Astrobiology

Biomolecules of terrestrial life

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Giovanni Vladilo (INAF-OATs)

Biological macromolecules

The most important biomolecules of terrestrial life are macromolecules with a large number of atomic units

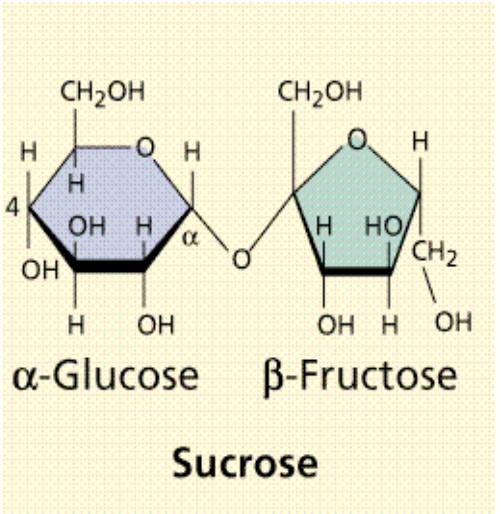
Created by polymerization of a large number of subunits (monomers)

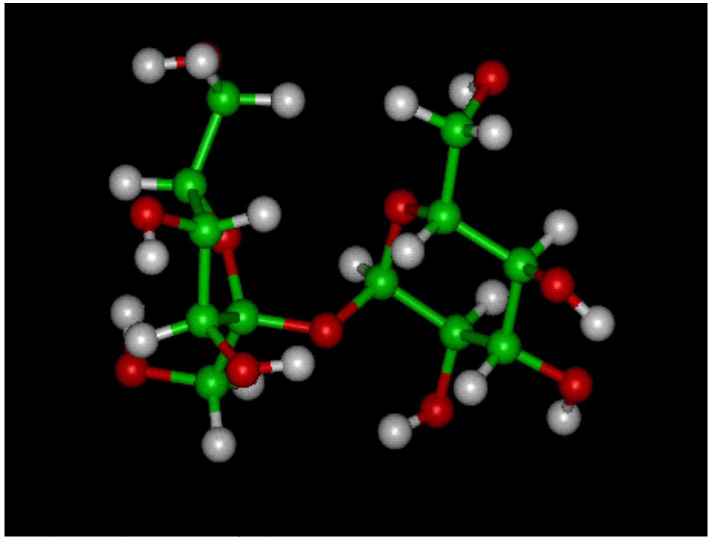
Terrestrial life features 4 types of macromolecules:

carbohydrates, lipids, proteins and nucleic acids

- carbohydrates → energy storage
- lipids → compartmentalization
- proteins → metabolic
- nucleic acids → genetic

Carbohydrates (saccharides)





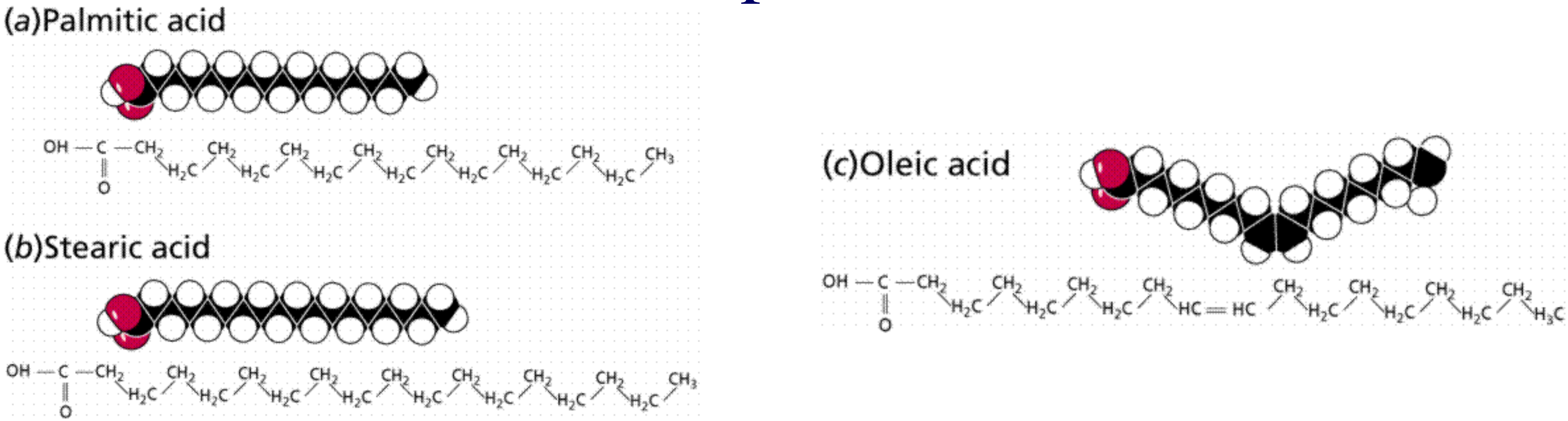
The most abundant molecules in the biological world

- Primary source of <u>chemical energy</u> for most organims

General formula: $C_x(H_2O)_y$

- Monosaccharides (simple sugars)
- Oligosaccharides
  - From 2 to 10 units of monosaccharides
- Polysaccharides
  - More than 10 monosaccharides

Lipids



Heterogeneous class of organic molecules with common solubility properties

- Insoluble in water
- Soluble in certain types of non-polar solvents

Larger number of C–H bonds with respect to carbohydrates

- Used for long-term storage of energy

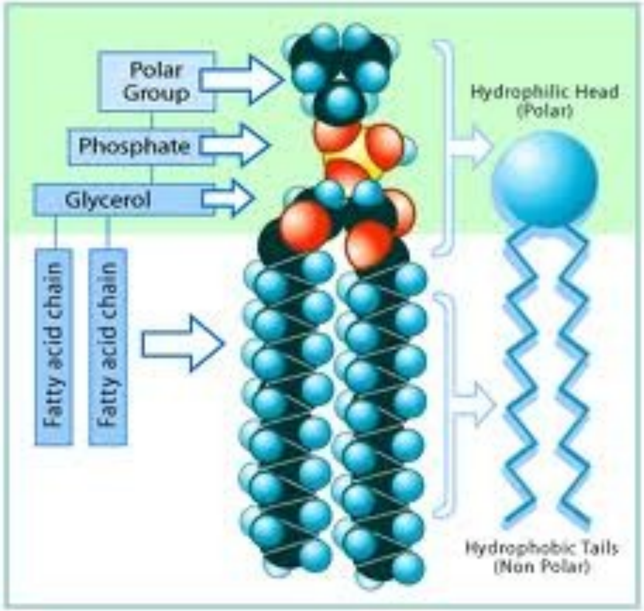
Phospholipids and cell membranes

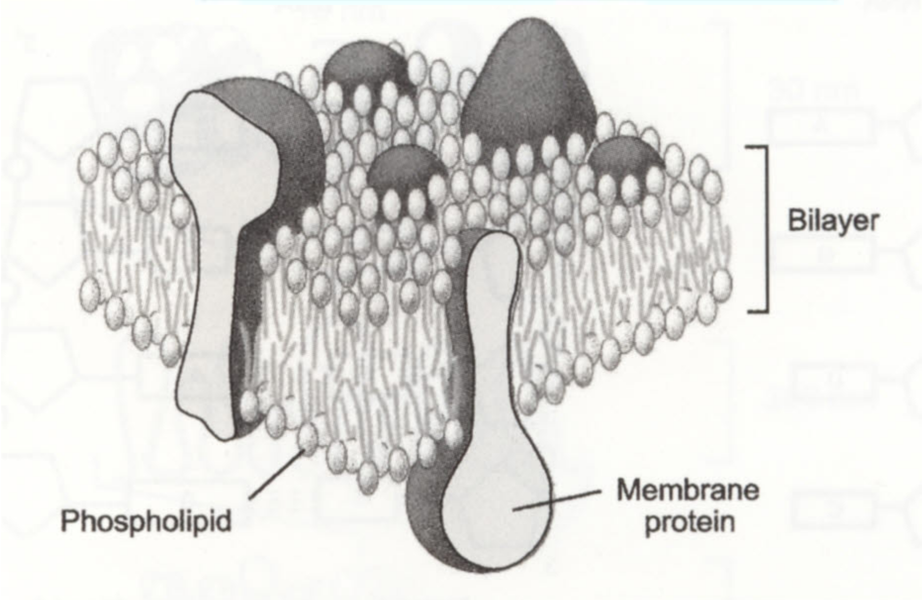
Phospholipids

Examples of amphiphilic molecules with a hydrophilic end and a hydrophobic end

In liquid water phospholipids spontaneously form a double layer of molecules (bilayer), with the hydrophobic ends facing each other in the inner part, and the hydrophilic ends facing the water

Bilayers of phospholipids are the main structural components of cell membranes



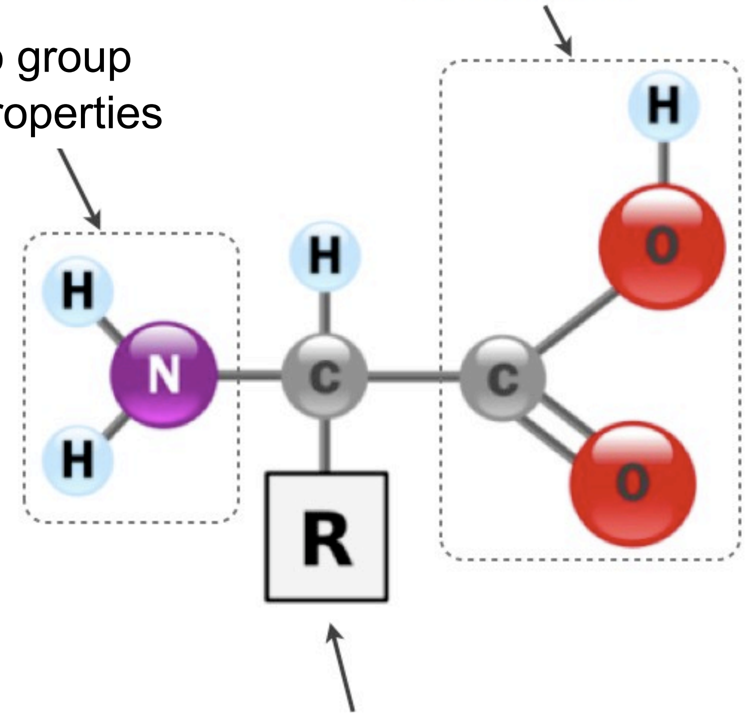


Biological amino acids

Constituents of proteins

The carboxyl group
has acid properties

The amino group
has basic properties



The lateral group determines the
chemical properties specific of each
amino acid

Proteins

Proteins are polymers of amino acids

Short chains of amino acids are called peptydes

Long, unbranched peptyde chains are called polypeptides

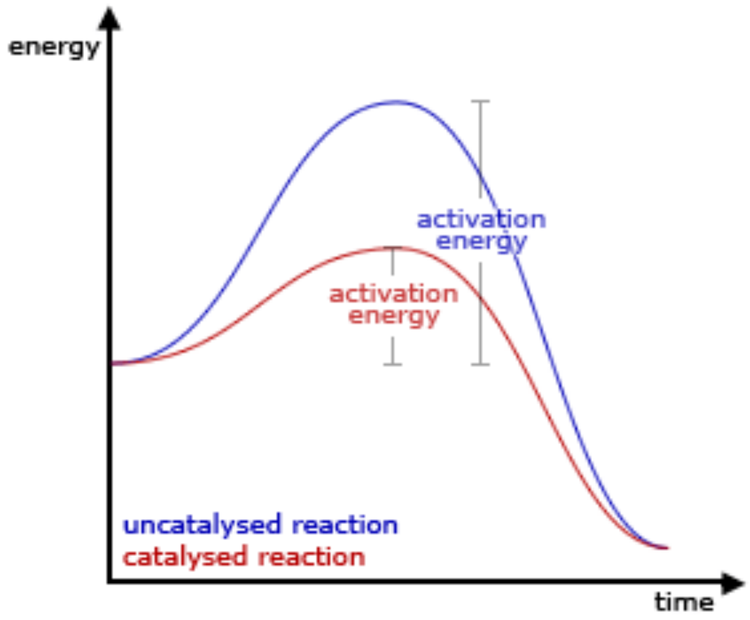
Proteins are formed by one or more chains of polypeptides

Molecular masses of proteins vary between ~10^3 e ~10^6 atomic mass units

They contribute to about half the mass of the cell

Proteins play fundamental functions in living organisms

Mostly structural and enzymatic (i.e., catalytic) functions



Terrestrial biological amino acids

Proteins use only 20 types of amino acids

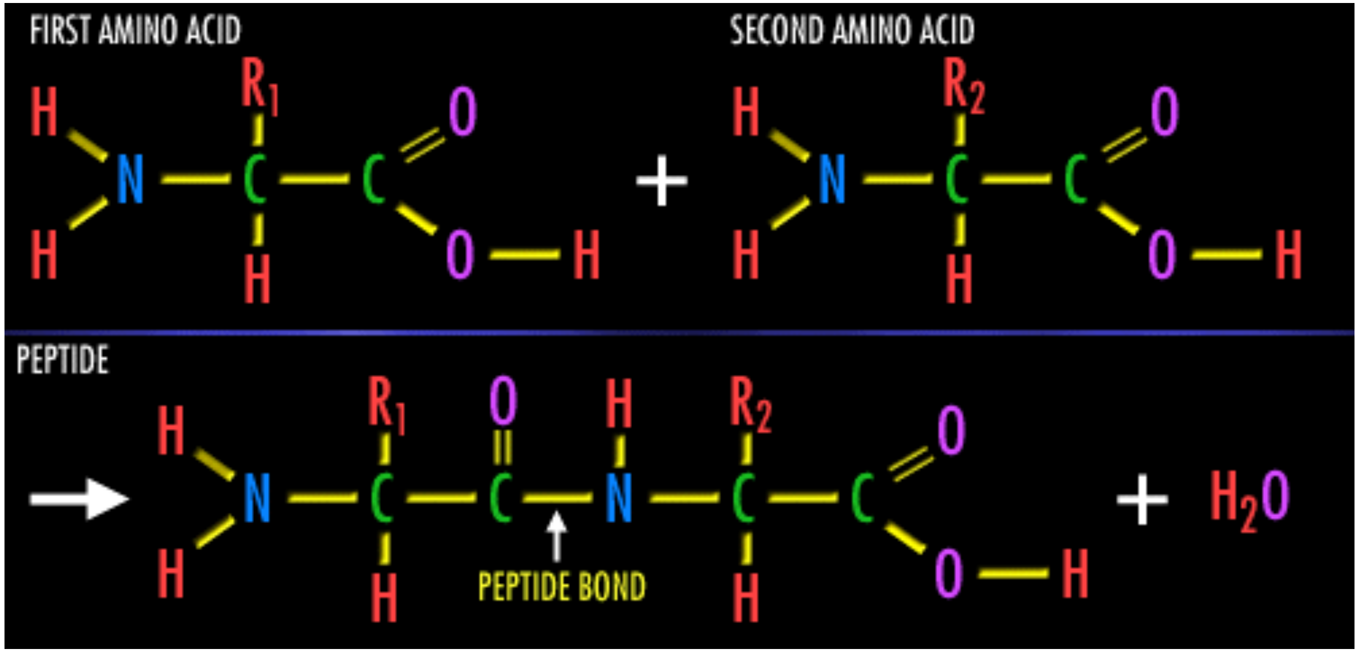
Organic chemistry allows for the existence of thousands of amino acids

Apparently, terrestrial life has "chosen" a short list of amino acids, sufficiently representative of the different types of chemical properties that are required to build up the variety of proteins necessary to living organisms

Table 7.2 *The Twenty Amino Acids Found in Living Organisms*

*Amino Acid**	*Chemical Formula*	*Number of Atoms*
L-Alanine	$C_3H_7O_2N$	13
L-Arginine	$C_6H_{15}O_2N_4$	27
L-Asparagine	$C_4H_8O_3N_2$	17
L-Aspartic Acid	$C_4H_6O_4N$	15
L-Cysteine	$C_3H_7O_2NS$	14
L-Glutamic Acid	$C_5H_8O_4N$	18
L-Glutamine	$C_5H_{10}O_3N_2$	20
Glycine	$C_2H_5O_2N$	10
L-Histidine	$C_6H_9O_2N_3$	20
L-Isoleucine	$C_6H_{13}O_2N$	22
L-Leucine	$C_6H_{13}O_2N$	22
L-Lysine	$C_6H_{15}O_2N_2$	25
L-Methionine	$C_5H_{11}O_2NS$	20
L-Phenylalanine	$C_9H_{11}O_2N$	23
L-Proline	$C_5H_9O_2N$	17
L-Serine	$C_3H_7O_3N$	14
L-Threonine	$C_4H_9O_3N$	17
L-Tryptophan	$C_{11}H_{12}O_2N_2$	27
L-Tyrosine	$C_9H_{11}O_3N$	24
L-Valine	$C_5H_{11}O_2N$	19

From amino acids to polypeptides



Amino acids are bound to each other with peptide bonds

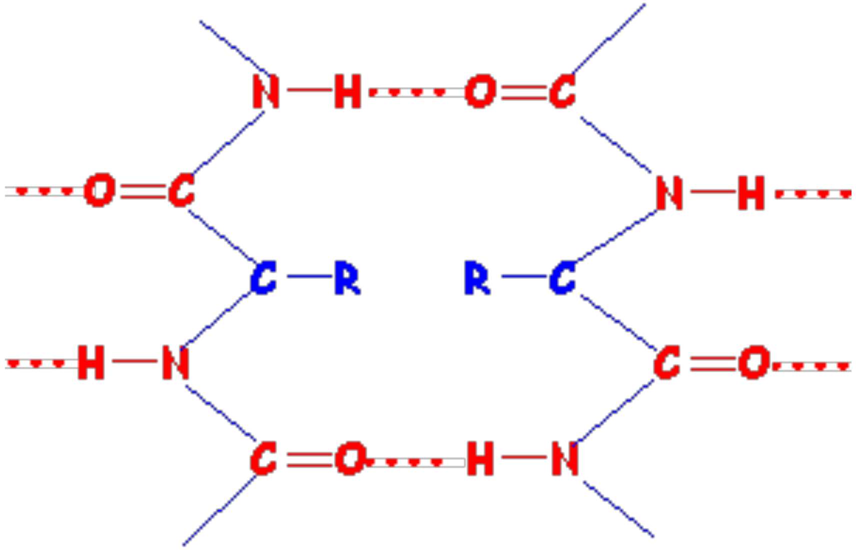
The carboxyl end ties to the amino end of the next molecule

A sequence OC-NH is formed (peptide bond)

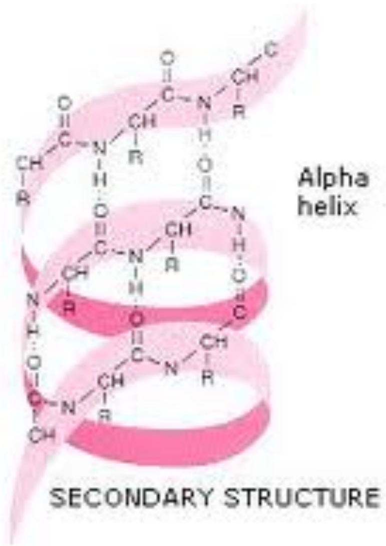
A water molecule is released each time a peptide bond is created

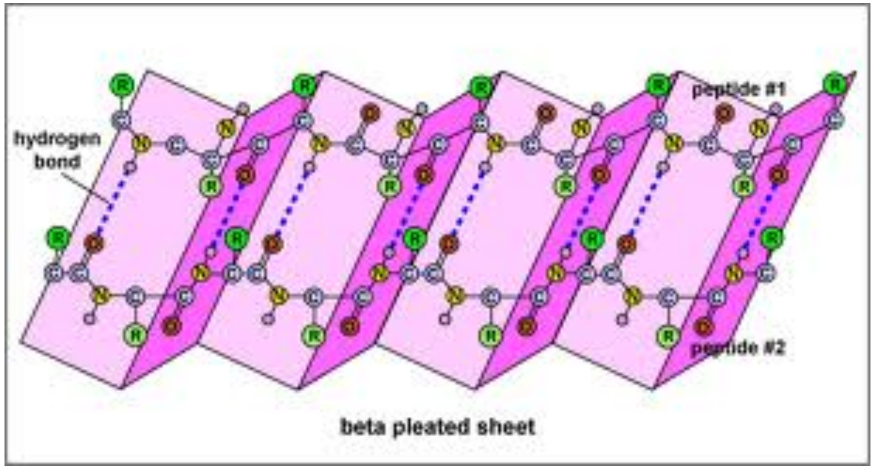
A water molecule is required to break a peptide bond

From polypeptides to 3D proteins
Importance of hydrogen bonds as intramolecular forces



Spontaneous formation of geometrical configurations with lowest potential energy

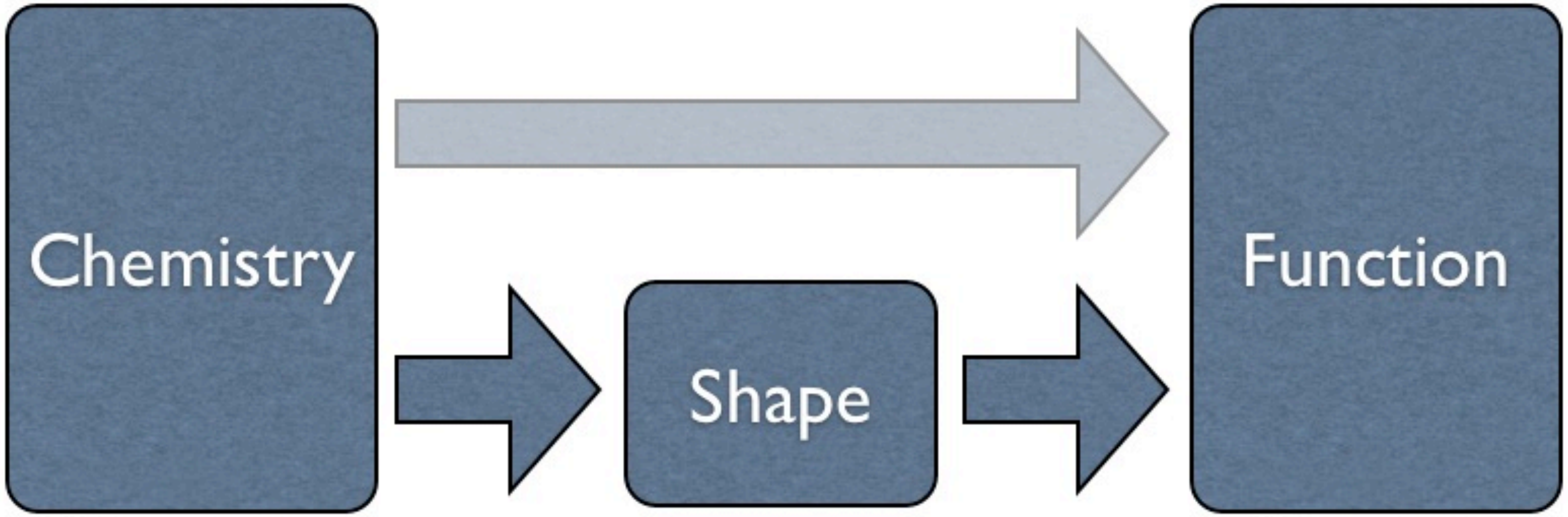


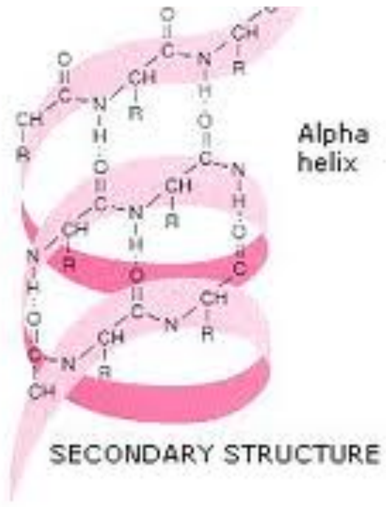


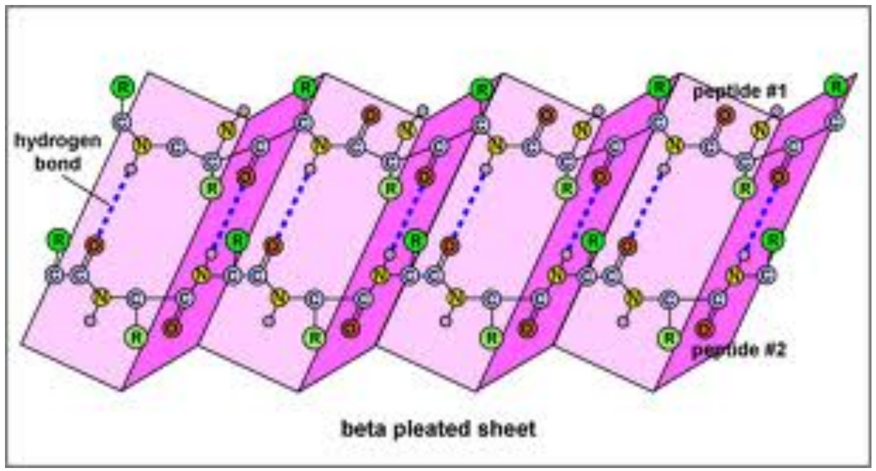
Proteins

The importance of 3D structures

The shape of proteins determines, in large part, their function







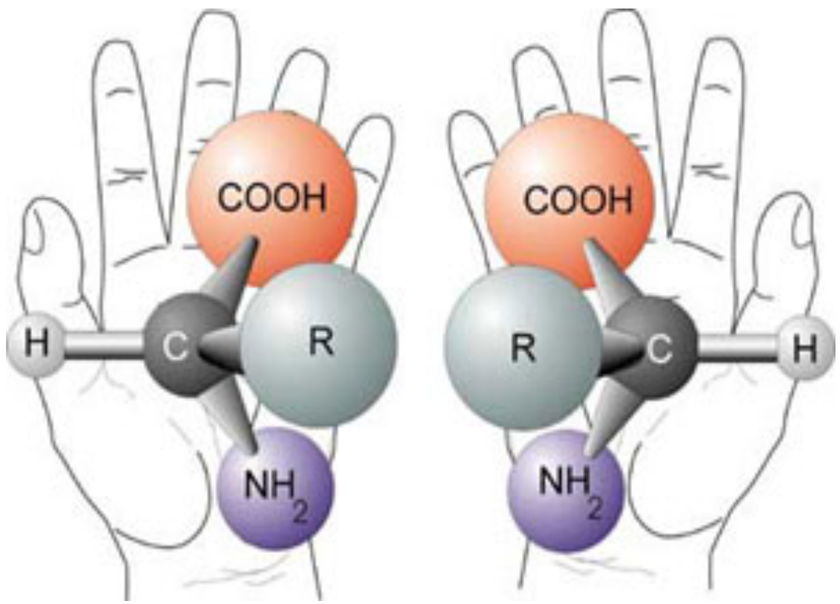
Chirality

Molecules with same chemical formula but different structure are called isomers

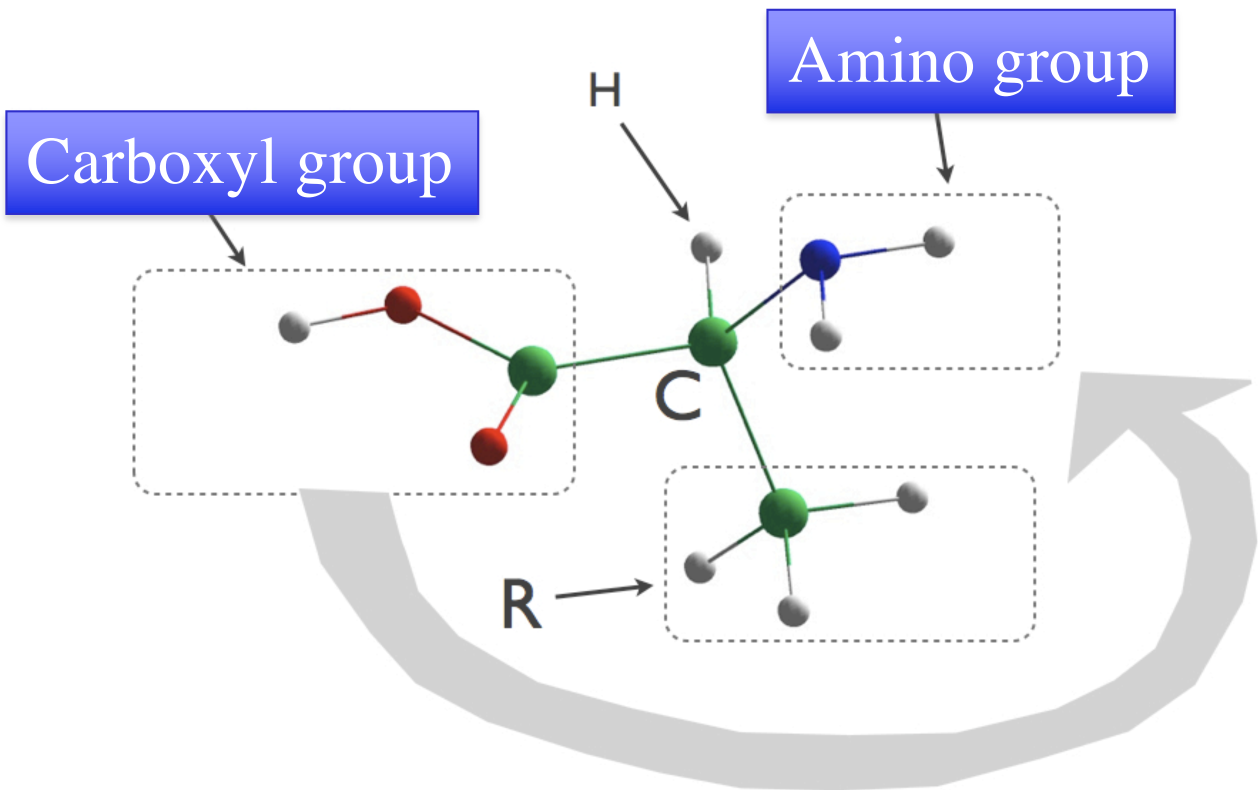
Chiral molecules are isomers with a center of symmetry ("stereocenter")
They cannot be superimposed to their mirror image
The two mirror images of a chiral molecule are called enantiomers

Amino acids are chiral

The carbon atom at the center of the amino acid is the stereocenter



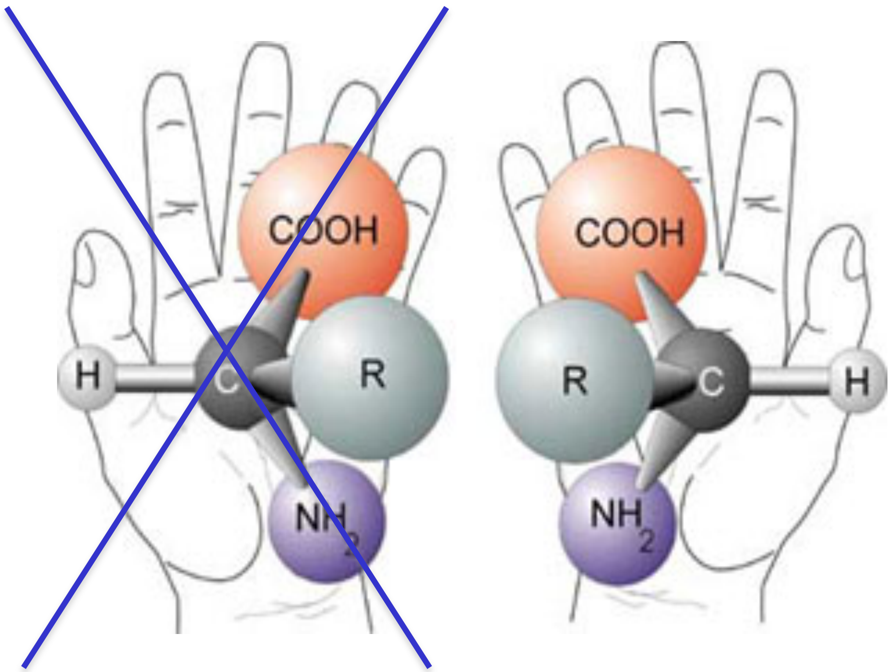
The two enantiomers of amino acids are called L and D according to the “CORN” convention



Example of L-type amino acid: L-alanine

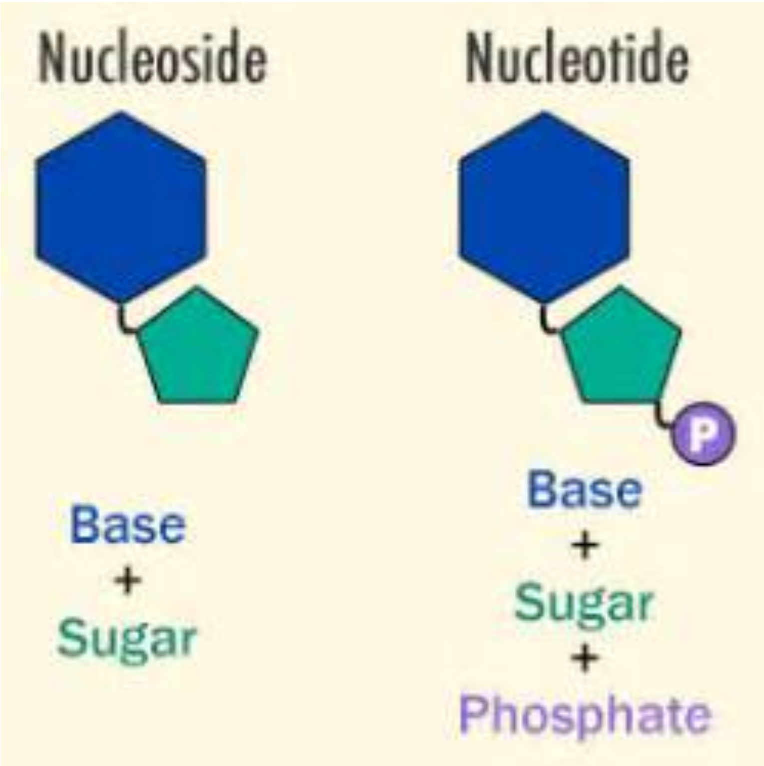
Homochirality of biomolecules

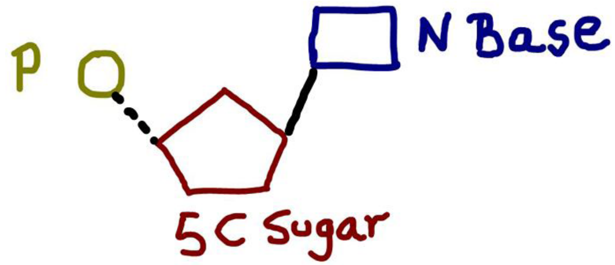
Protein amino acids are homochiral:
they only show the L-type enantiomer



Nucleosides and nucleotides

Constituents of the DNA and RNA





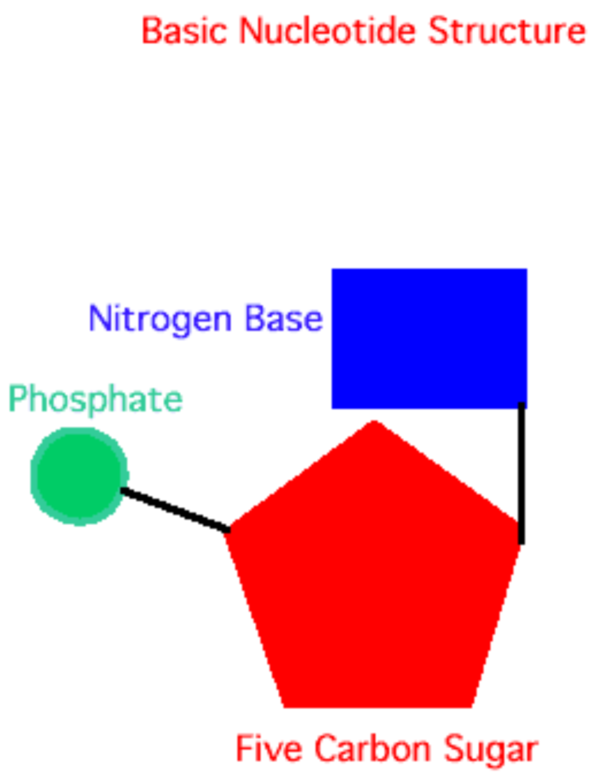
NUCLEO –

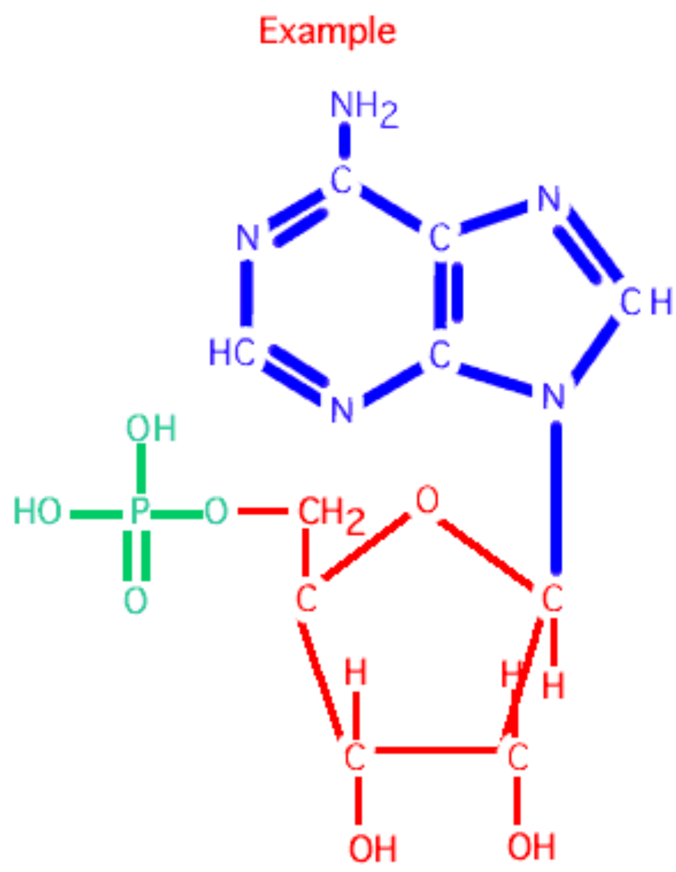
SIDE = SUGAR + BASE

TIDE = SIDE + PHOSPHATE

Nucleotides

Constituents of the DNA and RNA





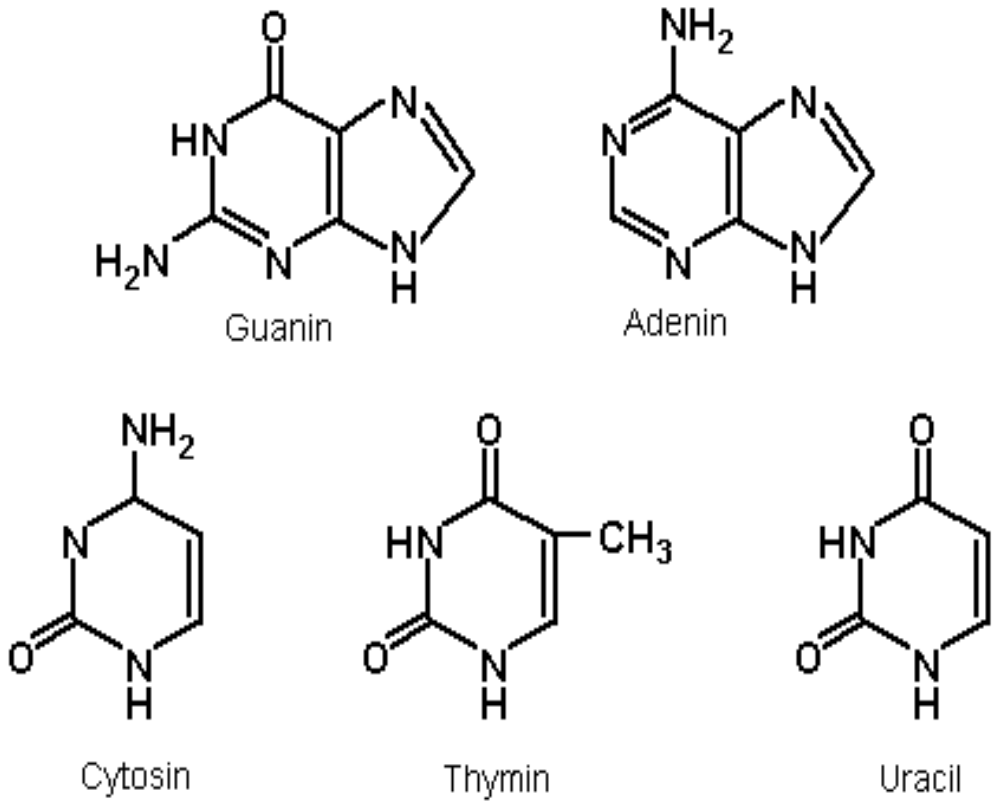
Adenosine 5' phosphoric acid

Nitrogen bases

aromatic rings with N substitutions

Purines

Pyrimidines



Nucleic acids

Nucleic acids are polymers of nucleotides

Depending on the type of organism,
they may contain ~ 10^6 – 10^8 nucleotides

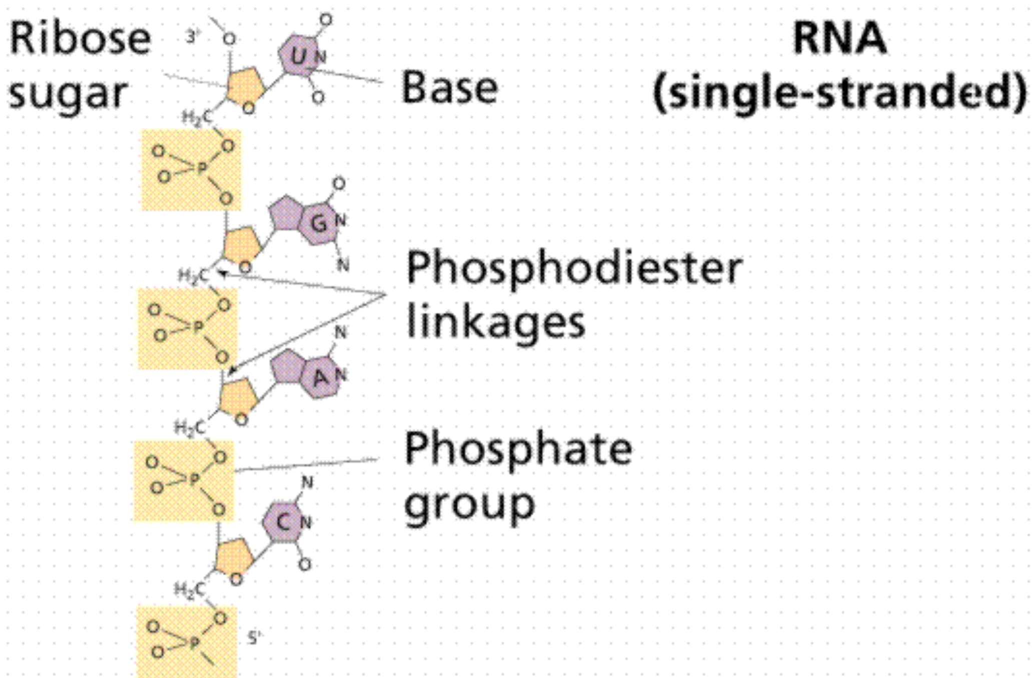
Nucleic acids store and use the genetic information

There are two types: DNA and RNA
DNA preserves the information
RNA, which comes in different forms, uses the information
for driving metabolic/replication processes

Nucleic acids: RNA

RNA has a single strand of nucleotides

The backbone of the strand is made up of a sequence of phosphate groups and ribose sugars



Has 4 types of nucleobases

Purines

Adenine, Guanine

Pyrimidines

Cytosine, Uracyl

RNA drives the synthesis of proteins

The order of the nitrogen bases on the backbone determines the sequence in which amino acids are assembled

Nucleic acids: DNA

DNA has two strands that form a double helix structure

The backbone of each strand is made up of a sequence of phosphate groups and <u>deoxyribose</u> sugars

DNA has 4 types of nucleobases

- 2 purins
  - Adenine e Guanine
- 2 pyrimidins
  - Cytosine e Thymine
    - Thymine replaces Uracyl, which is instead used in the RNA

The complementarity of purines and pyrimidines is essential for pairing the two strands

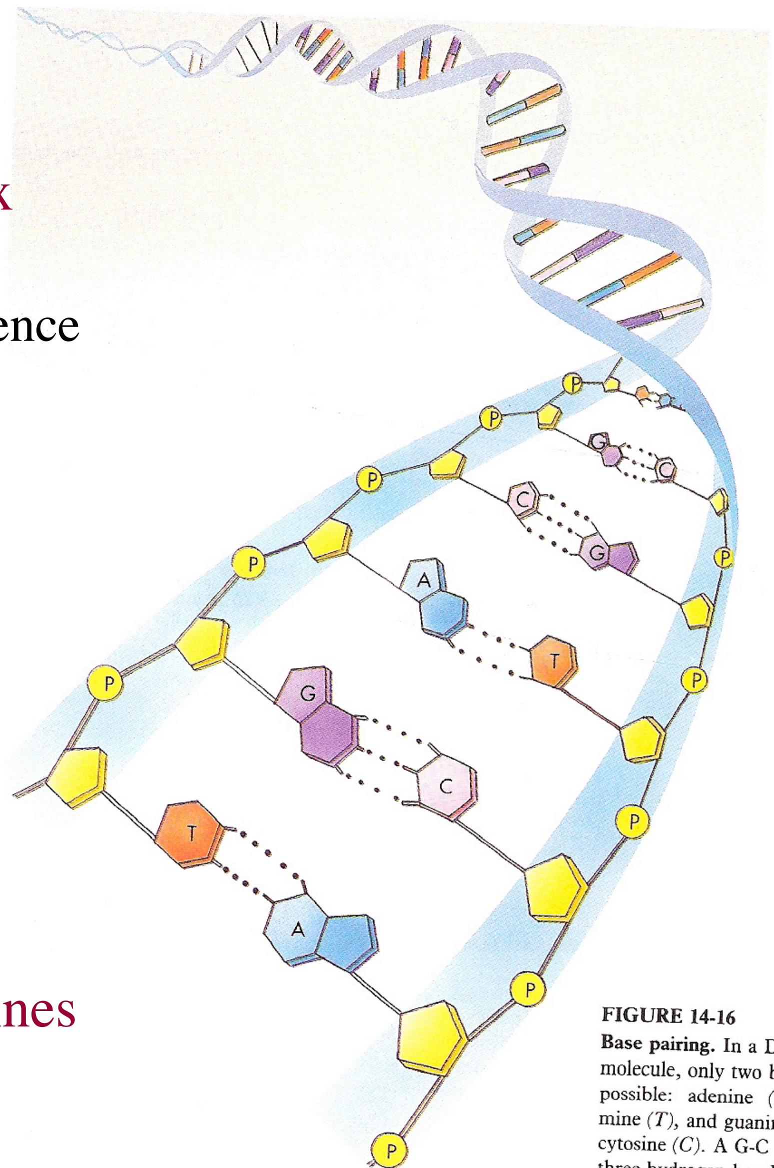


FIGURE 14-16
Base pairing. In a DNA molecule, only two base p possible: adenine (*A*) w mine (*T*), and guanine (*G* cytosine (*C*). A G-C base three hydrogen bonds; an base pair, only two.

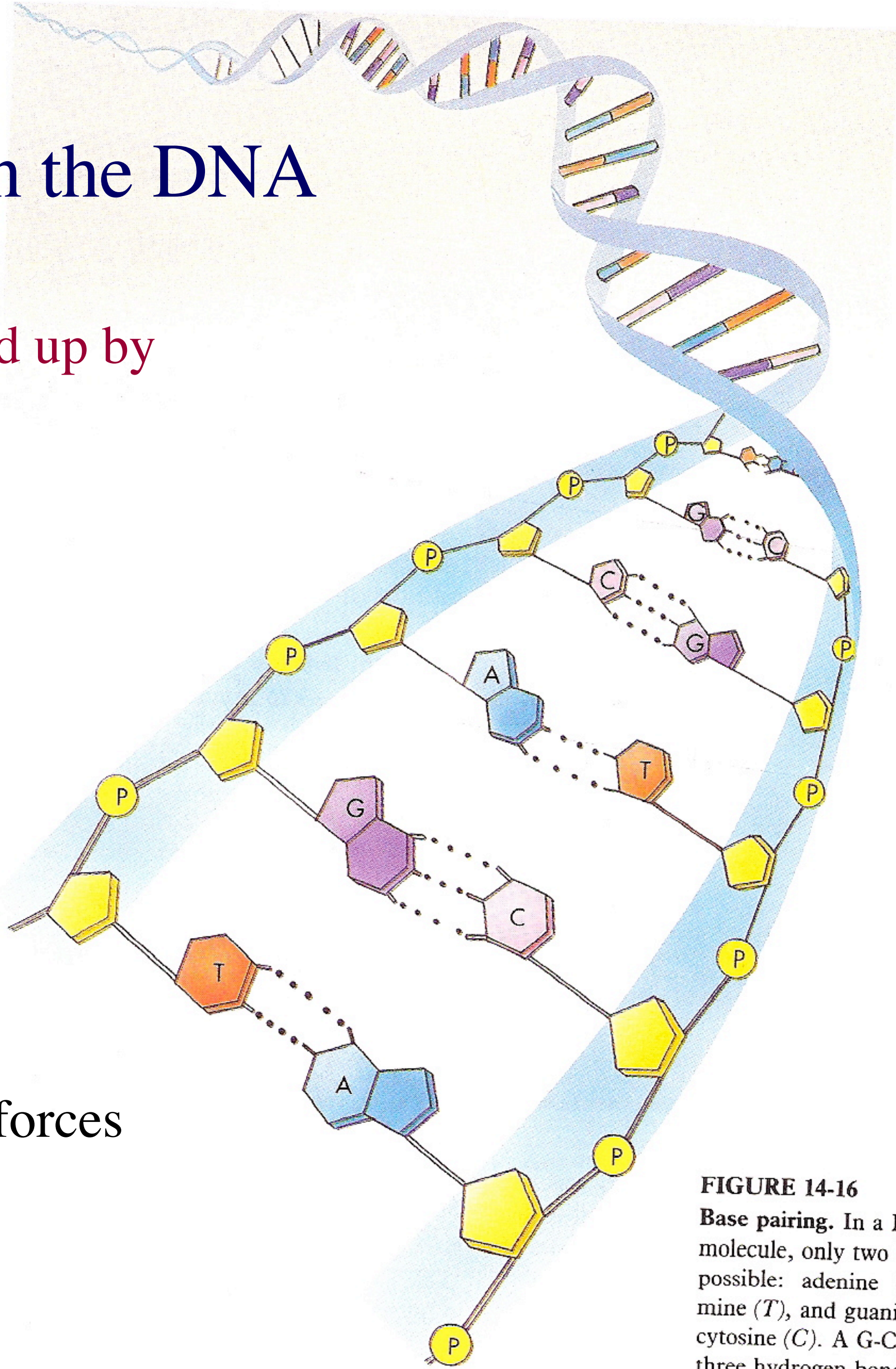
Hydrogen bonds in the DNA

The two strands of the DNA are tied up by hydrogen bonds

G-C pairs have 3 bonds

T-A pairs have 2 bonds

Hydrogen bonds as intramolecular forces



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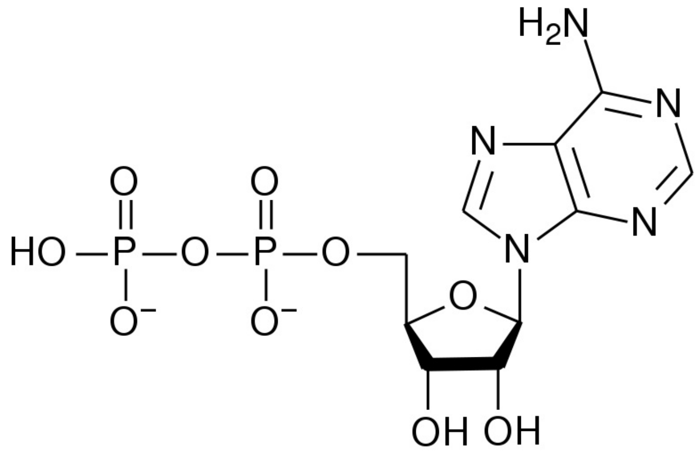
Base pairing. In a DNA molecule, only two base p… possible: adenine (A) w… mine (T), and guanine (G… cytosine (C). A G-C base… three hydrogen bonds; an… base pair, only two.

ADP & ATP
Energy exchange molecules

ADP

Adenosine diphosphate



ATP

Adenosine triphosphate