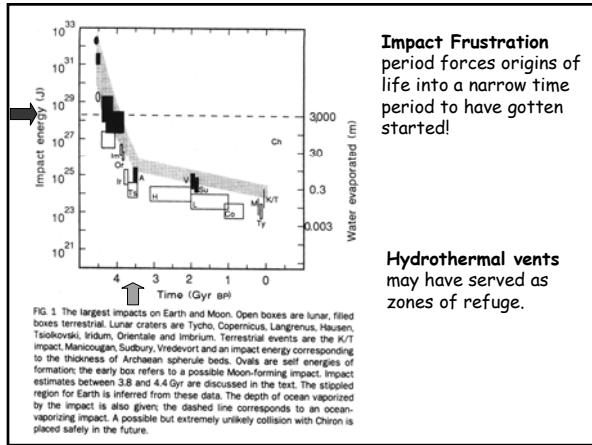
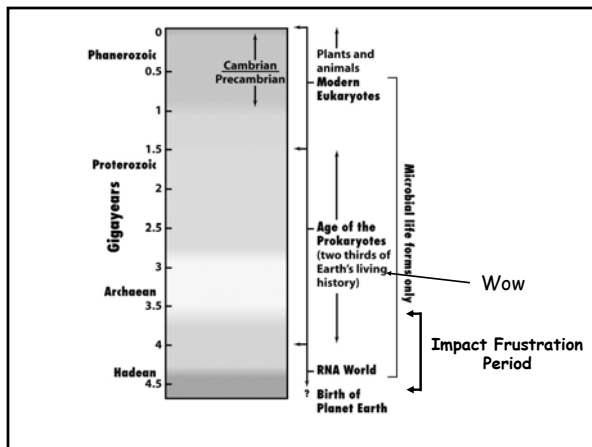


Microbes and Origins of Life

Evolution has occurred almost elusively in a microbial world !!!





The Chemical Aspects of The Origin of Life

Life is the cumulative product of interactions among the many kinds of chemical substances that make up the cells of an organism.

The abiotic chemical evolution of life follows four major hurdles:

- (1) The abiotic synthesis and accumulation of small organic molecules, or monomers, such as amino acids and nucleotides.
- (2) The joining of these monomers into polymers, including proteins and nucleic acids.
- (3) The aggregation of abiotically produced molecules into droplets, e.g., protobionts, that had chemical characteristics different from their surroundings.
- (4) The origin of heredity or information transference.

To understand how the origin of life from abiotic material occurred, we have to consider **two critical concepts**:

(1) The extension of the idea of natural selection to the chemical level.

(2) The realization that the condition of the early Earth when life first arose must have been vastly different from present:

- (a) Non-oxidizing atmosphere: present level of oxygen, which began to accumulate around 2.1 billion years ago with the presence of cyanobacteria, would have been lethal to primitive organisms
- (b) Abundant resources produced non-biologically
- (c) Long time scale without competition

Origins of Life Models

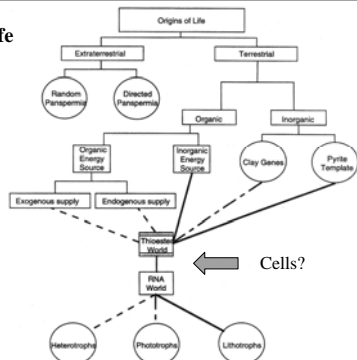
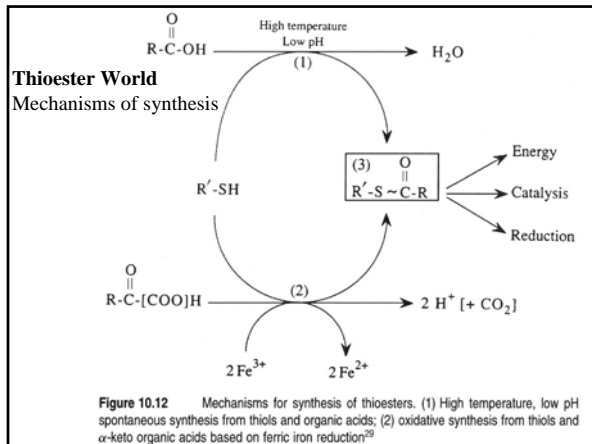
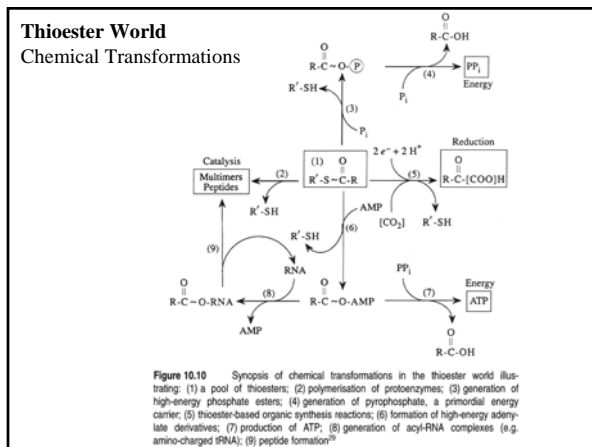


Figure 10.6 Relationships among various theoretical or conceptual models for the origins of life.⁷⁷ Dashed and solid lines at the bottom of the figure connect mechanisms with putative metabolic type of first organisms. The thioester world is proposed as an intermediate leading to an RNA world

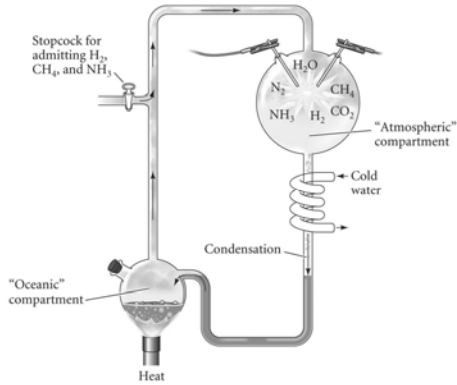




The Molecular Clues to the Origin of Life on Earth

- Molecules of living organisms are rich in **hydrogen-containing carbon** compounds that are highly reduced. This suggests that there was little or no free molecular oxygen on early Earth.
- All **amino acids** exist in both the right-handed and left-handed state. However, only 20 amino acids of the left-handed variety are used by living organisms in proteins. Therefore, suggesting there was a single origin of life.
- **DNA & RNA** are the universal informational basis of all life forms on Earth.
- **ATP** is the universal energy currency of all living organisms; suggesting a common origin of metabolism.
- In any cell, first steps of carbohydrate metabolism involve **fermentation**, with the last steps in aerobic organisms the usage of oxygen via **respiration** – suggesting that aerobic organisms evolved from anaerobic ones.

The apparatus Miller et al. (1950s) used to simulate the conditions of early Earth

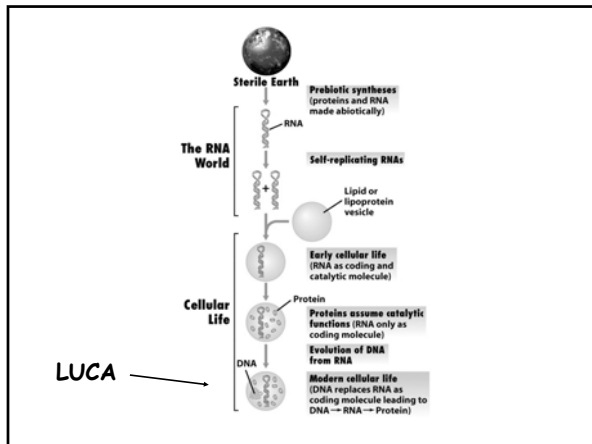


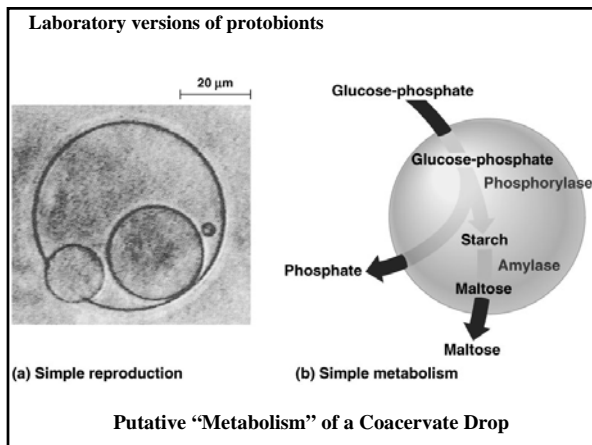
Necessary Conditions for the Origin of Life

- Before life appeared, polymerization reactions generated the carbohydrates, lipids, amino acids, and nucleic acids of which organisms are composed. These molecules accumulated in the oceans.
- Originally “Darwin’s Warm Pond” Hypothesis

A painting of early Earth showing volcanic activity and photosynthetic prokaryotes in dense mats

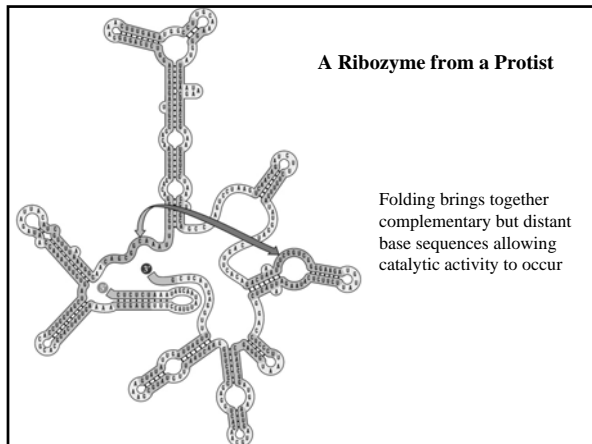


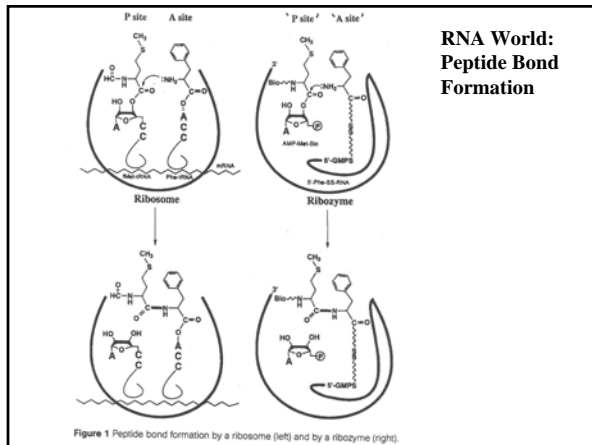


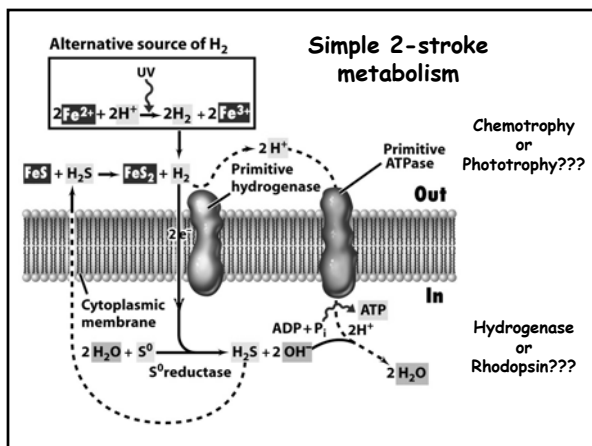


Protobionts: Enclosing Prebiotic Systems

- DNA probably evolved after RNA-based life became surrounded by membranes that provided an environment in which DNA was stable.







**Some Lessons from the BIG TREE:
Map of the Biological Record**

Single origin for all life on Earth...

- Central Dogma intact
 - ATP and PMF are universal themes
 - Uniformity among chiral carbon compds (sugars & AAs)
 - Hot start origin...
- Also Cyanobacteria did not arrive first on the scene!

**Some Lessons from the BIG TREE:
Map of the Biological Record**

General topology implies:




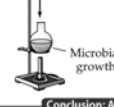
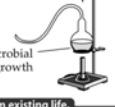
- Three “primary lines of evolutionary descent.”
- The Eucarya “*nuclear*” lineage almost as old as the prokaryote lines.
- Prokaryotes split between *Bacteria* and *Archaea*.
- Mitochondria and chloroplasts proven to be of bacterial origin.



Is Life Evolving from Nonlife Today?


- Because most of the chemical reactions that gave rise to life occur readily under the conditions that prevailed on early Earth, life's evolution was "probably" inevitable.
- Experiments by Louis Pasteur and others convinced scientists that life does not come from nonlife on Earth today.....

EXPERIMENT
Question: Pasteur asked "Does life generate spontaneously or does it come only from already existing life?"

Experiment 1	METHOD	Experiment 2
		
	RESULTS	

Conclusion: All life comes from existing life.

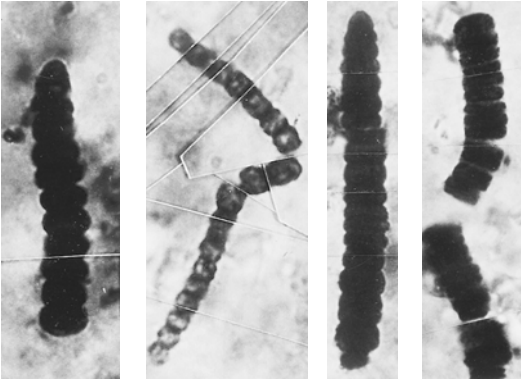
Pasteur (1860s) was also the father of "origins of life" research



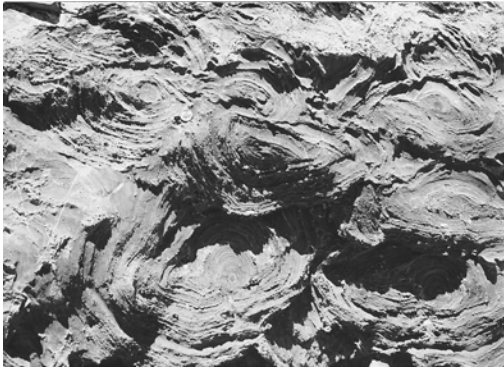
Is Life Evolving from Nonlife Today?

- New life is no longer being assembled from nonliving matter because simple biological molecules that form in today's environment are oxidized or consumed by existing life.
- Now we have competition & oxygen!
- Everywhere.....?

Oldest Known Fossils of Living Organisms (~3500 Mya)



Fossil Stromatolites from Glacier Natl. Park



Living Columnar Stromatolites, Shark Bay, Western Australia



Modern Stromatolites from Yellowstone Natl. Park

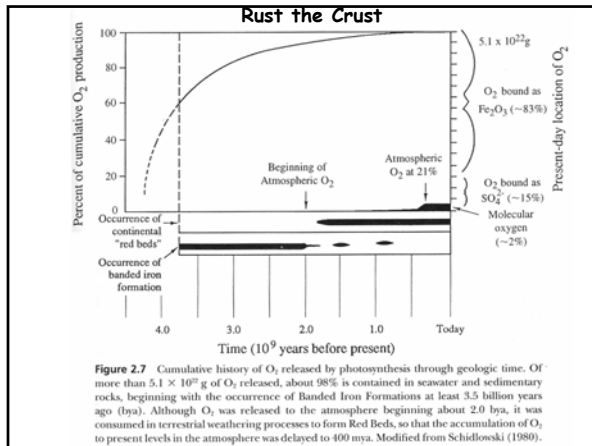


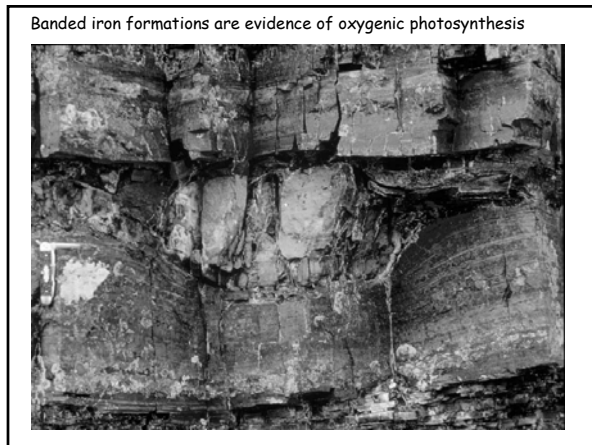
Photosynthesis Is the Source of Atmospheric O₂

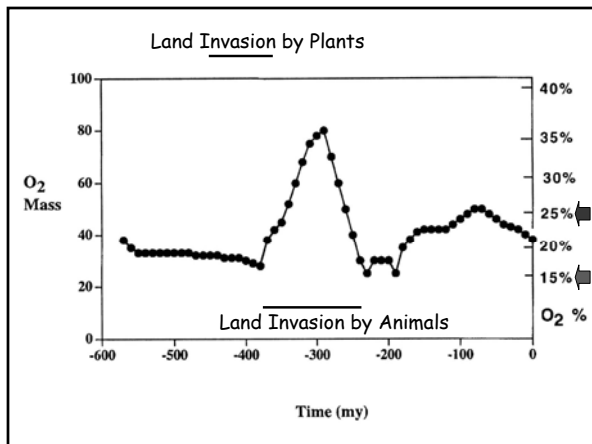
- Cyanobacteria, which evolved the ability to split water into hydrogen ions and O₂, created atmospheric O₂. Accumulation of free O₂ in the atmosphere made possible the evolution of aerobic metabolism.

Extant Microbial Mat Communities





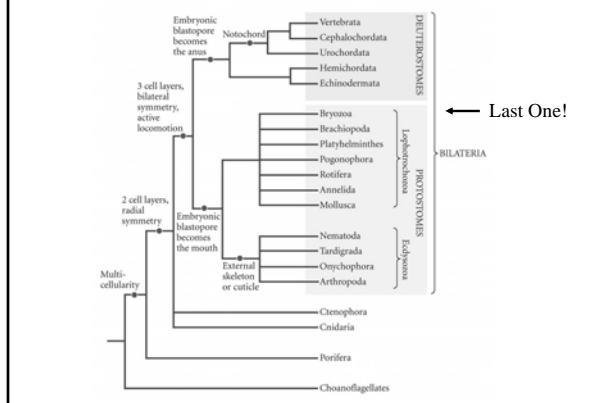


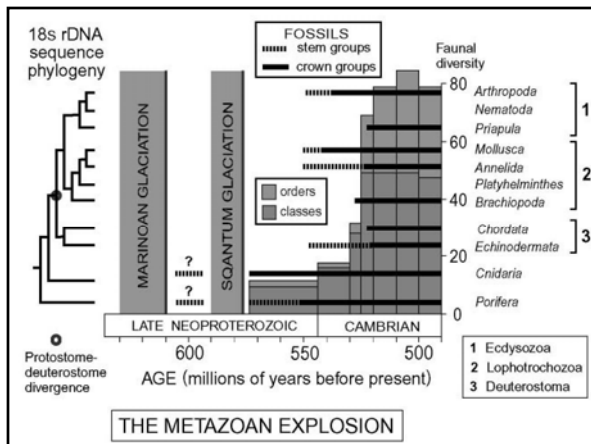


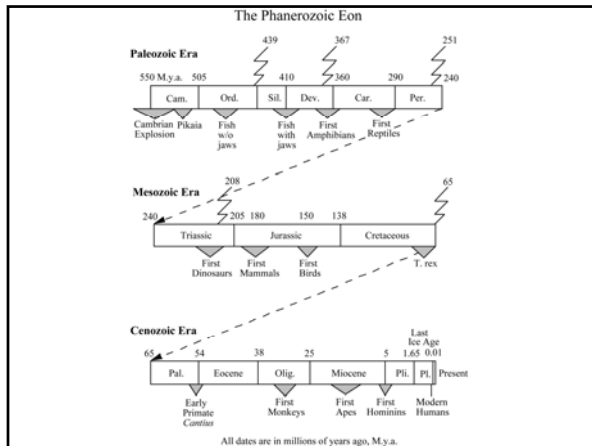
Patterns of Evolutionary Change

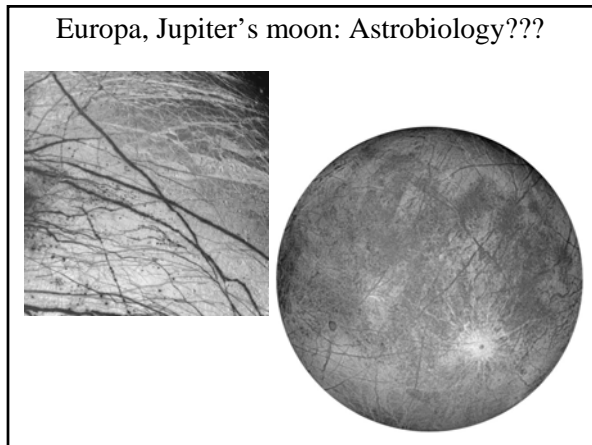
- Multicellularity requires atmospheric oxygen and aerobic respiration (i.e., **mitochondria**)!
 - This gave rise to the **Cambrian Explosion**
- The Oxygen “Blip” @ ~300 Mya resulted from the invasion of land by plants!
 - This gave rise to:
 - **Gigantic Insects**
 - **Origin of Flight by Dragonflies**
 - **Invasion of land by Vertebrate Animals**

A recent estimate of relationships among animal phyla









Does Life Exist Elsewhere in the Universe?

- Conditions that permit the evolution and maintenance of simple bacterial life may be widespread in the universe, but multicellular life has more stringent requirements.
 - ◆ a planet with a relatively circular orbit
 - ◆ a rapid rate of spin
 - ◆ nearby planets that intercept impacts
 - ◆ a large moon that stabilizes the planet's orbit
 - ◆ a magnetic field

Such conditions may be very rare.
