Astronomy 330

This class (Lecture 12):

Origin of Life
Dale Sormaz
David Luedtke

Next Class:

Life in the Solar System

HW 5 is due Thursday

Midterm March 4th!

Music: *Life Begins at the Hop* – XTC

Eclipsed

- Did you see it?
- If not, you will need to wait until December 20th, 2010 to see another!

HW #3

- **Cheryl Cwik**: http://www.aliensandchildren.org
- **Ryan Ross:** http://www.ufowatch.com
- **Steven Kallal:** http://www.abduct.com/support.php

Presentations

- **Dale Sormaz:** Black Holes
- **David Luedtke:** Creating Life in the Lab

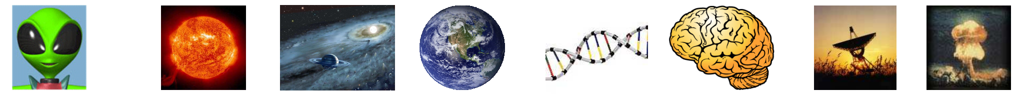
Outline

- Alternative places to make monomers.
- Making polymers ain't easy.
- Transition to Life
- The RNA World: Protolife

Drake Equation

Frank Drake

That's 0.67 Life-liking systems/year

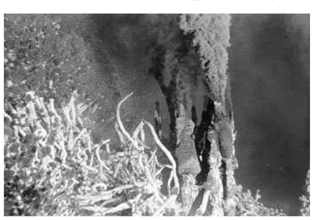


$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

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
	19 stars/yr	0.4 systems/star	1.25 x 0.07 = 0.0875 planets/system	life/planet	intel./life	comm./intel.	yrs/comm.

The Hot Origins Theory

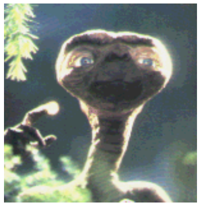
- Vents are examples of a food chain that does not rely ultimately on photosynthesis.
- Demonstrates that pre-biotic synthesis can occur, but did life begin there?
- And current vents are short-lived– a few decades.
- And hot– if synthesis first occurred there, it might have been quickly destroyed.



http://www.xenon.com/vents.html

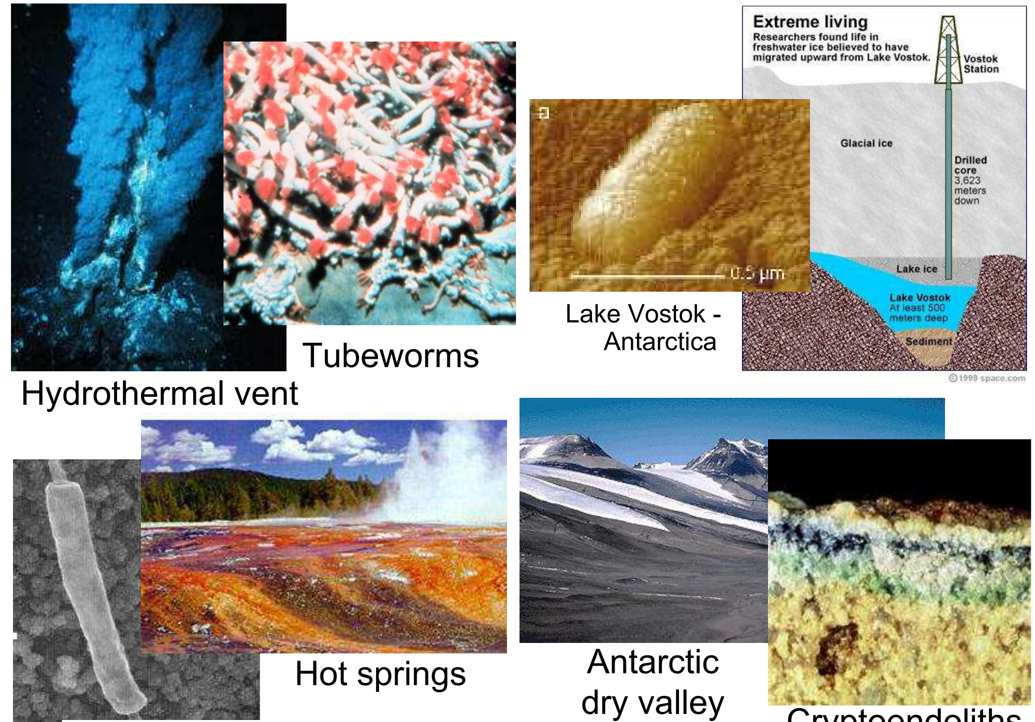
The Hot Origins Theory

- But life is common in hot environments
  - Hot Springs (like in Yellowstone)
  - Hot oil reservoirs up to 2 miles underground.
- Many of those organism display old genetic characteristics, but some say not ancient enough.
- Did life start somewhere cushy and move there?



Not your Parent's ET--Extremophiles

- These are microbes that live in the most extreme places on Earth.
- Temperature extremes
  - boiling or freezing, 100^0C to -1^0C (212F to 30F)
- Chemical extremes
  - vinegar or ammonia (<5 pH or >9 pH)
  - highly salty, up to ten times sea water
- They are exciting, as they are the most likely candidate for extraterrestrial life.
- Probably dominated life on early Earth until fairly recently.



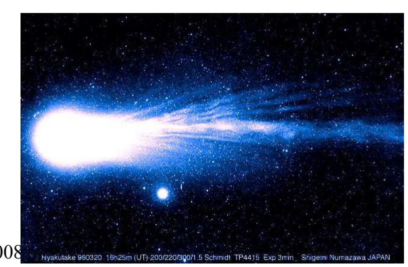
Interstellar Space

- Another reducing atmosphere is space and the circumstellar disk from which our solar system formed.
- We have seen complex molecules in space.
- The ices would have been destroyed this close to the Sun, but farther out would have been fine.
- Comets could transport the molecular binding dust grains back to the Earth.

http://stardust.jpl.nasa.gov/science/images/pach7.jpg

Comets

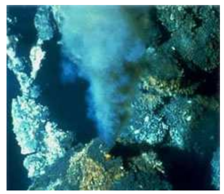
- Have similarities to interstellar ices
- Comets hit the Earth, and did so much more often in the past.
- About 5% of comets are carbonaceous chondrites, which contain about 1-2% of their mass in organic compounds, including amino acids of non-biological origins (e.g. the Murchison meteorite).
- Can life get transported?
- Panspermia again.



http://stardust.jpl.nasa.gov/science/images/num2.jpg

So?

- We don't know the origin of the monomers that are needed for life.
- But, there are a variety of processes that could produce them.
  - In Earth's early atmosphere
  - Near hydrothermal vents
  - In interstellar space
- The next step is polymerization



http://origins.jpl.nasa.gov/habitable-planets/images/ra6-early-earth-th.jpg

Synthesis of Polymers

- If we assume that the early monomers for proteins and nucleic acids existed on the early Earth, then is it plausible that they would polymerize?
- The standard idea of the prebiotic soup would suggest that it is easy to form polymers, but not so fast.
- The problem is that the separate monomers are a lower energy state. They like to be separate.
- It's an uphill battle for the early monomers to turn into polymers.

http://www.heartsong3.com/Images%202000/Uphill.jpg

Polymer Pressure

- Hmm.. Does this mean that the key polymers that keep us alive are intrinsically unstable?
- Yes. Sort of kinda.

http://www.thanhniennews.com/society/?catid=3&newsid=6557

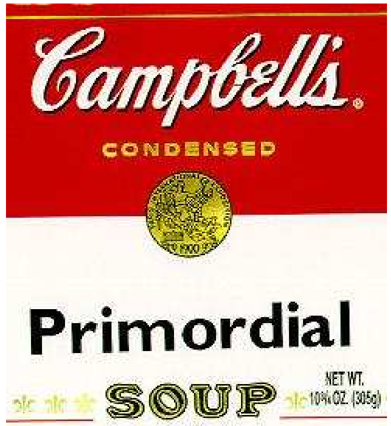
Polymer Pressure

- We are constantly inputting energy into the system– our body.
- A simple pattern: simple components + energy leads to greater complexity
- But for early life, the problem was for polymers to stay together, even water wanted to pull them apart.

http://www.thanhniennews.com/society/?catid=3&newsid=6557

Making Them Hook Up.

- One idea is for the early soup to quickly evaporate into a condensed soup– so the monomers can join up.



http://www.physics.uc.edu/~hanson/ASTRO/LECTURENOTES/ET/Earth2/PrimordialSoup2.jpg

Making Them Hook Up.

- Another idea, is to find an energy producing reaction that promotes polymerization.
  - Energy currency in life now is ATP (adenosine triphosphate), which is an adenine base, a ribose sugar, and a tail of 3 phosphates. The phosphates bonds are broken to provide energy and allow bonding.
  - Too complicated for early life, but there are other similar molecules that could do a similar job. Maybe produced in a Miller-Urey procedure?

http://www.physics.uc.edu/~hanson/ASTRO/LECTURENOTES/ET/Earth2/PrimordialSoup2.jpg

Hooking up Dirty?

- Polymerization in clay soils?
- Clay has layers of silicates and water.
- Add water, the layers expand and amino acids can move between layers.
- Remove water, the layers contract and the amino acids get absorbed onto the clay surfaces.

http://www.clw.csiro.au/education/soils/images/clay_soil.jpg

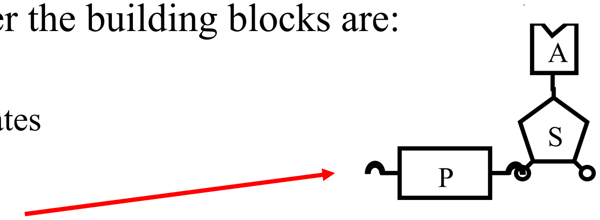
Totally Tidal

- Experiments have shown that certain clays, promote polymerization of 50 or more amino acids chains with high efficiency.
- Add water, and the polymers are released.
- Think of the ocean tides fueling the polymerization.

So… And RNA/DNA?

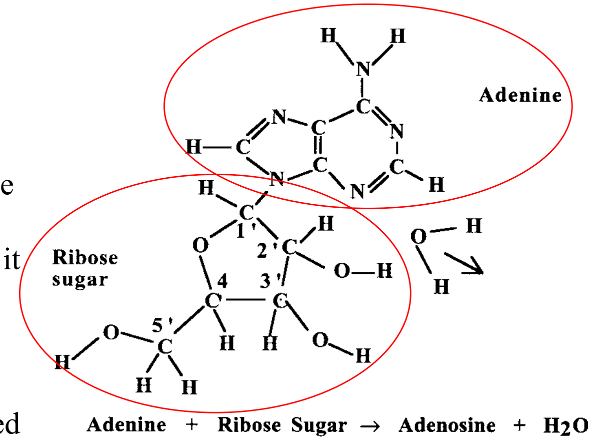
- There are a few ways that amino acids can hook-up and form polymers, but nucleic acids are more difficult to understand as they are more complex.
- What is the basic monomer of RNA or DNA?

- Remember the building blocks are:
  - Sugars
  - Phosphates
  - Bases



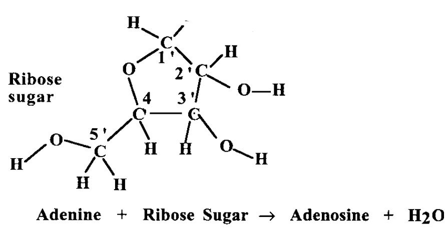
Synthesis?

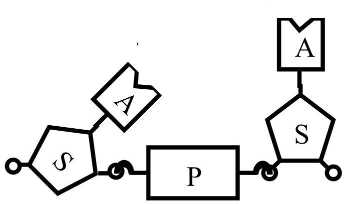
- Not well understood.
- Can number the carbon atoms in the ribose sugar.
  - It is essential that the base attach at the number 1 carbon only. Otherwise, it is not a nucleoside.
  - The base could attach at the 2 or 3 carbon too.
  - Why was bond 1 preferred on the early Earth?



Phosphate Issues

- And the phosphates **must** then attach at the 3 and 5 carbons.
- In the lab, the phosphates tend to attach to the 2 and 5 carbons.
- This causes a misalignment, which prevents long stands – warped.





Nucleotide Synthesis

- Nucleotide synthesis is not very efficient
- Heating ribose sugar with some purine bases can produce a few nucleotides, and salt can produce a better yield.

Nucleotide Synthesis

- So, again, maybe an evaporating pool with geothermal energy– monkeys from the pool?
- But nucleotides with pyrimidine bases are more difficult.
- Some have argued for catalyst with metal ions can work.
- So, some ionized metals in the pool too?

http://www.themonkees.com/quizzes18.htm

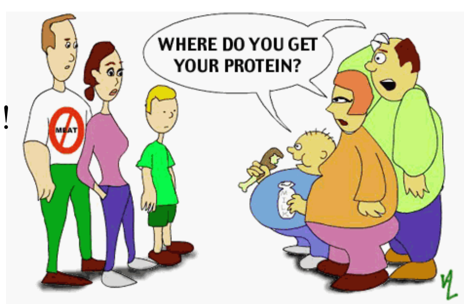
Protein Probability

- Seems easiest to produce a protein, so what is the chance of getting a useful protein with the proper order of amino acids from chance?
- Toss of a coin. 50/50 (or ½) chance of heads or tails.
  – If you want 10 heads in a role you can multiple the chance of
    1 throw (½) times 1 throw (½) times…etc…
    or $(½)^{10}$ or 1 time out of 1024 attempts.

http://cruel.org/kitchen/shrunken.html

Probability of Randomly Forming Life?

- The polymer game is more complex with 20 options of amino acids so if random, the chance of getting a single amino acid is 1/20.
- For a protein with a specific 10 amino acids in order.
  – $(1/20)^{10}$ or about $1/10^{13}$
    or 1 chance in 10 trillion!!!!



Latest studies: A third of Americans are overweight, and an additional quarter are obese.

http://www.citypaper.net/hth/

Getting Lucky?

- If we throw enough coins, we <u>will</u> get 10 heads in a row.
- And if there were very large numbers of monomers, then even a very unlikely event can happen.
- Perhaps **<u>time</u>** is the hero of the story?
- But, don't forget a typical protein can have easily more than 200 amino acids. That is a chance of success of $(1/20)^{200}$!

http://members.aol.com/LILAUTHOR1/hourglass.jpg

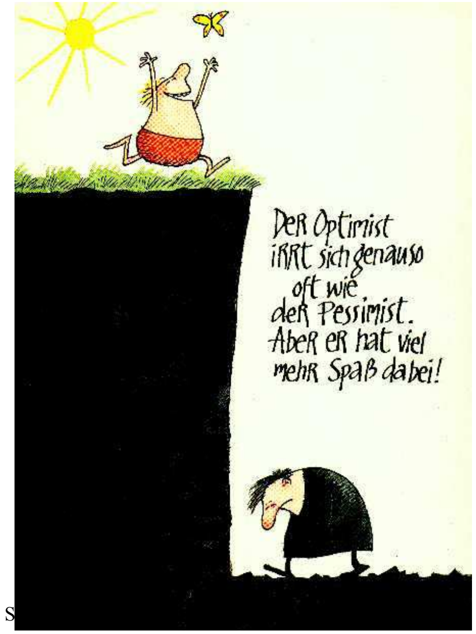
Pessimistic?

- A generous estimate of the number of trials that the early Earth had was about 10^{51}.
- But, maybe the early Earth only had a few amino acids at first. Then the odds are better for certain proteins.
- But, we require more than just 1 protein to be formed.
- And first life probably needed many proteins as well.

http://www.physics.brown.edu/Studies/Demo/solids/demos/1a2020.jpg

Pessimist?

- Bottom line is that we can not expect life to arise from completely random combinations of molecules to make more complicated molecules.
- Something else must play a role.
- Some proteins might have a preferred assembly.



Poly Summary

- Polymerization of amino acids on the early Earth is plausible.
- Synthesis of nucleic acids seems to be much harder.
- Perhaps proteins from amino acid polymers played a role? Chicken came first?
- It is still more difficult, because life requires useful polymers. The order of the monomers determines the properties.

Life – Gen Eds

1. Precise way to reproduce instruction set (but not perfect)
2. Ability to control chemical reactions via catalysts.
3. A protective enclosure that separates the instructions and the catalysts from the environment. Becomes an individual not just a soup of chemicals
4. Method for acquiring and using energy.
5. Interconnections of the above.

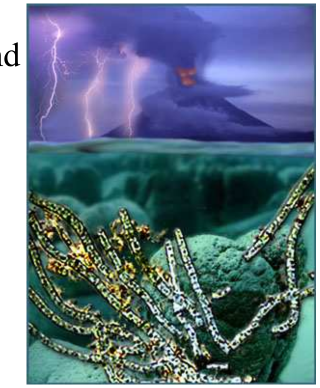
Life

- Life is based on cells
  - Protective enclosures formed from lipids
- Cells contain nucleic acids and protein enzymes
  - Instructions and catalysts that allow replication of nucleic acids
- Methods for acquiring energy
  - **Most** organism now on Earth get energy from the Sun– either directly or indirectly. But that requires pigments (e.g. chlorophyll).
  - Not sure if pigments are a primary need or if chemical sources of energy were used for early life.

http://www.internetcash.com/en/images/baby-crying.jpg

Transition to Life

- **Two possibilities**
  - Primitive versions of proteins, nucleic acids, and protocells arose independently and combined to form a life form, called **primitive life**.
  - One of the components was dominant and the first "life" was based on only one polymer, then developed into life as we know it. We can call it **protolife**.
- The statistical arguments would argue **against** primitive life and **for** protolife.



http://www.lbl.gov/Science-Articles/Archive/sb/July-2004/2_spinach.html

Transition to Life?

- Really the big question.
- How difficult is it for the collection of polymers to become life?
- The last step in chemical evolution is really biological evolution.