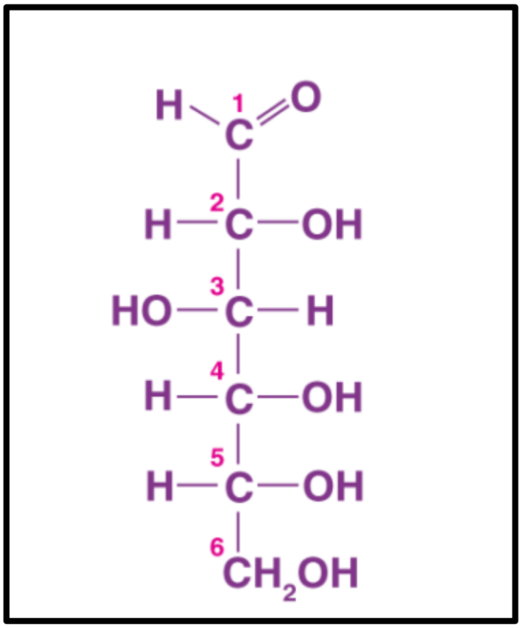
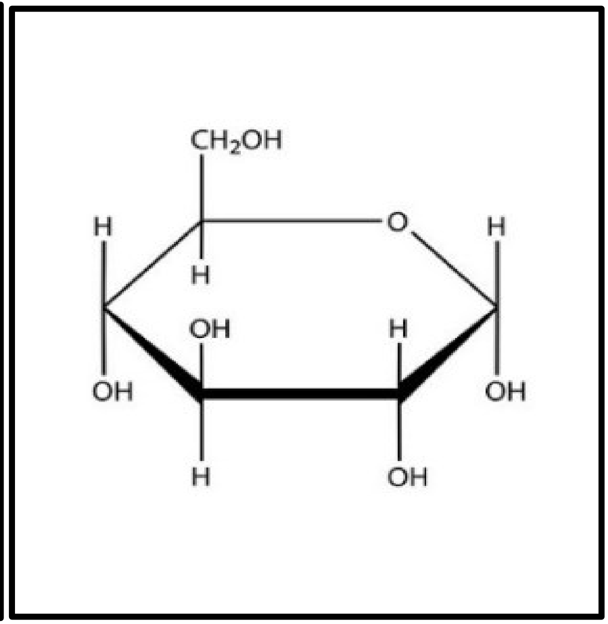
Carbohydrate: is a biomolecule composed of carbon (C) , hydrogen (H) , and oxygen (O) atoms .





Metabolism: is the entire network of chemical reactions carried out by living cells. It is also refer to the intermediate steps within the cells in which the nutrient molecules or foodstuffs are metabolized and converted into cellular components catalyzed by enzymes.

The fate of dietary components after digestion and absorption constitutes metabolism the metabolic pathways taken by individual molecules, their interrelationships and the mechanisms that regulate the flow of metabolites through the pathways. However, in cells, these reactions occur in isolation, but rather are organized into multistep sequences called pathways, where the product of one reaction becomes the substrate for the next reaction, such as glycolysis. Different pathways can also intersect, forming an integrated and purposeful network of chemical reactions. These are collectively called metabolism, which is the sum of all the chemical changes occurring in a cell, a tissue, or the body.

Most pathways can be classified as either catabolic (degradative) or anabolic (synthetic):

1- Catabolic pathways: involve reactions that breakdown complex molecules, such as proteins, polysaccharides, and lipids, to a few simple molecules, like, CO2, NH3 (ammonia) and water.

Catabolic reactions serve to capture chemical energy in the form of ATP from the degradation of energy – rich fuel molecules.

Catabolism also allows molecules in the diet (or nutrient molecules stored in cells) to be converted into building blocks needed for the synthesis of molecules energy generation by degradation of complex molecules occurs in three stages:

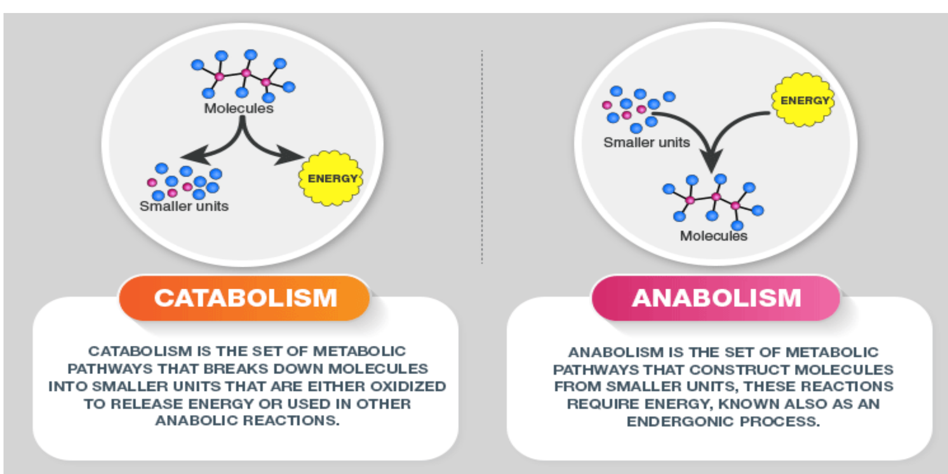
1- Hydrolysis of complex molecules.

2- Conversion of building blocks to simple intermediates. 3- Oxidation of acetyl CoA.

Anabolic pathways: form complex end products from simple precursors, like synthesis of glycogen, polysaccharides from glucose.

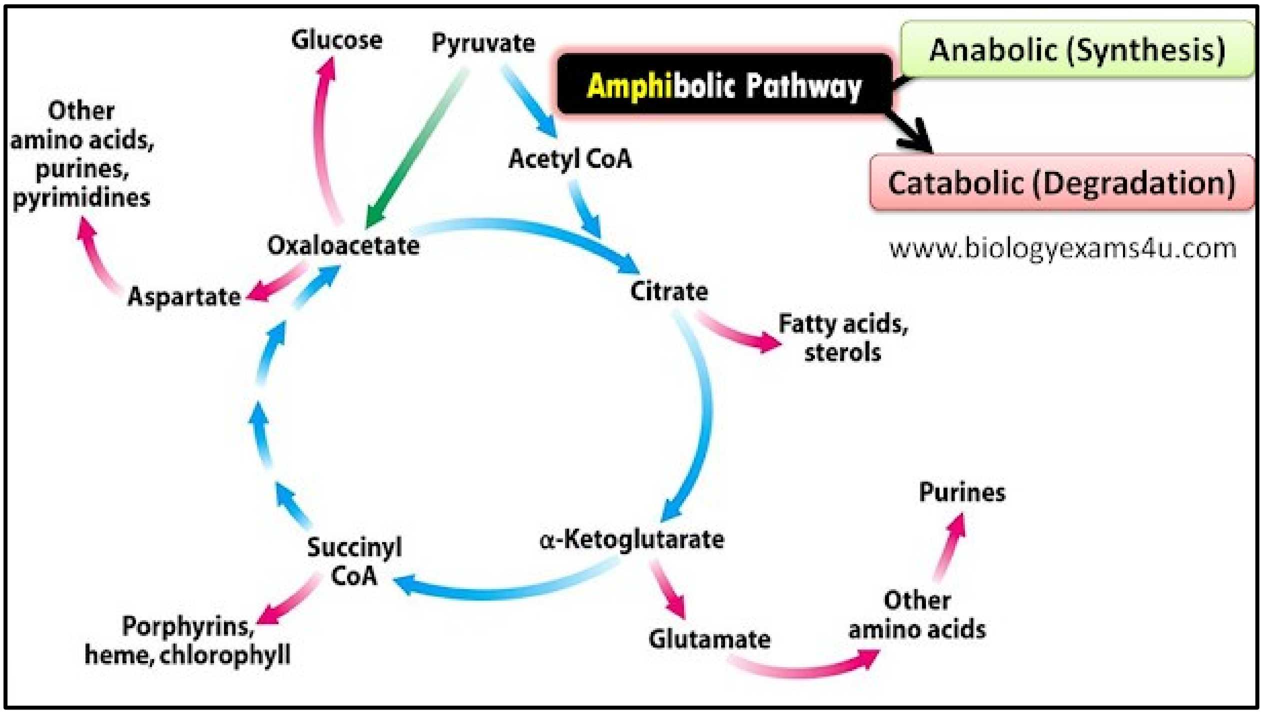
Anabolic reaction required energy, which is generally provided by the breakdown of ATP to ADP and Pi.

Also anabolic reactions involve chemical reductions in which the reducing power is most frequently provided by the electron donor NADPH.



Catabolism	Anabolism
It is a chemical process that releases energy when breaking complex molecules into smaller molecules.	It is a process used to build molecules for building cells in the body.
In this process, the body releases energy in different activities.	In this process, the body requires energy to maintain the body an anabolic state.
In this process, energy conversion is from potential energy to kinetic energy.	In this process, energy conversion is from kinetic energy to potential energy.
This process helps in burning fats and calories.	The anabolism process helps in the growth of the muscle.
Catabolism requires oxygen.	The anabolism process requires less amount of oxygen compared to catabolism.
Catabolism functions in any activity irrespective of time.	Anabolism function only in the night or rest position.
Catabolism is involved in the destruction process of metabolism.	Anabolism is involved in the construction process of metabolism.
During the catabolism process, it takes the help of some hormones called Adrenaline, cytokines, cortisol, and glucagon.	During the anabolism process, it takes the help of some hormones called Estrogen, testosterone, growth hormone, and insulin.
In this catabolism chemical process proteins turn to amino acids, glycogen turns to glucose, and triglycerides become fatty acids.	In this anabolism chemical process amino acids turn into proteins, glucose turns into glycogen, and fatty acids become triglycerides.

Metabolic pathways may have a third category called **Amphibolic** pathway occur at the "crossroads" of metabolism, acting as links between the anabolic and catabolic pathways, e.g., citric acid cycle.

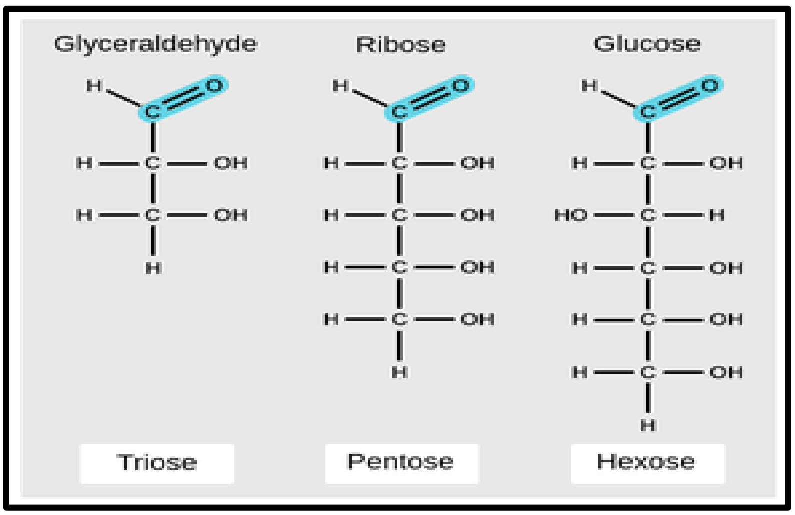


Carbohydrate Metabolism Introduction

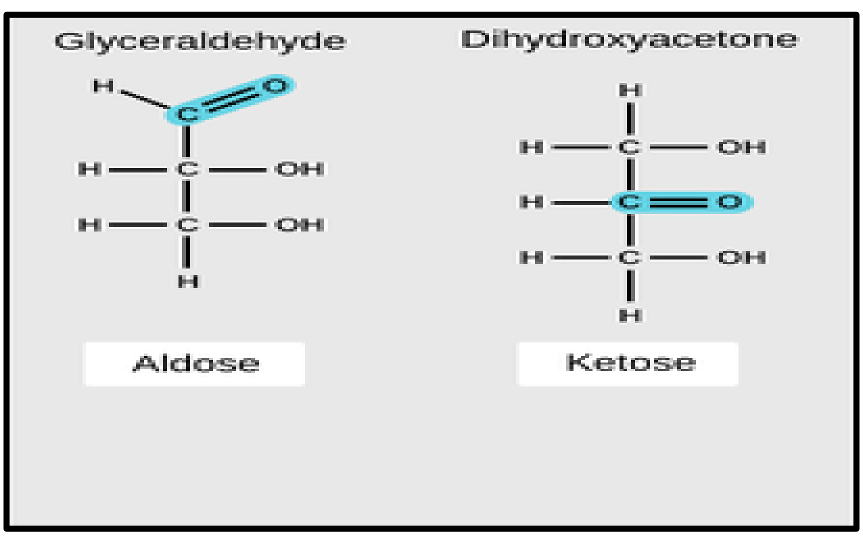
Carbohydrates are polyhydroxy aldehydes or ketones, with the formula $(CH_2O)n$. They may contain phosphate, amino, or sulfate group. Carbohydrates are divided into four major groups:

1) Monosaccharides: or called simple sugars with general formula CnH2nOn, these sugars don't hydrolysis to smaller units. They can be subdivided further:

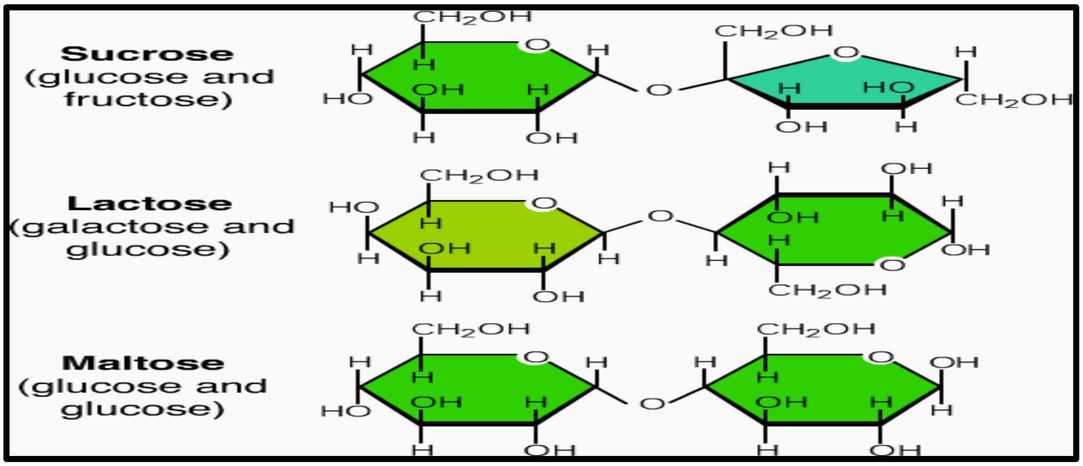
a) Depending upon the number of carbon atoms, as trioses, tetroses, pentoses, hexoses…



b) Depending upon whether aldehyde (-CHO) or ketone (-C=O) groups are present as aldoses or ketoses.

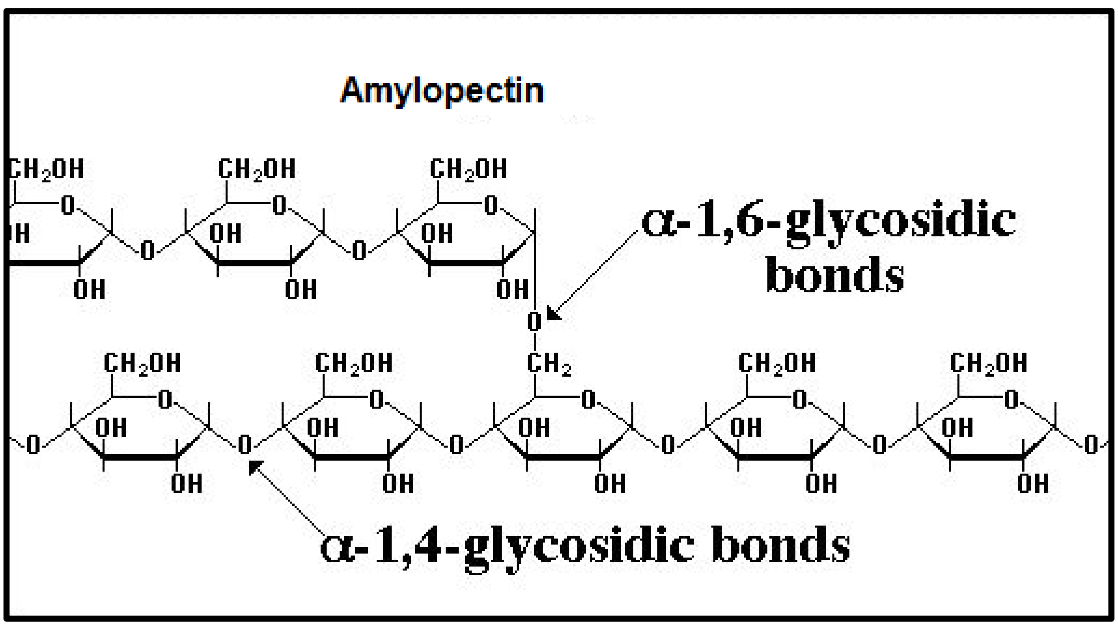


2) Disaccharides: are those sugars which yield two monosaccharides on hydrolysis. General formula Cn (H2O) n-1 Like: Maltose → glucose + glucose Lactose → glucose + galactose Sucrose → glucose + fructose



3) Oligosaccharides: are those which yield 3-10 monosaccharide units on hydrolysis like Maltotriose.

4) Polysaccharides (Glycan's): are those which yield more than ten molecules of monosaccharide on hydrolysis, with general formula (C6H10O5) n. Like: starch, glycogen, cellulose, dextrin's…



Biomedical importance of Carbohydrates

• Chief source of energy. Glucose is the preferred source of energy for most of the body tissues. Brain cells derive the energy mainly from glucose.

• Constituents of compound lipid and conjugated proteins.

• Degradation products act as "promoters" or "catalysts".

• Degradation products utilized for synthesis of other substances such as fatty acids, cholesterol, amino acid…

• Constituents of mucocpolysaccharides which form the ground substances of mesenchymal tissues.

• Inherited deficiency of certain enzymes in metabolic pathways of different carbohydrates can cause diseases, e.g. galactosemia, glycogen storage diseases (GSDs), lactose intolerance…

• Derangement of glucose metabolism is seen in diabetes mellitus.

Digestion of carbohydrates:

Digestion is the breaking down of the food that eat into other substances that bodies can absorb .

• Human can digest only polysaccharides consisting of $\alpha(1\rightarrow 4)$ glyosidic linkage or $\alpha\ (1\rightarrow 4)$ linkage with $\alpha\ (1\rightarrow 6)$ branch points.

Note / Carbohydrates that cannot be digested: indigestible polysaccharides are part of dietary fiber that passes through the intestine into the feces. For example, because enzymes produced by human cells cannot cleave the (β-1, 4) bonds of carbohydrates, these polysaccharides (like cellulose) are indigestible.

1-Digestion in Mouth:

• Salivary α - amylase (ptyalin) (which requires Cl- ion for activation, pH about 6.7) will hydrolyzes α-(1→ 4) glycosidic linkage, molecules like starch, glycogen, and dextrin will produce smaller molecules: maltose, glucose and maltotriose.

• There is no digestion for carbohydrates in stomach, but some dietary sucrose may be hydrolyzed to glucose and fructose by HCl.

• Digestion in the intestine: food bolus reaches the duodenum from stomach where it meets the pancreatic juice. Pancreatic juice contain bicarbonate (HCO_3^-) neutralizes the stomach acid, raising the pH into the optimal range for the action of the intestinal enzymes.

2- Digestion of pancreatic enzymes:

a- The pancreas secretes an α - amylase also called amylopsin, it is similar to salivary amylase, the enzyme hydrolyze α - (1→ 4) glycosidic linkages between glucose residues.

b- The products of pancreatic α - amylase are the disaccharides maltose, maltotriose, and small oligosaccharides containing α - (1→ 4) and α - (1→ 6) linkages.

3- Digestion by enzymes of intestinal cells:

Action of intestinal juice:

a- intestinal amylase: This hydrolyzes terminal α - (1→ 4) glycosidic linkage in polysaccharides and oligosaccharide molecules liberating free glucose molecule.

b- Isomaltase: It catalyze the hydrolysis of α-(1→ 6) glycosidic linkage, producing maltose & glucose.

c- Maltase: hydrolyze the α - (1→ 4) glycosidic linkage, producing two glucose molecules.

d- Sucrase: This enzyme converts sucrose to glucose and fructose.

Absorption of glucose, fructose and galactose:

Only monosaccharides are absorbed by the intestine. Absorption rate is maximum for galactose, moderate for glucose and minimum for fructose. Pentoses are absorbed slowly Mechanisms of absorption:

1-Simple Diffusion: This is dependent on sugar concentration gradients between the intestinal lumen, mucosal cells and blood plasma. All the monosaccharaides are probably absorbed to some extent by simple "passive" diffusion.

2-Active Transport Mechanisms:

• Glucose, fructose and Galactose, the final products generated by digestion of dietary carbohydrates, are absorbed by intestinal epithelial cells.

• Glucose has specific transporters, which are transmembrane proteins

A- Co-transport from lumen to intestinal cell, this process is mediated by Sodium Dependent Glucose Transporter-1 (SGluT-1) . The carrier protein has two binding sites one for Na and another for the glucose. The carrier protein is specific for sugar and it is mobile, a Na dependent and energy dependent.

The transporter in the intestine is named as **SGluT-1** and the transporter in the kidney is called **SGluT-2**.

B- Another uniport system releases glucose into blood are also called Glucose Transporters (GluT), it is a uniport, facilitated diffusion system.

♣ Glucose Transporters (Glu-T) are several (Glu-T-1 to 7). The most important are GluT-2 and GluT-4

♣ GluT-2: Operates in intestinal epithelial cells; it is not Na dependent.

♣ GluT-4: Operates principally in muscles and adipose tissue. The GluT-4 is under control of insulin and moves between cytoplasm and membrane. * ((Note: Other "GluT" molecules are not under control of insulin)).

♣ GluT-1: is present mainly in RB cells and brain. Also present in retina, colon and placenta.

Absorption of other sugars:

• Sugars like D-fructose and D-mannose are probably absorbed by "facilitated transport" which requires the presence of carrier protein but does not require energy

. • Other sugars like pentoses and L-isomers of glucose and galactose are absorbed passively by simple diffusion.

Factors influencing rate of absorption:

1- State of mucous membrane and length of time of contact.

2- Hormones: thyroid hormones increase hexoses absorption, while adrenal cortex hormones deficiency decrease the hexoses absorption due to decreased Na concentration in body fluids.

3- Vitamins: deficiency of B-vitamins decreased hexose absorption.

4- Inherited enzyme deficiencies like sucrase and lactase can interfere with hydrolysis of corresponding disaccharides and their absorption Utilization of Glucose in the Body General outline: After absorption of monosaccharide into the portal blood, it passes through the liver before entering the systemic circulation.

In liver two mechanisms operate:

1-Withdrawal of carbohydrates from blood:

This includes:

• Uptake of hexoses by liver cells: such as galactose and fructose and their conversion to glucose by liver cells.

• Conversion of glucose to glycogen for storage (glycogenesis).

• Utilization of glucose, by oxidation (glycolysis) for energy production.

• Utilization of glucose for synthesis of other compounds like fatty acids and certain amino acids.

2- Release of glucose by liver to the blood:

This includes:

• Formation of blood glucose from hexoses other than glucose by liver and its release from liver cells.

• Conversion of liver glycogen to blood glucose (glycogenolysis).

• Formation of blood glucose by the liver from non carbohydrate sources, like amino acids (glycogenic), pyruvates and lactates, glycerol and propionly CoA (gluconeogenesis).

Utilization of Glucose:

1- Oxidation:

a- For provision of energy: In response to physiological needs, human body requires energy, oxidation of glucose or glycogen to pyruvate and lactate by glycolysis pathway . Glycolysis occurs in all tissues.

b- HMP shunt: An alternative pathway for oxidation of glucose. It is not meant for energy. The pathway provides:

1) NADPH which is used for reductive synthesis.
2) Pentoses which is used for nucleic acids synthesis.

2- Storage: Excess of glucose taken is converted to glycogen in various tissues (glycogenesis) especially liver and skeletal muscle and stored there for future needs.
3- Conversion to Fats: Excess of glucose is converted to FA and stored as “triacylglycerol” (TG) in Fat depots (lipogenesis).

4- Conversion to other carbohydrates: small amounts of glucose are used directly or indirectly in synthesis other carbohydrates or derivatives, which play important role in the body.

• Formation of ribose and deoxyribose.
• Formation of fructose from glucose.
• Mannose, fucose, glucosamine and Neuraminic acid.
• Galactose.
5- Conversion to Amino acids