Astronomy 330

This class (Lecture 16):
Origin of Life
Katherine Woodruff

Next Class:

Biological Evolution
Daniel Cohen

HW 6 due Thursday

Music: *Chiron Beta Prime* – Jonathan Coulton

HW 2

- Feifei Lian
  http://www.alieninfluence.com/Aliens-blog.html
- Thomas Hymel
  http://www.alienresearchcorp.com/technology/anti-gravity/emdrive/china/

Presentations

- Katherine Woodruff
  Alien Artwork

Groupings

Explain to your non-bio major friend what exactly are proteins and nucleic acids. (Make sure to use the words monomer and polymer.)

Outline

- Where did the monomers of life come from?
- How were the polymers made?
- How were the polymers made?
- Origin of Life on Earth?
  - RNA World

Drake Equation

That's 1.27 Life-liking systems/year

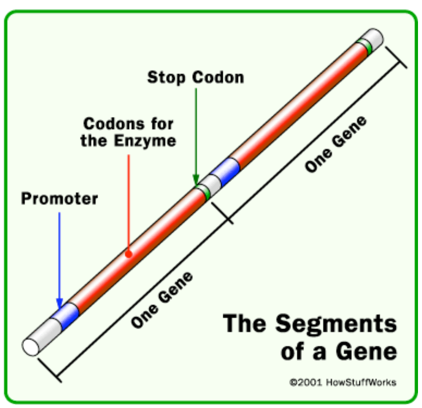
Frank Drake

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

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact 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
	15 stars/ yr	0.65 systems/ star	1. 3 x 0.1 = 0.13 planets/ system	life/ planet	intel./ life	comm./ intel.	yrs/ comm.

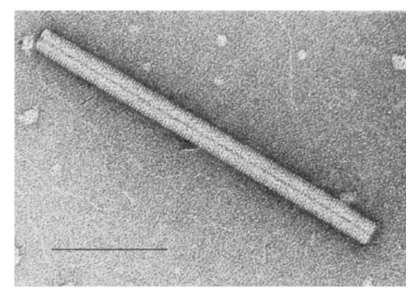
Genes

- Each codon specifies an amino acid, and a sequence of condons specifies a protein or enzyme.
- E. coli bacterium has about 4,000 genes, and at any time those genes specify about 1,000 enzymes. Many genes are duplicates.

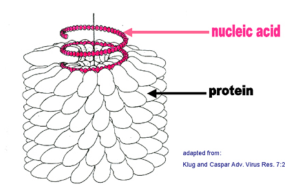


Ta-Backy

- Different organisms have different number of genes.
- Tobacco mosaic virus has 4 genes.
- A small bacterium has about 1000 genes– average sized bacterium has 4000 genes.



TOBACCO MOSAIC VIRUS



http://pathmicro.med.sc.edu/mhunt/intro-vir.htm

My Old Blue Genes

- The Human Genome Project found 30,000 genes
- If you took all of the nucleic acid in one human cell and stretched out the long sequence, it would be more than a meter long!
- Human cells have 3×10^9 base pairs, but 98% of it has no obvious function, and 99.9% is the same for all humans.

http://images.encarta.msn.com/xrefmedia/sharemed/targets/images/pho/t373/T373681A.jpg

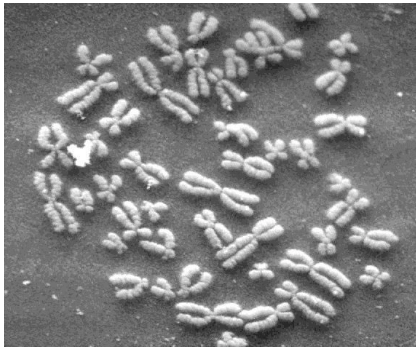
My Old Blue Genes

- This 98% is often called “junk” DNA (recent also called “Dark Matter”), but it is still unclear what it’s function is..
- Likely controls the early development from embryo to adult.
- May be as important as the protein encoding portion, but we don’t know.
- There is evidence that there is evolutionary conservation of "junk" DNA, which implies importance.

http://images.encarta.msn.com/xrefmedia/sharemed/targets/images/pho/t373/T373681A.jpg

Chromosomes

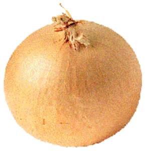
- Best way to package DNA is in chromosomes– DNA wrapped around proteins,
- Humans have 23 pairs of chromosomes (total of 46).
- Each ranges from 50 million to 250 million base pairs
- For each set, you got half from each parent.



http://folding.stanford.edu/education/GAH/gene.html

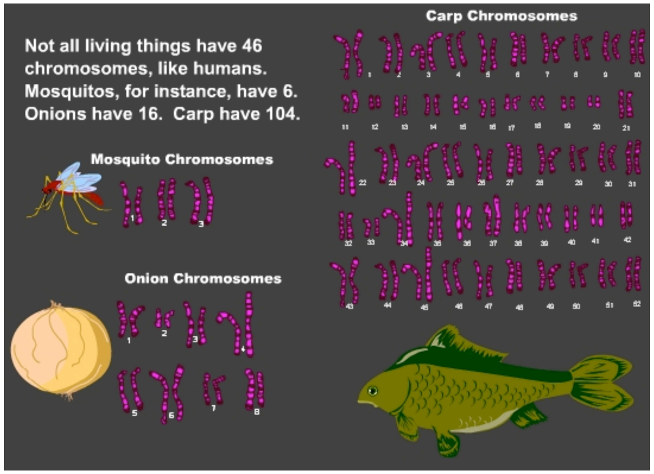
Which requires the most genes?

a) Onion
b) Mosquito
c) Carp
d) Human



http://www.thefishermom.com/images/071804small.htm
http://www.themoderatevoice.com/files/joe-mosquito.jpg
http://www.freewebs.com/flyingonion/Onion.gif

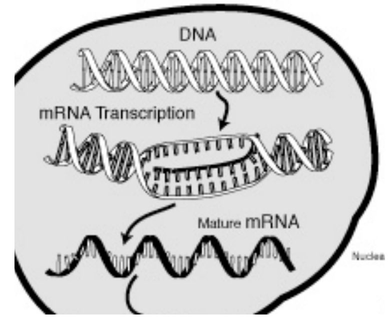
Chromosomes



http://gslc.genetics.utah.edu/units/basics/tour/chromosome.swf

DNA: Message in a Cell

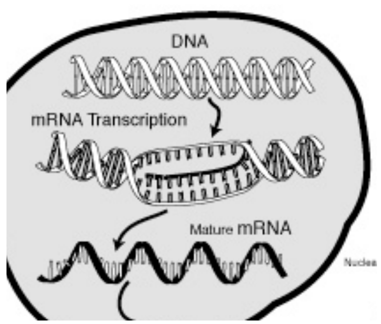
- A cell is informed it needs a enzyme– call it Z.
- Other enzymes in nucleus unravel and separate the easily broken DNA at the site where the gene for making that enzyme in encoded.



http://www.accessexcellence.org/AB/GG/mRNA.html

DNA: Message in a Cell

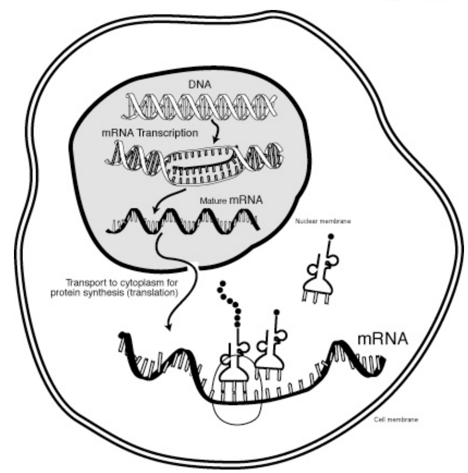
- Transcription of the gene is made via complementary bases and are assembled in a messenger RNA or mRNA.
- DNA zips itself back together.
- The mRNA (a series of codons) moves from the nucleus to the cytoplasm.



http://www.accessexcellence.org/AB/GG/mRNA.html

DNA: Message in a Cell

- Translation is the next step.
- A ribosome (the site of the protein synthesis) recognizes the mRNA by a special base sequence that attaches.
- The amino acids are built up from transfer RNA (tRNA) that move along the mRNA.
- The tRNAs have anticodon and carry amino acids.
- The chain of amino acids grows until the stop codon signals the completion of enzyme Z.



http://www.accessexcellence.org/AB/GG/mRNA.html

Reproduction

- DNA unzips itself, with appropriate enzyme.
- Each strand acts like a template for making a new strand.
- As each side is complementary, the molecule is successfully reproduced into 2 copies.

http://xupacabras.weblog.com.pt/ arquivo/zipper.jpg

Reproduction

- For dividing cells, a copy goes to each daughter cell.
- Really, the process includes many special enzymes, so sometimes errors can occur.
- Still, very efficient
- DNA is the stuff from which all life is made.
- Probably not the method of the first life– too complicated.

http://xupacabras.weblog.com.pt/ arquivo/zipper.jpg

Molecular Basis of Life

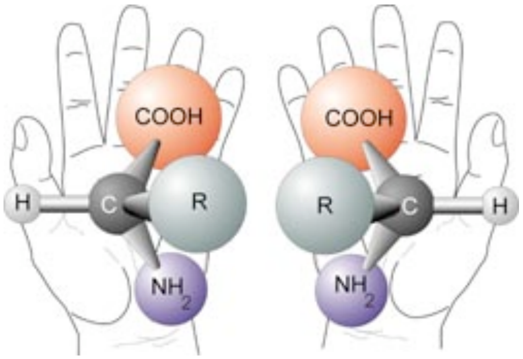
1. Atoms needed are H,O,N, and C with small amounts of P and S.
2. 2 basic molecules are essential for life: proteins and nucleic acids
3. Both are polymers– made of simpler monomers that make up the “alphabet” or code of life. These direct the transcription and translation of the proteins from the code.
4. Proteins and nucleic acids are closely linked at a fundamental level. Communicating through the genetic code that must have originated very early. In most cases, the same code is used by different messages for chicken or shark or human or even Elvis.

Molecular Basis of Life

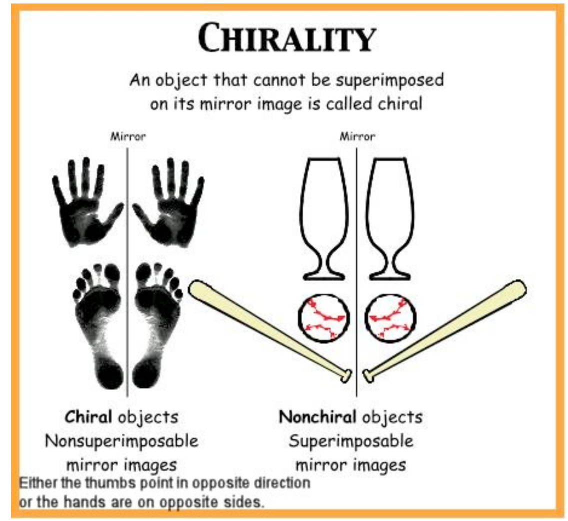
5. #4 rises an important question.
   - Proteins synthesis must be directed by nucleic acids, but nucleic acid transcription requires enzymes (proteins).
   - Chicken or the egg problem?
   - Did proteins arise on Earth first and give rise to nucleic acids, or vice versa?

Chirality

Handedness: Some molecules exist in two versions based on the position of the bonds. One molecule is the mirror image of the other, but they are not similar.



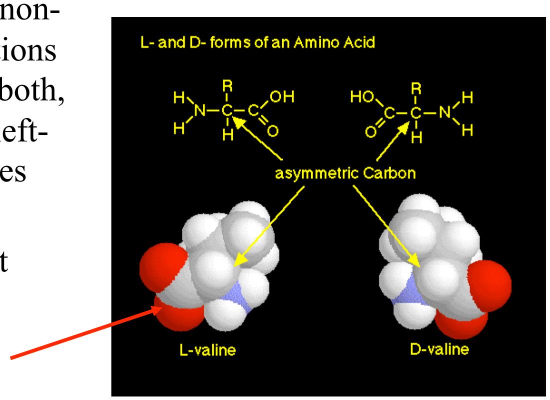
Chirality



http://universe-review.ca/I15-32-chirality.jpg

We are Left-Handed

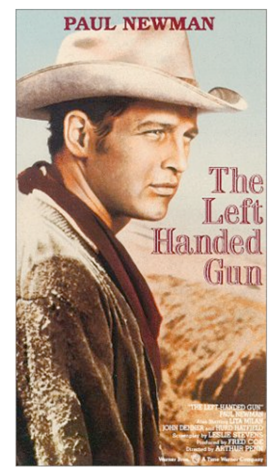
- Amino acids in non-biological situations are mixtures of both, but in life only left-handed molecules are used.
- Why? We don’t know.



http://www.sp.uconn.edu/~bi107vc/fa02/terry/proteins.html

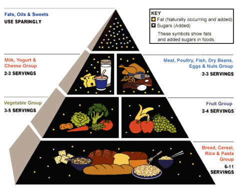
We are Left-Handed

- To match, sugars in life are right-handed
- Suggests a common ancestor for life.
- The opposite should have worked just as well, and this arrangement probably arose out of chance. Once a preponderance of one chirality occurred it was replicated



ET's Food Limitations

An ET organism may be made of the same stuff, but if they are made of right-handed amino acids, they couldn't process (i.e. eat) our food. Bummer.



Question

Imagine that we receive our first ET visitor, but their stomachs do not agree with Earth food. Why might this be true?

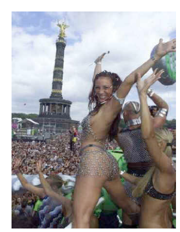
a) They actually eat humans, but are too polite to destroy our race.
b) As we are farther out in the Galaxy, our food has less iron.
c) ETs will probably be allergic to water, and our food is mostly water.
d) Chirality: they are right handed life.
e) None of the above.

From Space?

- The Murchison meteorite (Australia 1969) contained 70 different amino acids!
  - From space!
- Approximately even amount of left and right amino acids were found, but only 6 are used in living organisms.
- Recent results show that 4 of the amino acids had a slight excess of left-handed types.

First Life

- We currently think that life appeared on Earth around 3.8 billion years ago, or only 700 million years after the formation of the Earth. (Based on fossil evidence)
- That is about the same time as the heavy bombardment ended. So, that means life was fast– perhaps only a few 10-100 million years from sterile planet to <u>party town</u>.



http://youconnect.canon-europe.com/swedish/2003-10/images/earth/love_parade.gif

Life

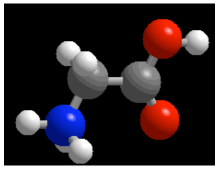
- The most crucial monomers required for life are:
  - Amino acids (20 flavors) for **proteins**
  - The nucleotides: sugar, phosphates, and nitrogenous bases for **DNA/RNA**.
- How did they occur in a useful configuration so **fast** on the early Earth?
  - Life on Earth happened soon after the Bombardment
  - Remember the early Earth was not a fun place.
    - Poisonous gas atmosphere, hot, lots of meteorites, and cable TV is still 3.8 billion years away.

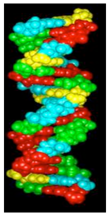
Molecular Basis of Life

i. Two basic molecules are essential for life: proteins and nucleic acids
ii. Both are polymers– made of simpler monomers
iii. Proteins and nucleic acids are closely linked at a fundamental level.
iv. Did proteins arise on Earth first and give rise to nucleic acids, or vice versa? Or from space?
v. This leads us to the chemical evolution of life.

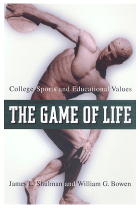
Chemical Evolution

- Chemical basis of life obviously crucial.
- Apparently evolution of life is a continuation of tendencies toward greater complexity
- Chemical evolution has 3 steps:
  - Synthesis of monomers
  - Synthesis of polymers from the monomers
  - Transition to life.





Synthesis of Monomers

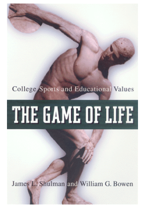


Life arose under the following conditions

- Liquid water
- Some dry land
- Energy sources, including UV light, lightning, geothermal.
- A neutral or slightly reducing atmosphere (This is somewhat new). Remember no OXYGEN, mostly methane (CH_4) and CO_2.

http://origins.jpl.nasa.gov/habitable-planets/images/ra6-early-earth-th.jpg
http://www.pupress.princeton.edu/titles/6903.html

Reducing/Oxidizing?

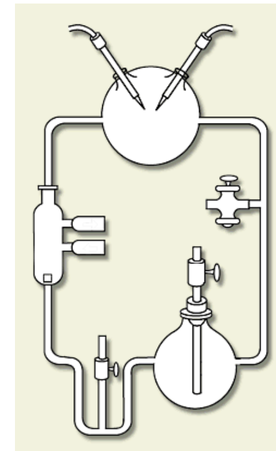


- Reducing atmosphere has elements that *give up* electrons, e.g. hydrogen. A good example is the atmosphere of Jupiter: CH_4, NH_3.
- Oxidizing atmosphere has elements that *take* electrons, e.g. oxygen. A good example is the atmosphere of Mars or modern Earth.
- Neutral is neither.

http://origins.jpl.nasa.gov/habitable-planets/images/ra6-early-earth-th.jpg
http://www.pupress.princeton.edu/titles/6903.html

Miller and Urey Experiment

- In 1953, Miller and Urey (UC) tried to duplicate conditions that they believed existed on the Early Earth– a heavily reducing atmosphere.
- They Mixed CH_4, H_2, and NH_3 gases in a flask for the atmosphere, and connected that to a flask with water for the oceans.   A spark was used in the atmosphere flask to simulate lightning.
- They found interesting organic molecules in the "ocean".



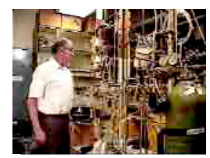
http://www.vobs.at/bio/evol/e05-millerurey.htm

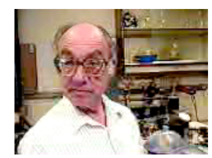
Miller and Urey Experiment

- 4 amino acids were made: glycine, alanine, aspartic acid, and glutamic acid. Also some nucleotide bases and acetic acid.
- It has been shown that **ALL** 20 amino acids needed for life can form in this way.
- Does not produce directly all monomers of nucleic acids, but intermediates were produced.

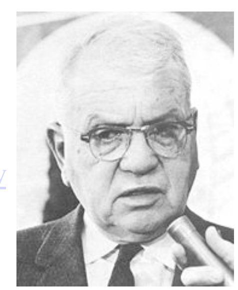
http://physicalsciences.ucsd.edu/news_articles/miller-urey-resurrected051903.htm

Miller and Urey Experiment





http://www.ucsd.tv/miller-urey



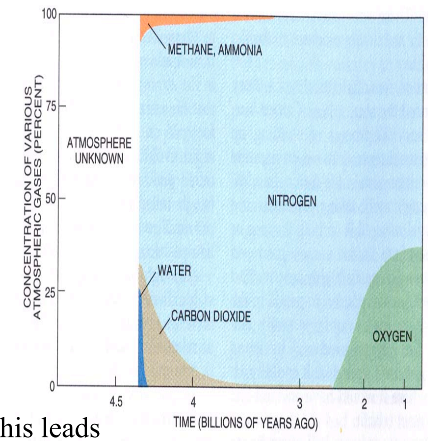
Early Monomers

The Miller-Urey experiment legitimized the scientific study of life. The production of amino acids under the presumed conditions of the early Earth was exciting.

Early Monomers

But the assumptions of the experiment have been questioned.

- Early notions of methane-rich reducing atmosphere are wrong; Earth's early atmosphere was more likely CO_2, N_2, and H_2O vapor.
- We still don't know early atmospheric composition well enough to make stronger case
- We still don't know how this leads to DNA, the basis of all terrestrial life.

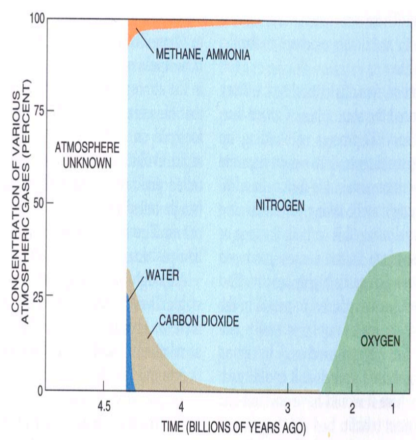


http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/earth.htm

Early Monomers

Recently, a group in Japan has showed that with enough energy, one can still get significant yields of amino acids in a mildly reducing environment.

So maybe Miller-Urey still important.



http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/earth.htm

Early Monomers

- We do not have a detailed theory of how all the monomers arose on the early Earth.
- General conclusion is that many of the monomers needed for life can be produced in a strongly reducing atmosphere, but that different environments are needed to get specific monomers.
- Don't forget that after the monomers are formed they MUST come together to form the polymers of life.

Question

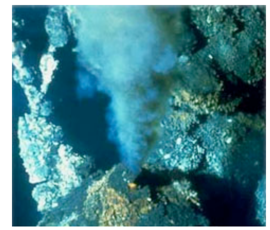
Arguably, the most important legacy of the Miller-Urey experiment is that

a) we now know how some amino acids were formed on the early Earth.
b) it legitimized the scientific study of the origin of life.
c) it proved the early atmosphere was mostly methane.
d) somehow a glass flask was necessary.
e) None of the above.

Other places

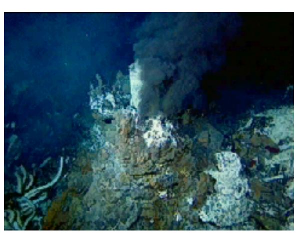
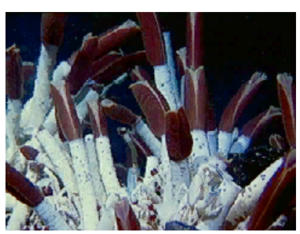
- Maybe if we require (still not sure) a strongly reducing environment, we have to look elsewhere.
  - Area around undersea hot vents, some of which have CH_4, NH_3, and other energy-rich molecules like hydrogen sulfide.
  - Interstellar space.

http://www.noaanews.noaa.gov/magazine/stories/mag114.htm
http://www.chl.chalmers.se/~numa/photo/keyhole-small.jpg

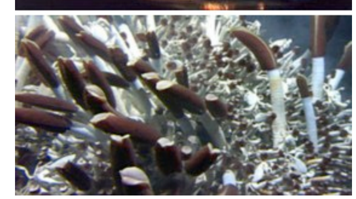



The Underwater Vents


- Miles below the ocean surface, life lives on the edge! Places were sunlight never reaches.
- From regions of volcanic spreading of the floor, hydrothermal vents or black smokers, underwater geysers, spew mineral-rich superheated water.
- No plant life, but life thrives. So what does life live on?

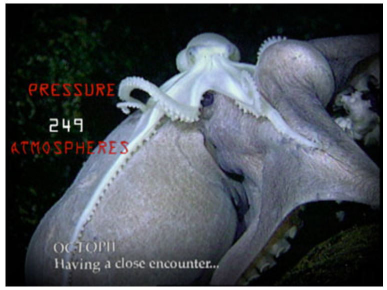
The Underwater Vents

- Chemical reactions or chemosynthesis to produce food instead of the Sun.
- Some life is bacteria, some eat the bacteria, some eat those that eat the bacteria, and some have bacteria inside them in a symbiotic relationship.
- http://www.xenon.com/

The Hot Origins Theory

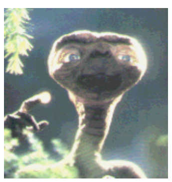
- Vents are examples of a food chain that does not rely ultimately on photosynthesis.
- Demonstrates that pre-biotic synthesis can occur, but did life begin there?
- And current vents are short-lived– a few decades.
- And hot– if synthesis first occurred there, it might have been quickly destroyed.



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^{0}C to -1^{0}C (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.