MONOSACCHARIDES

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- **Carbohydrates are organic compounds comprised of *carbon*, *hydrogen*, and *oxygen*, usually in the ratio of 1:2:1.**
- **They are one of the major classes of biomolecules, the other three being proteins, nucleic acids & lipids.**
- **They are an important source of energy.**
- **They also serve as structural components.**

As a nutrient, they can be classified into two major groups:

- ***simple carbohydrates* and**
- ***complex carbohydrates*.**

Simple carbohydrates, sometimes referred to as simply sugar, are those that are readily digested and serve as a rapid source of energy. Complex carbohydrates (such as cellulose, starch,

and glycogen) are those that need more time to be digested and metabolized. They often are high in fiber and unlike simple carbohydrates they are less likely to cause spikes in blood sugar.

Characteristics of monosaccharides:

- ✓ **The most fundamental type is the simple sugars called monosaccharides.**

- ✓ **This means that they cannot be broken down any further into simpler sugars by hydrolysis. Nevertheless, monosaccharides can combine with each other to form more complex types.**
- ✓ **Glycosidic bonds (also called glycosidic linkages) are the covalent bonds that join monosaccharides.**
- ✓ **The combination of two simple sugars is called a disaccharide whereas carbohydrates consisting**

of three to ten simple sugars are called oligosaccharides, and those with a larger number of monosaccharide units are called polysaccharides.

- ✓ **The chemical process of joining monosaccharide units is referred to as *dehydration synthesis* since it results in the release of water as a byproduct. The process, though, is reversible.**

Complex carbohydrates may be broken down into simple sugars, such as in *glycogenolysis* where stored glycogen is broken down into glucose units that could be used in energy metabolism.

A monosaccharide has a general chemical formula of $C_nH_{2n}O_n$. The ratio of hydrogen atoms to oxygen atoms is often 2:1. An exception to this is deoxyribose, a type of monosaccharide found in DNA. Because of this

chemical formula rule, monosaccharides and other carbohydrates are referred to as *hydrates of carbon*. Monosaccharides are often colorless, crystalline solids, and sweet-tasting. They can be dissolved in water and occur as syrups or liquid sugar. Just like the other carbohydrates, monosaccharides are organic compounds. They contain carbon covalently bound to

other atoms, especially Carbon-Carbon (C-C) and Carbon-Hydrogen (C-H).

Classifications of monosaccharides:

Monosaccharides can be classified by the number of carbon atoms they contain. The groups are as follows:

→ **A *triose* is a three-carbon monosaccharide. An example is *glyceraldehyde-3-phosphate* ($C_3H_7O_6P$).**

It is a triose that serves as an intermediate in different carbohydrate metabolic pathways.

→ **A *tetrose* is a monosaccharide with four carbon atoms. Some of the naturally-occurring tetroses are *D*-erythrose, *D*-threose, and *D*-erythrulose. The *erythrose*, $C_4H_8O_4$, is a tetrose with one aldehyde group. It was first isolated by French pharmacist Louis Feux Joseph Garot in 1849.**

The *erythrose 4-phosphate* is a metabolite in the Calvin cycle and in the pentose phosphate pathway. Threose is a tetrose and an enantiomer of erythrose. Another enantiomer is erythrulose. It has the same chemical formula: $C_4H_8O_4$. Nevertheless, the erythrulose is a ketotetrose for having a ketone group in its structure.

→ **A *pentose* is a five-carbon monosaccharide. Examples of pentoses are *ribose*, *deoxyribose*, *arabinose*, *lyxose*, *xylose*, *ribulose*, and *xylulose*. Ribose (chemical formula $C_5H_{10}O_5$) and deoxyribose (chemical formula $C_5H_{10}O_4$) are constituents of nucleotides and nucleic acids. In particular, ribose is the pentose sugar component of the nucleotides**

of RNA whereas deoxyribose is the sugar component of the nucleotides of DNA.

→ A *hexose* is a six-carbon monosaccharide. Examples of hexoses are glucose, mannose, galactose, gulose, idose, talose, allose, altrose, fructose, piscose, sorbose, and tagatose. Glucose, in particular, is the most common hexose that serves as a metabolic

intermediate of *cellular respiration*. Excess glucose is stored as glycogen in animals and as starch in plants.

→ **A *heptose* is a seven-carbon monosaccharide. Examples of naturally-occurring heptoses are *L-glycero-D-manno-heptose* and *sedoheptulose*. Their chemical formula is $C_7H_{14}O_7$. They are early intermediates in lipid A biosynthesis.**

→ An *octose* is an eight-carbon monosaccharide. Octoses have a chemical formula of $C_8H_{16}O_8$. An example is *methylthiolincosamide*, i.e. the sugar moiety of the antimicrobial agent lincomycin A.

→ A *nonose* is a nine-carbon monosaccharide. Examples of nonoses are *neuraminic acid*, *sialic acid*, *legionaminic acid*, and *psudaminic acid*.

Neuraminic acid (chemical formula of $C_9H_{17}NO_8$), in particular, is a synthetic nonose.

→ It should be noted that these terms (e.g. *triose*, *tetrose*, *pentose*, *etc*.) are different from the

terms *trisaccharide*, *tetrasaccharide*, *pentasaccharide*, and so on as the latter terms respectively signify the number of monosaccharide units in a

polymer, i.e. three monosaccharides, four monosaccharides, five monosaccharides, and so on.

→ Monosaccharides may also be classified based on the type of carbonyl group they contain: (1) *Aldose*, -CHO (aldehyde) and (2) *Ketose*, C=O (ketone). An aldose is a monosaccharide that contains an aldehyde group (-CHO) whereas a ketose is one that contains a ketone (C=O).

Common monosaccharides:

Fructose, glucose, and galactose are regarded as dietary monosaccharides since they are readily absorbed by the small intestines.

They are hexoses with a chemical formula: $C_6H_{12}O_6$. Glucose and galactose are aldoses whereas fructose is a ketose.

Glucose is a monosaccharide that occurs naturally and is ubiquitous.

It can join with other monosaccharide units to form disaccharides: *maltose* (i.e. two glucose molecules), *lactose* (i.e. glucose and galactose molecules), and *sucrose* (i.e. glucose and fructose molecules).

Glucose is one of the products of photosynthesis in plants and other photosynthetic organisms. In plants, glucose molecules are stored as repeating units of sugar (e.g. starch). It is also an important component of *amylopectin* and *cellulose*. Thus, it occurs abundantly in fruits, plant juices, and many other plant organs. It also serves as an important metabolic intermediate of cellular

respiration and a major source of energy (via aerobic respiration or anaerobic respiration).

In animals, it circulates in the blood and as such referred to as *blood sugar*. An excess of glucose in animals is stored as glycogen. Galactose is similar to glucose in terms of chemical structure. However, the orientations of H and OH on carbon 4 are exchanged. Unlike glucose, galactose generally does

not occur in free state. It usually is a constituent of complex biomolecules. For instance, galactose together with glucose forms lactose (milk sugar), which is a disaccharide. Lactose, the disaccharide of milk, consists of galactose joined to glucose by a -(1-4) glycosidic link. The joining of galactose and glucose is catalyzed by the enzymes *lactase* and *β-galactosidase*.

Galactose catabolism (where glucose is converted to glucose) is carried out via the *Leloir pathway*.

In human lactation, one of the sources of lactose in breast milk is through *de novo* synthesis of galactose and glucose through hexoneogenesis. In plants such as the axlewood (*Anogeissus latifolia*) and acacia trees, galactose monomers link together and form a polysaccharide referred to as galactan. *Fructose* is

regarded as the sweetest naturally-occurring carbohydrate. Some of the natural sources of fructose are *honey*, *fruits*, and *sugar cane*. It is a ketonic monosaccharide since it has a reducing group (carbonyl) at carbon 2. This is in contrast to glucose (which is an aldose) that has its carbonyl group at carbon 1. Fructose occurs naturally in plants, particularly in fruits, root vegetables, etc. It occurs

freely or bonded to glucose to form sucrose. Sucrose (the common table sugar) is a non-reducing disaccharide that forms when glucose and fructose are linked together by an alpha linkage between the carbon 1 of glucose and the carbon 2 of fructose. When present as a component of dietary sucrose, the enzyme *invertase* in the small intestine cleaves sucrose into glucose and fructose. Too much

fructose, though, could lead to malabsorption in the small intestine. When this happens, unabsorbed fructose transported to the large intestine could be used in fermentation by the colonic flora. This could lead to gastrointestinal pain, diarrhea, flatulence, or bloating.

Biological functions:

- Monosaccharides perform vital biological roles. One of their major functions is to serve as a structural unit for multifarious biological compounds. Through glycosidic bonds, they join together to form oligosaccharides and polymers (e.g. cellulose, starch, and glycogen).

- **They may also serve as a precursor or a constituent of other compounds, such as galactosamine, glucosamine, sialic acid, N-Acetylglucosamine, sulfoquinovose, ascorbic acid, mannitol, glucuronic acid, etc. Many of these compounds have a monosaccharide component that is involved in various biological functions.**

- **Monosaccharides, just like the other carbohydrates, are an important source of nutrition. Monosaccharides are found in fruits, vegetables, and many other dietary sources.**
- **They are consumed and metabolized to derive metabolic energy (e.g. ATP) that fuels various biological activities. ATPs are chemical energy**

biologically synthesized through aerobic and anaerobic respirations.

- **Glucose is the most common form of monosaccharide that the cell uses to synthesize ATP via substrate-level phosphorylation (glycolysis) and/or oxidative phosphorylation (involving redox reactions and chemiosmosis).**

- **Monosaccharides that are not yet needed are stored as energy-rich polysaccharides. In plants, they make glucose and other monosaccharides by photosynthesis, and then they store them as starch in various plant organs, especially in *fruits*, *seeds*, *rhizomes*, and *tubers*. Animals store them as glycogen in liver and muscle cells.**

Metabolic pathways involving monosaccharides:

Monosaccharides are involved in many important metabolic pathways. Some of these metabolic pathways are:

- **Glycolysis – the conversion of a monosaccharide into pyruvate, with the concomitant production of high-energy biomolecules**

- **Pentose phosphate pathway – an alternative metabolic route in breaking down glucose**
- **Gluconeogenesis – the conversion of non-carbohydrate precursors into a monosaccharide**
- **Glycogenolysis – the breaking down of stored glycogen into monosaccharide units**
- **Glycogenesis – the conversion of glucose into glycogen**

- **Fructose metabolism – where fructose, instead of glucose, enters the glycolytic pathway**
- **Galactose metabolism – where galactose enters the glycolytic pathway by first being phosphorylated and then converted into glucose-6-phosphate.**

THANK YOU