# OVERVIEW OF BIOLOGICALLY ACTIVE MOLECULES

**Lecture №10 (part 1)**

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Organic compounds are called "*organic*" because they are associated with living organisms. These molecules form the basis for life and are studied in great detail in the chemistry disciplines of ***organic chemistry*** and ***biochemistry***.

There are 4 main types, or classes, of organic compounds found in all living things:

- carbohydrates,
- lipids,
- proteins,
- nucleic acids.

In addition, there are other organic compounds that may be found in or produced by some organisms. <u>All organic compounds contain carbon, usually bonded to hydrogen (other elements may be present as well).</u>

Chemical elements that are necessary for the construction and life of cells and organisms are called **biogenic elements**. All living systems are based on six elements: carbon **C**, hydrogen **H**, oxygen **O**, nitrogen **N**, phosphorus **P**, and sulfur **S**, which are called <u>**organogens**</u> (97% of them).

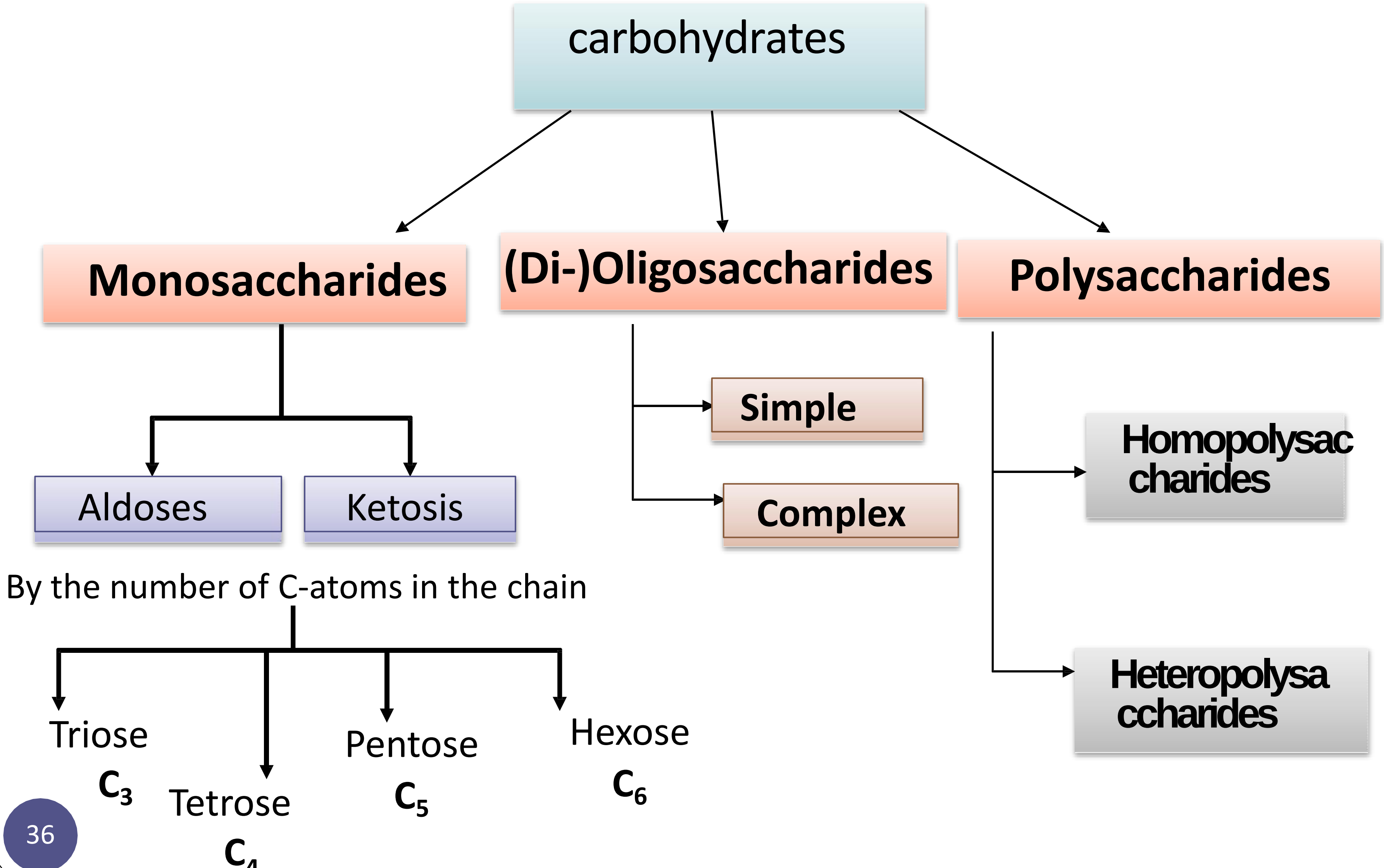
In addition, vital **macroelements** also include s-elements of the third (sodium, magnesium) and fourth (potassium, calcium) periods, and p-elements of the third period (chlorine).

# HETEROPOLYFUNCTIONAL COMPOUNDS. CARBOHYDRATES (OVERVIEW)

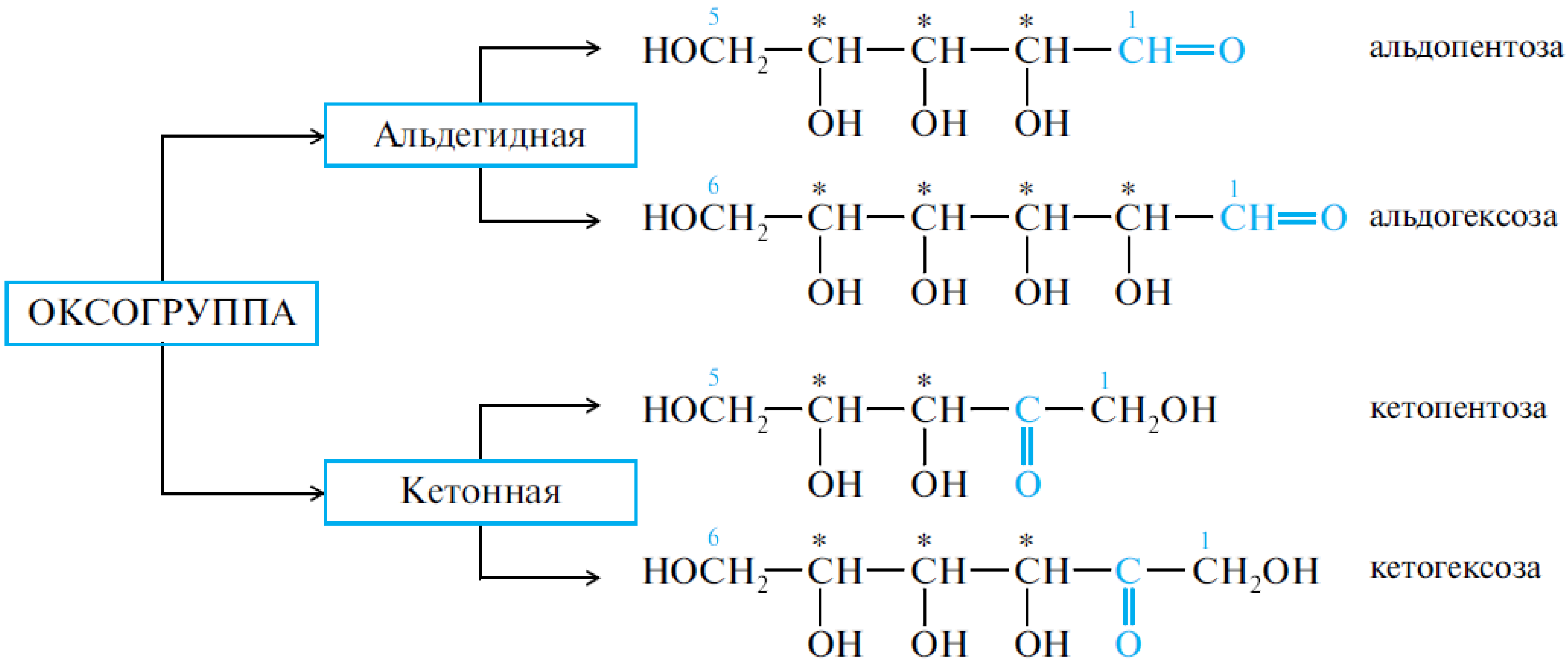
- Carbohydrates (sugars) are organic compounds with the general formula $Cn(H_2O)m$.
- Carbohydrates (sugars) are carbonil derivatives of polyhydric alcohols

- Carbohydrates are organic compounds made of the elements carbon, hydrogen, and oxygen. The ratio of hydrogen atoms to oxygen atoms in carbohydrate molecules is 2:1.
- Organisms use carbohydrates as energy sources, structural units, and for other purposes.
- Carbohydrates are classified according to how many subunits they contain. Simple carbohydrates are called sugars. A sugar made of one unit is a **monosaccharide (Glucose, Fructose, Ribose and etc.).** If two units are joined together, a **disaccharide (Sucrose, Lactose and etc.)** is formed. More complex structures form when these smaller units link to each other to form **polymers (Starch, Chitin, Cellulose, Glycogen and etc.).**

# Classification of carbohydrates

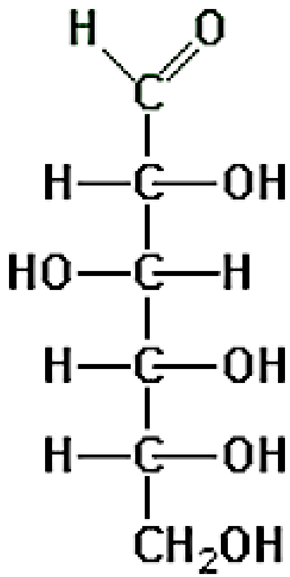


**Monosaccharides** are heterofunctional compounds containing both carbonyl (C=O) and several hydroxyl (-OH) groups.

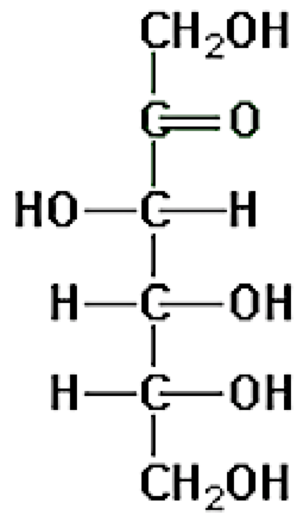



**C* - asymmetric (chiral) carbon atom**

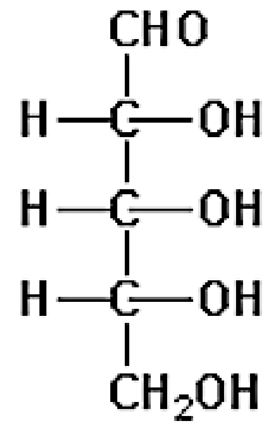
(in sp3 - hybridization, bonded to 4 different substituents).



**Glucose**
(eine **Aldohexose**)

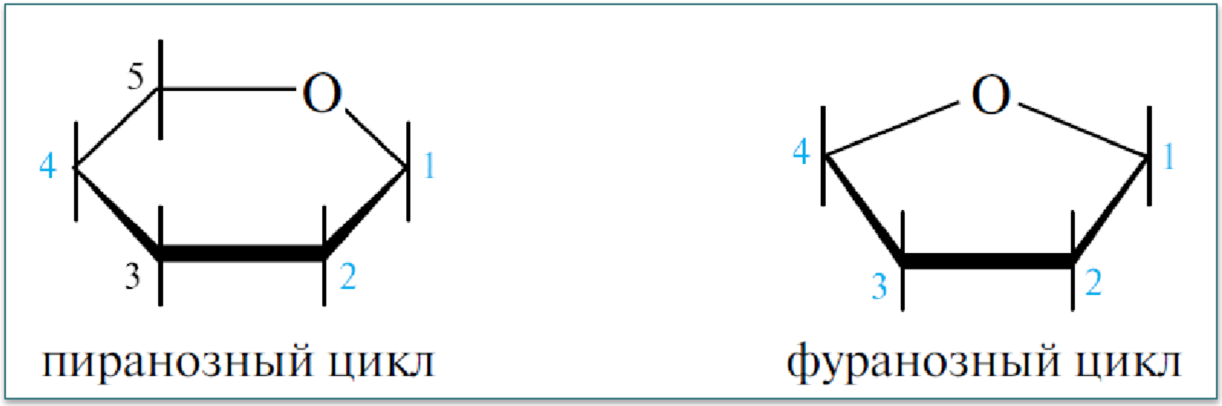


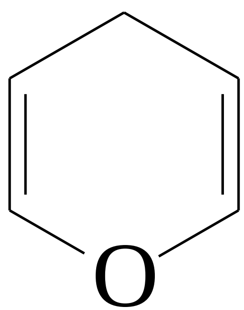
**Fructose**
(eine **Ketohexose**)



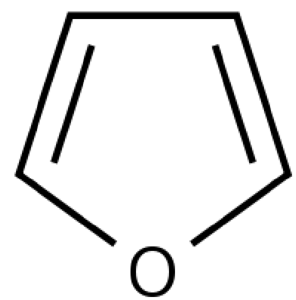
**Ribose**
(eine **Aldopentose**)

# Haworth's Formulas for Carbohydrates

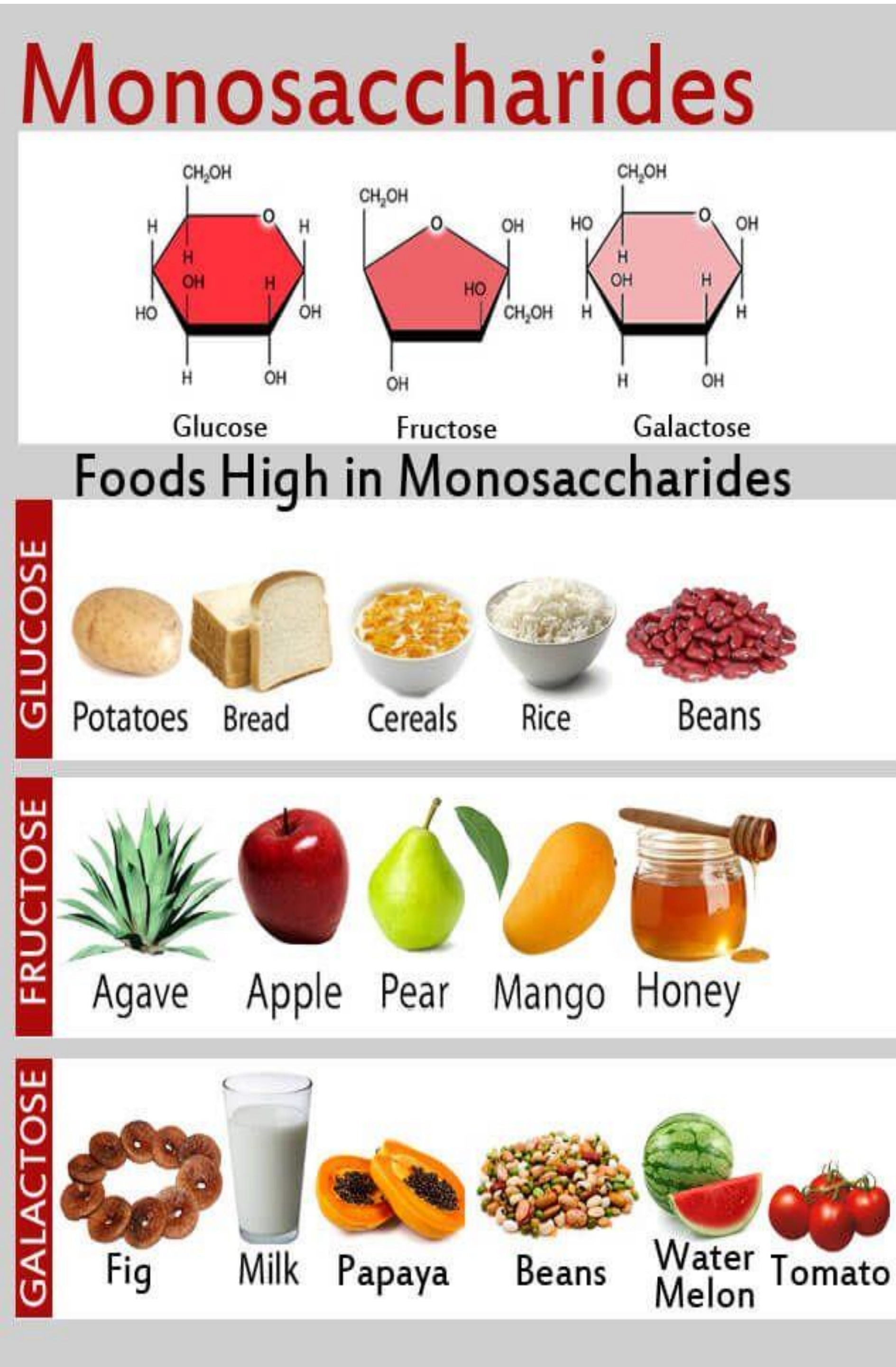


4H - piran



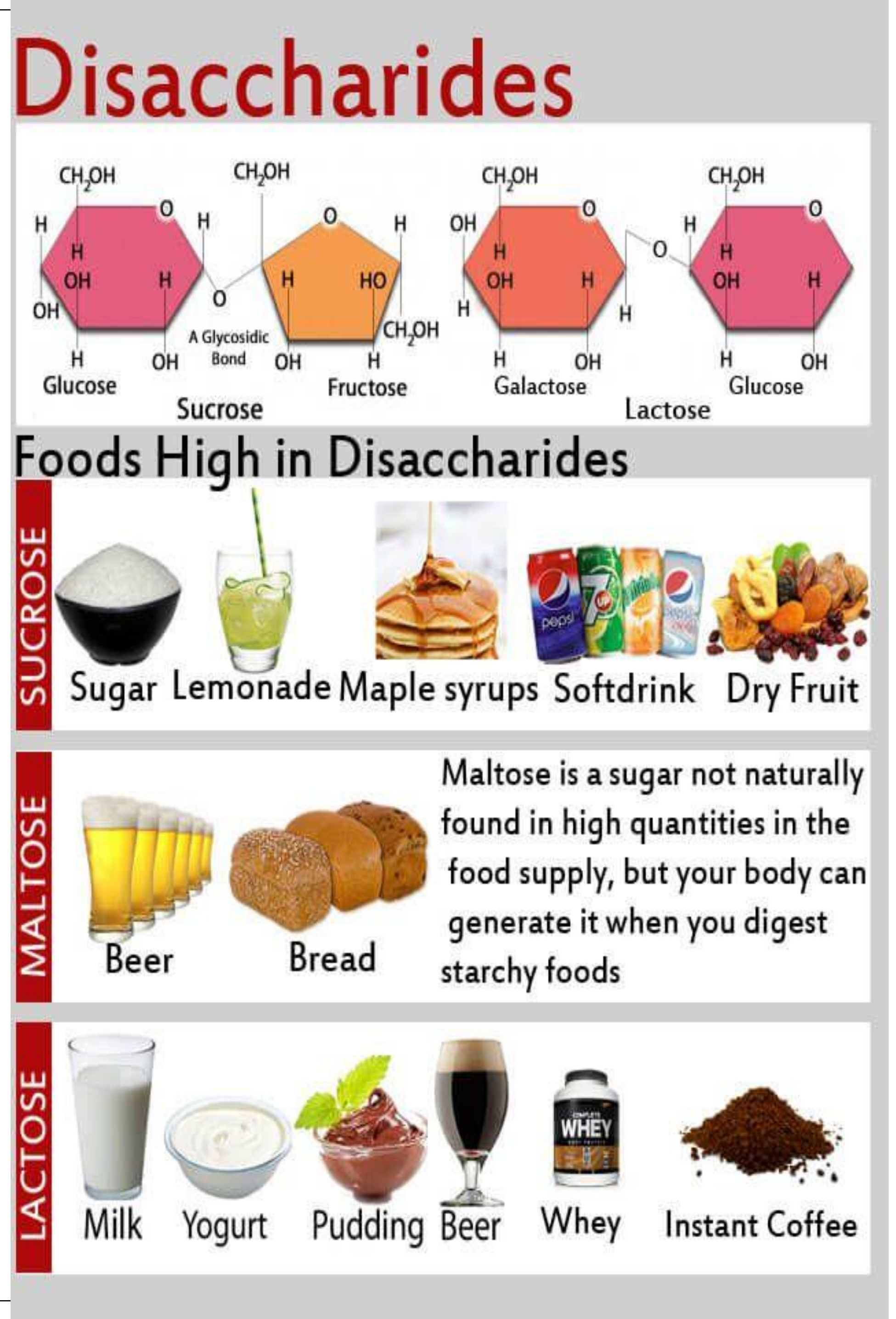
furan

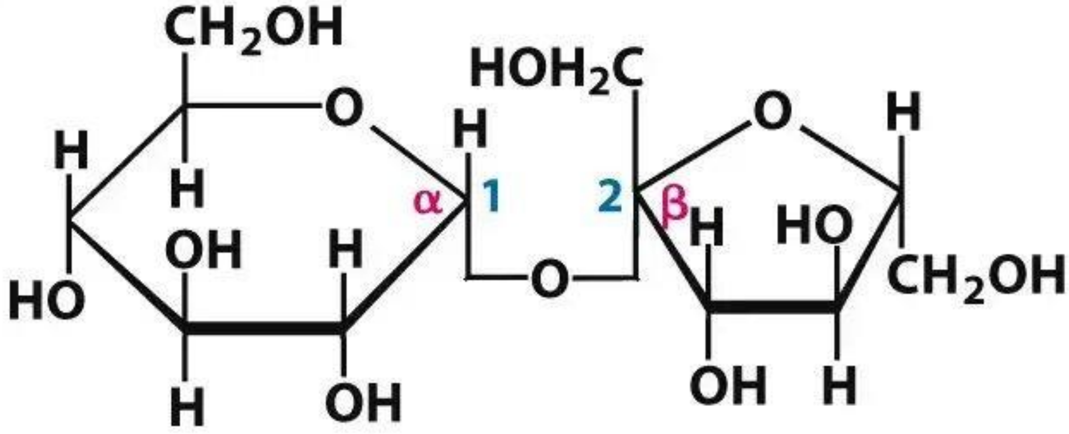



# FUNCTION OF MONOSACCHARIDE

Monosaccharides have many functions within cells. First and foremost, monosaccharides are used to produce and store energy. Most organisms create energy by breaking down the monosaccharide glucose, and harvesting the energy released from the bonds. Other monosaccharides are used to form long fibers, which can be used as a form of cellular structure. Plants create cellulose to serve this function, while some bacteria can produce a similar cell wall from slightly different polysaccharides. Even animal cells surround themselves with a complex matrix of polysaccharides, all made from smaller monosaccharides.

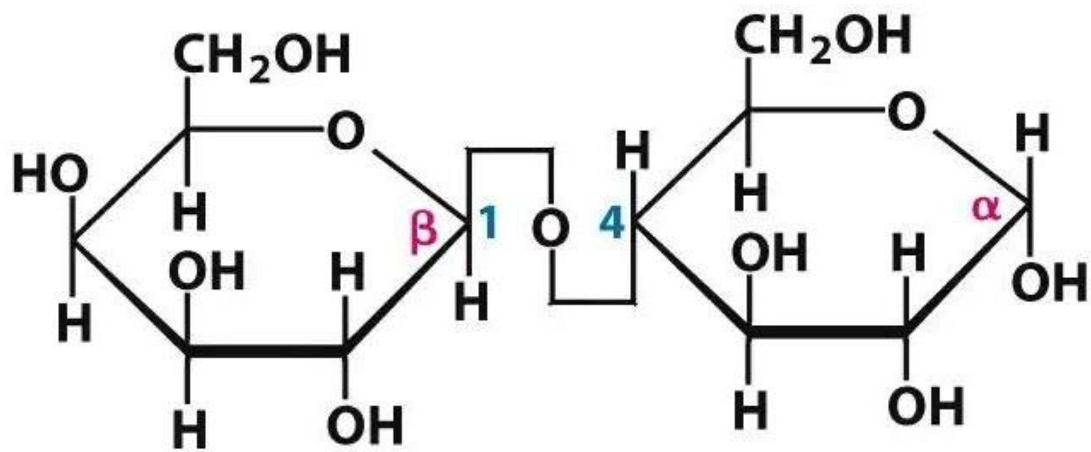
**A disaccharide, also called a double sugar, is a molecule formed by two monosaccharides, or simple sugars.** Three common disaccharides are sucrose, maltose, and lactose. They have 12 carbon atoms, and their chemical formula is $C_{12}H_{22}O_{11}$. Other, less common disaccharides include lactulose, trehalose, and cellobiose. Disaccharides are formed through dehydration reactions in which a total of one water molecule is removed from the two monosaccharides.





**Sucrose**

**(α-D-Glucopyranosyl-(1⟶ 2)-β-D-fructofuranose**



**Lactose**

**(β-D-Galactopyranosyl-(1⟶ 4)-α-D-glucopyranose**

# FUNCTIONS OF DISACCHARIDES

Disaccharides are carbohydrates found in many foods and are often added as sweeteners. Sucrose, for example, is table sugar, and it is the most common disaccharide that humans eat. It is also found in other foods like beetroot. When disaccharides like sucrose are digested, they are broken down into their simple sugars and used for energy. Lactose is found in breast milk and provides nutrition for infants. Maltose is a sweetener that is often found in chocolates and other candies.

Plants store energy in the form of disaccharides like sucrose and it is also used for transporting nutrients in the phloem. Since it is an energy storage source, many plants such as sugar cane are high in sucrose. Trehalose is used for transport in some algae and fungi. Plants also store energy in polysaccharides, which are many monosaccharides put together. Starch is the most common polysaccharide used for storage in plants, and it is broken down into maltose. Plants also use disaccharides to transport monosaccharides like glucose, fructose, and galactose between cells. Packaging monosaccharides into disaccharides makes the molecules less likely to break down during transport.

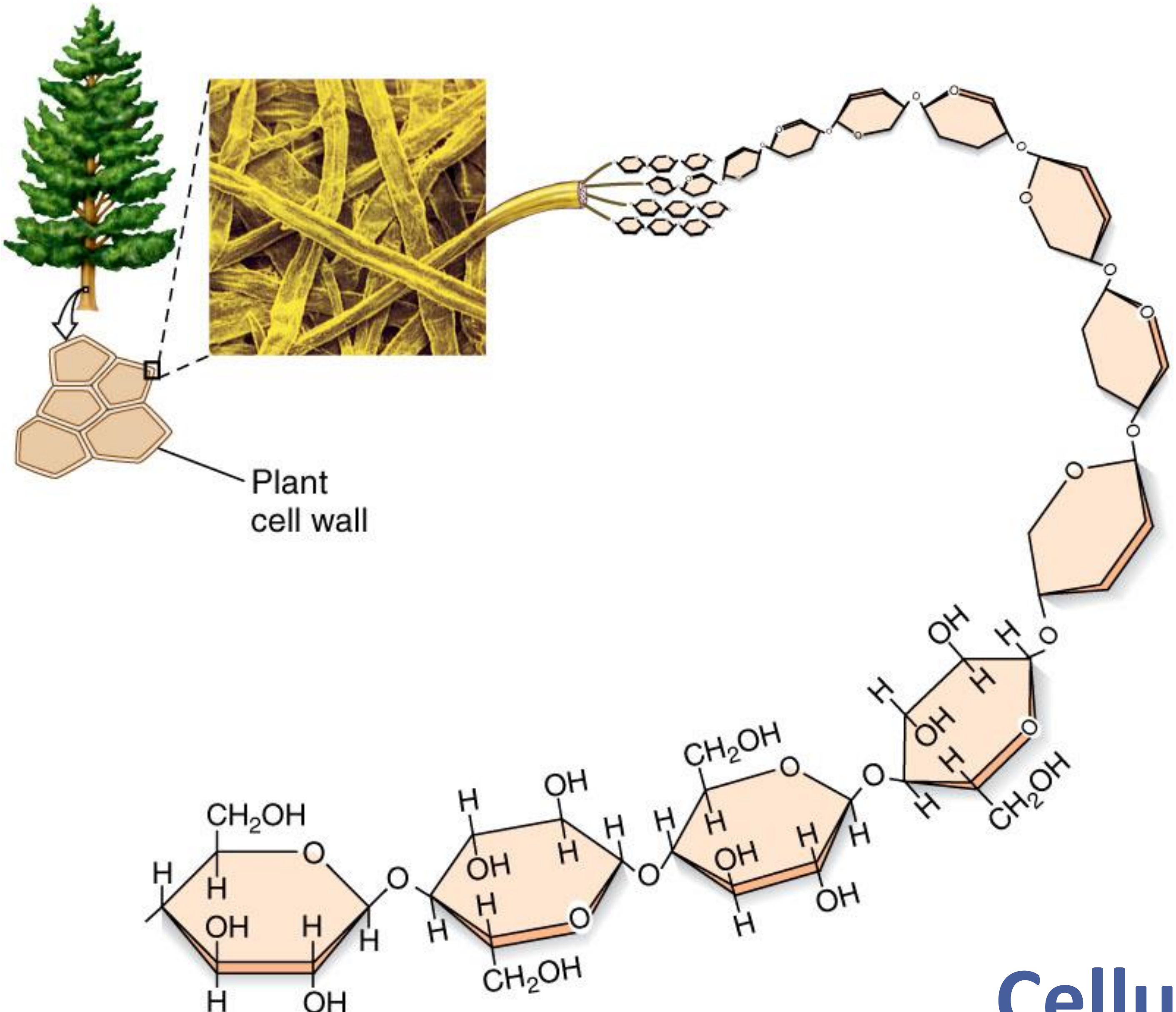
**A polysaccharide** is a large molecule made of many smaller *monosaccharides*.

**POLYSACCHARIDE**

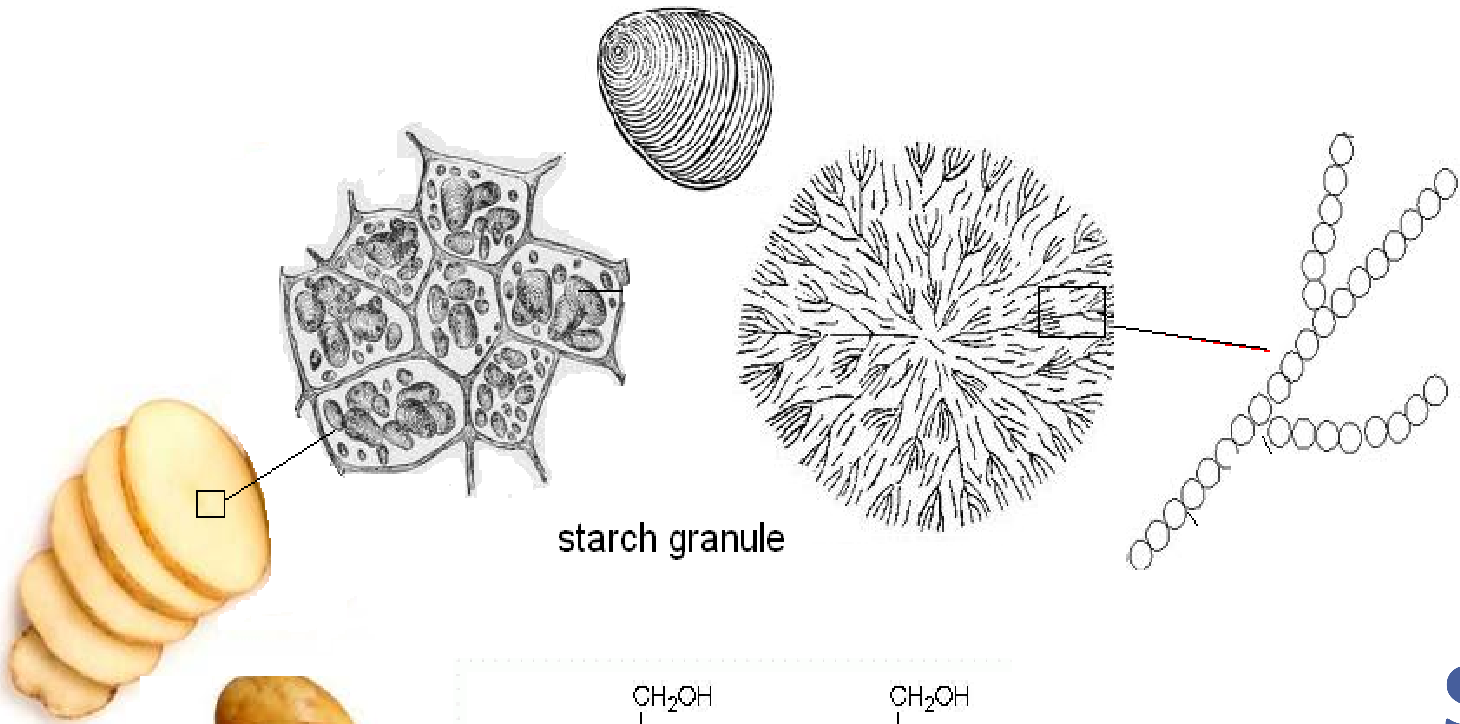
- branched
- unbranched

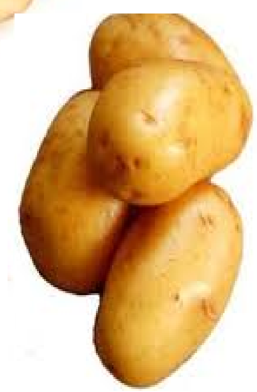
**POLYSACCHARIDE**

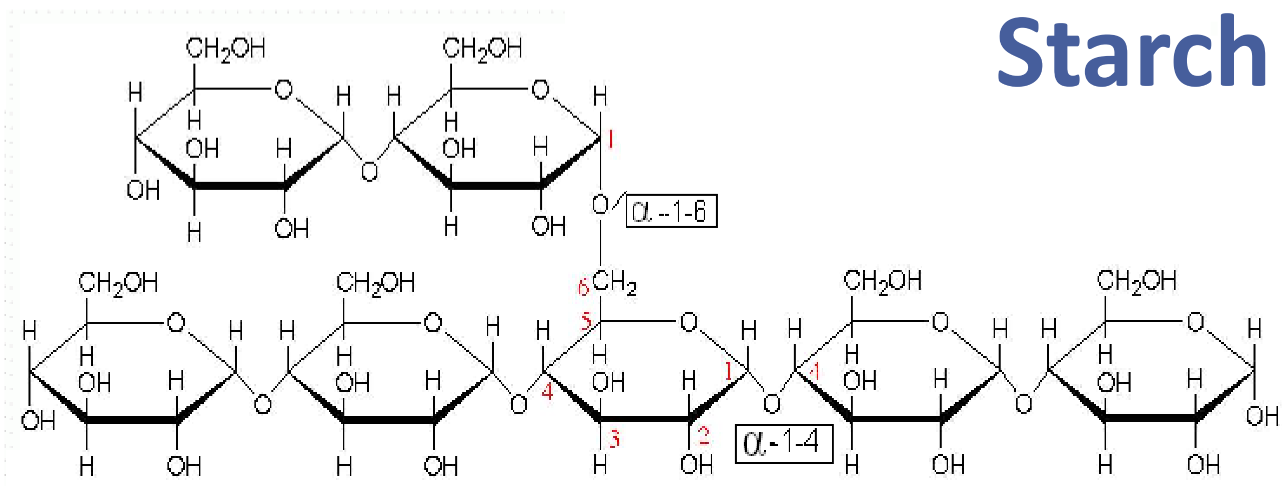
- Homopolysaccharides
  - Starch
  - Cellulose
  - Pectin
  - Glycogen
  - Chitin
  - Dextrans
- Heteropolysaccharides
  - chondroitin sulfates
  - hyaluronic acid



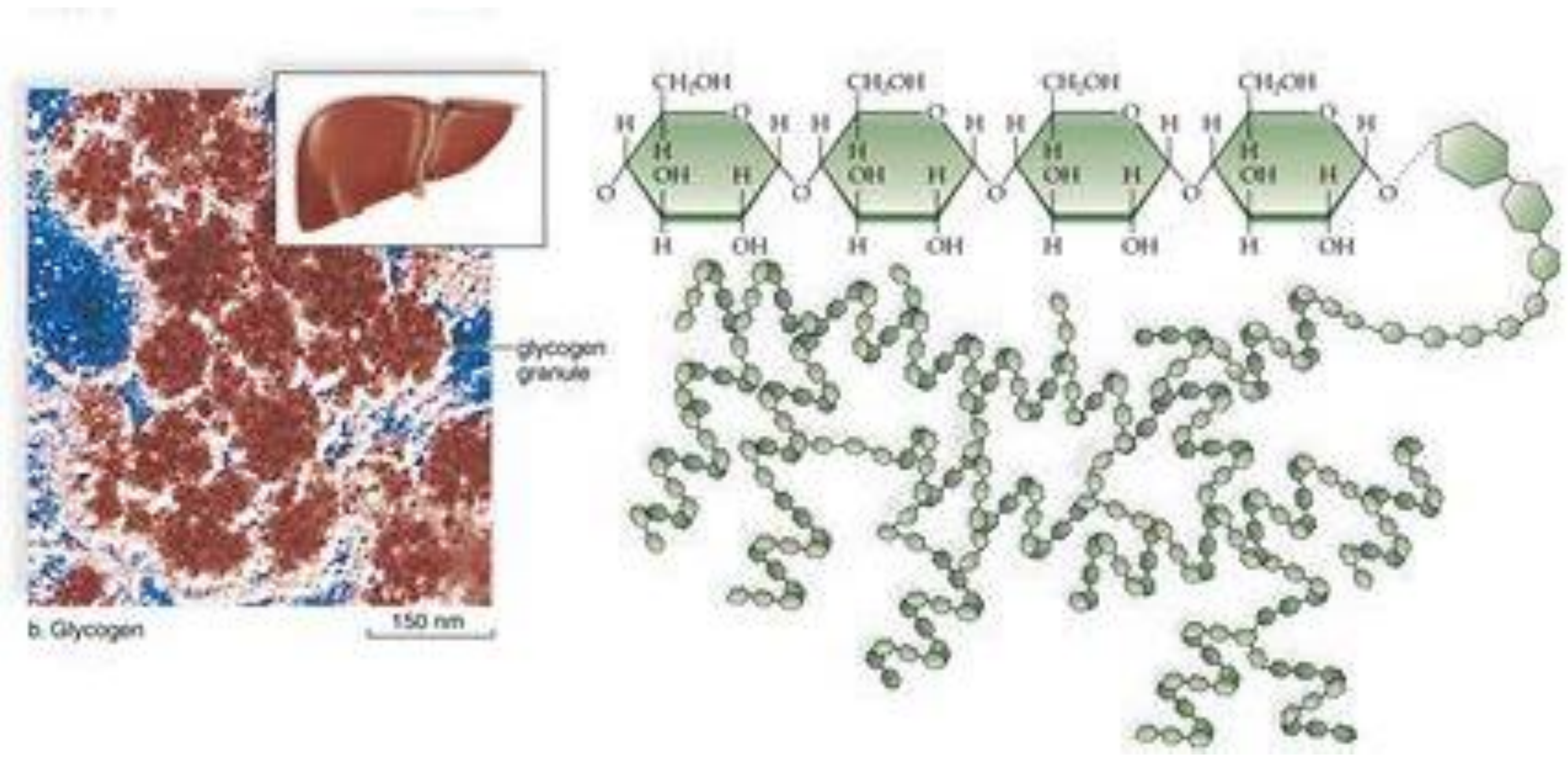

# Cellulose





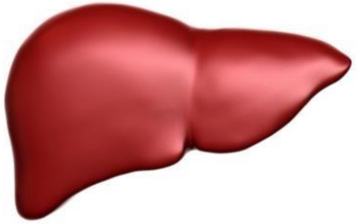

# Starch




# Glycogen

# CONNECTIVE TISSUE POLYSACCHARIDES

| CHONDROITIN SULPHATES | HYALURONIC ACID | HEPARIN |
|---|---|---|
| skin, cartilage, tendons | vitreous body of the eye, umbilical cord, cartilage, joint fluid | liver |

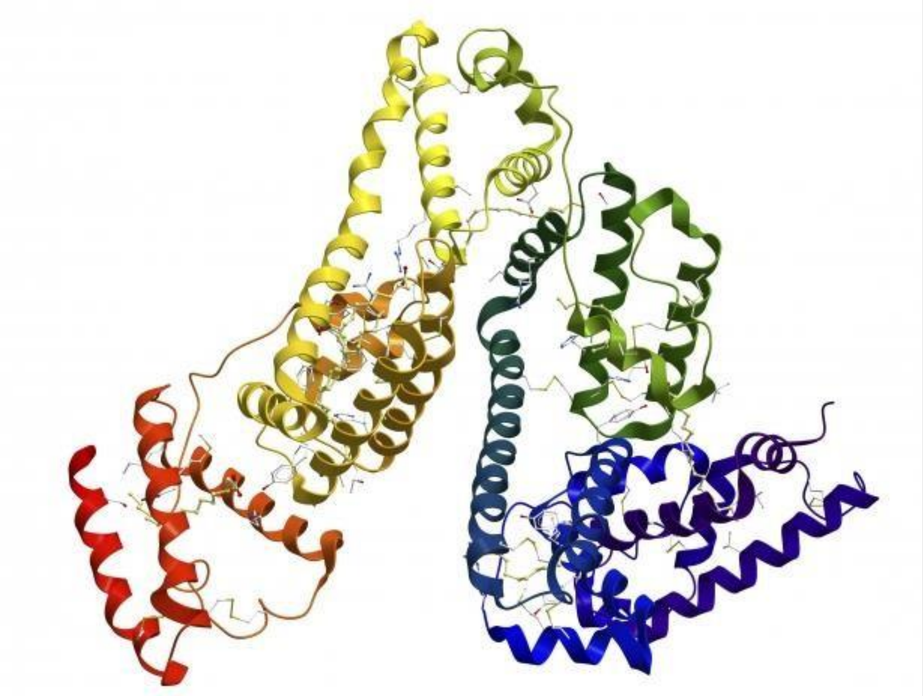


# FUNCTIONS OF A POLYSACCHARIDE

Depending on their structure, polysaccharides can have a wide variety of functions in nature. Some polysaccharides are used for storing energy, some for sending cellular messages, and others for providing support to cells and tissues.

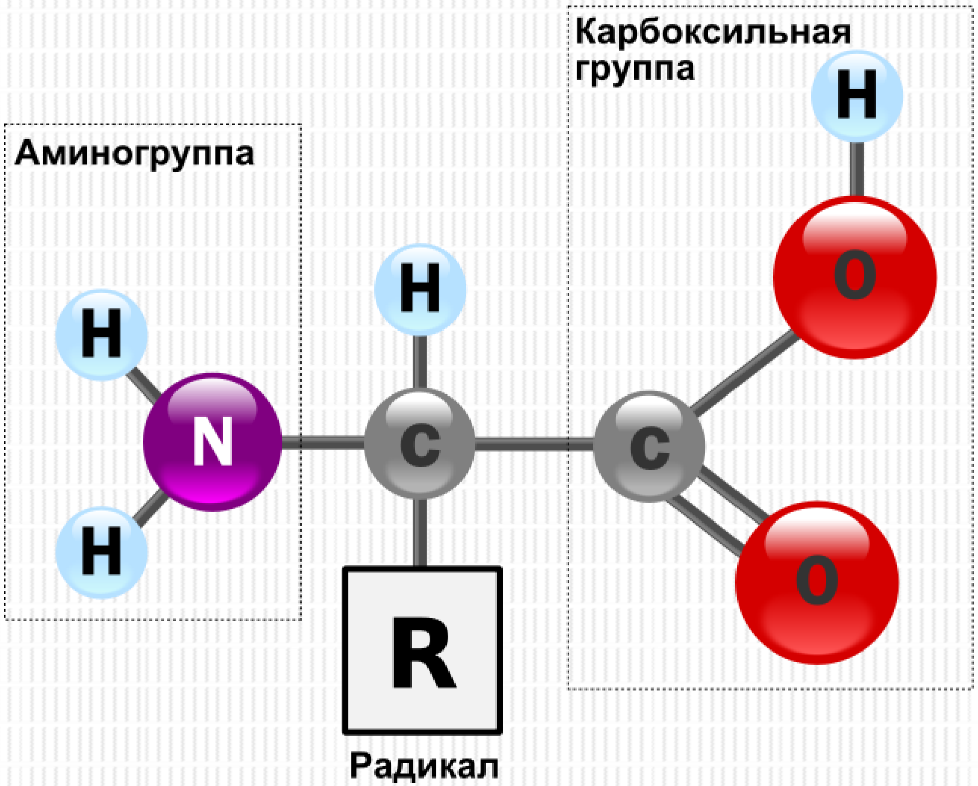
# STORAGE OF ENERGY

Many polysaccharides are used to store energy in organisms. While the enzymes that produce energy only work on the monosaccharides stored in a polysaccharide, polysaccharides typically fold together and can contain many monosaccharides in a dense area. Further, as the side chains of the monosaccharides form as many hydrogen bonds as possible with themselves, water cannot intrude the molecules, making them *hydrophobic*. This property allows the molecules to stay together and not dissolve into the cytosol. This lowers the sugar concentration in a cell, and more sugar can then be taken in. Not only do polysaccharides store the energy, but they allow for changes in the concentration gradient, which can influence cellular uptake of nutrients and water.



# AMINO ACIDS, PEPTIDES, PROTEINS

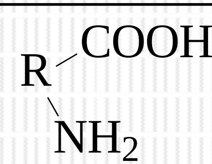
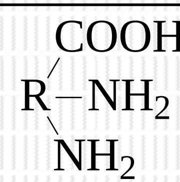
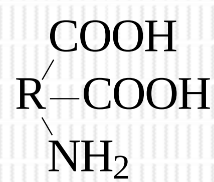
**Amino acids** are heterofunctional compounds whose molecules contain both an amino group (аминогруппа) and a carboxyl group (карбоксильная группа).




General formula of α-amino acids

# Classification of amino acids

## 1. By the number of functional groups

| Group | General form | pH |
|---|---|---|
| NEUTRAL |   | ~7 |
| BASE |   | >7 |
| ACID |   | <7 |

# Classification of amino acids

## 2. By the position of the amino group

| | | |
|---|---|---|
| **α-amino acids (protein)** | γ β α<br>$CH_3 - CH_2 - CH\ \ COOH$<br>$\quad\quad\quad\quad |$<br>$\quad\quad\quad\quad NH_2$ | α-aminobutyric acid |
| **β-amino acids** | γ β α<br>$CH_3 - CH - CH_2 - COOH$<br>$\quad\quad |$<br>$\quad\quad NH_2$ | β-aminobutyric acid |
| **γ-amino acids** | γ β α<br>$CH_2 - CH_2 - CH_2 - COOH$<br>$|$<br>$NH_2$ | γ-aminobutyric acid |

# Classification of amino acids based on their R-groups (according to Leninger):

**1.Non-polar or hydrophobic (8):**

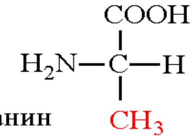
**Alanine (**Аланин**), Valine (**Валин**), Isoleucine (**Изолейцин**), Leucine (**Лейцин**), Methionine (**Метионин**), Proline (**Пролин**), Tryptophan (**Триптофан**), Phenylalanine (**Фенилаланин**).**

**2.Polar, but uncharged (7):**
**Asparagine (**Аспарагин**), Glycine (**Глицин**), Glutamine (**Глутамин**), Serine (**Серин**), Tyrosine (**Тирозин**), Threonine (**Треонин**), Cysteine (**Цистеин**).**

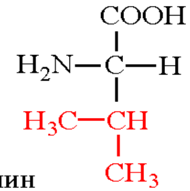
**3.Negatively charged (2): Aspartic acid (**Аспарагиновая кислота**), Glutamic acid (**Глутаминовая кислота**).**

**4.Positively charged (3): Arginine (**Аргинин**), Histidine (**Гистидин**), Lysine (**Лизин**).**

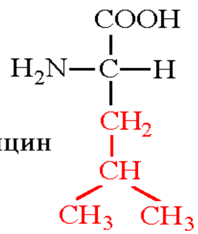
Аланин



Валин

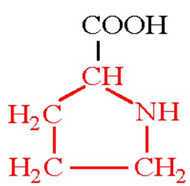


Лейцин

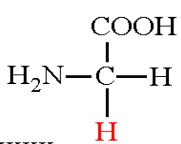


Изолейцин

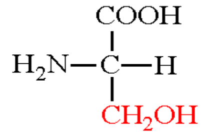
Пролин



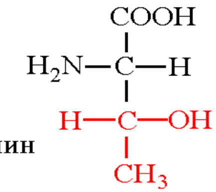
Глицин



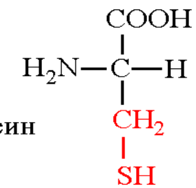
Серин



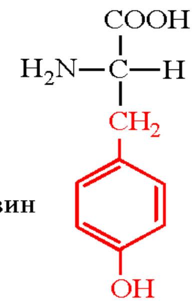
Треонин



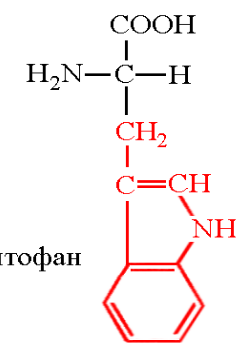
Цистеин



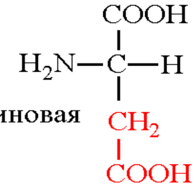
Тирозин



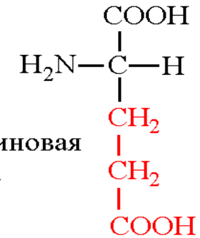
Триптофан



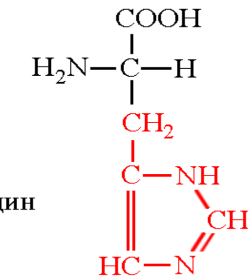
Аспарагиновая кислота



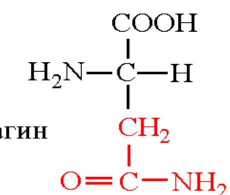
Глутаминовая кислота



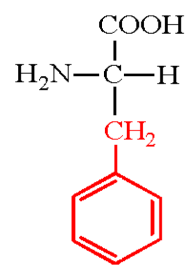
Гистидин



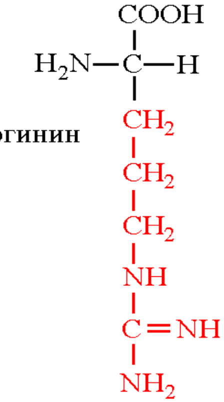
Аспарагин



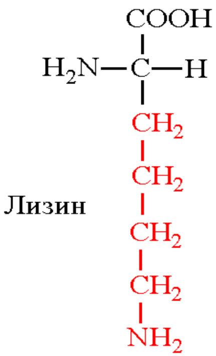
Фенилаланин



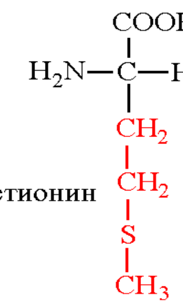
Аргинин



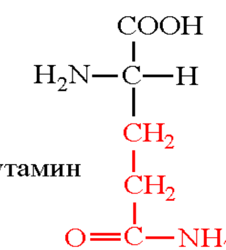
Лизин



Метионин

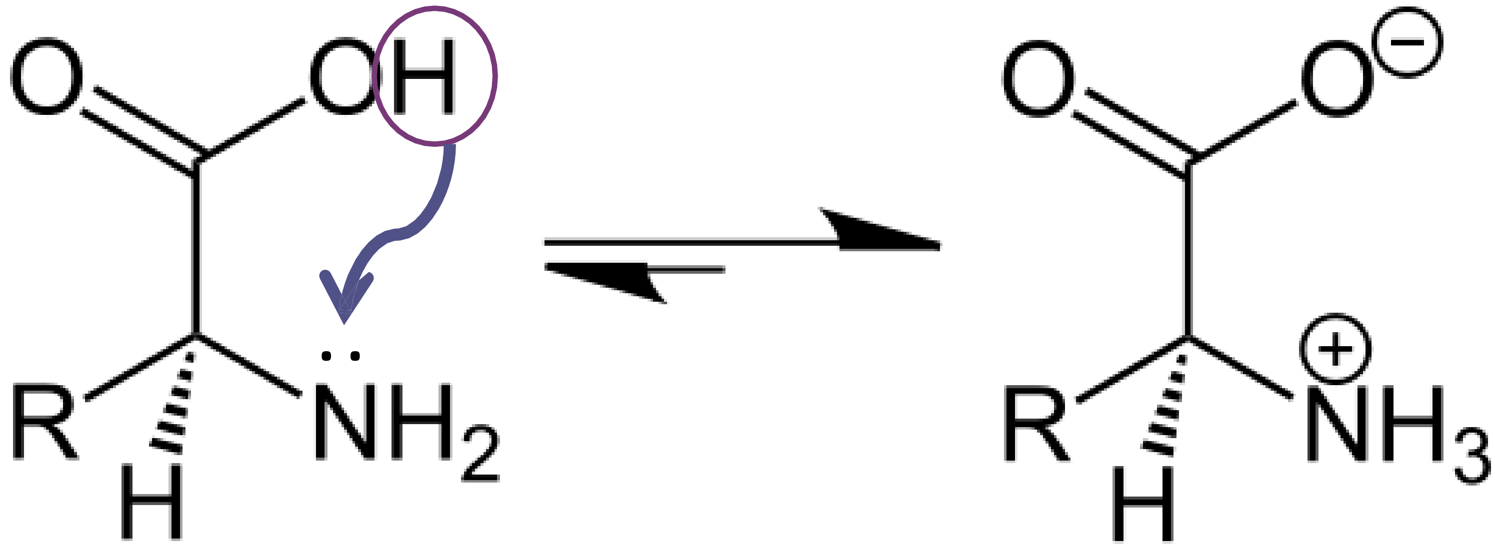


Глутамин



- **Ampholites are molecules in the structure of which there are both acidic and basic groups that exist in the form of “zwitter” ions at certain pH values.**
- **This pH is denoted as the isoelectric point of the molecule (pI)**


| **Ampholites form solutions with good buffer properties:** |
|---|
| in the presence of acids, they take on protons, removing them from the solution, and counteract the increase in its acidity. |
| When the bases are added, the ampholites release hydrogen ions into the solution, preventing the pH from increasing, and thus maintaining its equilibrium. |



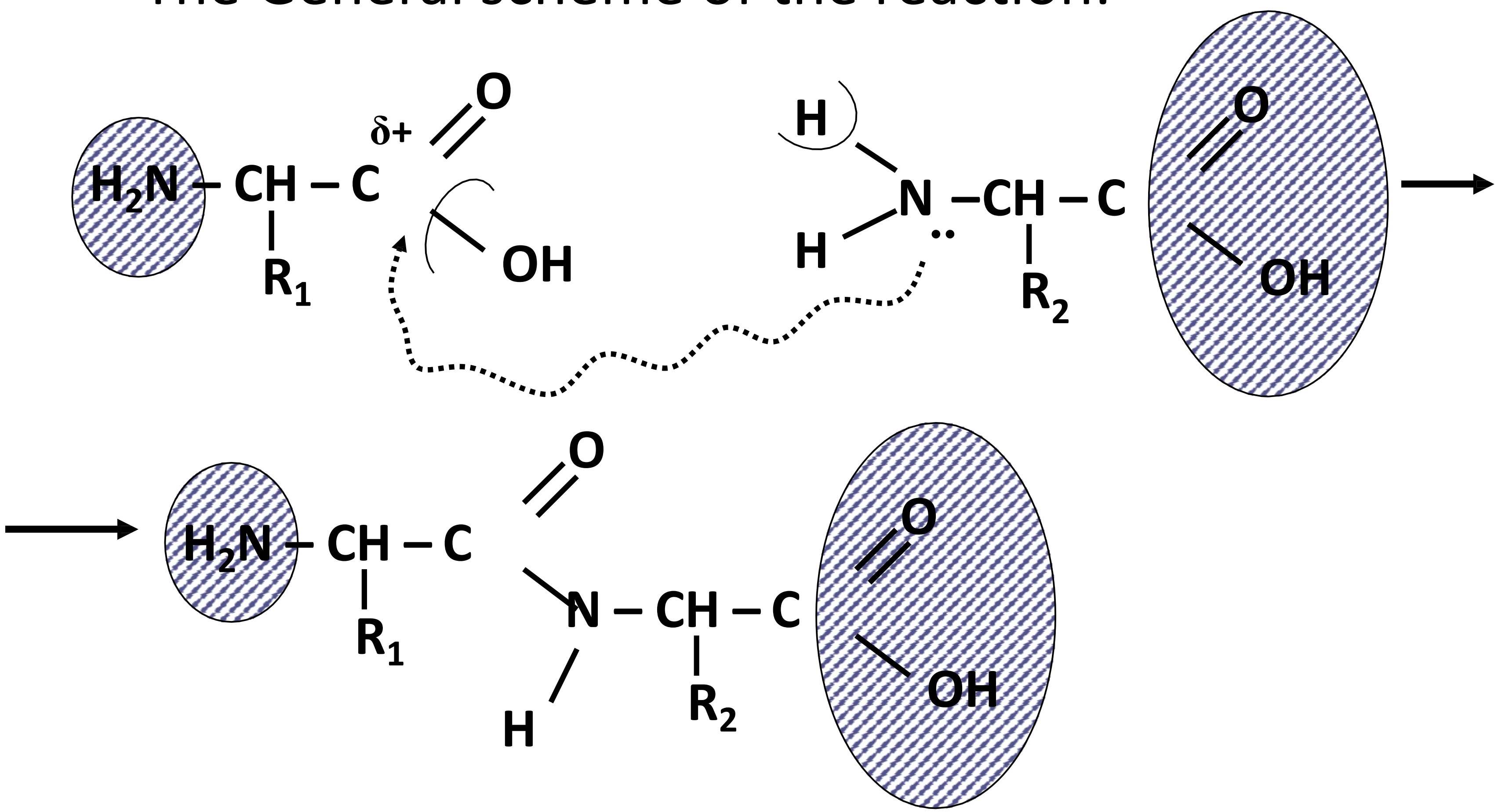

1
Amino acid in molecular form

2
Amino acid in the form of a zwitter ion

**The isoelectric point (pI)** is the pH of the medium at which the zwitter ion content is maximum.

# FORMATION OF PEPTIDES AND PROTEINS

- The General scheme of the reaction:



# Structural organization of a protein molecule

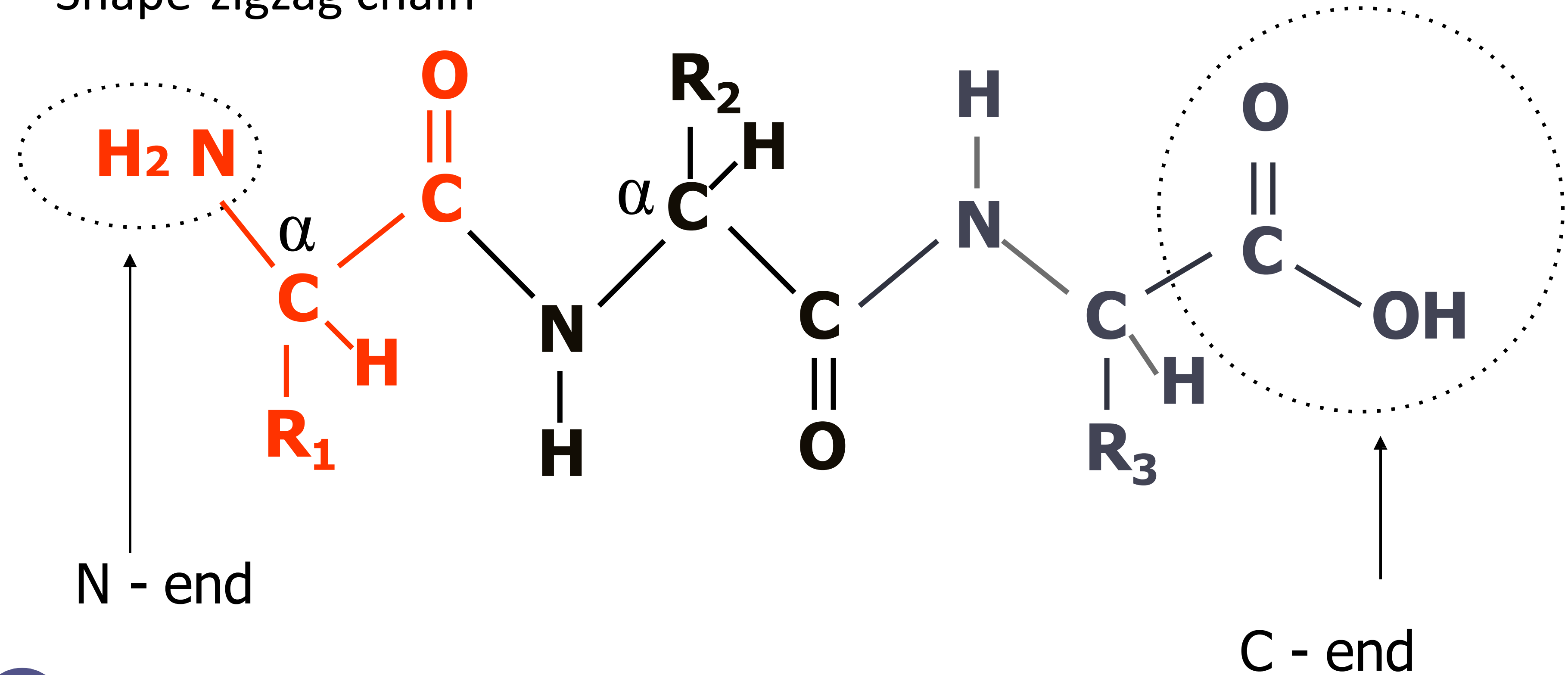
- The primary structure
- Secondary structure
- Tertiary structure
- Quaternary structure

# The primary structure

- it is a sequence of amino acids in a polypeptide chain.

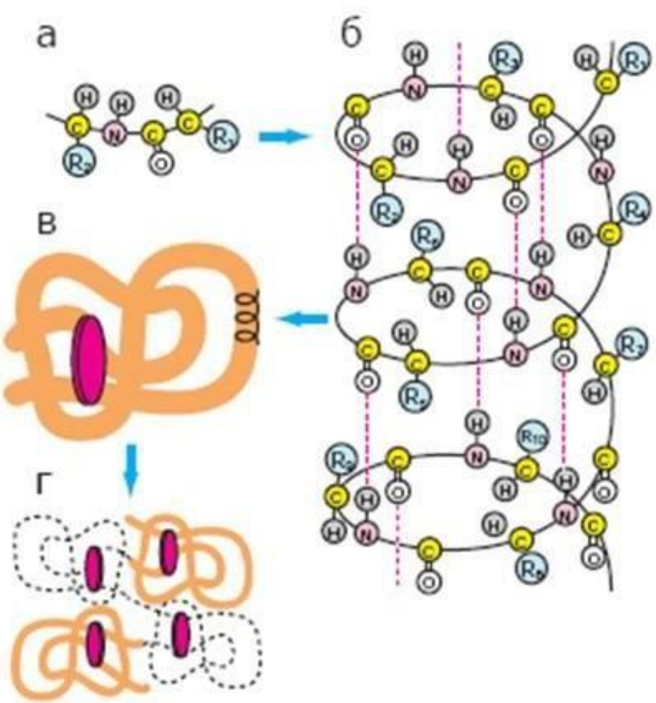
The bonds that stabilize this structure are peptide bonds.

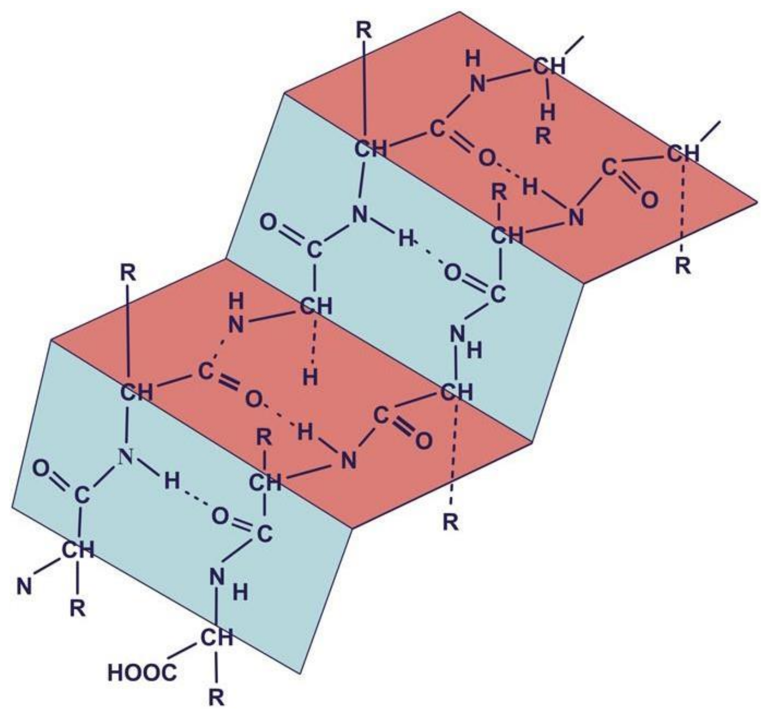
Shape-zigzag chain



# Secondary structure

- This is a regular arrangement of the polypeptide chain in space.
- The bonds that stabilize this structure are hydrogen bonds between the peptide groups.
- Shape: α-spiral or β-folded sheet



# Tertiary structure

The tertiary structure of a protein is a compact packaging of polypeptide chains in space, resulting from the interaction of amino acid radicals.

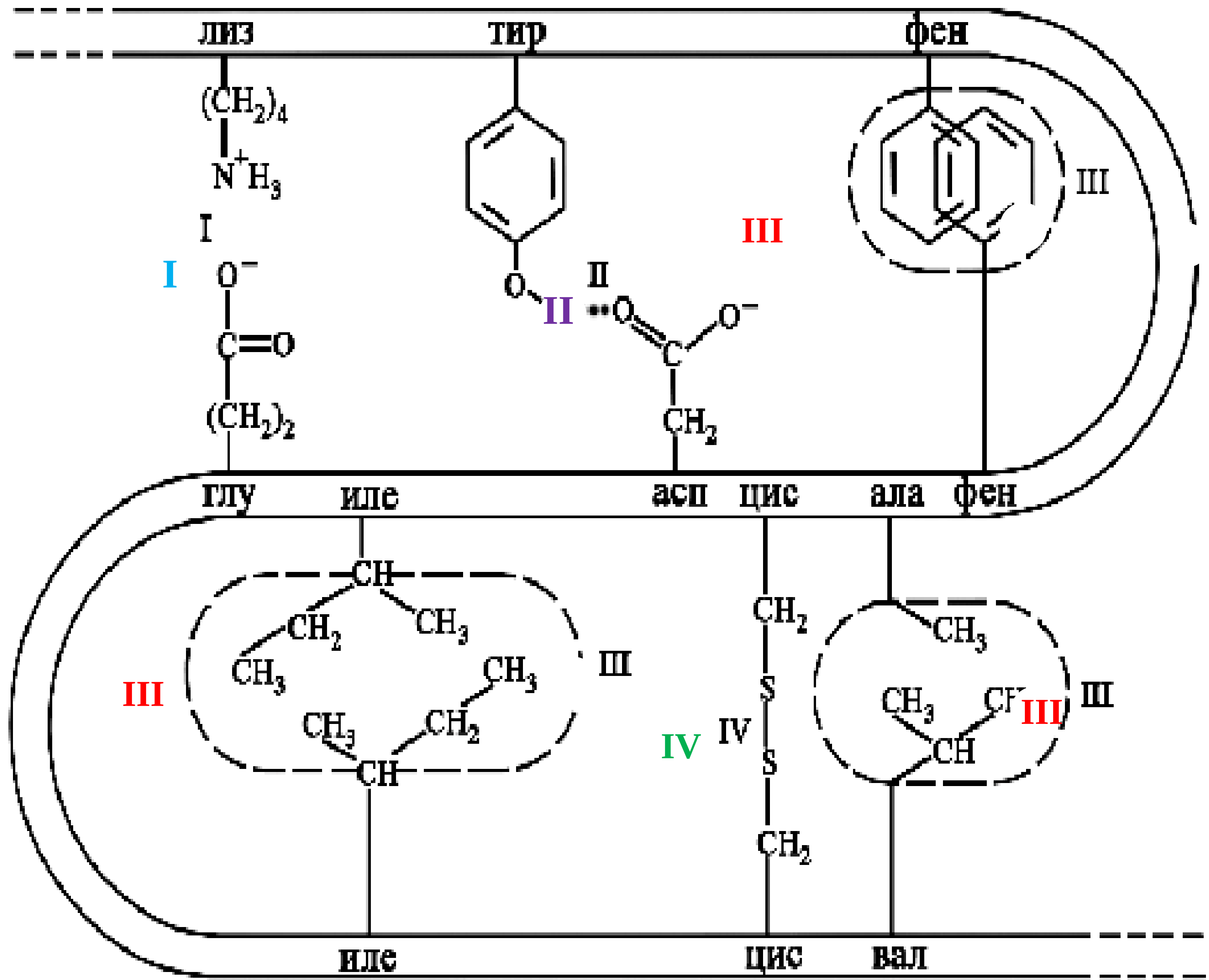
Various types of bonds are involved in the formation and stabilization of the tertiary structure of the protein:

I – ionic (salt)

II-hydrogen

III-hydrophobic interactions

IV-covalent (disulfide)



лиз
тир
фен
$(CH_2)_4$
$N^+H_3$
I
I
$O^-$
C=O
$(CH_2)_2$
O
II
II
O
C
$O^-$
$CH_2$
III
III
глу
иле
асп
цис
ала
фен
CH
$CH_2$
$CH_3$
$CH_3$
$CH_3$
$CH_3$
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CH
III
III
$CH_2$
S
IV
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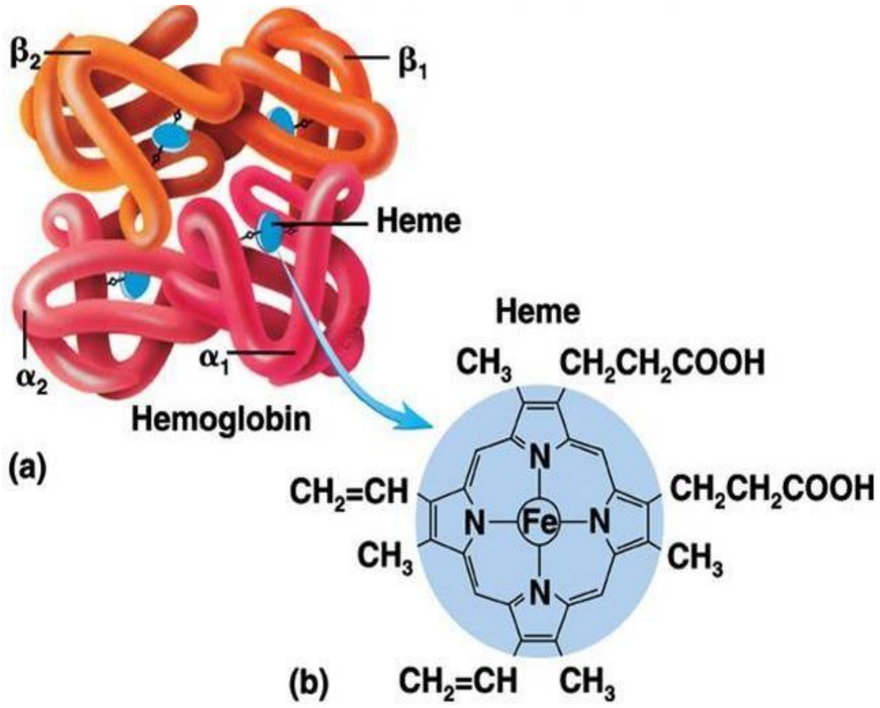
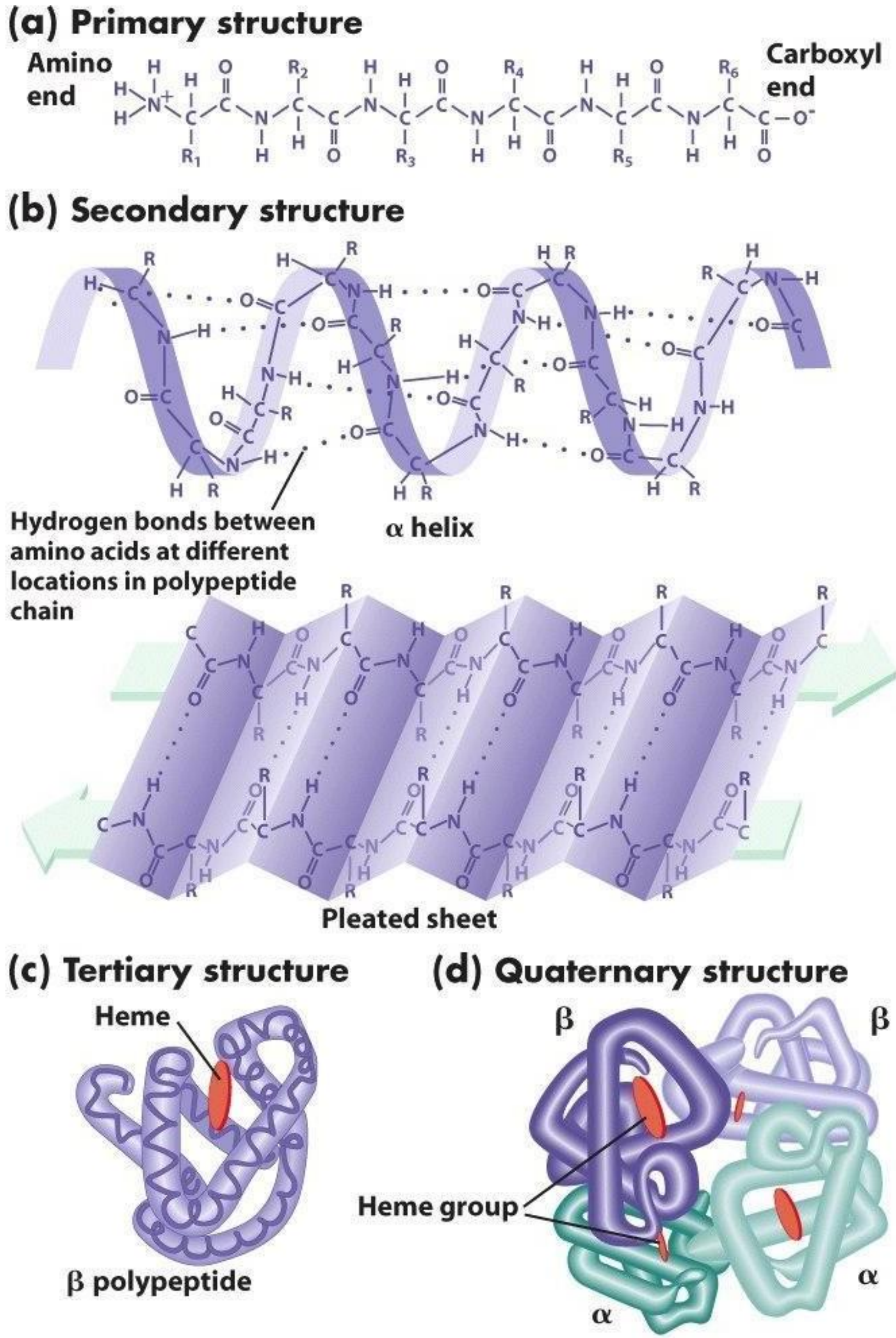
# Quaternary structure

- Some proteins are assembled into an oligomeric complex of several subunits (protomers) by means of non-covalent bonds.
- Quaternary structure - the spatial arrangement of subunits in an oligomeric protein.




(a) Primary structure
Amino end
Carboxyl end
(b) Secondary structure
Hydrogen bonds between amino acids at different locations in polypeptide chain
α helix
Pleated sheet
(c) Tertiary structure
Heme
β polypeptide
(d) Quaternary structure
β
β
Heme group
α
α