# Astronomy 230

This class (Lecture 11):

Origins of Life
**Margaret Gelman**
**David Esquivel**

Next Class:

Life Alternatives
**Greg Frazier**
**Alex Waite**

**HW 4 is due**

Music: *Bring me to Life* – Evanescence



# Paper Rough Draft

- Worth 5% of your grade, but really worth more.
- Due before Thanksgiving break!
- Should include most of the details of the final paper.
- Will be looking for scope, ease-of-read, scientific reasoning, **proper citation**, and general style.
- 8 to 10 pages double-spaced 12-point font, not including references.
- ***Mars is a planet without an overzealous monkey population (Holt et al. 2000; James & Mann 2006; Walker 20007).***



# HW #3

- **Ross & Darcy & Greg**
  http://www.ufoevidence.org
- **Christine**
  http://www.crypticthinking.com



# Presentations

- **Margaret Gelman**: Psychological Astrobiology
- **David Esquivel** : Public Perception of ETs

# Outline

- Which came first? Protein or nucleic acid?
- You are all left-handed (amino acids)
- The beginning of life.
- The Miller-Urey experiment

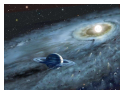


# Drake Equation

Frank Drake

**That's 3 Life-liking systems/year**







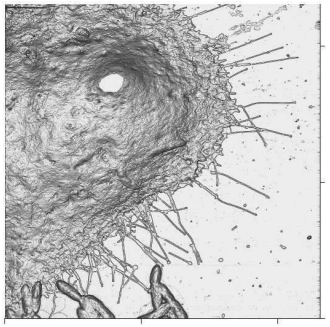

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

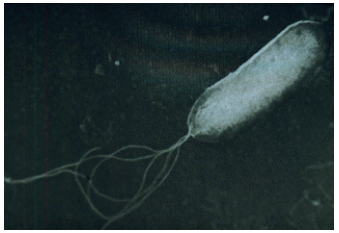
| $N$ | $R_*$ | $f_p$ | $n_e$ | $f_l$ | $f_i$ | $f_c$ | $L$ |
|---|---|---|---|---|---|---|---|
| # of advanced civilizations we can contact in our Galaxy today | Star formation rate | Fraction of stars with planets | # of Earthlike planets per system | Fraction on which life arises | Fraction that evolve intelligence | Fraction that commun-icate | Lifetime of advanced civilizations |
| | 15 stars/ yr | 0.5 systems/ star | 0.5 x 0.8 = 0.4 planets/ system | life/ planet | intel./ life | comm./ intel. | yrs/ comm. |



# All Made from the Same Stuff



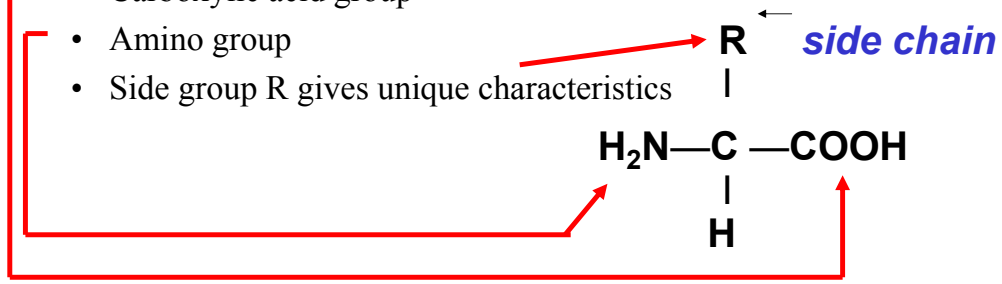




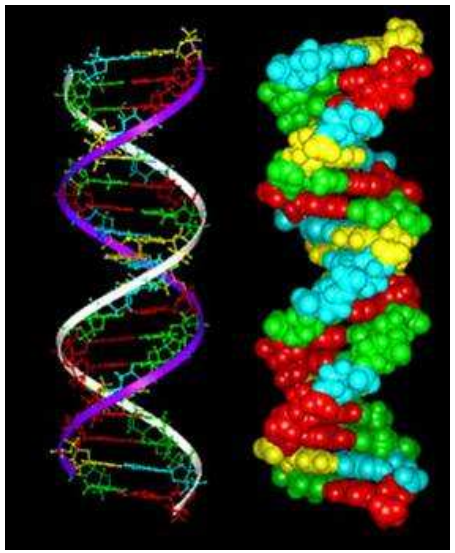
# Amino Acids

- Are the monomers from which proteins (polymers) are made– building blocks.
- Combinations of the amino acids make the proteins needed– only 20 amino acids used by life.
- Carboxylic acid group
- Amino group
- Side group R gives unique characteristics



# DNA / RNA

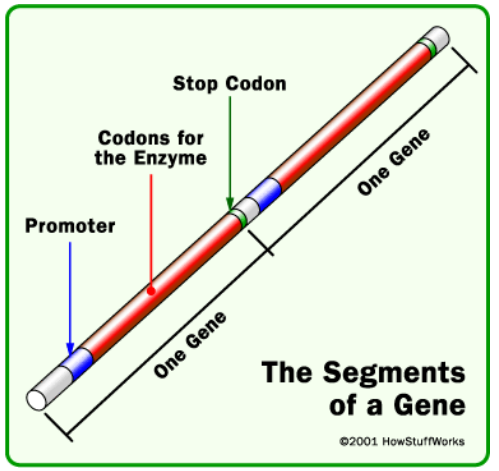
- The origins of DNA and RNA are mysterious and amazing
- DNA/RNA are complex: Built from three basic types of monomers
  1. Sugar (deoxyribose or ribose)
  2. A phosphate $PO_4$
  3. One of four "nitrogenous bases"
     - Adenine (A)
     - Guanine (G)
     - Cytosine (C)
     - Thymine (T) in DNA / Uracil (U) in RNA





# Genes

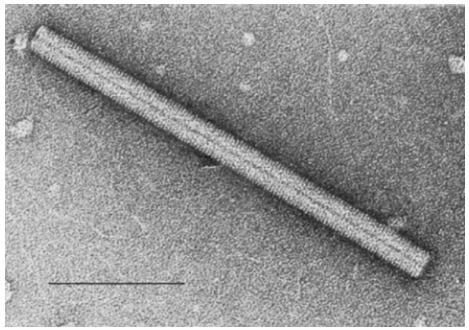
- Each codon specifies an amino acid, and a sequence of condons specifies a protein or enzyme.
- E. coli bacterium has about 4,000 genes, and at any time those genes specify about 1,000 enzymes. Many genes are duplicates.



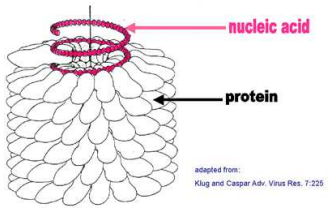



# Ta-Backy

- 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



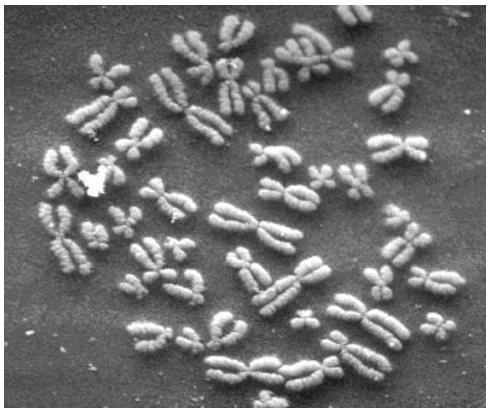
# My Old Blue Genes

- 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 $3 \times 10^9$ 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

# 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.

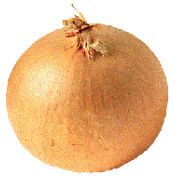


http://folding.stanford.edu/education/GAH/gene.html



# Which requires the most genes?

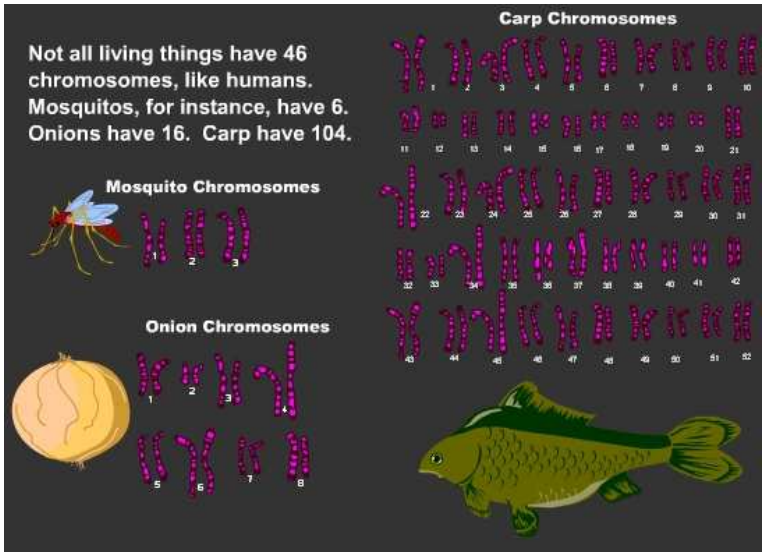
1. Onion
2. Mosquito
3. Carp
4. Human



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



# Chromosomes

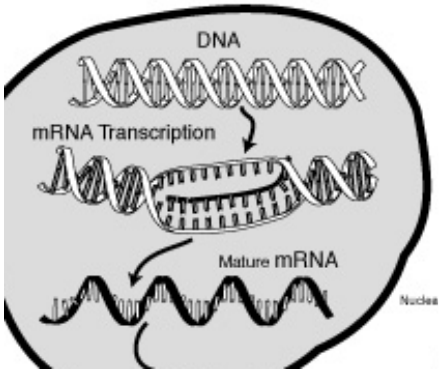



http://gslc.genetics.utah.edu/units/basics/tour/chromosome.swf



# DNA: Message in a Cell

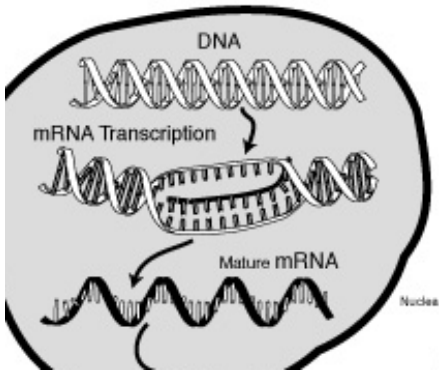
- A cell is informed it needs a enzyme– call it Z.
- Other enzymes in nucleus unravel and separate the easily broken DNA at the site where the gene for making that enzyme in encoded.




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.

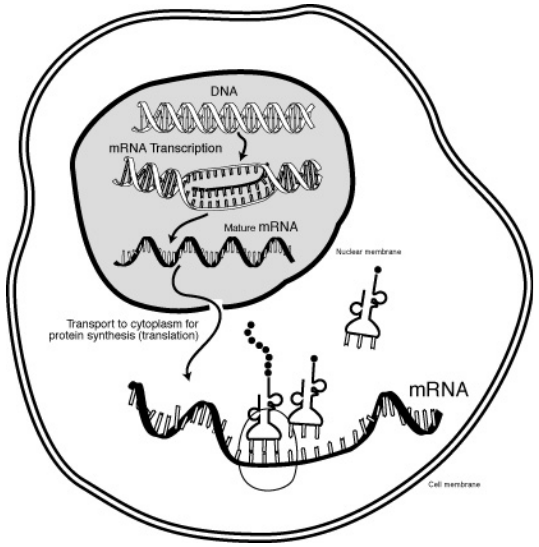



http://www.accessexcellence.org/AB/GG/mRNA.html



# 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.



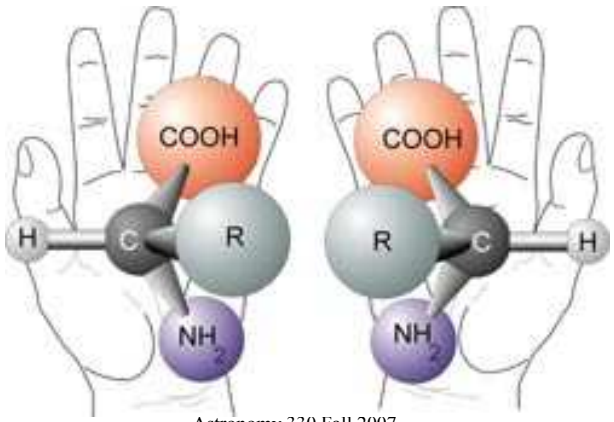
# Molecular Basis of Life

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?



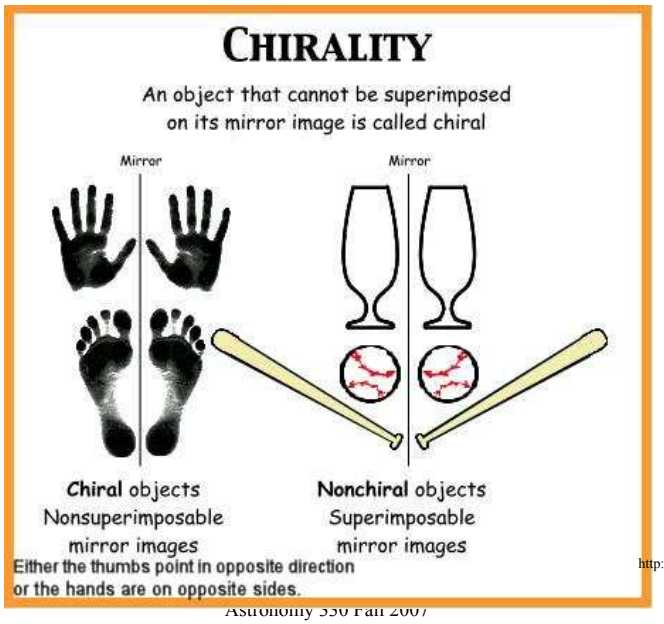

# Chirality

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.





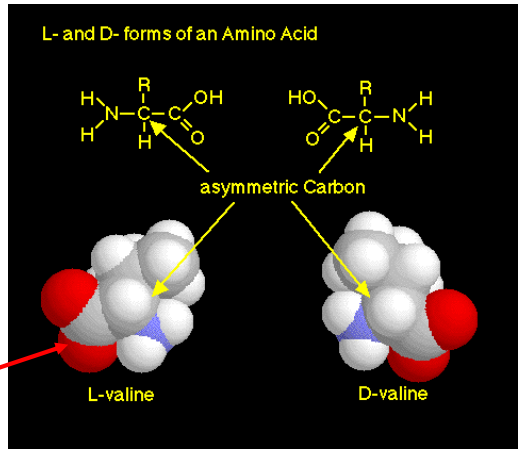

# Chirality




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.

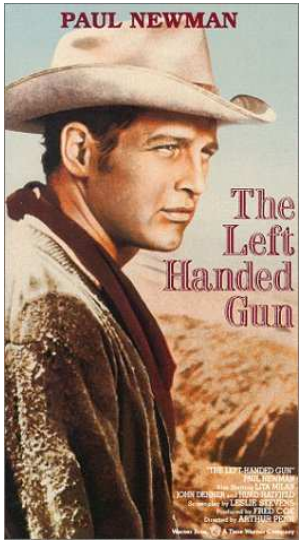



http://www.sp.uconn.edu/~bi107vc/fa02/terry/proteins.html



# We are Left-Handed

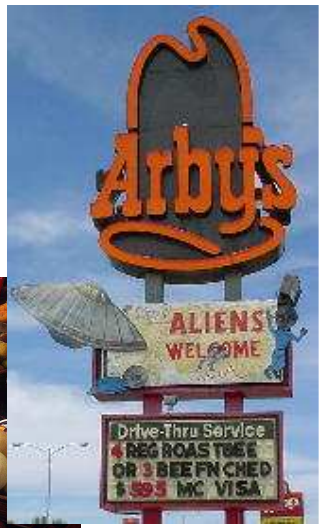
- To match, sugars in life are right-handed
- Suggests a common ancestor for life.
- The opposite should have worked just as well, and this arrangement probably arose out of chance. Once a preponderance of one chirality occurred it was replicated

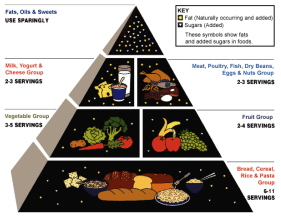





# ET's Food Limitations

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



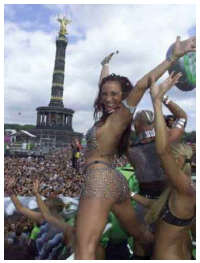


# From Space?

- The Murchison meteorite (Australia 1969) contained approximately even amount of left and right amino acids
- 70 different amino acids were found in it, but only 6 are used in living organisms.
- New 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 party town.



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?
  - Remember the early Earth is not a fun place.
    - Poisonous gas atmosphere, hot, lots of meteorites, and cable TV is still 3.8 billion years away.



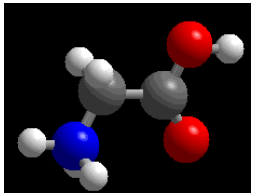
# Molecular Basis of Life

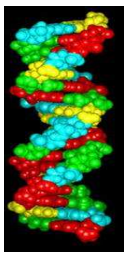
i. Two basic molecules are essential for life: proteins and nucleic acids
ii. Both are polymers– made of simpler monomers
iii. Proteins and nucleic acids are closely linked at a fundamental level.
iv. Did proteins arise on Earth first and give rise to nucleic acids, or vice versa? Or from space?
v. This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



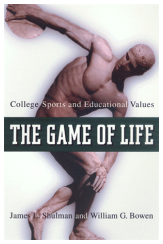
# Chemical Evolution

- 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

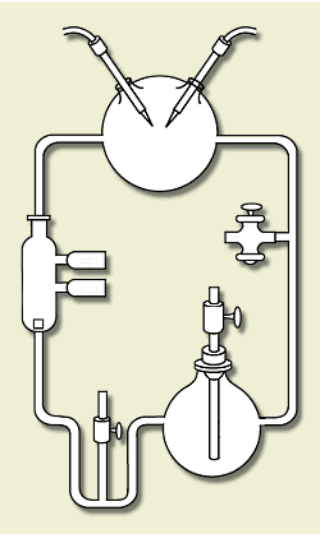
- Liquid water
- Some dry land
- Energy sources, including UV light, lightning, geothermal.
- A neutral or slightly reducing atmosphere (This is somewhat new). Remember no OXYGEN, mostly methane ($CH_4$) and $CO_2$.
  - Reducing has elements that *give up* electrons, e.g. hydrogen. A good example is the atmosphere of Jupiter: $CH_4$, $NH_3$.
  - Oxidizing 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.
- http://www.ucsd.tv/miller-urey/
- 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.
- 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
- 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.



# Early Monomers

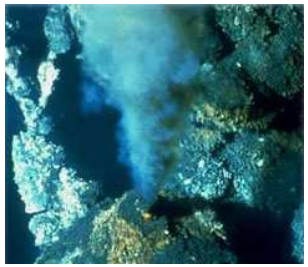
- We do not have a detailed theory of how all the monomers arose on the early Earth.
- General conclusion is that many of the monomers needed for life can be produced in a strongly reducing atmosphere, but that different environments are needed to get specific monomers.
- Don't forget that after the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



# 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