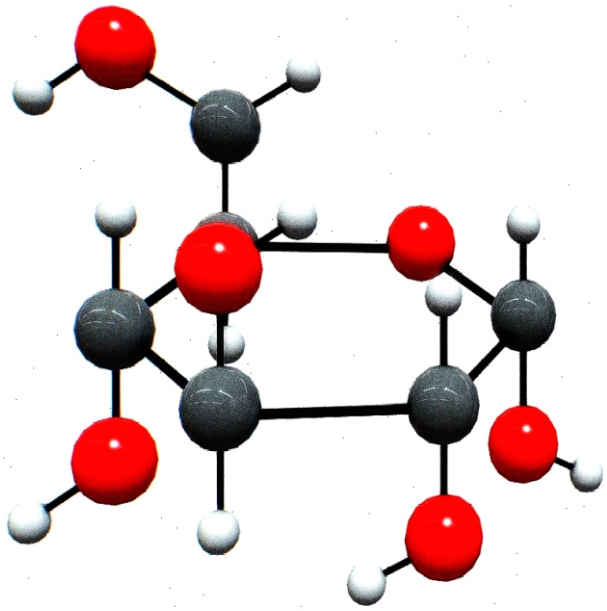
CHAPTER 10

BIOCHEMISTRY

Teaching Periods	06	Assessment	01	Weightage %	05



Students will be able to:

- ✓ Discuss the natural sources of Carbohydrates and classification based on structure. (understanding)
- ✓ Enlist the role of various Carbohydrates in health and diseases. (Applying)
- ✓ Identify the nutritional importance and their role as energy storage (Applying)
- ✓ Explain the classification of protein on the basis of structure and their functions. (Applying)
- ✓ Explain classification and Functions of Lipids. (Applying)
- ✓ Enlist sources and the role of Iron, Calcium, Phosphorous and Zinc in nutrition. (Applying)

INTRODUCTION

"Biochemistry is the branch of science that deals with the chemical processes taking place in the organisms". It focuses on the study of structure, function and interaction of biological macromolecules such as proteins, carbohydrates and lipids as well as the chemical reactions and pathways that occur within cells.

Biochemistry aims to investigate the structure, function and interaction of biological molecules. It describes the metabolic pathways that regulate cellular energy production, biosynthesis and degradation of molecules. It plays a vital role in understanding the molecular basis of disease and the impact of drugs on the biological molecules.

10.1 CARBOHYDRATES

Carbohydrate is an essential group of foods in human and animal diets. It is more realistic to define a carbohydrate as **"polyhydroxy aldehydes and ketones or the substances that yield such compounds when they react with water on hydrolysis."** Carbohydrates are the main source of energy for, tissues, and organs of our body. They are components of DNA and RNA (that transmit and store genetic information). Rice, potatoes, wheat and barley are some natural sources of carbohydrates.

10.1.1 Classification based on structure

"Carbohydrates are classified as monosaccharides, disaccharides, oligosaccharide and polysaccharides". This classification is based on the number of sugar unit present in carbohydrates.

Monosaccharides contain a single sugar unit for example glucose, fructose, and galactose. Disaccharides contain two sugar units, examples are sucrose, lactose and maltose. Oligosaccharide are carbohydrates that are made up of 3 to 10 sugar units, for example kestose (glucose-fructose-fructose) and melezitose (glucose-fructose-glucose). Polysaccharides Contain more than 10 sugar units, Cellulose, starch and glycogen are examples of polysaccharides.

Monosaccharides are classified on the basis of the number of carbons present in the molecule. In this classification prefix is used to indicate number of carbon atoms in the molecule and the suffix *–ose*, is used to indicate carbohydrate as a class of biomolecule.

Table 10.1	Examples of some monosaccharide sugar

Class of Monosaccharide	Formula	Examples
Triose	$C_3H_6O_3$	Glyceraldehyde
Tetrose	$C_4H_8O_4$	Erythrose
Pentose	$C_5H_{10}O_5$	Ribose
Hexose	$C_6H_{12}O_6$	Glucose

Among these monosaccharide`, hexose sugar is important since it plays a crucial role in biological system. Hexose sugars are classified into aldohexose and ketohexose. An example of aldohexose is glucose where as ketohexose is fructose.

Glucose and fructose exist in both open chain and close chain form however, the open chain form is relatively unstable. The close chain form of glucose is called pyranose since it resembles with pyran where as the close chain form of fructose is known a furanose since it resembles with furan .

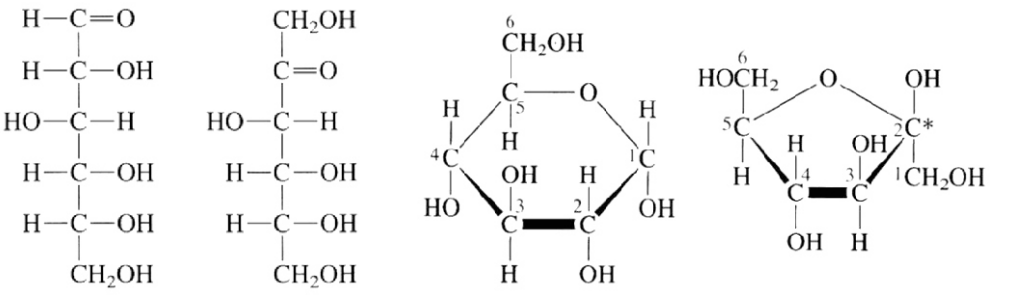


Fig 10.1: (a) Open structure of glucose (b) open structure of fructose (c) pyranose structure of glucose (d) furanose structure of fructose

Disaccharides are carbohydrates consisting of two monosaccharide units join together through glycosidic bond. **"A glycosidic bond (O-C-O) is a type of covalent bond that join two monosaccharide units together to form a larger carbohydrate molecule"**. It is formed through a condensation reaction

with the elimination of water molecule (Fig.10.2). Disaccharides are water soluble crystalline solids and represented by molecular formula $C_{12}H_{22}O_{11}$.

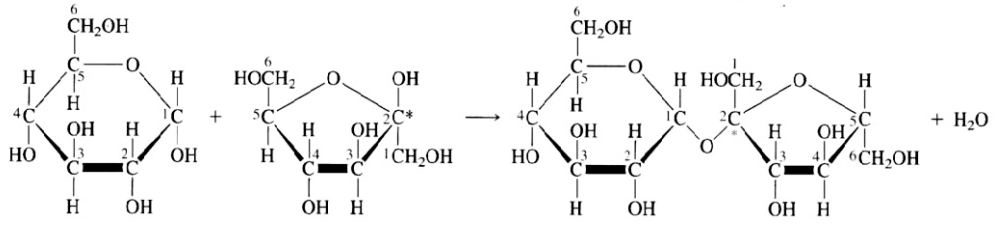


Fig 10.2: Structure of sucrose showing glycosidic linkage between ∝-glucopyrnose and a ß-fructofuranose molecules

"Polysaccharides are macro bio molecules. They are amorphous, water insoluble and made up of more than ten hexose sugars". These hexose molecules are associated with each other through glycosidic linkage. Polysaccharides are further classified into animal polysaccharides and plant polysaccharides. Example of animal polysaccharide is glycogen, which is found in the muscles and liver of animals. It is a storage carbohydrate and commonly known as animal starch.

DO YOU KNOW?

In carbohydrates, "alpha" and "beta" refer to the position of the hydroxyl group attached to the anomeric carbon (the carbon bearing the carbonyl group). "+ (plus)" denotes the configuration when the hydroxyl group is below the plane of the ring, and "- (minus)" denotes the configuration when the hydroxyl group is above the plane of the ring.

Plant polysaccharide are the reserved carbohydrates of plants. Example of plant polysaccharides are starch and cellulose which are composed of thousands glucose units. Starch is a main component of our carbohydrate intake. It is found in potato, wheat, burley etc. cellulose is found in the cell wall of plant. It is used in making cotton, cellulose fiber and paper etc.

Self Assessment

What is glycosidic linkage? Draw the structure of maltose and show glycosidic linkage in it.

10.1.2 Importance of Carbohydrates

Carbohydrates are nutritionally significant bio molecules and are essential part of our balanced diet.

Carbohydrates such as starch, sucrose, maltose etc convert into glucose in our digestive system which is then absorbed into the bloodstream and transported to the various cells where it is utilized for the energy production for maintaining the biological processes.

DO YOU KNOW?

Complex carbohydrates are important as they provide a slow and steady release of energy, aiding in maintaining stable blood sugar levels. For example, starch found in foods, supporting prolonged physical and mental activities without sudden spikes in blood glucose levels.

$$C_6H_{12}O_6\ \textbf{(glucose)} + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Glucose plays a vital role in energy storage within the body. The extra glucose of the bloodstream is converted into glycogen which serves as a primary form of energy storage in animals including humans. Glycogen is stored in muscles and liver. Another way glucose can be stored by converting it into triglycerides which are then stored as body fat.

Glucose serves as fuel for the brain. The adequate intake of carbohydrate ensures normal brain function. Certain carbohydrates like dietary fibers are not digested by human enzymes and pass through the digestive system. However, they regulate bowel movements and promote the digestive health. Certain non-digestible carbohydrates (fibers) help promoting growth and activity of good bacteria in digestive gut.

Role of Common Carbohydrates in Health and Disease

Glucose: It is a vital component of our blood. Typically, the normal range of glucose in blood ranges between 70 to 110mg per 100 dl. However, if glucose

level exceeds this range, it can lead to the Diabetes which can be managed through insulin control.

Fructose: Fructose is a simple sugar that found in many fruits and honey. It is the sweetest among all other carbohydrates. Its main function is to provide energy during metabolism in the body. However, a high intake of fructose has been associated with weight gain and obesity.

Lactose: It is a disaccharide. It is found in milk and hence also known as milk sugar. During intake, it is broken down into glucose and galactose in the alimentary canal by the enzymatic activity. Lactose is difficult to digest by adult human because they lack the enzyme needed to break down lactose into glucose and galactose. Lactose provides energy. In infants, it is very important for the growth and development. In some adult humans where lactase enzyme is not produced by the body, its intake causes indigestion which is symptomized by bloating gas, abdominal pain and diarrhea.

DO YOU KNOW?

Lactose is present from 5 to 8 percent in human milk, 4 to 6 percent in cow milk and 3 to 4 percent in goat milk that is why goat milk is relatively easily digestible in adult human.

Sucrose: It is also a disaccharide and made up of a glucose and a fructose sugar. It is known as table sugar or cane sugar. An excess amount of sucrose in our diet can cause the development of gum disease such as fatness, plaque formation in the teeth, and even tooth decay.

Self Assessment

What do plant and animal starch means? What is the role of animal starch for energy storage in the body.

10.2 PROTEINS

Proteins are naturally occurring macromolecules made up of long chain of amino acids that fold into precise three dimensional configurations (Fig.10.3). All living organisms including plants, animals and bacteria contain proteins and their presence is vital for the life.

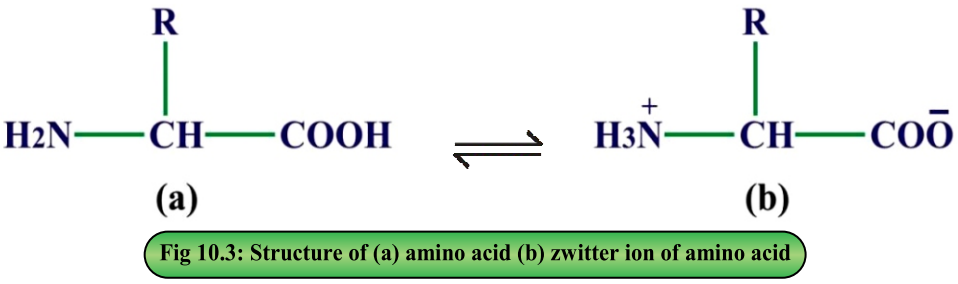


Fig 10.3: Structure of (a) amino acid (b) zwitter ion of amino acid

There are twenty two (22) different types of alpha amino acids that can be used to build proteins. Each amino acid consists of an amino group as well as a carboxyl group. These amino acids are associated with each other through poly peptide linkage (CONH). The specific arrangement and sequence of these amino acids determine the structure and function of the protein (Fig.10.4).

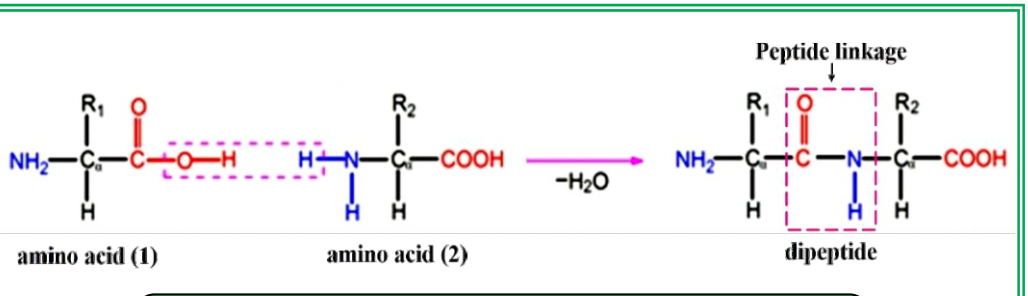


Fig 10.4: Formation of dipeptide by the condensation of two amino acids

10.2.1 Classification of proteins

Proteins may be classified into several groups based on their functions and structures. Based on functions, proteins are classified into following types.

(i) Catalytic proteins (Enzymes):

Enzymes are biological catalysts. They increase the rate of the biological reaction multiple fold as compared to a chemical catalyst. Our bodies contain numerous catalytic proteins which facilitate the chemical reactions inside the body. For example, lipase catalysis the decomposition of lipids into fatty acids in our alimentary canal.

$$\text{Starch} + H_2O \xrightarrow{\text{Amalyase}} \text{Glucose}$$

$$\text{Protein} + H_2O \xrightarrow{\text{Protease}} \text{Amino acid}$$

$$\text{Lipid} + H_2O \xrightarrow{\text{Lipase}} \text{Fatty acid}$$

(ii) Storage proteins:

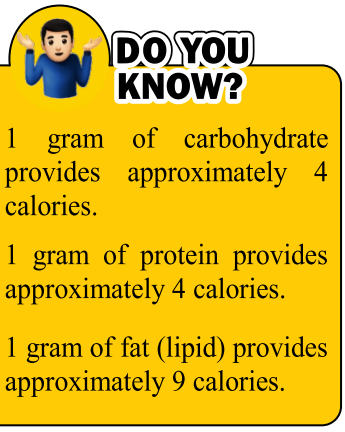
These proteins store nutrients or metal ions in a particular part of plants or animals. For example, Albumin, Globulin and Casein etc.

(iii) Transport proteins:

These proteins facilitate the movement of molecules, ions and other substances across cellular membranes and in the blood stream. For example, haemoglobin.

(iv) Regulatory or hormonal proteins:

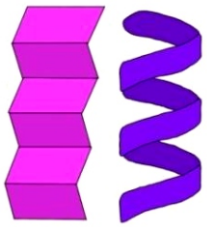
These proteins play a critical role in regulating the function of body by transmitting signals between the cells.



10.2.2 Classification of proteins on the basis of their structure

Proteins are essential macromolecules classified into four main types based on their structure.

Table 10.2 **Classification of proteins**

Classification	Description	Structure
Primary	➢ It is a linear sequence of amino acids in the protein chain. ➢ This sequence plays a crucial role in determining the overall shape and function of the protein.	
Secondary	➢ It refers to the folding patterns in polypeptide chains due to interactions between nearby amino acids. ➢ The two secondary common structures are alpha helix and beta sheets. ➢ The Stabilization of secondary structure is due formation of hydrogen bonds between N-H and C=O groups of amino acids	
Tertiary	➢ It refers to three-dimensional arrangement of a protein molecule having folded and refolded polypeptide chain. ➢ The stability of molecule is due to the presence of following types of forces among polypeptide chain; • Salt bridge (ionic bond) • Disulfide bridge (covalent bond) • Van der Waals forces • Hydrogen bond ➢ Example: Myoglobin exhibits a tertiary structure.	
Quaternary	➢ It is a large complex protein molecule and formed by the interaction of multiple protein subunits. Example: Hemoglobin, which consists of four subunits and illustrates the quaternary structure.	

10.2.3 Properties of proteins

(i) Proteins are water soluble due to the di polar terminal of amino acids in the polypeptide chain.
(ii) Proteins are amphoteric in nature because of the presence of–COOH as well as $–NH_2$ group in their structure of amino acid sequences.
(iii) Proteins exhibit flexibility due to the ability of amino acid chain rotation.
(iv) Certain proteins exist in various colours i.e. haemoglobin.
(v) Proteins are thermally stable, however the structure of proteins are disrupted by heating, at elevated temperature or by a sharp change in the pH.

10.2.4 Importance of proteins

(i) Proteins provide energy for the body and in a rough estimation, 1g of protein provides four calories.
(ii) Haemoglobin is a protein, it transports oxygen from the lungs to every tissue of the body.
(iii) Harmones are proteins which regulate various physiological functions in the body.
(iv) Antibodies are proteins which play a very important role in the immune system of the body.

Self Assessment

Haemoglobin, harmones and antibodies are categorized as proteins. What is the biological role of these proteins in human body.

10.3 LIPIDS

"Lipids are naturally occurring heterogeneous organic compounds that are insoluble in water but soluble in Bloor's reagent". The term "lipid" originates from the Greek word "Lipos" meaning "fat like" due to their greasy or oily texture when touched.

DO YOU KNOW?

Bloor's reagent (a mixture of diethyl ether and ethyl alcohol in the ratio of 2:1).

Lipids are vital components of our diet and can be obtained from various sources such as animal fat (e.g. butter, ghee) vegetable oil etc.

10.3.1 Classification of lipids

On the basis of chemical composition lipids are classified into three main groups, named as simple lipids, compound lipids and steroids.

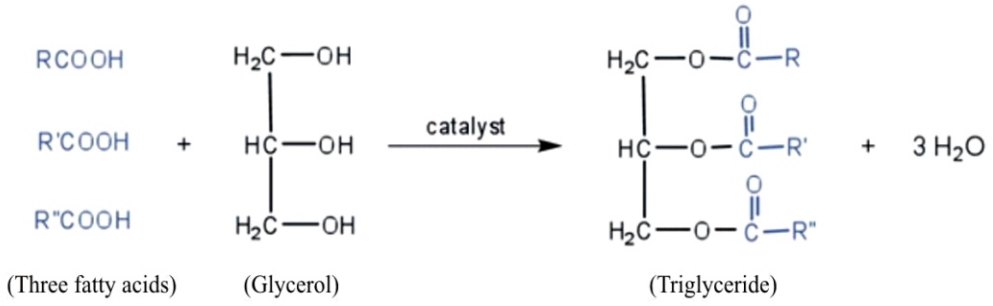
Most of the lipids hydrolysed with alkalis to form soap, these are known as saponifiable lipids. Lipids of steroid family cannot form soap with an alkali and are called nonsaponifiable lipids.

Simple Lipids

These lipids are chemically esters, made up of fatty acids and alcohols, mainly serve as energy source to the body.
Simple lipids are further classified into fat, oil and waxes.

Fats and Oils

"These lipids are abundantly found in nature and chemically known as triglycerides or triesters". They are formed by the condensation of three fatty acid and a glycerol molecule.



The fatty acid chains in the molecules of fat and oil consists of C_{12} to C_{24} carbon atoms which may be saturated or unsaturated. Vegetable oil contains unsaturated fatty acids and are liquid at room temperature. Animals fats are composed of saturated fatty acids and usually solids at room temperature.

Table 10.3 Types of fatty acids

Type of Fatty Acid	Description	Examples
Saturated Fatty Acid	Contains only single bonds between carbon atoms	Stearic Acid, Palmitic Acid
Unsaturated Fatty Acid	Contains at least one double bond between carbon atoms	Oleic Acid, Linoleic Acid.

Self Assessment

Fat and oil are both triacylglycerol how you can differentiate between them?

Waxes

"Waxes are the naturally occurring esters of long-chain fatty acids and long chain alcohols". Waxes are solids with water repellent nature. In plants they form coating on the surface of leaves, fruits and other parts helping to prevent water loss and protect against environment. Honey bees produce wax to build honey combs for the protection of hives.

$$C_{15}H_{31} - COO - C_{16}H_{33}$$

(Bees wax)

Compound lipids

"These are esters of glycerol with two fatty acids and some other compounds such as carbohydrates, amino acids, phosphoric acid etc".

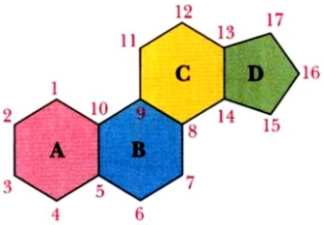
These are classified into phospho lipids, glyco lipids and lipo proteins on the basis of introduction of additional groups like phosphoric acid, glycogen and protein etc. Example: LDL (low-density lipoprotein).

DO YOU KNOW?

Cholic acid is a derivative of cholesterol. It is found in bile juice as sodium salt. It serves as enzyme that participates in the digestion of fat.

Steroids

These are derived lipids that are composed of specific structure of four interconnected carbon rings (Cyclopentenophenanthrene nucleus). Examples of steroids are cholesterol and cholic acid.



10.3.2 Structure of lipids

The structure of lipids varies depending on their classification. However the basic structure consists of a hydrophilic head and a hydrophobic carbon tail.

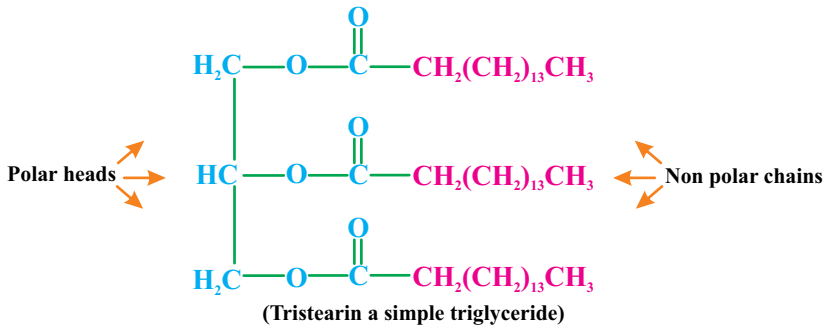


Fig. 10.5: Structure of a simple lipid showing its polar heads and non polar carbon chains

10.3.3 Properties of lipids

Physical Properties

- Lipids exist in different physical states depending upon their chemical nature and temperature. For example, fat exists in solid state, wax is semisolid state and oil in liquid state at room temperature.
- Lipids are translucent or opaque in nature.
- Lipids are insoluble in water and soluble in the organic solvents; like Bloor's reagent.
- Lipids have low density which enables them to float on water.
- Melting point of saturated lipids is higher than unsaturated lipids.
- Lipids are poor conductors of heat and electricity therefore serve as insulators for the animal body.

Chemical Properties

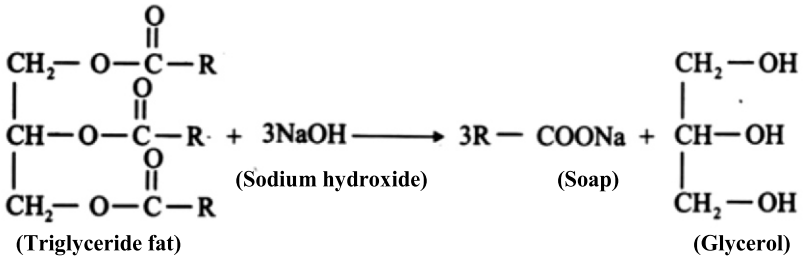
Addition reactions

Oils undergo addition reactions with hydrogen in the presence of nickel (catalyst) to produce fats. In this chemical reaction, unsaturated fatty acids of oil convert into saturated fatty acids.

$$R\text{-}CH{=}CH\text{-}COOH + H_2 \text{ ----------} R\text{-}CH_2\text{-}CH_2\text{-}COOH$$

Saponification

Fat and oil are hydrolysed when heated with an alkali to produce soap and glycerol, this process is known as saponification.



Rancidity

When animal fats are exposed to moist air, they undergo oxidation and hydrolysis reactions simultaneously leading to the development of an unpleasant taste and odour. This process is commonly referred to as rancidity.

10.3.4 Importance of lipids

Lipids play important role in human body.

(i) They store chemical energy in the form of triglycerides in adipose tissues. They store more than twice energy as compared to carbohydrates and proteins. This stored energy is used during fasting.

(ii) They are fundamental building blocks of cell membranes. Due to their water insolubility, they protect the cell by forming a phospholipid layer which allows the movement of substances in and out of the cell.

(iii) Lipids in adipose tissues help maintaining the body temperature and serve as insulation of the body.

(iv) They help in the absorption and utilization of fat soluble vitamins such as vitamin A, D, E and K.

10.4 MINERALS OF BIOLOGICAL SIGNIFICANCE

"Minerals are inorganic substances that are required to maintain physical health and prevent us from certain diseases". Although more than twenty five minerals are present in our body but sixteen minerals are recognized as essential for the body health. Some minerals are required in the larger quantity and known as macro minerals while others are needed in small quantity and referred as micro minerals.

Minerals and water are smaller sized inorganic substances that are directly absorbed into the blood without being digested through enzymatic process in the alimentary canal.

10.4.1 Sources of important minerals

Minerals are generally found in fruits, vegetables, whole grains, dairy products, meats, sea food and water etc.

Sources of some minerals are listed in the Table 10.4.

Table 10.4 Sources of some essential minerals

Minerals	Sources
Calcium	Milk, Cheese, Yogurt, Leafy greens
Iron	Red meat, Poultry, Sea Food, Bean, Lentils
Zinc	Beef, Chicken, Sea Food, Beans
Phosphorous	Meat, fish, dairy products, nuts, seeds, and whole grains.

10.4.2 Biological Significance of Iron, Calcium, Phosphorous and Zinc

Minerals perform a diverse range of functions in the body such as maintenance of pH, acid-base balance, hormonal control. However; each mineral has its specific role in the body.

Iron:

Iron is crucial for the body because it involves in the oxygen transport, immune function, temperature regulation and the production of red cells.

Calcium:

Calcium is used to build strong bones and teeth. It helps muscles contract and relax. It also helps in blood clotting and immune system. Its deficiency causes bone weakness and poor body growth.

Phosphorous:

Phosphorous is important for healthy bones and teeth. Being a part of DNA and RNA, it is important for protein synthesis and transferring genetic information. It is also important for muscular system and to maintain heartbeat.

Zinc:

Zinc is important for normal growth, wound healing and the working of nervous system. It improves our immune system and enhances insulin activity. It also activates our sense of smell and taste. Deficiency of zinc causes loss of weight, appetite and taste.

SOCIETY, TECHNOLOGY AND SCIENCE

Insulin and Diabetes

Diabetes is a complex metabolic disorder marked by elevated blood sugar levels. It is triggered by either insufficient production of insulin or the body's inability to effectively use it. Insulin is a protein hormone secreted by pancreas and plays a significant role in controlling blood sugar levels. The glucose level in the blood fluctuates throughout the day, increasing after meals and then gradually returning to normal within approximately two hours. The typical range of normal blood glucose level for adults in a fasting state is 70 to 110 mg/dl.

SUMMARY

- The study of chemical reactions in living things is known as biochemistry.
- Carbohydrate is essential group of foods in human and animal diet.
- Carbohydrates are defined as polyhydroxy aldehydes and ketones or the compounds which give polyhydroxy aldehyde or ketone on hydrolysis.
- Carbohydrates are classified as monosaccharides, disaccharides, oligosaccharides and polysaccharides.
- The basic function of carbohydrates is to supply energy to all cells in the body.
- Body stores excess amount of glucose in the liver and muscles in the form of glycogen.
- Proteins are macro-molecules consist of amino acids linked together through peptide bonds.
- There are four levels of the structures of protein; primary, secondary, tertiary and quaternary.
- Tertiary structure of protein is stabilized by disulfide bridges, Van der Waals' forces, hydrogen bonds and ionic bonds.
- Physical, chemical and biological properties of proteins are temperature and pH dependent.

- Lipids are water insoluble heterogeneous organic compounds, which are chemically ester of fatty acid and alcohols.
- Meat, nuts, cereals, fish, milk and dairy foods, fruits and vegetables, are sources of minerals.
- Saponification is a chemical reaction of fat and oil with an alkali.
- Rancidity involves two simultaneous reactions named as oxidation and hydrolysis which makes the animal fat bad taste and bad odour.

Multiple Choice Questions

(i) Starch and Sucrose are examples of:
(a) Monosaccharides and Disaccharides
(b) Disaccharides and Oligosaccharides
(c) Polysaccharides and Disaccharides
(d) Monosaccharides and Polysaccharides

(ii) Amino acid units bonded in protein molecule through:
(a) Glycosidic linkage (b) Ether linkage
(c) Peptide linkage (d) Hydrogen bridge

(iii) Proteins are composed of:
(a) Amino acids (b) Carbohydrates
(c) Lipids (d) Nucleic acids

(iv) A condensation polymer of amino acid is:
(a) Protein (b) Lipids
(c) Starch (d) Glycogen

(v) Saponification is the formation of soap by the reaction of fat and oil with:
(a) An alkali (b) An acid
(c) Sugar (d) Glycerol

(vi) Which of the following mineral is considered to be essential for immune system:

(a) Iron (b) Zinc
(c) Magnesium (d) Calcium

(vii) Rancidity is a chemical process involving:

(a) Oxidation and hydrolysis (b) Condensation and reduction
(c) Polymerization (d) Decarboxylation

(viii) Lipid which is a major component of cell membrane is:

(a)Triglyceride (b) Phospholipid
(c) Glycolipid (d) Steroid

(ix) Total numbers of alpha amino acids are:

(a) 19 (b) 22
(c) 25 (d) 28

(x) Sugar molecules are classified as:

(a) Fats (b) Proteins
(c) Carbohydrates (d) Lipids

Short Questions

1. Mention the three main functions of lipids.
2. Comparing with other nutrients, why lipids are better source of energy?
3. Carbohydrates are necessary component of our diet. Give two dietary importance of carbohydrates.
4. What is meant by saponification? Give the reaction.
5. What is rancidity which chemical reaction involves in this process?
6. Write three essential functions of protein in the body.
7. Write down the sources from which we intake fructose and lactose.

Descriptive Questions

1. What are Carbohydrates? Give their classification on the basis of structure.
2. Explain the role of glucose, fructose, sucrose and lactose in the health of human being.
3. What are Proteins? Classify various types of proteins on the basis of their function.
4. What are Lipids? Give their classification, properties and biological significance.
5. How can you explain primary, secondary and tertiary structure of proteins?
6. Describe physical properties of proteins.
7. Why minerals are essential for our health? Give the biological significance of Calcium, Iron, Zinc, and phosphorus.