Astronomy 330

<u>This class (Lecture 9):</u>

Habitable Planets

<u>Next Class:</u>

Planets of Life

Allison Hanna

Nick Mucia

HW 3 is due Thursday

Music: *Baby, I'm a Star* – Prince

Presentations

- The presentation schedule has been decided by random selection.
- It is posted in the schedule section of the webpage.
- Make sure to check those dates ASAP.

Presentations

- Will be treated like a real talk.
- I will keep you to 10 minutes with 5 minutes of questions.
- Any speculative claims *MUST* have a scientific reference source.
  - Can't just claim that monkeys live on the Moon.

Presentations

- Can give presentation in any format you want.
- Over last few semesters:
  - 97.9% powerpoint (**CAREFUL** if it is Apple or Office 2007)
  - 1% talking with pics from webpages
  - 1% dedicated webpage
  - 0.1% overhead slides
- If presentation is electronic, I want to see it 1-2 days in advance
  - Email me
  - Or, on netfiles, email me URL location
  - Or, bring in burned CD (present to me class BEFORE)

Oral Presentation

1. How relevant is the general topic to this class
   (e.g. search for extraterrestrial life)?
2. How interesting is the topic for the general class audience?
3. Rate the extent of the speakers knowledge on the topic?
4. Rate the quality of the overall presentation?
5. Does the research have a solid scientific basis?

These questions are rated 1-10 out of 10 scale by your peers!

Common Mistakes

- Too much text on a slide.
- Too long.
- Background graphics or color makes text hard to read.
- Reading the slides is boring, use as points but not the whole message.
- 10 minutes is not as long as it sounds.

Last Semester Example

Light the Universe and forty-two or how I learned to stop worrying and love the time-space continuum

Highest grade: 99.86%

Lowest grade: 81%

Outline

- The effects of the star on life.
- What is Life today?
- What is a protein?
- What is an amino acid?

Drake Equation

That's 7.6 planetary 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
	19 stars/yr	0.4 systems/star	planets/system	life/planet	intel./life	comm./intel.	yrs/comm.

$$n_e = n_p \times f_s$$

n_p: number of planets suitable for life per planetary system

Class number is 1.25

http://nike.cecs.csulb.edu/~kjlivio/Wallpapers/Planets%2001.jpg

$$n_e = n_p \times f_s$$

n_p: number of planets suitable for life per planetary system

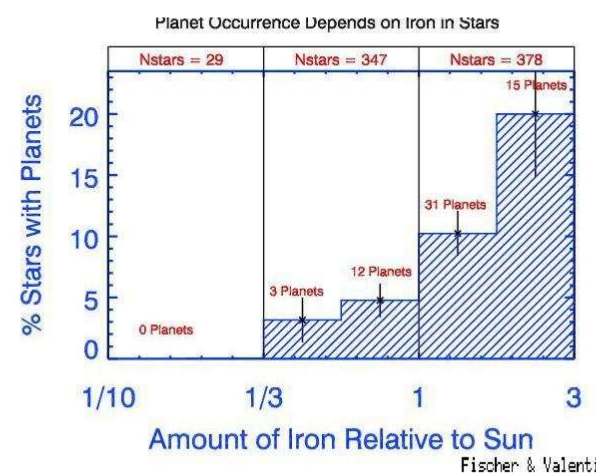
f_s: fraction of stars whose properties are suitable for life to develop on one of its planets

We can list 5 situations that will have an effect on f_s.

http://nike.cecs.csulb.edu/~kjlivio/Wallpapers/Planets%2001.jpg

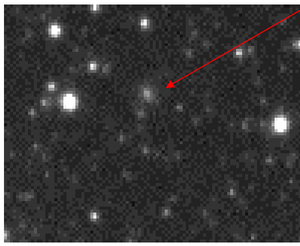
Differences of Stars to Life

1. **Metal rich stars**. Stars with heavy elements, probably more likely to have planets. Suggested in the current planet searches. About 90% of all stars have metals.



Differences of Stars to Life

2. **Main sequence stars**. Need the brightness to stay as constant as possible. Otherwise the temperature changes dramatically on the planets. This is 99% of all stars.

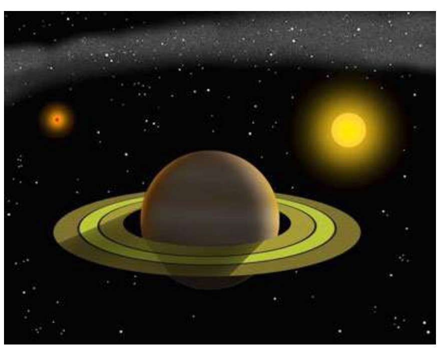


Differences of Stars to Life

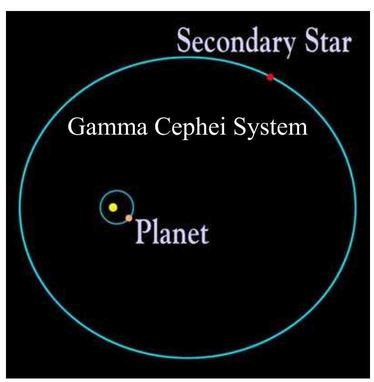
3. **Length of time on the main sequence**. We need temperature stability for 5 billion years to get intelligence on Earth. This rules out stars more massive than 1.25 solar masses! 90% of all stars are less massive than that.
4. **Minimum mass of star**. If ice exists close to the star, that would imply the formation of Jupiter-like planets not Earth-like planets. And, any life bearing planet would have to be closer to the star– and closer to stellar effects (e.g. tidal locking and more flares from low mass stars). That limits us to a minimum of 0.5 solar masses. 25% of all stars are more massive than that.

Differences of Stars to Life

5. **Binarity**. Planets may form. But they may have odd orbits unless the 2 stars are far enough apart or the planet orbits the pair. Only 30% of all stars are single stars. 50% of all stars are single stars or wide binary stars.



http://spaceflightnow.com/news/n0210/11planet/



Adding it all up

Stellar Requirement	***Mass Limit***	***Fraction OK***	***Cumulative Fraction***
Heavy Elements	…	0.9	0.9
Main Sequence	…	0.99	0.891
Main Sequence Lifetime	$M < 1.25\ M_{sun}$	0.90	
Synchronous Rotation/ Flares	$M > 0.5\ M_{Sun}$	0.25	
Not a Binary	…	0.30	0.267
Wide Binary Separation	…	0.50	

Adding it all up

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Not a Binary	…	0.30	
✓ Wide Binary Separation	…	0.50	

f_s: fraction of stars that life can exist around

Stellar Requirement	*Mass Limit*	*Fraction OK*	*Cumulative Fraction*
Heavy Elements	…	0.9	
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Wide Binary Separation	…	0.50	

Value can range from ~ 0.06 to ?

Drake Equation

That's ? 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
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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

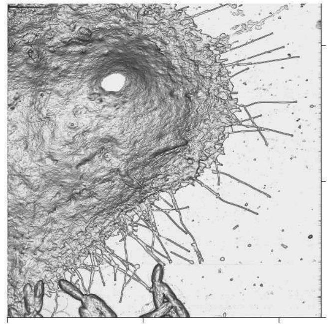
- In our scientific approach, we look at life as a result of chemical evolution of complexity.
- We will view the formation of "life" on planets as we did star formation
  - A natural consequence of natural laws
  - More specifically, as a consequence of the complex chemistry that is sometimes achieved.

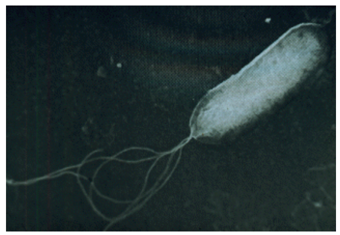
http://www.toothpastefordinner.com/052802/science-only-happens.gif

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?

All Made from the Same Stuff





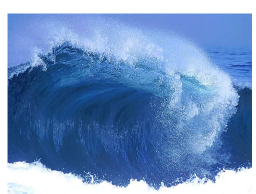
Element Basis of Life

- 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.

Trace Elements

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

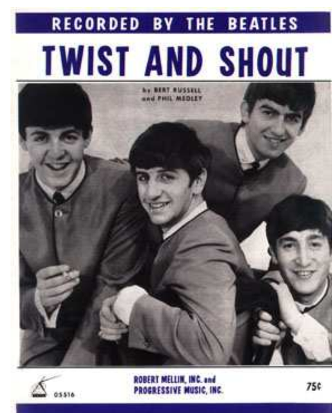
- Sulfur, magnesium, chlorine, potassium, sodium
  - These other elements make up about 1% of mass of living organisms
  - Exist in roughly the same concentration in organisms as in ocean water
  - Highly suggestive that life began in oceans
  - Furthermore suggests that the evolutionary processes occurred 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 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?

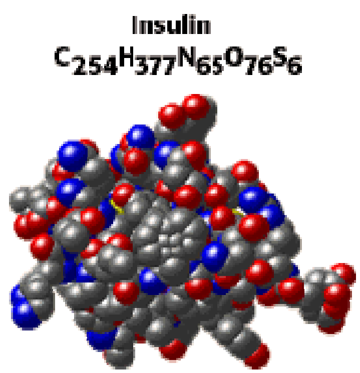
http://europa.eu.int/comm/environment/life/toolbox/logo_life_high_resolution_2.jpg

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?

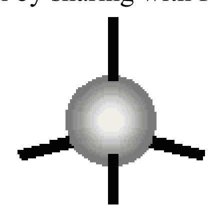
- Carbon's electronic structure allows it to form long chains
  - Chains of atoms and chains of molecules– complexity
  - Life needs bonds to be stable but breakable
- Good for us, at temperatures at which water is liquid, carbon bonds are stable but breakable
- Organic chemistry is the special branch devoted to carbon chemistry.



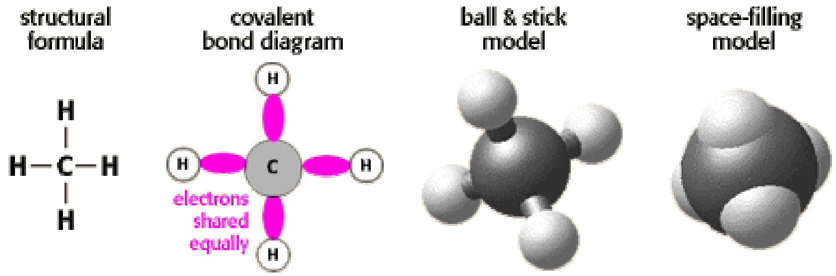
http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page2.html

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



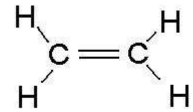
The Simplest C Bond–Methane

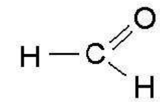


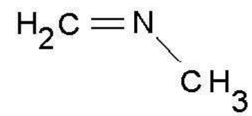
Not many other elements can share 4 bonds.
Silicon, which is much more abundant, can.
Silicon based life?

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

More Bonds

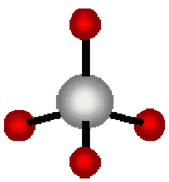






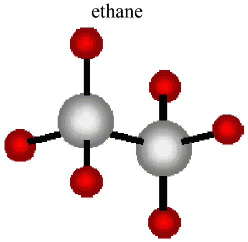
http://www.colossusblog.com/mt/archives/images/drno5.jpg

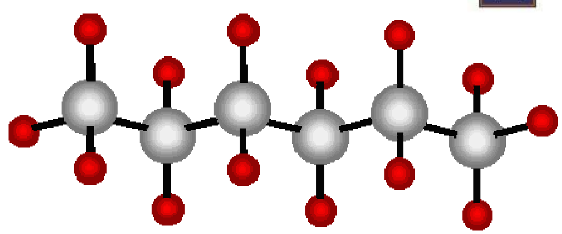
Bonding Variation



methane

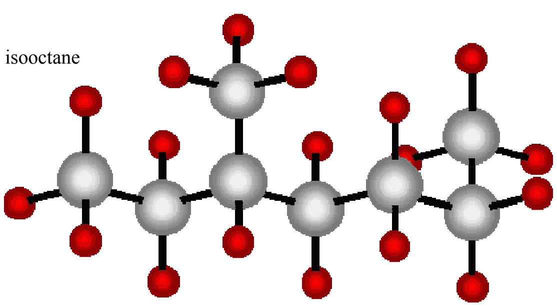
ethane



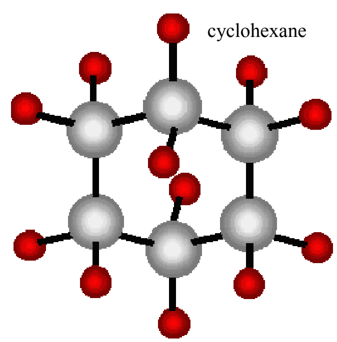


hexane

isooctane



cyclohexane



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

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

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!**

Proteins & Nucleic Acids

- 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.

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 DNA (deoxyribonucleic acid)?

DNA Based Life

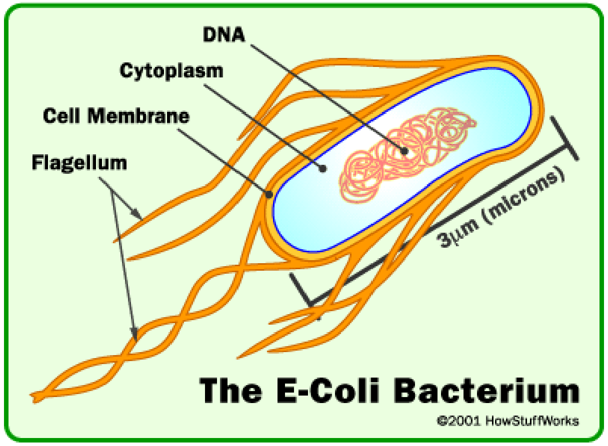
- All life is based on DNA. What does this mean?
  - The basic reproducible unit of all living organisms is centered around the complex DNA molecule.
  - DNA lives in cells
    - Except in viruses, which are basically pure DNA
  - Cells of different types form different parts of each organism
    - Heart cells different from blood cells.
    - Leaf cells different from root cells.

Cell Bits

- The cell function directly relates to a different organic polymer:
  - <u>Proteins</u>: Polymers of amino acid monomers that form the structural components of the cell or form enzymes that do all the real chemical work inside the cell.
  - <u>DNA</u>: The genetic coding molecules that controls enzyme and cell reproduction. Polymers of a sugar, phosphate, and nucleotides monomers.

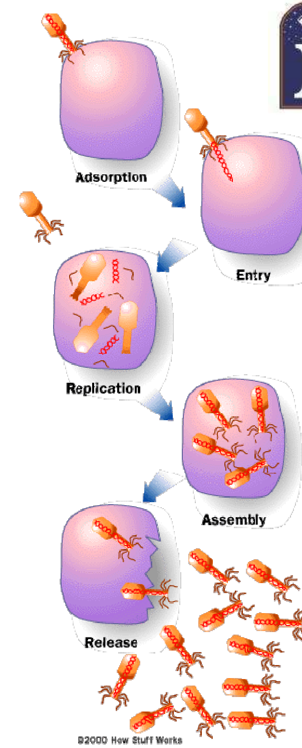
Bacteria Cells

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



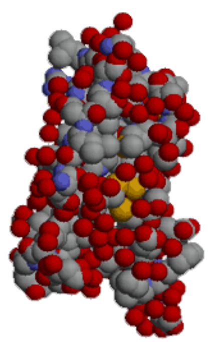
Viruses

- 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.



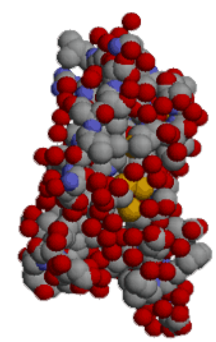
Focus on Proteins

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



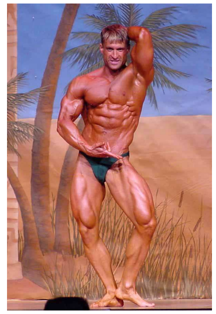
Focus on Proteins

- Example: Proteins are made up of 100s to 1000s of 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.



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



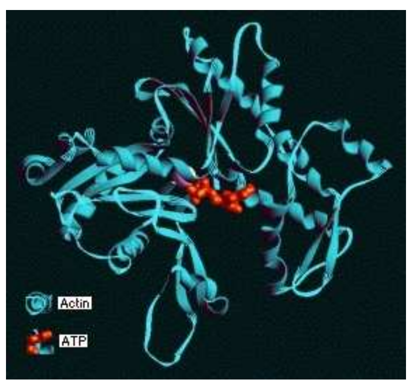
http://66.41.139.241:8000/fitam/muscle.JPG

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?

A Type of Protein: Enzymes

- All of the day-to-day work of life is being done by enzymes. Enzymes are little chemical-reaction machines.
- The purpose of an enzyme is to allow the cell to carry out chemical reactions very quickly.
- These reactions allow the cell to build things or take things apart as needed– grow and reproduce.



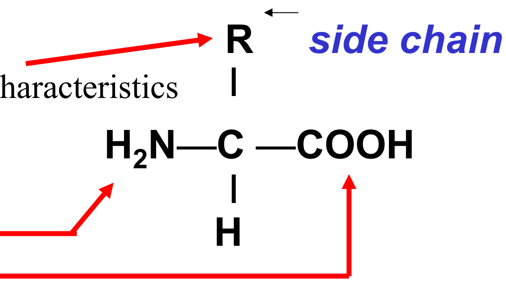
A Type of Protein: Enzymes

- E. coli has about 1,000 different types of enzymes floating around in it at any given time.
- To understand enzymes is to understand cells. To understand cells is to understand life on Earth.
- Maybe similar to life in space?
- Enzymes are made from 3-D structures of amino acids orchestrated by the DNA.

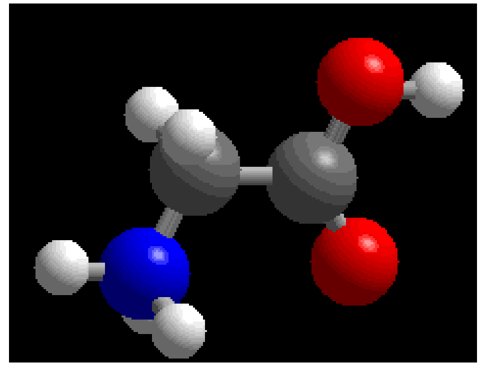
http://res2.agr.ca/lethbridge/emia/images/SEMproj/Ecoli.jpg

Amino Acids

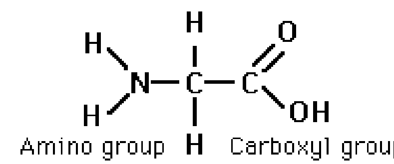
- Are the monomers from which proteins (polymers) are made– building blocks.
- Combinations of the amino acids make the proteins needed– only 20 amino acids used by life.
- Carboxylic acid group
- Amino group
- Side group R gives unique characteristics



Glycine

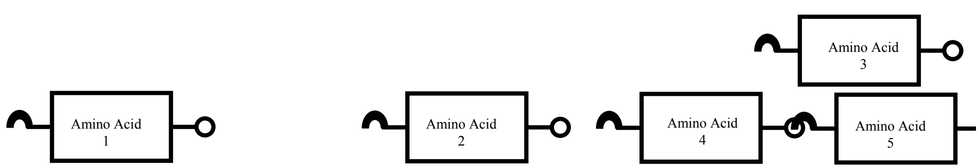


- Simplest amino acid. Just an H in the R position.
- Main ingredients are HONC– other amino acids contain Sulfur (S) as well.



Getting Hooked Up

- Proteins are polymers, made of the monomer, amino acids.
- A number of specific amino acids "hook up" to form a specific protein.
- As a chain grows, there is always a hook (the amino group) on one end and an eye (the carboxyl group) on the other.



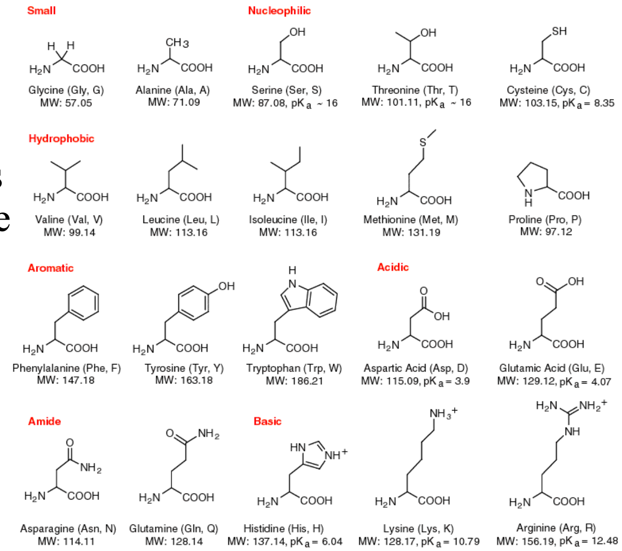
Amino Acids

- Can think of the 20 amino acids as different color Legos.
- Each color is a different piece, but they can all be put together into a tower.
- This tower is a specific protein.
- The function depends on the colors used.

http://www.frepa.org/wp/wp-images/lego-torn.jpg

Build Me Up

- Amino acids are essential for life– building blocks.
- But who orchestrates or writes the message (the special proteins) that the amino acids make up?
- Need something to teach them how to spell.



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