Outline 10:
Origin of Life

Better Living Through Chemistry

What is Life?

- Internal chemical activity providing growth, repair, and generation of energy.
- The ability to reproduce.
- The capacity to respond to outside stimuli, i.e., their environment.

Components of Life

5 Principal components for all life:

- Water
- Carbohydrates: starches and sugars for energy
- Fats: for energy storage
- Proteins: structural tissues
- Nucleic acids: for reproduction

6 Dominant Elements of Life

H, hydrogen
O, oxygen
C, carbon
N, nitrogen
P, phosphorous (in rocks)
S, sulfur

Combining Elements into complex Organic compounds

- Miller's 1953 experiment:

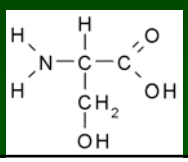
  Combine gases of the early atmosphere in a sealed system with no oxygen.

  Heat the gases, add electrical sparks, cool the mixture.

  Amino acids formed after several days. They are the building blocks of protein.

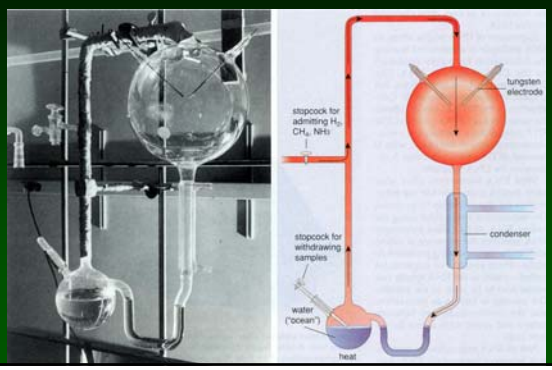
Combining Elements into complex Organic compounds

- Miller combined CO_2, NH_3 (ammonia), CH_4 (methane), H_2O and H_2
- Added electrical spark, plus cooling
- Formed amino acids, e.g., Serine

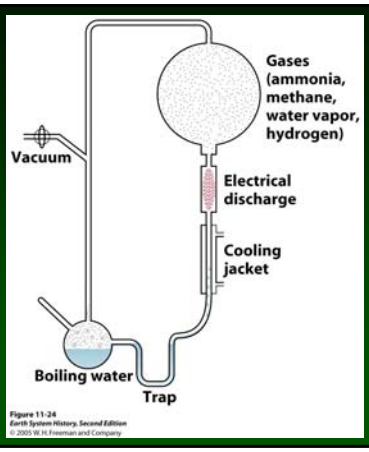


$C_3H_7NO_3$

Miller's apparatus for creating amino acids from simple compounds in an anoxic atmosphere.

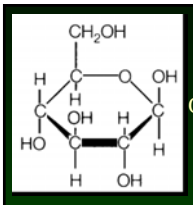


Miller's experimental apparatus -- note the black organics in the spark chamber



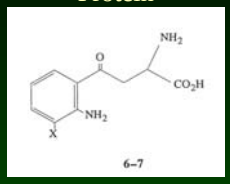
Combining Elements into complex Organic compounds

Several variations of Miller's experiment have been run. These experiments have produced carbohydrates, fats, simple proteins, and the building blocks of nucleic acids: sugars, phosphates, and nitrogenous bases (ATCG).

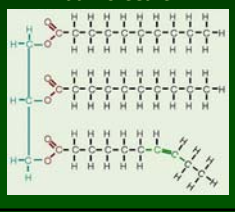


Carbohydrate:
Sugar: glucose

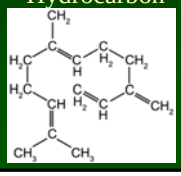
Protein



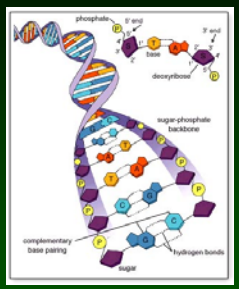
Fat molecule



Hydrocarbon



Nucleic Acid: DNA



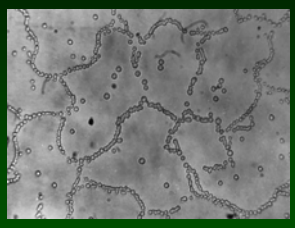
Nitrogenous bases: A, T, C, G
Sugars and phosphates form the DNA backbone

How did life begin?

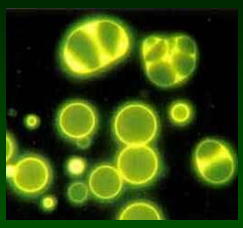
No one has yet been able to create life in the lab. However, scientists have had only 60 years. Nature had 100s of millions of years.

Scientists create synthetic life in laboratory
(man-made DNA forms a new bacterium)

Experimental evidence: polymer synthesis

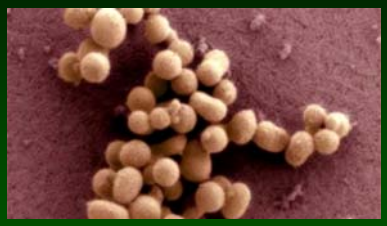


proteinoids



lipid spheres

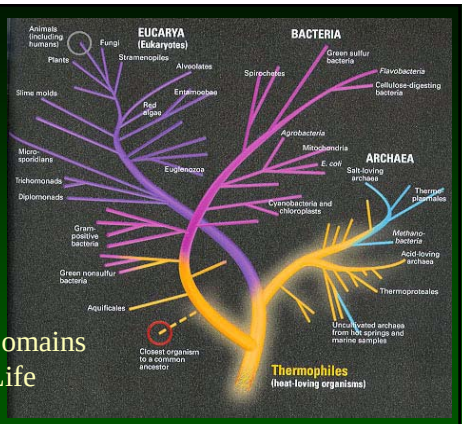
Experimental evidence: synthetic bacteria



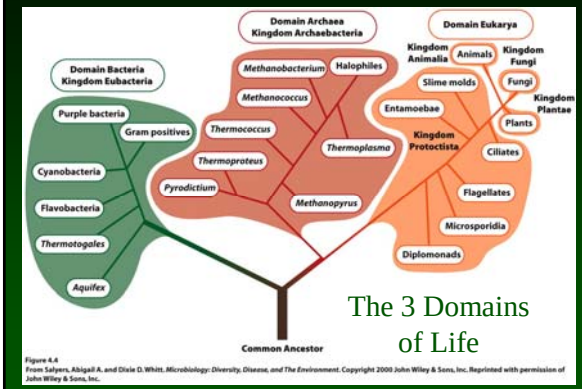
Craig Venter Institute
A scanning electron micrograph image of the synthetic bacteria of *M. mycoides* JCVI-syn1.

What was earliest life like?

- Certainly it was single celled.
- Single celled life today, 3 domains:
  - Archaea or Archaebacteria - prokaryotic cells
  - Bacteria or Eubacteria - prokaryotic cells
  - Eukarya - eukaryotic cells



The 3 Domains of Life



The 3 Domains of Life

Figure 4.4
From Salyers, Abigail A. and Dixie D. Whitt. *Microbiology: Diversity, Disease, and The Environment*. Copyright 2000 John Wiley & Sons, Inc. Reprinted with permission of John Wiley & Sons, Inc.

Which came first? Proteins or DNA?

Could there have been one without the other?

- In modern cells:

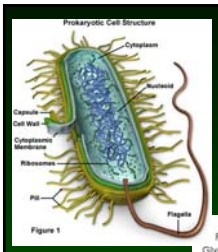
DNA directs protein synthesis

AND

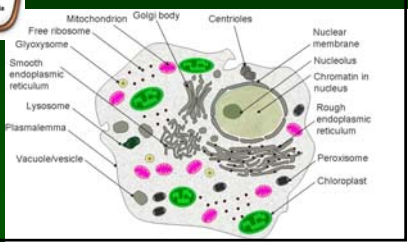
proteins catalyze DNA replication

Prokaryotes vs. Eukaryotes

- Prokaryotes - simple, single-celled organisms lacking a nucleus, organelles, and sexual reproduction. Many are anaerobic. Archaea and Bacteria.
- Eukaryotes – single-celled (protists) or multi-celled (plants, fungi, and animals), have a nucleus, organelles, sex, and are strictly aerobic.



Prokaryotic cell vs. the Eukaryotic cell with a nucleus and various organelles



Eukaryotic protozoan in pond water: an amoeba

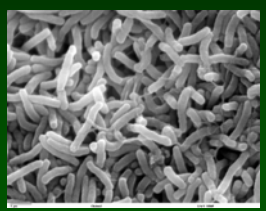
Archaea, the most primitive forms of life

- Archaea use to be included with bacteria, but geneticists have separated them on the basis of their unique genetic composition.
- Living archaea are all anaerobic and they can tolerate extremes of heat and chemistry.

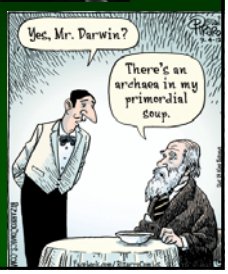
Archaea and Bacteria.

Both are prokaryotes.

Very small!



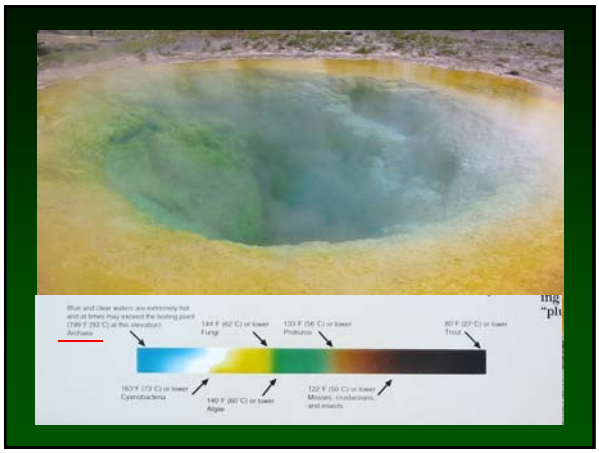
Cholera bacteria



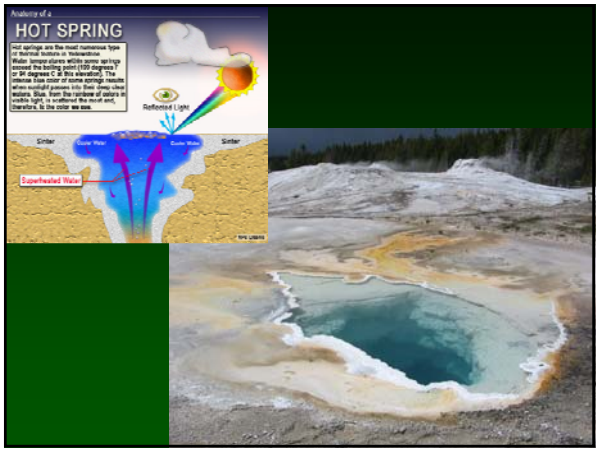
Archaea

- Retain evidence for life on early earth.
- Tolerate:
  - boiling water
  - poisonous gases: e.g., hydrogen sulfide, carbon monoxide, etc.
  - high doses of UV radiation

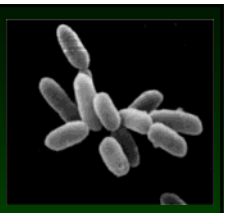
Hot springs at Yellowstone National Park. Analog for the early earth?



Populations of archaea and bacteria in hot springs runoff, Yellowstone National Park



Archaea



Living archaea include:

- fermenters: eat sugars
- methane producers: energy from CO_2 and hydrogen
- chemoautotrophs: make their food from chemicals in their environment

Where on earth did life start?

- Darwin's "warm little pond?"

  concentrated "organic soup" (+)

  no protection from UV radiation (-)

- Deep-sea volcanic vents?

  protection from UV radiation (+)

  heat destroys amino acids (-)

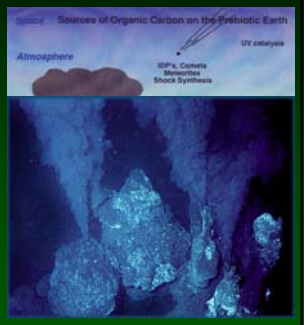


Figure 11-24b
Earth System History, Third Edition
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The 5 Major Biochemical Steps in the Evolution of Life

1. Fermentation – archaea
   Sugar → ethyl alcohol + 2 units of energy

2. Methane production – archaea
   $CO_2 + 4H_2 \rightarrow CH_4 + 2\ H_20 + 1$ unit of energy

The 5 Major Biochemical Steps in the Evolution of Life

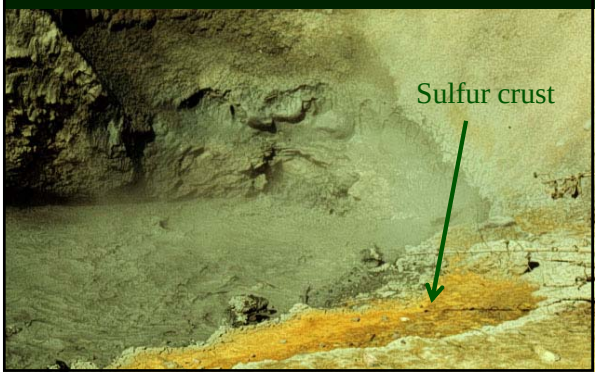
3. Anaerobic photosynthesis – bacteria
   $H_2S + CO_2 \rightarrow$ sugar + water + sulfur
   uses sunlight for energy

4. Aerobic photosynthesis - bacteria, 3.5 BY
   $H_20 + CO_2 \rightarrow$ sugar + O_2
   uses sunlight for energy

The 5 Major Biochemical Steps in the Evolution of Life

5. Aerobic respiration - bacteria and eukarya
   Sugar + $O_2 \rightarrow H_20 + CO_2$ + 36 units of energy

Anaerobic photosynthetic bacteria in boiling mud



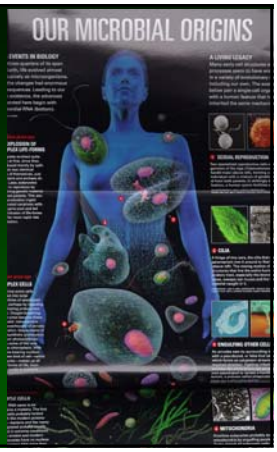
Populations of archaea and bacteria in hot springs runoff, Yellowstone National Park

Sampling Organisms from Hot Springs

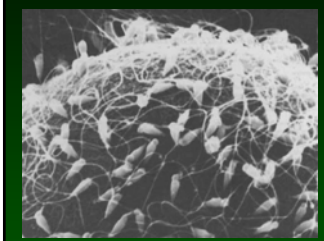
A new perspective on life

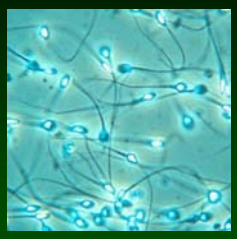
Heated by fires as old as Earth itself, a steaming spring in Yellowstone National Park provides a sample of its inhabitants to Anna-Louise Reysenbach, a microbial biologist at Rutgers University. "It looks like slime now," she says, "but under a microscope it's a forest of organisms." Such samples usually include archaea as well as bacteria. Very different life

Our Microbial Origins

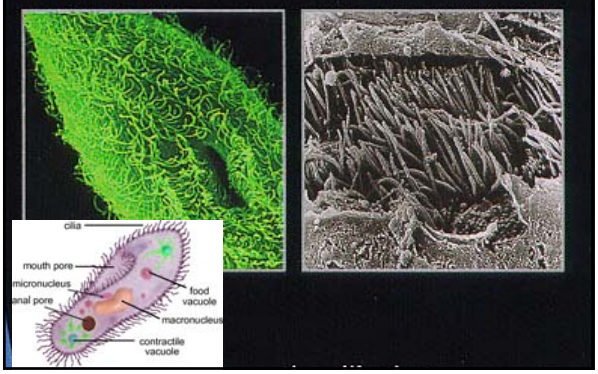


Sex cells resemble free-living eukaryotes

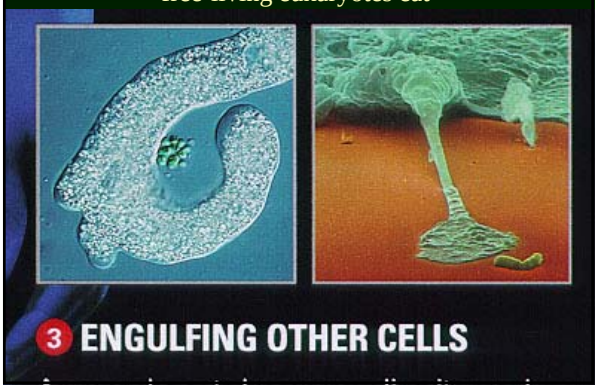




Cilia are used by free-living eukaryote cells



White blood cells eat invaders the same way free-living eukaryotes eat



Mitochondria were once free-living, aerobic purple bacteria