



Carbohydrates



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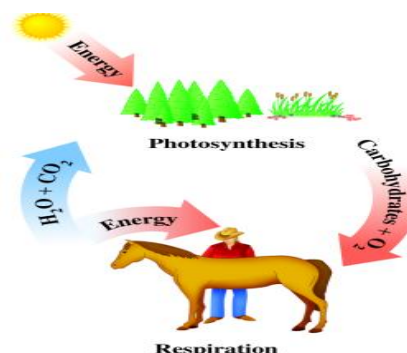
Definition:-

Carbohydrates may be defined chemically as *aldehyde* or *ketone* derivatives of polyhydroxy alcohols or as compounds that yield these derivatives on hydrolysis

Carbohydrates are

- A major source of energy from our diet.
- Composed of the elements C, H, and O.
- Also called saccharides, which means “sugars.”
- Carbohydrates are produced by photosynthesis in plants.

glucose is synthesized in plants from CO_2 , H_2O , and energy from the sun then oxidized in living



cells (respiration) to produce CO_2 , H_2O , and energy.

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Functions of Carbohydrates:

- 1 - Source of energy for living beings, e.g. *glucose*
- 2 - Storage form of energy, e.g. *glycogen* in animal tissue and *starch* in plants
- 3 - Serve as structural component, e.g. *glycosaminoglycans* in humans, *cellulose* in plants and *chitin* in insects
- 4 - Non-digestible carbohydrates like cellulose, serve as dietary fibers
- 5 - Constituent of nucleic acids RNA and DNA, e.g. *ribose* and *deoxyribose* sugar
- 6 - Play a role in lubrication, cellular intercommunication and immunity
- 7 - Carbohydrates are also involved in detoxification, e.g. *glucuronic acid*



Classification of Carbohydrates

Carbohydrates are classified into three groups:

1. Monosaccharides=single unit
2. Oligosaccharides =2-10 units
3. Polysaccharides >10 units

The suffix ose indicates that a molecule is a carbohydrate .e.g maltose, glucose, lactose, fructose ,ribose

Monosaccharides (Greek: Mono = one)

- Monosaccharides are also called *simple sugars*. The term sugar is applied to carbohydrates that are soluble in water and sweet to taste
- They consist of a single unit
- polyhydroxy aldehyde or ketone unit, and thus cannot be hydrolyzed into a simpler form.

Monosaccharides may be subdivided into two groups as follows:

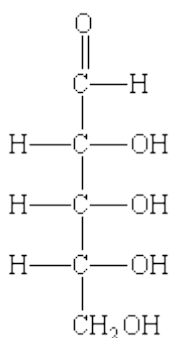
1. Depending upon the number of carbon atoms they possess, e.g.

- | | | |
|-------------|----------|------------------------------|
| • Trioses | 3 carbon | Glyceraldehyde |
| • Tetroses | 4 carbon | Erythrose |
| • Pentoses | 5 carbon | Ribose, Xylose |
| • Hexoses | 6 carbon | Glucose, Galactose, fructose |
| • Heptoses. | 7 carbon | Glucoheptos |

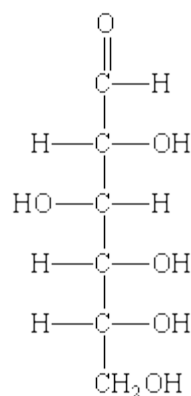
2. Depending upon the functional aldehyde (CHO) or ketone (C=O) group present:

- | | | |
|-----------|-----|--------------------|
| • Aldoses | CHO | Glucose, Galactose |
| • Ketoses | C=O | Fructose |

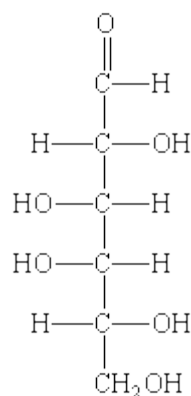
ALDOSES:



D-ribose



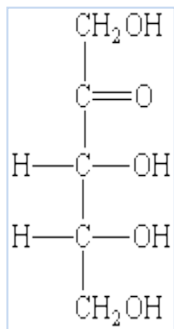
D-glucose



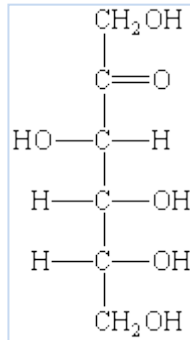
D-galactose



KETOSES:



D-ribulose



D-fructose

GLUCOSE

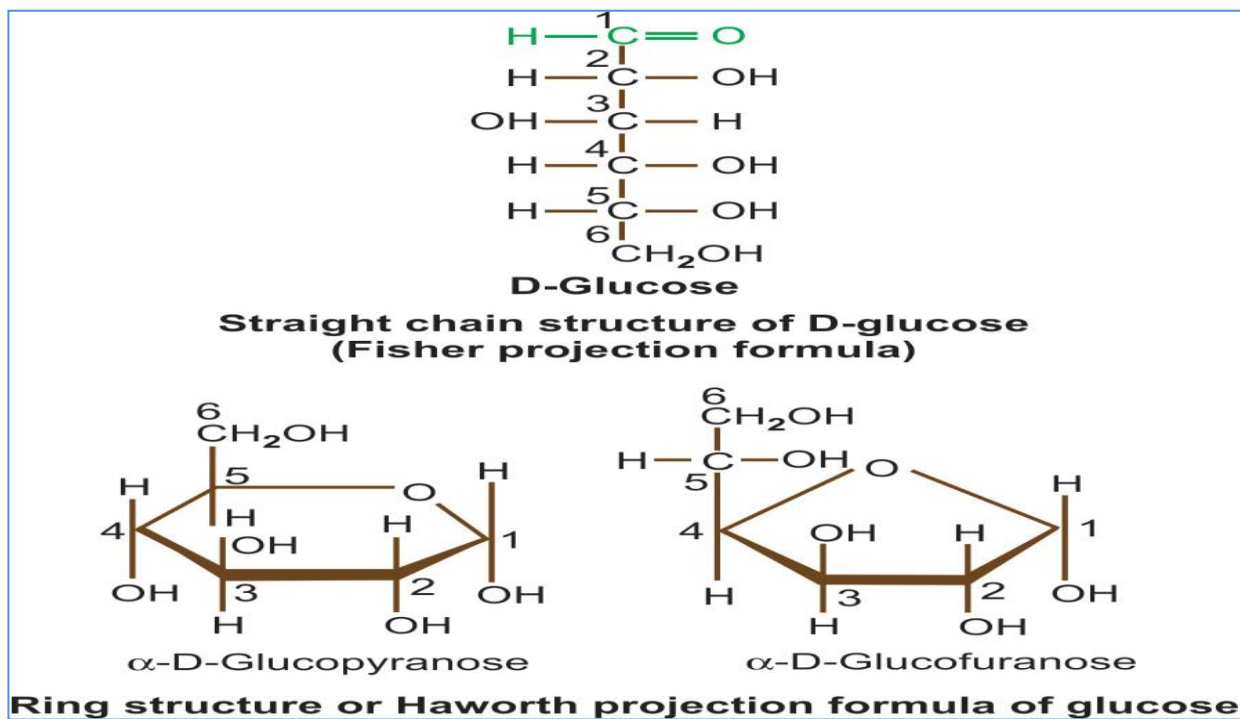
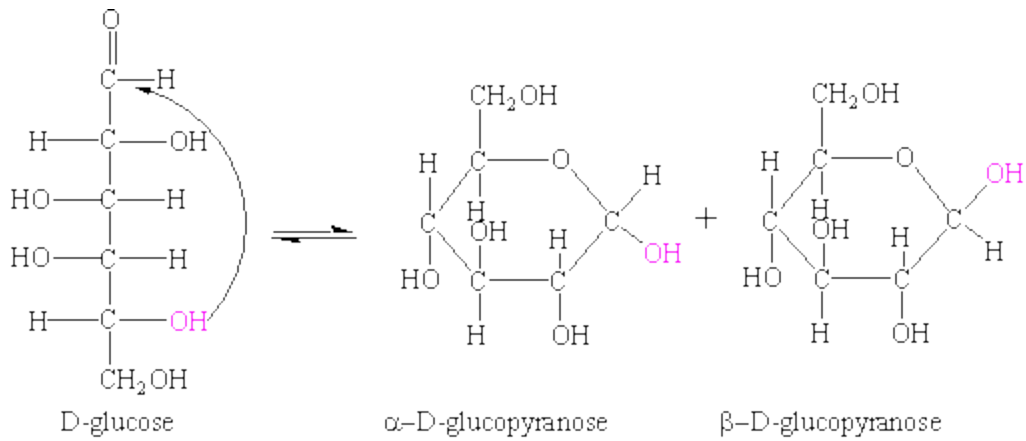
- Physiologically and biomedically , glucose is the most important monosaccharide
- It is called blood sugar
- $\text{C}_6\text{H}_{12}\text{O}_6$
- It is monosaccharide (aldose)
- It is source of energy
- It is produced by hydrolysis of glycogen

Anomerism

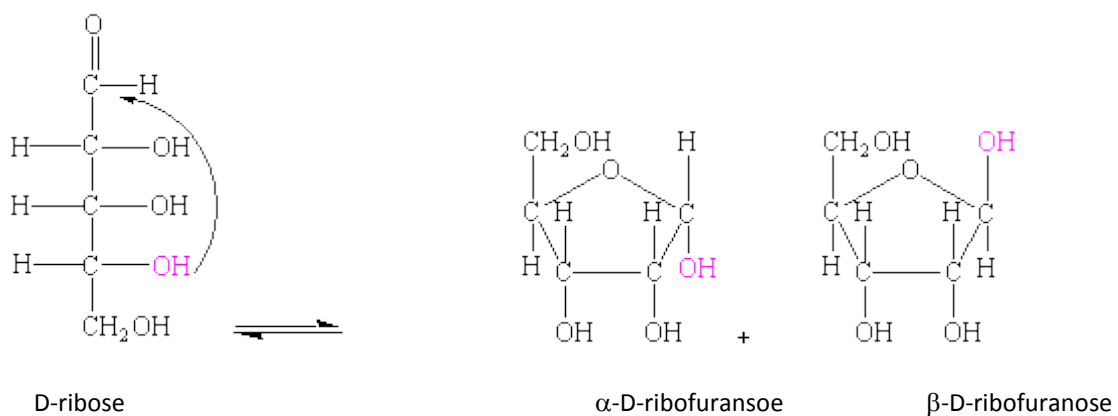
α and β Anomerism

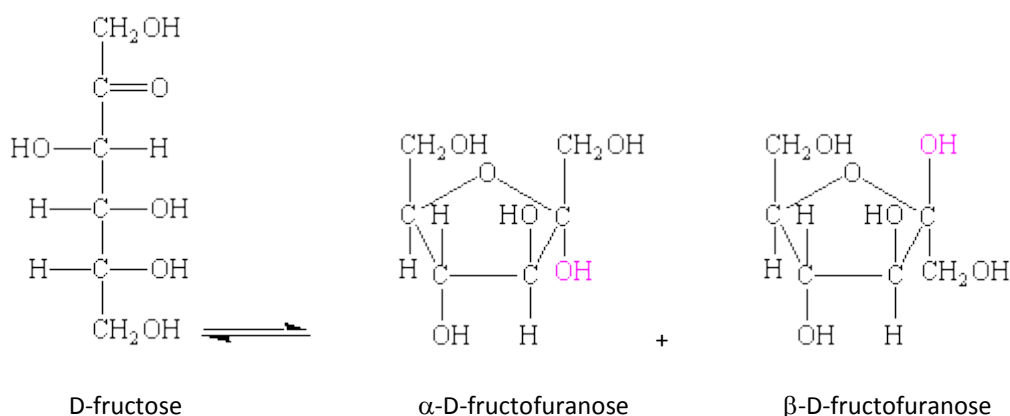
- The predominant form of glucose and fructose in a solution are not an open chain. Rather, the open chain form of these sugar in solution cyclize into rings. An additional asymmetric center is created when glucose cyclizes. Carbon-1 of glucose in the open chain form, becomes an asymmetric carbon in the ring form and two ring structures can be formed. These are:
 - α -D-glucose
 - β -D-glucose.
- The designation α means that the hydroxyl group attached to C-1 is below the plane of the ring, β means that it is above the plane of the ring. The C-1 carbon is called the **anomeric carbon atom** and so, α and β forms are anomers





.When a five-membered ring is formed, it is called a *furanose*, shown in the figure below





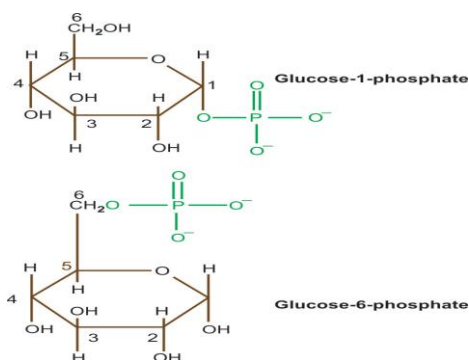
- **isomerism**

- Glucose and fructose are isomers of each other having the same chemical (molecular) formula $C_6H_{12}O_6$, but they differ in structural formula. There is a **keto** group in position 2 of fructose and an **aldehyde** group in position 1 of glucose. This type of isomerism is known as **ketose-aldose isomerism**.

GLYCOSIDE FORMATION: Glycosides are formed when the hydroxyl group of anomeric carbon of a monosaccharide reacts with **OH** or **NH** group of second compound that may or may not be a carbohydrate. The bond so formed is known as **glycosidic bond**.

- The monosaccharides are joined by glycosidic bonds to form **disaccharides**, **oligosaccharides** and **polysaccharides**.

Phosphoric acid ester of glucose



Asymmetric carbon: Asymmetric carbon: carbon atom which attached to four(4)different groups

D and L isomerism

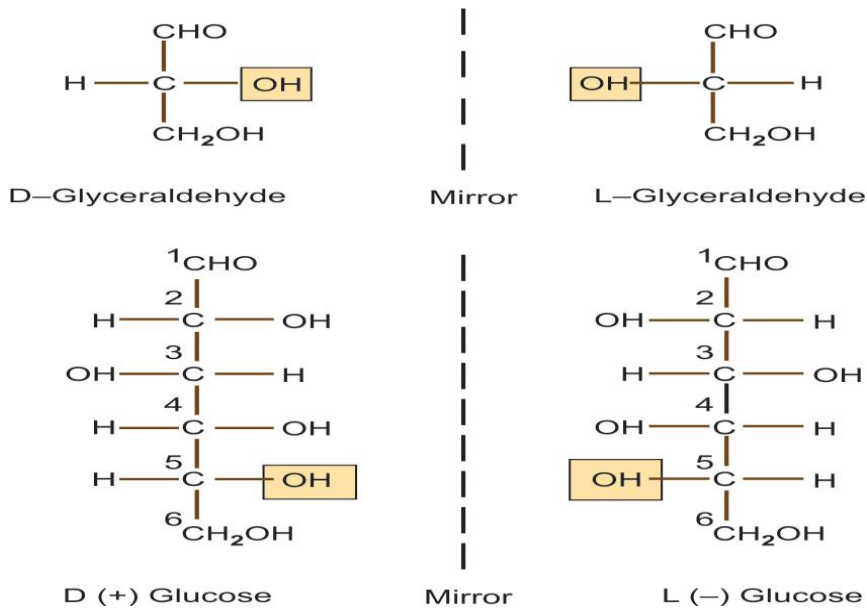
D and L isomerism depends on the orientation of the H and OH groups around the asymmetric carbon atom adjacent to the terminal primary alcohol carbon, e.g. carbon atom number 5 in glucose determines whether the sugar belongs to D or L isomer.

- When OH group on this carbon atom is on the right, it belongs to **D-series**, when it is on the left, it is the member of the **L-series**.



- The structures of D and Lglucose based on the reference monosaccharide, D and L glyceraldehyde, a three carbon sugar

D and L isomerism



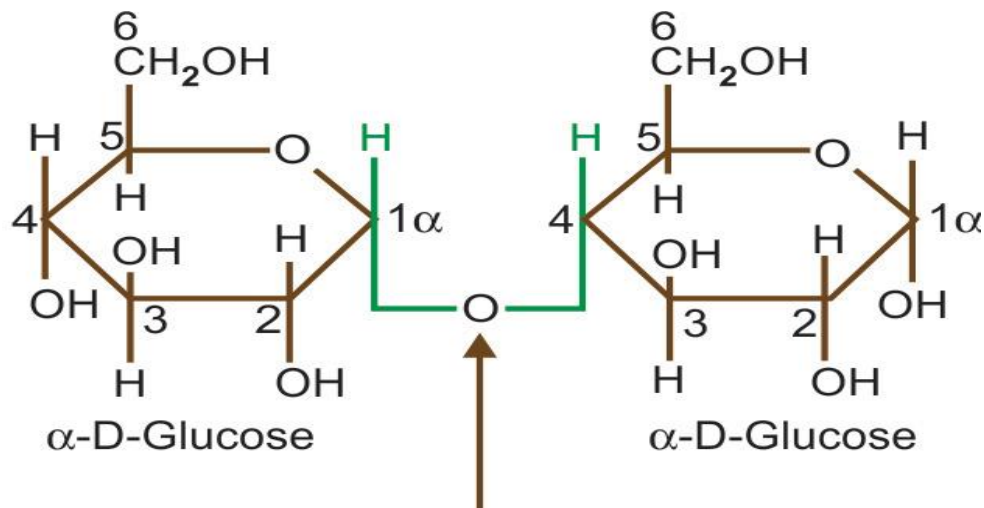
Disaccharides

- Disaccharides consist of two monosaccharide units.
- They are crystalline, water soluble and sweet to taste. they are divided to:
 - 1.Reducing disaccharides with free carbonyl group , e.g. maltose, lactose
 2. Non-reducing disaccharides with no free carbonyl group, e.g. sucrose.

Maltose

- Maltose contains two glucose residues, joined by glycosidic linkage between C-1 (the anomeric carbon) of one glucose residue and C-4 of the other ,leaving one free anomeric carbon of the second glucose residue, which can act as a reducing agent. Thus, maltose is a **reducing disaccharide**.





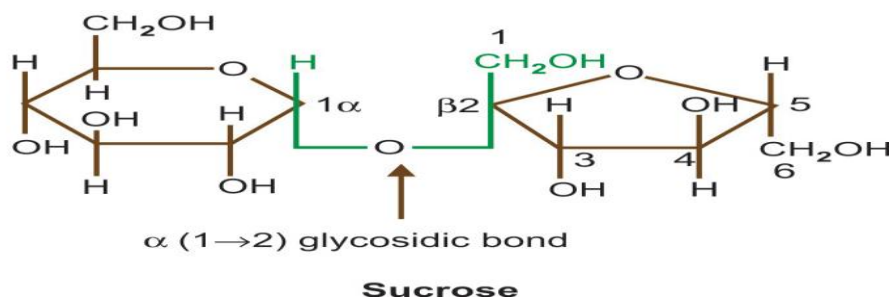
- Maltose=Glucose + Glucose it is reducing sugar

Sucrose (Common Table Sugar)

- Sucrose is a **disaccharide of glucose and fructose**. it is formed by plant but not by human beings. Sucrose is the commonly used **table sugar**. In contrast to maltose and lactose, sucrose is **non reducing** sugar (why?)

because sucrose contains no free anomeric carbon atom the anomeric carbon of both glucose and fructose are involved in the formation glycosidic bond.

Sucrose= Glucose + Fructose



Oligosaccharides (Greek: oligo = few)

- Oligosaccharides consist of a short chain of monosaccharide units (2 to 10 units), joined together by a characteristic bond called **glycosidic bond** which, on hydrolysis, gives two to ten molecules of simple sugar (monosaccharide) units.

Polysaccharides

- Carbohydrates composed of ten or more units of monosaccharide



- Polysaccharides are colloidal in size. In polysaccharides, monosaccharide units are joined together by glycosidic linkages. Another term for polysaccharides is a "**glycans**". Polysaccharides are subclassified in two groups :-

1. **Homopolysaccharides** (Homoglycans): When a polysaccharide is made up of several units of one and the same type of monosaccharide unit only, it is called homopolysaccharide. e.g. starch, glycogen

2. **Heteropolysaccharides** (Heteroglycans): They contain two or more different types of monosaccharide units or their derivatives. e.g. hyaluronic acid.

Starch

- It is the storage form of glucose in plants, e.g. in potato. Starch is composed of two constituents. 1- ***amylose*** and. 2- ***amylopectin***

Amylose is a linear polymer of D-glucose units joined by α -1 \rightarrow 4 glycosidic linkages

- Amylopectin: amylopectin is a **branched** polymer, it is structurally identical to those of amylose (α -1 \rightarrow 4 glycosidic linkages) but with side chains joining them by α -1 \rightarrow 6 linkages. Thus, having both α -(1 \rightarrow 4) and α -(1 \rightarrow 6) linkages.

- Glycogen (Animal Starch)**
- Glycogen is the major storage form of carbohydrate (glucose) in animals, found mostly in liver and muscle.
- It is often called ***animal starch***.
- The structure of glycogen is similar to that of amylopectin, except that it is more highly branched,

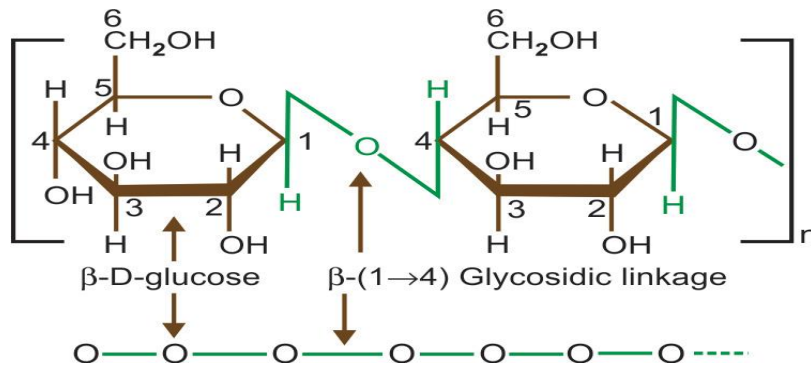
Functions of glycogen

- The function of muscle glycogen is to act as a readily available source of glucose for energy within muscle itself.
- Liver glycogen is concerned with storage and maintenance of the blood glucose

Cellulose



- Cellulose is the chief constituent of cell wall of plants.
- It is an unbranched polymer of glucose and consists of long straight chains which are linked by β -(1 \rightarrow 4) glycosidic linkages and not α -(1 \rightarrow 4) as in amylose.
- Since humans lack an enzyme **cellulase** that can hydrolyze the β -(1 \rightarrow 4) glycosidic linkages, ***cellulose cannot be digested and absorbed*** and has no food value unlike starch. However, the ruminants can utilize cellulose because they have in their digestive tract microorganisms whose enzymes hydrolyze cellulose



Structure of cellulose

