BIOCHEMISTRY 1

2ND CLASS

UNIVERSITY OF ANBAR

COLLOGE OF SCIENCE

BIOLOGY DEPARTMENT

2020-2021

Carbohydrates

Lecture one(1)

Hameed Hussein Ali

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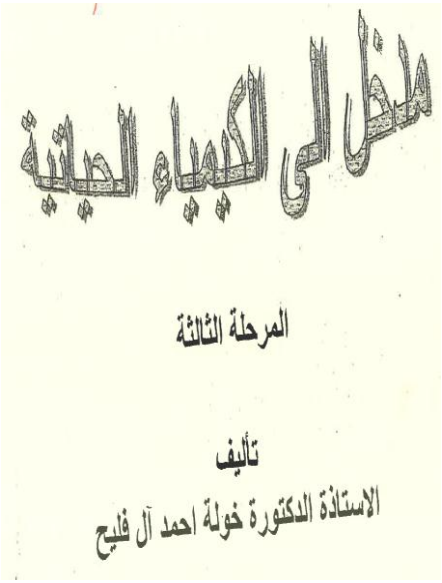
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وزارة التعليم العالي والبحث العلمي
جامعة الموصل
الكيمياء الحياتية
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Textbook of Medical Biochemistry

Eighth Edition

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Harper's Illustrated Biochemistry

Twenty-Eighth Edition

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References:

Harper's Illustrated Biochemistry

Lippincott Biochemistry

Lehninger Principles of Biochemistry

Stryer Biochemistry

SYLABUSE

1- Carbohydrates
2- Amino Acids, Peptides and Proteins.
3- Lipids.
4- Enzymes.
5- Vitamins and Coenzymes.
6- Nucleotides and Nucleic acids.
7- Biological Oxidation.

Carbohydrates

Major Concepts

A. What are carbohydrates? Their general properties and biomedical importance.
B. List the monosaccharides of biological importance and learn their properties.
C. List the disaccharides of biological importance and learn their properties.
D. Study the chemistry and properties of various polysaccharides.

Learning outcomes

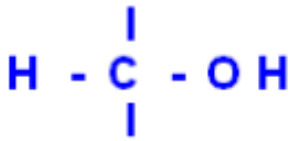
- To know the formation of carbohydrates
- To understand the nature of glycosidic bonds
- To understand the structural organisation of carbohydrates
- To appreciate the various functions of carbohydrates

Definition

- Carbohydrates are essentially hydrates of carbon (i.e. they are composed of carbon and water and have a composition of $(CH_2O)_{n.}$

- Carbohydrate - polyhydroxy aldehyde, ketones and their derivatives.

Carbohydrates have the following basic composition:

$(CH_2O)_n$ or 

Functions of CHO

- Carbohydrates spare protein so that protein can concentrate on building, repairing, and maintaining body tissues instead of being used up as an energy source.

- For fat to be metabolized properly, carbohydrates must be present. If there are not enough carbohydrates, then large amounts of fat are used for energy.

- Carbohydrate is necessary for the regulation of nerve tissue and is the ONLY source of energy for the brain.

- Certain types of carbohydrates encourage the growth of healthy bacteria in the intestines for digestion.

- Some carbohydrates are high in fiber , which helps prevent constipation and lowers the risk for certain diseases such as cancer, heart disease and diabetes.

Importance of carbohydrates

- Carbohydrates serve as energy store and metabolic intermediates.
- Ribose and deoxyribose sugars form part of the structural framework of RNA and DNA.
- Carbohydrates are important for tissue formation
- Carbohydrates form the basis of human blood groups
- Polysaccharides are structural elements in the cell walls of bacteria and plants and in the connective tissues of animals..
- Carbohydrates are linked to many proteins and lipids, where they play key roles in mediating interactions among cells and interactions between cells and other elements in the cellular environment.

Several classifications of carbohydrates

Basics	Types
Complexity	***Simple Carbohydrates***: *monosaccharaides* ***Complex Carbohydrates***: *disaccharides, oligosaccharides & polysaccharides.*
Size	***Tetrose***: C_4 *sugars,* ***Pentose***: C_5 *sugars* ***Hexose***: C_6 *sugars* ***Heptose:*** C_7 *sugars, Etc.*
C=O Function	***Aldose***: *sugars having an aldehyde function or an acetal equivalent.* ***Ketose:*** *sugars having a ketone function or an aketal equivalent.*
Reactivity	***Reducing:*** *sugars oxidized by Tollens' reagent (or Benedict's or Fehling's reagents).* ***Non-reducing***: *sugars not oxidized by Tollens' or other reagents.*

Classification

- The carbohydrates are divided into three major classes depending upon whether or not they undergo hydrolysis, and if they do, on the number of products formed.

- Monosaccharides: The monosaccharides are polyhydroxy aldehydes or polyhydroxy ketones which cannot be decomposed by hydrolysis to give simpler carbohydrates. Examples are glucose and fructose, both of which have molecular formula, $C_6H_{12}O_6$.

Classification

- **Oligosaccharides:** The oligosaccharides (Greek, oligo, few) are carbohydrates which yield a definite number (2-9) of monosaccharide molecules on hydrolysis.

  They include,

  (a) Disaccharides, which yield two monosaccharide molecules on hydrolysis. Examples are sucrose and maltose, both of which have molecular formula, $C_{12}H_{22}O_{11}$.

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+} 2\underset{\text{glucose}}{C_6H_{12}O_6}$$

Classification

- (b) Trisaccharides, which yield three monosaccharide molecules on hydrolysis. Example raffinose, which has molecular formula, $C_{18}H_{32}O_{16}$.

Classification

- Polysaccharides: The polysaccahrides are carbohydrates of high molecular weight which yield many monosaccharide molecules on hydrolysis. Examples are starch and cellulose, both of which have molecular formula, $(C_6H_{10}O_5)_n$.

$$\underset{\text{starch}}{(C_6H_{10}O_5)_n} + nH_2O \xrightarrow{H^+} \underset{\text{glucose}}{nC_6H_{12}O_6}$$

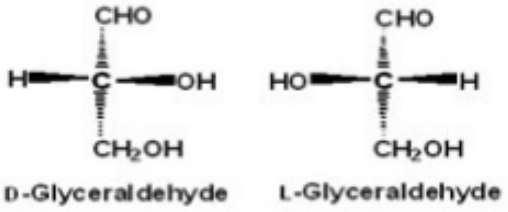
Monosaccharide

- Monosaccharides are classified according to three different characteristics:
  - the placement of its carbonyl group
  - the number of carbon atoms it contains
  - its chiral handedness.

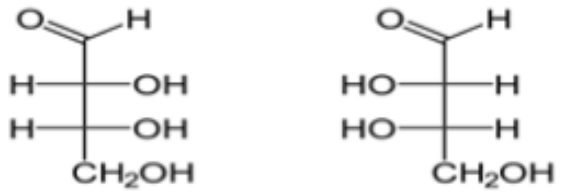
- If the carbonyl group is an aldehyde, the monosaccharide is an aldose; if the carbonyl group is a ketone, the monosaccharide is a ketose.

- Monosaccharides with three carbon atoms are called trioses, those with four are called tetroses, five are called pentoses, six are hexoses, and so on.

- Triose- Glyceraldehydes

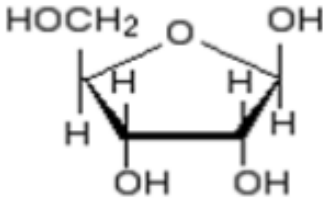


- tetrose- Erythrose



- pentose- Ribose

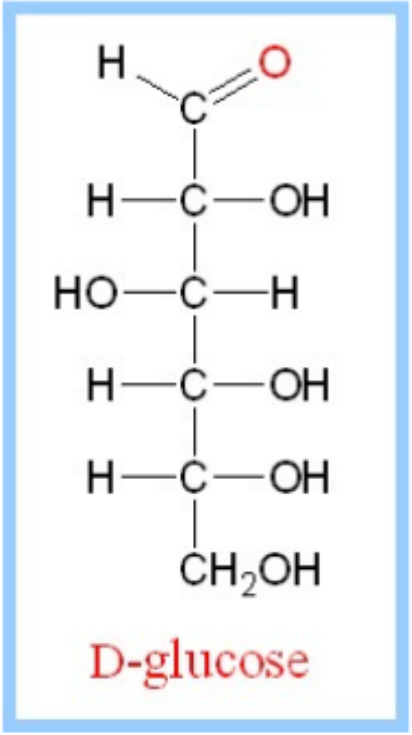
RIBOSE



- Hexose- Glucose, Fructose

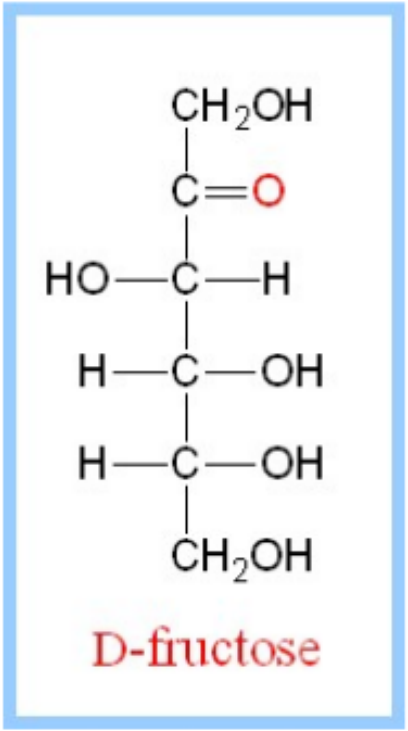
Monosaccharides

Aldoses (e.g., glucose) have an aldehyde group at one end.



D-glucose

Ketoses (e.g., fructose) have a keto group, usually at C2.

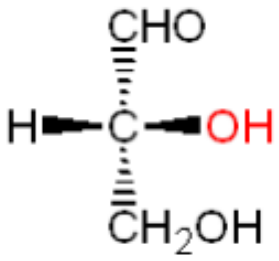


D-fructose

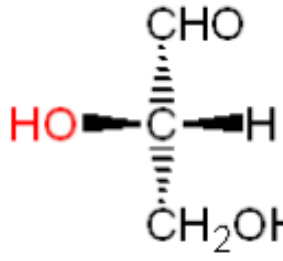
D vs L Designation

D & L designations are based on the configuration about the single asymmetric C in glyceraldehyde.

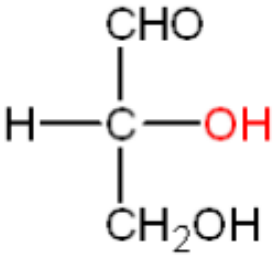
The lower representations are Fischer Projections.



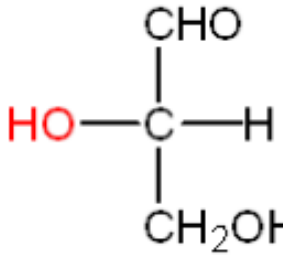
D-glyceraldehyde



L-glyceraldehyde



D-glyceraldehyde

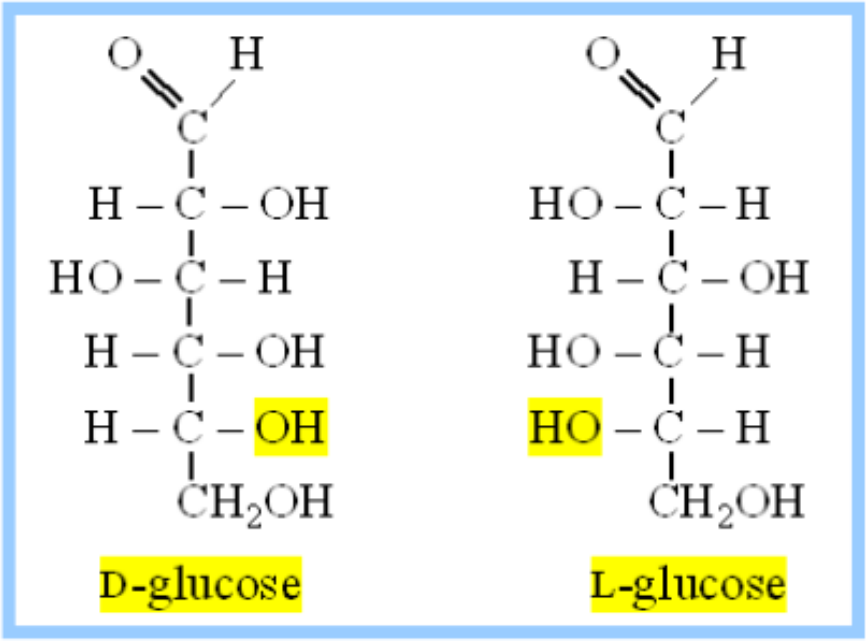


L-glyceraldehyde

Fischer Projections

For sugars with more than one chiral center, **D** or **L** refers to the asymmetric **C** farthest from the aldehyde or keto group.

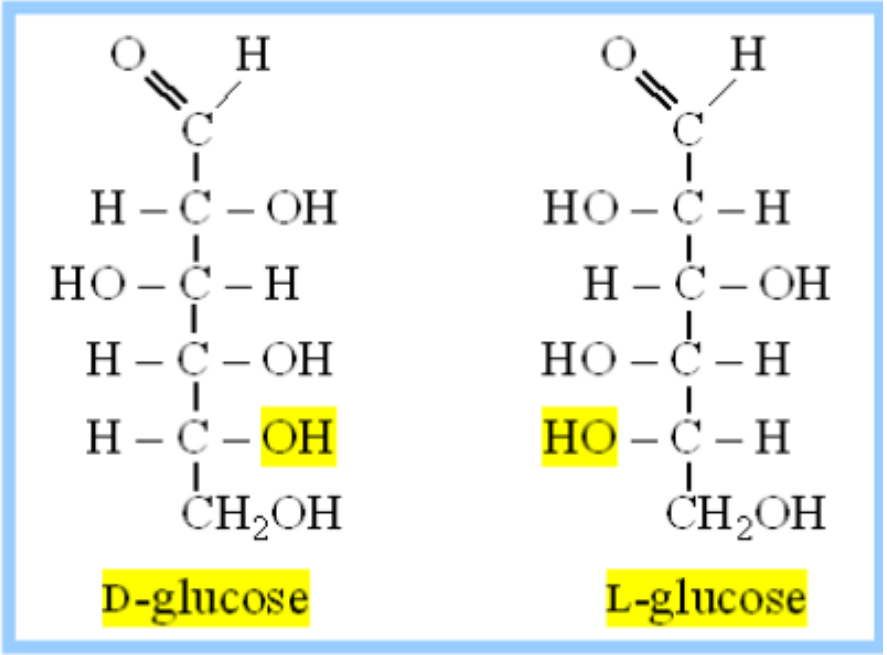
Most naturally occurring sugars are D isomers.



D & L sugars are mirror images of one another.

They have the same name, e.g., D-glucose & L-glucose.

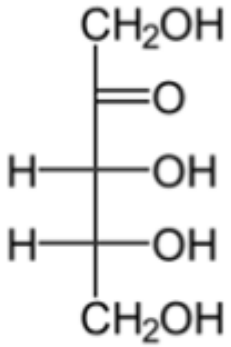
Other stereoisomers have unique names, e.g., glucose, mannose, galactose, etc.



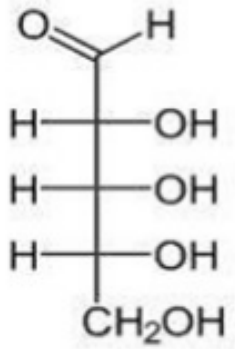
The number of stereoisomers is 2^n, where n is the number of asymmetric centers.

The 6-C aldoses have 4 asymmetric centers. Thus there are 16 stereoisomers (8 D-sugars and 8 L-sugars).

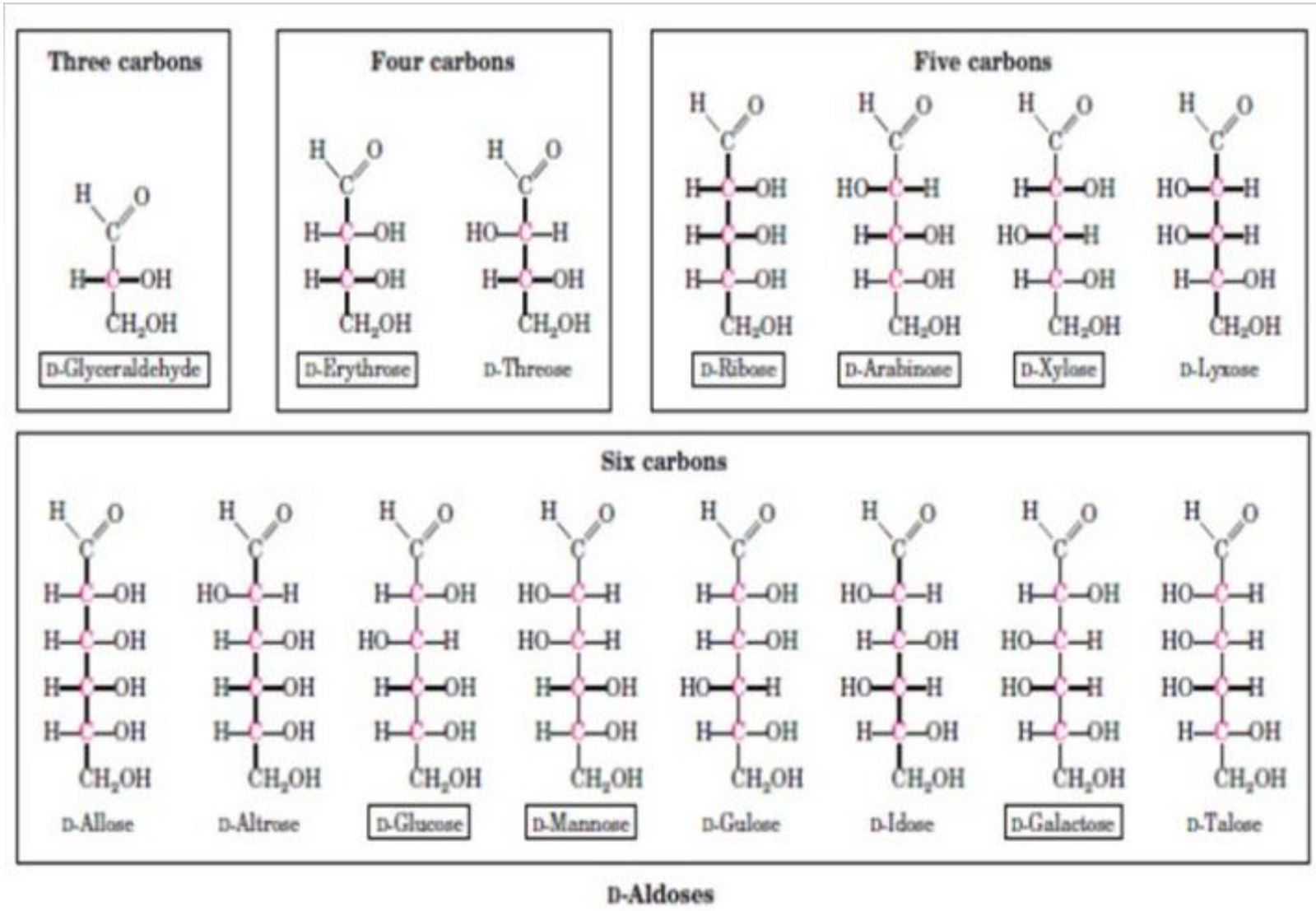
- The four & five carbon ketoses are designated by inserting ‘ul’ into the name of a corresponding aldose;
- For example, D-ribulose is the ketopentose corresponding to the aldopentose D-ribose

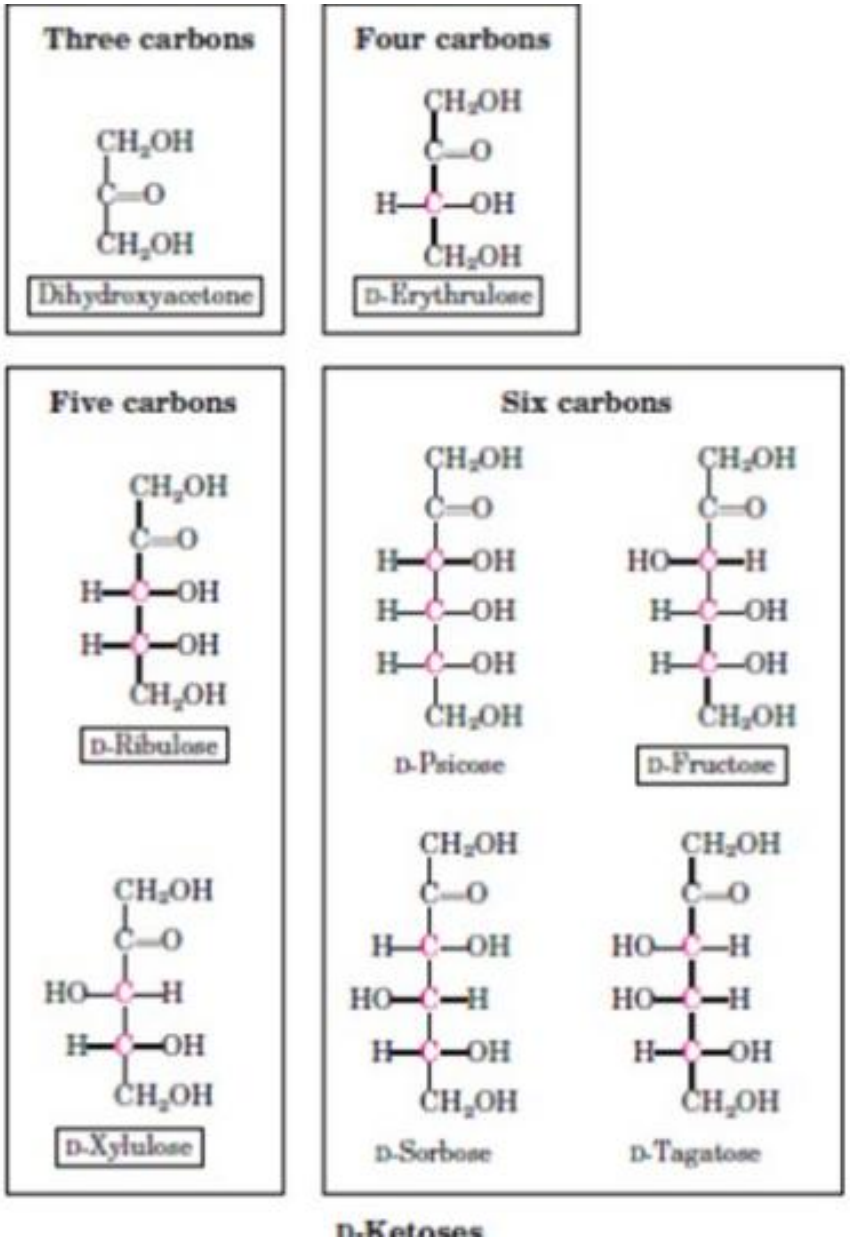


D-Ribulose



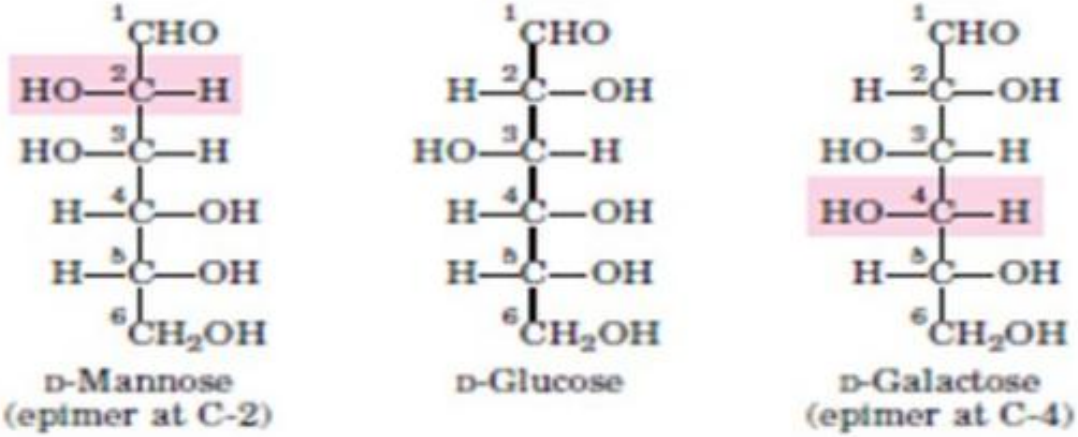
D-Ribose

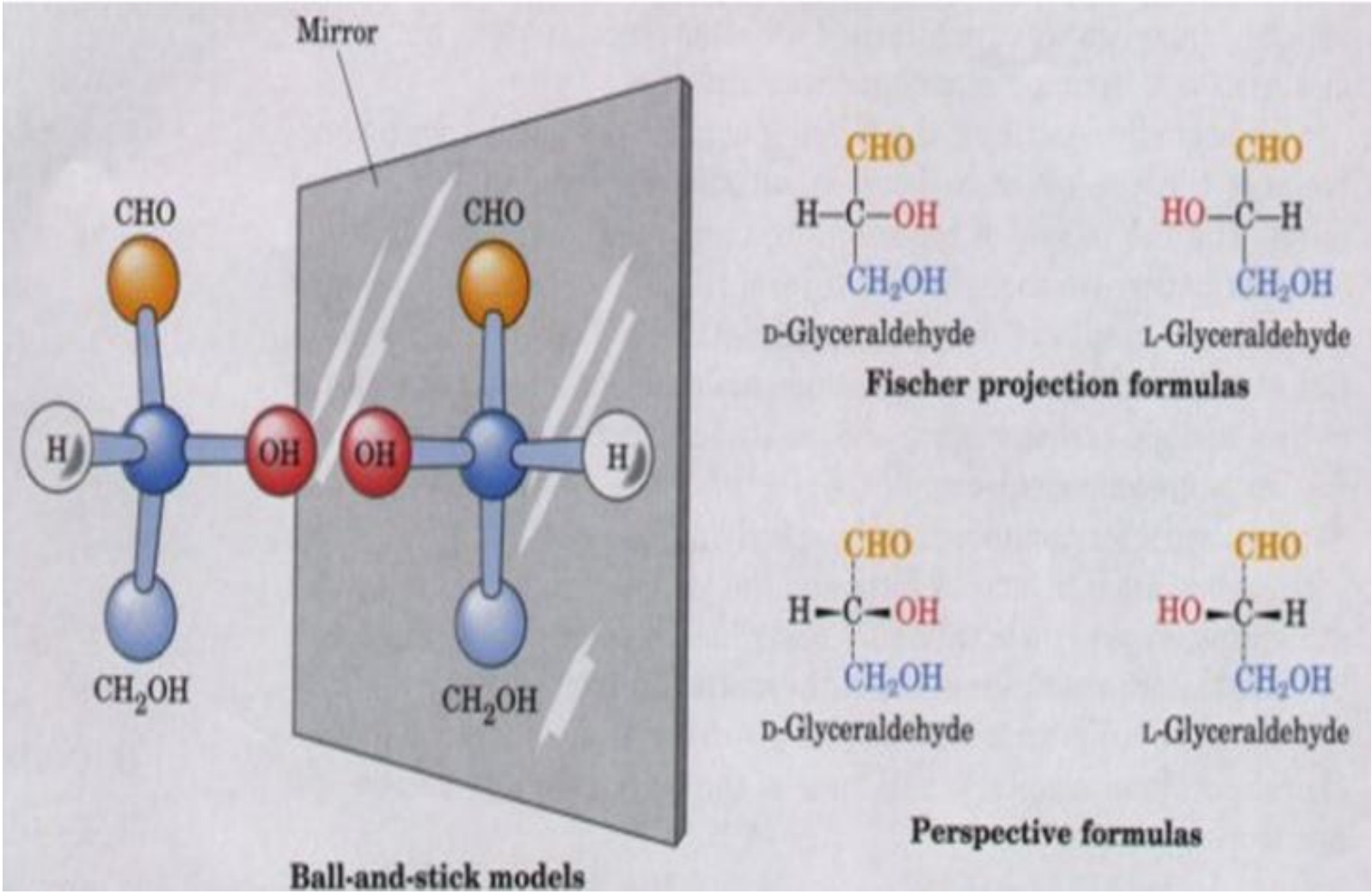

Three carbons
D-Glyceraldehyde
Four carbons
D-Erythrose
D-Threose
Five carbons
D-Ribose
D-Arabinose
D-Xylose
D-Lyxose
Six carbons
D-Allose
D-Altrose
D-Glucose
D-Mannose
D-Gulose
D-Idose
D-Galactose
D-Talose
D-Aldoses


Three carbons
Dihydroxyacetone
Four carbons
D-Erythrulose
Five carbons
D-Ribulose
D-Xylulose
Six carbons
D-Psicose
D-Fructose
D-Sorbose
D-Tagatose

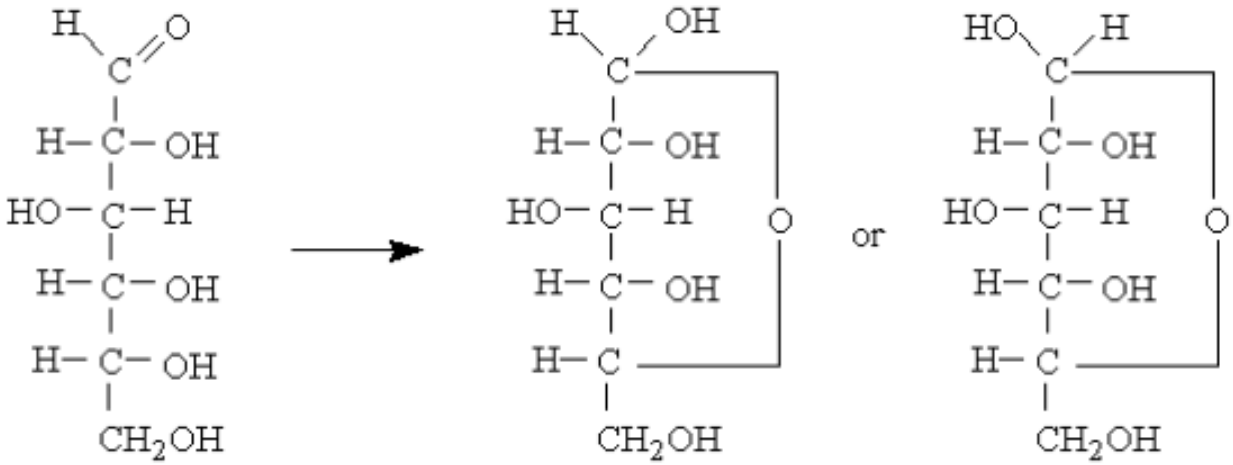
D-Ketoses

- Two sugars that differ only in the configuration around one carbon atom are called epimers
- D-glucose and D-mannose which differ only in the stereochemistry at C-2 are epimers, as are D-glucose & D-galactose which differ at C-4

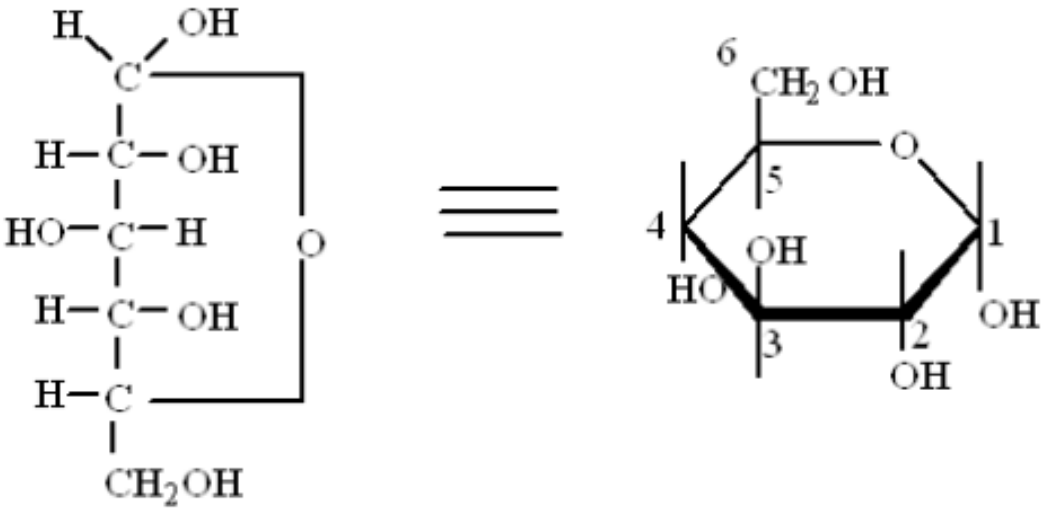



Mirror
CHO
CHO
H
OH
OH
H
CH2OH
CH2OH
Ball-and-stick models
CHO
H–C–OH
CH2OH
D-Glyceraldehyde
CHO
HO–C–H
CH2OH
L-Glyceraldehyde
Fischer projection formulas
CHO
H–C–OH
CH2OH
D-Glyceraldehyde
CHO
HO–C–H
CH2OH
L-Glyceraldehyde
Perspective formulas

FISHER PROJECTION FORM



HAWORTH PROJECTION FORMULAS FOR SUGARS

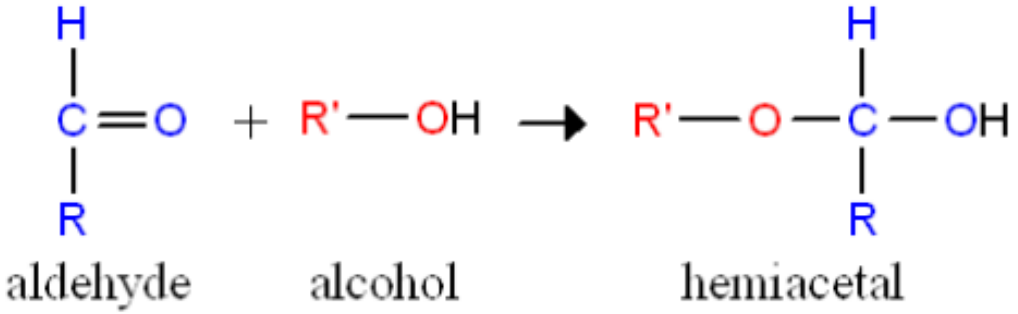


Monosaccharides have cyclic structures

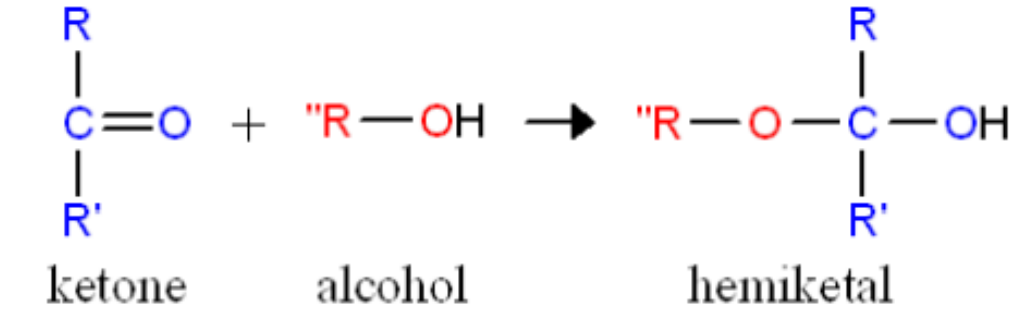
- In aqueous solution, aldotetroses and all monosaccharides with five and more carbon atoms in the backbone occur predominantly as cyclic structures in which the carbonyl group has formed a covalent bond with oxygen of a hydroxyl group along the chain
- The formation of these ring structures is the result of a general reaction between alcohols and aldehydes or ketones to form derivatives called hemiacetal or hemiketals

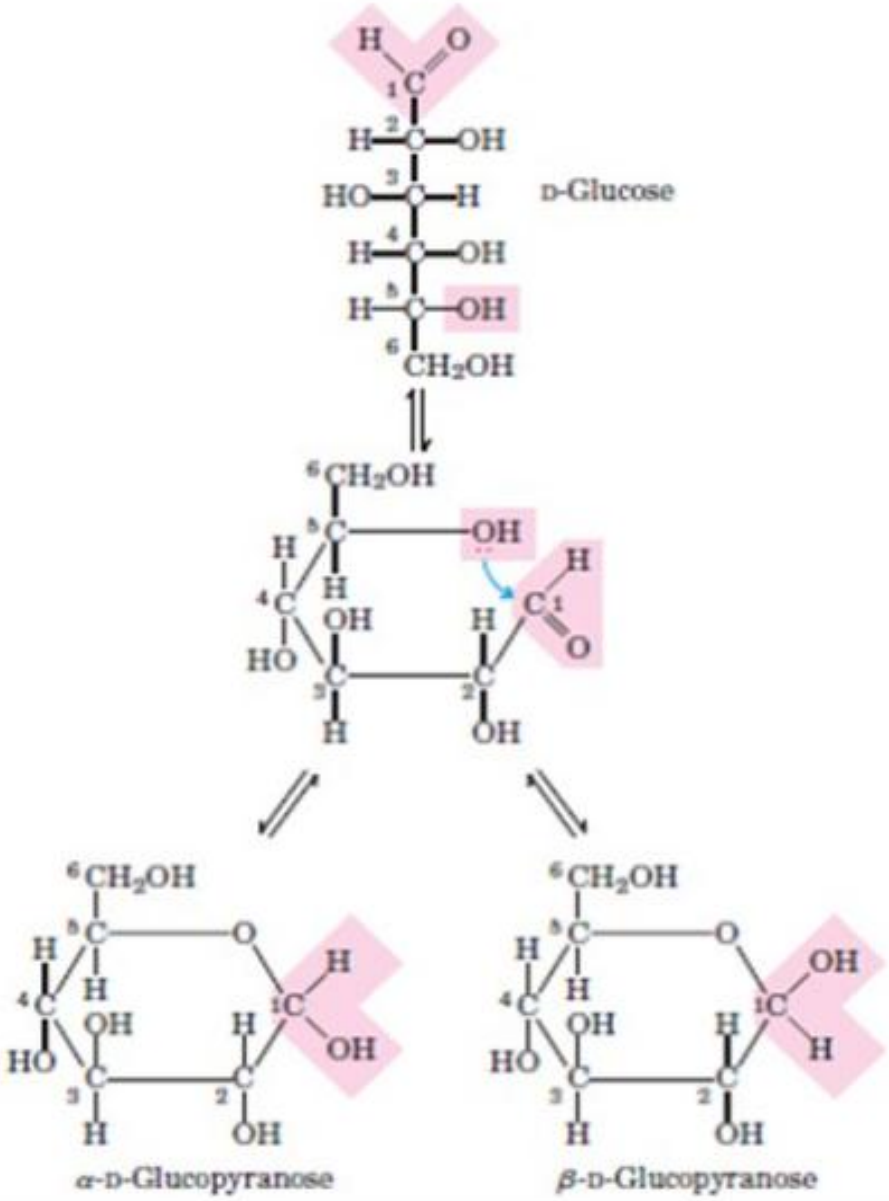
Hemiacetal & hemiketal formation

An aldehyde can react with an alcohol to form a hemiacetal.



A ketone can react with an alcohol to form a hemiketal.

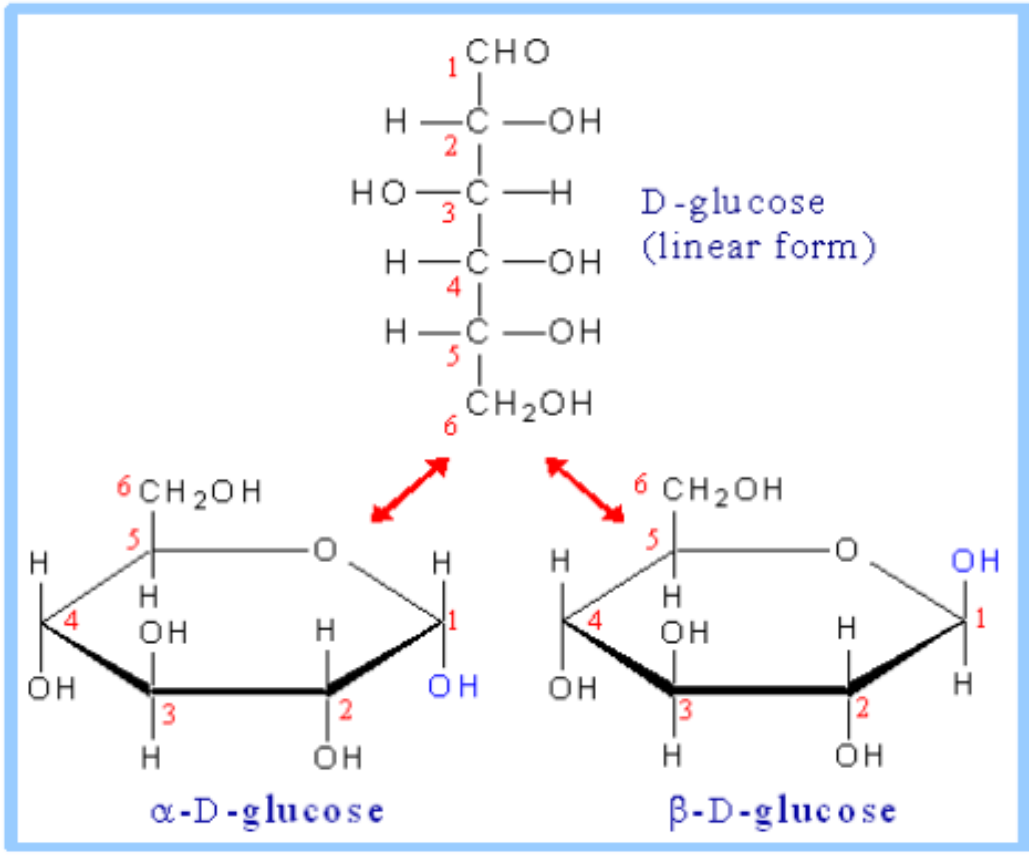



D-Glucose
α-D-Glucopyranose
β-D-Glucopyranose

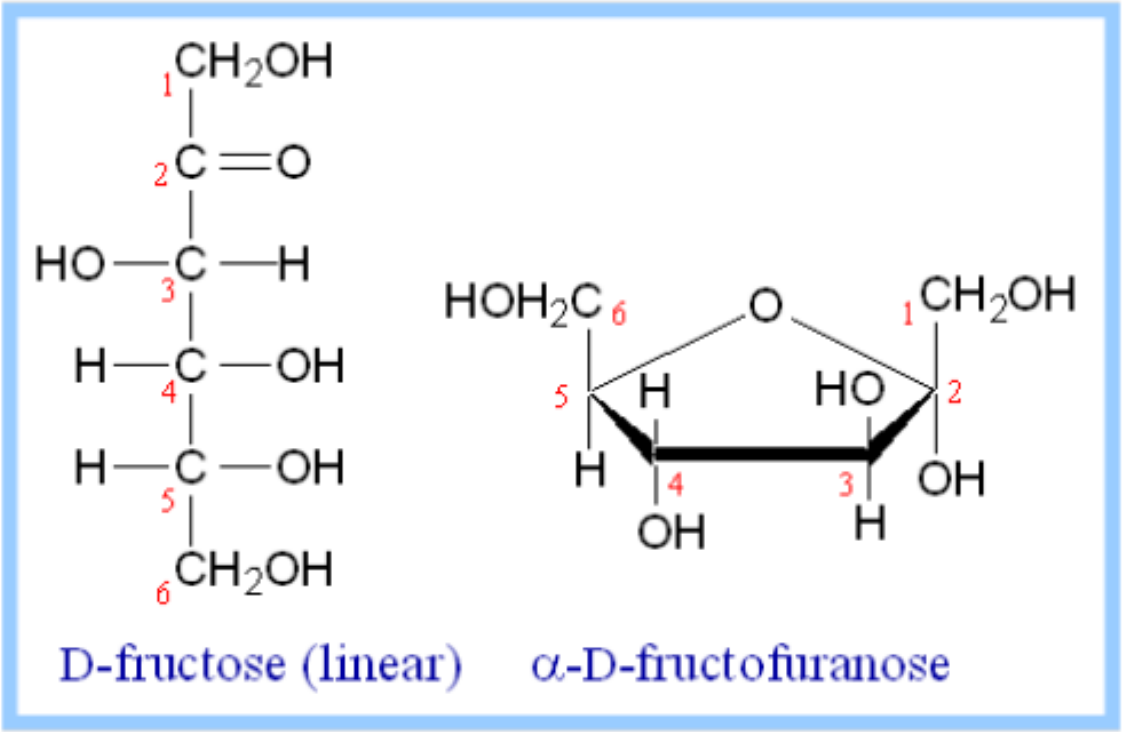
Cyclic Structure of Glucose

Pentoses and hexoses can cyclize as the ketone or aldehyde reacts with a distal OH.

Glucose forms an intra-molecular hemiacetal, as the C1 aldehyde & C5 OH react, to form a 6-member pyranose ring, named after pyran.



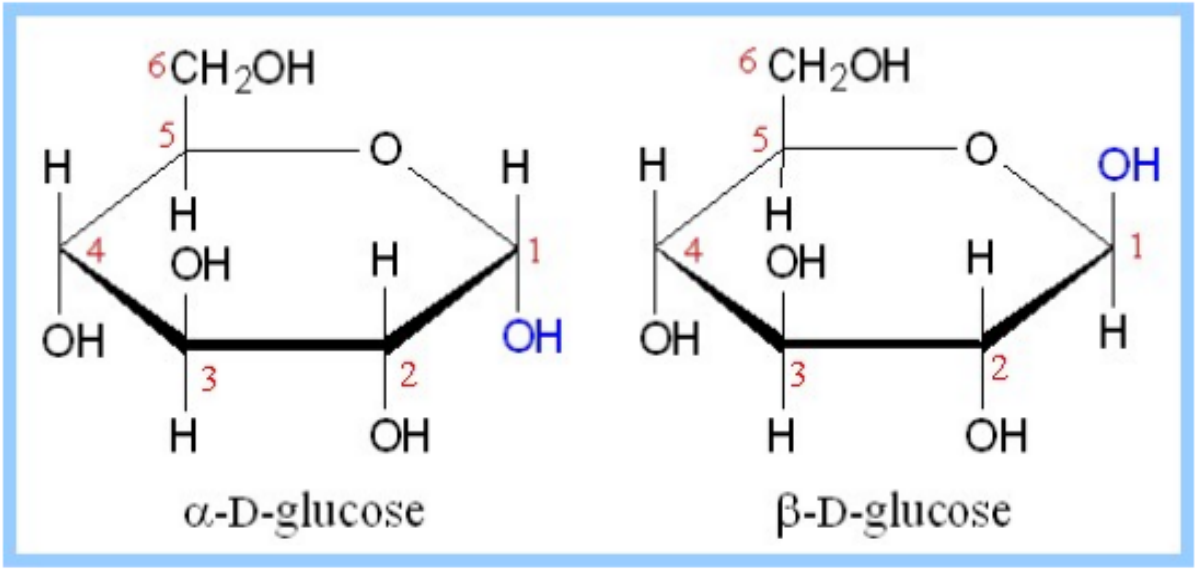
These representations of the cyclic sugars are called Haworth projections.



D-fructose (linear) α-D-fructofuranose

Fructose forms either

- a 6-member pyranose ring, by reaction of the C2 keto group with the OH on C6, or
- a 5-member furanose ring, by reaction of the C2 keto group with the OH on C5.



Cyclization of glucose produces a new asymmetric center at C1. The 2 stereoisomers are called anomers, α & β.

Haworth projections represent the cyclic sugars as having essentially planar rings, with the OH at the anomeric C1:

- α (OH below the ring)
- β (OH above the ring).

Disaccharide

- A **disaccharide** is the carbohydrate formed when two monosaccharides undergo a condensation reaction which involves the elimination of a small molecule, such as water, from the functional groups only.

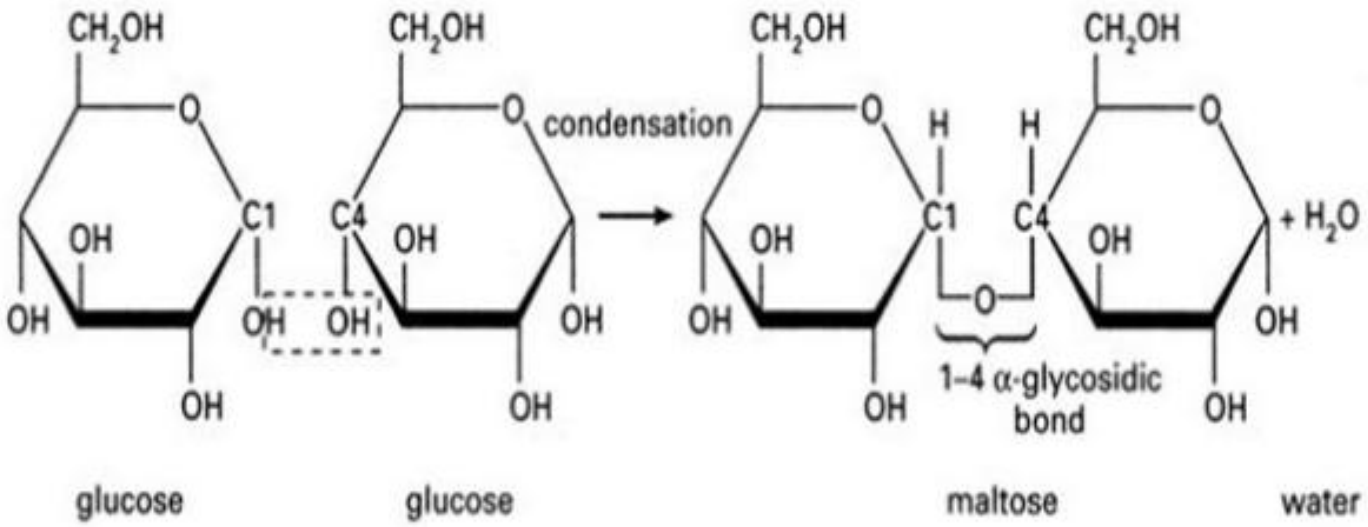
- Like monosaccharides, disaccharides form an aqueous solution when dissolved in water.

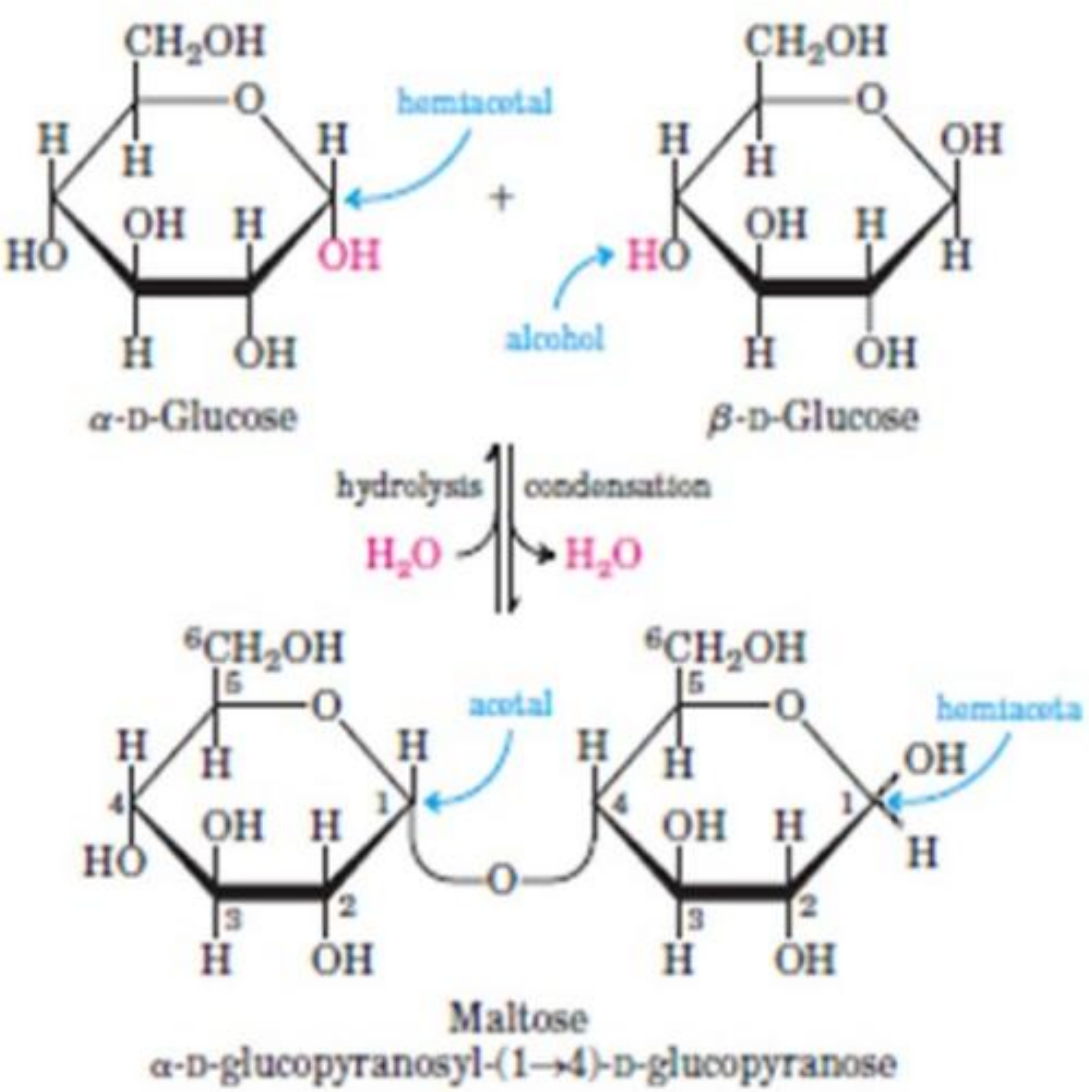
- Three common examples are sucrose, lactose and maltose.

Formation of Disaccharide

- Disaccharides are formed when two monosaccharides are joined together and a molecule of water is removed, a process known as dehydration reaction.
- For example; milk sugar (lactose) is made from glucose and galactose whereas the sugar from sugar cane and sugar beets (sucrose) is made from glucose and fructose.
- Maltose, another notable disaccharide, is made up of two glucose molecules.
- The two monosaccharides are bonded via a dehydration reaction (also called a condensation reaction or dehydration synthesis) that leads to the loss of a molecule of water and formation of a glycosidic bond.

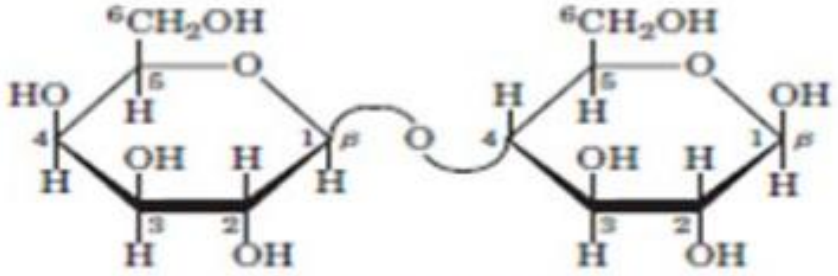
Glycosidic bond



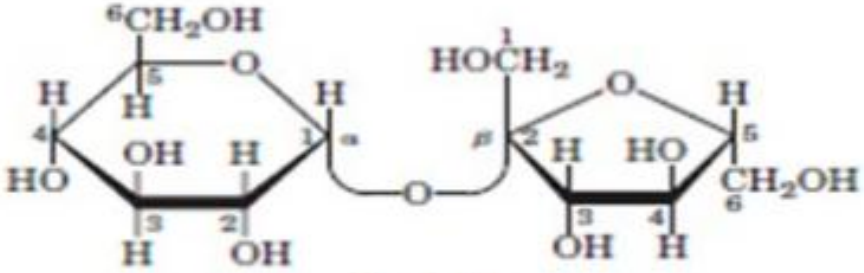

hemiacetal
alcohol
α-D-Glucose
β-D-Glucose
hydrolysis
condensation
H_2O
H_2O
acetal
hemiaceta
Maltose
α-D-glucopyranosyl-(1→4)-D-glucopyranose

Some common Disaccharide

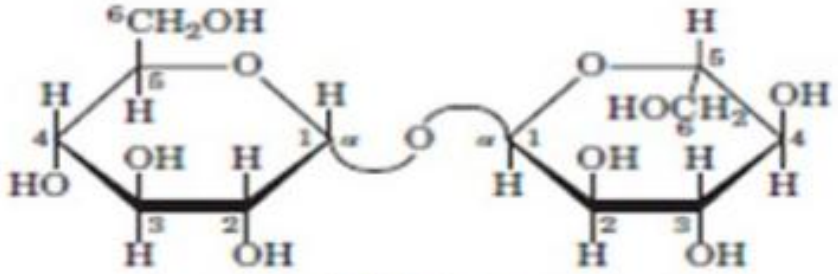
Disaccharide	Unit 1	Unit 2	Bond
Sucrose (*table sugar*, *cane sugar*, *beet sugar*, or *saccharose*)	glucose	fructose	α(1→2)β
Lactulose	galactose	fructose	β(1→4)
Lactose (*milk sugar*)	galactose	glucose	β(1→4)
Maltose	glucose	glucose	α(1→4)
Trehalose	glucose	glucose	α(1→1)α
Cellobiose	glucose	glucose	β(1→4)



Lactose (β form)
β-D-galactopyranosyl-(1→4)-β-D-glucopyranose
Gal(β1→4)Glc

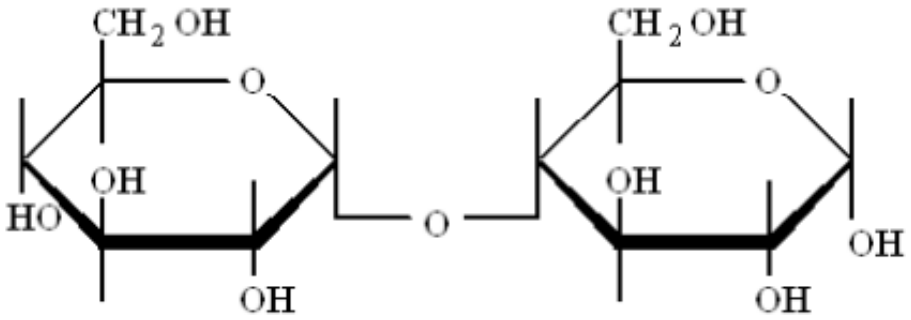


Sucrose
α-D-glucopyranosyl β-D-fructofuranoside
Glc(α1↔2β)Fru

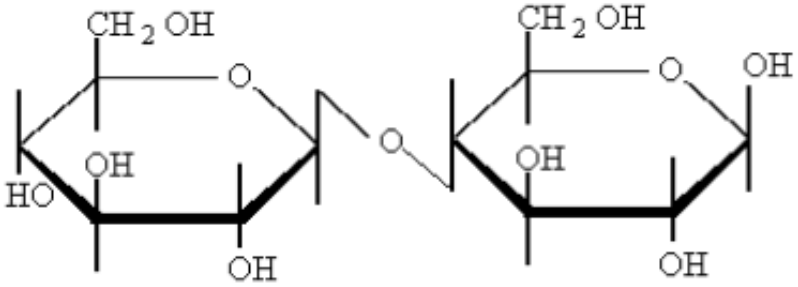


Trehalose
α-D-glucopyranosyl α-D-glucopyranoside
Glc(α1↔1α)Glc

Some common Disaccharide



Maltose



Cellobiose

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THANKS FOR LISTENING