Astronomy 330

This class (Lecture 12):

Origin of Life

Next Class:

Origin of Life

HW 5 is due Sunday

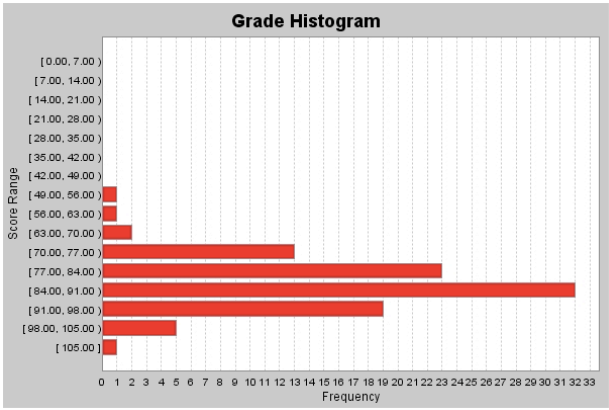
Music: *Bring Me to Life*– Evanescence

Exam 1

Good job class!

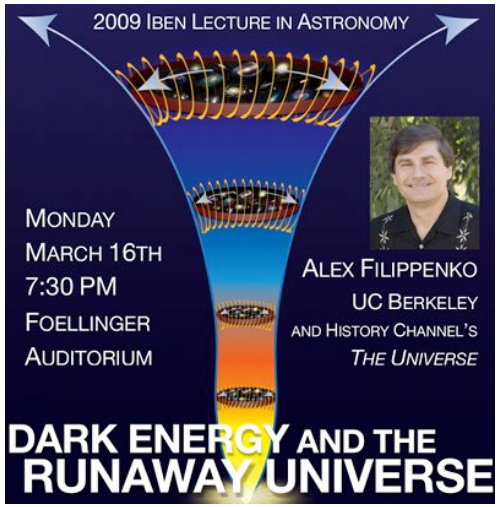
Average: 85%
Median: 87%

Don't forget, there is a chance to increase score on the final exam.



Extra Credit?

0.5 % added to final grade for attending (and writing a short report) on Alex's talk on the 16th.



Outline

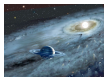
- Proteins
- Nucleic acids

Drake Equation

Frank Drake

That's 0.36 Life-liking systems/year








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

# 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
	20 stars/ yr	0.12 systems/ star	1.25 x 0.12 = 0.15 planets/ system	life/ planet	intel./ life	comm./ intel.	yrs/ comm.

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!**

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 nucleic acids?

DNA Based Life

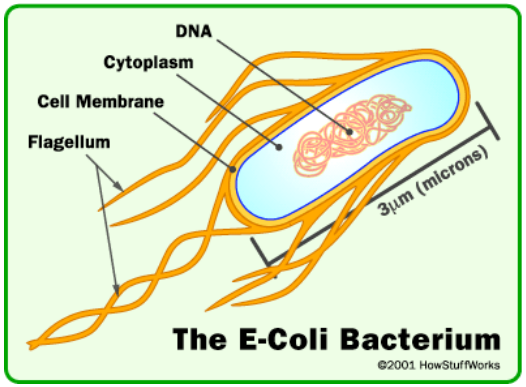
- All life is based on DNA/RNA. What does this mean?
  - The basic reproducible unit of all living organisms is centered around the complex DNA molecule.
  - DNA lives in cells
    - Except in viruses, which are basically pure DNA
  - Cells of different types form different parts of each organism
  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

Cell Bits

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

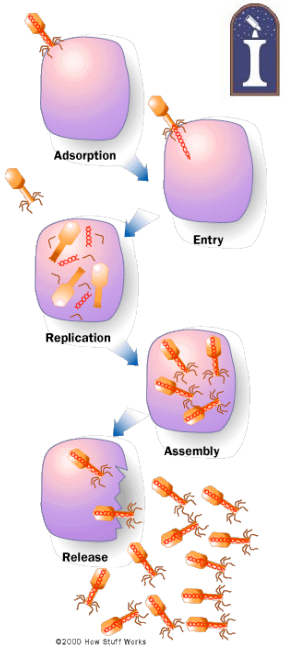
Bacteria Cells

- 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.



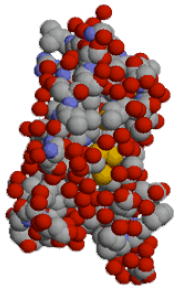
Viruses

- 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.

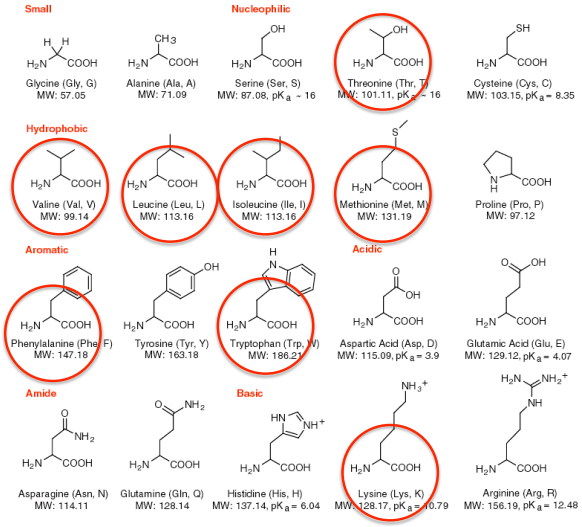


Focus on Proteins

- 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).



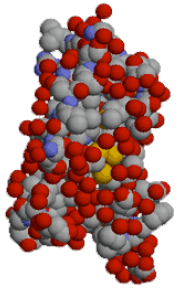
Amino Acids Are for Lovers



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

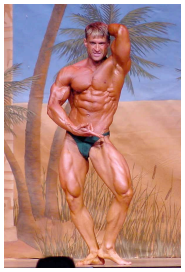
Focus on Proteins

- 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.

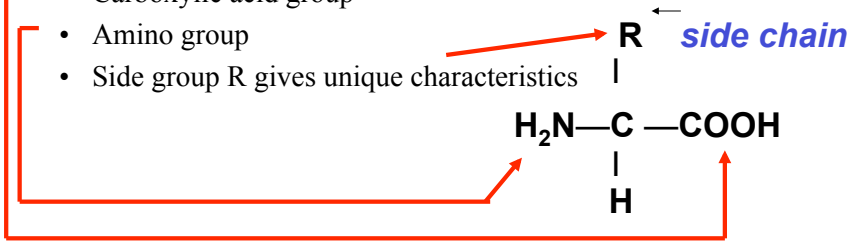
A Type of Protein: Enzymes

- 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.

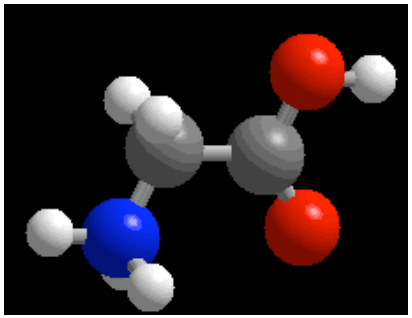
http://res2.agr.ca/lethbridge/emia/images/SEMproj/Ecoli.jpg

Amino Acids

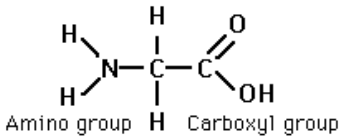
- Are the monomers from which proteins (polymers) are made– building blocks.
- Combinations of the amino acids make the proteins needed– only 20 amino acids used by life.
- Carboxylic acid group
- Amino group
- Side group R gives unique characteristics



Glycine

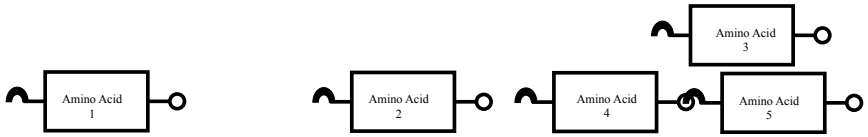


- Simplest amino acid. Just an H in the R position.
- Main ingredients are HONC– other amino acids contain Sulfur (S) as well.



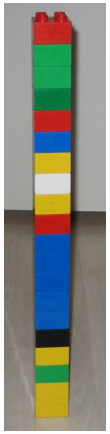
Getting Hooked Up

- 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

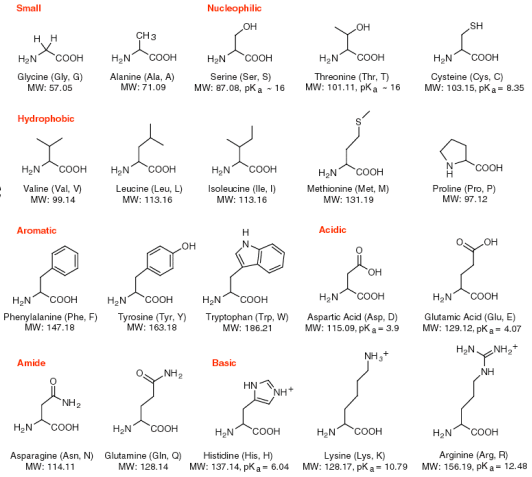
Question

If we think of a protein as a stack of Legos, then what are the blocks?

a) Amino acid
b) Ribonucleic Acid
c) Protein
d) Deoxyribonucleic Acid
e) Enzyme.

Build Me Up

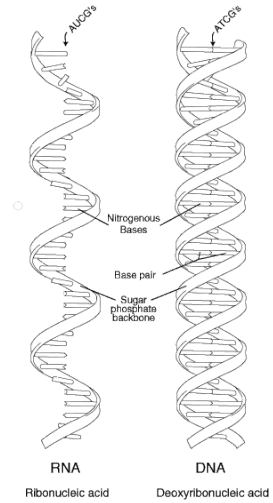
- Amino acids are essential for life– building blocks.
- But who orchestrates or writes the message (the special proteins) that the amino acids make up?
- Need something to teach them how to spell.



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

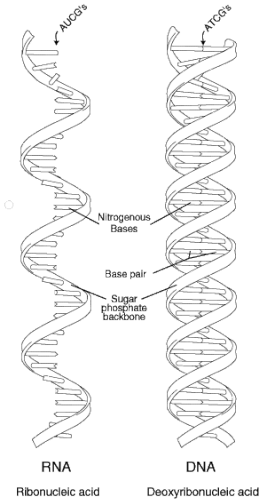
Nucleic Acid: DNA and RNA

- Two types of nucleic acid.
- A polymer built up from monomers we'll come back to which ones.
- RNA (RiboNucleic Acid) is usually a long strand
- DNA (DeoxyriboNucleic Acid) is the double helix– visualize as a spiral ladder.



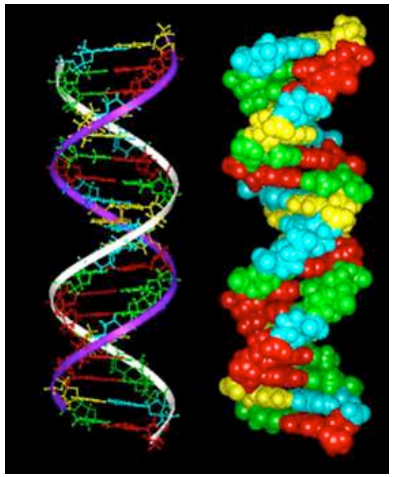
Nucleic Acid: DNA and RNA

- These molecules carry the genetic information of the organism– the message that gets coded into the amino acid chain.
- It is very much like computer code in many ways– and teaches how to spell useful word (proteins) out of the letters of the available amino acids.



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

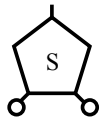


Question

What is the DNA molecule role?

a) Telling proteins what to do.
b) A dictionary for protein spellings.
c) Sitting around all day and lord over the other parts of the cell.
d) Deoxyribonucleic Acid
e) Invading other animals.

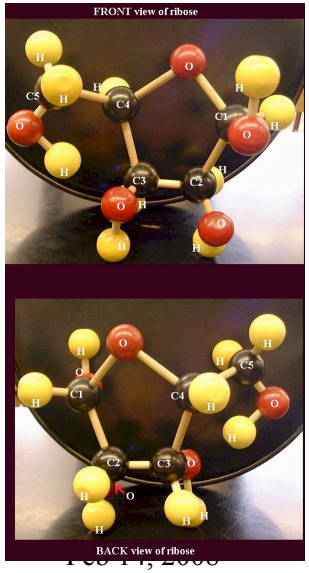
Sugars: Ribose or Deoxyribose

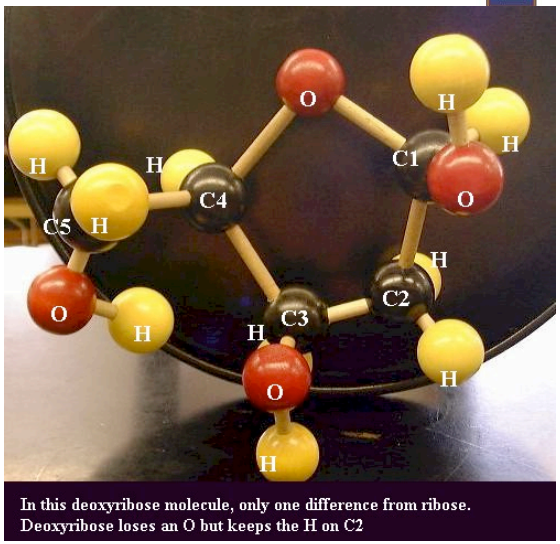


We will represent the sugar molecule (either ribose or deoxyribose) as a pentagon with two eyes.

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

Sugars: Ribose or Deoxyribose

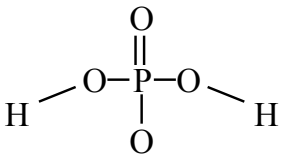


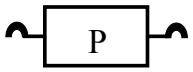


http://www.dscc.edu/bwilliams/Biology/biology1molemodels.htm

Phosphates

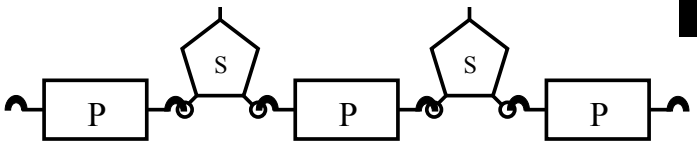
- Is often referred to as phosphoric acid.
- Makes five bonds with oxygen.





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.



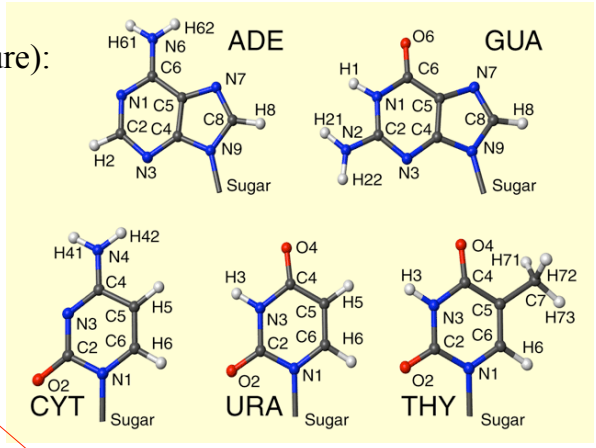
And the Bases

5 types in 2 groups (based on structure):

- Purines:
  - Adenine
  - Guanine
- Pyrimidines:
  - Cytosine
  - Uracil
  - Thymine

For DNA

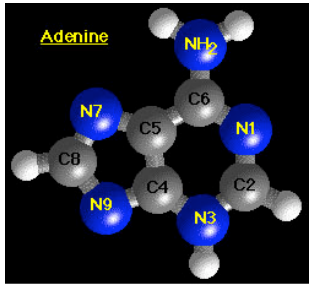
For RNA

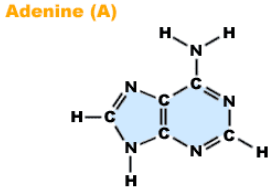


http://www.bmrb.wisc.edu/referenc/nomenclature/figures/bases.gif

Purines: Adenine

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





A

Adenine

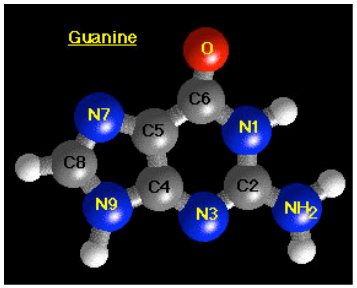
$H_5C_5N_5$

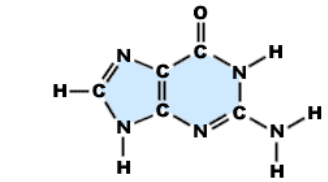
http://resources.emb.gov.hk/biology/english/inherit/genetics.html

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

Purines: Guanine

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





G

Guanine

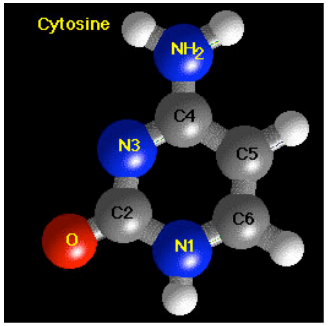
$H_5C_5N_5O$

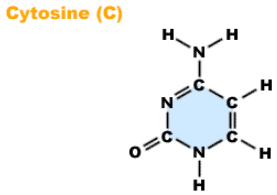
http://resources.emb.gov.hk/biology/english/inherit/genetics.html

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

Pyrimidines: Cytosine

- 6 sided rings (without a 5 sided ring)





C

$H_5C_4N_3O$

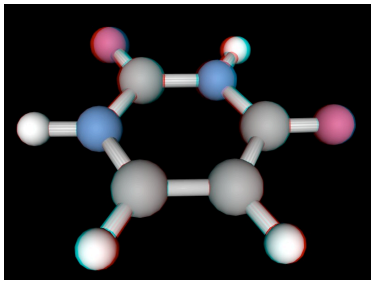
Cytosine

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

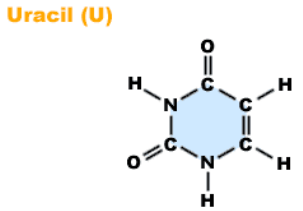
http://dlm.tmu.edu.tw/phase2/glossary/image/adenine.gif

Pyrimidines: Uracil

- 6 sided rings (without a 5 sided ring)



For RNA



U

$H_4C_4N_2O_2$

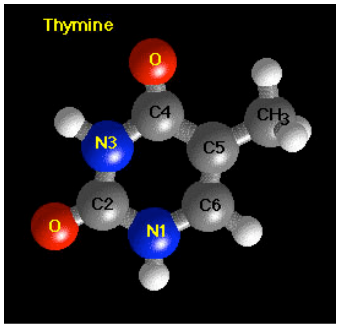
Uracil

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

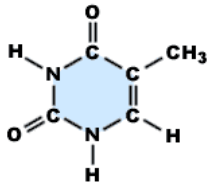
http://dlm.tmu.edu.tw/phase2/glossary/image/adenine.gif

Pyrimidines: Thymine

- 6 sided rings (without a 5 sided ring)



For DNA



T

$H_6C_5N_3O_2$

Thymine

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

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

Monomers and Polymers

<u>Monomer:</u>

1. Amino acids → 1. Proteins
2. Sugar → 2. Nucleic acids

   phosphate

   nitrogenous bases

<u>Polymer:</u>

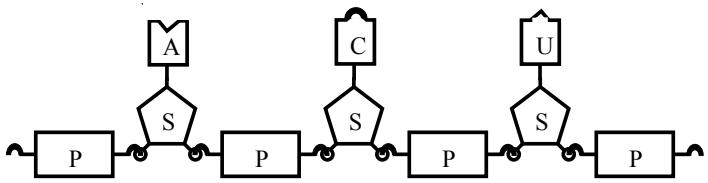
Question

Which of the following is not a polymer?

a) Amino acid
b) Ribonucleic Acid
c) Protein
d) Deoxyribonucleic Acid
e) Enzyme.

Making RNA Mean Something

- Schematic of an 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 amino acid (**the 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.



Meaning in Mystery

FIRST LETTER	SECOND LETTER U	SECOND LETTER C	SECOND LETTER A	SECOND LETTER G	THIRD LETTER
U	Phenylalanine	Serine	Tyrosine	Cysteine	U
	Phenylalanine	Serine	Tyrosine	Cysteine	C
	Leucine	Serine	Stop	Stop	A
	Leucine	Serine	Stop	Tryptophan	G
C	Leucine	Proline	Histidine	Arginine	U
	Leucine	Proline	Histidine	Arginine	C
	Leucine	Proline	Glutamine	Arginine	A
	Leucine	Proline	Glutamine	Arginine	G
A	Isoleucine	Threonine	Asparagine	Serine	U
	Isoleucine	Threonine	Asparagine	Serine	C
	Isoleucine	Threonine	Lysine	Arginine	A
	(Start) Methionine	Threonine	Lysine	Arginine	G
G	Valine	Alanine	Aspartate	Glycine	U
	Valine	Alanine	Aspartate	Glycine	C
	Valine	Alanine	Glutamate	Glycine	A
	Valine	Alanine	Glutamate	Glycine	G

For DNA replace U with T

http://library.thinkquest.org/C004535/PF_amino_acids.html

Question

The Codon code is

a) a bad movie starring Tom Hanks.
b) how DNA encodes the 20 amino acids by using bases.
c) how RNA encodes the 10,000 proteins by using bases.
d) a three letter word using the 20 letters of the Wasibi alphabet.
e) a bad book starring Tom Hanks.

Overconstrained

- 4 options for each letter in the Codon
- 4 x 4 x 4 = 64 options (can think if it as bits)
- But only 20 amino acids ⇒ over constrained
- 4 x 4 = 16 wouldn't work.
- Life picked the next highest number and copes with redundancy.

FIRST LETTER	SECOND LETTER U	SECOND LETTER C	SECOND LETTER A	SECOND LETTER G	THIRD LETTER
U	Phenylalanine	Serine	Tyrosine	Cysteine	U
	Phenylalanine	Serine	Tyrosine	Cysteine	C
	Leucine	Serine	Stop	Stop	A
	Leucine	Serine	Stop	Tryptophan	G
C	Leucine	Proline	Histidine	Arginine	U
	Leucine	Proline	Histidine	Arginine	C
	Leucine	Proline	Glutamine	Arginine	A
	Leucine	Proline	Glutamine	Arginine	G
A	Isoleucine	Threonine	Asparagine	Serine	U
	Isoleucine	Threonine	Asparagine	Serine	C
	Isoleucine	Threonine	Lysine	Arginine	A
	(Start) Methionine	Threonine	Lysine	Arginine	G
G	Valine	Alanine	Aspartate	Glycine	U
	Valine	Alanine	Aspartate	Glycine	C
	Valine	Alanine	Glutamate	Glycine	A
	Valine	Alanine	Glutamate	Glycine	G

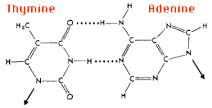
DNA

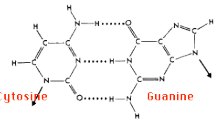
- For life more complicated than viruses, the genetic code is stored in DNA.
- Differs from RNA in a few ways: uses deoxyribose sugar rather than ribose sugar and it uses thymine instead of uracil.
- Forms the double strand where two complementary bonds are held together with weaker hydrogen bonding–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

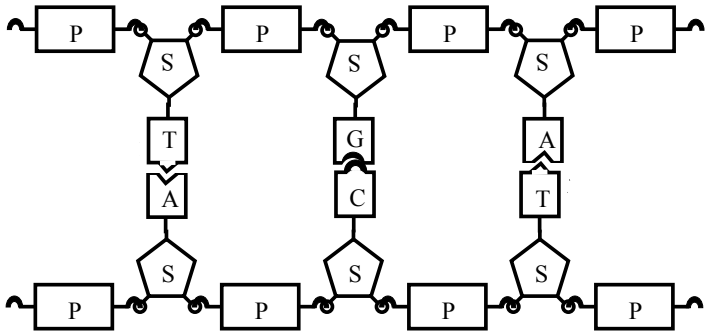
http://mbsu.sus.mcgill.ca/POST_MIDTERM PICS/DNA is my life.jpg

DNA

- A codon of DNA: AT, CG, TA
  - purine to pyrimidine connections

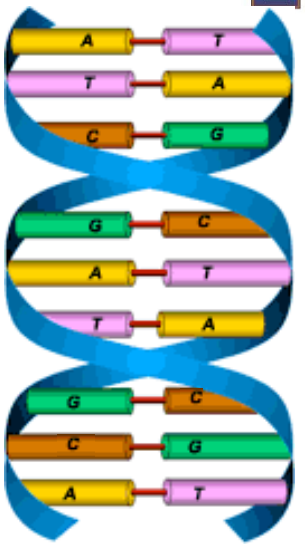






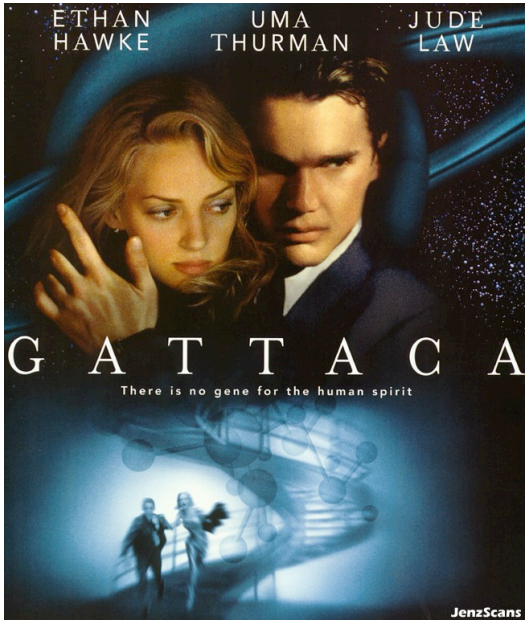
The Double Helix

- 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
- In other words, if you know the sequence on one side, you can deduce the sequence on the other side.



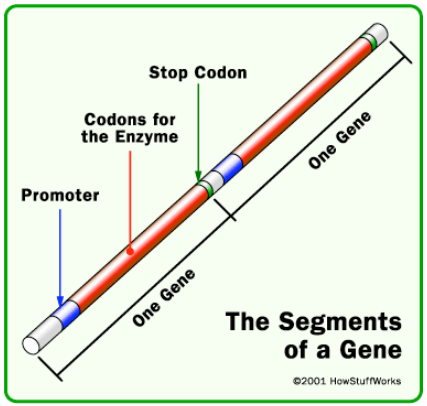
The Double Helix

- The ladder is twisted into the helix shape since the hydrogen bonds are at an angle.
- 3 pairs make up a codon, like RNA (4x4x4 = 64)
- Each codon is info on the amino acid, but only 20 of those– again over constrained.



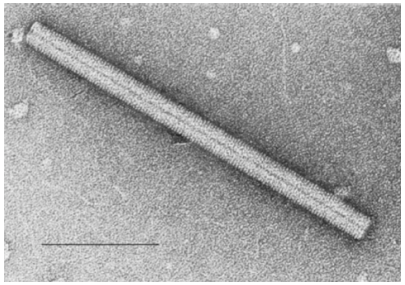
Genes

- 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.

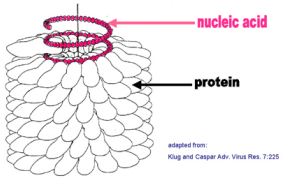


Ta-Backy

- 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 x 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

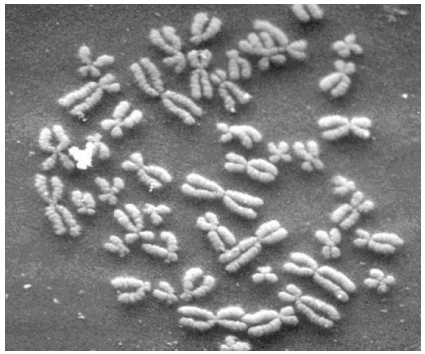
My Old Blue Genes

- This 98% is often called “junk” DNA, but it is still unclear what it’s function is..
- May control 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

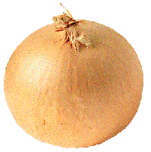
- Best way to package DNA is in chromosomes– DNA wrapped around proteins,
- Humans have 23 pairs of chromosomes (total of 46).
- Each ranges from 50 million to 250 million base pairs
- For each set, you got half from each parent.



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

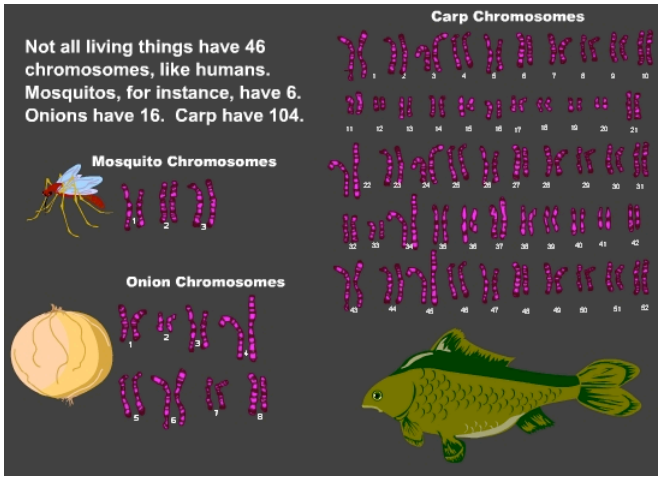
Which requires the most genes?

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

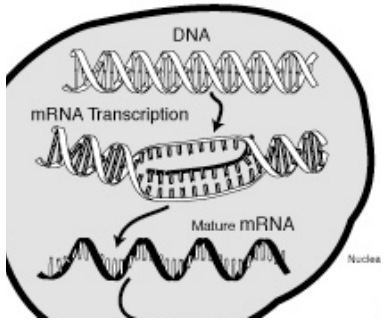
Chromosomes



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

DNA: Message in a Cell

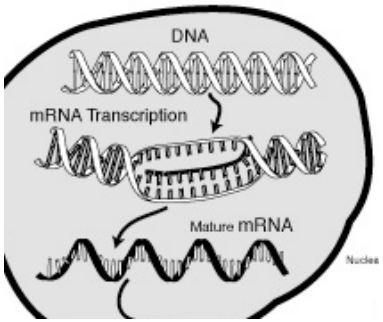
- A cell is informed it needs a enzyme– call it Z.
- Other enzymes in nucleus unravel and separate the easily broken DNA at the site where the gene for making that enzyme in encoded.



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

DNA: Message in a Cell

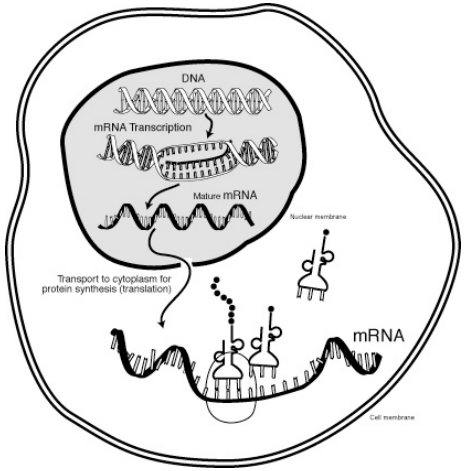
- Transcription of the gene is made via complementary bases and are assembled in a messenger RNA or mRNA.
- DNA zips itself back together.
- The mRNA (a series of codons) moves from the nucleus to the cytoplasm.



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

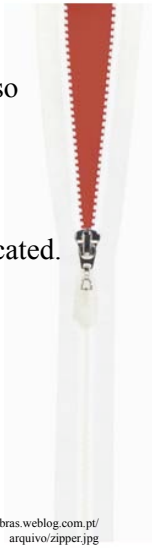
Reproduction

- 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.



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