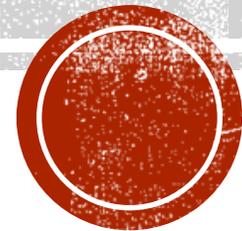


Carbohydrate chemistry



Students Learning Outcomes

❖ **By the end of this lecture, the students should be able to:**

- 1. Define Carbohydrates: mono, di, and polysaccharides.**
- 2. Classify carbohydrates.**
- 3. Identify the different types and functions of monosaccharides, disaccharides and polysaccharides.**
- 4. Summarize the biological importance of different types of carbohydrates**



PART 1

- **Monosaccharides**



CASE SCENARIO

- Hossam is a 45 years old male patient, presented to emergency room (ER) with complaints of fatigue, dizziness, pale skin, sweating, headache and rapid heartbeats. The patient **blood pressure** was **110/70 mmHg**, His random blood sugar was **49 mg/dl**.

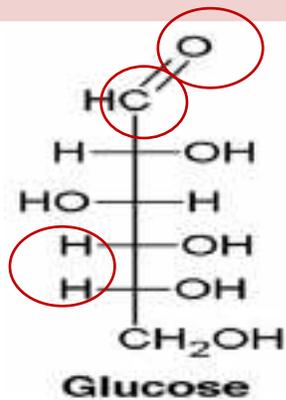


Definition:

Carbohydrates are Organic compounds characterized by 3 features:

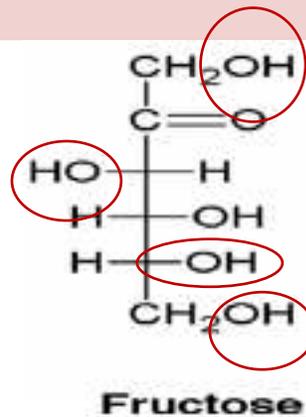
Containing :
(C, H & O).

- Carbon
- Hydrogen,
- Oxygen



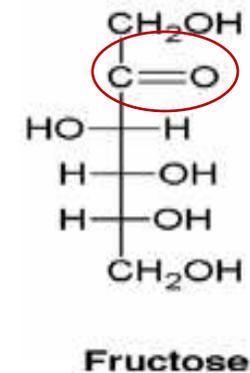
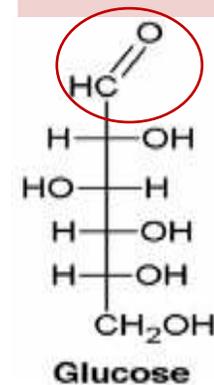
Containing more than one "OH" group

- (Poly-hydroxyl)



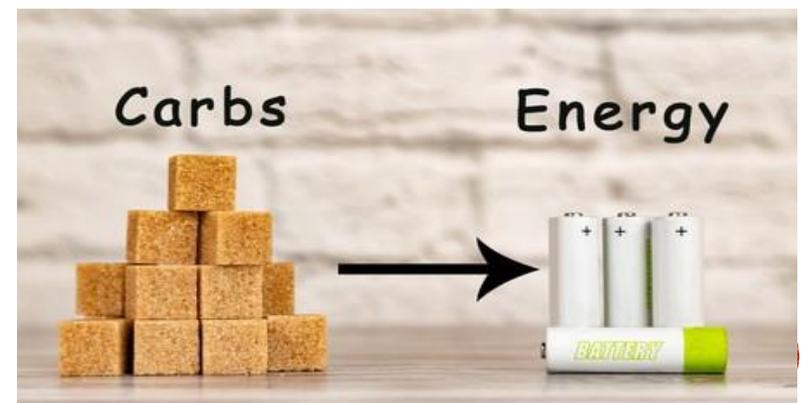
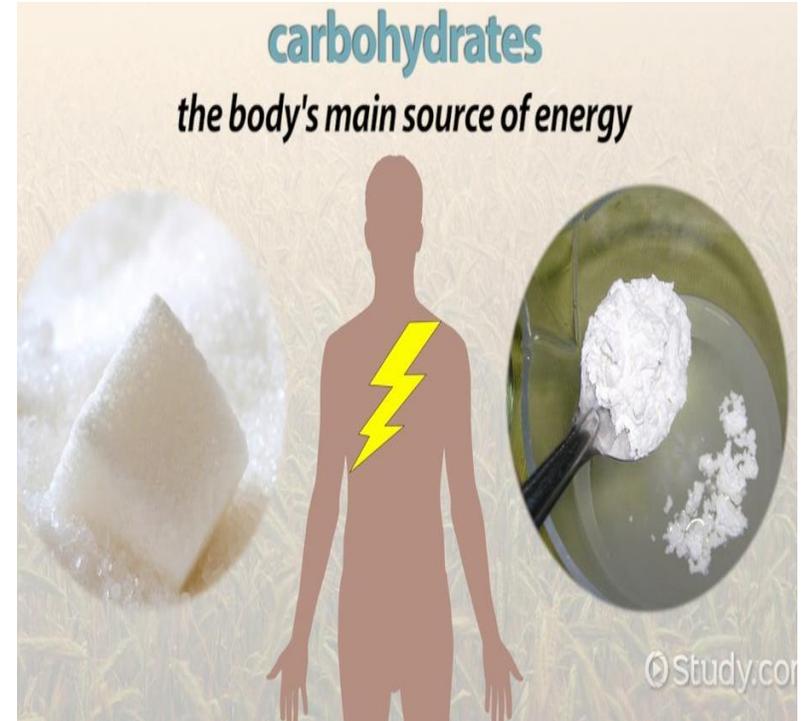
Containing free active **carbonyl group**

- Either aldehyde (HC=O) or ketone (C=O) group



Why we study CHO

- CHO is the **primary source for production of energy** for tissues e.g. brain, muscles and erythrocytes.
- Is there any other functions of CHO?



Classification of Carbohydrates

THEY ARE CLASSIFIED ACCORDING TO THE NUMBER OF **SUGAR UNITS** INTO:

1) Simple carbohydrates

2) Complex carbohydrate

Monosaccharides

Disaccharides

Oligosaccharides

Polysaccharides

1 sugar unit

2 sugar unit

3-10 sugar units

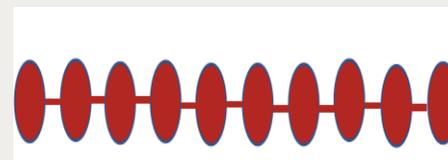
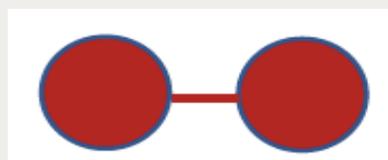
> 10 sugar units

Glucose, fructose,
galactose

Maltose,
sucrose, lactose

Raffinose, sesamose

Starch, glycogen,
fibers



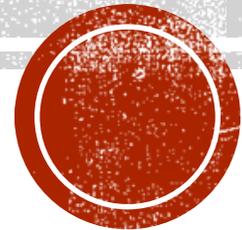
Monosaccharides

Definition

Classification

Biological importance

Monosaccharides' derivatives



Definition of monosaccharides

They are the simplest sugar :

1. Formed of **one sugar unit**
2. **cannot be hydrolyzed** into smaller units

Classification of monosaccharides

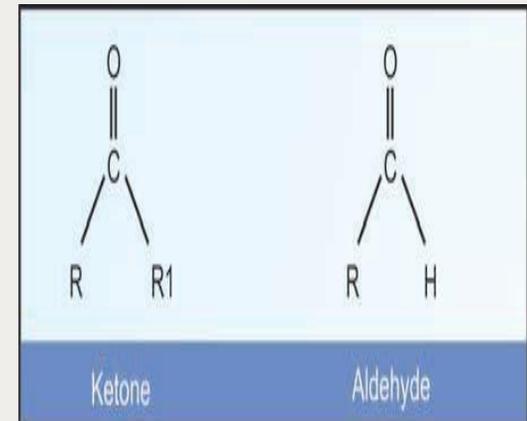
Monosaccharides are further classified according to:

Number of C atom

- **Trioses:** 3 carbon atoms.
- **Tetroses:** 4 carbon atoms.
- **Pentoses:** 5 carbon atoms.
- **Hexoses:** 6 carbon atoms

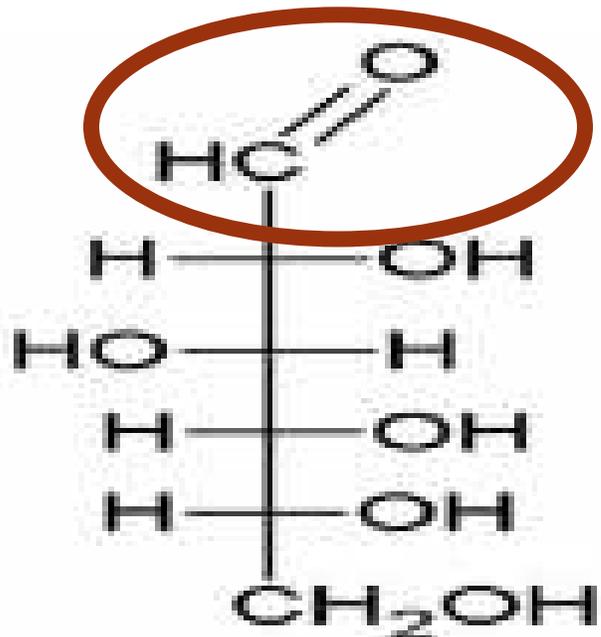
Active sugar gp

- **Aldehyde:** (aldoses)
(H-C=O)
- **Ketone:** (Ketoses).
(C=O)



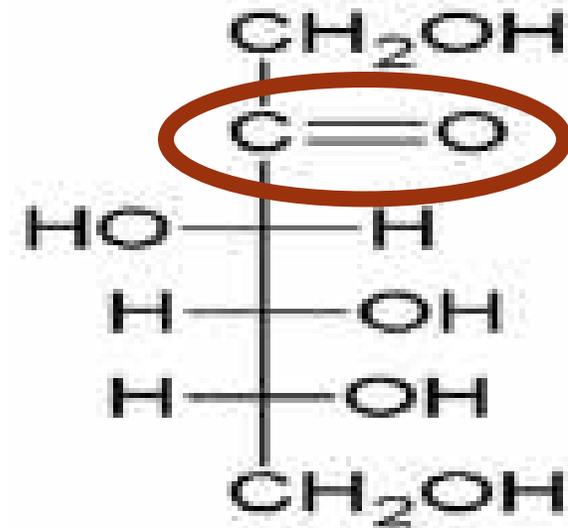
(6 carbons)
Hexoses

(**aldehyde** group)
Aldoses



Glucose

(**ketone** group)
Ketoses



Fructose



Monosaccharides of Biological Importance

Type	Biological importance
1-Glucose (Dextrose or Grape Sugar)	<ol style="list-style-type: none">1. Principal famous sugar in the blood.2. Primary source for energy for tissues e.g. brain and erythrocytes (RBCs) .Ingested carbohydrates are absorbed in the form of glucose.It can convert to other sugars like: galactose, lactose, fructose, ribose, glycogen. Where/why??
2-Fructose	<ol style="list-style-type: none">It is the sugar of seminal plasma (sperms utilize fructose for energy production).It enters in the formation of:<ol style="list-style-type: none">disaccharide sucrosepolysaccharide inulin



Monosaccharides of Biological Importance

Type	Biological importance
3-Galactose	It enters in the formation of a) Lactose (milk sugar): in mammary gland b) Galactolipids & glycoproteins.
4-Pentoses (Ribose)	Enter in the formation of:- a. Nucleic acids: RNA b. Energy compound: ATP. c. Co-enzymes : NAD & NADP d. 2nd messenger : cAMP e. Vitamins: riboflavin
5-Mannose	Enter in the formation of glycoproteins



Sugar Derivatives (Derived Sugars)

Monosaccharides Derivatives

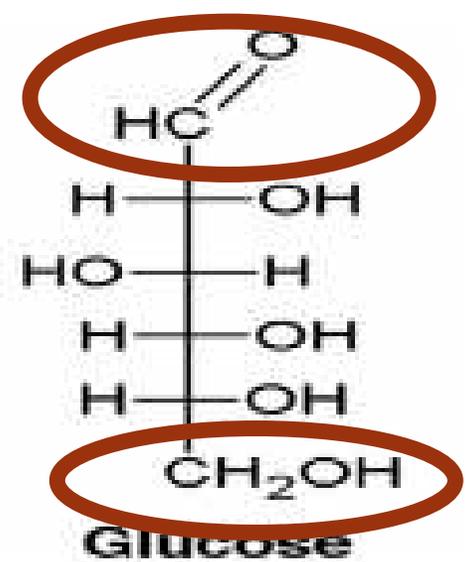
- ❑ They are substances that are **derived** from **monosaccharides**
- ❑ They include:
 1. **Sugar acids**
 2. **Sugar alcohol**
 3. **Deoxy sugars**
 4. **Amino sugars**



Monosaccharides Derivatives

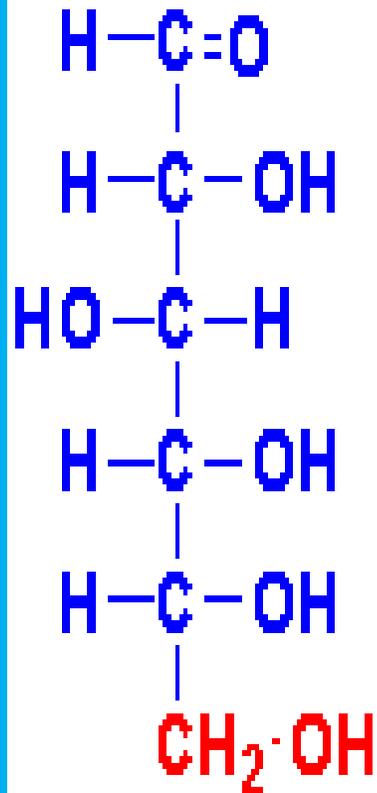
- ✓ They are substances that are **derived** from **monosaccharides**
- ✓ Includes

1. Sugar acids
2. Sugar alcohols
3. Deoxy sugar
4. Amino sugars

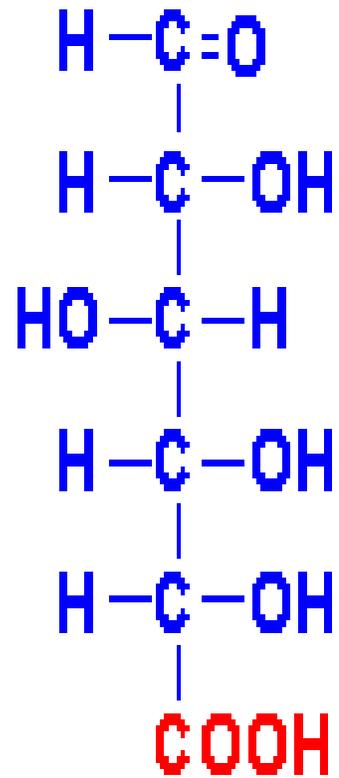


Derivative	Results of	Clinical importance
1- Sugar acids: a) Aldonic acids	Due to Oxidation of monosaccharides ✓ Oxidation of the carbonyl group gives aldonic acid . <p style="text-align: center;">Glucose oxidase</p> Eg: Glucose \longrightarrow Gluconic acid	Oxidation of glucose by Glucose oxidase is the principle of measuring the amount of glucose in urine and in blood using test strips .
b) Uronic acids	✓ Oxidation of the last carbon gives uronic Eg: Glucose \longrightarrow D glucuronic acid	Glucuronic acid is used in 1. Formation of mucopolysaccharides 2. Detoxification and excretion of certain substances.

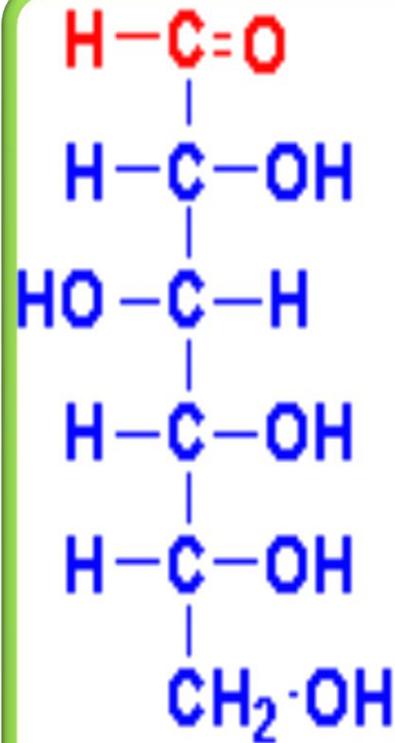
SUGAR ACIDS



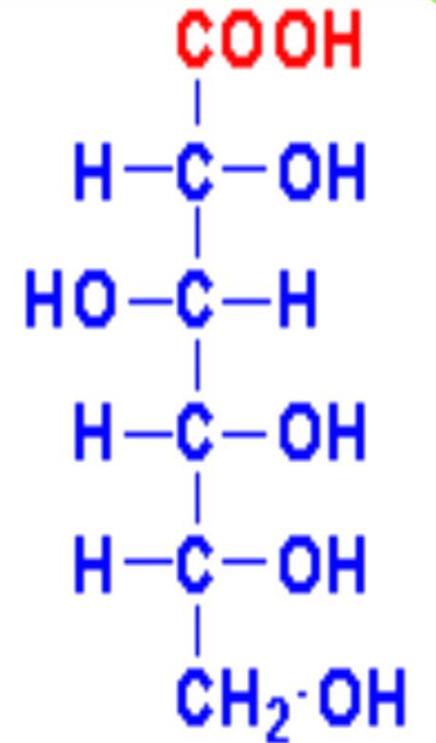
Glucose



Glucuronic acid



Glucose



Gluconic acid

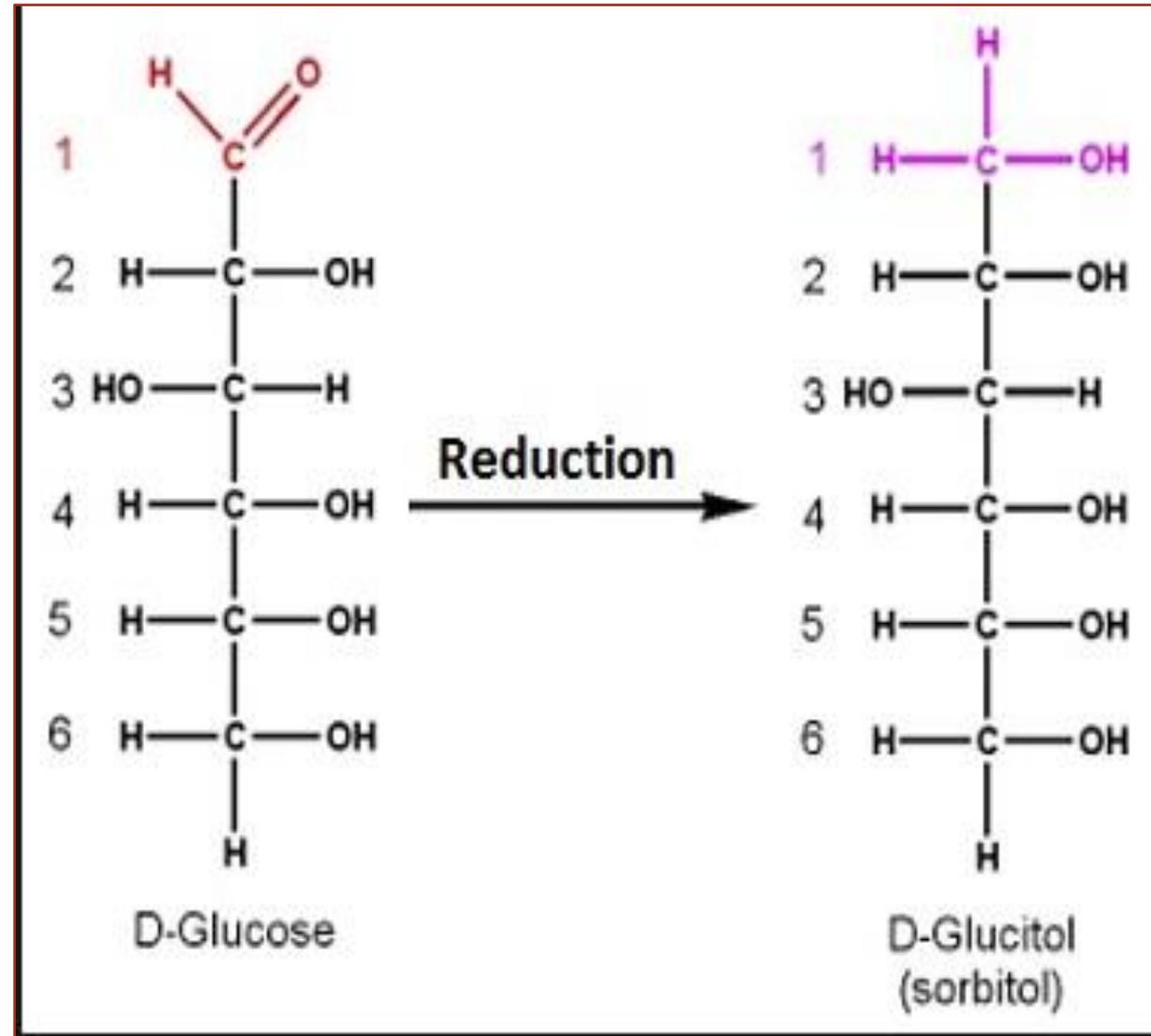


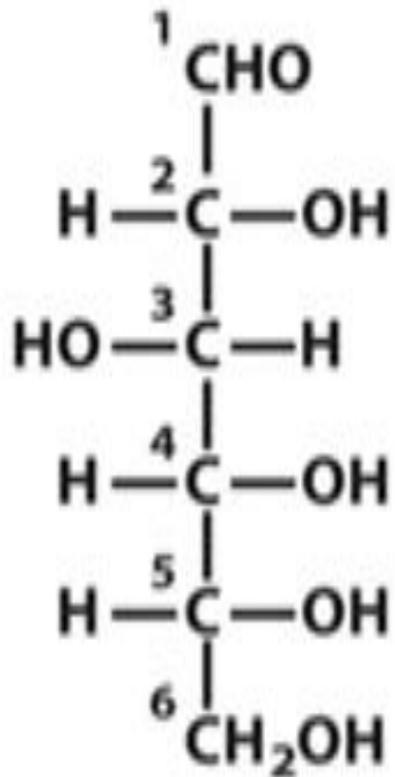
Monosaccharides Derivatives cont.

Derivative	Results of	Clinical importance
2-Sugar alcohols (Alditols)	✓ Reduction of mono-saccharides.	1. Glucose → Sorbitol, 2. Mannose → Mannitol, 3. Galactose → Galactitol (Dulcitol). 4. Fructose → Sorbitol or Mannitol.
3-Deoxy-sugars:	✓ one OH group is replaced by H at C-2 (1 oxygen is missed) Eg. 2-Deoxy-D-ribose	2-Deoxy-D-ribose is a constituent of DNA
4-Amino-sugars:	✓ OH group is replaced by an amino group at the C-2 position. e.g. D-glucosamine and D-galactosamine.	Amino sugars are found in glycosaminoglycans and glycoproteins

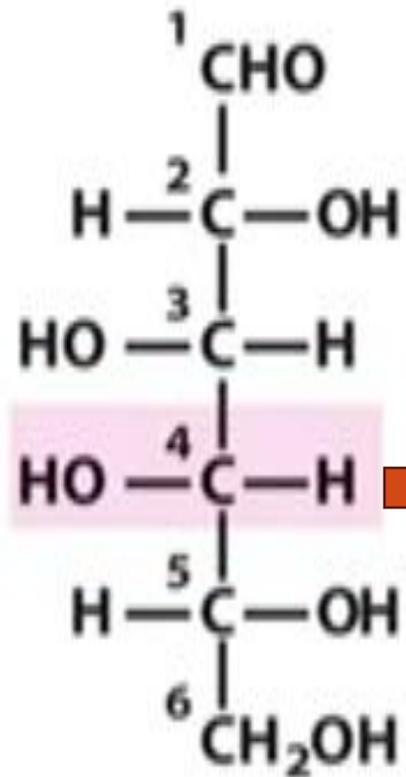


SUGAR ALCOHOLS (ALDITOLS)

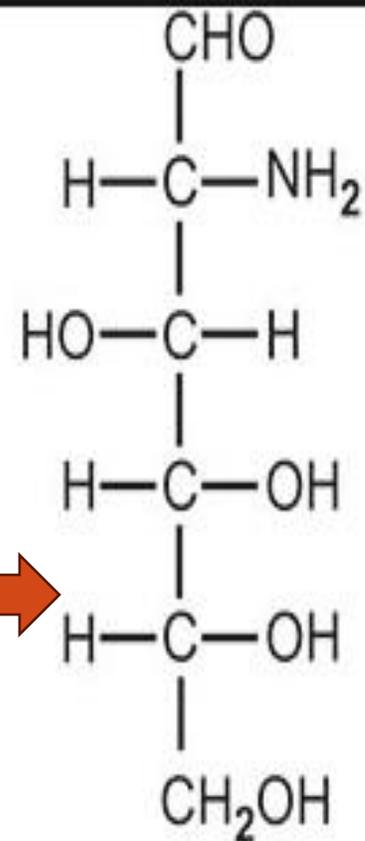




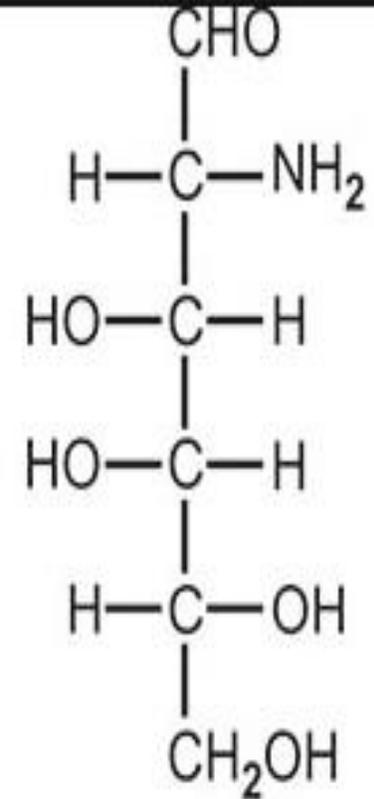
D-Glucose



D-Galactose



Glucosamine



Galactosamine

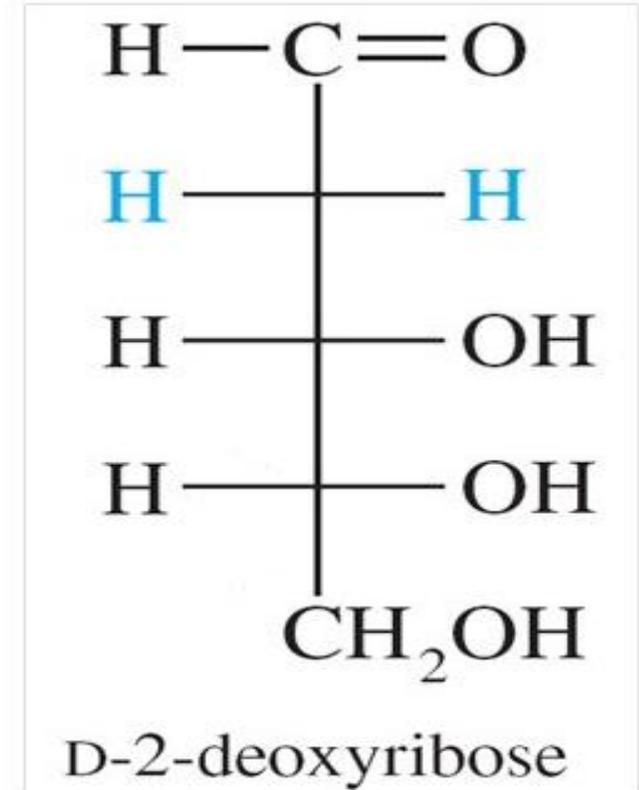
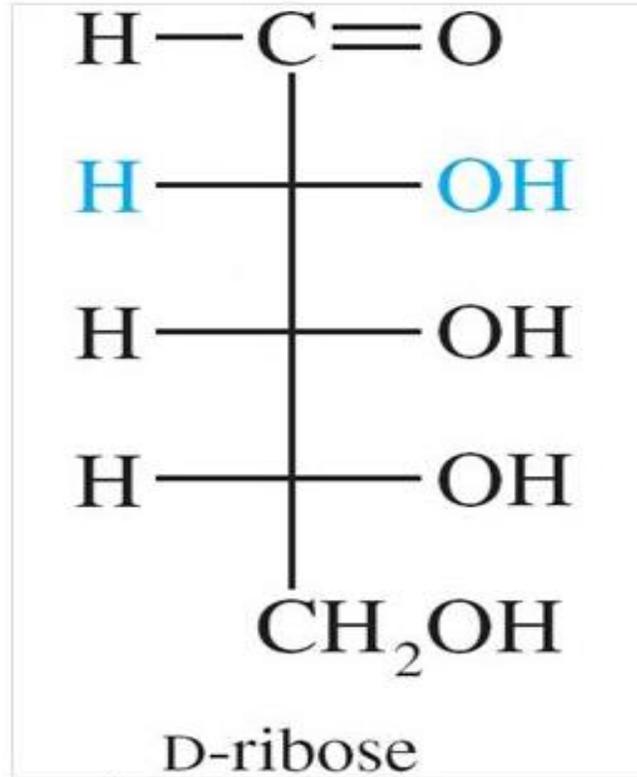
AMINO-SUGARS

Figures are for demonstration ONLY



DEOXY-SUGARS

(Ribose and Deoxyribose)



Figures are for demonstration **ONLY**





Assessment





Galactose is a main constituent of :

a) Milk sugar

b) Cane sugar

c) Honey

d) Chitin

e) Malt sugar



MCQ2

The highest concentration of fructose is found

a) Aqueous humor

b) Vitreous humor

c) Synovial fluid

d) Seminal Fluid

e) Amniotic fluid



**TRUE OR
FALSE**

1) Polysaccharides are large carbohydrate molecules that made up of more than 3 units of monosaccharides ()

2) Pentose is a disaccharide important in RNA ()

3) Maltose is a polysaccharide formed of glucose and fructose()



**SHORT
ANSWER
QUESTIONS**

1. Classify carbohydrate

2. Define disaccharides and give 2 examples

3. Enumerate the biological importance of pentoses

4. Enumerate the biological importance of glucuronic acid

PART 2

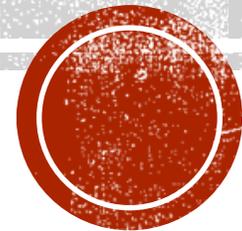
- **Disaccharides**
- **Polysaccharides**



Disaccharides

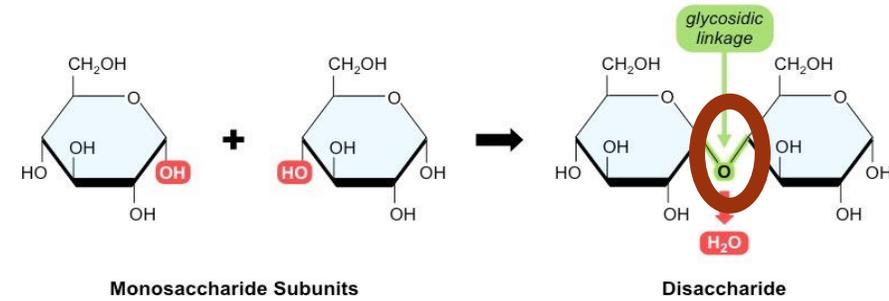
Definition

Classification



Definition of Disaccharides

- Disaccharides consist of **2 monosaccharide** units
- joined by an **O-glycosidic bond**.



Classification of Disaccharides

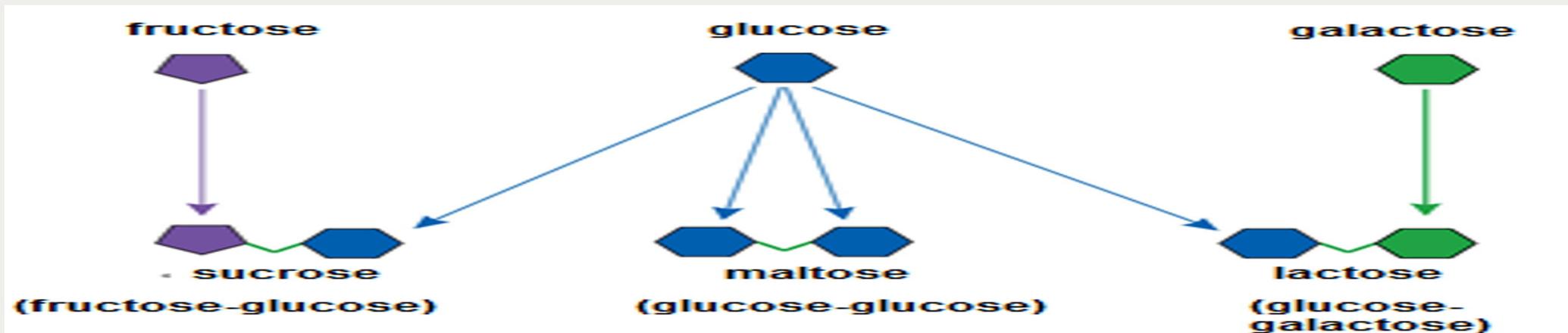
Homodisaccharides:

formed of the **same** monosaccharide e.g. **maltose**, **isomaltose** and **cellobiose**.

Heterodisaccharides:

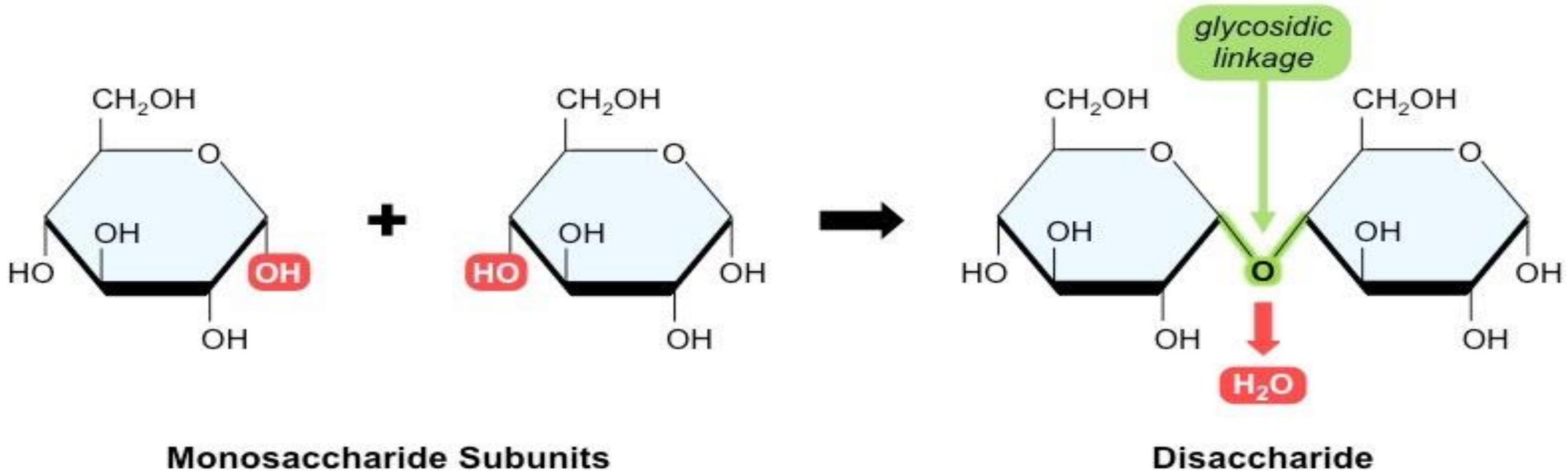
formed of **different** monosaccharide units e.g. **sucrose** and **lactose**

The most abundant disaccharides are sucrose, maltose, and lactose



Definition of Disaccharides

- Disaccharides consist of **2 monosaccharide** units
- joined by an **O-glycosidic bond**.



Classification of Disaccharides

1) Homodisaccharides:

formed of the **same**
monosaccharide

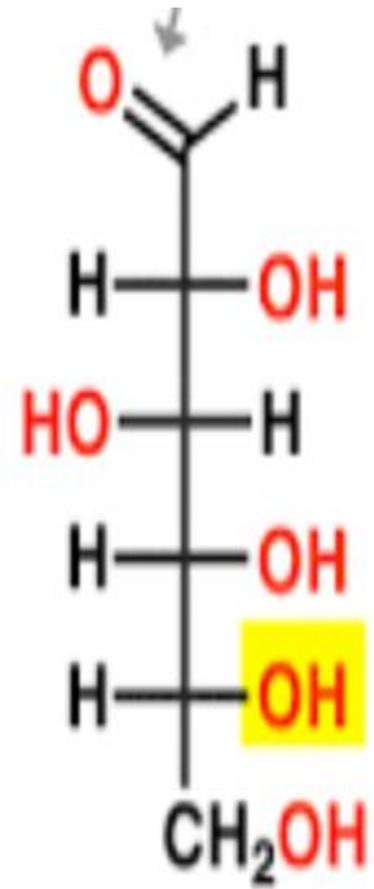
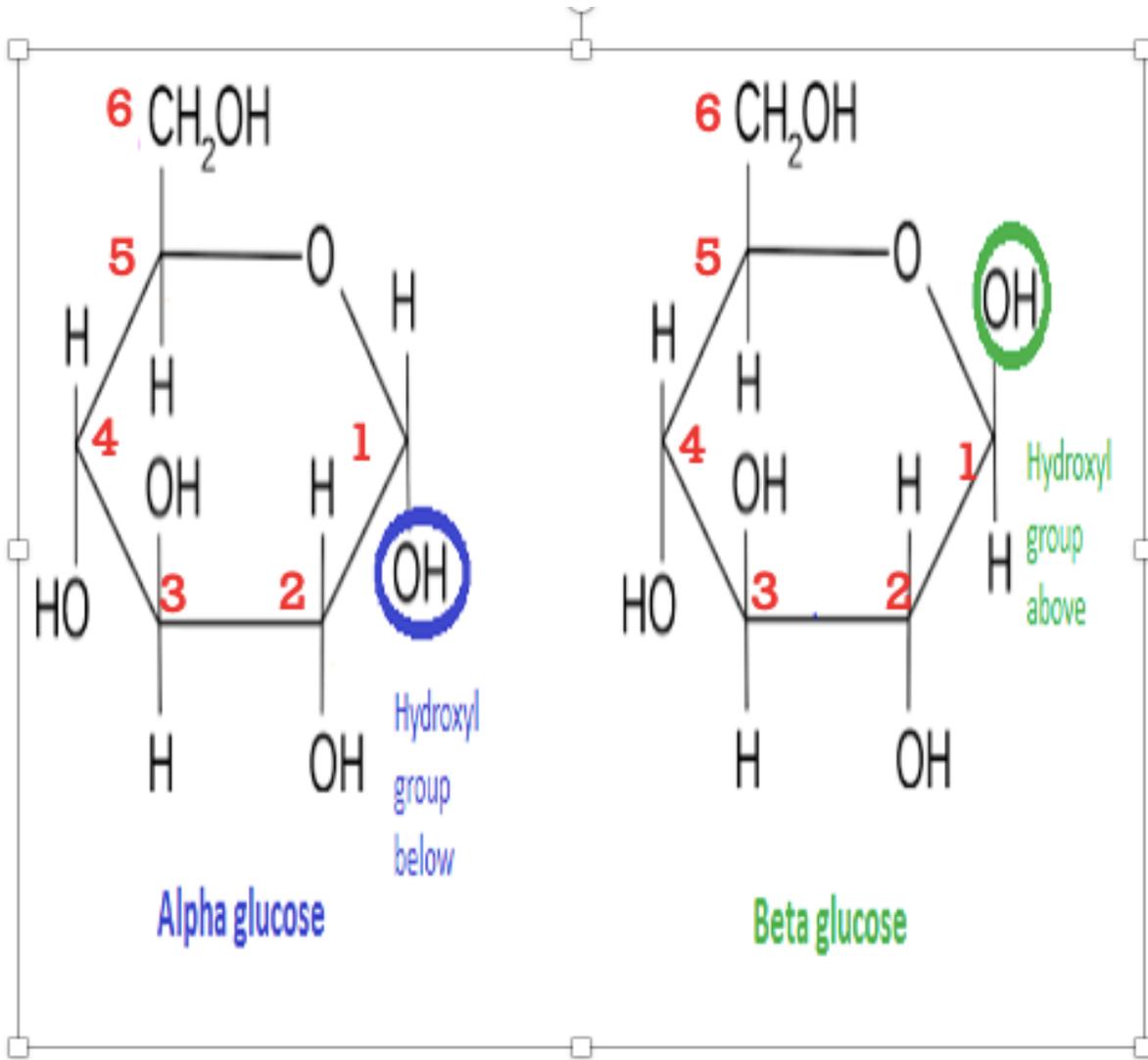
e.g. **maltose, isomaltose** and
cellobiose.

2) Heterodisaccharides:

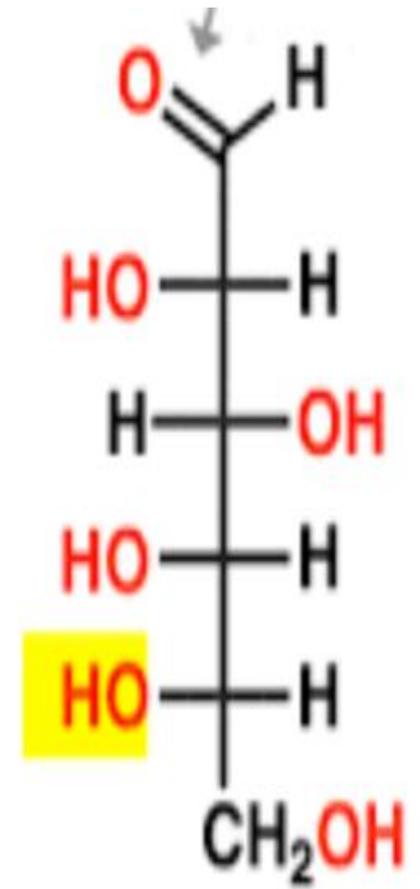
formed of **different**
monosaccharide units e.g.

e.g. **sucrose** and **lactose**





D-Glucose



L-Glucose



1.HOMODISACCHARIDES

Maltose (malt sugar)

Isomaltose

Cellobiose

Structure

Two α -glucose units

Two α -glucose units

Two units β D-glucopyranose

Bond

α 1-4 glycosidic

α 1-6 glycosidic

β 1-4 glycosidic

Reduction

Reducing sugar

Reducing sugar

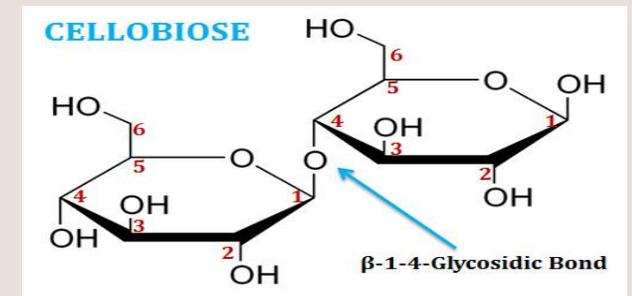
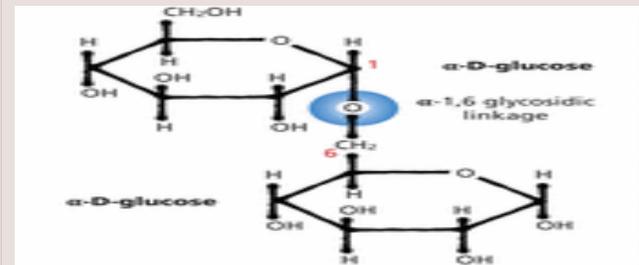
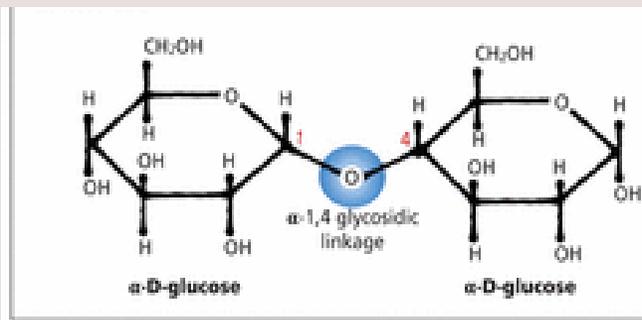
Reducing sugar

Source

From **starch** by the action of **amylase** enzymes

Hydrolysis of polysaccharides such as **dextran**.

some Acid hydrolysis of **cellulose**



2. HETERODISACCHARIDES

Disaccharide

Sucrose

Lactose (milk sugar)

Structure

α -glucose and β -fructose

β -galactose and β -glucose

Bond

α -1- β -2 glycosidic bond
(involving the anomeric Cs)

β (1-4) link with free

anomeric C.

Reduction

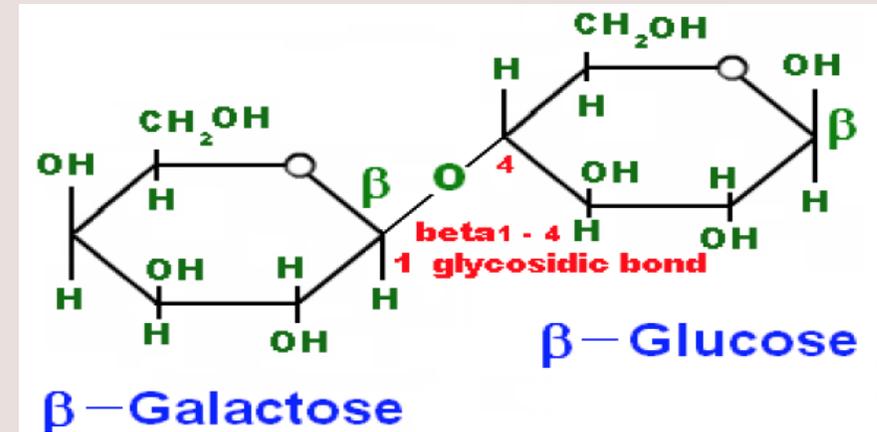
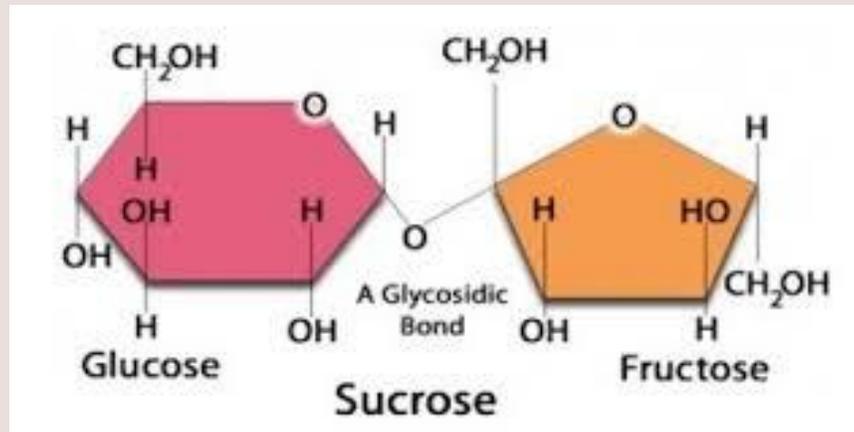
non reducing sugar
(no free active carbonyl group)

It is a reducing sugar
(presence of free active carbonyl group)

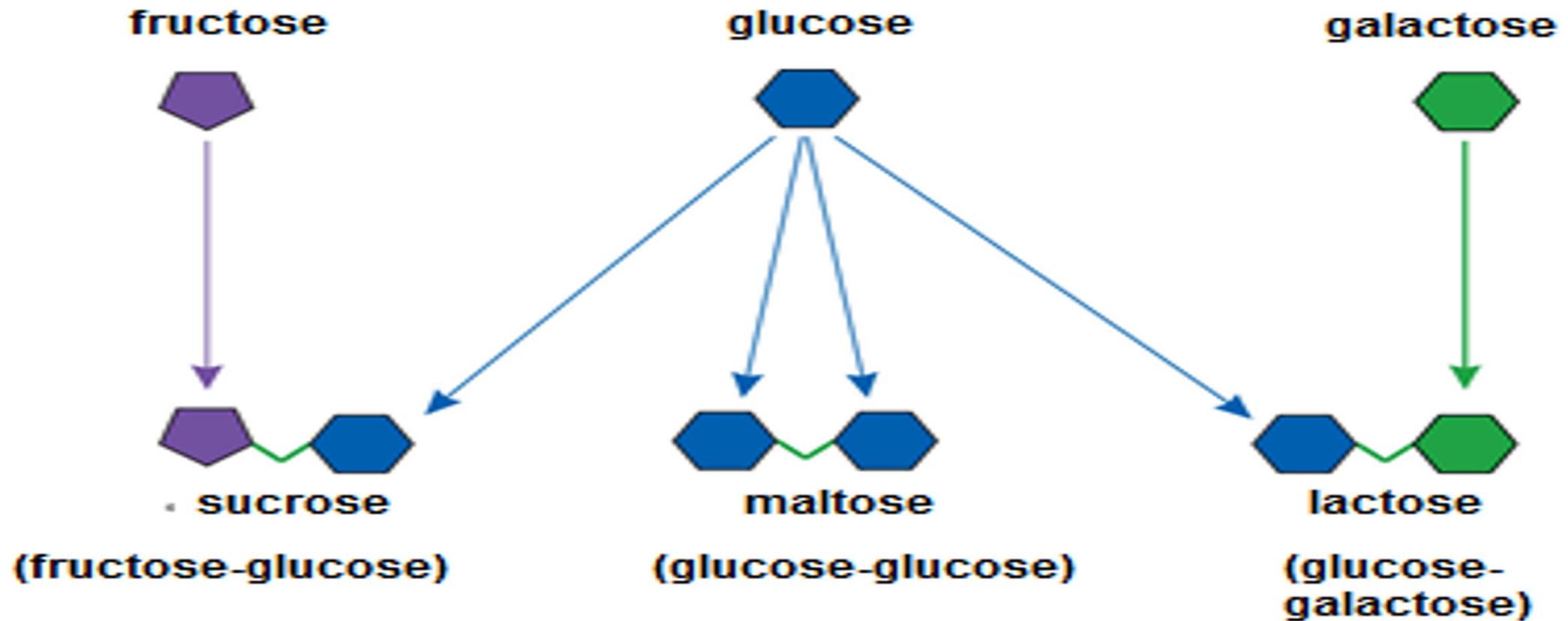
Source

Fruits and vegetable

principal carbohydrate in milk



The most abundant disaccharides are sucrose, maltose, lactose



Polysaccharides

Definition

Classification

Biological importance



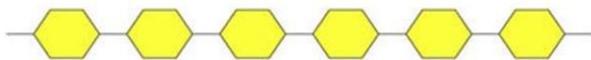
Definition of polysaccharides

Polysaccharides, also called **glycans**, consist of **more than 10** monosaccharide units and/or their derivatives joined together by **glycosidic linkage**.

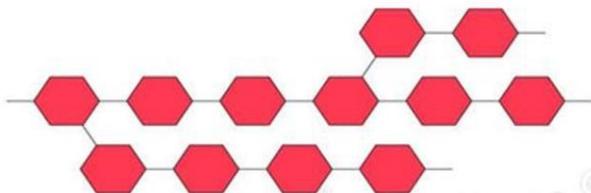
Classification of polysaccharide

Homopolysaccharides (homoglycans):

contain only **one type of monosaccharide**. E.g. starch, glycogen, dextrin, cellulose, inulin



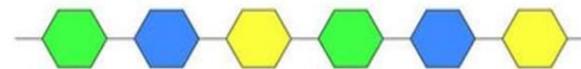
HOMOPOLYSACCHARIDE
UNBRANCHED



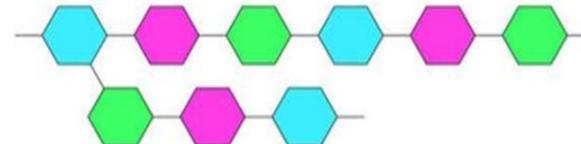
HOMOPOLYSACCHARIDE
BRANCHED

Heteropolysaccharides (heteroglycans):

contain **more than one type of monosaccharides**. E.g. glycosaminoglycans (GAGs, mucopolysacchrides),

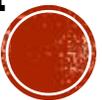


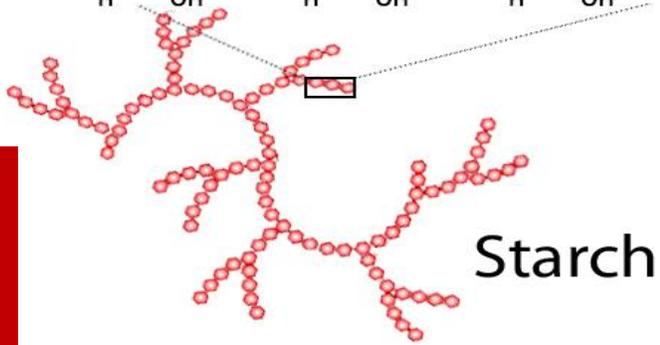
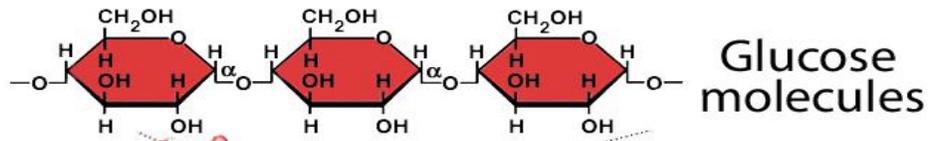
HETEROPOLYSACCHARIDE
UNBRANCHED



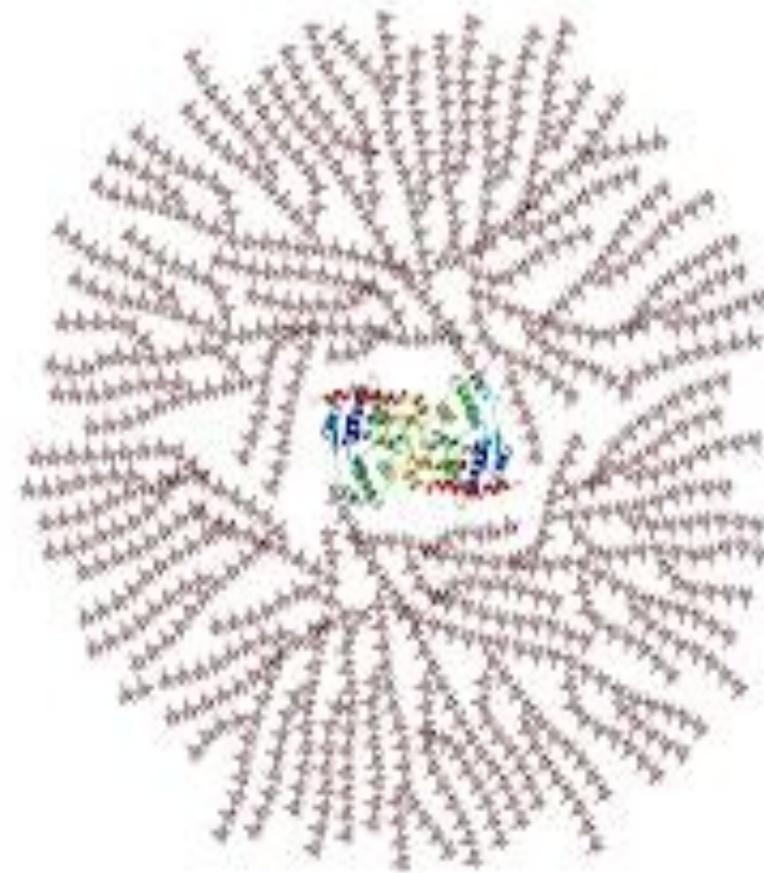
HETEROPOLYSACCHARIDE
BRANCHED

1. HOMOPOLYSACCHARIDES

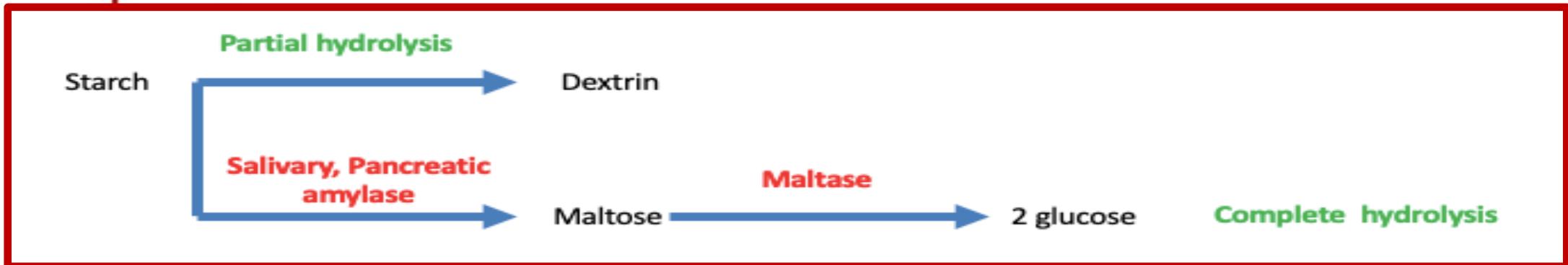
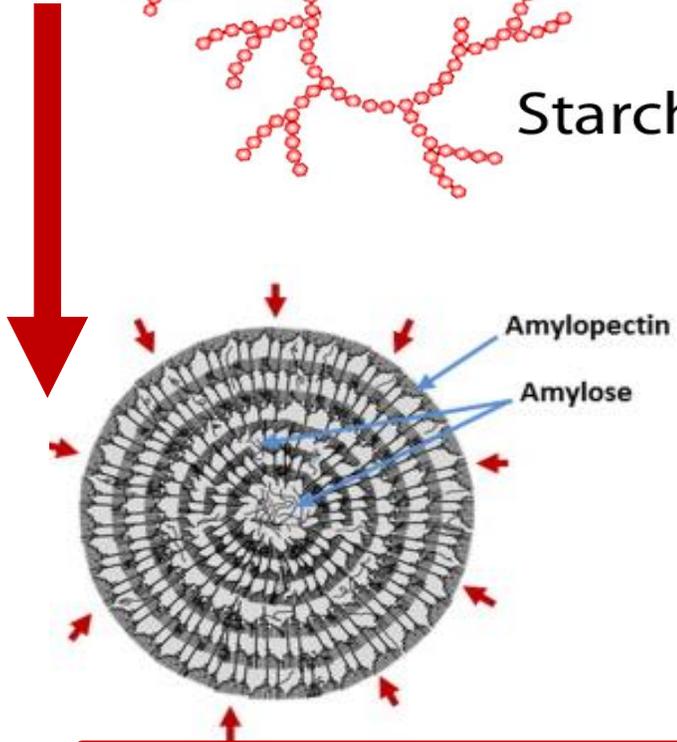
Disaccharide	1-Starch	2-Glycogen (animal starch)
Structure	<ul style="list-style-type: none"> ➤ It is a glucosan (α-D glucose units) ➤ consists of 2 layers: <ol style="list-style-type: none"> 1. Inner linear non branching layer called amylose. 2. Outer highly branched layer called amylopectin. 	<ul style="list-style-type: none"> ➤ It is formed of α-glucose units (glucosan) ➤ It is highly branched molecule
Function	<ol style="list-style-type: none"> 1. It is the most common storage polysaccharide in plants 2. Acts as a basic source of energy (more than half of CHO taken by human are starch). 	<ol style="list-style-type: none"> 1. The major form of storage polysaccharides in animals and human body. 2. It is found mainly in liver (about 10% of liver mass) and skeletal muscle (about 1 to 2 % of muscle mass). In fasting: breakdown of glycogen to maintain blood glucose level during fasting 



STARCH



GLYCOGEN



1.HOMOPOLYSACCHARIDS CONT.

	3-Dextrin	4-Cellulose
Structure	Several α -glucose units linked by α 1-4 linkage, and the link α 1-6 at the branching point	Several β -D-glucose units.
Function	Dextrin is used 1. As mucilage 2. in infant feeding	<ul style="list-style-type: none"> ➤ Most abundant natural polymer found in the world. It is the structural component of the cell walls of nearly all plants. ➤ Cellulose is not digested in human due to absence of β glucosidase enzyme → increase bulk of food in intestine → increase peristalsis → prevent constipation??? <p>application</p> 

2. HETEROPOLYSACCHARIDES

- **Other names:** = Glycosaminoglycans (**GAGs**) = Mucopolysaccharides
- **Structure of GAGs :** long linear unbranched chains composed of a repeating disaccharide unit (sugar acids-amino sugar)ⁿ.
 1. **The amino sugar :** either **D-glucosamine** or **D-galactosamine**)
 2. **The sugar acid:** either **glucuronic** or **L- iduronic**



➤ TYPES OF HETEROPOLYSACCHARIDES (GAGS)

Type	Site	Main function
1-Heparin	Intracellular GAGs	Anticoagulant
2-Heparan sulfate	Extracellular GAG	Component of cell surface
3-Hyaluronic acid	Synovial fluid of joints	lubricant and shock absorbent
4-Keratan sulfate	cornea, cartilage	
5-Chondroitin sulfate	cartilage, tendons, ligaments	Protective and supportive
6-Dermatan sulfate	skin, bone, blood vessels	



BELIEVE IN
YOURSELF



REFERENCES

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- ❑ **Vasudevan's Textbook of Biochemistry For Medical Students, 6th Edition.**
- ❑ **Lippincott's Illustrated Reviews: Biochemistry, 8th edition.**

