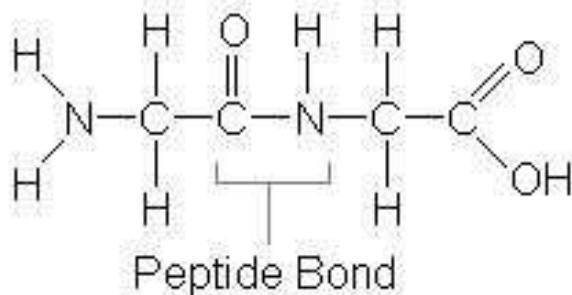
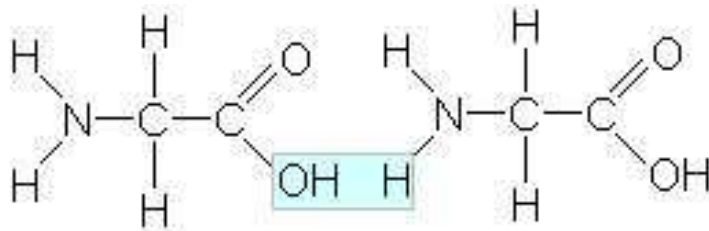
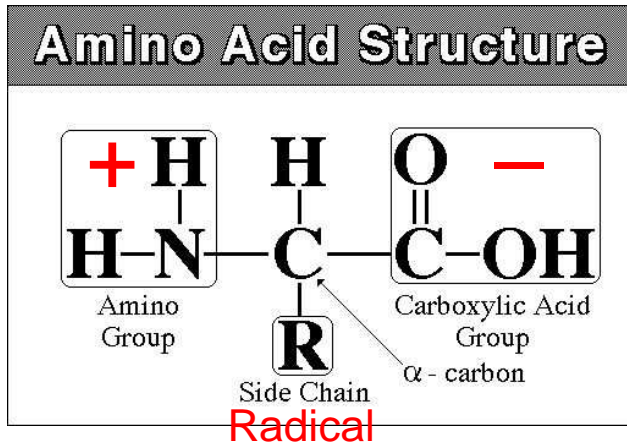


# Amino Acids



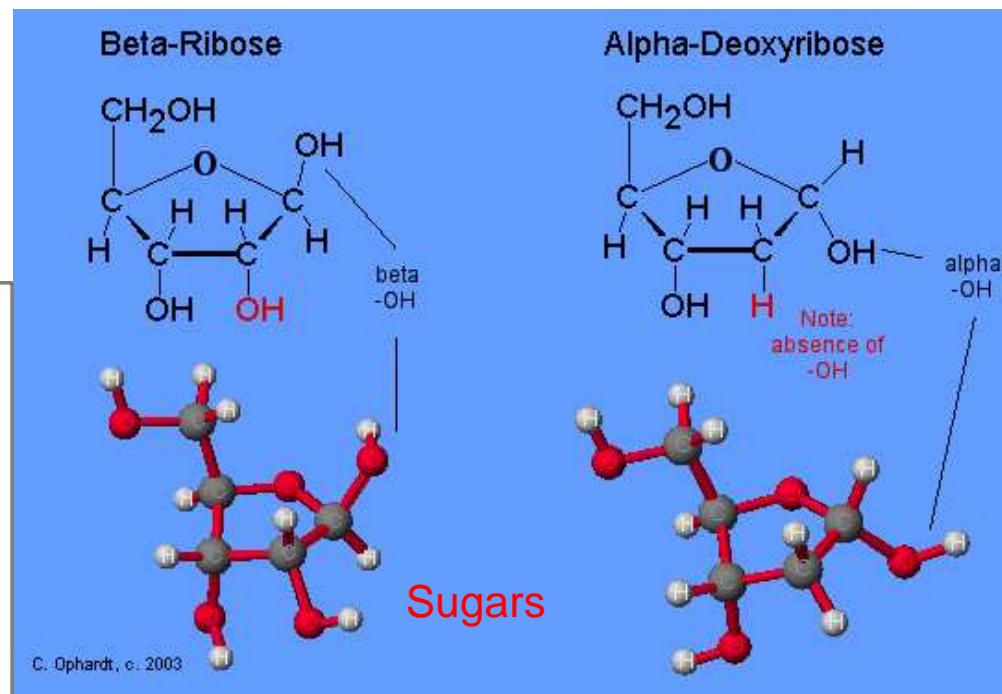
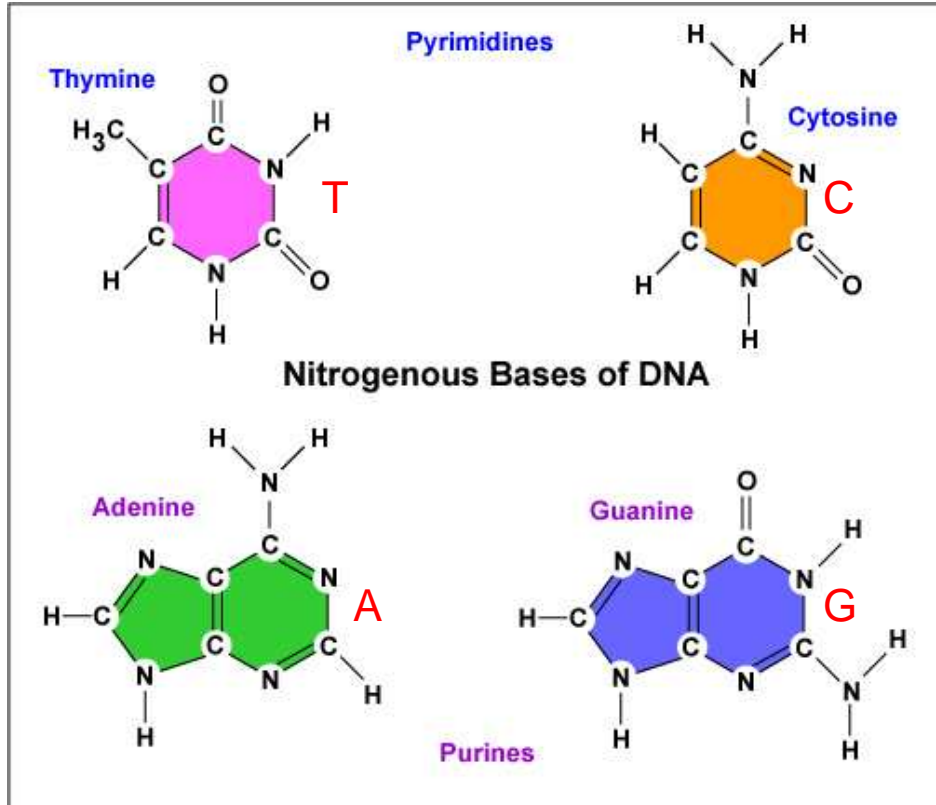
A molecule of water is removed from two glycine amino acids to form a peptide bond.

Amino Acid	Abbreviation	# atoms	Radical
glycine	gly (G)	10	H
alanine	ala (A)	13	CH <sub>3</sub>
cysteine	cys (C)	14	CH <sub>3</sub> S
serine	ser (S)	14	COH <sub>3</sub>
aspartic acid	asp (D)	15	C <sub>2</sub> H <sub>2</sub> O <sub>2</sub>
asparagine	asn (N)	17	C <sub>2</sub> H <sub>4</sub> NO
proline	pro (P)	17	C <sub>3</sub> H <sub>5</sub>
threonine	thr (T)	17	C <sub>2</sub> H <sub>5</sub> O
glutamic acid	glu (E)	18	C <sub>3</sub> H <sub>4</sub> O <sub>2</sub>
valine	val (V)	19	C <sub>3</sub> H <sub>7</sub>
glutamine	gln (Q)	20	C <sub>3</sub> H <sub>6</sub> ON
histidine	his (H)	20	C <sub>4</sub> H <sub>5</sub> N <sub>2</sub>
methionine	met (M)	20	C <sub>3</sub> H <sub>7</sub> S
isoleucine	iso (I)	22	C <sub>4</sub> H <sub>9</sub>
leucine	leu (L)	22	C <sub>4</sub> H <sub>9</sub>
phenylalanine	phe (F)	23	C <sub>7</sub> H <sub>7</sub>
tyrosine	tyr (Y)	24	C <sub>7</sub> H <sub>7</sub> O
lysine	lys (K)	25	C <sub>4</sub> H <sub>11</sub> N
arginine	arg (R)	27	C <sub>4</sub> H <sub>11</sub> N <sub>3</sub>
tryptophan	try (W)	27	C <sub>9</sub> H <sub>8</sub> N

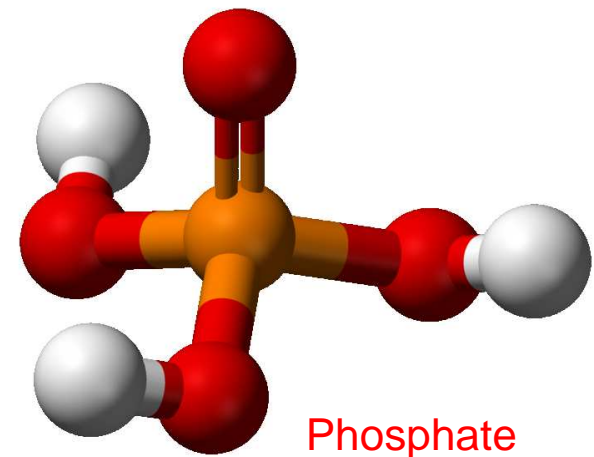
$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ (\text{CH}_2)_3 \\   \\ \text{NH} \\   \\ \text{C}=\text{NH}_2 \\   \\ \text{NH}_2 \end{array}$ <p>Arginine (Arg / R)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{CH}_2 \\   \\ \text{C}=\text{O} \\   \\ \text{NH}_2 \end{array}$ <p>Glutamine (Gln / Q)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{C}_6\text{H}_5 \end{array}$ <p>Phenylalanine (Phe / F)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{C}_6\text{H}_4 \\   \\ \text{OH} \end{array}$ <p>Tyrosine (Tyr / Y)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{C}_8\text{H}_6\text{N} \end{array}$ <p>Tryptophan (Trp, W)</p>
$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ (\text{CH}_2)_4 \\   \\ \text{NH}_2 \end{array}$ <p>Lysine (Lys / K)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{H} \end{array}$ <p>Glycine (Gly / G)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_3 \end{array}$ <p>Alanine (Ala / A)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{C}_4\text{H}_4\text{N}_2 \end{array}$ <p>Histidine (His / H)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{OH} \end{array}$ <p>Serine (Ser / S)</p>
$\begin{array}{c} \text{H}_2 \\   \\ \text{C} \\ / \quad \backslash \\ \text{H}_2\text{C} \quad \text{CH}_2 \\   \quad \quad   \\ \text{H}_2\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \end{array}$ <p>Proline (Pro / P)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{CH}_2 \\   \\ \text{COOH} \end{array}$ <p>Glutamic Acid (Glu / E)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{COOH} \end{array}$ <p>Aspartic Acid (Asp / D)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{CH}_3 \end{array}$ <p>Threonine (Thr / T)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{SH} \end{array}$ <p>Cysteine (Cys / C)</p>
$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{CH}_2 \\   \\ \text{S} \\   \\ \text{CH}_3 \end{array}$ <p>Methionine (Met / M)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{CH} \\ / \quad \backslash \\ \text{CH}_3 \quad \text{CH}_3 \end{array}$ <p>Leucine (Leu / L)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH}_2 \\   \\ \text{C}=\text{O} \\   \\ \text{NH}_2 \end{array}$ <p>Asparagine (Asn / N)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{HC}-\text{CH}_3 \\   \\ \text{CH}_2 \\   \\ \text{CH}_3 \end{array}$ <p>Isoleucine (Ile / I)</p>	$\begin{array}{c} \text{H} \\   \\ \text{H}_3\text{N}^+ - \overset{\ominus}{\text{C}} - \overset{\ominus}{\text{C}} \\   \\ \text{CH} \\ / \quad \backslash \\ \text{CH}_3 \quad \text{CH}_3 \end{array}$ <p>Valine (Val / V)</p>

- Phenylalanine hydroxylase needed to turn phenylalanine into tyrosine which can be easily eliminated from body
  - PKU is a genetic disorder in which a person lacks phenylalanine hydroxylase
  - Newborns by law must be tested for this disorder, and a special diet, low in phenylalanine, is required, possibly for life
- Nutrasweet and Neotame are aspartame and are made of (left-handed) aspartic acid and the methyl ester of phenylalanine, so people with PKU can't have it.
- At moderate temperatures (86° F), methyl group breaks off, releasing methanol, which is toxic and in large quantities causes blindness.
- The liver turns methanol into formaldehyde, a known carcinogen.
- Equal is made of glucose and Nutrasweet, so as to make the volume of sweetener more or less the same as ordinary sugar (sucrose). Otherwise people won't buy it.
- Equal also contains silicon dioxide (SiO<sub>2</sub>) (sand) to prevent caking.
- Thus Equal, Nutrasweet and Neotame shouldn't be used in hot drinks and bottles or cans of these artificially-sweetened soft drinks that sit in the hot sun are suspect.
- Sucralose (Splenda) does not seem to be subject to these concerns, but has others. Got a bad rep because it was discovered accidentally when a new insecticide was being developed.
- There are two bulk additives to increase volume, dextrose and maltodextrin, which are carbohydrates and contain calories.
- Sucralose, which more properly is called trichlorogalactosucrose, also contains chlorine, a carcinogen contained in poison gas, plastics and pesticides.
- Bottom line: in the absence of long-term studies of humans, one is trading a known risk (obesity) for unknown risks.

# Other Monomers



Wikipedia



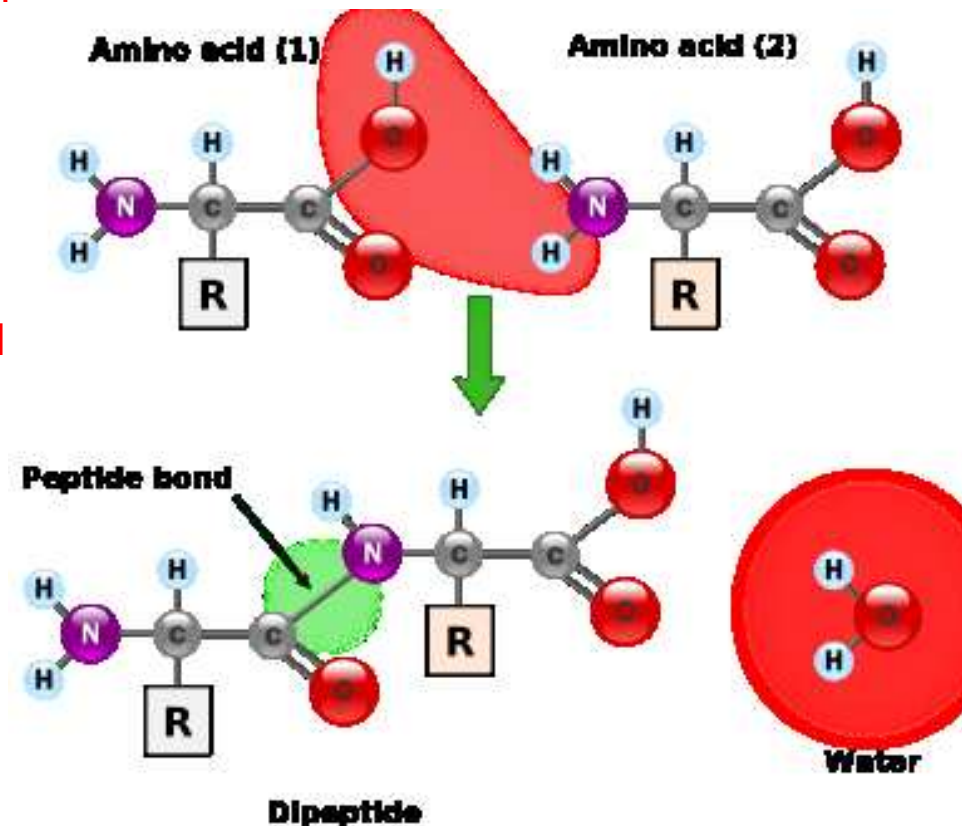
# Polymerization

- Polymerization is the process of joining monomers into long chains
- Two types:
  - Addition polymerization – linking molecules incorporating double or triple chemical bonds. These extra bonds can break and serve as the links.
  - Condensation polymerization – linking molecules containing functional groups (amines or carboxyls) which form a peptide bond and release water.
- Biological systems rely on condensation polymerization, which requires

- Concentration of monomers
- Availability of activation energy used to break certain bonds
- Removal of water (dehydration). This is essential to prevent reversal of polymerization into monomers through the Law of Mass Action:



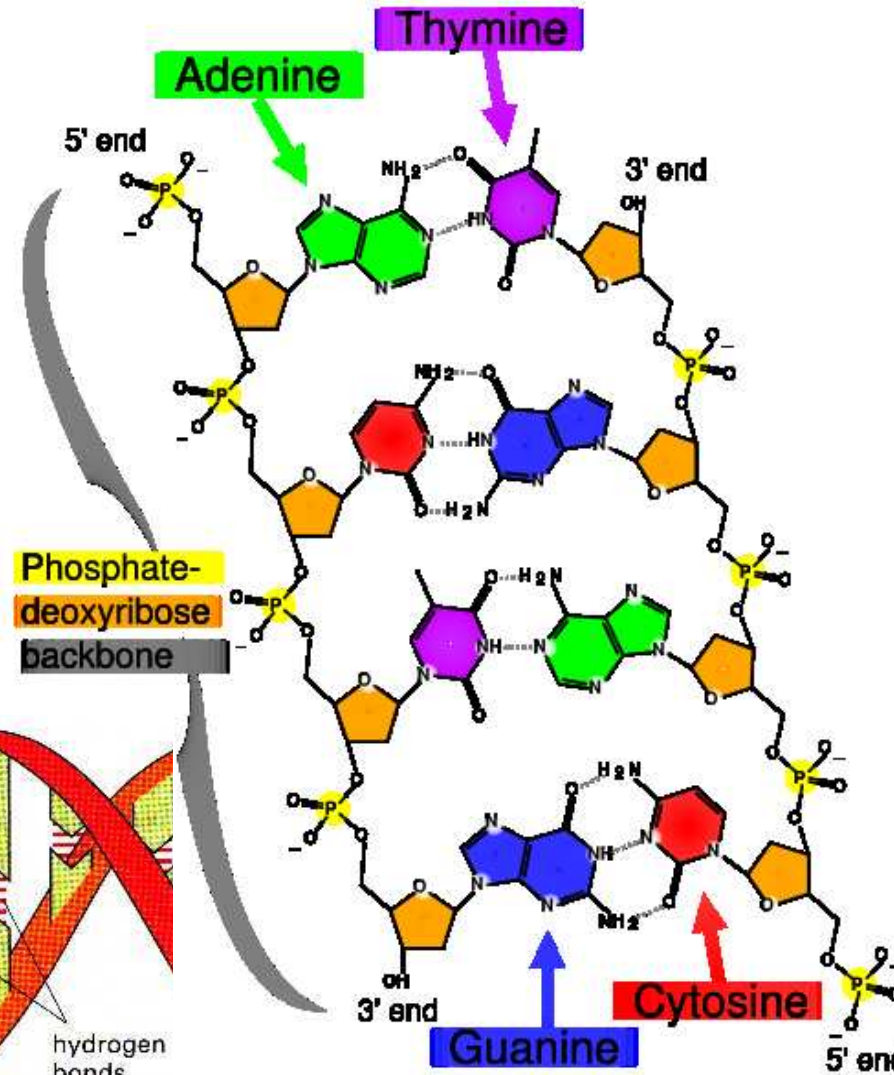
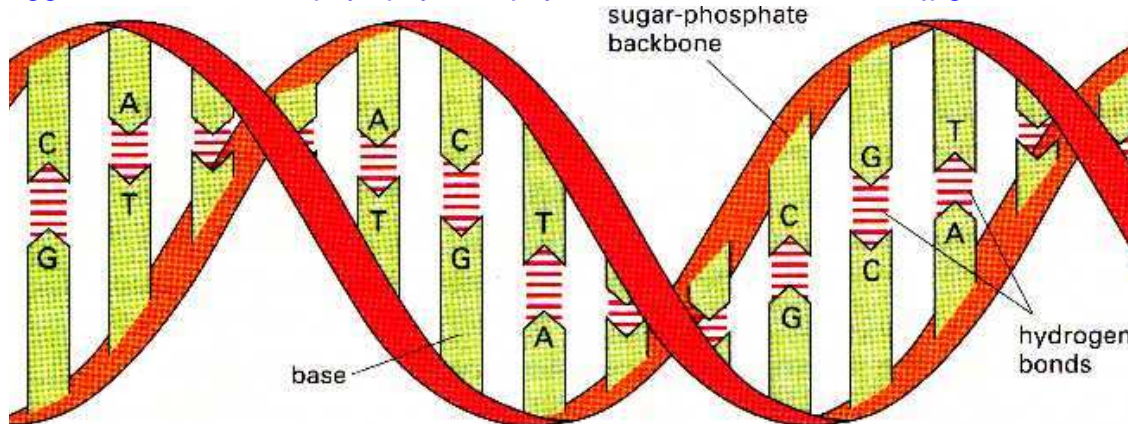
A, B are monomers,  
C is a polymer, D is H<sub>2</sub>O (water)



# DNA

- DNA is the molecule that stores the information necessary for life to exist and reproduce. Stretched out, it is shaped like a double helix or a twisted ladder, with two bases (a base-pair) forming each rung, and sugar and phosphate groups forming the sides.
- A single human DNA molecule contains about 100 million base-pairs.
- If stretched, it would extend about 5 cm.
- Since the bases pair only in certain combinations (A with T, C with G), the sequence of bases on one side of the DNA are the complements of the opposite side.
- Information is therefore stored in duplicate.

[tiger.uic.edu/classes/phys/phys461/phys450/ANJUM04/DNAhelix.jpg](http://tiger.uic.edu/classes/phys/phys461/phys450/ANJUM04/DNAhelix.jpg)



Wikipedia

# Genetic Code

- The stored information codes the sequencing of amino acids needed for the synthesis of proteins.
- A segment of DNA sequencing a useful protein is known as a gene.
- With 20 different amino acids, 3 sequential bases (a codon) are needed for each.

3 at a time

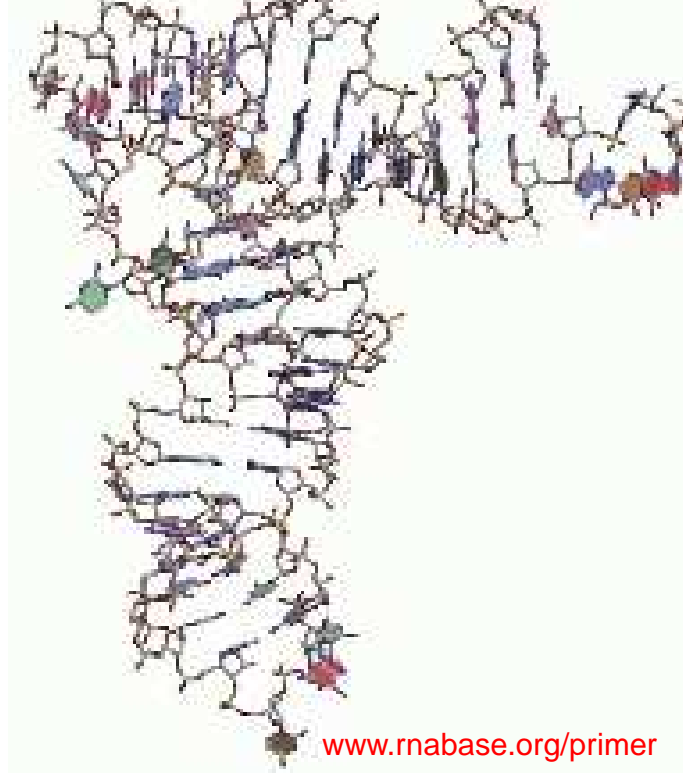
TTT phe	TCT ser	TAT tyr	TGT cys
TTC phe	TCC ser	TAC tyr	TGC cys
TTA leu	TCA ser	TAA stop	TGA stop
TTG leu	TCG ser	TAG stop	TGG try
CTT leu	CCT pro	CAT his	CGT arg
CTC leu	CCC pro	CAC his	CGC arg
CTA leu	CCA pro	CAA gln	CGA arg
CTG leu	CCG pro	CAG gln	CGG arg
ATT ile	ACT thr	AAT asn	AGT ser
ATC ile	ACC thr	AAC asn	AGC ser
ATA ile	ACA thr	AAA lys	AGA arg
ATG met	ACG thr	AAG lys	AGG arg
GTT val	GCT ala	GAT asp	GGT gly
GTC val	GCC ala	GAC asp	GGC gly
GTA val	GCA ala	GAA glu	GGA gly
GTG val	GCG ala	GAG glu	GGG gly

2 at a time

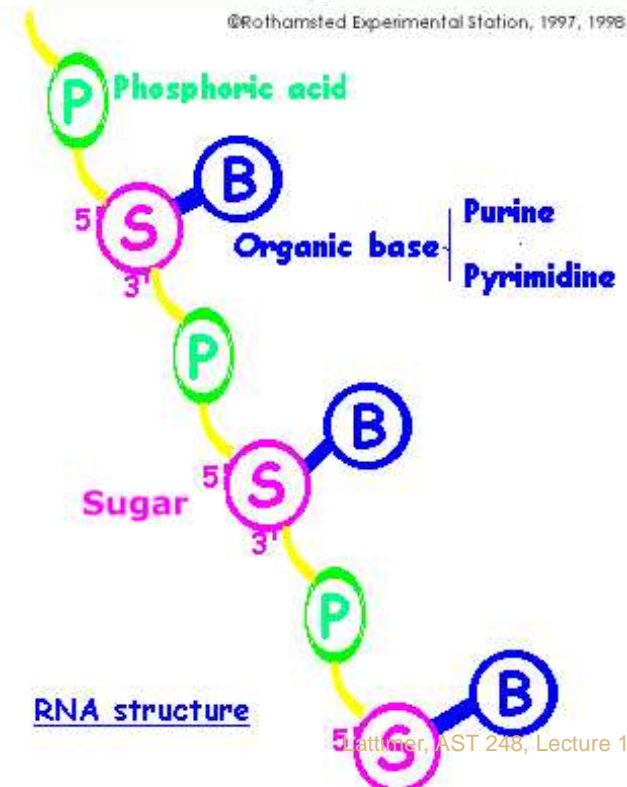
AA	AT	AC	AG
TA	TT	TC	TG
CA	CT	CC	CG
GA	GT	GC	GG

# RNA

- RNA transmits genetic information from DNA to the cytoplasm of the cell and is involved with the synthesis of proteins that control chemistry within the cell.
- RNA is made of the sugar ribose, phosphate, and bases.
- RNA bases are adenine (A), guanine (G), cytosine (C) and uracil (U). U substitutes for the T (thymine) of DNA.
- RNA molecules are relatively small single nucleotide chains, with a backbone of alternating molecules of ribose and phosphate.
- An RNA base is attached to each sugar.
- There are 3 main types of RNA:
  1. Ribosomal RNA – rRNA – exist outside the nucleus in ribosomes, small structures where protein synthesis takes place. Ribosome is a complex consisting of 60% rRNA and 50% proteins.
  2. Messenger RNA – mRNA – nucleic acids that record information copied (transcription) from a DNA segment and carry it to ribosomes.
  3. Transfer RNA – tRNA – deliver amino acids one by one to protein chains growing at ribosomes.

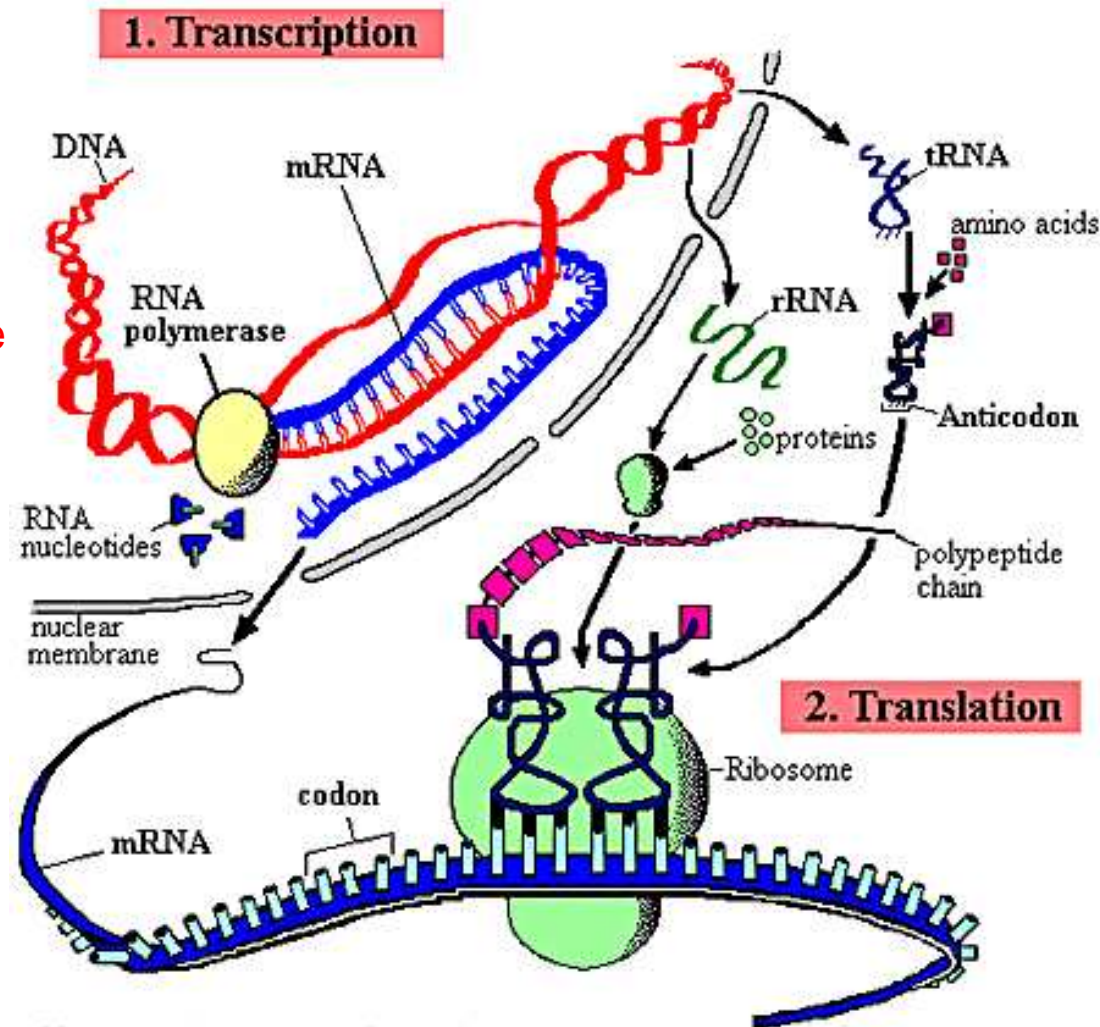


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# Protein Synthesis

- In transcription, an enzyme (protein) causes part of a DNA to unwind, exposing single strands which serve as templates for the construction of mRNA. An mRNA contains the coding, in the sequence of codons, for the structure of a protein.
- In translation, the mRNA and tRNAs are utilized to form a polypeptide chain that, when finished, will be a protein. tRNA is fed into the ribosome and the anticodon is detached and added to the polypeptide chain.



## Protein synthesis

[folding.stanford.edu/education/Assets/proteinsynthesis.gif](http://folding.stanford.edu/education/Assets/proteinsynthesis.gif)

# Reproduction

- Asexual reproduction involves unwinding and separation of DNA strands (unzipping), with complementary strands being reconstructed. It involves a single parent.
- Sexual reproduction is more complicated, involving a two-step process and two parents.
  - Meiosis involves halving the number of chromosomes by division.
  - Fertilization involves fusing two gametes and restoration of original number of chromosomes
- Chromosomes are distinct DNA molecules, containing many genes, ranging from tens of kilobase-pairs to hundreds of megabase-pairs, depending on the organism.
- A human cell contains 46 chromosomes, which forms the complete set of instructions for making an organism and is called the genome.
- In total, a human cell contains about 3 billion base-pairs, with a total length of about 3 meters.
- The total length of all DNA in a person is about  $2 \cdot 10^{13}$  meters, equivalent to 130 AU.
- The genome size varies widely among organisms. The smallest, about 4000 base-pairs, occurs in viruses. The largest known genome occurs in amoeba, about  $7 \cdot 10^{11}$  base-pairs, 200 times the length of the human genome.
- Much of the genome is “junk DNA” whose purpose is unknown but seems to be not critical. It could be remnants of earlier coding, much like exists in Windows software.