CARBOHYDRATE CHEMISTRY

BY

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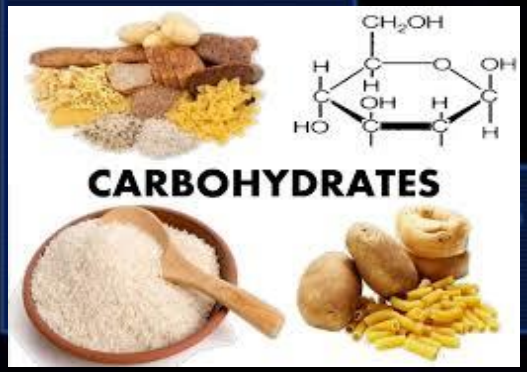

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Carbohydrates

- **Definition:** ***Polyhydroxy-aldhyde*** 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)

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)..

Classification and Nomenclature

Carbohydrates

1 monosaccharide unit

Monosaccharides

- Functional group
  - Aldoses e.g Glucose
  - Ketoses e.g Fructose
- Number of carbon atoms
  - Trioses
  - Tetroses
  - Pentoses
  - Hexoses
  - Heptoses

2 units

Disaccharides

- Maltose
- Lactose
- Sucrose

3-10 units

Oligosaccharides

- Tri-saccharide
  - Raffinose
- Tetra-saccharide
  - Stachyose

>10 units

Polysaccharides

- Homopoly-saccharide
  - Starch
  - Dextrin
  - Glycogen
  - Cellulose
  - Inulin
- Hetropoly-saccharide
  - Hyaluronic acid
  - Heparin
  - Chondroitin sulfate
  - Dermatan Sulfate
  - Keratan Sulfate

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

- **Definition:**

  The simplest sugars (cannot be hydrolyzed to simpler ones)

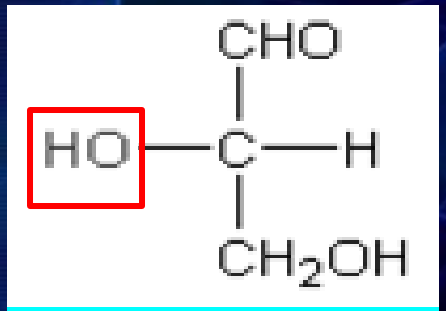
- **Classification:**

  1. Number of carbon atoms

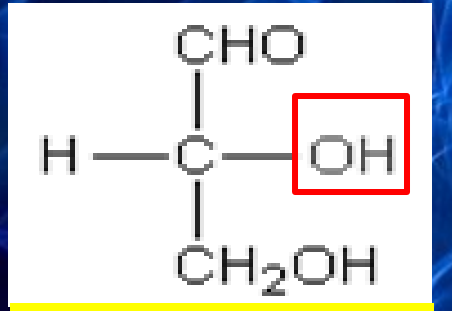
  2. The active group

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

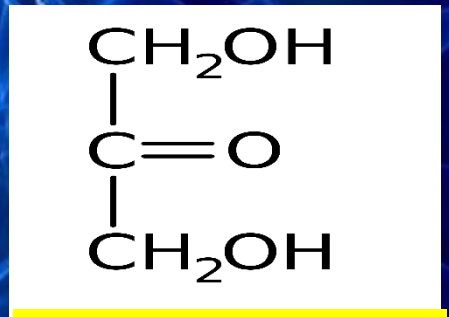
* Trioses



L- Glyceraldehyde



D- Glyceraldehyde



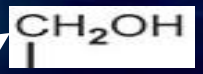
Dihydroxy acetone

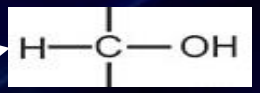
D & L sugars → absolute configuration Not the direction of rotation

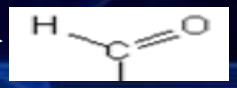
OH of subterminal carbon

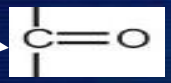
Left → L

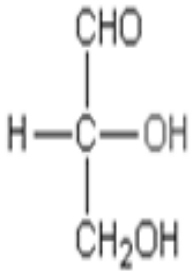
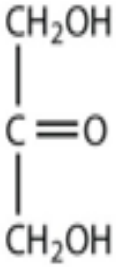
Right → D

N.B: primary alcoholic group 

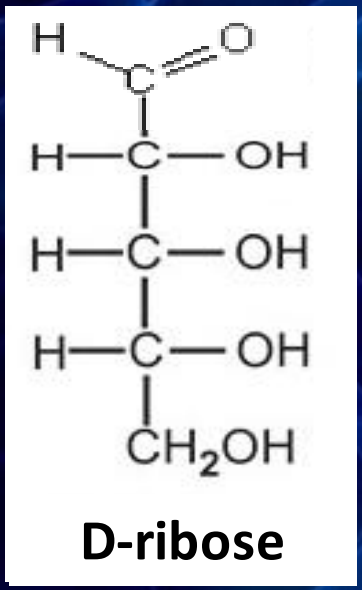
secondary alcoholic group 

aldehyde group 

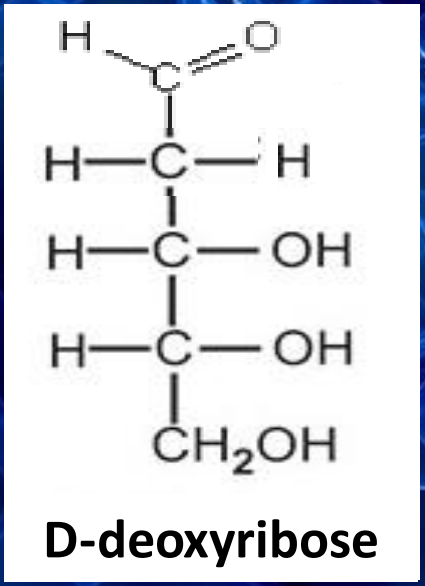
ketone group 

	Aldoses	Ketoses
Trioses	 **D- Glyceraldehyde**	 **Dihydroxyacetone**
Importance	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)**	1. It is the **simplest ketose** and the **mother compound of any ketose.**
	Also 1. Glyceraldehyde 3-phosphate and dihydroxyacetone phosphate are intermediates in **glycolysis** (major pathway of glucose oxidation). 2. Both are precusors of **glycerol** important for lipid synthesis.	
Tetroses	**Erythrose**	**Erythrulose**
Importance	Erythrose 4-phosphate is intermediate in **hexose monophosphate shunt (HMP shunt)**	

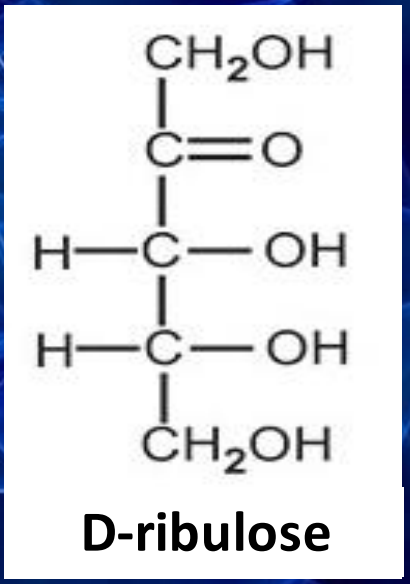
* Pentoses



D-ribose



D-deoxyribose

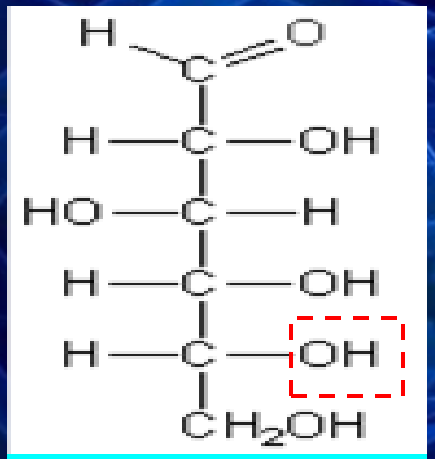


D-ribulose

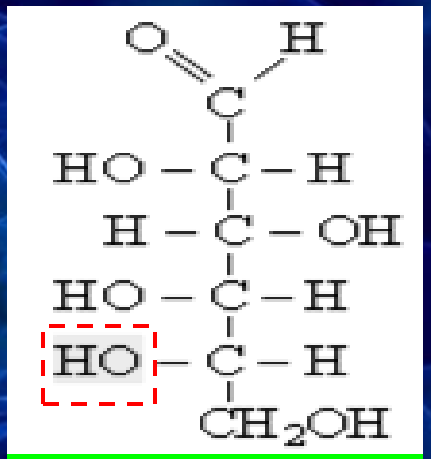
Functions:

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

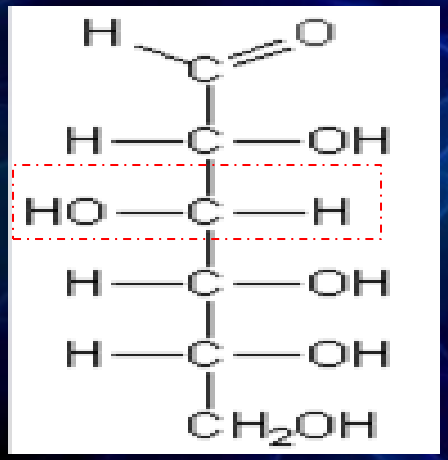


L - Glucose

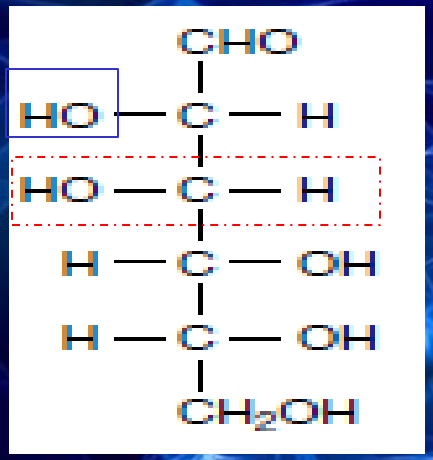
* D-glucose "grape sugar":

- 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)

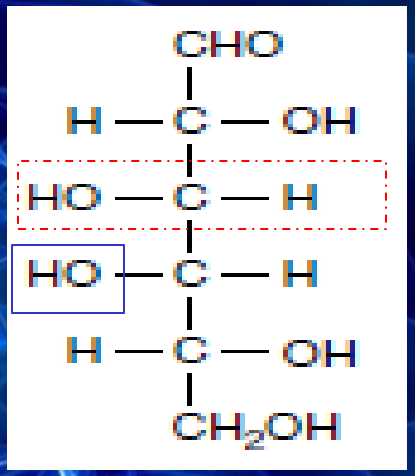
* Hexoses



D- Glucose



D- Mannose



D- Galactose

*** D-galactose:**

Synthesized in the lactating mammary gland

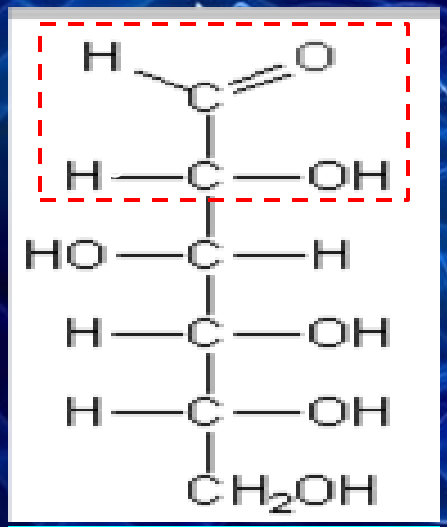
Converted in the liver to glucose

Enter in glycolipids found in the central nervous system

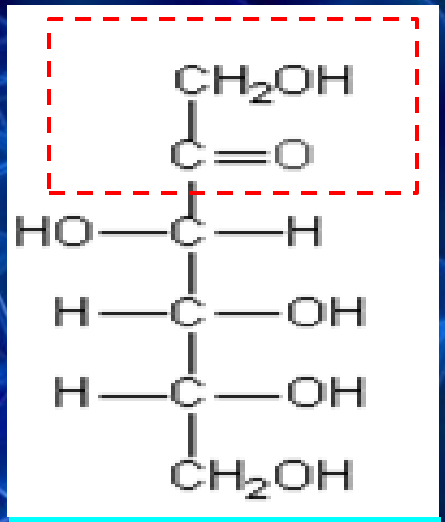
*** D-mannose:**

Constituent of prosthetic polysaccharide of albumin, globulin & mucoids

* Hexoses



D- Glucose



D- Fructose

*** Fructose: Called levulose (levorotatory) "l"**

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

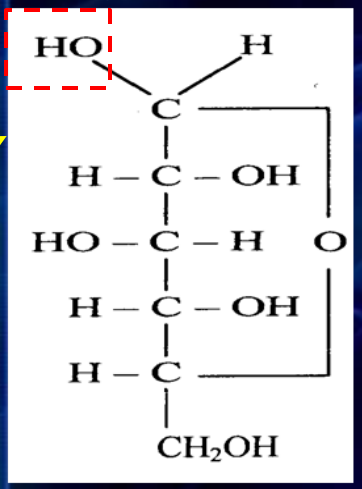
Ring structure

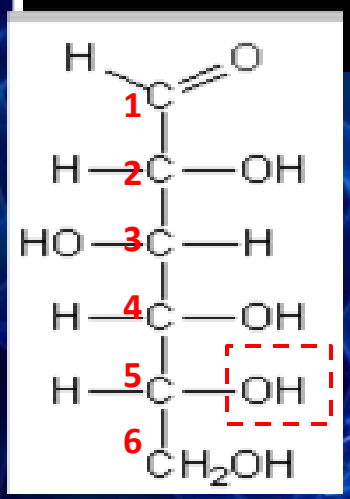
Straight chain

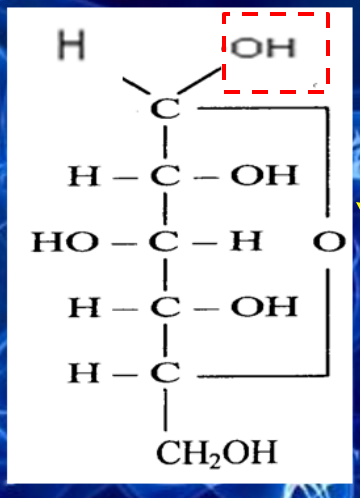
Ring structure

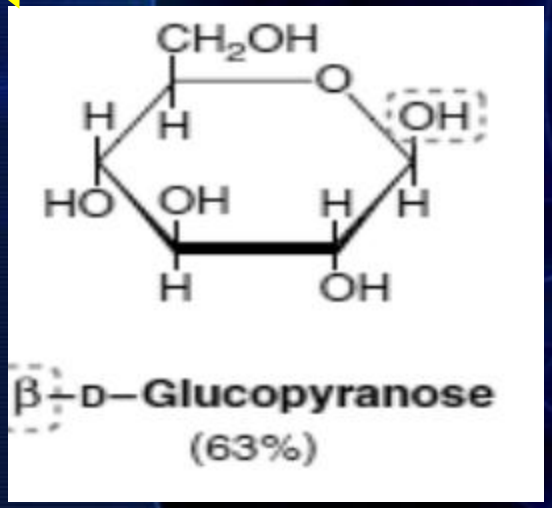
β-D glucose

α-D glucose

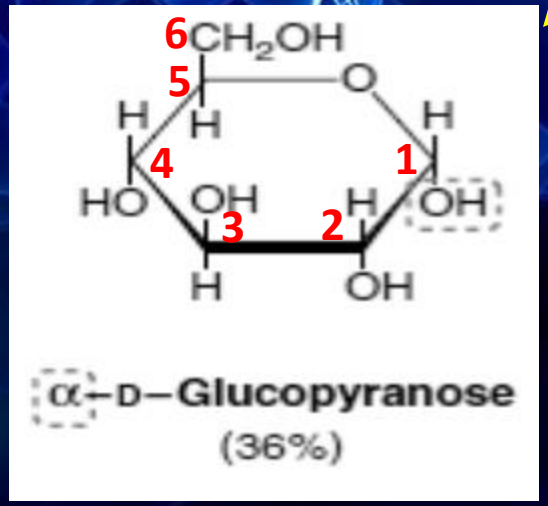








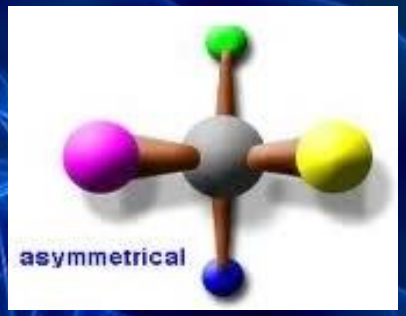
Haworth Formula

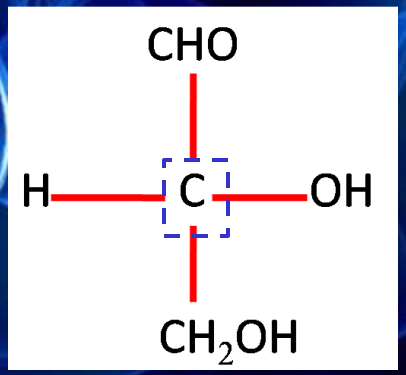


Haworth Formula

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

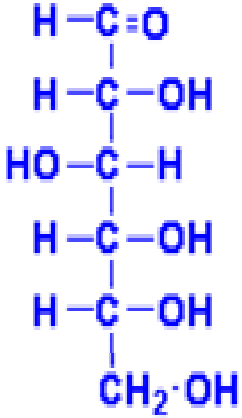
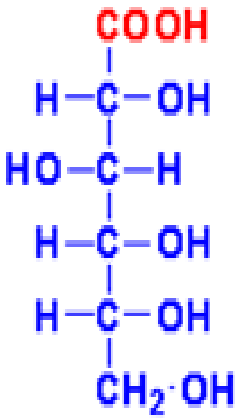
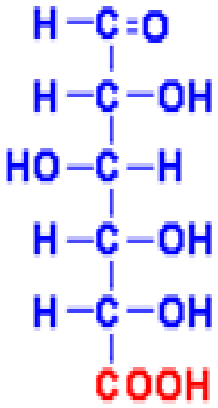
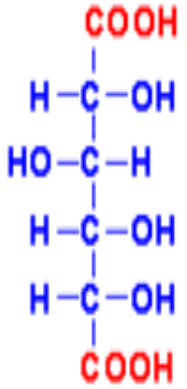
Differences	Glucose	Fructose
Nature	Aldo-hexose	Keto-hexose
Optical activity	Dextrorotatory = (+) or (d)	Levorotatory = (-) or (l)
Another name	Dextrose	Levulose
Ketose test (heating with HCl)	No change	Red brown color
Distribution	Mainly in blood	Mainly in semen
Function	Major source of energy in body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

Monosaccharide derivatives

- Sugar acids
- Amino sugars
- Amino sugar acids
- Sugar alcohol
- Deoxysugars

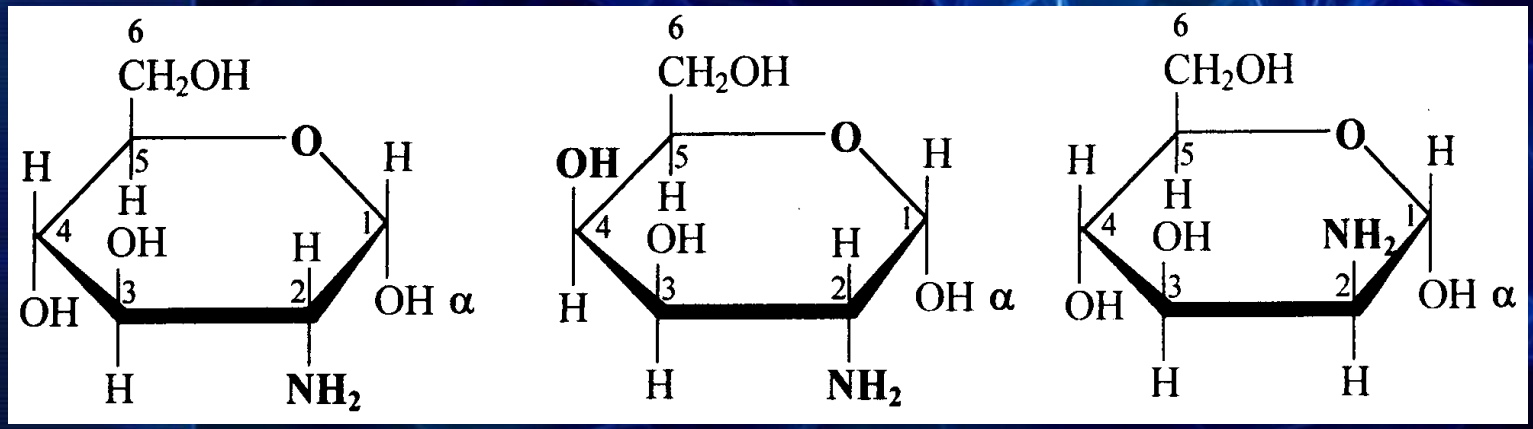
A. Sugar acids:

- 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)

 **Glucose**	 **Gluconic acid**	 **Glucuronic acid**	 **Saccharic acid (Glucaric 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

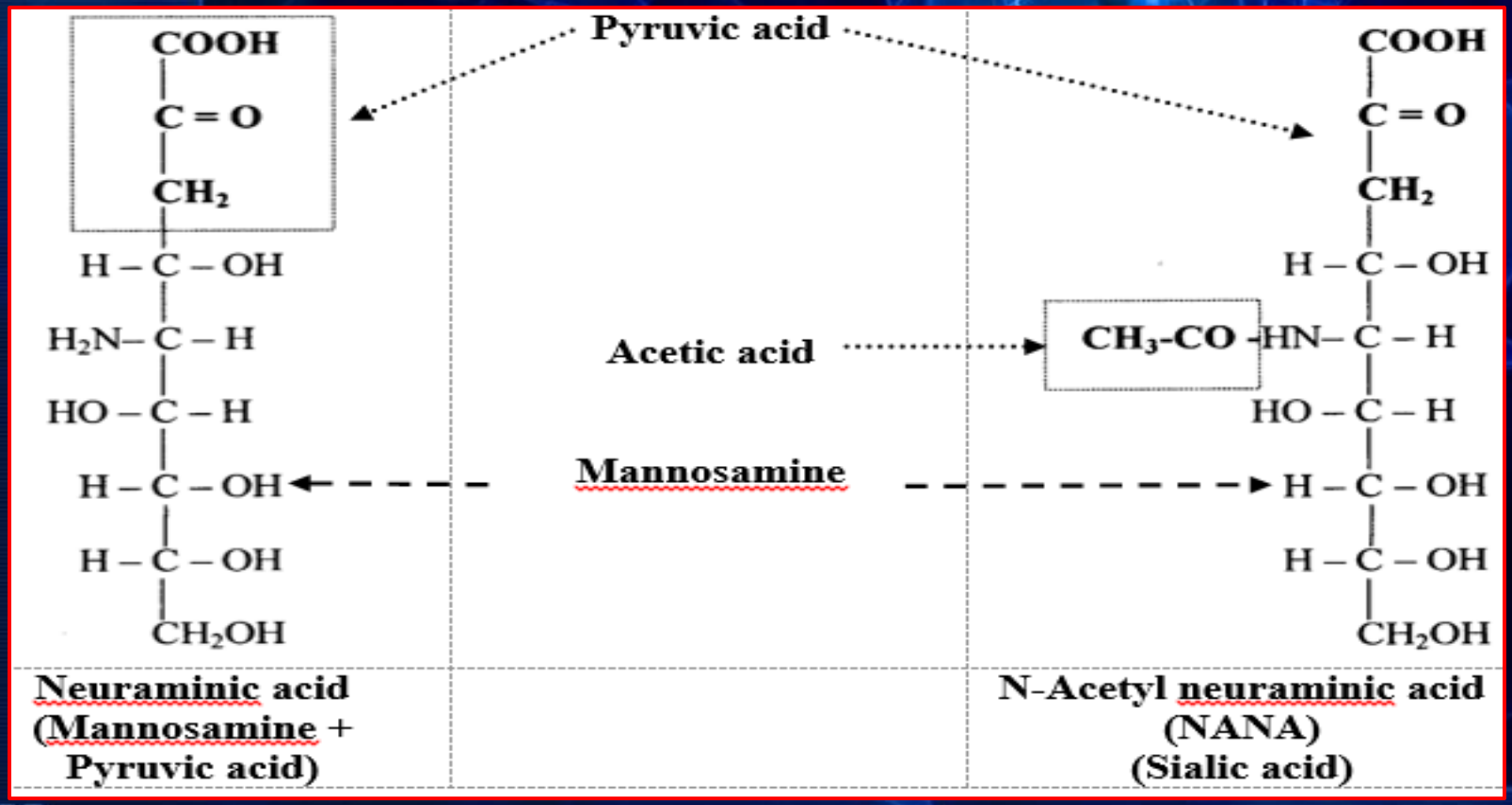


α, D-Glucosamine **α, D-Galactosamine** **α, D-Mannosamine**

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)

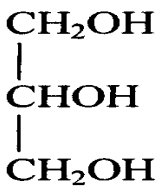


D. Sugar alcohols:

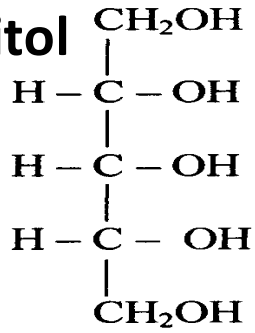
- Produces by reduction of monosaccharides to the corresponding alcohols (hydrogenation of aldoses & ketoses)

e.g. $-CHO \xrightarrow{2H} CH_2OH$ $\quad -C=O \xrightarrow{2H} CHOH$

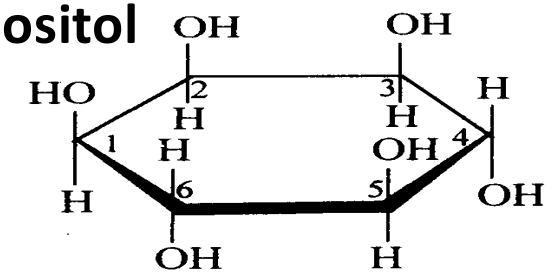
Glycerol



Ribitol



Inositol

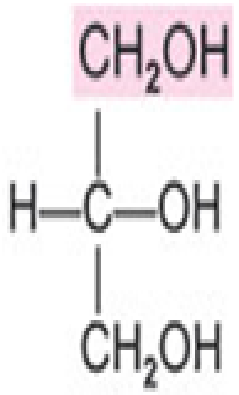
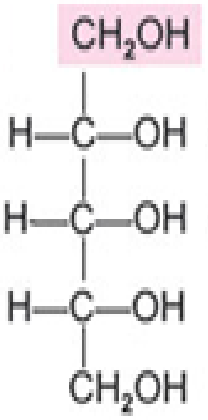
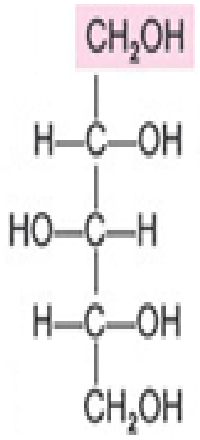


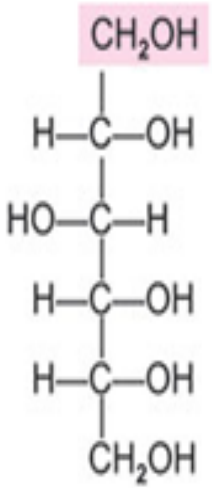
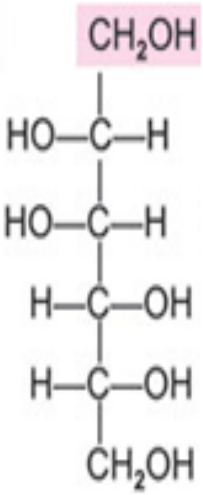
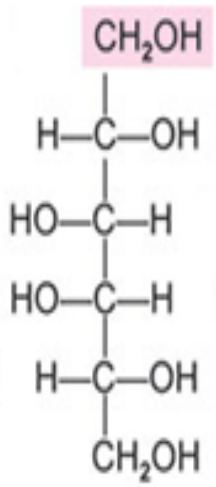
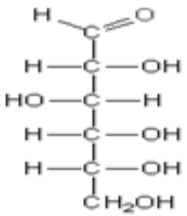
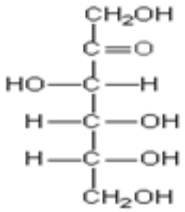
Inositol: is called myoinositol or muscle sugar

Enters in phospholipids

Present in liver, heart and muscle

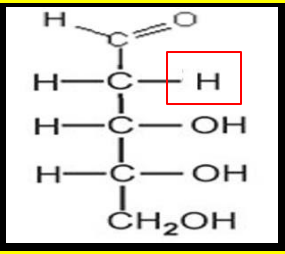
In plant, phytic acid (inositol hexaphosphate) inhibits the absorption of Ca^{+2}, Mg^{+2}, Mn^{+2} & Fe^{+2} from intestine → phytate salts

Example	Glycerol	Ribitol	Xylitol
			
Importance	Glyceraldehyde or dihydroxyacetone phosphate → glycerol which is : 1- Component of triacylglycerol & phospholipids **(Lipid)** 2- Used in pharmaceuticals as a base &drug (glyceryl trinitrate)	Ribose → ribitol which is a constituent of riboflavin (vitamin B2)	L-Xylulose → xylitol which is artificial sweetener.

Example	Sorbitol	Mannitol	Galactitol
			
Importance	D-Glucose or D-fructose →Sorbitol Sorbitol accumulates in ocular lens in diabetes leading to cataract (lens opacity)  	D-mannose or D-fructose → mannitol which is used as an osmotic diuretic and reduce intracranial tension in brain tumors and reduce intraocular pressure in acute glaucoma	D-galactose → galactitol Galactitol accumulates in ocular lens in galactosemia leading to cataract (lens opacity)

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