Lecture : 8 section 4 , 5 , 6

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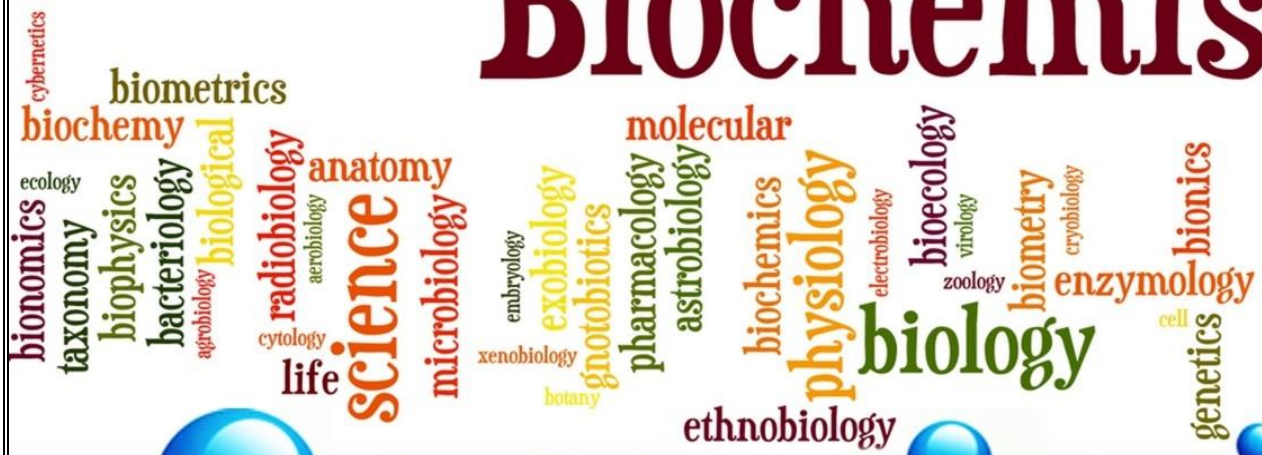
Medical Committee
The University of Jordan

# Biochemistry




Mousa Suboh

# Carbohydrates

There are **two topic goals** in our study of carbohydrates:

- **Monosaccharides**: to recognize their structure, properties, & their stereochemistry.
- The nature of **di-, oligo- & polysaccharides**.

## Lectures outline:

- 1. Monosaccharide structures
  - ✓ Aldoses and ketoses
  - ✓ Optical isomers
    - Fischer projections
    - Enantiomers, Diastereomers, & Epimers
  - ✓ Cyclic structures
    - Hemiacetals and hemiketals
    - Anomers & Haworth projections
    - Furanoses and pyranoses
- 2. Monosaccharide reactions
  - ✓ Oxidation-reductions, Esterification, glycosides, & Sugar derivatives
- 3. Oligosaccharides
  - ✓ Sucrose & Lactose
- 4. Polysaccharides
  - ✓ Cellulose & starch (Forms of starch: Amylose & Amylopectin)
  - ✓ Glycogen
  - ✓ Chitin
  - ✓ Cell walls
  - ✓ Glycosaminoglycans
- 5. Glycoproteins

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## Isomers

What does "**Isomers**" mean?
- Compounds that have the same atomic structure but they differ in the bond structure or the orientation of bonds in space.

Isomers are classified in two main forms:

- **Structural (constitutional) isomerism**; they differ in the attachments between the atoms.

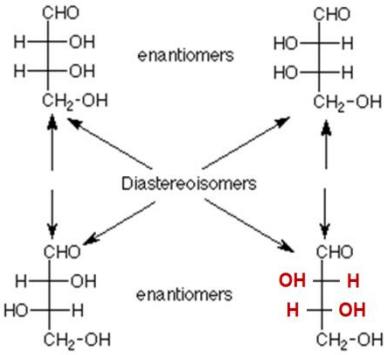
- **Stereoisomerism (spatial isomerism)**; they have the same bond structure but they differ in how the bonds are orientated in the space.

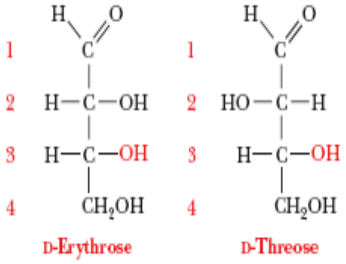
Do Isomers share **similar properties**?
- Isomers do **not** necessarily share similar properties; they do share some (like some physical properties or functional properties) but they differ in others. Being isomers they should have a **difference**; don't expect to have isomers with typical features.

**Stereoisomers** are classified into different groups:

- **Enantiomers**; non-superimposable mirror-images.

- **Diastereomers**; they are stereoisomers but they are **NOT** mirror images of each other.




- **Epimers**; they are **diastereomers** that differ at **one** chiral center.

Ex: D-Erythrose and D-Threose differ in the spatial arrangement around the second carbon.

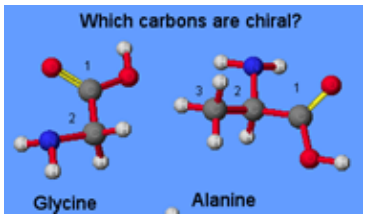
**Chirality**:

- **Chiral** carbon is a carbon with four different groups attached to it.

* The **chiral** carbon in a molecule is called "stereocenter"; around it the molecule can have different isomers.

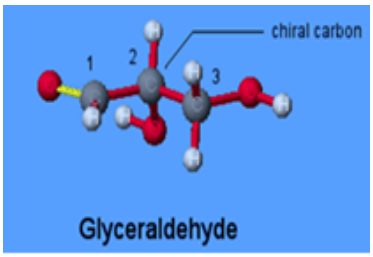
- **Achiral** carbon is **not** a chiral carbon; it has at least two similar groups attached to it.

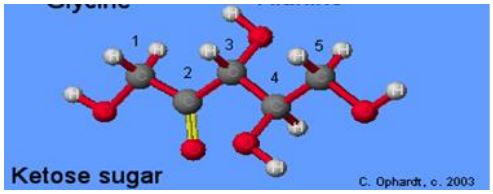
*The possible number of stereoisomers that we can have is $2^n$ (where n is the number of chiral carbons).




- Glycine: one stereoisomer; no chiral centers.

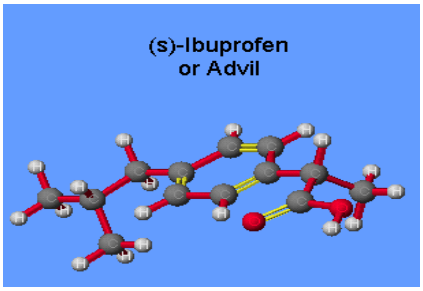
- Alanine: two stereoisomers.




- Four isomers; two chiral centers

- Glyceraldehyde: two isomers; one chiral center.




- Two isomers;

One chiral center

**<u>Biomacromolecules:</u>**

- **Subunits**: the small building blocks (precursors) used to make macromolecules.

- Macromolecules: large molecules made of subunits.

There are four different major groups for macromolecules:

- ✓ **Carbohydrates (Monosaccharides)**.
- ✓ **Proteins (amino acids).**
- ✓ **Nucleic acids (nucleotides)**.
- ✓ **Lipids (fatty acids)**.

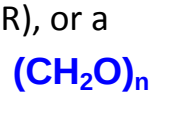
*<u>Except</u> for <u>lipids (Lipids are not polymers)</u>, these macromolecules are also considered **polymers**.

Polymerization happens by **condensation reaction** (removing of water from the two monomers by removing "H" from one side & "OH" from the other side, or by removing "$H_2$" from one side & "O" from the other side).

*__Condensation__ is done by **removing** water,
**Hydrolysis (breaking down molecules)** is done by **adding** water,
Enzymes that add water and break their substrates are called **hydrolases**,

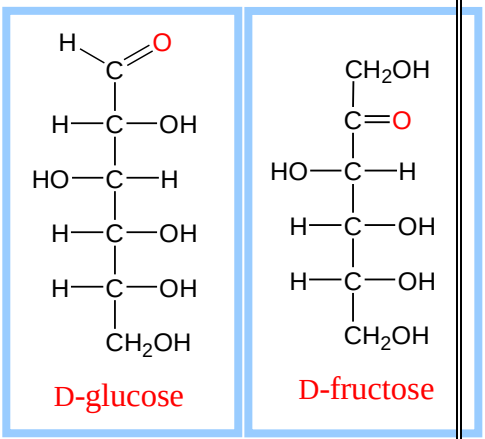
* You can add water without breaking the substrates. However, you won't name this reaction a hydrolysis reaction, it is a **hydration** reaction and the enzymes that catalyze this reaction are called **lyases**.

## Carbohydrates "Saccharides":

- **Carbohydrates**: glycans that have the following basic formula (n varies from 3-8).
- It is a **polyhydroxy** (**aldehyde** -CHO) or (**ketone** -C(=O)R), or a substance that gives these compounds on hydrolysis. $(CH_2O)_n$ or 

**Aldose**: a monosaccharide containing an **aldehyde** group (glyceraldehyde is the simplest), ex: Glucose.

**Ketose**: a monosaccharide containing a **ketone** group(dihydroxyacetone is the simplest), ex: Fructose.




**Carbohydrates - Functions**:

**1- Source of energy**: Energy is stored as bonds.
**2- Structural function**: polysaccharides such as cellulose, in bacterial cell walls and is the principle component of wood, and our body can't

benefit from cellulose because we don't have enzymes to digest it, how can we know that cellulose has energy? By burning it, it releases heat.

**3- cell–cell interactions & immune recognition, activation of growth factors.**

**4- Intermediates in biosynthesis** of other basic biochemical structures (fats and proteins); after the breaking down of carbohydrates, their content can go and enter the synthesis pathway of other biochemical structures.

There are many amino acids, but there are 20 amino acids the make up proteins and 11 of these 20 amino acids are glucose-related.

* Breaking down of amino acids can also give rise to carbohydrates.

**5- Associated with other structures** (vitamins & antibiotics).

- **Monosaccharide**: a carbohydrate that cannot be hydrolyzed to a simpler one.

- **Disaccharides** – carbohydrates that can be hydrolyzed into two monosaccharide units (sucrose → glucose + fructose).

- **Oligosaccharides** – carbohydrates that can be hydrolyzed into a few monosaccharide (fructo-oligosaccharides (FOS), found in many vegetables).

Some of them consist of more than one type of subunits and some of them consist of one repeated monosaccharide such as galacto-oligosaccharide and fructo-oligosaccharides.

- **Polysaccharides** – carbohydrates that are polymeric sugars (starch or cellulose).

When you look at carbohydrates, you rarely find it alone by itself. Mostly you will find them attached to other structures to form:

- **Polysaccharides** (starch, cellulose, inulin, gums)

- **Glycoproteins** and **proteoglycans** (hormones, blood group substances, antibodies), carbohydrates attach to proteins at specific sites (N-glycosites & O-glycosites).

-**Glycolipids** (cerebrosides, gangliosides; in nervous tissue)

- **Glycosides** (carbohydrates attached to other molecules – to a phosphate or two Monosaccharides together with a glycosidic linkage)

- **Mucopolysaccharides** (hyaluronic acid)

- **Attached to Nucleic acids (DNA, RNA)**

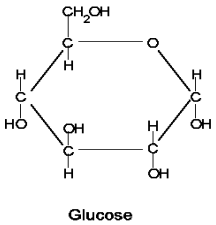
**Carbohydrates - Classification**

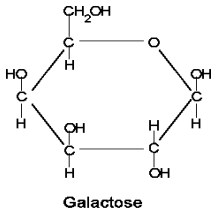
Classification is based on the differences between the groups such as:
- Number of carbons (for monosacharides).
- Aldehyde and Ketones (for monosacharides).
- Number of monosacharides after hydrolysis (classified simple for mono- and di- and complex for oligo- and polysaccharides).

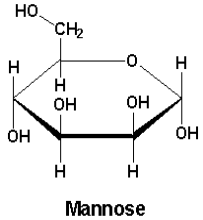
**Common Monosaccharides**

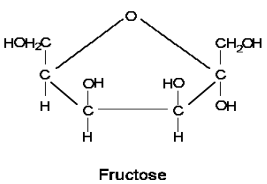
Glucose, fructose, galactose, and mannose: All are 6 carbon hexoses:

6 Cs, 12 Hs, 6 Os



Arrangement of groups & atoms differs: varying sweetness

**Glucose:**

- Mild sweet flavor.

- Known as blood sugar.

- Essential energy source (is the major sugar in the carbohydrates metabolism in the body, other carbohydrates such as galactose are compared to glucose and its pathways)

- Found in every disaccharide & polysaccharide (not always in oligosaccharides)

**Fructose:**

- Sweetest sugar, found in fruits & honey

- Added to soft drinks, cereals, deserts

- Galactose:

- Hardly tastes sweet & rarely found naturally as a single sugar