University of Al-Qadisiyah

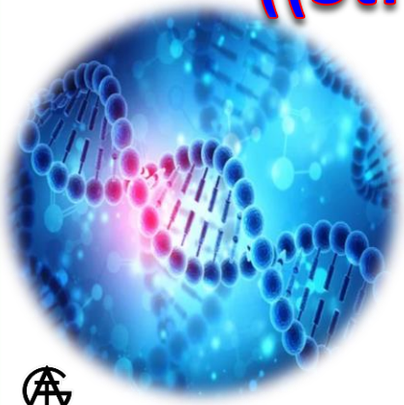
College of Medicine

Medical Chemistry/ Part 1-Biochemistry

1st year / (2022-2023) / 1st Semester

L 2 - Carbohydrates

((Structures, Functions, Classification and Reactions))



Dr. Ahmed Ghdhban Al-Ziaydi

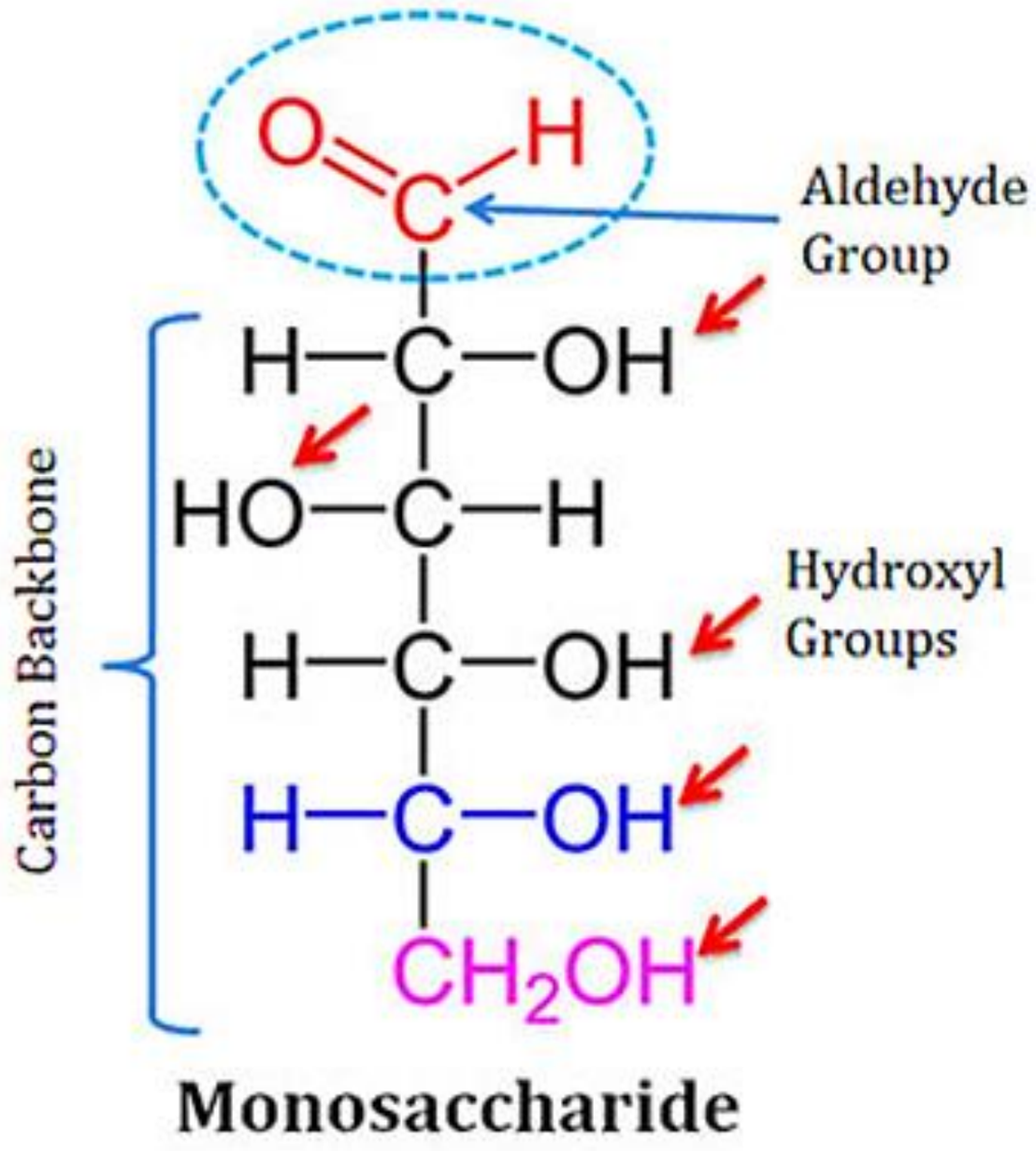
PhD. Medical Biochemistry

Carbohydrates

((Structures, Functions, Classification and Reactions))

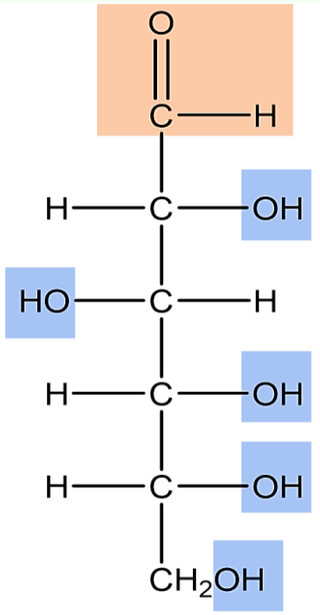
Carbohydrates are the most abundant organic molecules in nature.

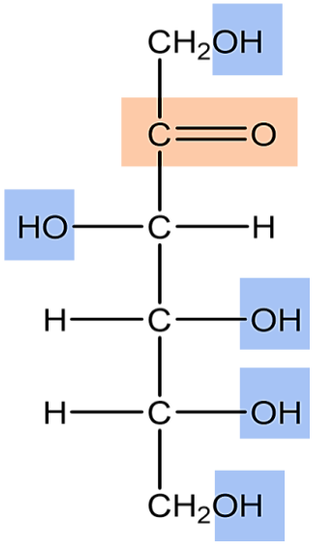
They are primarily composed of the elements carbon, hydrogen and oxygen. The name carbohydrate literally means ‘hydrates of carbon.

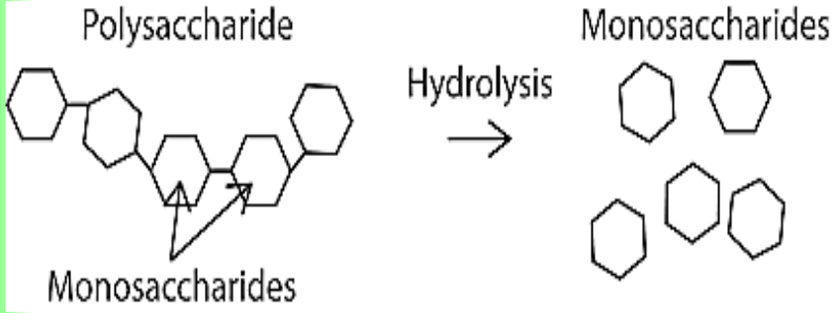


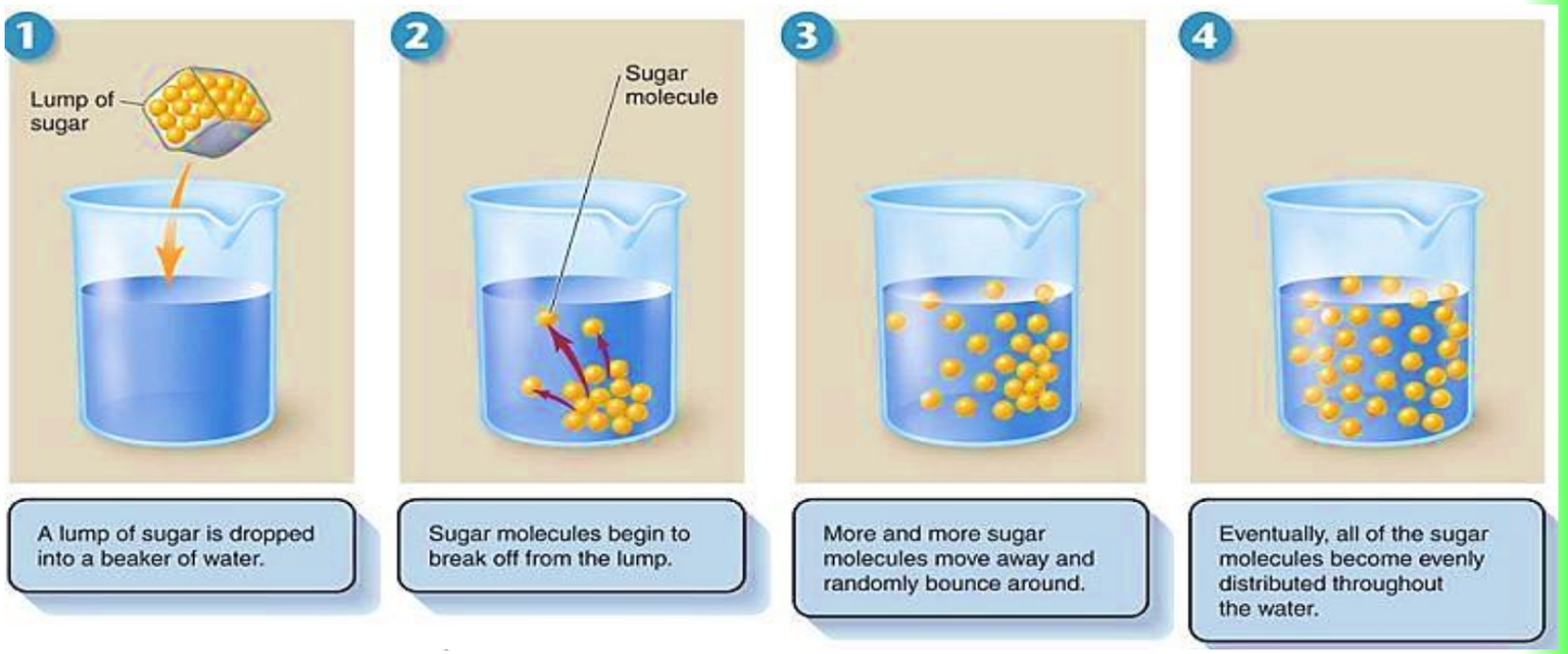
Carbohydrates

Carbohydrates may be defined as polyhydroxyaldehydes or ketones or compounds which produce them on hydrolysis. The term ‘sugar’ is applied to carbohydrates soluble in water and sweet to taste.









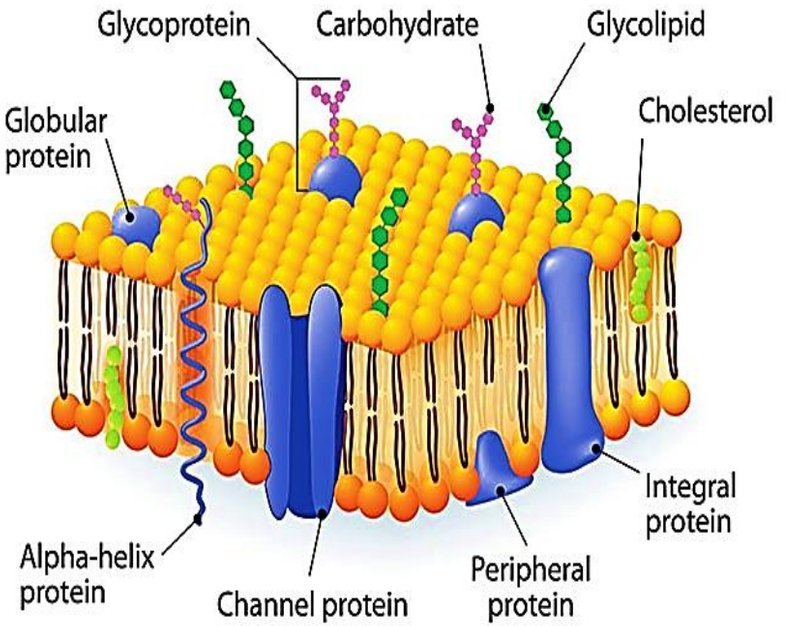
Functions of carbohydrates:

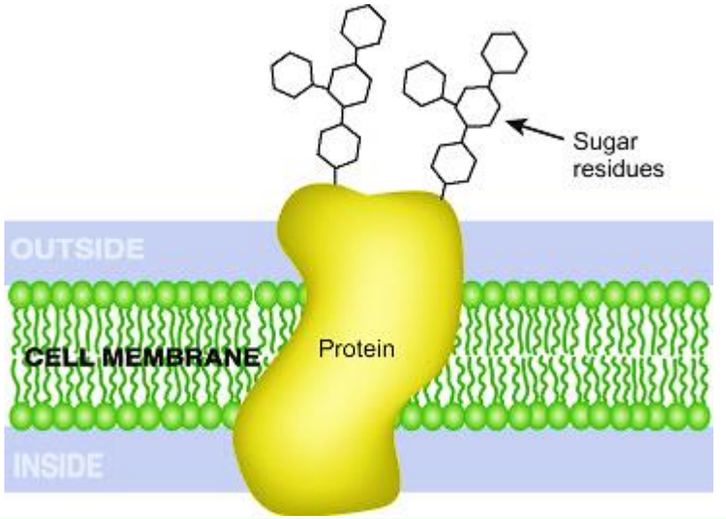
Carbohydrates participate in a wide range of functions:

1. They are the most abundant dietary source of energy (4 Cal/g) for all organisms.

2. Carbohydrates are precursors for many organic compounds (fats, amino acids).

3. Carbohydrates (as glycoproteins and glycolipids) participate in the structure of cell membrane and cellular functions such as cell growth, adhesion and fertilization.

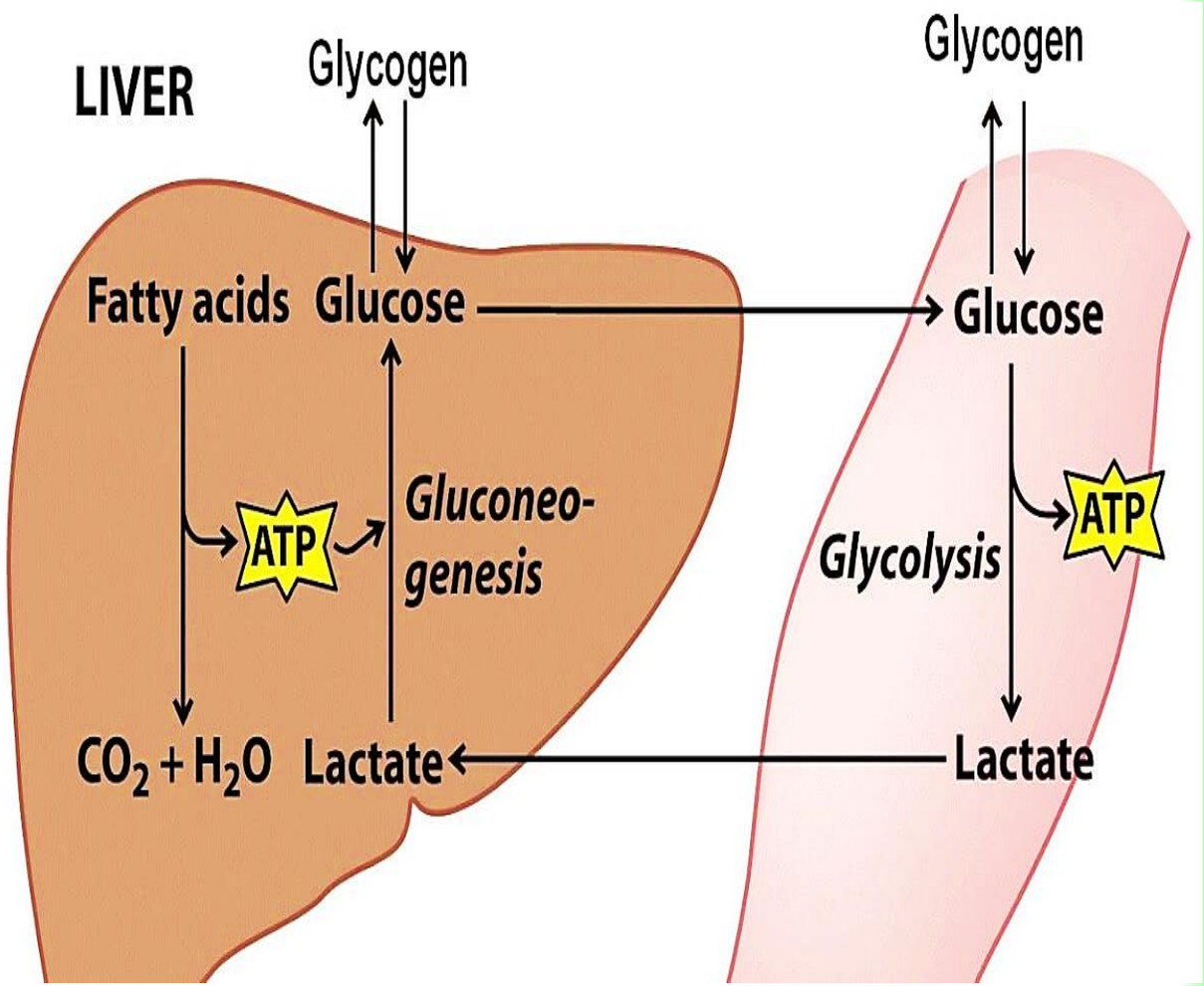




Functions of carbohydrates:

4. They are structural components of many organisms. These include the fiber (cellulose) of plants, exoskeleton of some insects and the cell wall of microorganisms.

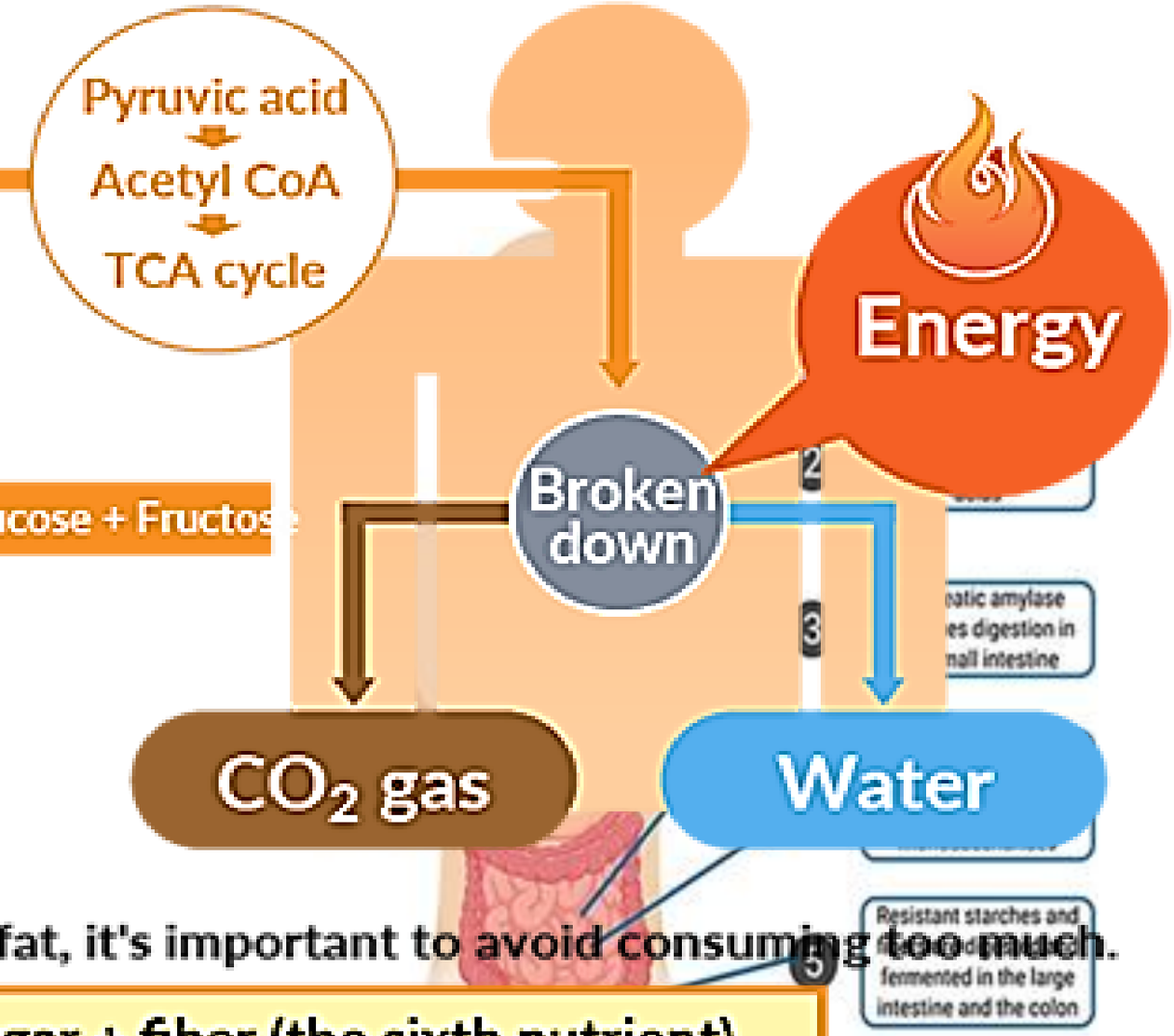
5. Carbohydrates also serve as the storage form of energy (glycogen) to meet the immediate energy demands of the body.



Sugar

Class	Types
Monosaccharides	Galactose
	Glucose
	Fructose
Disaccharides	Sucrose
	Maltose
Polysaccharides	Starch
	Glycogen

* The main component of sugar is sucrose



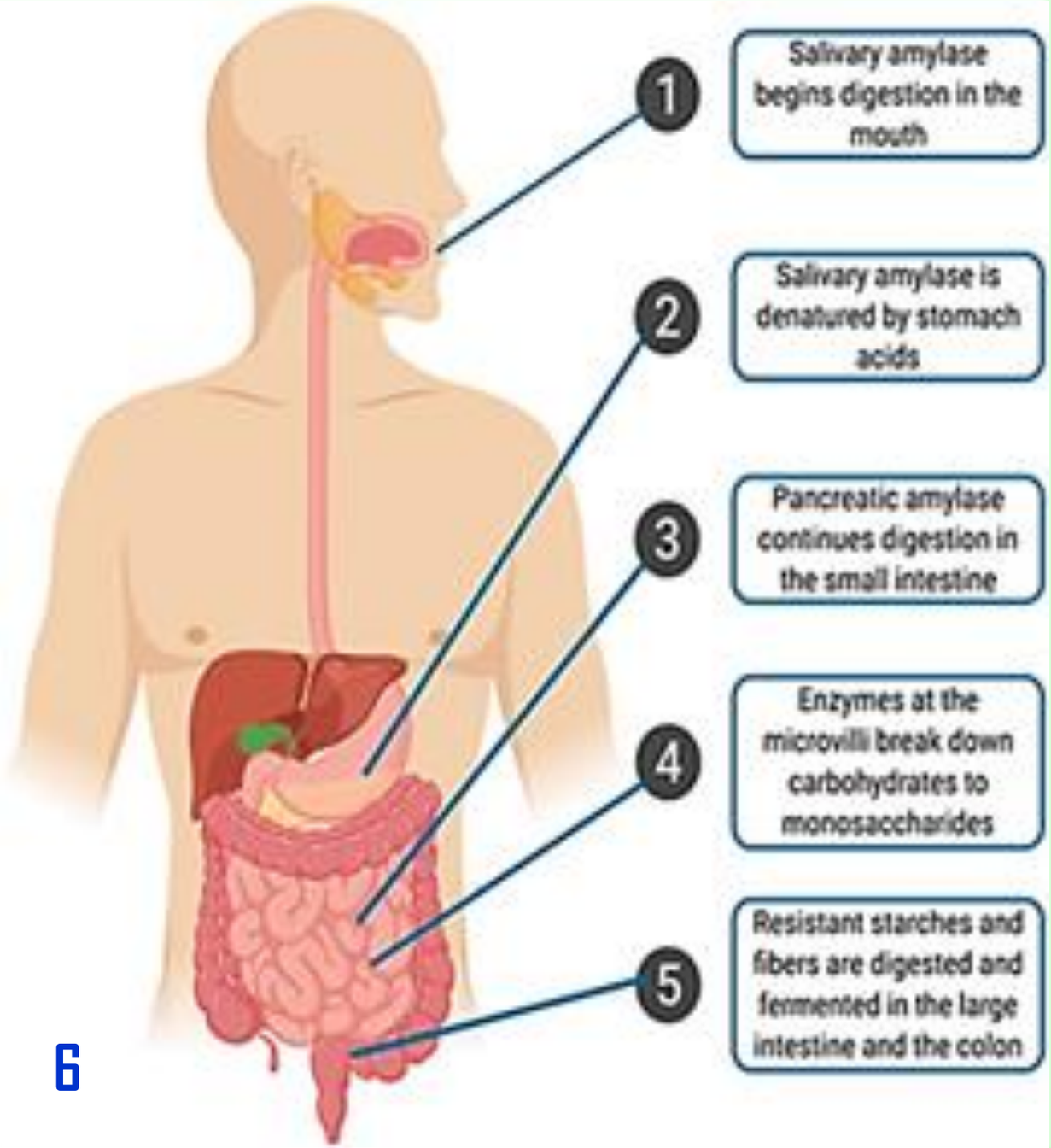
Since excess sugar will be stored as fat, it's important to avoid consuming too much.

Carbohydrates = sugar + fiber (the sixth nutrient)

Sugar: as food, this becomes energy once processed by the body
Dietary fiber: this cannot be broken down by human digestive enzymes, making it an indigestible component of food

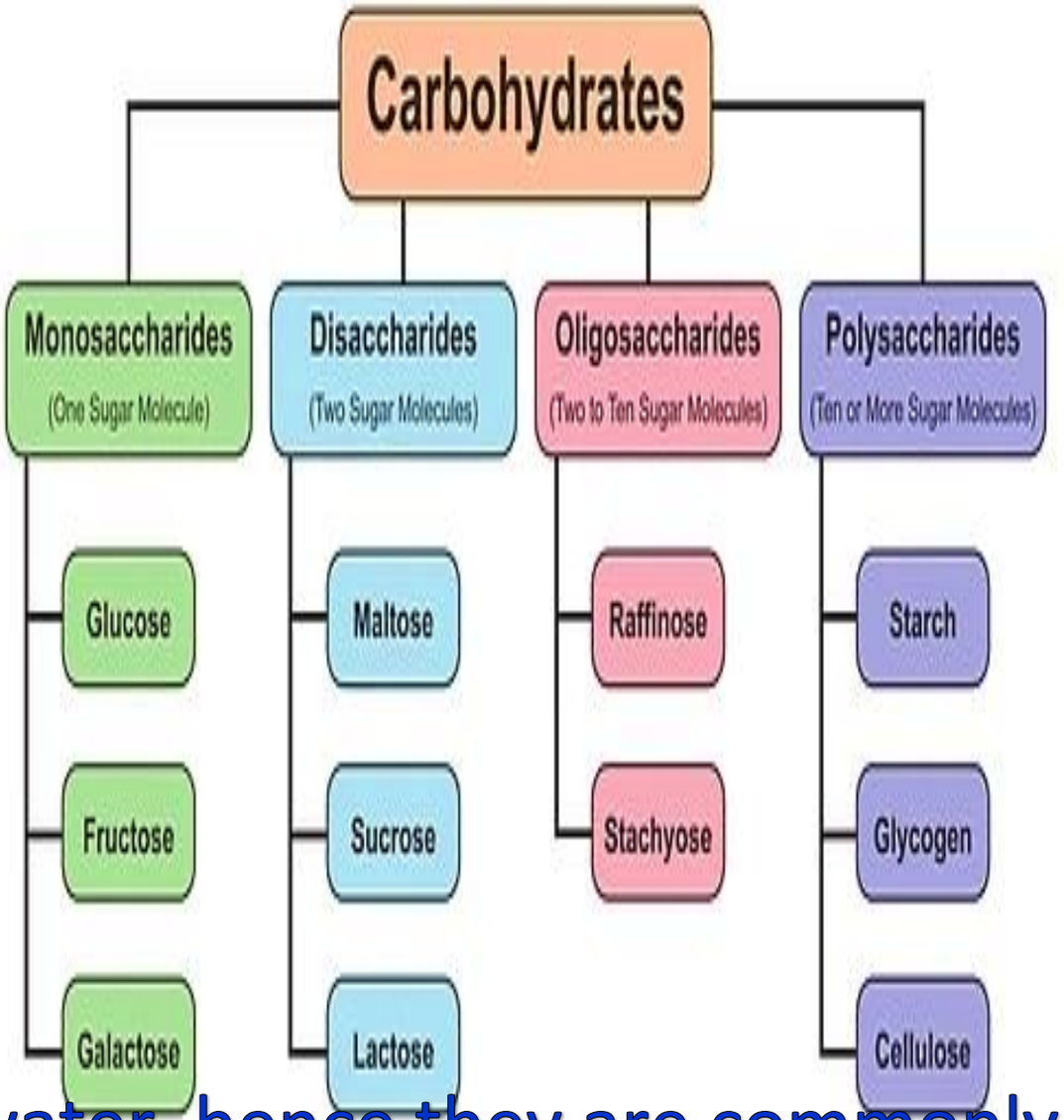
Glyceraldehyde: the reference carbohydrate Glyceraldehyde (triose) is the simplest monosaccharide with one asymmetric carbon atom.

It exists as two stereoisomers and has been chosen as the reference carbohydrate to represent the structure of all other carbohydrates.



Classification of Carbohydrates

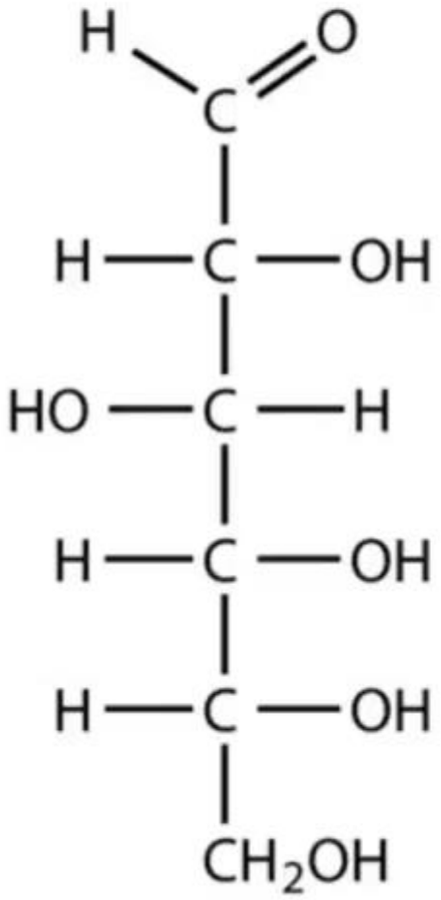
Carbohydrates are often referred to as saccharides. They are broadly classified into three major groups (monosaccharides, oligosaccharides and polysaccharides).



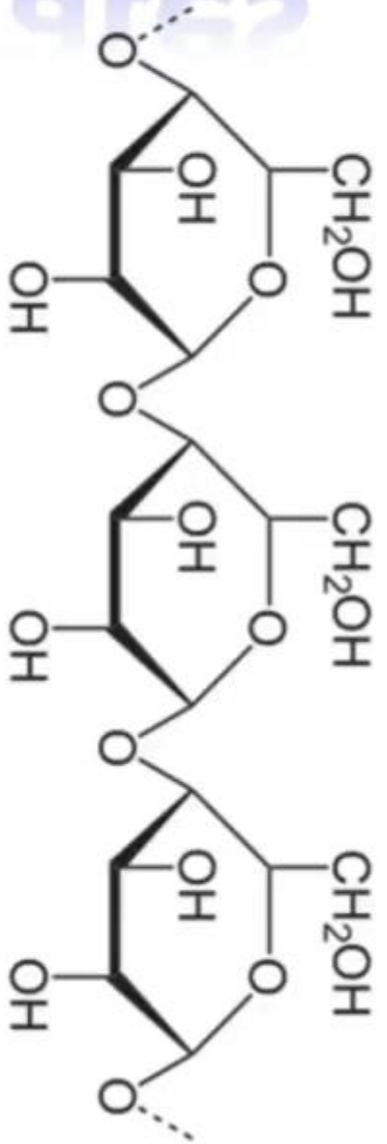
This categorization is based on the number of sugar units. Mono- and oligosaccharides are sweet to taste.

Crystalline in character and soluble in water, hence they are commonly known as sugars.

Classification of carbohydrates

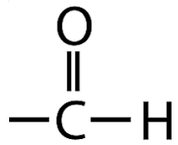


- Monosaccharides
- Oligosaccharides
- Polysaccharides



Monosaccharides:

Monosaccharides are the simplest group of carbohydrates and are often referred to as simple sugars. They have the general formula $C_n(H_2O)_n$, and they cannot be further hydrolysed. The monosaccharides are divided into different categories, based on the functional group and the number of carbon atoms.

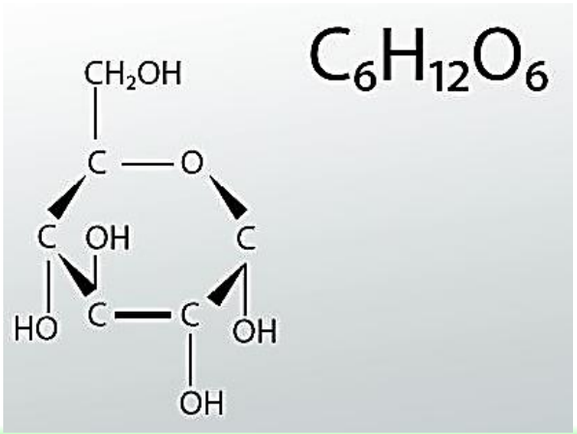
Aldoses : When the functional group in monosaccharides is an aldehyde  , they are known as aldoses e.g. glyceraldehyde, glucose.

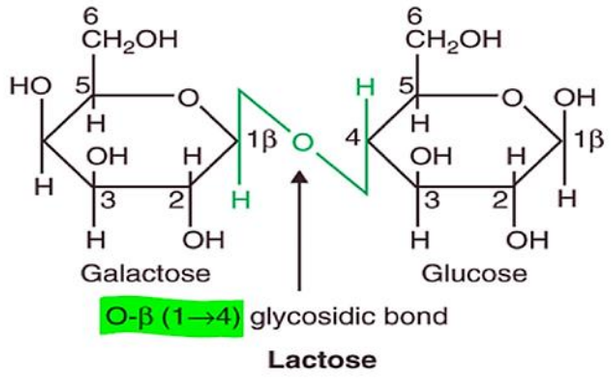
Ketoses : When the functional group is a keto –C=O group, they are referred to as ketoses e.g. dihydroxyacetone, fructose.

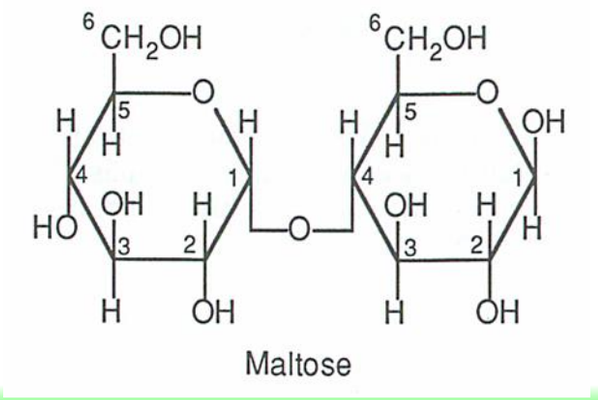
Monosaccharides

Based on the number of carbon atoms, the monosaccharides are regarded as trioses (3C), tetroses (4C), pentoses (5C), hexoses (6C) and heptoses (7C).

These terms along with functional groups are used while naming monosaccharides. For instance, glucose is an aldohexose while fructose is a ketohexose. The common monosaccharides and disaccharides of biological importance are given in the table 2.2

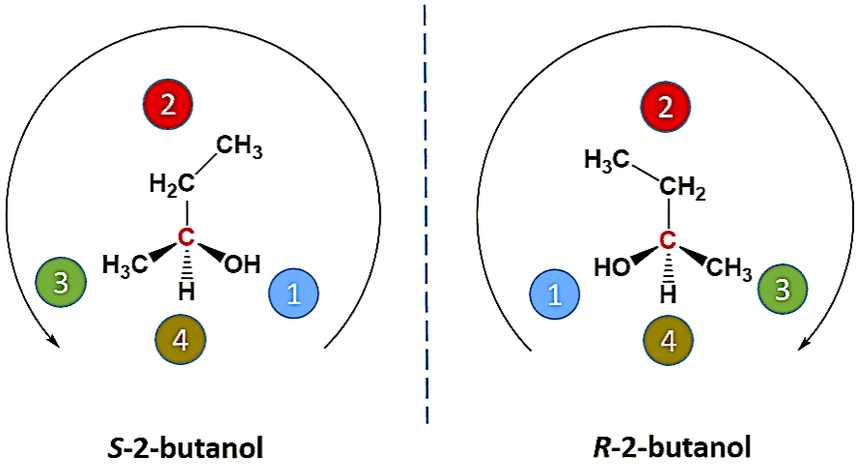






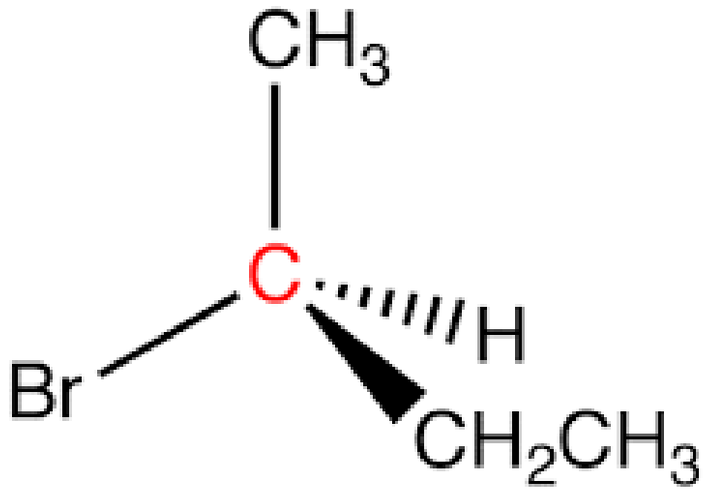
Stereoisomerism is an important character of monosaccharides. Stereoisomers are the compounds that have the same structural formulae but differ in their spatial configuration.

A carbon is said to be asymmetric when it is attached to four different atoms or groups. The number of asymmetric carbon atoms (n) determines the possible isomers of a given compound which is equal to 2n. Glucose contains 4 asymmetric carbons, and thus has 16 isomers.



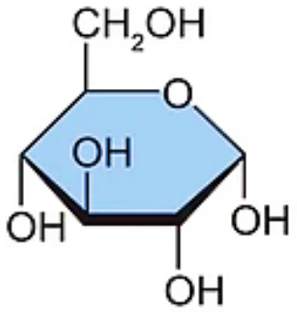
S-2-butanol

R-2-butanol

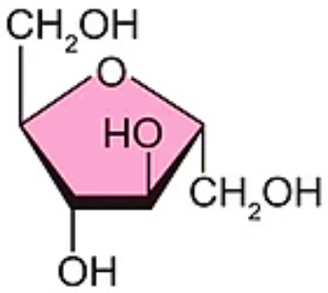


Classification of Monosaccharides

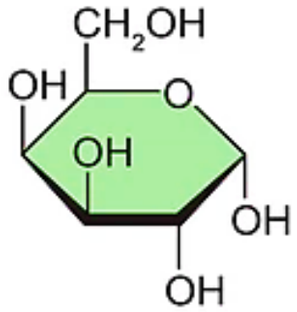
Number of 'C' atoms	Name of the monosaccharide	Aldose	Ketose
3	Triose	Glyceraldehyde (Glycerose)	Dihydroxyacetone
4	Tetrose	Erythrose	Erythrulose
5	Pentose	Ribose	Ribulose
6	Hexose	Glucose	Fructose
7	Heptose	Glucoheptose	Sedoheptulose



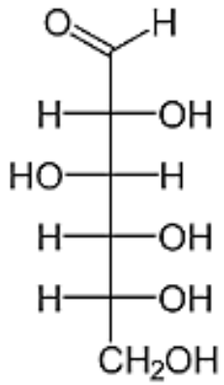
Glucose



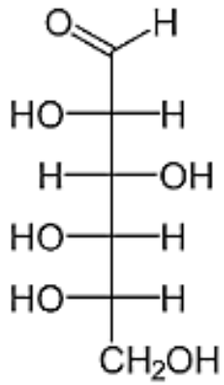
Fructose



Galactose



D-Glucose

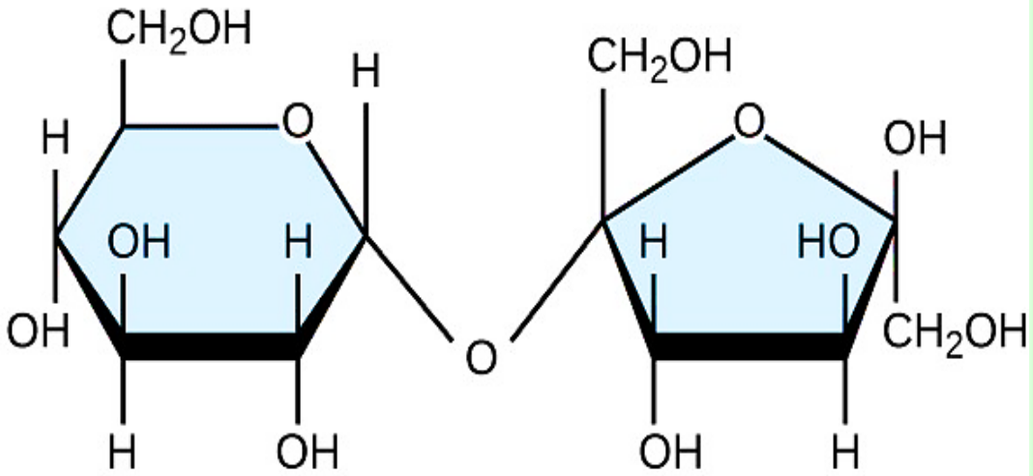


L-Glucose

Disaccharides

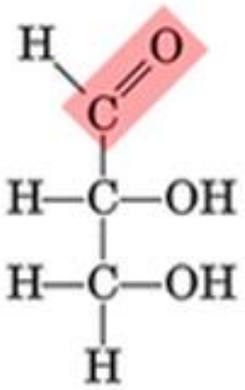
A disaccharide consists of two monosaccharides.

Disaccharide		Monosaccharides
Maltose	$+ H_2O \longrightarrow$	Glucose + Glucose
Lactose	$+ H_2O \longrightarrow$	Glucose + Galactose
Sucrose	$+ H_2O \longrightarrow$	Glucose + Fructose

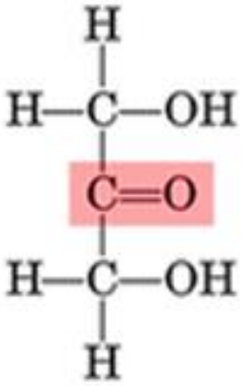


glucose fructose

sucrose

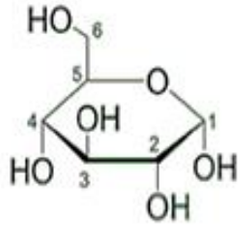


Aldose

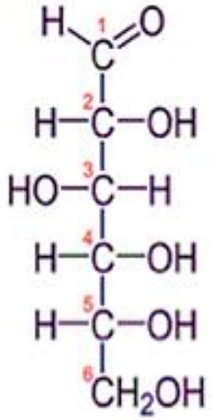


Ketose

Glucose



Haworth Projection



Fischer Projection

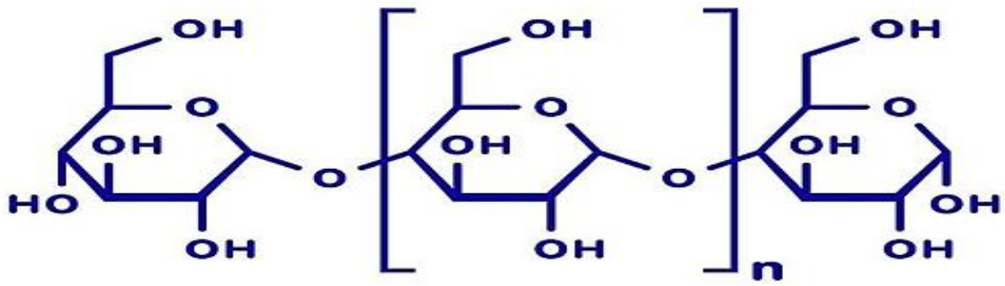
biological important of monosaccharides and Disaccharides

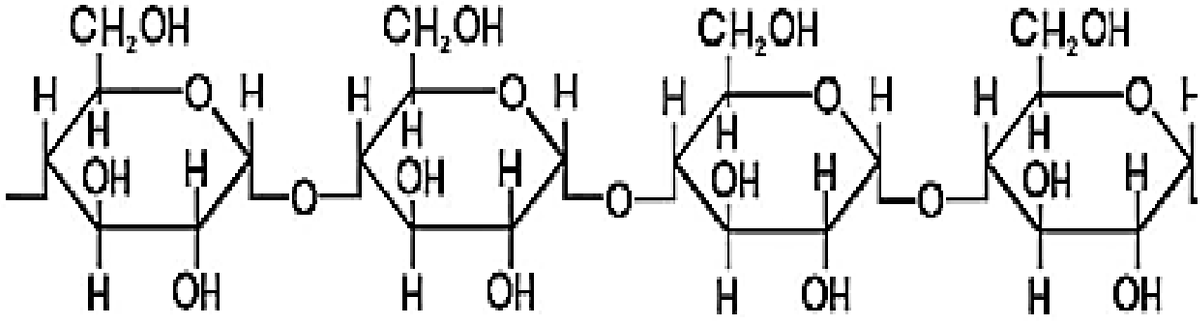
Monosaccharides	*Occurrence*	*Biochemical importance*
Trioses		
Glyceraldehyde	Found in cells as phosphate	Glyceraldehyde 3-phosphate is an intermediate in glycolysis
Dihydroxyacetone	Found in cells as phosphate	Its 1-phosphate is an intermediate in glycolysis
Tetroses		
D-Erythrose	Widespread	Its 4-phosphate is an intermediate in carbohydrate metabolism
Pentoses		
D-Ribose	Widespread as a constituent of RNA and nucleotides	For the structure of RNA and nucleotide coenzymes (ATP, NAD^+, $NADP^+$)
D-Deoxyribose	As a constituent of DNA	For the structure of DNA
D-Ribulose	Produced during metabolism	It is an important metabolite in hexose monophosphate shunt
D-Xylose	As a constituent of glycoproteins and gums	Involved in the function of glycoproteins
L-Xylulose	As an intermediate in uronic acid pathway	Excreted in urine in essential pentosuria
D-Lyxose	Heart muscle	As a constituent of lyxoflavin of heart muscle

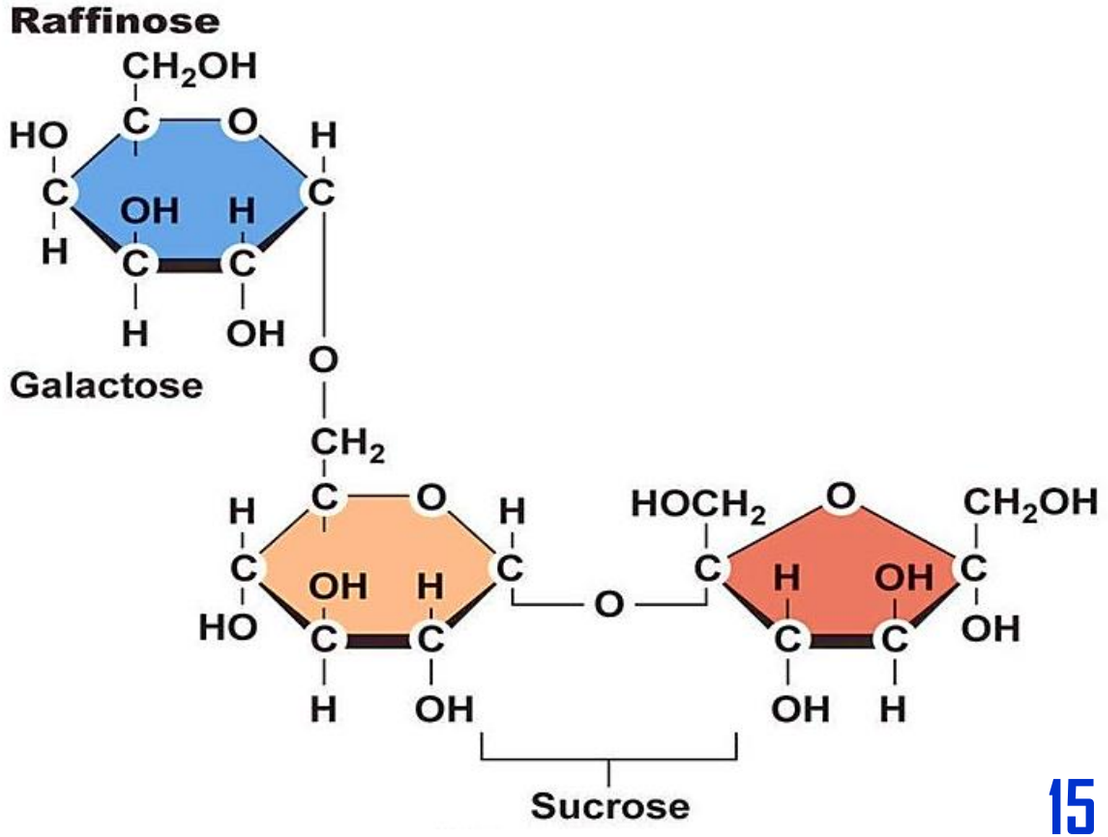
Hexoses		
D-Glucose	As a constituent of polysaccharides (starch, glycogen, cellulose) and disaccharides (maltose, lactose, sucrose). Also found in fruits	The 'sugar fuel' of life; excreted in urine in diabetes. Structural unit of cellulose in plants
D-Galactose	As a constituent of lactose (milk sugar)	Converted to glucose, failure leads to galactosemia
D-Mannose	Found in plant polysaccharides and animal glycoproteins	For the structure of polysaccharides
D-Fructose	Fruits and honey, as a constituent of sucrose and inulin	Its phosphates are intermediates of glycolysis
Heptoses		
D-Sedoheptulose	Found in plants	Its 7-phosphate is an intermediate in hexose monophosphate shunt, and in photosynthesis
Disaccharides	***Occurrence***	***Biochemical importance***
Sucrose	As a constituent of cane sugar and beet sugar, pineapple	Most commonly used table sugar supplying calories
Lactose	Milk sugar	Exclusive carbohydrate source to breast fed infants. Lactase deficiency (lactose intolerance) leads to diarrhea and flatulence
Maltose	Product of starch hydrolysis, occurs in germinating seeds	An important intermediate in the digestion of starch

Oligosaccharides:

Oligosaccharides contain 2-10 monosaccharide molecules which are liberated on hydrolysis. Based on the number of monosaccharide units present, the oligosaccharides are further subdivided to disaccharides, trisaccharides etc.

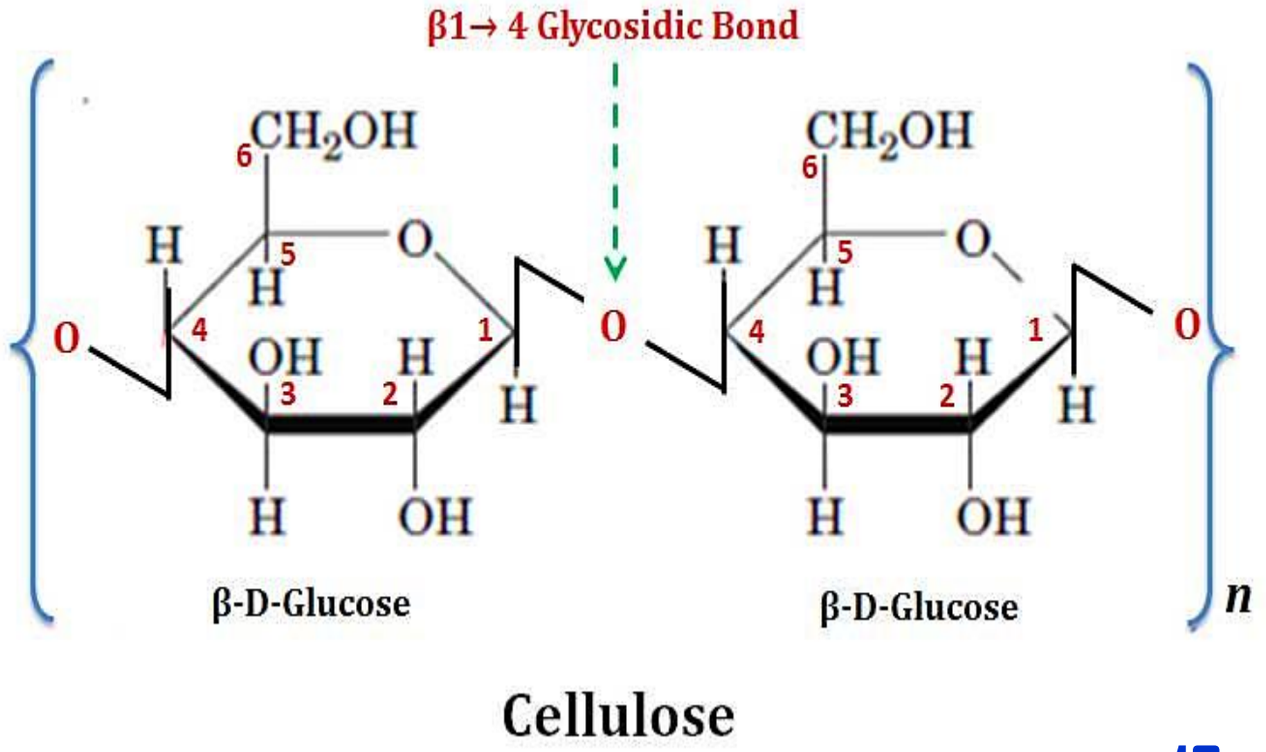




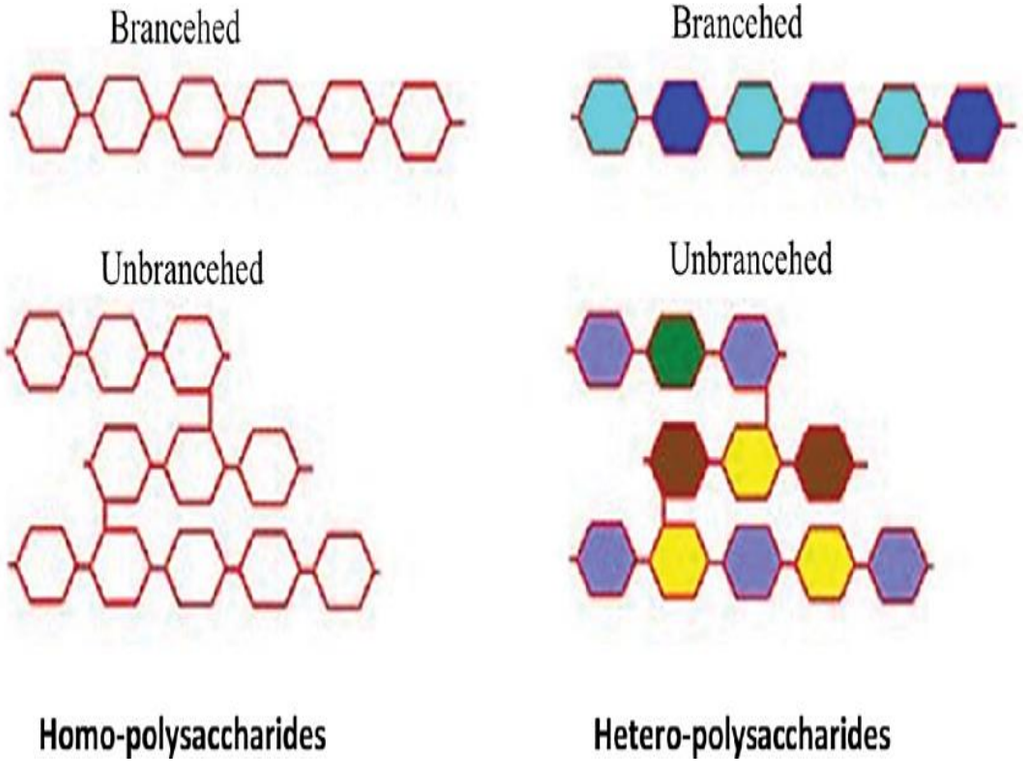


Polysaccharides:

Polysaccharides are polymers of monosaccharide units with high molecular weight (up to a million). They are usually tasteless (non-sugars) and form colloids with water. The polysaccharides are of two types: homopolysaccharides and heteropolysaccharides.



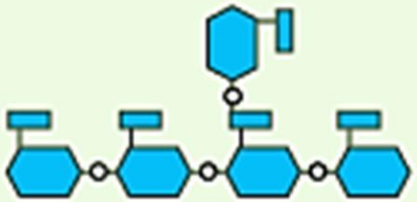
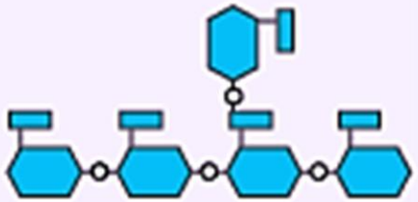
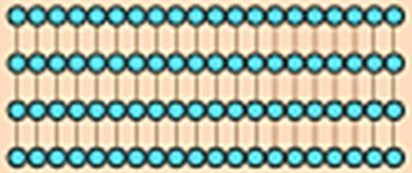
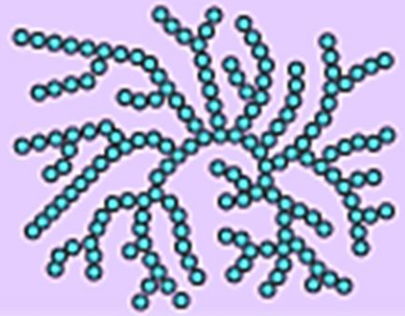
Cellulose



Homo-polysaccharides

Hetero-polysaccharides

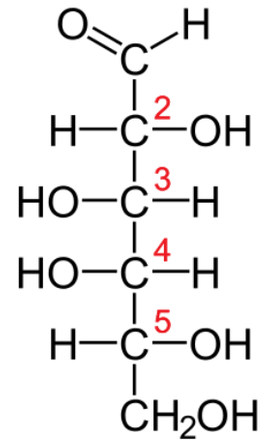
Polysaccharides

	Cellulose	Starch		Glycogen
		Amylose	Amylopectin	
Source	Plant	Plant	Plant	Animal
Subunit	β-glucose	α-glucose	α-glucose	α-glucose
Bonds	1-4	1-4	1-4 and 1-6	1-4 and 1-6
Branches	No	No	Yes (~per 20 subunits)	Yes (~per 10 subunits)
Diagram				
Shape				

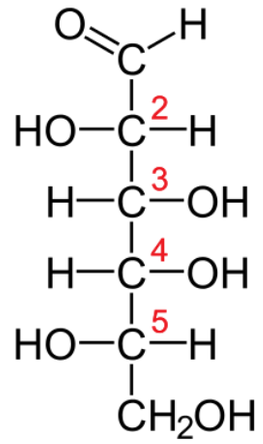
D- and L-isomers

The D and L isomers are mirror images of each other. The spatial orientation of H and OH groups on the carbon atom (C5 for glucose) that is adjacent to the terminal primary alcohol carbon determines whether the sugar is D- or L-isomer.

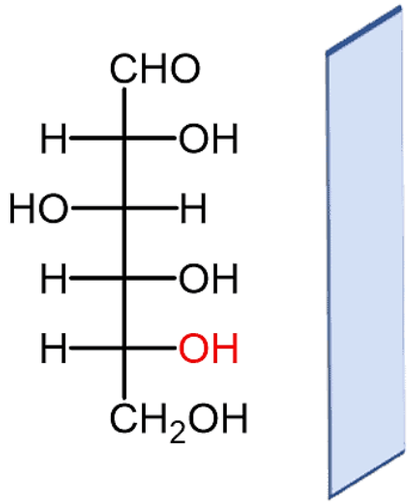
If the OH group is on the right side, the sugar is of D-series, and if on the left side, it belongs to L-series. The structures of D- and L-glucose based on the reference monosaccharide, D- and L-glyceraldehyde (glycerose).



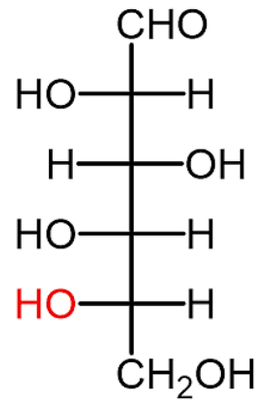
D-Galactose



L-Galactose



D-glucose



L-glucose

Enantiomers

https://www.youtube.com/watch?v=wxzc_2c6GMg

https://www.youtube.com/watch?v=D5RdWVBAN1c

https://www.youtube.com/watch?v=fUKUwADHZt8

https://www.youtube.com/watch?v=xIIVUAAn1zM

For your listening..

Dr. Ahmed Ghdhban Al-Ziaydi

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Biochemistry