea-level drop continues
- Global cooling
- Synapsids radiating over terrestrial plane
– (ancestors to mammals)

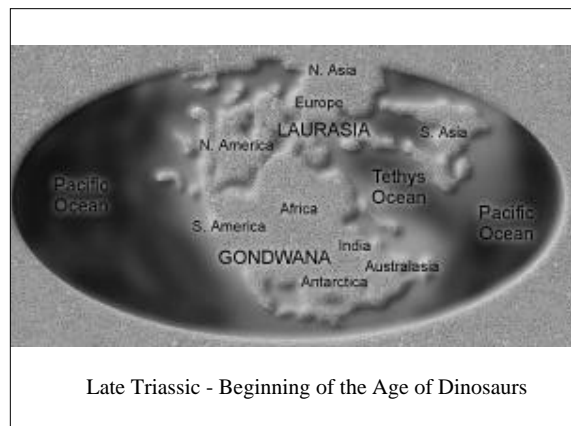




- ### Triassic
- Synapsida dominant terrestrial vertebrate
 - The other branch of the Amniotes is Reptilia
 - Anapsid
 - Diapsida
 - Lepidosauromorpha (lizards and snakes)
 - Archosauria (crocodiles, dinosaurs, pterosaurs, birds)

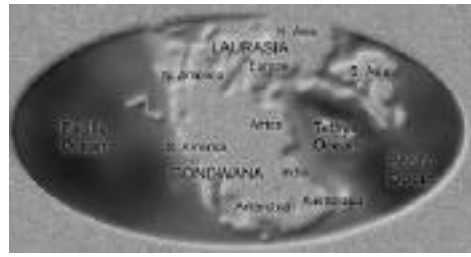


- ### Late Triassic
- All Continents still together in Pangaea
 - No Polar Ice Caps
 - Warm and generally stable climate
 - Might have been highly monsoonal
 - Dinosaurs first appear as do mammals, turtles, and pterosaurs
 - Shallow warm seas
 - Land plants seed ferns, conifers, ginkgoes
 - ➔ Gymnosperms



Early/Middle Jurassic

- 208 - 157 Ma
- Dinosaurs became the largest, most successful terrestrial group
- Pangaea was breaking apart
- Huge deserts in parts of Pangaea
- still gymnosperms - seed ferns gone
- Large amphibians gone



Early Jurassic



Middle Jurassic
190 million years ago

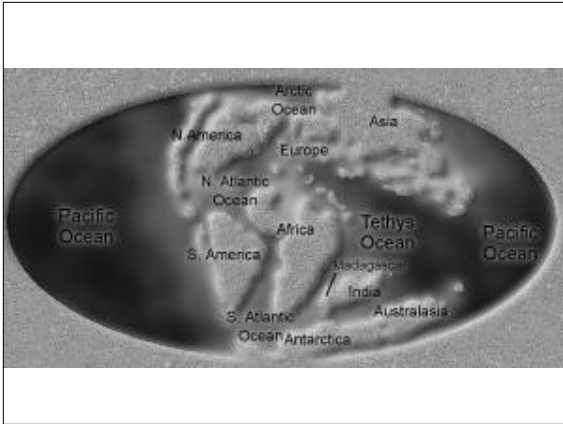
Late Jurassic

- Golden Age of Dinosaurs
- largest dinosaurs
- Laurasia and Gondwana totally separated by Tethys Sea
- warmer and wetter climate



Early Cretaceous

- 145 - 100 Ma
- profound change
- world wide sea level rise
- flowering plants appear - angiosperms
- Gondwana breaks up
- temperate - low gradient



136 million years ago

Middle to Late Cretaceous

- 100 - 65 Ma
- Gondwana is split and Laurasia is breaking up
- sea-level at a high
- temperate - “wall to wall Jamaica”
- hot and wet greenhouse
- flowering plants dominate land
- very different dinosaurs



65 million years ago



Present