Big Idea 1: The process of evolution drives the diversity and unity of life.

Enduring understanding 1.D: The origin of living systems is explained by natural processes.

Essential knowledge 1.D.2: Scientific evidence from many different disciplines supports models of the origin of life.

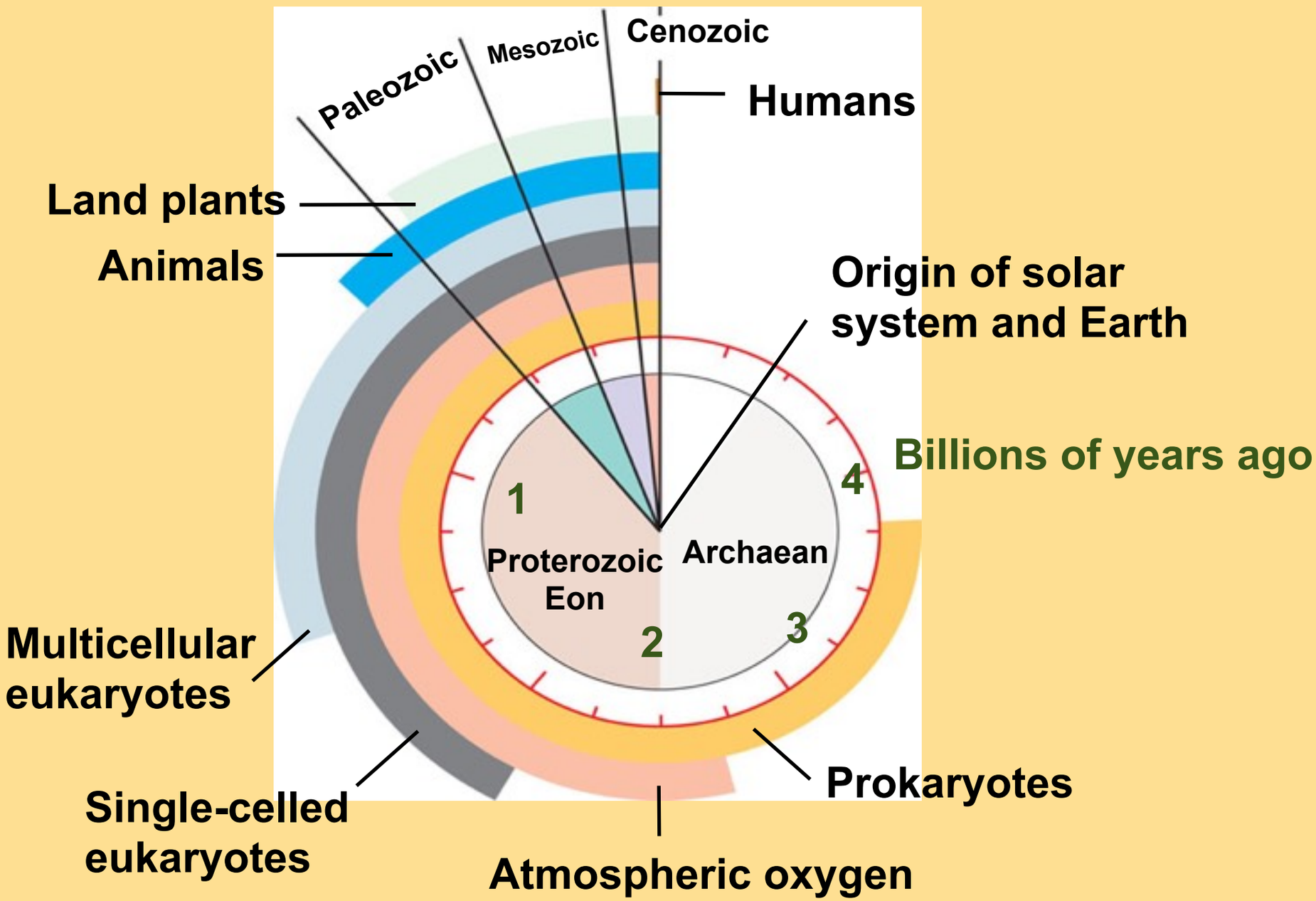
a. Geological evidence provides support for models of the origin of life on Earth.

b. *Evidence of student learning is a demonstrated understanding of each of the following:*

1. The Earth formed approximately 4.6 billion years ago (bya), and the environment was too hostile for life until 3.9 bya, while the earliest fossil evidence for life dates to 3.5 bya. Taken together, this evidence provides a plausible range of dates when the origin of life could have occurred.

Major Events in Earth History

- **Formation of earth and abiogenesis 3.8 bya**



What did the first cells look like?

- Nobody can say for sure. (I have found conflicting information but here is what I can say)
- Science agrees the first cell was a very simple prokaryotic.
- Science agrees that the first cell would have been anaerobic (does not require oxygen)
- Science also agrees that this prokaryote was a chemotroph (uses chemicals for energy source)
- Most feel that these prokaryotes were heterotrophs (carbon source from organic compounds)
  - *Some sources feel believe that the first cell would have used carbon dioxide as its carbon source thus making it an autotroph.*

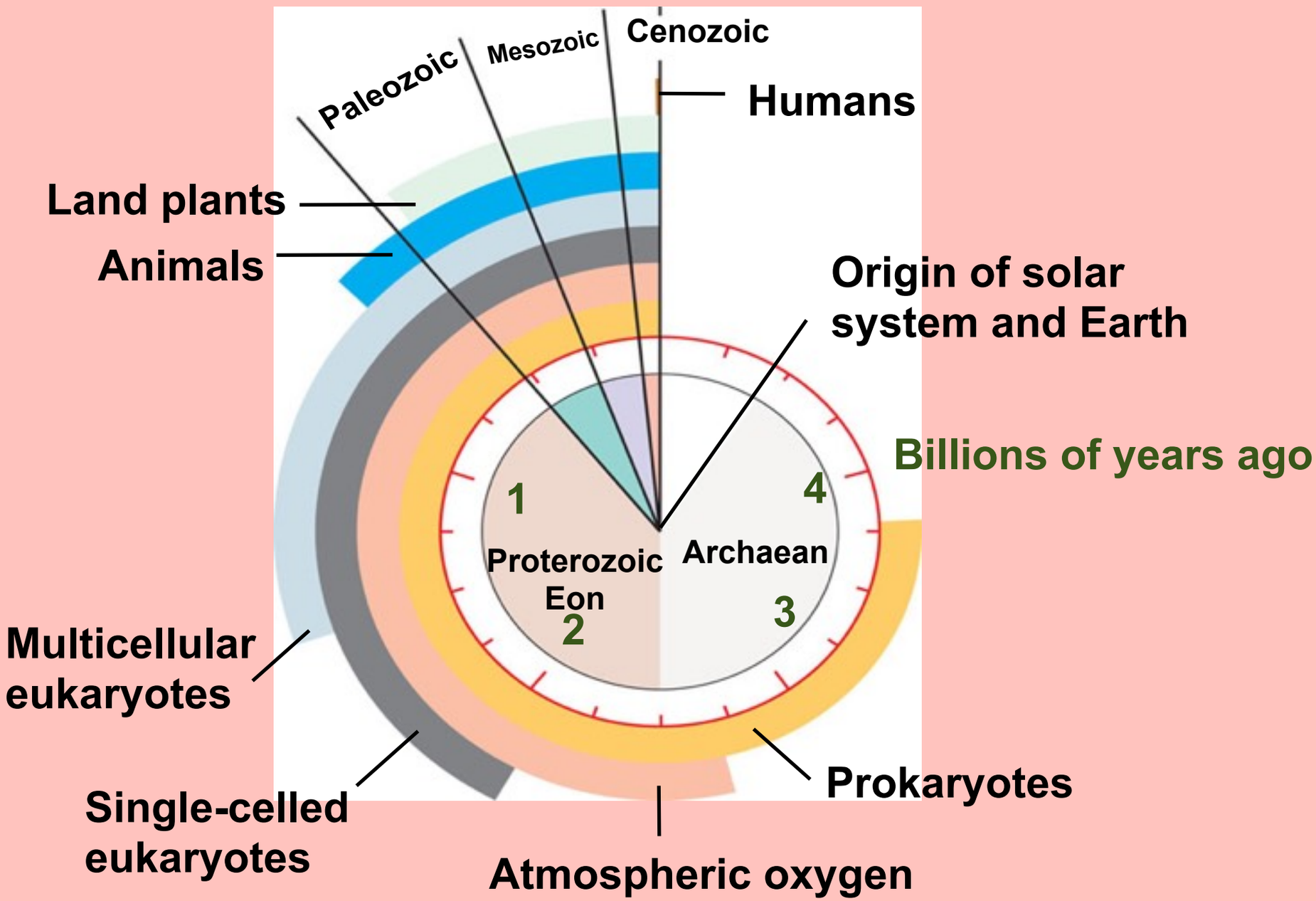
Final Verdict: **Anaerobic Chemoheterotrophic Bacteria**

What did the earliest fossils look like?

- The earliest known fossils date back to 3.5 billion years ago.
  - **Stromatolites** are rock like structures composed of layers of bacteria and sediment.
- Life itself likely evolved prior to this as result we estimate the first cells evolved somewhere around 3.8 billion years ago.

Major Events in Earth History

- **Atmospheric Oxygen ~2.5 bya**



Major Events in Earth History

- **The earliest metabolism likely produced ATP via glycolysis.**

↓

- **The earliest form of photosynthesis likely used the electrons from hydrogen sulfide (used up quickly).**

↓ Life's First Major Crisis

- **The earliest form of photosynthesis likely used the electrons from water.** (cyanobacteria)

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

→ Produces atmospheric oxygen

Major Events in Earth History

- **The production of oxygen accumulates on earth around 2.3 - 2.7 billion years ago.**
  - *theme...biotic effecting the abiotic*
- **The oxygen rich atmosphere has a significant effect on the evolution of living organisms**
  - *theme...abiotic effecting the biotic*

Major Events in Earth History

- **The oxidative (degradative) atmosphere posed a challenge to living organisms.**

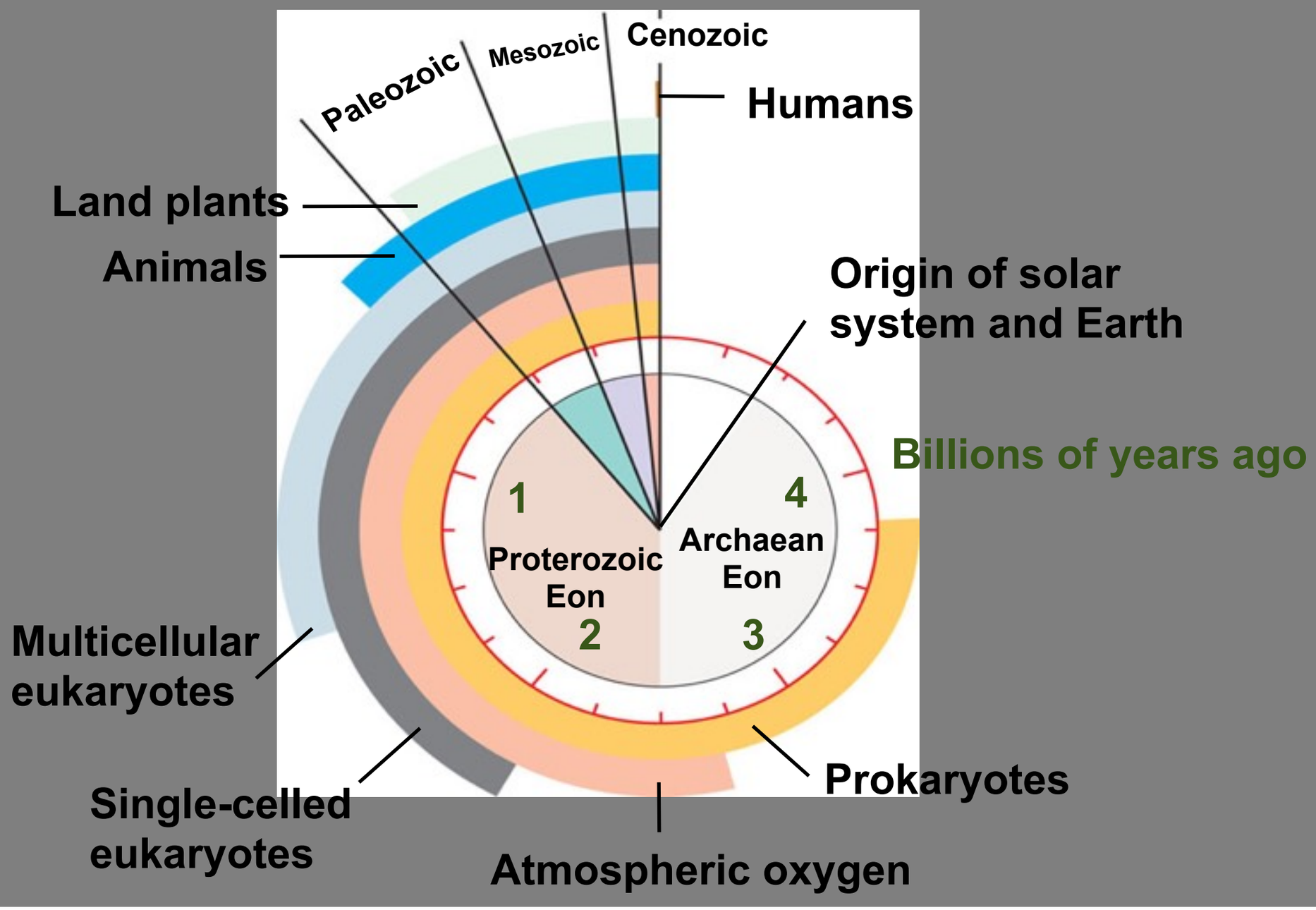
  Second Major Crisis

- **The oxidative atmosphere also provided an opportunity for living organisms to gain energy.**

  Aerobic Respiration- A Major Innovation

Major Events in Earth History

- **Evolution of Eukaryotes 2.1 bya**

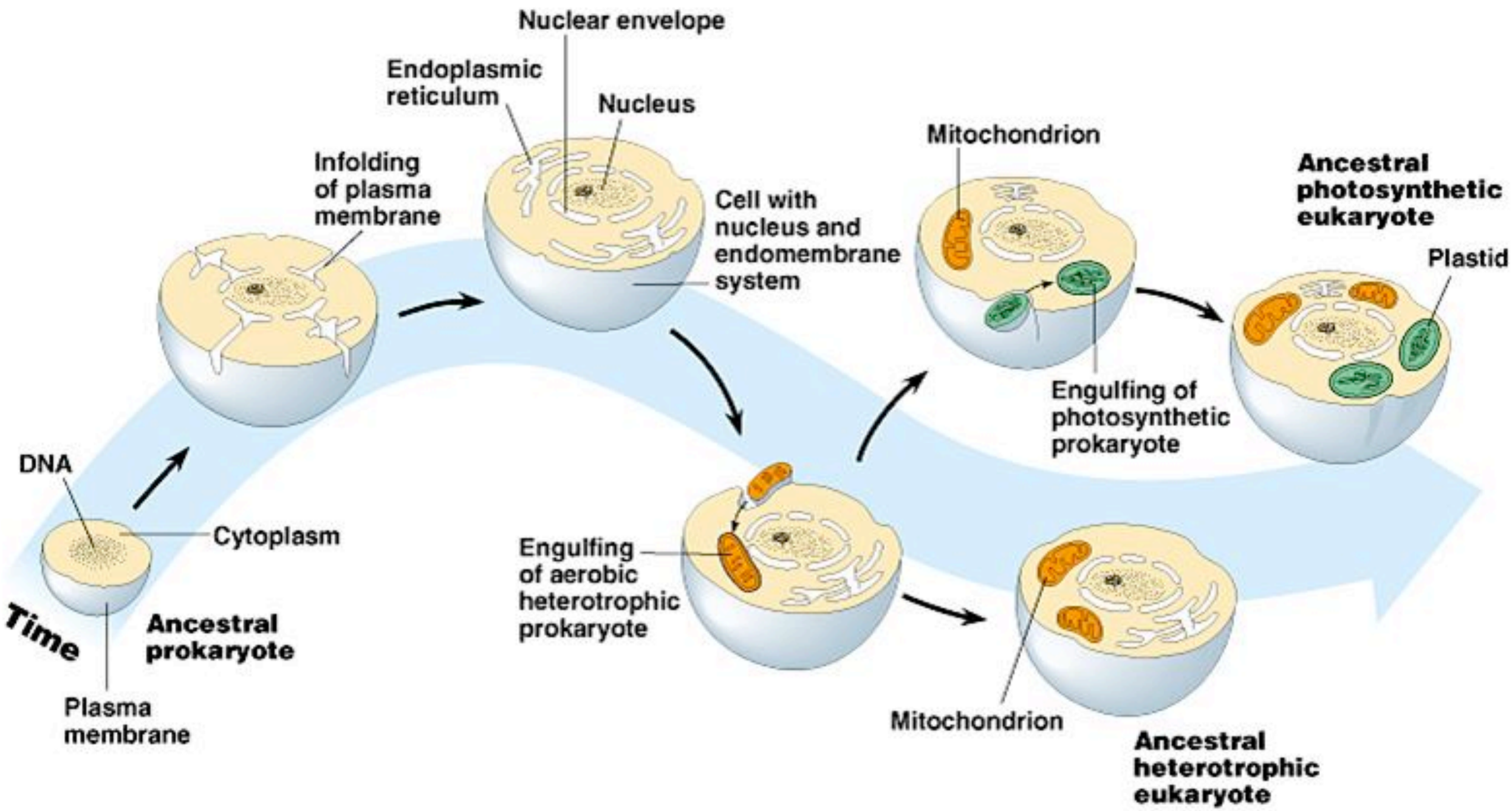


Major Events in Earth History

- **Evolution of Eukaryotes dates back to 2.1 BYA**
- **It is possible that the oxygen revolution provided the selective pressure for eukaryotic evolution.**
- **These cells are more complex than prokaryotes**
  - **They possess membrane organelles**
    - ***nucleus, mitochondria, chloroplasts, etc***
  - **They possess a cytoskeleton**
  - **The endosymbiont theory explains how this may have occurred.**

Endosymbiont Theory

...could have been undigested prey or a parasite



Major Events in Earth History

- The endosymbiont lives within the host cell.
- The prey/parasite form a mutualistic relationship.
- At some point the host and the prey/parasite become dependent on one another.
  - It is likely that the heterotroph/mitochondria came first.
  - Then later the autotrophic bacteria/chloroplast came second.

There is an overwhelming amount of evidence to support this theory and and these ideas.

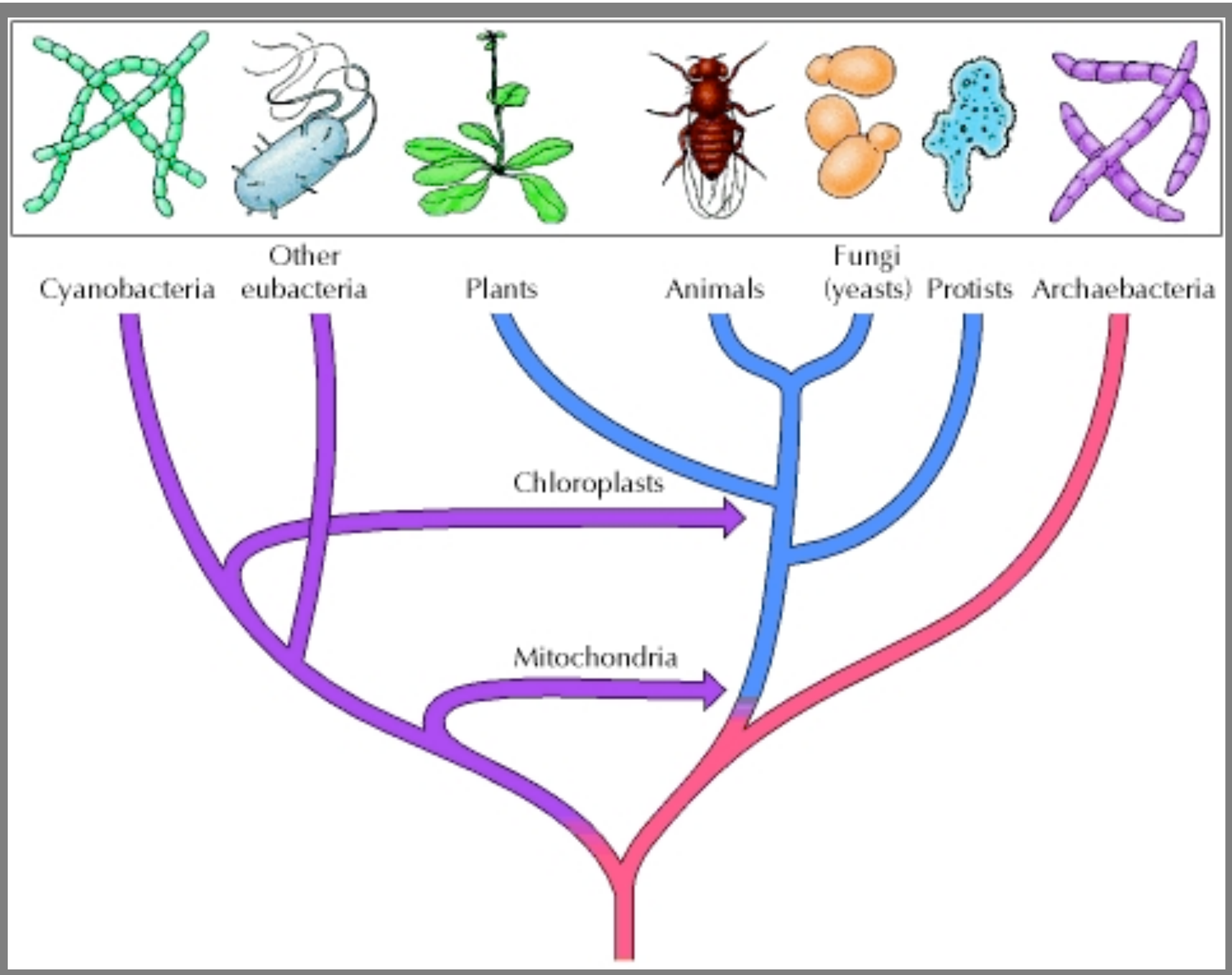
Evidence for Endosymbiosis

Prokaryotes	Mitochondria & Chloroplasts
• plasma membrane enzymes	• membrane enzymes homologous to prokaryotic plasma membrane
• plasma membrane transport systems	• membrane transport proteins homologous to prokaryotic plasma membrane
• replicate via binary fission	• replicate similar to binary fission
• single, circular chromosome with no histones	• organelles both posses their own single circular chromosome also with no histones even though eukaryotic chromosomes have histones
• ribosomes have unique size and sequence	• organelles posses their own ribosomes, which are equal in size to the prokaryotes and their RNA sequences are nearly identical

What are the advantages of membrane bound organelles?

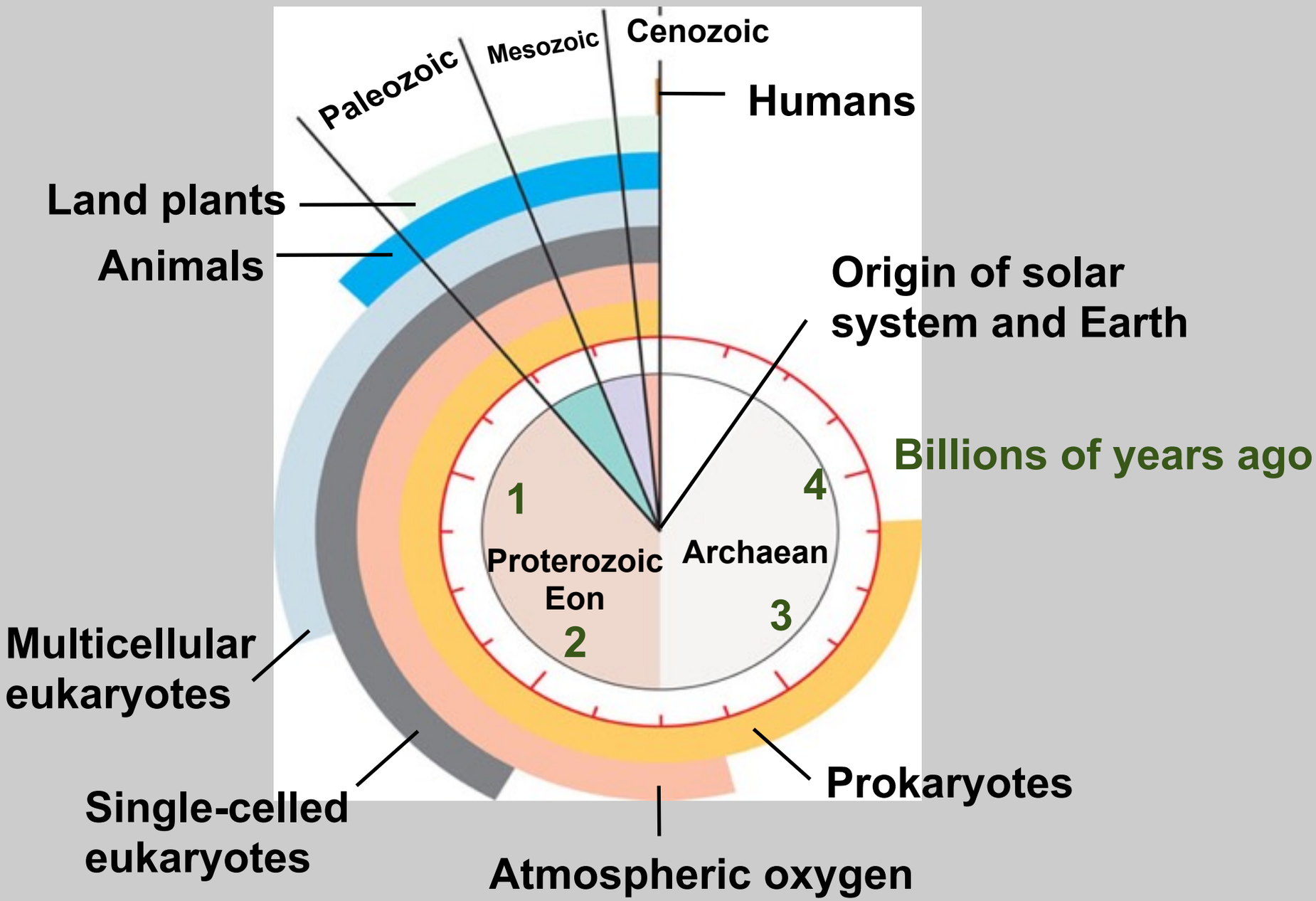
- **Protection**
  - *DNA has an added layer of protection*
- **Specialization**
  - *each organelle can do something different*
- **Efficiency**
  - *digestion, energy production gets better*
- **Diversity**
  - *gain new metabolic pathways*

Evolution of Cells



Major Events in Earth History

- **Evolution of Multicellular Organisms 1.7 bya**



How did multicellularity evolve?

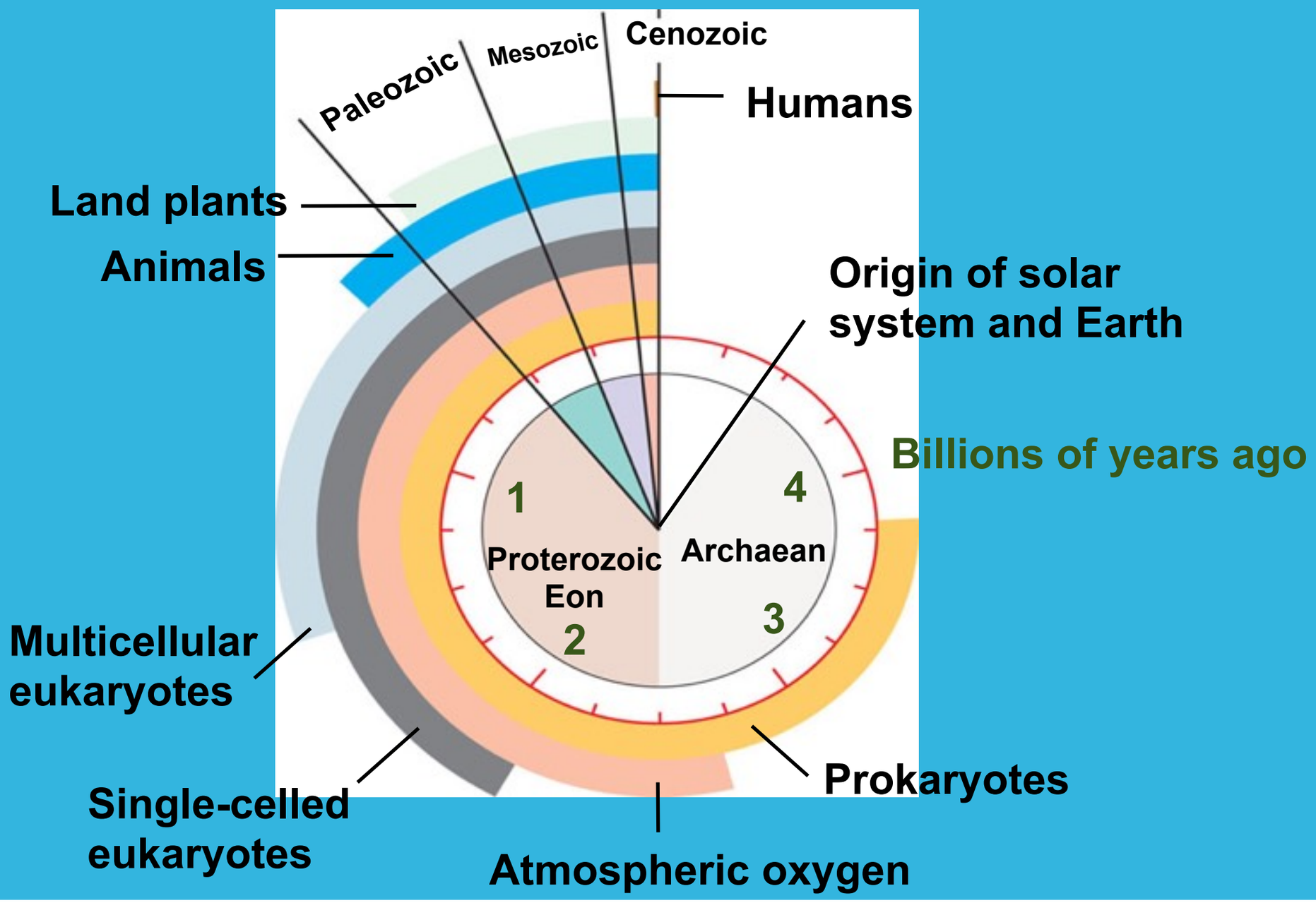
- Around 1.7 BYA multicellularity evolves.
- Unicellular eukaryotes form aggregates.
- These aggregates form multicellular colonies.
- The cells in the colony become specialized.
- Division of labor becomes pronounced.
- The colony cells become dependent on each others survival and you now a precursor for multicellular organism.

How did multicellularity evolve?

A collection of autonomously replicating cells form a colony

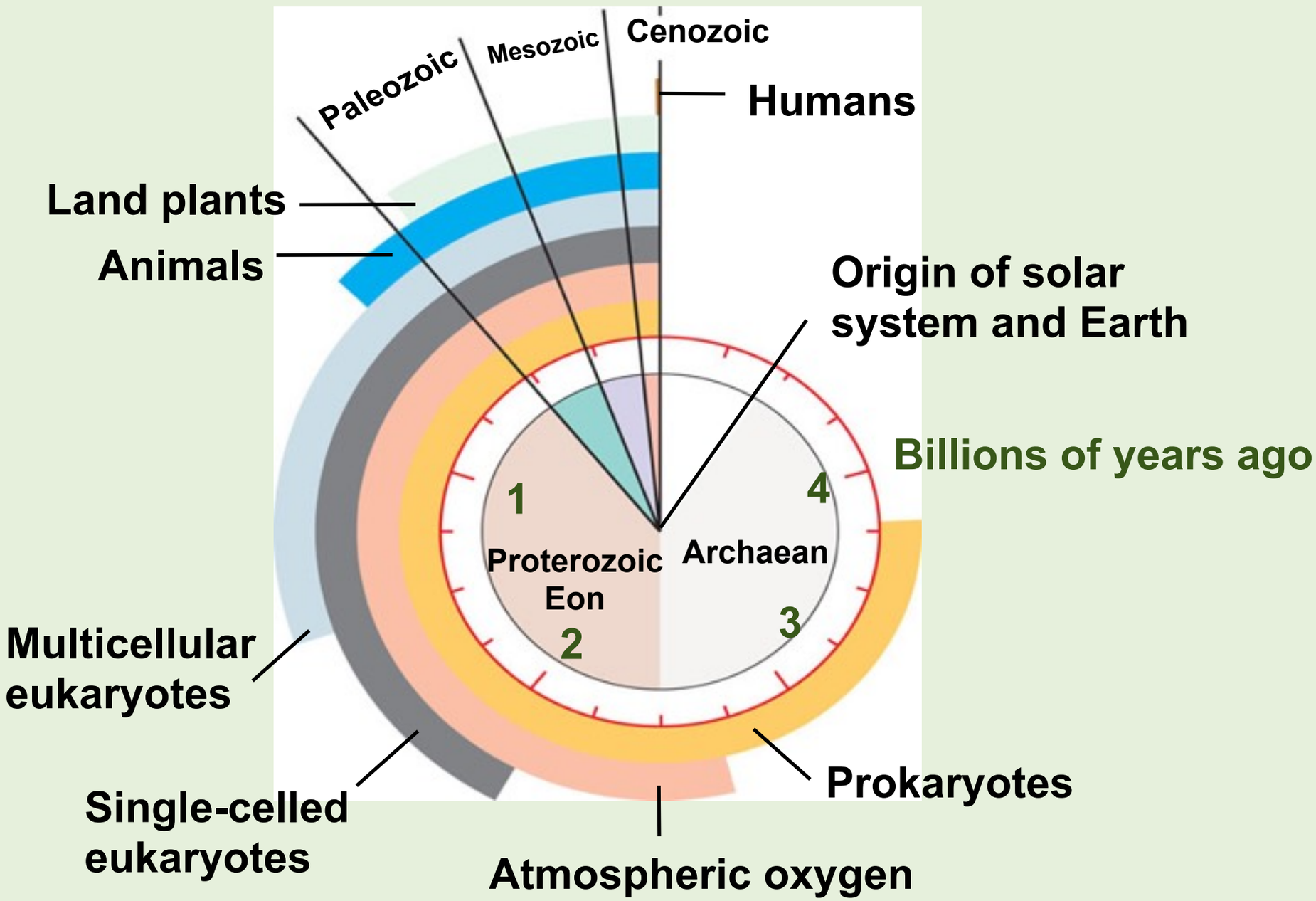
Major Events in Earth History

- **Evolution of Animals- (700-630 MYA)**
  - **Cambrian Explosion (530 MYA)**



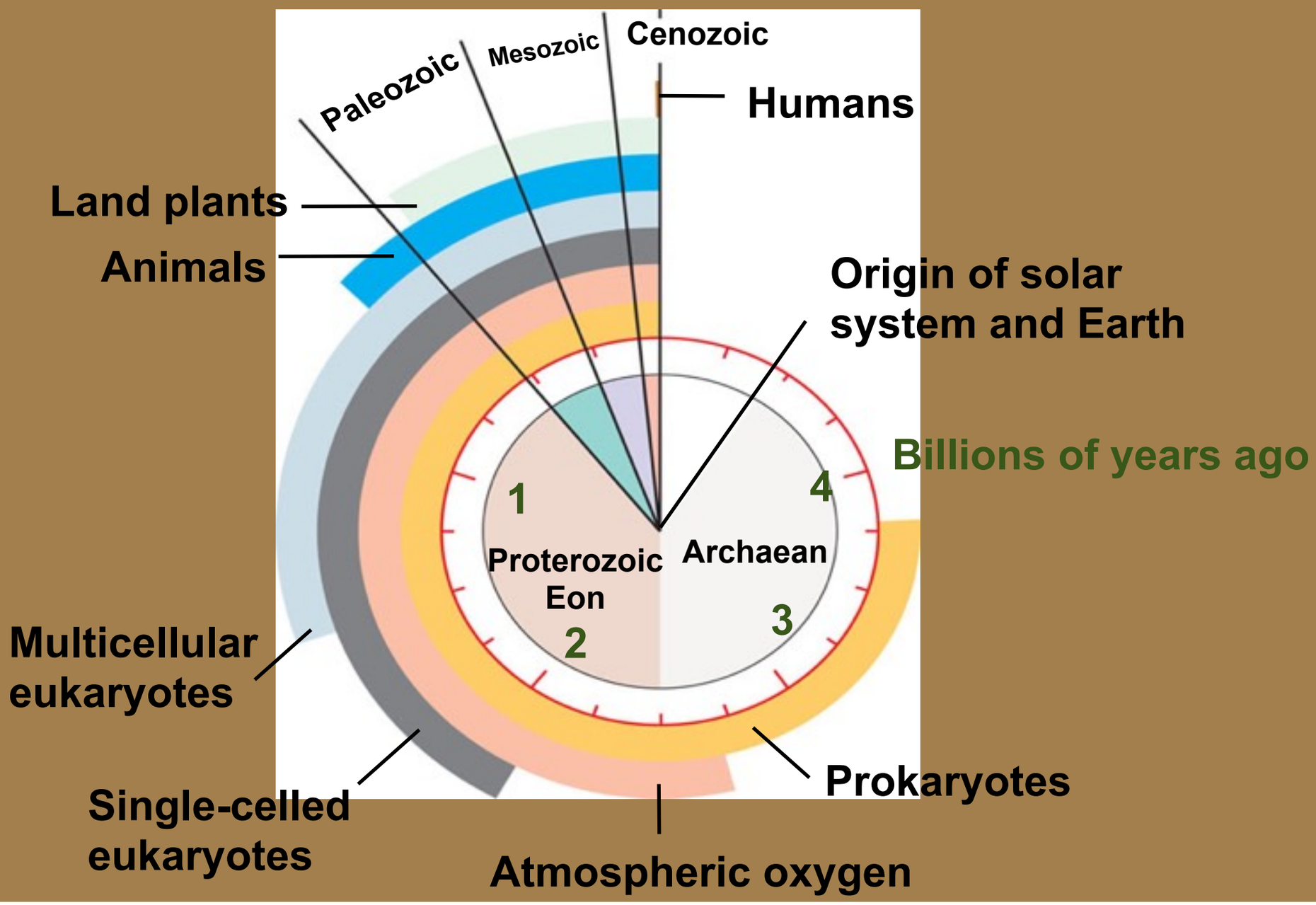
Major Events in Earth History

- **Colonization of Land- 500 - 420 MYA**
  - **plants, fungi and animals**



Major Events in Earth History

- **Evolution of Humans- 6-7 MYA**



Essential knowledge 1.D.2: Scientific evidence from many different disciplines supports models of the origin of life.

a. Geological evidence provides support for models of the origin of life on Earth.

Evidence of student learning is a demonstrated understanding of each of the following:

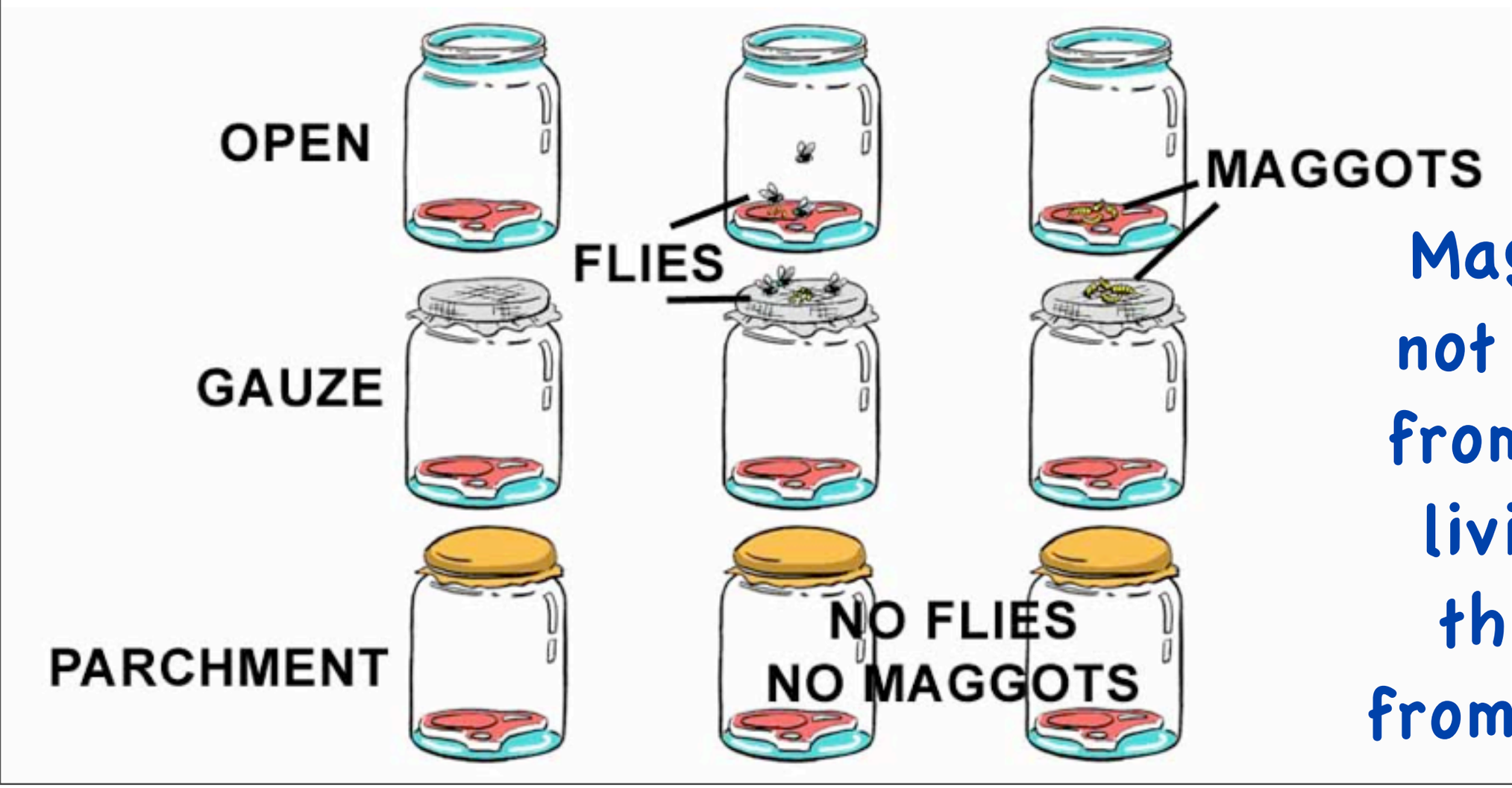
2. Chemical experiments have shown that it is possible to form complex organic molecules from inorganic molecules in the absence of life.

How did life begin? Spontaneous Generation

- Dating back at least to Aristotle was the thought that life originated from a "life force".
  - This idea ***spontaneous generation*** or abiogenesis held that living organisms could arise from non-living material.
- This idea has been dispelled and today we know that cells come from cells, life from life.
- Ironically we support the idea of abiogenesis, however, its meaning is more limited and specific.
  - Modern abiogenesis refers only to the origin of the first living organism(s), some 3.5+ billion years ago!

Classical Spontaneous Generation Dispelled

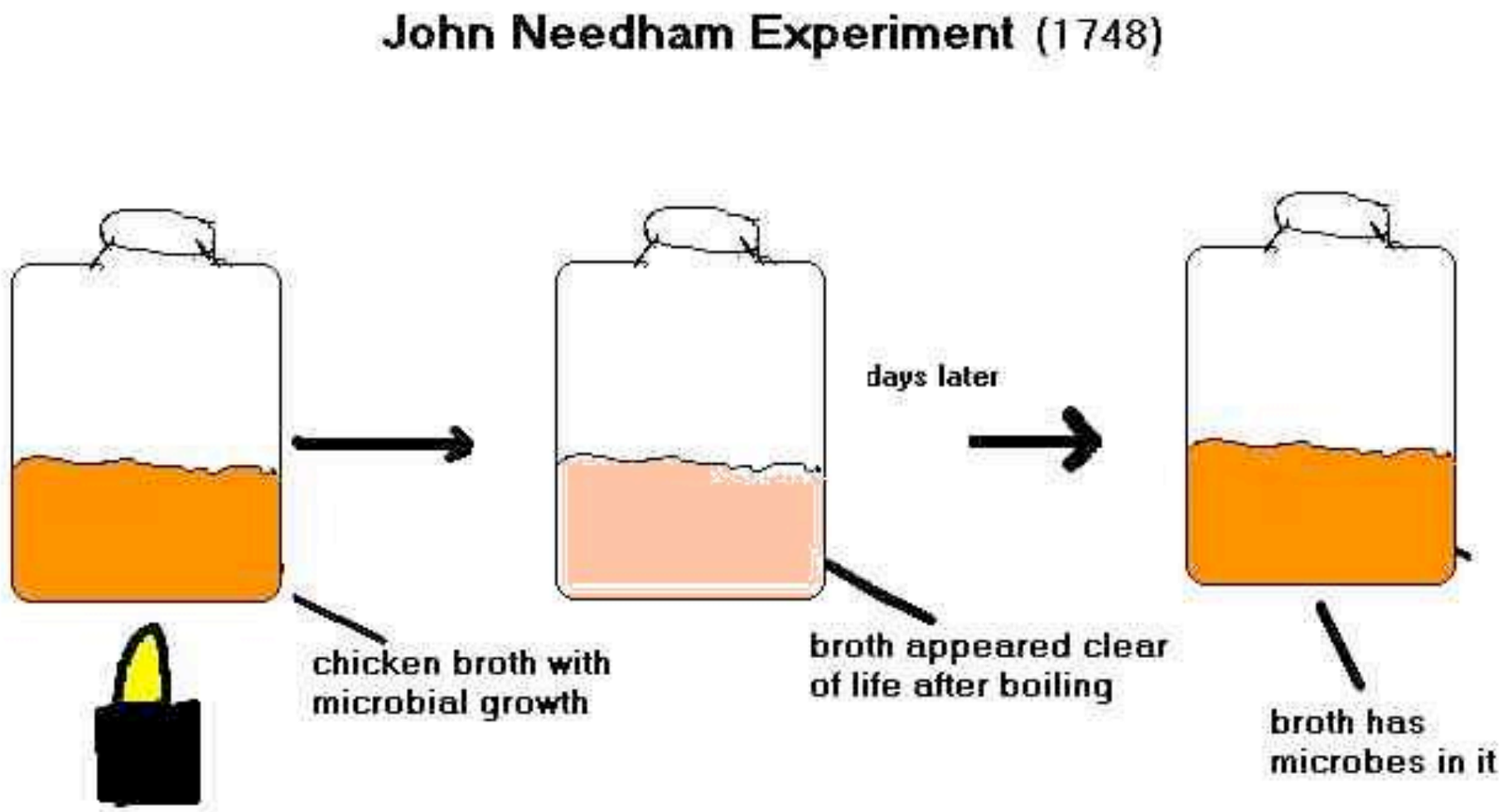
- The first evidence against this idea dates back to 17th century.
- Francesco Redi carried out a simple experiment that did not support the idea of spontaneously generation.



Maggots did not originate from the non living beef, they came from fly eggs.

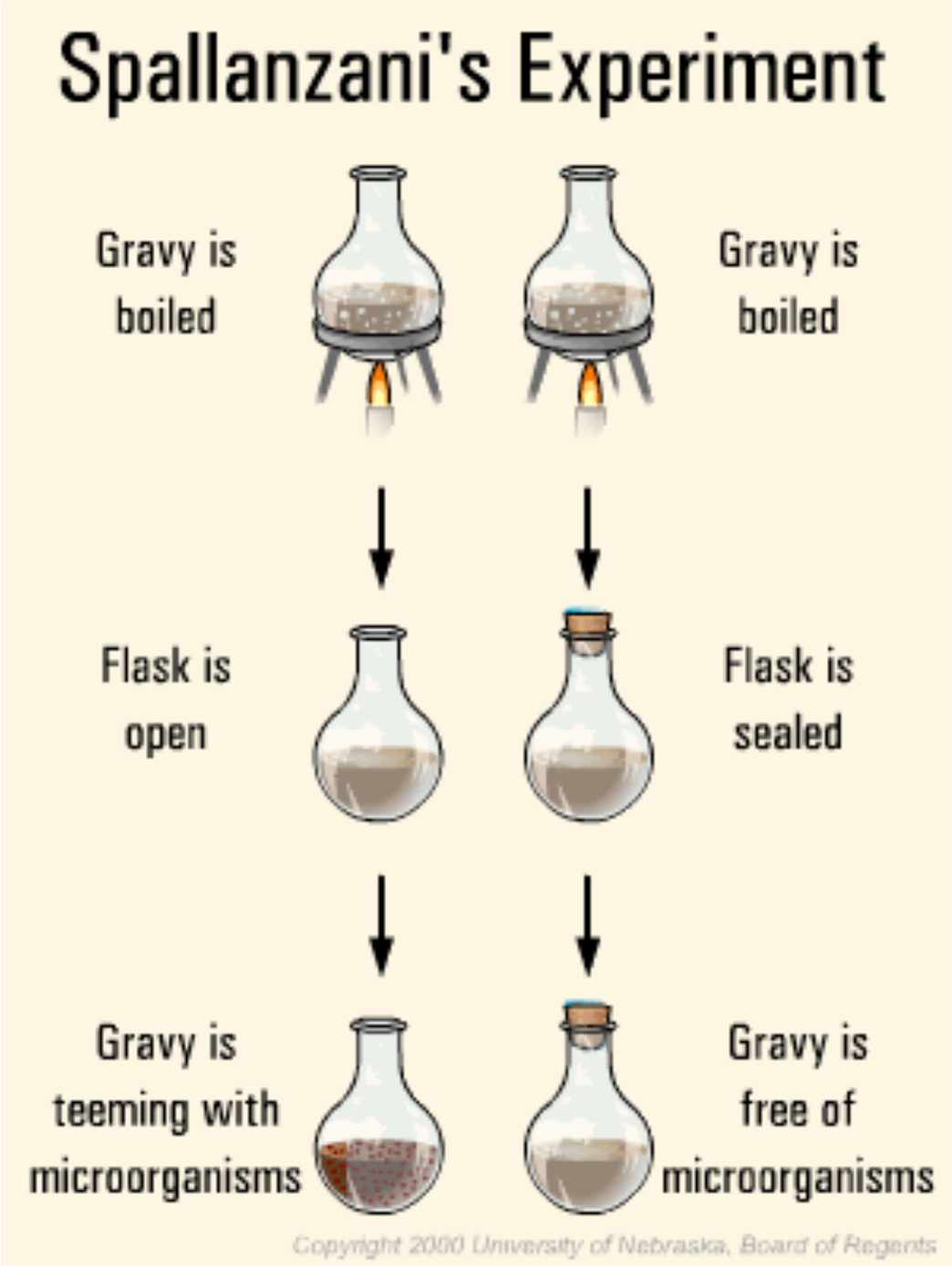
Classical Spontaneous Generation Dispelled

- In the 1748 John Needham, rekindles the debate.
- Knowing that heat killed organisms Needham boiled his nutrient broth and left it out on the table, only to find microbes growing days later.



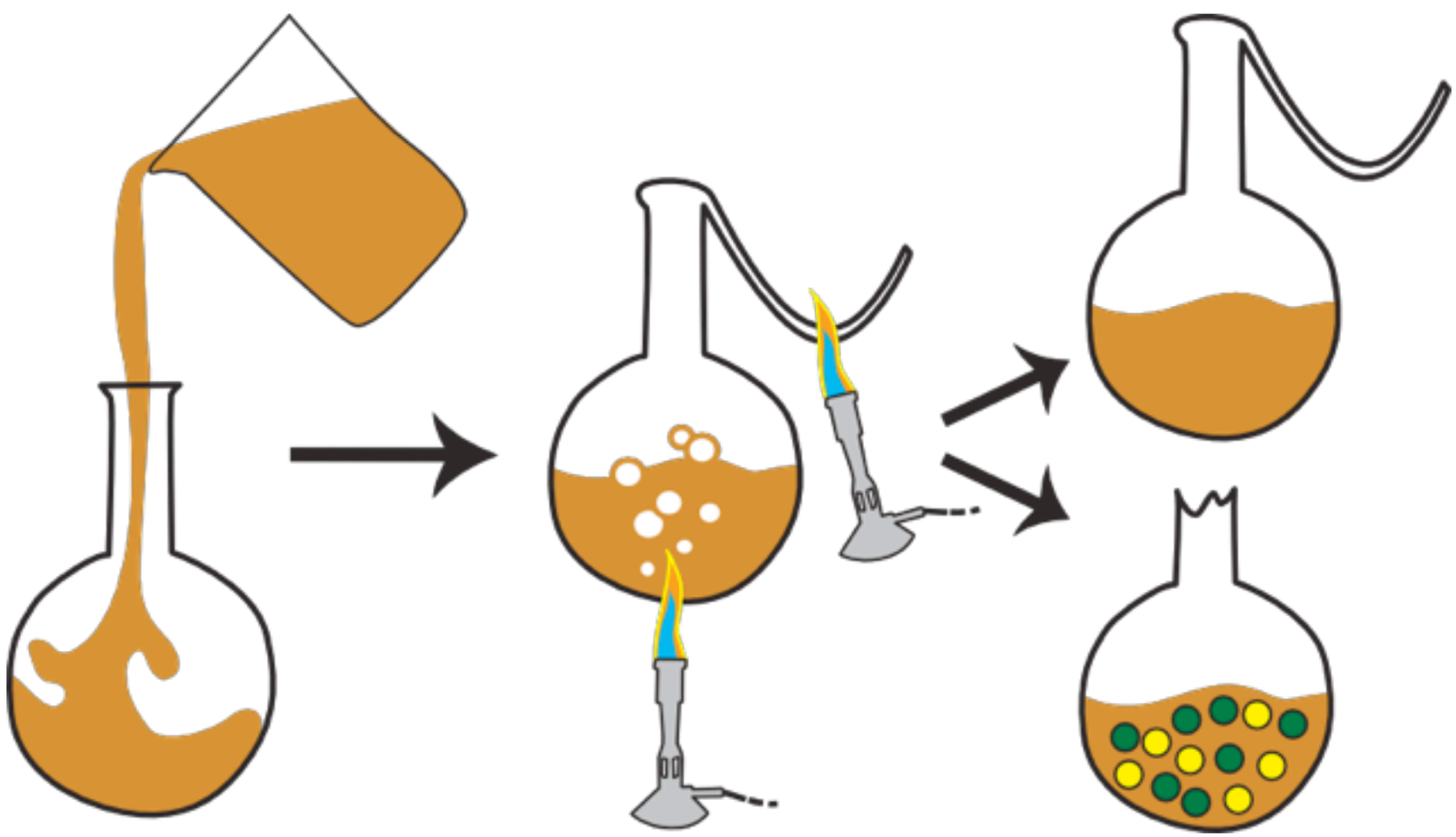
Classical Spontaneous Generation Dispelled

- Lazzaro Spallanzani answers Needham later that century with yet another definitive experiment.
- Spallanzani carried out yet another simple experiment that showed microbes could travel in the air.
- Some were still not convinced they said that removing the air was unfair because it contained the “life force”.



Classical Spontaneous Generation Dispelled

- Enter Louis Pasteur.
- Pasteur puts the debate to rest with the experiment below.



Its amazing just how many scientific discoveries involved a little "luck". For example both Spallanzani and Pasteur were lucky to show no growth in their respective bottles because neither of them sterilized their glassware at that time.

Stanley Miller & Harold Urey Experiment

- These scientists set out to test Oparin & Haldane's hypothesis.
- They tried to recreate the conditions of early life in the laboratory to see if they could in fact create organic compounds from inorganic precursors:
  - They were able to create some organic compounds (amino acids for instance)
  - *Latest evidence suggests that the atmosphere was not the reducing atmosphere that this experiment assumed but instead a neutral atmosphere made of primarily nitrogen and carbon dioxide. New experiments like Miller & Urey's have confirmed that a neutral atmosphere also produces organic compounds.*

Stanley Miller & Harold Urey Experiment

Experiment

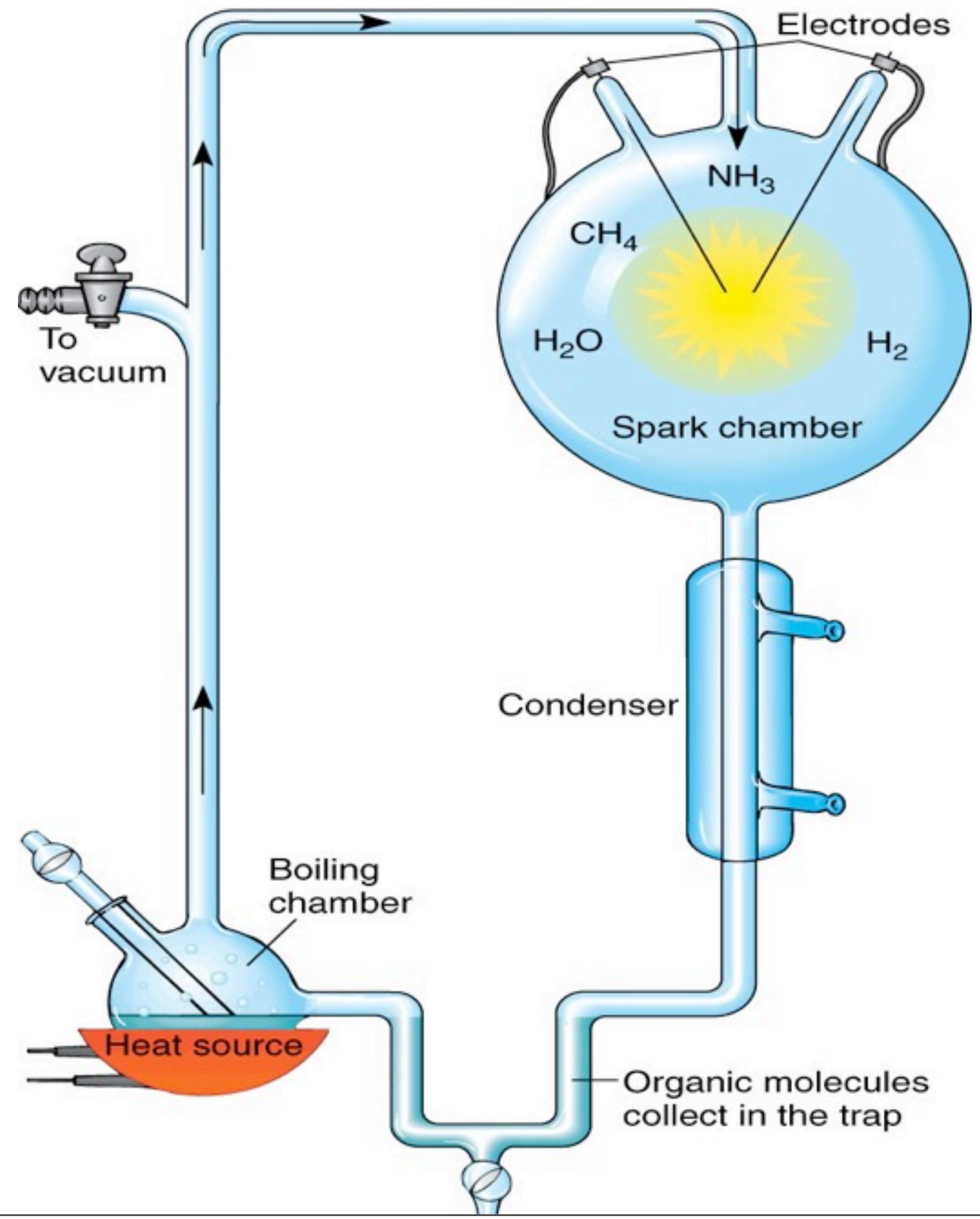
Miller and Urey set up a closed system in their laboratory to simulate conditions thought to have existed on early Earth. A warmed flask of water simulated the primeval sea. The strongly reducing "atmosphere" in the system consisted of H_2, methane (CH_4), ammonia (NH_3), and water vapor. Sparks were discharged in the synthetic atmosphere to mimic lightning. A condenser cooled the atmosphere, raining water and any dissolved compounds into the miniature sea.

Results

As material circulated through the apparatus, Miller and Urey periodically collected samples for analysis. They identified a variety of organic molecules, including amino acids such as alanine and glutamic acid that are common in the proteins of organisms. They also found many other amino acids and complex,oily hydrocarbons.

Conclusion

Organic molecules, a first step in the origin of life, can form in a strongly reducing atmosphere.

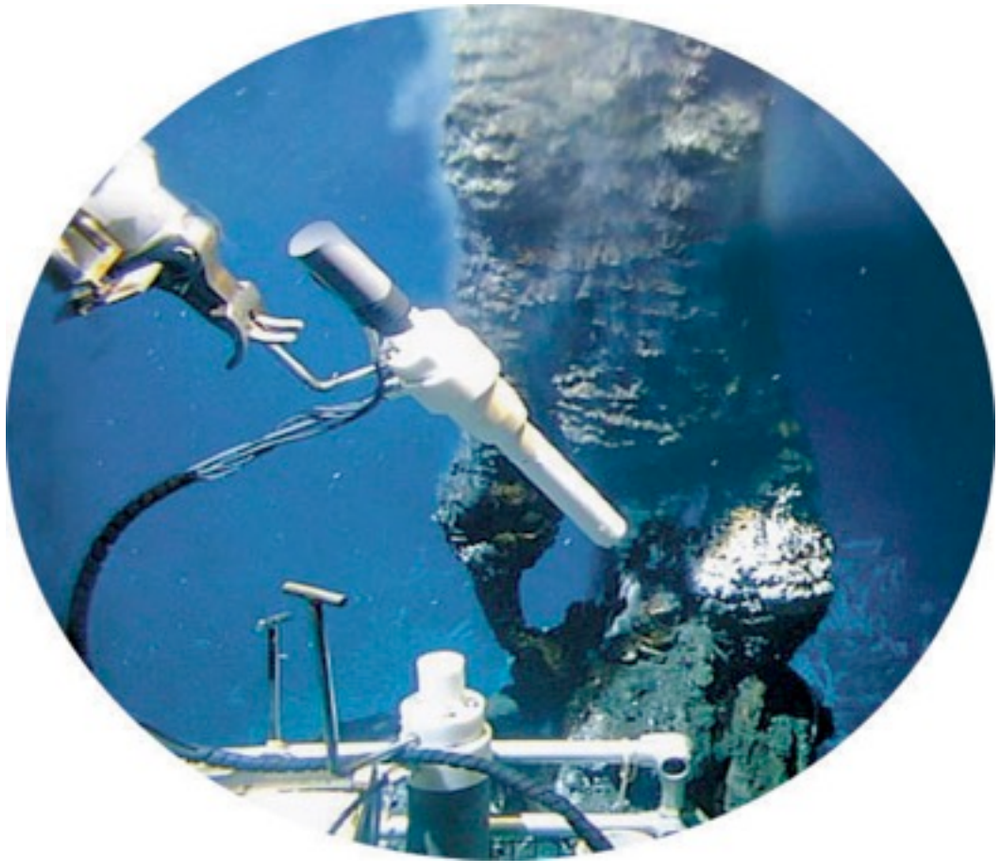


Stanley Miller & Harold Urey Experiment

- Latest evidence suggests that the atmosphere was not the reducing atmosphere that this experiment assumed but instead a neutral atmosphere made of primarily nitrogen and carbon dioxide. New experiments like Miller & Urey's have confirmed that a neutral atmosphere also produces organic compounds.

- Also even with neutral atmosphere some suggest that local areas around hydrothermal vents and volcanoes may have had reducing characteristics

Iron-Sulfur World Hypothesis



Essential knowledge 1.D.2: Scientific evidence from many different disciplines supports models of the origin of life.

b. Molecular and genetic evidence from extant and extinct organisms indicates that all organisms on Earth share a common ancestral origin of life.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Scientific evidence includes molecular building blocks that are common to all life forms.

Molecules of life

- Carbohydrates – energy, structural
- Lipids/fats – energy, membranes
- Proteins – structure, function
- DNA - information

1.molecular building blocks that are common to all life forms

	Protein	Nucleic Acid	Lipid	Carbohydrates	Small molecules
Made of	Long chains of 20 kinds of amino acids	Long & short chains of nucleic acid bases form DNA, RNA, also ATP, GTP, ...	Phosphate or or other charged "head" with long hydro-carbon tail	Long & short chains of sugar molecules like glucose, fructose.	Various molecules such as hormones, vitamins, neurotransmitters, porphyrins
Functions	Most of the structure and function of living things; enzymes	Information storage (RNA, DNA), structure, enzymes, energy transfer	Energy storage Insulation Cushioning Membranes	Energy source Energy storage Structure	Mostly sending signals

Essential knowledge 1.D.2: Scientific evidence from many different disciplines supports models of the origin of life.

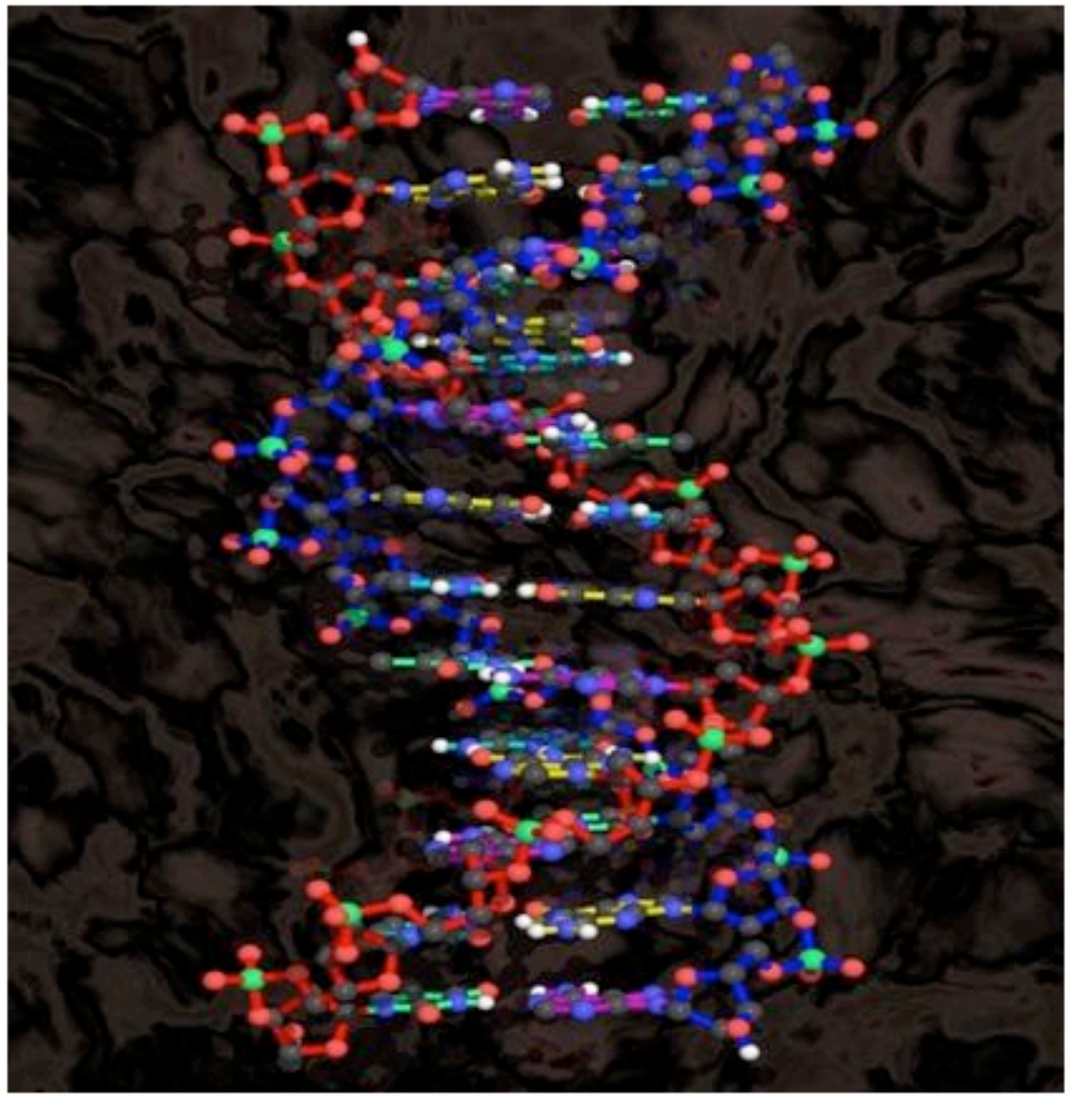
b. Molecular and genetic evidence from extant and extinct organisms indicates that all organisms on Earth share a common ancestral origin of life.

Evidence of student learning is a demonstrated understanding of each of the following:

2. Scientific evidence includes a common genetic code.

Universal Genetic Code

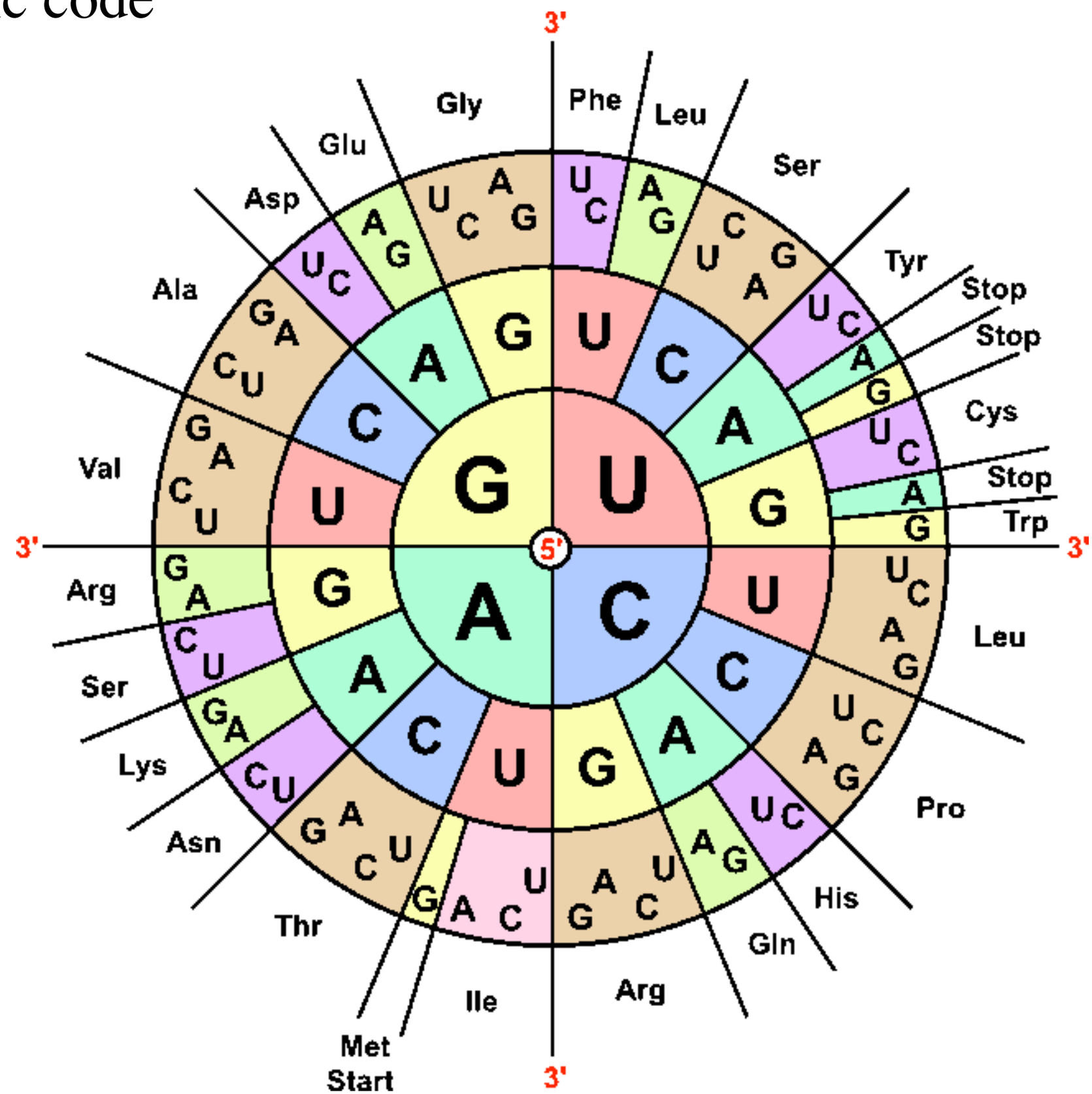
**Everything living is based on this→
the molecule of inheritance



Universal genetic code

- All living organisms use the same genetic code: CCC encodes proline in all cells
- All organisms are descended from a common ancestor – all life on earth evolved from a common point of origin
- The impressive variation in living organisms arose through random changes in nucleotide sequence (mutation) acted upon by natural selection over billions of years

...common genetic code



Learning Objectives

LO 1.32 The student is able to justify the selection of geological, physical, and chemical data that reveal early Earth conditions. [See **SP 4.1**]