Astronomy 230

Section 1– MWF 1400-1450

106 B6 Eng Hall

This Class (Lecture 13):

Origin of Life

Midterm is March 12!

Next Class:

Origin of Life– Part II

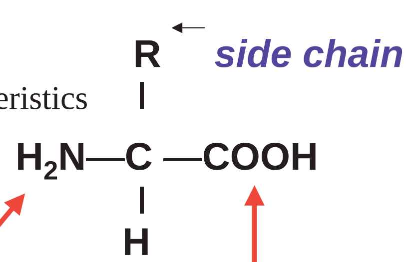
The Exam will be in the Astronomy Building Classroom, room number 134.

Outline

- Hooking up amino acids into longer chains.
- DNA/RNA. What are they?
- How do they transfer information?
- What is a gene?
- Chirality of life.
- Origin of life?
- The Miller-Urey Experiment.
- Early monomers
  - Formed in the atmosphere?
  - Around hydrothermal vents?
  - In space?

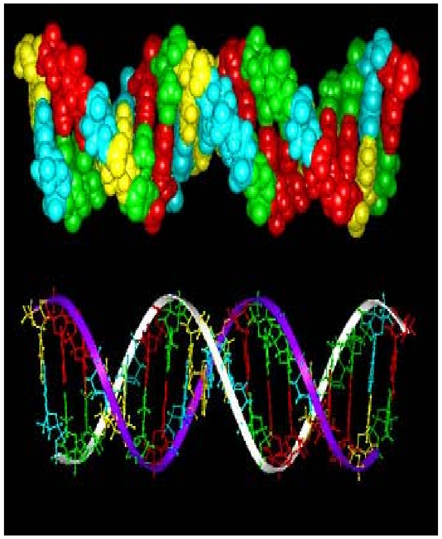
Amino Acids

- 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



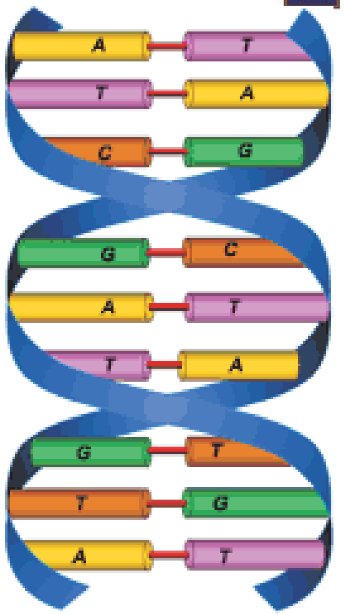
DNA / RNA

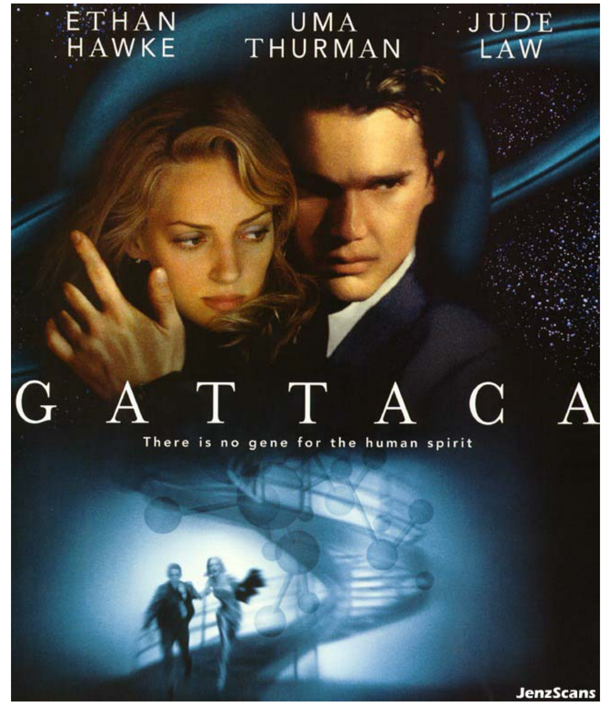
- The origins of DNA and RNA are mysterious and amazing
- DNA/RNA is complex: Built from three basic types of monomers
  1. Sugar (deoxyribose or ribose)
  2. A phosphate PO_4
  3. One of four "nitrogenous bases"
     - Adenine (A)
     - Guanine (G)
     - Cytosine (C)
     - Thymine (T) in DNA / Uracil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



The Double Helix

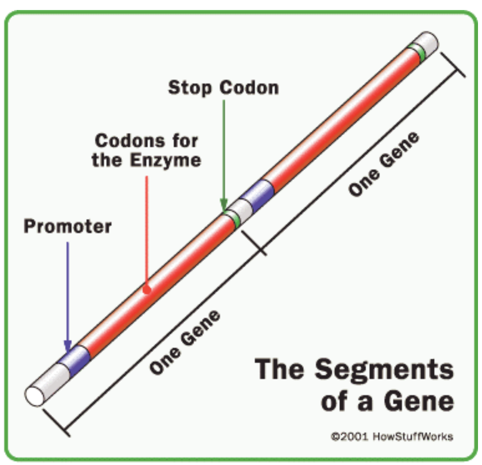
- Resembles a twisted ladder
- The sides of the DNA ladder are made of the sugar and phosphate.
- The steps or rungs of the ladder are composed of one of the 4 nitrogenous base pairs.
  - AT, TA, GC, CG
- The ladder is twisted into the helix shape since the hydrogen bonds are at an angle.
- 3 pairs make up a codon (4x4x4 = 64)
- Each codon is info on the amino acid, but only 20 of those– over constrained.





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.

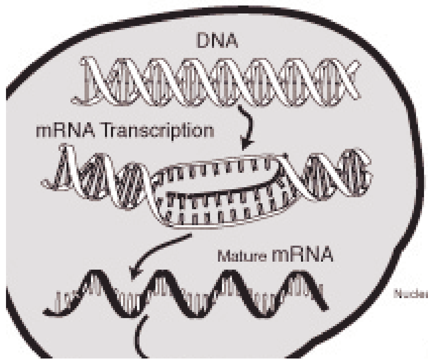


My Old Blue Genes

- 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.
- The Human Genome Project found 30,000 to 40,000 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 x 10^9 base pairs, but 98% of it has no obvious function, and 99.9% is the same for all humans.

DNA: Message in a Cell

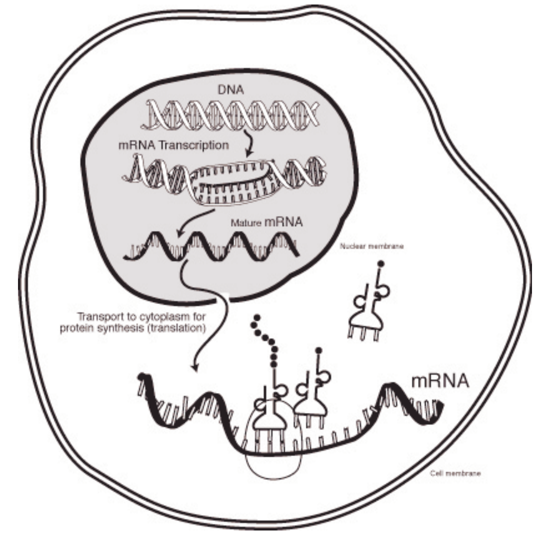
- A cell is informed it needs a protein– call it Z.
- Enzymes in nucleus unravel and separate the easily broken DNA at the site where the gene for making that enzyme in encoded.
- Transcription of the gene is made via complementary bases and are assembled in a messenger RNA or mRNA.
- DNA zips itself 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 protein Z.



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

Reproduction

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

Molecular Basis of Life

1. Atoms needed are H,C,O, and N 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.

Molecular Basis of Life

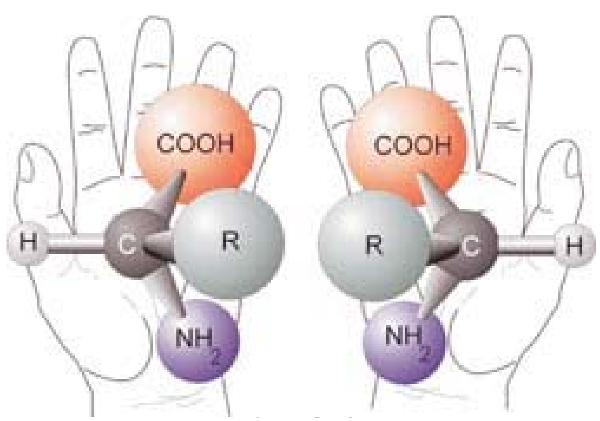
5. #4 rises an important question.
   - Proteins synthesis must be directed by nucleic acids, but nucleic acids transcription requires enzymes (proteins).
   - Chicken or the egg problem?
   - Did proteins arise on Earth first and give rise to nucleic acids, or vice versa?

Molecular Basis of Life

6. Careful to distinguish DNA from RNA. RNA probably developed first. Still, a related question is how did the connection between RNA/DNA and the connection with Life's genetic code originate?
7. Also, there are some instances of a few organism where there are small differences in the code of life. The code has evolved, albeit very slightly, since the last common ancestor of all life.
8. This leads us to consider the chemical basis of life, implying a tendency toward greater complexity.

Chirality

Handedness': Some molecules exist in two versions based on the position of the bonds. One molecule is the mirror image of the other



We are Left-Handed Based

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

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.

First Life

- We current think that life appeared on Earth around 3.8 x 10^9 years ago, or only 0.7 x 10^9 years after the formation of the Earth.
- That is about the same time as the heavy bombardment ended. So, that means life was fast– perhaps only a few 100 million years.

Synthesis of Monomers

- Life arose under the following conditions
  - Liquid water
  - Some dry land
  - A neutral or slightly reducing atmosphere (This is somewhat new).
    - Reducing has elements that *give up* electrons, e.g. hydrogen. A good example is the atmosphere of Jupiter.
    - Oxidizing has elements that *take* electrons, e.g. oxygen. A good example is the atmosphere of Mars.
    - Neutral is neither.
  - Energy sources, including UV light.

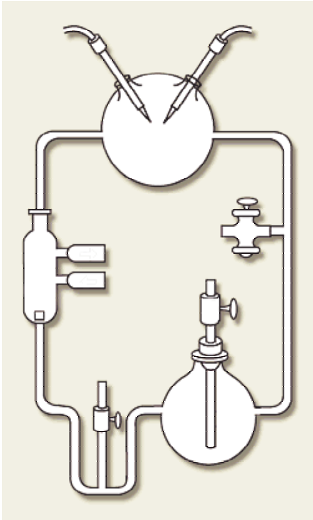
Miller and Urey Experiment

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

Miller and Urey Experiment

- In particular 4 amino acids were made: glycine, alanine, aspartic acid, and glutamic acid. Also 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://www.vobs.at/bio/evol/e05-millerurey.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.

Early Monomers

- Still, 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
  - 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, you can still get significant yields of amino acids in a mildly reducing environment.

Other places

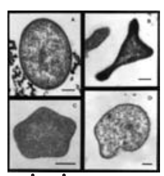
- Maybe if we require (still not sure) a strongly reducing environment, we have to look elsewhere.
  - Area around undersea hot vents, some of which have CH_4, NH_3, and other energy-rich molecules like hydrogen sulfide.
  - Interstellar space.

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?
- 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.

The Hot Origins Theory

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

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 to the Earth.

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 (remember the Murchison meteorite).
- Can life get transported?
- Panspermia again.

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.
- Does life begin easily?