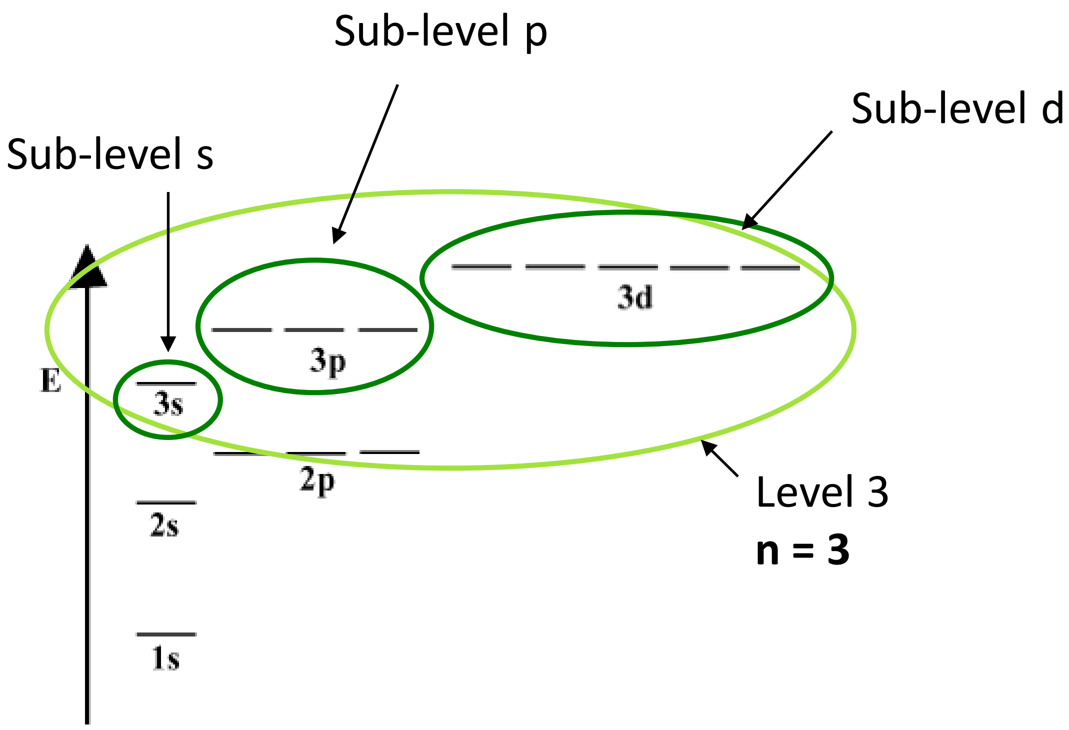
Chemistry of Life

Prof. Dr. Chiara Valsecchi

Atomic Orbitals Levels



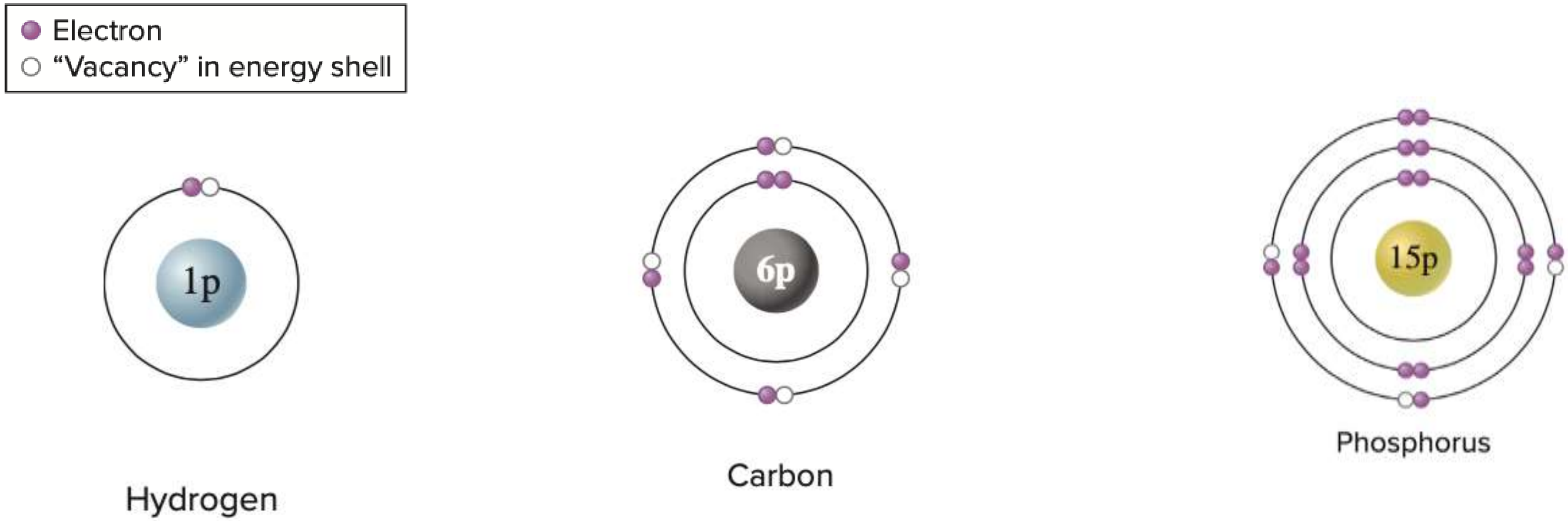
Each level can have sub-levels

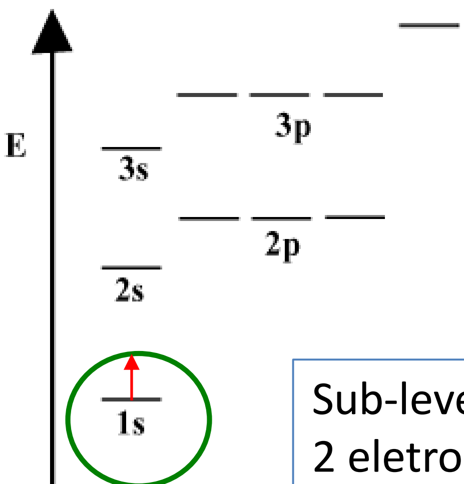
The outmost atomic orbital level is the one that will affect the capacity of the atoms to create bonds

↓

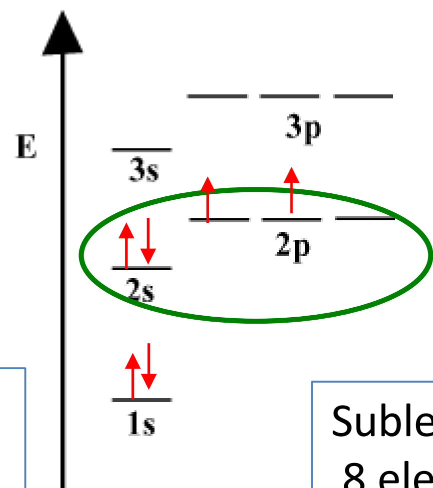
VALENCE SHELL

Valence Shell

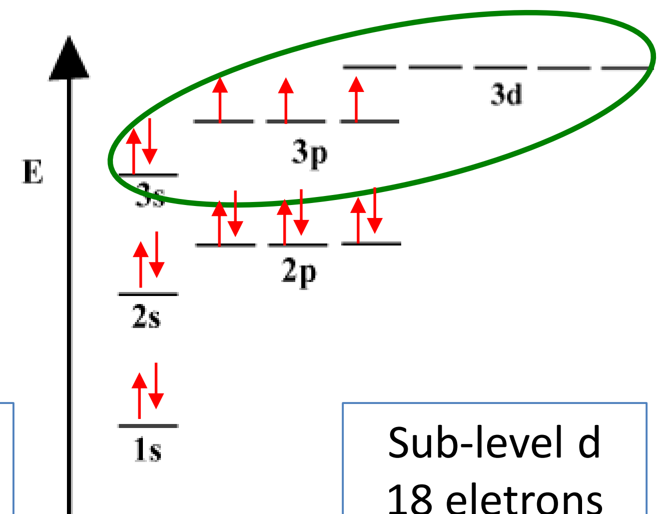




Sub-level s
2 eletrons

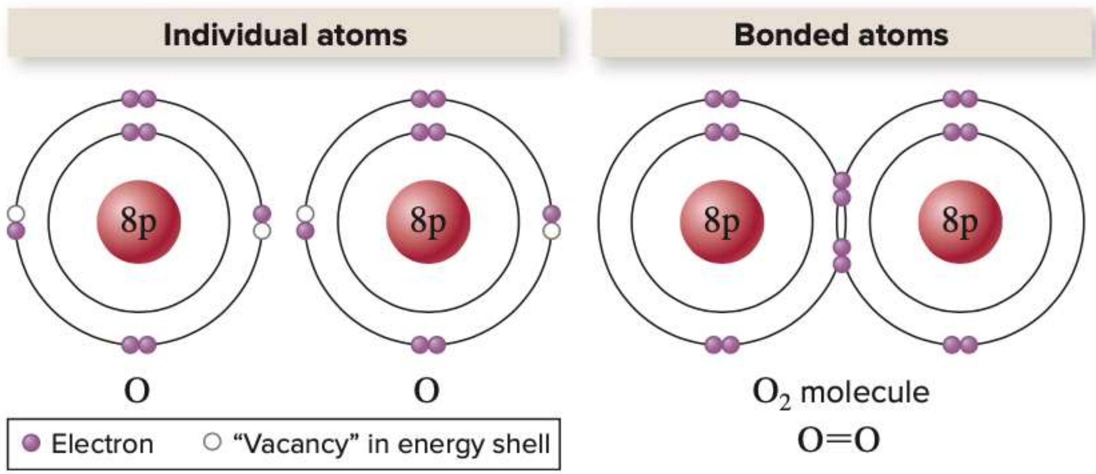


Sublevel p
8 eletrons



Sub-level d
18 eletrons

Covalent bond

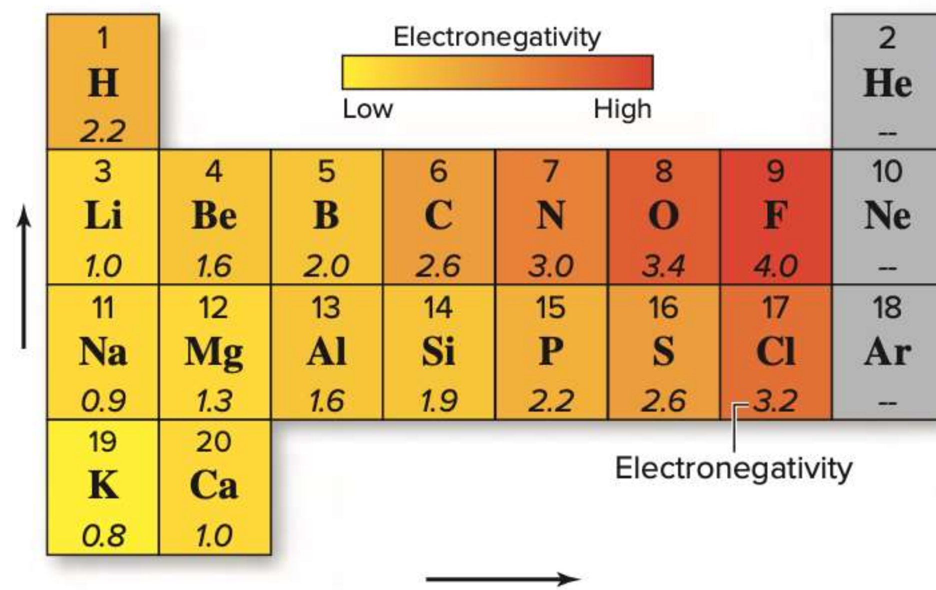


Electrons are shared

However, this is NOT na equal sharing

Atoms that are more electronegative (like O, F and Cl) keep the electron more close

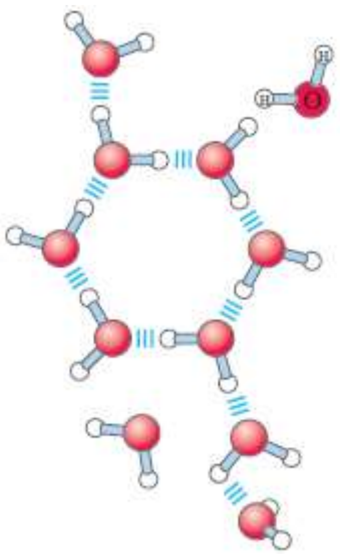
They have a partial negative charge
The others, a partial positive charge

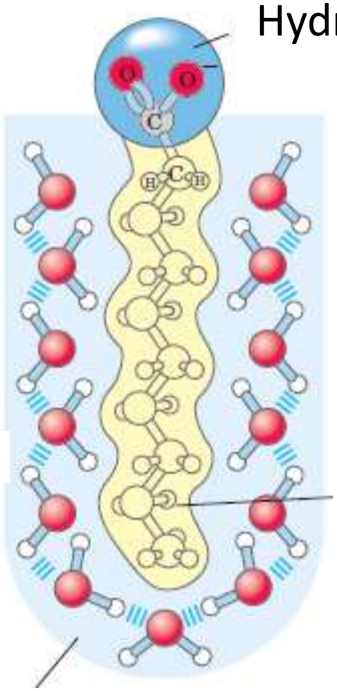


Polar or Apolar ?

Polar molecules interact between themselves and with water. They are called **HYDROPHILIC**.

Apolar molecules tend to separate from water (like oil): they are called **HYDROPHOBIC**.





pH Scale

Concentration of H^+ ions in water

To avoid scientific notation, due to small number, the pH Scale is actually a logaritmic scale

p : means: “minus logarithm of... ”

Ex.:

$[H^+] = 1,0 \times 10^{-5}$

pH= **-log** $[H^+] = -\log [10^{-5}] = +5$

pH is negative logarithm of H^+ concentration

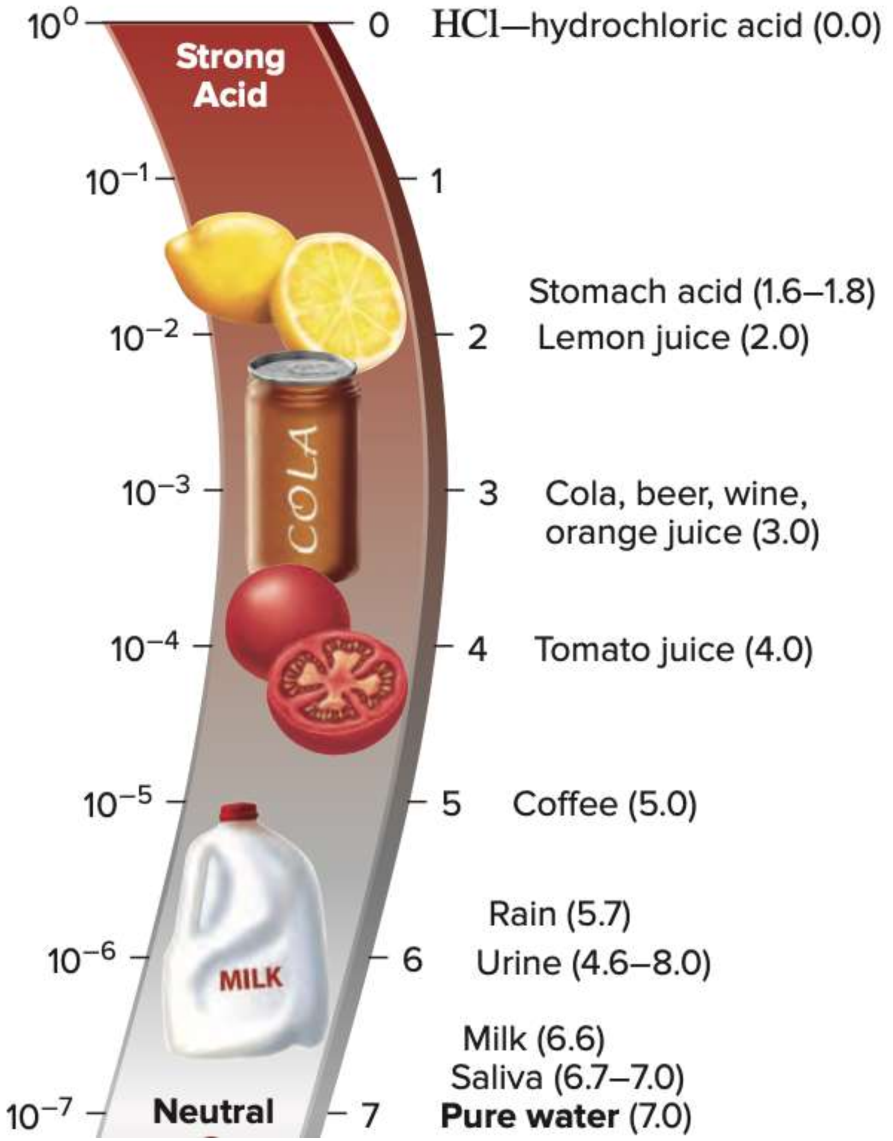
pH Scale

Acidic solution:

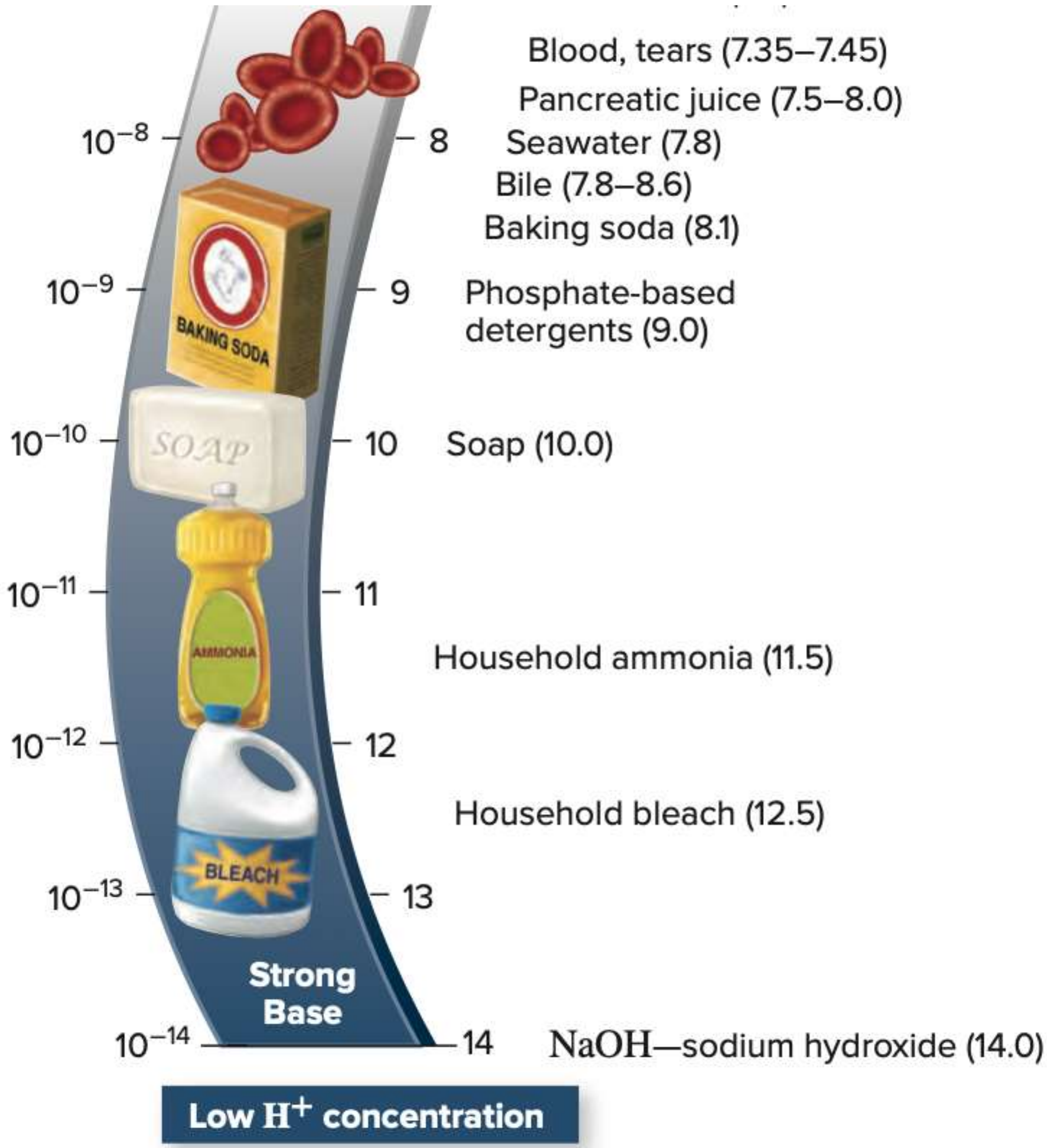
$0 < pH < 7$

An acid molecule generate H^+ ions, like HCl

$HCl \rightarrow H^+ + Cl^-$



pH Scale



Basic solution:

$7 < pH < 14$

A basic molecule generate OH^- ions, like NaOH

$NaOH \rightarrow Na^+ + OH^-$

pH Scale

Neutral solution: pH = 7

Pure water is neutral

$$[H^+] = [OH^-]$$

pH Scale

Neutral solution:

pH = 7

Pure water is neutral

$[\ H^+\ ] = [\ OH^-\ ]$

OBSERVATIONS

✓[H+] x [OH-] is always equal to 10^{-14}

✓**<u>pH + pOH is always equal to 14</u>**

Chemistry of Life
Pt. 2

Prof. Dr. Chiara Valsecchi

Course Goals

- Understand what are funtional groups
- Understand basic concepts about the Building Block of Biomolecules
- Lear characteristics to distinguish protein, limpids and sugards

Carbon Based Molecules

Organic means "to contain carbon" and "to come from living things".

Compounds that are organic contain carbon atoms that are covalently bonded together with other carbon atoms as well as other elements.

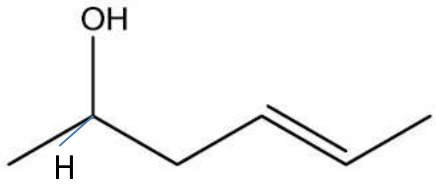
Carbon atoms that bond with each other and hydrogen atoms are called **hydrocarbons**.

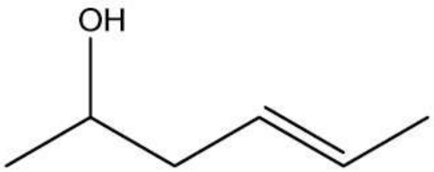
Functional Groups

ORGANIC MOLECULE :
The core structure (**backbone**) is made by **apolar** covalent bonds, and can form long chains.

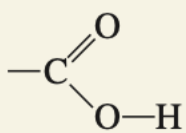
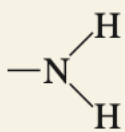
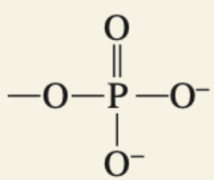
However, to determine diferente functionality for each molecule, we have specific groups of atoms (with O, N, P, S) called **functional groups**

All of this is possible because Carbon can make up to 4 covalents bonds





Functional Groups

Name	Structure	Formula
Hydroxyl group	—O—H	$-OH$
Carboxyl group		$-COOH$
Amino group		$-NH_2$
Phosphate group		$-PO_4^{-2}$

<u>Most important in</u>:

Carbohydrates

Lipids/protein

Protein

Nucleotides

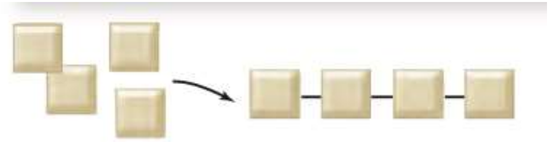
These 4 families of molecules constitute the building block of life!

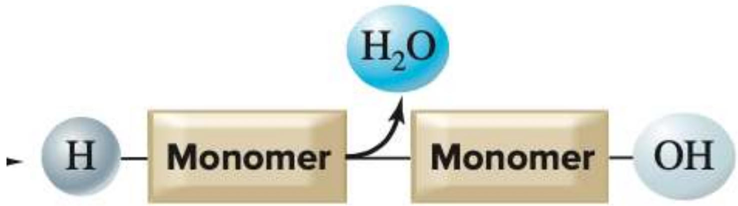
Polymers

Carbohydrates, Lipids, Protein, Nucleotide are all POLYMERS:

Smaller units make up for long and large molecules.

The reaction to form polymers involves the **elimination of water**, so it is called DESHYDRATION.





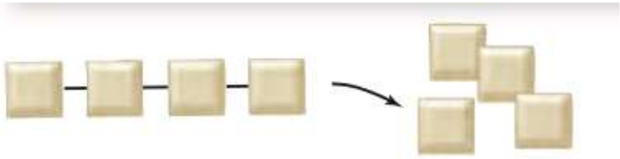
Polymers

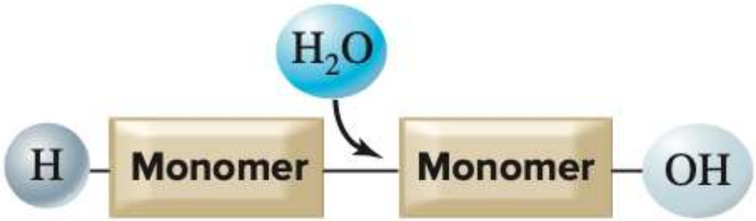
Sugars, Lipids, Protein, Nucleotide are all POLYMERS:

Smaller units make up for long and large molecules.

The reaction to form polymers involves the elimination of water, so it is called DESHYDRATION.

The reaction to break down polymers needs **addition of water**, so it is called HYDROLYSIS.





Biological Polymers

1. Carbohydrates
2. Proteins
3. Lipids
4. Nucleotides

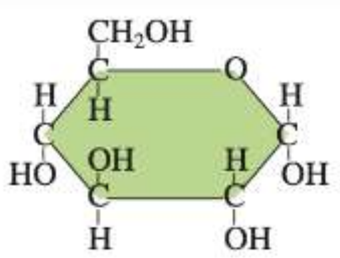
Any biological importante molecule inside the call can be classified into one of these 4 groups of organic molecules.

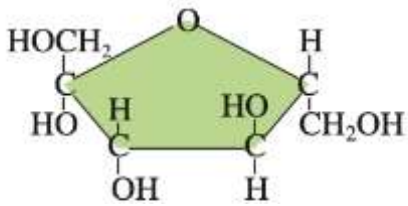
1. Carbohydrates

SUGARS

Monosaccharide

Dissacharide





Glucose

Fructose

Energy for the brain

Important in celular respiration

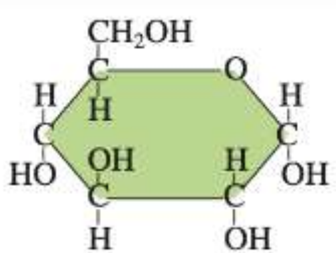
1. Carbohydrates

SUGARS

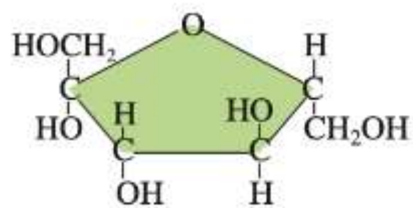
POLYSACCHARIDES

Monosaccharide

Dissacharide



Glucose

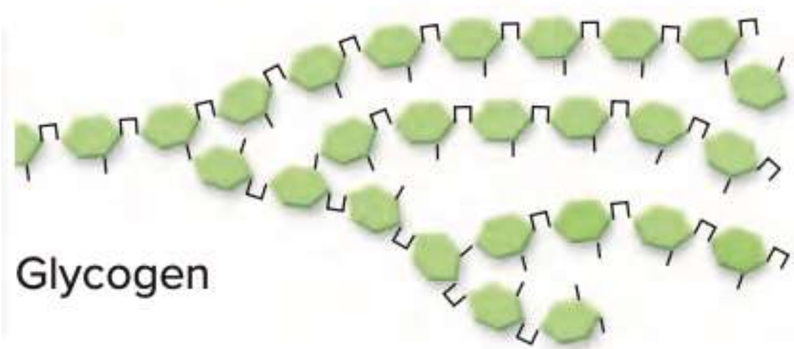


Fructose

Energy for the brain

Important in celular respiration

Cellulose



Glycogen

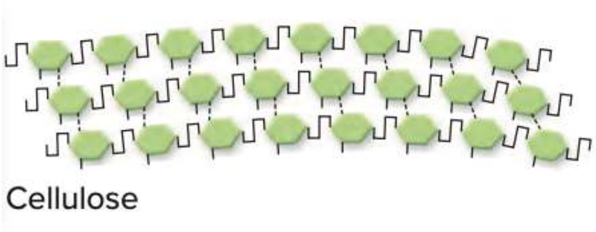
1. Carbohydrates

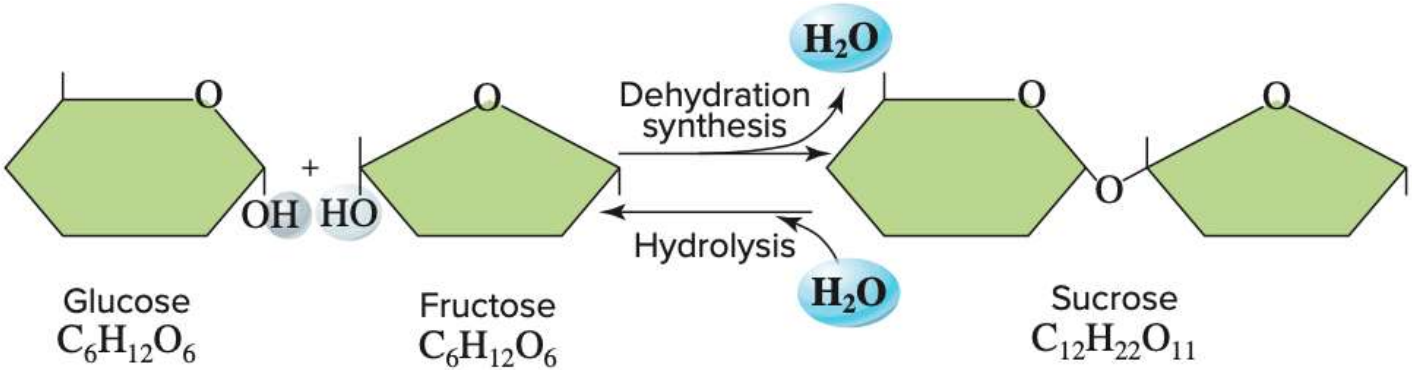
SUGARS

Monosaccharide

Dissacharide

POLYSACCHARIDES

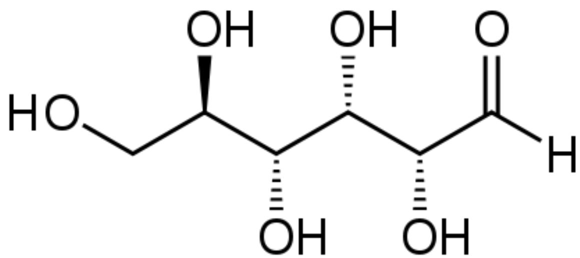




Common sugar!

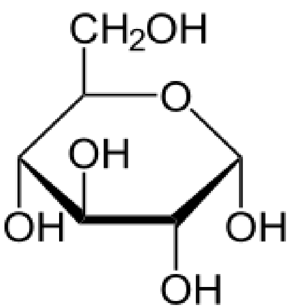
1. Carbohydrates

Monossacharides are rarely in the linear form, the tend to close up in a **cyclic structure**



Open structure

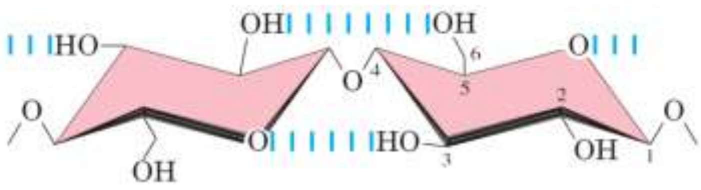
D-glicose



Closed structure

The reaction is called Glycoside formation

Cellulose



D-glicose β(1→4).

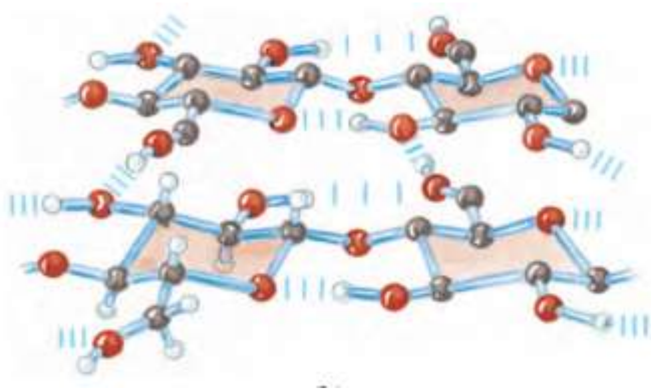
Linear, stabilized by hydrogen bond

Fibrous, resistant

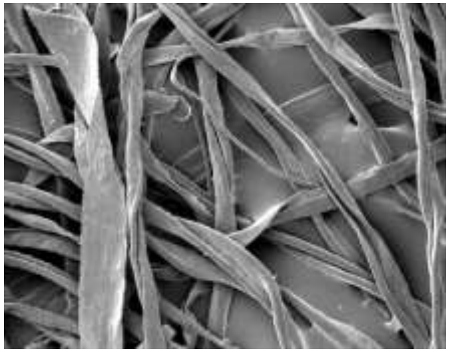
Insoluble in water

Plant cellular wall, wood structure,

Cotton is almost pure celulose

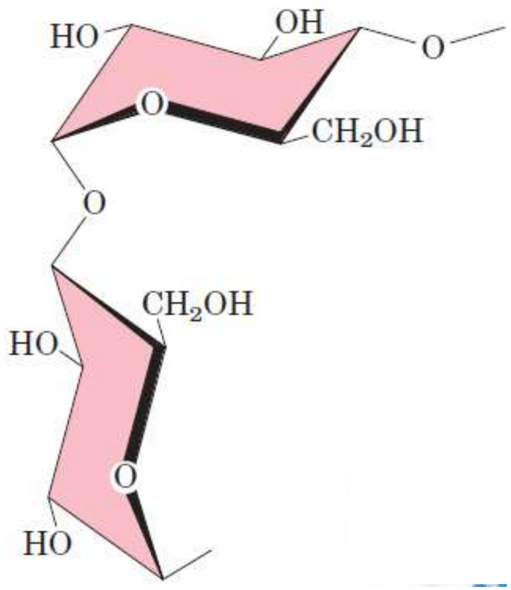


Cotton Fibers



Cotton Fibers

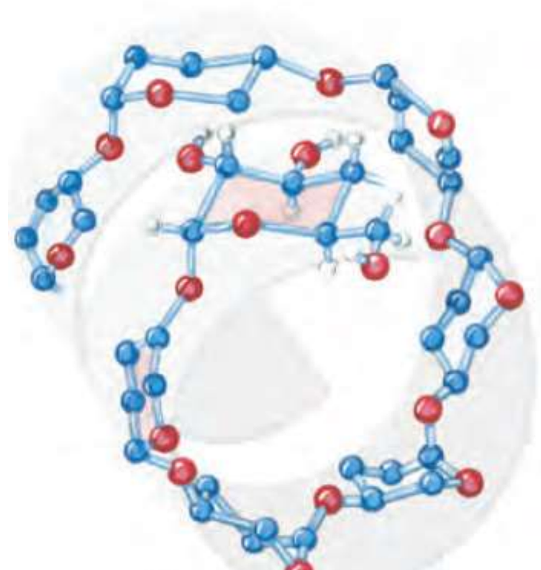
Starch



only GLUCOSE

The structure is folded in a helix shape

Energy storage for living beings.



(b)

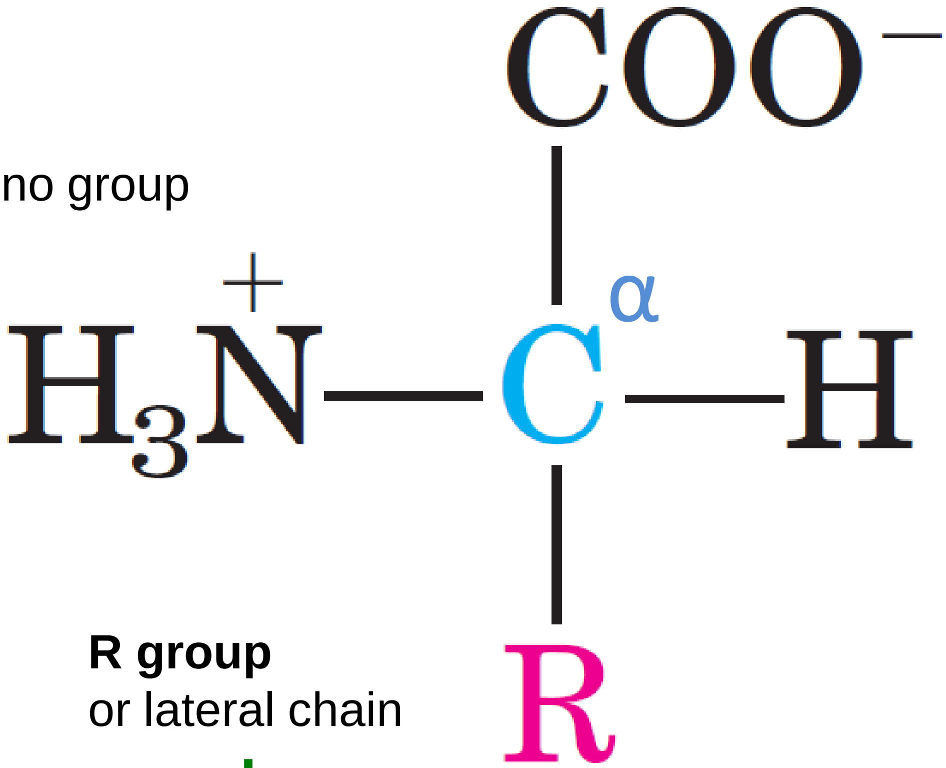
Starch in plants

GLYCOGEN in animals and fungi

2. Proteins

Carboxilic group

Amino group



Hydrogen

R group
or lateral chain

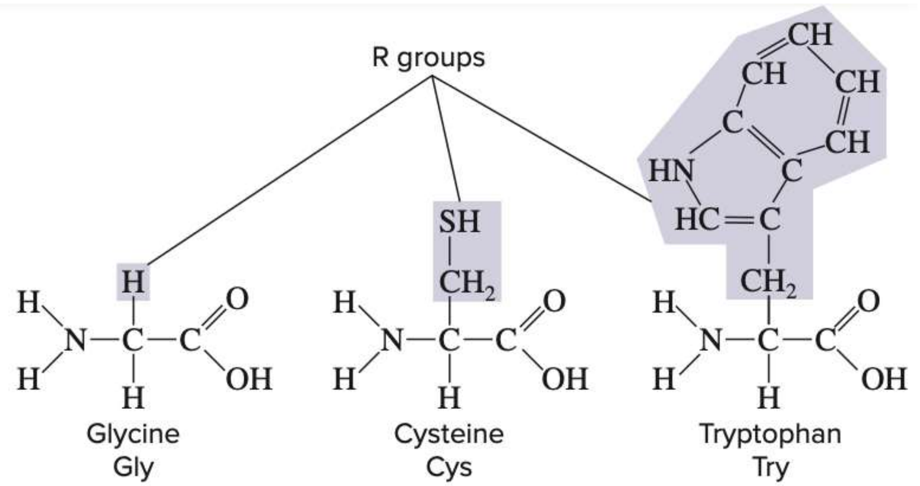
The R group defines aminoacid properties, as structure, size, charge and solubility

Aminoacid classification

CATHEGORY	HOW MANY
1. Apolar:	7
2. Polar:	5
3. Aromatic :	3
4. Positively cherged:	3
5. Negatively charged:	2

R group
↓
TOTAL: 20 different types

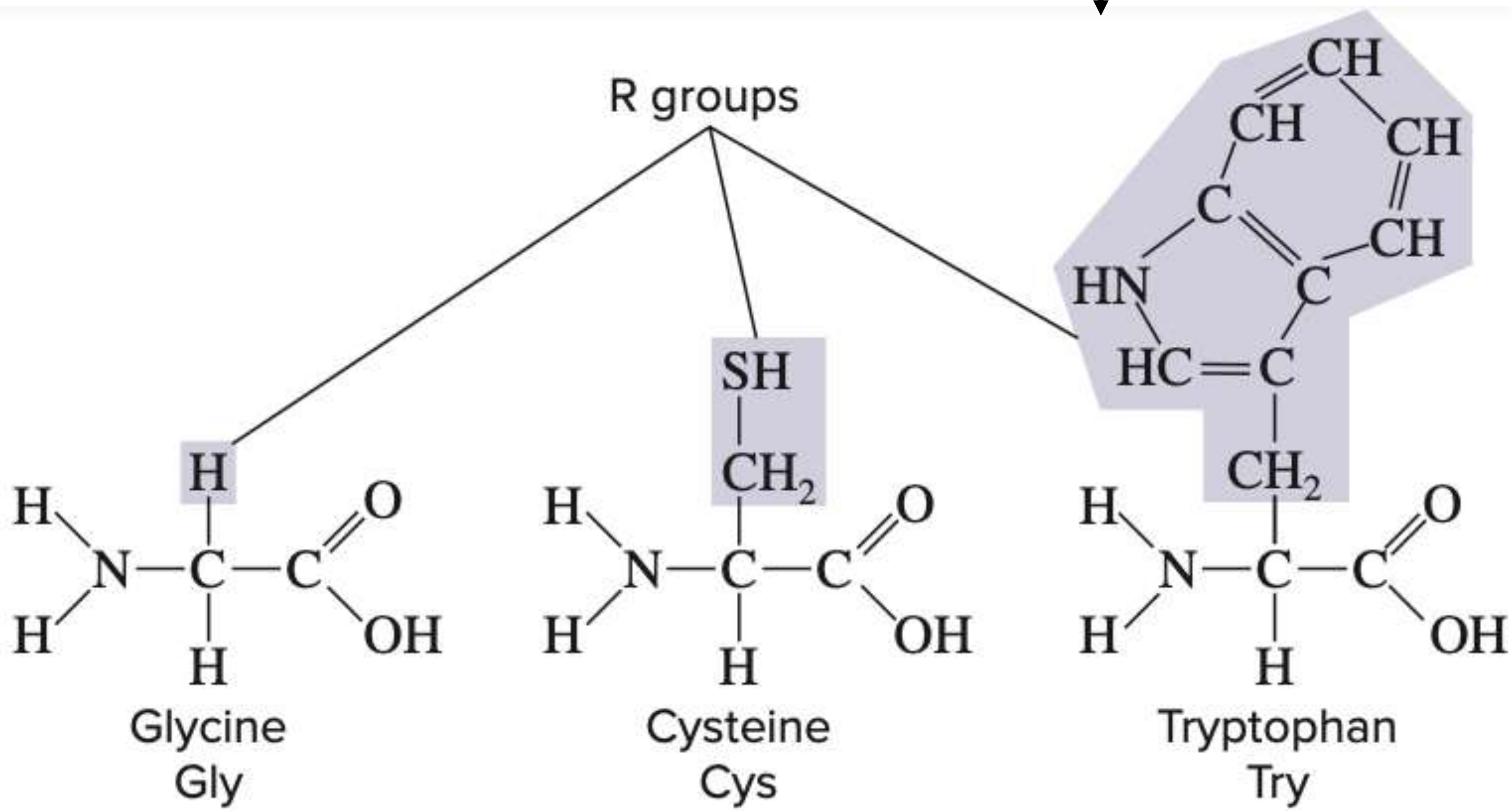
Aminoacid = aa



Aminoacid classification

CATHEGORY **HOW MANY**

R group



Aminoacid Interactions Overview

__Int. van der Waals__:

Apolars

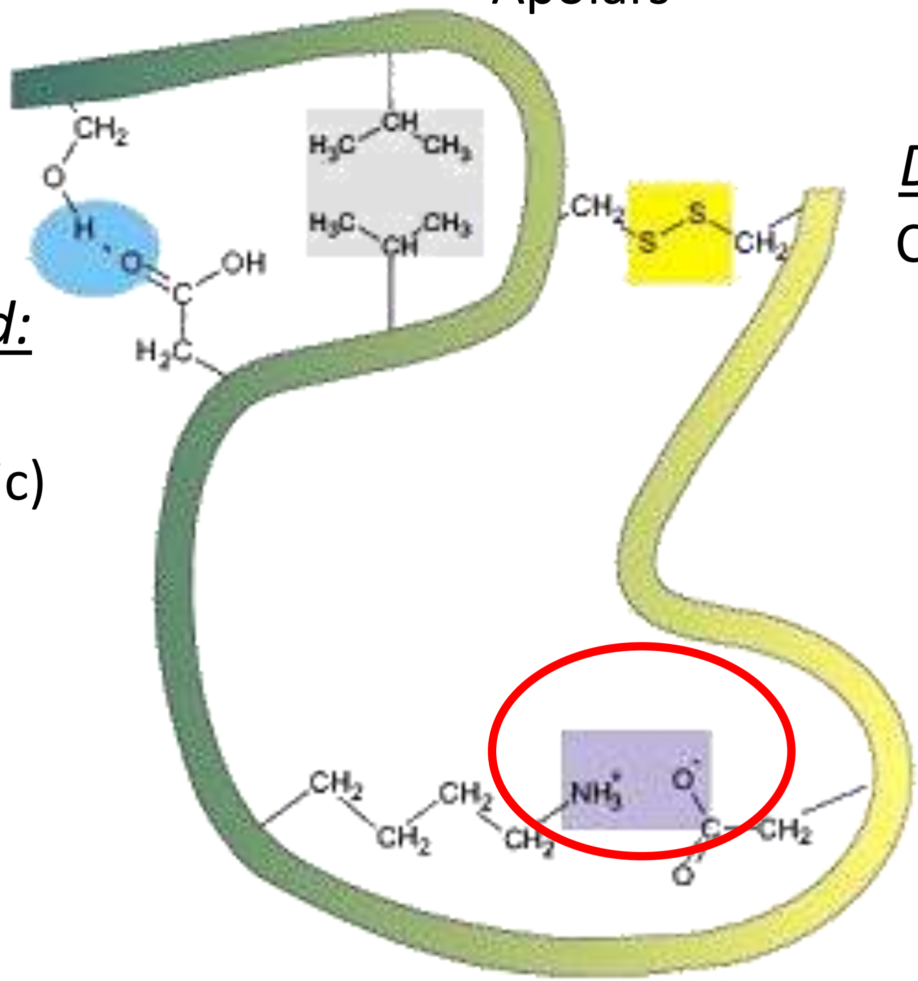
__Dissulfite bond__:

Cystine

__Hydrogen Bond:__

Polars

Tyrosin (aromatic)



__Ionic Bond__:

Charged
aminoacids

2. Proteins

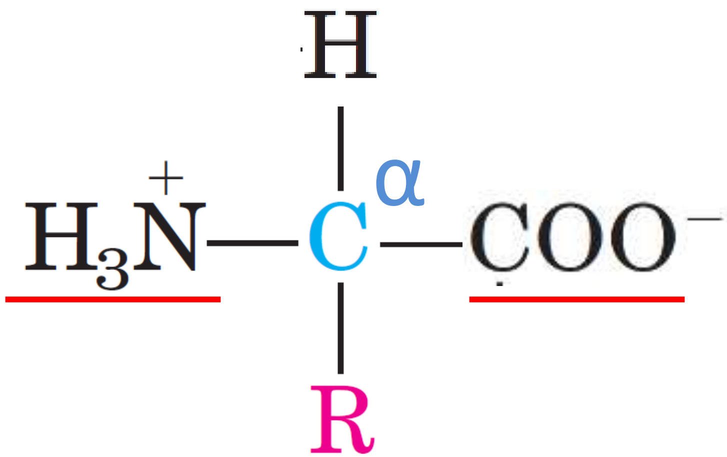
Peptides: less then 10 aa

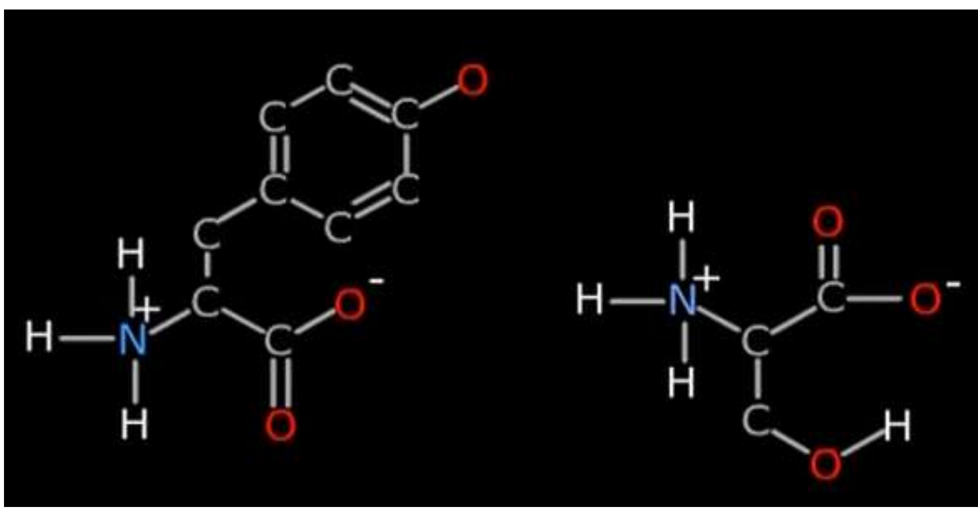
Oligopeptides (10 < aa < 100) and Polypeptides (> 100 aa)

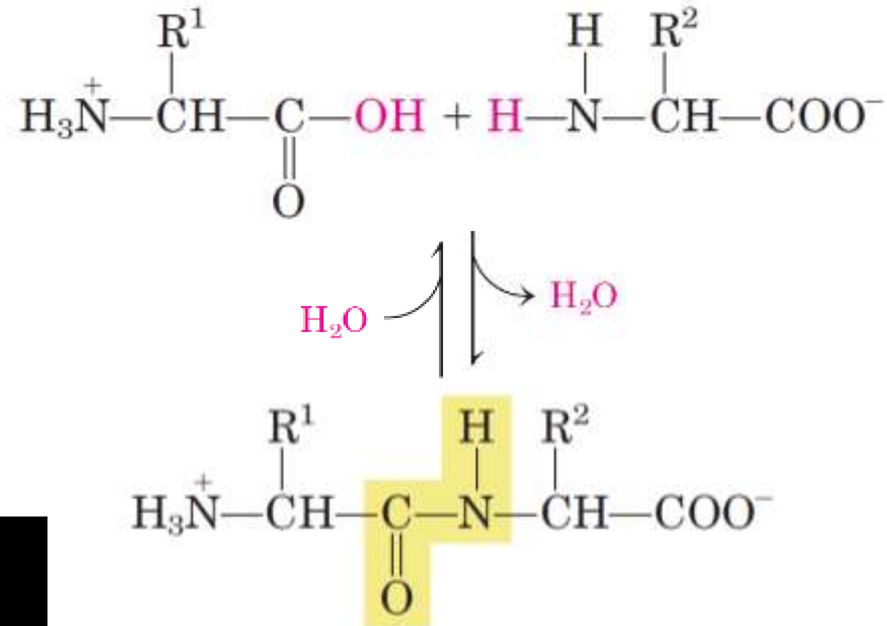
Proteins are the functional core of the cell: antibodies, enzimes, receptors and cell skeleton.

The **fuction depends on their structure**, so it is extremely important

Protein Formation

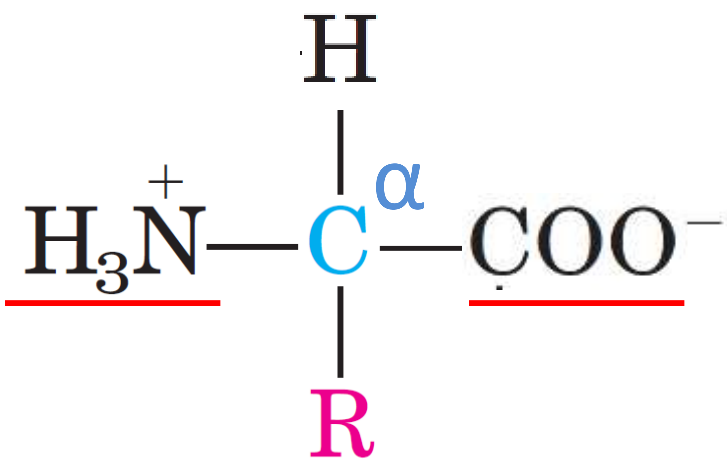


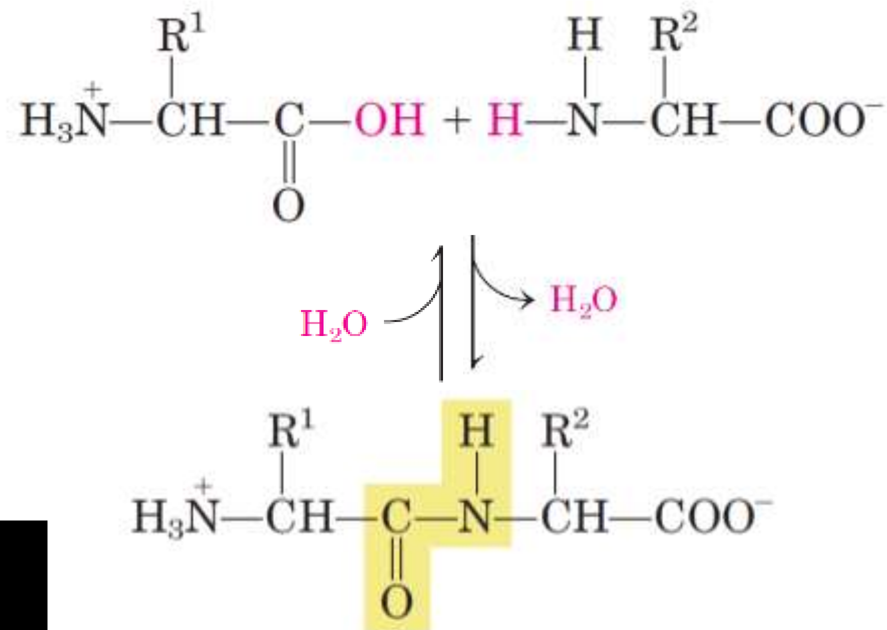


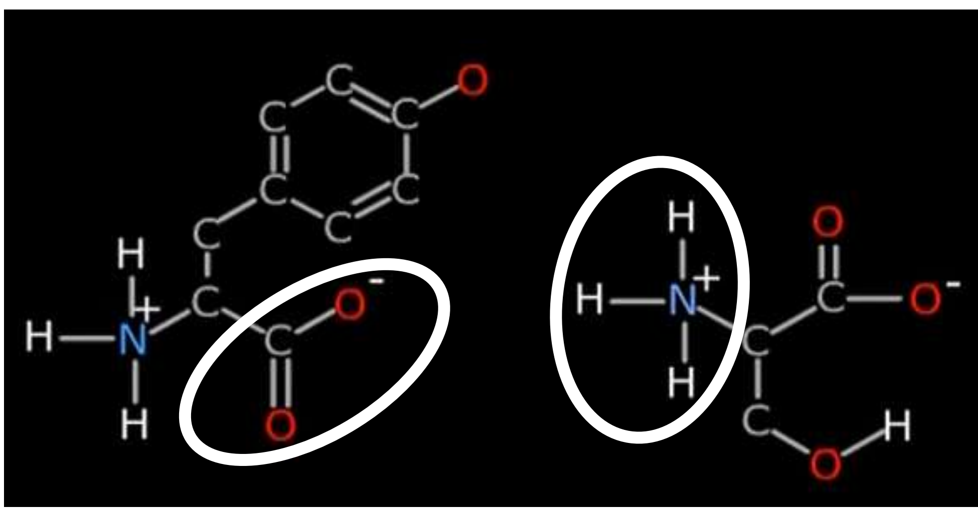


Condensation / Hydrolisis

Protein Formation

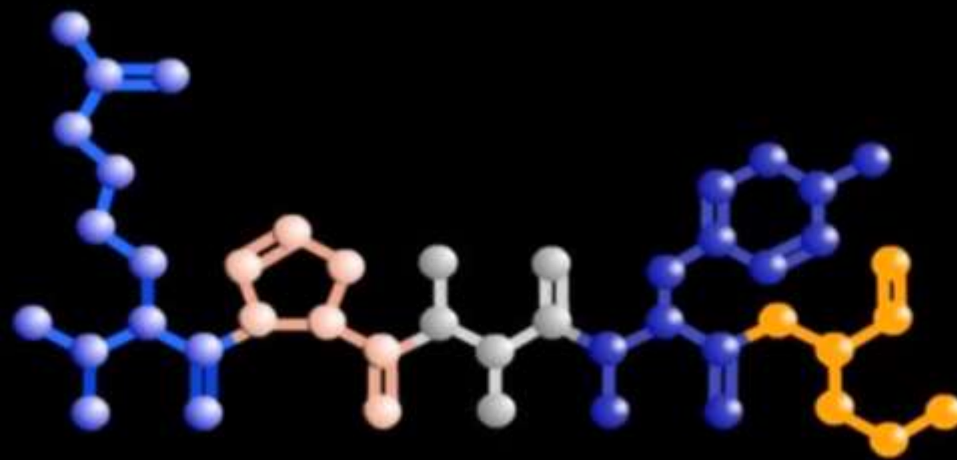




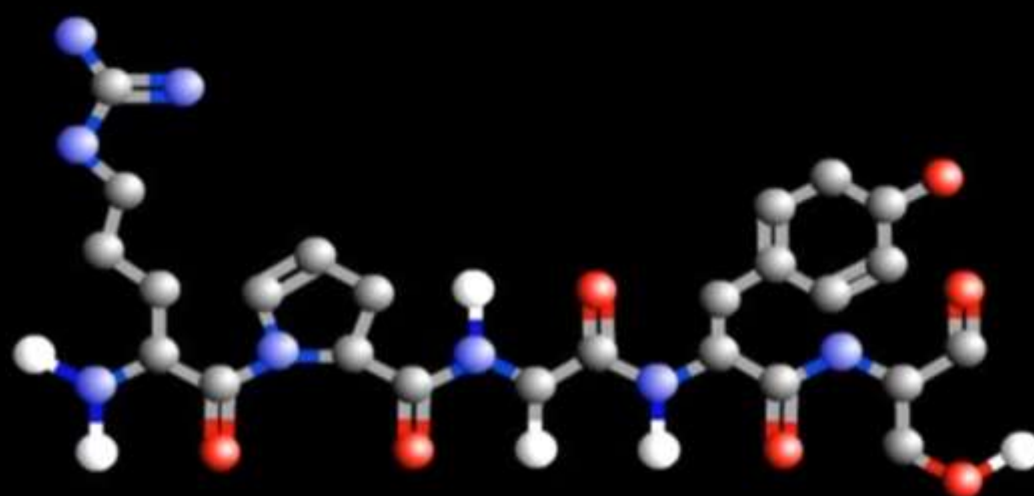


Condensation / Hydrolisis

2. Proteins

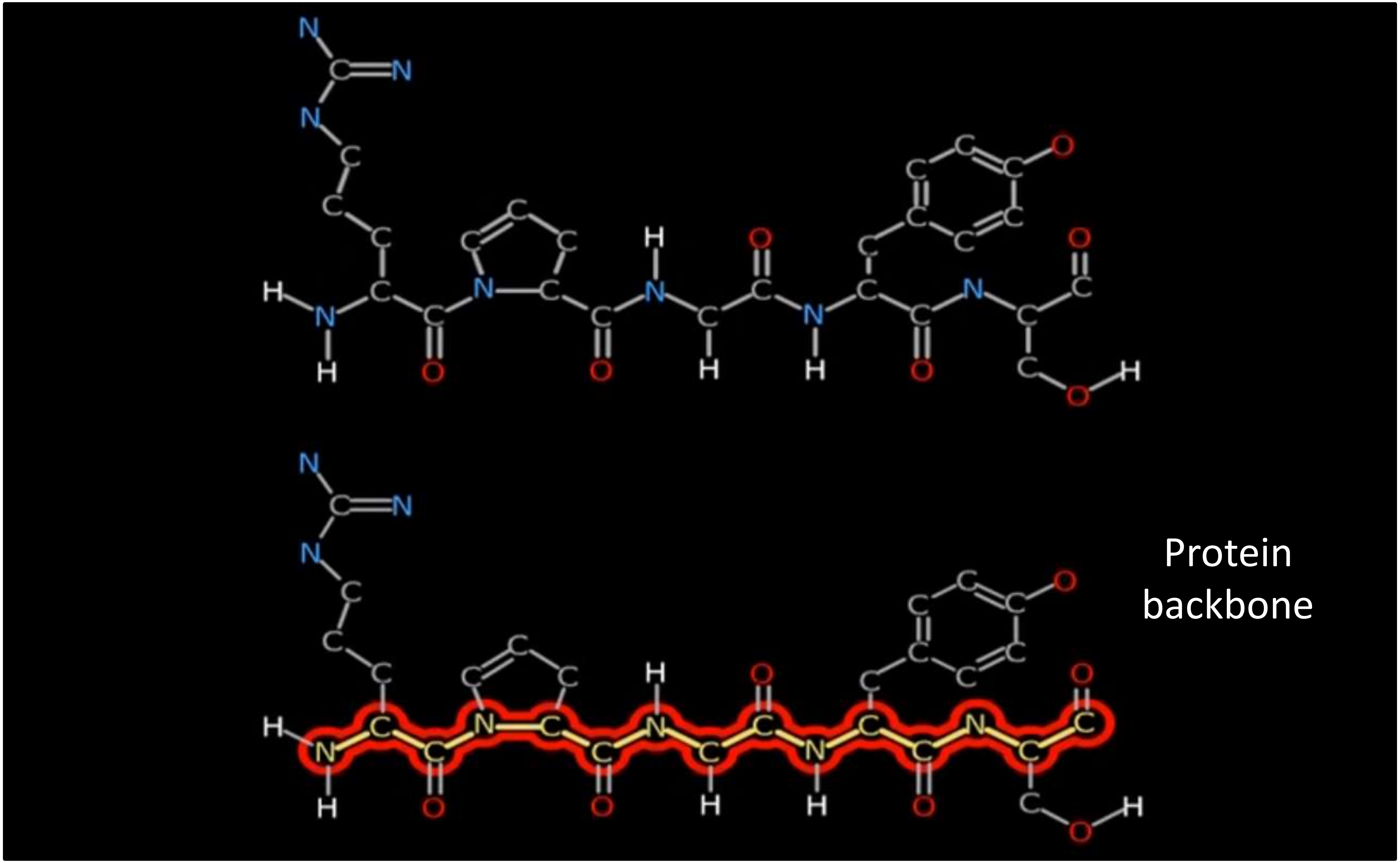


Peptide: 5 aminoacids

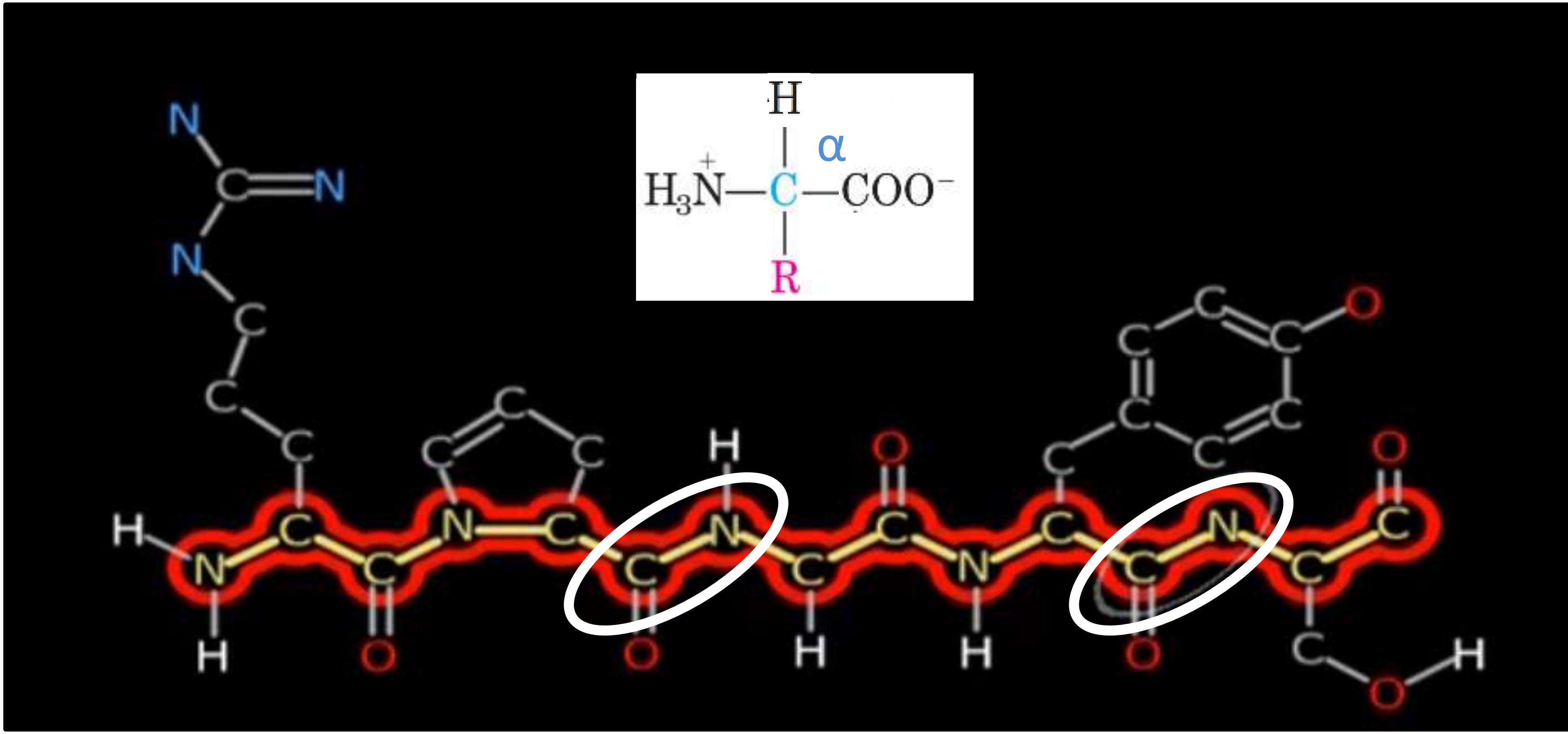


Atomic model, without H

Ligação Peptídica



Primary Structure



Primary Structure: the linear sequence of aminoacid

Secondary Structure

Secondary Structure: spatial arrangment of close aminoacid, which create well-defined 3D structures.

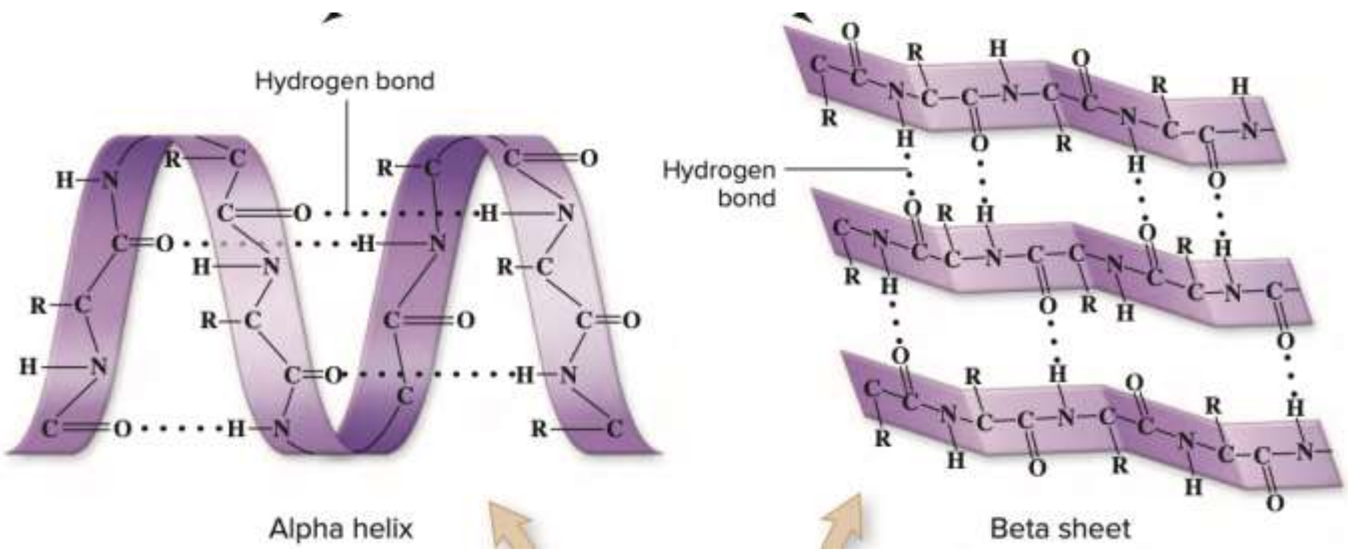
Types:

α Helix

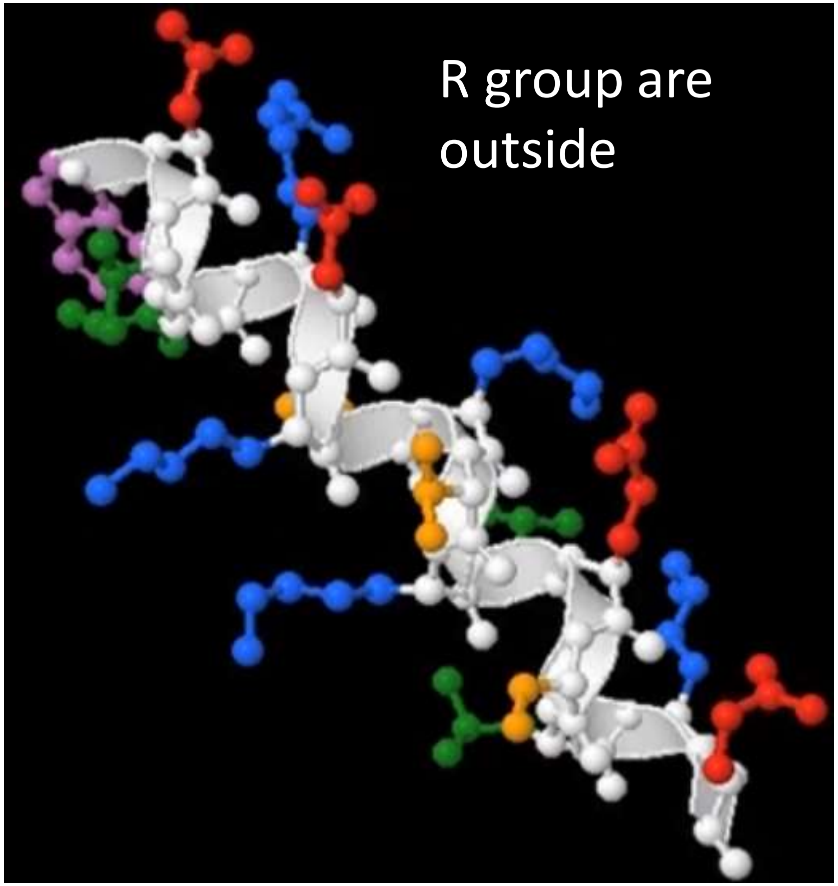
β sheets

Coils

Turns



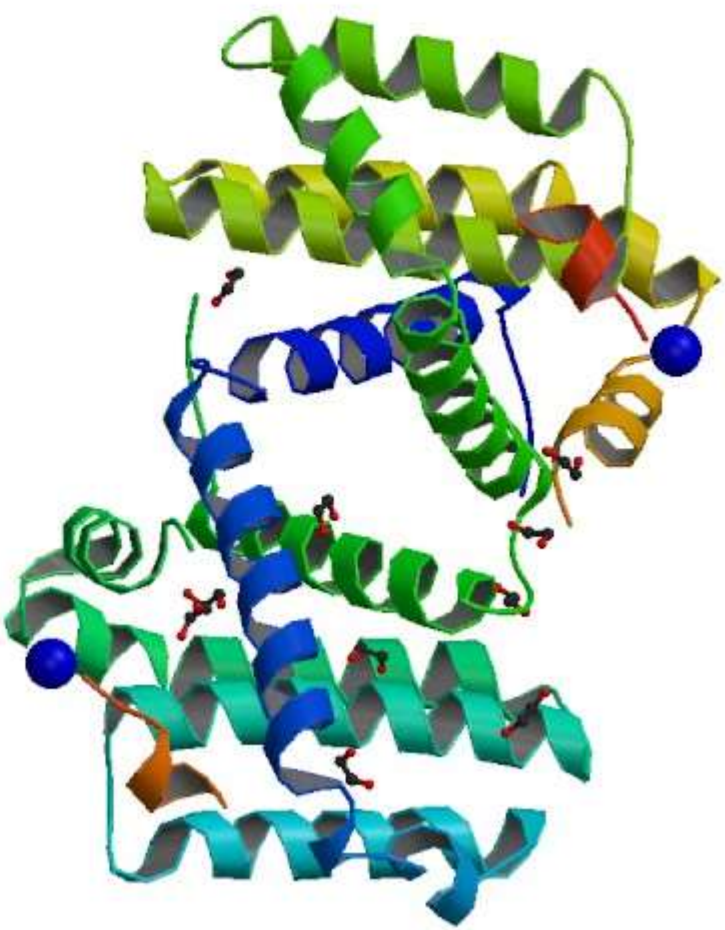
α - helix

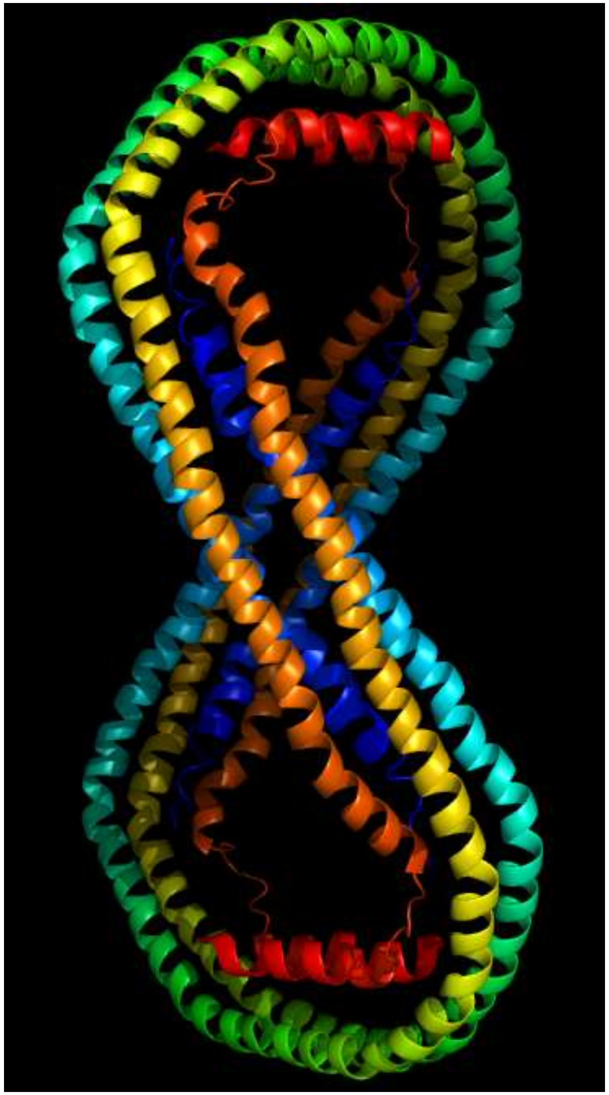


IMPORTANT! Is the primary structure that determine the correct sequence for these structure to happen!

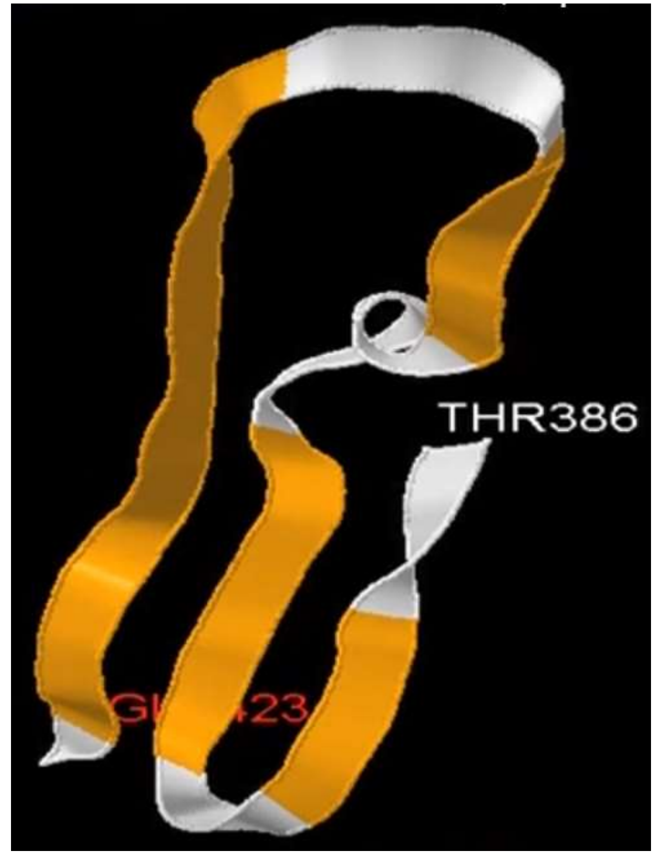
α – helix protein

apolipoprotein A-I (PDB code 1AV1)





β sheets



The interaction is between atoms that can be far apart in the primary structure

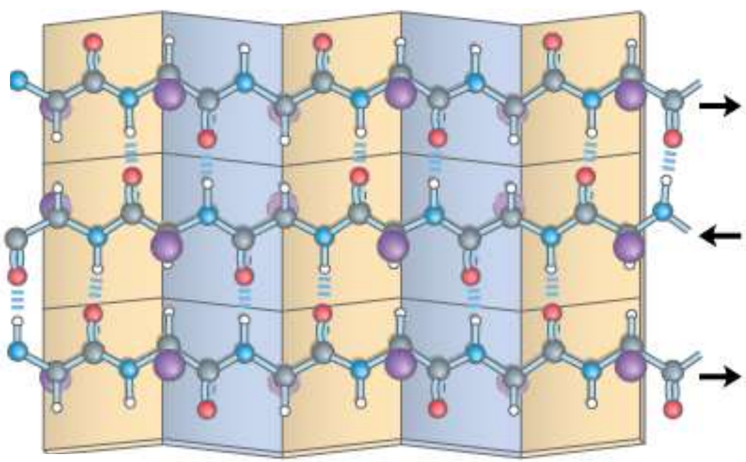
β sheets

R groups are above and below the sheet plane

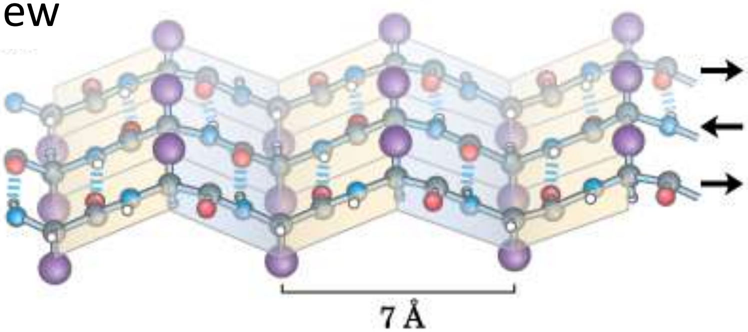
The sequence is like a zig-zag due to hydrogen bonds

ANTIPARALLEL

Top view

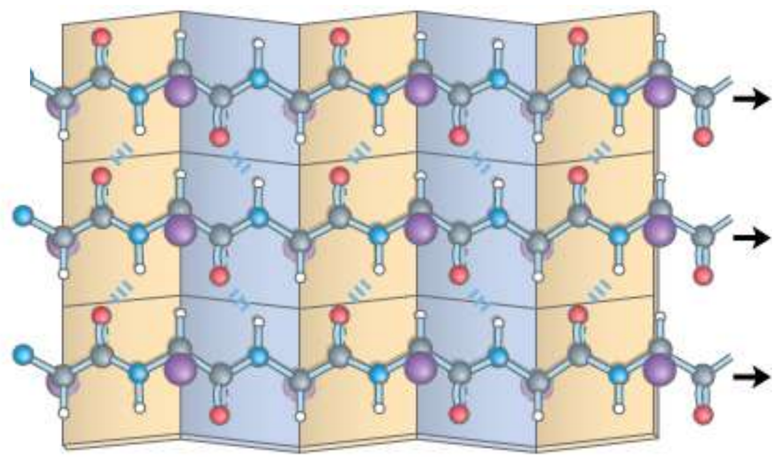


Lateral view

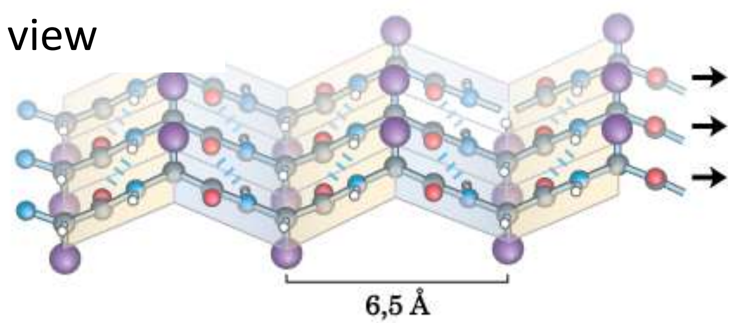


PARALLEL

Top view

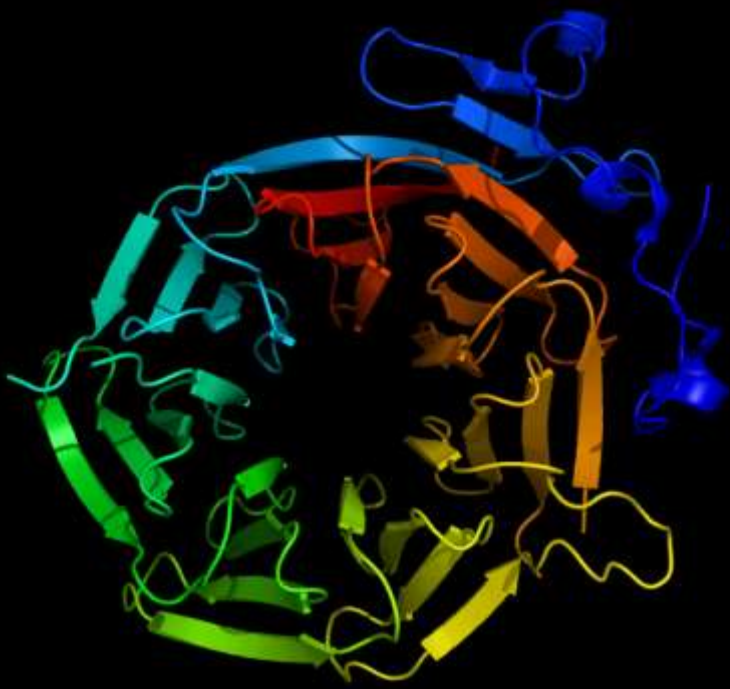


Lateral view

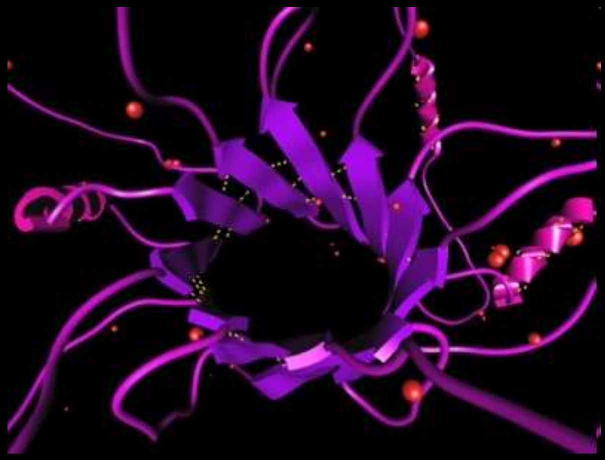


β sheets protein

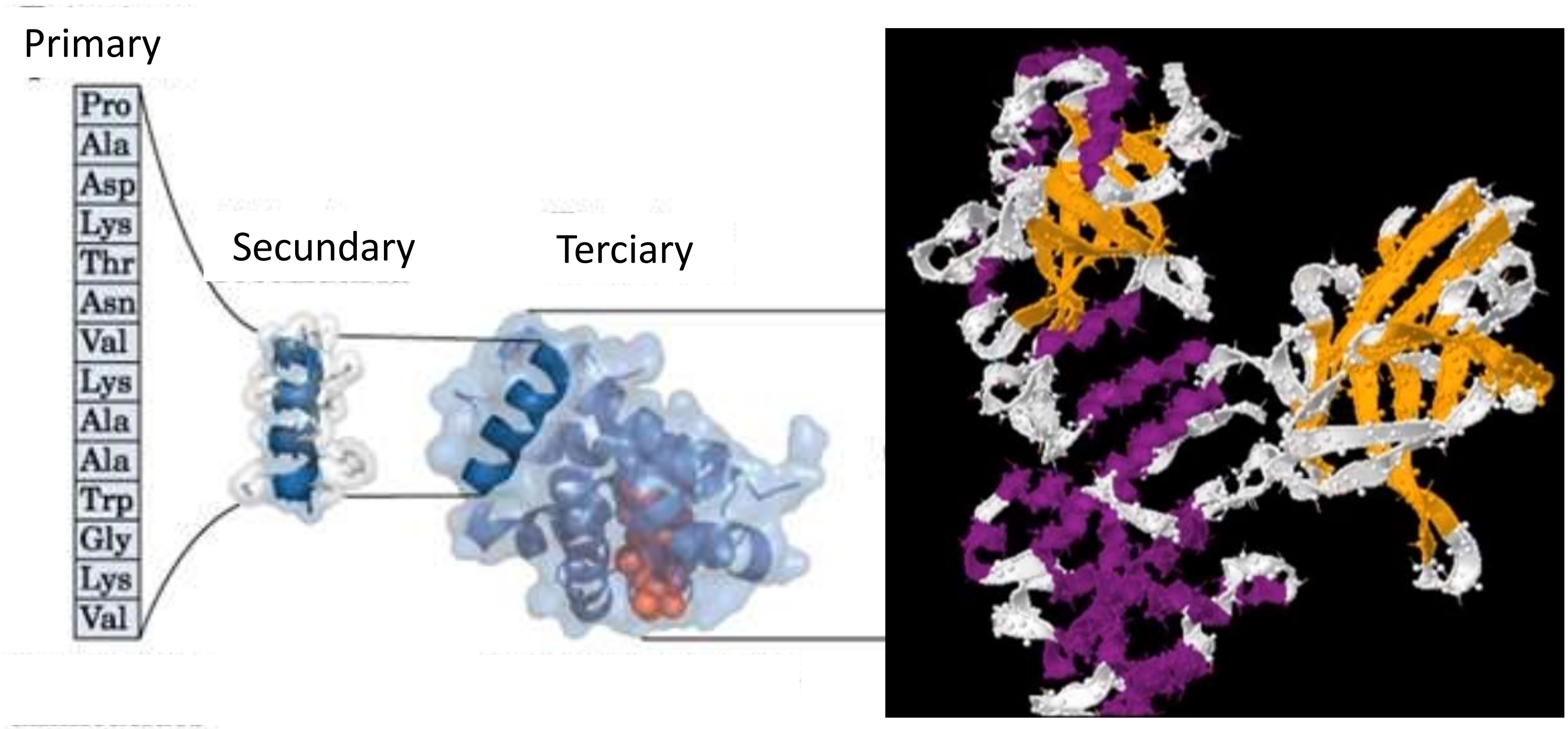
Beta-prupolsor



Beta-barrel

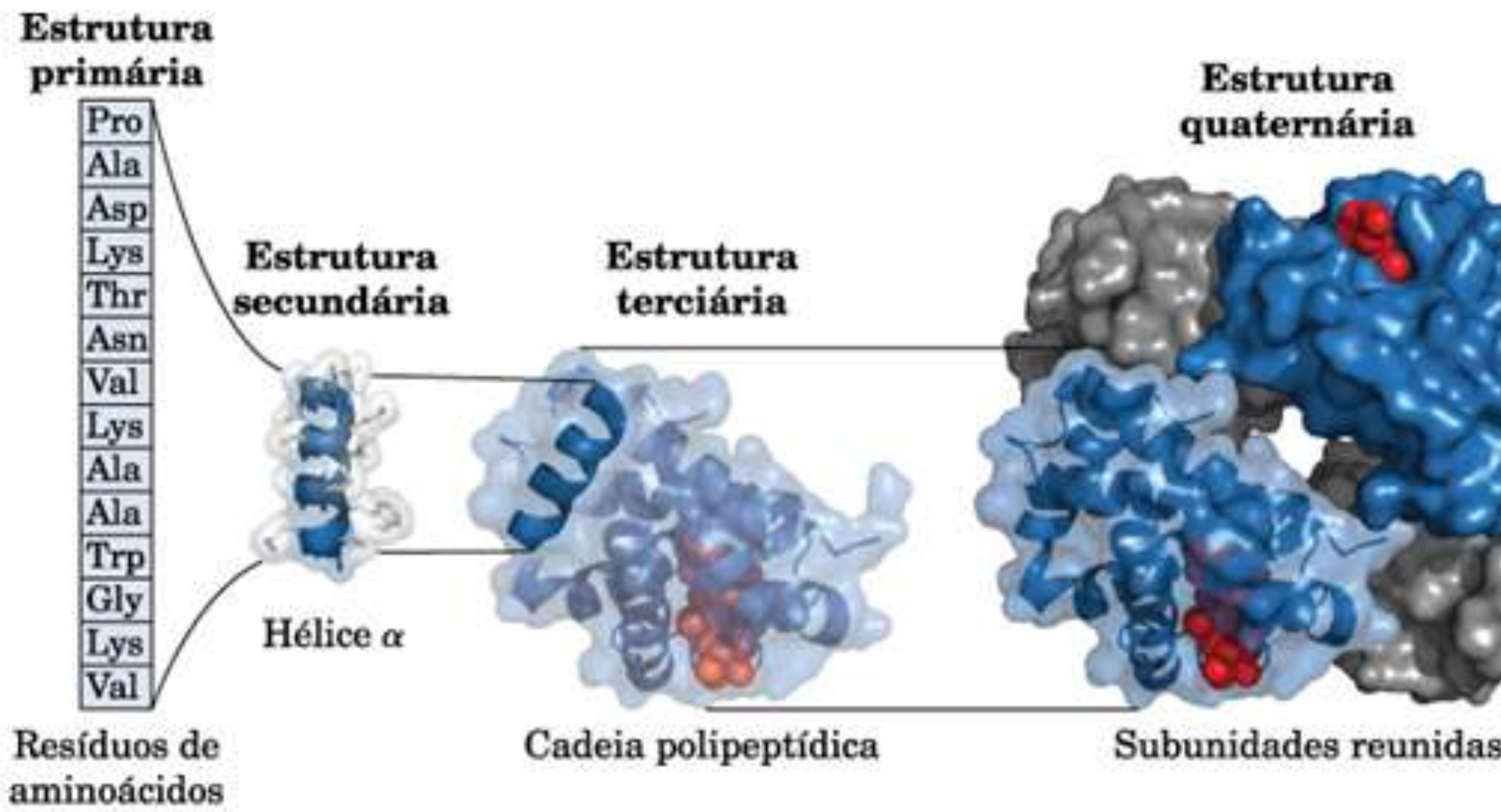


Tertiary Structure



Tertiary Structure: how the protein fold in space after the formation of the secondary structure patterns.

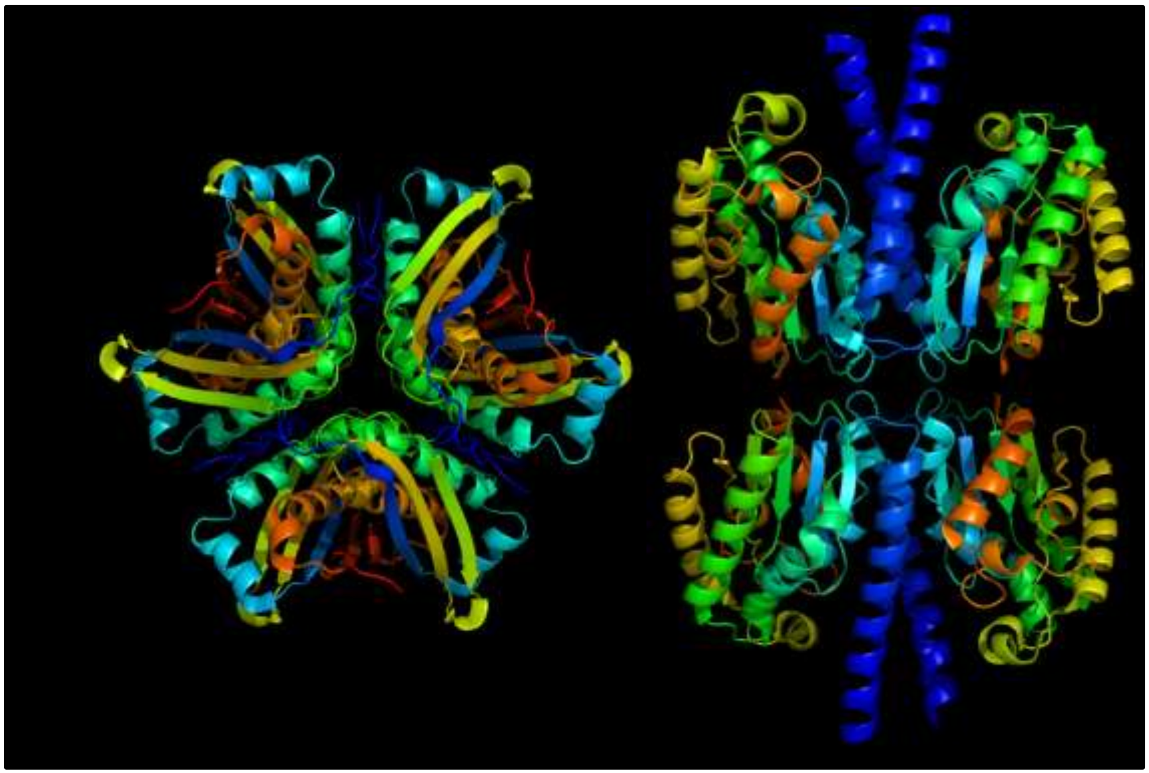
Quaternary Structure

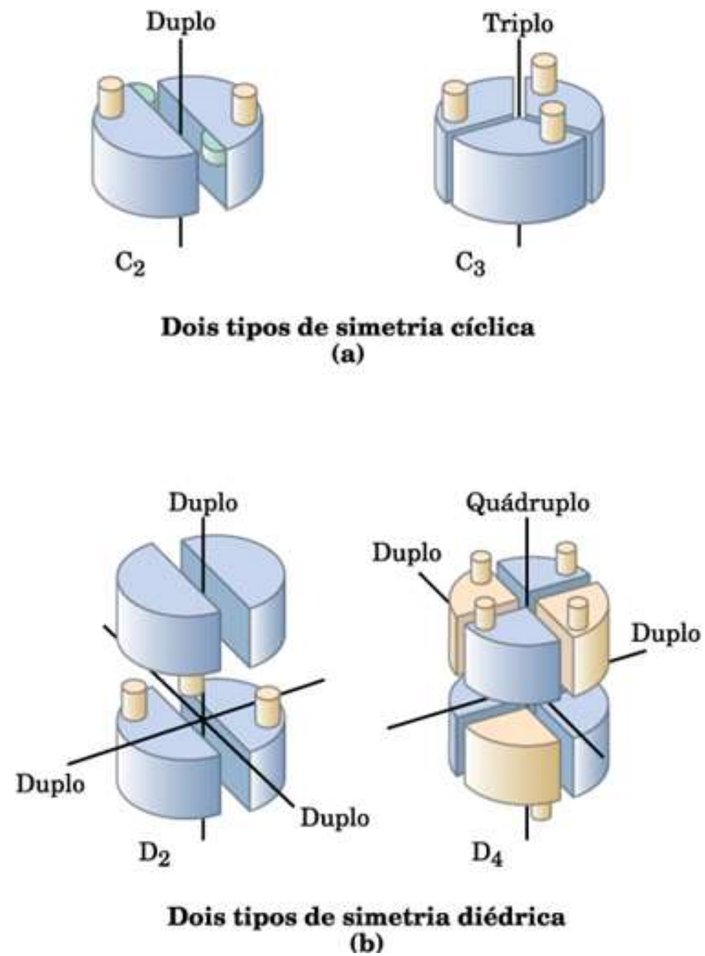


Quaternary Structure: different subunits of tertiary structures together to form complexes

Quaternary Structure

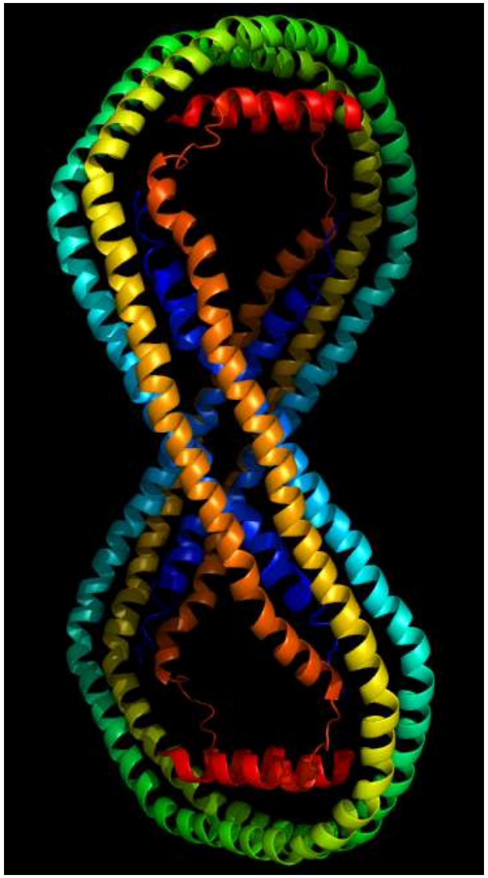
Dimers, Trimers, Oligomers





Important facts

1. The 3D conformation depends on the AA sequence
2. The main stabilyzing forces are non covalente interactions
3. Common patterns (helix and sheets) help to stabilize
4. Protein always interact with water: hydration sphere
5. To function correctly, each protein has a specific structure, called NATIVE CONFORM



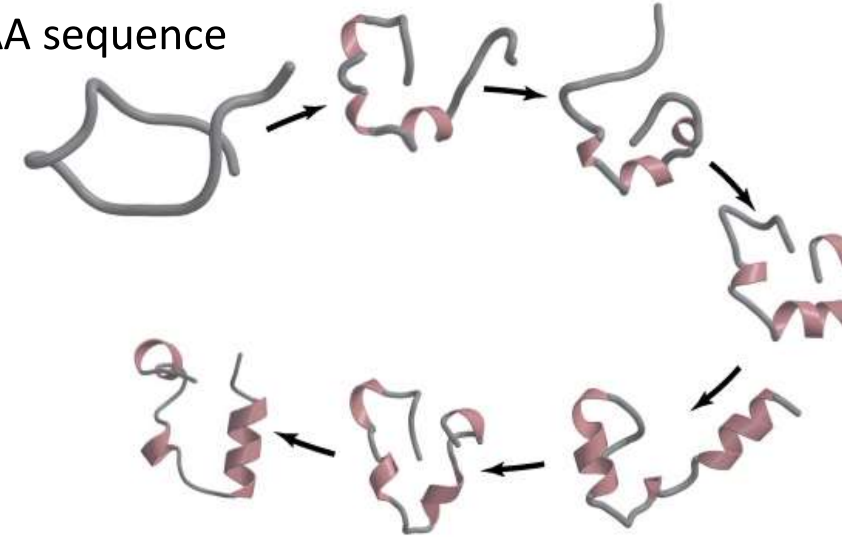
apolipoprotein A-I (PDB code 1AV1)
Estrutura formada apenas por alfas-hélices

Native Conformation

NATIVE CONFORMATION: the shape that gives the protein its function!

DESNATURATED CONFORMATION: part or all of the protein loses its folding: the function is also lost. Normally due to heat or Strong chemical attack.

AA sequence



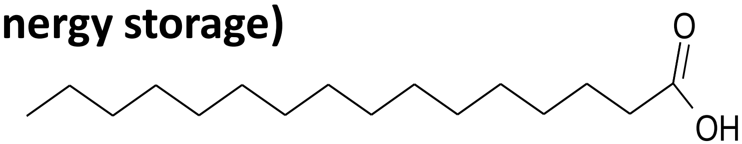
NATIVE conf.

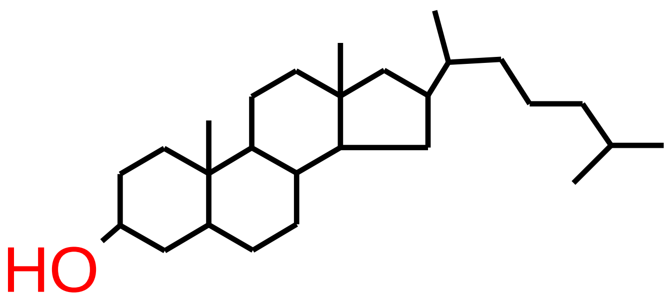
3. Lipids

Biological Lipids

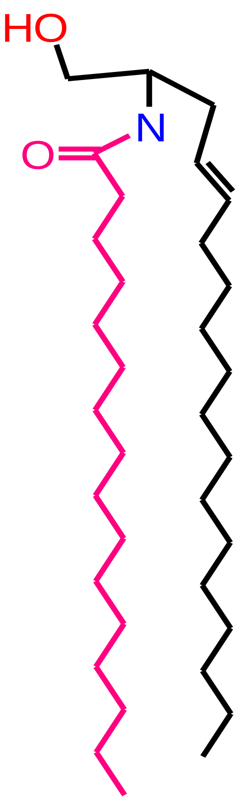
- It is a big group with many **different types** of molecules, depending on the function
- One common feature : **water insoluble**

Fatty acid
(energy storage)

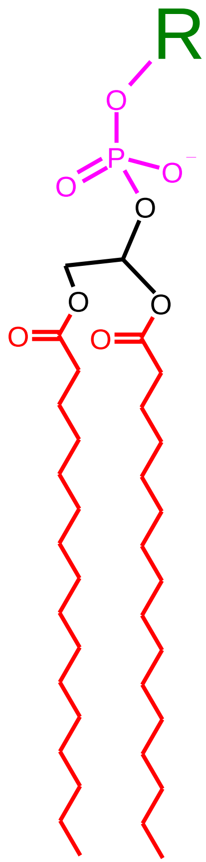




Steroids
(hormon)



sphingolipid



Phospholipid

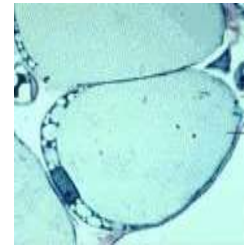
Cell membranes

Lipid Functions

Lipids

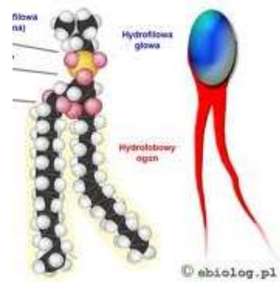
Energy Storage: fat

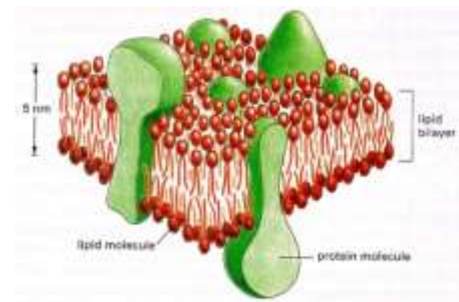
Triglycerides



Structural:

- Phospholipids
- Waxes
- Cholesterol

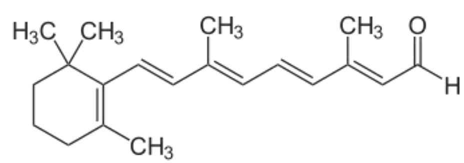




Phospholipids

Pigments

Retina pigment



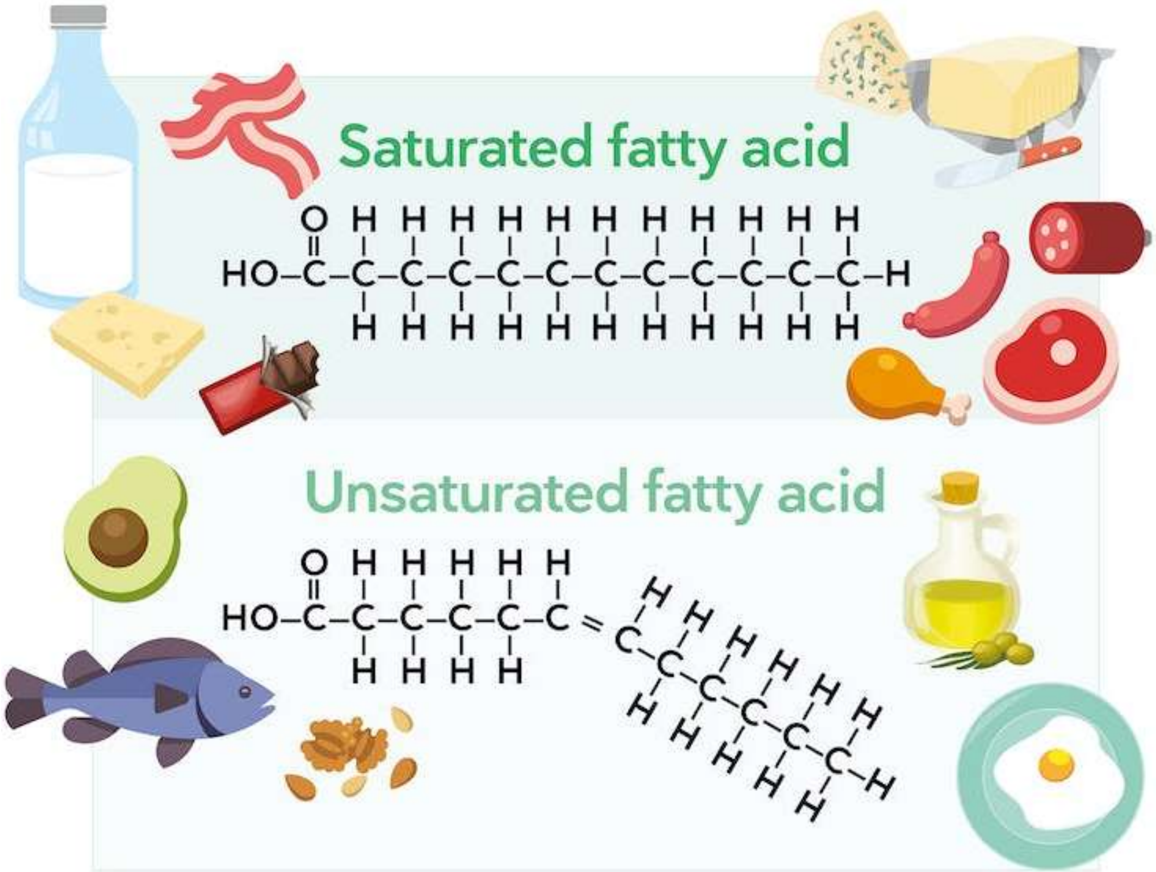
All-trans-retinal

Sinalizadores:

Hormons

Vitamin A, D, K; coenzimes

Saturated or Unsaturated



- **SATURATED:**

Each Carbon has the maximum number of Hydrogens (2).

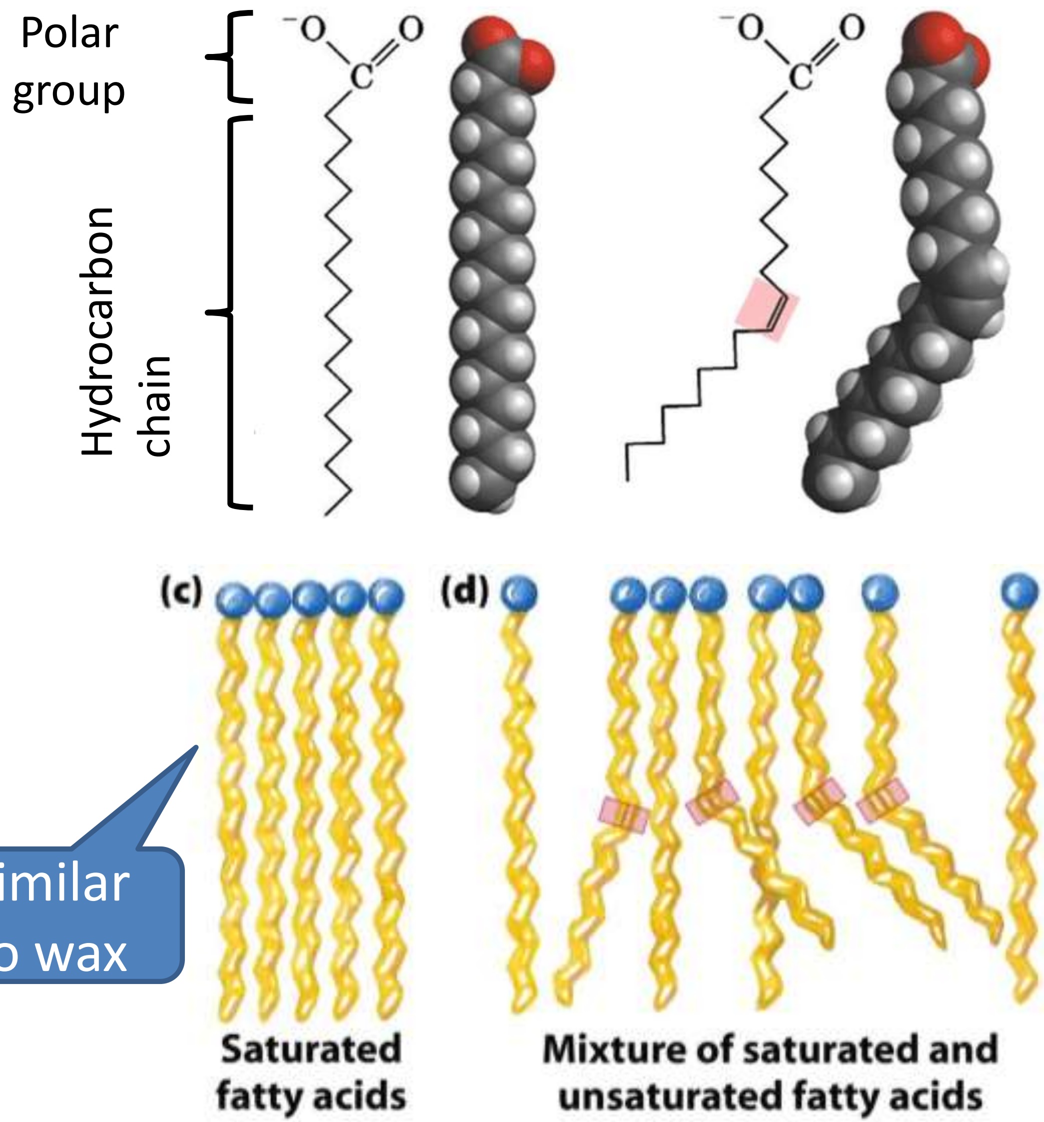
No healthy

- **UNSATURATED:**

Some carbons involved in double-bonds with other carbons, **less** Hydrogens.

Easy to break down, more healthy

Fatty Acids



Similar to wax

greasy liquid, oil

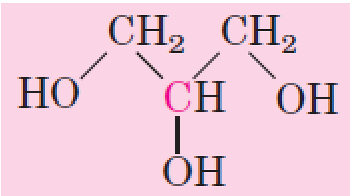
The saturation degree affects molecule stacking

The bend in unsaturated fatty acid causes more mobility and weaker interactions:

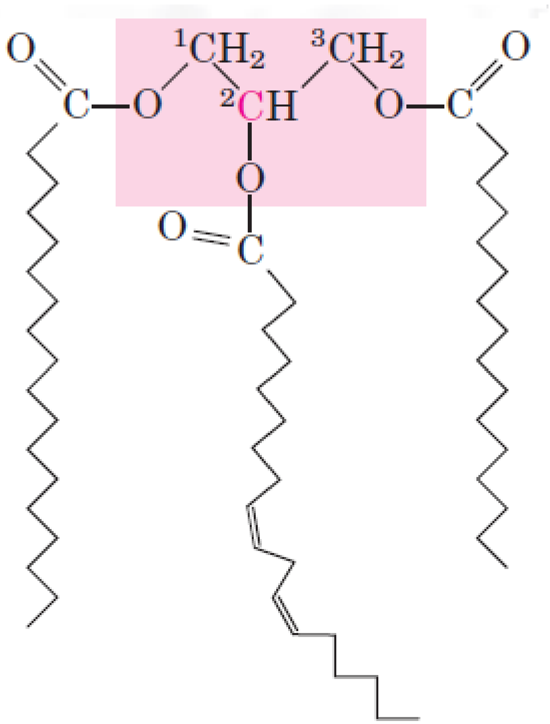
↓

Less fusion temperature, so they are more soft or liquid at room temperature

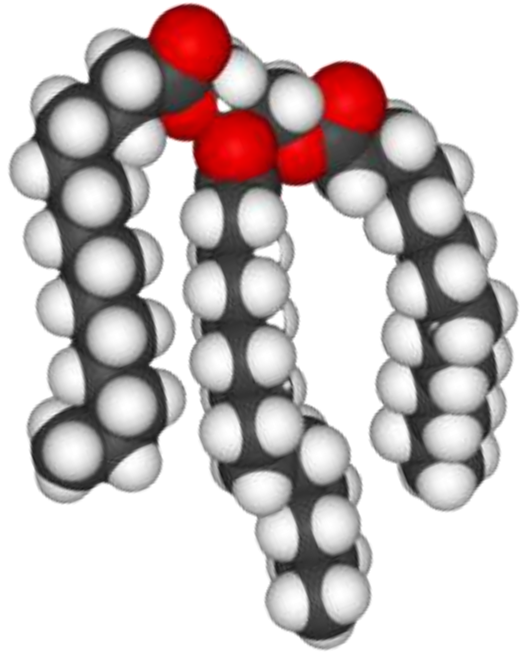
Triglycerids



Glycerid



1-Stearoyl , 2-linoleoyl, 3-palmitoyl glicerol: a mixed triglycerid



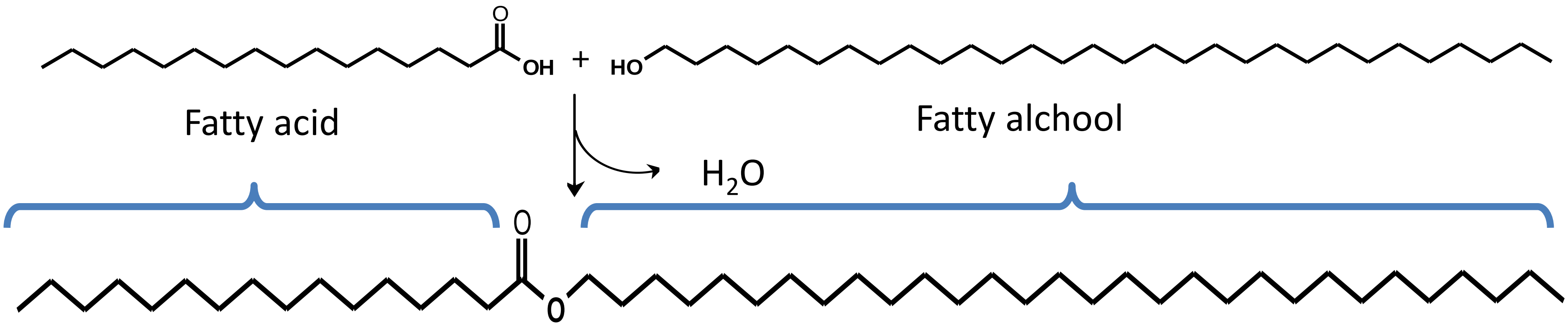
Most important family of lipid for energy storage:

3 long fatty acid chain linked to a glycerol molecule.

Stored in the adipocytes, the “fat” cells

Waxes

- Long fatty acid chains
- Highly water repellant



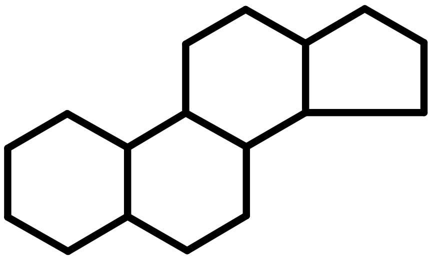
Triacontanyl Palmitate: bee wax !

At 25°C the bee wax is completely waterproof

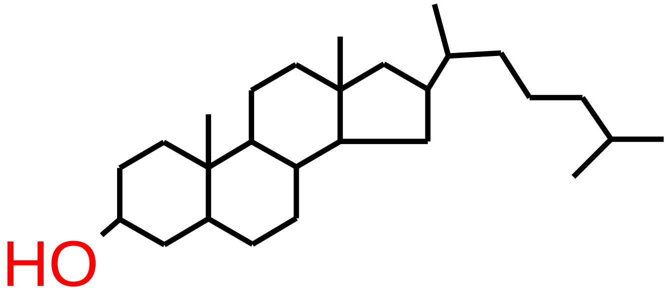
Wax color pencils

Steroid Family

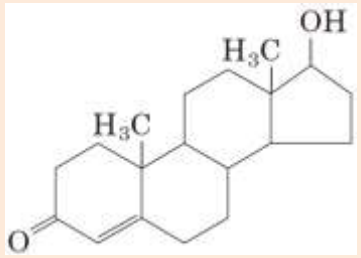
- Structural lipids present in most Eukaryotic membranes
- Core structure is rigid
- Cholesterol is the most important, however, it can be bad for health (good and bad cholesterol)
- Cholesterol is the base material for sex and anti-inflammatory hormons, vitamins (D) and biliar salts

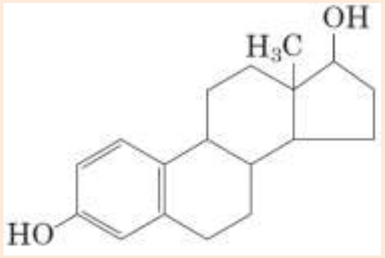


Steroids core structure



Cholesterol



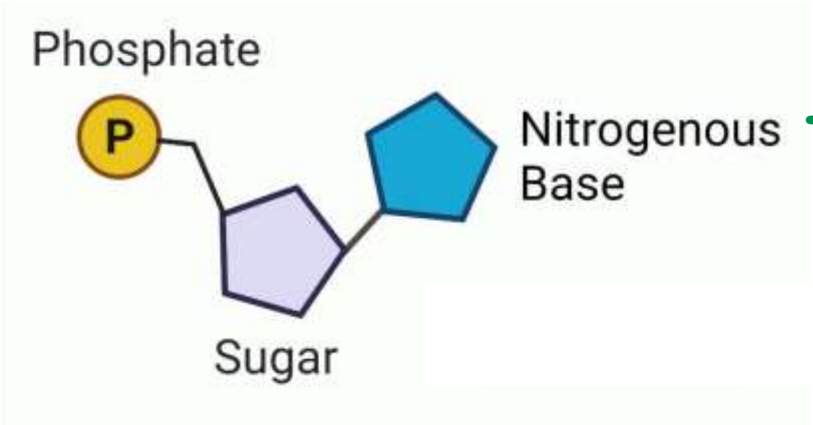


Testosterone **Estradiol**

4. Nucleotides

Monomers that constitute the two nucleic acids: DNA (deoxyribonucleic acid) and RNA (ribonucleic acid).

The difference is in the sugar.



ADENINE

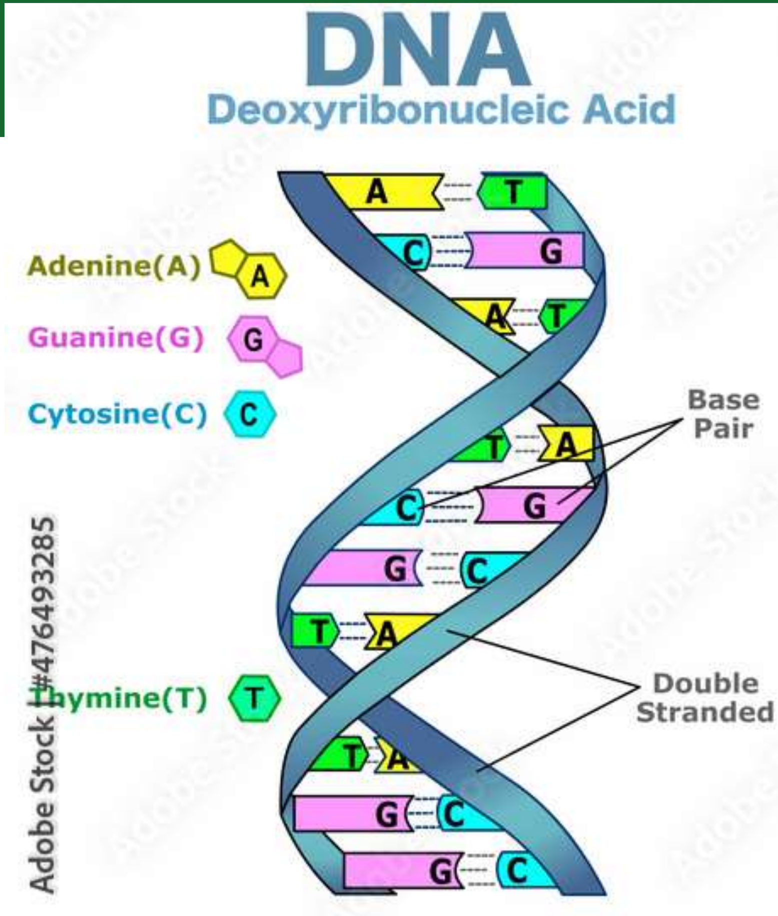
GUANINE

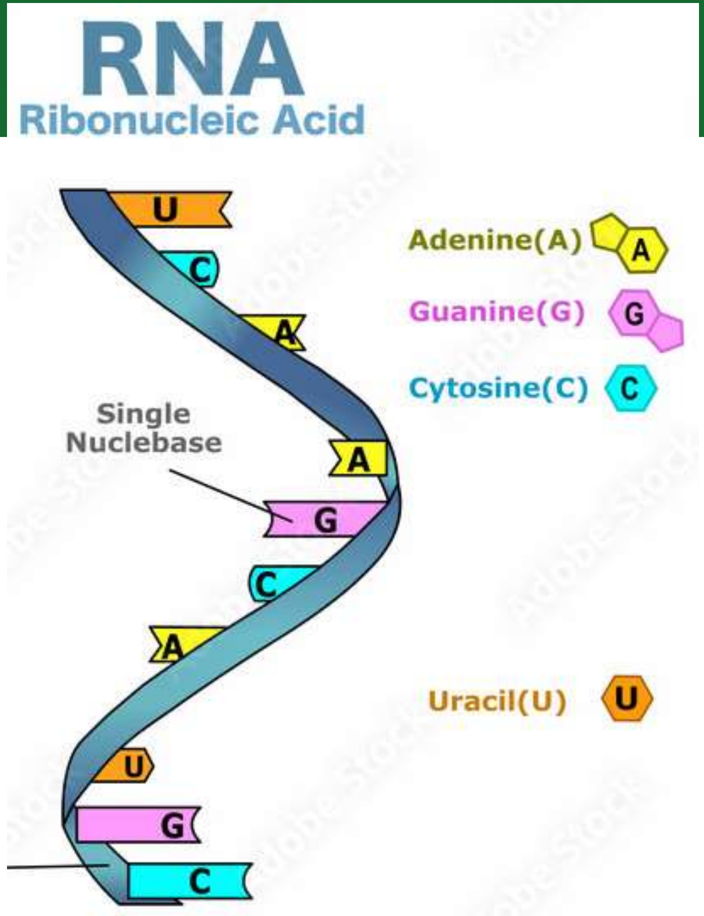
CYTOSINE

THYMINE

URACYL

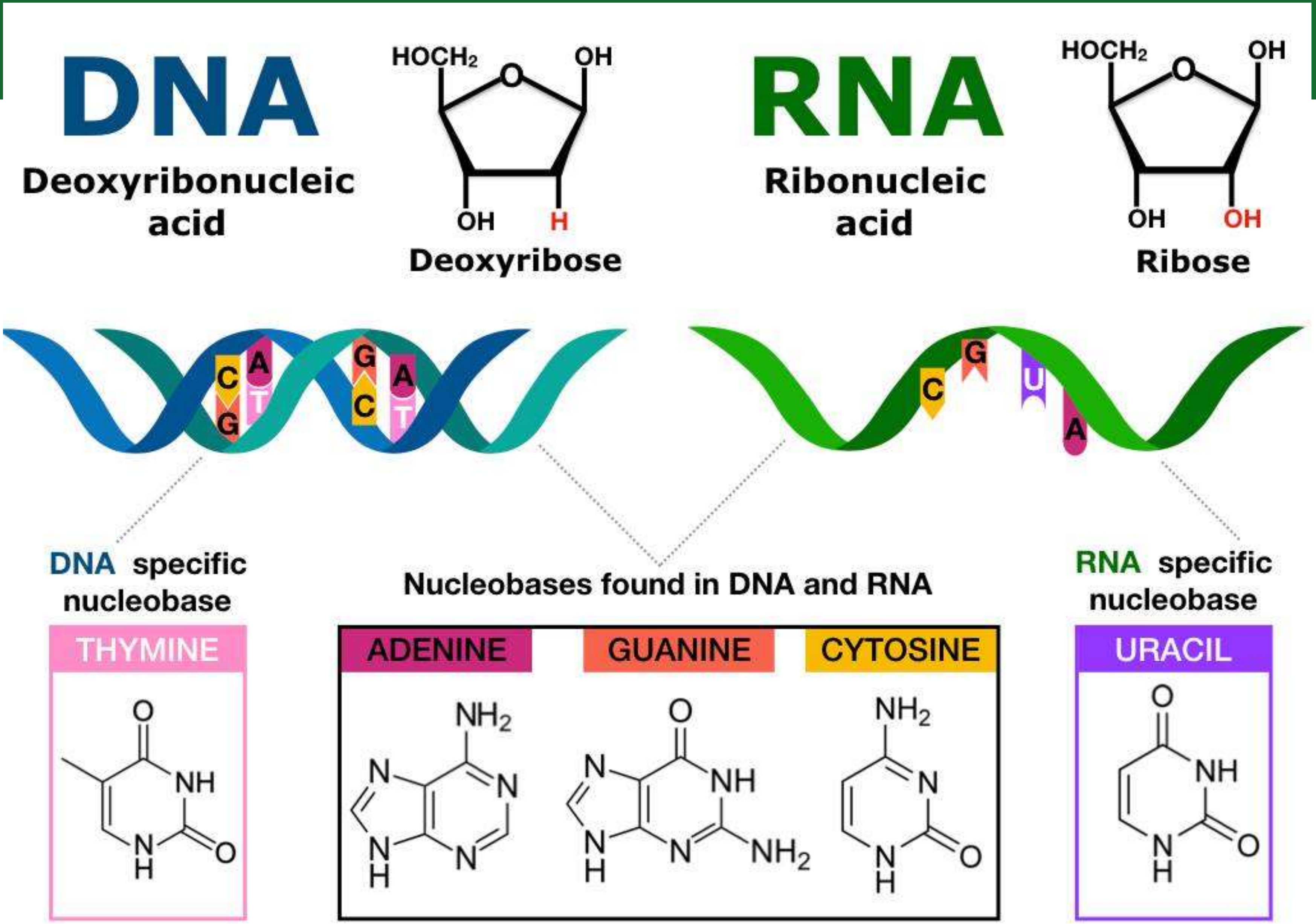
<u>Pairs:</u> A-T
G-C





DNA is double-helix, with hydrogen bonds between the nitrogenous bases.
DNA stores genetic information.

RNA is single strand.
RNA carries DNA information is order to produce proteins.


DNA
Deoxyribonucleic acid
HOCH2
OH
OH
H
Deoxyribose
RNA
Ribonucleic acid
HOCH2
OH
OH
OH
Ribose
C
G
A
T
G
C
A
T
C
G
U
A
DNA specific nucleobase
Nucleobases found in DNA and RNA
RNA specific nucleobase
THYMINE
ADENINE
GUANINE
CYTOSINE
URACIL
O
NH
N
H
O
NH2
N
N
N
N
H
O
N
NH
N
NH2
N
H
NH2
N
N
H
O
O
NH
N
H
O