Astronomy 330

This class (Lecture 15):
Life on Earth
Mary Heaton
Alison Melko

Next Class:
Origin of Life
Jeremy Morton

HW 6 due next Thursday.

Music: *Life Begins at the Hop*– XTC

HW 2

- Praneet Sahgal
  http://alien-ufo-research.com/alien_moon_bases/
- Se-Joon Chung
  http://www.cropcircleresearch.com/articles/alienface.html

Presentations

- Mary Heaton
  Area 51
- Alison Melko
  Is Looking for Aliens Dangerous?

Outline

- Monomers and polymers
- Proteins and nucleic acid?
- Where did the monomers of life come from?
- How were the polymers made?

Drake Equation

Frank Drake

That's 3.5 Life-liking systems/decade








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

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	20 stars/ yr	0.8 systems/ star	2 X 0.11 = 0.22 planets/ system	life/ planet	intel./ life	comm./ intel.	yrs/ comm.

Question

The best type of life sustaining stars are

a) Low mass stars (less than 0.5 solar masses), as life can exist nearer the star where more terrestrial planets are probably located.

b) Binary stars, as they double the chances of life.

c) Stars off the main sequence, as they have lived the longest, they are the best chance for finding intelligent life.

d) Middle mass stars (less than 1.25 and more than 0.5 solar masses), as they live longer and don't require the planets to be too close.

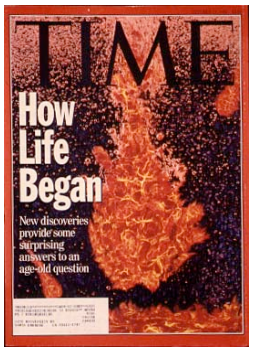
e) Massive stars (more than 2 solar masses), as they have more mass from which to form planets.

So Far, We have Studied

- The Universe
  - Big Bang
    - Creation of hydrogen, helium…
  - Galaxy formation
    - Swirls of elements embedded in self-gravitating cloud of dark matter
  - Star birth
    - Energy generation and element production in self-gravitating mass of gas
  - Planets
    - Ice, rock, gas surrounding stars form planetesimals, then planets

Life on Earth

- Time to examine terrestrial evolution.
- Need to understand what is needed for life to arise.
- Again, some Earth chauvinism.
- Relies on chemical evolution
- Eventually life began?



http://www.accessexcellence.org/bioforum/bf02/awramik/bf02a1.html

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?

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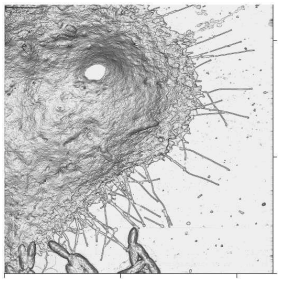
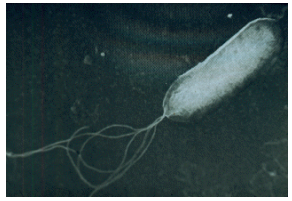
All Made from the Same Stuff





Element Basis of Life

- About 95% of the mass of all terrestrial organisms is composed of only 4 out of 90 elements
  - **H**ydrogen (61% in humans)
  - **O**xygen (26% in humans)
  - **N**itrogen (2.4% in humans)
  - **C**arbon (10.5% in humans)

- **HONC** is essential to life, and it's common in space.

Question

Life on Earth is varied in how its made on the molecular level, i.e. elephants are made out of different stuff than bacteria.

a) True
b) False

Trace Elements

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

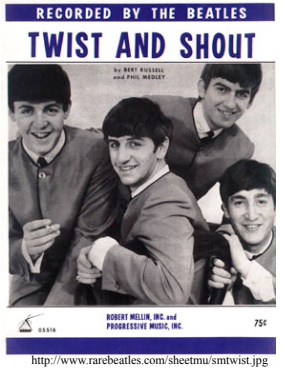
– Sulfur, magnesium, chlorine, potassium, sodium

- These other elements make up about 1% of the 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?

http://www.maxxiweb.com/pics/wallpapers/paysages/oceans-006.jpg

Good News

- H,O,N,C is 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



http://www.rarebeatles.com/sheetmu/smtwist.jpg

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 to 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?

http://europa.eu.int/comm/environment/life/toolbox/logo_life_high_resolution_2.jpg

We Are Special Stuff?

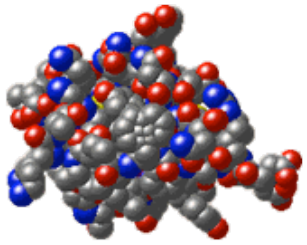
- Why is Earth life based on H,O,N,C instead of the more abundant elements found on Earth?
  - Suggests that the formation of life is not able to be formed just out of anything lying around.
  - The selection of H,O,N,C seems to be a necessity of the chemistry of life.
  - In general, Earth life is a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

Insulin

$C_{254}H_{377}N_{65}O_{76}S_6$



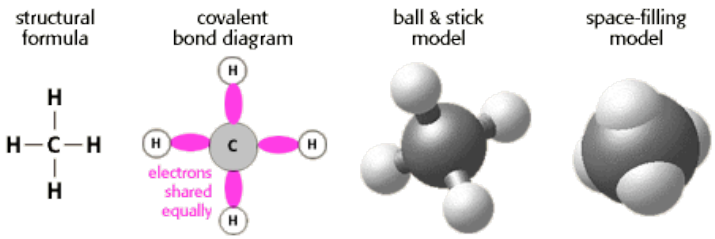
http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page2.html

Bond, Carbon Bond

Carbon has 6 protons, 6 neutrons, and 6 electrons

- Electrons distribute themselves in "shells"
  - Pauli exclusion principle
  - 1st (inner-most) shell wants to be filled by 2 electrons
  - 2nd shell wants to be filled with 8 electrons
  - BUT, Carbon only has 6 electrons!
    - So, Carbon has 2 electrons in inner shell and 4 in 2nd shell
    - It likes to bond: to "fill" second shell by sharing with four other electrons

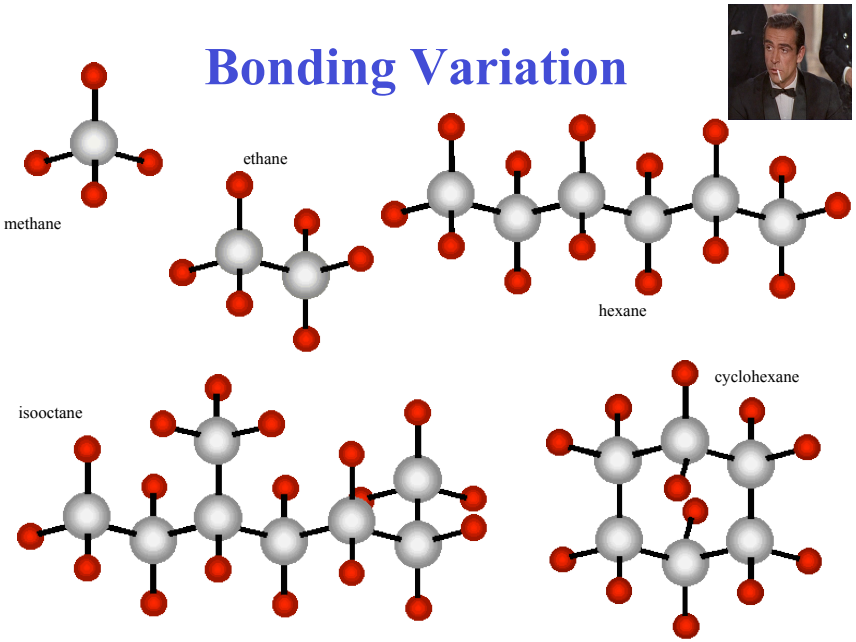
The Simplest C Bond– Methane



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

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

Bonding Variation



http://www.colossusblog.com/mt/archives/images/drno5.jpg

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

Question

Life uses carbon for making long molecular chains because

a) it is much more abundant than silicon.
b) it likes to share 4 electrons.
c) it is abundant in the ocean.
d) it makes chains that are not easily broken.
e) it is the most abundant element.

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 All Life

- Great diversity of Life on Earth, but still it is 70% water and 24% four large molecules:
  - Proteins
  - Nucleic Acids
  - Lipids
  - Carbohydrates

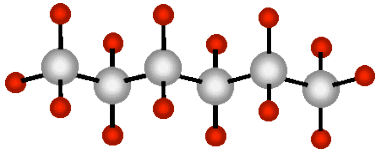
In this class, we will focus on the 2 most important molecules

Not completely true. The simplest life, viruses, can have a single molecule of nucleic acid surrounded by a protein coating.

Monomers and Polymers

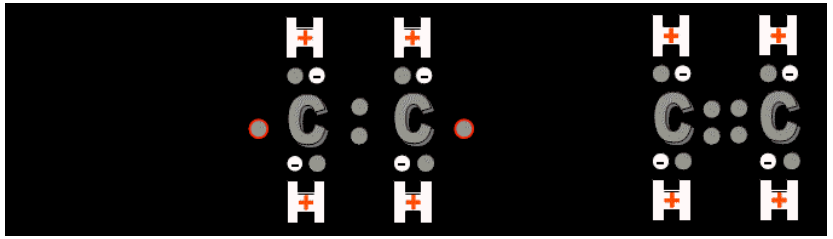
- All of the fundamental chemicals of life are organic polymers
  - A monomer is a small molecule (like carbon bonds we have seen).
  - A polymer is a number of monomers joined together to form larger, more complex molecules.
  - Polymers are nice for life, as they can form complex and repetitive sequences

Monomer of C

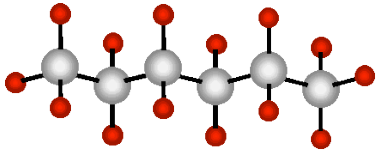


Polymer of hexane

Making A Polymer



Monomer of C



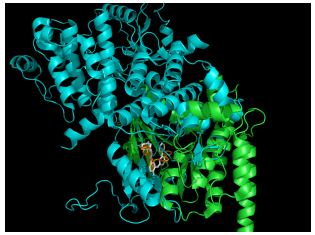
Polymer of hexane

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.

Proteins & Nucleic Acids

- Proteins are either structural elements or provide catalytic reactions (enzymes).
- Nucleic acids carry the genetic information– Replication of nucleic acid is crucial to reproduction of organism.
- **They are the polymers of life!**



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 nucleic acids?

DNA Based Life

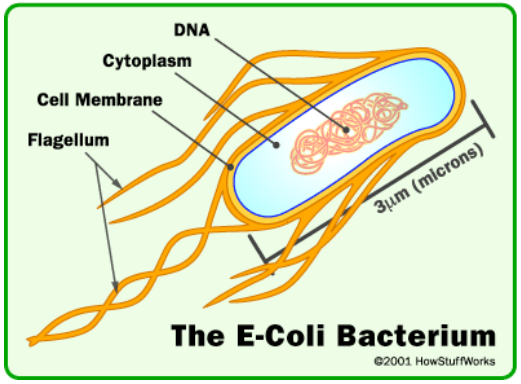
- All life is based on DNA/RNA. What does this mean?
  - The basic reproducible unit of all living organisms is centered around the complex DNA molecule.
  - DNA lives in cells
    - Except in viruses, which are basically pure DNA
  - Cells of different types form different parts of each organism
    - 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: They form the structural components of the cell or form enzymes that do all the real chemical work inside the cell. Polymers of amino acid monomers.
  - DNA: The genetic coding molecules that control enzyme and cell reproduction. Polymers of a sugar, phosphate, and nucleotides monomers.

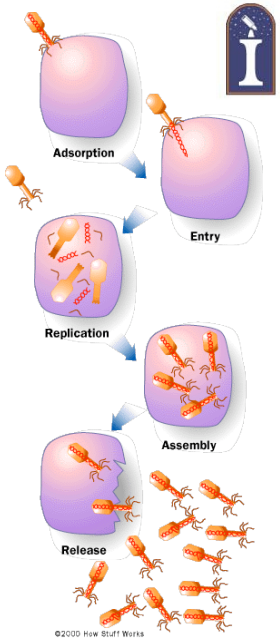
Bacteria Cells

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



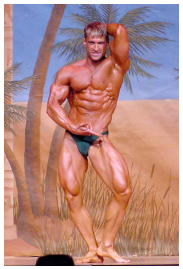
Viruses

- 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.



General Protein Types

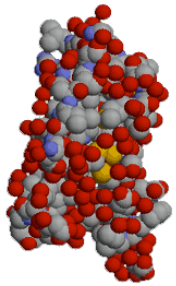
Type	Examples
• Structural	tendons, cartilage, hair, nails
• Contractile	muscles
• Transport	hemoglobin
• Storage	milk
• Hormonal	insulin, growth hormone
• Enzyme	catalyzes reactions in cells
• Protection	immune response



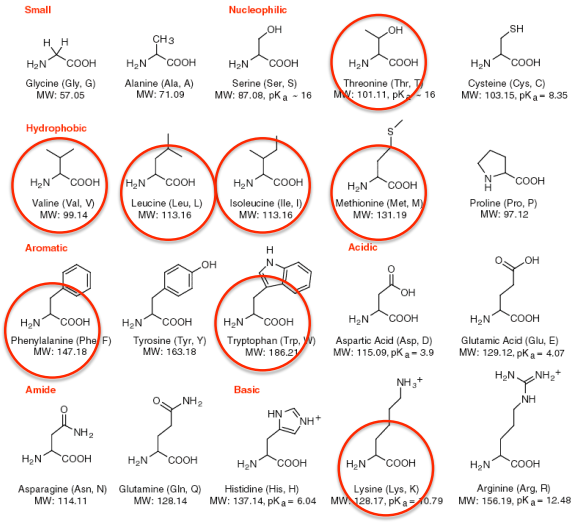
http://66.41.139.241:8000/fitam/muscle.JPG

Focus on Proteins

- Proteins are large, very complex, and very numerous.
- Yet, all proteins in living organisms are made from combinations of **20 types** of amino acids (about 100 available though).



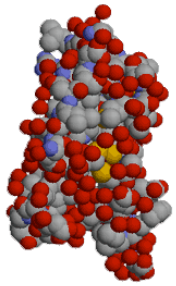
Amino Acids Are for Lovers



http://www.neb.com/neb/tech/tech_resource/miscellaneous/amino_acid.html

Focus on Proteins

- Proteins are made up of 100s to 1000s of ONLY 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.



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?