Lec. 2

CARBOHYDRATES

The carbohydrates are widely distributed both in animal and plant tissues Chemically, they contain the elements carbon, hydrogen and oxygen. The empirical formula of many simple carbohydrates is **$[CH_2O]_n$**. Hence, the name ***"carbohydrate",*** i.e. hydrated carbon. They are also called ***"saccharides".*** In Greek, saccharon means sugar.

Carbohydrates may be defined chemically as ***aldehyde*** or ***ketone*** derivatives of polyhydroxy (more than one hydroxy group) alcohols or as compounds that yield these derivatives on hydrolysis.

Functions of Carbohydrates

Carbohydrates have a wide range of functions. The following are few of them:

• Source of energy for living beings, e.g. ***glucose*** Storage form of energy, e.g. ***glycogen*** in animal tissue and ***starch*** in plants

• Serve as structural component, e.g. ***glycosaminoglycans*** in humans, ***cellulose*** in plants and ***chitin*** in insects

• Non-digestable carbohydrates like cellulose, serve as dietary fibers

• Constituent of nucleic acids RNA and DNA, e.g. ***ribose*** and ***deoxyribose*** sugar

• Play a role in lubrication, cellular intercommunication and immunity

• Carbohydrates are also involved in detoxification, e.g. ***glucuronic acid***.

Classification of Carbohydrates

Carbohydrates are classified into three groups:

1. Monosaccharides
2. Oligosaccharides
3. Polysaccharides.

Monosaccharides (Greek: Mono = one)

Monosaccharides are also called ***simple sugars.*** The term sugar is applied to carbohydrates that are soluble in water and sweet to taste. They consist of a single polyhydroxy aldehyde or ketone unit, and thus cannot be hydrolyzed into a simpler form. They may be subdivided into two groups as follows:

1. Depending upon the number of carbon atoms they possess, e.g.

– Trioses

– Tetroses

– Pentoses

– Hexoses

– Heptoses.

2. Depending upon the functional aldehyde (CHO) or ketone (C=O) group present:

– Aldoses

– Ketoses.

Classification of monosaccharides based on the number of carbon and the type of functional group present with examples is given in **Table 2.1.** ***The most abundant monosaccharide in nature is six carbon sugar-D-glucose.***

Table 2.1: Classification of monosaccharides and their examples

No.of Carbon	*Empirical formula*	*Type of sugar*	*Aldoses*	*Ketoses*
3	$C_3H_6O_3$	Trioses	Glyceraldehyde	Dihydroxyacetone
4	$C_4H_8O_4$	Tetroses	Erythrose	Erythrulose
5	$C_5H_{10}O_5$	Pentoses	Ribose, Xylose	Ribulose, Xylulose
6	$C_6H_{12}O_6$	Hexoses	Glucose, Galactose and Mannose	Fructose
7	$C_7H_{14}O_7$	Heptoses	Glucoheptose	Sedoheptulose

Oligosaccharides (Greek: oligo = few)

Oligosaccharides consist of a short chain of monosaccharide units (2 to 10 units), joined together by a characteristic bond called ***glycosidic bond*** which, on hydrolysis, gives two to ten molecules of simple sugar (monosaccharide) units.

Oligosaccharides are subdivided into different groups based on the number of monosaccharide units present **(Table 2.3).**

Table 2.3: Classification of oligosaccharides and their examples

Type of oligosaccharide	*Number of monosaccharide*	*Example*	*Type of monosaccharide present*
Disaccharide	Two	Maltose	Glucose + Glucose
		Lactose	Glucose + Galactose
		Sucrose	Glucose + Fructose
Trisaccharide	Three	Raffinose	Glucose + Galactose + Fructose
Tetrasaccharide	Four	Stachyose	2 Molecules of Galactose + Glucose + Fructose
Pentasaccharide	Five	Verbascose	3 Molecules of Galactose + Glucose + Fructose

The disaccharides which have two monosaccharide units are the most abundant in nature. Oligosaccharides with more than three subunits are usually found inglycoproteins; such as blood group antigens.

Polysaccharides (Greek: Poly = many) or Glycans

Polysaccharides are polymers consisting of hundreds or thousands of monosaccharide units. They are also called ***glycans*** or ***complex carbohydrates.*** They may be either ***linear,*** (e.g. cellulose) or ***branched,*** (e.g. glycogen) in structure.

Polysaccharides have high molecular weight and are only sparingly soluble in water. They are not sweetish and do not exhibit any of the properties of aldehyde or ketone group. Polysaccharides are of two types **(Table 2.4).**

i. Homopolysaccharides (homoglycans)

ii. Heteropolysaccharides (heteroglycans).

Homopolysaccharides (Homoglycans)

• When a polysaccharide is made up of several units of one and the same type of monosaccharide unit, it is called homopolysaccharide.

• The most common homoglycans are:

– Starch

– Dextrins

– Glycogen– Insulin

– Cellulose.

• Some homopolysaccharides serve as a storage form of monosaccharides used as fuel, e.g. starch and glycogen, while others serve as structural elements in plants, e.g. cellulose.

Heteropolysaccharides (Heteroglycans)

• They contain two or more different types of monosaccharide units or their derivatives.

• Heteropolysaccharide present in human beings is glycosaminoglycans (mucopolysaccharides), e.g.

– Heparin

– Chondritin sulfate

– Hyaluronic acid

– Dermatan sulfate

– Keratan sulfate

– Blood group polysaccharides.

Table 2.4: Classification of polysaccharides

Polysaccharides

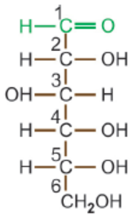
Homopolysaccharides or Homoglycans, e.g.	Heteropolysaccharides or Heteroglycans, e.g.
Starch	Glycosaminoglycans or Mucopolysaccharides
Dextrin	
Glycogen	
Cellulose	
Inulin	

STRUCTURE OF GLUCOSE

Physiologically and biomedically, glucose is the most important monosaccharide. The structure of glucose can be represented in the following ways **(Figure 2.1)**:

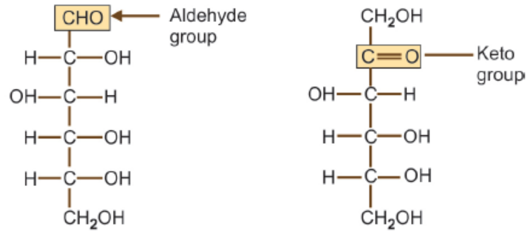
1. The straight chain structural formula (Fisher projection).

2. Cyclic formula (Ring structure or Haworth projection)



D-Glucose

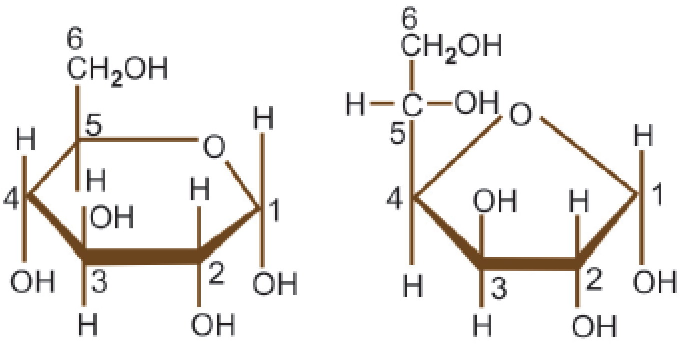
Straight chain structure of D-glucose
(Fisher projection formula)



Glucose ($C_6H_{12}O_6$), (Aldose)

Fructose ($C_6H_{12}O_6$), (Ketose)

Figure 2.2: Ketose-Aldose isomerism



α-D-Glucopyranose

α-D-Glucofuranose

Ring structure or Haworth projection formula of glucose

Figure 2.1: Structure of D-Glucose

DERIVATIVES OF MONOSACCHARIDES

Some important sugar derivatives of monosaccharides are:

• Phosphoric acid ester of monosaccharides

• Amino sugar

• Deoxy sugars

• Sugar acids

• Sugar alcohols

• Neuraminic acid

• Sialic acid.

Phosphoric Acid Ester of Monosaccharide's

These are formed from the reaction of phosphoric acid with hydroxyl group of the sugar, e.g. glucose-1- phosphate or glucose-6-phosphate **(Figure 2.12).**

Importance

• Phosphorylation of sugar within cells is essential to prevent the diffusion of the sugar out of the cell. contain sugar phosphates of ribose and deoxyribose.

Amino Sugar

Amino sugars have a hydroxyl group replaced by an amino or an acetylated amino (acetyl amino) group. For example, glucosamine, N-acetyl glucosamine **(Figure 2.13),** galactosamine and mannosamine.

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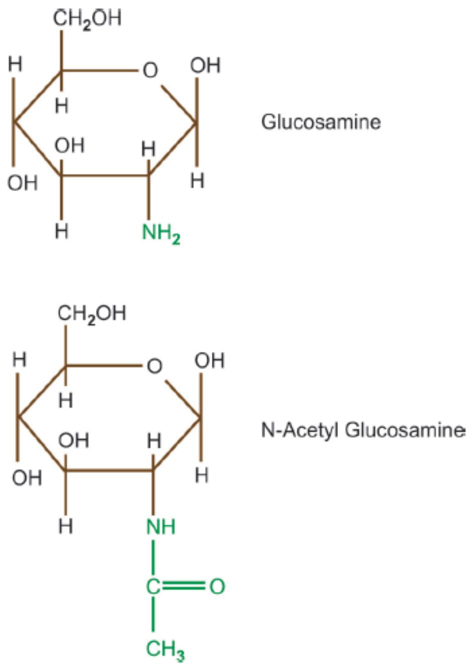

Figure 2.13: Structure of amino sugars

DISACCHARIDES

• Disaccharides consist of two monosaccharide units.

• They are crystalline, water soluble and sweet to taste.

• They are subclassified on the basis of the presence or absence of free reducing (aldehyde or ketone) group **(Table 2.5).**

1. Reducing disaccharides with free aldehyde or keto group, e.g. maltose, lactose
2. Non-reducing disaccharides with no free aldehyde or keto group, e.g. sucrose.

Maltose

• Maltose contains two glucose residues, joined by glycosidic linkage between C-1 (the anomeric carbon) of one glucose residue and C-4 of the other, leaving one free anomeric carbon of the second glucose residue, which can act as a reducing agent. Thus, maltose is a ***reducing disaccharide***.

• The numerical description like (1 → 4) of glycosidic bond represents the number of carbon atoms that connect the two sugars as shown in **Figure 2.16**. The sugar contributing anomeric carbon is written first.

• Maltose is produced as an intermediate product in the digestion of starch and glycogen by the action of the enzyme α-amylase.

Sucrose (Common Sugar)

• Sucrose is a disaccharide of glucose and fructose. It is formed by plant but not by human beings. Sucrose is an intermediate product of photosynthesis. Sucrose is the commonly used **table sugar.**

• In contrast to maltose and lactose, sucrose contains no free anomeric carbon atom. The anomeric carbon of both glucose and fructose are involved in the glycosidic bond **(Figure 2.16).** Sucrose is therefore, a non-reducing sugar.

• Sucrose is hydrolyzed to fructose and glucose by an enzyme ***sucrase*** which is also called ***invertase.***

polysaccharides (glycans)

Carbohydrates composed of ten or more monosaccharide units or their derivatives (such as amino sugars and uronic acids) are generally classified as **polysaccharides.** Polysaccharides are colloidal in size. In polysaccharides, monosaccharide units are joined together by glycosidic linkages. Another term for polysaccharides is a ***"glycans".***

Polysaccharides are subclassified in two groups **(Table 2.4).**

1. Homopolysaccharides (Homoglycans): When a polysaccharide is made up of several units of one and the same type of monosaccharide unit only, it is called homopolysaccharide.

2. Heteropolysaccharides (Heteroglycans): They contain two or more different types of monosaccharide units or their derivatives.

Homopolysaccharides or Homoglycans

Starch

It is the storage form of glucose in plants, e.g. in potato, in grains and seeds and in many fruits. Starch is composed of two constituents viz. ***amylose*** and ***amylopectin.***

Cellulose

Cellulose is the chief constituent of cell wall of plants. It is an ***unbranched polymer*** of glucose and consists of long straight chains which are linked by β-**(1→4) glycosidic linkages** and not α-(1→ 4) as in amylose

glycoproteins

• Glycoproteins are proteins to which oligosaccharides are covalently attached to their polypeptide chain.

• Glycoproteins contain much shorter carbohydrate chain than proteoglycans.

• The distinction between glycoproteins and proteoglycans may be based on the amount of carbohydrate.

– Glycoproteins contain less than 4 percent carbohydrate in the molecule.

– Proteoglycans contain more than 4 percent carbohydrate.

Functions of Glycoproteins

• Almost all the plasma proteins of humans are nglycoproteins, except albumin.

• Many integral membrane proteins are glycoproteins.

• Most proteins that are secreted, such as antibodies, hormones and coagulation factors are glycoproteins.