

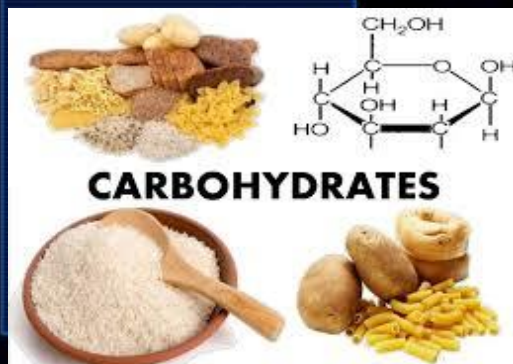
CARBOHYDRATE CHEMISTRY

BY

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Carbohydrates $(C_nH_{2n}O_n) (CH_2O)_n$

- Definition: Polyhydroxy-aldehyde or -ketones & compounds that produce them on hydrolysis
- Importance:
 1. Energy
 2. Synthesize biological compounds (Fatty a & glucogenic aa)
 3. Enter in many compounds e.g. Ribose in nucleoprotein, galactose in certain fats & lactose of milk.
 4. Cellulose can function as structural units within the cell.
 5. Stored (starch in plants & glycogen in mammalian tissues)



12/12/2020

Classification of CHO

(number of sugar units)

1. Monosaccharides (1 sugar unit).
2. Disaccharides (2 sugar units).
3. Oligosaccharides (3 – 10 sugar units).
4. Polysaccharides (> 10 sugar units)..



12/10/2020

Classification and Nomenclature

Carbohydrates

1 monosaccharide unit

2 units

3-10 units

>10 units

Monosaccharides

Disaccharides

Oligosaccharides

Polysaccharides

Monosaccharides		Disaccharides		Oligosaccharides		Polysaccharides		
Functional group	Number of carbon atoms	Maltose	Lactose	Sucrose	Tri-saccharide	Tetra-saccharide	Homopoly-saccharide	Heteropoly-saccharide
Aldoses e.g Glucose	Trioses				Raffinose	Stachyose	Starch	Hyaluronic acid
	Tetroses						Dextrin	Heparin
Ketoses e.g Fructose	Pentoses						Glycogen	Chondroitin sulfate
	Hexoses						Cellulose	Dermatan Sulfate
	Heptoses						Inulin	Keratan Sulfate

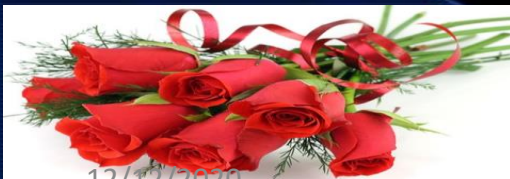


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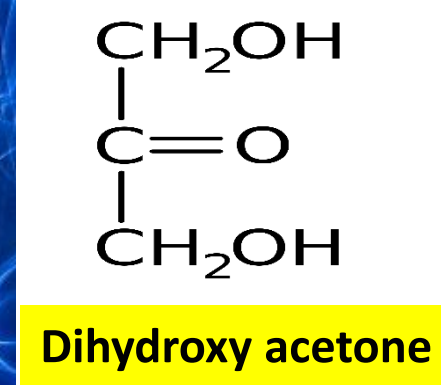
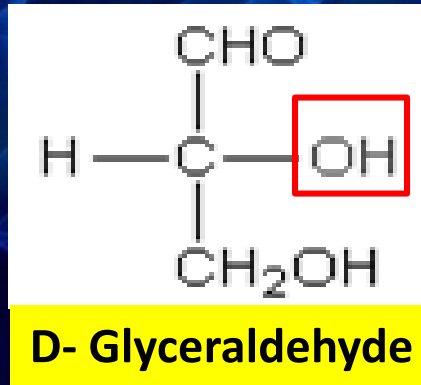
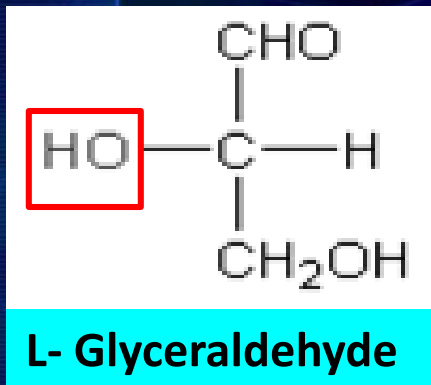
Monosaccharides

- **Definition:**
The simplest sugars (cannot be hydrolyzed to simpler ones)
- **Classification:**
 1. **Number of carbon atoms**
 2. **The active group**

n. of Carbon	Aldo-sugars	Keto-sugars
<u>Trioses</u> (3 C)	<u>Glycerose</u> (glyceraldehyde)	<u>Dihydroxy acetone</u>
<u>Tetroses</u> (4 C)	<u>Erythrose</u>	<u>Erythulose</u>
<u>Pentoses</u> (5 C)	<u>Ribose</u>	<u>Ribulose</u>
<u>Hexoses</u> (6 C)	<u>Glucose</u>	<u>Fructose</u>

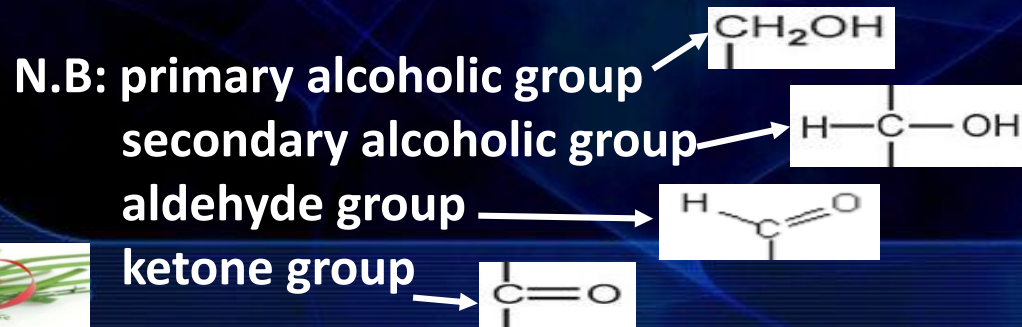


* Trioses



D & L sugars → absolute configuration Not the direction of rotation

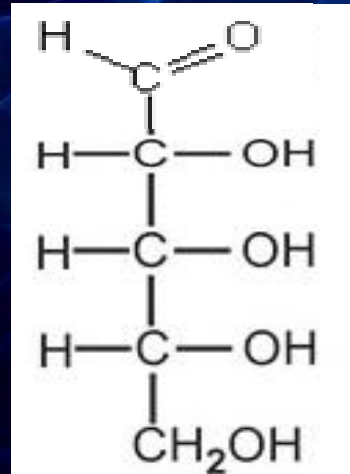
OH of subterminal carbon



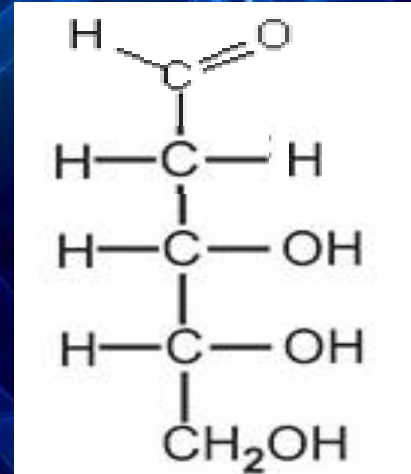
	Aldoses	Ketoses
Trioses	$ \begin{array}{c} \text{CHO} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p style="text-align: center;">D- Glyceraldehyde</p>	$ \begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{C}=\text{O} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p style="text-align: center;">Dihydroxyacetone</p>
Importance	<ol style="list-style-type: none"> 1. It is the simplest aldose and the mother compound of any aldose. 2. Glyceraldehyde 3-phosphate is intermediate in hexose monophosphate shunt (a minor pathway of glucose oxidation). (HMP shunt) 	<ol style="list-style-type: none"> 1. It is the simplest ketose and the mother compound of any ketose.
	<p><i>Also</i></p> <ol style="list-style-type: none"> 1. Glyceraldehyde 3-phosphate and dihydroxyacetone phosphate are intermediates in glycolysis (major pathway of glucose oxidation). 2. Both are precursors of glycerol important for lipid synthesis. 	
<u>Tetroses</u>	<u>Erythrose</u>	Erythrulose
Importance	<u>Erythrose</u> 4-phosphate is intermediate in hexose monophosphate shunt (HMP shunt)	



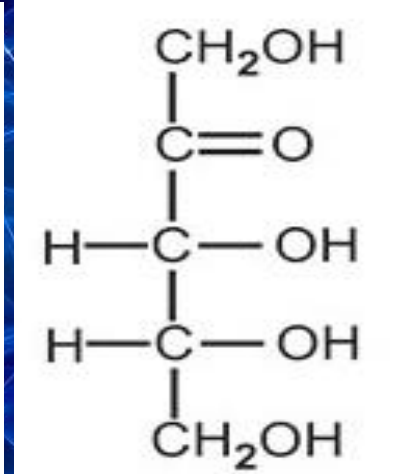
* Pentoses



D-ribose



D-deoxyribose



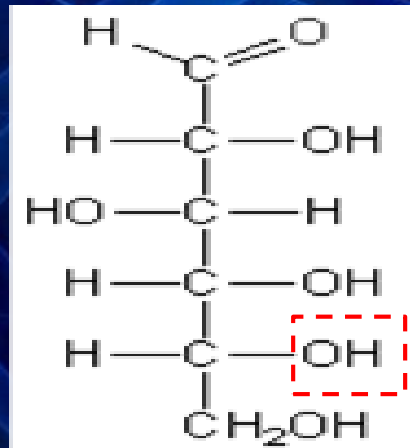
D-ribulose

Functions:

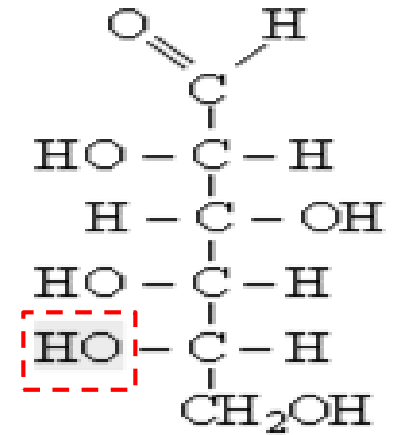
1. In RNA & DNA
2. In high energy phosphate nucleotides (eg. ATP, GTP)
3. In Coenzymes (NAD, NADP & flavoproteins)
4. Intermediates in metabolism (ribose-P & ribulose-P)
5. Ribose 5-P, ribulose 5-P & D-xylulose 5-P are intermediates of HMP shunt
6. L-xylulose is intermediate of uronic acid pathway



* Hexoses



D - Glucose



L - Glucose

* D-glucose “grape sugar”:

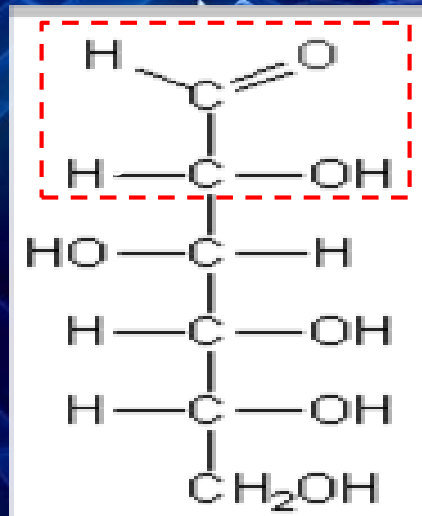
- Called dextrose (dextrorotatory) “d”
- The main sugar in blood (70-110 mg/dl) & main tissue sugar
- A major source of energy
- Enter in di- & polysaccharides
- In liver and other tissues, it is converted to all carbohydrates in the body (glycogen – galactose – ribose – fructose)



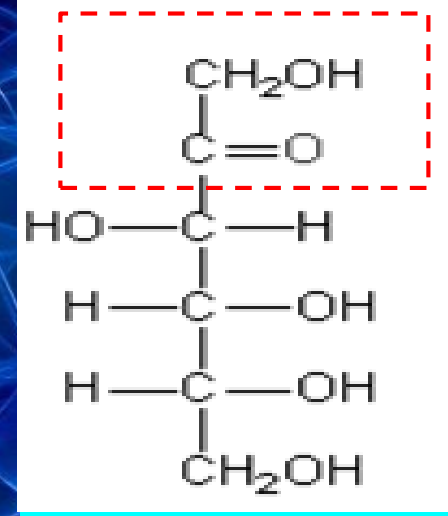
* Hexoses

* Fructose: Called levulose (levorotatory) "l"

- The main semen sugar
- Much sweeter than glucose
- Enter in sucrose formation
- In liver, it is converted to glucose



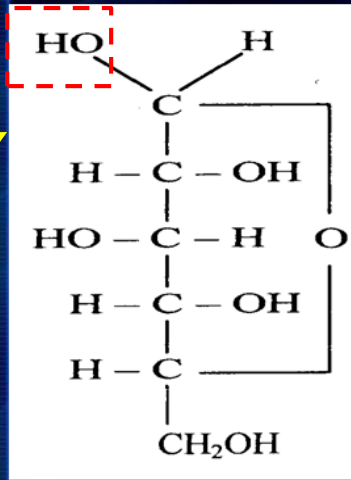
D- Glucose



D- Fructose

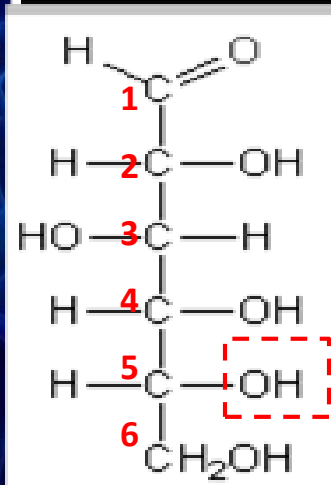


Ring structure

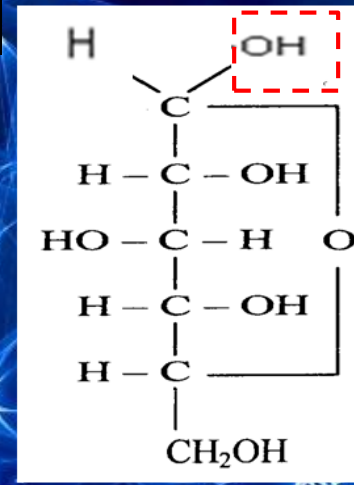


β -D glucose

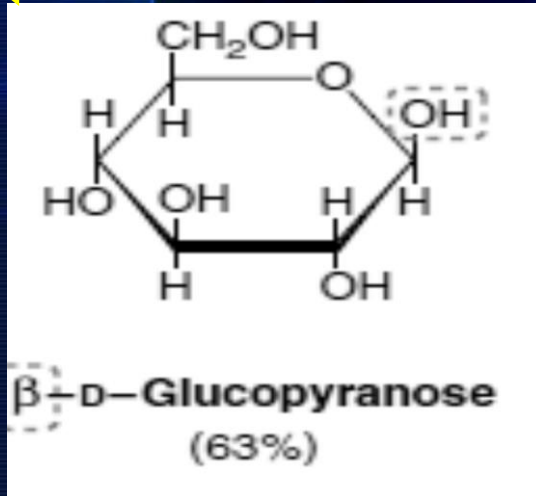
Straight chain



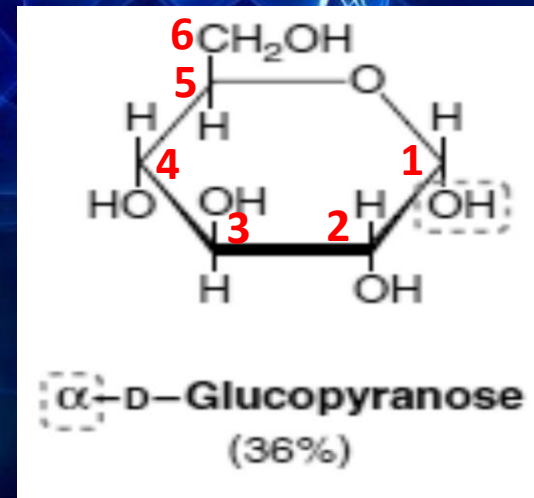
Ring structure



α -D glucose



Haworth Formula



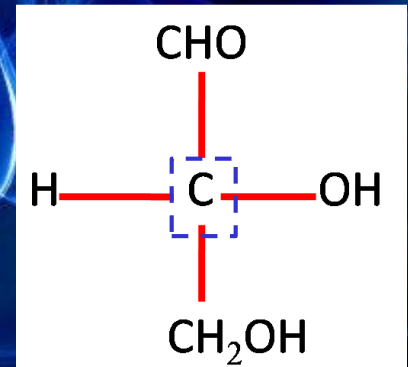
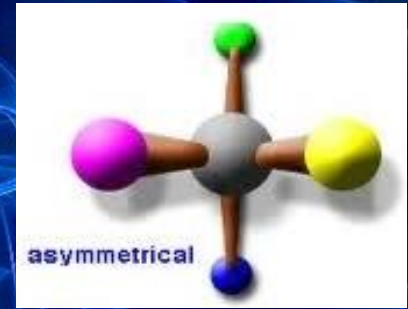
Haworth Formula

Forms of Monosaccharide Structure (Straight - Ring - Haworth)



* An asymmetric carbon atom

- It is a carbon atom to which 4 different atoms or groups of atoms are attached.
- Optical activity is given by any compounds that has asymmetrical carbon atom.
- Optically active compound rotate plane polarized light (PPL) to right (d) or to left (l).
- e.g. glucose is dextrorotatory "d"
fructose is levorotatory "l"



Differences between glucose and fructose

Differences	Glucose	Fructose
Nature	Aldo-hexose	Keto-hexose
Optical activity	Dextrorotatory = (+) or (d)	Levorotatory = (-) or (l)
Another name	Dextrose	Levulose
Ketose test (heating with HCl)	No change	Red brown color
Distribution	Mainly in blood	Mainly in semen
Function	Major source of energy in body	Major source of energy in semen



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Monosaccharide derivatives

Sugar acids

Amino sugars

Amino sugar acids

Sugar alcohol

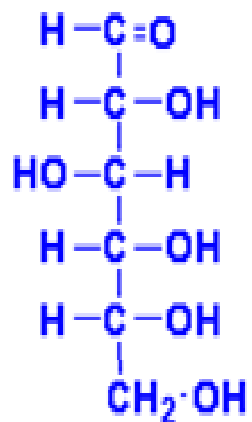
Deoxysugars

A. Sugar acids:

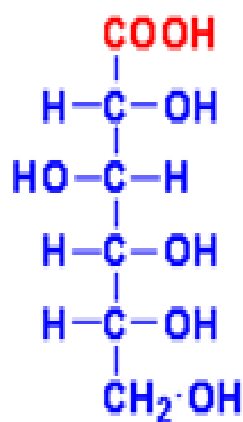
- Aldonic acids produced by oxidation of active carbonyl group (e.g. **gluconic** acid)
- Uronic acid produced by oxidation of last carbon (e.g. **glucuronic** a)
- Aldaric acids: dicarboxylic acids (oxidation of both active carbonyl group and last carbon) (e.g. **glucaric** acid)



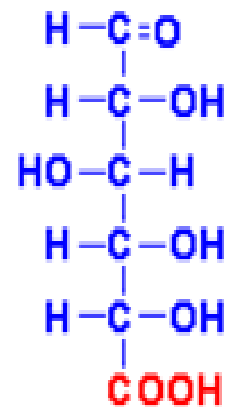
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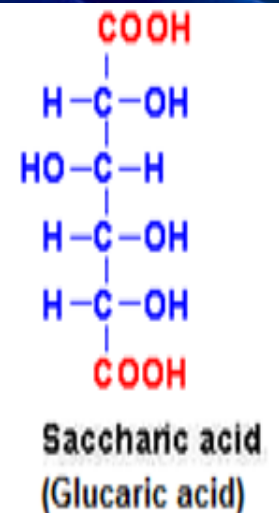
Glucose



Gluconic acid



Glucuronic acid



Importance

Glucose oxidase reaction is used for estimation of blood glucose

UDP-glucose → UDP-glucuronic acid in the liver by the uronic acid pathway.

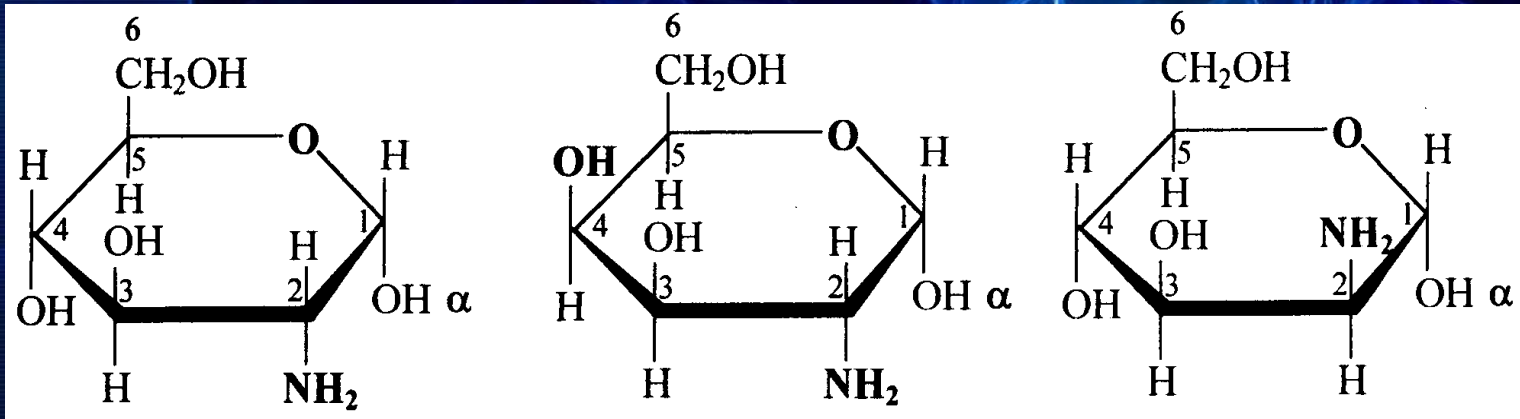
Importance:

1. Synthesis of mucopolysaccharides
2. Conjugates with -Toxic substances - Drugs - hormones - bilirubin & converts them into soluble non-toxic substance; a glucuronide, which is excreted in urine



B. Amino sugars:

- Replacing the hydroxyl group of carbon 2 by an amino group
- Amino sugars are constituents of **glycoprotein** and **GAGs**.
eg. Glucosamine – galactosamine - mannosamine



α, D-Glucosamine

α, D-Galactosamine

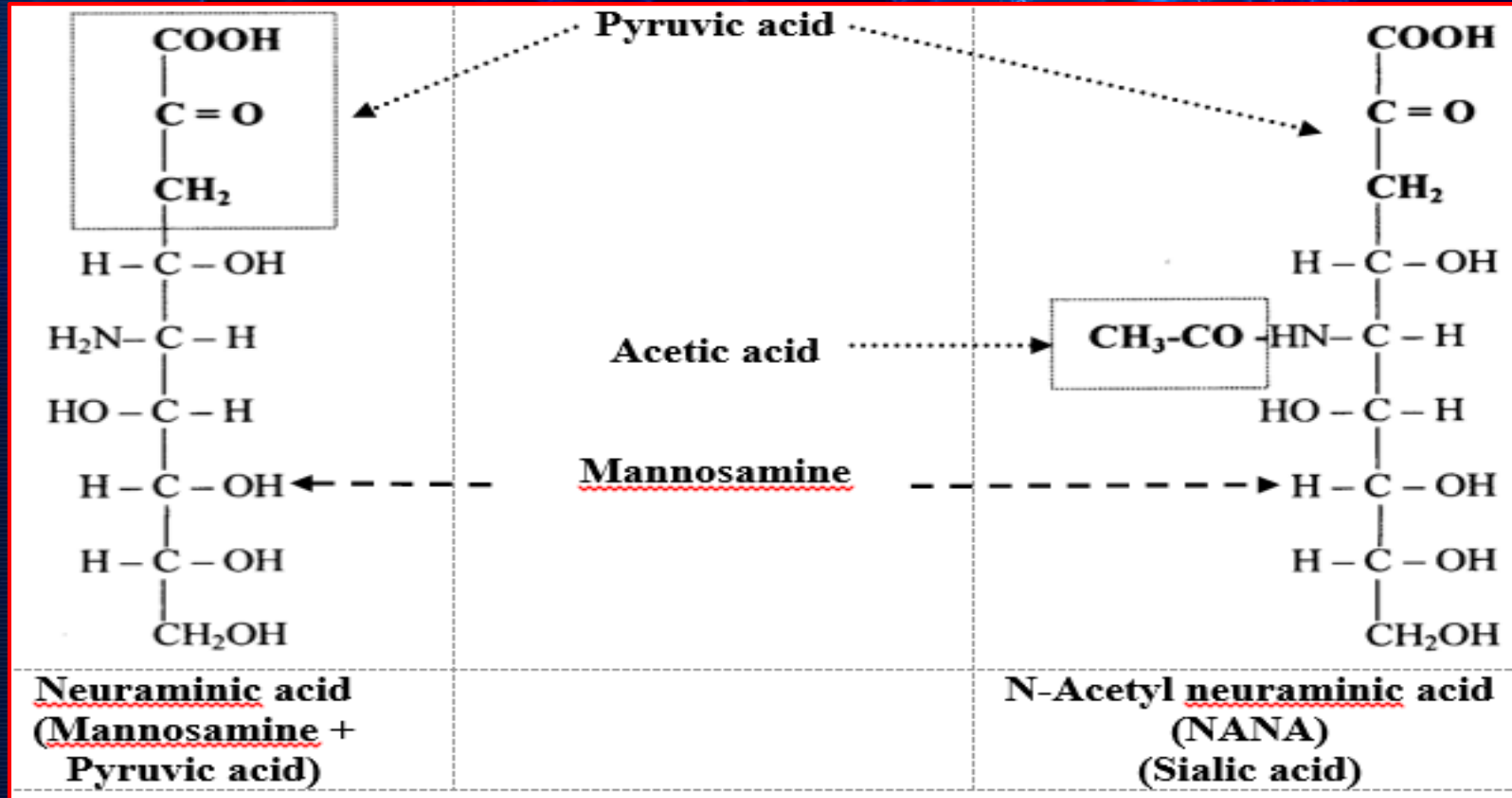
α, D-Mannosamine



C. Amino sugar acids:

- They are condensation of aminosugars & some acids
- They are occurring in glycoproteins

eg. **Neuraminic acid** & **N-acetyl neuraminic acid (NANA or sialic acid)**

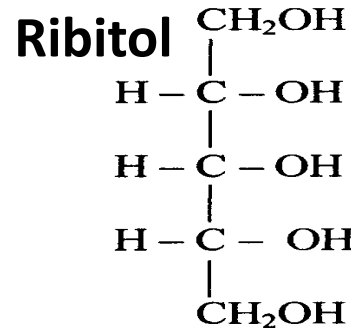
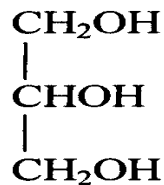


D. Sugar alcohols:

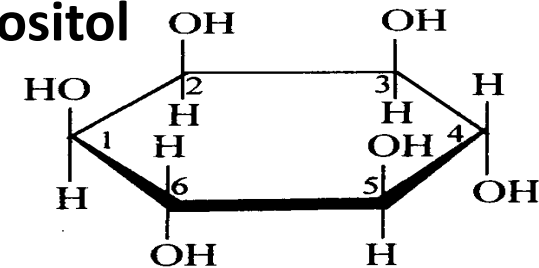
- Produces by reduction of monosaccharides to the corresponding alcohols (hydrogenation of aldoses & ketoses)



Glycerol



Inositol



Inositol: is called myoinositol or muscle sugar

Enters in phospholipids

Present in liver, heart and muscle

In plant, phytic acid (inositol hexaphosphate) inhibits the absorption of Ca^{+2} , Mg^{+2} , Mn^{+2} & Fe^{+2} from intestine \rightarrow phytate salts



Example	Glycerol	Ribitol	Xylitol
	$ \begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $	$ \begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $	$ \begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{HO}-\text{C}-\text{H} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $
Importance	<p>Glyceraldehyde or dihydroxyacetone phosphate → glycerol which is :</p> <ol style="list-style-type: none"> 1- Component of triacylglycerol & phospholipids (Lipid) 2- Used in pharmaceuticals as a base & drug (glyceryl trinitrate) 	<p>Ribose → ribitol which is a constituent of riboflavin (vitamin B2)</p>	<p>L-Xylulose → xylitol which is artificial sweetener.</p>

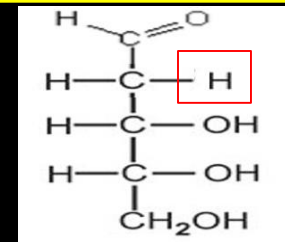


Example	Sorbitol	Mannitol	Galactitol
	$ \begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{HO}-\text{C}-\text{H} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $	$ \begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{HO}-\text{C}-\text{H} \\ \\ \text{HO}-\text{C}-\text{H} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $	$ \begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{HO}-\text{C}-\text{H} \\ \\ \text{HO}-\text{C}-\text{H} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $
Importance	<p>D-Glucose or D-fructose → Sorbitol</p> <p>Sorbitol accumulates in ocular lens in diabetes leading to cataract (lens opacity)</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> $\begin{array}{c} \text{H}-\text{C}=\text{O} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{HO}-\text{C}-\text{H} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array}$ </div> <div style="text-align: center;"> $\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{C}=\text{O} \\ \\ \text{HO}-\text{C}-\text{H} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array}$ </div> </div>	<p>D-mannose or D-fructose → mannitol</p> <p>which is used as an <u>osmotic diuretic</u> and <u>reduce intracranial tension</u> in brain tumors and <u>reduce intraocular pressure</u> in acute glaucoma</p>	<p>D-galactose → galactitol</p> <p>Galactitol accumulates in ocular lens in galactosemia leading to cataract (lens opacity)</p>



E. Deoxysugars:

- Replacement of the hydroxyl group of carbon 2 by hydrogen atom eg. Deoxyribose in DNA



Glycosidic bond & glycosides

Glycosidic bond:

- Form between a carbohydrate & another compound
- Between hydroxyl group of anomeric carbon of monosaccharide & another compound (monosaccharide → disaccharide or non-CHO aglycon → glycoside)

eg. of glycosides:

- Glycolipids, glycoprotein,
- Sugar nucleotides (ATP & GTP): aglycon is purine and pyrimidine
- Cardiac glycosides: aglycon is steroid nucleus
(Digitalis is a cardiac glycoside used in treatment of heart failure)
- Phlorizin (blocks active transport of glucose by the kidney)





Thank you