Announcements

- Final Exam Wednesay morning 12/14
  - More reviews during scheduled sections tomorrow.
- The exam covers all lectures, readings, and lab material
- ***Bring 2 pages of notes, pencil, eraser***

Life in the Universe

Stranger than Cosmology!

Topics

- When and how did life arise on Earth?
- What are the necessities of life?
- Life in the Solar System
- Life Around Other Stars
- Searching for Life (Thursday)

Brief History of Life

- 4.4 billion years - early oceans form
- 3.5 billion years - cyanobacteria start releasing oxygen.
- 2.0 billion years - oxygen (plant respiration) begins building up in atmosphere
- 540-500 million years - Cambrian Explosion
- 225-65 million years - dinosaurs and small mammals (dinosaurs ruled)
- Few million years - earliest hominids
- http://www.youtube.com/watch?v=[illegible]
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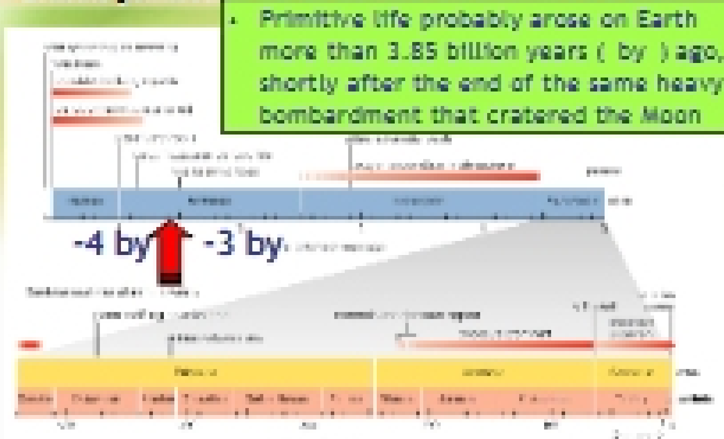
When did life arise on Earth?

Within the first billion years — or perhaps less since delicate primordial life forms may not have left a record.

- Primitive life probably arose on Earth more than 3.85 billion years (by) ago, shortly after the end of the same heavy bombardment that cratered the Moon

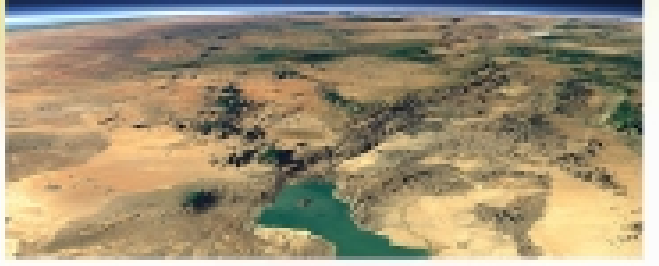


Earliest Life Forms

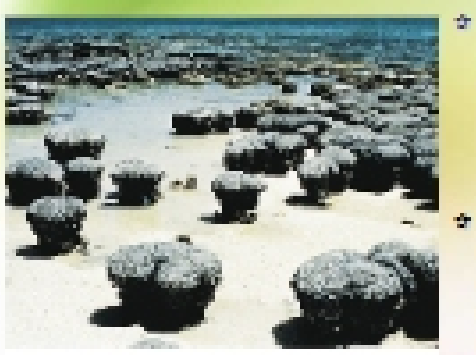
- Bombardment era: extreme conditions, too hot, dark, unsettled, no water, too much atmospheric acid…
- Life requires a bit of time and stable, gentle environment so that the necessary complex chemistry can be productive
- ➔ If Earth is indicative, primitive life arrives quickly (0.7 by?) once conditions are stable

Fossils in Sedimentary Rock

- deeper layers containing fossils are thrust upward by tectonics.
- Look for fossils in sedimentary rocks formed in water, not basalt

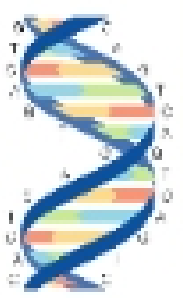


Earliest Fossils



- Oldest fossils show that bacteria-like organisms were present over 3.5 billion years ago
- Carbon isotope evidence pushes origin of life to more than 3.85 billion years ago

The Chemistry of Life on Earth: Step 1: DNA!

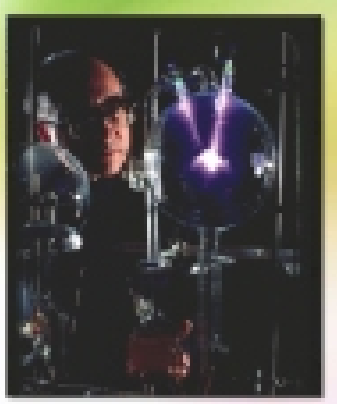


- DNA is incredibly complex. A full understanding of its first formation has not (yet) emerged.

Some claim DNA is highly unlikely to be a chemical accident. It must have been 'designed' somehow.

If unwound, a single DNA molecule is about 2 meters long. All the DNA in your body would reach beyond the Moon!

Laboratory Experiments



- The Miller-Urey experiment (1950s, and many recent experiments) show that simple building blocks of life (amino acids) form easily under conditions of early Earth.
- Making DNA? The path isn't known.
- Require lots of time for "mistakes" to happen

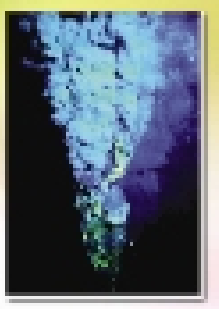
Necessities for Life

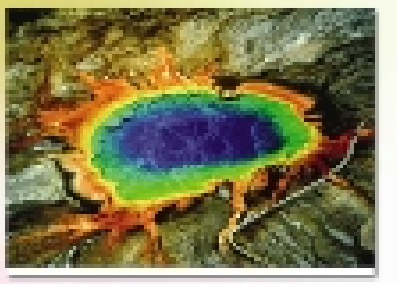
- Nutrient source (e.g., carbon, calcium)
- Energy (sunlight, chemical reactions, internal heat)
- Liquid water (or possibly some other liquid) for gentle assembly of big molecules

Great way to identify potential life-bearing planets

Primitive Life on Earth

- resembled the heat-loving bacteria today near deep ocean volcanic vents (black smokers) and geothermal hot springs.



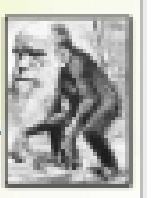


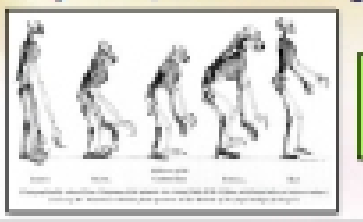
Origin of Oxygen

- Cyanobacteria paved the way for more complicated life forms by releasing oxygen into atmosphere via photosynthesis

Then assemble DNA into ever more complex organisms

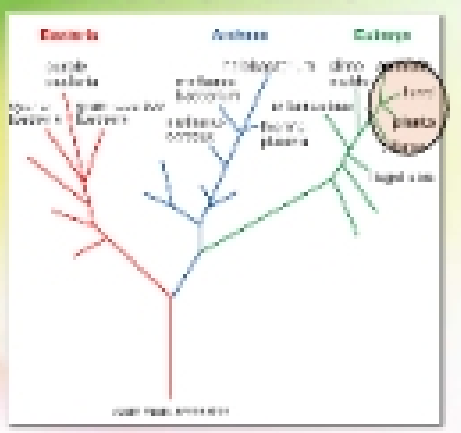
- The fossil record shows that evolution has occurred through time.
- Darwin's theory suggests HOW evolution occurs: through natural selection.
  - evolution proceeds through mutations. The best adapted succeed at the expense of their competitors, so evolution is gradual.



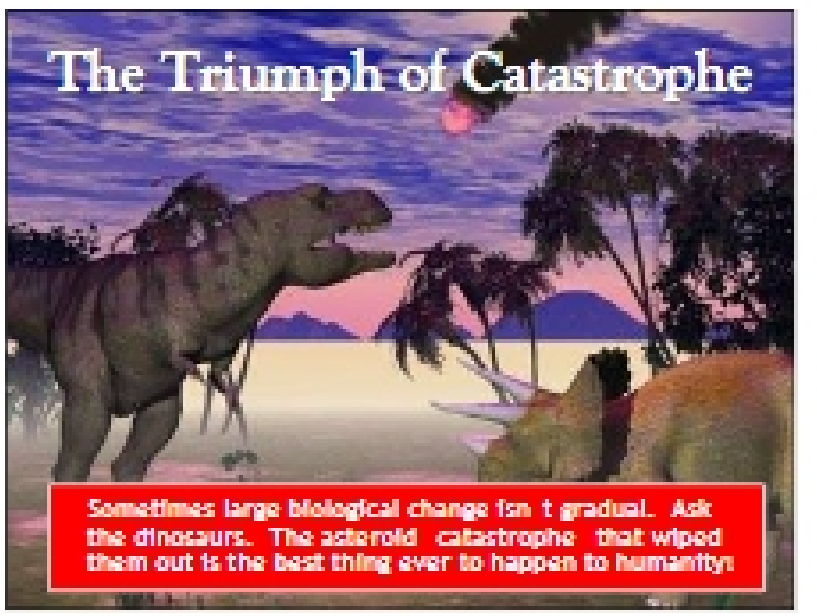


Biological Capitalism!

Tree of Life



Evolution: Life climbs the branches



Life in the Solar System

- Could there be life on Mars?
- Why not Mercury and Venus?
- Could there be life on Europa or other Jovian moons?
- Where should we look first? What strategy?