

**AL- MUSTAQBAL UNIVERSITY**  
**College Of Health And Medical Techniques**  
**Prosthetic Dental Techniques Department**  
**Second Grade**  
**Second Semester**



## **Advanced chemistry**

### **Lecture 4 (The theoretical part)**

### **(Carbohydrates)**

**By:**

**Prof.Dr. Hussein Kadhem AL-Hakeim**

**Assist.Prof.Dr.Ahmed A. AL-Khafagi**

- **Objectives of the Semester:**
- **General goal:**

**Informing the student of all the structural and chemical properties of most dental materials and how to deal with them.**

- **Own goal:**

**Enabling the student of the Department of Prosthetic Dental Techniques to know the molecular structure of dental materials..**

1. Introduction to Carbohydrates (CHO)
2. Carbohydrate Nomenclature-Monosaccharides -Disaccharides-Polysaccharides-Glycogen-Starch

## Introduction

Carbohydrates are organic compounds that contain large quantities of hydroxyl groups. It has the general formula (C<sub>n</sub>H<sub>2n</sub>O<sub>n</sub>). The simplest carbohydrates also contain either an aldehyde moiety (these are termed **polyhydroxyaldehydes**) or a ketone moiety (**polyhydroxyketones**).

### Importance of Carbohydrates:

1. Glucose is a major fuel of the tissues of mammals and can be stored as glycogen for energy.
2. Ribose and deoxyribose is a component of RNA and DNA, respectively.
3. Galactose is the main component of milk.
4. Many diseases associated with defects in CHO metabolism e.g. {diabetes mellitus (DM), glycogen storage diseases}.
5. Polysaccharides are structural elements in the cell wall of bacteria, plants, and exoskeleton of arthropods.
6. CHO play a key role in cell-cell recognition process.

## Carbohydrate Classifications

1. **Monosaccharides**,
2. **Disaccharides**,
3. **Oligosaccharides** (from two to ten monosaccharide units, linked by glycosidic bonds),
4. **Polysaccharides** (hundreds of monosaccharide units).

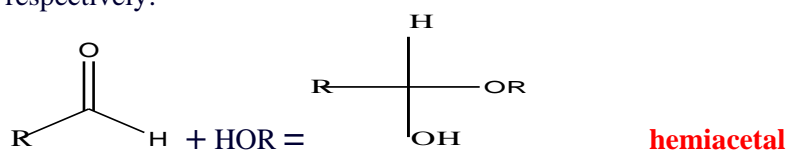
Carbohydrates can combine with lipid to form **glycolipids** or with protein to form **glycoproteins**.

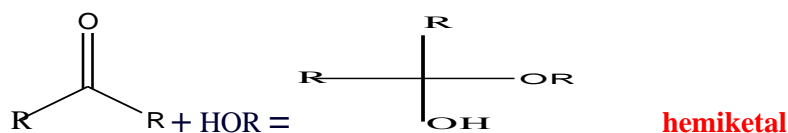
### I-Monosaccharides

The monosaccharides commonly found in humans are classified according to the number of carbons they contain in their backbone structures. The major monosaccharides contain four to six carbon atoms.

# Carbons	Category Name	Relevant examples
3	Triose	Glyceraldehyde, Dihydroxyacetone
4	Tetrose	Erythrose
5	Pentose	Ribose, Ribulose, Xylulose
6	Hexose	Glucose, Galactose, Mannose, Fructose
7	Heptose	Sedoheptulose
9	Nonose	Neuraminic acid also called sialic acid

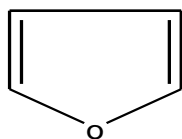
\*The aldehyde and ketone moieties of the carbohydrates with five and six carbons will spontaneously react with alcohol groups present in neighboring carbons to produce intramolecular **hemiacetals** or **hemiketals**, respectively:



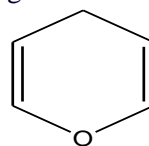


This results in the formation of five- or six-membered rings.

- **Furanoses:** Five-membered ring structure resembles the organic molecule **furan**
- **Pyranose:** Those with six-membered rings resemble the organic molecule **pyran**.



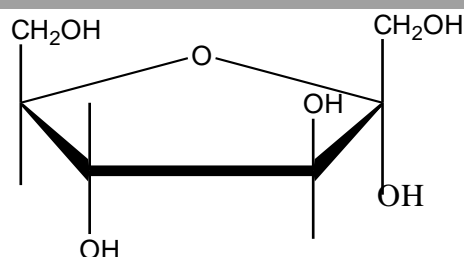
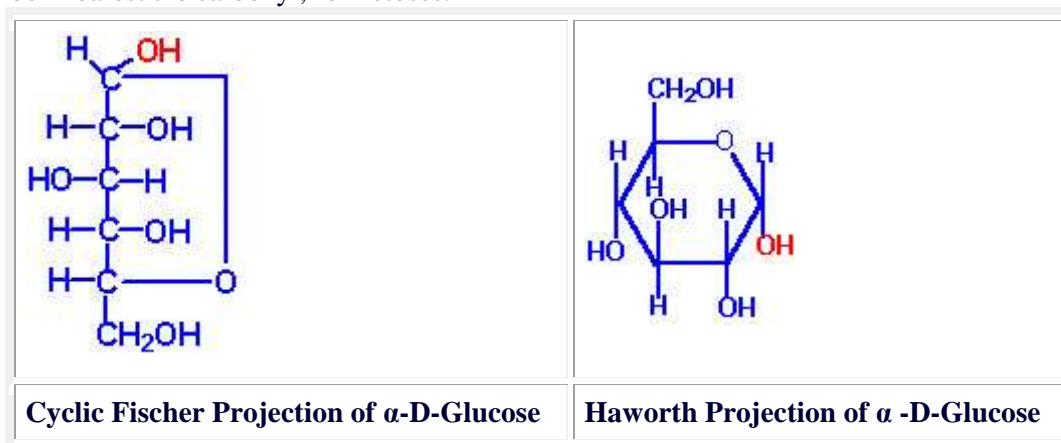
**Furan**



**Pyran**

\*Plotting methods: such structures can be depicted by either **Fischer** or **Haworth** style diagrams.

\*Numbering: the numbering of the carbons in carbohydrates proceeds from the carbonyl carbon, for aldoses, or the carbon nearest the carbonyl, for ketoses.



**$\alpha$ -D-Fructose**

**Stereoisomerism:** Compounds have the same structural formula but differ in spatial configuration.

$$\# \text{ Number of isomers} = 2^{\text{Number of asymmetric atoms}}$$

The rings can open and re-close, allowing rotation to occur about the carbon bearing the reactive carbonyl yielding two distinct configurations ( $\alpha$  and  $\beta$ ) of the hemiacetals and hemiketals.

**anomeric carbon:** the carbon about which this rotation occurs and forming the sugar types ( $\alpha$  and  $\beta$ ) and its carbon number (1) in glucose. The two forms are termed anomers.

**Mutarotation:** Carbohydrates can change spontaneously between the ( $\alpha$  and  $\beta$ ) configurations.

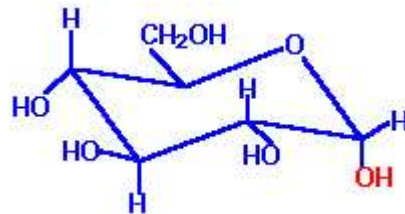
@When drawn in the Fischer projection, the  $\alpha$  configuration places the hydroxyl attached to the anomeric carbon to the right, towards the ring.

@When drawn in the Haworth projection, the  $\alpha$  configuration places the hydroxyl downward.

The spatial relationships of the atoms of the furanose and pyranose ring structures are more correctly described by the two conformations identified as the **chair form** and the **boat form**.

\* The chair form is the more stable of the two.

@In the chair conformation, the orientation of the hydroxyl group about the anomeric carbon of  $\alpha$ -D-glucose is axial and equatorial in  $\alpha$ -D-glucose.



Chair form of  $\alpha$ -D-Glucose

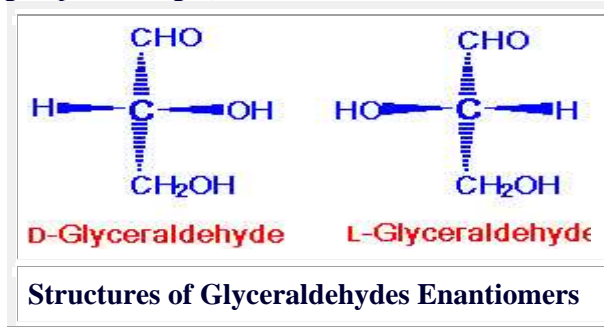
\* The simplest carbohydrates encountered in the body are **glyceraldehyde** (aldotriose) and to the **dihydroxyacetone** (ketotriose).

\* All carbohydrates contain at least one asymmetrical (**chiral**) **carbon** (carbon atom attached to four different groups) and are, therefore, optically active (can rotate the plane of the polarized light (to the right = dextro(+) and to the left (-).

\* **Racemic mixture:** When equal amounts of D and L isomers are present in solution cause elimination of optical activity.

\* **Enantiomers:** The mirror-image conformations of the same compound depending on the orientation of the hydroxyl group about the asymmetric carbon farthest from the carbonyl. (e.g. carbon atom number 5 in glucose). They are in the **L-conformation** (hydroxyl group to the left) and **D-conformation** (hydroxyl group to the right)

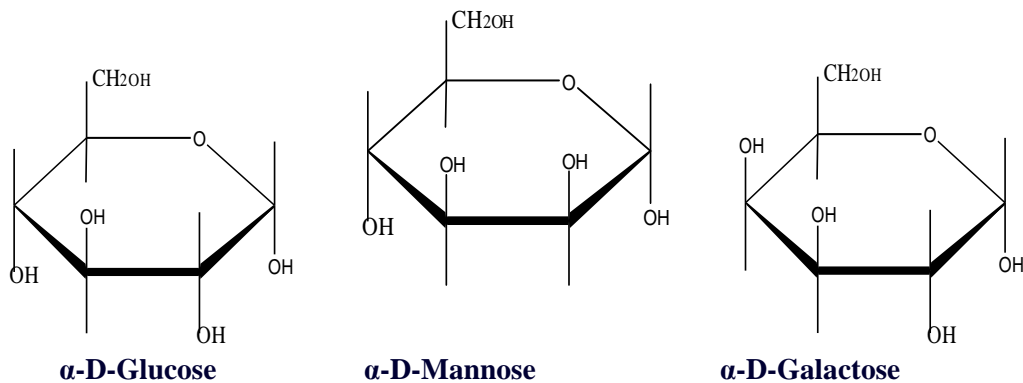
- With a few exceptions, those carbohydrates that are of physiological significance exist in the **D-conformation** (hydroxyl group to the right)



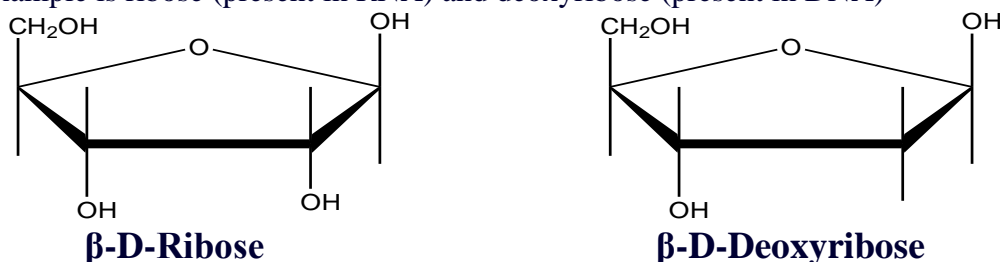
# **Diastereomers:** compound that have the same chemical formula but they are not mirror image for each other.

\* **Epimers:** Isomers differ in the orientation of -OH groups around carbon atoms number 2, 3, or 4. For examples (glucose, galactose are epimers)

\* **Epimerization:** Conversion of one sugar to another as a result of rotation of hydroxyl groups around carbon atoms number 2, 3, or 4.



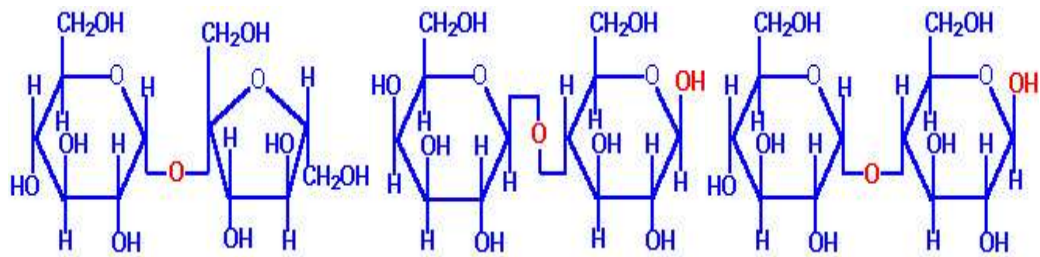
# **Deoxy sugars:** One of the hydroxyl groups of the sugars reduced (-OH into -H). The most important example is ribose (present in RNA) and deoxyribose (present in DNA)



## II-Disaccharides

Covalent bonds between the anomeric hydroxyl of a cyclic sugar and the hydroxyl of a second sugar (or another alcohol containing compound) are termed **glycosidic bonds**, and the resultant molecules are **glycosides**. The linkage of two monosaccharides to form disaccharides involves a glycosidic bond. Several physiologically important disaccharides are sucrose, lactose and maltose.

- **Sucrose**: prevalent in sugar cane and sugar beets, is composed of glucose and fructose through an  $\alpha$  (1,2) -glycosidic bond.
- **Lactose**: is found exclusively in the milk of mammals and consists of galactose and glucose in a  $\beta$ -(1,4) glycosidic bond.
- **Maltose**: the major degradation product of starch, is composed of 2 glucose monomers in an  $\alpha$ -(1,4) glycosidic bond.



Sucrose

Lactose

Maltose

# **Reducing sugar** : A molecule containing free carbonyl group that can reduce the indicators such as cupric ions reagent into cuprous ions. (Lactose and Mannose are reducing sugars while sucrose are not reducing sugar)

## III-Polysaccharides

Most of the carbohydrates found in nature occur in the form of high molecular weight polymers called **polysaccharides**.

The monomeric building blocks used to generate polysaccharides can be varied; in all cases, however, the predominant monosaccharide found in polysaccharides is D-glucose.

\* **homopolysaccharides**: polysaccharides are composed of a single monosaccharide building block, they are termed.

\* **heteropolysaccharides**: Polysaccharides composed of more than one type of monosaccharide are termed.

1. **Glycogen**:Glycogen is the major form of stored carbohydrate in animals. This crucial molecule is a homopolymer of glucose in  $\alpha$ -(1,4) linkage; it is also highly branched, with  $\beta$ -(1,6) branch linkages occurring every 8-10 residues. Glycogen is a very compact structure that results from the coiling of the polymer chains. This compactness allows large amounts of carbon energy to be stored in a small volume, with little effect on cellular osmolarity.
2. **Starch**:Starch is the major form of stored carbohydrate in plant cells. Its structure is identical to glycogen, except for a much lower degree of branching (about every 20-30 residues). Unbranched starch ( $\alpha$ -(1,4) linkage only) is called **amylose** (15-20%); branched starch ( $\alpha$ -(1,4) and  $\alpha$ -(1,6) linkages) is called **amylopectin**.
3. **Cellulose**: The main polysaccharide in plants. It is a homopolymer of glucose in  $\beta$ -glycosidic linkages.
4. **Inulin** :Present in Dahlias. Consists of fructose only.
5. **Chitin**: structural elements of invertebrates and in the exoskeleton of arthropods. It is poly(N-acetyl-D-glucosamine units) joined by  $\beta$ (1,4) linkages.
6. **Dextrin** : formed during the course of starch hydrolysis.
7. **Dextran**: A storage polysaccharide present in yeast and bacteria consists of glucoselinked by ( $\alpha$ -(1,6) linkages and for branches ( $\alpha$ -(1,2)  $\alpha$ -(1,3) and  $\alpha$ -(1,4).

**Glycosides**: Compounds consists from condensation between -OH group of anomeric carbon of a monosaccharide and a second compound called (aglycan e.g. glycerol, sterol, phenol ...etc.)

\*Examples of glycosides: digitoxin (cardiac glycoside with steroid aglycan)

\* If from condensation between -OH group of anomeric carbon of a monosaccharide and nitrogen atom of a second compound the linkage called (N-glycosidic linkage)

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