Astronomy 230

Section 1– MWF 1400-1450

106 B1 Eng Hall

This Class (Lecture 11):

Nature of Life.

HW 2 Due today!

Next Class:

David Sederquist
Pranay Patel
Doug Jones

Oral Presentations on Sept 24 and 27!

Michael Chou
Eric Mazzone
Chris Varney

Craig Colbrook
Kevin Korinek
Nick Lyon

Music: *Holes in the Skies* – Heaven's Burning

Outline

- Time to turn to life on Earth.
- What are the main properties of life?
- H, O, N, and C are the main elements of life. Why?
- Carbon has 4 bonding sites.
- Amino Acids
- Build up proteins (structural and enzymes) based on nucleic acids orchestration. The essentials for life.

n_e

- Complex term, breaks into two terms:
  - n_p: number of planets suitable for life per planetary system
  - f_s: fraction of stars whose properties are suitable for life to develop on one of its planets

http://nike.cecs.csulb.edu/~kjlivio/Wallpapers/Planets%2001.jpg

$$n_e = n_p \times f_s$$

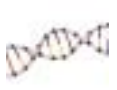
$$n_e = 1.2 \times 0.33 = 0.396$$

Drake Equation

Frank Drake








$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact	Rate of star formation	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that communicate	Lifetime of advanced civilizations
	25 stars/yr	**0.34** systems/star	**.396** life planets/system				

= 3.4 Life Planets /year

Life on Earth

- In our scientific approach, we look at life as a result of chemical evolution of complexity.
- We will view the formation of "life" on planets as we did star formation
  - A natural consequence of natural laws
  - More specifically, as a consequence of the complex chemistry that is sometimes achieved.

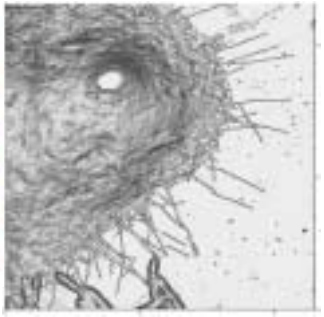
http://www.toothpastefordinner.com/052802/science-only-happens.gif

Cosmic Imperative?

- But is life a cosmic imperative?
- Just like gas forms galaxies, and in galaxies stars and planets form, do chemicals on some planets form molecules that lead to life?

All Made from the Same Stuff






Element Basis of Life

- About 95% of the mass of all terrestrial organisms is composed of only 4 out of 90 elements
  - Hydrogen (61% in humans)
  - Oxygen (26% in humans)
  - Nitrogen (2.4% in humans)
  - Carbon (10.5% in humans)
- HONC is essential to life, and it is common in space.

Trace Elements

In addition to HONC, there are some other elements that are essential for life but in *smaller* amounts:

- Sulfur, magnesium, chlorine, potassium, sodium
  - These other elements make up about 1% of mass of living organisms
  - Exist in roughly the same concentration in organisms as in ocean water
  - Highly suggestive that life began in oceans
  - Furthermore suggests that the evolutionary processes occurred on Earth. Panspermia problems?

Good News

- H,O,N,C very common in universe everywhere as far as we can tell
  - If life were based totally on rare elements, we might expect its occurrence to be extremely rare…
- So, we expect ET life to be based primarily on HONC. The four primary chemical elements of life with some other simple components can produce staggering complexity.
- But, each planet will feature its own environment of trace elements giving each planet's life a unique twist to the standard HONC chemistry

Nature's Complexity

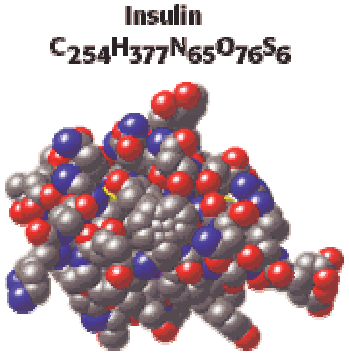
- The workings of biological molecules are an absolute marvel
  - How did this complexity develop?
  - How did it evolve?
- As complex and mysterious as life on Earth may be, we can begin understand it
- Start with the basics:
  - Why are H,O,N,C the basis for living organisms?
  - How do the molecules formed by these (and other elements) work to make DNA, proteins, life?

Special Stuff?

- Why is Earth life based on H,O,N,C instead of the more abundant elements found on Earth?
  - Suggests that the formation of life is not able to be formed just out of anything lying around.
  - The selection of H,O,N,C seems to be a necessity of the chemistry of life.
  - In general, Earth life is a carbon based life. Carbon is the main backbone of the chemistry.
- Is this good news?

Why Carbon Based Life?

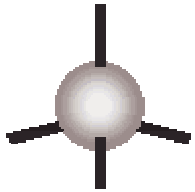
- Carbon's electronic structure allows it to form long chains
  - Chains of atoms and chains of molecules– complexity
  - Life needs bonds to be stable but breakable
- Good for us, at temperatures at which water is liquid, carbon bonds are stable but breakable
- Organic chemistry is the special branch devoted to carbon chemistry.



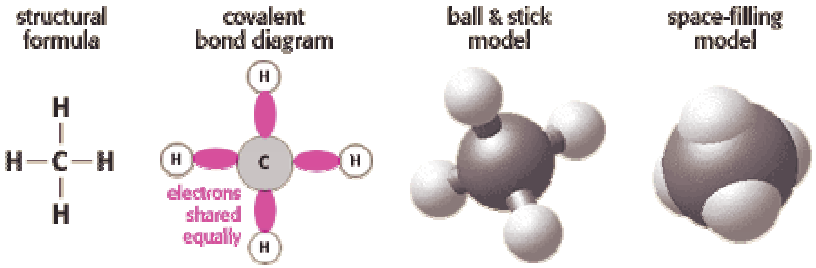
http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page2.html

Bond, Carbon Bond

- Carbon has 6 protons, 6 neutrons, and 6 electrons
  - Electrons distribute themselves in "shells"
    - Pauli exclusion principle
    - 1st (inner-most) shell is filled by 2 electrons
    - The 2nd shell would be 'filled' by 8 electrons, but its only got 4
      - So, Carbon has 2 electrons in inner shell and 4 in 2nd shell
      - It likes to bonds to "fill" second shell by sharing with four other electrons



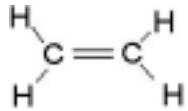
The Bond– Methane

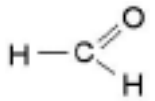


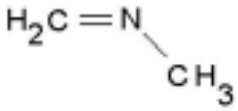
Not many other elements can share 4 bonds.
Silicon, which is much more abundant, can.

http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page2.html

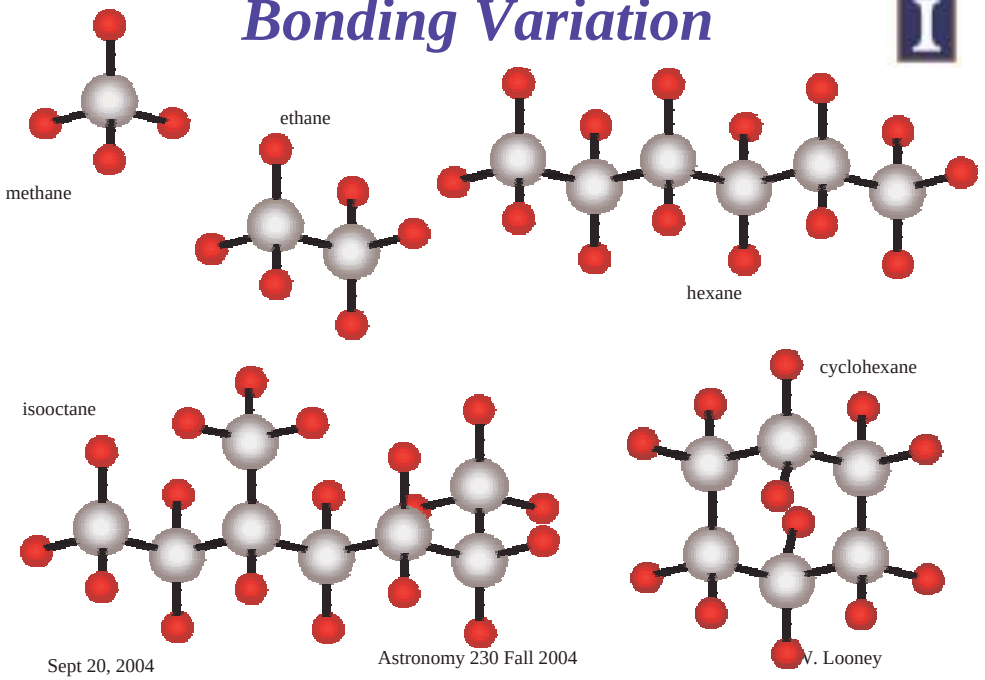
More Bonds







Bonding Variation



Unique?

- As far as we know, the complexity of terrestrial biochemistry can only be achieved with carbon-based molecules.
  - Especially considering the need for liquid water
    - Which puts restrictions on the temperature in which the chemical reactions occur

Nitrogen

- Actually plays a central role in organic chemistry.
- It is prominent in biological compounds due to its reactivity with carbon and its propensity to form chains in organic compounds

Molecular Basis of Life

- Great diversity of Life on Earth, but still it is 70% water and 24% four large molecules:
  - Proteins
  - Nucleic Acids
  - Lipids
  - Carbohydrates
- Not completely true. The simplest life, viruses, can have a single molecule of nucleic acid surrounded by a protein coating.

Lipids and Carbohydrates

- Lipids are almost entirely composed of carbon and hydrogen with some oxygen.
- Lipids are essential for cell membranes.
- Carbohydrates are comprised of sugar molecules.
- Carbohydrates are used for energy storage in cells.
- In this class, we will concentrate on proteins and nucleic acids as the crucial bits for life.
- That's enough for viruses, and probably protolife was similar?

Monomers and Polymers

- All of the fundamental chemicals of life are organic polymers
  - A monomer is a small molecule (like carbon bonds we have seen).
  - A polymer is a number of monomers joined together to form larger, more complex molecules.
  - Polymers are nice for life, as they can form complex and repetitive sequences

Proteins vs Nucleic Acids

- Proteins are either structural elements or for catalytic reactions (enzymes).
- Nucleic acids carry the genetic information– Replication of nucleic acid is crucial to reproduction of organism.
- Both are made of polymers.
- Can form complex, repetitive sequences.
- The order of the monomers determines the function of the polymers.
- Monomers are the letters and words in the molecular basis of life, and polymers are the messages.

How is Life Put Together?

- Living things are not just bags of large molecules and polymers mixed in a big soup
  - Living things have structure
  - Plants, animals have different parts
    - Skin, Hair, Leaves, Hearts, etc.

How do these structures relate to the complex organic polymers and DNA?

DNA Based Life

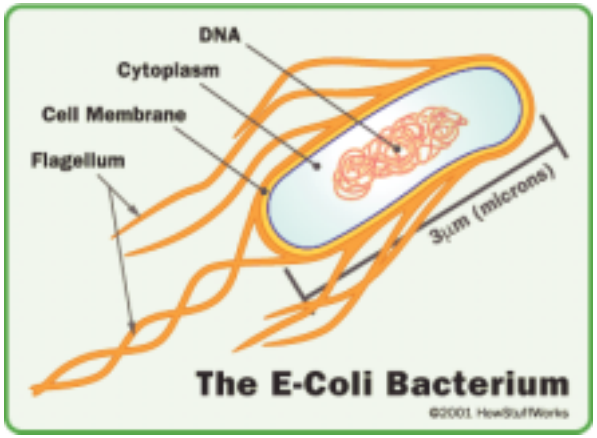
- All life is based on DNA. What does this mean?
  - The basic reproducible unit of all living organisms is centered around the complex DNA molecule.
  - DNA lives in cells
    - Except in viruses, which are basically pure DNA
  - Cells of different types form different parts of each organism
    - Heart cells different from blood cells.
    - Leaf cells different from root cells.

Cell Bits

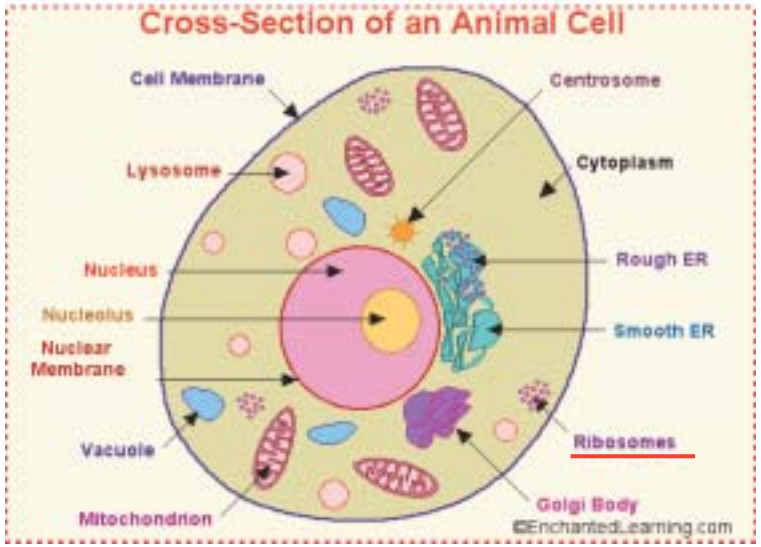
- The cell function directly relates to a different organic polymer:
  - Proteins: Polymers of amino acid monomers that form the structural components of the cell or form enzymes that do all the real chemical work inside the cell.
  - DNA: The genetic coding molecules that controls enzyme and cell reproduction. Polymers of a sugar, phosphate, and nucleotides
  - Sugars: The energy source of cells

Bacteria Cells

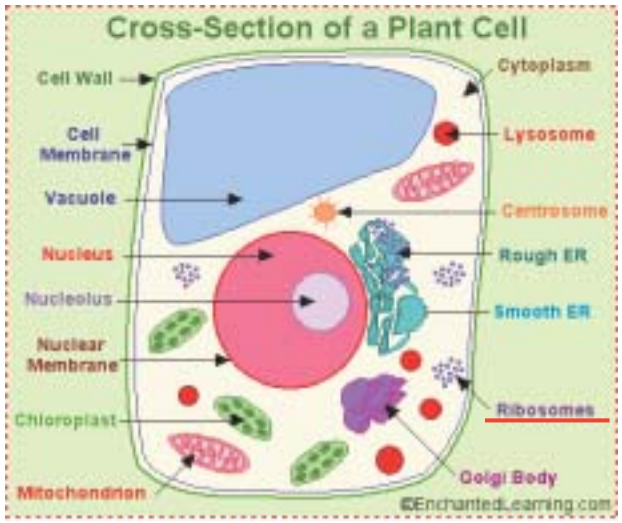
- Simplest cell that exists today.
- Completely self-contained organism.
- Human cells are much more complicated.
- 1 trillion cells in a typical human and they're usually 10 microns in diameter.



Animal Cells



Plant Cells

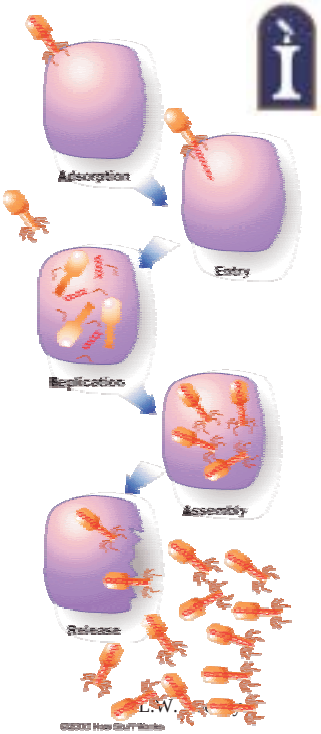


Cell Variation

- Bacterial cells lack a nuclear membrane enclosing the cell's nucleus
- Animal cells have a nuclear membrane but lack a distinct cell wall
- Plant cells have both a nuclear membrane and a cell wall

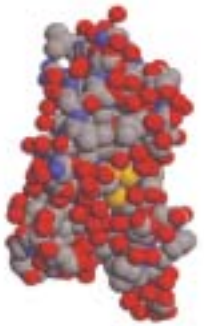
Viruses

- Straddles between the living and non-living
- The protein protects the virus until it enters a living cell, where the nucleic acid is released.
- Using the cell's machinery, the nucleic acid reproduces itself.
- They are all parasites, so thought to be from free-living organisms and not descendents of early life.



Focus on Proteins

- Proteins are large, very complex, and very numerous.
- All proteins in living organisms are made from combinations of 20 types of amino acids (about 100 available though).
- Example: Enzymes (a type of protein) are made up of 100s to 1000s of those 20 amino acids, with a particular sequence and shape.
  - This gives 20^{100+} possible combinations
    - How many 100 character sequence can you form from the alphabet?
- BUT, only about 10,000 proteins are used.
- Note, the human body is about 20% protein.



General Protein Types

Type	Examples
• Structural	tendons, cartilage, hair, nails
• Contractile	muscles
• Transport	hemoglobin
• Storage	milk
• Hormonal	insulin, growth hormone
• Enzyme	catalyzes reactions in cells
• Protection	immune response

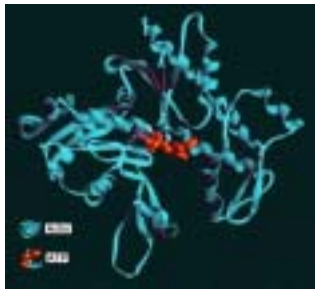
http://66.41.139.241:8000/fitam/muscle.JPG

Protein Desert

- The fact that only 10,000 of the billions+ of proteins are used, suggests that life is a little picky.
- Only certain combinations seem to work?
- Does this mean that ET life would find the same useful permutations as Earth life found.
  - Many options were available
  - But, only a small fraction actually worked?

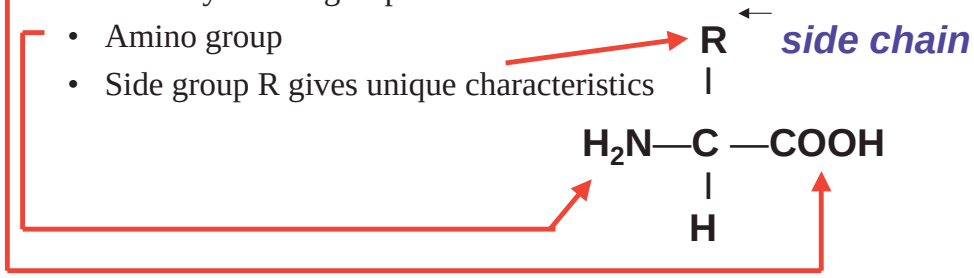
A Type of Protein: Enzymes

- All of the day-to-day work of life is being done by enzymes. Enzymes are little chemical-reaction machines.
- The purpose of an enzyme is to allow the cell to carry out chemical reactions very quickly.
- These reactions allow the cell to build things or take things apart as needed– grow and reproduce.
- E. coli has about 1,000 different types of enzymes floating around in it at any given time.
- To understand enzymes is to understand cells. To understand cells is to understand life on Earth.
- Maybe similar to life in space?
- Enzymes are made from 3-D structures of amino acids orchestrated by the DNA.

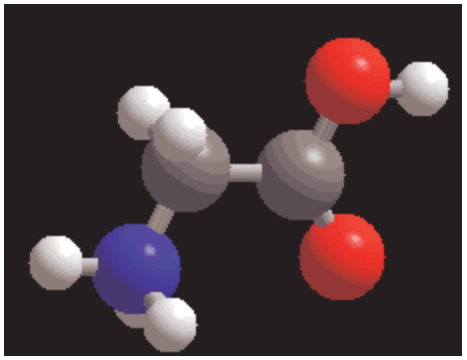


Amino Acids

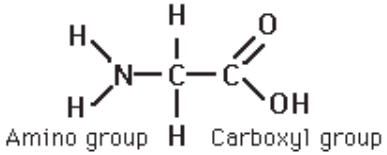
- Are the monomers from which proteins (polymers) are made– building blocks.
- Combinations of the amino acids make the millions of proteins needed– only 20 amino acids.
- The order of the amino acids determine the formed protein.
- Carboxylic acid group
- Amino group
- Side group R gives unique characteristics



Glycine



- Simplest amino acid. Just an H in the R position.
- Main ingredients are HONC– other amino acids contain Sulfur (S) as well.



Getting Hooked Up

- Amino acids are monomers
- Proteins are polymers of amino acids of a certain type. A number of specific amino acids "hook up" to form a specific protein.
- As a chain grows, there is always a hook (the amino group) on one end and an eye (the carboxyl group) on the other.
- Really a peptide bond.