Lecture 15

The Chemistry of Life

Astronomy 141 – Winter 2012

This lecture is about the chemistry responsible for life.

Metabolism is the set of chemical processes that provide energy or nutrients for cells.

All life on Earth uses the ATP Cycle for transporting chemical energy within cells for metabolism.

Classify living organisms by their sources of carbon for metabolism into *Autotrophs* and *Heterotrophs*.

Further distinguish the energy sources used to power their metabolism into sunlight (*photo*) and chemical (*chemo*)

Water is the ideal solvent medium for life.

The primary elements of life are Carbon, Hydrogen, Oxygen and Nitrogen ("CHON")

Carbon chemistry is the basis of life ("organic chemistry")

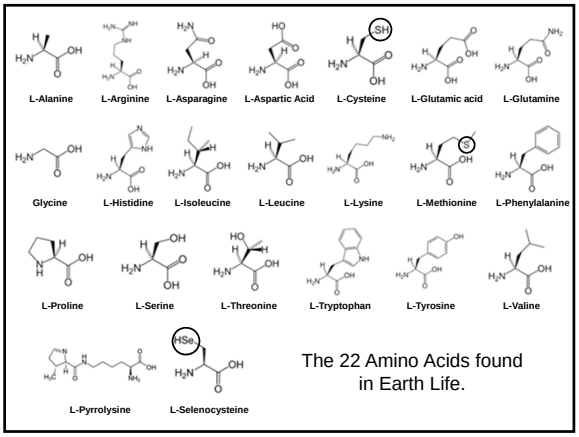
Water is the universal solvent of life (H_2O) 

Nitrogen is a key component of amino acids and DNA

Also need other elements:

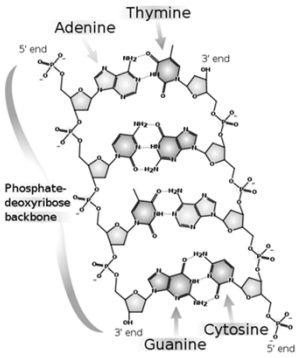
P – Phosphorus (DNA, RNA, and ATP/ADP)

S – Sulfur (amino acids cysteine & methionine)

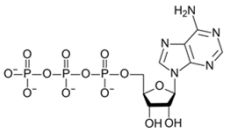


The 22 Amino Acids found in Earth Life.

DNA
Deoxyribonucleic Acid



ATP
Adenosine Triphosphate



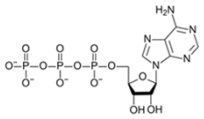
Metabolism is the set of chemical processes that occur in cells to provide energy or nutrients.

Metabolism has two basic requirements:

Source of Raw Materials
- Carbon for making organic compounds
- Elements needed for chemistry (O, H, N, etc.)

Source of Energy
- Powers the conversion of carbon into useful organic compounds (e.g., sugars)

ATP (Adenosine Triphosphate) is the main energy source in cells.



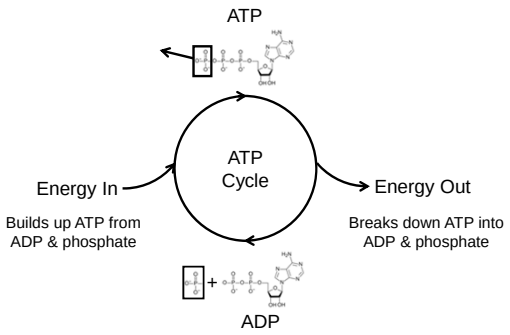
Used by most cellular functions:
- Protein synthesis
- DNA and RNA synthesis
- Transport of big molecules across cell membranes

ATP is produced in cells by photosynthesis and respiration.

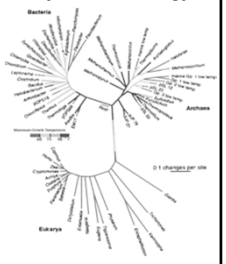
ATP is broken down by energy-releasing processes.

Provides a common energy source for a wide variety of biochemical processes.

The ATP Cycle is the "engine" of cellular chemistry.



All living cells on Earth use the ATP cycle for energy storage and transport.



Taken as further evidence of a common ancestor for all life on Earth.

There are other possible energy cycles that could be used, but aren't, and we don't know why.

Might give us a way to recognize truly alien life:

It might use something other than the ATP cycle…

Sources of carbon and sources of energy help distinguish organisms by their metabolisms.

Sources of Carbon:
Autotrophs (self+feed): get carbon from CO_2

Heterotrophs (other+feed): get carbon by eating organics

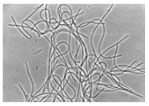
Sources of Energy:
Photosynthesis: energy from sunlight

Chemosynthesis: energy from inorganic oxidation (Hydrogen, Iron, Sulfur, etc.)

Heterotrophs are organisms that get their carbon by "eating" organic compounds.

Chemoheterotrophs get energy from organic and inorganic compounds in their environment

Examples: animals, fungi, many bacteria



Photoheterotrophs get energy from sunlight

Examples: *Chloroflexi* bacteria, heliobacteria (very rare)

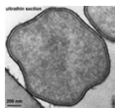
Chloroflexus aurantiacus

Autotrophs are organisms that get their carbon from Carbon Dioxide (CO_2)

Sources of CO_2:
CO_2 in the air
CO_2 dissolved into water

Photoautotrophs use energy from sunlight

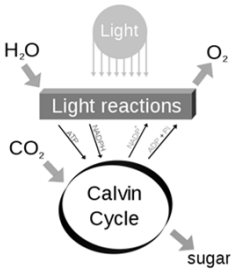
Examples: plants & photosynthetic bacteria

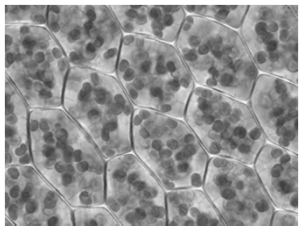


Chemoautotrophs use energy from oxidation of inorganic chemicals (iron, sulfur, ammonia)

Examples: some bacteria and archaea

Photosynthesis in photoautotrophs is the conversion of CO_2 and Water via sunlight into O_2 and sugars.





Cells of the moss *Plagiomonium afine* showing chloroplasts

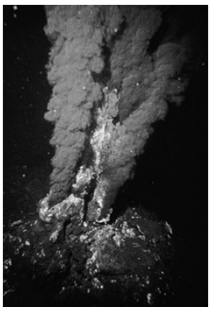
Chemosynthesis in chemoautotrophs is the conversion of CO_2 into organics by oxidation of inorganic compounds or methane.

Very diverse set of organisms, mostly bacteria and archaea.

Many occur in the deep ocean near undersea volcanic vents.

Vents provide inorganics (mostly iron, but also sulfur, H_2S, etc.), get CO_2 dissolved into sea water.

May have been the first forms of life to emerge on Earth.



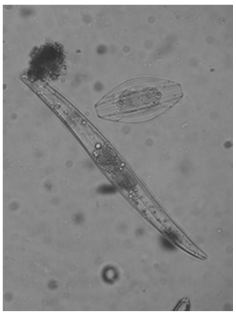
The complex chemistry of life appears to require a liquid "solvent" to occur in.

Provides a medium for chemical reactions

Carries nutrients in and wastes out

Helps maintain proper thermal balance (high heat capacity)

Provides protection from the outside environment



Liquid Water is the ideal solvent for the chemistry of life.

- Water is Abundant
- Liquid from 0 – 100°C (ideal for most reactions)
- Dissolves most chemicals
- Large heat capacity
- Less dense when it freezes
- High surface tension

The requirements of metabolism and cell chemistry suggest some of the general requirements for life.

- Source of energy (photo or chemical) to fuel chemical reactions
- A warm environment with abundant liquid water.
- Complex chemistry (primarily carbon chemistry?)
- Source of raw materials (carbon and other heavy elements)