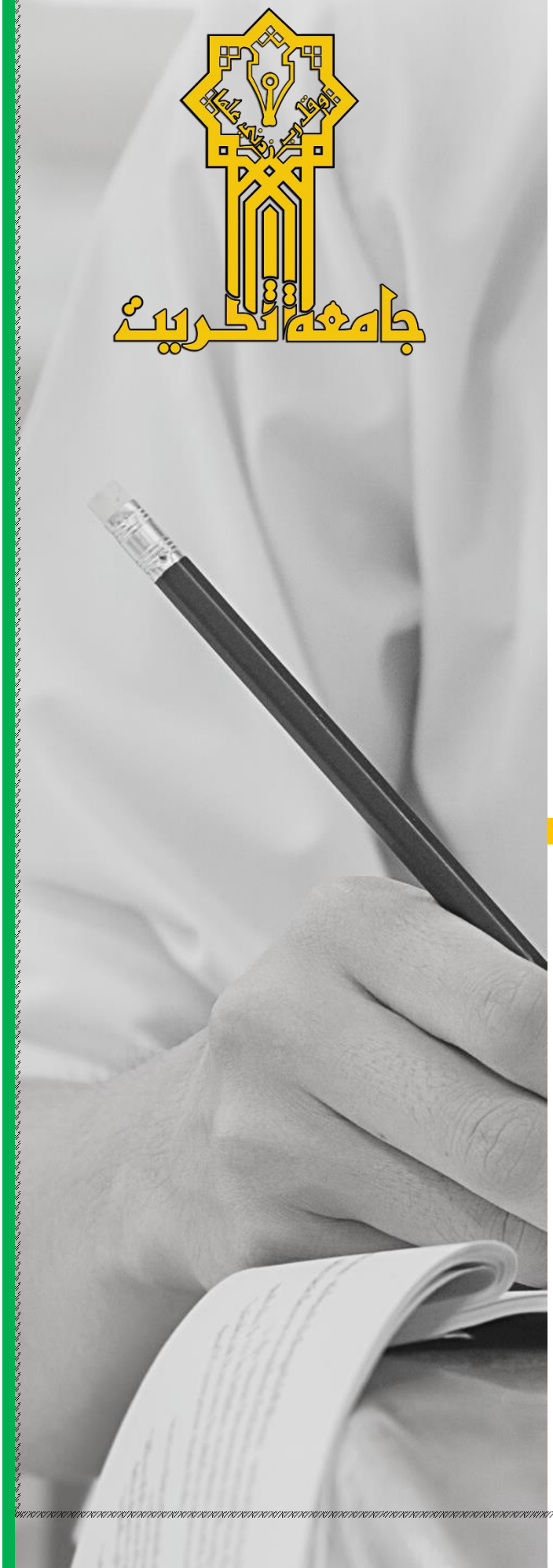

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carbohydates

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Carbohydrates

Definition:-

***Carbohydrates** are the most abundant macromolecules in nature. They are the main source and storage of energy in the body. They serve also as structural component of cell membrane. The general molecular formula of carbohydrate is $C_nH_{2n}O_n$ or $(CH_2O)n$, Chemically, they contain the elements Carbon, hydrogen and oxygen. Thus, they are Carbon compounds that contain large quantities of Hydroxyl groups. Carbohydrates in general are polyhydroxy aldehydes or ketones or compounds which give these substances on hydrolysis.

***Carbohydrates** in general are polyhydroxy aldehydes or ketones or compounds which give these substances on hydrolysis.

Functions of Carbohydrates:-

1 - Carbohydrates act as energy reserves, also stores fuels, and metabolic intermediates. e.g. glucose.

2 - Storage form of energy, e.g. glycogen in animal tissue and starch in plants.

3 - Polysaccharides like cellulose are the structural elements in the cell walls of bacteria and plants.

4 - Non-digestable carbohydrates like cellulose, serve as dietary fibers.

5 - Ribose and deoxyribose sugars forms the structural frame of the genetic material, RNA and DNA.

6 - Carbohydrates are linked to proteins and lipids that play important roles in cell interactions.

7 - Carbohydrates are also involved in detoxification, e.g. glucuronic acid.

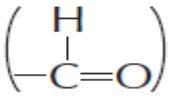
CLASSIFICATION OF CARBOHYDRATES

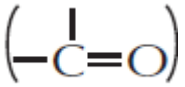
Carbohydrates are often referred to as saccharides (Greek: sakcharon–sugar). They are broadly classified into three major groups— **monosaccharides, oligosaccharides and polysaccharides**.

TABLE 2.1 Classification of monosaccharides with selected examples

Monosaccharides (empirical formula)	*Aldose*	*Ketose*
Trioses ($C_3H_6O_3$)	Glyceraldehyde	Dihydroxyacetone
Tetroses ($C_4H_8O_4$)	Erythrose	Erythrulose
Pentoses ($C_5H_{10}O_5$)	Ribose	Ribulose
Hexoses ($C_6H_{12}O_6$)	Glucose	Fructose
Heptoses ($C_7H_{14}O_7$)	Glucoheptose	Sedoheptulose

Monosaccharides

Monosaccharides (Greek : mono-one) are the simplest group of carbohydrates and are often referred to as simple sugars. They have the general formula Cn(H2O)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  are known as aldoses e.g. glyceraldehyde, glucose.

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

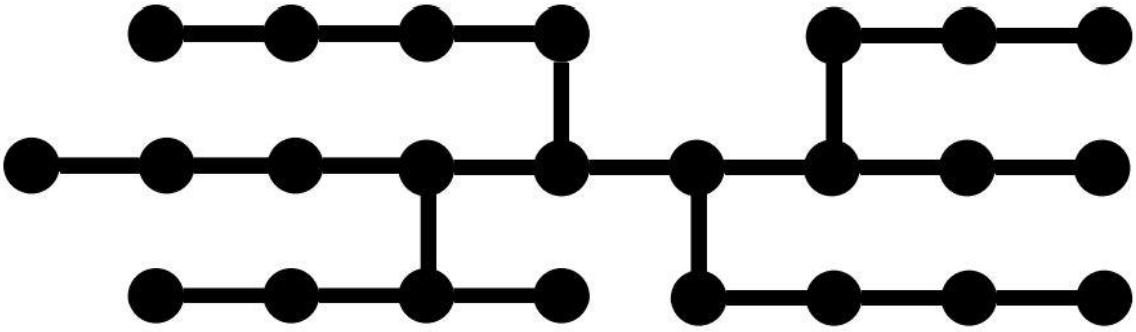
- Based on the number of carbon atoms, the monosaccharides are regarded as trioses (3C), tetroses (4C), pentoses (5C), **hexoses (6C)** and heptoses (7C). These terms along with functional groups are used while naming monosaccharides. For instance, **glucose is an aldohexose while fructose is a ketohexose** (**Table 2.1**).

• **Disaccharides** consist of two monosaccharide units linked together by a covalent bond (e.g., sucrose).

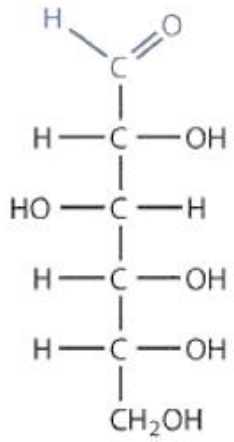
• **Oligosaccharide**s contain from 3 to 10 monosaccharide units (e.g., raffinose).

• **Polysaccharides** contain very long chains of hundreds or thousands of monosaccharide units, which may be either in straight or branched .

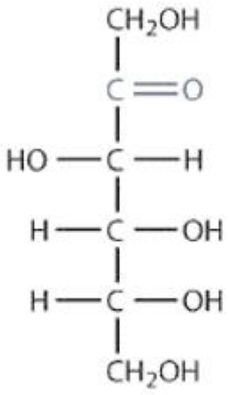
The polysaccharides are of two types – **homopolysaccharides** chains (e.g., cellulose, glycogen, starch) and **heteropolysaccharides**.



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



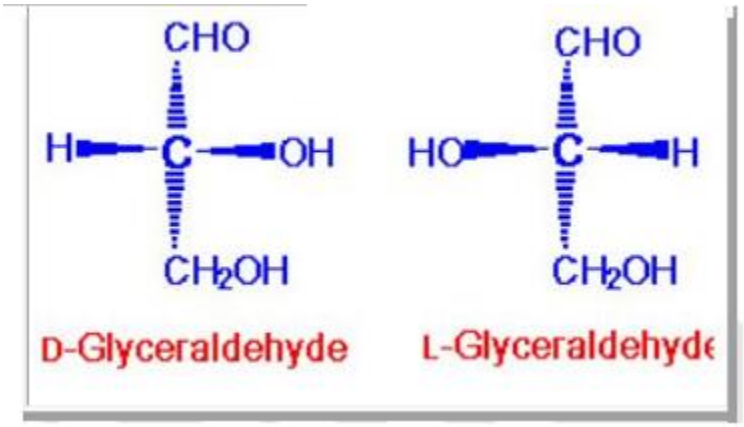
Glucose
(an aldohexose)



Fructose
(a ketohexose)

The Stereochemistry of Carbohydrates:-

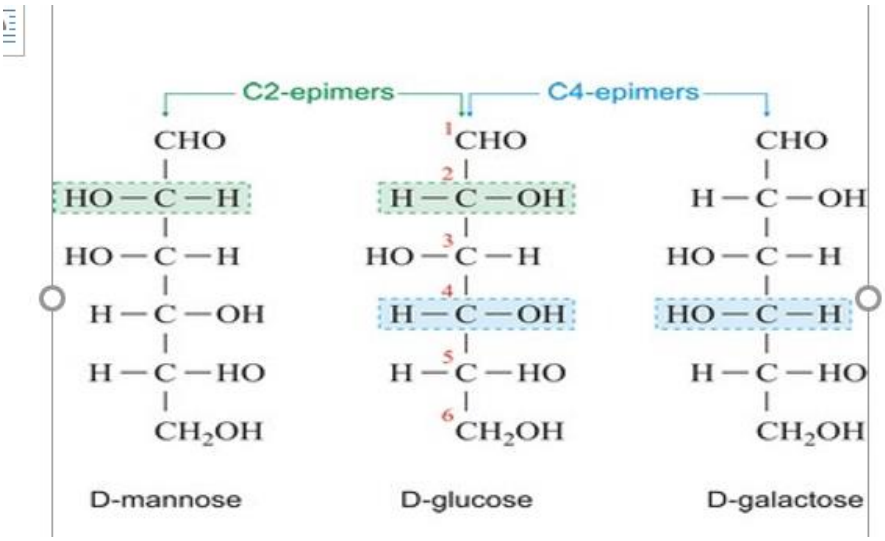
- **Stereoisomerism** is an important character of monosaccharides. Stereoisomers are the compounds that have the same structural formulae but differ in their spatial configuration.,
- **Glyceraldehyde** (triose) is the simplest monosaccharide with one asymmetric carbon atom. It exists as two stereoisomers and has been chosen as the reference carbohydrate to represent the structure of all other carbohydrates.



- A carbon is said to be **asymmetric when** it is **attached to four different atoms or groups**. or chiral carbon atoms and thus occur in optically active isomeric forms.
- The **D** and **L** isomers are mirror images of each other. When the - OH group on this carbon is on the right, the sugar is a member of the D-series, when it is on the left, it is a member of the L-series.
- These D and L configuration are also called Enantiomers.
- Optical activity is a characteristic feature of compounds with **asymmetric carbon** atom. When a beam of polarized light is passed through a solution of an optical isomer, it will be rotated either to the right The term **dextrorotatory (d+) and to the left levorotatory (l–)** are used to compounds that respectively rotate the plane of polarized light to the right or to the left.
- Molecules which rotate the plane of polarized light are optically active.
- Many biologically important molecules are chiral and optically active. Often, living systems contain only one of the possible stereochemical forms of a compound, or they are found in separate systems .

– L-lactic acid is found in living muscles; D-lactic acid is present in sour milk.

- – In some cases, one form of a molecule is beneficial, and the enantiomer is a poison.
- When sugars are different from one another, only in configuration with regard to a single carbon atom (around one carbon atom) they are called epimers of each other. For example glucose and mannose are epimers. They differ only in configuration around C2. Mannose and Galactose are epimers of Glucose.



- Mutarotation is defined as the change in the specific optical rotation representing the interconversion of α and β.
- 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 sugar molecules exist in two type of rings which are as follows

(a)Furanose Ring – 5 membered ring.

(b)Pyranose Ring- 6 membered ring.

- The alpha anomer: Where- OH group is down (Haworth)
- The beta anomer:Where- OH group is up (Haworth)

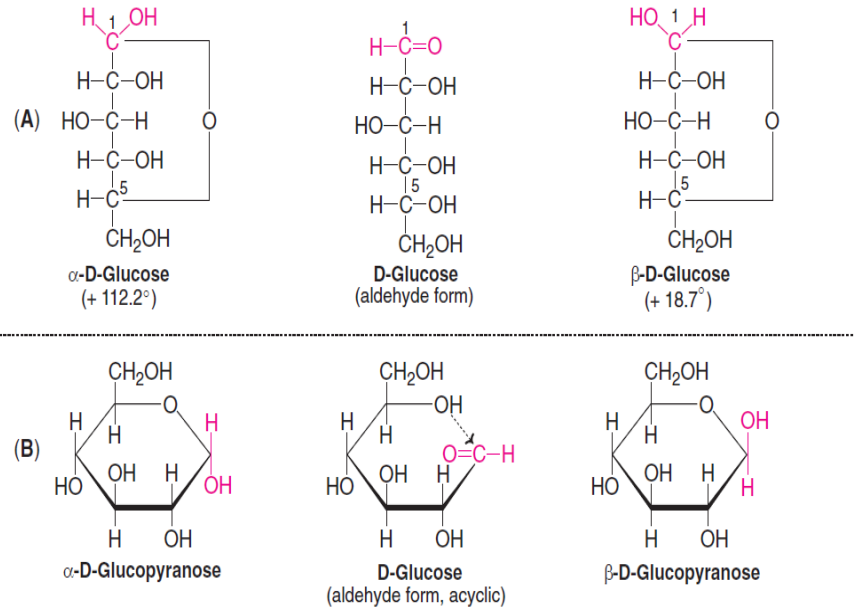


*Fig. 2.6 : Mutarotation of glucose representing α and β anomers (**A**) Fischer projections (**B**) Haworth projections.*

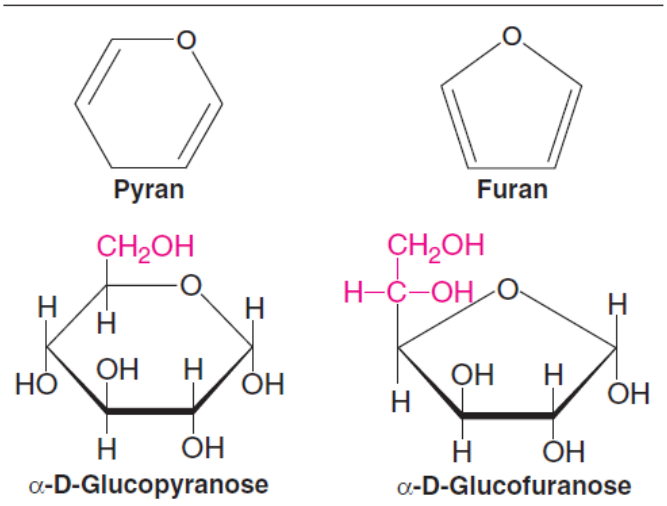


***Fig. 2.7 :** Structure of glucose-pyranose and furanose forms.*

Disaccharides

When two monosaccharides are covalently bonded together by glycosidic linkages a disaccharide is formed. Glycosidic bond is formed when the hydroxyl group on one of the sugars reacts with the

anomeric carbon on the second sugar. , Biologically important disaccharides are sucrose, maltose, and Lactose.

- **Maltose** is contains two D glucose residues joined by a glycosidic linkage between OH at the first carbon atom of the first glucose residues and OH at the fourth carbon atom of the second glucose forming a α-(1,4) glycosidic linkage as shown in Figure below.
- **Lactose** is a disaccharide of β-D galactose and β-D- glucose which are linked by β-(1,4) glycosidic linkage. Lactose acts as a reducing substance since it has a free carbonyl group on the glucose. It is found exclusively in milk of mammals (Milk sugar).
- **(Cane sugar)_Sucrose** is a disaccharide of α- D- glucose and β-D-fructose. It is obtained from cane sugar. It is also present in various fruits.

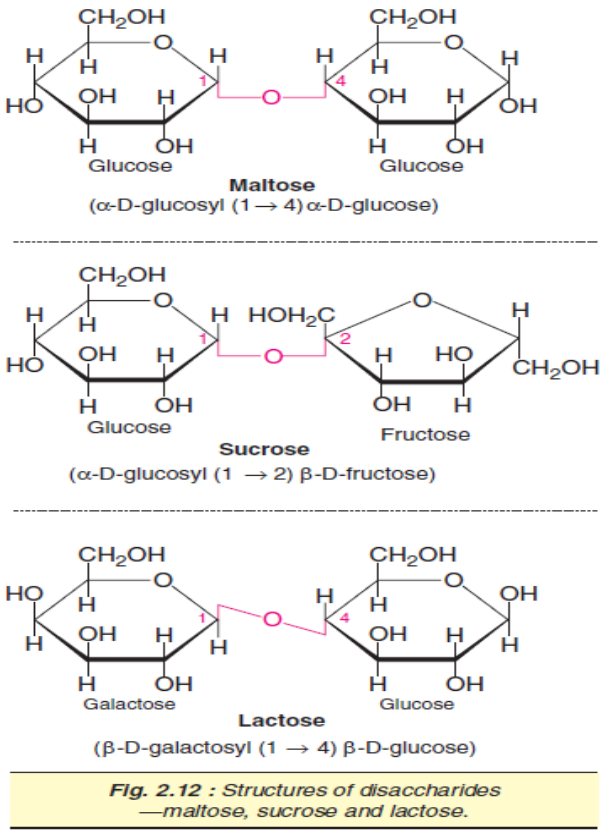


Fig. 2.12 : Structures of disaccharides —maltose, sucrose and lactose.

Polysaccharides

- consist of repeat units of monosaccharides or their derivatives, held together by glycosidic bonds.
- Polysaccharides are linear as well as branched polymers.
- They are primarily concerned with two important functions-structural, and storage of energy.
- There are two types of polysaccharides .
- Homopolysaccharides that contain only one type of monosaccharide building blocks.
- Heteropolysaccharides, which contain two or more different kinds monosaccharide building blocks.
- **Starch** consists of two polysaccharide components-water soluble amylose (15-20%) and a water insoluble amylopectin (80-85%).
- Chemically, amylose is a long unbranched chain with D-glucose units held by α (1 → 4) glycosidic linkages. Amylopectin, on the other hand, is a branched chain with α (1 → 6) glycosidic bonds .

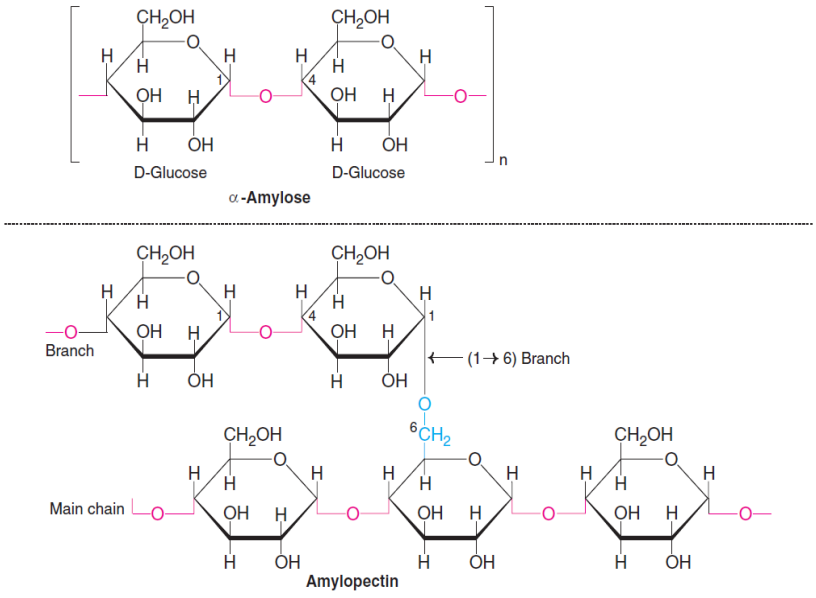


Fig. 2.13 : Structure of starch (α-amylose and amylopectin).

- **Glycogen** is the carbohydrate reserve in animals, hence often referred to as animal starch.

- It is present in high concentration in liver,
- followed by muscle, brain
- The structure of glycogen is similar to that of
- amylopectin with more number of branches. Glucose is the repeating unit in glycogen joined together by α (1 → 4) glycosidic bonds, and α (1 → 6) glycosidic bonds at branching points.

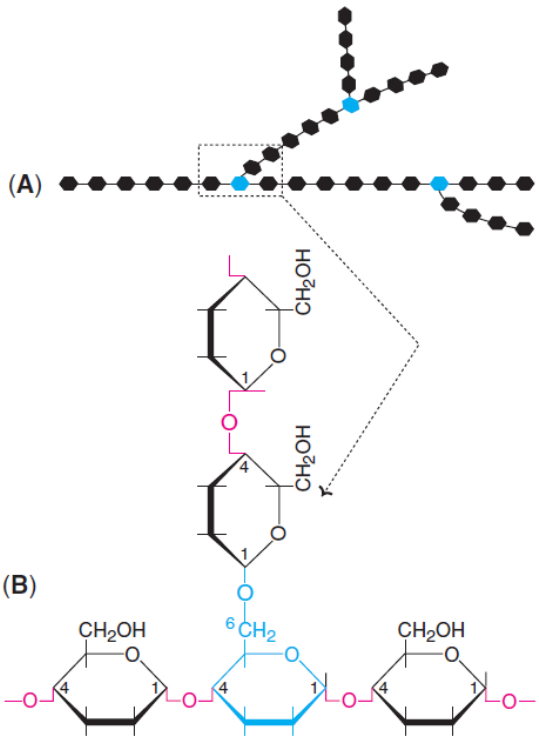
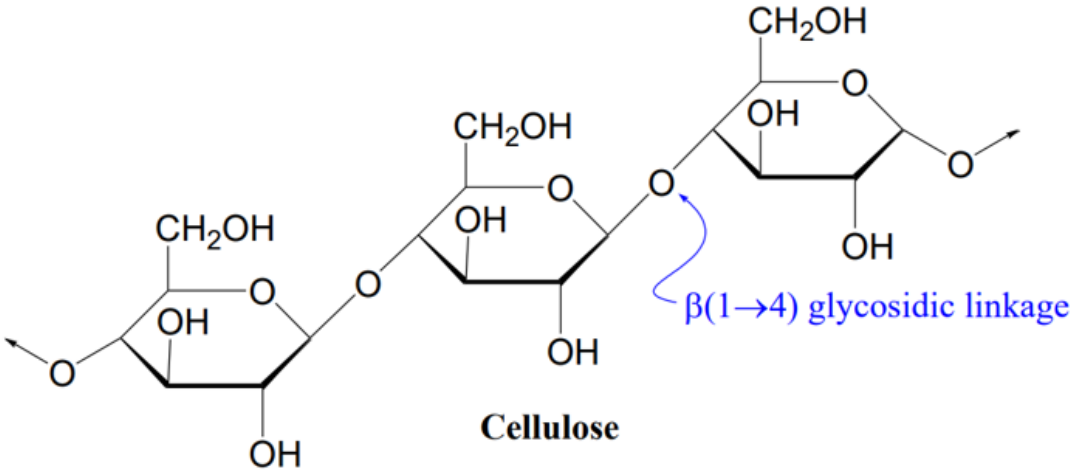


*Fig. 2.14 : Structure of glycogen (**A**) General structure (**B**) Enlarged at a branch point.*

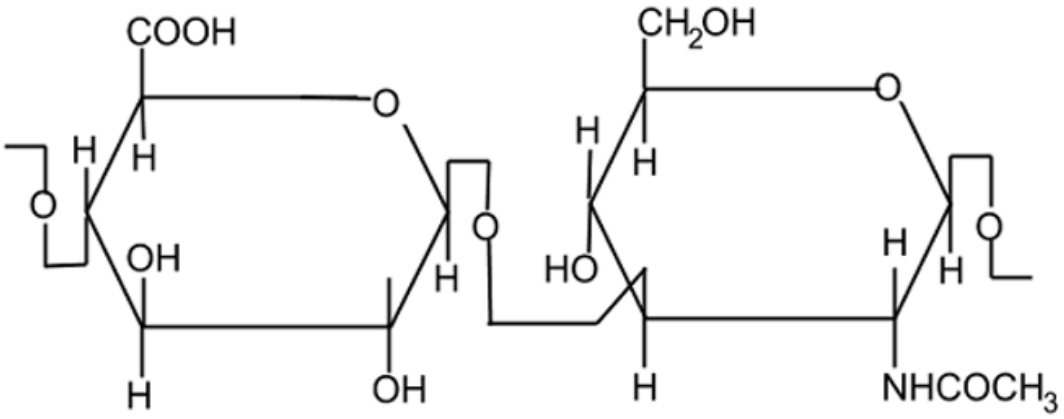
- **Cellulose** is a polymer consisting of long, unbranched chains of D-glucose connected by β (1→4) glycosidic linkages; it may contain from 300 to 3000 glucose units in one molecule.
- Most animals lack the enzymes needed to digest cellulose, but it does provide roughage (dietary fiber) to stimulate contraction of the intestines and help pass food through the digestive system.
- Some animals, such as cows, sheep, and goats (ruminants), process cellulose using colonies of bacteria in the digestive system which are

capable of breaking down cellulose, and a series of stomachs to give cellulose a longer time to digest.



Cellulose

- **Hetero polysaccharides** These are polysaccharides containing more than one type of sugar residues of derivatives of sugars such as amino sugars and uronic acid (Polysaccharides that are composed not only of a mixture of simple sugars but al are called mucopolysaccharides)
- These are more commonly known as **glycosaminoglycans (GAG).**
- example Hayluronic acid, Heparin and. chondroitin 4-sulfate of derivatives of sugars such as amino sugars and uronic acid
- **Hyaluronic acid**
- Hyaluronic acid is an important GAG found
- in the ground substance of synovial fluid of joints
- and vitreous humor of eyes.
- It is also present as a ground substance in connective tissues,



D-glucuronic acid N-acetylglucosamine

Hyaluronic Acid (HA) Unit