Carbohydrates of biological importance

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What does biochemistry deal with?

- Metabolism:
  - Anabolism
  - Catabolism

- Foods:
  - Oxidizable: carbohydrates, lipids, proteins
  - Non-oxidizable: minerals, vitamins, water

Syllabus

- 6.1 Define carbohydrates and list their classification.

- 6.2 Recognize the structure and functions of monosaccharides.

- Carbohydrates are organic compounds composed of carbon, hydrogen, and oxygen.

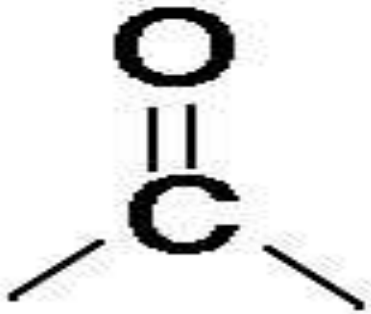
- Carbo=carbon, hydrates=hydrogen and oxygen in their proportion in water H2O

- They generally have the common formula **(CH2O)n** where the least number of n=3

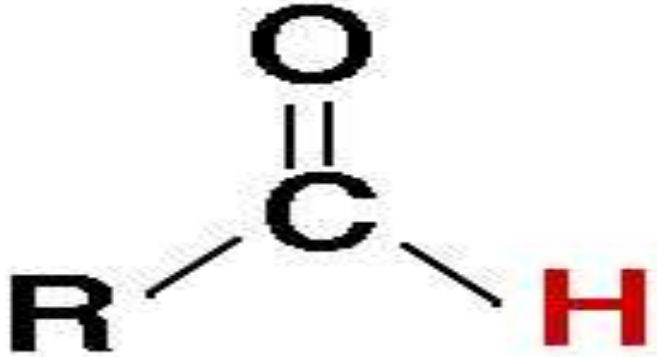
Definition of carbohydrates

- Simple sugars or its derivatives

- Simple sugars are considered as **polyhdroxyketones** or **polyhydroxyaldehydes**

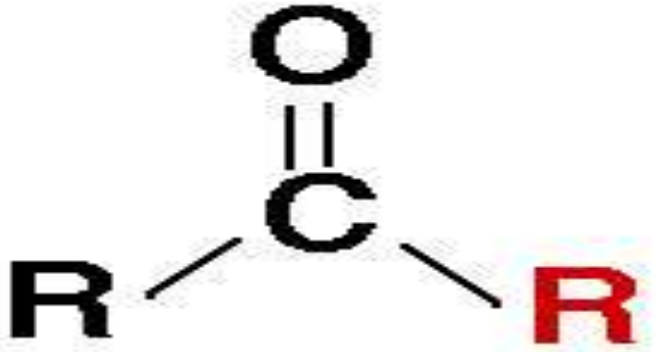


Carbonyl group



Aldehyde

Makes Aldose (aldo sugar)



Ketone

Makes Ketose (keto sugar)

- **Ketones and aldehydes are simple compounds that contain a carbonyl group (a carbon-oxygen double bond).**

- ***where R can be a carbon-containing substituent.***

Classification of Carbohydrates (according to hydrolysis):

- **Monosaccharides**: contain one sugar unit
  - E.g. glucose.
- **Disaccharides:** contain two sugar units
  - Maltose.
- **Oligosaccharides**: contain 3-10 sugar units
  - E.g. Raffinose
- **Polysaccharides**: contain more than 10 sugar units
  - Starch or glycogen.

I. Monosaccharides

- **Definition:** They are simple sugars that cannot be hydrolyzed into smaller one.
- **Classification of monosaccharides:**

I. According to the number of carbon atoms: e.g.

1) Trioses: contain three carbon atoms.

2) Tetroses: contain four carbon atoms.

3) Pentoses:contain five carbon atoms.

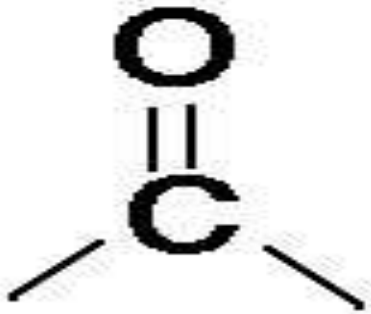
4) Hexoses: contain six carbon atoms.

Classification of monosaccharides:

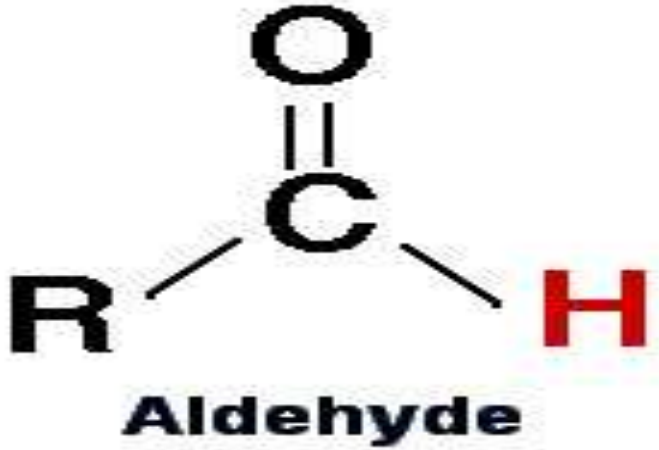
Classification of monosaccharides:

II. According to function group:

- **Aldose**
- **Ketose**

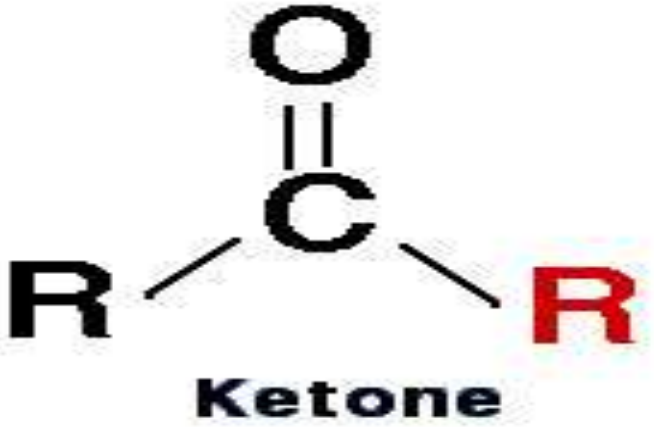


Carbonyl group



Aldehyde

Aldose (aldo sugar)



Ketone

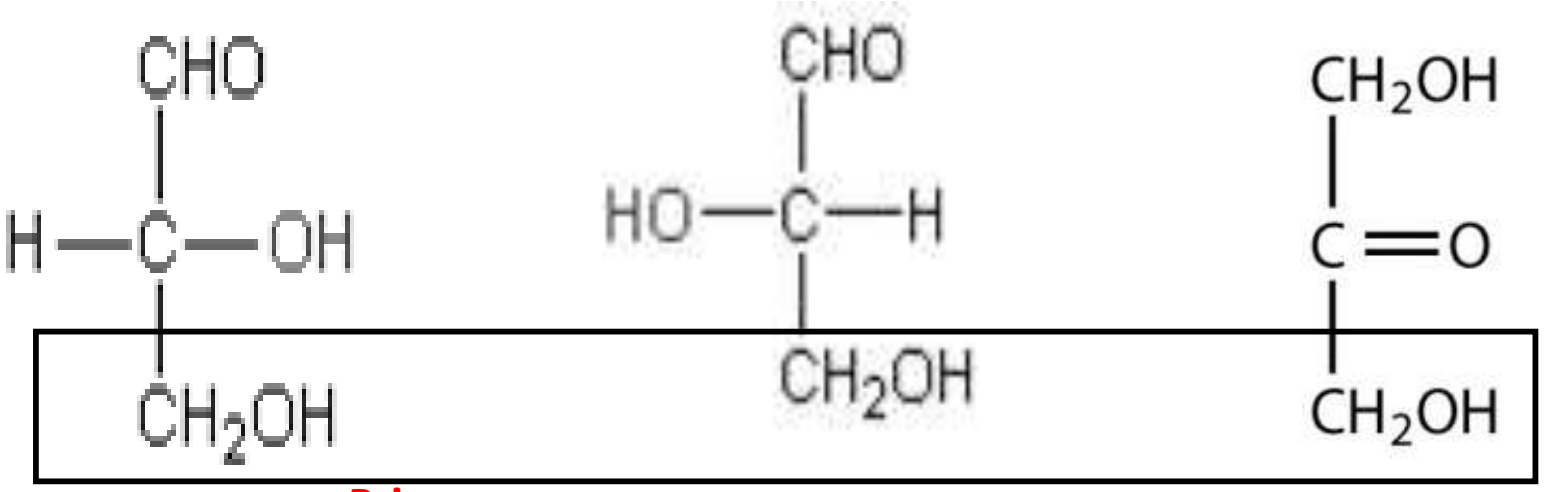
Ketose (keto sugar)

- **Ketones and aldehydes are simple compounds that contain a carbonyl group (a carbon-oxygen double bond).**

- ***where R can be a carbon-containing substituent.***

Number of carbons	Aldo-sugars (e.g.)	Keto-sugars (e.g.)
3C (triose)	Glyceraldehyde	Dihydroxy acetone
4C (tetraose)	Erythrose	Erythrulose
5C (pentose)	Ribose Aldopentose	Ribulose
6C (hexose)	Glucose	Fructose

- Glyceraldehyde and dihydroxyacetone.(They are intermediates in the break down of glucose).



Primary group

D- Glyceraldehyde

Dihydroxyaldose

L- Glyceraldehyde

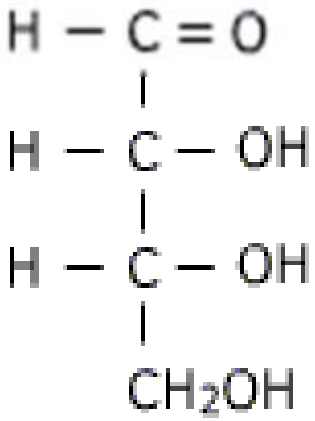
Dihydroxyacetone

Dihydroxyketose

D & L denote the absolute configuration. i.e. D means that OH group on the subterminal carbon atom is at the right but L means OH group on the subterminal carbon atom is at the left.

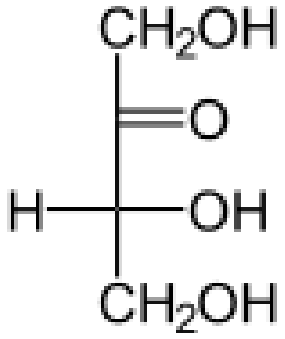
- **Examples of Tetroses are:**
- Aldotetrose: Erythrose
- Ketotetrose: Erythulose

Erythrose was first isolated in 1849 from rhubarb



D-Erythrose

Erythrulose/DHA reacts with the amino acids in the proteins of the first layers of skin (the stratum corneum and epidermis)



D-Erythrulose

D-Erythrulose

- **Most physiologically important isomers that can be utilized in the body are the D form**

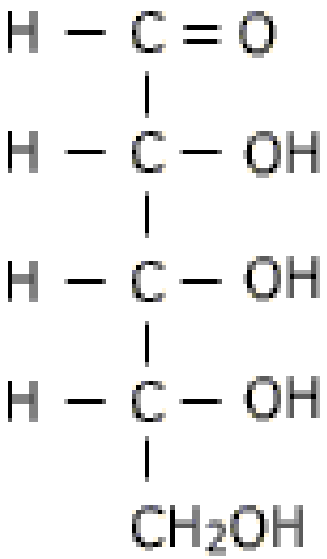
- Some sugars occur naturally in their L-forms:

- L-arabinose and L-fucose ($C_6H_{12}O_5$) which are components of glycoprotein

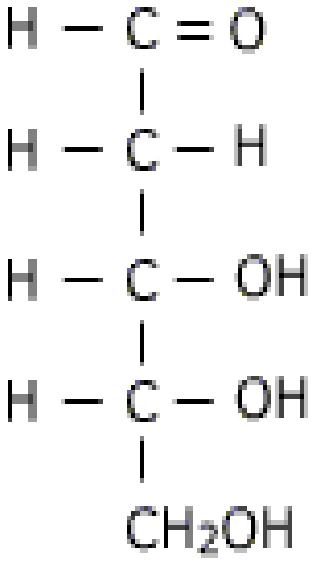
- L-xylulose (pentose) is an intermediate in metabolism and can be utilized by isomerization into D-form

- L- arabinose is an aldopentose present in some fruits such as cherries, grapes, plums, and prunes. Ingestion of large quantaties of these fruits leads to the appearance of L-arabinose in the urine, a condition called **alimentary pentosuria**.

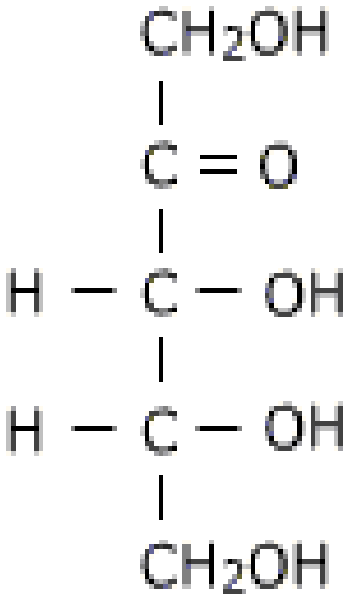
- **Examples of pentoses are:**
- aldopentoses: ribose and deoxyribose, ketopentose: ribulose



D-Ribose



D- deoxyribose

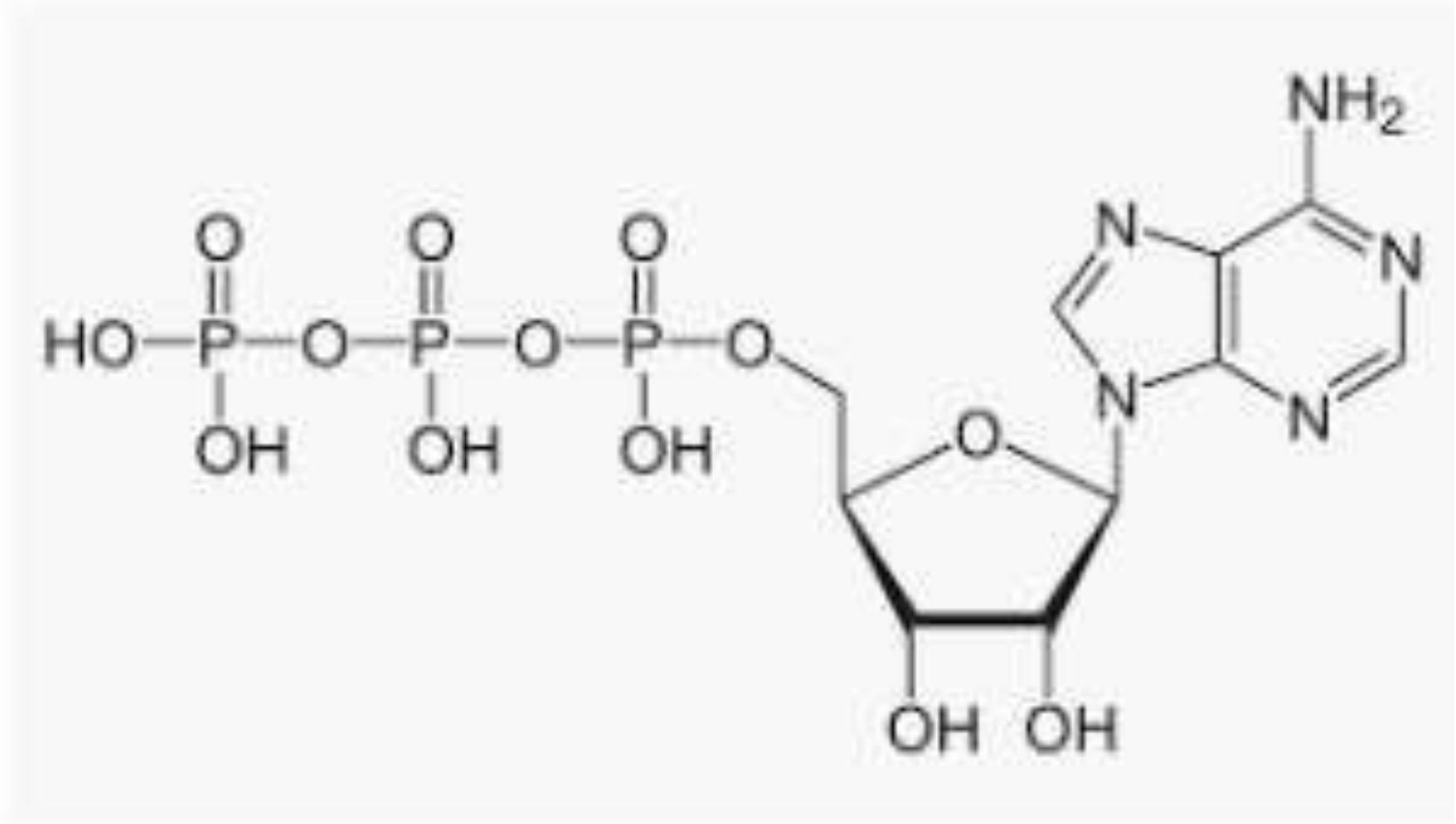


D-Ribulose

Functions of pentoses:

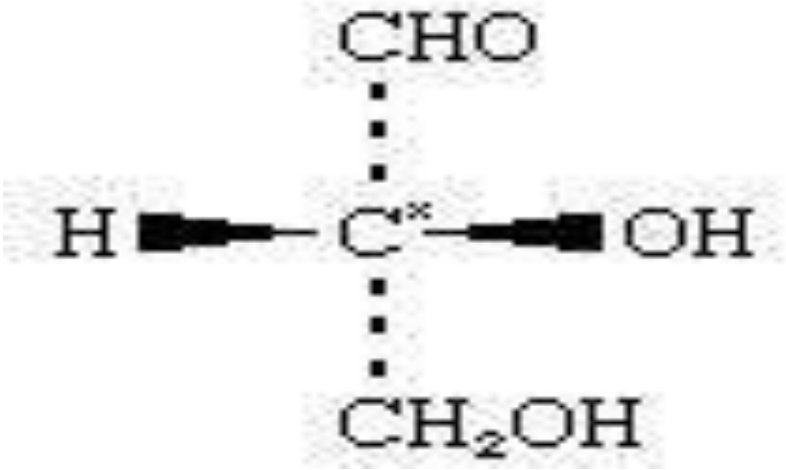
- Ribose and deoxyribose enter in the structure of nucleic acids RNA and DNA.
- Ribose enters in the structure of ATP, GTP and other high energy phosphate compounds.
- Ribose enters in the structure of coenzymes NAD,NADP and flavoproteins.
- Ribose phosphate and ribulose phosphate are intermediates in pentose phosphate pathway (a minor pathway for glucose oxidation).
- They are components of some vitamins (ribitol in vitamin **B2)**

ATP

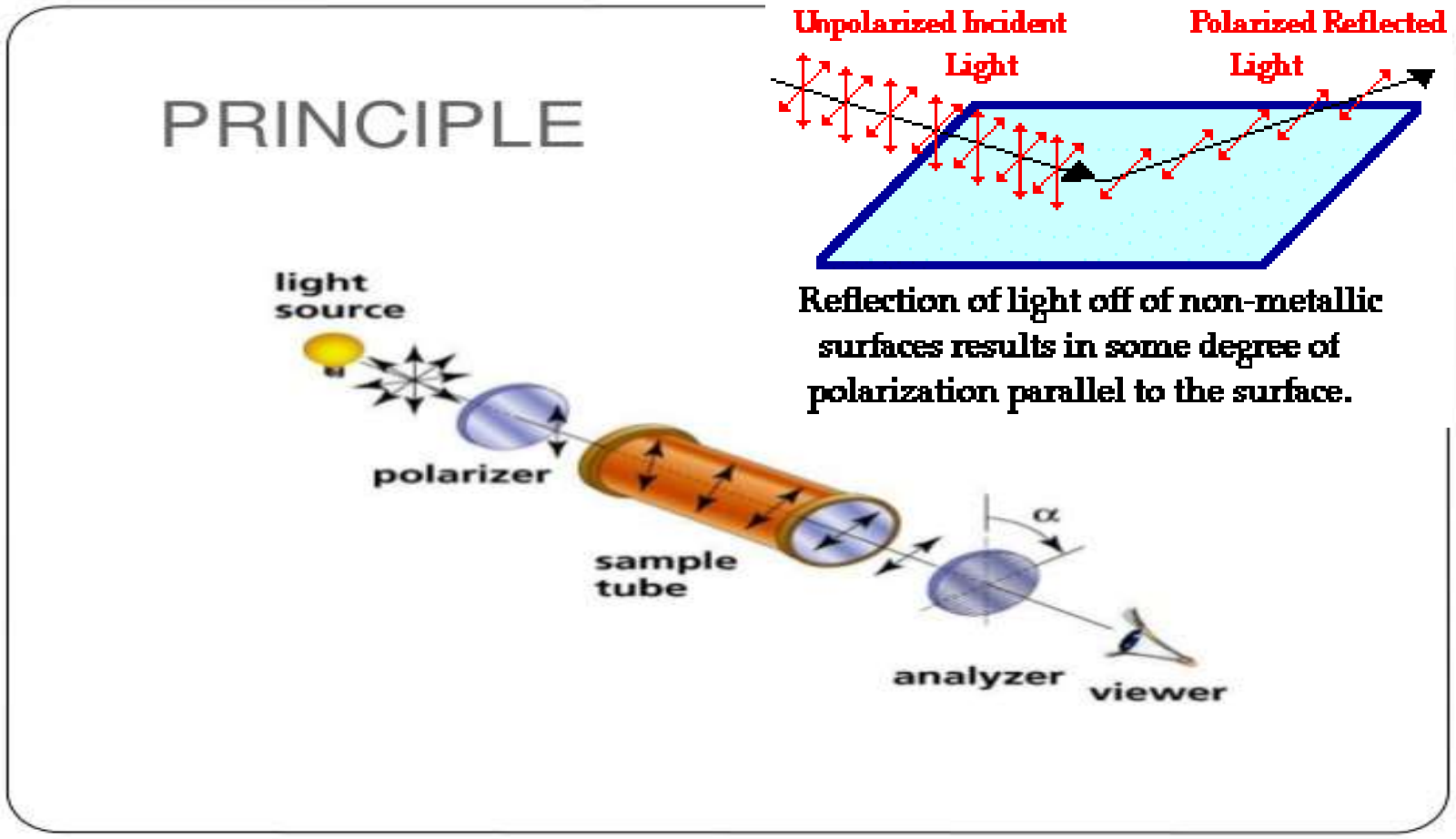


Asymmetric carbon atom:

- It is the carbon atom to which four different groups or atoms are attached. Any substance containing asymmetric carbon atom has optical activity & optical isomerism



- A **polarimeter** is a scientific instrument used to measure the angle of rotation caused by passing polarized light through an optically active substance.

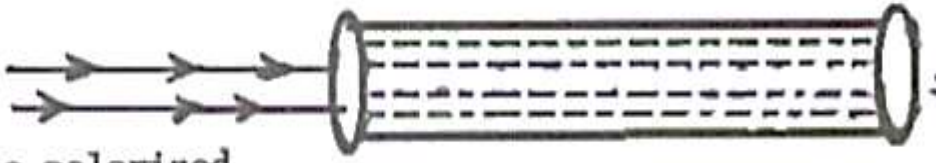


Optical activity

- It is the ability of substance to rotate plane polarized light (P.P.L) either to the right or to the left.
- If the substance rotates plane polarized light (light vibrate in one direction) to the right it is called: **dextrorotatory** or d or **(+)**.
- If it rotates plane polarized light to the left it is called **levorotatory** or **l** or **(-)**.
- Glucose contains 4 asymmetric carbon atoms. It is dextrorotatory so it is named **dextrose**. Fructose contains 3 asymmetric carbon atoms. It is levorotatory so it is called **levulose**.

Ordinary light
(i.e. light vibrates in all directions)

Plane polarized light
(i.e. light vibrates in one direction)



Plane polarized light

Solution of optically active substance

Right
Dextrorotatory
(d or +)

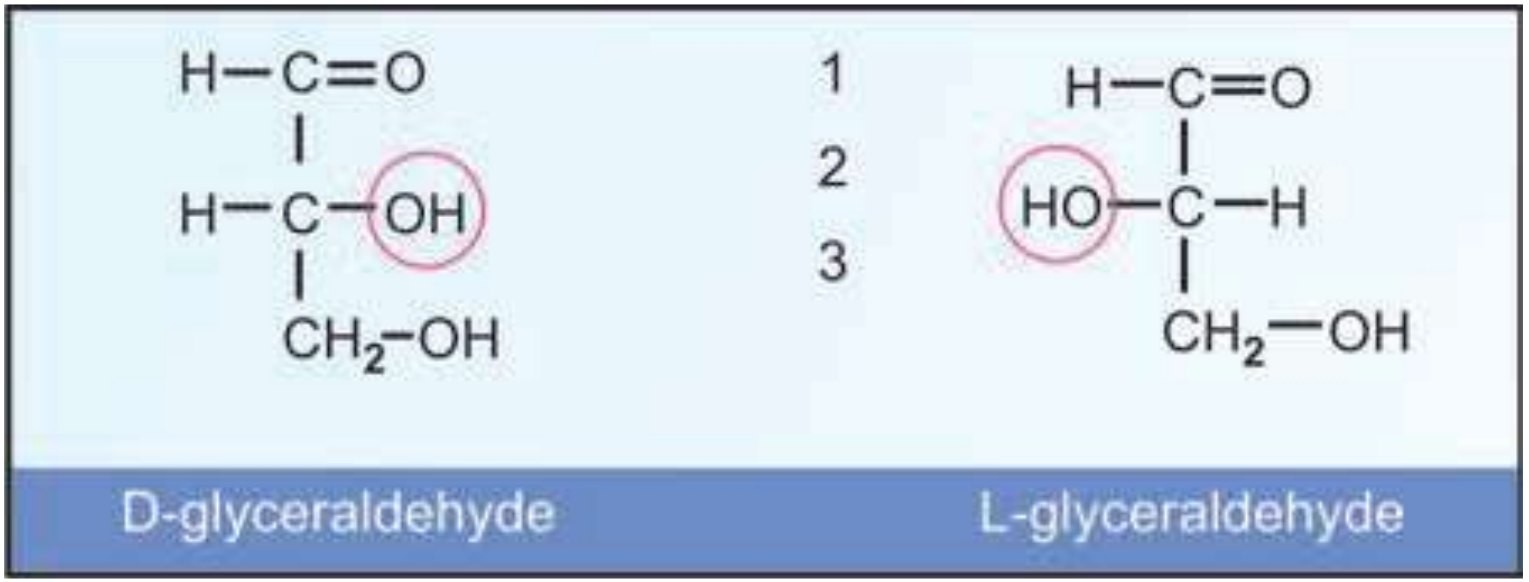
Left
Levorotatory
(l or -)

- The optical rotation is proportional to the concentration of the optically active substances in solution. Polarimetry may therefore be applied for concentration measurements
- Concentration and purity measurements are especially important to determine product or ingredient quality in the food & beverage and pharmaceutical industries.

Steroisomerism

- It is the ability of substance to present in more than one form (isomer).
- A substance containing one asymmetric carbon atom has 2 isomers.
- A substance containing 2 or more asymmetric carbon atoms can exist in a number of isomers = 2^n where n is the number of asymmetric carbon atoms. e.g. glucose has 4 asymmetric carbon atoms so the number of its isomers equal 2^4= 16 isomers.

Isomers



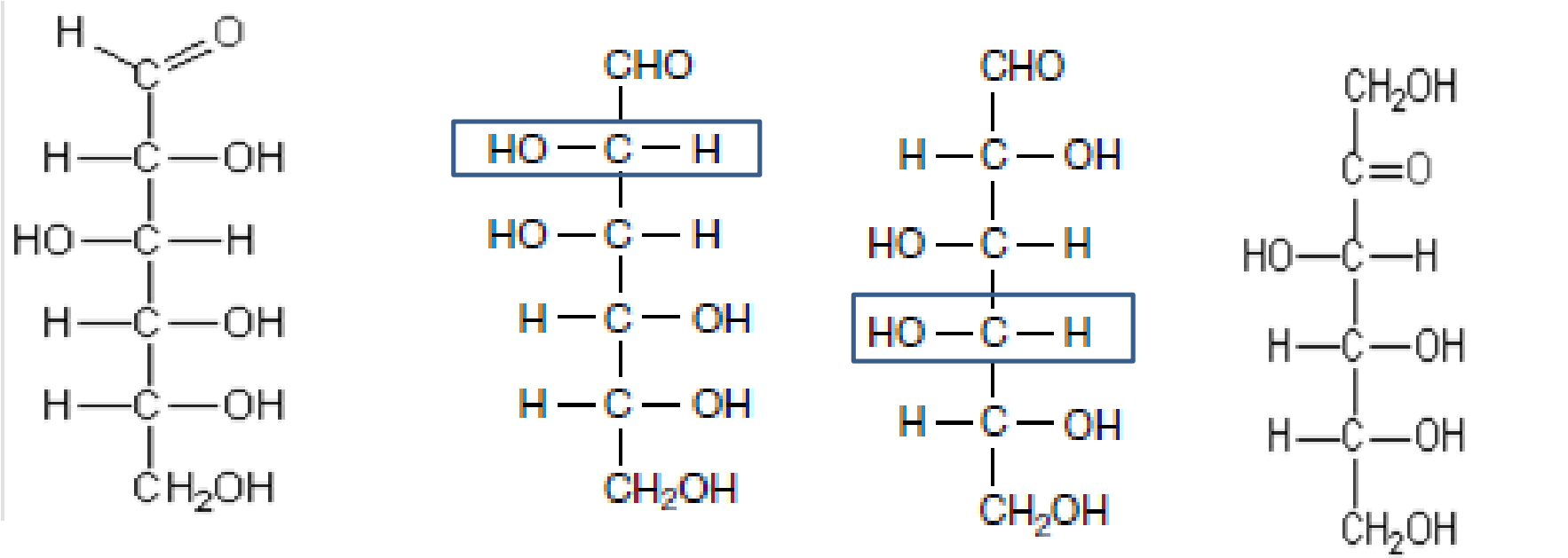
Compounds having same structural formula, but differing in spatial configuration are known as stereoisomers

Epimeric carbon &epimers:

- **Epimers:** These are sugars which differ only in the configuration around a single carbon atom. e.g. Glucose & mannose with respect to C_2. Also, glucose & galactose with respect to C_4.
- The contain more than one asymmetric carbon atom, all of which identical but only one is different.
- **Epimeric carbon:** e.g. carbon number 2 in glucose & mannose & carbon number 4 in glucose and galactose.

Examples of hexoses are:

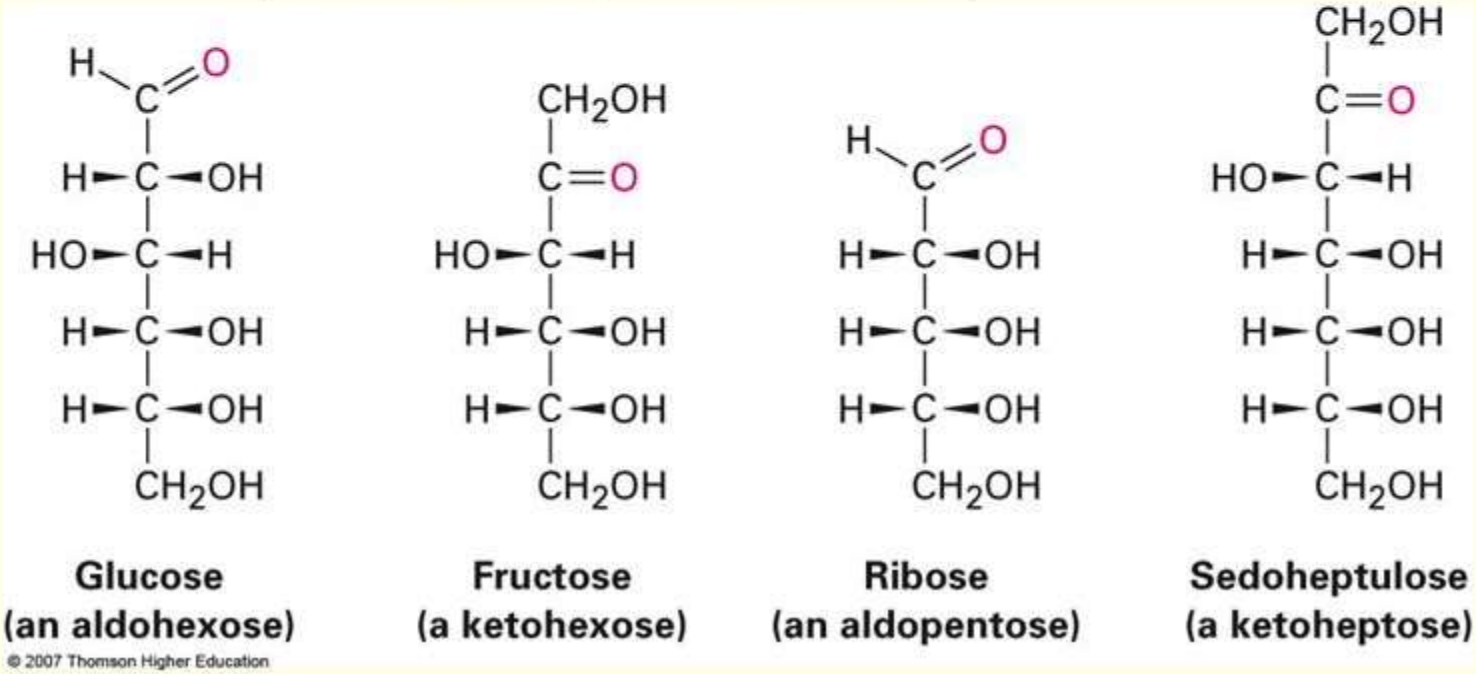
- aldohexoses: glucose, mannose and galactose,
- ketohexoses: fructose



Galactose and mannose are not epimers but diastereo-isomers.

Aldoses and Ketoses

- *aldo-* and *keto-* prefixes identify the nature of the carbonyl group
- *-ose* suffix designates a carbohydrate
- Number of C's in the monosaccharide indicated by root (-tri-, tetra-, penta-, hexa-)



- **Importance of hexoses:**

D-glucose "grape sugar":

- It is called dextrose (dextro-rotatory).
- It is the most important sugar of carbohydrates.
- It is the main sugar in blood, ranging from 70-110 mg/dl.
- It is one of major sources of energy in the body.
- It is the principle sugar used by the tissues.
- It is widely present in fruits & vegetables associated with fructose.
- It enters in the formation of disaccharides & polysaccharides.
- In the liver & other tissues, it is converted to all carbohydrates in the body e.g. glycogen, galactose, ribose &fructose.

D-fructose "fruit sugar":

- It is called Levulose (levo-rotatory).
- It is the main sugar of semen (Source of energy for the sperms).
- It is sweeter than glucose.
- It is present in honey & fruits.
- It enters in the formation of sucrose.
- In the liver, it is converted into glucose.

D-galactose"milk sugar":

- It is synthesized in mammary gland to make the lactose of milk.
- In the liver, it can be converted into glucose.
- It enters in the structure of **glycolipids** which are found in many tissues especially in C.N.S.

D- mannose:

- It is a constituent of many glycoproteins.