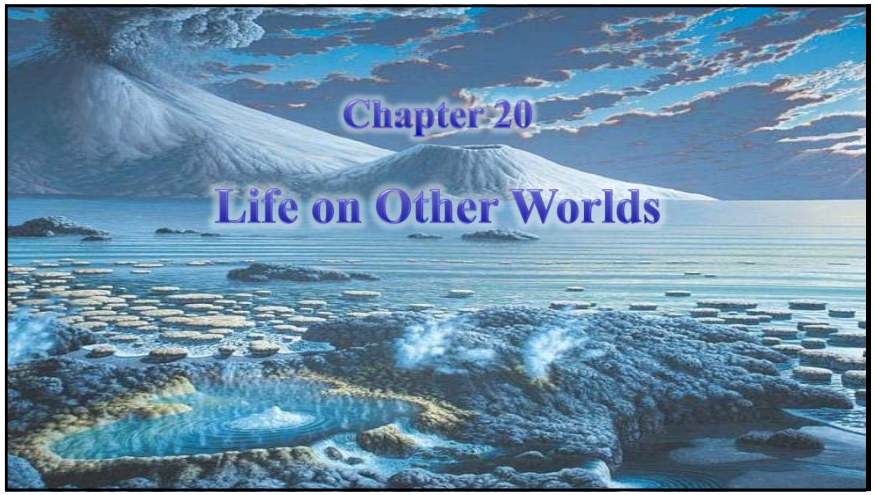
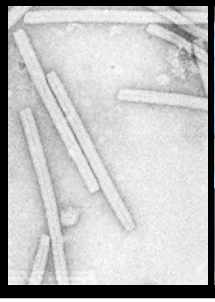


The Physical Basis of Life

All life forms on Earth, from viruses to complex mammals (including humans) are based on carbon chemistry.

Carbon-based DNA and RNA molecule strands are the basic carriers of genetic information in all life forms on Earth.

The tobacco mosaic virus contains a single strand of RNA, about 0.1 mm long



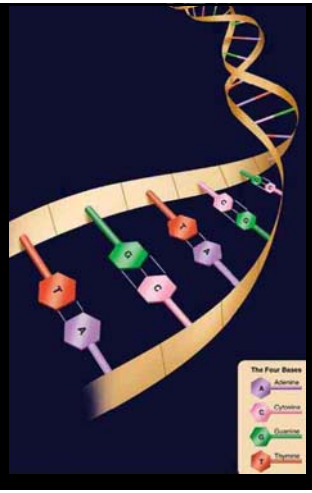
This complex mammal contains about 30 AU of DNA.

Information Storage and Duplication

All information guiding all processes of life are stored in long spiral molecules of DNA (= desoxyribonucleic acid)

Basic building blocks are four amino acids: adenine, cytosine, guanine, and thymine

Information is encoded in the order in which those amino acids are integrated in the DNA molecule.



The Origin of Life on Earth

Life develops into more complex forms through gradual evolution, spanning many thousands of generations.

Life began in the sea as single-celled creatures.

Those as well as early multi-celled creatures had no hard parts to leave fossils.

Earliest, microscopic fossils date back ~ 4 billion years.

The Origin of Life on Earth (II)

~ 1/2 billion years ago, in the Cambrian period, the diversity and complexity of life on Earth dramatically increased → "Cambrian explosion"

Best-known fossils from the Cambrian period: trilobites.

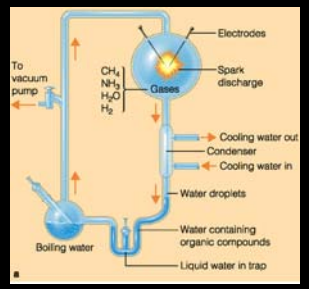
All known fossils from the Cambrian period are from sea creatures.

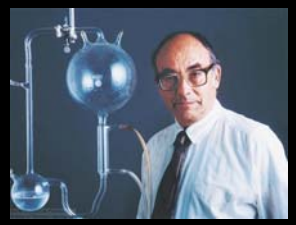
No traces of life on land until ~ 400 million years ago.

The Miller Experiment

Miller Experiment in 1952: Simulating conditions on Earth when life began ~ 4 billion years ago:

Water (oceans), primitive atmosphere gases (hydrogen, ammonia, methane), and energy from electric discharges (lightning).



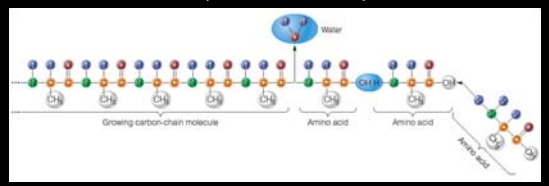


Experiment produced some of the fundamental building blocks of life: amino acids, fatty acids, and urea.

The Origins of Life on Earth (III)

Miller experiment shows that basic building blocks of life form naturally.

Amino acids and other organic compounds naturally tend to link up to form more complex structures.



Early oceans on Earth were probably filled with a rich mixture of organic compounds: the **primordial soup**

Chemical evolution leads to the formation and survival of the most stable of the more complex compounds.

Extraterrestrial Origin of Life on Earth?

Alternative theory: Most primitive living entities transported to Earth in meteorites or comets.

Some meteorites do show traces of amino acids.

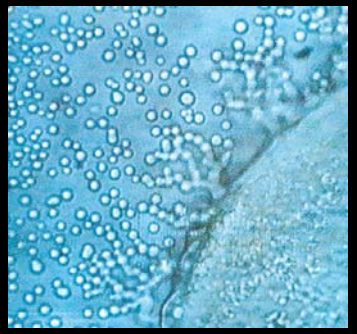
Theory of extraterrestrial origin of life is currently untestable.

Formation of Cells

First cell membranes may have formed before the beginning of life:

Single amino acids can be assembled into long protein-like molecules, which form microspheres when they cool in water.

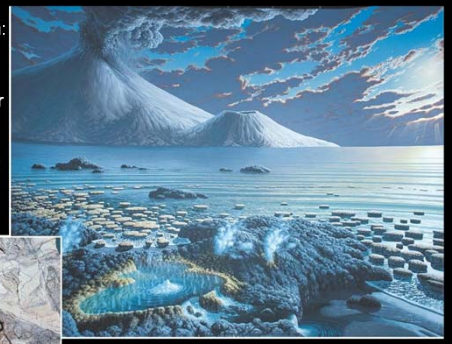
→ Cell membranes



The Earliest Fossils

Earliest fossils known: stromatolites.

Built up layer by layer from single-celled creatures, similar to bacteria, ~ 3.5 billion years ago.



Three Questions About the Evolution of Life

1) Could life originate on another world if conditions were suitable?

Miller experiment etc. indicate: probably yes.

2) Will life always evolve toward intelligence?

If intelligence favors one species over another: probably yes.

3) How common are suitable conditions for the beginning of life?

→ Investigate conditions on other planets and statistics of stars in our Milky Way

Some Requirements of Life

- Liquid water (for chemical reactions and as transport medium).
- Atmosphere (to avoid rapid vaporization of water; gases needed for organic compounds)
- Moderate temperatures (keep water liquid; avoid disintegration of organic compounds; activate complex chemical reactions)
- Time for life to evolve from simple organic compounds into higher life forms: several billion years.

Requirements for Life in Other Planetary Systems

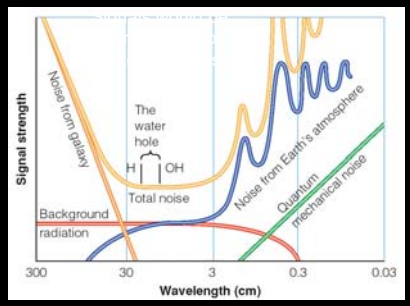
- Planetary systems are probably common.
- Stable orbit around the star
  → consider only single stars.
- Time for evolution
  → consider only F5 or less massive stars.
- Moderate temperatures
  → Life zone around the star

The Search for Extraterrestrial Intelligence (SETI)

In addition to sending messages to possible extraterrestrial civilizations, there are also programs to listen for intelligent messages from space: SETI.

Only certain wavelength ranges are suitable for this search

SETI program is highly controversial because of the uncertain prospects of positive results.



The Drake Equation

Factors to consider when calculating the number of technologically advanced civilizations per galaxy:

Table 20-1 | The Number of Technological Civilizations per Galaxy

	Variables	Estimates: Pessimistic	Estimates: Optimistic
N^*	Number of stars per galaxy	2×10^{11}	2×10^{11}
f_p	Fraction of stars with planets	0.01	0.5
n_{LZ}	Number of planets per star that lie in life zone for longer than 4 billion years	0.01	1
f_L	Fraction of suitable planets on which life begins	0.01	1
f_I	Fraction of life forms that evolve to intelligence	0.01	1
F_S	Fraction of star's life during which a technological society survives	10^{-6}	10^{-4}
N_c	Number of communicative civilizations per galaxy	2×10^{-6}	10×10^6

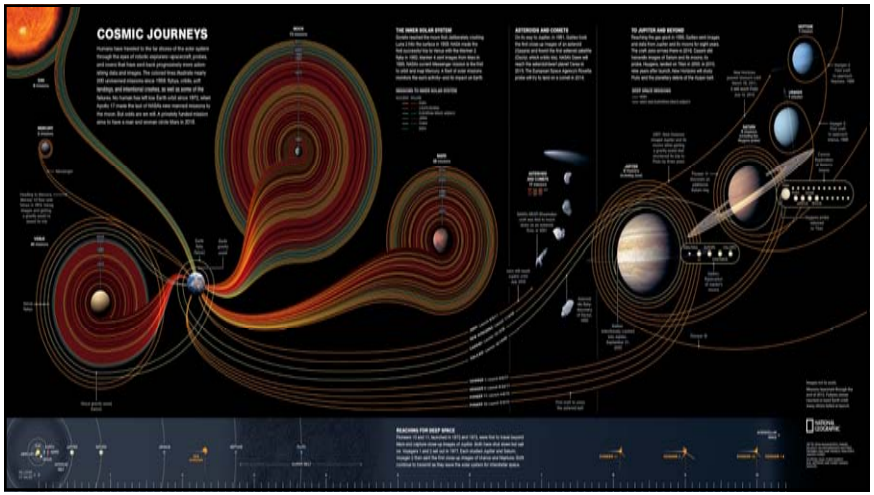
$$N_c = N^* \cdot f_p \cdot n_{LZ} \cdot f_L \cdot f_I \cdot F_S$$

Most of the factors are highly uncertain.

Possible results range from 1 communicative civilization within a few dozen light years to us being the only communicative civilization in the Milky Way.

A Short Story About Using the Drake Equation


What Would Aliens Look Like??


COSMIC JOURNEYS
THE INNER SOLAR SYSTEM
ASTEROIDS AND COMETS
TO JUPITER AND BEYOND
REACHING FOR DEEP SPACE

For The Final Week

- Go to observatory
- Get Sleep – Please do this!
- Do not do an "all nighter"
- Print out the tests with the answers and study them
- Brings food/carbohydrates and water

Student Learning Outcomes (SLO).

1. Understanding of the methods astronomers use to explore the natural phenomena of the universe, including observation, hypothesis development, and evaluation of evidence. This understanding will be demonstrated by quizzes and tests and in-class discussions.

2. Have a working knowledge of the historical development of key astronomical concepts such as the ever-unfolding discovery of our place in the universe, including the latest developments in planetology and cosmology. This knowledge will be demonstrated by quizzes and tests and in-class discussions.

3. Acquire a sense of social responsibility in areas of environmental concern such as global warming, resource conservation and pollution, as evidenced by in-class discussions.

Thank You!

Thank you for attending this class. You truly have enriched my life with your presence.

I hope that I have provided you with a better understanding of the universe, of science and of the scientific method.

Good Luck on the final and good luck in life.

Sincerely,
Prof. M.