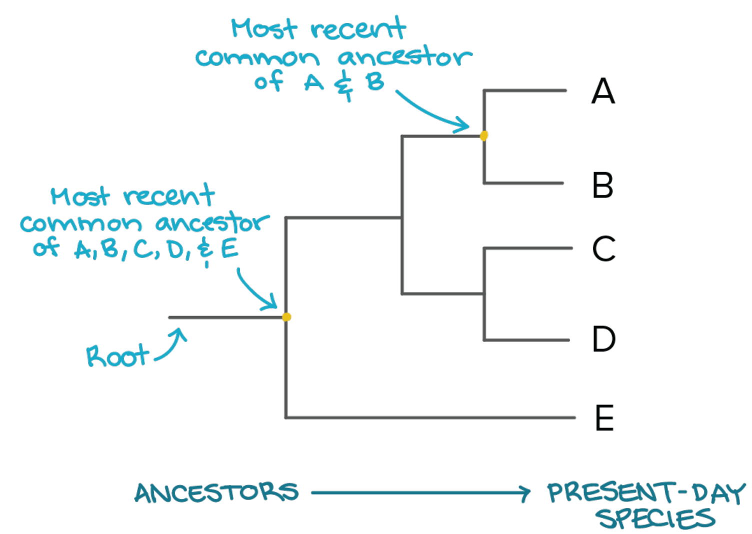
Molecular clock

- How do we estimate the time of divergence of two lineages?
- Molecular clock studies use both fossil and molecular data

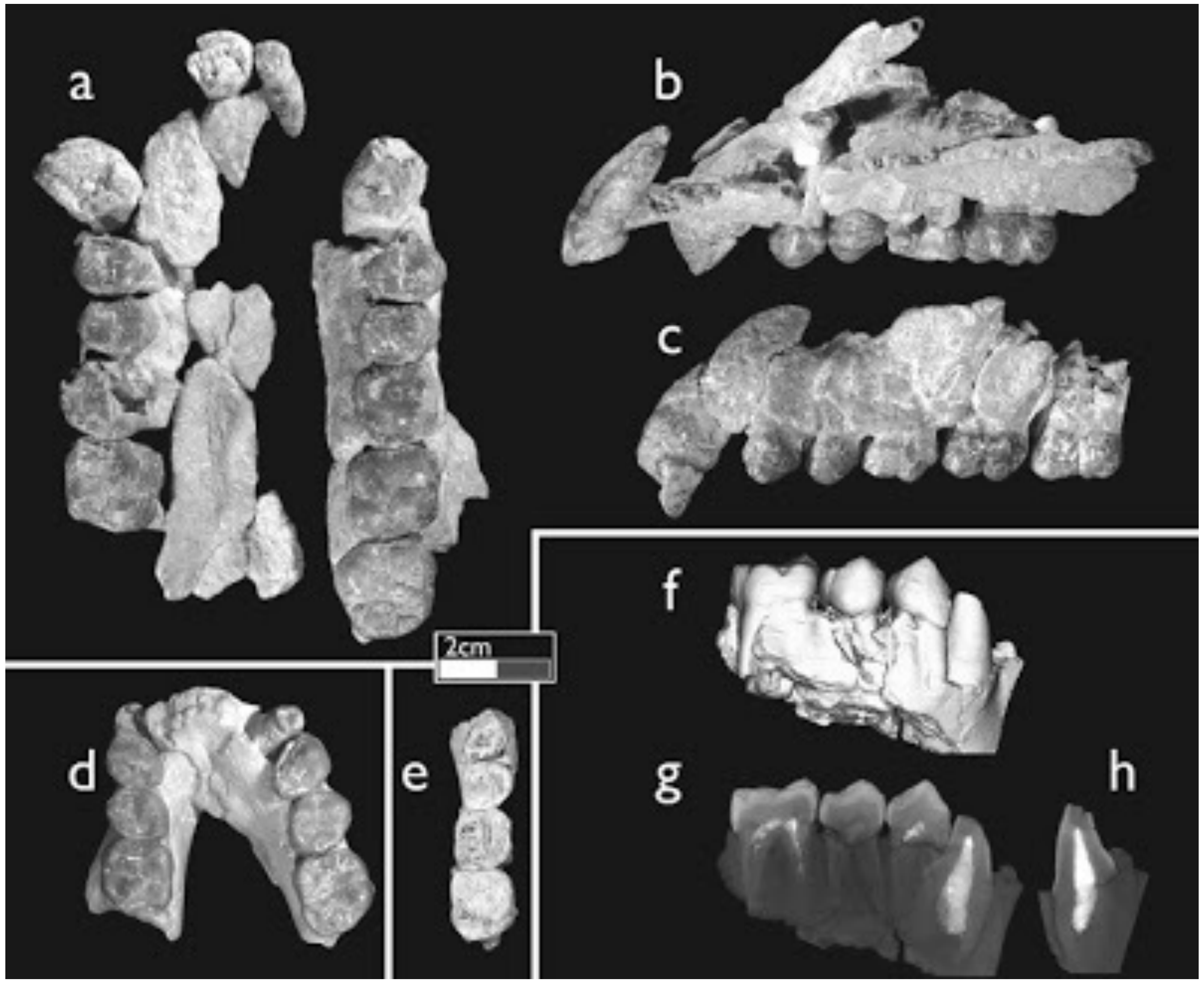


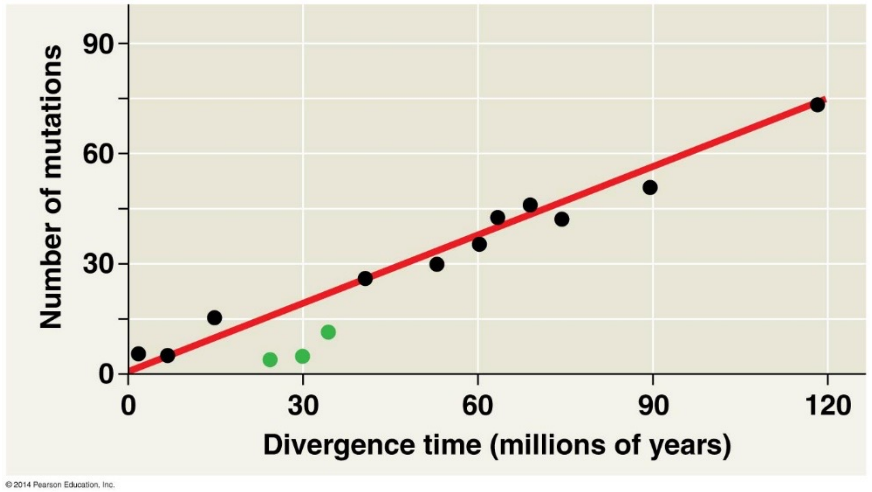
Molecular clock

- Some parts of the genome will accumulate changes (mutations) at a relatively steady rate
- The speed of accumulation depends on the part of DNA under study (some fast, some slow)
- The "clock" is calibrated using the fossil record (e.g. orangutan fossils have been securely dated for apes), or the accumulation of mutations over generations

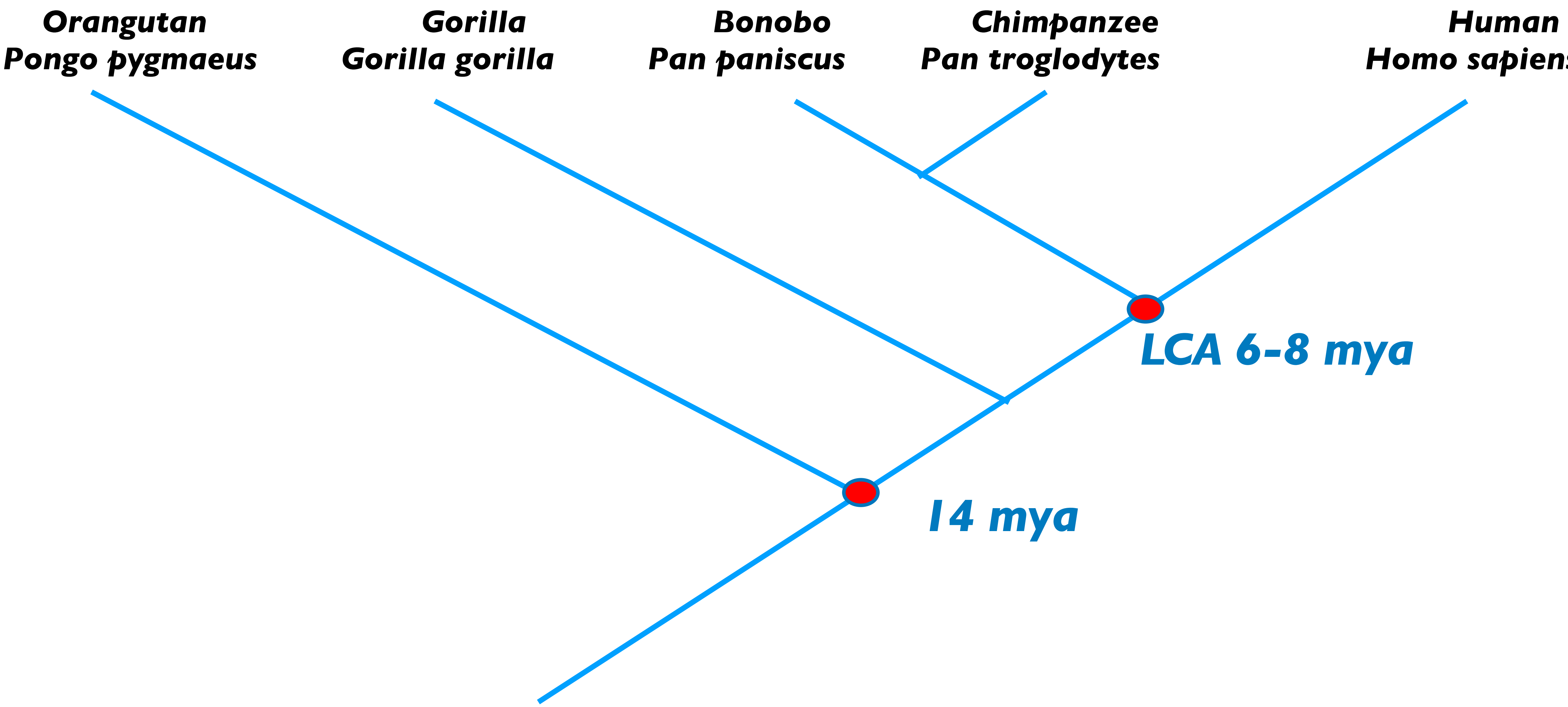
orangutan-

like fossils





Molecular clock

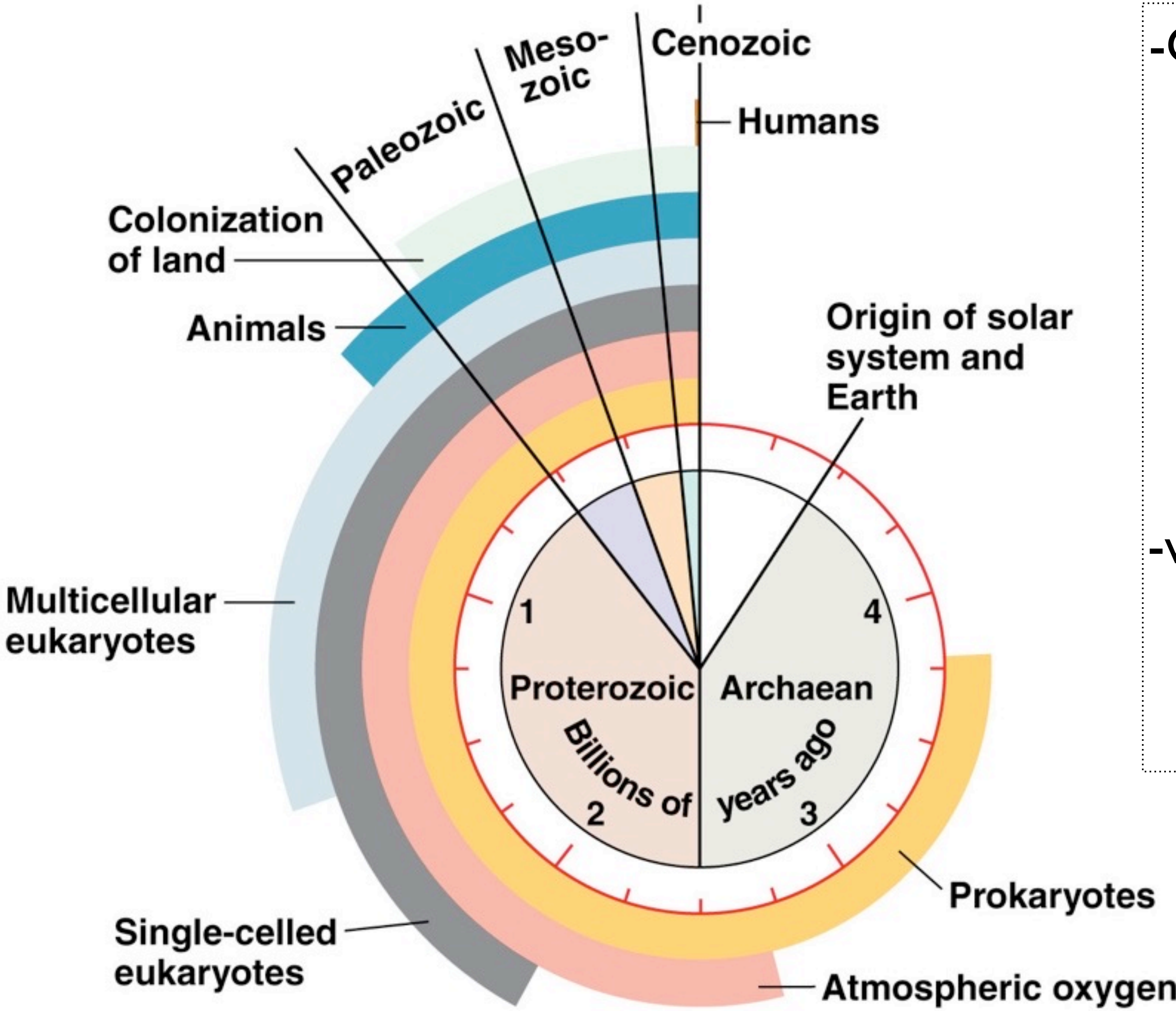


-By using the known age of the orangutan split, plus info on orangutan DNA, we know the rate of mutations in certain parts of the ape genome

- Count known differences in DNA between humans and chimps

-The data indicates a date of the split between *Pan* and *Homo* at about 6-8 mya

Studying the origin of life poses some unique problems



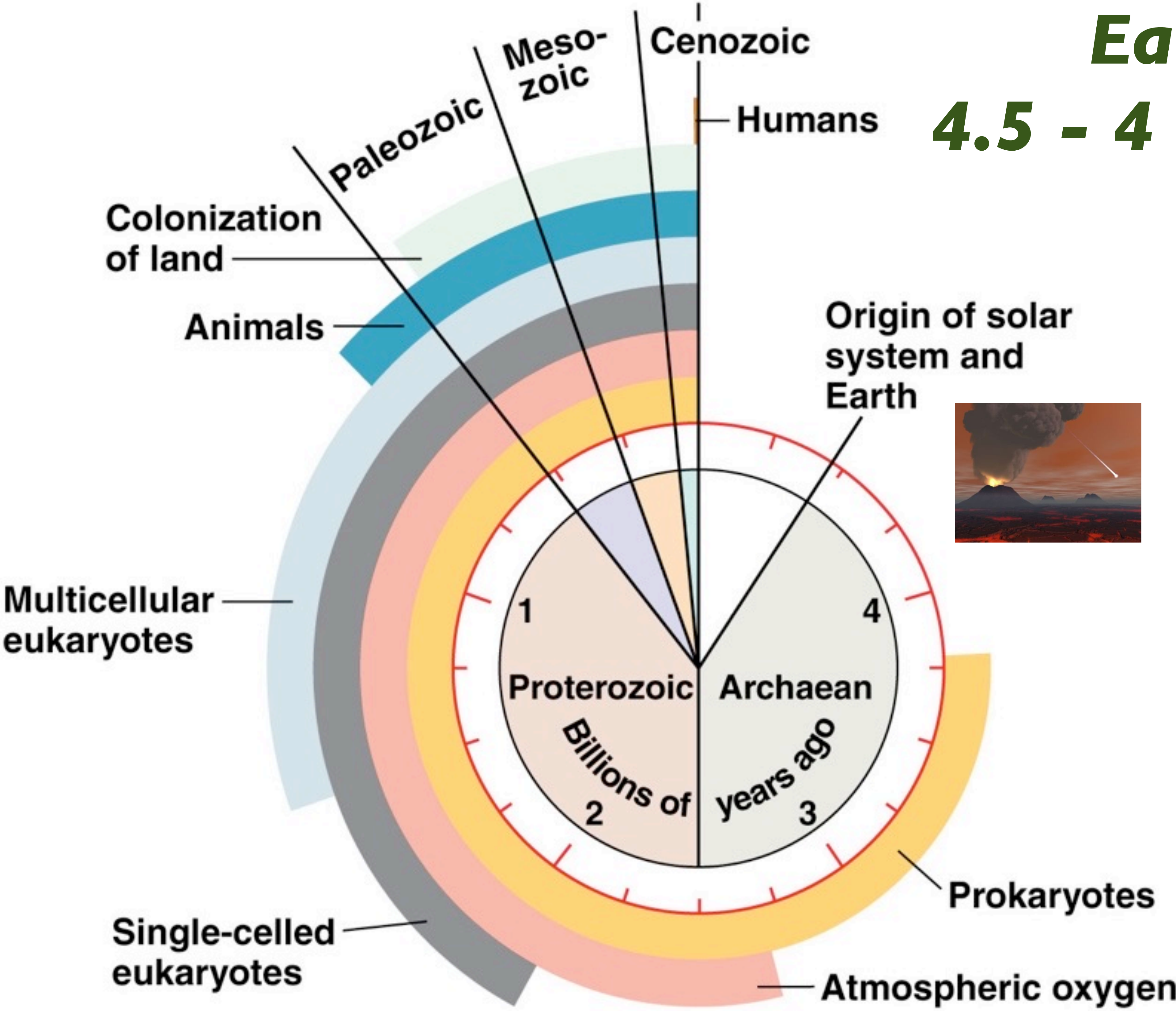
-Organic molecules do not form fossils

-when did it occur?

-Earth is 4.5 billion years old

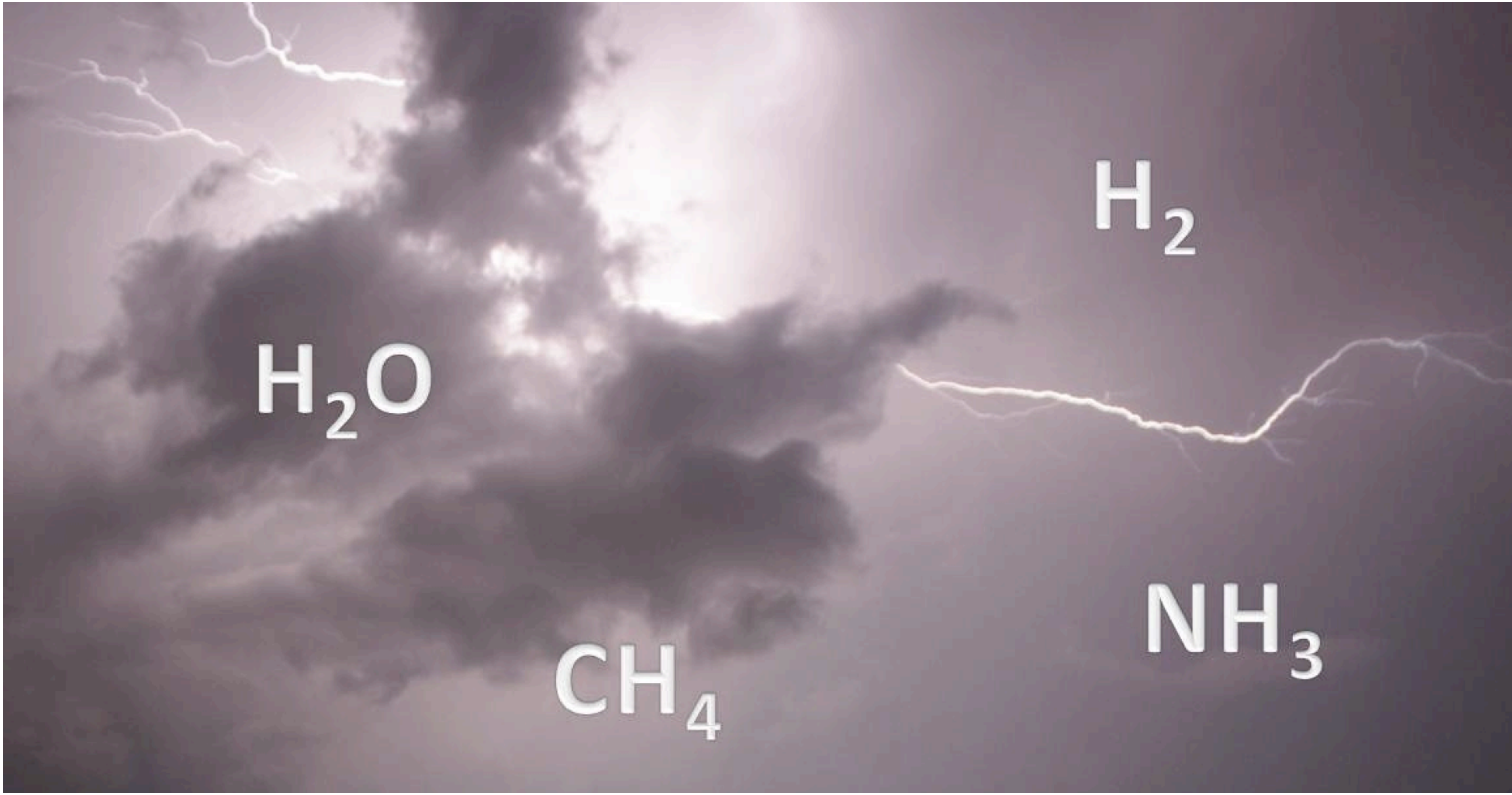
-we know prokaryotes were around 3.5 billion years ago or more

Early Earth
4.5 - 4 bill. years ago



Early Earth:
Hadean, 4.5 - 4 billion y.a.

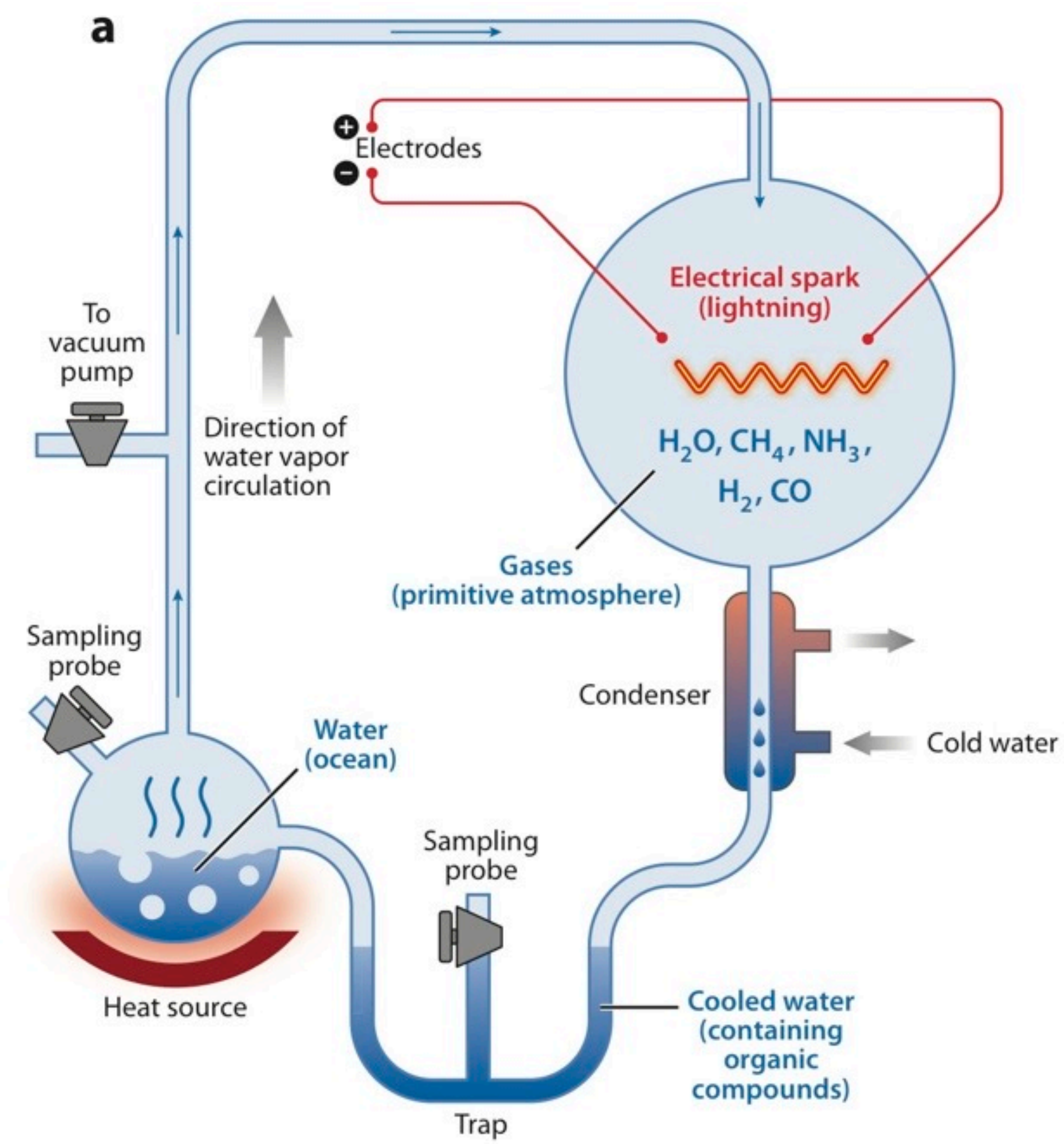
-A lot of volcanism, meteors
-Gradual cooling ca 4 bill. y.a. ; water condenses and forms oceans



- The early atmosphere had little to no oxygen
- Water, nitrogen, carbon dioxide, ammonia, hydrogen
- Lightning and UV light could have provided energy for the spontaneous production of organic molecules
- Early oceans might have been a "primitive soup" of simple organic molecules

“Primitive soup” hypothesis

Stanley Miller



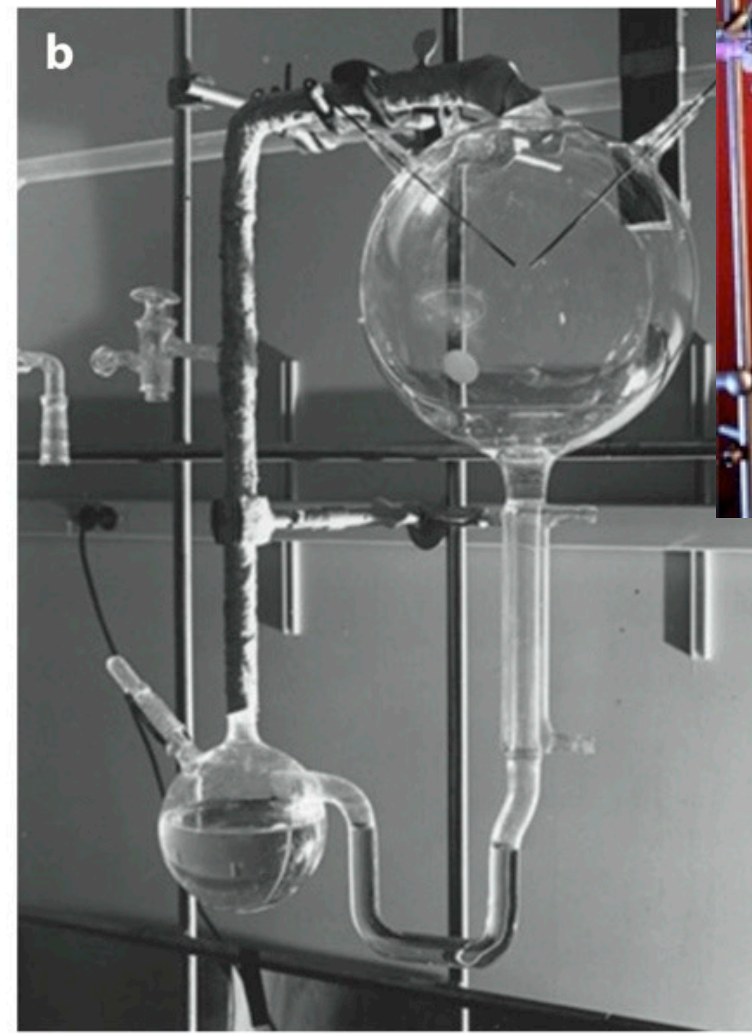


Figure 1

The spark-discharge apparatus used in the Miller-Urey experiments. (*a*) Schematic drawing of the apparatus. (*b*) Photo of the apparatus taken by Stanley Miller (image courtesy of Jeff Bada).

*-Today’s atmosphere is **oxidizing***

*-**Miller & Urey** made an experiment with a hypothetical early atmosphere (**reducing**) to see if organic molecules could be produced*

-in this model, a major source of energy is from lightning (and the sun)

- Chromatography ***showed that very simple compounds had now turned into larger organic monomers (in this case, amino acids)***

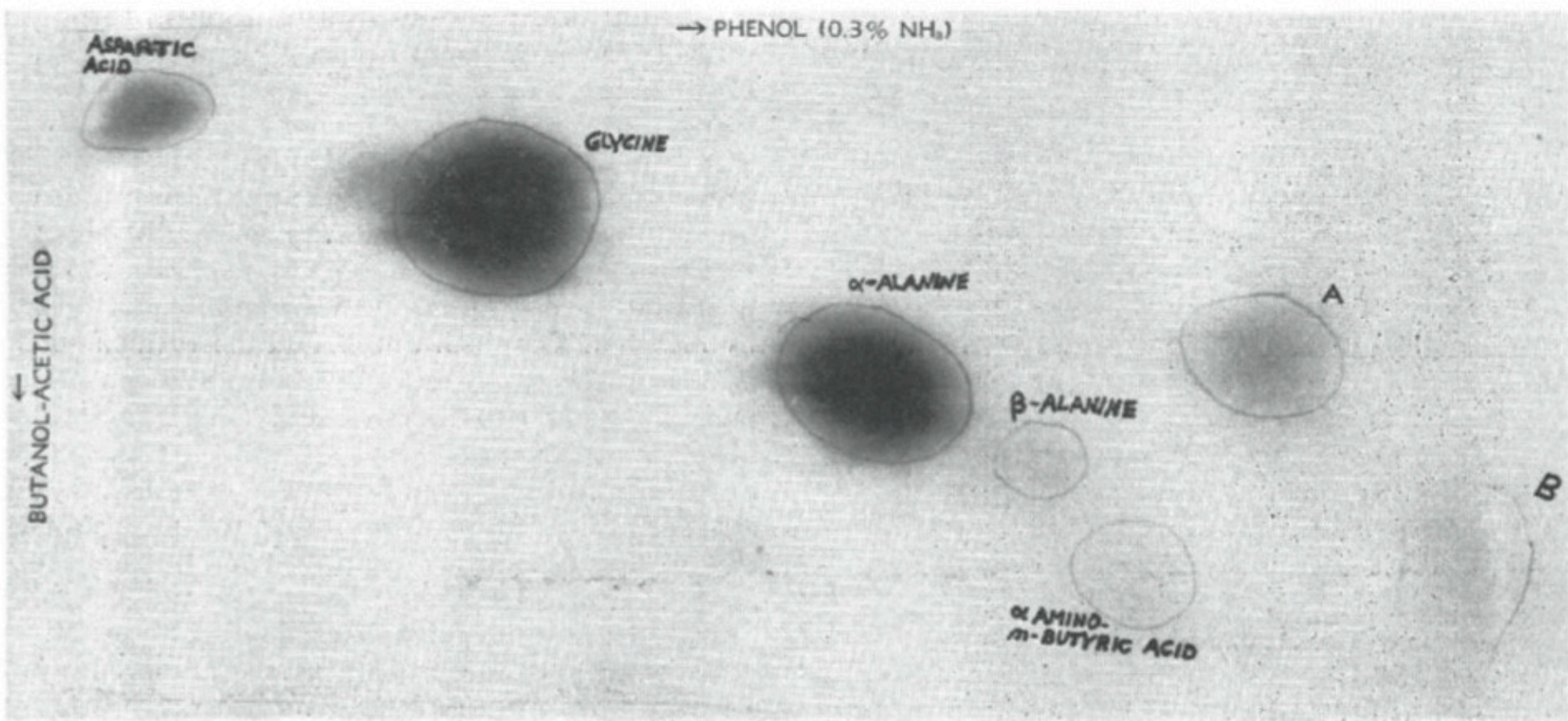


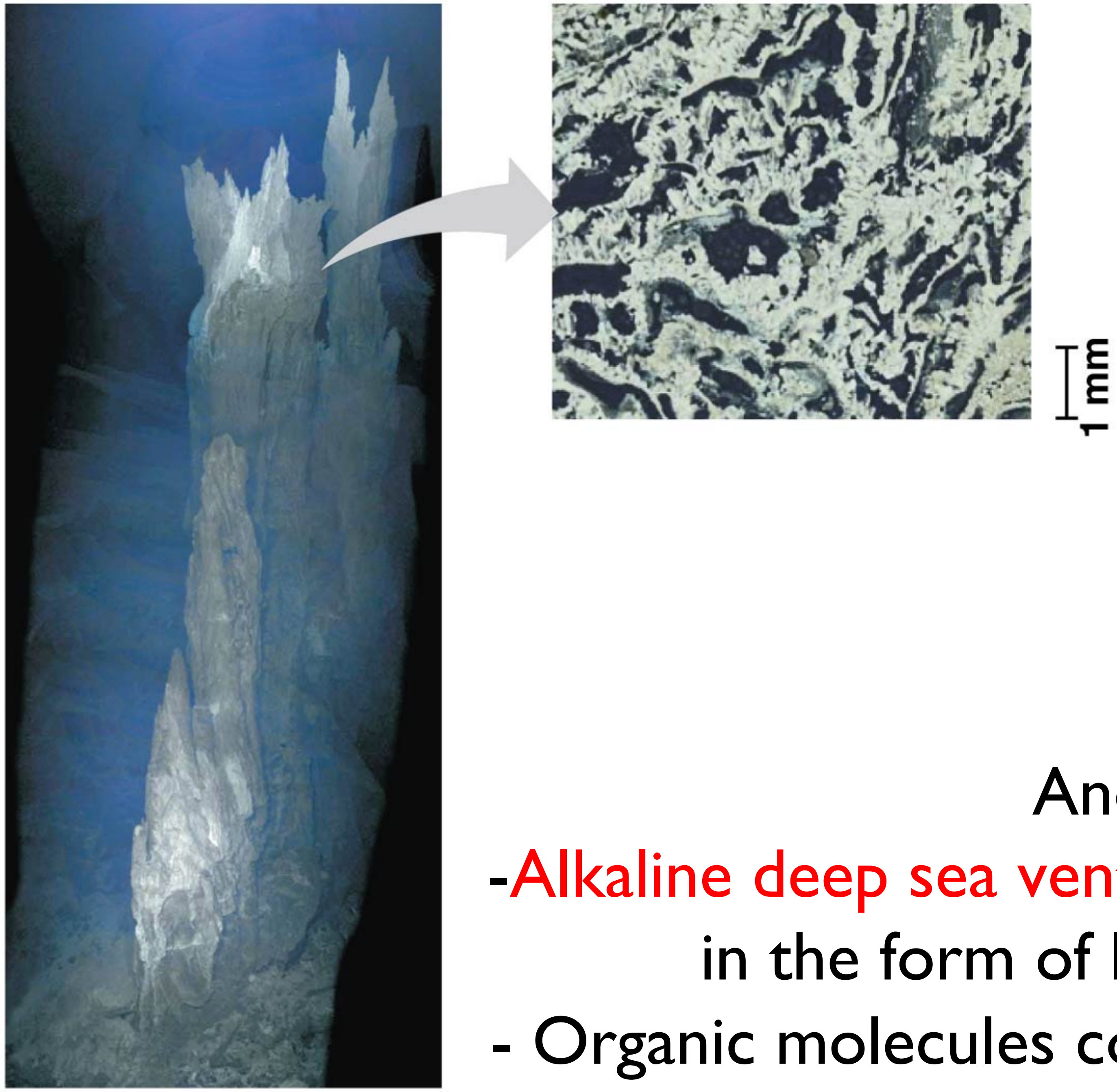
Figure 2

Two-dimensional paper chromatograph used to identify amino acid products from the Miller-Urey experiments. The primary products are glycine and α-alanine. From Miller (1953); reprinted with permission from AAAS.

-Amino acids were produced in this "primitive" reducing environment

-Others have later shown that other hypothetical atmospheric compositions (neutral) could do the same – and also produce RNA monomers and fatty acids

Deep sea vent hypothesis



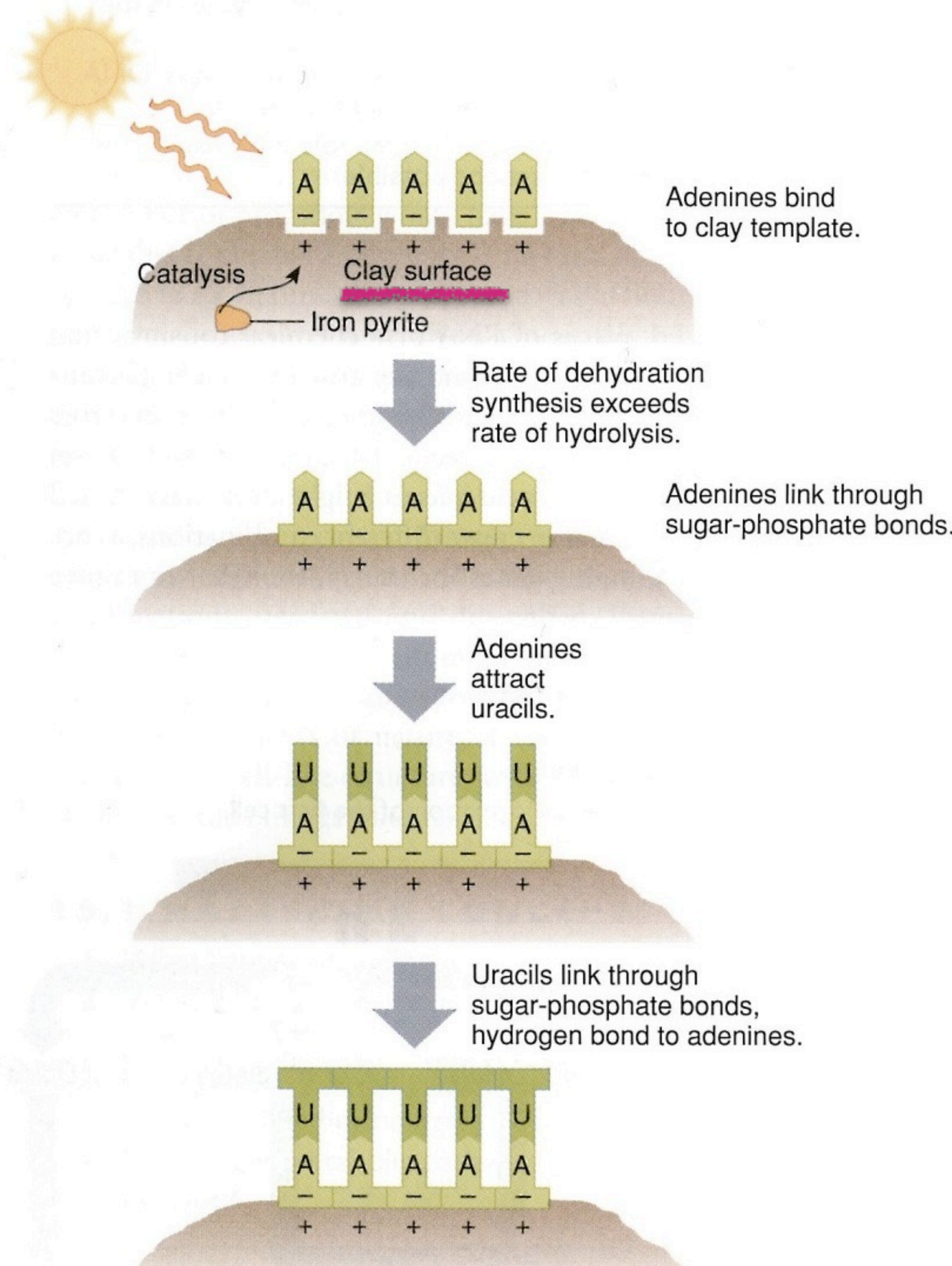
Another idea:

-Alkaline deep sea vents could have provided energy in the form of heat and a pH gradient

- Organic molecules could have formed in the pores of the vent

Volcanic clay hypothesis

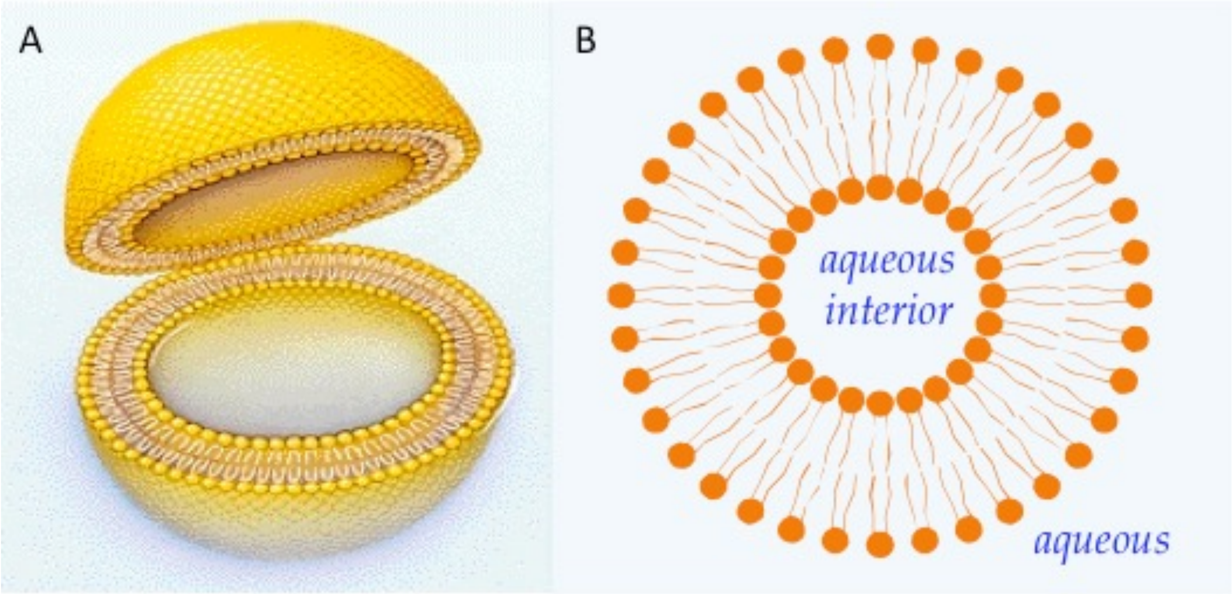
- Volcanic clays + sun energy can also induce polymerization of macromolecules e.g. RNA



In either case, at some point, protocells with membranes must have formed

Packaging of molecules into "***protocells***"

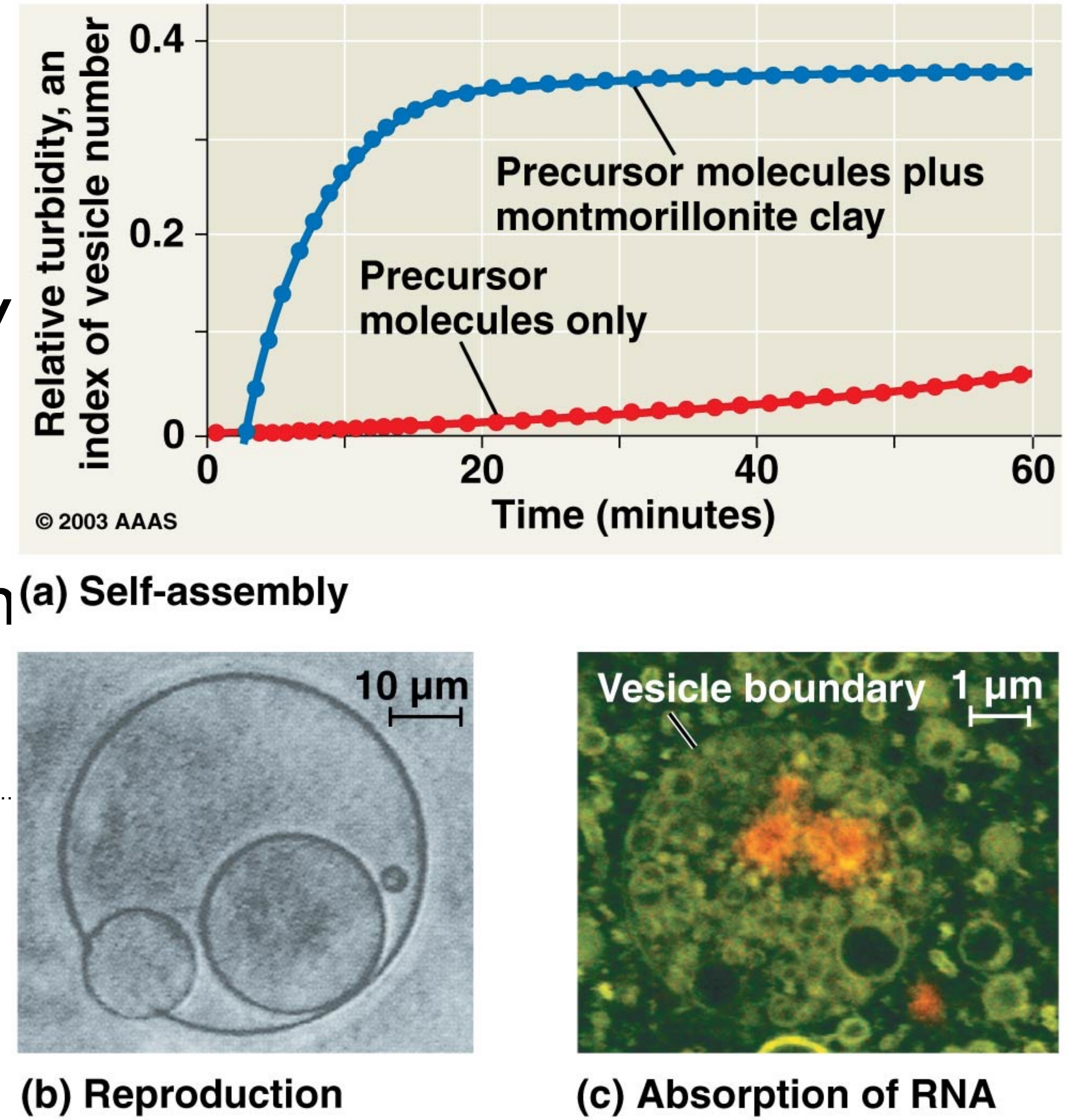
- Vesicles could have formed spontaneously – fatty acids (lipids) and other organic molecules added to water
- Maintain an internal chemical environment



water+clay environment

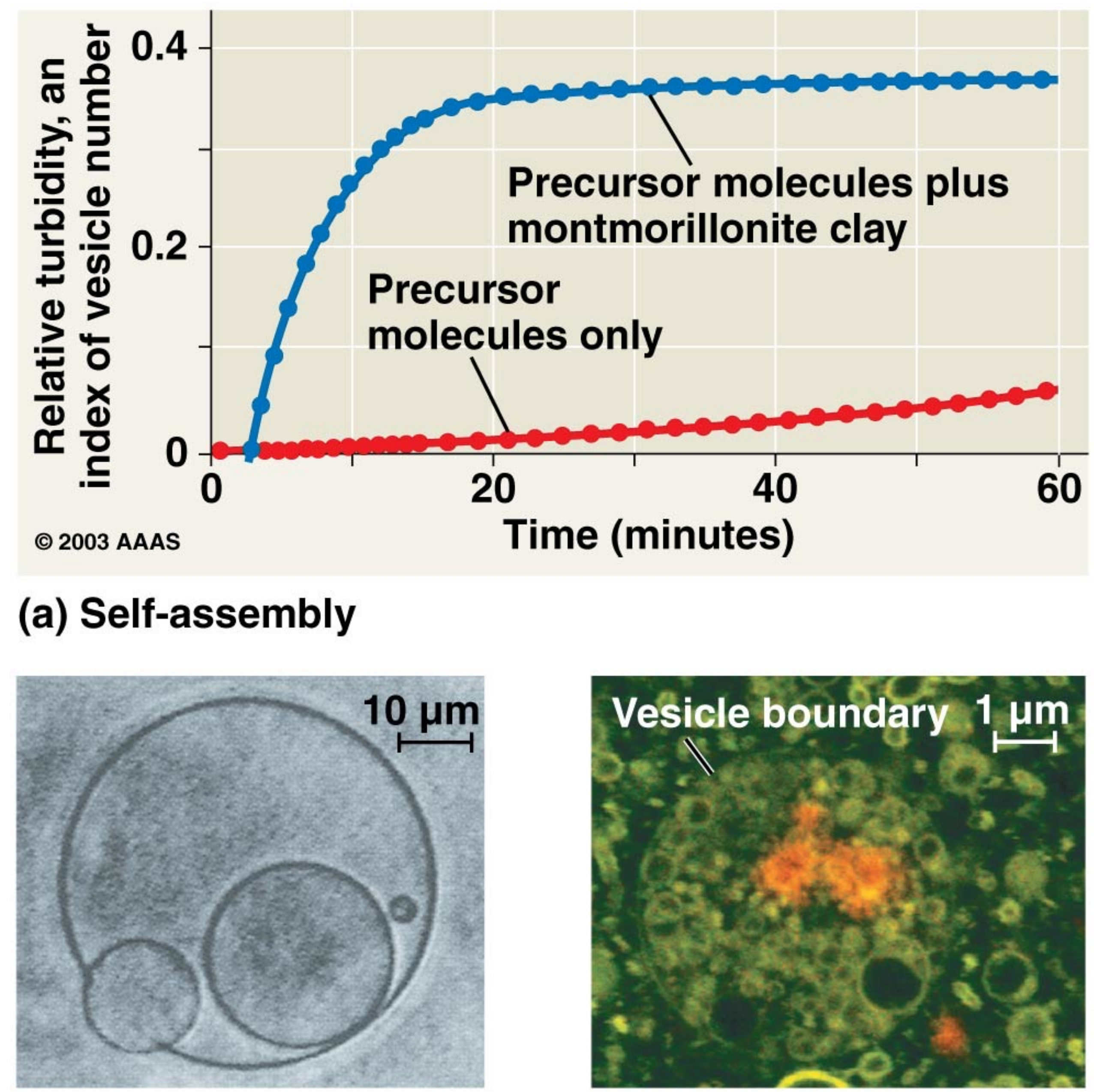
-both vesicle formation and RNA polymerization happen more readily on clay surface

-some experiments show replication of RNA within lipid vesicles



Origin of self-replication and evolution

- RNA molecules called ribozymes have been found to catalyze many different reactions
- Early protocells with self-replicating, catalytic RNA could have absorbed compounds from surroundings (likely on clay surface)
- Some RNA copies would have been more effective at obtaining resources and would have increased in number through natural selection



(a) Self-assembly
(b) Reproduction
(c) Absorption of RNA

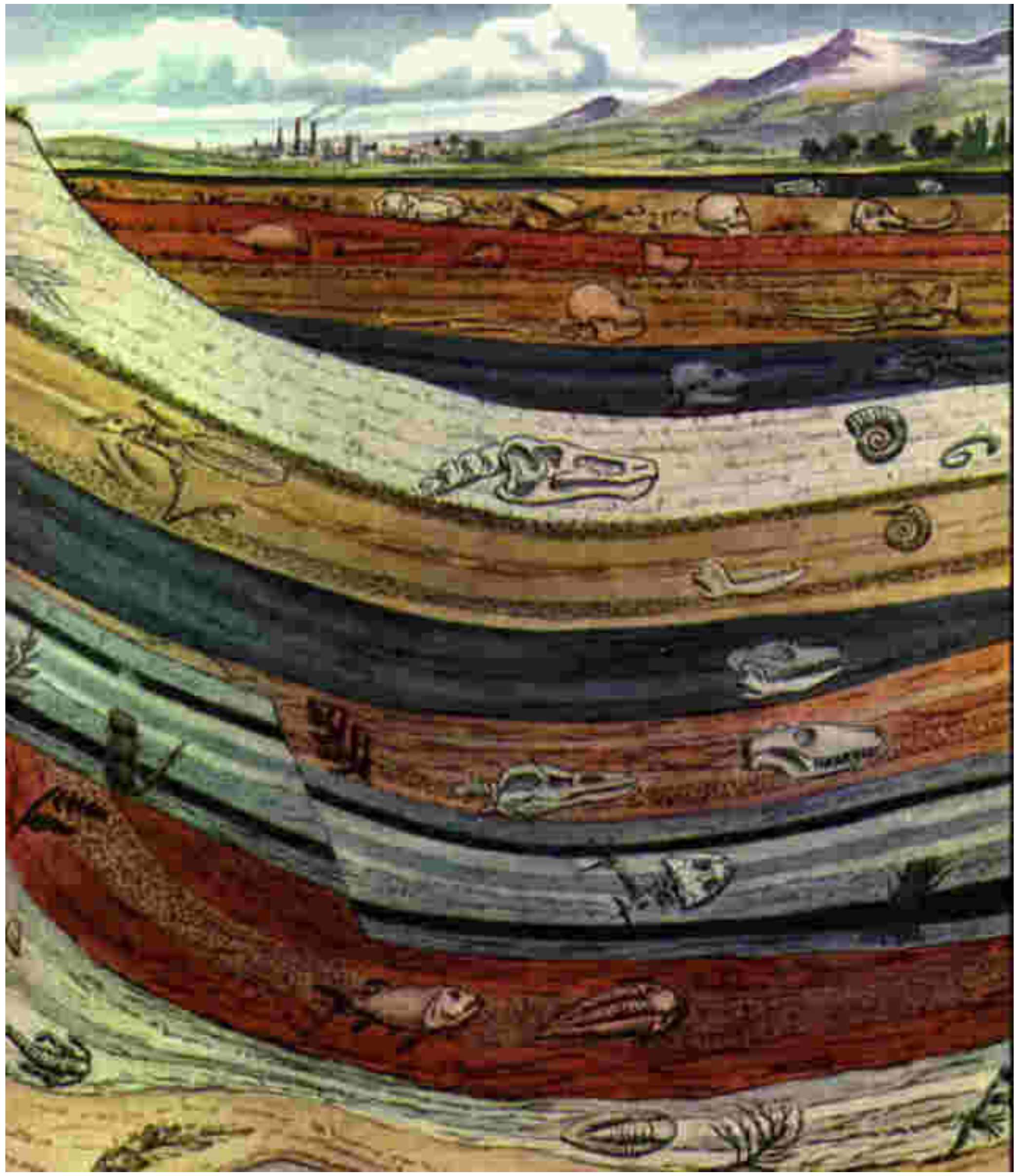
Paleontology: Scientific study of fossil organisms

Fossils:

- Preserved mineralized parts of organisms (shells, teeth, bone)
- Trace fossils left by organisms (indirect evidence)
- Coprolites and other remains
- More rarely: soft parts preserved as minerals

Paleontology: Dating fossils

- **Dating fossils**
  Stratigraphy



- Relative dating:
  -Principle of superposition

- Absolute dating (chronometric) :
  -Radiometric dating

The history of the Earth is recorded in its strata

Principle of Superposition

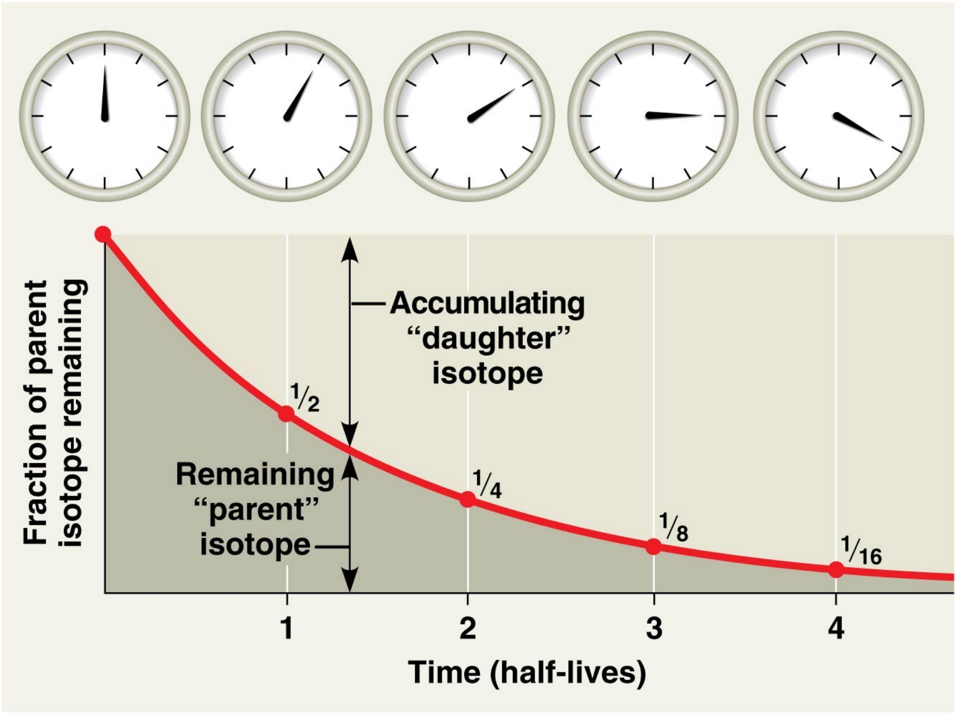
- In a sequence of layered sedimentary rocks, any layer is older than the layer above it and younger than layers below it

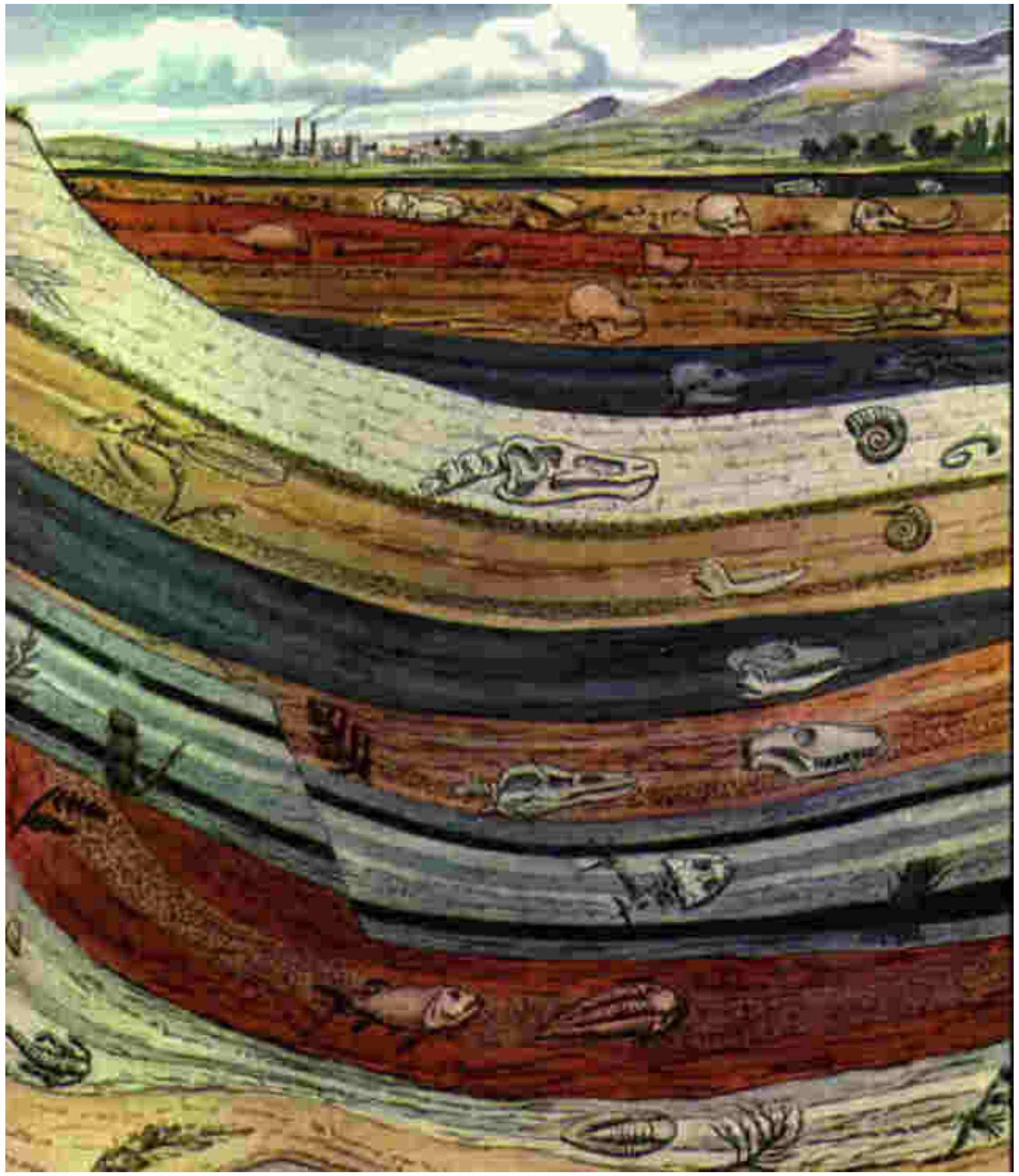
Paleontology: Dating fossils

Absolute dating :

-Radiometric dating

- Using the known half-life of radioactive isotopes in sediments





Paleontology: Dating fossils

Radiometric dating

- **Uranium series dating (U-Series)** - ^{238}U Turns to lead (Pb) – Series of half-lives (several isotopes)

- **Argon-Argon (^{40}*Ar*-^{39}*Ar*) dating** is often used on volcanic rock
  - 1.25 billion y. half-life

- **Carbon 14 (^{14}C) dating (Radiocarbon dating)**
  - Carbon 14 is radioactive, and will slowly disappear (5730 y half-life)

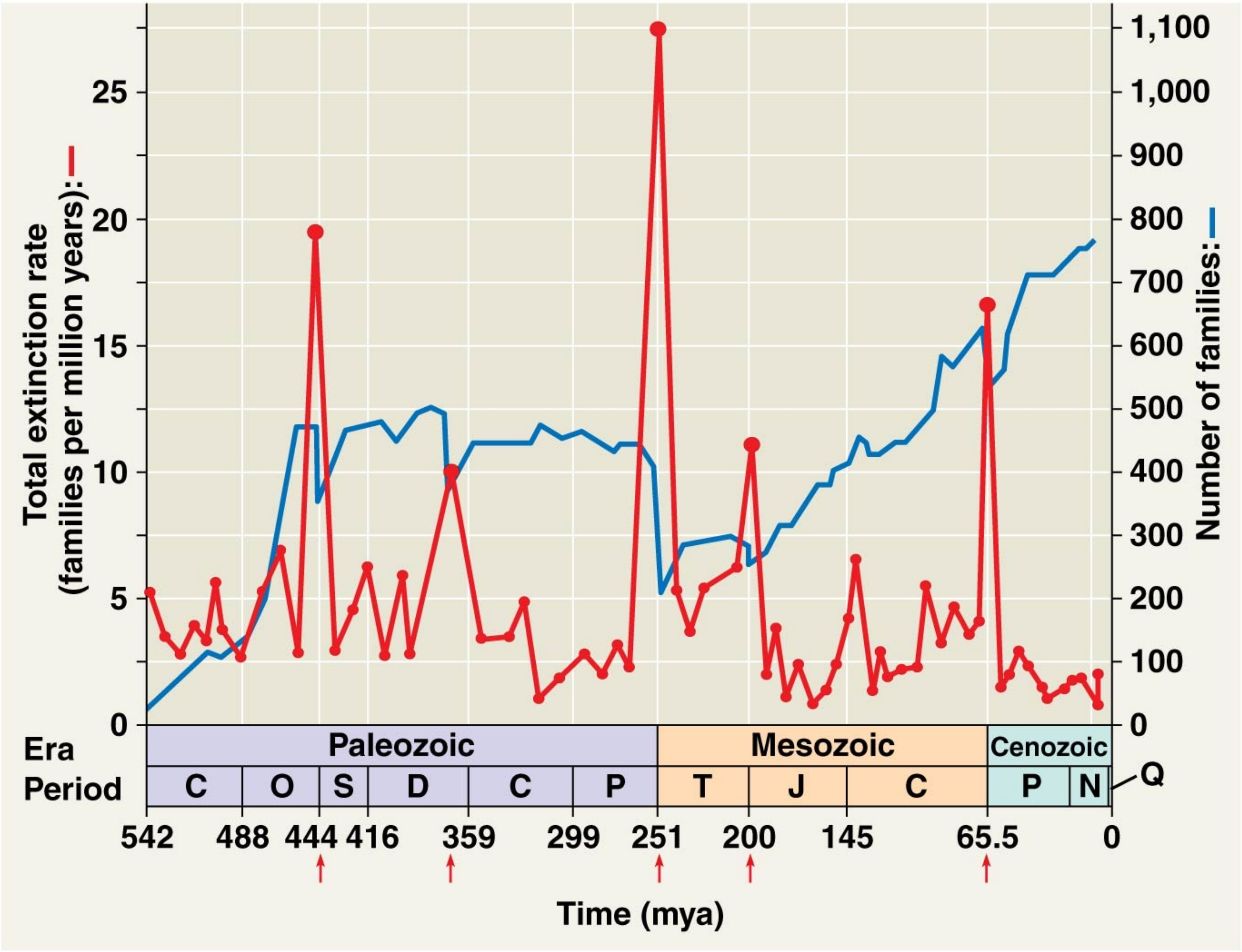
Ötzi, 5200y old

Patterns of Extinctions

- Background Extinctions
  - “Normal” slow rate of extinction
  - 96% of extinctions

- Mass Extinctions
  - Global Extent
  - Broad Range of Species
  - Often rapid

Big 5 - Mass Extinctions



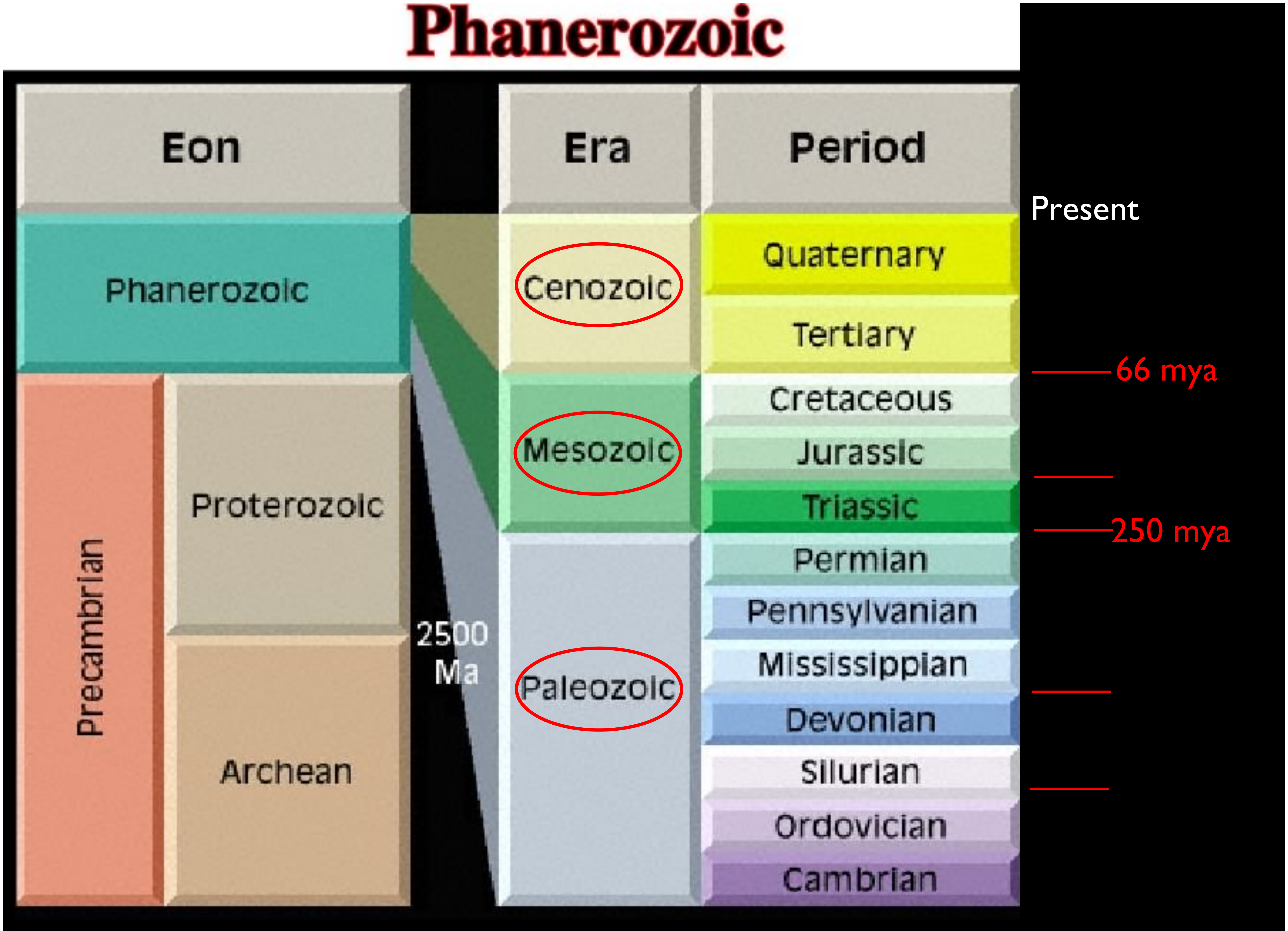
Five mass extinctions, effect on marine life.
Some marking the end of geologic eras.

Mass Extinctions

Catastrophic events

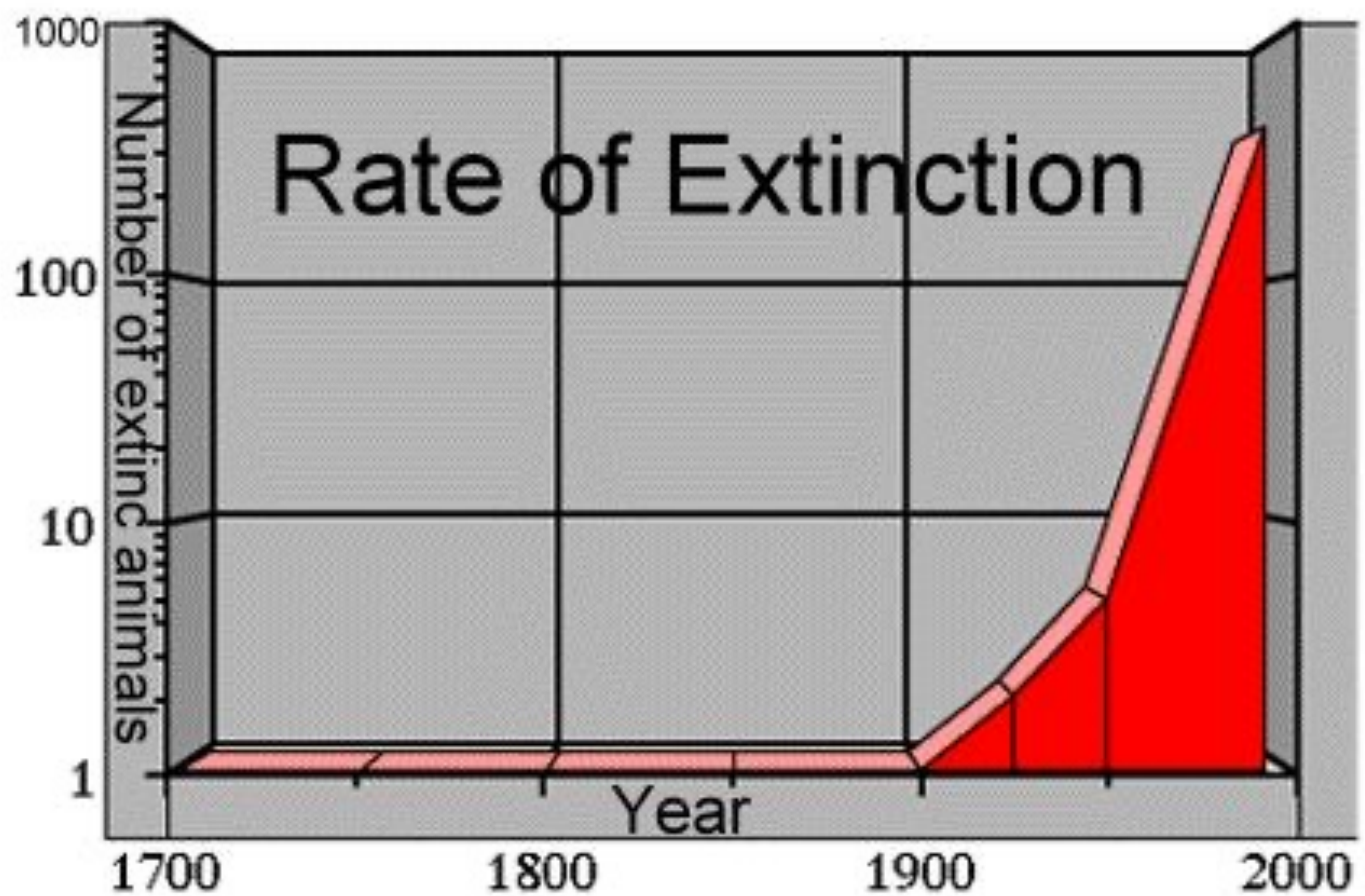
- Largest = Permian Mass Extinction ca 250 mya; volcanism in Siberia - 96% of marine life
- Cretaceous Mass Extinction ca 65-66 mya; iridium layer-asteroid/large meteor impact –coast of Mexico
- Life can take a long time to recover – adaptive radiations

Mass extinctions- marking the ends geologic periods and eras



6th Mass Extinction?

- 1,100 species extinct since 1600
  - Habitat loss
  - Hunting
  - Introduction of non-native species
- Previous mass extinctions: at least 5 mill y. to recover species diversity



- Current rate of extinction = 100-1000X larger than background extinction