# Astronomy 230

*Section 1– MWF 1400-1450*

*106 B6 Eng Hall*

This Class (Lecture 12):

Nucleic Acids

Next Class:

Killer Supernovae!

*Some Oral Presentation on Feb 25th and 27th!*

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*Jon Huff*
*Rachel Pidu*



# Outline

- Amino Acids
- Build up proteins (structural and enzymes) with amino acids from the commands of the amino acids. These are the essentials for life.
- Hooking up amino acids into longer chains.
- DNA/RNA. What are they?
- How do they transfer information?



# Molecular Basis of Life

- Great diversity of Life on Earth, but still it is 70% water and 24% four large molecules:
  - Proteins
  - Nucleic Acids
  - Lipids
  - Carbohydrates
- Not completely true. The simplest life, viruses, can have a single molecule of nucleic acid surrounded by a protein coating.



# Lipids and Carbohydrates

- Lipids are almost entirely composed of carbon and hydrogen with some oxygen.
- Lipids are essential for cell membranes.
- Carbohydrates are comprised of sugar molecules.
- Carbohydrates are used for energy storage of cells.
- But we will concentrate on proteins and nucleic acids as crucial for life.
- They are enough for viruses, and there may have been protolife that was similar?

# 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 and Nucleic Acids

- Proteins are either structural elements or catalyze reactions (enzymes).
- Nucleic acids carry the genetic information– Replication of nucleic acid is crucial to reproduction of organism.
- Both are made of polymers.
- 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?



# 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.

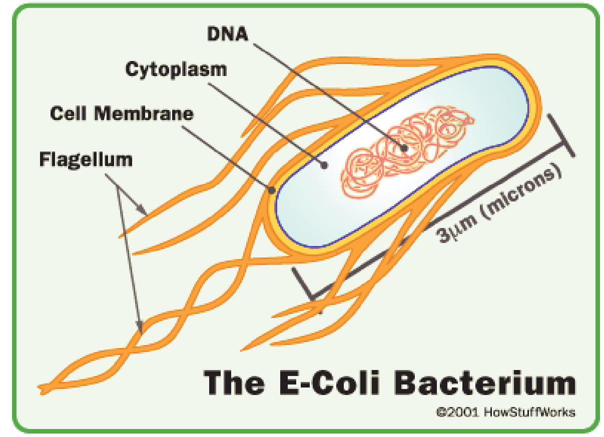
# Cells

- The cell function directly relates to a different organic polymer:
  - Proteins: 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.
  - DNA: The genetic coding molecules that controls enzyme and cell reproduction
  - Sugars: The energy source of cells



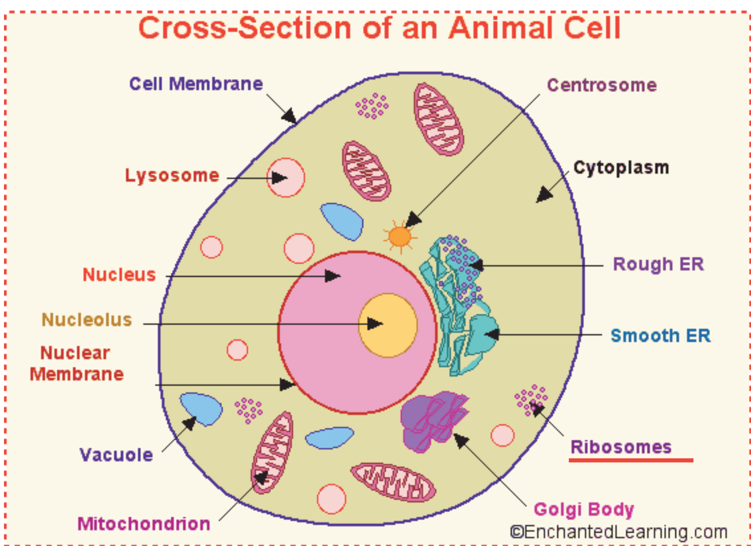
# Bacteria Cells

- 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.



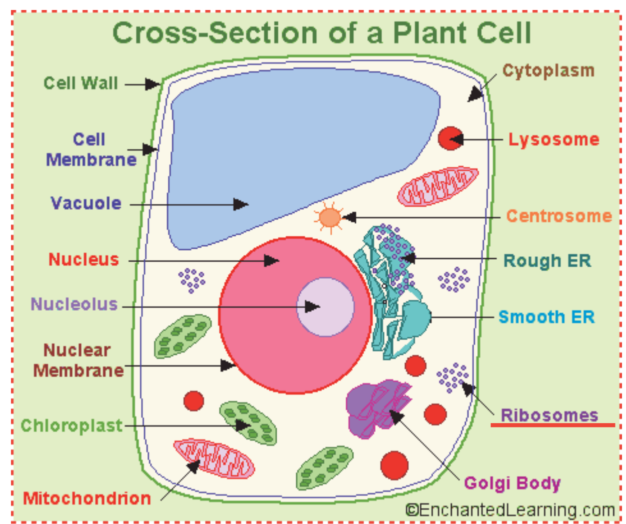



# Animal Cells






# Plant Cells



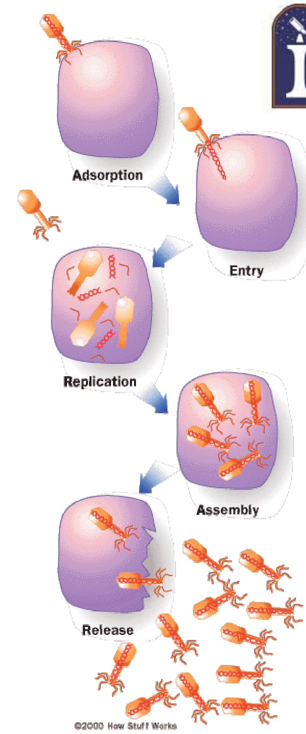
# *Cell Variation*

- Bacterial cells lack a nuclear membrane enclosing the cell's nucleus
- Animal cells have a nuclear membrane but lack a distinct cell wall
- Plant cells have both a nuclear membrane and a cell wall



# *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.






# *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).
- Example: Enzymes are made up of 100s to 1000s of those 20, 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.



# *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?

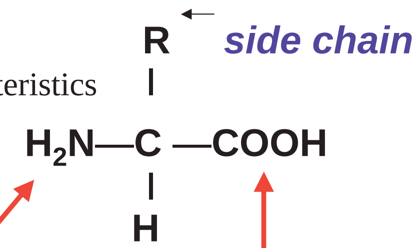
# A Type of Protein: Enzymes

- 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.
- 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 (or proteins) orchestrated by the DNA.



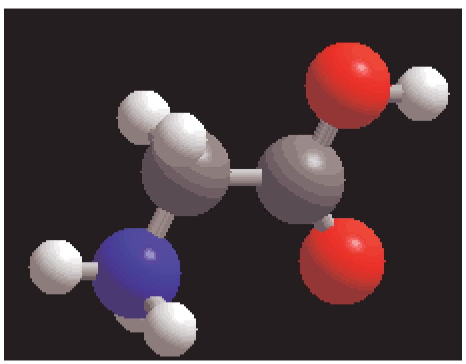
# Amino Acids

- 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

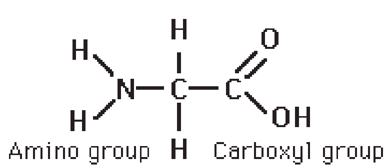





# Glycine



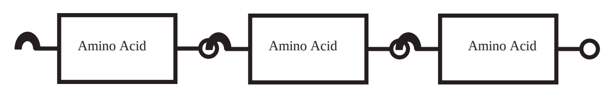
- Simplest amino acid. Just an H in the R position.
- Main ingredients are HOCN– other amino acids contain Sulfur (S) as well.





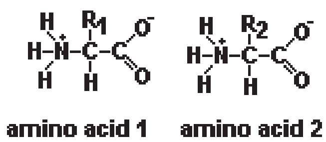

# Getting Hooked Up

- Amino acids are monomers
- Proteins are polymers of amino acids of a certain type. 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.
- Really a peptide bond.



# Peptide Bond

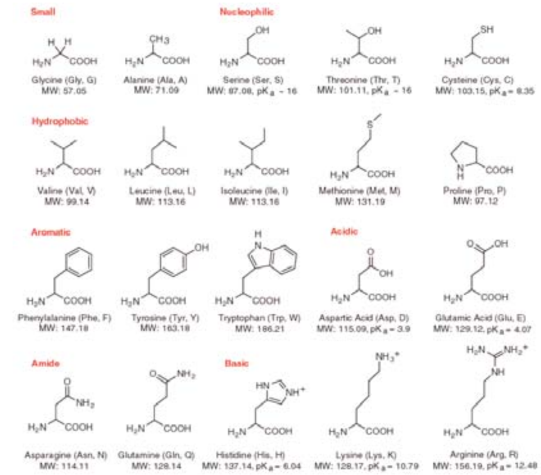
- When in a solvent (water), the OH loses an H, and the $NH_2$ gains an H.
- We have positive and negative attracted to each other.
- A peptide bond is formed! (Just think of the hook and eye.)
- The bonding is very important to life, as some of the nucleic acids can be huge (up to $10^{10}$ atoms)






# So?

- Amino acids are essential for life.
- But who orchestrates or writes the message that the amino acids make up?
- Need something to teach them how to spell.

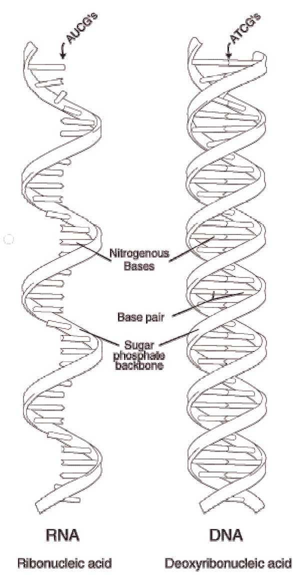


http://www.neb.com/neb/tech/tech_resource/miscellaneous/amino_acid.html



# Nucleic Acid: DNA and RNA

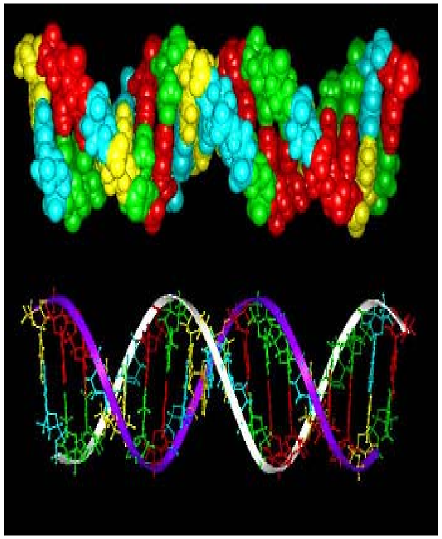
- Two main types of nucleic acid.
- A polymer built up from monomers.
- RNA (RiboNucleic Acid) is usually a long strand
- DNA (DeoxyriboNucleic Acid) is the double helix– visualize as a spiral ladder.
- These amino acids carry the genetic information of the organism– coded into the amino acid chain.
- It is very much like computer code in many ways– and teaches them to spell.



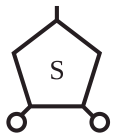



# DNA / RNA

- 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"***



# Sugars: Ribose or Deoxyribose

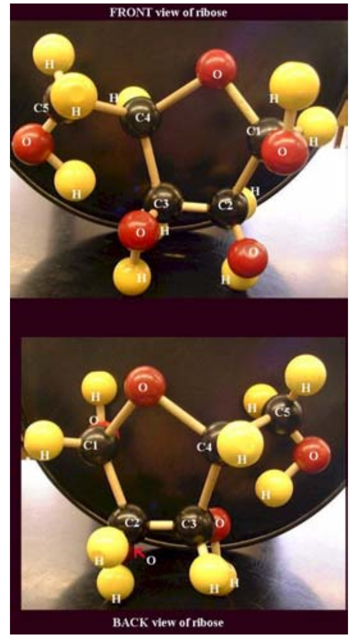


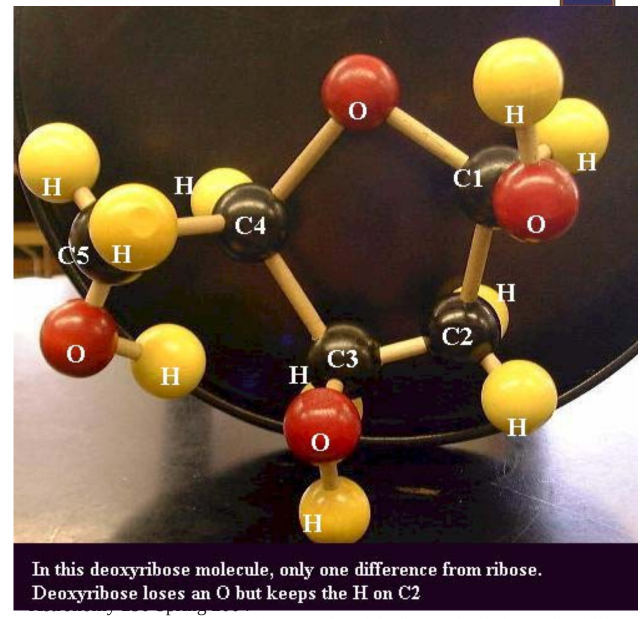

We will represent the sugar molecule (either ribose or deoxyribose) as a pentagon with two eyes.



http://www.dscc.edu/bwilliams/Biology/biology1molemodels.htm

# Sugars: Ribose or Deoxylribose

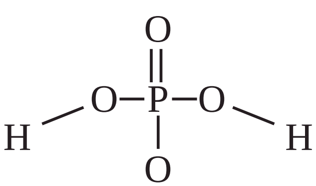


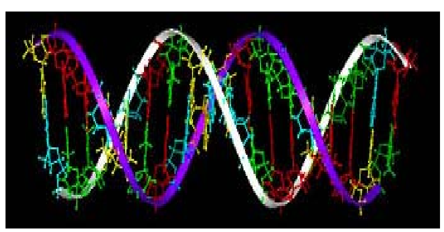




http://www.dscc.edu/bwilliams/Biology/biology1molemodels.htm

# Phosphates

- Is often referred to as phosphoric acid.
- Makes five bonds with oxygen.

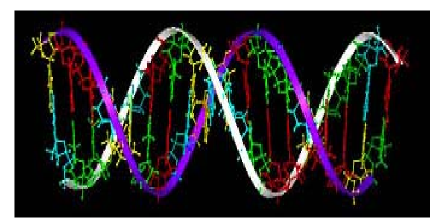


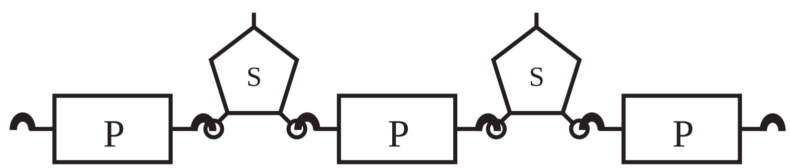






# Phosphates and Sugars

- Make the sides of the twisted DNA ladder structure.
- Sugars and phosphates connect up in alternating bonds. P-S-P-S-P-S-P
- These are phosphodiester bonds.





# *And the Bases*

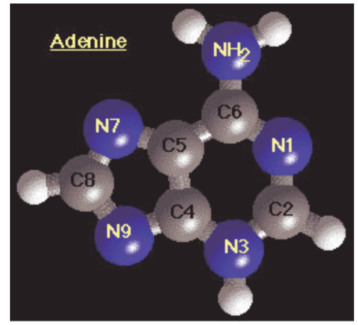
5 types in 2 groups:

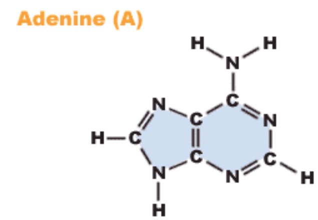
- Purines– Adenine and Guanine
- Pyrimidines-- Cytosine, Thymine, and Uracil

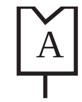


# *Purines: Adenine*

- 5-sided ring built on the side of a 6-sided ring.




Adenine

$H_5C_5N_5$

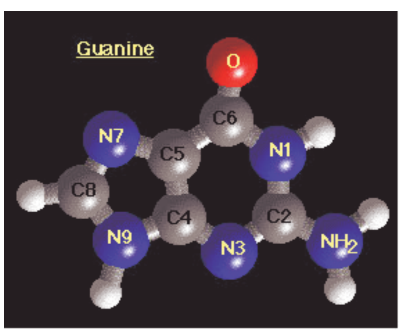
http://resources.emb.gov.hk/biology/english/inherit/genetics.html

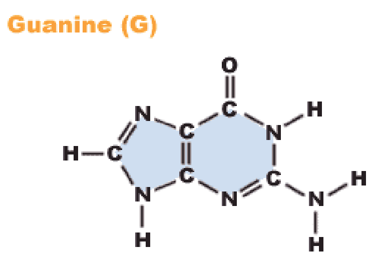
http://dlm.tmu.edu.tw/phase2/glossary/image/adenine.gif



# *Purines: Guanine*

- 5-sided ring built on the side of a 6-sided ring.





$H_5C_5N_5O$

Guanine

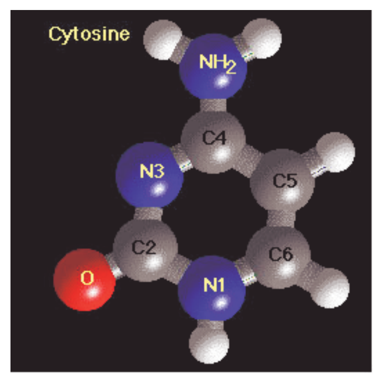
http://resources.emb.gov.hk/biology/english/inherit/genetics.html

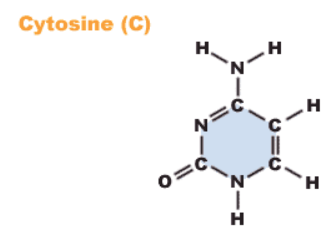
http://dlm.tmu.edu.tw/phase2/glossary/image/adenine.gif



# *Pyrimidines: Cytosine*

- 6 sided rings (without a 5 sided ring)





$H_5C_4N_3O$

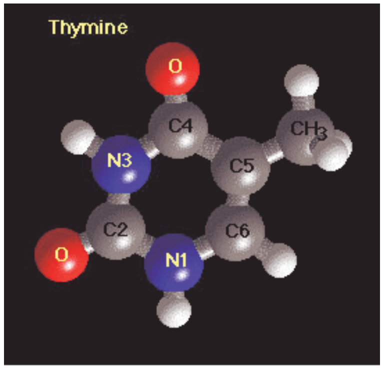
Cytosine

http://resources.emb.gov.hk/biology/english/inherit/genetics.html

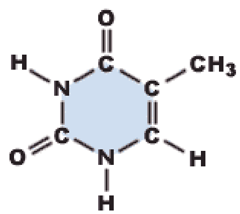
http://dlm.tmu.edu.tw/phase2/glossary/image/adenine.gif

# Pyrimidines: Thymine

- 6 sided rings (without a 5 sided ring)




Thymine (T)





Thymine

$H_6C_5N_3O_2$

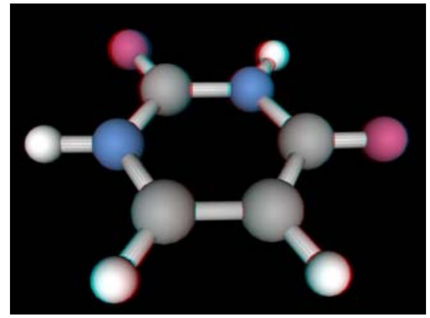
http://resources.emb.gov.hk/biology/english/inherit/genetics.html

http://dlm.tmu.edu.tw/phase2/glossary/image/adenine.gif

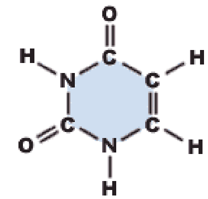


# Pyrimidines: Uracil

- 6 sided rings (without a 5 sided ring)



Uracil (U)





Uracil

$H_4C_4N_2O_2$

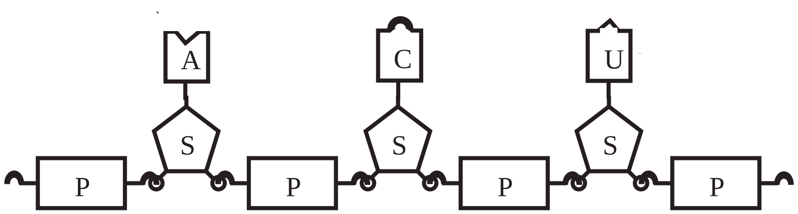
http://nautilus.fis.uc.pt/molecularium/stereo/

http://dlm.tmu.edu.tw/phase2/glossary/image/adenine.gif



# Making RNA

- Schematic of a RNA molecule.
- This segment can be read from left to right as ACU– called a codon (a three letter word, so to speak)
- Can be translated to a specific genetic code– this corresponds to the amino acid Threonine. GGU is gylcine.
- By building up these amino acid codons, we can spell out (and thus construct) a protein.



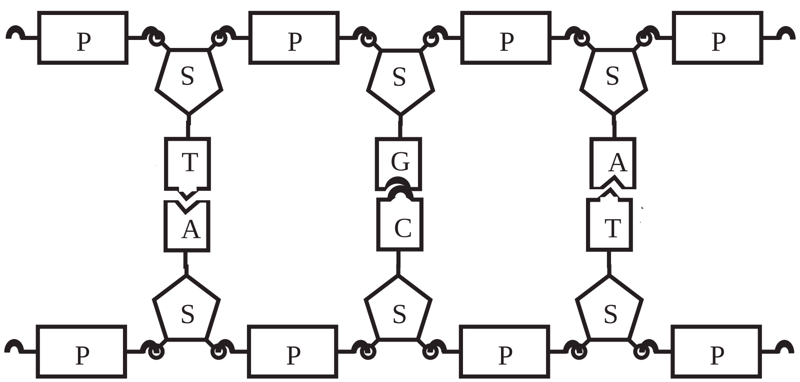



# DNA

- For life more complicated than viruses, the genetic code is stored in DNA.
- Differs from RNA in a few ways: uses deoxyribose sugar rather than ribose sugar and it uses thymine instead of uracil.
- Forms the double strand where two complementary bonds are held together with weaker hydrogen bonding– allowing easier separation.
- In that case, bases form unique pairs:
  - AT, TA, GC, CG

# DNA

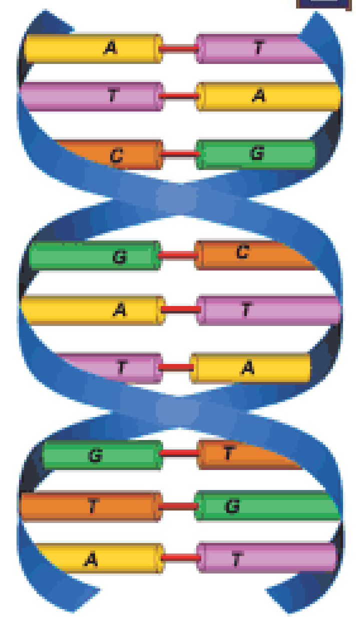
- A codon of DNA: AT, CG, TA



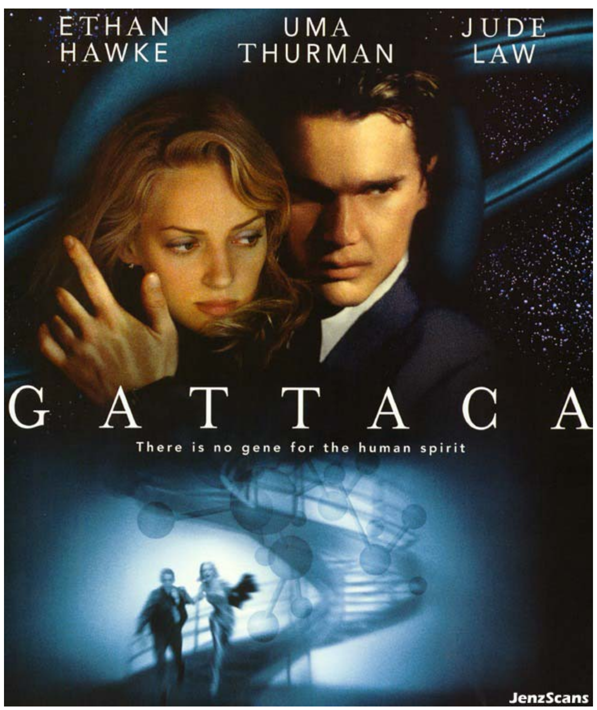



# The Double Helix

- 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.



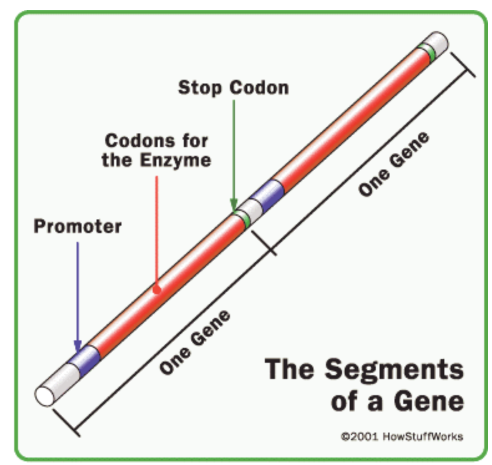





# Genes

- 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 $3 \times 10^9$ base pairs, but 98% of it has no obvious function, and 99.9% is the same for all humans.