Carbohydrates

What are the carbohydrates?

Carbohydrates are the major biomolecules. The molecules which are produced by living organisms called as "biomolecules". There are four major types of biomolecules which includes carbohydrates, lipids, amino acid and protein, and nucleic acid. Carbohydrates are the type of biomolecules and widespread in nature. Carbon, hydrogen and oxygen are necessary elements of carbohydrates. This is the most dominant class of biomolecules. It is the class of organic compounds that contain aldehyde, ketones and several hydroxyl group. It is important point the Carbon is not the part of functional such as aldehyde and ketones.

Characteristic of carbohydrates

These can be defined as polyhydroxy aldehyde or ketones or compounds which produce them on hydrolysis. They are linked to gather by covalent bond called as glycosidic bond. They form different structures of living organisms and supply energy. Examples includes glucose, sucrose etc. Carbon, hydrogen and oxygen are the basic elements of the carbohydrates. These are known as "Hydrated carbon" because the ratio of oxygen and hydrogen is always 1:2 as in the water H_2O.

Carbohydrates always are not invented to be hydrated carbon because several carbohydrates are not hydrated carbon such as "Deoxyribose" and several non-carbohydrate compounds are look like to hydrated carbon .The general formula of carbohydrates is $(CH_2O)_n$, n is any number between three to eight. The term "Sugar" is used for only those carbohydrates which are sweet in taste and soluble in water.

Occurrence of carbohydrates

This is the most widely and plentiful organic group in nature. Mostly Carbohydrates are produced by plants during the process of "photosynthesis". This is the process in which plant use CO_2 and H_2O in the presence of sun light and carbohydrates (glucose) is produced. This whole process take place in chloroplast (chlorophyll a and b). Glucose, cellulose and starch are the some examples of carbohydrates which are produced by the plants. Carbohydrates also present in in different parts of cells of animals which comes from green plants (by eating of fruits and other parts of plants).

Energy from carbohydrates

Carbohydrates are the energy rich biomolecules. They provide energy to the body in the form of chemical energy and this energy is used to produce ATP. These are include in necessary nutrients which are required by living organisms. A famous carbohydrate which is called glucose used to produce ATP.ATP is the energy currency of the cells. Our brain use glucose directly for the energy. The breakdown of glucose take place in the process of cellular respiration and energy is released which is used in the formation of ATP.

In plants, unused carbohydrates are converted into starch for energy purpose in future use.In animals, it is converted into glycogen.

Classification of carbohydrates

These are classify into two ways.

1) On the basis of digestion of carbohydrates, these are classify into main two food groups

A) Simple carbohydrates

These are the sugar. These carbohydrates are digested readily and are the immediate source of energy. So, that's why they are called simple carbohydrates. They raise blood glucose rapidly. They contain less nutrients.

B) Complex carbohydrates

These are the fibers and starch. They take more time to digested, they are rich in fiber and they are not metabolized rapidly. It include fruits vegetables and whole grain. They raise blood glucose level slowly. They contain more nutrients then simple carbohydrates.

Comparison between simple and complex carbs for food

Complex carbohydrates are rich in fiber. Fiber control the cholesterol level. Some important source of complex carbohydrates are fruits, vegetables, nuts and beans. Some food contain more starch than fiber for example potato.

On the other hand simple carbohydrates are rich in sugar and they contain glucose level in body. So they are not consider good for health. So complex carbs are good for health.

2) Carbohydrates are classify in to three groups.

A) Mono saccharides

B) Oligosaccharides

C) Polysaccharides.

Now we take a little introduction of these three groups one by one.

A) Mono saccharides

These are the simple sugar. They cannot be hydrolyzed further. They combine to form complex carbohydrates such as oligosaccharides and polysaccharides. The most common mono saccharides are glucose and fructose. When two mono saccharide unit combine they form disaccharides for example sucrose, lactose and maltose are most famous disaccharides. These are sweet in taste and soluble in the water.

B) Oligosaccharides

These are the polymers of the mono saccharides. Polymers are the compound which are formed by polymerization process or reaction in which small molecules combine to form large molecules. These are consist on three to nine saccharides or simple sugar molecules. Sucrose, lactose and maltose are the examples of the oligosaccharides. Two or more units of mono saccharides combine

glycosidic bond to form oligosaccharide. Specific enzymes are used to catalyze the reaction. These are present in cell membrane where they have important role which is known as recognition of cell.

C) Polysaccharides

Carbohydrates which are made up of many mono saccharide units are called poly saccharides. There are two types of poly saccharides, if poly saccharides made up of same type of saccharide units called as “homo poly saccharides” and if they are made op of different type of saccharide units then these are called “hetero poly saccharides”. Starch, cellulose and glycogen are the examples of the poly saccharides.

Polysaccharides, in plants store in the form of starch. Glycogen is also called as animal starch and polysaccharides store in animal body as glycogen. Cellulose form the structure of the plants. Cotton is pure cellulose.

Formation of simple carbohydrates (Monosaccharides)

Green plants are the main source of carbohydrates. Carbohydrates are formed in plants by the process of photosynthesis. Photosynthesis is a complex process which take place in the presence of sunlight. Sunlight is used as source of energy. Leaves are the main part of the plants where photosynthesis occur. Other system are also involved in photosynthesis such as chlorophyll (a, and b) which are used to capture sunlight. In the process of photosynthesis, a biochemical reaction of carbon dioxide and water take place in presence of sunlight and chlorophyll and energy is stored in the form of carbohydrates. Mainly plant produce glucose as carbohydrates.

Photosynthesis equation

$6CO2+6H2O+ \longrightarrow C6H12O6$

Sunlight and chlorophyll are necessary for this reaction.

O_2 is produce as a byproduct.

Glucose is produced during dark reactions of photosynthesis which is called "Calvin cycle" or "C3 pathway" in which carbon dioxide is and as a result glucose and energy produced. The reactions which take place in Calvin cycle are explain by diagram.

These all reactions take in the presence of enzymes and a specific enzyme is required by each reaction.

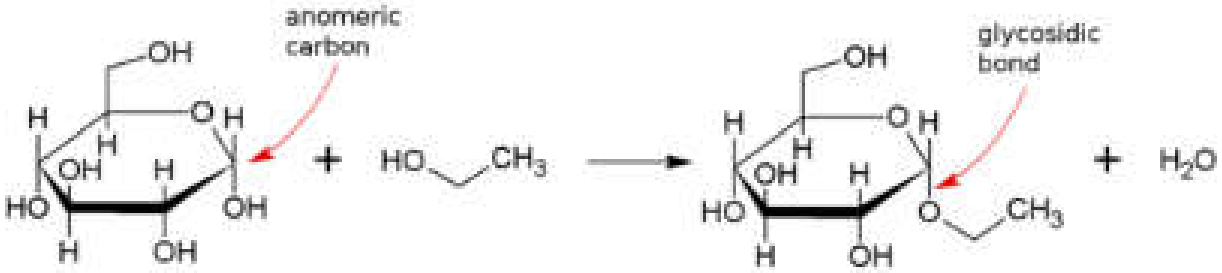
Formation of complex carbohydrates (oligo and poly saccharides)

As we know that complex carbohydrates (oligosaccharides and poly saccharides) are the polymers of the monosaccharides. When mono saccharide units combine, they give raise to complex carbohydrates. They combine with each other by covalent bond called glycosidic bond.

A) GLYCOSIDIC BOND

A glycosidic bond is formed when one molecule of carbohydrate combine with hydroxyl group of other molecule through its hemiacetal or hemiketal group (the compound of carbon which contain both aldehyde or ketone and alcohol is called as hemiacetal or hemiketal respectively). As a result a molecule of water is released and covalent bond is formed called as glycosidic bond.
The compound in which glycosidic bond is present called as glycoside.

Diagram.



(formation of glycosidic bond. Source google images)

Functions of carbohydrates

Carbohydrates are important source of energy for animals and humans and they form many structures of the cell. Following are some important functions of carbohydrates.

1) **For energy**

The main and important function of carbohydrates for consumers is to provide energy. When energy is not needed to the plants and animals they are converted into the starch and cellulose in plants and in animal formation of glycogen take place.

2) **Role in different systems of body**

Other biologicals molecules such as lipids, proteins and nucleic acid contain sugar molecules which play important role in other body function such as immune response, blood cloting, fertilization etc.....

3) **Muscles and skeleton**

As we know that carbohydrates are source of energy, they prevent breakdown of other biological molecules (lipids and proteins) for the sake of energy. Amino acid is the building blocks of protein and they also present in muscles of animals. These proteins are to form enzymes antibodies receptors and other important organelles of the cell. Except all of these, a specific amount of this bio molecule prevent degeneration of skeleton muscles heart muscles and kidney muscles.

4) **Use as sweeteners**

These are also use as sweeteners because they have sweet taste. There are two types of sweeteners, they may be nutritive or alternative. The nutritive sweetener are glucose fructose and lactose e.t.c …Glucose and fructose are not only sweetener but they also provide energy to the living organisms. On the other hand alternative are only sweet in taste and they do not provide energy. Saccharin cyclamate acesulfame are included in this group.

5) **Dietary fiber**

There are two types of dietary fibers one is soluble in the water and other is insoluble in water. When we take soluble dietary fiber, it helps in elimination of waste material from the body.

6) **Recognition of biological molecules**

Glycoprotein sequence is present in many antibodies and peptides. In these sequences amino acid is linked to the carbohydrates. Liver can recognize the difference in length of many protein and store protein. It prevent degradation of liver.

7) **Blood group substances**

Antigens present in the blood group contain carbohydrates as glycoproteins or glycolipids. Galactose, fructose and sialic acid and others are found in blood group substance. These carbohydrates contant play an important role in blood grouping.

MONOSACCHARIDES

Word "monosaccharide" is derived from Greek language which is combination of words "monos" meaning single or one and "saccharide" meaning is sugar. It consists on single sugar molecule. Saccharide or sugar is basic unit of carbohydrates. This is the simple sugar, give raise to other more complex sugar when they combine togather.

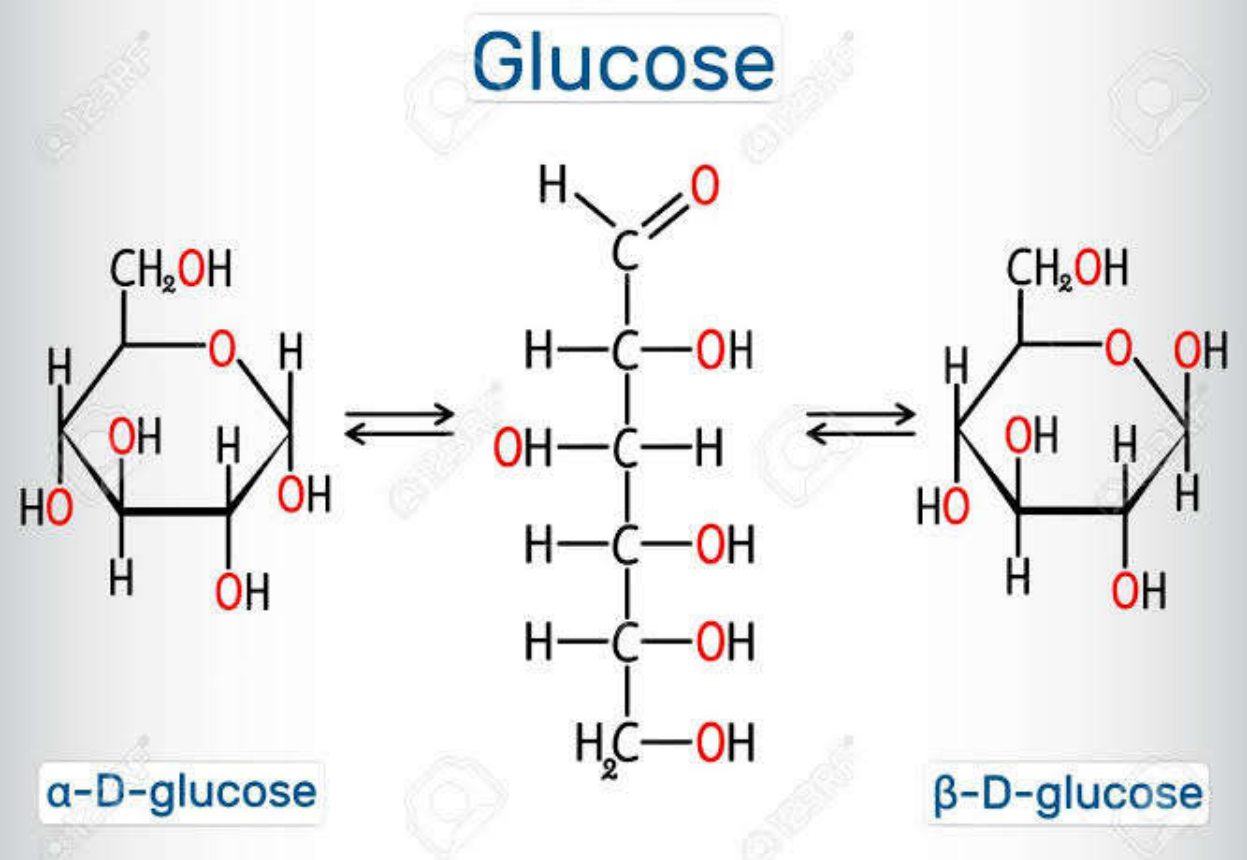
What are the mono saccharides?

This is a simple sugar that creates the base of a more complex molecule of sugars such as oligosaccharides and polysaccharides. These are the examples of mono saccharides fructose, glucose, and ribose

Explanation/defination of mono saccharides

The term monosaccharide means single saccharide. A saccharide is the structural unit of the carbohydrates. So, a monosaccharide is a carbohydrate consist on only one saccharide or sugar unit.

Mono saccharides and disaccharides are called sugar. Mono saccharides are also called simple sugars because they are the most part of the sugar. Sucrose (table sugar), which is a disaccharide consist of two mono saccharides units one is glucose and other is fructose.



Characteristics of monosaccharide

Mono saccharides are the simplest sugar. They cannot be break down into simpler sugars by hydrolysis. Mono saccharides can combine with each other to form more complex carbohydrates. Glycosidic bonds are the covalent bonds through which monosaccharides combine and form complex carbohydrates.

Disaccharides

. The combination of two simple sugars is called a disaccharide. The common example of disaccharide is sucrose which consist on glucose and fructose. The biochemical process/reaction through which monosaccharide units combine called as" dehydration synthesis" (formation of glycosidic bond take place) and water is released as byproduct. This is a reversible type process. When water added large molecules of carbohydrates are changed into simple sugars molecules, one common example is the process glycogenolysis in which stored glycogen is converted into glucose.

General formula of monosaccharides

Common chemical formula of monosaccharides is $_{CnH2nOn}$. The ratio of hydrogen and oxygen atoms in most molecules is 2:1. Deoxyribose, which is found in DNA do not obey this formula, which is a type of monosaccharide. Mono saccharides and other carbohydrates are also called as hydrates of carbon.

Physical properties of monosacchrides

Monosaccharides are the colorless, crystalline solids, and sweet in taste. They are soluble in water and occur as syrups or liquid sugar. Monosaccharides are organic compounds and carbon is covalently bound to other atoms, such as oxygen and hydrogen.

Classifications of mono saccharides

According to length of carbon chain in molecule of mono saccharides. They are classify into following groups

1) Trioses

Triose contain three-carbon monosaccharide units. Glyceraldehyde-3-phosphate (C3H7O6P) is an example of triose. This is intermediate compound in Calvin cycle through which glucose is produced.

2) Tetroses

Monosaccharide contain four carbon atoms called tetrose. These are naturally-occurring tetroses D-erythrose, D-threose. The erythrose, C4H8O4, is a tetrose with one aldehyde group. The erythrulose is a ketotetrose for having a ketone group in its structure.

3) Pentoses

Monosaccharide having five carbon atom or saccharide unit called pentose. These are the very important mono saccharides. The most famous examples of pentose is ribose, deoxyribose. Ribose and deoxyribose are fundamental unis of nucleotides and nucleic acids. In particular, ribose is the part of the RNA and deoxyribose is the sugar part of the DNA.

4) Hexoses

This is another common and famous class of monosaccharides .A hexose is consist on six-carbon monosaccharide. Glucose, fructose,are the very common and famous examples of the hexose. Some other examples are the piscose, sorbose, and tagatose. Glucose, is the most common hexose and act as intermediate molecule in cellular respiration. Extra glucose is stored as glycogen in animals and as starch in plants.

4) Heptoses

Monosaccharide in which seven carbon are present calles heptose. These are some naturally occurring heptoses L-glycero-D-manno-heptose and sedoheptulose. Their chemical formula is C7H14O7.

5) Octoses

Monosaccharide having eight carbon called octose. Octoses have a chemical formula of C8H16O8. The example of octose is methylthiolincosamide.

6) Nonoses

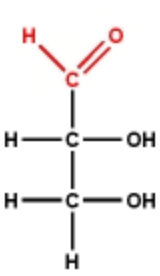
The carbohydrates in which nine-carbon monosaccharide is present called nonose. The examples of nonoses are included neuraminic acid and sialic acid. Neuraminic acid is a synthetic nonose.

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.

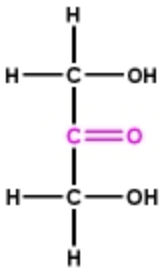
Classification on the base of functional groups

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).

Hexoses, the common mono saccharides which include glucose which is aldose sugar.Other examples are galactose and glyceraldehyde. On the other hand, fructose is a ketose sugar. Other examples are sorbose and tagatose.



An Aldose



A Ketose

Some important mono and disaccharides

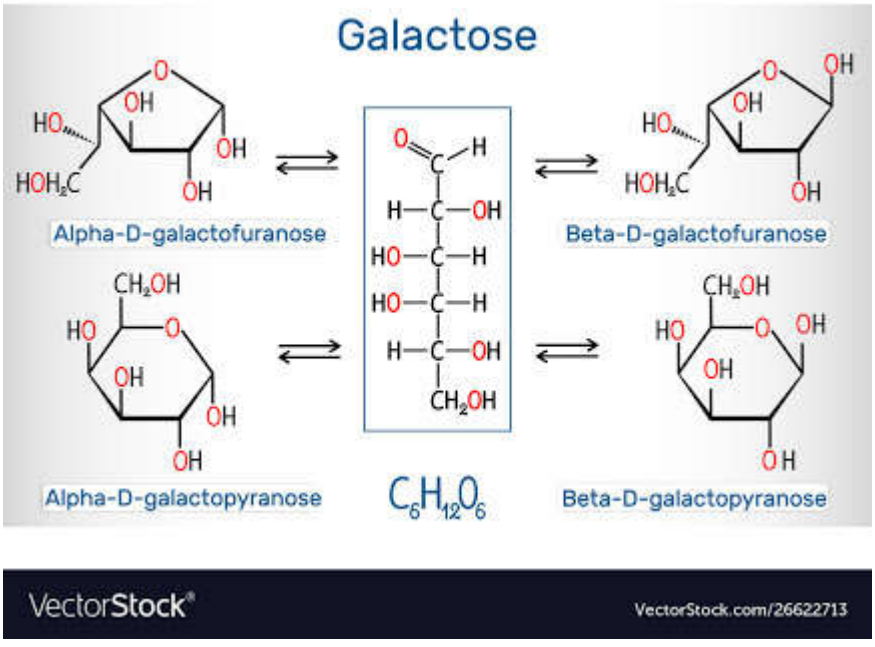
Fructose, glucose, and galactose are the dietary monosaccharides because they are absorbed by the small intestines rapidly. They are hexoses with a chemical formula: C6H12O6. Glucose and galactose are aldoses whereas fructose is a ketose.

Glucose

It is a monosaccharide that occurs naturally and is and it is very important for plants and animals to gain energy. 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. Structure of glucose is shown in previous diagram.

Galactose

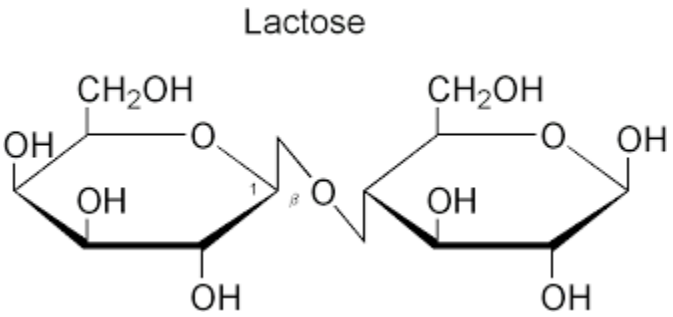
Galactose is similar to glucose in relations of chemical structure. But, the orientations of H and OH on carbon 4 are exchanged. Unlike glucose, galactose generally does not occur in free state. It usually is a part of complex biomolecules. For instance, galactose together with glucose forms lactose (milk sugar), which is a disaccharide.



Lactose

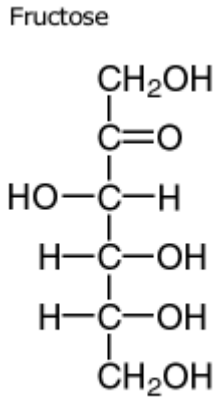
Lactose, the disaccharide of milk, consists of galactose joined to glucose by a –(1-4) glycosidic link. The joining of galactose and glucose is catalyzed by the enzymes lactase. Galactose catabolism (where glucose is converted to galactose) is carried out by the Leloir pathway. In human

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 called to as galactan.



Fructose

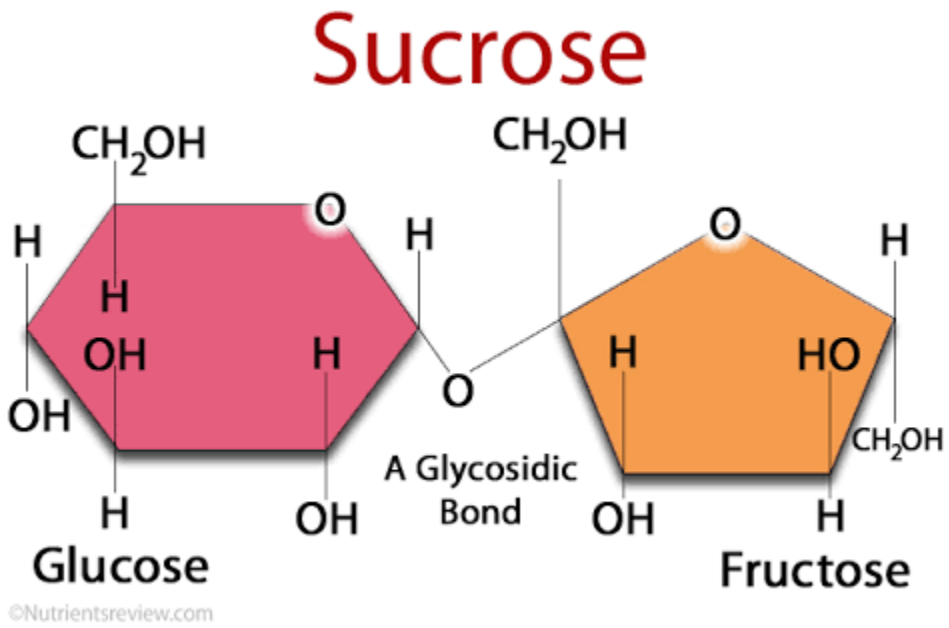
Fructose is called as the sweetest naturally-occurring carbohydrate. Some of the natural sources of fructose are honey, fruits, and sugar cane. It is a ketonic monosaccharide since it has a reducing group (carbonyl) at carbon 2. This is in contrast to glucose (which is an aldose) that has its carbonyl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

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

Mono saccharides perform vital biological roles. Some functions of monosacchrides are given below

1) Role in forming of structural units

One of their major functions is to serve as a structural unit in plants and animals 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.

2) Source of nutrients

Mono saccharides, just like the other carbohydrates, are an important source of nutrition. Mono saccharides 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.

3) Source of ATP

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).

4) Storage of monosaccharides

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.

Some important biochemical reactions of monosaccharides

These take part in many important biochemical reactions. Here, we discuss some biochemical reactions. Here are only names and brief description of the biochemical reaction because these biochemical reaction mostly occur in cyclic form and having complex mechanisms.

1) **Glycolysis**

The biochemical reactions in which conversion of a monosaccharide into pyruvate take place, and produce high-energy biomolecules.

2) **Gluconeogenesis**

The process in which non-carbohydrate raw material converted into a monosaccharide

3) **Glycogenolysis**

In this reaction stored glycogen is converted into glucose (monosaccharide units)

4) **Glycogenesis**

Biological reactions in which glucose is converted into glycogen.

5) **Fructose reactions**

In these reactions fructose is entered into Calvin cycle, in place of glucose.

6) **Galactose reactions**

It is the series of biochemical reactions in which galactose enter in place of glucose. At first phosphorus is added to it called as phosphorylation and then change into into glucose-6-phosphate.

Tautomerization

In this process shifting of hydrogen atom from one carbon atom to other carbon take place which produce enediols. This process is known as tautomerization. When glucose is placed in alkaline solution, isomerization occur. Glucose is converted into d-fructose and d-mannose. The enediols are highly reactive.

Formation of esters

Through the non-enzymatic or enzymatic reactions, the alcoholic group of mono saccharides may be converted into the ester. In metabolism esterification of carbohydrates with phosphoric acid is a common reaction. The examples are glucose-6-phosphate and glucose-1-phosphate.

Reducing properties

Sugars can be reducing or non-reducing and these have reducing ability because of aldehyde and ketone group that is present in them of anomeric carbon. Many test are performed in laboratory to check the reducing action of these sugars. For example Benedict's test, Fehling's test, Barfoed's test etc. Reduction reaction occurs in alkaline medium. Enediols can reduce copper sulphate cupric ion to cuprous ions. And preciptates of colour yellow and red are formed of hydroxide and cuprous oxide respectively. This reaction cannot be used for identification of type of sugar as this reaction is general.

Oxidation

Both the aldehyde + keto group as well as alcohol present at terminal position can get oxidized depending upon what type of oxidizing agent is used. For example if we consider glucose: o If aldehyde groups gets oxidized it form an acid gluconic acid. If alcoholic group gets oxidized then glucuronic acid.

DERIVATIVES OF MONOSACCHARIDES:

There are many derivatives of mono saccharides. These have great significance in physiological processes.

1. Sugar acids:

   If aldehyde or alcoholic group of mono saccharides gets oxidizied it produces sugar acids. For example oxidation of alcoholic group at carbon 1 of glucose produces Gluconic acid and when alcoholic group at carbon 6 is oxidized it produces glucuronic acid.

2. Alditols:

   Reduction of monosaccharides produces polyhydroxy alcohol which is called alditols. Ribitol is a component of flavin coenzyme.Glycerol and myo-inositol are consiteunts of lipids. Sweetener used for sugarless gums and sweets is Xylitol.

3. Amino sugars:

   By of one or more replacement of hydroxyl of monosaccharides by amino group form amino sugars. Such as D-glucosamine,D-galactosamine. These are component of heteropolysaccharides. Derivative of N-acetylmannose and pyruvic acid is NAcetylneuraminic acid (NANA). It is said to be an important component of glycoproteins

   and glycolipids. Sialic acid also contains NANA along with its dervatives. Antibiotics also posses amino sugars like erythromycin to perfom antibiotic activity.

4. Deoxysugars:

These are those sugars whose one number of oxygen is less then parent molecule.

Groups like CHOH and CH2OH becomes CH2 and CH3 respectively. This is because oxygen is less. The most important deoxysugar D-2-Deoxyribose is considered to be most important since it present in DNA.

Deoxyribose sugar can be detected by Feulgen staining method and can be used to fine DNA. Other deoxysugars like deoxy L-galactose is present in blood group antigens and also in glycoproteins

5. .L-Ascorbic acid (vitamin C):

It is a vitamin which is water soluble and its structure is quite similar to monosaccharides.