Biochemistry

Lec.4 :- Carbohydrates- definition, classification

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Carbohydrates- definition, classification with structure and functions

Carbohydrates Definition

Carbohydrates are a large group of organic compounds consisting of carbon, hydrogen, and oxygen which can be typically broken down into monomers to release energy in living beings.

- These are the most abundant biomolecules in the living body in terms of mass.
- Carbohydrates are also known as saccharides since many of those have a relatively small molecular weight with a sweet taste.
- The empirical formula for carbohydrates is Cm(H2O)n, which holds for most monosaccharide's.
- Carbohydrates are hydrates of carbon and are broadly defined as polyhydroxy aldehydes or ketones and their derivatives.
- These are widely distributed molecules in both plant and animal tissues serving as skeletal structures in plants .
- They also occur as food reserves in the storage organs of plants and the liver and muscles of animals.
- They are an essential source of energy required for the various metabolic activities of living organisms.
- Plants are considerably more abundant in carbohydrates in comparison to animals.
- Glucose, sucrose, cellulose, etc. are some of the most known and important carbohydrates found on earth.

What is Monomer?

 A monomer is the simplest molecule that forms the basic unit of polymers and thus is considered as the building blocks of polymers.
 Monomers bind with another monomer to form a chain of repeating molecules by the process of polymerization.

What is a Polymer?

 A polymer is s substance consisting of large molecules that are composed of many repeating subunits or monomers.

 Polymers are formed by the binding of several monomeric units in the process termed polymerization.

 Polymers, like monomers, can be both synthetic and natural. Natural polymers include biomolecules like carbohydrates and proteins.

What is a Macromolecule?

 A macromolecule is a large molecule composed of thousands of atoms formed by the polymerization of smaller subunits called monomers.

 Macromolecules are composed of a large number of atoms that are bound together by covalent bonds. These macromolecules together form polymers.

 Macromolecules are also of two types; natural and synthetic.

 Natural macromolecules are biomolecules like carbohydrates and lipids, and synthetic macromolecules are synthetic polymers like plastics and rubber.

What are Covalent Bonds?

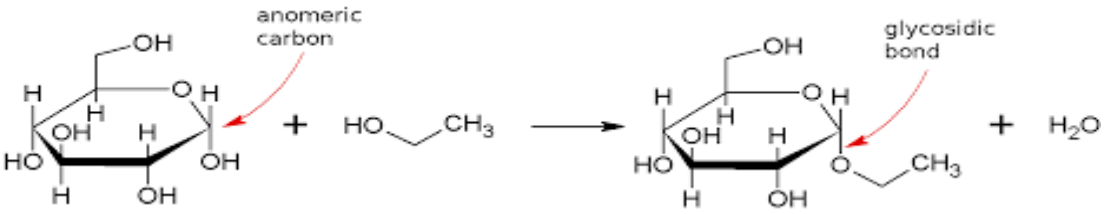


Figure: Formation of ethyl glycoside from glucose and ethanol

Monomeric units of carbohydrates are liked to one another by covalent bonds called glycosidic bonds.

- A glycosidic bond is formed between the carboxyl group present on the anomeric carbon of one monomer and the alcohol group present in another monomer

- The covalent bonds in carbohydrates are either α or β-glycosidic linkages depending on the stereochemistry of the carbon atoms bound together.
- The linear chain in a carbohydrate molecule contains either an α-1,4-glycosidic bond or a β-1,4-glycosidic bond.
- The branching in carbohydrates, however, results due to a 1,6- glycosidic bond.

Reducing and non-reducing sugars

What are Reducing sugars?

Reducing sugar is a sugar or a carbohydrate molecule with a free aldehyde group or a free ketone group which causes the molecule to act as a reducing agent.

 All monosaccharide's, along with some disaccharides and polysaccharides, are reducing sugars.

 In the case of other polysaccharides and disaccharides, the aldehyde and ketone groups remain bound in the cyclic form.

 Most reducing sugars are sweet in taste. These sugars can be detected by tests like Benedict's test and Fehling's test as they give a positive result to these tests.

 Examples of reducing sugars include monosaccharide's like galactose, glucose, glyceraldehyde, fructose, lactose, and maltose, and polymers like glycogen

What are Non-reducing sugars?

 A non-reducing sugar is a sugar or carbohydrate molecule that doesn't have a free aldehyde or ketone group and thus cannot act as a reducing agent.

 Non-reducing sugars have aldehyde and ketone groups, but they are involved in the cyclic form of the sugar molecule.

 Some disaccharides and all polysaccharides are non-reducing sugars.

 Non-reducing sugars have a less sweet taste than the reducing sugars.

These sugars can also be detected by tests like Benedict's test and Fehling's test as they give a negative result to these tests.

 Examples of non-reducing sugars include disaccharides like sucrose,

maltose, and lactose and polysaccharides like starch and cellulose.

Formation of a glycosidic bond by condensation

 The process of formation of glycosidic bonds in carbohydrates is a condensation reaction which means that a molecule of water is formed during the process.

 The condensation reaction is formed between the OH group and the anomeric carbon of a sugar.

 These glycosidic bonds are formed in a dehydration synthesis reaction.

 When the alcohol attacks the anomeric carbon, the OH group of the carbon is replaced by the oxygen atom of the alcohol molecule. The OH group of the carbon and the remaining H atom of the alcohol are released in the form of a water molecule.

Breakage of a glycosidic bond by hydrolysis

 The breakage of a glycosidic bond occurs by the process of hydrolysis

by the addition of a water molecule.

 Hydrolysis of glycosidic bond occurs both in the presence of acid or an alkali.

 The OH group from the water molecule attacks the carbon atom involved in the glycosidic linkage.

 In the case of polysaccharides, hydrolysis results in smaller polysaccharides or disaccharides, or monosaccharide's.

 In the living system, hydrolysis of polysaccharides occurs in the presence of a group of enzymes termed hydrolases that catalyze the hydrolysis process.

Classification of Carbohydrates

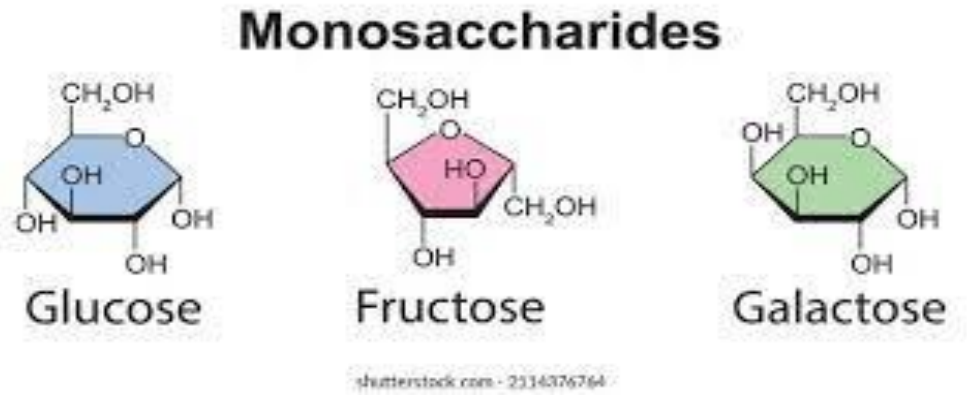
Carbohydrates are classified into three different groups based on the degree of polymerization;

A. Monosaccharide's

 Monosaccharide's are the simplest form of sugar that cannot be hydrolyzed into smaller units.

 The monosaccharide's, often called simple sugars, are compounds that possess a free aldehyde (—CHO) or ketone (= CO) group and two or more hydroxyl (—OH) groups.

 Monosaccharide's are considered as fuel molecules that are involved in the formation of polymers like polysaccharides and nucleic acids.



Monosaccharide's are of two types;

- **Aldoses:** Monosaccharide's having an aldehyde group as the carbonyl group are termed as aldoses.
- **Ketoses:**
- Monosaccharide's having a ketone group as the carbonyl group are termed as ketoses
- Based on the number of carbon atoms, monosaccharide's are divided into trioses, tetroses, pentoses, hexoses, and heptoses having three, four, five, six, and seven carbon atoms.
- Monosaccharide's are further divided into D and L forms based on the orientation of the asymmetric carbon furthest from the carbonyl group.

Structure

- The formula of all monosaccharide's is (CH2)O which indicates that the central carbon atom bonded to two hydrogen atoms and an oxygen atom.
- A carbonyl group is present in all monosaccharide's where if the group is present at the end, it forms an aldose and if it is present in the middle, it forms a ketose sugar.
- Monosaccharide's with more than five carbon atoms exist in the form of rings in the solution state.
- Monosaccharide's are composed of a single molecule of sugar with no glycosidic bond.
- All Monosaccharide's are reducing sugars with a free aldehyde or ketone group.

Functions

- Monosaccharide's are one of the main fuels for energy in living beings with most of them providing 4kcal energy per gram of the carbohydrate.
- Monosaccharide's are involved in the synthesis of various biomolecules like ribose and ribulose involved in the synthesis of nucleic acids, coenzymes like NAD, NADH, Coenzyme A, etc.
- Several monosaccharide's linked together by glycosidic bonds result in the process of polymerization, forming larger polysaccharides.

Example of Monosaccharide

Glucose

- Glucose is an important monosaccharide that provides energy and structure to different parts of a cell.
- Glucose is a six-carbon compound with the molecular formula $C_6H_{12}O_6$.
- Glucose exists in two forms; α-glucose and β-glucose.
- These two forms, however, can interconvert as the glucose changes structure from open-chain to cyclic or ring form.
- Glucose is an essential monosaccharide that is broken down during glycolysis providing energy and precursors for cellular respiration.
- Long chains of glucose molecules are linked together by glycosidic bonds to form essential polysaccharides like starch and glycogen.

B. Disaccharides

A disaccharide is a sugar molecule composed of two monomeric units linked together by a glycosidic bond, resulting from a condensation reaction.

- Disaccharides are the simplest polysaccharides composed of either identical or two different monosaccharide's.
- The most common and unmodified disaccharides have the molecular formula $C_{12}H_{22}O_{11}$.

- Disaccharides are of two types; reducing and non-reducing saccharides. Reducing disaccharides have a free carbonyl group, whereas non-reducing disaccharides do not have a free carbonyl group.
- Disaccharides like maltose, sucrose, and lactose have the same molecular formula but have different atomic arrangements.
- Disaccharides are an important source of energy as they can be broken down to produce monosaccharide's that are involved in the metabolic pathways within living beings.

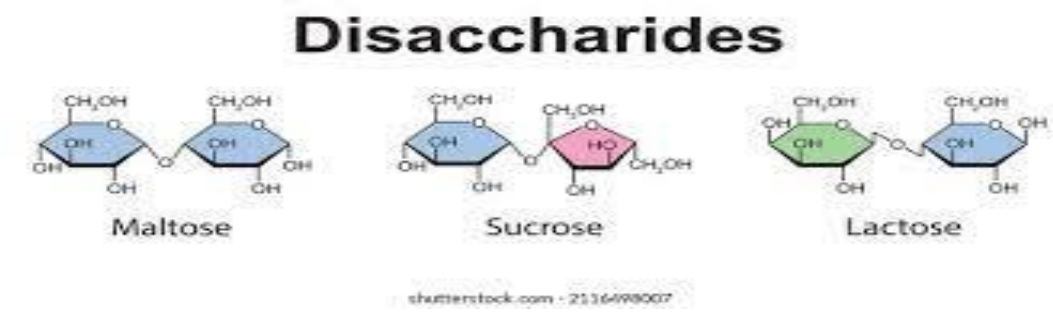


Figure:Disaccharides

C. Polysaccharides

- Polysaccharides are sugar molecules with more than ten monosaccharide units bonded together by glycosidic bonds.
- Polysaccharides are also termed glycan.
- Polysaccharides are a long chain of monosaccharide's where the polysaccharide can be either homopolysaccharide or heteropolysaccharide.
- Homopolysaccharides are formed of identical monosaccharide's, and heteropolysaccharides are formed of different monosaccharide's.
- Polysaccharides have different forms depending on the monosaccharide's present and the carbon atoms connected to one another.
- Some polysaccharides are linear, while others are branched.

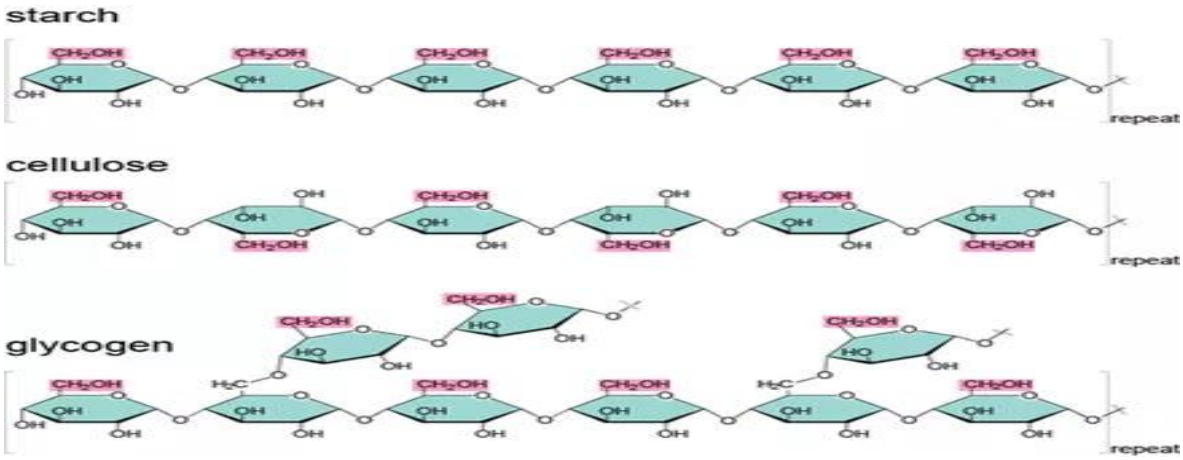


Figure: polysaccharides

Examples of Polysaccharide

1. Starch

Starch is a polysaccharide comprising glucose monomers joined together by glycosidic linkages. Starch is the form of reserve food in plants stored in chloroplasts in the form of granules and storage organs like roots, tuber, stem, and seeds.

Structure

- Starch is a homoglycan composed of a single type of sugar unit.
- A single starch molecule has 300 to 1000 glucose units bound together.
- Most starches are composed of two kinds of polysaccharides, a linear α-(1→4) linked glucan, called amylose, and an α-(1→4) linked glucan with 4.2 to 5.9% α-(1→6) branch linkages, called amylopectin.

Functions

- Starch is the most common and essential storage form of carbohydrates in plants.

- It is a major source of energy in a carbohydrate diet where the hydrolysis of starch yields glucose which is further metabolized to produce energy.

2. Glycogen

Glycogen is a branched polysaccharide that is a major form of glucose in animals and humans. It is often termed as 'animal starch' and is stored in the liver and muscles of animals.

Structure

- Glycogen is a branched-chain polysaccharide and resembles amylopectin in its structure.
- Glycogen molecule is composed of glucose subunits that are linked together by α-1,4 linkages that branch off via α-1,6 linkages every ten glucose residues.
- Glycogen is similar to starch but has more branches and is more compact than starch.
- Glycogen is synthesized in the body when there is an excess of glucose produced in the body.

Functions

- The primary function of glycogen is the storage of excess glucose in the body when the blood glucose level increases.
- Glycogen then breaks down into glucose molecules to provide energy to the body when the blood glucose level decreases.
- About 6-10% of the weight of the liver is made up of glycogen which is converted into glucose molecules during fasting.

3. Cellulose

Cellulose is the most abundant extracellular structural polysaccharide in plants .

Cellulose is found in all land plants but is absent in meat, egg, fish, and milk. Cellulose occurs in the cell walls of plants where it contributes in a major way to the structure of the organism.

Structure

- It is formed by the glycosidic linkage between the OH group on C1 of one β-D-glucose molecule and the alcoholic OH group on C4 of the adjacent β-D-glucose molecule.
- It resembles in structure with amylose except that the glucose units are linked together by β-1, 4-glucoside linkages.

Functions

- Cellulose is the major structural polysaccharide in plants that forms the various structure of plant cells, including the cell wall