ET: Astronomy 230

This Class (Lecture 18):

Nature of Life

Next Class:

Sujay Javdekar
Christopher Norman
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HW #5 is due Friday

Presentations Friday Oct 7th
Sujay Javdekar
Christopher Norman
Mark Lenkowski

Presentations Wednesday Oct 12th
Michael Cellini
Elisha Reichert
Corey Osland

Music: *Blister in the Sun* – Violent Femmes

Outline

- Proteins (structural and enzymes) and nucleic acids: the essentials for life.
- Amino Acids
- Proteins
- DNA/RNA

Drake Equation

= 0.42

Earth-like planets /year

Earth Chauvinism?

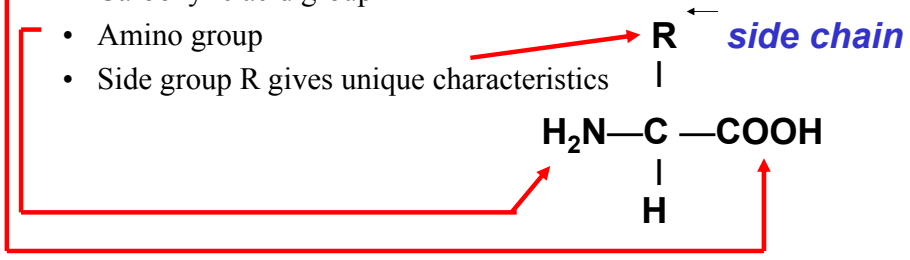
Frank Drake

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

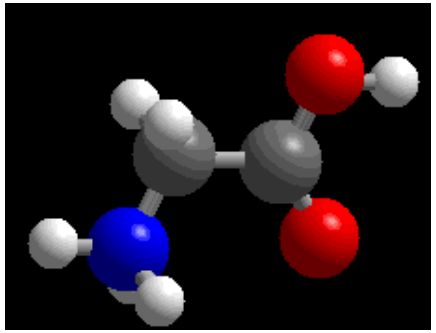
N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Rate of star formation	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	10 stars/ yr	0.38 systems/ star	0.11 planets/ system	life/ planet	intel./ life	comm./ intel.	yrs/ comm.

Amino Acids

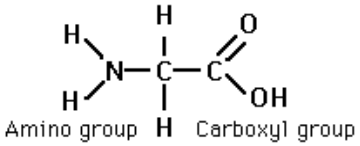
- Are the monomers from which proteins (polymers) are made– building blocks.
- Combinations of the amino acids make the proteins needed– only 20 amino acids used by life.
- Carboxylic acid group
- Amino group
- Side group R gives unique characteristics



Glycine

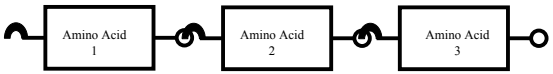


- Simplest amino acid. Just an H in the R position.
- Main ingredients are HONC– other amino acids contain Sulfur (S) as well.



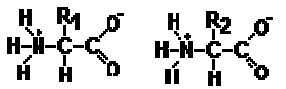
Getting Hooked Up

- 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.



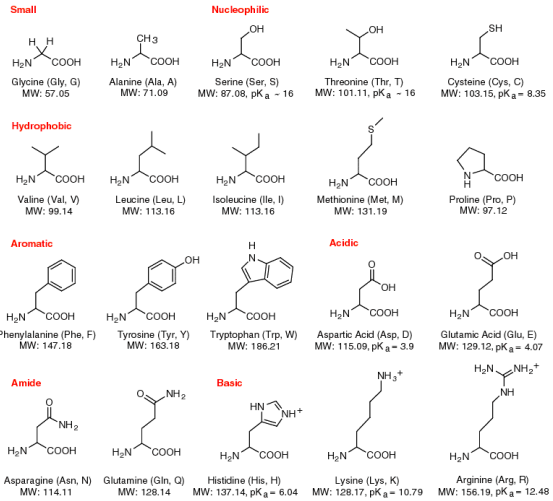
Peptide Bond

- 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.)
- Good bonding is very important to life– some of the nucleic acids can be huge (up to 10^{10} atoms)



So?

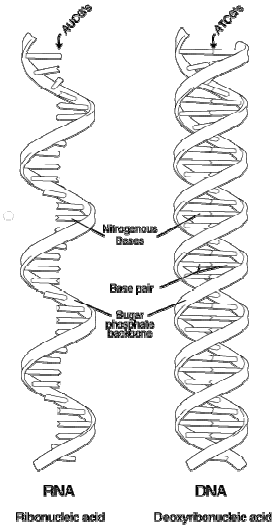
- Amino acids are essential for life– building blocks.
- But who orchestrates or writes the message (the special proteins) that the amino acids make up?
- Need something to teach them how to spell.



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

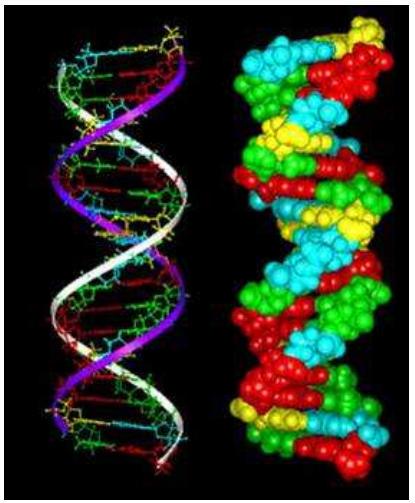
Nucleic Acid: DNA and RNA

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

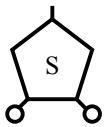


DNA / RNA

- 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
       - ***These four monomers are collectively called "nucleotides"***



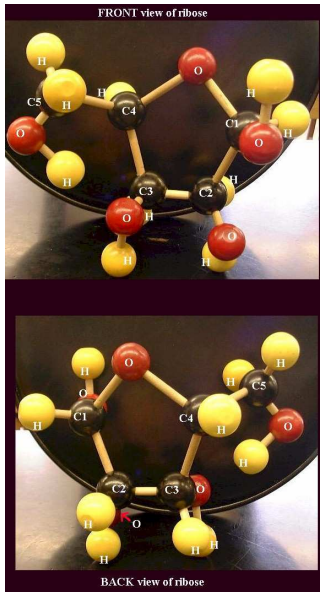
Sugars: Ribose or Deoxyribose

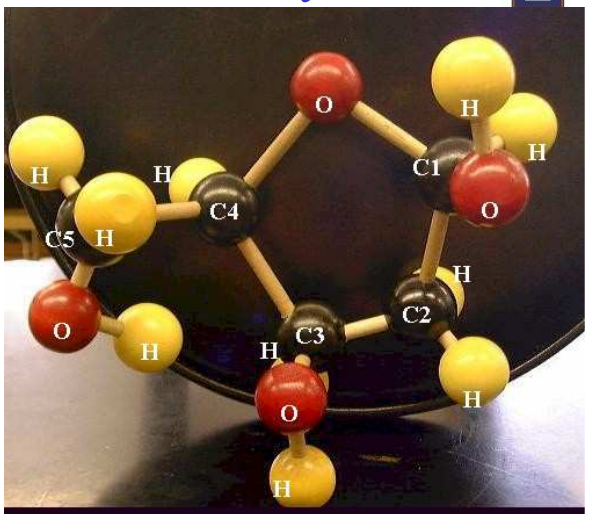


We will represent the sugar molecule (either ribose or deoxyribose) as a pentagon with two eyes.

http://www.dscc.edu/bwilliams/Biology/biology1moremodels.htm

Sugars: Ribose or Deoxylribose

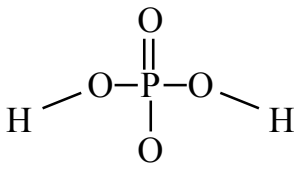


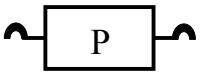


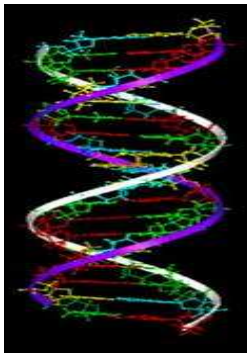
http://www.dscc.edu/bwilliams/Biology/biology1moremodels.htm

Phosphates

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

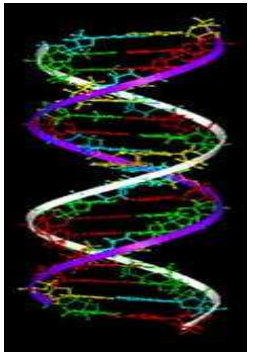


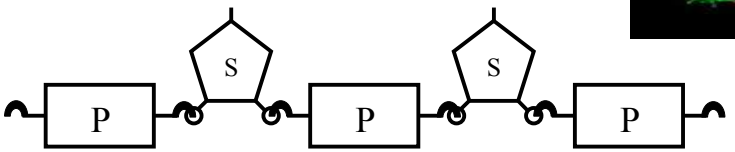




Phosphates and Sugars

- 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.

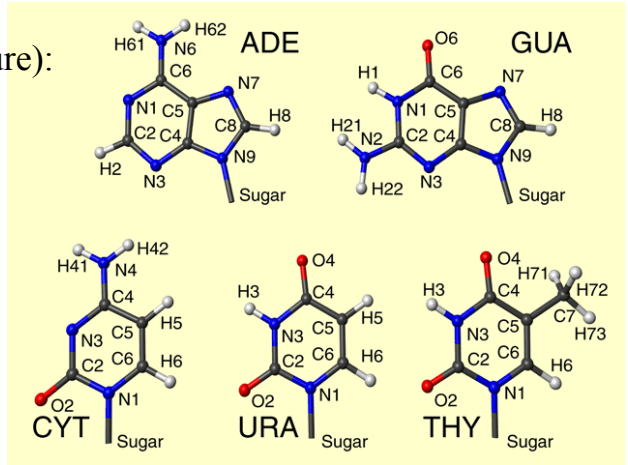




And the Bases

5 types in 2 groups (based on structure):

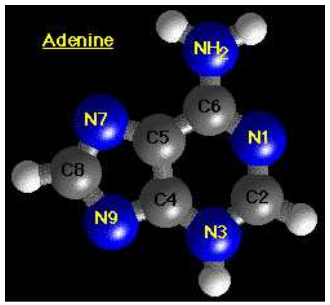
- Purines:
  - Adenine
  - Guanine
- Pyrimidines:
  - Cytosine
  - Uracil
  - Thymine

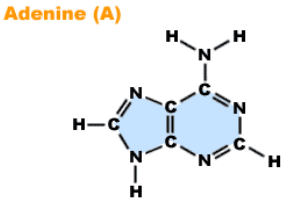


http://www.bmrb.wisc.edu/referenc/nomenclature/figures/bases.gif

Purines: Adenine

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





Adenine

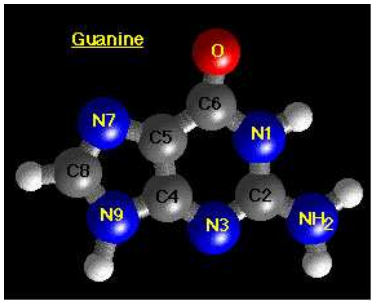
$H_5C_5N_5$

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

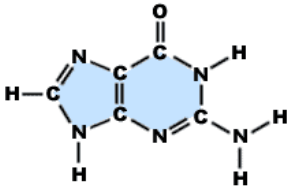
http://dlm.tmu.edu.tw/phase2/glossary/image/adenine.gif

Purines: Guanine

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



Guanine (G)



G

$H_5C_5N_5O$

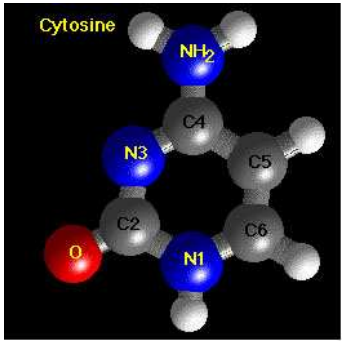
Guanine

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

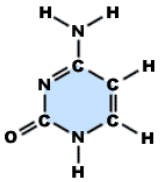
http://dlm.tmu.edu.tw/phase2/glossary/image/adenine.gif

Pyrimidines: Cytosine

- 6 sided rings (without a 5 sided ring)



Cytosine (C)



C

$H_5C_4N_3O$

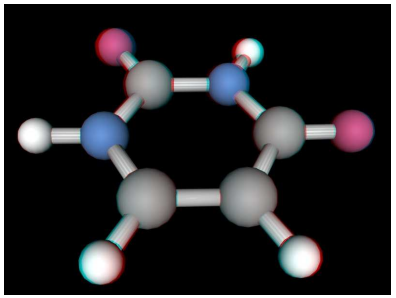
Cytosine

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

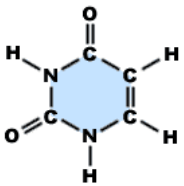
http://dlm.tmu.edu.tw/phase2/glossary/image/adenine.gif

Pyrimidines: Uracil

- 6 sided rings (without a 5 sided ring)



Uracil (U)



U

$H_4C_4N_2O_2$

For RNA

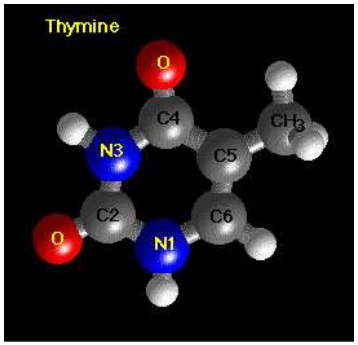
Uracil

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

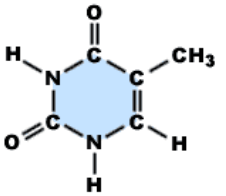
http://dlm.tmu.edu.tw/phase2/glossary/image/adenine.gif

Pyrimidines: Thymine

- 6 sided rings (without a 5 sided ring)



Thymine (T)



T

$H_6C_5N_3O_2$

For DNA

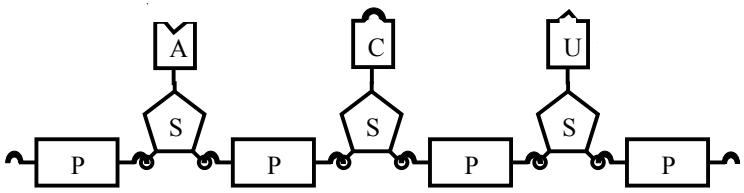
Thymine

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

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

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 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.



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

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

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.

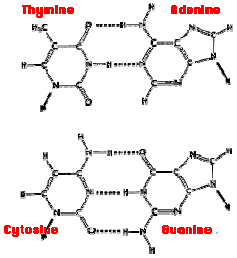
FIRST LETTER	SECOND LETTER U	SECOND LETTER C	SECOND LETTER A	SECOND LETTER G	THIRD LETTER
U	Phenylalanine	Serine	Tyrosine	Cysteine	U
	Phenylalanine	Serine	Tyrosine	Cysteine	C
	Leucine	Serine	Stop	Stop	A
	Leucine	Serine	Stop	Tryptophan	G
C	Leucine	Proline	Histidine	Arginine	U
	Leucine	Proline	Histidine	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

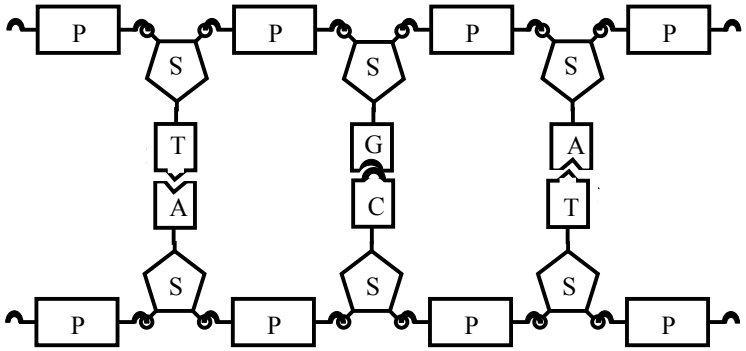
- For life more complicated than viruses, the genetic code is stored in DNA.
- Differs from RNA in a few ways: uses deoxyribose sugar rather than ribose sugar and it uses thymine instead of uracil.
- Forms the double strand where two complementary bonds are held together with weaker hydrogen bonding– 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

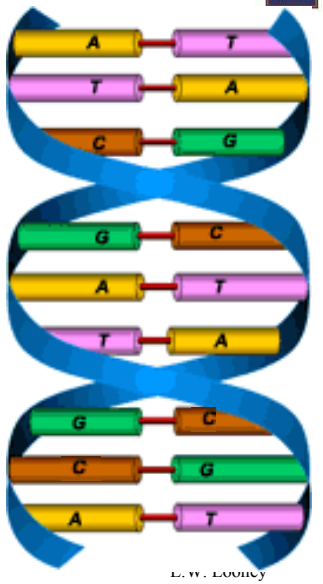
DNA



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



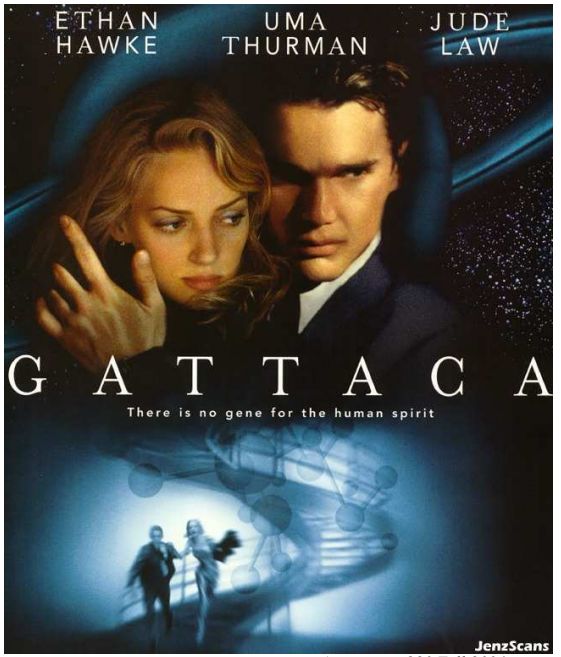
The Double Helix



- 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.

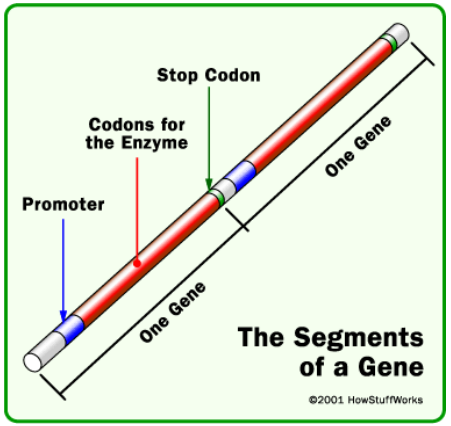
The Double Helix

- 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.



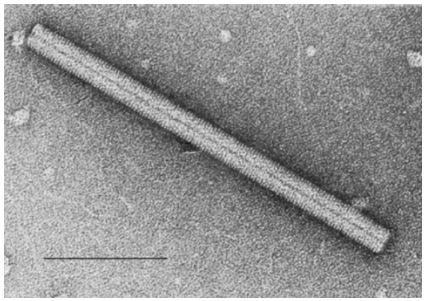
Genes

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

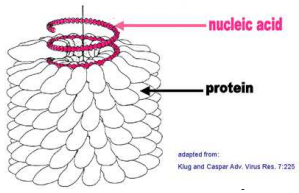


Backy

- 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

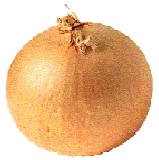
My Old Blue Genes

- The Human Genome Project found 30,000 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.

http://images.encarta.msn.com/xrefmedia/sharemed/targets/images/pho/t373/T373681A.jpg

Which requires the most genes?

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

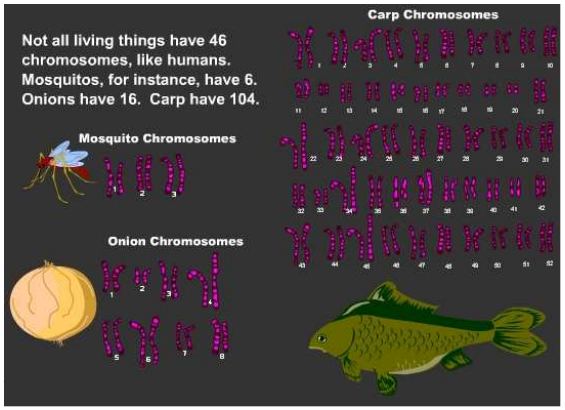


http://www.thefishermom.com/images/071804small.htm
http://www.themoderatevoice.com/files/joe-mosquito.jpg
http://www.freewebs.com/flyingonion/Onion.gif

Chromosomes

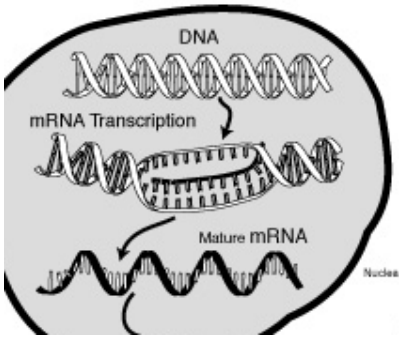
- Best way to package DNA is in chromosomes– DNA wrapped around proteins,
- Humans have 23 sets of chromosomes (total of 46).
- Each ranges from 50 million to 250 million base pairs
- For each set, you got half from each parent.

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



DNA: Message in a Cell

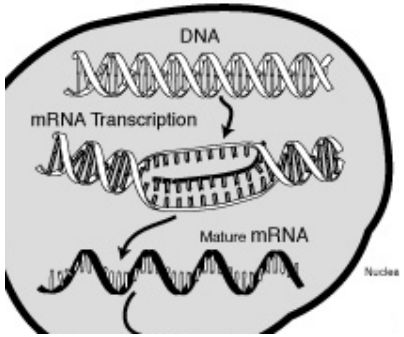
- A cell is informed it needs a enzyme– call it Z.
- Other enzymes in nucleus unravel and separate the easily broken DNA at the site where the gene for making that enzyme in encoded.



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

DNA: Message in a Cell

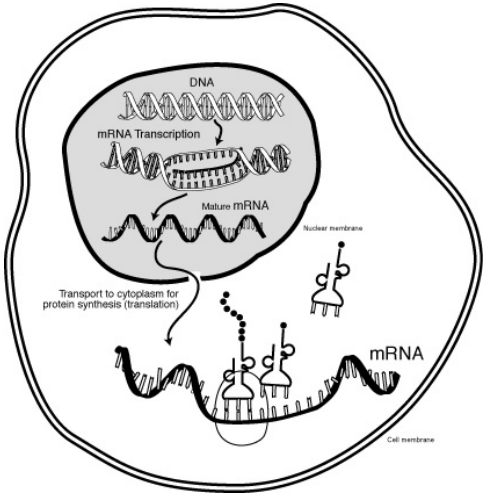
- Transcription of the gene is made via complementary bases and are assembled in a messenger RNA or mRNA.
- DNA zips itself back together.
- The mRNA (a series of codons) moves from the nucleus to the cytoplasm.



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