قال رسول الله(ص):(حسين مني وانا من حسين احب الله من احب حسينا) وقال عليه الصلاة والسلام(ان الحسين مصباح الهدئ وسفينة النجاة)

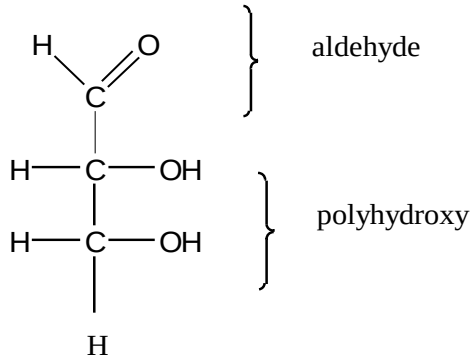
(Carbohydrates)

دکتور محمد طلعت عباس قاسم

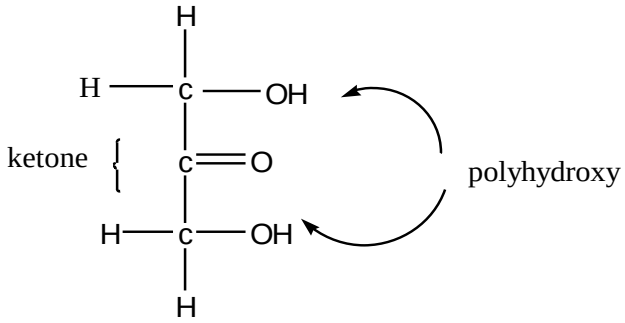
Carbohydrates are the most abundant organic molecules in nature. They have a wide range of functions, including providing a significant fraction of the energy in the diet of most organisms, acting as a storage form of energy in the body,

and serving as cell membrane components that mediate some forms of intercellular communication. Carbohydrates also serve as a structural component of many organisms, including the cell walls of bacteria, the exoskeleton of many insects, and the fibrous cellulose of plants.

Carbohydrates are defined as polyhydroxyaldehydes or polyhydroxyketones, or substances that produce these compounds on hydrolysis.



Glyceraldehyde
(simplest carbohydrate with an aldehyde group)



Dihydroxy acetone
(simplest carbohydrate with a ketone group)

Carbohydrates are the main sources of energy in the body. Brain cells and RBC_s are almost wholly dependent on carbohydrates as the energy source.

The general molecular formula of carbohydrates is $C_n(H_2O)_n$. for example, glucose has the molecular formula $C_6H_{12}O_6$.

The sugar is a carbohydrate and is sweet to taste, soluble in water and chars on hearing. Glucose (Grape sugar), fructose (fruit sugar), sucrose (cane sugar), lactose (milk sugar), and maltose (malt sugar) are few example of sugar.

All sugars are carbohydrates but all carbohydrates are not sugars. Glycogen and inulin are carbohydrates but not sugars.

Classes of carbohydrates:-

1-Monosaccharides: The monosaccharides are often called the simple sugar. are those sugars that cannot be hydrolyzed into simpler carbohydrates. They may be classified as **trioses, tetroses, pentoses, hexoses,** or **heptoses,** depending upon the number of carbon atoms, and as **aldoses** or **ketoses,** depending upon whether they have an aldehyde or ketone group.

Generic names	Examples
3 carbons: trioses	Glyceraldehyde
4 carbons: tetroses	Erythrose
5 carbons: pentoses	Ribose
6 carbons: hexoses	Glucose
7 carbons: heptoses	Sedoheptulose
9 carbons: nonoses	Neuraminic acid

Figure 7.1
Examples of monosaccharides found in humans, classified *according to the number of* carbons they contain.

2-Disaccharides: Yield two molecules of monosaccharide when hydrolyzed: Example are maltose, yielding two molecules of glucose, and sucrose, yielding one molecules of glucose and one of fructose.

3-Oligosaccharides: Yield two to ten monosaccharide units on hydrolysis: maltotriose is an example.

4-Polysaccharides: The polysaccharides are large, complex carbohydrates. When more than 10 sugar units are combined, they are generally named as polysaccharides. Polysaccharides having only one type of monosaccharide units are called **homopolysaccharides** and those having different monosaccharide units are **heteropolysaccharides.**

Stereoisomers:- Compounds having same structural formula, but differ in spatial configuration are called stereoisomers. Also defined as the different molecules resulting from different arrangements of the same number and kinds of atoms.

Asymmetric (chiral) atom:- carbon atom with four different groups attached with it.

Symmetric atoms:- carbons atoms with fewer than four different groups attached were said to be symmetrical and did not show optical properties, that is, they did not rotate the plane of polarized light.

Monosacchrides

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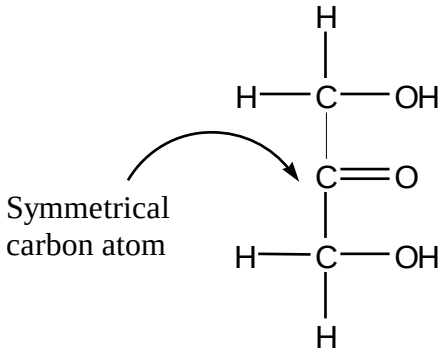
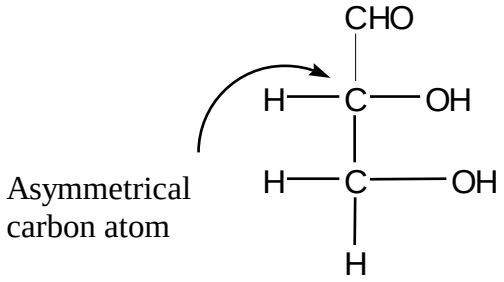
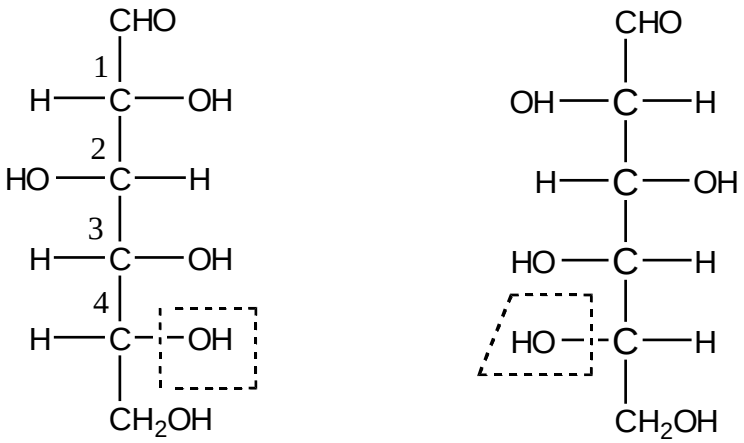


Dihydroxy acetone



D-Glyceraldehyde

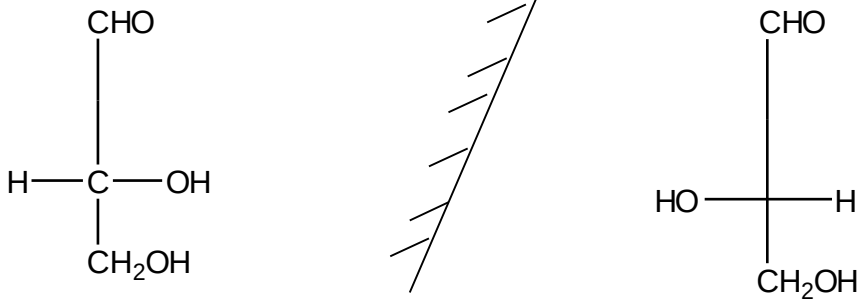
- The presence of asymmetric carbon atoms in the compound results in the formation of isomers of that compound.
- The number of isomers of an compound depends on the number of asymmetric carbon atoms and is given by **2n** , where *n* indicates the number of asymmetric carbon atoms in that compound.
- Glucose with four asymmetric carbon atoms will have 24 that are mean 16 isomers. 8 of these isomers will belong to D-series and other 8 to L-series.



D-Glucose L-Glucose

Enantiomers

- **Enantiomers**:- molecules that are not superimposable on their mirror images also we can be defined as mirror image isomers.
- The difference between D-glucose and L-glucose is the position of the H and OH on the asymmetric carbon atom. We call any monosaccharide the **L** form if it has the OH on the left of the second carbon from the bottom. If the OH on this carbon is on the right, we call the monosaccharide the **D** form. mirror



D-sugar mirror L-sugar

- The presence of asymmetric carbon atom causes optical activity. When a beam of plane-polarized light is passed through a solution of carbohydrates, it will rotate the light either to right, and the optically active substance is said to be *Dextrorotatory* **(+)** or to left and the sugar is *Levorotatory* **(-).**

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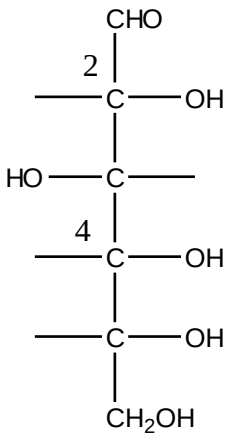
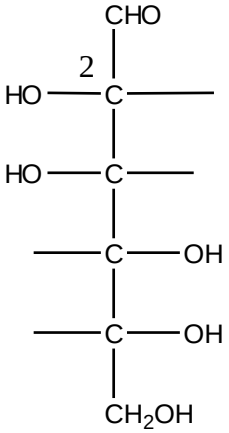
- **Epimers** :- carbohydrates that differ in their configuration about a specific carbon atom other than the carbonyl carbon atom are called epimers. For example glucose and mannose are epimers as they differ at C-2 carbon atom. Similarly, glucose and galactose are epimers as they differ at C-4 carbon atom. In glucose, the hydroxyl group at C-4 is on the right hand side whereas in galactose, the hydroxyl group at C-4 is on the left hand side.

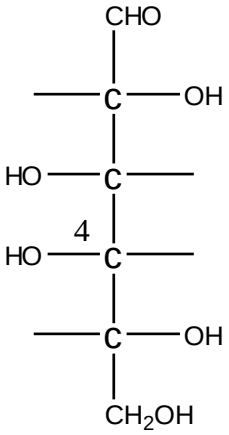
- **EpimersEpimers**



D-Glucose



D-mannose



D-galactose

Epimers

Epimers

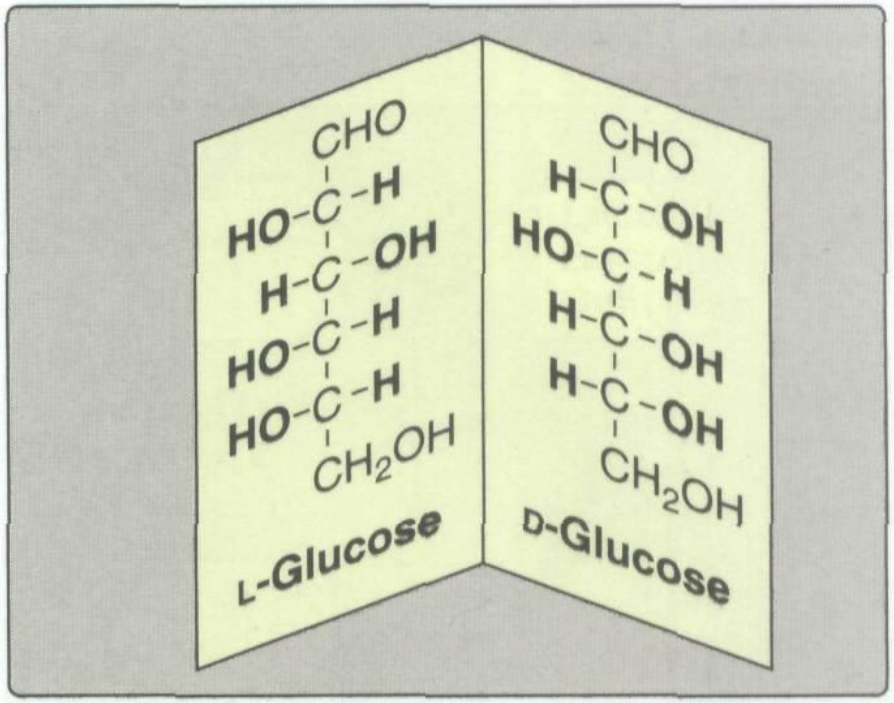


Figure 7.5
Enantiomers (mirror images) of glucose.

- The presence of asymmetric carbon atom causes optical activity. When a beam of plane-polarized light is passed through a solution of carbohydrates, it will rotate the light either to right, and the optically active substance is said to be *Dextrorotatory* **(+)** or to left and the sugar is *Levorotatory* **(-).**

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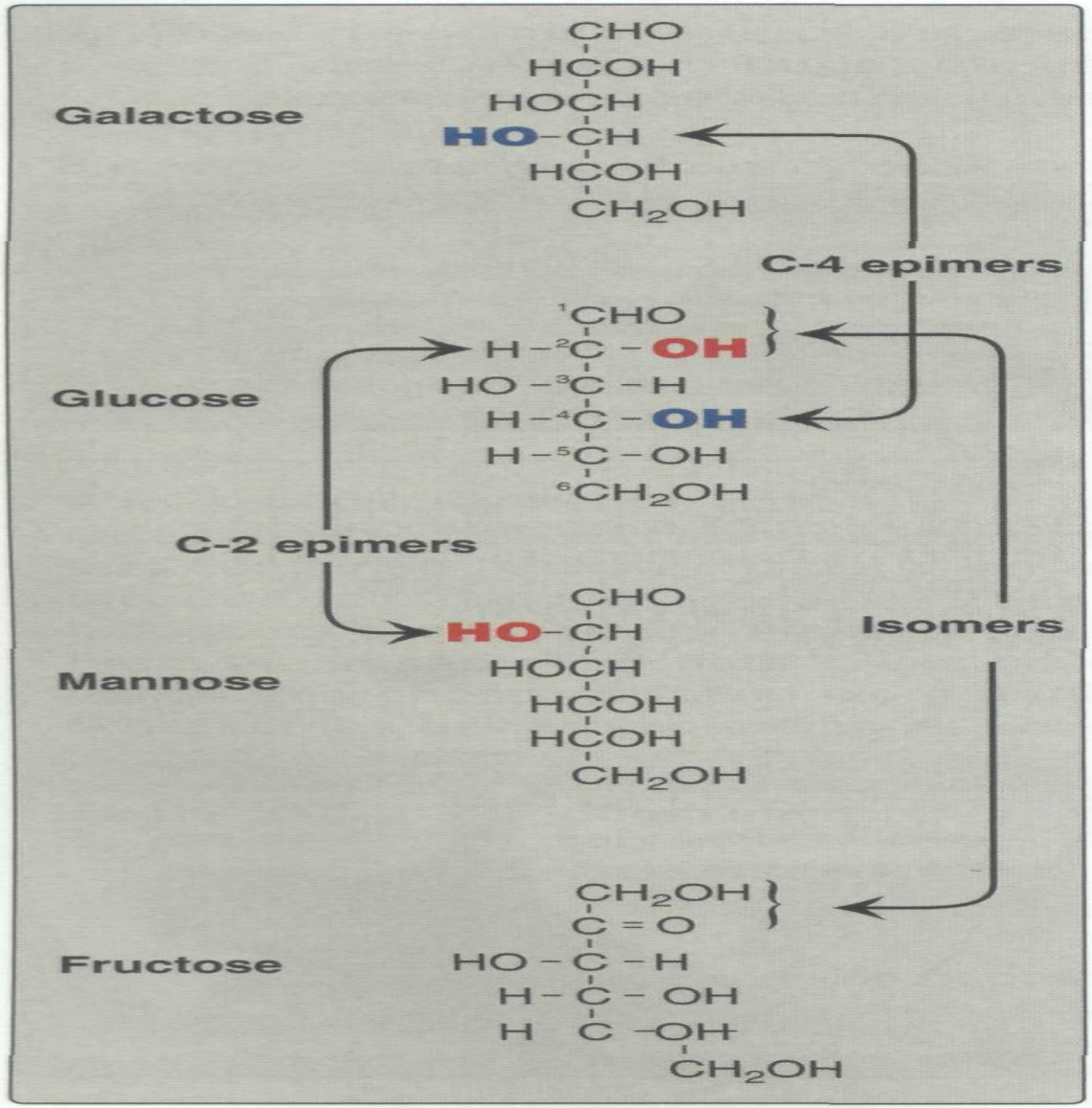
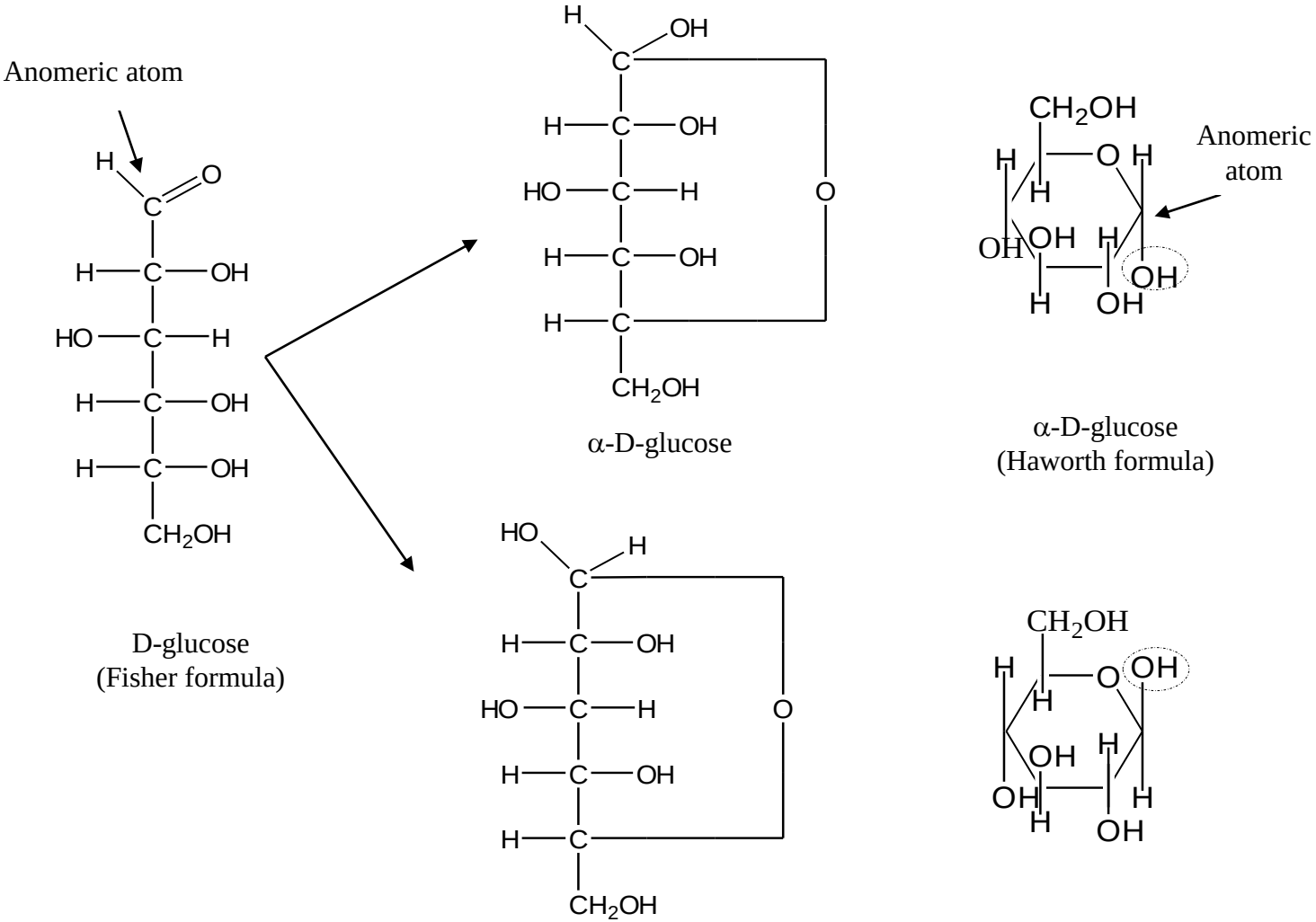
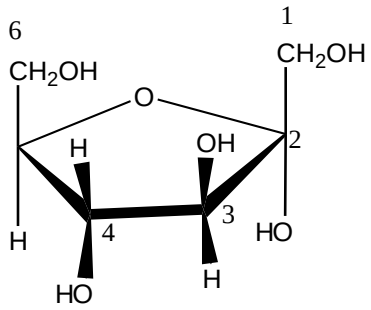


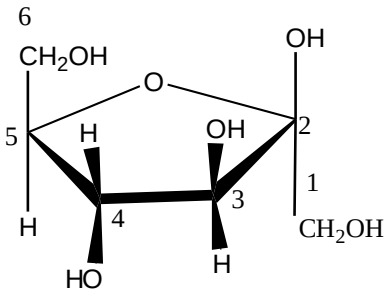
Figure 7.4
C-2 and C-4 epimers and an isomer of glucose.

- **Anomers:-** carbohydrates that differ only in their configuration around the carbonyl carbon atom are called anomers. The carbonyl carbon atom is called the anomeric carbon atom.
- In α-D-glucose, the hydroxyl group at C-1(i.e., carbonyl carbon atom) is on the right hand side whereas in β-D-glucose, the hydroxyl group at C-1 is on the left hand side. (In Fischer structures)
- If the hydroxyl group (OH) projects up, it is the beta (β) form; if it projects down, it is the alfa (α) form. (In Haworth structures)

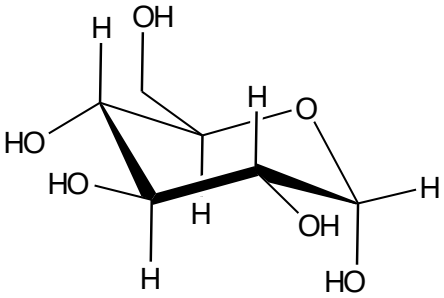


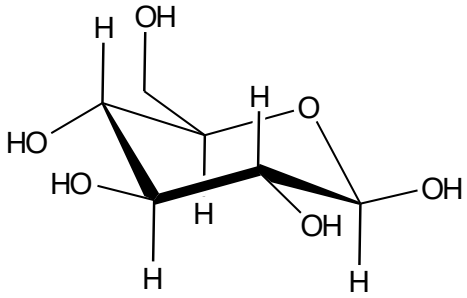
Anomers of D-glucose


6
1
CH2OH
CH2OH
O
H
OH
2
3
4
H
HO
HO
H


6
CH2OH
OH
O
5
H
OH
2
1
3
4
H
CH2OH
HO
H

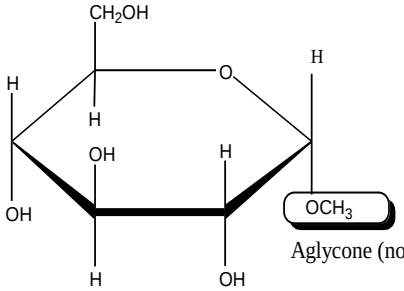
- **Mutarotation:-** is defined as the change in specific rotation of optically active solution without any change in other properties.
- Mutarotation occurs due to the cyclization of open chain form glucose into α and β form with equal probability. This α and β cyclic form of glucose have different optical rotation. This is because the α and β form are not mirror images of each other. They differ in configuration about the anomeric carbon C-1 but have the same configuration at C-2, C-3, C-4, and C-5 asymmetric carbons. These cyclic form are in equilibrium with open chain structure in aqueous solution.
- α- form 36%, β- form 63% and open chain form 1%. The predominance of the β-form in aqueous solution is due to its more stable conformation relative to the α- form.


H
OH
H
O
HO
HO
H
H
OH
H
HO


H
OH
H
O
HO
HO
H
H
OH
OH
H

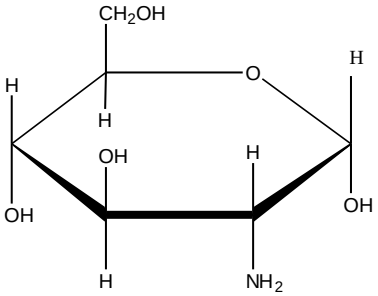
Sugar derivatives

- **Glycosides formation**:- glycosides are sugar derivatives in which hydrogen of the hydroxyl group of hemiacetal or hemiketal form of the sugar is replaced by an organic moiety. A molecule of water is elimination when this reaction takes place.
- If the organic moiety is derived from another monosaccharide, the product formed is disaccharide. If the organic moiety is a noncarbohydrate, then it is called **aglycone**.

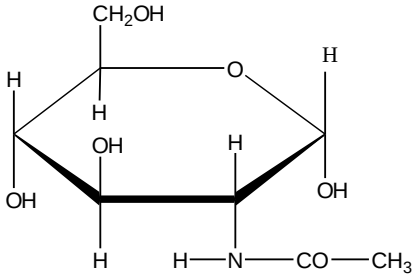


Aglycone (non-carbohydrate part)

- **Amino sugars:-** amino groups may be substituted for hydroxyl group of sugars to give rise to amino sugars. Generally, the amino group is added to the second carbon atom of hexoses. The amino sugars occurring most frequently are glucosamine and galactosamine. They occur as N-acetyl compounds. Glucosamine is present in chitin, shells of insects and mammalian polysaccharides whereas galactosamine is present in polysaccharides of cartilage and chondroitin

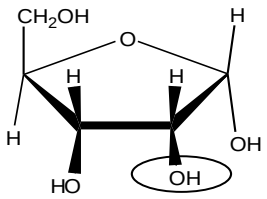


Glucoseamine

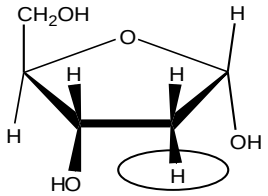


N-acetyl glucoseamine

Deoxy sugars:- oxygen of the hydroxyl group may be removed to form deoxy sugars.



D-riibose



2-deoxy -D-ribose

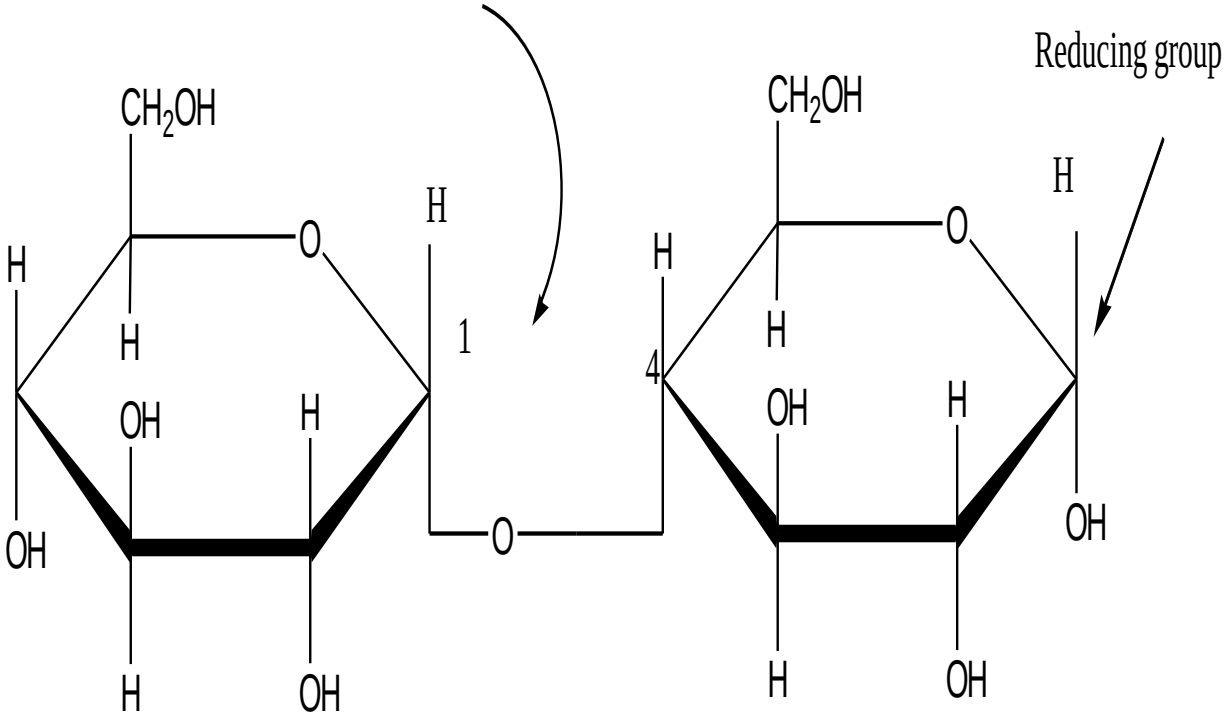
Oligosaccharides:- are arbitrarily defined as carbohydrates that contains two to ten monosaccharide units per molecule joined by *glycosidic linkages*. On hydrolysis they yield monosaccharides.

Oligosaccharides are reducing sugars if one of the carbonyl group is free (not involved glycosidic linkage).

Maltose, lactose, sucrose are oligosaccharides (disaccharides).

1-Maltose contains two glucose residues with α-1,4 glycosidic linkage. The anomeric carbon of second glucose molecule is free. So maltose is a reducing disaccharide. Maltose or malt sugar occurs as intermediate product of the digestion of starch and glycogen.

Alpha_ 1-4

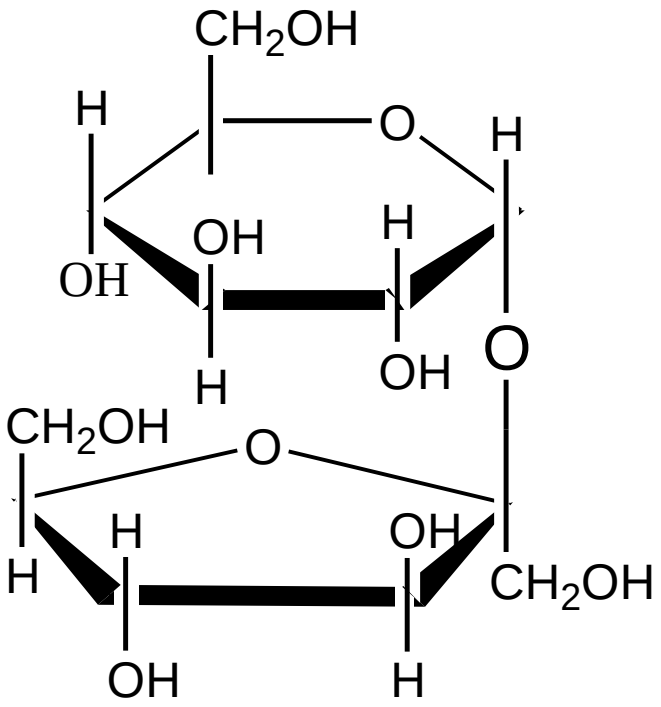

Reducing group
CH2OH
CH2OH
H
O
O
H
H
H
H
1
4
OH
H
OH
H
OH
OH
O
H
H
H
OH
OH

2-Sucrose consists of glucose and -2 β-1-αfructose joined by glycosidic linkage. The anomeric carbon C-1 of glucose configuration is αmolecule in linked to anomeric carbon C-2 of configuration βfructose in

. So sucrose is a non-reducing disaccharide as both the reducing groups of glucose and fructose are linked together

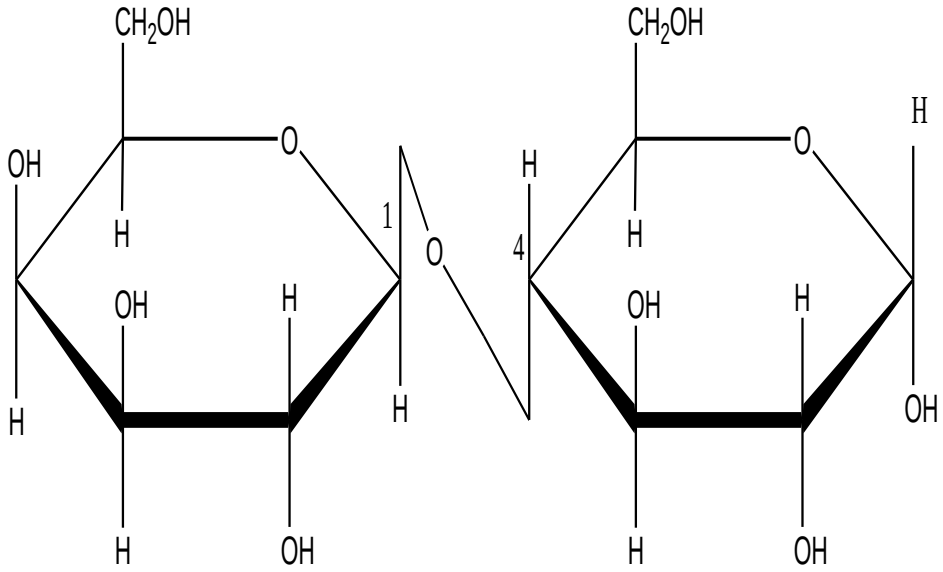
. Sucrose on hydrolysis yields equimolecular amount of glucose and fructose. Since this mixture is levorotatory whereas the original sucrose is dextrorotatory, the process is known as inversion because of the inversion of

the sign of rotation and the mixture of glucose and fructose obtained is called as invert sugar. Honey contain large amount of invert sugar.

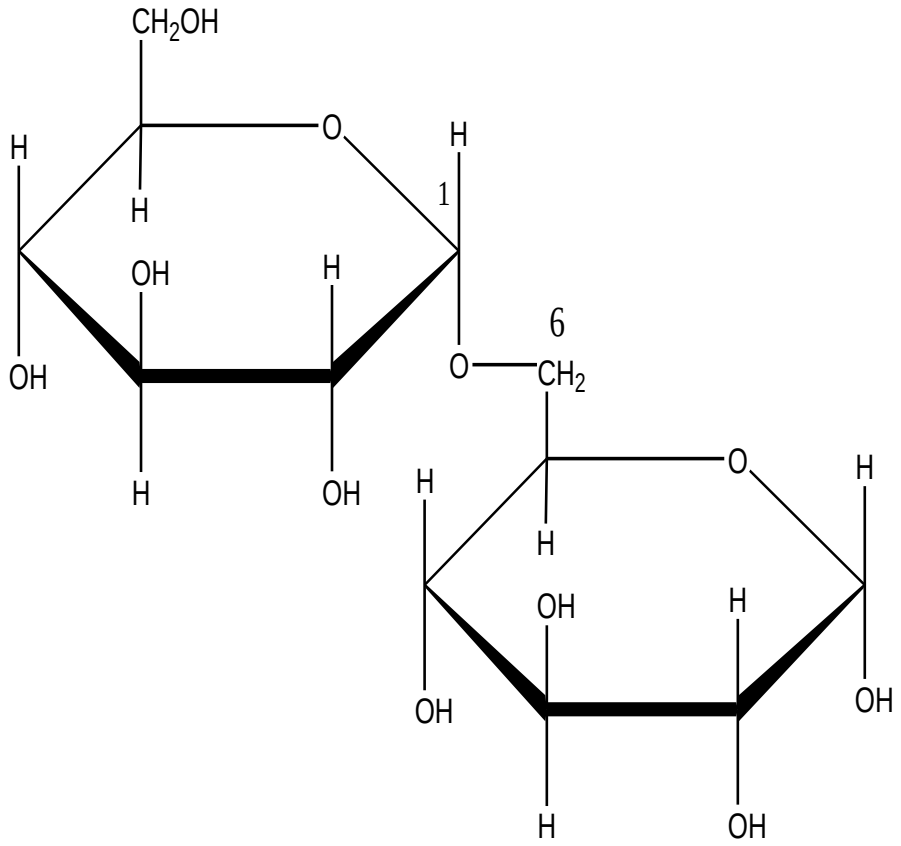

CH2OH
H
O
H
OH
H
OH
OH
H
O
CH2OH
O
H
OH
H
CH2OH
OH
H

3-Lactose consist of galactose and glucose joined by β-1,4 glycosidic linkage. The anomeric carbon of D-glucose is free, so lactose is a reducing disaccharide. It is present in milk and synthesized in mammary gland and during lactation may appear in the urine.

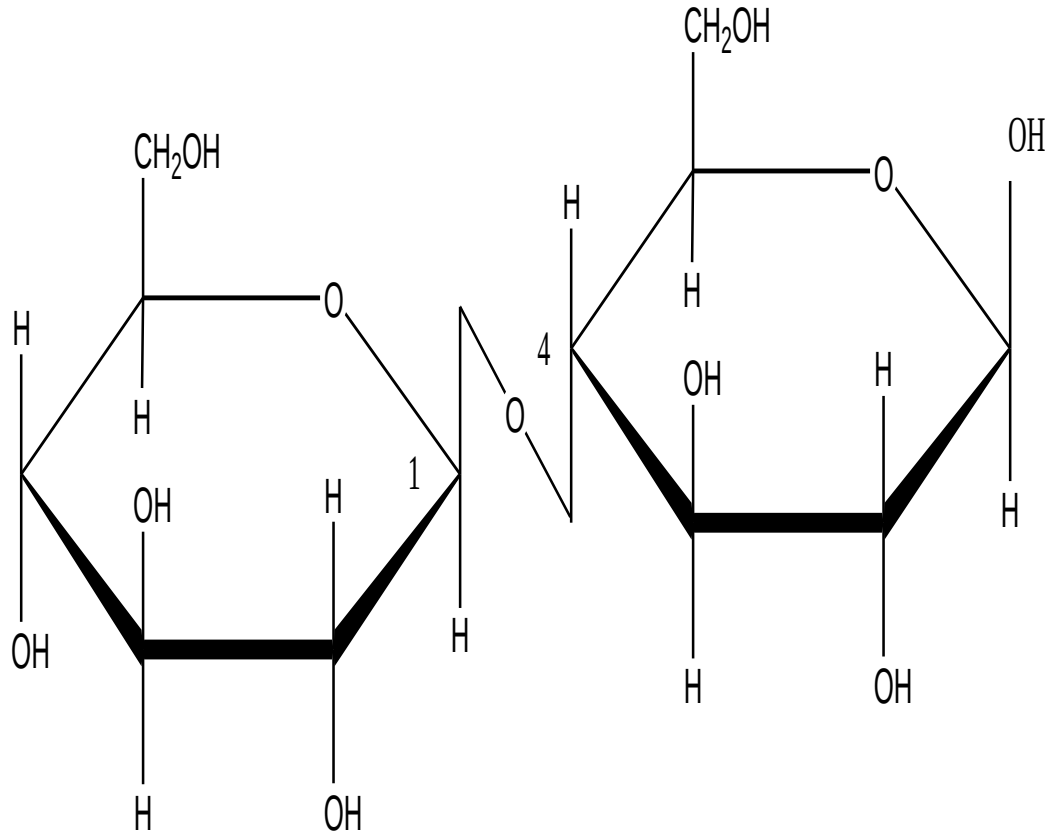
β-1,4 linkage


CH2OH
O
OH
H
OH
H
H
OH
H
1
O
4
CH2OH
O
H
H
H
OH
H
OH
H
OH

4- Isomaltose contain 2 glucose units combined in α-1,6 linkage. Partially hydrolysis of glycogen and starch produced isomaltose.



Isomaltose unit



Cellobiose unit

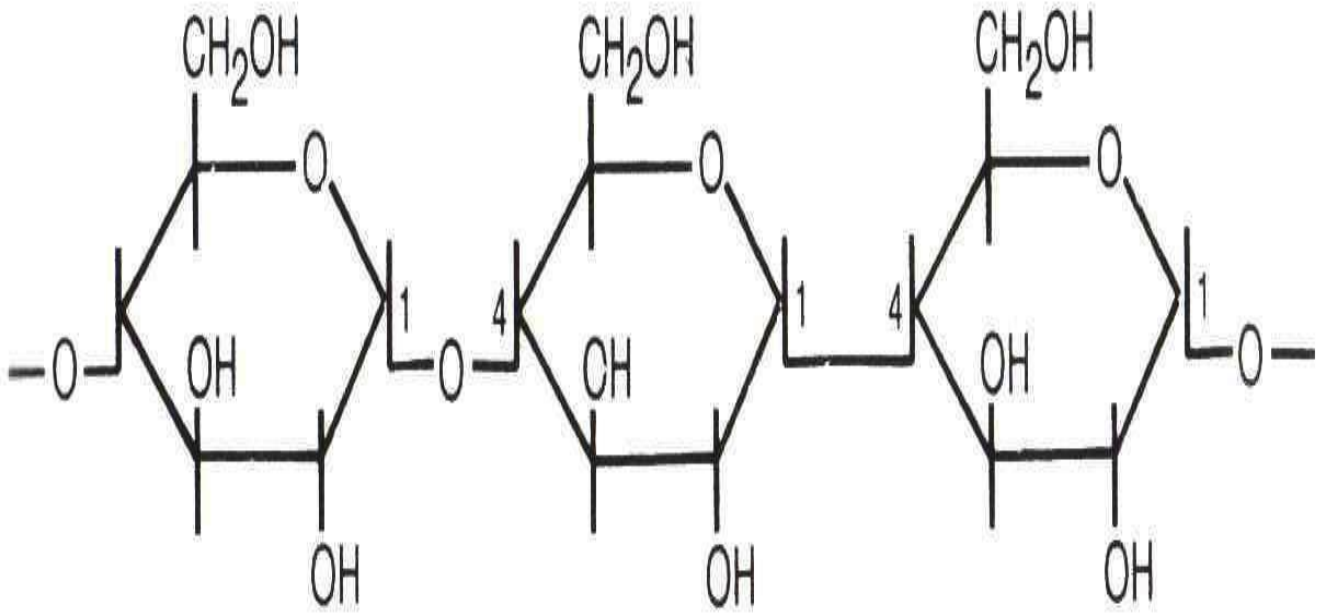
5-Cellobiose is similarity in structure to maltose except it involves a β-1,4 glycosidic linkage of glucose, rather than the α-linkage seen in maltose.

Polysaccharides

Homopolysaccharides:- they contain only one type of monosaccharides as the repeating unit and on hydrolysis gives only one type of sugar. For example starch, cellulose, glycogen, dextrins,…etc.

Starch

is a mixture of two polysaccharides, amylose and amylopectins. It is the reserve carbohydrate of plant kingdom and present abundantly in potatoes, tapioca, rice, wheat and other food grains. Starch is a non reducing polysaccharides, gives glucose only when hydrolysis with dilute mineral acids

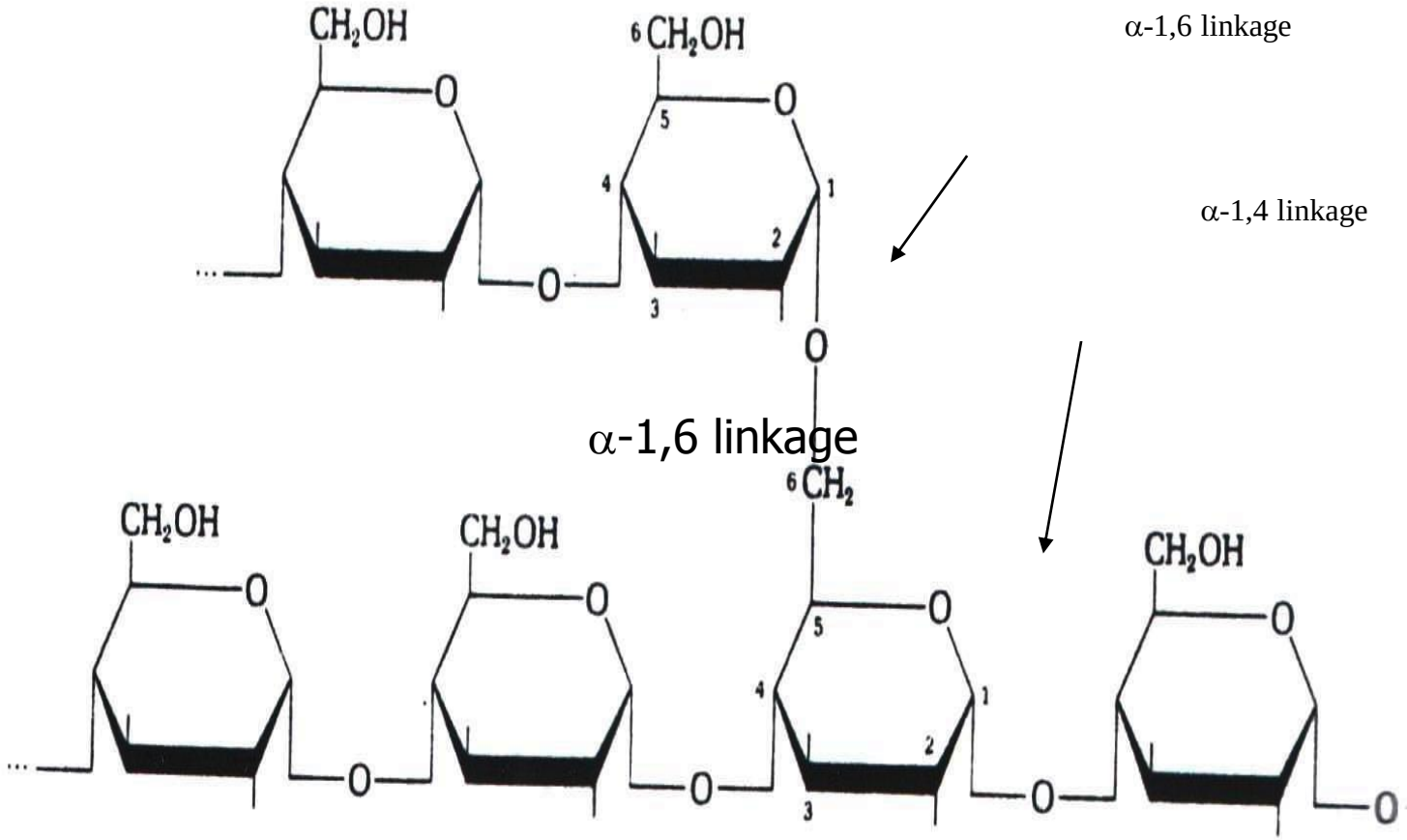


Amylose (-1,4 linkages)

Amylose

is a linear unbranched molecule in which D-glucose units are linked by a (α-1,4) glycosidic linkages. It is soluble in water.

Amylopectins is a branched chain molecule in which D-glucose units in addition to (α-1,4) linkages are branched by (α-1,6) glycosidic linkages. This branching occurs on an average of 24 to 30 D- glucose units. It is insoluble in water.



Amylopectin

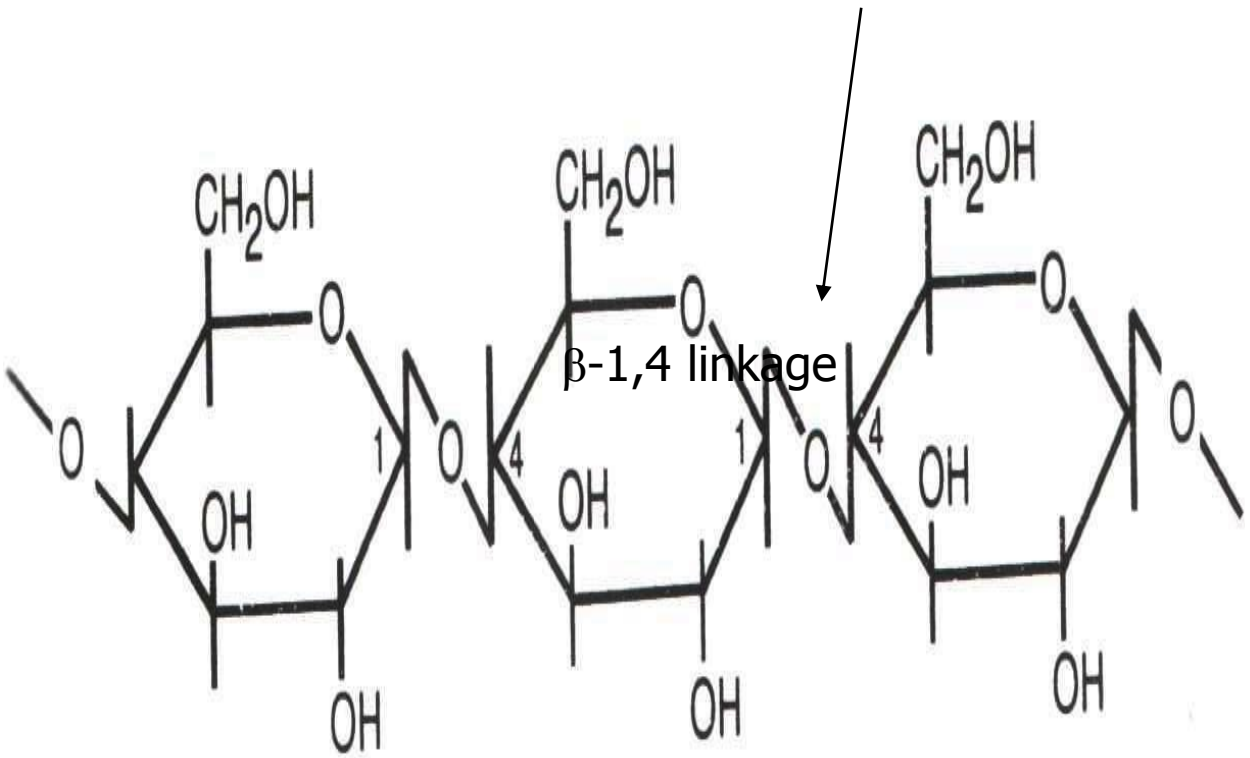
Cellulose is a linear polymer of D-glucose units joined together by (-1,4) glycosidic

. On partial hydrolysis, cellulose -1,4 disaccharides βyields cellobiose instead of maltose. Cellulose is insoluble in water and no reducing carbohydrate

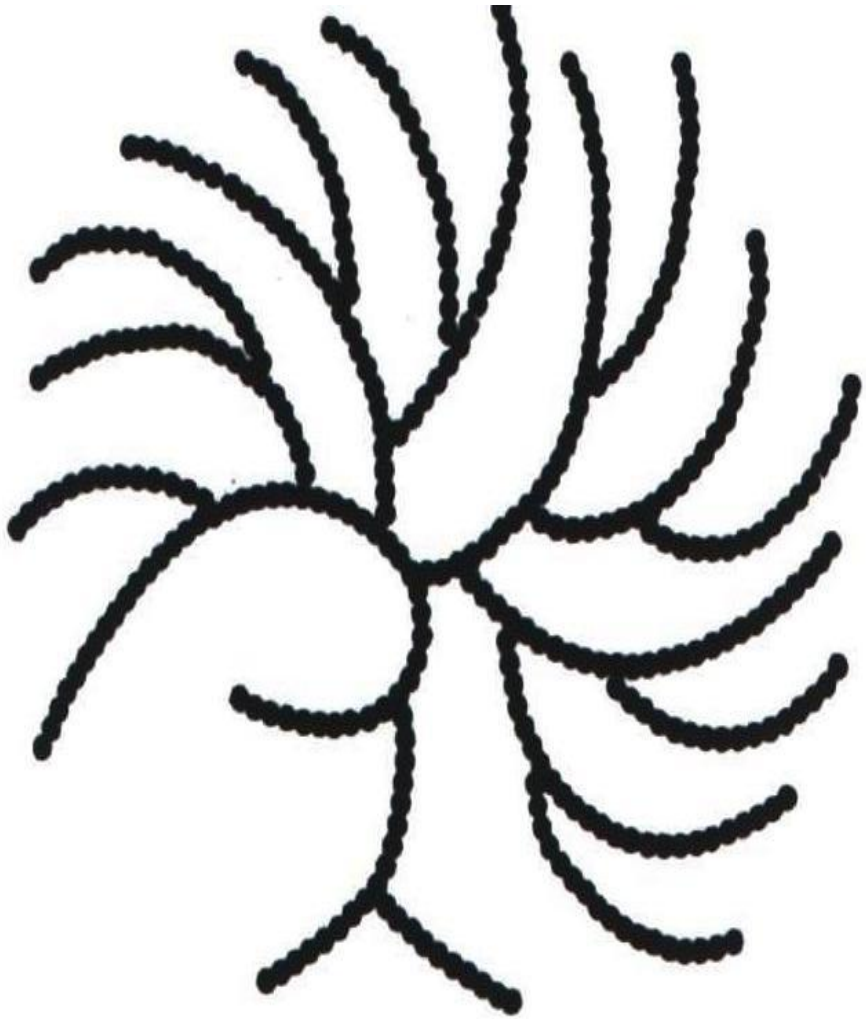
. It is component of fiber (nondigestable carbohydrate) in the diet. It aids intestinal mobility and act as an stool softener.

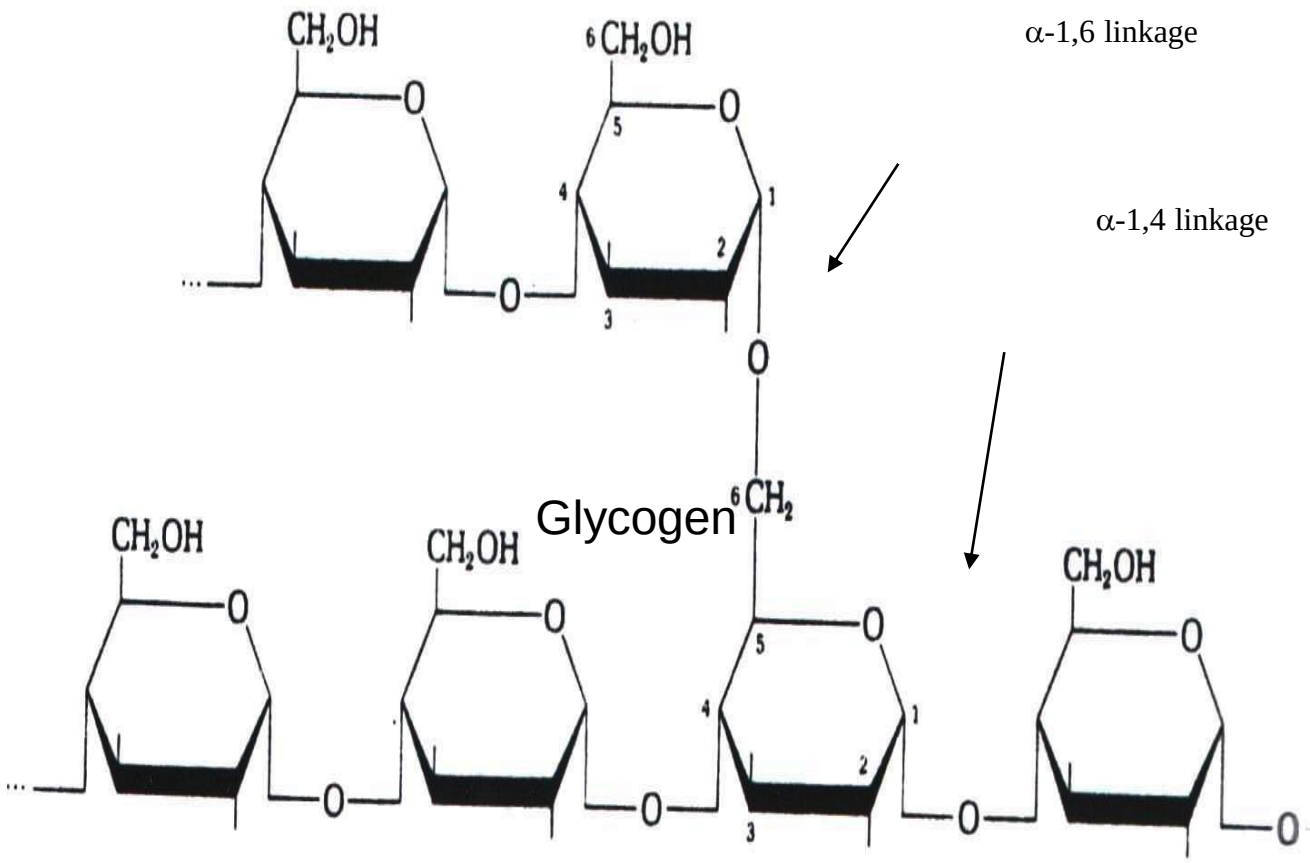
Note\ cellulose can not be utilized for energy purposes by human beings, because the enzyme which cleavage β-1,4 linkage is missing in the gastrointestinal tract.

β-1,4 linkage



Glycogen is a highly branched chain molecule in which glucose unit in addition to linear (α-1, 4) linkage are also linked by (α-1, 6) at the branched point. This branching repeats every 8-10 glucose units. Glycogen is soluble in water and has not reducing property. It is stored in liver and muscle as carbohydrate reserve of the body.




α-1,6 linkage
α-1,4 linkage
Glycogen

Starch1-

Starch is of plant origin2- It is reserve carbohydrate in plant.3- The branching is after every 24 to 30 glucose unit 4- Starch gives blue color with iodine solution.

Glycogen

Glycogen is animal origin It is reserve carbohydrate in animals. Glycogen much more branched than starch, the branching is after every 8 to 10 glucose units. Gives red color.

Dextrins

are the partial hydrolytic products of starch by α- amylase,β-amylase and acid. Dextrins formed from amylose have unbranched chains while those formed from amylopectins are branched.

Heteropolysaccharides: -

These are polysaccharides containing more than one type of sugar residues. For example mucopolysaccharides, mucoproteins,hemicellulose, gums, pectin and chitin

Mucopolysaccharides
are carbohydrates containing uronic acid and amino sugars.

Hyaluronic acid is present in the connective tissues, synovial fluid and vitreous fluid in combination with proteins. It is an unbranched polymer composed of repeating unit

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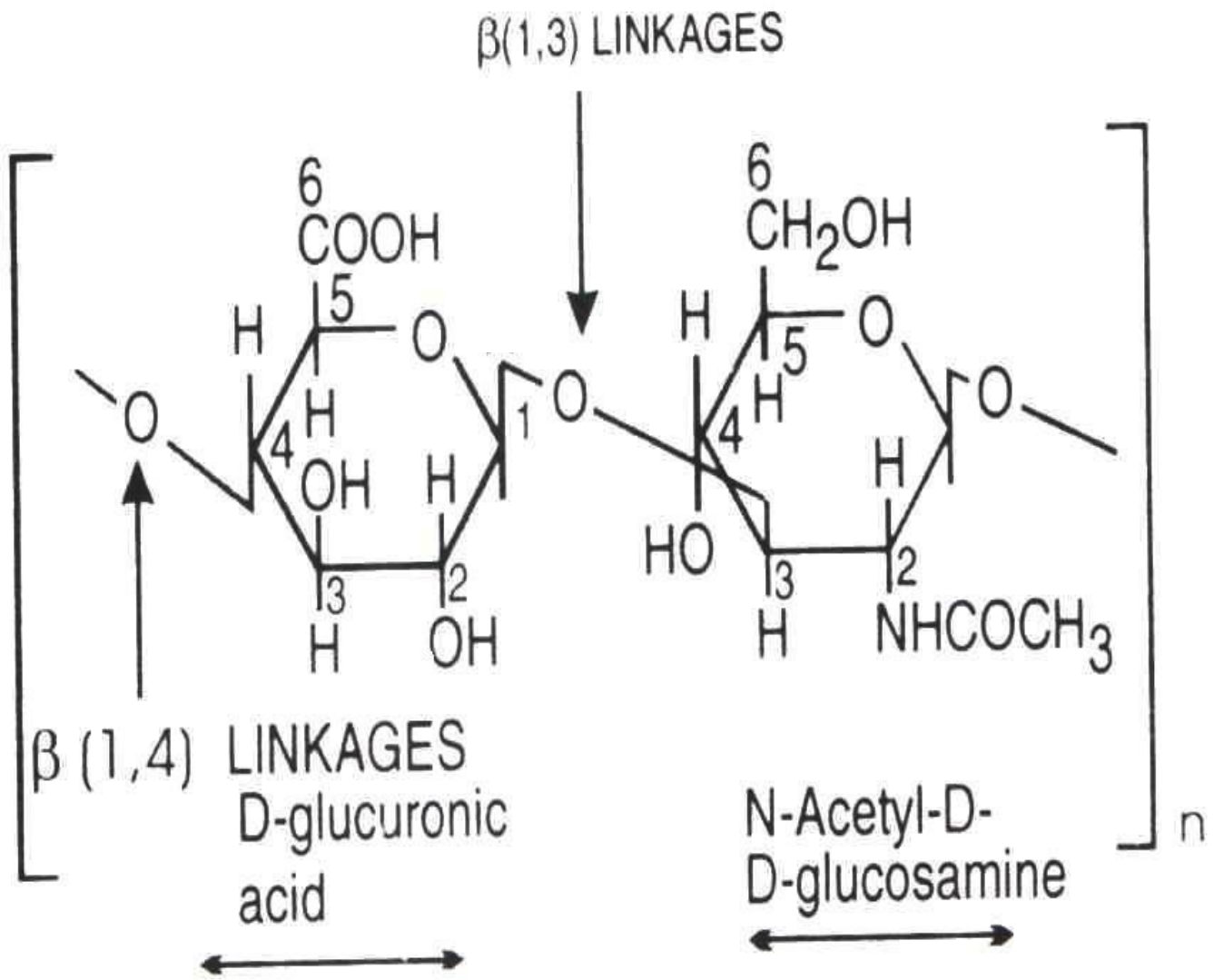
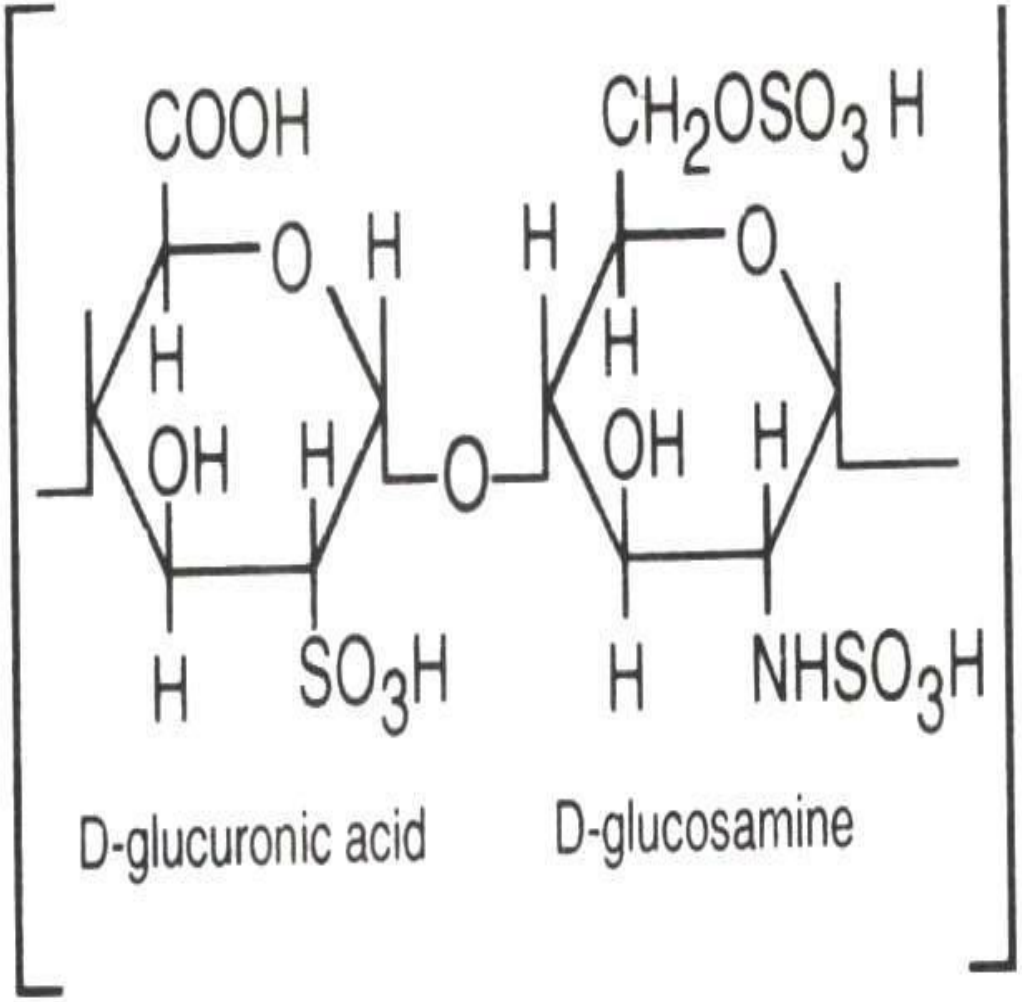
of D-glucuronic acid and N-acetyl D-glucosamine. The monosaccharide subunits are linked by (β-1,4) and (β-1,3) glycosidic linkage.


β(1,3) LINKAGES
6
COOH
5
H
O
H
4
H
OH
H
1
O
3
2
H
OH
O
6
CH2OH
H
5
O
H
4
H
HO
H
3
2
H
NHCOCH3
O
n
β (1,4) LINKAGES
D-glucuronic
acid
N-Acetyl-D-
D-glucosamine

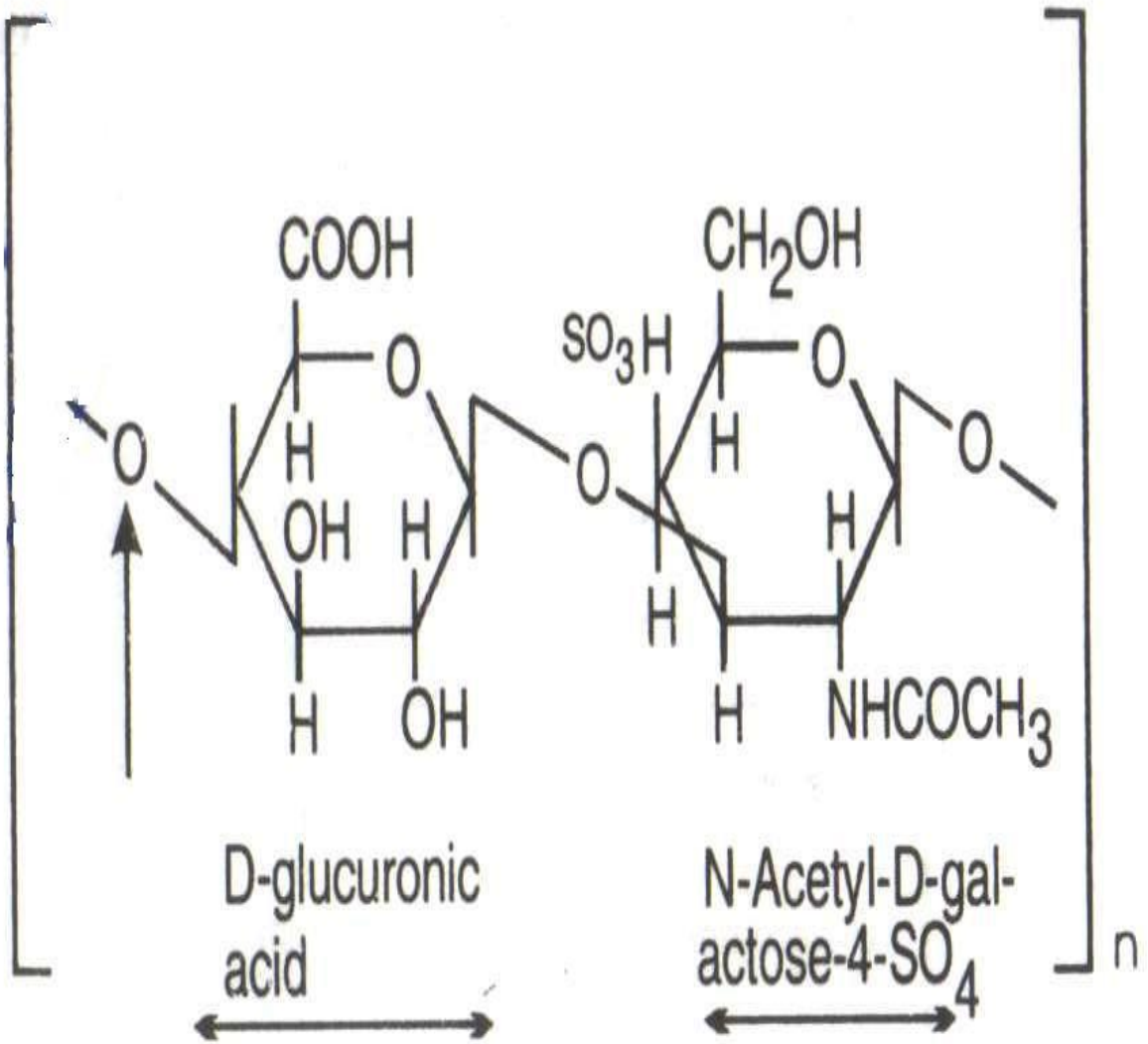

COOH
O
H
H
OH
H
O
H
SO3H
CH2OSO3 H
H
O
H
OH
H
H
NHSO3H
D-glucuronic acid
D-glucosamine

b- Heparin:-

Heparin contains D-glucosamine, D-glucuronic acid as the repeating disaccharide units. The glycosidic linkage is (α-1,4). It is present in the liver, lungs thymus, spleen and blood. It is anticoagulant.

c- Chondroitin sulphate:

it is composed of repeating unit of glucuronic acid, and N-acetyl galactosamine sulphate. The glycosidic linkage is (β-1,3) and (β-1,4).


COOH
O
H
OH
H
H
OH
O
O
CH2OH
SO3H
O
H
H
H
H
NHCOCH3
O
n
D-glucuronic acid
N-Acetyl-D-galactose-4-SO4

Gum acacia is used as an adhesive. It is contains galactose, arabinose and glucuronic acid

Chitin is found, for example in the exoskeletons of crustaceans an insect. Structurally, chitin consist of N-acetyl-D-glucosamine unit joined by β-1,4 glycosidic linkage.

Mucoproteins and glycoprotein :- if the carbohydrate associated with protein is greater than 4%, the complex protein is called *mucoprotein* or proteoglycans. If the carbohydrate content is less than 4% , then is called *glycoprotein*

. Mucoprotein and glycoprotein are present in all tissues and cell membranes. Glycoprotein are composed of varying number of the following carbohydrate residue: glucose, mannose, galactose, N-acetyl glucosamine, N-acetyl galactosamine. Arabinose, xylose, L-fructose and N-acetyl neuraminic acid.

THANK YOU