Biochemistry
Carbohydrates
Dr Jilna Alex N

BIOGENIC ELEMENTS

- About 22 out of 100 odd elements of periodic table are essentially found in living organisms and are generally called Biogenic elements
- They fall under four major categories

1) Macro biogenic: C, H, O and N
2) Oligo biogenic: Na, K, Ca, Mg, S, P, Fe etc.
3) Micro biogenic: Cu, Co, Mn, Zn, Cl, F, Br, I etc.
4) Ultramicro biogenic: Bo, Al, Ni, Cd, Cr, As, Si, Se etc.

BIOMOLECULES

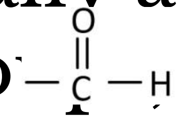
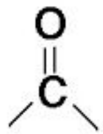
- The complex, mysterious constituents of living matter are generally called ***Biomolecules.*** These compounds may be ionic, molecuar, organic or inorganic
- Generally Organic biomolecules are two major groups

1) Micro molecules : Mono, Oligo saccharides, Amino acids, Fatty acids, Glycerol, Nucleoties

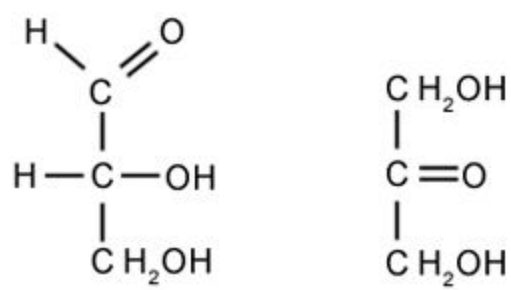
2) Macro molecules : Polysaccharides, Proteins, Fats, Nucleic acids, Enzymes, Hormones, Vitamins etc.

- Inorganic biomolecules include water and mineral salts

CARBOHYDRATES

- A carbohydrate molecule is essentially a chain of several hydroxyl (-OH) gro  with  erminal aldehyde ( ) or keto ( ) group

- Those carbohydrates which contain aldehyde group are called ***aldoses*** and those contain keto group are known as ***ketoses***
- The carbonyl group is attached to the C-1 in aldoses (ulti to C-2 (penultimat bonyl carbon or anomeric



D-Glyceraldehyde Dihydroxyacetone

CLASSIFICATION

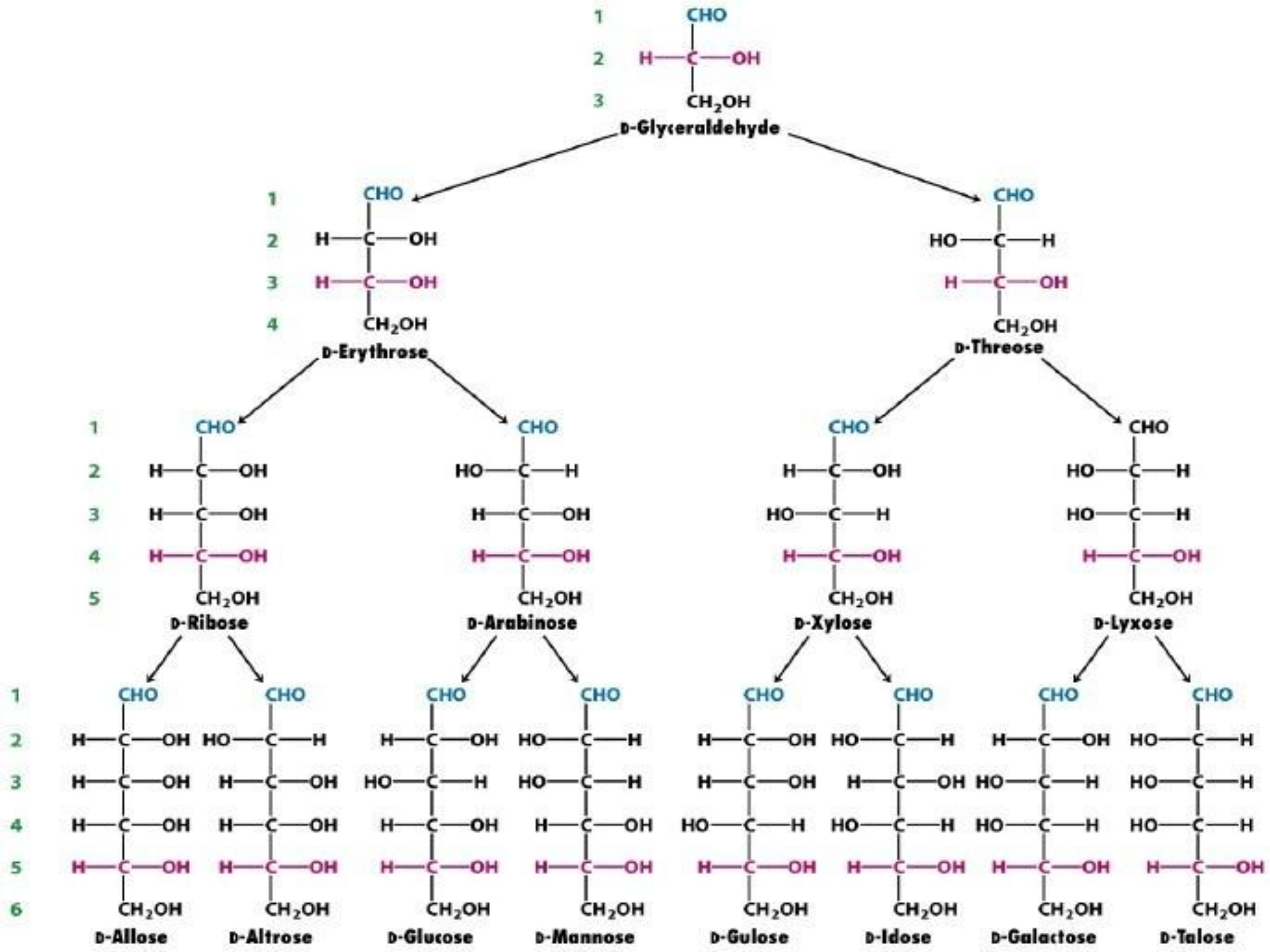
- **Based on Physico-chemical properties**
- Neutral : Have only hydroxyl and carboxyl groups
- Basic : Have amino group in addition to hydroxyl and carboxyl groups
- Acidic : Have additional carboxyl group apart from usual hydroxyl and carboxyl groups
- **Based on molecular complexity**
- Monosaccharides

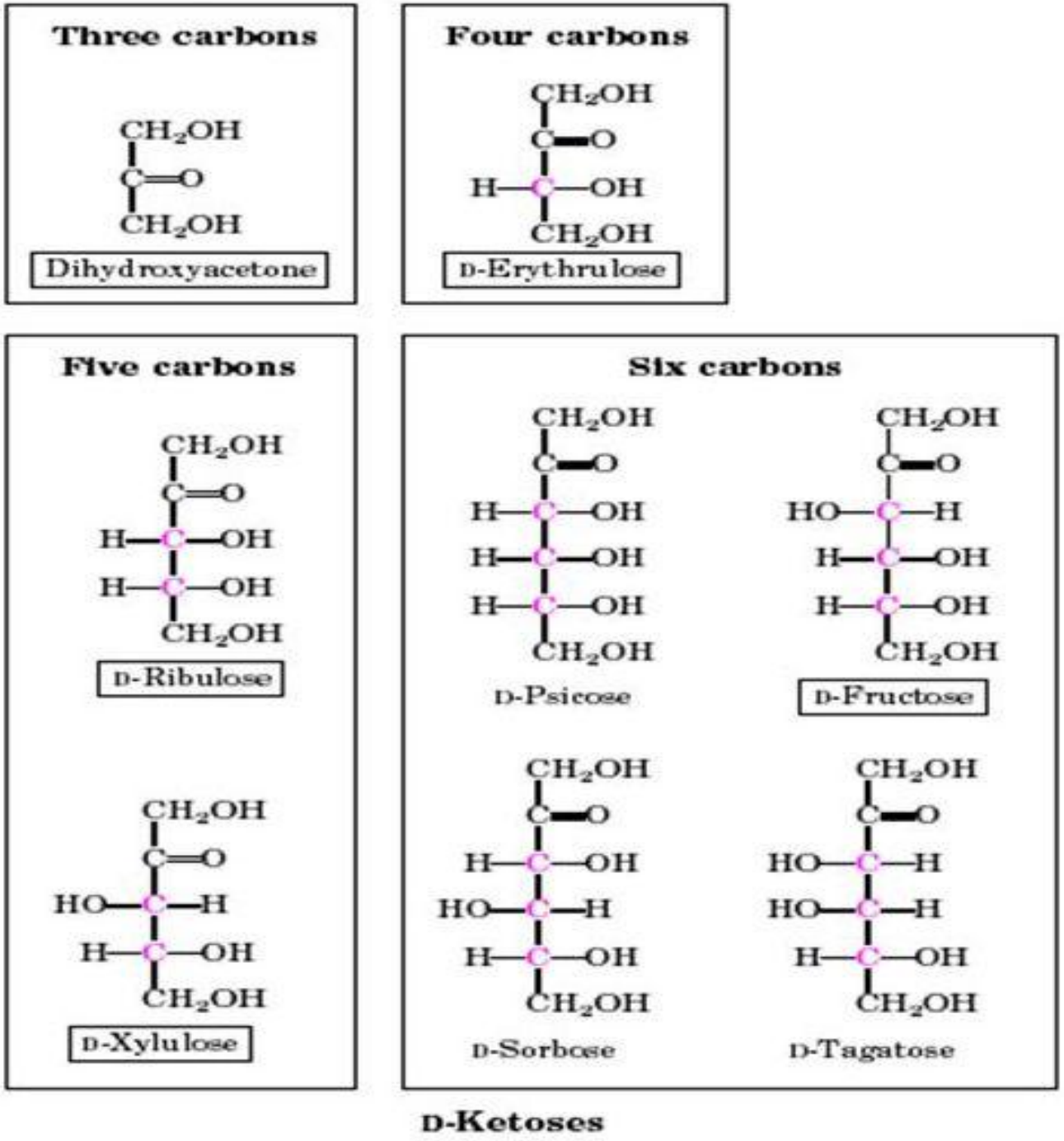
MONOSACCHARIDES

- Are the simplest monomeric carbohydrates that cannot be further hydrolysed into simpler carbohydrates
- The backbone of a monosaccharide is an unbranched, single-bonded carbon chain (usually having 3-7 carbon atoms) with a single polyhydroxy aldehyde or polyhydroxy ketone unit

MONOSACCHARIDES OF BILOGICAL SIGNIFICANCE

MONOSACCHARIDE	ALDOSES	KETOSES
Trioses ($C_3H_6O_3$)	Glycerose (glyceraldehyde)	Dihydroxyacetone
Tetroses ($C_4H_8O_4$)	Erythrose	Erythrulose
Pentoses ($C_5H_{10}O_5$)	Ribose, Arabinose, Xylose	Ribulose, Xylulose
Hexoses ($C_6H_{12}O_6$)	Glucose, Galactose. Mannose	Fructose
Heptoses ($C_7H_{14}O_7$)	----------	Sedoheptulose


D-Glyceraldehyde
D-Erythrose
D-Threose
D-Ribose
D-Arabinose
D-Xylose
D-Lyxose
D-Allose
D-Altrose
D-Glucose
D-Mannose
D-Gulose
D-Idose
D-Galactose
D-Talose


Three carbons
Dihydroxyacetone
Four carbons
D-Erythrulose
Five carbons
D-Ribulose
D-Xylulose
Six carbons
D-Psicose
D-Fructose
D-Sorbose
D-Tagatose

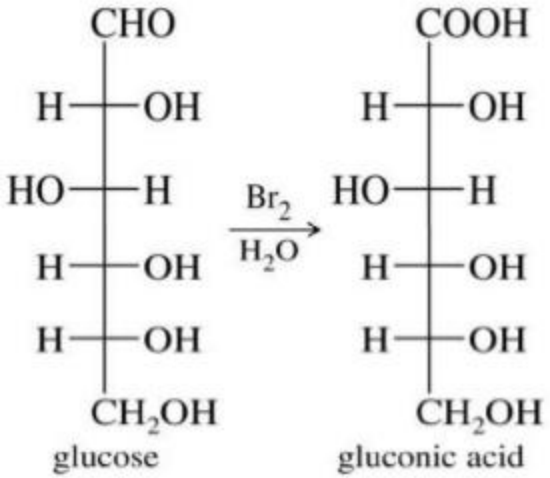
D-Ketoses

Chemical properties

1) Are ***reducing sugars*** capable of reducing some oxidising agents such as hydrogen peroxide, ferric cyanide, ferric ion (Fe^{3+}), cupric ion (Cu^{2+}), Ag^{+}, Hg^{2+}, Bi^{3+} etc due to the presence of free carbonyl carbon.

- Here, the c anomeric carbon) ge oxylic acid and the ox redused.

Example



2) Exhibits ***stereoisomerism*** where the molecules have same chemical composition, but have different spatial configuration

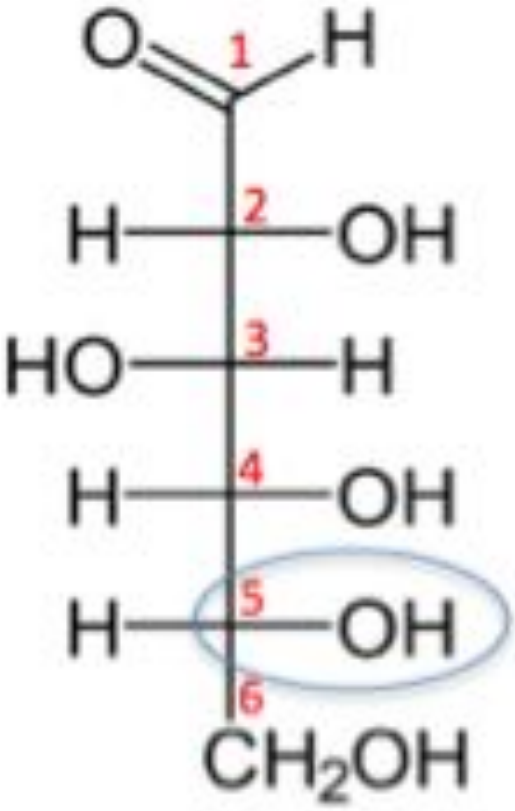
- Are also optically active strerioisomers which differ from each other in their ability to rotate the plane of polarised light either to the left or right
- The number of optical isomers of a molecule depends on the number of its asymmetric (chiral) atoms. It is always equal to 2^n, where n represents the number of asymmetric atoms.
- Thus a molecule having two asymmetrical

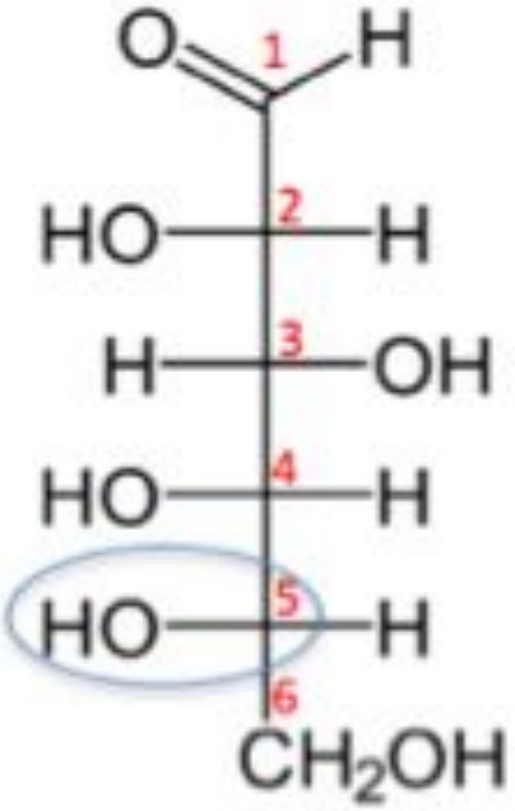
- Optical isomers are of two groups, enatiomers and diastereomers.

- Enatiomers are a pair of optical isomers which are non-superimposable mirror images of each other. One form in which –OH of the primary alcohol (Chiral C- atom farthest from aldehyde group) is located towards the right side and is designated as Dextro/D form. And in the other form the –OH of the primary alcohol is located towards the left side and is designated as Laevo/L form

  Eg: D-Glucose and L-Glucose

- Usually, molecules having right-handed configuration (D-isomers) are



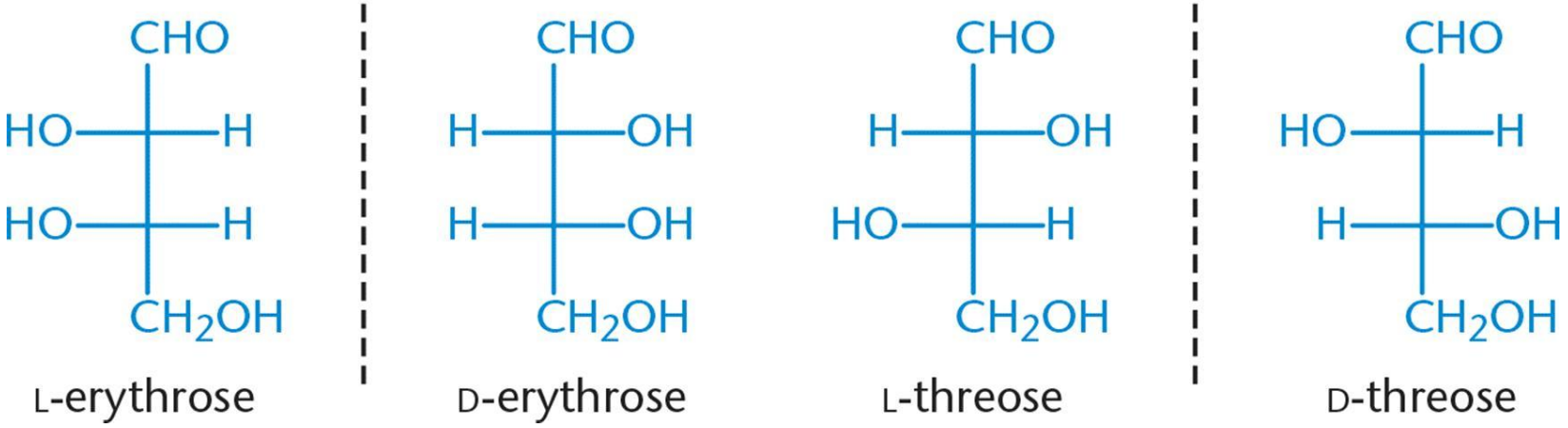


D- Glucose

L-Glucose

- Diastereomers include all optical isomers occurring in a compound either in D-series or L-series. They are not mirror images each other

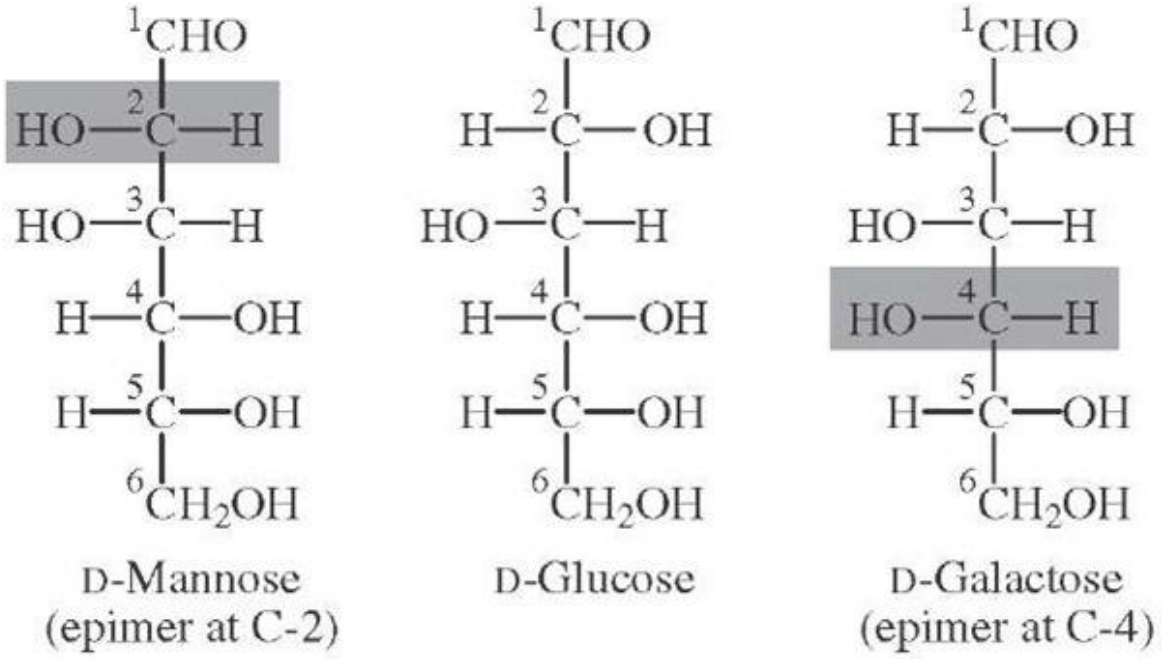
  Eg: A compound having two asymmetrical carbon (aldotetrose, $C_4H_8O_4$) will have four optical isomers, a pair of D isomers and a pair of L isomers. The two D forms are not mirror image of each



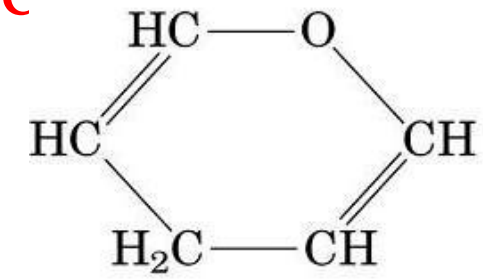
3) Exhibits *epimerism*

- Epimerism is the phenomenon in which the diastereomers of sugar differ from each other in their configuration with respect to only a single carbon atom

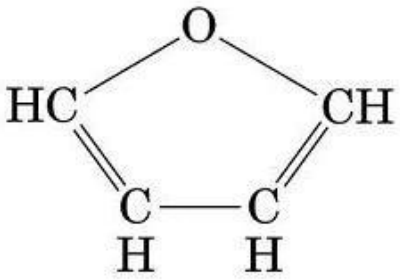
  Eg: D-glucose and D-mannose are epimers with respect to carbon atom C-2 and D-glu with respe



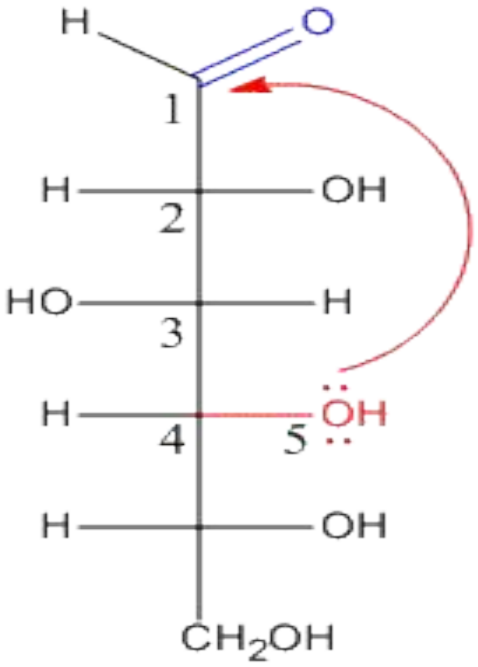
4) Monosaccharides with five or more carbon atom can also exist in ***cyclic form***. Pentoses exist as five-membered furanose rings and hexoses exists both as five-membered furanose and six membe rings



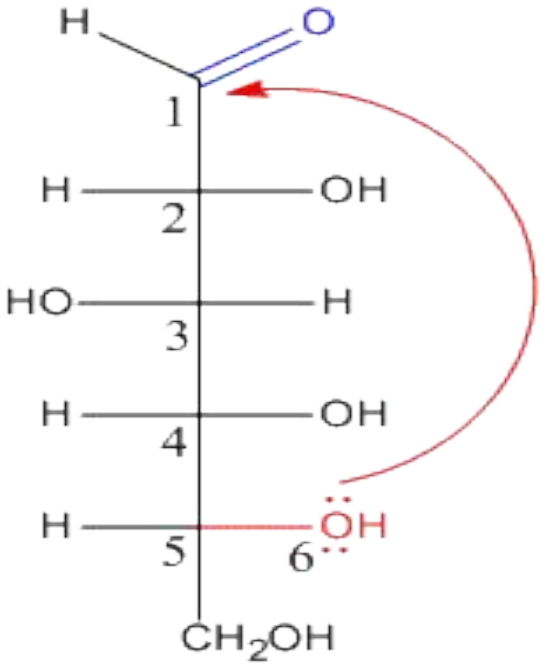
Pyran

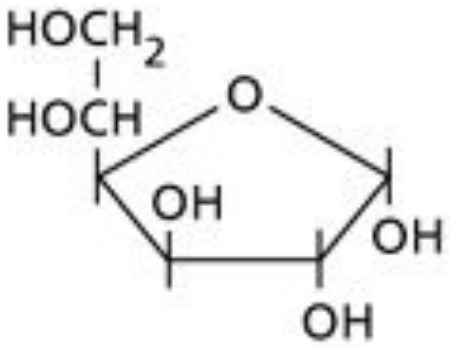


Furan

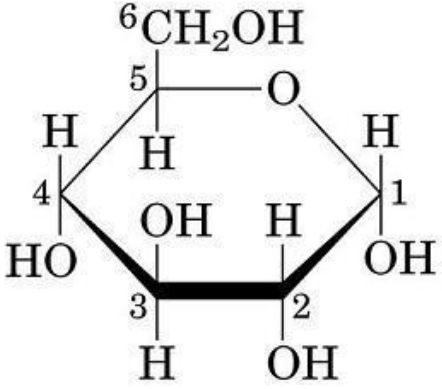


OR





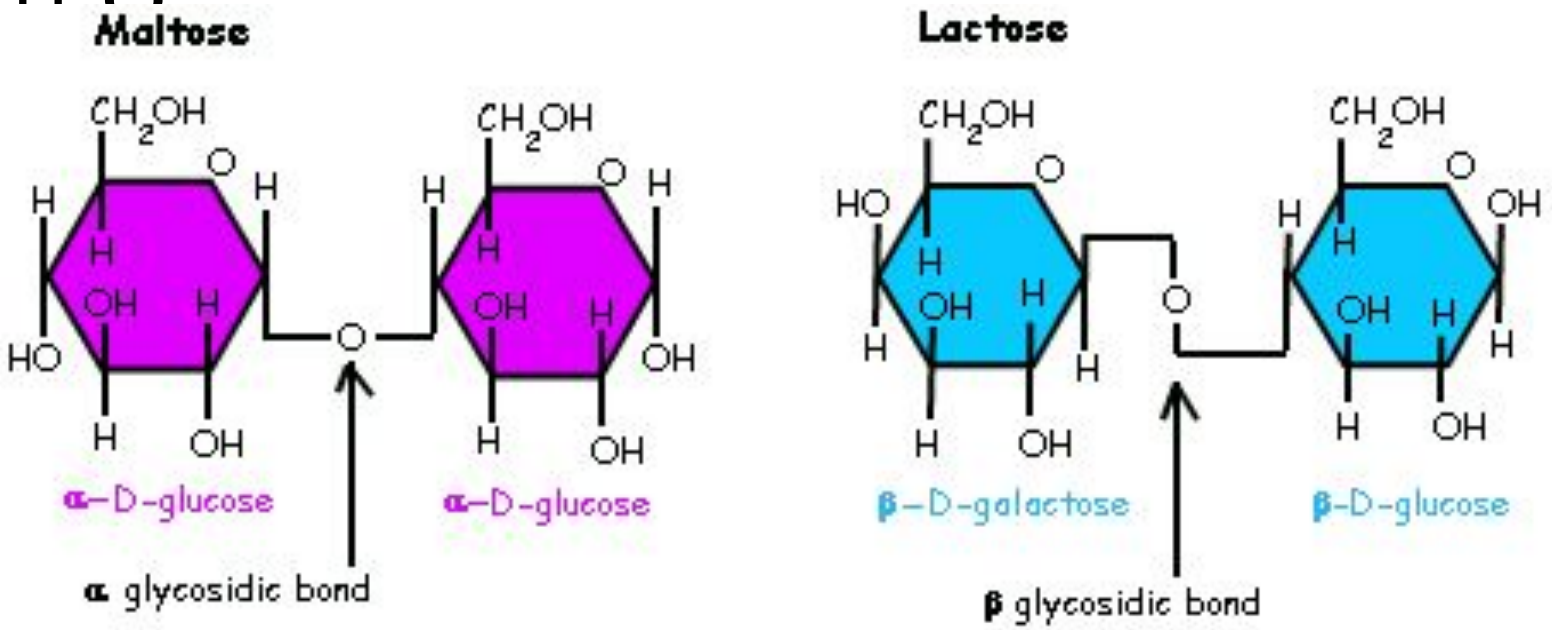
α D- Glucose in furanose form

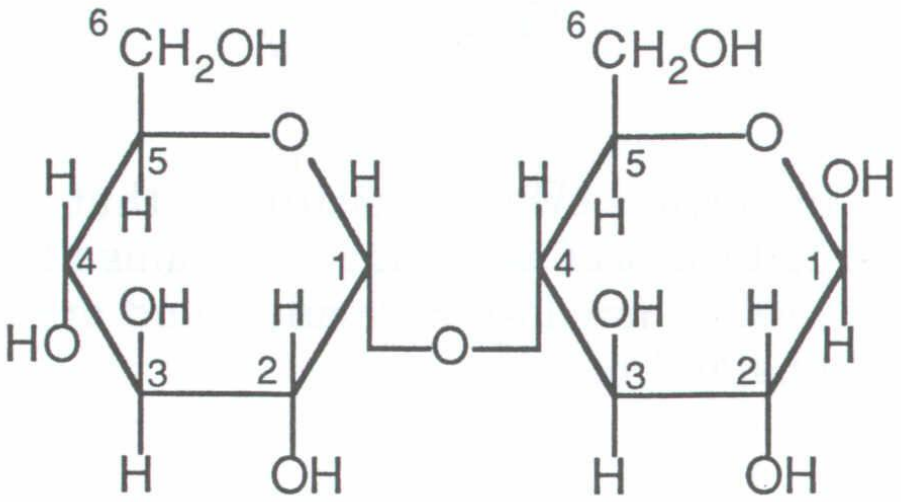


α-D-Glucopyranose

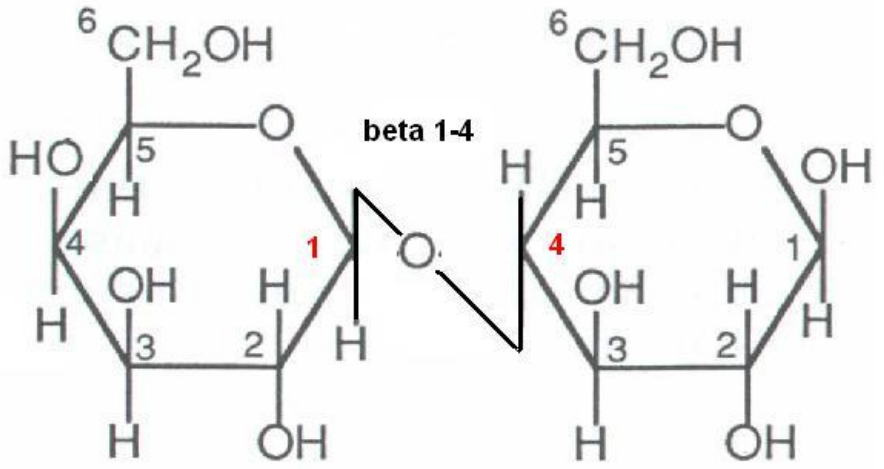
5) form ***Glycosidic bonds***

- Glycosidic bonds are covalent bonds that joins two monosaccharide units. It is formed by ***<u>dehydration condensation</u>*** of the hydroxyl group of the C-1 of one monosaccharide and the hydroxyl group of the C-2, C-4, C-6 of another monosaccharide with the elimination of H_2O.
- M





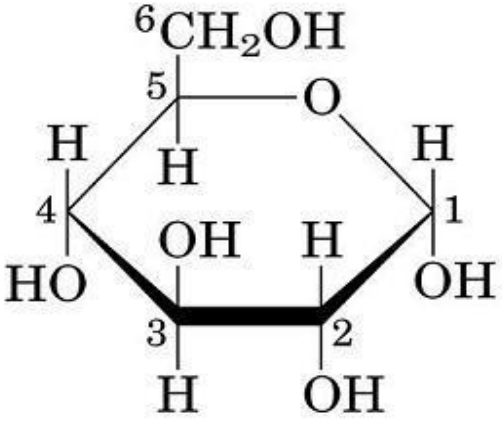
Maltose



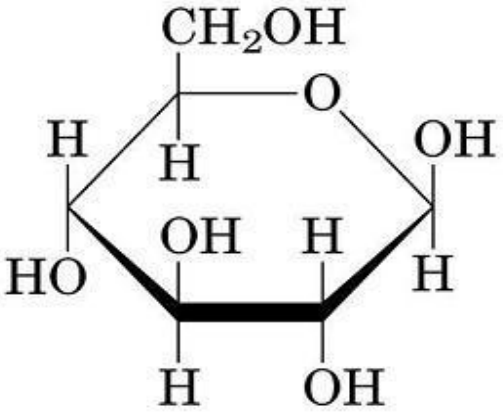
lactose

- Based on the steric configuration of C-1 which is involved in glycosidic linkage, two kinds of glycosidic bonds are recognised

1) Alpha (α) linkage : where –OH is attached to the C-1 is below the plane of the ring
2) Beta (β) linkage : where –OH is attached to the C-1 is above the plane of the ring



α-D-Glucopyranose



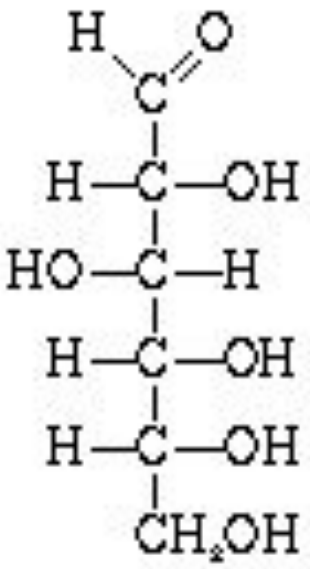
β-D-Glucopyranose

GLUCOSE, $C_6H_{12}O_6$

- Also called Dextran, grape sugar or corn sugar is sweet water soluble monosaccharide
- It has 6 – C atoms, Five –OH groups and a terminal aldehyde group
- Exist as both straight chain and six-membered glucopyranose ring
- Is a reducing sugar
- Has four asymmetric C atoms and hence exist in 16 optically active isomeric forms which are categorised into enatiomers and diastereomers
- Naturally occurs in D-glucose form and rotates plane polarised light in clockwise direction

- Functions

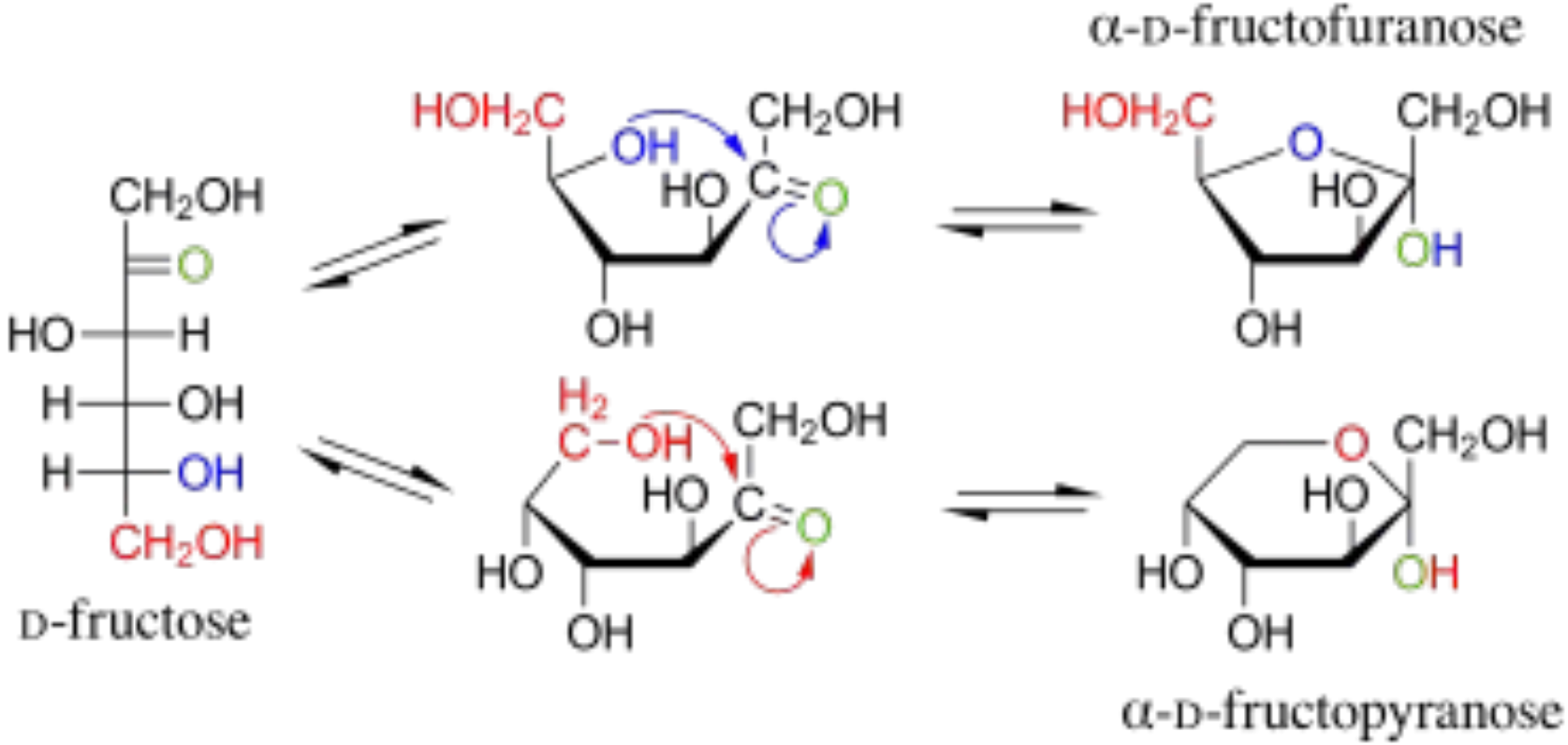
1. Serves as immediate source of energy
2. Essential for proper functioning of brain cells
3. Constitute the basic unit from which energy rich starch and glycogen are derived
4. In plant body it constitute the c
5. Is an essential constituent of blo
6. Mainly produced by photosynt



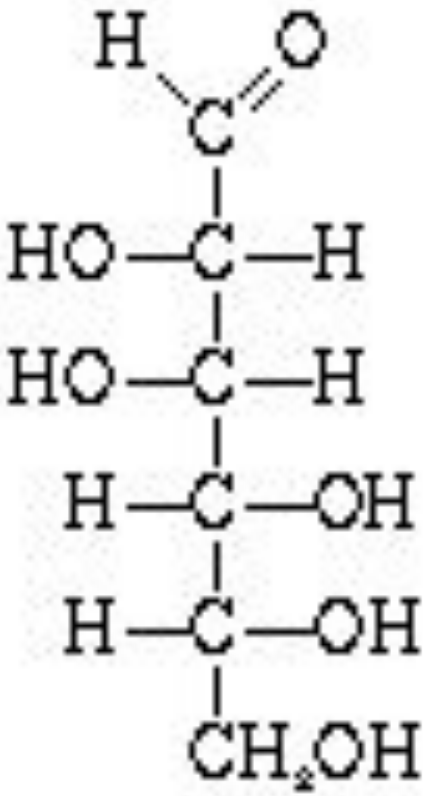
D-Glucose

FRUCTOSE, $C_6H_{12}O_6$

- Fruit sugar or levulose (levo rotatory)
- Major component in honey
- Obtained by hydrolysis of corn sugar, Dahlia
- Exist as keto chain and also α & β furanose and pyranose form


α-D-fructofuranose
D-fructose
α-D-fructopyranose

MANNOSE, $C_6H_{12}O_6$

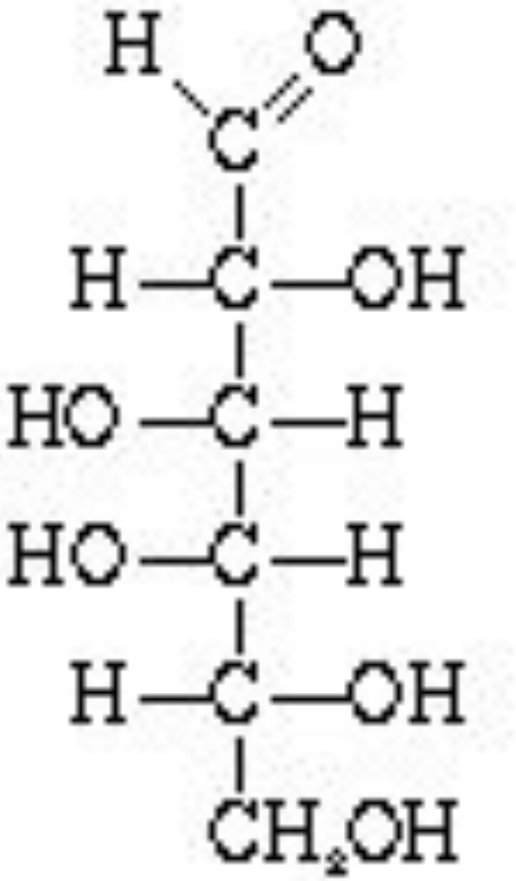


D-Mannose

- C 2 Epimer of glucose found in many fruits apple, orange, peaches etc

- Important in human metabolism, especially in the N-linked glycosylation of certain proteins (is a post –translational modification of proteins occurring in ER)

GALACTOSE, $C_6H_{12}O_6$



D-Galactose

- Also known as milk sugar
- When combined with glucose forms the disaccharide lactose
- Enhances immune system
- Maintains bacterial flora
- Helps in healing wounds, lowering the risk of cataract and decreasing inflammation while boosting absorption of calcium
- Act as a chemical chaperon enhancing assembly of proteins within the body
- Is a component of antigens present on blood cells – In O and A antigens there are two monomers of galactose whereas in the B antigens there are three monomers of galactose

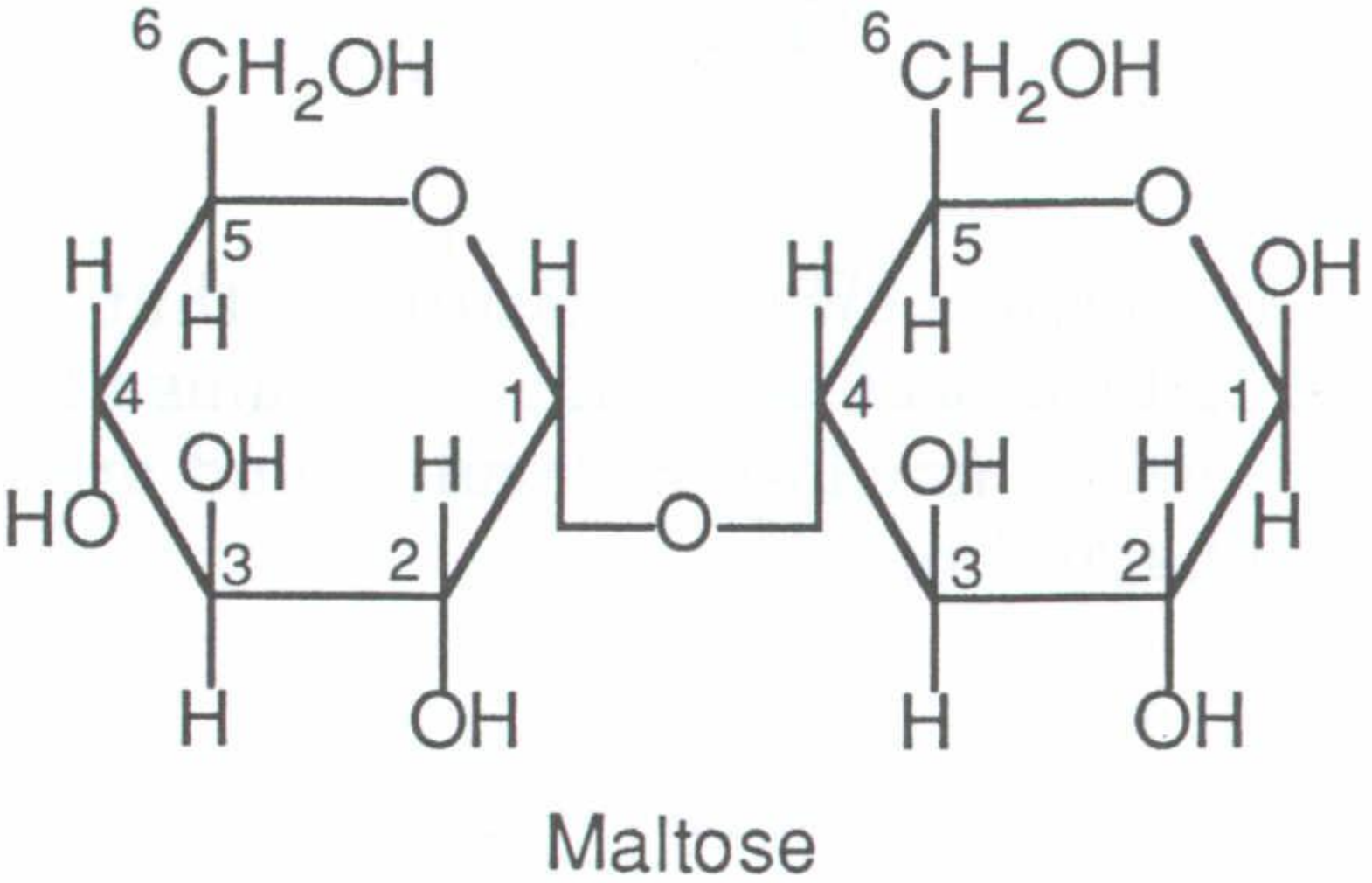
DISACCHARIDES – $C^{12}H^{22}O^{11}$

- Are condensation products of two monosaccharide units with the loss of H_2O eg: Maltose (α 1-4 linkage between two α glucose units) and Sucrose (α 1 – β 2 linkage between a α glucose and a β fructose unit)

- When the anomeric carbon (Carbonyl carbon) is involved in glycosidic bonding, those sugars will not be oxidised by Fe^{3+} or cupric ion (Cu^{2+}) ions. Such sugars are known as non-reducing sugars and those having a free anomeric carbon are known as

MALTOSE

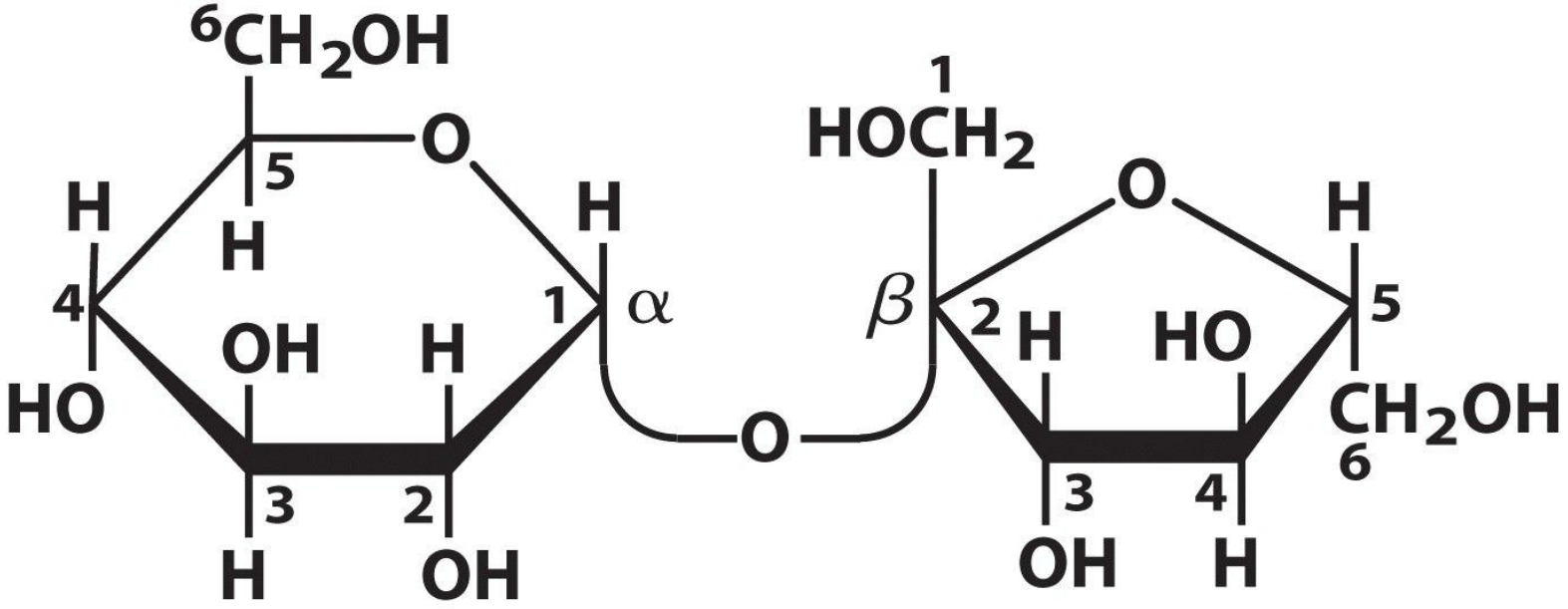
- Colourless, Crystalline, Water soluble, Reducing sugar found in starch and glycogen
- Formed by condensation polymerisation of two glucose units through α, 1-4 linkage
- Maltose is a reducing sugar because the ring of one of the two glucose units can present a free aldehyde group depending on the nature of the glycosidic bond
- In higher animals, maltose is the end product of the oral and intestinal digestion of starch by ***amylase*** which can be further broken down to glucose units by ***maltase***
- An isomer of maltose is isomaltose, formed by condensation polymerisation of two glucose



Maltose

SUCROSE

- Cane sugar or table sugar
- Sweet, water soluble non-redusing sugar found in sugar cane, beetroot, pineapple, honey, fruits etc
- Formed by condensation polymerisation of one molecule of α - D glucopyranosyl and one molecule of β – D fructofuranoside units through α 1 – β 2 linkage
- Since the linkage is formed between aldehyde group of glucose and ketone group of fructose , it is a non-reducing sugar
- Sucrose as such is dextrorotatory but its hydrolysis product is levo rotatory due to the predominance levorotatory effect of fructose. This phenomenon is called inversion



Sucrose

α-D-glucopyranosyl β-D-fructofuranoside

Glc(α1↔2β)Fru

Biological functions

- Important source of metabolic energy
- Act as a storage form of enegy in sugarcane and beetroot

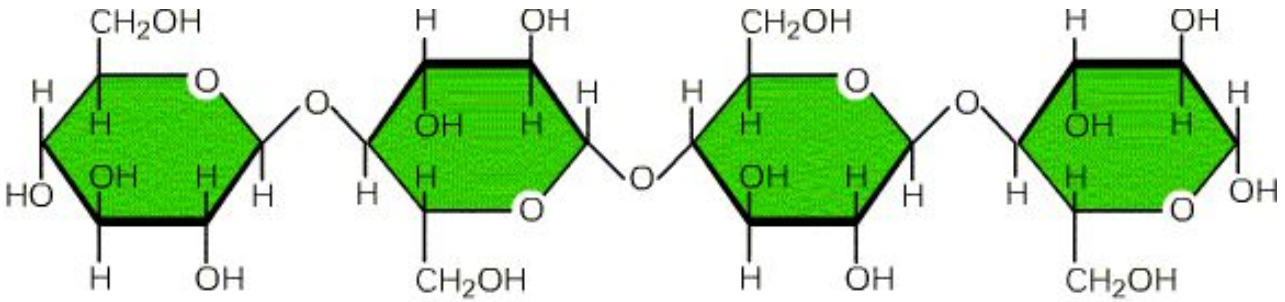
POLYSACCHARIDES [GLYCANS] $(C_6H_{10}O_5)n$

- Are the most complex type of carbohydrates formed by the condensation polymerisation of many monosachharide units
- Hydrolysable, long, linear, branched/unbranched chains

  either formed by same units (homopolysachharides –eg: starch, glycogen, chitin, inulin etc.) or different units (heteropolysachharides eg: agar)
- Polysaccharides containing aminosugars and uronic acid are known as

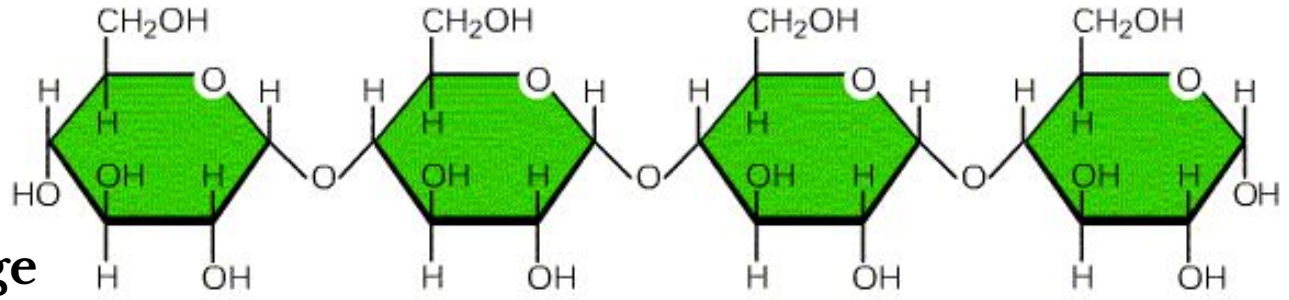
Cellulose

β 1,4 glycosidic linkage



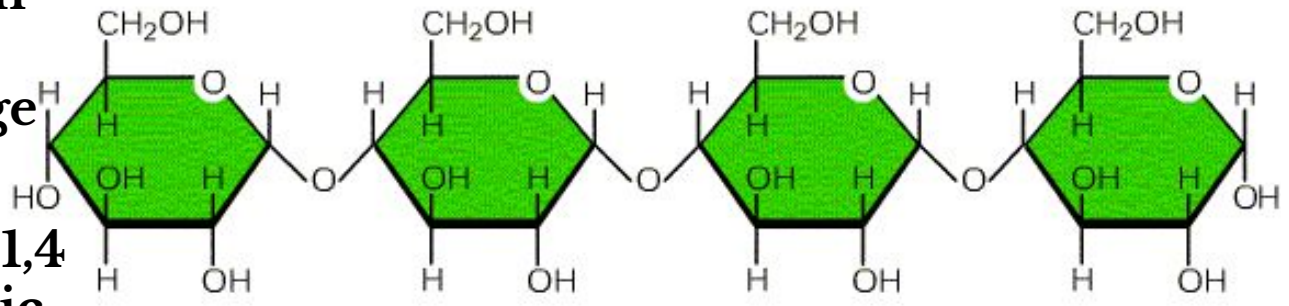
Starch

Amylose - α 1,4 glycosidic linkage and Amylopectin α 1,4 & α 1,6 glycosidic linkage



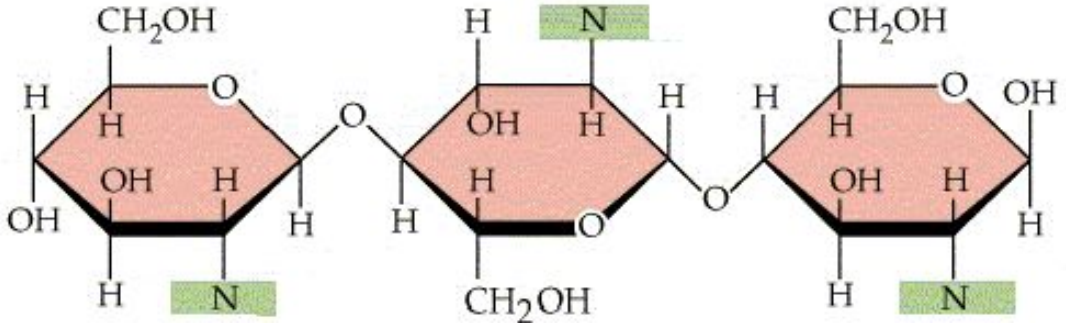
Glycogen

Amylopectin α 1,4 & α 1,6 glycosidic linkage

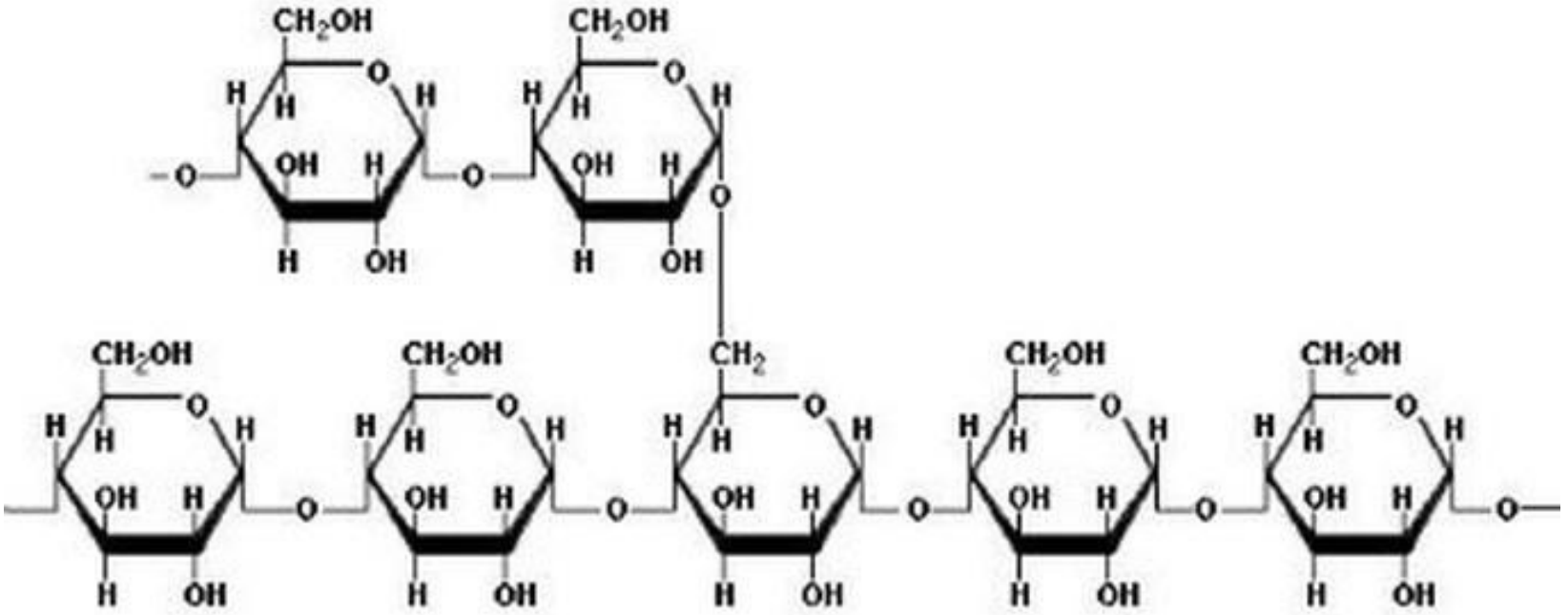


Chitin

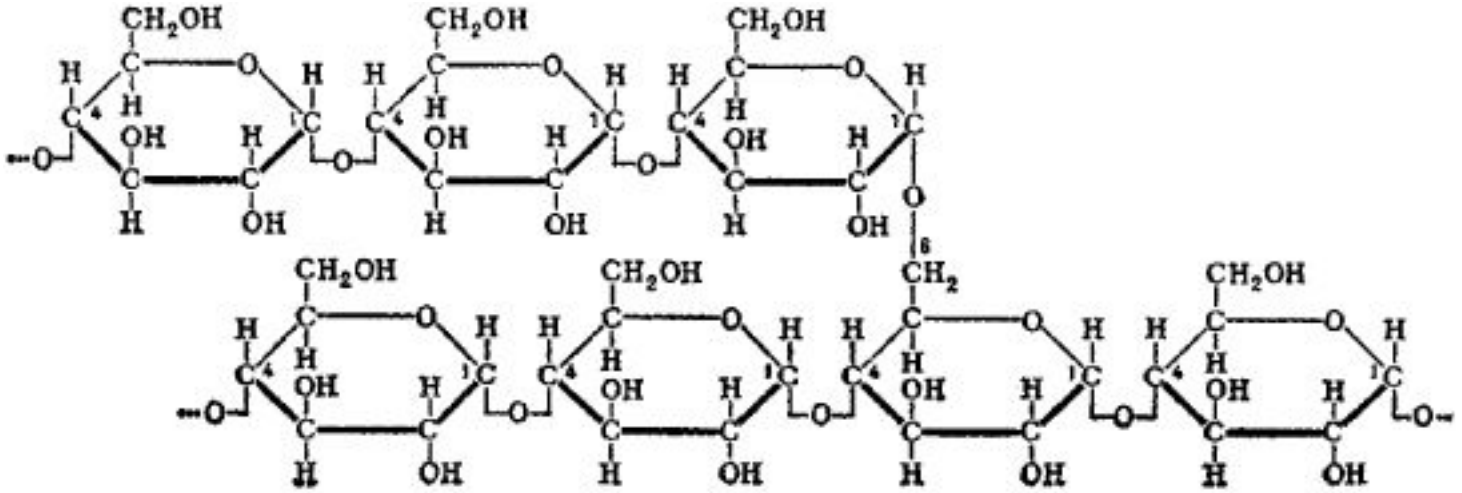
β 1,4 N acetyl glucosamine



starch



glycogen



CLASSIFICATION OF CARBOHYDRATES

(2) Disaccharides are condensation products of two monosaccharide units; examples are maltose and sucrose.

(3) Oligosaccharides are condensation products of three to ten monosaccharides.

(4) Polysaccharides are condensation products of more than ten monosaccharide units; examples are the starches and dextrins, which may be linear or branched polymers.

DISACCHARIDES OF BILOGICAL SIGNIFICANCE

Sugar	Composition	Source
Isomaltose	*O*-α-D-glucopyranosyl-(1->6)-α-D-glucopyranose	Enzymic hydrolysis of starch (the branch points in amylopectin)
Maltose	*O*-α-D-glucopyranosyl-(1->4)-α-D-glucopyranose	Enzymic hydrolysis of starch (amylase); germinating cereals and malt
Lactose	*O*-α-D-galactopyranosyl-(1->4)-β-D-glucopyranose	Milk (and many pharmaceutical preparations as a filler)
Sucrose	*O*-α-D-glucopyranosyl-(1->2)-β-D-fructofuranoside	Cane and beet sugar, sorghum and some fruits and vegetables

POLYSACCHARIDES OF BIOLOGICAL SIGNIFICANCE

A) Homopolysacchrides	Glucosan	Fructosan	Galactosan
	Starch	Inulin	Agar
	Glycogen	-	-
	Dextrins	-	-
	Cellulose	-	-
B) Hetero polysaccharides	Non sulfated	Sulfated	Neutral polysaccharides
	Hyaluronic acid	Keratan sulfate	Blood group substances
	Chondroitin	Chondroitin sulfate	
		Dermatan sulfate	
		Heparin	