

The background features a collage of chemistry-related elements. On the left, a test tube with a cork stopper contains a green liquid. In the center, a large Erlenmeyer flask is filled with a yellow liquid. To the right, a round-bottom flask contains a red liquid. In the foreground, a small pile of yellow powder sits on a surface, and a cork stopper lies nearby. Faint, white chemical structures are overlaid on the background, including a carboxylic acid group (HO-C=O) and a benzene ring with various substituents.

Amino acids

Proteins

Organic chemistry

Peptides

Lipids

Primary biomolecules

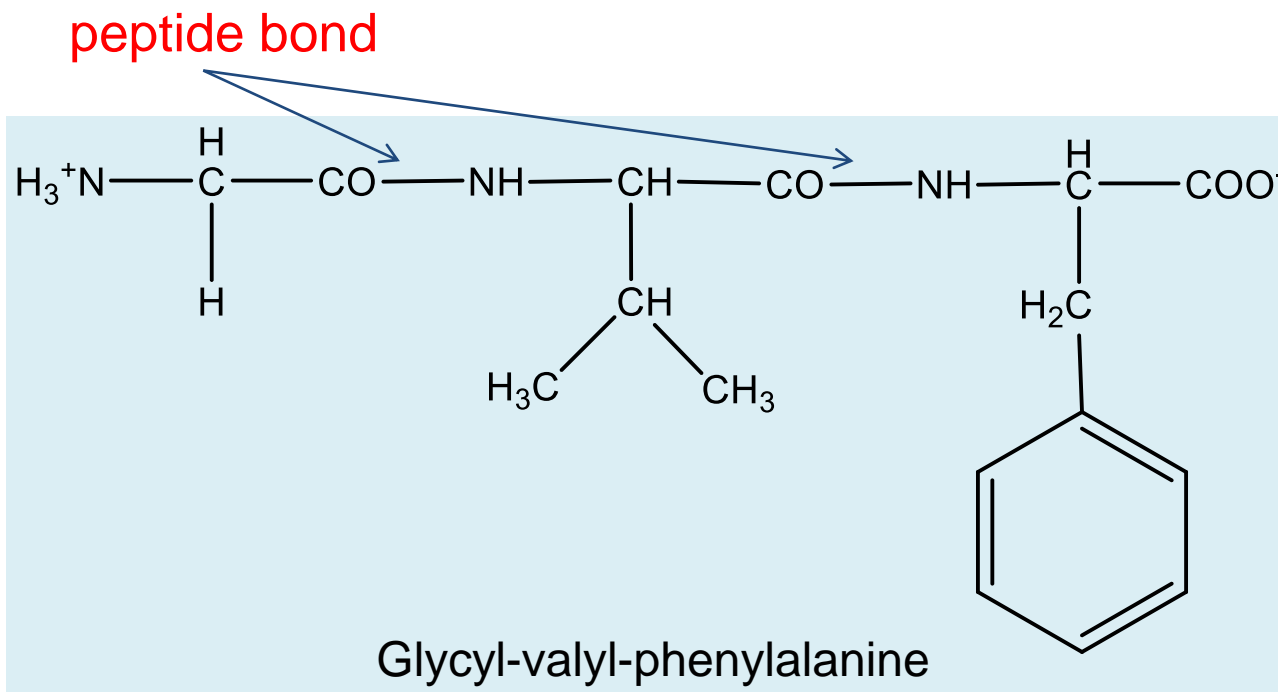


- **Peptides:** less than 50 amino acids
- Dipeptides: 2 amino acids
- Tripeptides: 3 amino acids
- Polypeptides: more than 10 amino acids
- **Proteins:** more than 50 amino acids



Peptides

- **Peptides** are amides that are formed by the reaction of amino and carboxyl groups of amino acids.
- The amide group -NH-CO- in these compounds is called a **peptide bond**





Peptides:

dipeptides - consist of two amino acids

oligopeptides - 3 to 10 amino acids

polypeptides (proteins) - contain more than one hundred amino acids

Biologically important peptides

Arg-Pro-Pro-Gly-Phe-Ser-Pro-Pro-Arg



Bradykinin

(reduces blood pressure)

Cis-Tyr-Ile-Gln-Asn-Cis-Pro-Leu-Gly



Oxytocin

(in childbirth, causes contractions of the uterus and lactation)

Cis-Tyr-Phe-Gln-Asn-Cis-Pro-Arg-Gly



Vasopressin

(acts on kidney and CNS)



Insulin is a pancreatic hormone.
Participates in regulation
carbohydrate metabolism
(diabetes)

CONTAINS TWO POLYPEPTIDE CHAINS

A HAS 21 AK

B HAS 30 AK

WHICH ARE CONNECTED
VIA 2 DISULPHIDE BRIDGES
(S-S)

Proteins

МЕДИЦИНСКИ ФАКУЛТЕТ
УНИВЕРЗИТЕТ У КРАГУЈЕВЦУ



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- The name comes from the Greek word **proteios** - the first
- Together with nucleic acids, they represent the most important components of the cell
- **Role:** Structural; - spare;
- defensive; - regulatory; - transport

Protein structure

Primary structure - sequence of binding of amino acids

Secondary structure - way of twisting peptide molecules in space

α -helix

β -pleated configuration

Tertiary structure - twisting into a spiral and aggregation of polypeptides

Quaternary structure - occurs in proteins that have two or more chains of amino acids and represents their combination



- Proteins are polymers of amino acids that make up more than 50% of the dry weight of cells
- Proteins are found in every cell in the body
- The sequence of amino acids is determined by DNA.

PRIMARY STRUCTURE

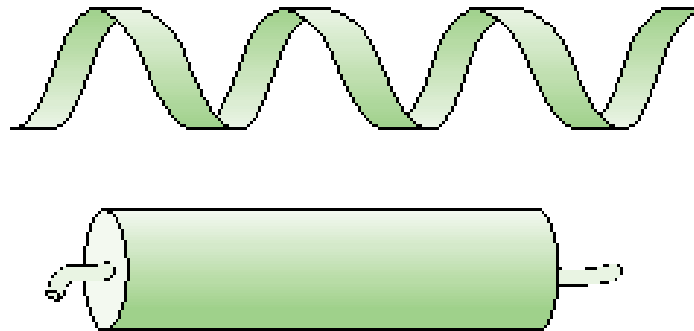
– order or sequence of amino acids





SECONDARY STRUCTURE - (conformation of linear proteins) spatial arrangement of polypeptide series

- α -HELICOID (SPIRAL) STRUCTURE



α – the helix goes clockwise

β – the helix goes in the opposite direction

NH of one amino acids forms a hydrogen bond with CO of another amino acids

R-residues face outwards

α -Helix



Coiled coil of two α -helices



Protofilament (pair of coiled coils)



Filament (four right-hand twisted protofibrils)



α -keratin has an α -helix structure

It is present in wool and hair

Natural hair fibers make up 3 intertwined helix forming a PROTOFIBRIL.

11 protofibrils make microfibril

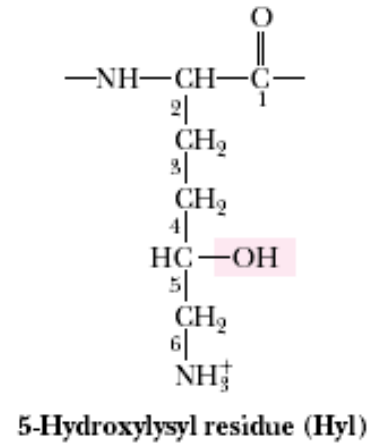
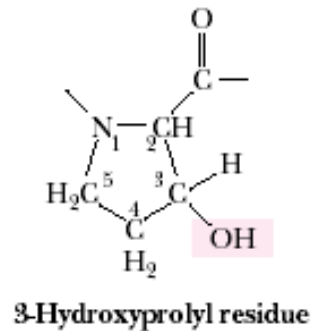
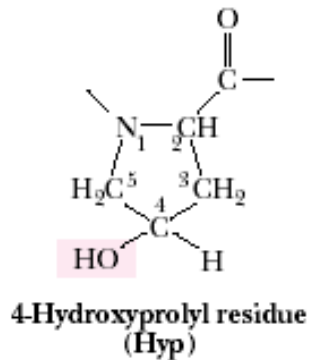
100 microfibril makes a macrofibril

Multiple macrofibrils join in a cell,

And the greater number of cells makes it hair or wool fiber



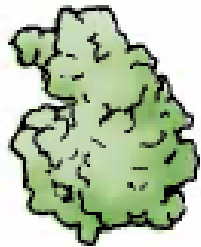
COLLAGEN



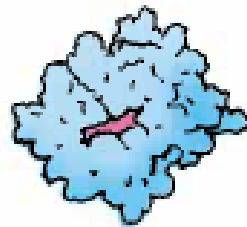
- Represents linear proteins which make up the basic building of the connective tissue of the skin and bone
- The peptide chain is composed of 2 Pro or Hyp (hydroxyproline) and 1 Gly building a steep helix
- Pro causes the formation of a steep spiral
- Three spirals build TROPOCOLLAGEN

TERTIARY AND QUATERNARY STRUCTURE

- GLOBULAR PROTEINS
- INFLUENCE OF R-RESIDUES
- TERTIARY STRUCTURE: LYSOLYM, RIBONUCLEASE, CYTOCHROME C, MYOGLOBIN



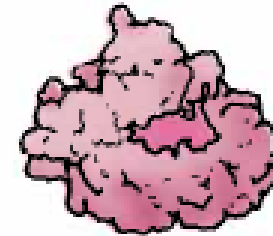
Lysozyme



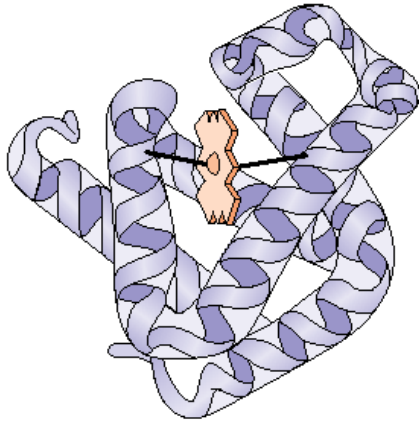
Cytochrome *c*



Ribonuclease



Myoglobin



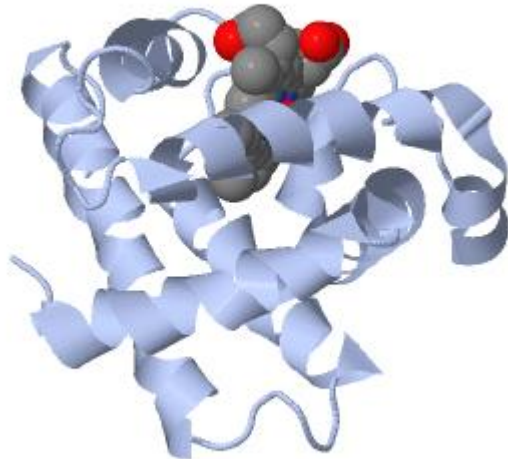
Myoglobin is a globular protein whose function is to store molecular oxygen in muscles
(myo = muscles).

It has two main components: a single polypeptide chain, and heme ligand.

The eight structurally conserved alpha helices are labelled **A through H**.

Does not contain disulfide bonds

It is stabilized by hydrogen bonds and van der waals forces



QUATERNARY STRUCTURE

- HEMOGLOBIN has 4 heme and 4 polypeptide chains (2 α и 2 β) and 574 amino acids
- each chain has a tertiary structure

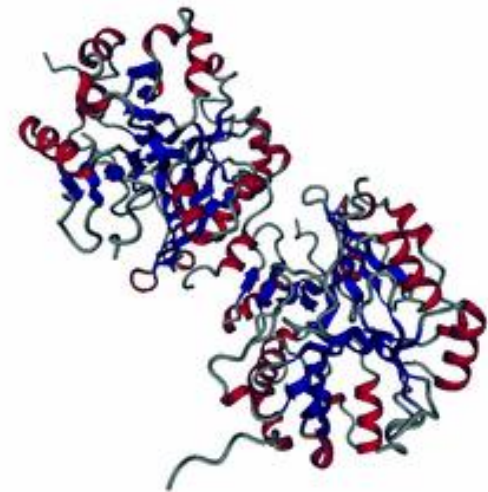
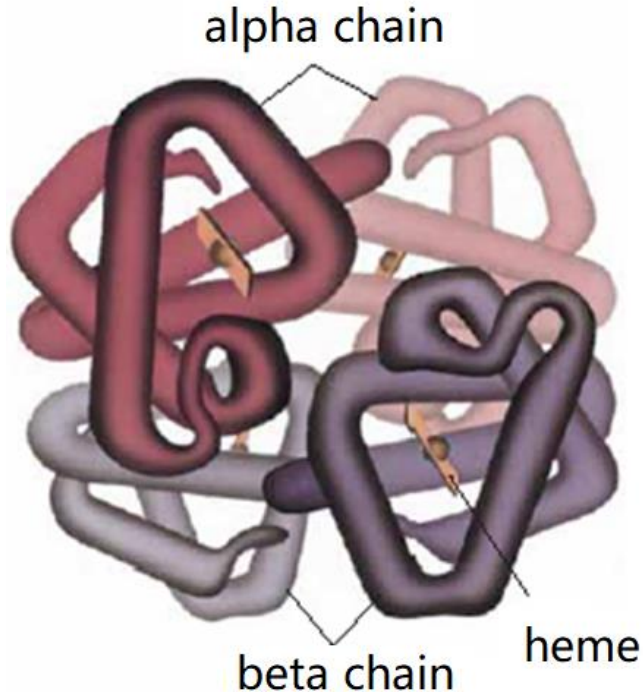
Hemoglobin (human)

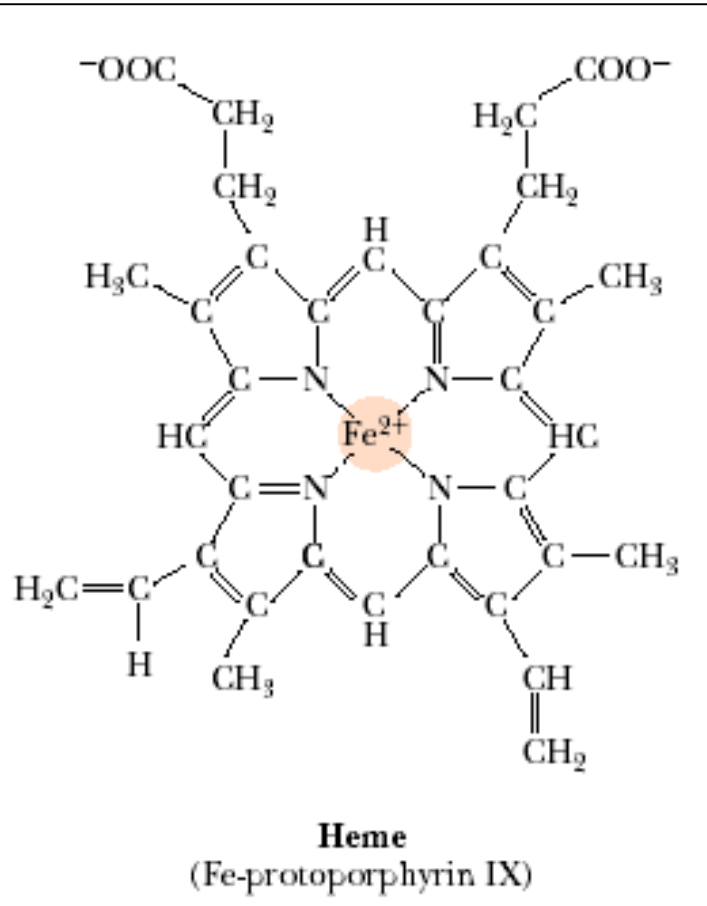
64,500

141 (α)

146 (β)

$\alpha_2\beta_2$





In the center of the heme, there is an **iron (2+) ion** to which oxygen is bound



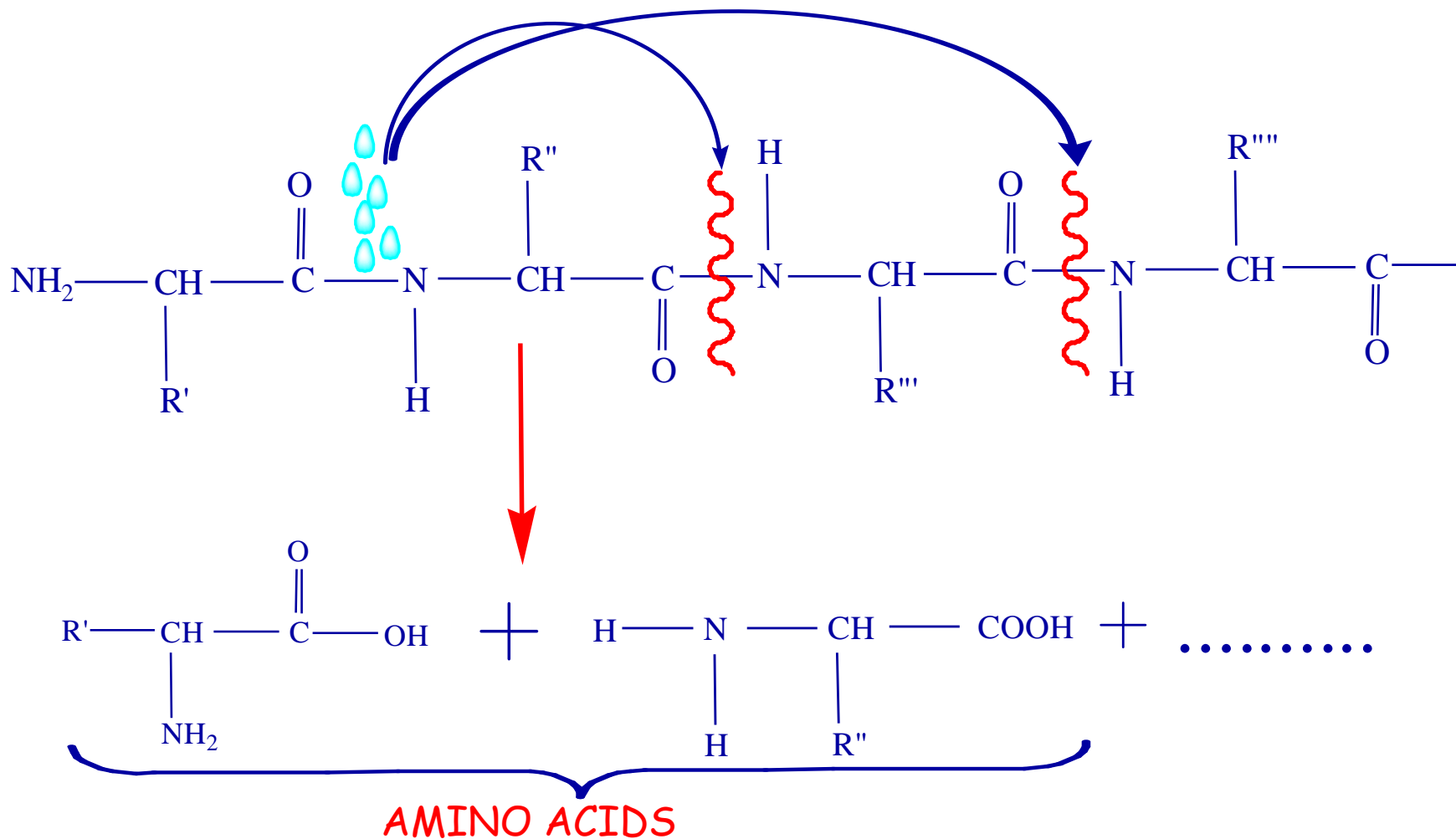
Determination of the amino acid composition of proteins involves three basic steps:

1. **Hydrolysis of the protein to its constituent amino acids.**
With concentrated acid solution (6N HCl) at a very high temperature (usually 110 °C)
2. **Separation of the amino acids in the mixture.**
3. **Quantification of the individual amino acids.**

ion exchange chromatography, gas chromatography, high-performance liquid chromatography



PROTEIN HYDROLYSIS





Denaturation of protein is a process in which proteins lose the quaternary structure, tertiary structure, and secondary structure which is present in their native state.

Denaturation can be done using

temperature change,

pH,

UV radiation,

detergents, carbamide,

ions of liquid metals,



Cysteine and methionine are two essential **amino acids** which contain **sulfur**.

These acids form a **black precipitate** with lead hydroxyde **Pb(OH)₂**

Xanthoproteic test

– Aromatic amino acids give a **yellow precipitate** by heating with conc **HNO₃**

Biuret Test



Blue Color
(Proteins Absent)

Negative Biuret Test



Purple Color
(Proteins Present)

Positive Biuret Test

– **Biuret test** (for
PEPTIDE BONDS)

CuSO₄ solution in alkaline
solution - **purple complex**



CARBOHYDRATES



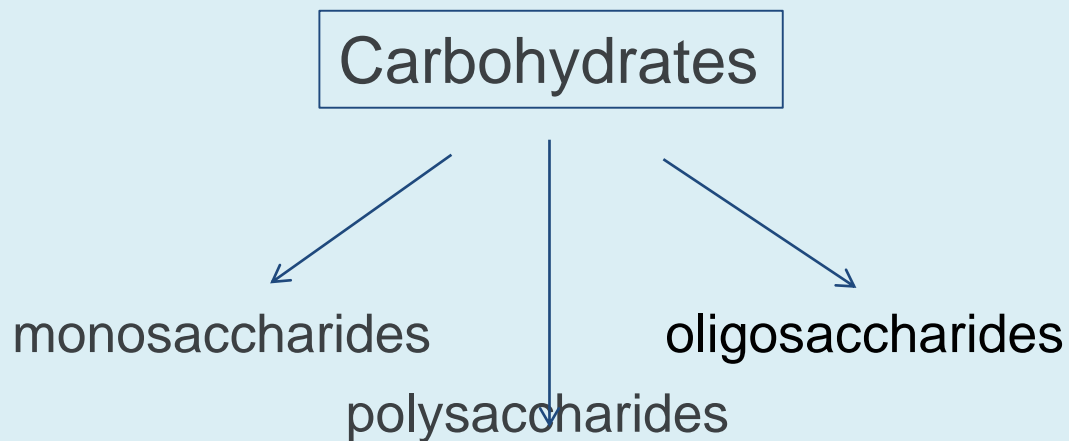
fructose

CARBOHYDRATES



Carbohydrates (sugars)

- The most widespread compounds in the living world.
- Together with proteins and lipids, **they form the basic components of biological systems.**
- These are **polyhydroxyl aldehydes, polyhydroxyl ketones** or compounds that can be converted into them by hydrolysis.
-





- **Oligosaccharides** (Greek - oligos, small number) are built from 2 to 10 monosaccharide units
- **Disaccharides** - built from two monosaccharide units
- **Polysaccharides** contain hundreds and thousands of monosaccharide units
- Sugars that reduce Fehlin's reagent are called **reducing sugars**
- All monosaccharides are reducing sugars.
- Most disaccharides are reducing sugars (except sucrose, trehalose)



Monosaccharides

Monosaccharide is a carbohydrate consisting of one sugar unit.

Monosaccharides are polyhydroxyl aldehydes and ketones:

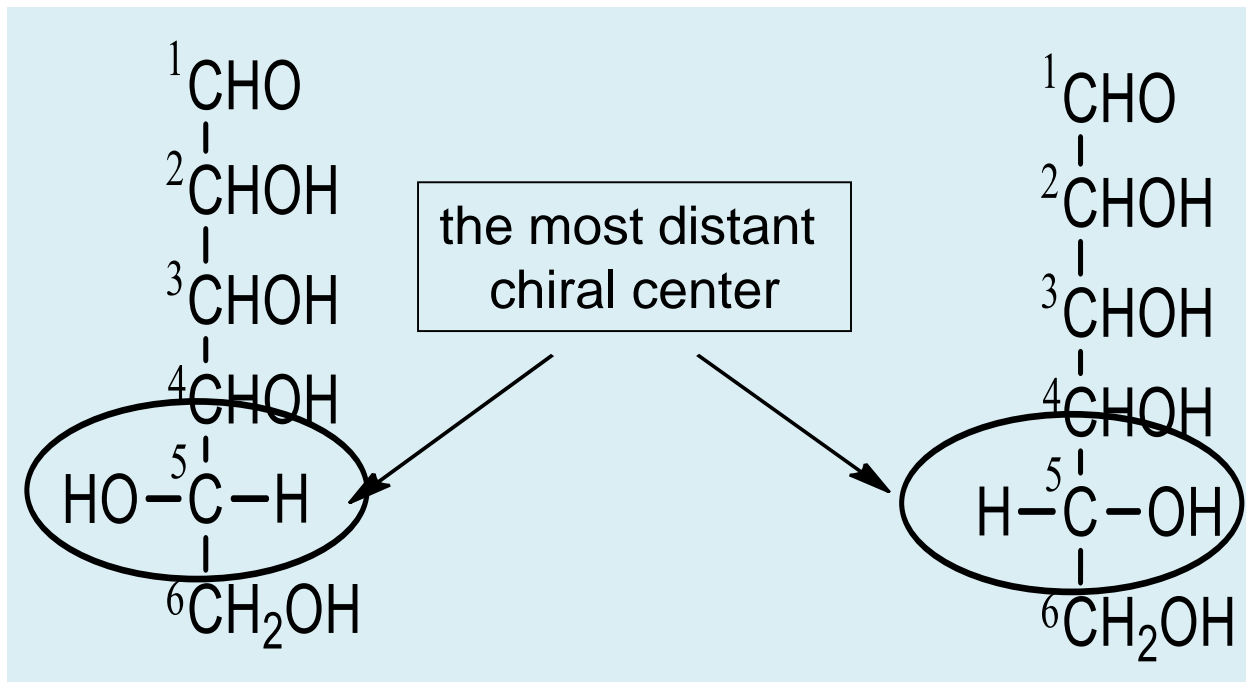
- aldoses
- ketosis

According to the number of carbon atoms, they are clasified into:

- trioses
- tetrosis
- pentoses
- hexoses
- heptose



Relative configuration of monosaccharides

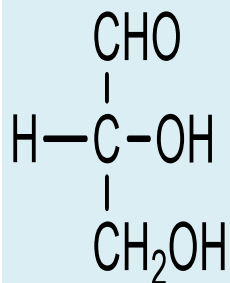


L-aldohexose

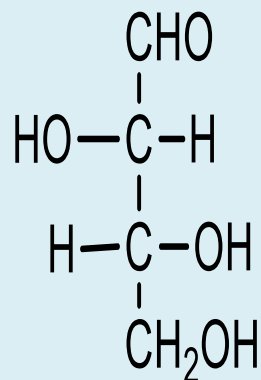
D-aldohexose



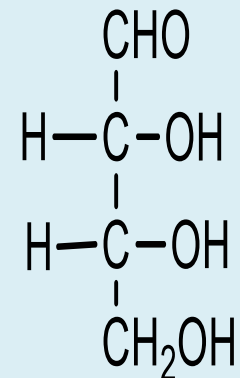
Monosaccharides aldotriose and aldotetrose



D-glyceraldehyde



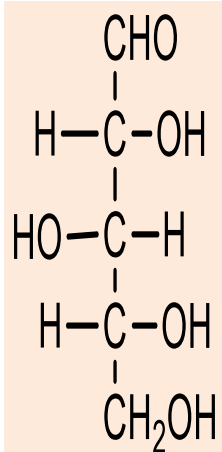
D-threose



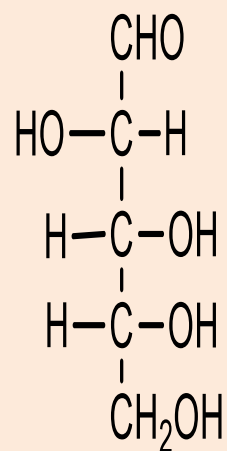
D-erythrositis



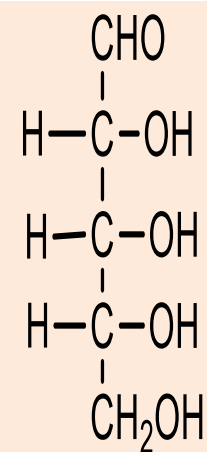
Aldopentoses



D-xylose



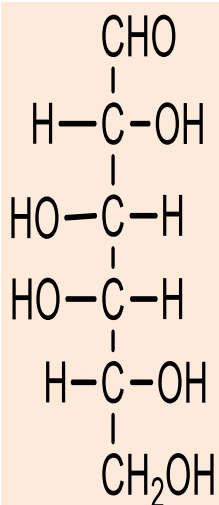
D-arabinose



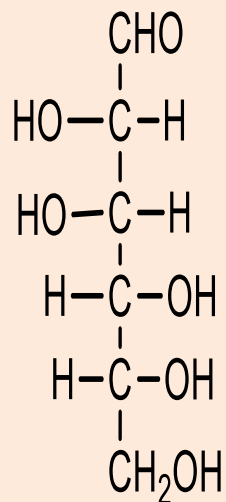
D-ribose



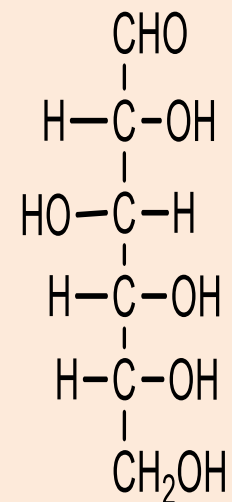
Aldohexoses



D-galactose



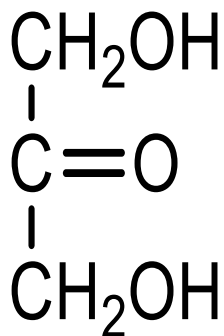
D-mannose



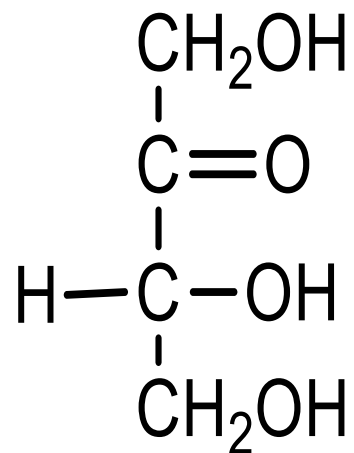
D-glucose



Ketotrioses, Ketotetroses



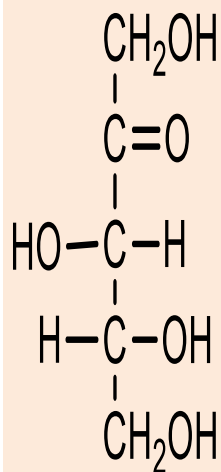
Dihydroxyacetone



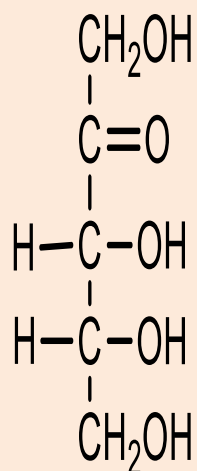
D-erythrulose



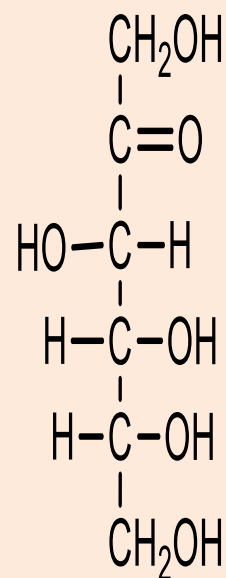
Ketopentoses, Ketohehexoses



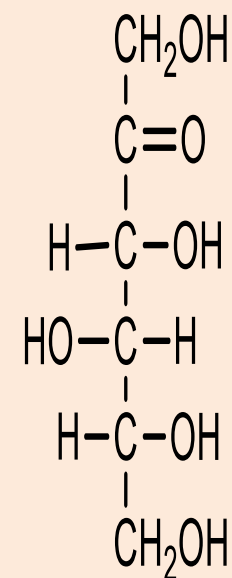
D-Xylulose



D-ribulose



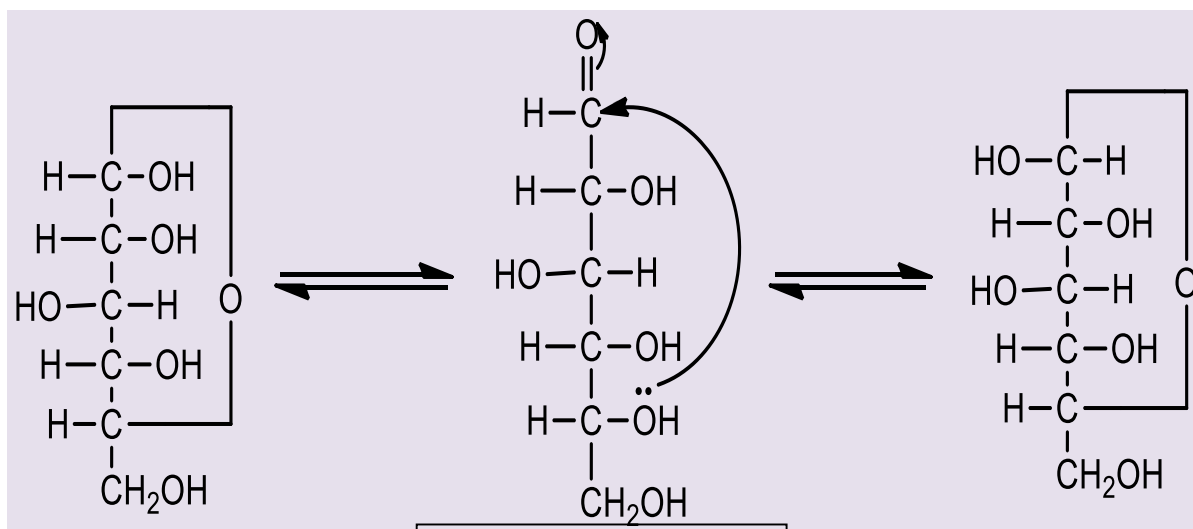
D-fructose



D-sorbose



Formation of cyclic polyacetals



α -D-(+)-glucopyranose

the open form
of D-glucose

β -D-(+)-glucopyranose



Glucose in Water

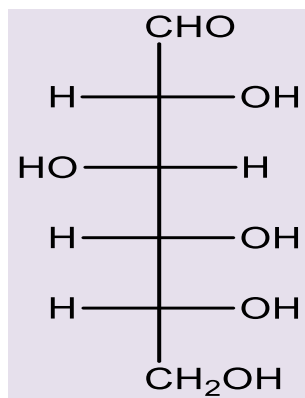


Glucose in water

cyclization



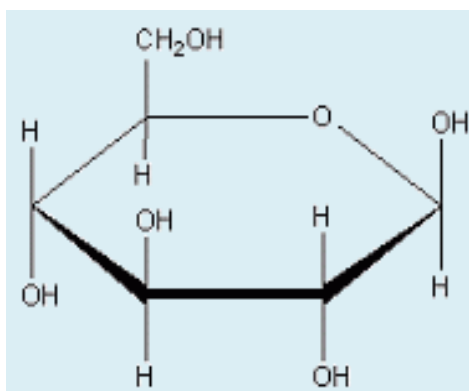
Fisher's formulas



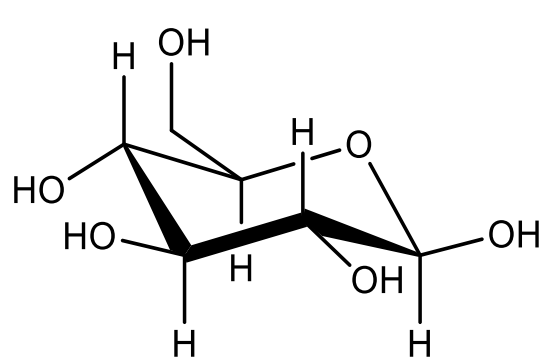
D-glucose

Glucose in blood

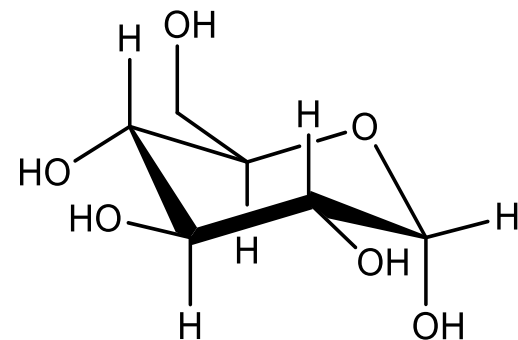
Haworth's formulas



β -D-(+)- glucopyranose



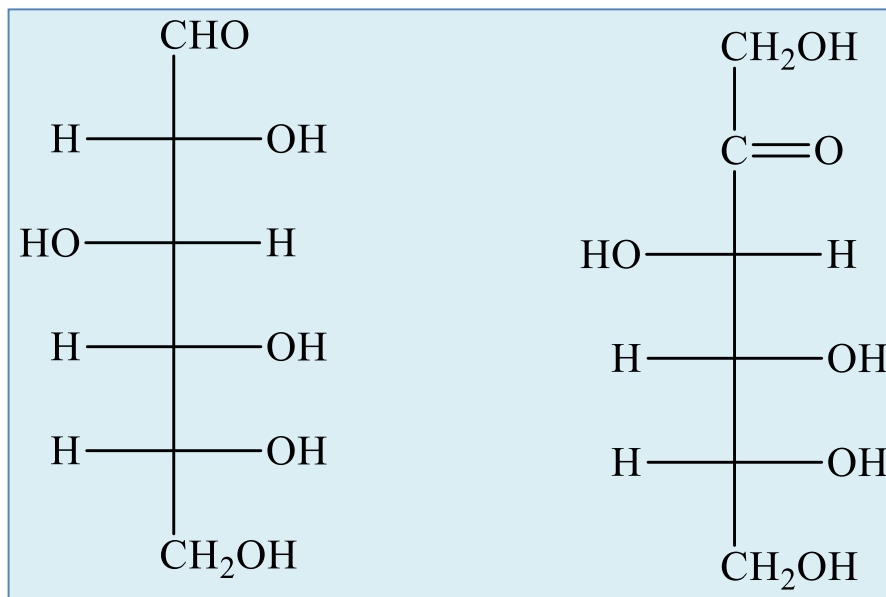
β -D-(+)- glucopyranose



α -D-(+)- glucopyranose



- Monosaccharides are **solid, crystalline substances** with a sweet taste.
- Typical representatives of monosaccharides are glucose and fructose.
- A mixture of these two monosaccharides in a 1:1 ratio is called **inverse sugar**

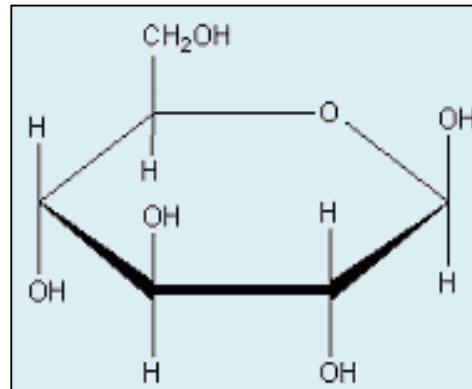


glucose and fructose



Glucose (dextrose)

- Glucose is the most abundant and important monosaccharide.
- It is a constituent of starch, cellulose and glycogen.
- Molecular formula $C_6H_{12}O_6$
- It is found in fruits and honey and is the major free sugar circulating in the blood of higher animals.



A level between 3.5 mmol/L and 5.6 mmol/L is considered a normal blood sugar value.

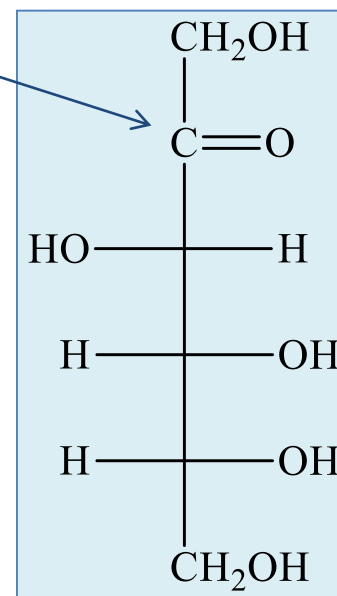
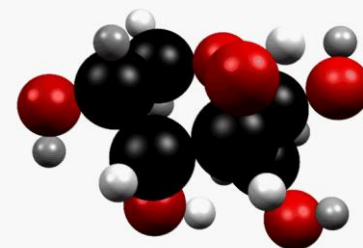


Fructose “fruit sugar”

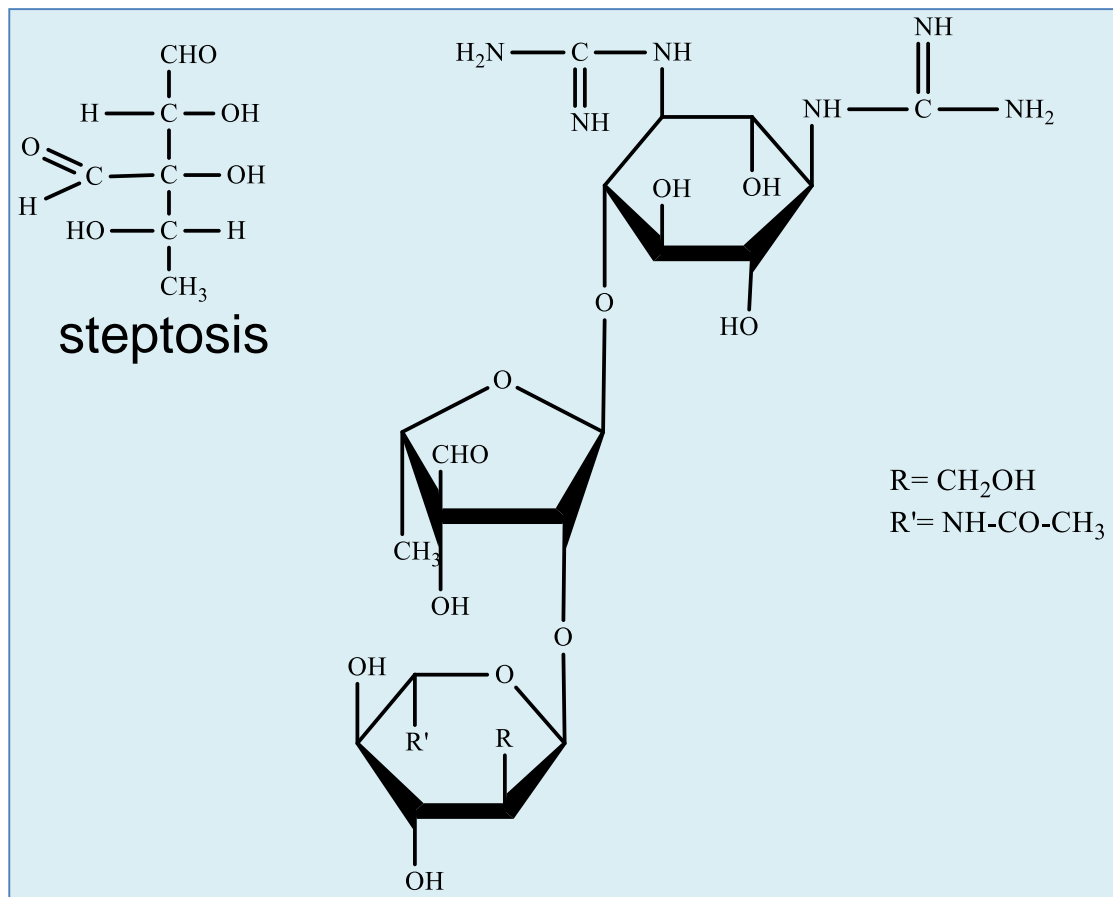
- The most important **ketosis**, which is found in a large percentage in fruit, vegetable and honey.
- Fructose is **sweet, white, odorless, crystalline solid**.
- **The liver converts both fructose and galactose into glucose**, so that dissolved glucose, known as blood sugar, is the only monosaccharide present in circulating blood.
- **High-fructose corn syrup** is a mixture of glucose and fructose.



β -D-fructopyranose



Monosaccharides that are part of some important molecules

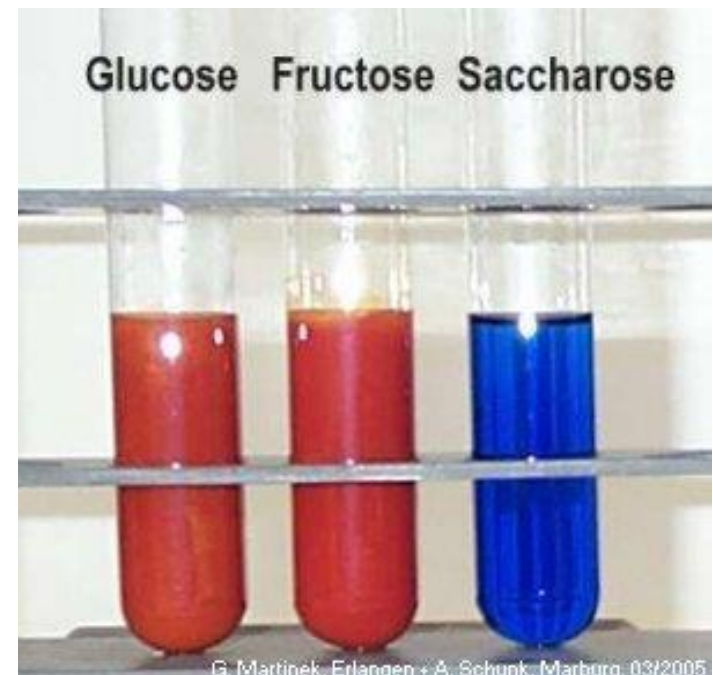
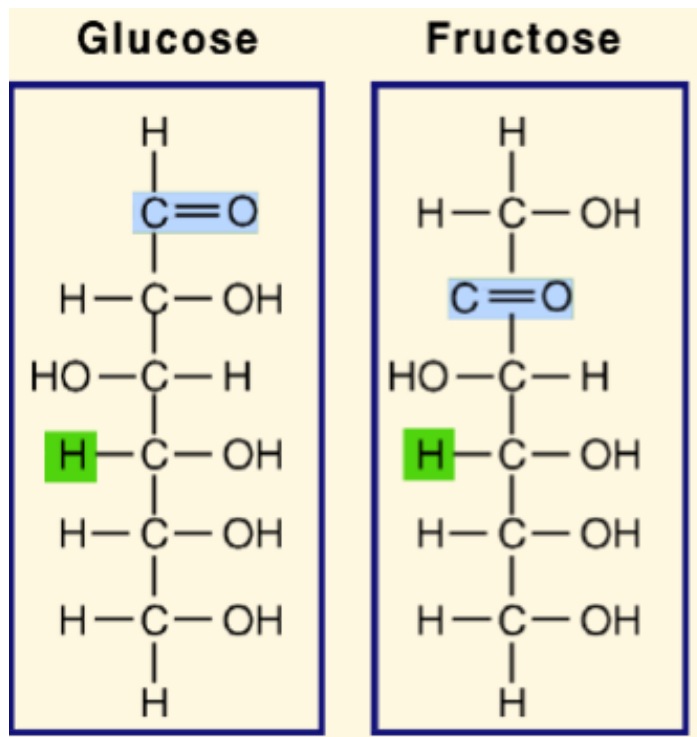


antibiotic

Streptomycin

Fehling's test

- Fehling's reagent (solution A: $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)
- Fehling's reagent (solution B: Sodium potassium tartrate)





Disaccharides

Disaccharides consist of two monosaccharides, i.e. they yield two monosaccharide units by hydrolysis.

The most common disaccharides are:

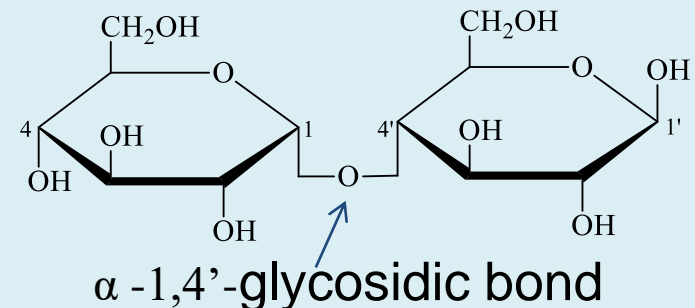
- **Maltose** - two units of glucose
- **Lactose** (milk sugar) - glucose and galactose
 - **Sucrose** - glucose and fructose

Maltose

Molecular formula $C_{12}H_{22}O_{11}$

It is formed as an intermediate product of starch hydrolysis with dilute acids.

Reducing sugar



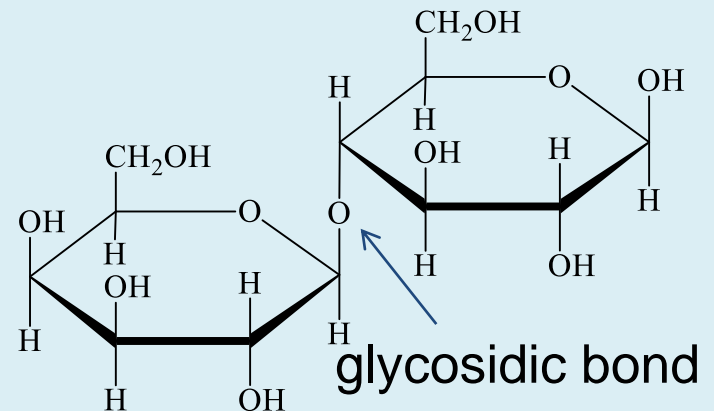


Lactose

Molecular formula $C_{12}H_{22}O_{11}$

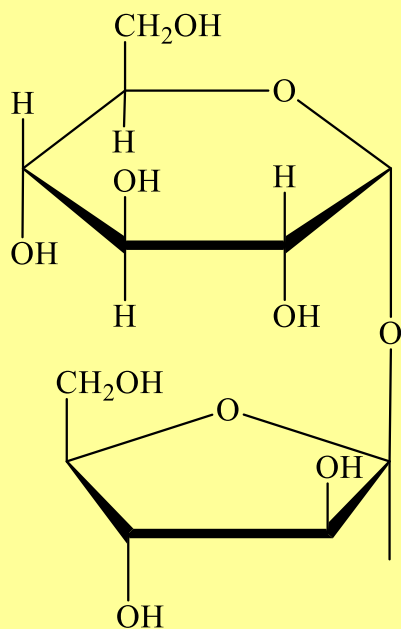
- Lactose makes up around 2–8% of milk (by mass).
- Lactose is a disaccharide derived from the condensation of galactose and glucose.

Reducing sugar



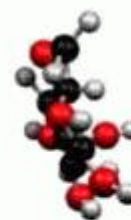
Sucrose

- Molecular formula $C_{12}H_{22}O_{11}$
- It is obtained from sugar cane and sugar beet It does not contain a free aldehyde or keto group
- Non-reducing sugar

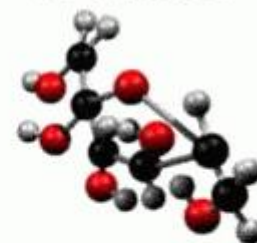


- Glucose and fructose forms the disaccharide sucrose.

Glucose



Fructose





Polysaccharides

- **Polysaccharides** are macromolecules composed of a large number of monosaccharide units.

Homopolysaccharides contains one type of monosaccharide units.

Heteropolysaccharides contain two or more monosaccharide units.

The role:

- **reserve** - storage of chemical energy needed by living organisms
 - starch - reserve sugar in plants
 - glycogen - reserve sugar in animals
- **structural** - construction of cellular structures
 - cellulose
 - chitin



Starch

- **Starch** is glucose polymer.
- It is found in plants in the form of grains.
- Undamaged grains are insoluble in cold water, while damaged ones swell and form a gel.
- In hot water, the grains swell and fall apart.
- **Starch** contains about 20% amylose, which is soluble in water, and 80% amylopectin, which is insoluble in water.
- In the presence of acids or enzymes, **starch hydrolyzes** into dextrin, maltose and finally glucose

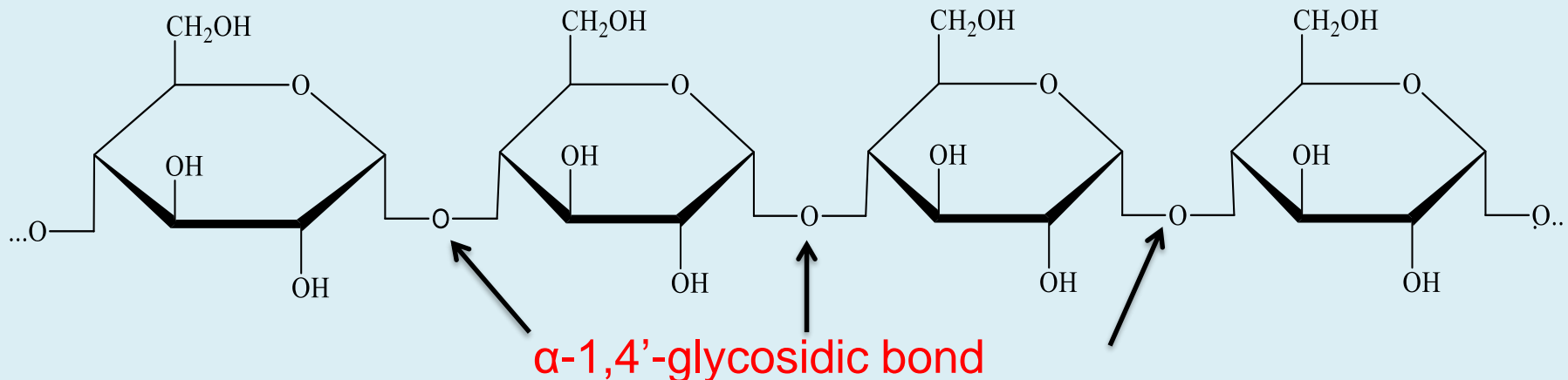
Amylose

МЕДИЦИНСКИ ФАКУЛТЕТ
УНИВЕРЗИТЕТ У КРАГУЈЕВЦУ



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- **Hydrolysis** of amylose produces **maltose**, and further hydrolysis produces glucose.
- Amylose is an unbranched, long chain composed of 1000 or more D-glucose units.
- D-glucose is bound to two other D-glucose units, one through C-1 and the other through C-2
- Amylose gives an intense blue color with iodine.

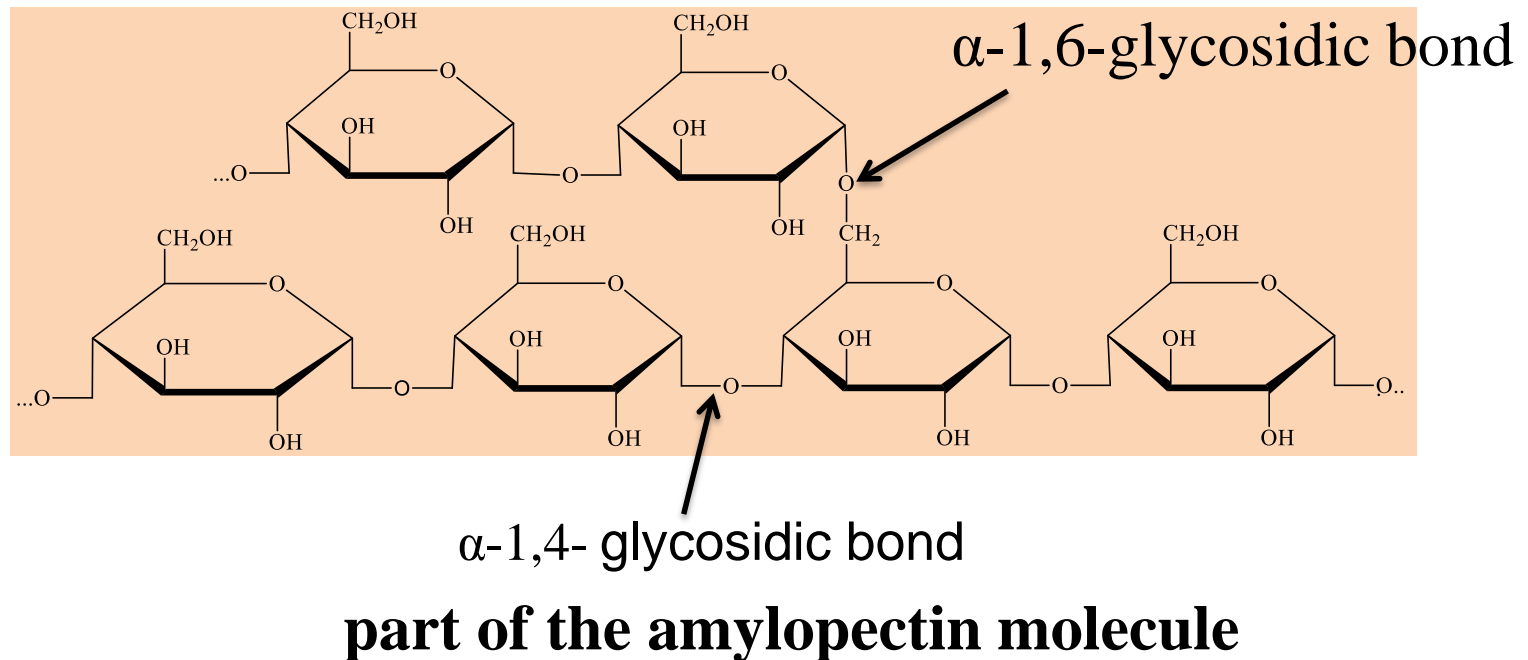


part of the amylose molecule



Amylopectin

- Amylopectin** has a **branched structure** consisting of several hundred short chains, and each chain has about 20-25 D-glucose units.



Cellulose

МЕДИЦИНСКИ ФАКУЛТЕТ
УНИВЕРЗИТЕТ У КРАГУЈЕВЦУ



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- The main component of wood and plant fibers.

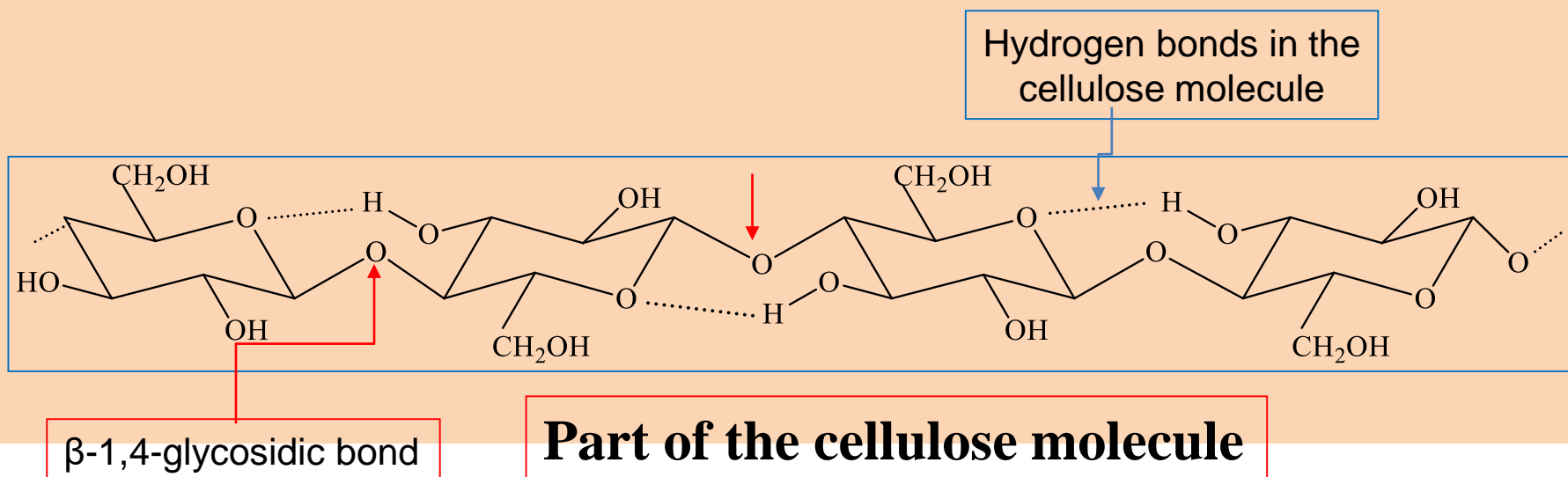
- Insoluble in water;
- tasteless

cellulose fibers

It differs from starch in the configuration of the glycosidic bond (β -1,4-glycosidic bond)

- Cotton - almost pure cellulose

cellulose molecule





Lipids

Lipids are a group of organic compounds which include:

- fats,
- fatty acids,
- glycerides,
- phospholipids,
- fat-soluble vitamins
(such as vitamins A, D, E and K),
- waxes,
- sterols and
- others.

Bears put on fat in summer and burn fat in winter.

Lipids

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УНИВЕРЗИТЕТ У КРАГУЈЕВЦУ



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Lipids function: energy reserve, regulate hormones, transmit nerve impulses, and transport fat-soluble nutrients.

Fat in food serves as an energy source with high caloric density

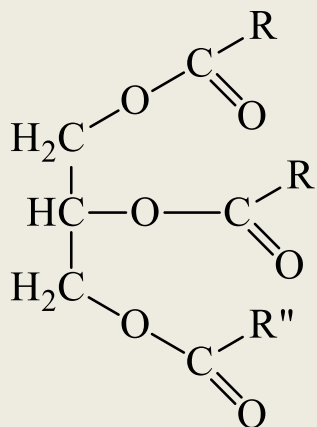
Characteristics

- they are insoluble in water, but soluble in organic solvents (ether, benzene, acetone...)
- their molecules contain both polar (hydrophilic) and non-polar (hydrophobic) groups

Whales represent a large amount of lipids floating in the sea.



From the chemical point of view, **fats** are esters of higher fatty acids and alcohol-glycerol, so they are also known as glycerides or triacylglycerides.



triglyceride

Hydrophobic part = long hydrocarbon chain

Hydrophilic part=polar carboxyl group



FATTY ACIDS are monocarboxylic acids, most often with an even number of C-atoms (4 to 30).

Fatty acids can be saturated and unsaturated.

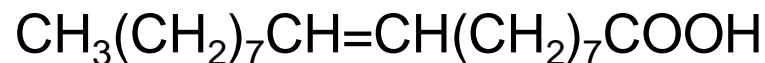
Some saturated fatty acids - fats of animal origin

Lauric	$\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$
Myristic	$\text{CH}_3(\text{CH}_2)_{12}\text{COOH}$
Palmitic	$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$
Stearic	$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$



Some unsaturated fat acids - oils of plant origin

Oleic [C 18:1(9)]



Linoleic [C 18:2(9,12)]



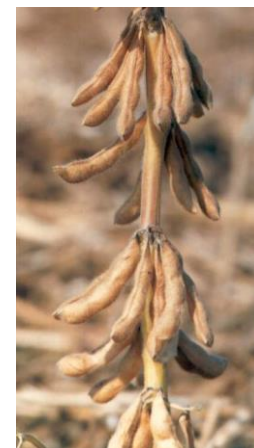
Linolenic [C 18:3(6,9,12)]





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soybeans

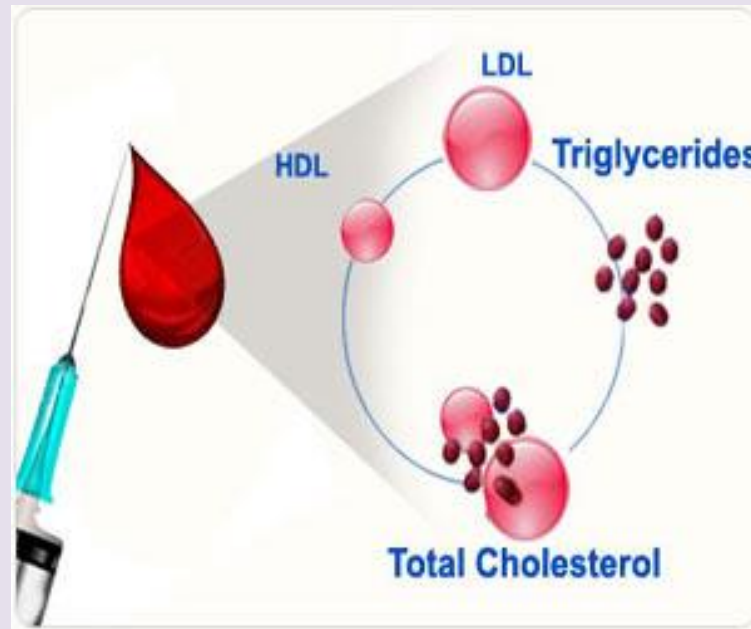


sunflower

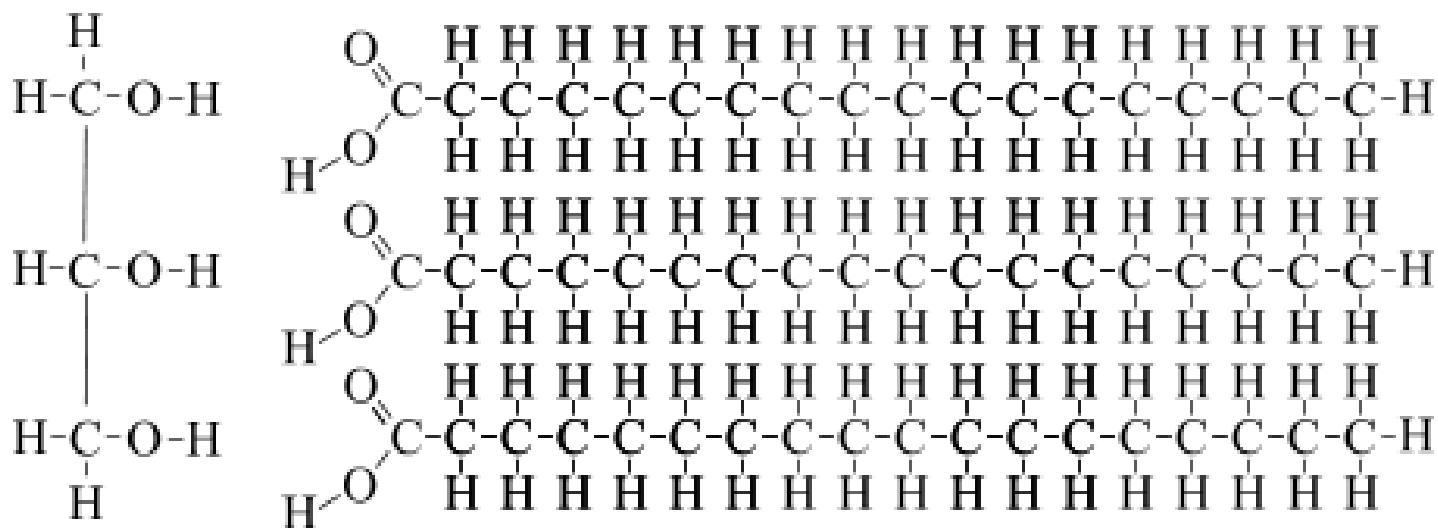
Fatty Acid Compositions of Some Dietary Lipids*

Source	Lauric and Myristic	Palmitic	Stearic	Oleic	Linoleic
Beef	5	24-32	20-25	37-43	2-3
Milk		25	12	33	3
Coconut	74	10	2	7	—
Corn		8-12	3-4	19-49	34-62
Olive		9	2	84	4
Palm		39	4	40	8
Safflower		6	3	13	78
Soybean		9	6	20	52
Sunflower		6	1	21	66

Triglycerides – glycerides that have all 3 hydroxyl groups of glycerol esterified with fatty acids.



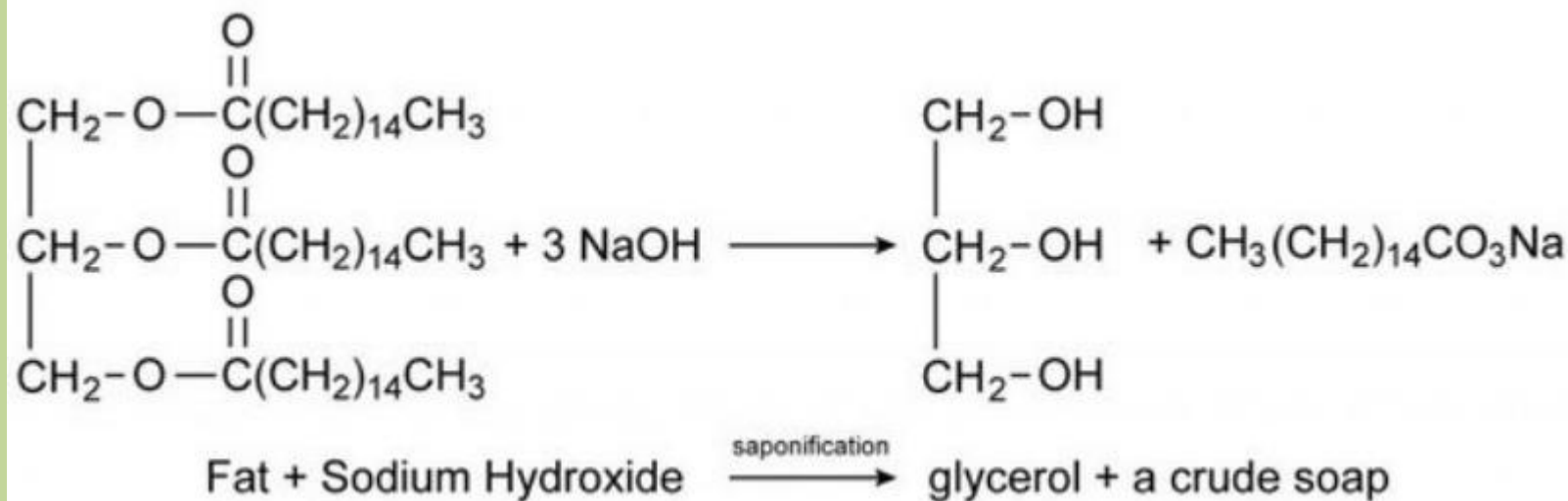
High triglyceride level in the blood can increase your risk of a heart condition.



Soaps

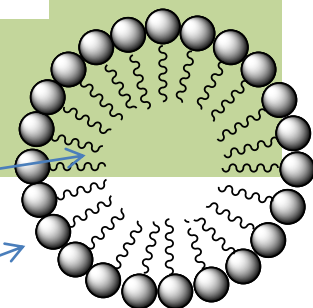


- Making soap is one of the oldest chemical processes
- Soap is a mixture of sodium salts of higher fatty acids



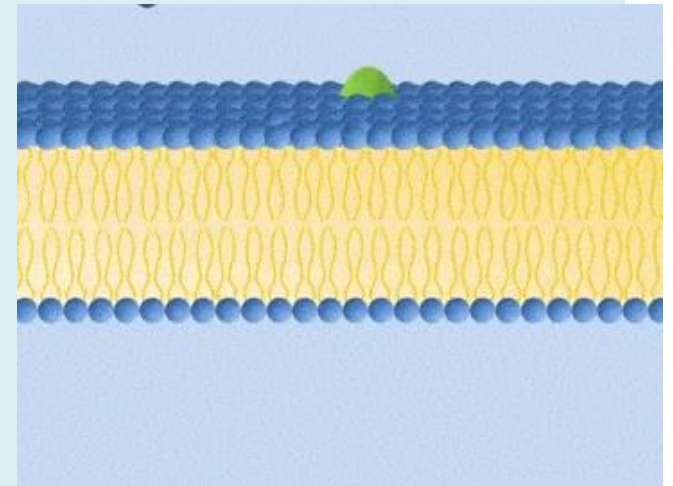
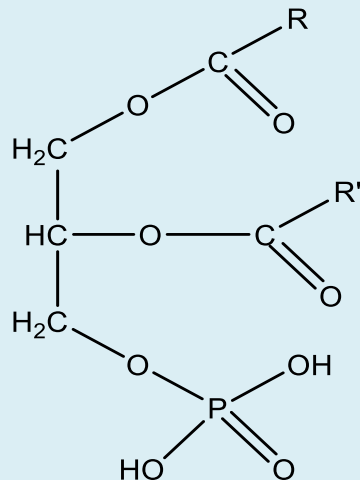
non-polar part

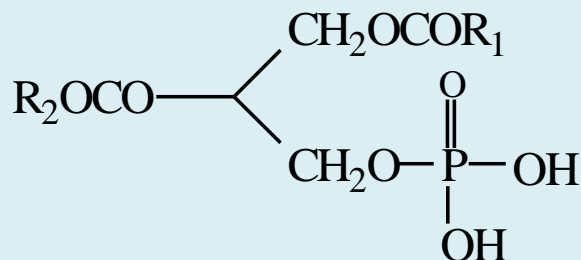
polar part



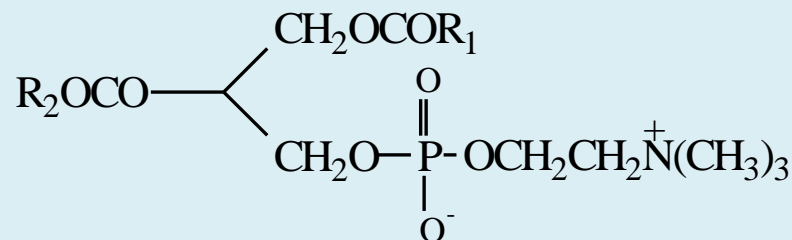
Phospholipids contain two acyl groups, while the third is replaced by a phosphoric acid residue.

The cell membrane contains phospholipids



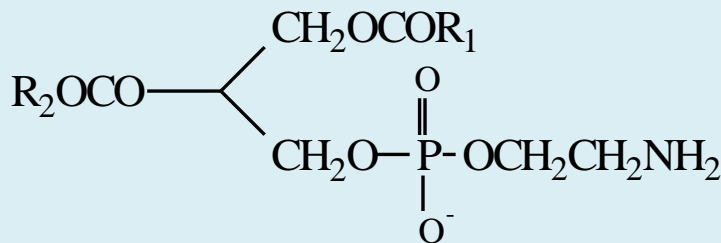


L-phosphatidic acid

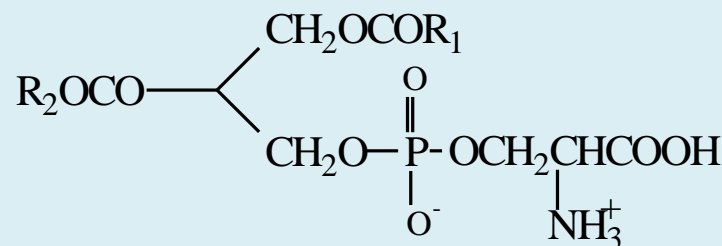


phosphatidylcholine

Phosphatidylcholine (lecithin) is found in larger quantities in the brain, nerve tissue, egg yolk, soybean oil and other edible oils.



phosphatidylethanolamine (kephalin)



phosphatidylserine



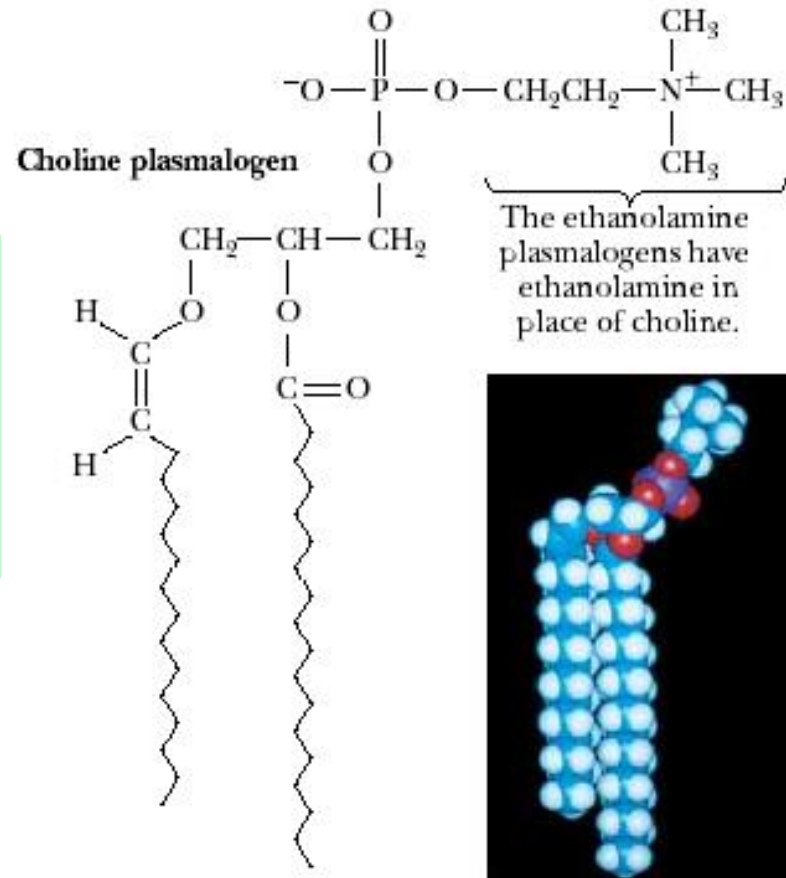
- Snake venom contains phospholipase enzymes that break down phospholipids.
- Cobra contains phospholipase A2 which hydrolyzes at C-2, building lysolecithin which acts as a detergent and dissolves red blood cell membranes.
- The Indian cobra kills several hundred people every year.

Indian cobra



Plasmalogens are ethers of glycerophospholipids in which the alkyl residue is $\text{cis-}\alpha,\beta$ -unsaturated

Most of them are in muscle membranes and nerve cells (heart muscle, brain and liver), and in soy, peanut and other plants.

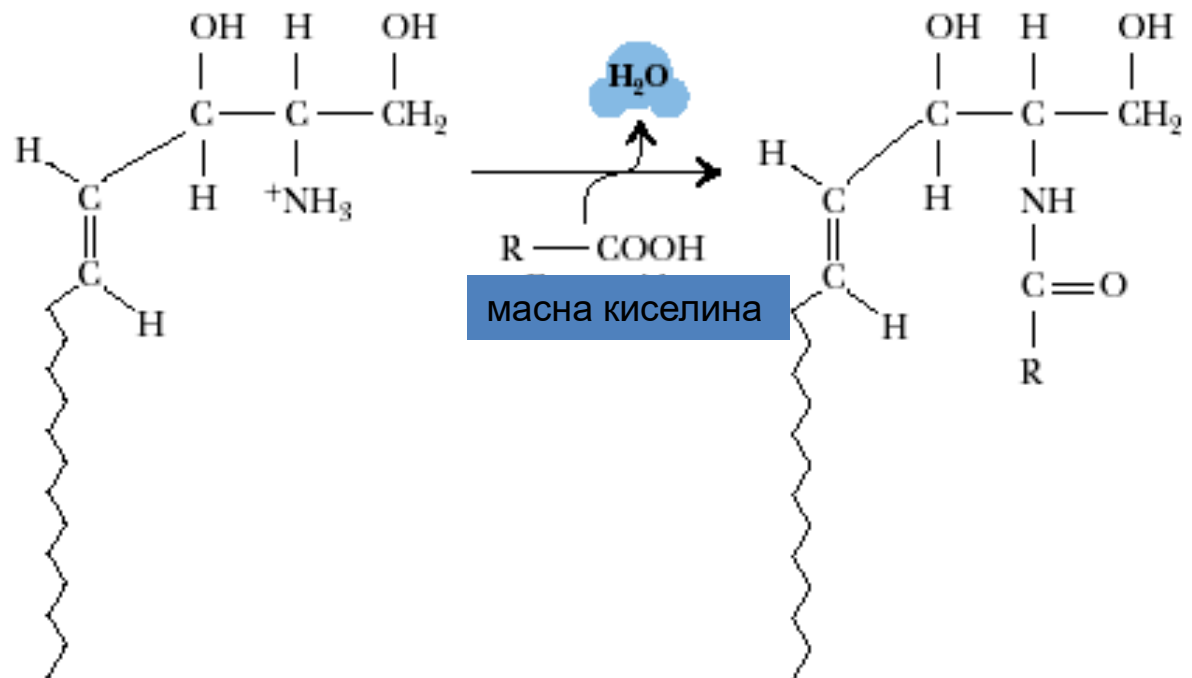




Sphingolipids are amides of fatty acids and high molecular weight alcohols

They are of plant and animal origin.

They enter the structure of membranes, mostly in the brain and nervous tissue.



sphingosine

ceramide