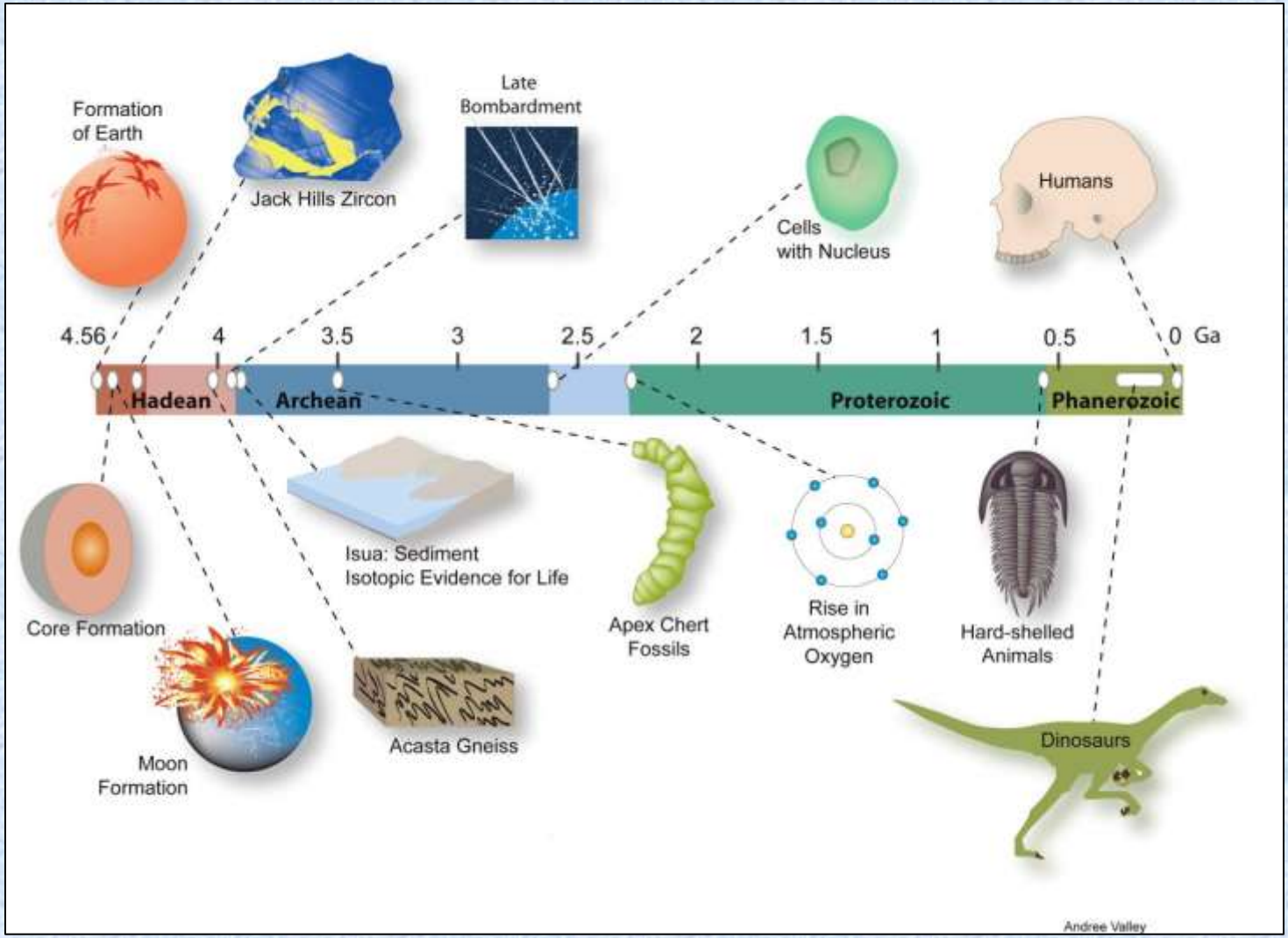
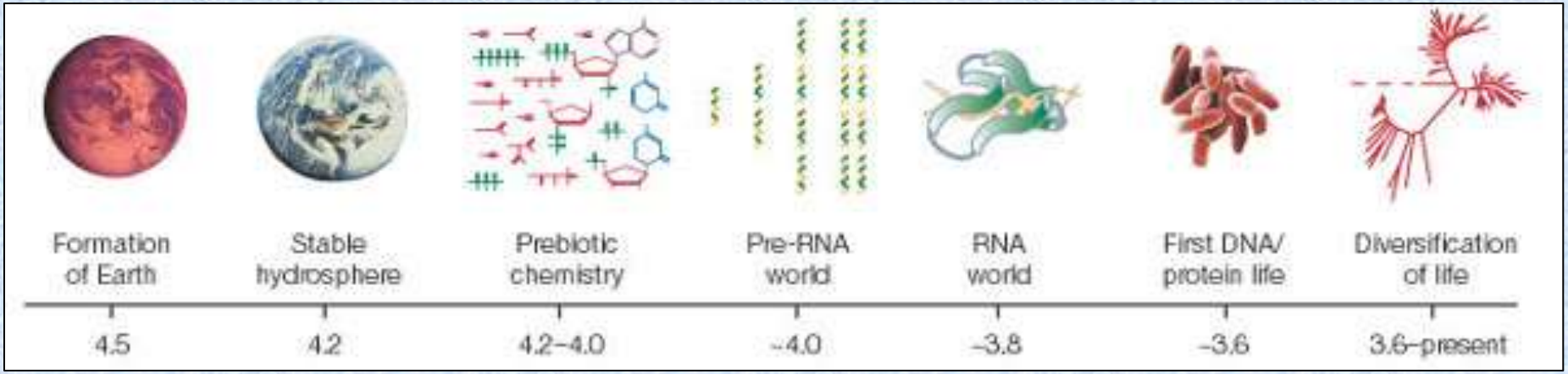
Origin of Life:
Major Steps in Evolution



Origin of Life:
Major Steps in Evolution

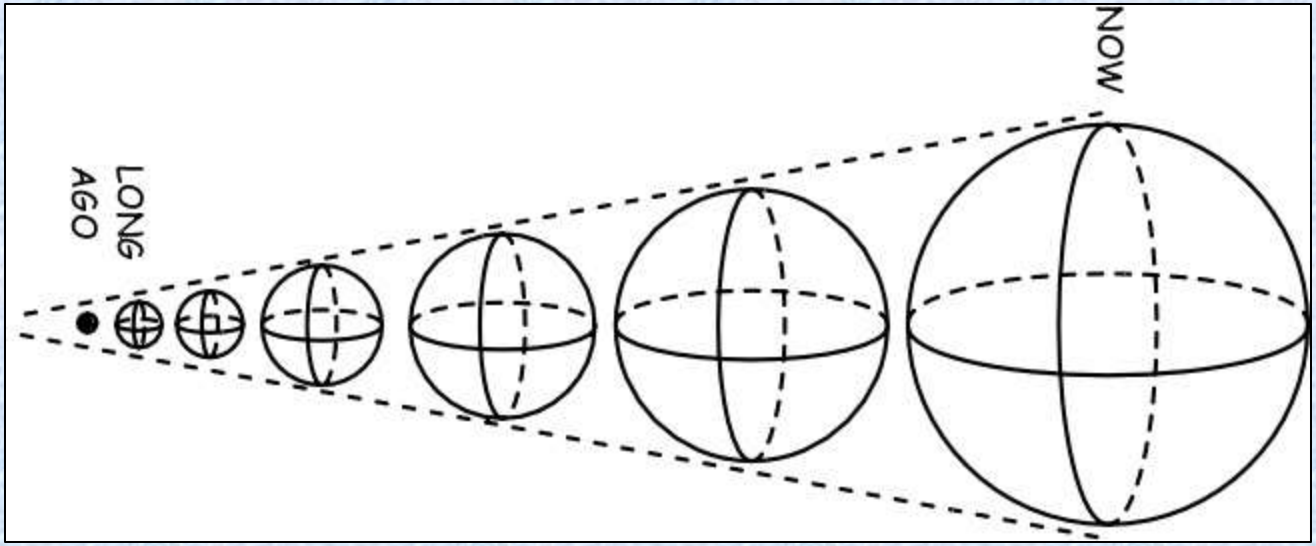


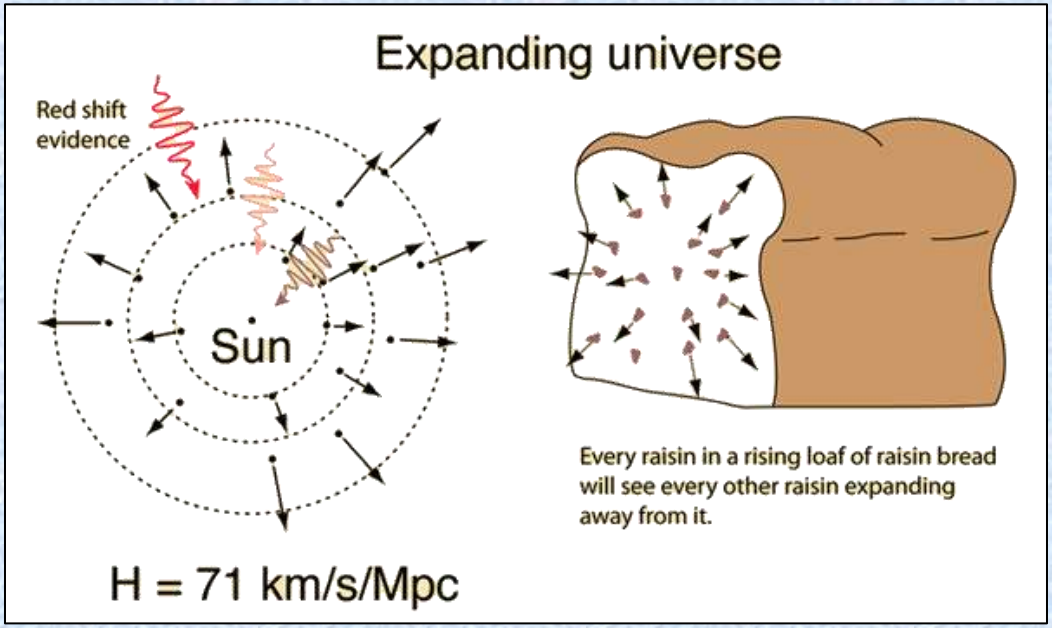
Big Bang Theory

- How did everything get started?

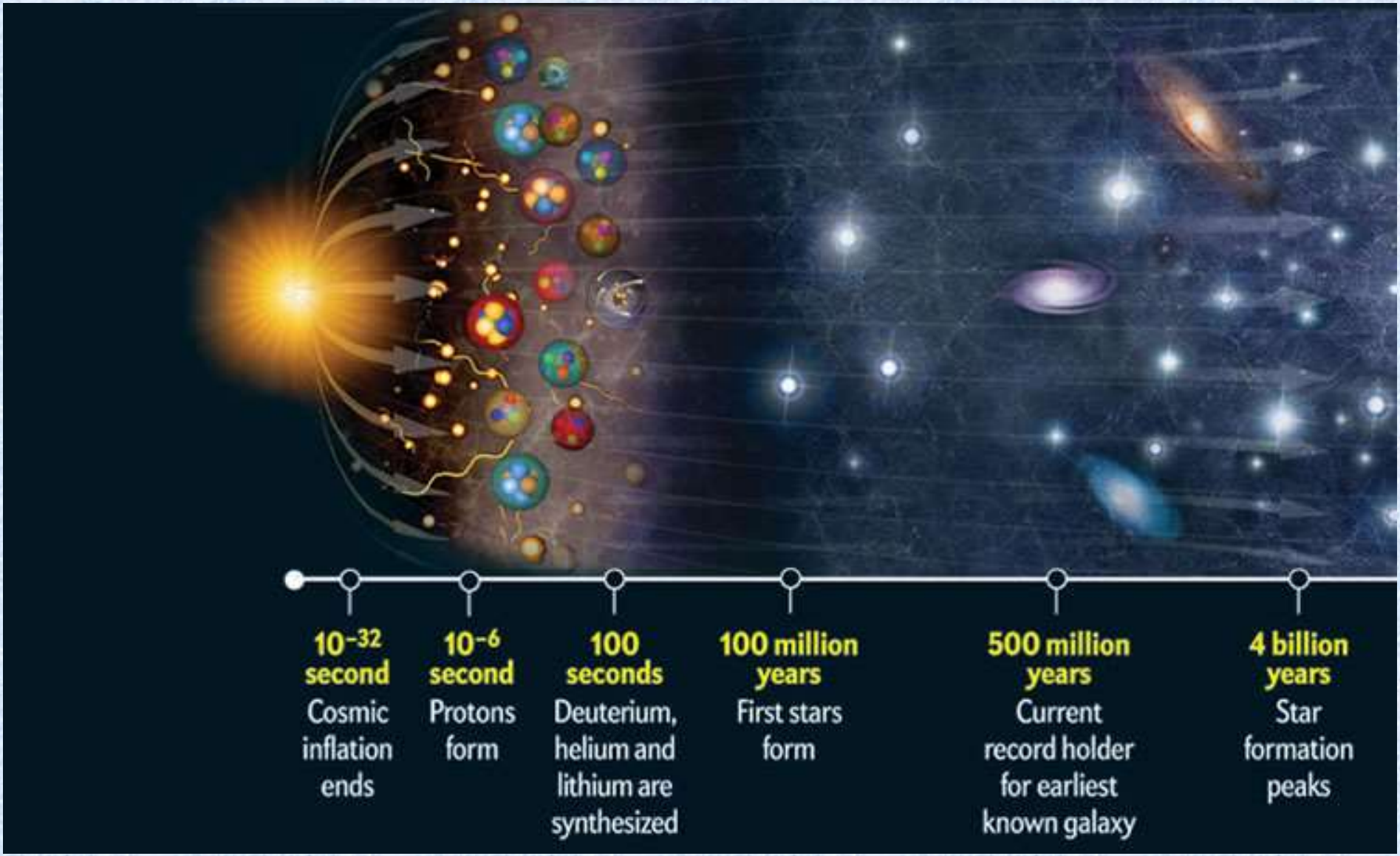
Evidence – distant galaxies are moving away from us rapidly (Hubble, red shift)

Expanding Universe – space itself is expanding

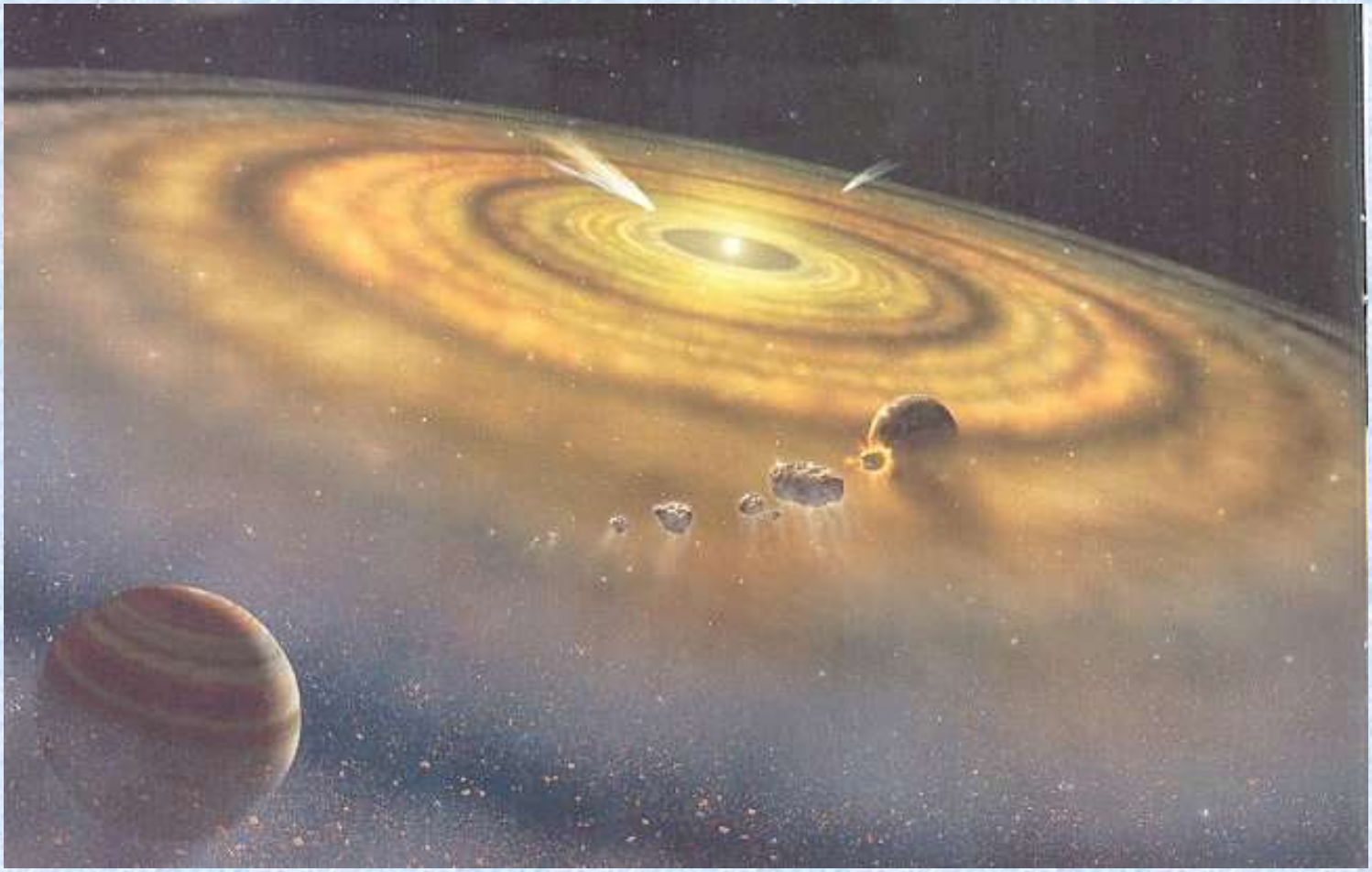




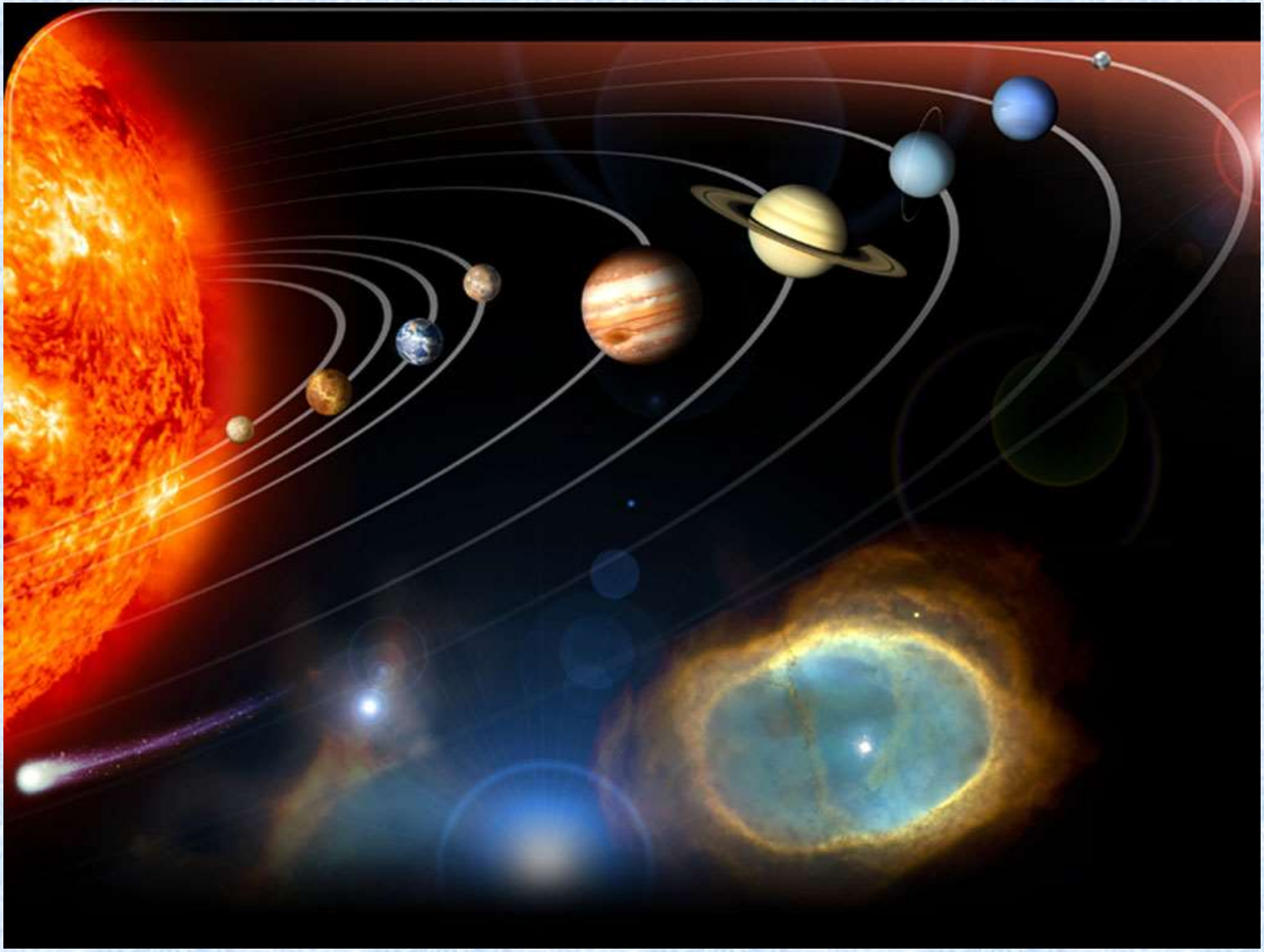
Big Bang – rapid expansion and cooling



Formation of the Solar System



4.6 billion years ago
Our solar system forms

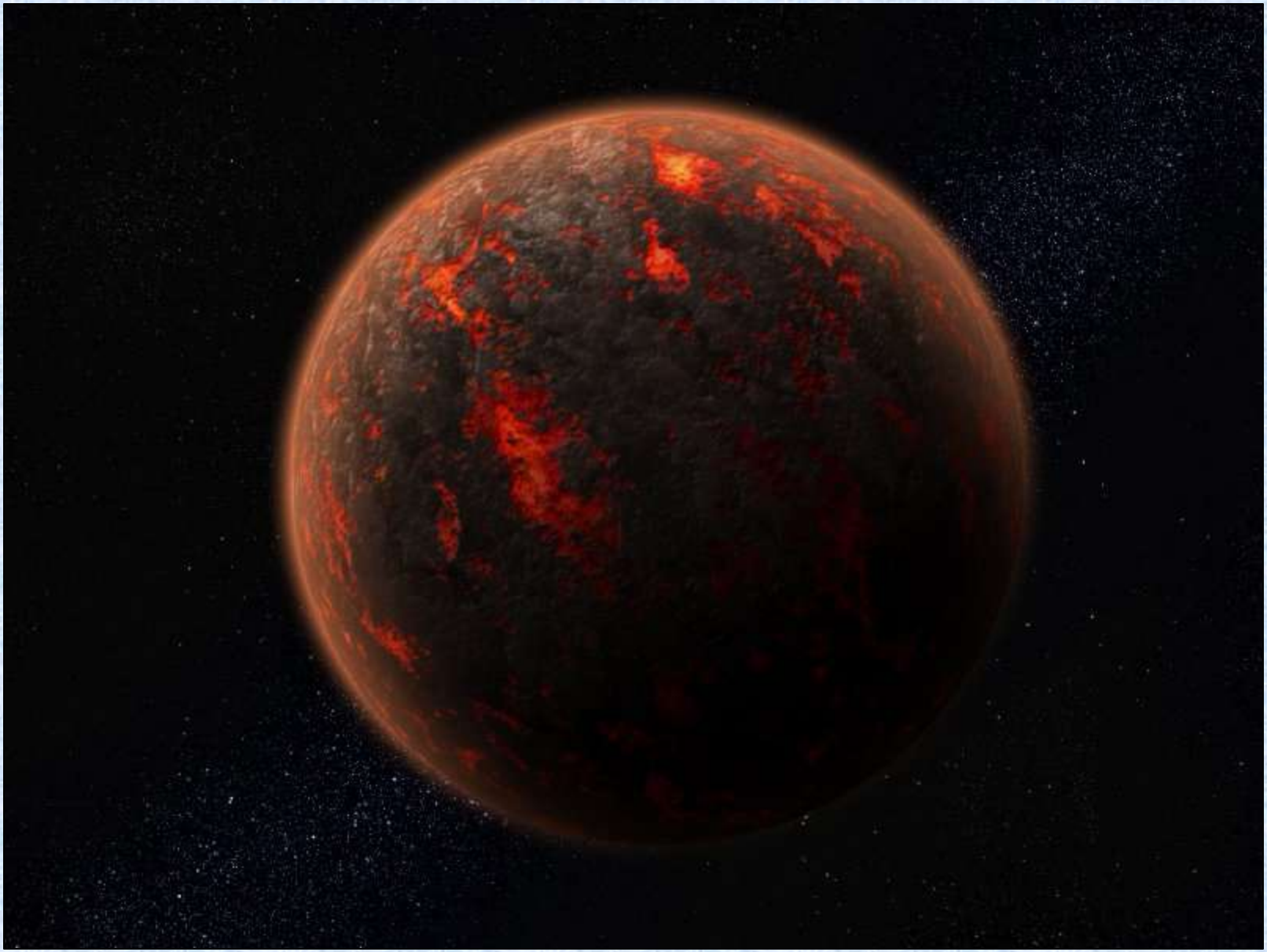


Origin of the Moon

The Earth–Moon system formed as a result of a giant impact, where a Mars-sized body (named **Theia**) collided with the newly formed proto-Earth, blasting material into orbit around it that accreted to form the Moon

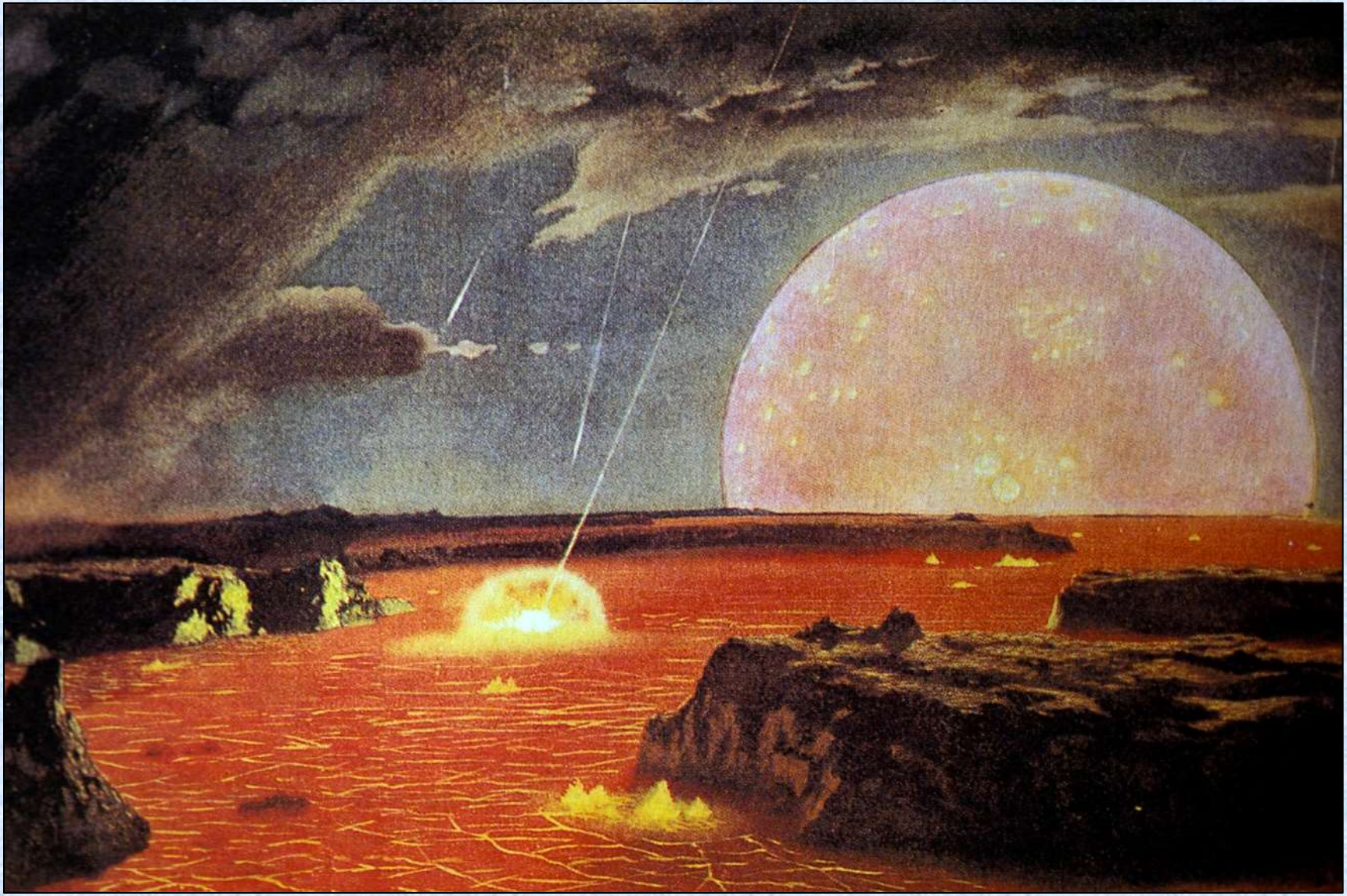
The two hemispheres of the Moon are very different. While the near side is covered with large basaltic plains called maria, the far side is almost completely covered in craters.

Hadean Earth 4.5 BY Ago



Molten Earth – 4.5 BY

Hadean - Era of Large Impacts

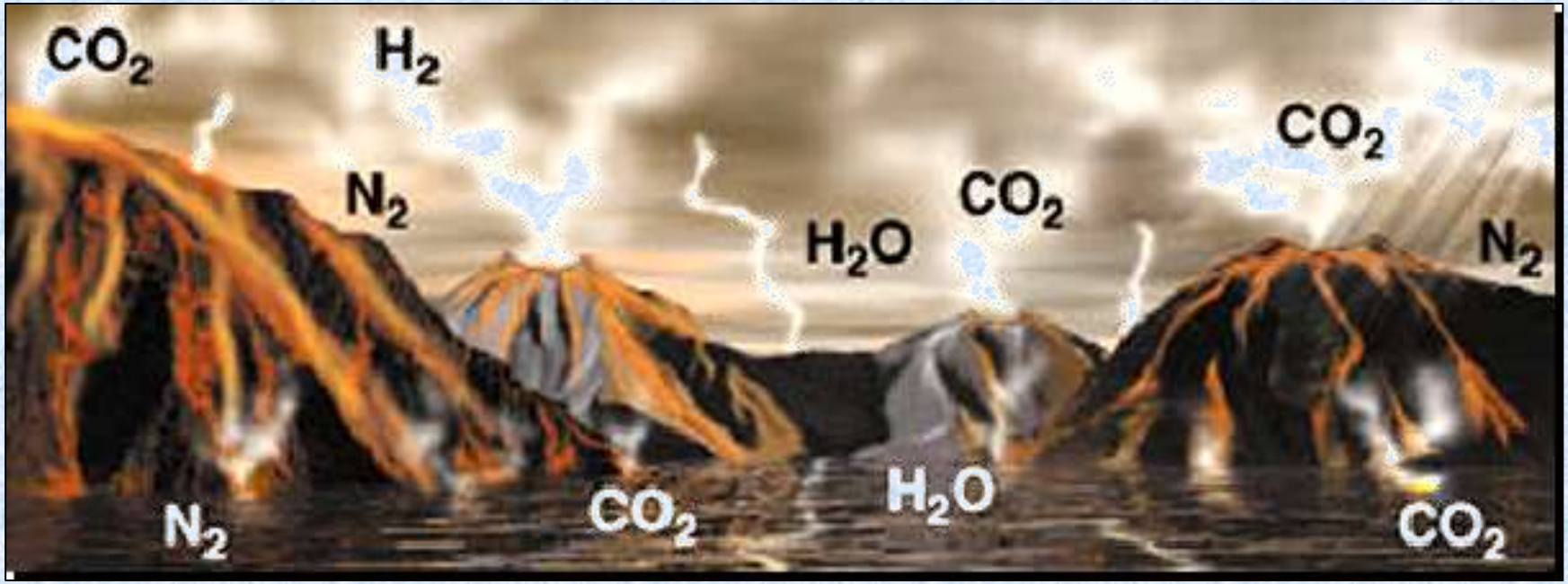


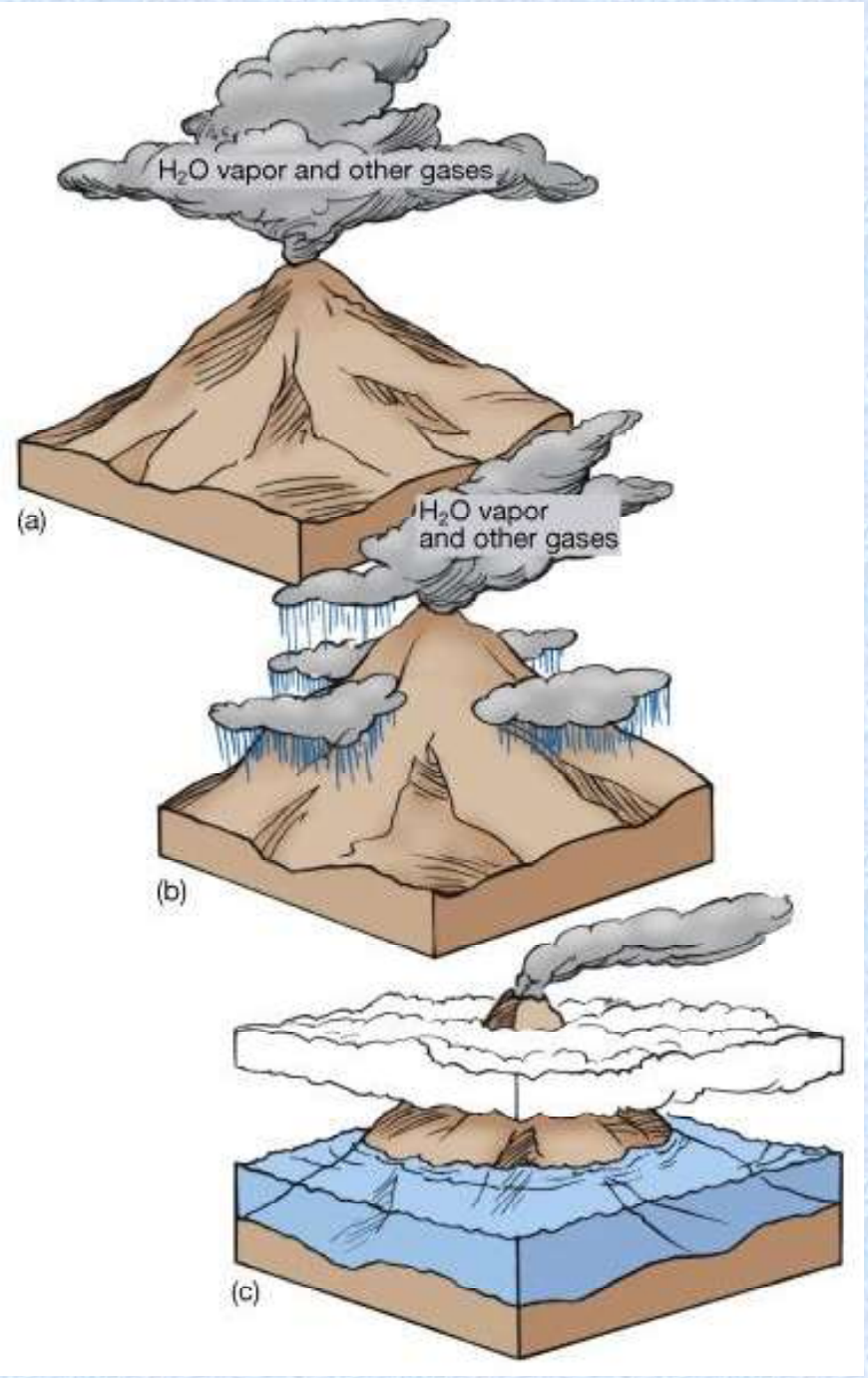
Archean Eon, 4 – 2 BY

Archean Eon: 4-2 BYA

Origin of the Atmosphere

- Sun's energy stripped away 1st atmosphere
- 2nd atmosphere formed from volcanic outgassing
- Primitive atmosphere: CO2, water vapor, lesser amounts of CO, N2, H2, HCl, traces of NH3 and CH4
- Important for formation of life





Formation of Earth's Oceans (4 by ago):

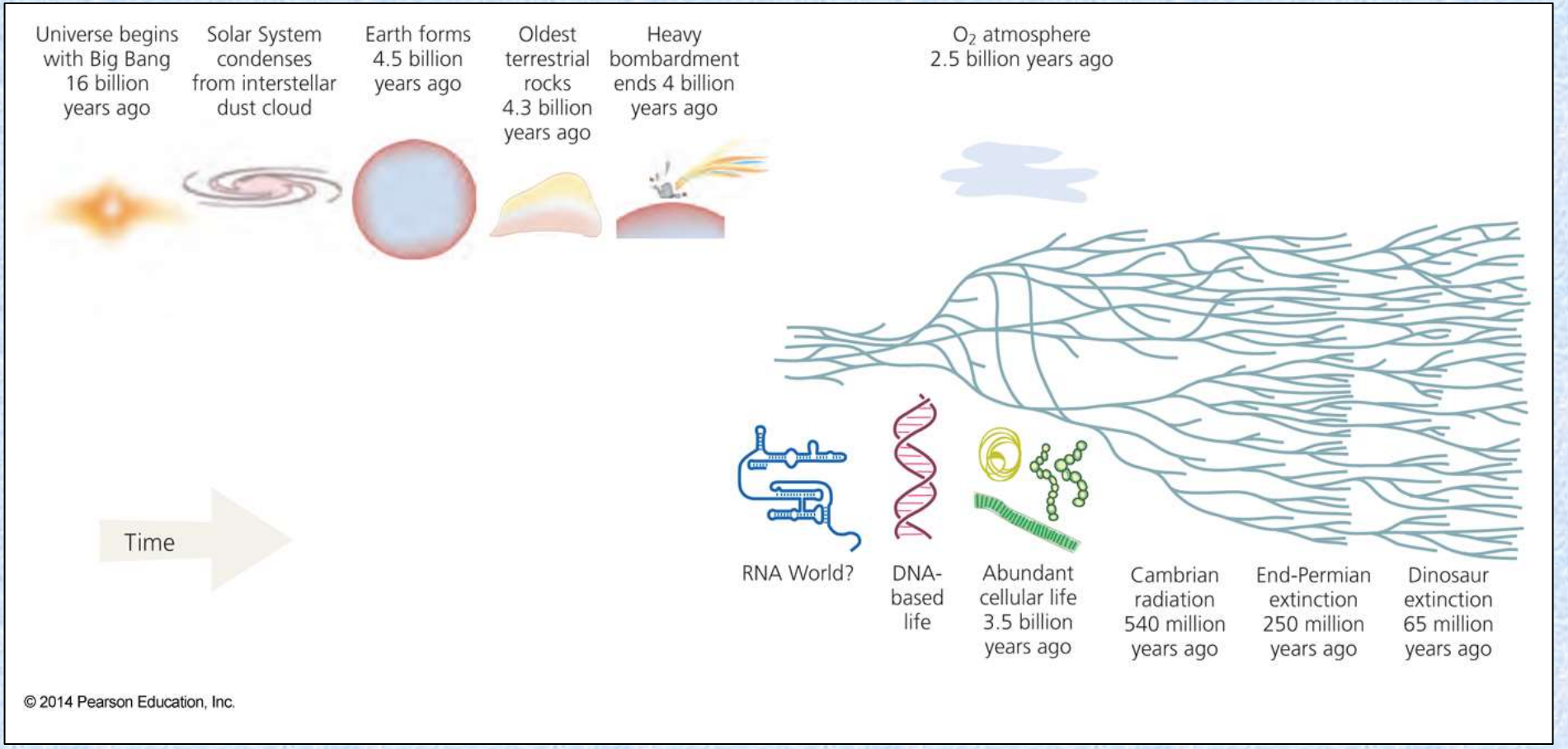
Off gassing of water vapor from volcanos

Condensation

Rain

Water from Comets?
Meteors?

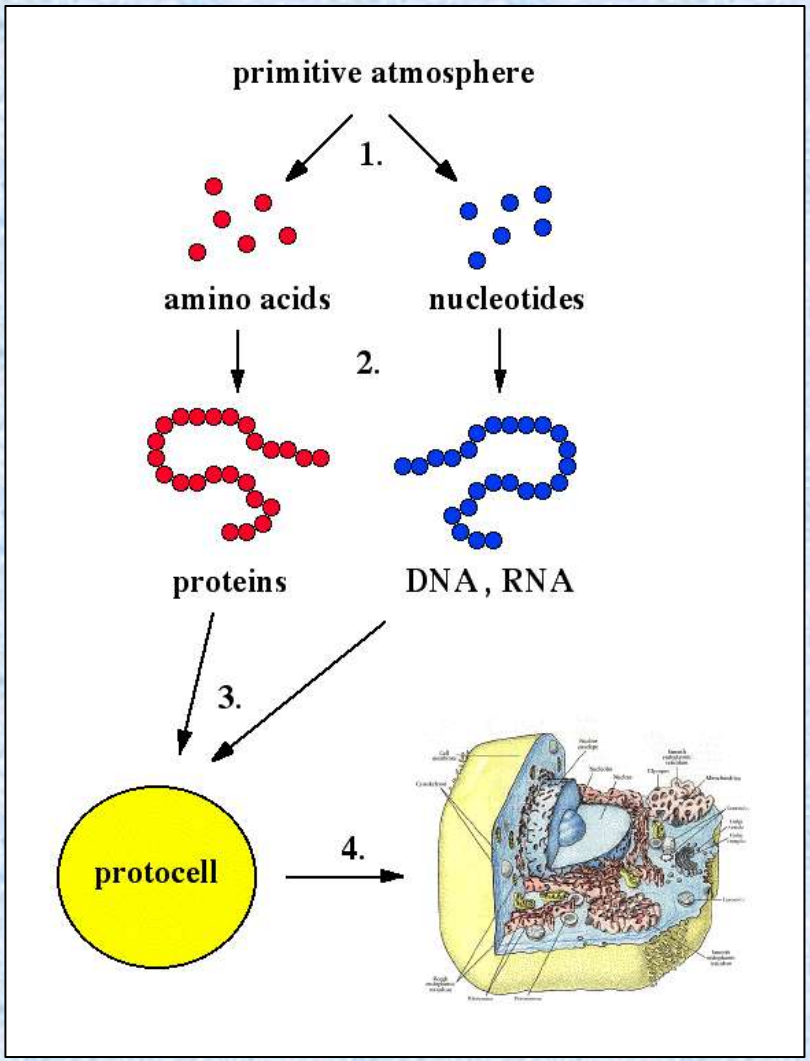
Origin of Life



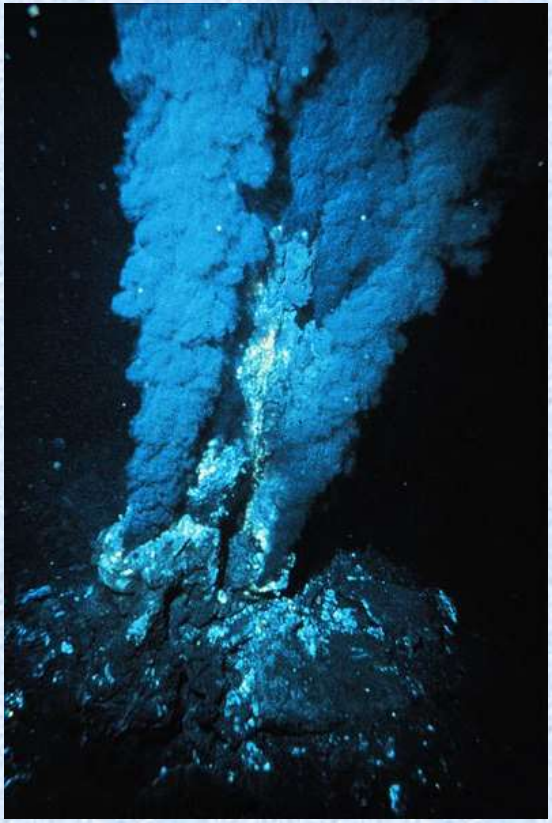
Chemical Evolution of Life on Earth

Necessary requirements:

1. Synthesis and accumulation of <u>small organic molecules</u>
2. Joining of monomers into <u>polymers</u> (protein, nucleic acids)
3. Aggregation of these molecules into protocells to form microenvironments
4. Origin of heredity molecules and reproduction
5. Origin of metabolism



Origin of Life – Possible Locations



Deep-sea vents
- conditions suitable for Archaea,
- Thermophilic (heat-loving)

Ocean's edge
- bubble hypotheses

Within clay
- positively-charged clay
- **polymerizing** templates

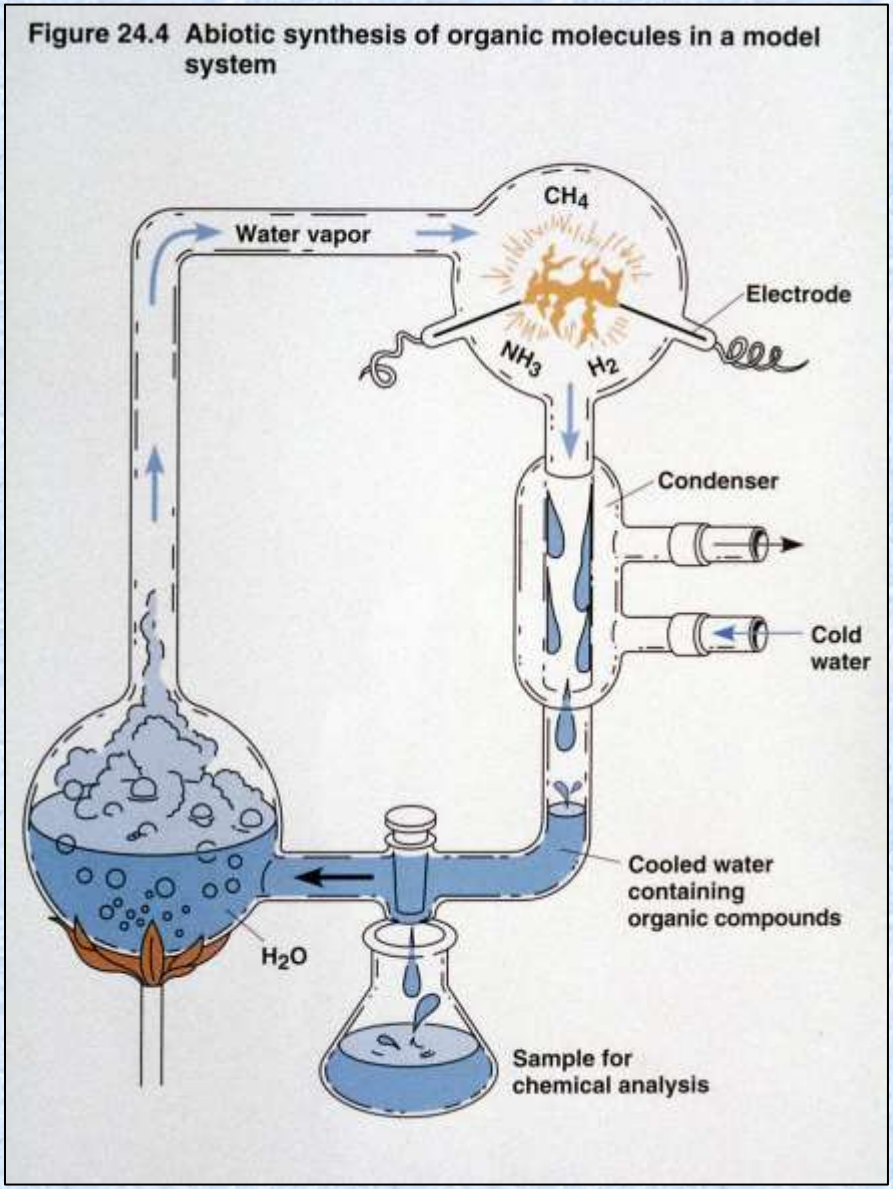
Under frozen seas
- problematic due to necessary conditions

Deep in Earth's crust
- byproduct of volcanic activity

In Ice?
- chemicals concentrate in bubbles

Organic precursors - Stanley Miller Experiments - 1953

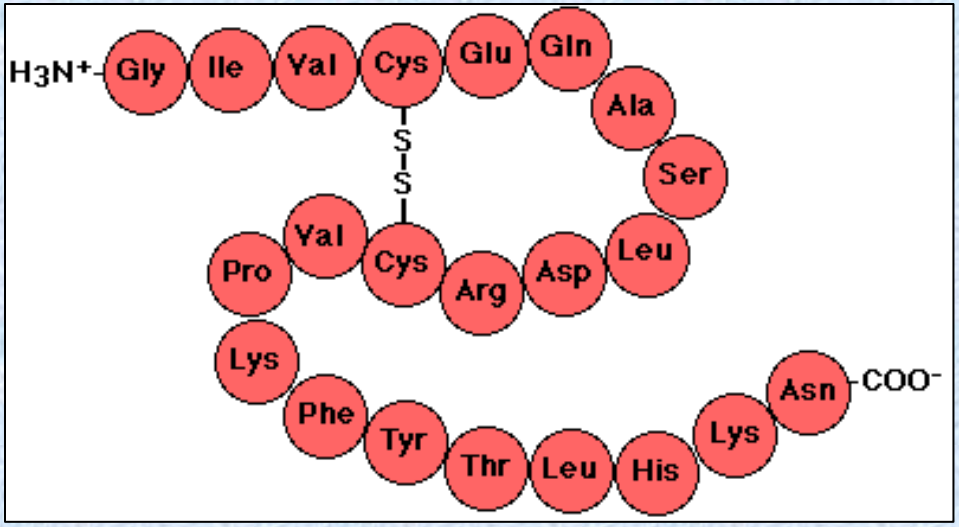
- Mixed water, molecular hydrogen, methane, and ammonia in a flask.
- Passed mixture through electrical discharge as input energy to this mixture.
- Spark simulated the energy provided by lightning on the early Earth.
- 13 Amino acids formed, + adenine

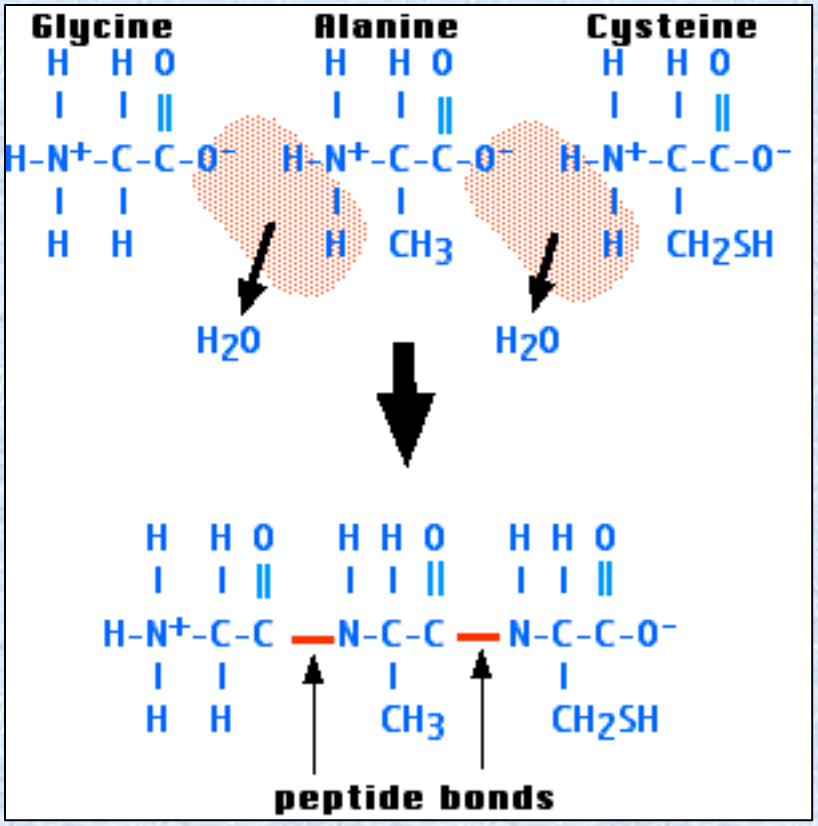


Polymer Synthesis - Proteins

Amino acids are monomers

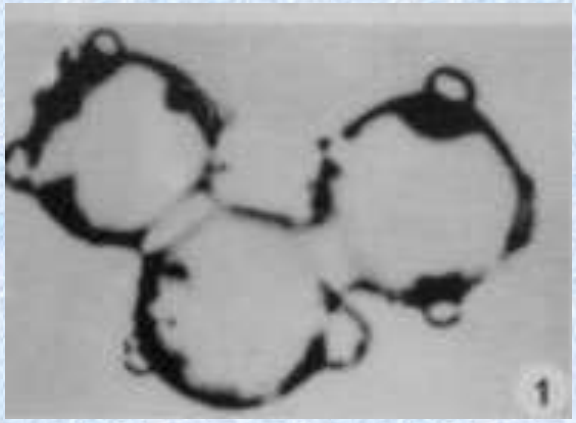
- Monomers must form peptide bond to form proteins
- This requires an input of energy and removal of water





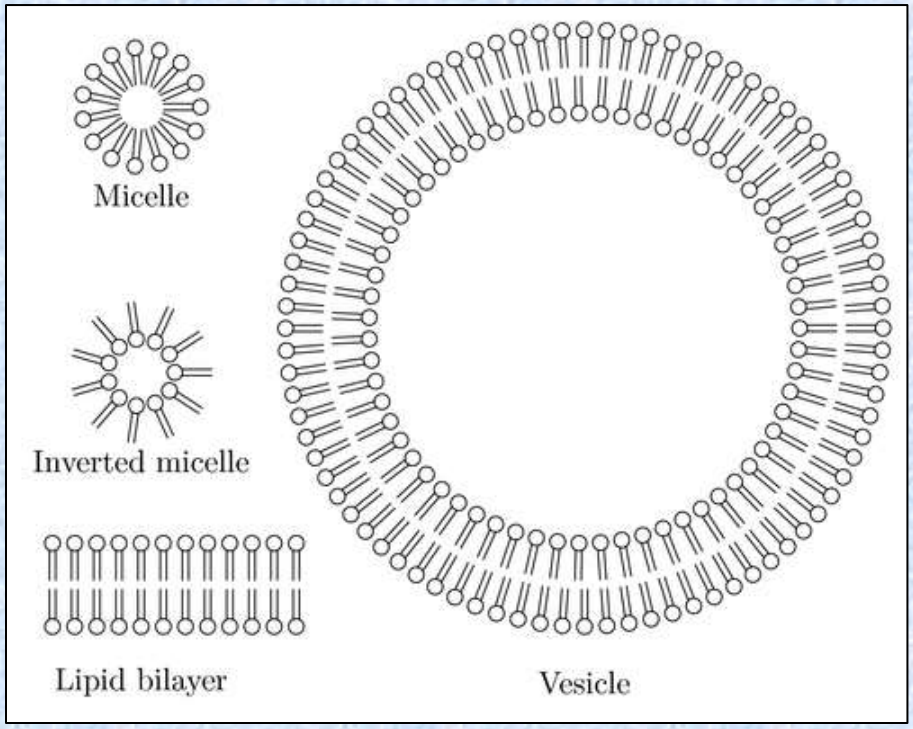
Polymer Formation - Proteins

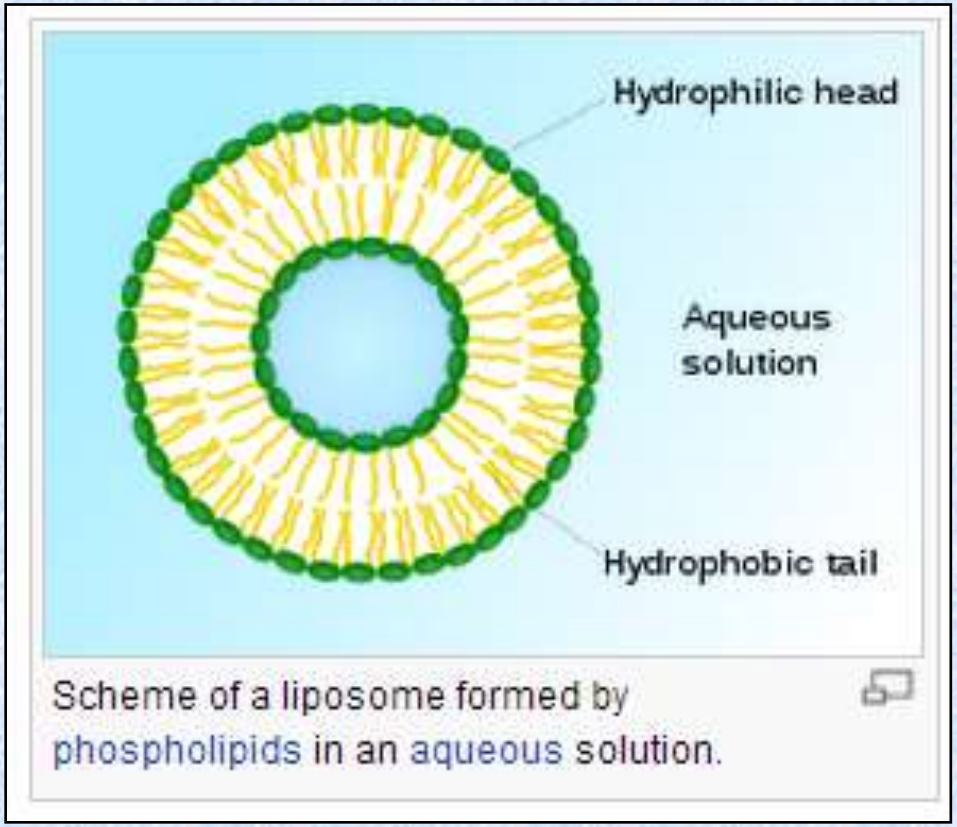
- Sidney Fox (Univ. of Miami), 1950's
- Cross-linked polymers formed when organic molecules dripped onto hot sand, clay, or rock
- Proteinoids, protein-enclosed droplets;
- Grow, reproduce by budding; a lot like living cells, but not alive
- Protein world first? Which came first?



Polymer Synthesis – Lipid Membranes

- Lipids in water form organized droplets (liposomes) with bilayer much like that of a plasma membrane.



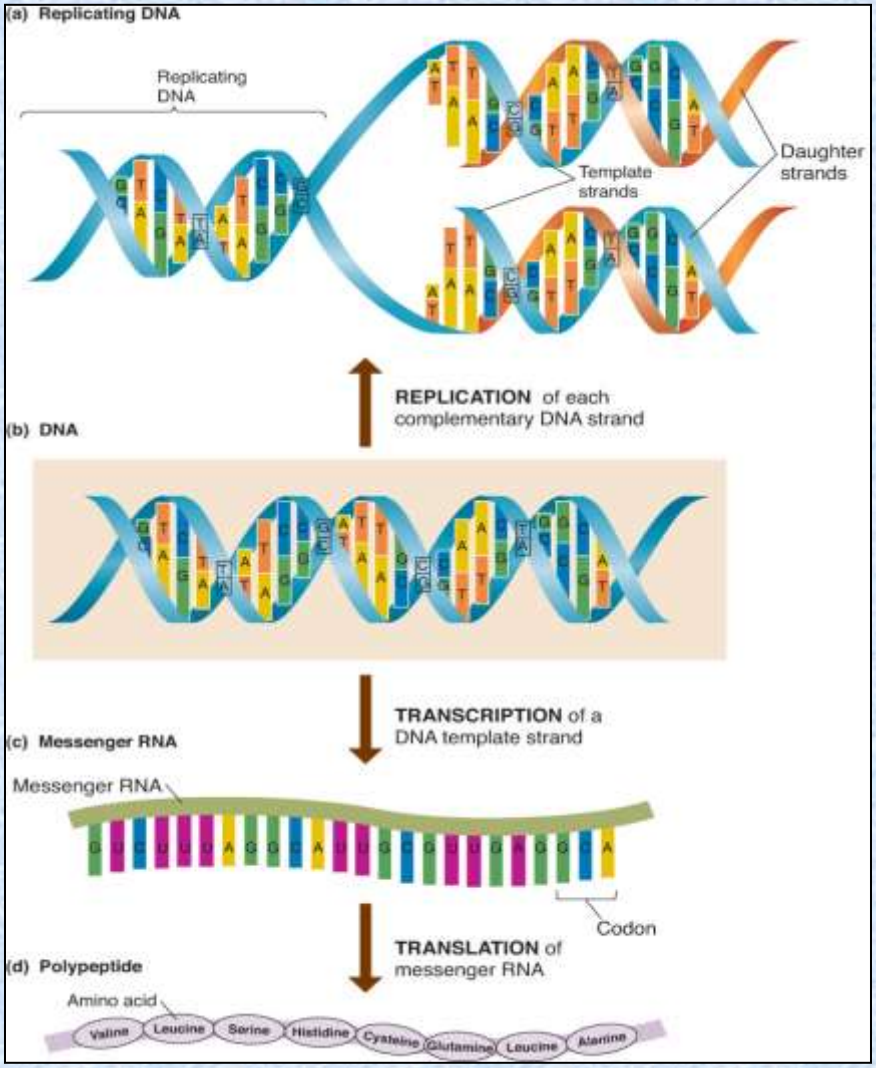


Hereditary Material - DNA, RNA and Proteins?

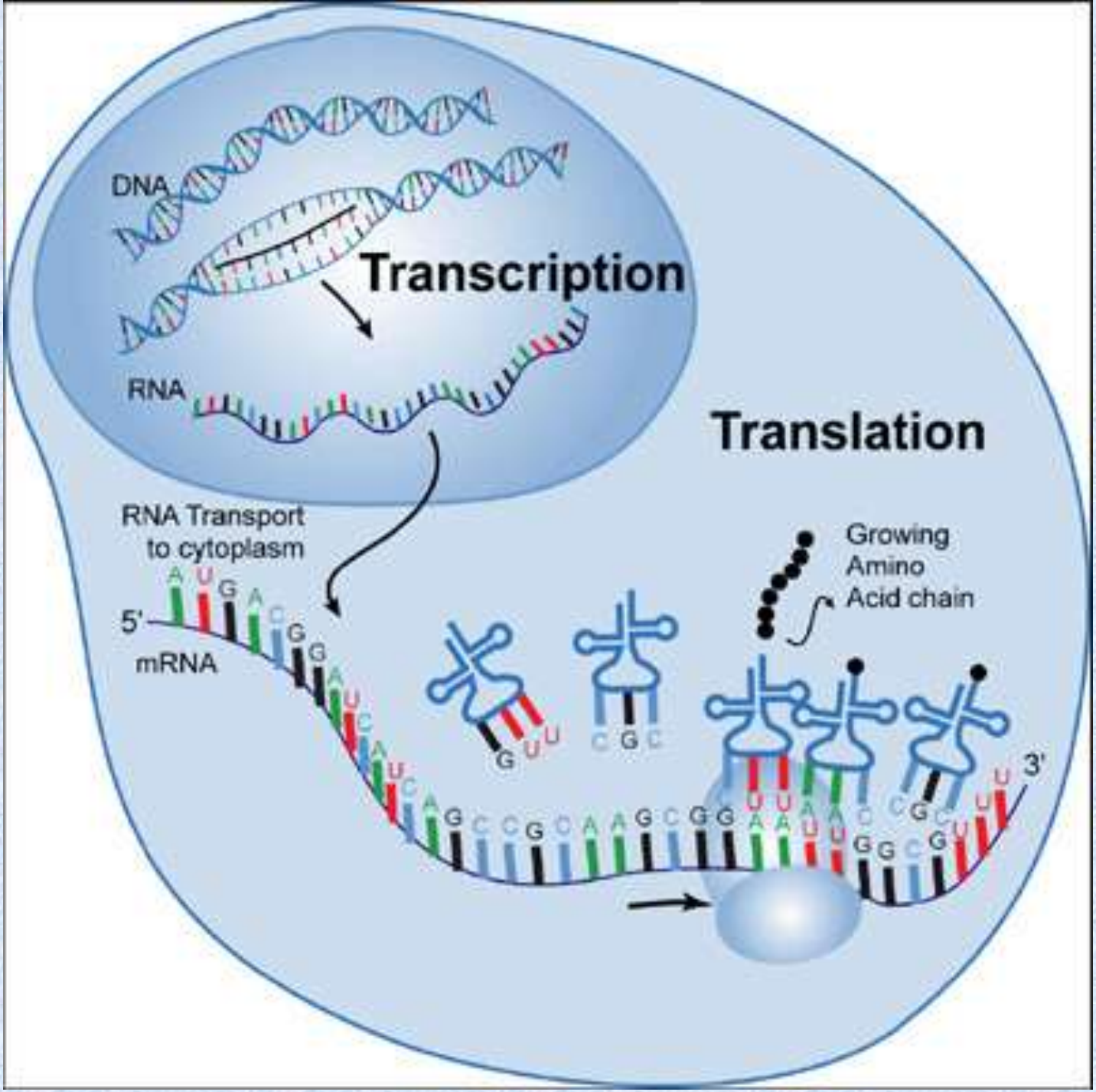
Three fundamental classes of molecules are associated with modern life:

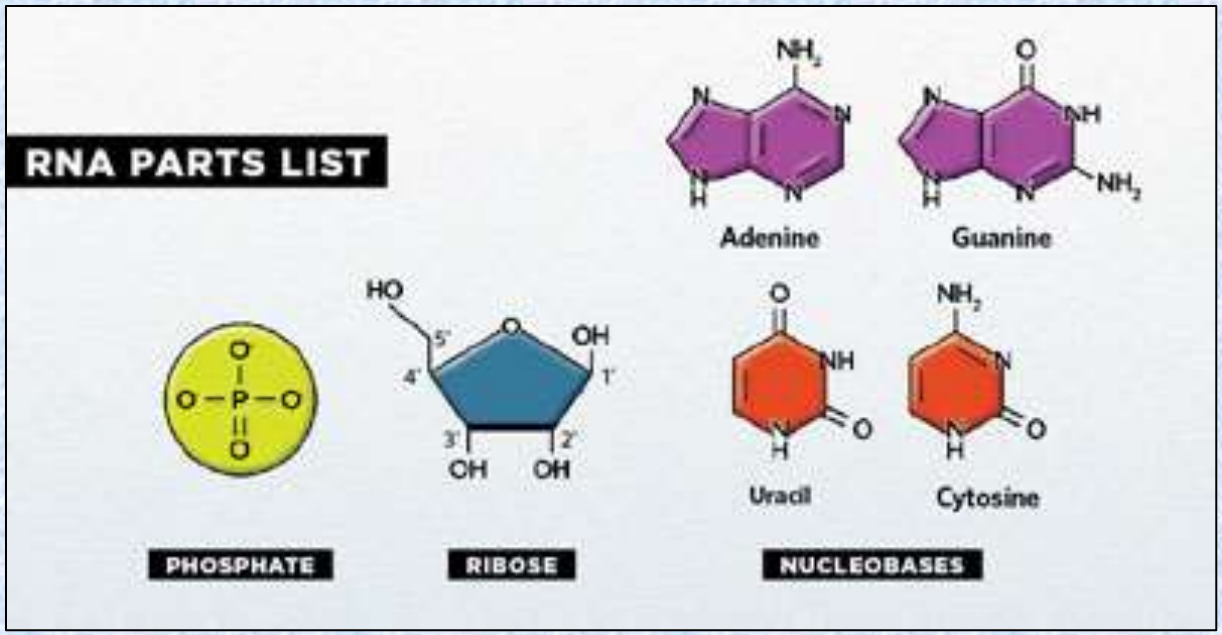
- DNA – Replication
- RNA - Transcription
- Protein – Translation

Which came first?



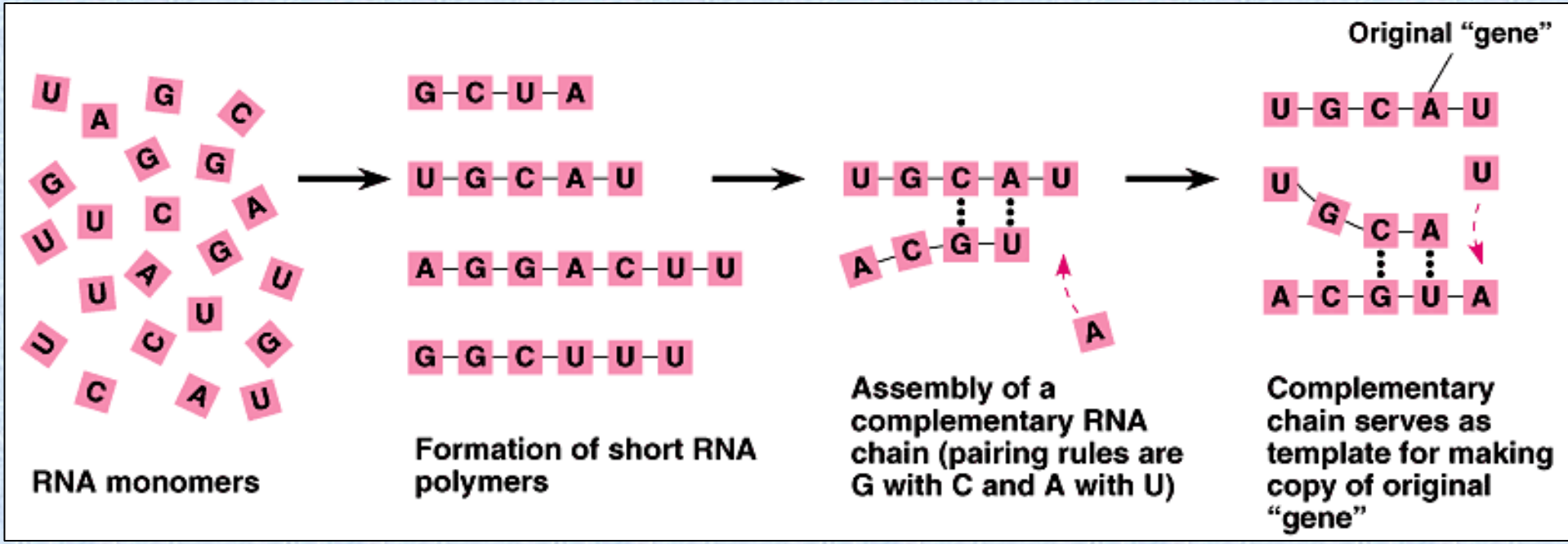
Today DNA replicates and information is transferred from DNA to RNA to protein


DNA
Transcription
RNA
Translation
RNA Transport
to cytoplasm
5'
mRNA
Growing
Amino
Acid chain
3'


RNA PARTS LIST
Adenine
Guanine
Uracil
Cytosine
PHOSPHATE
RIBOSE
NUCLEOBASES

Short polymers of ribonucleotides can be synthesized abiotically in the laboratory.

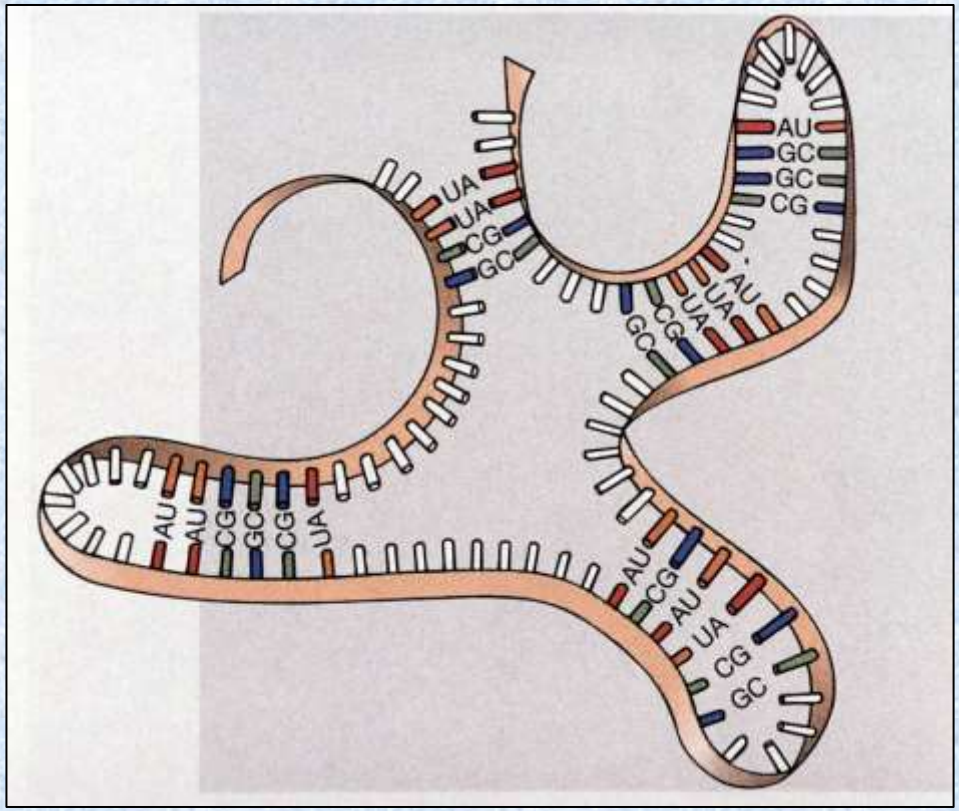
- If polymers are added to a solution of ribonucleotide monomers, sequences up to 10 based long are copied from the template according to base-pairing rules.



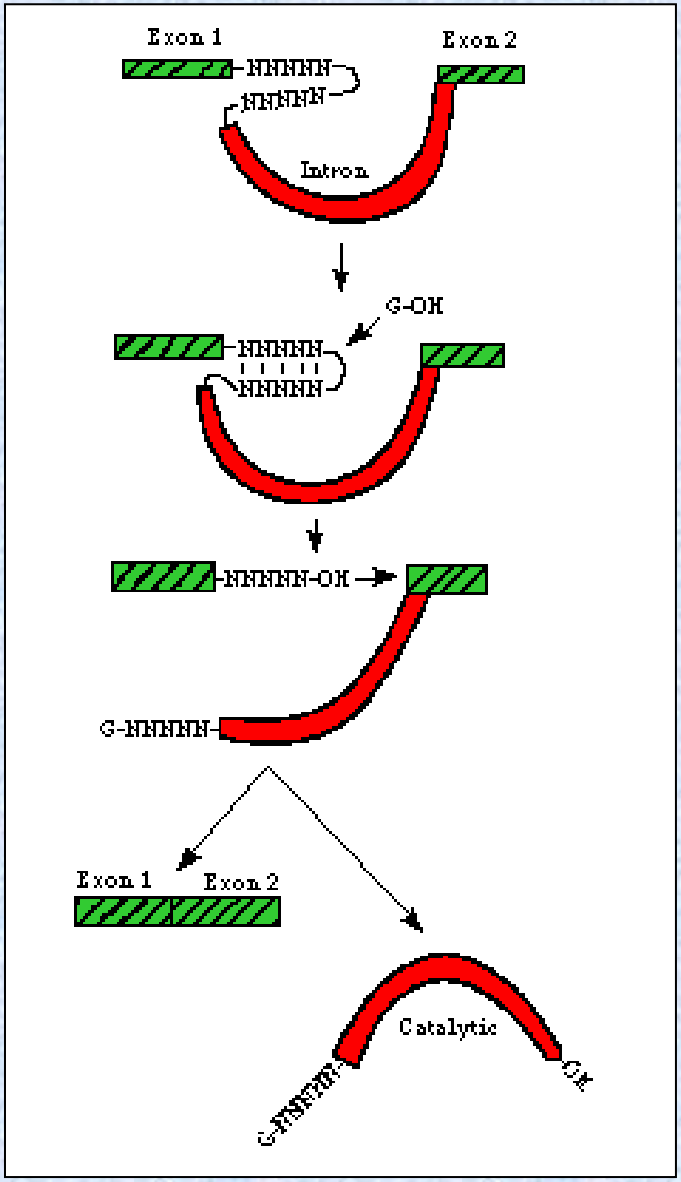
Clay might have acted as the first template

Ribozymes

RNA that catalyzes reactions



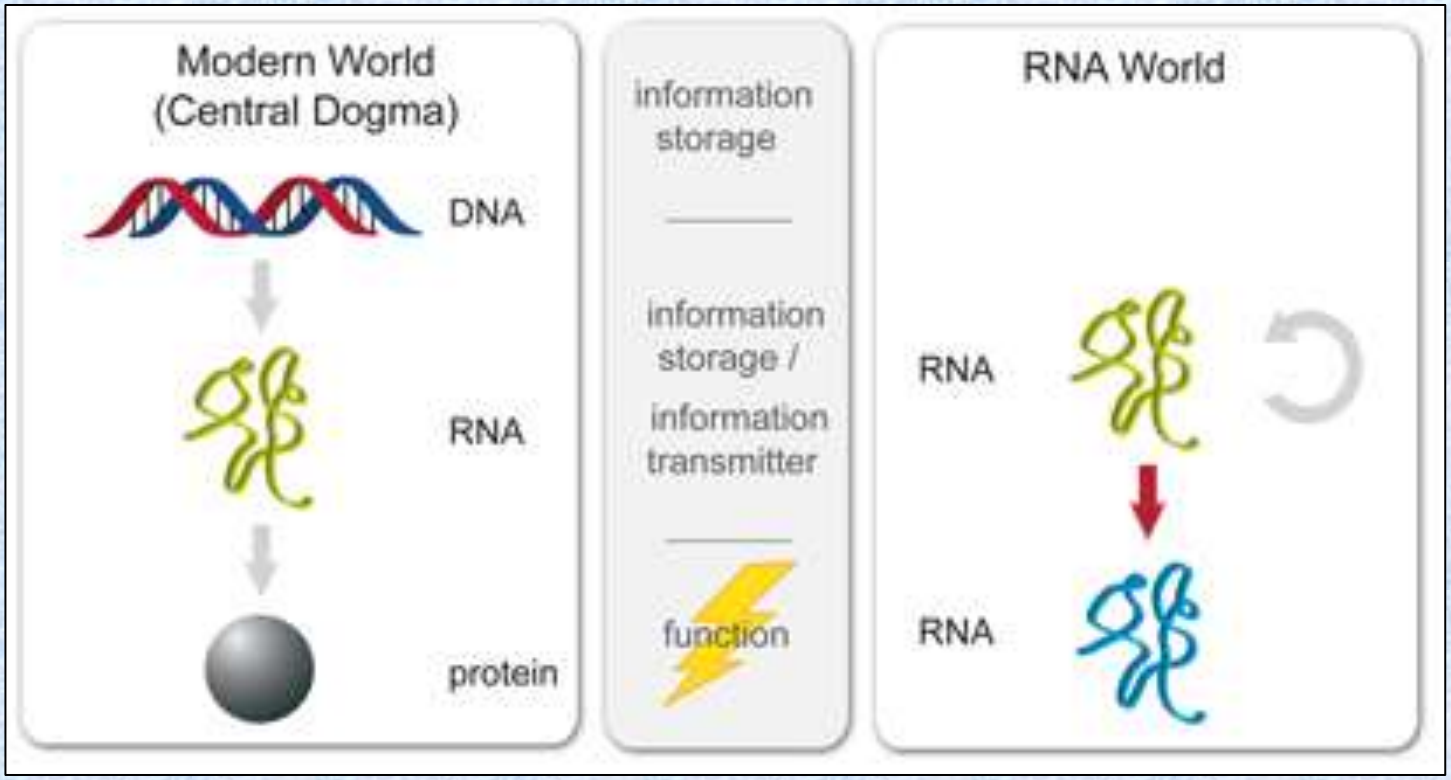
Has genotype and phenotype



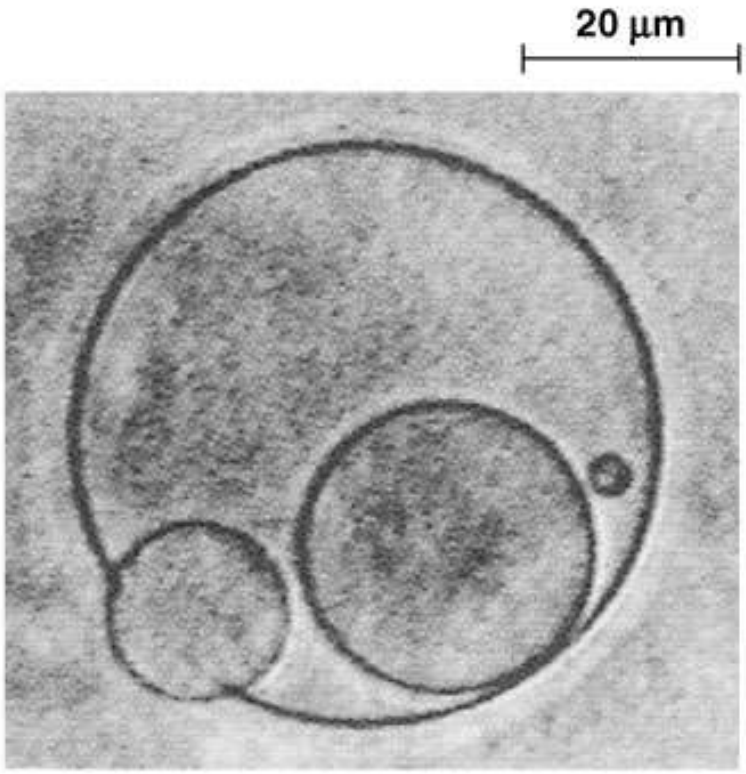
Self-splicing RNA

RNA World?

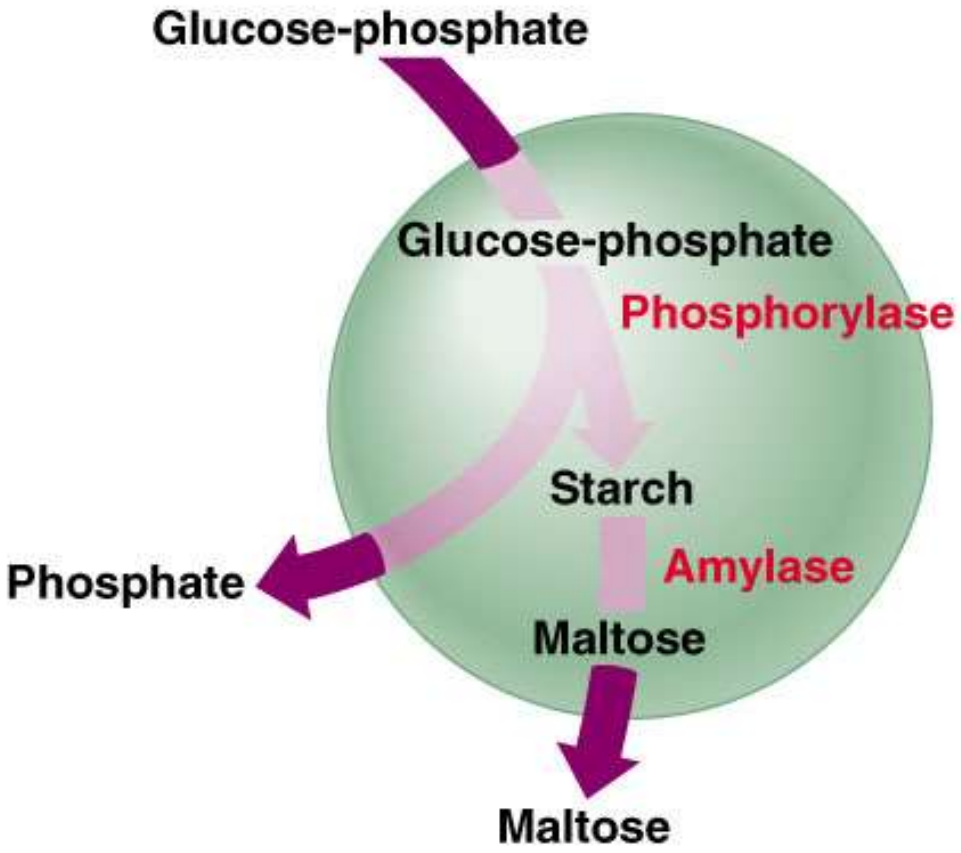
- RNA acts as both information storage and as catalyst
- DNA comes later, more stable for information storage



Proto-cells and Metabolism

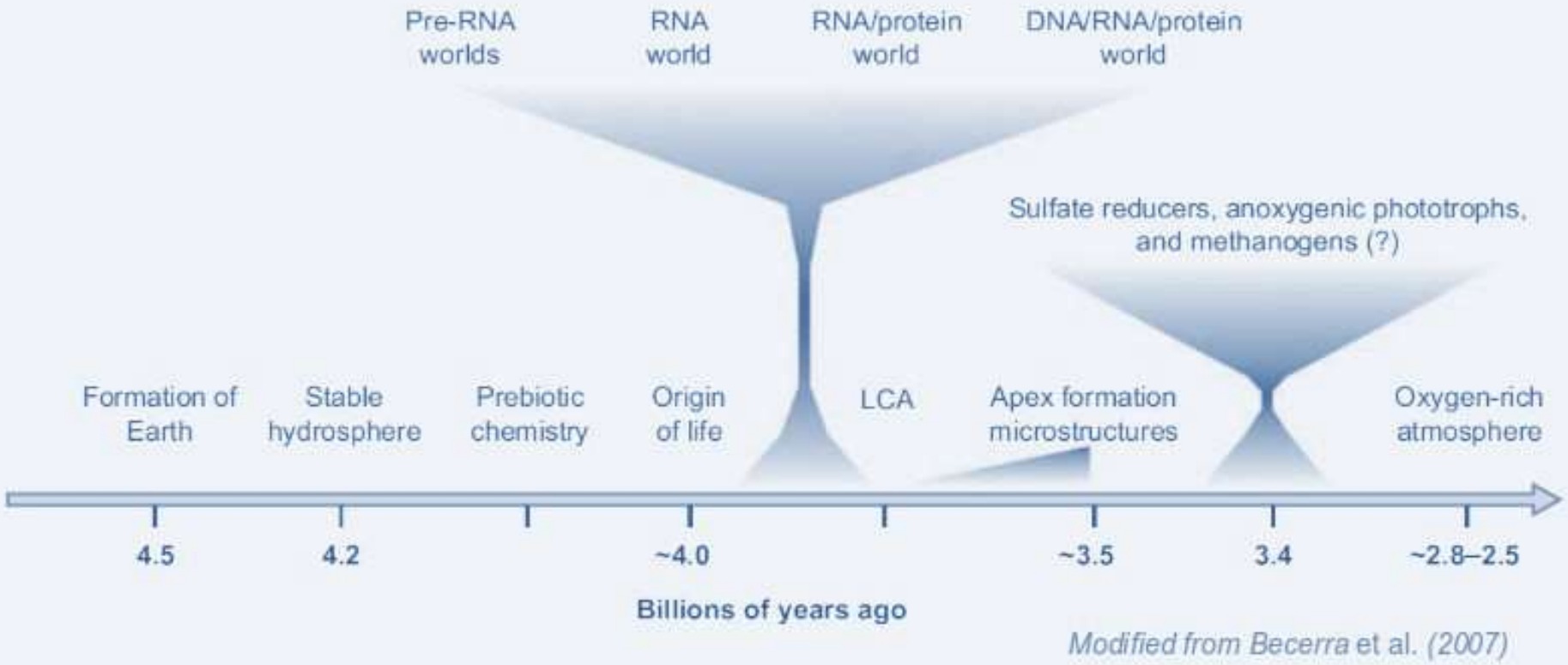


(a) Simple reproduction



(b) Simple metabolism

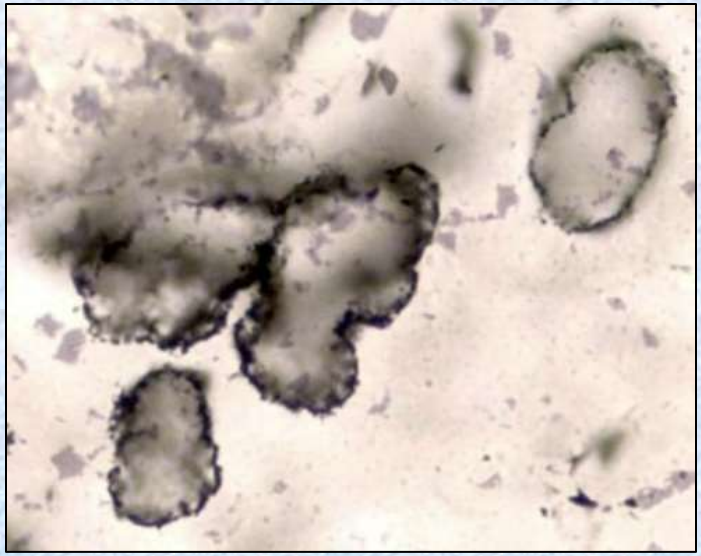
Timeline

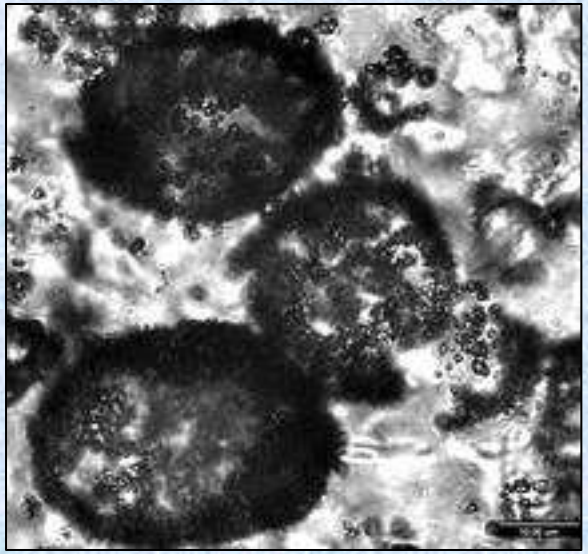


Modified from Becerra et al. *(2007)*

Oldest definite fossils 3.4 BY

Older fossil evidence questionable





- Found in a remote part of Western Australia
- Well preserved between the quartz sand grains of the oldest beach known on Earth, in some of the oldest sedimentary rocks that can be found anywhere.

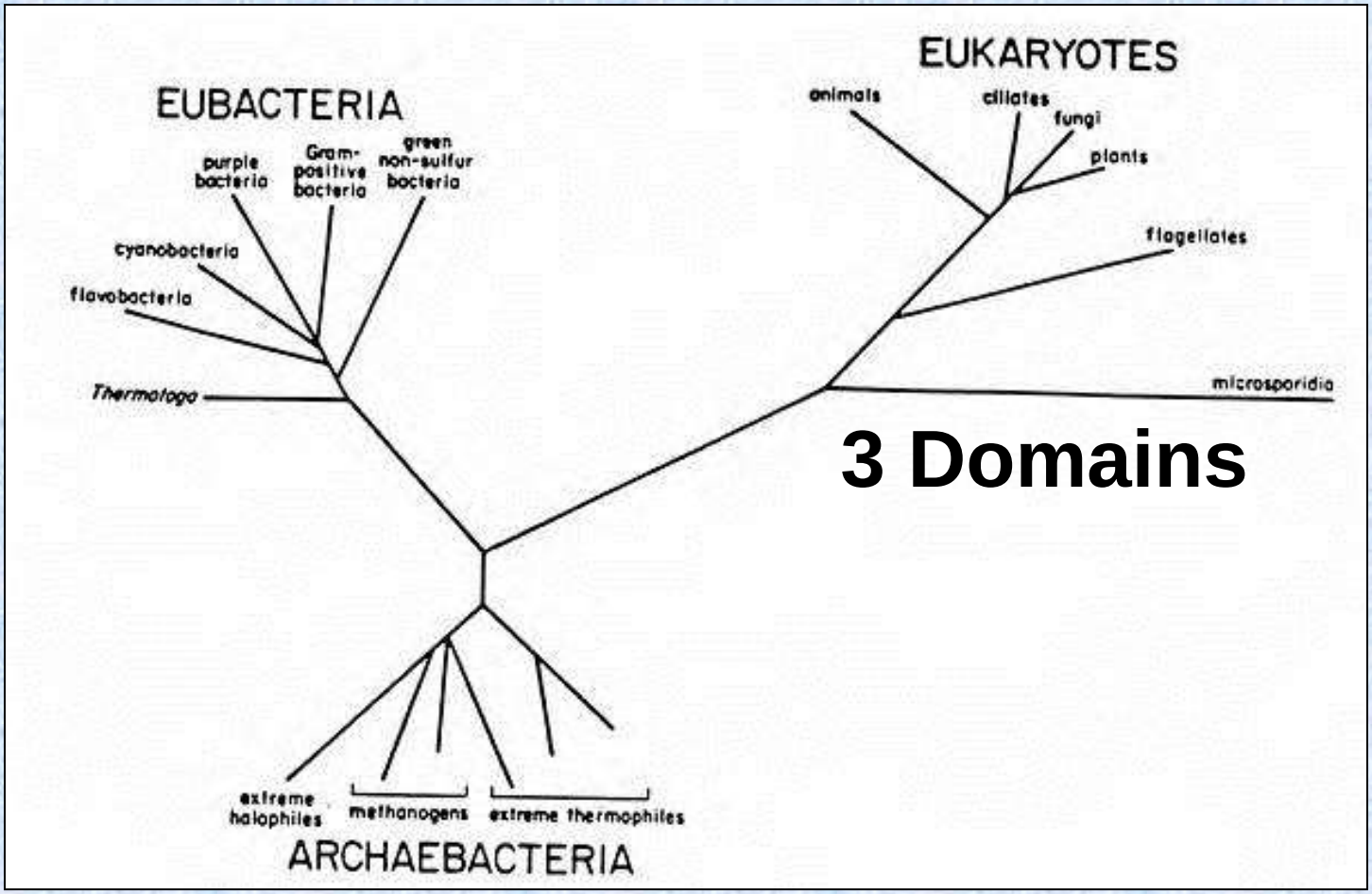
Characteristics of living organisms:

1. Have one or more cells with DNA.
2. Capable of reproducing, growing, and developing.
3. Capable of capturing and using energy and raw materials.
4. Able to sense and respond to the environment.
5. Capable of evolving over generations.

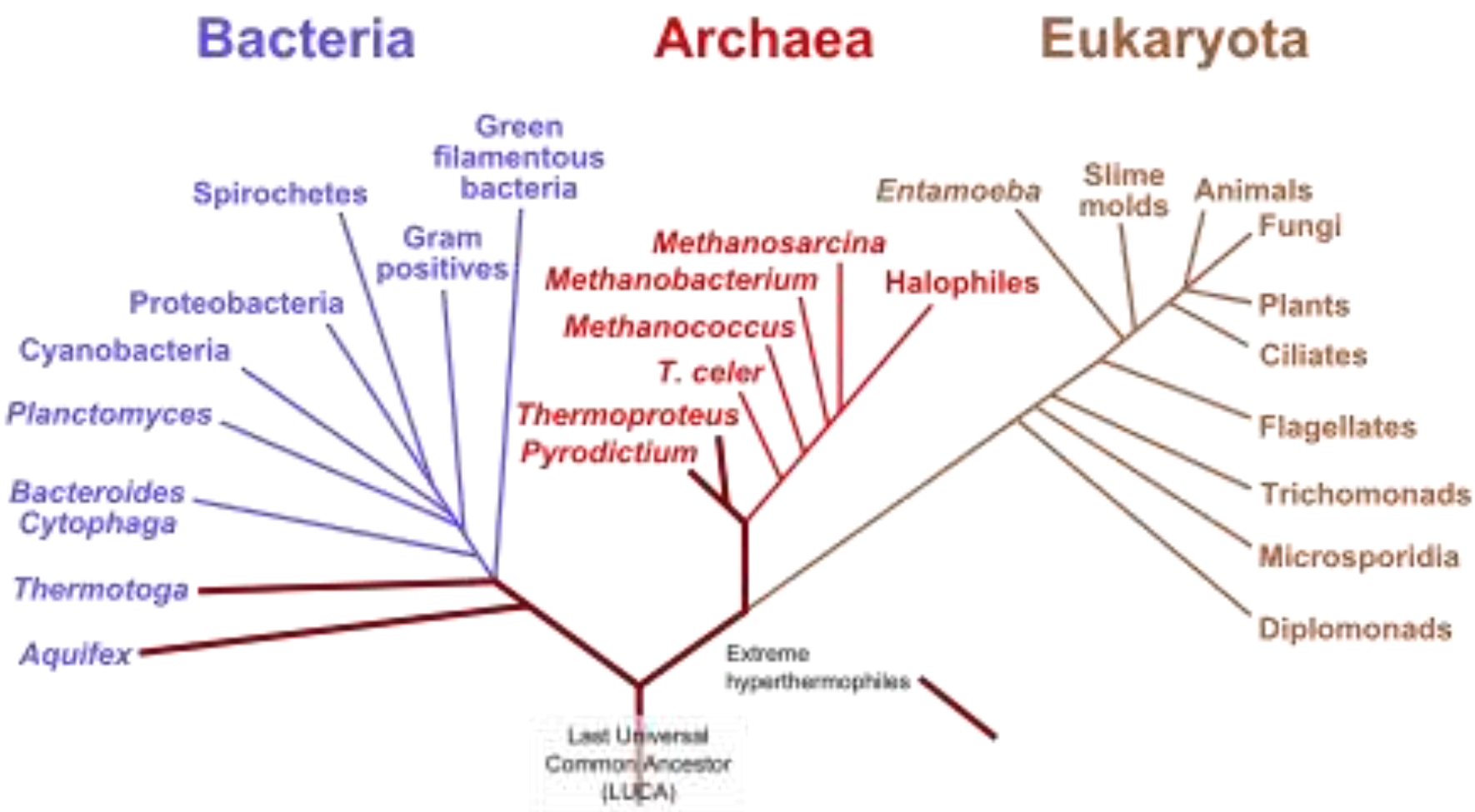
Archean Eon: 4-2 BYA

Carl Woese and the rRNA Tree of Life

Carl Woese
1980s
ssRNA
Sequences



Phylogenetic Tree of Life

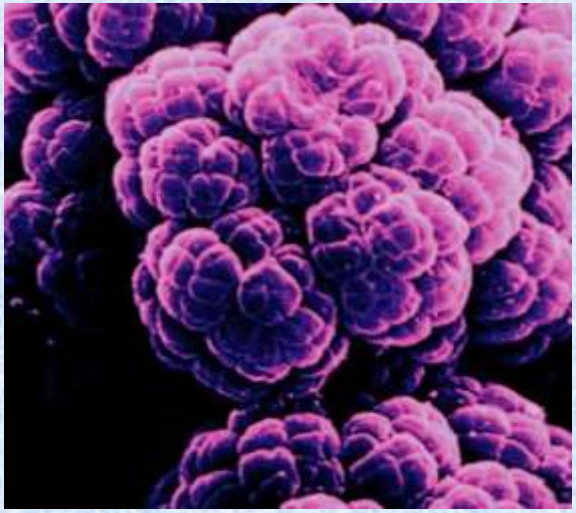


Archaea (Archaebacteria)

- Cell walls lack peptidoglycan which Bacteria cell walls have
- Ribosomal RNA different
- Membrane lipids with branched hydrocarbons which Bacteria do not have
- Archaea has more in common with Eukarya than with Bacteria

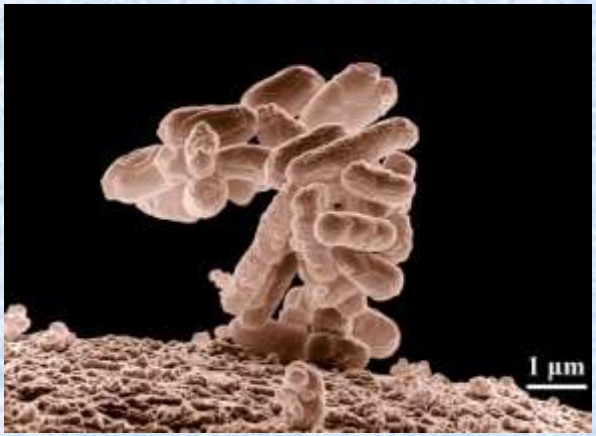
Some live in <u>extreme conditions</u>

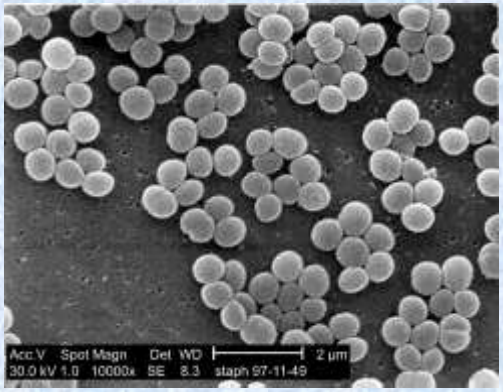
- methanogens
- extreme halophiles
- extreme thermophiles



Bacteria (Eubacteria)

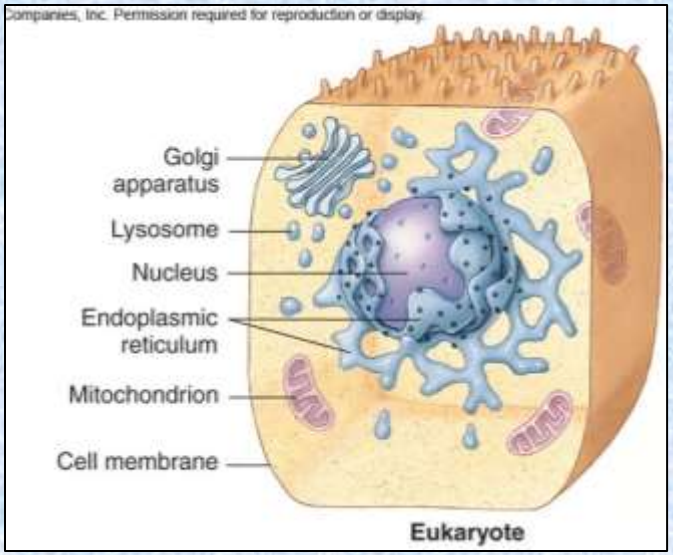
- Major group of prokaryotes
- Strong cell walls (peptidoglycan)
- Simple gene structure
- Contains most modern prokaryotes
- Includes photosynthetic bacteria (cyanobacteria)

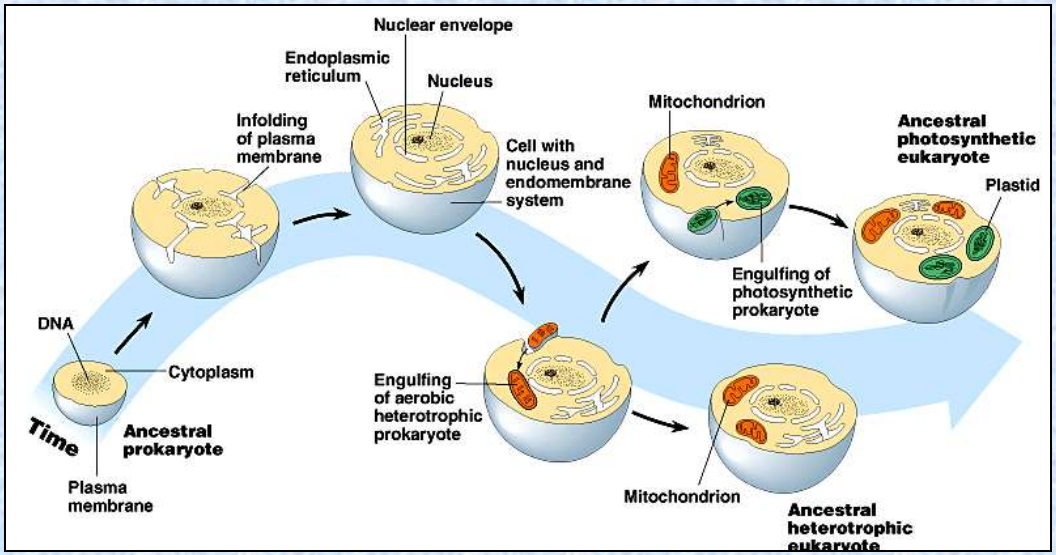




Eukarya

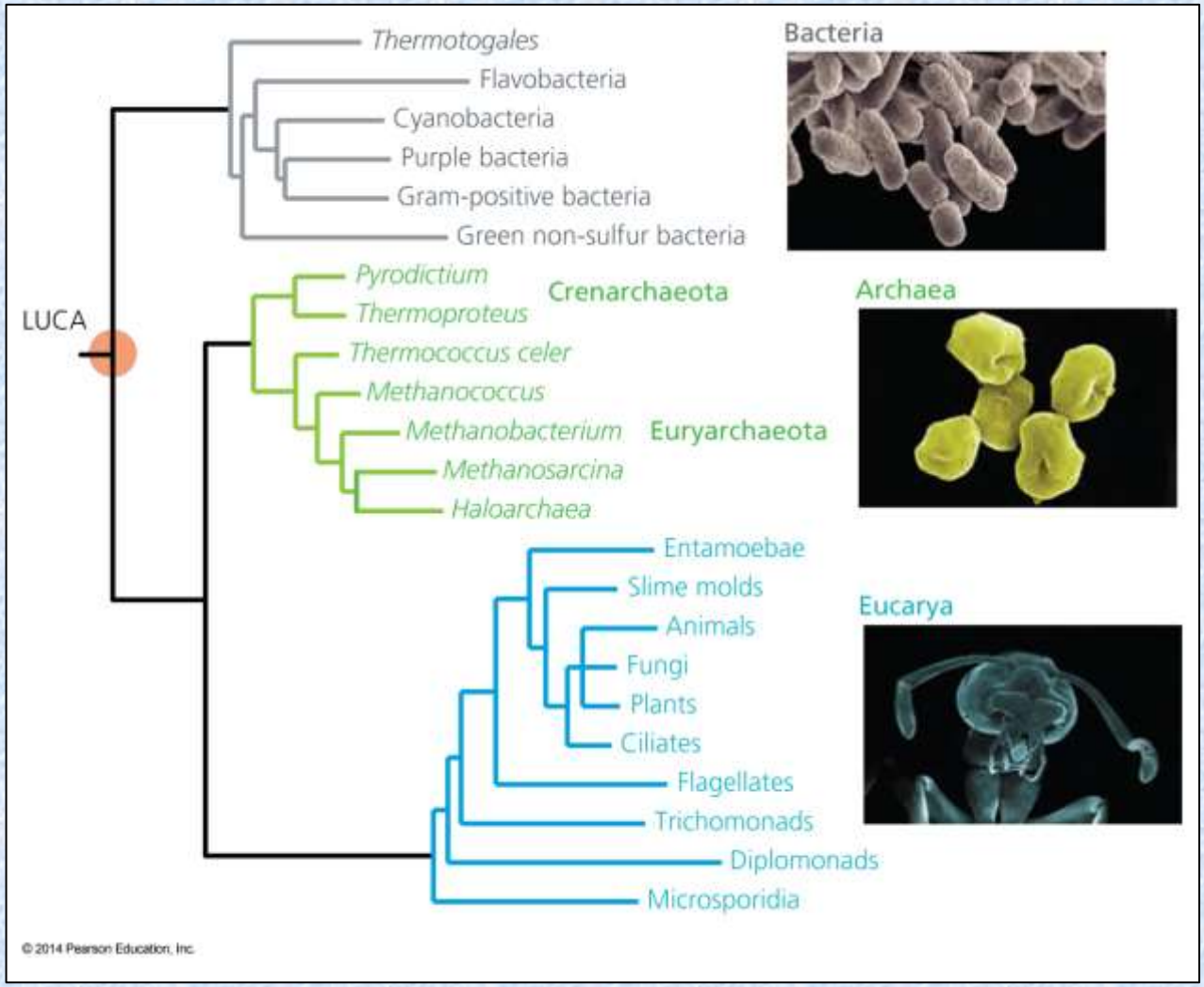
- Arose about 1.5 BYA.
- Origin of Nucleus? Infolding of plasma membrane
- Internal membrane-bound structures such as mitochondria and chloroplasts are thought to have evolved via endosymbiosis.





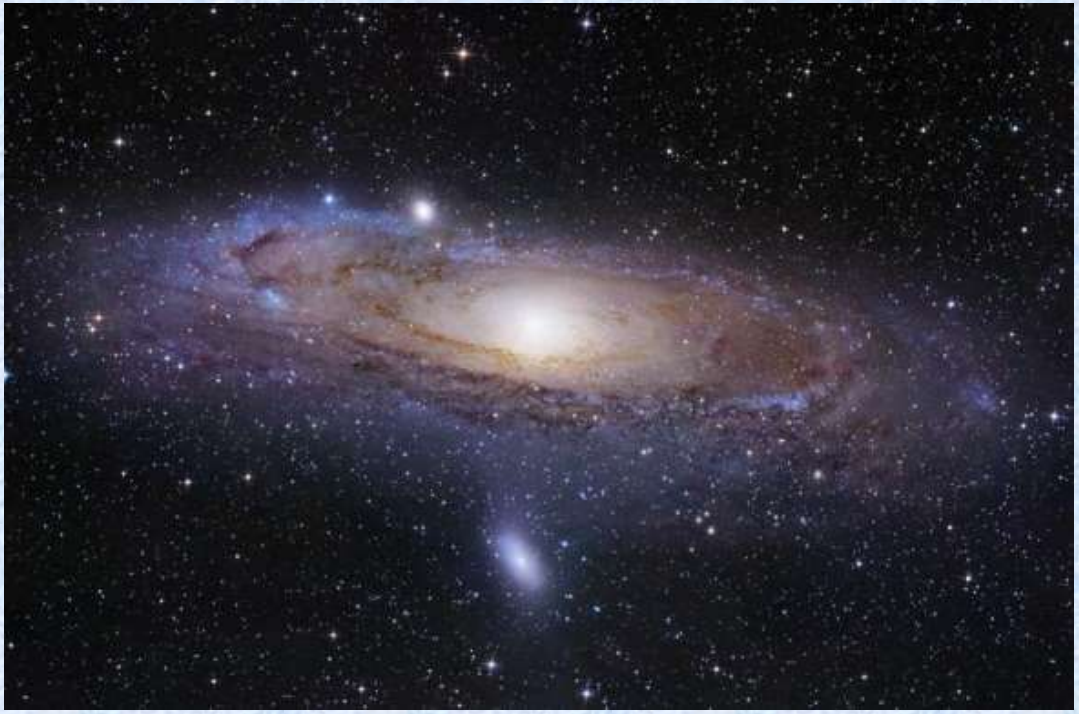
Phylogeny of All Living Organisms

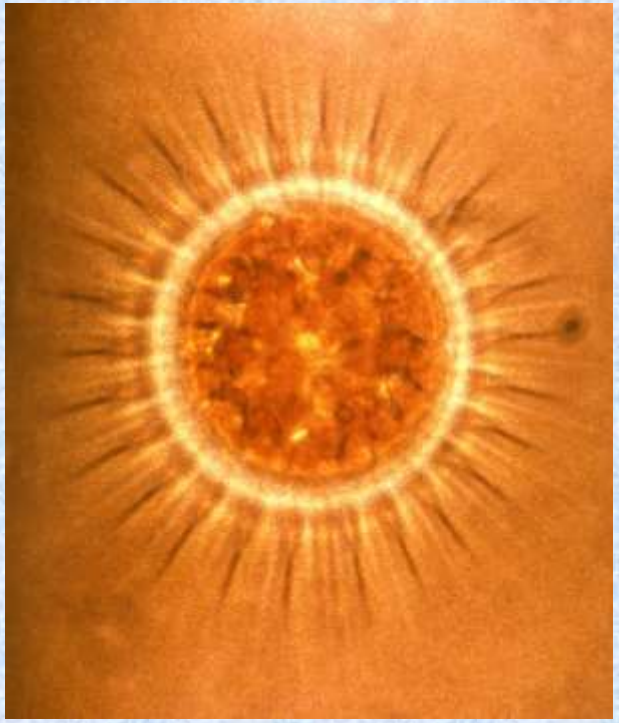
LUCA – Last Universal Common Ancestor

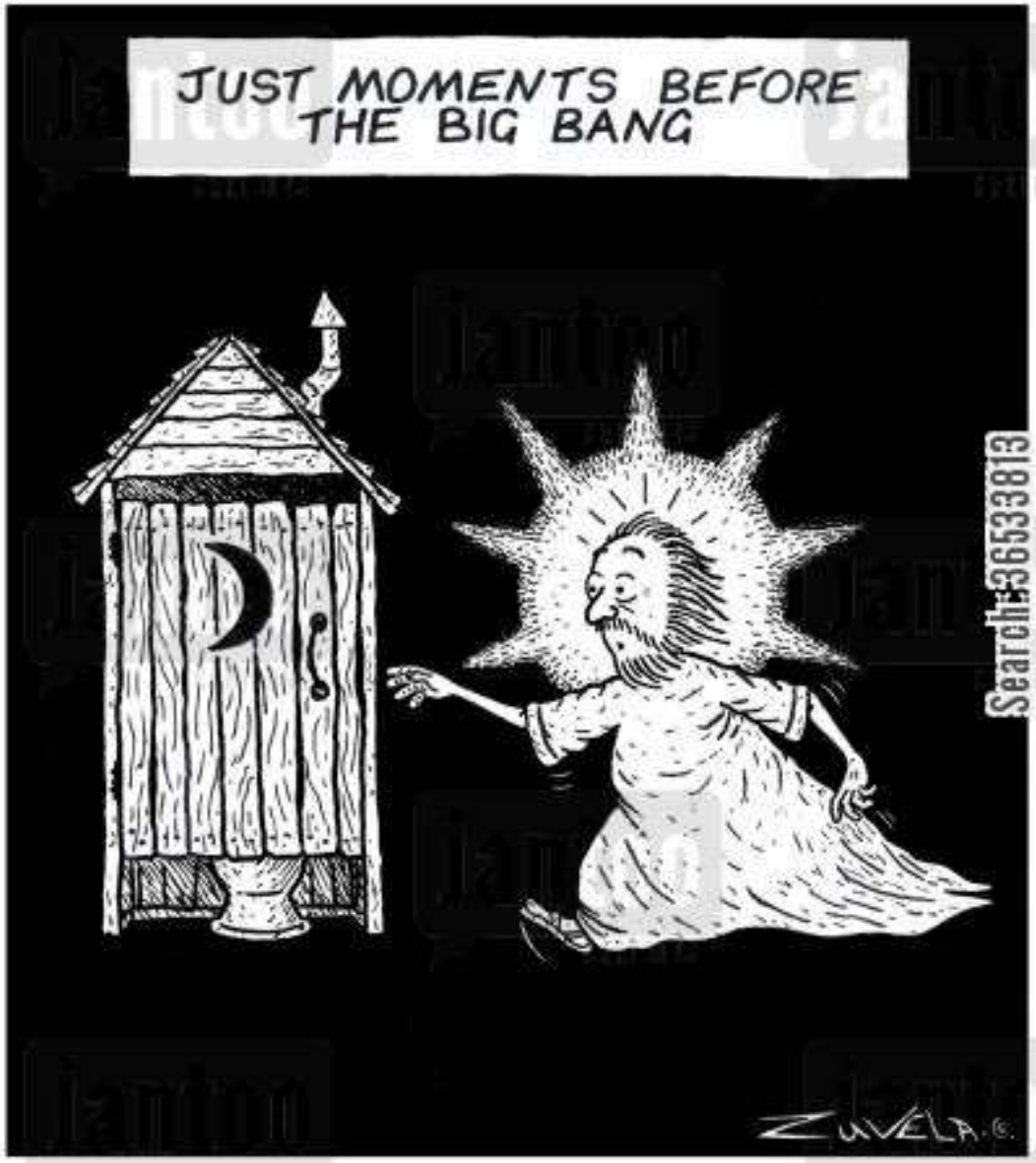


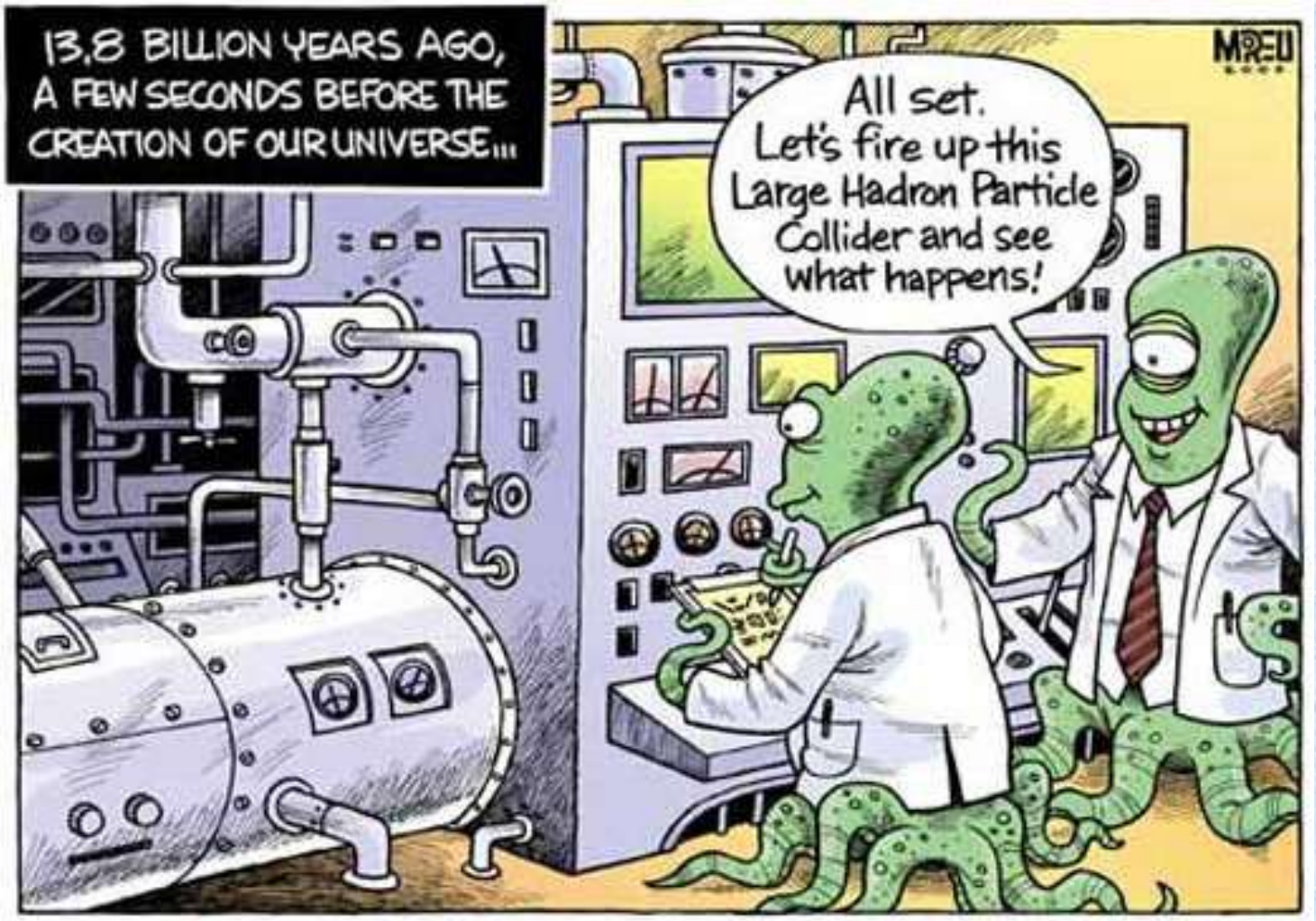
Eukarya is more closely related to domain Archaea than to domain Bacteria. Analysis of rRNAs and other highly conserved genes and proteins provide the strongest evidence

End






JUST MOMENTS BEFORE
THE BIG BANG
ZUVELA.©


13.8 BILLION YEARS AGO, A FEW SECONDS BEFORE THE CREATION OF OUR UNIVERSE...
All set. Let's fire up this Large Hadron Particle Collider and see what happens!
MOREAU

How life on Earth really got its start.