Introduction to Carbohydrates

Carbohydrates are the most abundant organic molecules in nature. They have a wide range of functions, including providing a significant fraction of the dietary calories for 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. The empiric formula for many of the simpler carbohydrates is $(CH_2O)n$, hence the name “hydrate of carbon”.

Classification and Structure of carbohydrate

1-Monosaccharides: (simple sugars) can be classified according to the number of carbon atoms they contain. Examples of some monosaccharides commonly found in humans are listed in Figure 1.

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 1: Examples of monosaccharides found in humans, classified according to the number of carbons they contain.

Carbohydrates with an aldehyde as their most oxidized functional group are called aldoses, whereas those with a keto as their most oxidized functional group are called ketoses (Figure 2). For example, glyceraldehyde is an aldose, whereas dihydroxyacetone is a ketose. Carbohydrates that have a free carbonyl group have the suffix –ose.

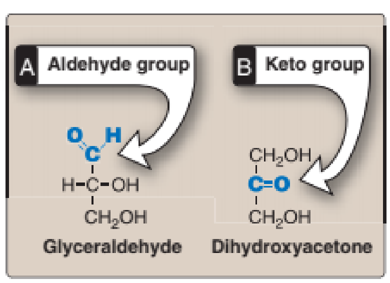


Figure 2: Examples of an aldose (A) and a ketose (B) sugar

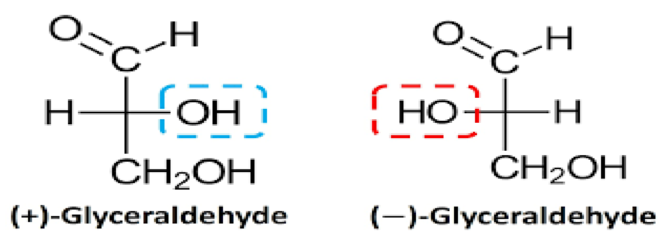
Carbohydrate isomers that differ in configuration around only one specific carbon atom (with the exception of the carbonyl carbon), so the number of isomers can be obtained from the equation

$$\mathbf{I = 2^n}$$

n=The number of asymmetric carbon atoms

Enantiomers

A special type of isomerism is found in the pairs of structures that are mirror images of each other. These mirror images are called enantiomers, and the two members of the pair are designated as a D- and an L-sugar (figure 3).



Figur 3: D and L Glyceraldehyde

The vast majority of the sugars in humans are D-sugars. In the D isomeric form, the –OH group on the asymmetric carbon (a carbon linked to four different atoms or groups) farthest from the carbonyl carbon is on the right, whereas in the L-isomer it is on the left(figure 4).

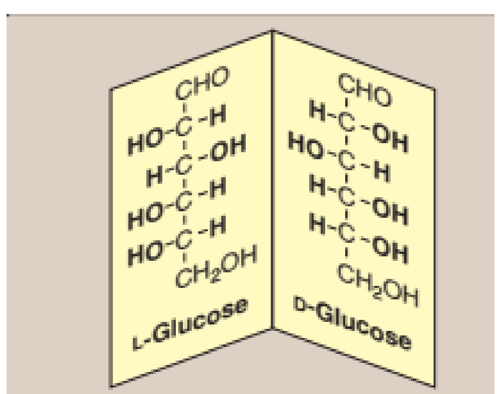
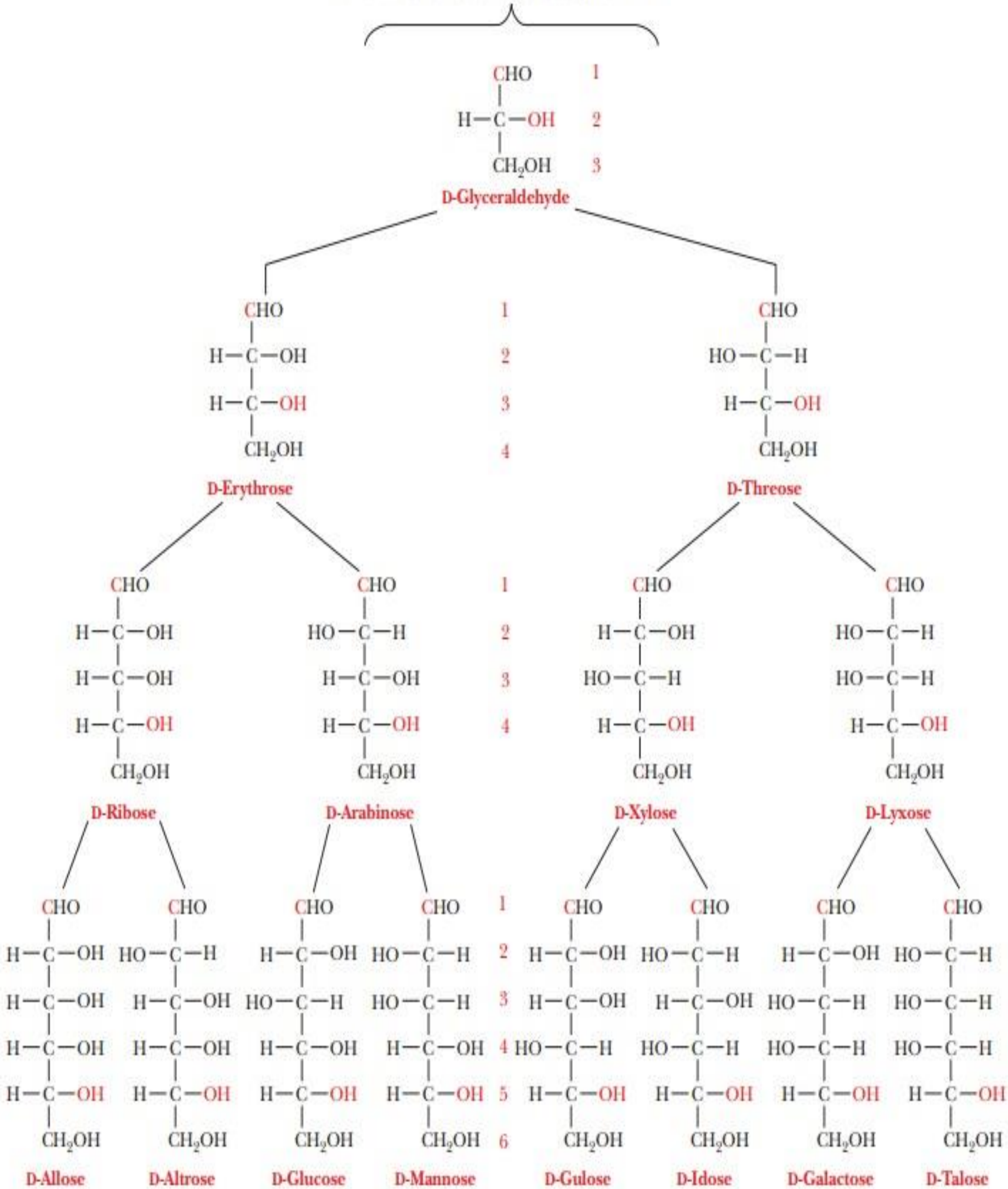


Figure 4: Enantiomers (mirror images) of glucose.

A Aldoses containing from three to six carbon atoms, with the numbering of the carbon atom shown. Note that the figure shows only half the possible isomers. For each isomer shown, there is an enantiomer that is not shown, the L series.



Cyclization of monosaccharide

Monosaccharides can form two types of rings, 5-membered called **Furanose**, and 6-membered called Pyranose (figure 5).

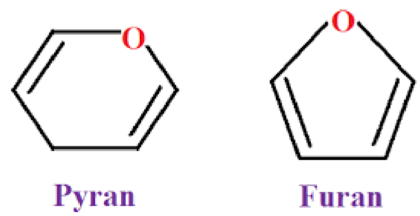
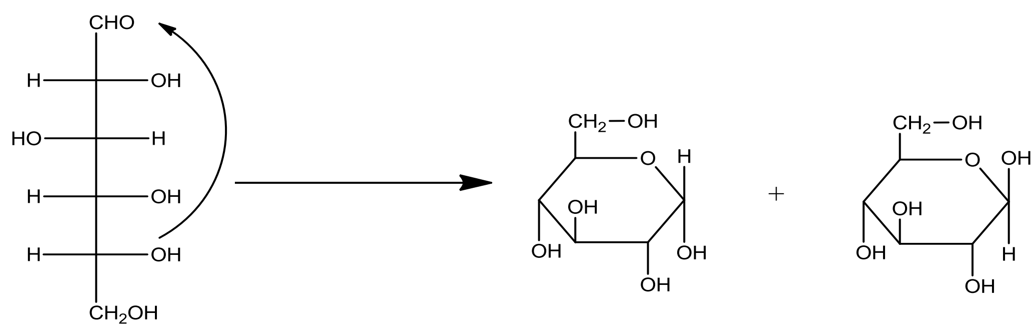


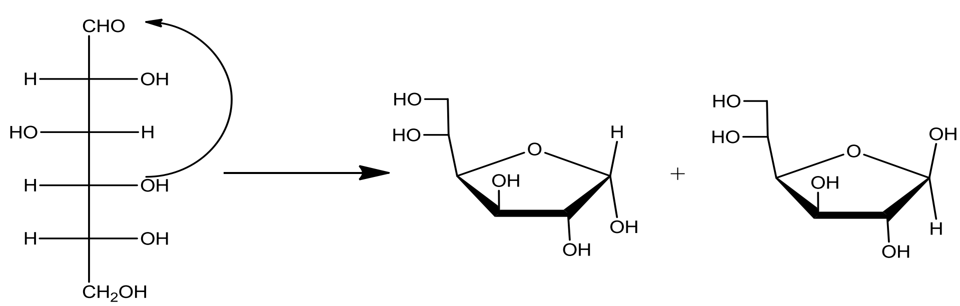
Figure 5: Pyran and Furan ring

Pentoses and hexoses can cyclize, as the aldehyde or keto group reacts with a hydroxyl on one of the distal carbons. e.g., glucose forms an intra-molecular hemiacetal by reaction of the aldehyde on C1 with the hydroxyl on C5, forming a six-member pyranose ring, named after the compound pyran.



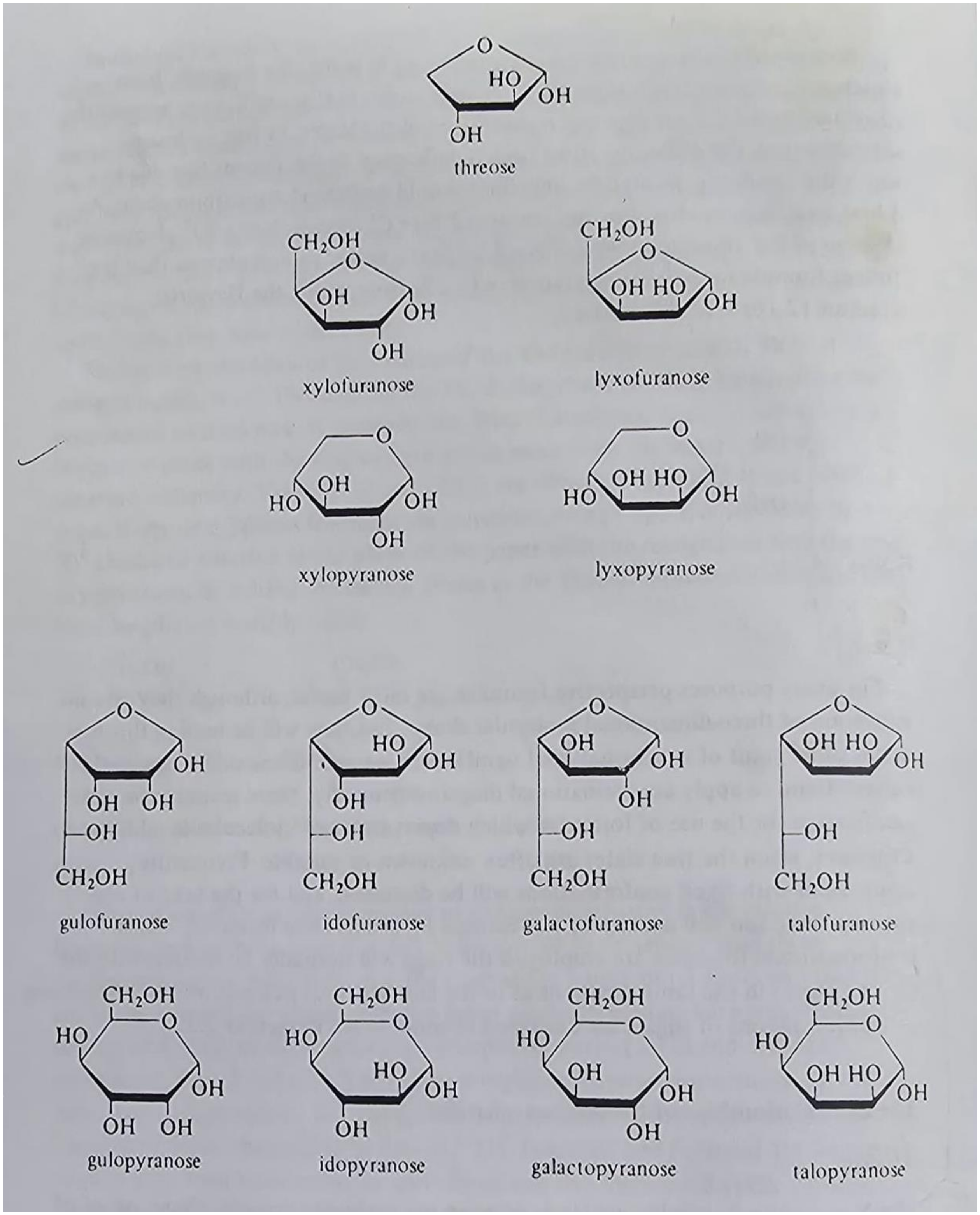
D-Glucose **α-D-Glucopyranose** **β-D-Glucopyranose**

It can also be a form a 5 member ring as a result of the reaction of an aldehyde group with a hydroxyl group on C-4 and it is called a furan ring.

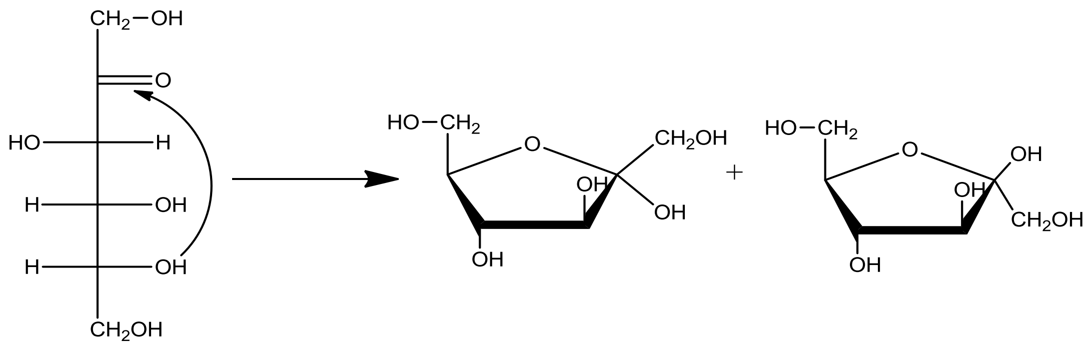


D-Glucose **α-D-Glucofuranose** **β-D-Glucofuranose**

Cyclization of glucose produces a new asymmetric center at C-1, with the two stereoisomers called **Anomers**, **α** and **β**.



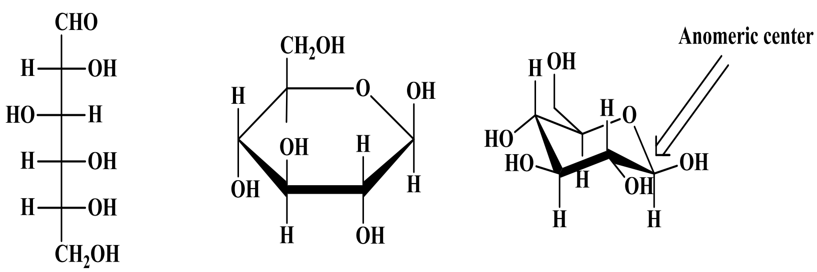
Fructose can form either: 5-member furanose ring, by reaction of the C-2 (keto group) with the hydroxyl on C-5



D-Frucose **α-D-Fructofuranose** **β-D-Fructofuranose**

-Aldoses and ketoses equilibrate between cyclic and open forms.

-Most oxidized carbon (C-1; attached to 2 oxygen atoms) is known as an **Anomeric carbon**.

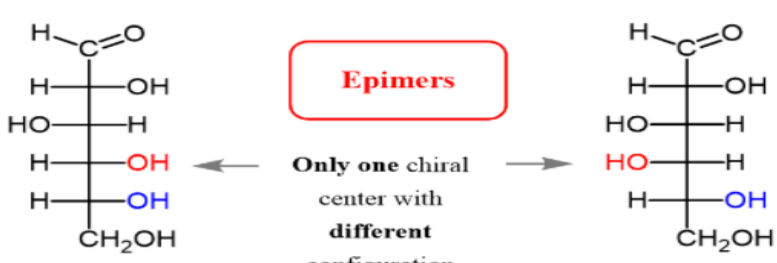


D-Glucose β-D-Glucopyranose (β-D-Glucose)

Epimers

Epimers are carbohydrates that differ in the location of the -OH group in one location.

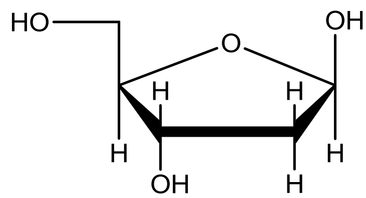
D-glucose and D-galactose are epimeric at carbon-4



D-Glucose **D-Galactose**

- **Deoxyribose sugars**

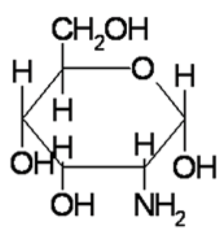
Are sugars in which the hydroxyl group in the ring is replaced by a hydrogen atom. The most common type of deoxyribose sugar in nature is 2-deoxyribose, which is part of DNA.



2-Deoxy ribofuranose

- **Amino sugars**

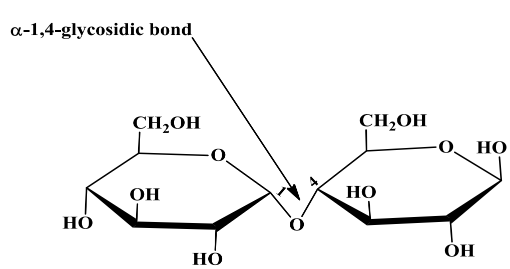
Amino sugars contain an amino group replacing a hydroxyl group. Examples include glucoseamine, a major component of chitin, a polysaccharide found in the exoskeleton of cartilage, and galactoseamine, a major component of the polysaccharides found in cartilage. This type of sugar is also found in some antibiotics, such as erythromycin and carbomycin.



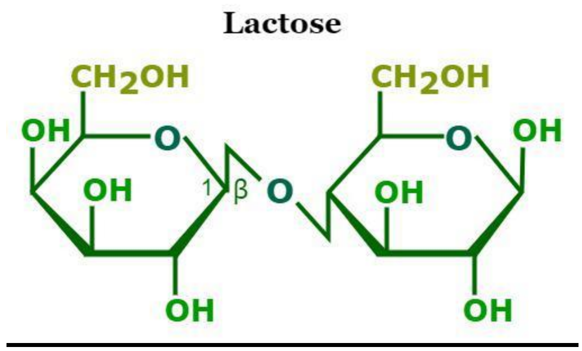
D-Glucosamine

2- Disaccharides: Monosaccharides can be linked by glycosidic bonds to create larger structures called disaccharides which have contain two monosaccharide units.

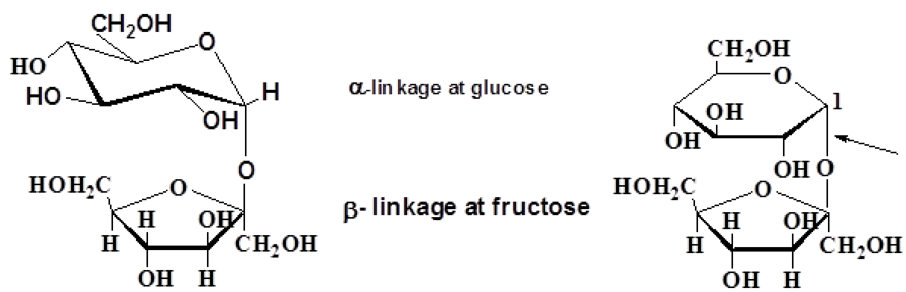
A: Maltose(two glucose)



B: Lactose



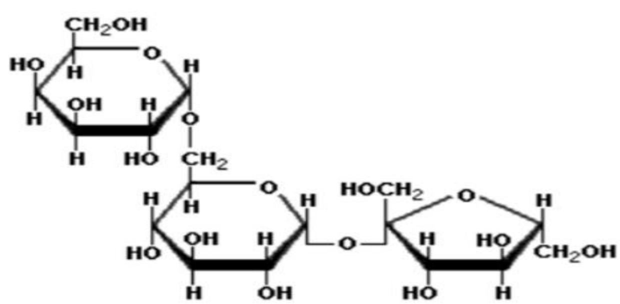
C: Sucrose(Glucose-Fructose)



(+)-sucrose or α -D- glucopyranosyl-β -D-fructofuranoside

3-Oligosaccharides: contain from three to about ten monosaccharide units.

Raffinose



4-polysaccharides: contain more than ten monosaccharide units, and can be hundreds of sugar units in length.

It can be divided in to two classes:

1) homoglycans (homopolysaccharides): composed on one monosaccharide

2) heteroglycans (heteropolysaccharides): made of more than one type of monosaccharide

Often classified according to their biological role:

1-Starch - mixture of amylose and amylopectin

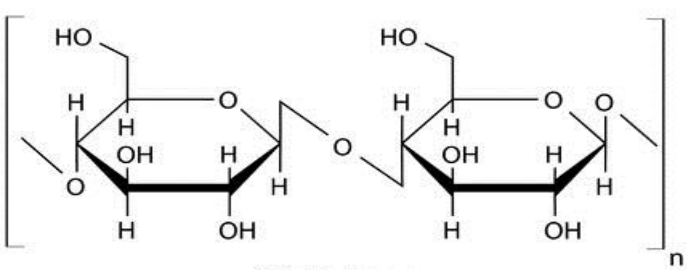
-Amylose is an unbranched polymer of 100-1000 D-glucose in an α-(1-4) glycosidic linkage.

-Amylopectin is a branched polymer α-(1- 6) branches of residues in an α-(1-4) linkage; overall between 300-6000 glucose residues, with branches once every 25-30 residues; side chains are 12 residues long

Glycogen - branched polymer of glucose residues with branches every 8-12 residues with branches containing as many as 50,000 glucose residues

2-Cellulose

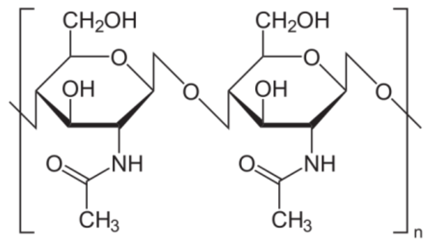
Cellulose, the most widely distributed plant skeletal polysaccharide, constitutes almost half of the cell waft material of wood. Cotton is almost pure cellulose, Cellulose is a linear polysaccharide of D-glucose units joined by β-(1-4) glycosidic bonds. It has an average molecular weight of 400,000 g/mol, corresponding



Cellulose

3-Chitin

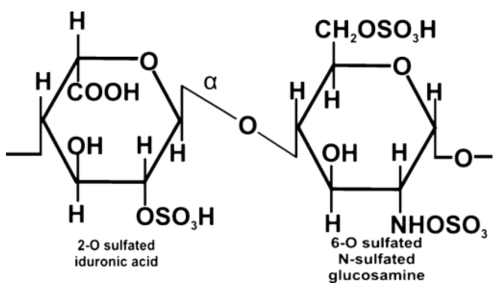
Chitin is a polymer of *N*-acetyl-D-glucosamine (or, as it is known systematically, 2-acetamido-2-deoxy-D-glucose .(Residues of this carbohydrate are connected by β-1,4-glucosidic linkages within the chitin polymer .



Chitin

4-Heparin

Consisting of a glucosamine and uronic acid. The initial disaccharide unit that constitutes the growing chain during biosynthesis has a D-glucuronic acid β1 → 4 linked to a D-N-acetylglucosamine



Heparin