

# BIOCHEMISTRY

Introductory lecture

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## Carbohydrates (CHO)

**Definition:** Aldehyde or Ketone derivatives of the higher polyhydric alcohols or compounds which yield these derivatives on hydrolysis.

**Classification:** (mono, di, oligo, poly) saccharide.

**Monosaccharides:** Can be classified as **trioses, tetroses, pentoses, hexoses** and **heptoses** depending upon the number of carbon atoms, and as **aldoses** or **ketoses**, depending upon whether they have an aldehyde or ketone group.

Aldehyde (-CHO) → Aldoses

Ketone (-C=O) → Ketoses

### **Polysaccharides (glycans):**

- Homopolysaccharides (homoglycans): e.g. starch, glycogen, inulin, cellulose, dextrans, dextrans.
- Heteropolysaccharides (heteroglycans): e.g. mucopolysaccharides (MPS) or glycosaminoglycans.

### **Function of CHO:**

- 1) Chief source of energy (immediate and stored energy).
- 2) Constituent of compound lipids and conjugated protein.
- 3) Structural element like cellulose.
- 4) Drugs like cardiac glycosides and antibodies.
- 5) Lactating mammary gland (Lactose in milk).
- 6) Synthesis of other substances like fatty acids, cholesterol, amino acids...etc. by their degradation products.
- 7) Constituent of mucopolysaccharides.

### 1) Stereo-isomerism

Stereo-isomers: D-form, L-form

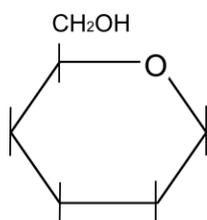
### 2) Optical isomers (optical activity)

Enantiomers: dextrorotatory (d or + sign)

Levorotatory (l or - sign)

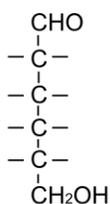
Racemic (d l)

### 3) Cyclic structures or open chain



Plane

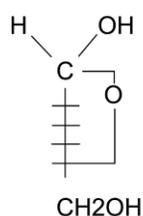
(Haworth)



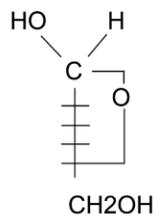
(Fischer)

### 4) Anomers and Anomeric carbon

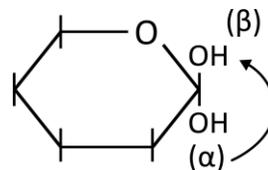
OH on carbon number 1, if below the plane then its  $\alpha$ -form, if above the plane then  $\beta$ -form.



$\alpha$ -D-Glucose  
( $\alpha$ -anomer)



$\beta$ -D-Glucose  
( $\beta$ -anomer)

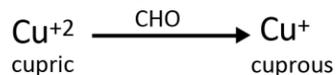


**Mutarotation:** the changes of the initial optical rotation that takes place in an aldohexose **e.g.** glucose ( $\alpha$ -form) when put (dissolved) in water and the solution is put in optical path (plane polarized light). Sugar  $\alpha$ -glucose will change into  $\beta$ -form and a mixture of both ( $\alpha$  and  $\beta$ ).

Glucose contains 4 asymmetrical carbon atoms no.s 2,3,4,5 whereas no.s 1 and 6 are symmetrical C atoms, which means that glucose has 16 isomers (8 of D-form and 8 of L-form) and according to OH position will have 16 D & 16 L, a total of **32** isomers

## Reactions:

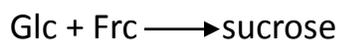
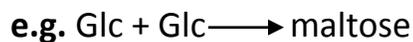
1- Reducing action



2- Phenyl hydrazine  $\rightarrow$  osazone

3- Ester formation with  $\text{H}_2\text{SO}_4$ ,  $\text{H}_3\text{PO}_4$ , Glc1P, Glc6P, Frc6P, glucosamine, glucose Sulphate.

4- Glucoside formation



☆ Glucose is found in nature in cyclic form either Pyranose  and called glucopyranose or furanose  and called glucofuranose.

☆ Epimers of Glucose are: Galactose - orientation of OH on C no. 4

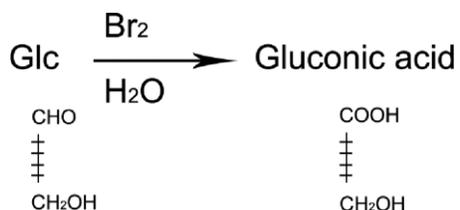
Mannose - orientation of OH on C no. 2

Allose - orientation of OH on C no. 3

5- Oxidation to produce sugar acids:

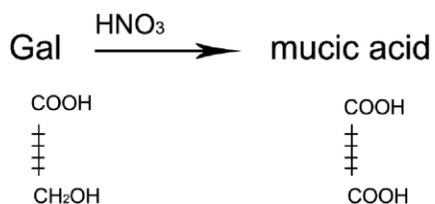
(a) Aldonic acid

e.g.



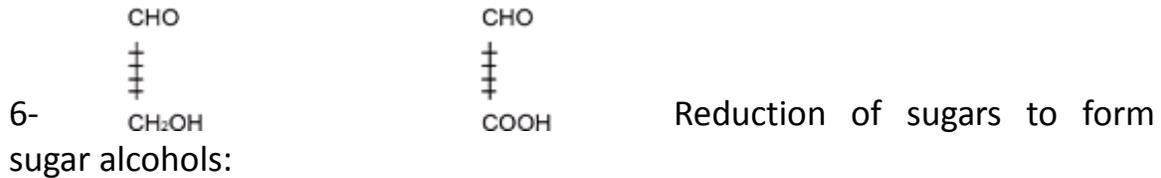
(b) Saccharic acid

e.g. Aldaric acid



(c) uronic acid

e.g.



e.g.



Gal. forms Dulcitol ; Man. forms mannitol.

### Sugar Derivatives:

1) Deoxy sugars: the oxygen of OH group has been removed.

e.g. 2-deoxyribose found in DNA.

2) Amino sugars (contain an  $\text{NH}_2$  group)

e.g. Glycosylamine (OH is replaced by  $\text{NH}_2$  group) like ribosylamine involved in purine synthesis.

e.g. Glycosylamine like the two naturally occurring derivatives of Glc and Gal the glucosamine & galactosamine (OH on C-2 is replaced by  $\text{NH}_2$ ), found in MPS.

3) Amino sugar acids

e.g. Neuraminic acid: found in nature in acylated derivative known as sialic acid (N- acetyl neuraminic acid, NANA) found in MPS and gangliosides.

4) Glycosides: CHO residue (glycone) linked to non-CHO residue (aglycone) by an acetal linkage by carbon 1.

aglycone may be methyl alcohol, glycerol, phenol, sterol ... etc.

If the sugar molecule (glycone) was Glc, Gal, then it's called glucoside,

galactoside.

**e.g.** cardiac glycosides are important for its action on heart and antibiotics like streptomycin.

**Disaccharides:** (mono + monosaccharides)

1) Maltose: Glc + Glc

It is linked by 1→4 glycosidic linkage and is α-form, found in starch on hydrolysis by amylase.

2) Lactose: Glc + Gal

It is linked by 1→4 glycosidic linkage and is in β-form, found in milk.

3) Sucrose: Glc + Frc

It is linked by 1→2 glycosidic linkage and is α-glucopyranosyl β-fructofuranoside, found in cane (table sugar) and beet.

**Oligosaccharides:** 3-6 monosaccharides residues

- 1) Carbohydrate units that are attached to integral membrane proteins.
- 2) Attached to side chain O<sub>2</sub> atom of Ser or Thr (aminoacids) by O-glycosidic linkage, or nitrogen atom of Asn by N-glycosidic linkage.
- 3) N-linked oligosaccharides contain a common pentasaccharide core consisting of 3 mannose and 2 N-acetyl glycosamine residues.
- 4) Glycoproteins function in molecular targeting and cell-cell recognition.
- 5) Found in proteins like antibodies and coagulation factors and peptide hormones.

**Polysaccharides:**

**A- Homopolysaccharides:**

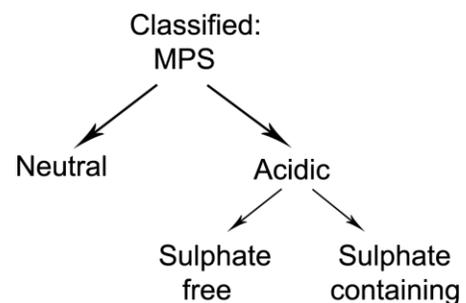
- 1) Starch-Polymer of Glc found in many plants, composed of two units Amylose and amylopectin, hydrolyzed by Amylase to give soluble starch → Amylodextrin → Erythro-dextrin → Achrodextrin → Maltose, then by maltase to give 2 Glc
- 2) Glycogen (animal starch) – polymer of Glc found in animals (storage

form of Glc), found in the liver and muscles. Its synthesis from Glc is called glycogenesis, and its breakdown back into Glc is called Glycogenolysis.

- 3) Inulin-polymer of fructose found in tubers and roots of certain plants, used for the determination of GFR (Glomerular Filtration Rate) and body water volume.
- 4) Cellulose- polymer of Glc and its disaccharide is cellobiose made of two D-Glc linked by  $\beta$ -glucosidic linkage (so its  $\beta$ -form) between C1 and C4.
- 5) Dextrin, it's formed of starch hydrolysis used with maltose in infant feeding.

## 6) Heteropolysaccharides (MPS)

- 1- Hyaluronic acid  
(N-acetyl glucosamine + glucuronic Acid) acts as a cementing substance and as lubricant and shock absorbent, so it's found in synovial fluid and skin, in free form or combined with proteins (so called ground substance of connective and other tissues).



Hyaluronidase enzyme acts on it, and reduces its viscosity.

- 2- Chondroitin  
(N-acetyl galactosamine + Glucuronic acid)  
Found in the cornea of the eye and in the cranial cartilage.  
Both hyaluronic acid and chondroitin are sulphate free.

- 3- Keratan sulphate  
Found in costal cartilages and Cornea  
(N-acetyl glucosamine + galactose)  
No uronic acid present.

#### 4- Chondroitin sulphate

Major MPS in the ground substance of mammalian tissue and cartilage, occurs combined with proteins (N-acetylgalactosamine (sulphated) + ☆ Glucuronic acid). Cartilage, bone, cornea, tendons.

☆ Iduronic acid may replace in some types of the 4 chondroitin sulphates (Types A, B, C, D).

#### 5- Heparin (sulphated MPS)

Anticoagulant; produced by mast cells of liver.

Found in lungs, thymus, spleen, wall of large arteries, skin, and blood.

**Glucosamine +**  **Glucuronic acid (Glc UA)**  
**Iduronic acid (IDUA) ☆**

Combine to proteins as in proteoglycans

☆ Iduronic acid is an isomer of glucuronic acid (an epimer) it is formed in liver from D-glucose

#### 6- Neutral MPS.

e.g. Blood group substances (blood groups A,B,O) contain peptides or aminoacids as well as CHO. Four monosaccharides and derivatives are found in all types of blood group substances; Gal, L-Fucose, Galactosamine (acetylated) & acetylated glucosamine.

#### **Mucopolysaccharidosis:**

Group of related disorders due to inherited enzyme defect.

Deposits of MPS in tissues and excess excretion in urine.

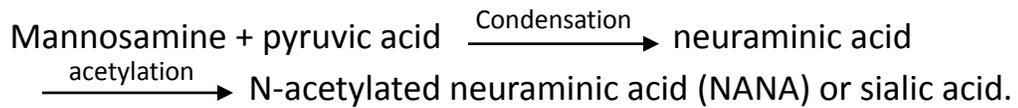
Six types are known and Clinical signs are skeletal changes, mental retardation, corneal clouding...etc.

☆ Iduronic acid is an isomer of glucuronic acid (an epimer).It is formed in liver from D-glucose.

#### **Sialic Acid:**

- Neuraminic acid, it is an amino sugar acid and structurally an aldol condensation product of pyruvic acid and D-Mannosamine.

- Neuraminic acid is unstable and found in nature in the form of acetylated derivatives known as sialic acid (N-acetyl Neuraminic acid – “NANA”)
- Neuraminic acid sialic acids occur in a number of mucopolysaccharides (MPS) and in glycolipids like Gangliosides.



- Sialic acid is found in mucin and blood groups substances.
- For its synthesis, Mannose sugar and pyruvic acid (end product of glycolysis) are required.
- Sialic acid level in the blood is considered to be a tumor marker.

Its level is increased in cases of tissue destruction due to certain diseases. Its level is decreased after surgical removal of the tumor to its normal levels.

If carcinoma is reactivated (back again), its level is again increased so patients should test blood sialic acid every 3-4 months.