

Extraterrestrial Life: Lecture #9

Reminder: homework #2 due Thursday... my office hours after class today (tomorrow afternoon also good)

Last class: radioactive dating of rocks

Today: what are the characteristics of life on Earth, and how general are those properties?

Reading: textbook Chapter 5 'The nature of life on Earth'

Extraterrestrial Life: Spring 2008

Definition of life

Life is a self-sustaining chemical system capable of undergoing Darwinian evolution

Very general definition: requires source of energy, and some hereditary 'memory'

Single known example of life: involves a set of very specific molecules and reactions with limited variety

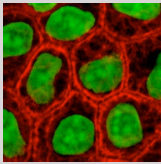
When searching for life (e.g. on Mars) which aspects of life on Earth should we assume are likely to be general to life elsewhere?

Extraterrestrial Life: Spring 2008

All life on Earth shares common features:

Contained within cells

Molecules called *lipids* form cell membranes that enclose the cell

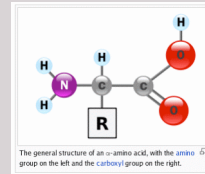


Cell membranes contain the chemical reactions within the cell

Can form spontaneously when lipids are placed in contact with water

Extraterrestrial Life: Spring 2008

Relies on proteins made from subset of amino acids



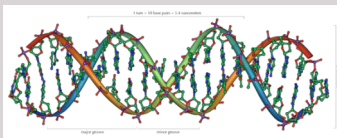
Contains an amino group (NH_2) and a COOH group

Proteins make up both the structure of cells and act as catalysts (enzymes) for chemical reactions

Almost all life on Earth uses a *subset* of 20 specific amino acids to make proteins... but many more amino acids are possible

Extraterrestrial Life: Spring 2008

DNA as the carrier of hereditary information



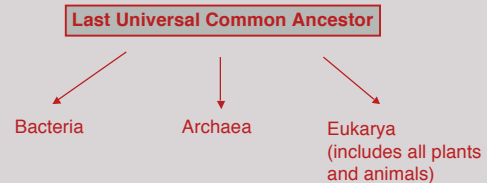
Synthesis of proteins via an intermediate molecule *RNA*

Energy storage

Storage of energy within the cell via the synthesis and breakup of adenosine triphosphate (ATP)

Extraterrestrial Life: Spring 2008

Existence of conserved features in all life: cell membranes, genetic code, expression of the code via RNA, amino acids etc suggest a common source:



Properties of the LUCA at the time of diversification are not clear. Extremely unlikely that the last common ancestor represented the first life on Earth - no traces of what came before...

Extraterrestrial Life: Spring 2008

Universal requirements for life

A source of energy

Sunlight, heat, chemical energy

Second law of thermodynamics: the entropy (disorder) of an isolated system cannot decrease

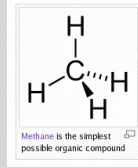
Living organism is not an isolated system: to create order (required for life) we need to supply energy (work) from outside

How efficient can life be?

Extraterrestrial Life: Spring 2008

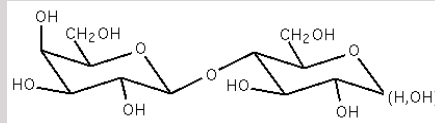
Carbon based

Carbon can form 4 chemical bonds, resulting in enormous variety of organic molecules



Many simple organic molecules are found in space

Unlikely that life based on any other element is possible

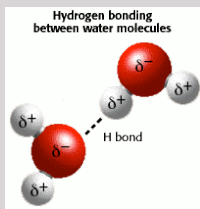


Extraterrestrial Life: Spring 2008

Water based

No organisms on Earth can survive without liquid water:

- dissolves organic molecules
- transports chemicals within and out of cells
- involved in many metabolic reactions



Many other solvents, seems unlikely that any could fulfill all the roles that water plays in life

Extraterrestrial Life: Spring 2008

Isotope fractionation

Stable isotopes of important elements (C, N) are not exactly chemically equivalent:

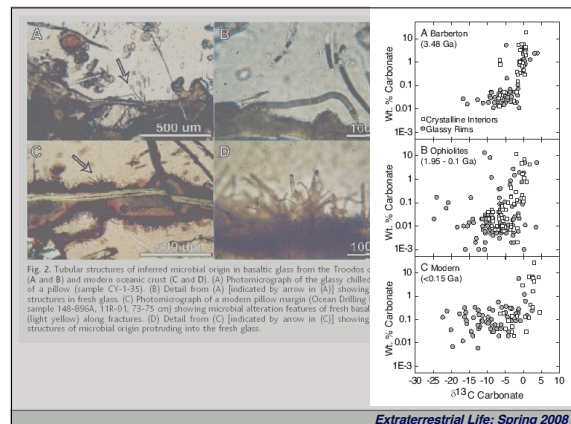
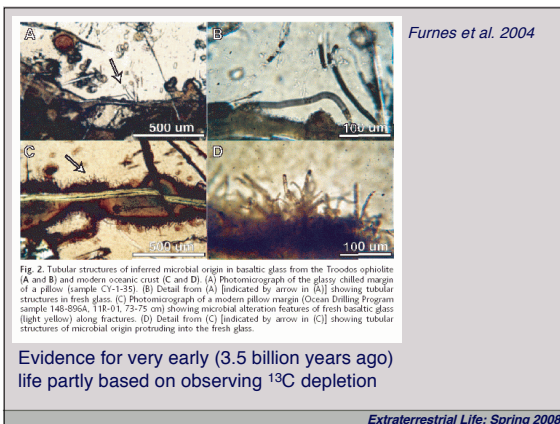
- different masses (number of neutrons)
- lighter isotope generally forms weaker bonds
- lighter isotope generally reacts faster

e.g. carbon: natural abundance is:

- ^{12}C - 99%
- ^{13}C - 1%

During photosynthesis ^{12}C is further enriched relative to ^{13}C

Extraterrestrial Life: Spring 2008



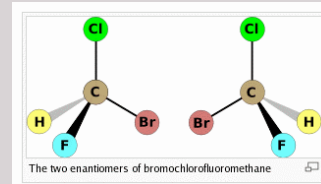
Notes:

- identifying life from morphology of fossils is difficult and controversial
- ^{12}C enrichment in living things seems a fairly robust signature of life
- **dating** of these structures depends upon knowing the 'fossils' date from same time as the surrounding rock

Extraterrestrial Life: Spring 2008

Chirality

Many complex molecules are chiral: come in 'left-hand' and 'right-handed' forms that are **non-superimposable mirror images**



Extraterrestrial Life: Spring 2008

All living organisms on Earth use just one of the two mirror image versions

Often, the 'wrong' version has completely different biological activity

Probably (?) the specific choice made on Earth was random - could have 'left-handed' and 'right-handed' life in different places

But... most chemical processes that do not involve life do not discriminate strongly: observing a large imbalance in left-handed / right-handed forms in complex molecules may be a sign of biology

Extraterrestrial Life: Spring 2008

Non-universal aspects of life on Earth

DNA / RNA - require some molecule to carry genetic information, but need not be the specific molecules used on Earth

Amino acids - different sets of amino acids seem feasible

ATP - convenient to have some energy carrying molecule within cells, but other choices seem possible

What diversity of life is possible?

Extraterrestrial Life: Spring 2008