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C
CARBON

compounds

*in nature
and practice*

*Fats
Carbohydrates
Proteins*



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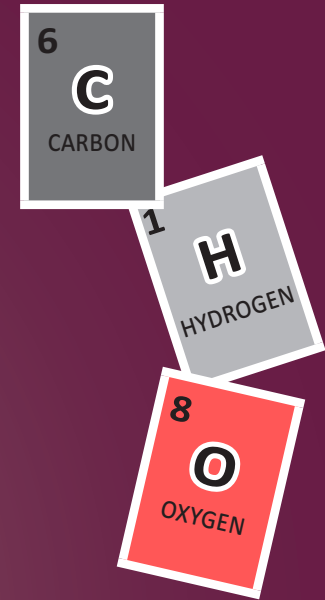
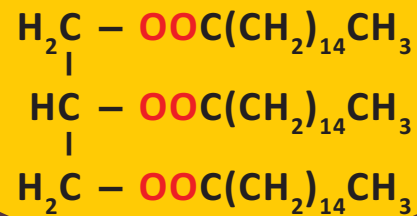
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FATS

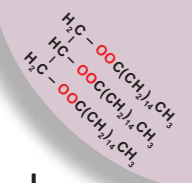
KEY TOPICS

1. What are fats?
2. Why do we need fats?
3. What fats are „good“ fats?
4. Which foods are rich in healthy fats?



KEY WORDS

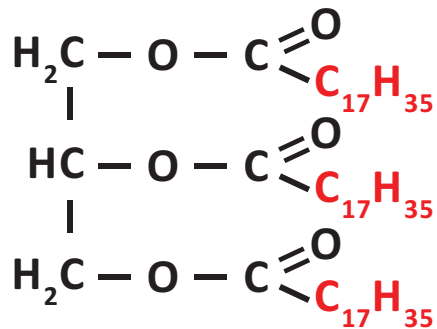
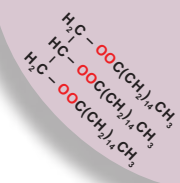
- Fats
- Oils
- Fatty acids
- Glycerides
- Triglycerides
- Saturated fats
- Unsaturated fats
- Rancidification



FATS and **OILS** are organic compounds of biological importance. They are esters of aliphatic (saturated and unsaturated) carboxylic acids, generally with straight chains of uneven number (up to 23) of C atoms (the so called **fatty acids**), and propane-1,2,3-triol (glycerol). Therefore they are also named **triglycerides** as they contain three acid residues. Fats were first synthesized by Marcelin Berthlot in the early XIXth century.

Some of the most important are the fatty acids with 16–18 C atoms (including the carbon atom of the –COOH group):

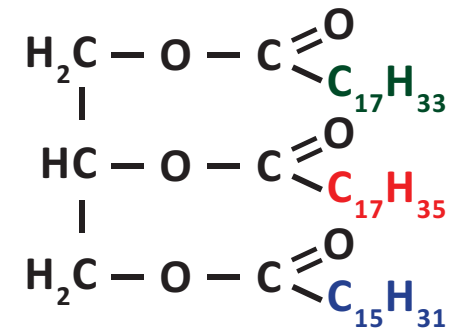
FATTY ACIDS	
CONDENSED AND MOLECULAR FORMULA	NAME
$\text{H}_3\text{C} - (\text{CH}_2)_{14} - \text{COOH}$ $\text{C}_{15}\text{H}_{31}\text{COOH}$	Palmitic acid
$\text{H}_3\text{C} - (\text{CH}_2)_{16} - \text{COOH}$ $\text{C}_{17}\text{H}_{35}\text{COOH}$	Stearic acid
$\text{H}_3\text{C} - (\text{CH}_2)_7 - \text{CH} = \text{CH} - (\text{CH}_2)_7 - \text{COOH}$ $\text{C}_{17}\text{H}_{33}\text{COOH}$	Oleic acid
$\text{H}_3\text{C} - (\text{CH}_2)_4 - \text{CH} = \text{CH} - \text{CH}_2 - \text{CH} = \text{CH} - (\text{CH}_2)_7 - \text{COOH}$ $\text{C}_{17}\text{H}_{31}\text{COOH}$	Linoleic acid
$\text{H}_5\text{C}_2 - \text{CH} = \text{CH} - \text{CH}_2 - \text{CH} = \text{CH} - \text{CH}_2 - \text{CH} = \text{CH} - (\text{CH}_2)_7 - \text{COOH}$ $\text{C}_{17}\text{H}_{29}\text{COOH}$	Linolenic acid



Simple triglyceride
(identical fatty acids residues)

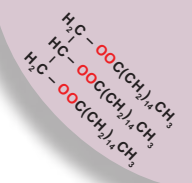
GLYCERYL TRISTEARATE

The fatty acids residues in the triglyceride molecule are identical or different. If all three -OH groups of propane-1,2,3-triol are esterified with the same fatty acid, the product is a **simple triglyceride**. Most often in the molecules of the natural triglycerides there are two or three different fatty acids residues and are called **mixed triglycerides**.



Mixed triglyceride
(different fatty acids residues)

Fats that contain only saturated fatty acids residues are called **saturated fats** (for example residues of palmitic acid, stearic acid). Those that contain unsaturated fatty acids residues are called **unsaturated fats**. The last are **monosaturated** if there is only one double carbon-carbon bond in the fatty acids residues (for example residues of oleic acid). If there are two or more double carbon-carbon bonds in the fatty acid residues, the fats are called **polyunsaturated** (for example residues of linoleic acid, linolenic acid). **Generally the „good“ for health fats are unsaturated fats.**



PHYSICAL PROPERTIES

Triglycerides are solid or liquid. Solid triglycerides are esters of saturated fatty acids (palmitic $\text{C}_{15}\text{H}_{31}\text{COOH}$, stearic $\text{C}_{17}\text{H}_{35}\text{COOH}$, etc.) with propane-1,2,3-triol. They are called **fats**. Liquid triglycerides are esters of unsaturated fatty acids (oleic $\text{C}_{17}\text{H}_{33}\text{COOH}$, linolic $\text{C}_{17}\text{H}_{31}\text{COOH}$, linolenic $\text{C}_{17}\text{H}_{29}\text{COOH}$, etc.) and propane-1,2,3-triol. Generally, plants triglycerides are liquid and are called **oils** – olive, linseed, sunflower, etc. The palm oil and the coconut oil are solid. Animal fats are solid (an exception is the cod liver oil). Fats and oils in plants and animals are natural mixtures of different triglycerides.

Fats are insoluble in water and are lighter than water. They dissolve well in organic solvents (tetrachloromethane, petrol, etc.).

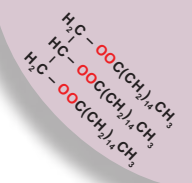
Usually unsaturated fatty acids melt and boil at lower temperatures than the saturated fatty acids. For example stearic acid melts at $+70^\circ\text{C}$, while the unsaturated fatty acids with the same number of carbon atoms melt at considerably lower temperature – oleic acid at $+16^\circ\text{C}$, linoleic acid at -5°C and linolenic acid at -11°C .

Natural fats are mixtures of different triglycerides (a couple of examples are shown in the table) and they melt over a range of temperature.

Fats are poor heat conductors.

Fat or oil	Saturated		Unsaturated		Other
	Palmitic	Stearic	Oleic	Linoleic	
Butter	29%	9%	27%	4%	31%
Beef	32%	25%	38%	3%	2%
Peanut	7%	5%	60%	21%	7%
Olive	6%	4%	83%	7%	

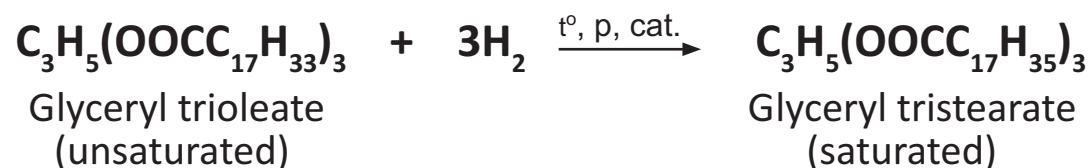
FATTY ACIDS COMPOSITION OF SOME COMMON FOODS



CHEMICAL PROPERTIES

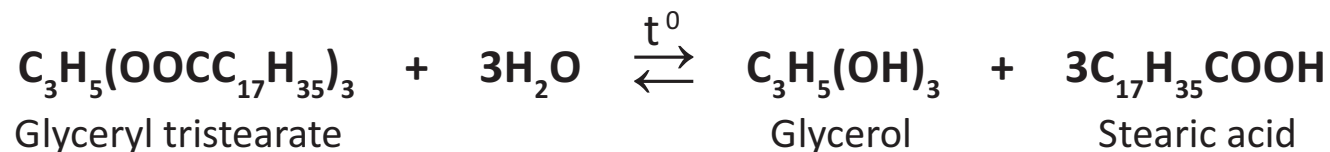
Important chemical reactions of fats and oils are hydrogenation and hydrolysis.

Hydrogenation of fats and oils. The catalytic addition of hydrogen to double bonded C atoms in the molecules of triglycerides undergoes at elevated temperature and pressure. Unsaturated triglycerides transform into saturated triglycerides. For example:

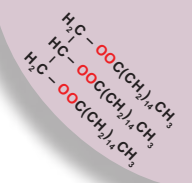


On an industrial scale this process is used for the production of margarine. Vegetable oils (sunflower, soybean, etc.) are hydrogenated and transformed into solid saturated triglycerides. Margarine is an emulsion of this mixture of solid triglycerides in milk or water. Also vitamins, artificial flavours and other components are added.

Hydrolysis of fats and oils. The process is reversible and undergoes under heating and in the presence of catalysts to give glycerol and fatty acids. In the human organism the enzyme lipase catalyzes the hydrolysis of glyceryl tristearate:



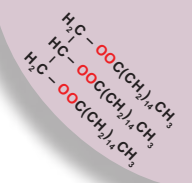
Hydrolysis of triglycerides is of industrial importance as fatty acids are produced from fats.



Triglycerides can react also with bases (NaOH, KOH). The products are soaps (sodium or potassium salts of fatty acids) and glycerol. The process is commonly known as **saponification** (see next lesson).

Exposed to air and under the action of sunlight, moisture and some bacteria fats and oils become rancid (in Latin language *rancidus* means *stinking*). The process is known as **rancidification**. This is a natural process of decomposition (degradation) of fats and oils – their appearance changes, they smell and taste bad. Rancid foods may be harmful, even poisonous.

Unsaturated oils can also polymerize under the action of oxygen in the air. If spread on a surface, after a period of exposure to air, the long chains crosslink and the oil hardens forming a solid film. These oils are called **drying oils**. They are used (for example the linseed oil or many synthetic oils) for wood protection and are key components of many varnishes and paints.



IMPORTANCE of FATS and OILS

Fats are essential to the body health. They are sources of energy and building material of animals and plants cells. In the human body fats accumulate under the skin and around the internal organs. In plants they accumulate in seeds and roots. Vegetable oils are extracted from oleaginous plants – sunflower, soy, corn, almond, nut, olive, peanut, etc. Animal fats used as foods are butter, lard, chicken, duck fat and others.

Fats are a high-calorie food – they give much more (about twice) energy than carbohydrates. The body needs 50 – 100 g of fats per day. If there are more fats in the daily food, weight may be gained as the amount of body fats increases. But fats and oils are vital to the human metabolism and always must be present in diets.

Vegetable oils like olive oil, sunflower oil, linseed oil and other are healthy food components especially the cold-pressed (extra virgin) oils – olives or seeds are only crushed and pressed to squeeze the oil out.

More than 1 000 different fats and oils are known today. They are used in the food industry, the pharmaceutical industry, the furriery, in cosmetics, soaps, lubricants, etc. Fats and oils are also raw materials for the production of pentane-1,2,3-triol (glycerol) and fatty acids.

CAN YOU ANSWER THESE QUESTIONS ?

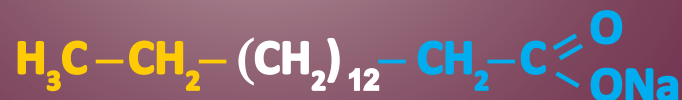
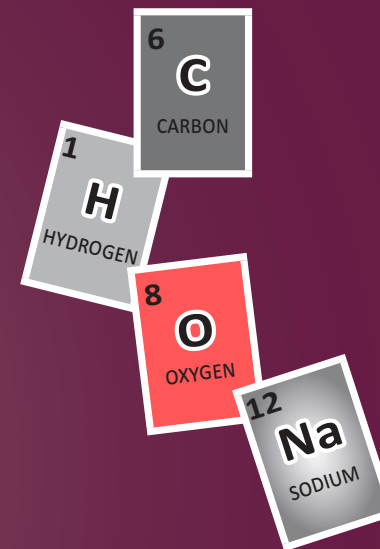
1. What are fats?
2. Why are fats important for the temperature regulation of the body?
3. What are the products of the hydrogenation of unsaturated oils?
4. How to produce propane-1,2,3-triol from fats or oils?
5. Why are blood triglycerides an important indicator of the body health?
6. It is not recommended to re-use in cooking the sunflower oil, which has already been heated and cooled. Why?
7. How to remove oil stains from clothes?
8. What happens to fats and oils if exposed to air and sunlight?
9. Why are fats indispensable for body functioning?

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SOAPS AND DETERGENTS

KEY TOPICS

1. What are soaps and detergents?
2. How do soaps clean?
3. Why are not soaps effective cleanser in hard waters?
4. Are synthetic detergents pollutants of water and soils?



KEY WORDS

- Soap
- Saponification
- Micelle
- Hard water
- Detergent

Soaps and detergents are substances that remove dirt. There is no universal soap or detergent. Different soaps or detergents are used for different purposes.

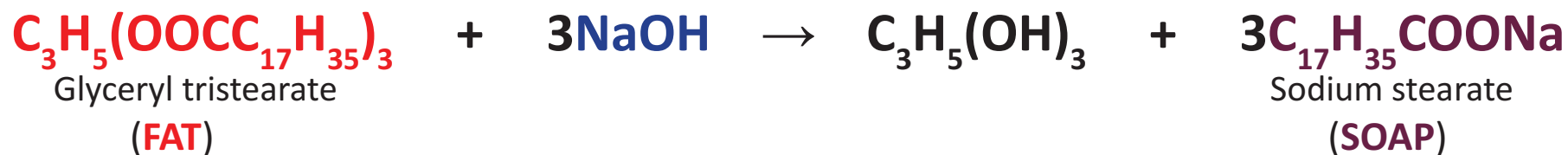
SOAPS

Since ancient times people have used natural substances (fats products) as cleansers. But about 200 years ago (in the early XIXth century) Marcelin Berthlot realized the hydrolysis of fats under heating and in the presence of NaOH. This is an irreversible reaction (remember that the hydrolysis of fats in water under heating is a reversible process). The products are glycerol (propane-1,2,3-triol) and salts of fatty acids. This is a process of **saponification** and the salts are called **soaps**.

SOAPS ARE SALTS OF FATTY ACIDS – MOST OFTEN SODIUM Na, POTASSIUM K OR LITHIUM Li SALTS.



For example glyceryl tristearate and sodium hydroxide react to produce glycerol (propane-1,2,3-triol) and soap (sodium stearate):



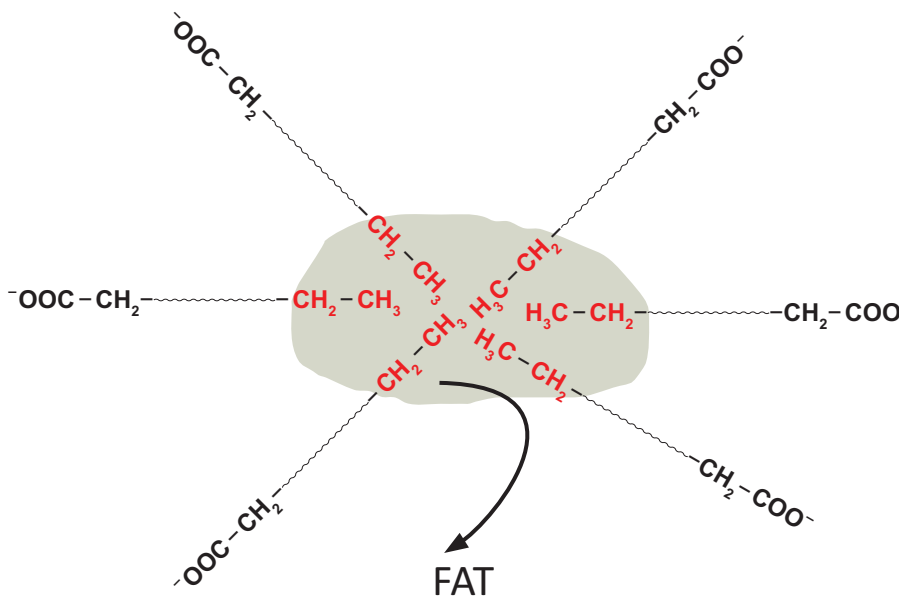
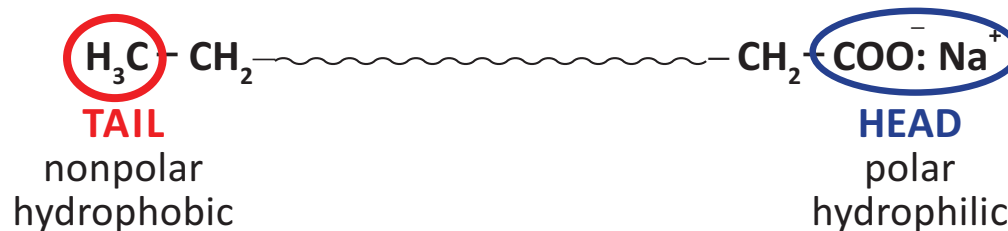
At room temperature sodium soaps are solid, while potassium soaps are liquid. Lithium soaps are components of some greases.

HOW DO SOAPS CLEAN?

Soaps are salts of straight carbon chain fatty acids. The chains are long enough so their nonpolar H₃C –... end is far from the polar ...–COO[–]:Na⁺ end. Usually the nonpolar hydrophobic (water-fearing) end is called „tail“, while the polar hydrophilic (water-loving) end is called „head“.

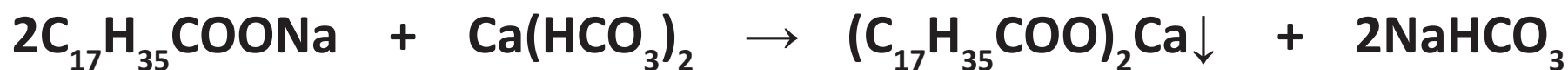
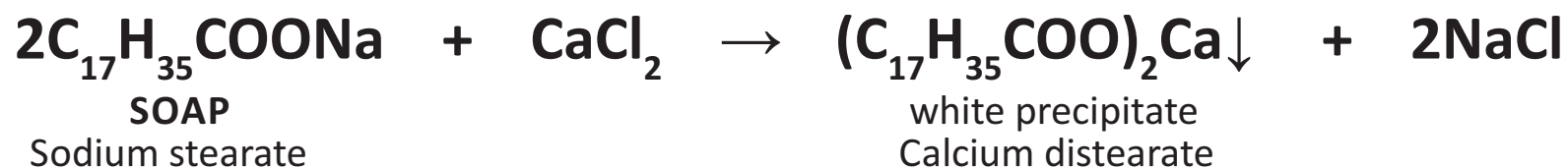
Soaps dissolve in water very well and decrease its surface tension. Thus aqueous soap solutions wet surfaces, crevices, etc. better than water can do.

Dirt usually contains fats or oils. They are insoluble in water. But if mixed with soap water solutions the nonpolar hydrophobic tail embeds into the fats or oils layer as fats and oils molecules are also nonpolar. The polar hydrophilic head is negatively charged as the Na⁺ or K⁺ ions move free. It attracts the polar water molecules. Structures called **micelles**, with the soiling fats or oil molecules inside, are formed. Finally an emulsion of fine „soapy“ fats particles or oils droplets is formed. If this emulsion is agitated, the soapy fats particles or oil droplets are elevated by air bubbles and the dirt is removed. When you rub your hands dirt is rinsed away. So **soaps are surface-active emulsifying agents**.

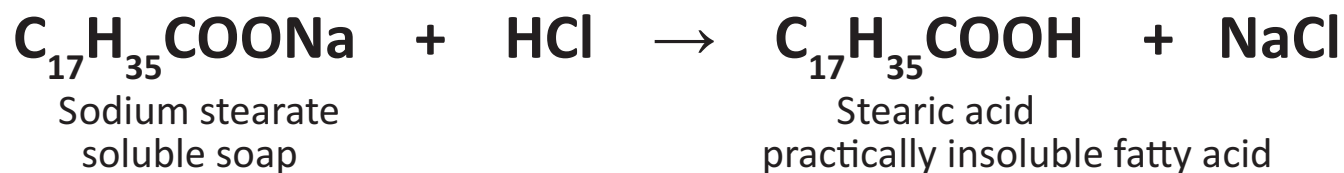


SOAPS EFFECTIVENESS

Soaps are not effective cleansers if hard water (containing Ca²⁺, Mg²⁺ ions) is used. Calcium and magnesium salts of the fatty acids are insoluble in water. White precipitates are formed and soaps lose their cleansing action:



In acidic water soaps are also ineffective as much less soluble fatty acids are formed:



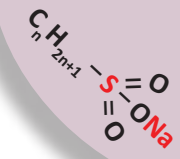
HOME MADE SOAPS

Soap can be prepared at home. Usually lard (or other animal or vegetable fats), water and sodium hydroxide NaOH are mixed, heated and stirred until the desired density of the mixture is reached. The hot mixture is poured in a large vessel. After some time it becomes solid and may be cut into pieces.

To prepare a better quality soap a salt (NaCl) is added to the liquid mixture of soap and propane-1,2,3-triol. The soap solubility decreases and it is easily removed from the mixture (soap is lighter than water and lies on the surface).

The home made soaps are delicate and do not irritate the skin.

! As sodium hydroxide (caustic soda) can „burn“ the skin safety precautions must be always respected when preparing soap at home – avoiding contact with skin, using rubber gloves and eye protection are obligatory.



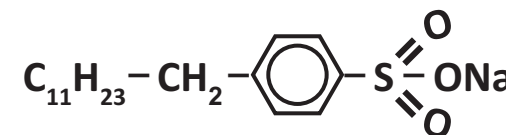
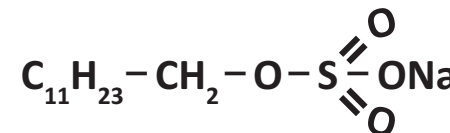
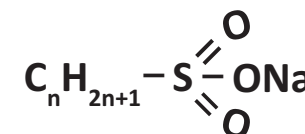
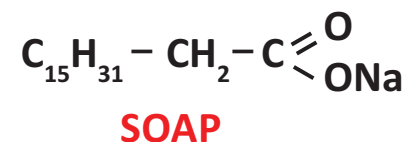
SYNTHETIC DETERGENTS

Soaps can not satisfy the increasing demands for more and more efficient cleansing agents. Today in our homes there are many synthetic detergents used in our everyday life – for dishwashers, laundry machines, furniture polish, windows cleaning, household cleaning, hand washing, liquid soaps, products for personal cleansing, etc.

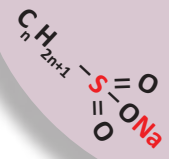
The most widely used detergents are organic compounds with long carbon chains but instead of the $-COONa$ group (as in soaps molecules) at the end of the molecules there is a $-SO_3Na$ or $-OSO_3Na$ group. The carbon chain may contain also an aromatic ring.

Detergents contain one or more surfactants and have many advantages over soaps as cleansing agents:

- Generally detergents have a stronger cleansing action than soaps;
- Detergents do not hydrolyze. So their aqueous solutions are neutral ($pH \approx 7$);
- Detergents do not lose their activity in hard water as the obtained salts are soluble;
- Detergents are petrochemical products;
- Some synthetic detergents are effective cleansing agents even at low temperature;
- Some synthetic detergent display a strong bactericidal action.



DETERGENTS



But detergents have also many disadvantages – they may cause skin problems (irritation, allergic reactions and fungal infection) and contaminate wasted water, thus having an environmental impact.

A regulation (648/2004) of the European Union establishes rules to sell and use detergents and surfactants across the EU, while providing a high degree of protection to the environment and human health. Modern technologies focus on the production of biodegradable (decomposed under the action of bacteria) synthetic detergents.

Synthetic detergents are not only cleansing agents but also emulsifying agents. They are used in the food industry, the metallurgy, the textile industry, to prepare insecticides, etc.

CAN YOU ANSWER THESE QUESTIONS ?

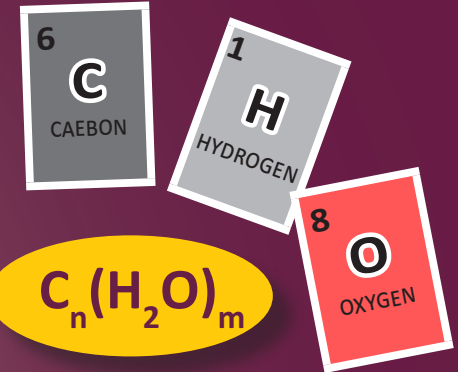
1. What are soaps?
2. Why are soaps dissolved in water?
3. Why are not soaps effective cleansing agents in acidic and hard waters?
4. What safety precautions should be respected when preparing home made soaps?
5. What are detergents?
6. Why do we need detergents in our everyday life?
7. Why is it important to stir or agitate soaps or detergent solutions?
8. Why is it important to read carefully the labels on the packages of the synthetic detergents used in housekeeping?

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CARBOHYDRATES. MONOSACCHARIDES

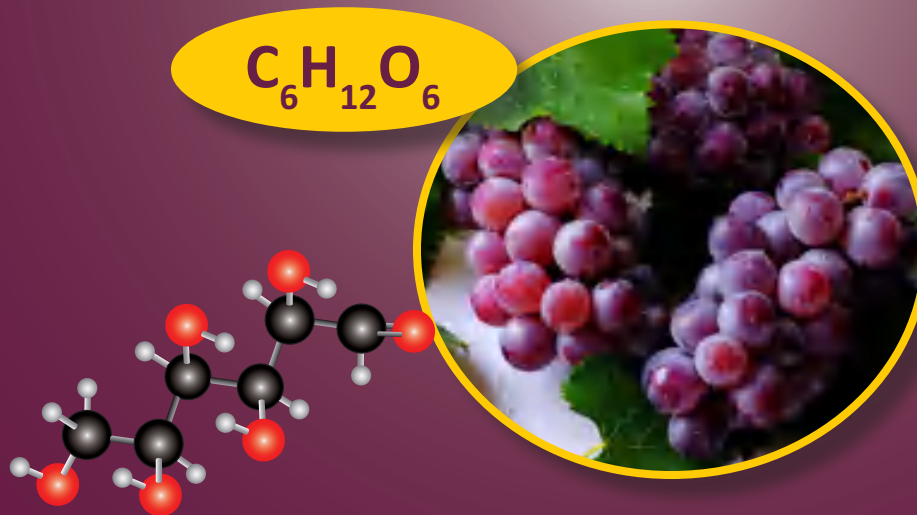
KEY TOPICS

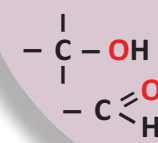
1. What are carbohydrates?
2. What is the glucose structure?
3. Why is glucose important for the body functioning?
4. What is diabetes?



KEY WORDS

- Carbohydrates
- Monosaccharides
- Polysaccharides
- Glucose
- Aldohexose
- Polyhydroxyaldehyde
- Fructose
- Ketohexose
- Polyhydroxyketone



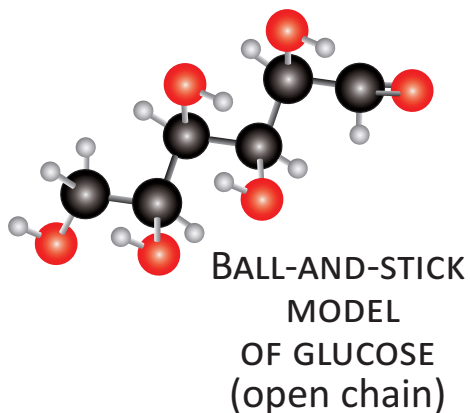


CARBOHYDRATES are the most abundant organic compounds in the living nature and basic foods (sugars, starch, fibres in vegetables, fruits, etc.). They constitute about 80% of the plants dry mass. The term carbohydrates has been introduced in the middle of the XIXth century as it was established that these compounds were built up of many $-\text{C}_n(\text{H}_2\text{O})_m-$ residues. These compounds were considered as *hydrates of carbon*. This formal analogy gave only the name of this class of organic compounds. Their structure is completely different but in all carbohydrates the oxygen - hydrogen atoms ratio is 1 : 2 (as in the water molecule).

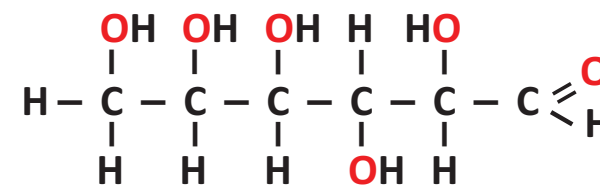
**CARBOHYDRATES ARE ORGANIC COMPOUNDS MADE UP OF CARBON, OXYGEN AND HYDROGEN ATOMS.
THEIR GENERAL FORMULA IS $\text{C}_n(\text{H}_2\text{O})_m$.**

Some short-chain carbohydrates are sweet and are commonly known as **saccharides** (or sugars).

One of the simplest carbohydrates is **glucose**.



GLUCOSE (or simple sugar) is a **monosaccharide**. Its molecular formula is $C_6H_{12}O_6$ (or $C_6(H_2O)_6$). It is found in fruits, plants and is commonly known as **grape sugar** (the content of glucose in grapes is very high).

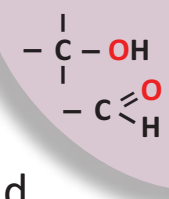


Structural formula
of glucose
(open chain)

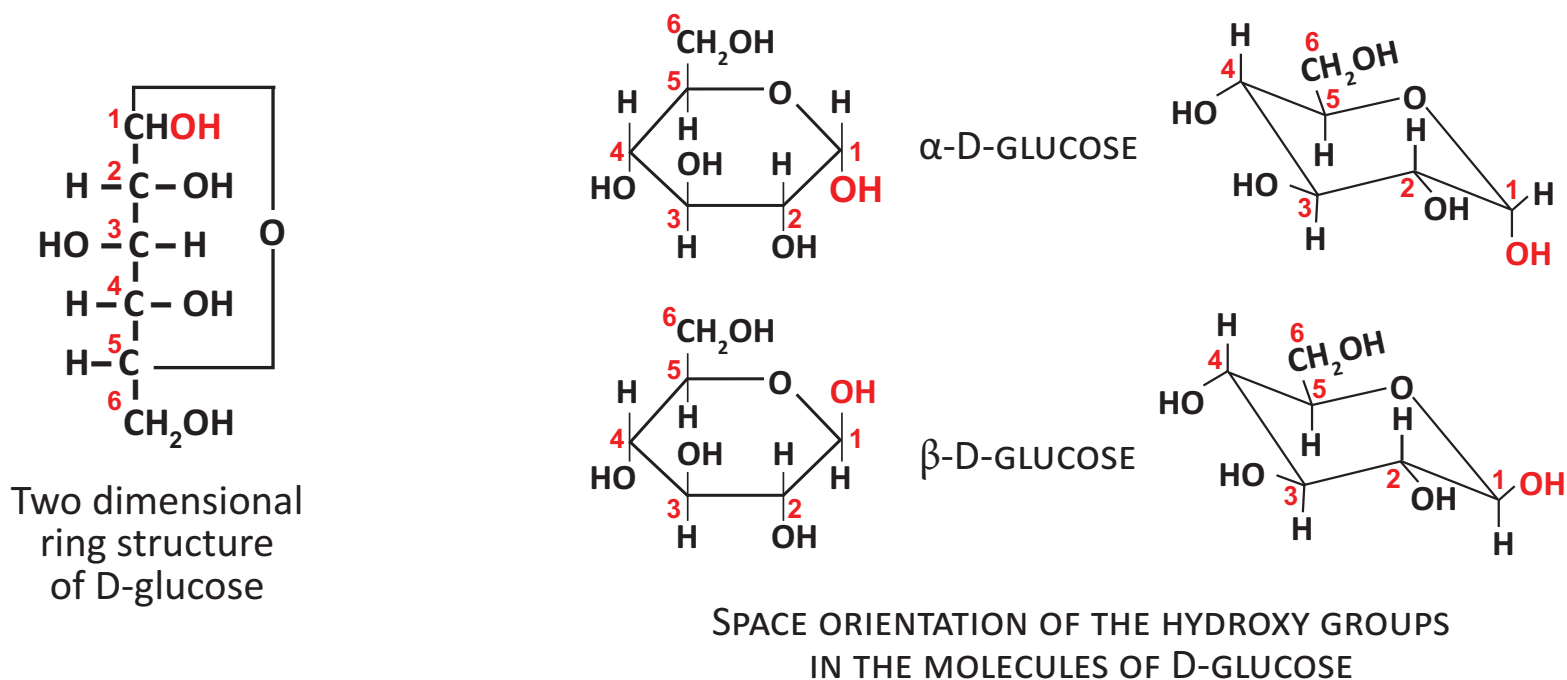
STRUCTURE and PHYSICAL PROPERTIES

Glucose is a colourless crystalline substance with a sweet taste (the name of the compound originates from the Greek word meaning sweet). Glucose dissolves well in water. At heating glucose first melts, then it turns yellow, caramelizes and finally carbonizes liberating water.

The backbone of the glucose molecule is a 6-carbon atoms straight chain which may be *open* or *closed* (a ring). The open chain molecules contain an aldehyde group and five $-OH$ groups bonded to the other carbon atoms (each C atom is bonded to one hydroxy group) – this is an **aldohexose**. In many plants, fruits and in the blood is found the so called **D-glucose**: the $-OH$ groups are arranged as it is shown in the figure above (the structural formula of glucose).

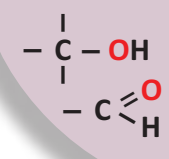


The ring structure of the glucose molecule is more complex. One of the bonds of the double C = O bond breaks down. The aldehyde group and the hydroxy group bonded to the 5th carbon atom combine to form a six-atoms ring including an oxygen atom. The 1st carbon atom is not any more part of an aldehyde group – it is bonded to a hydroxy group (marked in red). α -D-glucose and β -D-glucose differ in the position of this -OH group relative to the ring:



Keep in mind that the glucose molecules are nonplanar as the atoms form zigzag rings with carbon-carbon bond angles of $109,5^\circ$.

At STP in water solutions of glucose all three types of D-glucose are present but more than 60 % are the β -D-glucose molecules. Only 0,02 % are the open chain molecules.



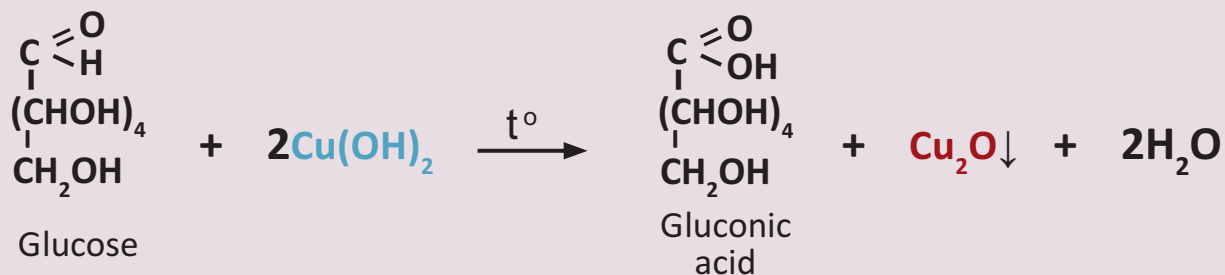
CHEMICAL PROPERTIES

Glucose is a **polyhydroxyaldehyde**. Some of its chemical properties are typical for aldehydes, other – for polyhydric alcohols: addition of H_2 ; oxidation by Ag_2O ; reaction with $Cu(OH)_2$ under heating or at common temperature; esterification:)

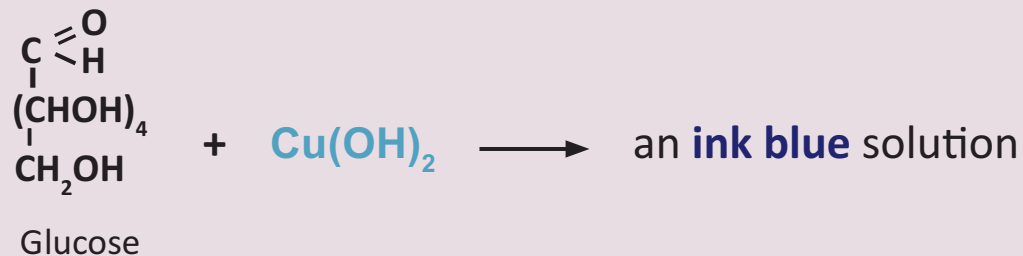
PROBLEM!

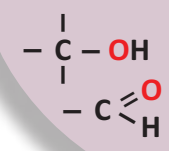
Express the chemical equations of the reactions of glucose with $Cu(OH)_2$.

SOLUTION: 1. Glucose is oxidized by $Cu(OH)_2$ under heating (reacts as an aldehyde):



2. At common temperature glucose reacts with $Cu(OH)_2$ as a polyhydric alcohol:

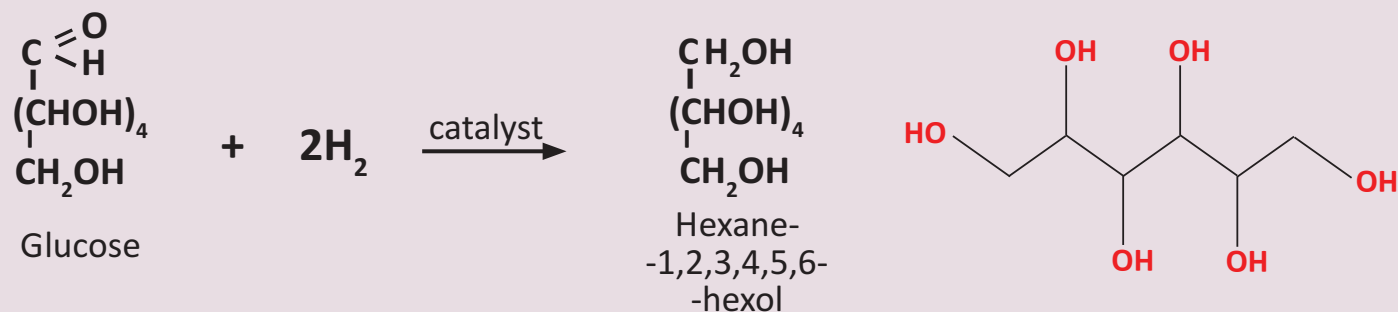




PROBLEM!

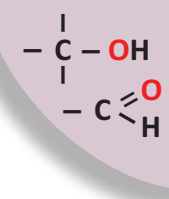
Hydrogen is added to glucose in a catalytic reaction. Express the chemical equation of the reaction. What is the name of the product?

SOLUTION: The addition of hydrogen to glucose is expressed as:



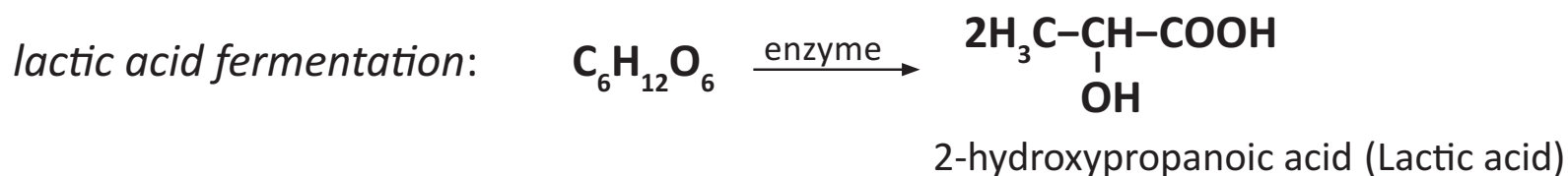
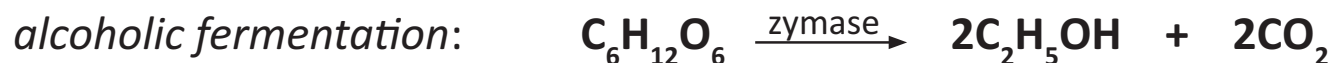
ANSWER: The name of the product is **hexane-1,2,3,4,5,6-hexol**, commonly known as *sorbitol*.

This reaction is used to produce sorbitol on industrial scale as this polyhydric alcohol is a sweetener and is used as a sugar substituent.



Glucose is also involved in reactions affecting the whole molecule.

Fermentation. Under the action of specific enzymes glucose is transformed into alcohols or carboxylic acids:

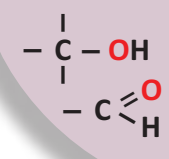


Reaction with oxygen. Glucose is an energy resource for the human body. It reacts with oxygen (a reaction inverse to the photosynthesis in green plants) to liberate a significant amount of energy:



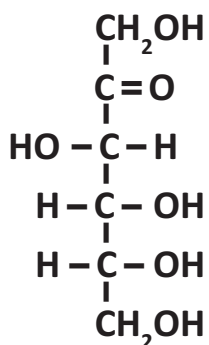
The content of glucose in the body depends on the action of the hormone *insulin*. It stimulates the „burning“ of glucose thus providing the energy necessary to the metabolic processes. If the pancreas does not make enough insulin or by some reason this hormone is not capable to catalyze the oxidation of glucose (the so called insulin resistance), the amount of glucose in the blood increases. This is **diabetes**. Both genetic factors and lifestyle (lack of physical activity, obesity, stress) can cause diabetes.

Glucose is used to synthesize pharmaceuticals (for example vitamin C), in the food industry, in the confectionery, etc.

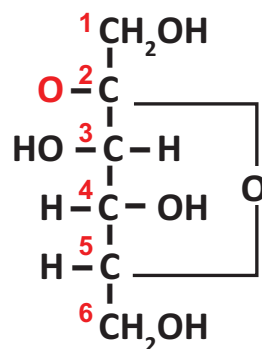


FRUCTOSE

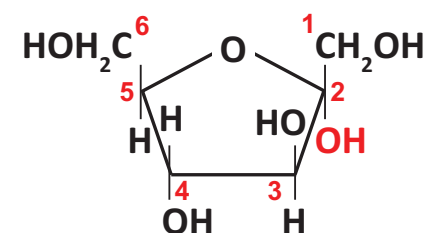
Fructose is an isomer of glucose. It is a **polyhydroxyketone** – a **ketohexose**. Fructose is found in many fruits (as suggests its name) and in honey. More often in the molecule of fructose exists a 5-atoms ring and similarly to glucose α -D-fructose and β -D-fructose are known:



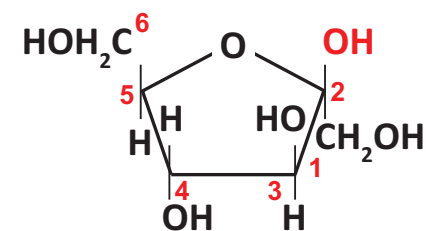
D-FRUCTOSE



RING STRUCTURE
OF D-FRUCTOSE



α -D-FRUCTOSE



β -D-FRUCTOSE

The fructose is not an energy resource for the human body but it is the sweetest carbohydrate and is used in confectionery.

CAN YOU ANSWER THESE QUESTIONS ?

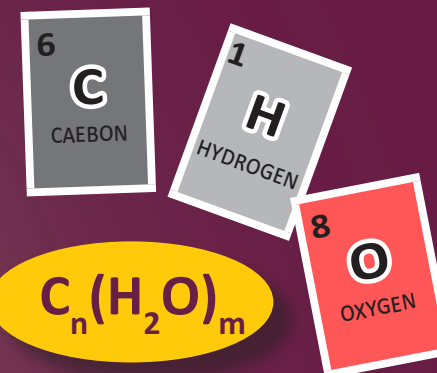
1. What are carbohydrates?
2. Why are glucose and fructose monosaccharides?
3. Why are α -D-glucose and β -D-glucose different substances? Are they isomers? Why?
4. Why does glucose react both as an aldehyde and as a polyhydric alcohol?
5. How is alcohol produced from fruits (grapes, plumes, etc.)?
6. Why are glucose and fructose isomers?
7. How to distinguish between glucose and glycerol (propane-1,2,3-triol)?
8. What is diabetes?
9. How to prevent the so called insulin resistance (diabetes type 2)?

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DISACCHARIDES. POLYSACCHARIDES

KEY TOPICS

1. What are polysaccharides?
2. Why is saccharose a disaccharide?
3. What are starch and cellulose?
4. Why is starch a food for humans, but cellulose is not?
5. WHAT IS THE MOST ABUNDANT POLYSACCHARIDE IN NATURE?



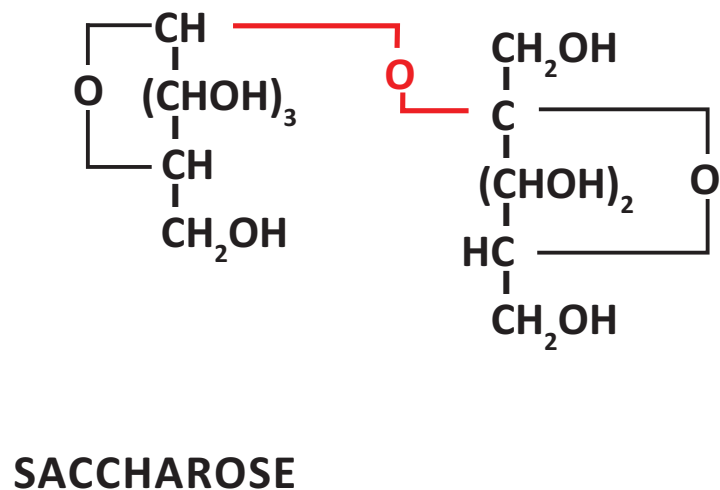
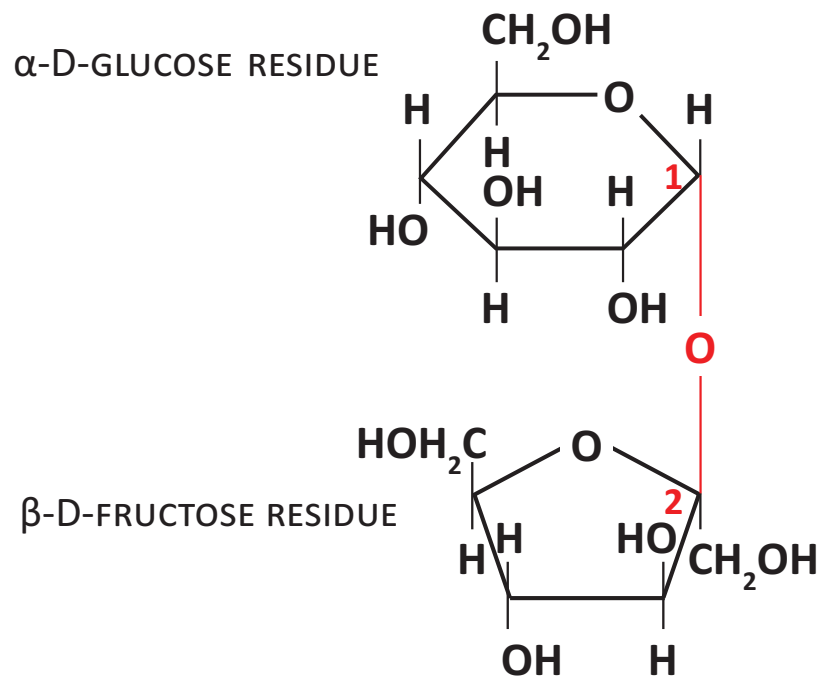
KEY WORDS

- Disaccharides
- Glycosidic linkage
- Saccharose
- Invert sugar
- Polysaccharides
- Starch
- Amylose
- Amylopectine
- Cellulose



DISACCHARIDES

DISACCHARIDES (as suggests their name) are carbohydrates composed of two monosaccharide residues (same or different) linked by the so called **glycosidic linkage** – two hydroxy groups (one from each monosaccharide) combine to bond the two residues trough an oxygen atom, liberating one water molecule. For example, if the water molecule is formed from a hydroxy group bonded to the first C atom of α -D-glucose and a hydroxy group bonded to the second C atom of β -D-fructose, 1 molecule of the disaccharide **saccharose** (or the well known white refined sugar) is obtained.



SACCHAROSE

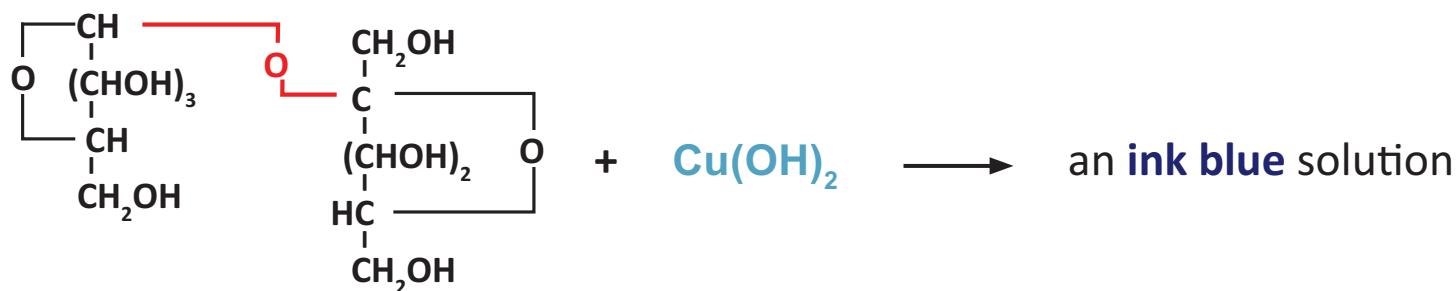
Saccharose C₁₂H₂₂O₁₁ or C₁₂(H₂O)₁₁ is the most common disaccharide. Sugar cane and sugar beet are rich in saccharose and both are raw materials for its production.

PHYSICAL PROPERTIES

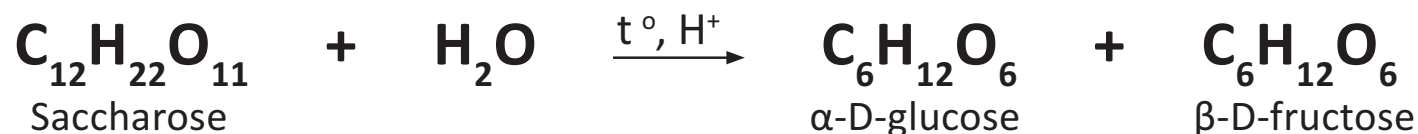
Saccharose is a white crystalline substance. It dissolves well in water and easily crystallizes. At 160 °C saccharose melts. At higher temperature it caramelizes (this process is widely used in confectionery) and after that carbonizes. Saccharose is sweeter than glucose.

CHEMICAL PROPERTIES

Saccharose is a polyhydric alcohol – there are 8 –OH groups in its molecule. That could be tested with freshly precipitated Cu(OH)₂ – the colourless aqueous solution of saccharose turns ink blue:



A very important chemical reaction of saccharose is its **catalytic hydrolysis**. Under heating and in the presence of acids saccharose reacts with water and α -D-glucose and β -D-fructose are obtained – the two monosaccharides whose residues build up saccharose molecules:



The mixture of equal parts of α -D-glucose and β -D-fructose is called **invert sugar**. It is less prone to crystallization than saccharose. Invert sugar is always found in honey and keeps it liquid for a long time. If saccharose is added to the honey it crystallizes more quickly.

In the human body the enzyme invertase (secreted by bees also) catalyses saccharose hydrolysis. The produced α -D-glucose is an important source of energy.

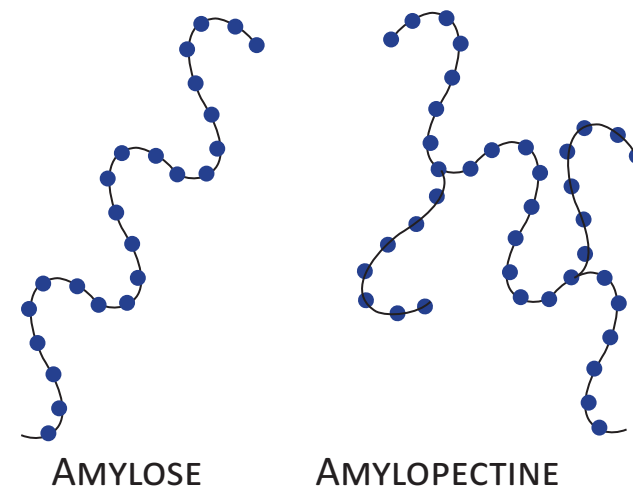
Maltose and **lactose** are also disaccharides. Both are isomers of saccharose and their chemical formula is C₁₂H₂₂O₁₁, but their structural formulae are different. Maltose molecules are formed of two α -D-glucose residues and lactose molecules – of one residue of α -D-glucose and one residue of α -D-galactose (isomer of glucose). Maltose is found in germinated barley seed and lactose – in the milk of mammals.

POLYSACCHARIDES

Polysaccharides are long chain carbohydrates – their molecules are made up of many monosaccharides residues. In living nature the most common polysaccharides are **starch** and **cellulose**. They are biopolymers.

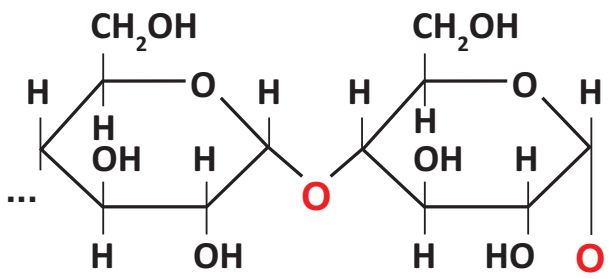
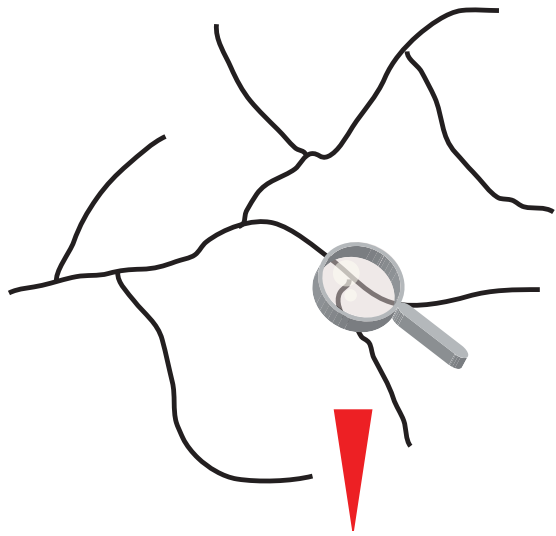
STARCH

Starch is made up of many residues of α -D-glucose bonded by glycosidic linkages. Its molecular formula is $(C_6H_{10}O_5)_n$. The starch long chains may be straight or branched. The polymer with long straight chains is called **amylose** and that with branched chains – **amylopectin**. Most often starch is composed of 20–30% amylose and 70–80% amylopectin.

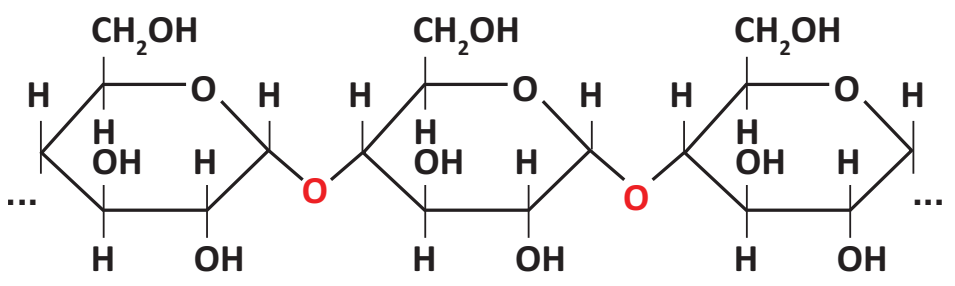
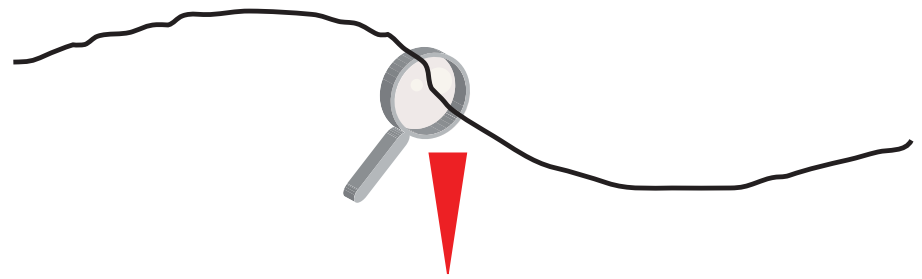


The number of glucose residues in the molecules of amylose may be many thousands. The linkage is between the 1st carbon atom of an α -D-glucose molecule and the 4th carbon atom of another α -D-glucose molecule. Amylose long chains form a coil like a spiral.

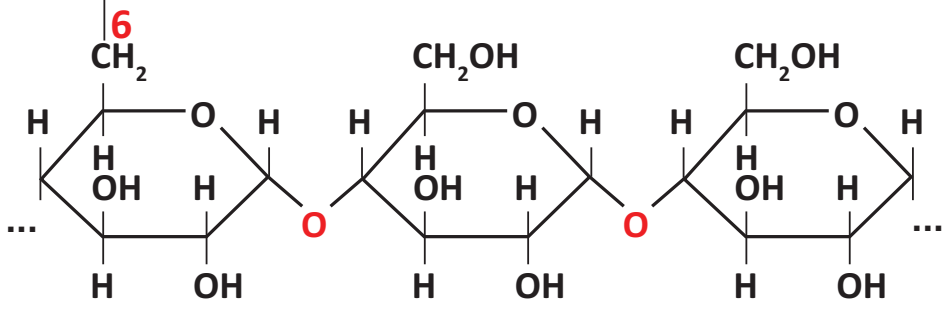
Amylopectin is a highly branched chain polymer with molecular mass greater than that of amylose. The glucose residues in the branches are linked as in the amylose chains, but the linkage of different branching is between a 1st carbon atom of an α -D-glucose molecule and the 6th carbon atom of another α -D-glucose molecule:



MACROMOLECULE OF AMYLOPECTIN



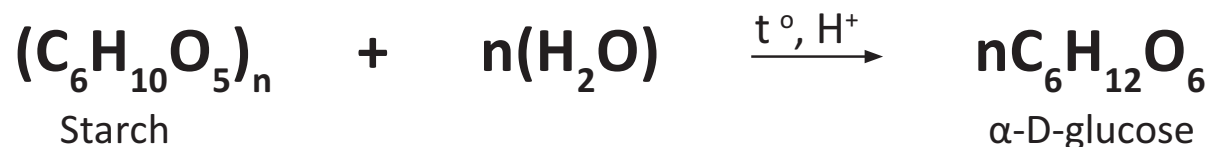
MACROMOLECULE OF AMYLOSE



Starch is an odourless and colourless white powder. Starch does not really dissolve in cold water – it forms a suspension. But if heated to boiling temperature, it dissolves well.

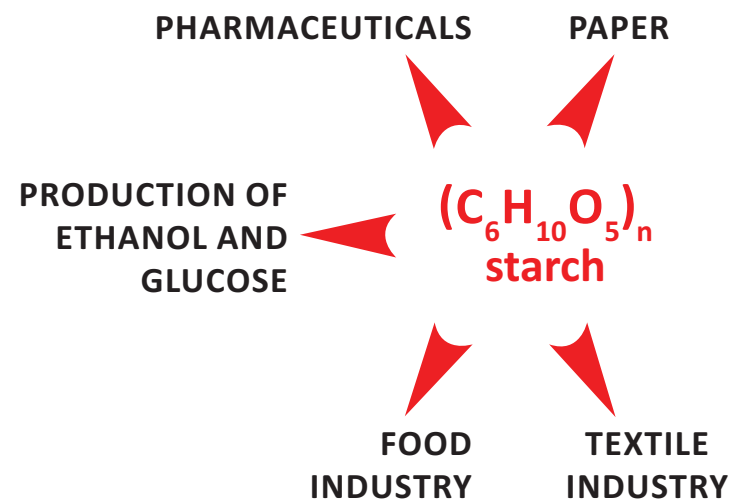
! Test reaction for starch (dissolved in water) is the addition of a few drops of iodine tincture (solution of iodine in ethanol). The solution turns blue-violet.

Starch hydrolyzes under the action of enzymes (amylases) or acids – first molecules of dextrin (a low molecular weight polysaccharide) are formed. They transform into disaccharides and finally α -D-glucose is produced:



USES

Starch is found in the plants roots, seeds and leaves. Rich in starch are cereals, potatoes. Starch is widely used in food, textile, paper, pharmaceutical industry, also to produce ethanol and glucose.

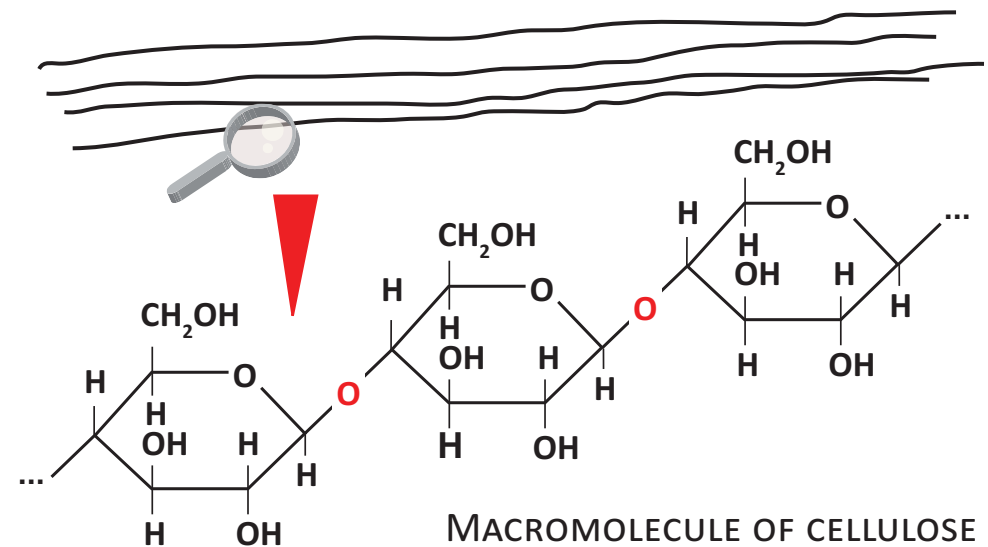


CELLULOSE

STRUCTURE and PHYSICAL PROPERTIES

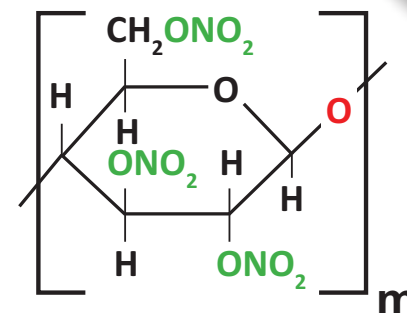
Cellulose (just like starch) is a natural biopolymer – a solid fibrous white substance. But unlike starch, which is a sort of „food“ for plants, cellulose is a „building material“ of cells (its name originates from the Latin word *cellula* meaning *cell*). The molecular formula of cellulose is $(C_6H_{10}O_5)_m$ (similar to that of starch) and it is made up of β -D-glucose residues.

The molecules of cellulose are straight – many thousands of β -D-glucose residues are linked just as in the amylose molecules. Strong intermolecular interactions keep these chains in bundles. So cellulose does not dissolve in water and may be processed to produce fibres.

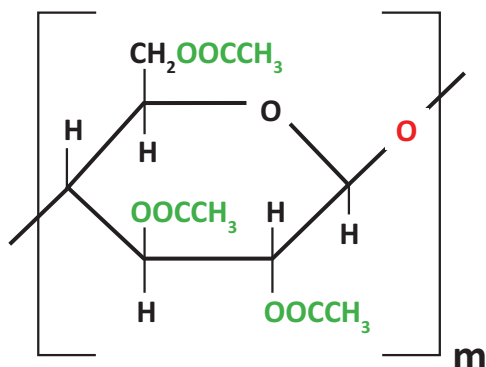


CHEMICAL PROPERTIES

The most important chemical reactions of cellulose are its esterification and hydrolysis. For example in the reaction with HNO_3 (mixed with concentrated H_2SO_4), depending on the amount of HNO_3 , mono-, di- or trinitrocellulose is produced. Nitrocellulose is highly flammable. Trinitrocellulose commonly known as *pyroxyline* is a highly explosive substance. It is used to produce varnishes, celluloid (the first synthetic plastic material), cordite (smokeless explosive powder), etc.



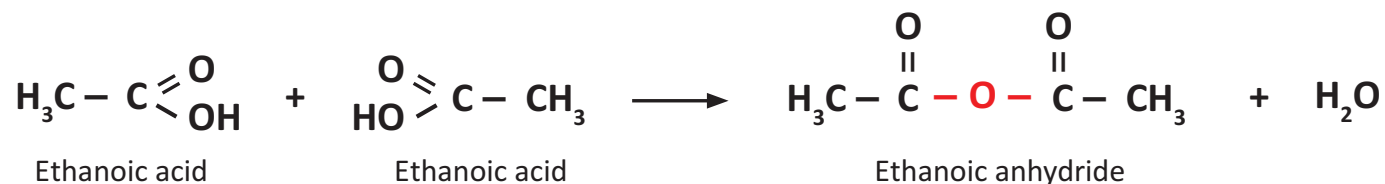
TRINITROCELLULOSE
(PYROXYLINE)



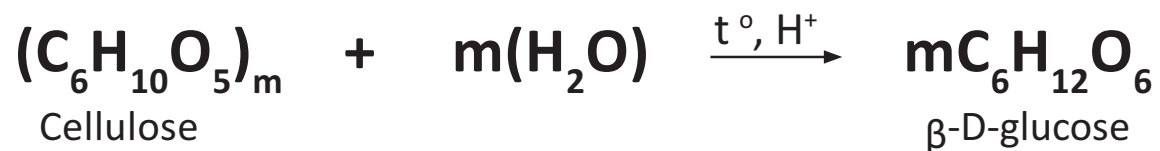
CELLULOSE TRIETHANOATE
(TRIACETATE)

Another reaction of industrial importance is the esterification of cellulose with ethanoic acid (actually with ethanoic anhydride* in the presence of ethanoic acid and sulfuric acid). The ester – *cellulose ethanoate* (common name *cellulose acetate*) is used in the production of synthetic fibres (acetate silk), plastics and others.

*Ethanoic anhydride $CH_3CO-O-OCH_3$ is formed from two molecules of ethanoic acid – one water molecule is liberated and the two acid residues are linked through an oxygen atom:



The hydrolysis of cellulose is difficult as compared to the hydrolysis of starch. The process undergoes under heating and in the presence of sulfuric acid H_2SO_4 . The final product of the complete hydrolysis of cellulose is β -D-glucose:



This process is catalyzed by specific enzymes and plants rich in cellulose are foods for many animals. The human body does not produce enzymes catalyzing the hydrolysis of cellulose and unlike starch, cellulose is not an energy source for our body. But it is essential to the balanced nutrition – microcrystalline and powdered cellulose is used as food additive E460 (emulsifying agent, free flowing agent, carrying agent).

Cellulose dissolves well in an ammonia solution of $Cu(OH)_2$ (the so called **Schweizer's reagent**) This process was used for the production of cellulose fibres.

USES and PRODUCTION

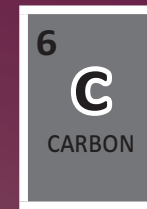
Cellulose is the most abundant biopolymer in nature. Cotton is composed mainly of cellulose (about 95%), 85% of the hemp is cellulose and 40 – 50% of the wood (exactly the cellulose fibres make the wood so strong). On an industrial scale cellulose is produced from wood and the resulting deforestation and water contamination are serious environmental problems. As cellulose is mainly used to produce paper, a way to overcome these negative impacts is to recycle the used paper. Therefore the household waste must be sorted and packing paper, boxes, sheets of paper, etc. must be put in the recycle bins.

CAN YOU ANSWER THESE QUESTIONS ?

1. Why are disaccharides and polysaccharides carbohydrates?
2. Nothing happens if under heating an ammonia solution of Ag_2O is mixed with an aqueous solution of saccharose. But if a few drops of an acid are added, metallic silver is disposed on the test tube walls. Why?
3. What is invert sugar?
4. Why is citric acid (lemon juice) always added when making fruit jams or jellies?
5. Why are amylose and amylopectin different compounds?
6. Why are not starch and cellulose isomers?
7. How to distinguish between starch and cellulose?
8. Why are barley, corn, rice used to produce alcohol beverages?

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PROTEINS

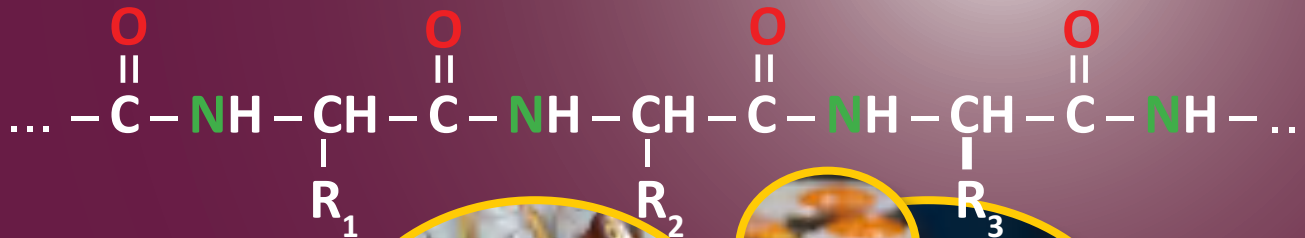


KEY TOPICS

1. What are proteins?
2. What is the 3D structure of proteins?
3. How do proteins lose their biological activity?
4. Why are proteins essential to life?

KEY WORDS

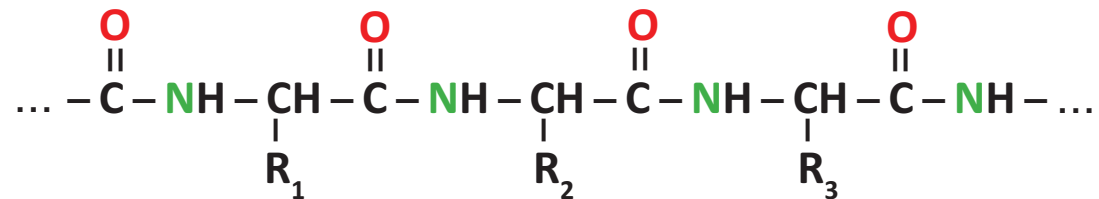
- Proteins
- Polypeptide backbone
- Side chains
- Primary structure
- Secondary structure
- Tertiary structure
- Quaternary structure
- Denaturation
- Peptization



PROTEINS (in Greek language *proteios* means *holding first place*) are natural biopolymers. They are a „life material“ as they are essential building blocks of animal and human tissues and are a vital energy resource. Enzymes, hormones, antibodies are proteins.

The basis of the modern theory of proteins structure has been formulated in the early XXth century by Emil Phisher. Proteins are made up mainly of many (can be thousands) residues of α -amino acids linked by *peptide bonds* ($-\text{CO}-\text{NH}-$) in long polypeptide chains. There are 20 amino acids building up proteins. They are designated by three or only one letter: for example Gly (glycine), Ala (alanine). All proteins contain carbon, hydrogen, oxygen and nitrogen, but also sulfur, phosphorus, iron and some other elements may be present.

PROTEINS ARE NATURAL BIOPOLYMERS MADE UP OF MANY α -AMINO ACIDS RESIDUES LINKED IN A SPECIFIC SEQUENCE BY PEPTIDE BONDS IN POLYPEPTIDE CHAINS.



The polypeptide chain is the **polypeptide backbone** of the protein molecule. The radicals ($\text{R}_1, \text{R}_2 \dots$) are called **side chains**. Proteins differ in the sequence and the type of the bonded α -amino acids residues.

3-DIMENSIONAL STRUCTURE OF PROTEINS

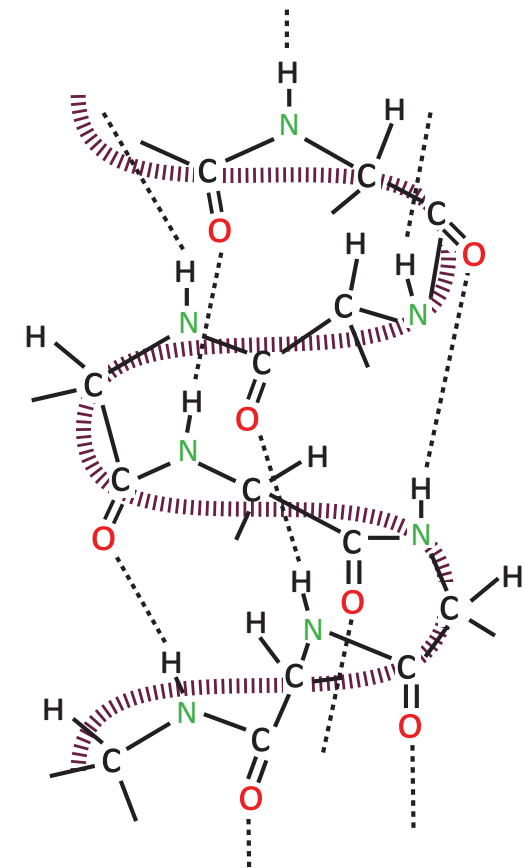
The polypeptide chains, building proteins, always fold to form a 3-dimensional pattern of lowest energy. This pattern is so complex that four structural levels are discerned.

PRIMARY STRUCTURE

The primary structure of each type of protein is unique – this is the linear sequence of α -amino acids residues in the polypeptide chain. It is determined by the side chains (R_1, R_2, R_3, \dots) of the different α -amino acids. Usually it is expressed using the abbreviations of the α -amino acids residues. For example a part of the primary structure of a protein molecule may look like that: **...Gly.Ala.Try.Lys.Gly.Gly...**

SECONDARY STRUCTURE

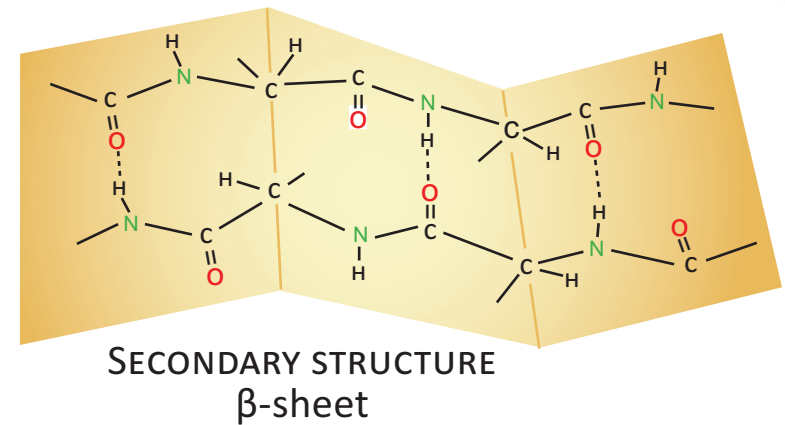
The long polypeptide chains are linear, but they do not look like a bundle of uncooked spaghetti. The N–H and C=O bonds are polar and electrostatic attraction occurs between H atoms of a peptide group and O atoms of another peptide group, 4 residues away. It results in a specific folding of the polypeptide chain, known as **secondary structure**. The most common is the so called **alpha-helix** (first predicted by Linus Pauling) configuration. The right handed is very stable. The distance between adjacent bends is about 0,55 nm.



SECONDARY STRUCTURE
 α -helix

Intermolecular electrostatic attraction may also occur and protein molecules are held together to form a secondary structure like a „pleated“ sheet called a **beta-sheet**.

Secondary structures are local structures and both alpha-helix and beta-sheet (and many others) may be present in the same protein.



TERTIARY STRUCTURE

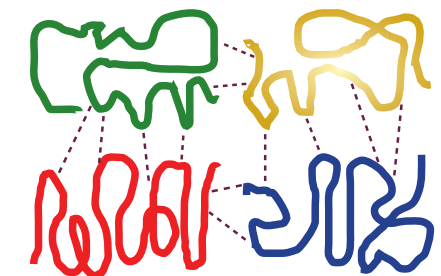
This is the final 3-dimensional compact conformation of the whole folded protein chain. For example alpha-helices, beta-sheets and random coils might be positioned relatively to each other to form a 3-dimensional structure with the lowest possible energy.



TERTIARY STRUCTURE

QUATERNARY STRUCTURE

This structure exists only in complex proteins constituted of more than one polypeptide chain. This is the arrangement in space of the individual folded chains relative to one another – they are held into clusters. For example haemoglobin (carrying oxygen to body cells) is made up of four individual polypeptide chains.



QUATERNARY STRUCTURE
(cluster of four polypeptide chains)



As a whole proteins may be classified as **fibrous** or **globular**.

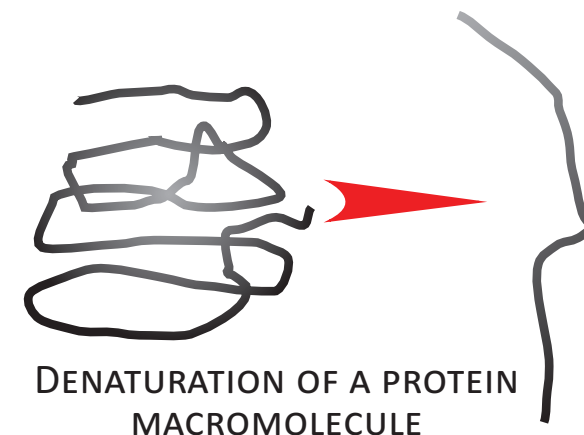
Fibroin (in silk), keratin (in wool and hair), collagen (in connective tissues) are *fibrous proteins*. As the name suggests, their macromolecules look like fibres. They are insoluble in water.

The globular proteins look like a ball. Enzymes, hormones and others are *globular proteins*. They are soluble in water and take part in many biochemical processes (for example insulin, haemoglobin, albumin). The proteins in the seeds of many cereals are also globular.

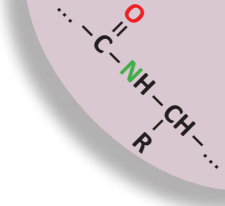
PROPERTIES OF PROTEINS

Proteins are very complex compounds. They hydrolyze, but also display some specific properties – they denature and peptyze.

Denaturation of proteins. Under the action of solvents, some acids and bases, irradiation, at high temperature and others, the secondary, tertiary and quaternary structures of the proteins macromolecules can be disrupted – the polypeptide chains unfold and proteins lose their biological activity. This process is called **denaturation of proteins**. This is an irreversible process.



A simple example of a denaturation process is the boiling of an egg. The main component of the egg white is the protein albumin. At a temperature higher than 65 °C after a few minutes albumin denatures – it transforms into a white solid substance. The unfolded polypeptide chains become irreversibly entangled with one another and the protein is not soluble in water any more.



Peptization of proteins. This is a process of reversible precipitation of proteins from their salt-containing (NaCl, MgCl₂, NH₄Cl) solutions. Precipitated proteins are „dissolved“ by adding water.

If salts of heavy metals are added to aqueous solutions of proteins, the precipitation process is irreversible as proteins denature. For this reason salts of heavy metals (Cu, Pb, Hg, Fe, Mn, etc.) are harmful for the organism and their content in air, soils and water is monitored.

Hydrolysis of proteins. This process is catalytic – proteins hydrolyze in the presence of acids or bases or under the action of enzymes. Heating is also needed. Hydrolysis affects the proteins primary structure – first peptide chains break down thus forming molecules with a lower molecular mass. The final product is a mixture of the α-amino acids building up the polypeptide chains:



If proteins contain not only α-amino acids residues but also other atomic groups (residues of carbohydrates, phosphoric acid, nucleic acids, etc.), besides the mixture of α-amino acids hydrolysis products are also all compounds whose residues build up molecules.

TEST REACTIONS FOR PROTEINS

Test reactions are known for both peptide bonds and proteins themselves. They are commonly known as **biuret test** and **xanthoproteic test**.

BIURET TEST is a test for **peptide bonds** (not only for proteins). Several variants are known. For example a solution of a strong base (NaOH, KOH) is added to the aqueous solution of the tested substance, followed by a few droplets of an aqueous solution of CuSO_4 . The solution turns violet to purple:



XANTHOPROTEIC TEST. This is a specific test for **proteins**. Concentrated nitric acid HNO_3 is added to the aqueous solution of the tested substance. Under heating the solution turns yellow:



IMPORTANCE OF PROTEINS

Proteins provide energy to the body (together with carbohydrates, fats and oils). High-protein foods are eggs, milk, yogurt, fishes and seafood, cheese, beef, veal, pork, chicken and turkey, soya, nuts, quinoa, oats, beans, lentils, etc.

Proteins are also of industrial importance. They are indispensable to produce rayon (synthetic silk) and are also used in the food, pharmaceutical, leather industry.

CAN YOU ANSWER THESE QUESTIONS ?

1. Why are proteins polymers?
2. Why is the proteins 3D structure so complex?
3. What is the proteins biological role?
4. Does the proteins biological activity depend on their 3D structure?
5. Why is a temperature above 40-42 °C dangerous for man?
6. Why are some proteins soluble in water but others are insoluble?
7. Why is it harmful to eat fruits or vegetables grown in contaminated with heavy metals soils?
8. What process does take place when pouring the egg white in boiling water?
9. Why is it recommended to add a pinch of salt to the boiling water?

● DRUGS (NARCOTICS)

KEY TOPICS

1. What are the fact about drugs?
2. What is drug abuse?
3. What is drug addiction?



KEY WORDS

- Psychoactive drugs
- Psychotropic drugs
- Drug abuse
- Drug addiction
- Opiates
- Cannabis
- Cocaine
- Barbiturates
- Tranquilants
- Amphetamines
- Hallucinogens
- Inhalants
- Alcoholism

NARCOTICS are compounds that affect the brain. They are **psychoactive** drugs (or **psychotropic** substances) – they change temporarily the mental and emotional state and the physical condition of man. Most narcotics are natural or synthetic organic compounds. But some inorganic compounds as N_2O (laughing gas) are also narcotics. Ethanol C_2H_5OH is a narcotic too.

The use of narcotics in Bulgaria is forbidden and is persecuted by the law. Only the use of some narcotics as medicines is legal – usually as anesthetics or to treat depressive and other mental disorders. The common pain relief medications are also narcotics. So they should be taken by prescription only.

Narcotics abuse results in a **drug addiction**. According to the USA National Institute of Drug abuse, addiction occurs when the **chemical dependency to narcotics combines with an overwhelming urge to use the substance**.

TYPES OF NARCOTICS

Generally, based on their origin, narcotics are classified as *natural*, *semi-synthetic* and *synthetic* drugs. Opium was the first known narcotic. Opium, cannabis and coca are natural drugs. They are extracted from plants. Semi-synthetic drugs are cocaine and heroin. They are chemically treated natural products. Synthetic drugs are produced in specific chemical reactions (for example amphetamines).

Depending on the **type of drug addiction** narcotics are classified as:

Opiates. They are similar to some compounds naturally synthesized in the body. Opium, morphine, heroin, codeine, methadone are opiates. *Morphine* (named after the ancient Greek god of dreams Morpheus) is derived from opium, but it is ten times stronger. It is used as pain relief medicine. Diacetylmorphine (known as *heroin*) is produced from morphine in a reaction with the ethanoic acid anhydride. Pure heroin is a white powder. It is much stronger than morphine. *Codeine* is extracted from opium, but may be also semi-synthetic – produced by treating morphine (it is called methylmorphine). *Methadone* is a synthetic opiate. It is used in the treatment of people addicted to drugs.

Opiates use very rapidly results in drug addiction.

Cannabis. It is extracted from some types of hemp (Cannabis) and is known also as *marijuana*. Usually it is green in colour. *Hashish* is also derived from hemp. It is light brown to black in colour and is stronger than marijuana.

Cannabis, marijuana and hashish cause euphoria.

Cocaine. It is extracted from the leaves of the bush *Erythroxylon coca*. The pure cocaine is called *crack*. It is a stimulant and may cause euphoria.

Barbiturates, tranquilants. *Barbital* (brand name veronal), *phenobarbital*, *diazepam* (brand name valium) are used to treat anxiety and are sedatives. The risk of addiction is high. If the person is already addicted to some tranquilizers or sedatives, it is not recommended to stop using them suddenly as this may be fatal.

Amphetamines. These synthetic stimulants make feel cheerful and strong. The risk of addiction is very high. Persons become psychologically addictive and overcoming the addiction is very difficult – feeling of fatigue, insomnia, lack of concentration, nervous breakdown are typical signs.

Hallucinogens. These narcotics, as suggests their name, cause hallucinations (auditory, visual and others). There are hundreds of natural hallucinogen. *Mescaline* for example is extracted from a sort of cactus. LSD is a very powerful semi-synthetic hallucinogen derived from a fungus. Hallucinogens affect perceptions, feelings, thinking. If used for a long time, hallucinogen can cause mental disorders.

Inhalants. Those are volatile compounds which if inhaled affect the brain. They are easily accessible products and the access to them is not controlled – some glues, dyes, sprays, organic solvents (acetone, benzene, ethyl acetate). They are similar in their effect to alcohol – excitement, slurred speech, lack of concentration, euphoria, dizziness. A long-term use may affect the brain.

Alcohol. All beverages contain ethanol, but it is a drug and overdoses affect the mind. It is a depressant as people lose coordination and control and brain reactions slow down. Liver gradually becomes damaged and cirrhosis is developed. The brain, the heart and the stomach become also damaged. The alcohol dependence (**alcoholism**) is a very serious disease. The symptoms are a strong need to drink, loss of control, physical dependence (nausea, shakiness, anxiety, sweating, convulsions, delirium tremens, etc.), a need to take greater and greater amounts of alcohol.

In Bulgaria the sale of alcohol beverages to persons under 18 years of age is prohibited.

MANY AND MANY PAGES MAY BE WRITTEN TO EXPLAIN THE EFFECTS OF NARCOTICS, HOW THEY ACT, WHY THEY ARE HARMFUL, ETC., ETC. BUT IT IS ALWAYS THE PERSONAL RESPONSIBILITY OF EVERYONE TO DECIDE TO NOT USE DRUGS.

PROJECTS

1. SACCHAROSE

Since when do people use sugar? How is sugar produced today from cane and sugar beet? What are the health benefits of molasses and brown sugar?

2. DIABETES

Learn about diabetes A and B. Who and when did discover the insulin? What are the risk factors for diabetes? Are there some „bad habits“ in your everyday lifestyle which may be risky for diabetes?

3. THE HEALTHY BODY WEIGHT

What does it mean „healthy body weight“? What is „BMI“? What are the modern standards for a healthy and nice body? Which foods are „good“ to maintain your body in good condition?

4. DETERGENTS IN HOUSEKEEPING

Inform yourself about the quality of the detergents offered to consumers in the nearest supermarket. Read carefully the labels on the products – are they conform to the European regulations concerning the sale and the use of detergents? Compare the different products and choose the best detergent for dish washing and for the washing machine.

5. THE DOUBLE HELIX

What is the „double helix“? Why is the discovery of the molecular structure of DNA of epoch-making significance?

6. SAY „NO“ TO DRUGS

Visit a clinic for drug addicts. Make sure how terrible are the consequences of drugs abuse. Ask doctors about every think you want to know about drugs.