

CHAPTER 9**BIOCHEMISTRY****Carbohydrates**

Carbohydrates are important naturally occurring organic compounds. Carbohydrates are hydrated carbons. The term carbohydrate is used for a group of materials found in nature as part of both plants and animals. They provide structural frame work for plants and serves as source of energy for both plants and animals. These are polyfunctional organic compounds. Carbohydrates are organic compounds that are poly hydroxyl aldehyde or ketones or substances which give these substances on acid hydrolysis are called carbohydrates. These include sugars such as glucose, fructose and sucrose as well as non-sugars such as starch and cellulose. Sugars are crystalline substances with a sweet taste and are soluble in water while non-sugars (starch and cellulose) are non-crystalline substances which are not sweet and are insoluble or less soluble in water.

Composition: They are composed of C, H and O. Some carbohydrates also contain sulphur and nitrogen. The ratio of hydrogen to oxygen is 2:1 as in water.

General formula: The general formula of carbohydrates is $C_x(H_2O)_y$. The x and y may be the same or different. The glucose $C_6H_{12}O_6$ can be written as $C_6(H_2O)_6$. There are many organic compounds with the $C_x(H_2O)_y$ formula but these are not carbohydrates and there are some organic compounds which do not follow the $C_x(H_2O)_y$ formula but these are carbohydrates. Rhaminose is a carbohydrate, having the formula $C_6H_{12}O_5$ while acetic acid having formula $C_2H_4O_2$ is not a carbohydrate.

Functional groups in carbohydrates: Alcoholic, aldehydic and ketonic groups are present in carbohydrates.

Examples: Sugar, wood, cotton, starch, milk and honey are the examples of carbohydrates.

Occurrence: Carbohydrates are the major constituents of most plants comprising upto 80% of their dry mass while animal tissues contains comparatively small amount of carbohydrate less than 1%. Plants use the carbohydrates both as energy sources and supporting materials while animals use it for energy production.

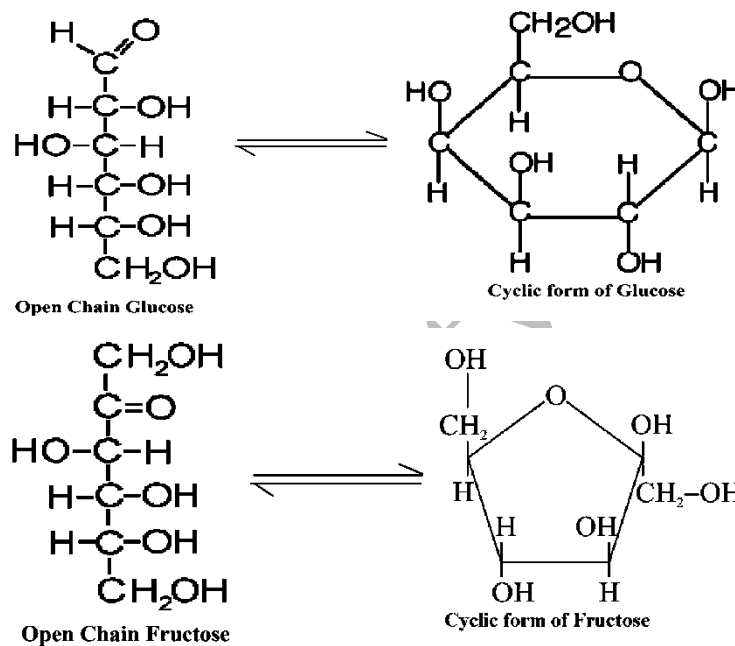
Classification of carbohydrates: Carbohydrates are classified into following types.

- (1) Monosaccharides
- (2) Oligosaccharides
- (3) Poly saccharides

1. Monosaccharides: These are also called simple sugars. These contain only one glucose unit per molecule. These cannot be further simplified on hydrolysis. Examples are glucose and fructose. These have an empirical formula of $(\text{CH}_2\text{O})_n$ where $n = 6$.

Types of monosaccharides on the basis of type of functional group: These may be classified as aldoses and ketoses.

Types of monosaccharides on the basis of number of carbon atoms: These may be classified as trioses, tetroses, pentoses and hexoses.



Depending upon whether they contain an *aldehyde* or *ketone* groups, they may be called aldoses or ketoses. For example, a five carbon monosaccharide having aldehyde group is called aldopentose and a six-carbon monosaccharide containing a keto group is called keto-hexose. A few examples of monosaccharides are given below:

Aldotetroses: Erythrose and Threose; $\text{CH}_2\text{CH}(\text{CHOH})_2\text{CHO}$.

Ketotetroses: Erythrulose, $\text{CH}_2\text{OHCOCHOHCH}_2\text{OH}$.

Aldopentoses: Ribose, Arabinose, Xylose and Lyxose. $\text{CH}_2\text{OH}(\text{CHOH})_3\text{CHO}$

Ketopentoses: Ribulose and xylulose; $\text{CH}_2\text{OHCO}(\text{CHOH})_2\text{CH}_2\text{OH}$

Aldohexoses: Glucose, Mannose, Galactose etc; $\text{CH}_2\text{CH}(\text{CHOH})_4\text{CHO}$

Ketohexoses: Fructose, Sorbose etc. $\text{CH}_2\text{OHCO}(\text{CHOH})_3\text{CH}_2\text{OH}$

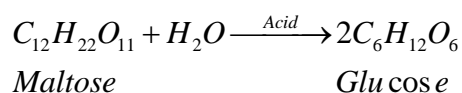
2. Oligosaccharides: These carbohydrates contain 2-10 monosaccharides units per molecule. These are hydrolysable and broken down into 2-10 monosaccharides upon acid hydrolysis. Upon hydrolysis these may yield similar or different types of

monosaccharides.

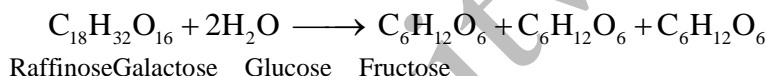
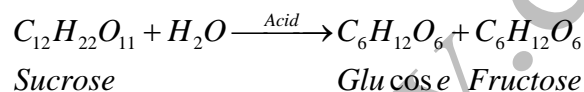
Types of Oligosaccharides: On the basis of monosaccharide units they contain the oligosaccharides may be of the following types.

- i. **Disaccharides:** Consist of two monosaccharide units.
- ii. **Trisaccharides:** Consist of three monosaccharides units.
- iii. **Tetrasaccharides:** Consist of four monosaccharide units.

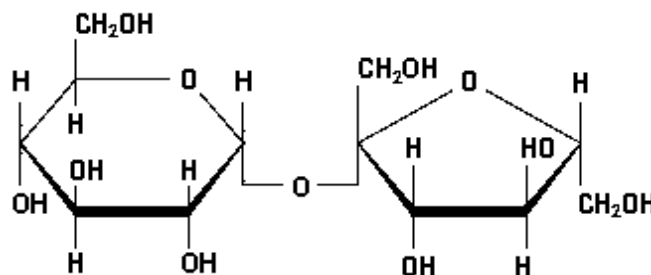
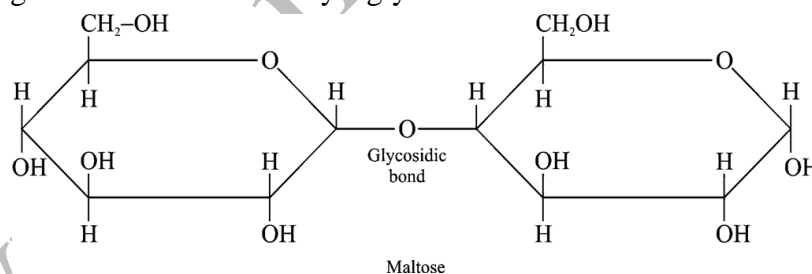
Maltose yields the same kind of monosaccharides (glucose and fructose) upon hydrolysis.



Sucrose yields two different types of monosaccharides (glucose, fructose) upon hydrolysis.

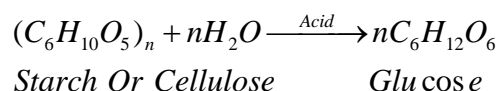


Glycoside linkage or bond: During the formation of a disaccharide, the two monosaccharides units combine together by an oxygen atom with the elimination of one water molecule. This type of linkage is called glycoside linkage or glycoside bond. Two glucose units combine by a glycoside bond and form maltose.



3. **Polysaccharides:** These are complex carbohydrates. These contain more than 10

units of monosaccharides per molecule. These are hydrolysable and yield a large number of similar or different kinds of monosaccharides. Examples of polysaccharides are starch, cellulose and glycogen.



Occurrence of Glucose

Glucose is the most important and abundant sugar and occurs in honey, sweet fruits (ripe grapes and mangoes), blood and urine of animals. It is a normal constituent of blood (0.1%, also known as blood sugar) and is present in the urine (8–10%) of a diabetic person. In the combined form, it is a constituent of many disaccharides such as sucrose and polysaccharides such as starch, cellulose etc.

Physical Properties

1. It is a colourless sweet crystalline compound having m.p. 419 K.
2. It is readily soluble in water, sparingly soluble in alcohol and insoluble in ether.
3. It forms a monohydrate having m.p. 391 K.
4. It is optically active and its solution is dextrorotatory (hence the name *dextrose*). The specific rotation of fresh solution is + 112°C.
5. It is about three-fourth as sweet as cane-sugar *i.e.* sucrose.

Functions of Carbohydrates

Carbohydrates are very useful for human beings. They provide us all the three basic necessities of life *i.e.*, *food* (starch containing grain), *clothes* (cellulose in the form of cotton, linen and rayon) and *shelter* (cellulose in the form of wood used for making our houses and furniture etc.). Not only this, our present civilization depends on cellulose to a surprising degree, particularly in the form of paper. Carbohydrates are also important to the economy of many nations. For example, sugar is one of the most important commercial commodities. Many things of daily use, such as paper, photographic films, plastics etc. are derived from carbohydrates. Carbohydrates are the major sources of energy for the activities of organisms. These are also called 'fuel of life' and produce energy by oxidation.

1. Glucose is used as an immediate source of energy for sportsmen and sick persons.
2. Glucose is used in the manufacturing of jams and sweets.
3. Fructose is used as sweetening agent in confectionary and also in medicinal syrups.
4. Fructose is used to prevent sandiness in ice-creams.

5. Fructose is used as table sugar substitute for the obese and diabetic patients.
6. Sucrose is used as a food and in the preparation of sucrose octaacetate, which is used for the denaturation of alcohols and making anhydrous adhesives.
7. Starch is principally used as food. It is also used for the preparation of ethanol by fermentation.
8. Starch is used as stiffening agent in textile industry and in laundry.
9. Starch is used as an adhesive to fasten paper.
10. Cellulose is used for the preparation of paper. It is also used as roughage in our diet for promoting the peristaltic motion of digestive tract.
11. Oligosaccharides are involved in the formation of secreted proteins like antibodies and blood clotting factors.
12. The receptors on the cell membranes are the complexes of carbohydrates with certain proteins. These receptors are involved in the molecular targeting or molecular recognition.
13. Protein glycol heparin sulphates are the derivatives of carbohydrates which are involved in the attachment of neurons to one another during the development of nervous system.

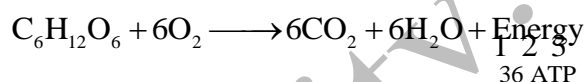
Role of Various Carbohydrates in Health and Diseases

1. **Sucrose:** Sucrose is a disaccharide. It has been used as a sweetening agent and as a source of production of energy for living organism. The use of sucrose is primary cause of tooth decay and obesity. The material known as “plaque” which sticks to our teeth is caused by sucrose.
2. **Lactose:** It is the disaccharide of glucose and galactose. It is also called milk sugar. Human milk it contain 6.8% while cow milk contain 4.8% of lactose. Lactose is digested by an enzyme known as lactase. This enzyme lactase is selected by the intestinal mucosal cell of young mammals. Milk is a complete diet but still many human adults are unable to digest milk because of the lack of lactase intolerance. The normal effects of this disease are abdominal bloating, cramps, flatulence and colic pains and water diarrhea. To avoid this disease fermented milk products such as yogurt and cheese must be consumed.
3. **Glucose:** It is the most common and popular monosaccharide that can be found in sweet fruits such as grapes contain 20–30% glucose. It is mainly used for the production of energy by living bodies. Human blood contains 65–110mg of glucose per 100ml. The surplus glucose is converted to a polymer called glycogen in the human bodies. This extra glycogen is stored in the liver and muscles and when body has deficiency of glucose this store glycogen is hydrolyzed and converted to glucose according to the body

requirements. Human pancreas secretes a hormone known as “insulin” which helps in metabolism of glucose. While in some cases the pancreas fail to secrete insulin which causes the defect of metabolism of glucose which results in the increasing sugar level in blood and this disease is called diabetes mellitus. If diabetes is unchecked from a patient blood then it may results in hardening blood vessels dysfunction of kidneys diabetic coma which caused sudden death.

Nutritional Importance

Carbohydrates are actually known as fuel of life. Living organisms both plants and animals have the ability to store the carbohydrates in the form of starch and glycogen respectively. Both the starch and glycogen upon oxidation gives Glucose a monosaccharide which is oxidized by body cells by different pathways to release energy. This energy is stored in the form of molecules known as ATP (Adenosine triphosphate) in different body parts. One mole of Glucose on complete oxidation by citric acid cycle produces 36 ATPs.



Proteins

The word protein has been derived from the Greek word “proteios” which means “first”, “prime” or “chief” as proteins are extremely important as food source, control variety of physiological functions and an object of genetically controlled synthesis. Proteins are complex nitrogenous organic compounds which are associated with life itself. Proteins are the high molecular weight organic materials, which upon complete hydrolysis yield Amino acids. Proteins are found in all animals and vegetable cells. These constitute major part of the living protoplasm of cells. Molecular mass of proteins ranges from 10,000 to 50 million. The human body contains at least 10,000 different kinds of proteins, which are present in muscles, skin, hair, nail and other tissues that make up the bulk of the body’s non-bony structure.

Proteins are the most abundant intra-cellular macromolecules and form more than 50% of the dry weight of most organisms. Proteins are present in all animals, plants, bacteria and viruses. They act as catalyst in the form of enzymes, as barriers such as skin and bacterial cell walls, as protective agent in immune system, as storage depots such as ferritin for iron storage in blood, as transporting agent such as hemoglobin oxygen carrier. As receptors of chemically transmitted information as well as the carrier of these information in the form of pheromones. These are also involved in the contraction and relaxation of muscles and in the transmission of heredity characters from parents to offsprings in the form of genes.

Composition: Proteins are composed of carbon, hydrogen, oxygen and nitrogen. Nitrogen is about 16% of the molecular weight of protein. Some proteins also contain smaller quantities of sulphur and phosphorous.

The building blocks of proteins: Proteins are made up of smaller basic units called amino acids. There are about 20 different amino acids which combine in different sequences and different numbers and produce an infinite number of different types of proteins. It is just similar to the case as only 26 letters of the alphabets form infinite number of words.

The bacterium, Escherichia Coli (E.coli) has been estimated to contain about 3000 different types of proteins and human body is made up of 10000 of different kinds of proteins, but none of the protein of E.coli is identical with any of the human proteins.

Classification on the Basis of Hydrolysis Products

Proteins have been classified into the following three major types.

- 1. Simple proteins:** These are proteins which upon hydrolysis yield only amino acids or their derivatives. Examples are Albumins, Globulins, Legumin, Collagen, Globins, Histones etc. Globulins are present in animals and plants. Legumins and collagen proteins are present in connective tissues throughout the body. Albumin is found in eggs.
- 2. Compound or Conjugated proteins:** These proteins upon hydrolysis give an amino acid and a non-protein group. Proteins which are a combination of two parts, a proteinous part and non-proteinous part, are called conjugate proteins. The non-proteinous part is called *prosthetic group*. Prosthetic group plays its part in biological function of the protein. Conjugated proteins are further classified as nucleoproteins, glycoproteins and chromoproteins. The prosthetic groups in such proteins are nucleic acid, carbohydrate and haemoglobin (or chlorophyll) respectively.

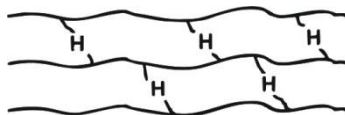
S.No.	Conjugated Protein	Prosthetic Group
1.	Nucleoproteins	DNA or RNA
2.	Phosphoproteins	Phosphoric acid
3.	Lipoproteins	Lipids
4.	Glycoproteins	Carbohydrates
5.	Chromoproteins	Coloured Compounds
6.	Metalloproteins	Zn, Cu, Fe, Mn etc.

- 3. Derived proteins:** These are proteins which are produced by the partial digestion of simple or conjugated proteins. These may be peptones, meta proteins, polypeptides, oligoproteins and coagulated proteins.

Classification of Proteins on the Basis of Structure

Proteins are classified into two types on the basis of structure:

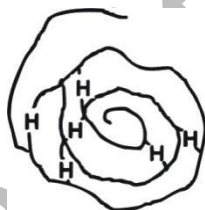
(a) **Fibrous proteins:** These proteins consist of thin linear molecules which lie side by side to form fibres. Intramolecular hydrogen bonding holds the peptide chain together. Fibrous proteins are insoluble in water.



Structure of fibrous proteins

Fibrous proteins are the main structural materials of tissues. Examples of important fibrous proteins are *keratin* in skin and hair, *collagen* in tendon, *fibroin* in silk and *myosin* in muscles.

(b) **Globular proteins:** In these proteins, polypeptides are folded into compact spheroidal shapes. Intramolecular hydrogen bonding holds the peptide chain in circular shape in such proteins. These are soluble in water or aqueous solutions of acids and bases.



Structure of globular proteins

These proteins have the role to regulate and maintain life processes. Examples of this class of proteins are enzymes, hormones, haemoglobin and albumin.

Classification on the Basis of Function

1. **Structural proteins:** These are fibrous proteins, present in the form of skin and bones.
2. **Hormones:** These communicate links with different parts of organisms. Insulin is a protein hormone.
3. **Enzymes:** The proteins of this group serve as catalysts for bio-chemical reactions. Pepsin and trypsin are examples.

Structure of Proteins

As proteins are complicated molecules so their structure is also very complicated. All the proteins appear in any of the following four different structures.

1. **Primary structure:** The primary structure of protein shows the sequence and number of different amino acid units along the peptide chain. It also shows whether the polypeptide chain is open, branched or cyclic.

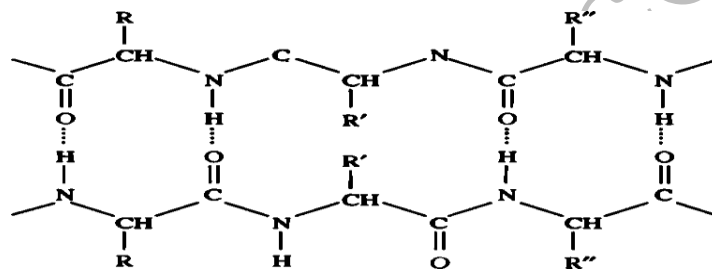
Primary structure determination of protein involves the following steps:

- (i) Determination of amino acid composition.
- (ii) Sequence of arrangement of amino acids.

2. Secondary structure: X-rays diffraction experiments (XRD) have shown that long running polypeptide chains tend to twist or coil upon themselves in a special pattern. Secondary structure shows this folding of the polypeptide chain to form a specific coiled structure held together by strong hydrogen bondings. Secondary structure may assume any of the following two different forms.

- a. Alpha-helix form
- b. Beta-pleated sheets

The β -structure: Peptide chains in silk fibroin are fully extended to form flat zig-zags. These chains of polypeptides lie side by side and are held to one another by hydrogen bonds as shown ahead:

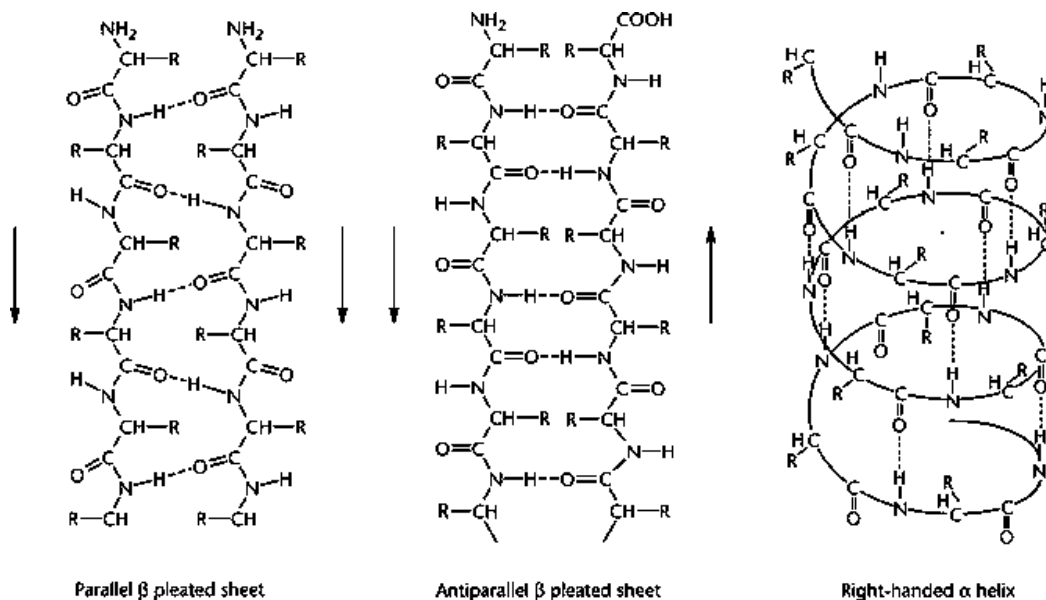


Flat sheet structure of a protein

Due to steric hindrance between R, R', R'' side chains, the flat sheet structure contracts and adopts pleated sheet structure (β -structure). The exact contraction depends upon the size of the side chains.

The α -helix: When the side chains in a polypeptide are bulky, the β -structure is not feasible. In such case, α -helix structure is adopted.

Pauling proposed α -helix structure for α -keratin, which is the constituent structural protein in hair, nails etc. In α -helix structure, each peptide chain is coiled to form helix as shown in the figure below. Each turn of the helix has about 3-7 amino acid residues and the distance between two helices is 5.4\AA . Two adjacent turns are linked by means of hydrogen bonds which involve NH— group of one amino group and the carbonyl oxygen of the fourth residue in the chain. Hydrogen bonding keeps the structure tight and prevents free rotation keeping the helix intact. The helix may be left or right-handed. But it is observed that the right-handed helix is more stable. Diameter of the helix is about 10\AA .



3. Tertiary structure: The long polypeptide chain of protein molecule undergoes folding and re-folding on itself and gives rise to a definite three dimensional structure called tertiary structure. This structure makes protein rounded and somewhat rigid molecule.

Three main types of bonds are responsible for the tertiary structure of a protein. These are:

- (i) Hydrogen bond
- (ii) Ionic bond
- (iii) Hydrophobic bond

(i) Hydrogen bond: Hydrogen bond may arise due to free $-\text{OH}$ groups or free $-\text{NH}_2$ groups in the peptide chain or due to peptide backbone.

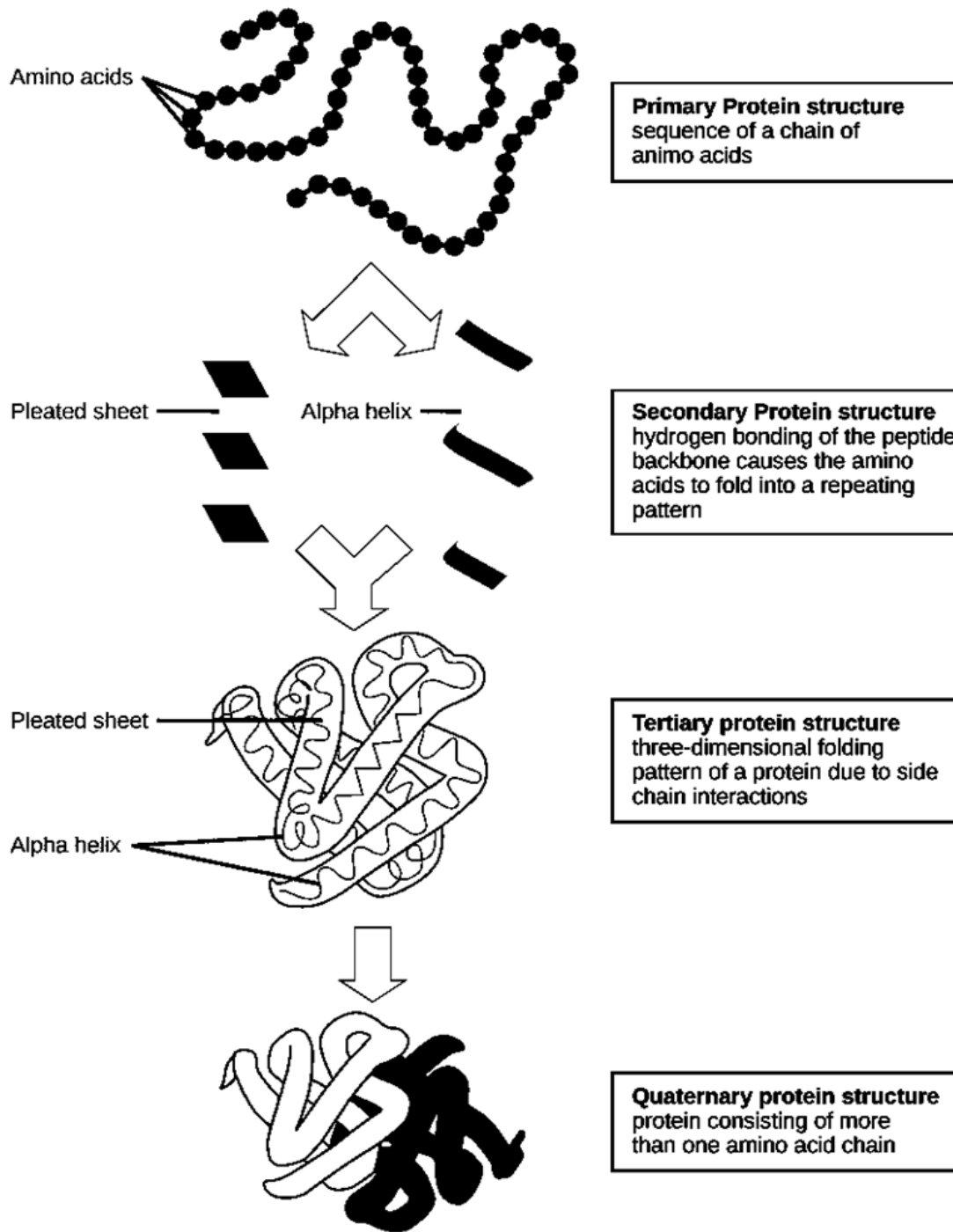
(ii) Ionic bond: Whenever there are positively or negatively charged groups present on the side chain *e.g.*, $-\text{COO}^-$ and $-\text{NH}_3^+$, these bonds are formed. These bonds have a tendency to be on the exterior of the molecule.

(iii) Hydrophobic bond: Such bonds are formed between the two methyl or two phenyl groups in the side chain. As they are hydrophobic groups, they prefer to remain in the interior where there is less water.

4. Quaternary structure: This structure shows the association of many individual protein sub-units, each with its own tertiary structure into a complex functional unit. Examples are myoglobin (oxygen storage) and hemoglobin (oxygen carrier).

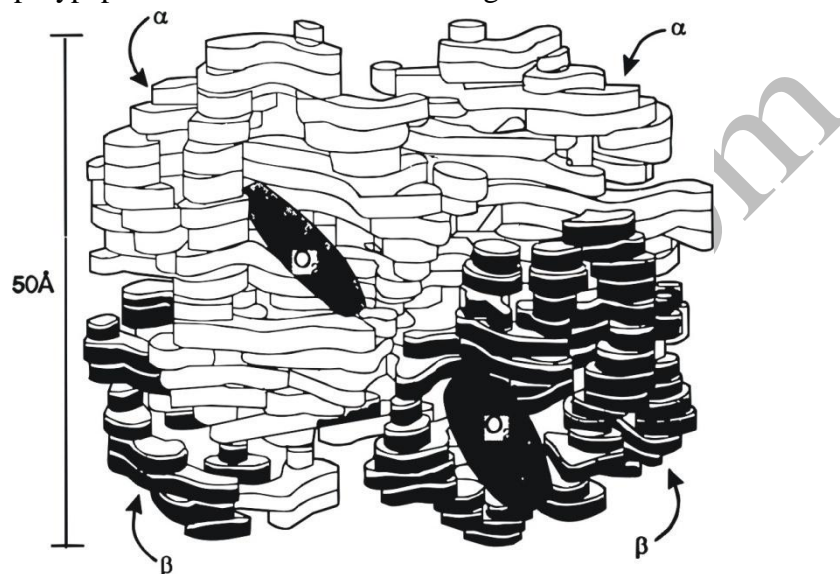
Fibrous and globular proteins contain one or more polypeptide chains. They are called monomeric and oligomeric respectively in the two types of proteins. The individual peptide chains of oligomeric proteins are called as *protomers*. Protomers,

whether same of different are held together by means of weak binding forces.



Structure of haemoglobin: The chromoprotein, haemoglobin, consists of four

protomeric chains, of which two are identical α -chains and the other two are identical β -chains. The approximate molecular mass of each chain is approximately 16000 and the molecular mass of whole molecule is about 64500. The four chains are held together by van der Waal (hydrophobic) forces giving the molecule a quaternary structure looking like a sphere. Structure of haemoglobin molecules showing interaction of 4 polypeptide chains is shown in the figure below.

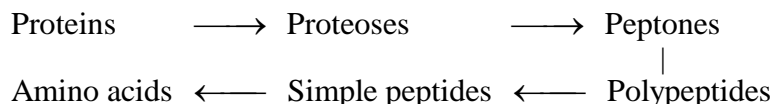


Structure of haemoglobin molecule showing interaction of 4 polypeptide chains

Properties of Proteins

1. **Composition:** The elements generally present in proteins are carbon, hydrogen, oxygen and nitrogen.
2. **High molecular weights:** As proteins molecules are obtained from hundreds and thousands of amino acid molecules, their molecular masses run into several thousands and sometimes into several lakhs.
3. **Physical state:** Generally speaking, proteins are colourless, tasteless, amorphous solids having no sharp melting points. They are colloidal size particles. This property is used to separate proteins from crystalline salts by the process of dialysis.
4. **Optical activity:** Because of the presence of asymmetric carbon atoms, proteins show optical activity. However, all naturally occurring proteins have the same configuration viz. the L-glyceraldehyde configuration.
5. **Amphoteric nature:** Protein molecules exist as dipolar ions. They contain both acidic ($-\text{COOH}$) and basic ($-\text{NH}_2$) groups, hence they react with both acids and alkalis and are thus amphoteric.
6. **Hydrolysis:** As amino acids are the constituents of proteins, the latter on hydrolysis in the presence of acids, bases or enzymes give back amino acids but in

steps. The steps involved during hydrolysis are represented as under:



7. Precipitation: They can be precipitated from their solution by salts of heavy metals, heat and alcohols etc.

8. Coagulation: When proteins are strongly heated or treated with certain reagents. They lose their structural organization and biological function, which is called coagulation.

Importance of Proteins

Proteins are vital to animal life. They perform a number of biological processes and play a pivotal role in the running and maintenance of body. They are hydrolyzed inside the body into its constituent amino acids before performing various functions. Some of the important functions of proteins are.

1. Many of the proteins act as living catalysts called enzymes. Enzymes increase the rate of biological reactions.
2. The nucleoproteins act as carrier of genetic information and serve as basis for inheritance of traits.
3. Hormones are proteins in nature and regulate the growth of living organisms and control physiological functions.
4. Hemoglobin acts as carrier of oxygen, ceruloplasmin acts as carrier of copper in the blood plasma.
5. Collagen, elastin and keratin contribute to the structure of tissues.
6. Proteins play vital role in the immune system of living organisms.
7. In the stomach, the proteins are hydrolyzed, in the presence of hydrochloric acid and enzyme pepsin, into lower molecular weight polypeptides.
8. In the intestine, proteins are hydrolyzed in the presence of enzymes trypsin and erepsin. The simple amino acids are then assimilated in the blood stream and transported to various cells of the body.
9. It is interesting to note that some of the amino acids are reconverted into some specific proteins which are needed by the body for specific requirements and other amino acids are oxidized to produce energy. Thus there is a continuous cycle of decomposition and synthesis of proteins in the body.

How to check that the given substance is a protein or not?

Following tests are performed to identify proteins:

1. Biuret test; A drop of copper sulphate is added to an alkaline solution of protein. A bluish colour develops. This test is also given by proteoses and peptones which are the hydrolytic products of proteins.

2. Ninhydrin test: Ninhydrin is triketohydrinene hydrate. A blue to red-violet color is obtained when a protein is treated with ninhydrin.

3. Xanthoproteic test: This test is given by proteins containing tyrosine or tryptophane. When warmed with conc. HNO_3 , such proteins give a yellow colour.

4. Millon's test: Millon's reagent is a mixture of mercurous and mercuric nitrates. Proteins containing tyrosine give a white precipitate turning red when treated with Millon's reagent.

5. Heller's test. This test is commonly employed for detecting albumin in urine. When conc. HNO_3 is poured along the side of a test tube containing protein solution, a white precipitate is obtained at the junction of the two layers.

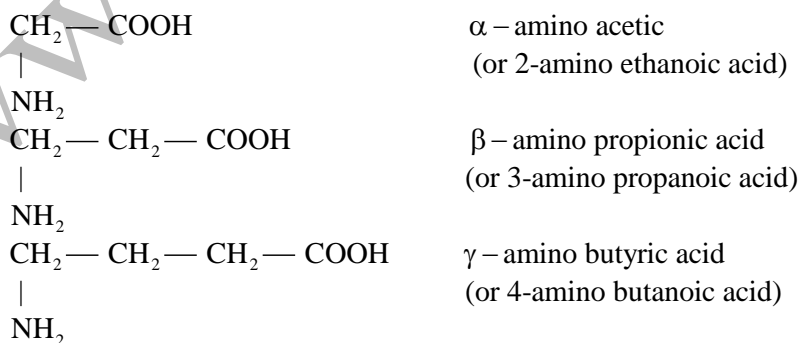
Denaturation: Proteins are very tender and delicate substances. When subjected to heat or action of acids or alkalis, they lose their biological activity. They are said to be denatured. This phenomenon in which the proteins lose their biological activity and other characteristics under the effect of temperature, is called denaturation.

Renaturation: The denatured proteins can be brought back to its original state by cooling the protein solution very slowly. This process is called renaturation.

During denaturation, there is a rearrangement in the secondary the tertiary structure of the protein but the primary structure remains unchanged. Coagulation of egg-white by the action of heat is an example of irreversible denaturation of proteins.

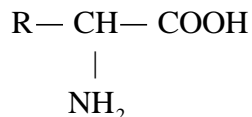
Amino Acids

Amino acids are compounds which contain at least one amino group and one carboxylic group. The amino group could be linked to carbon just next to carboxylic group or with a gap of one or two carbons. They are called α , β or γ acids respectively. Some examples of amino acids are:



Common system of nomenclature is still more popular in naming amino acids and proteins. It is mostly α -amino acids, which are involved in the building up of protein molecules. The simplest α -amino acid is α -amino acetic acid also called

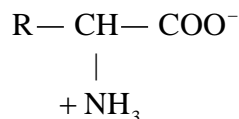
glycine. In general, an α -amino acid can be represented as



where R is an alkyl or aryl group. It could also represent highly branched or unsaturated carbon chain or heterocyclic ring.

Zwitterion

It has been found that an amino acid molecule appears as a dipole, one part of it carrying positive charge and the second negative charge. The dipolar ionic structure of amino acids can be represented as:



This is also called a *Zwitter ion* or *Internal salt*. There is no free amino or carboxylic group present in the molecule.

Types of Amino Acids

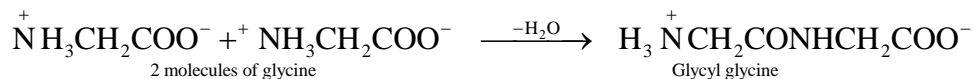
On the basis of nature of the amino acids, these are of three types.

1. **Neutral Amino Acids:** Amino acids having one amino and one carboxylic groups are called neutral amino acids. Examples are glycine and alanine.
2. **Basic Amino Acids:** Amino acids containing two amino (or imino) and one carboxylic groups are called basic amino acids. Examples: lysine and arginine.
3. **Acidic Amino Acids:** Amino acids having one amino (or imino) and two carboxylic groups are called acidic amino acids. Examples are aspartic acid and glutamic acid.

Isoelectric point: The pH at which a particular amino acid does not migrate under the influence of the electrical field is called *isoelectric point*. Every amino acid has a characteristic isoelectric point. Glycine has an isoelectric point at pH 6.1. It may be noted that amino acids have the minimum solubility at the isoelectric point. This is because at isoelectric point, there is maximum concentration of dipolar ions which are relatively less soluble.

Peptides

Peptides are amides obtained by interaction between the amino and carboxylic groups of two or more amino acid molecules. Two molecules of glycine, for example, combine to form amide substance known as glycyl glycine.



Peptide linkage: When two amino acids condense in such a way that a H from the amine group of one amino acid and a -OH group from the carboxylic group of another amino acid is removed in the form of water and two amino acids are bonded by amide group —CO—NH— it is called peptide linkages.

Classification of Peptides

Peptides are classified as under:

Dipeptide: A peptide obtained by the condensation of two amino acid molecules is called dipeptide.

Tripeptide: A peptide obtained by the condensation of three amino acid molecules is called tripeptide.

Tetrapeptide: A peptide obtained by the condensation of four amino acid molecules is called tetrapeptide.

Polypeptide: A peptide obtained by the condensation of more than four amino acid molecules is called polypeptide. A polypeptide may be represented as:



Peptides of molecular weight upto 10000 are known as polypeptides whereas peptides of higher molecular weight are the proteins.

Enzymes

Enzymes are complex organic substances which alter the rate of an already initiated biochemical reaction without itself being consumed permanently during the reaction. The word enzyme was originated from a Greek word “en” means “in” and “zyme” means “yeast” after studying the catalytic properties of yeast. Enzymes are obtained from both animals and plants but most enzymes are obtained from microorganisms mainly bacteria and fungi.

The catalysis of biological reactions is the most important task assigned to proteins. Hundreds of biological reactions are taking place every minute in different parts of the body for obtaining energy, synthesizing the protoplasmic and other structural materials, digestion, absorption and assimilation of food etc. These and so many other biological reactions are catalyzed by certain special proteins known as enzymes.

Each enzyme molecule possesses a region known as active site and the substrate binds itself with this active site. Enzymes are either pure protein or contain

proteins as essential component and in addition requires non protein component, which is also essential for life activities.

Apo-enzyme: The protein component of enzymes is called apo-enzyme.

Co-factors: These are atoms or group of atoms that join with enzymes altering their shape and making them functional. These are “on-off” switch for activating enzyme.

Prosthetic group: If the co-factor is a non-protein like a metallic ion (i.e. Zn, Cu, Fe etc.) then it is referred to as prosthetic group.

Co-enzyme: Some co-factors are small organic molecules these are called co-enzymes. Many of these co-enzymes are derived from vitamins and minerals that are essential for life. Examples of co-factors are nicotinamide adenine dinucleotide (NAD), flavin adenine dinucleotide (FAD), nicotinamide adenine dinucleotide phosphate (NADP) etc.

Substrate: The substance on which enzyme acts is called substrate. The substrate undergoes chemical change in enzyme catalysis.

Mechanism of Enzyme Catalysis

1. Michaulis, Mentee and Fischer hypothesis: Michaulis and mentee proposed a mechanism for enzyme catalysis. Enzymes usually have cavities on their surfaces. These cavities are provided with active groups like NH_2 , SH , OH and CO_2H . These groups are called active centers or allosteric sites. The point through which an enzyme attacks on the substrate is called active site. The molecule fit into these cavities just like a key into a lock. The molecules of the substrate enter the cavities form an enzyme-substrate complex and then changes to the product and finally comes out of the cavities.



2. Induced fit hypothesis: According to this hypothesis the enzymes are in an active form. To become active they must undergo a slight change in structure to more specifically accommodate the substrate. It is said to be “induced to fit” the substrate.

Properties of Enzymes

1. Enzymes are soluble, colloidal organic catalysts produced by living cells.
2. Most of the enzymes are proteins in nature and possess all the properties of proteins.
3. These are precipitated by the usual precipitating agents.
4. These are non-hydrolysable with nitrogen contents of about 16%.
5. These are deactivated by extreme alteration of pH and high temperature.
6. These are highly specific in nature.
7. These are biological catalysts and accelerate the speed of biochemical reactions.

Types of Enzymes

1. **Oxidoreductases:** Catalyze oxidation reduction reactions. e.g oxidase, dehydrogenase, peroxydase etc.
2. **Transferases:** Bring about an exchange of functional groups. e.g phosphor transferase.
3. **Hydrolases:** Catalyze the hydrolysis process. e.g proteases and protolytic enzymes.
4. **Lyases:** Catalyze the addition of ammonia, water and carbon dioxide to the double bonds and removal of these substances from the double bonds. Fumerase is the common example.
5. **Isomerases:** Catalyze the transfer of groups within a molecule. Phosphoglycerolmutase is an example.
6. **Ligases:** Link two molecules together. e.g carboxylase and succinic thiokinase.

Role of Enzymes as Biocatalyst

1. **Digestion of carbohydrates:** Saliva contains an enzyme called salivary amylase or ptyalin which catalyzes the hydrolysis of carbohydrates in mouth. In stomach the action of saliva comes to an end due to high pH. In intestine the pancreatic juice which contains amylase starts its function.
2. **Digestion of fats:** A slight hydrolysis of fats occurs in the mouth and stomach as no lipase is secreted by the salivary glands while the lipase of the gastric juice is weak and hydrolyzes only small fat molecules. The lingual lipase enzyme secreted by the Ebner's glands on the dorsum of the tongue remains active in stomach and hydrolyze 30% of the fats. In the intestine, the pancreatic juice secretes pancreatic lipase which completely hydrolyzes all fats of the food.
3. **Digestion of proteins:** As saliva contains no enzyme for the digestion of proteins so digestion of proteins starts in stomach where pepsin present in the gastric juice of stomach start its function. Pepsin show best activity at pH 1-2. Pepsin has milk curding properties also. Pancreatic juice also contains trypsin, chemotrypsin, carboxypeptidase A and B, elastase and collagenase enzymes. The inactive trypsinogen is activated by enterokinase enzyme to active trypsin

Factors Affecting Enzyme Activity

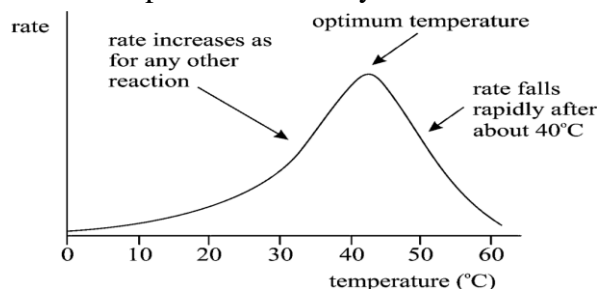
Important factors affecting the activity of enzymes are given below.

1. **Temperature:** With increase in temperature, K.E of the reactant molecules increases and the number of fruitful collisions increases, hence the rate of a chemical reaction increases with increase in temperature. In case of enzymatic reactions the rate increases upto a certain temperature. Above that temperature the enzymes undergo denaturation and their activity decreases rapidly. With decrease in

temperature, the activity of enzyme decreases and the enzyme becomes almost inactive at 0°C . Enzymes can be stored for many years in frozen state.

Optimum temperature: The temperature at which the enzymes show maximum activity is called optimum temperature. For most animal enzymes optimum temperature is the body temperature, 37°C . Some plant enzymes like urease has optimum temperature upto 60°C . Mammalian enzymes has optimum temperature is 40°C . Enzymes of snow flea work better at -10°C . Enzymes of thermophilic bacteria work best at 90°C .

The following graph show the relationship between rate of enzymatic reaction and temperature, optimum temperature is clearly shown.

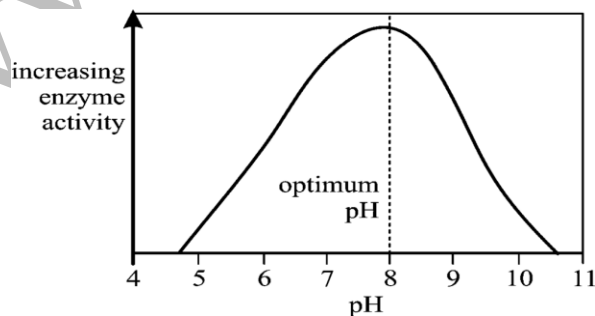


2. **pH:** Some enzymes work best in an alkaline pH while others work better in acidic pH. Most of the enzymes work better in the pH range of 5-9.

Optimum pH: For every enzyme there is a pH at which it shows its maximum activity which is called optimum pH. For most enzymes this is about pH 7-8 (physiological pH of most cells). The optimum pH of pepsin is 2 while that of trypsin is from 8-9. Protease enzyme has optimum pH of 1.

Minimum pH: The pH below which the enzyme loses its activity and at which the enzyme shows the lowest activity is called minimum pH.

The following graph shows the relationship between pH and enzymatic activity.



3. **Enzyme concentration:** As the enzyme concentration increase the rate of reaction increases linearly, because there are more enzyme molecules available to catalyze the reaction.

4. **Substrate concentration:** The rate of an enzyme catalyzed reaction shows a

curved dependence on substrate concentration. As the substrate concentration increases, the rate increases because more substrate molecules can collide with enzyme molecules, so more reactions will take place

5. Inhibitors: Inhibitors decrease the rate of enzymatic reactions.

Enzyme Inhibition

The process by which the activity of an enzyme is decreased or inhibited by certain substances is called enzyme inhibition.

Inhibitors: The substances which inhibit the activity of enzymes are called inhibitors or retarders. These are found naturally but are also used artificially as drugs, pesticides and research tools.

There are two types of enzyme inhibition.

1. Irreversible inhibition: When the inhibitor reacts and forms strong covalent bonds with the active sites of the enzyme, it is called irreversible inhibition. The inhibitor forms a stable and irreversible complex with the enzyme. This complex cannot be broken down by physical or chemical methods to restore the activity of the enzyme.

2. Reversible inhibition: The inhibition in which the activity of an enzyme is restored is called reversible inhibition. It is a temporary type of inhibition. It has the following types.

I. Competitive inhibition: When there is competition between the inhibitor and the substrate for the active sites of the enzyme, the inhibition is called competitive. The inhibitor binds to the same active sites of the enzyme to which the substrate binds and hence blocks the active sites so the substrate is unable to bind to the enzyme then.

II. Non-Competitive inhibition: When there is no competition between the inhibitor and the substrate for the active sites of the enzyme, the inhibition is called non-competitive. In this case, the inhibitor has no structural similarities with the substrate and therefore does not compete with the substrate for the active sites of the enzyme. The inhibitors bind to sites other than the active sites of the enzyme and two complexes are formed, the enzyme-substrate and the enzyme-inhibitor.

III. Uncompetitive inhibition: In this case, the inhibitor does not react directly with the enzyme but it binds to the enzyme-substrate complex.

IV. Feedback inhibition: In feedback inhibition, there is a second binding site on the enzyme where the inhibitor binds, so that the inhibitor is not necessarily similar in structure to the substrate. The absence or presence of the inhibitor at this second binding site activates or deactivates the enzyme, by changing the conformation of the enzyme so that the active site is made available or unavailable to the substrate. The inhibitor is usually the product of a reaction formed during the metabolic pathway.

Industrial Applications of Enzymes

Enzymes are used in these chemical industries where extremely specific catalysts are required. Some important industrial applications of enzymes are given below.

- 1. Biological detergents:** For washing most of the enzymes comes from bacteria adapted to live in hot springs. The enzymes are used for presoak condition and direct liquid applications helping removal of protein and starch stains. These are also able to digest fats, oils and grease stains.
- 2. Fruit juice production:** During the manufacture of fruit juice the cells of the fruits are broken down by cellulases and hemicellulases enzymes. As the plant cell wall is made up of cellulose fibers which are held together by pectins and hemicelluloses so it is extremely tough. High temperature will break the fruit tissues but it will affect colour and flavor of the juice. So enzymes are used for this purpose.
- 3. Production of ethanol:** Cellulase enzyme is used to break down cellulose into sugar which can then be fermented to produce alcohols.
- 4. High fructose syrup:** High fructose corn syrup is used as a sweetener in food and drinks which is manufactured from starch in corn fruit. The grains are milled to starch slurry and the enzyme amylase is added. Finally the syrup is passed down a column of immobilized glucose isomerase enzymes which convert glucose to fructose. It is added to sweeten foods without adding too many calories.
- 5. Paper industry:** Enzymes like amylase, xylinase, cellulose and ligninase etc. are used paper industry. Amylase degrades starch to lower viscosity, aiding sizing and coating of paper. Xylinase produce bleach required for decolorization. Cellulase smoothen fibers, enhance water drainage and promote ink removal. Lipase reduces pitch and lignin degrading enzymes remove lignin to soften paper.

Lipids

Lipids are greasy, heterogeneous, naturally occurring compounds of plants and animals origin. The word lipid originates from Latin word Lipas meaning fats. Lipids are naturally occurring organic compounds of animals and plants origin which are soluble in organic solvents and belongs to a heterogeneous group of substances. These are greasy substances which are relatively insoluble in water but considerably soluble in organic solvents.

Composition: Lipids mainly consist of fatty acids, glycerol and sterols. Fats and oils are the most important lipids found in nature.

Chemical nature: Chemically the lipids are either esters of fatty acids or substances forming such esters. They are very wide spread in nature.

Functions of Lipids

Lipids perform several important functions in living organisms which are given

below.

1. These act as storehouse of metabolic energy.
2. These are structural components of membranes.
3. These act as insulating and protective coatings.
4. Nervous tissues are rich in lipids where they play important role in their function.
5. The sub-cutaneous fat serves the role of insulating against atmospheric heat and cold.

Saponifiable lipids: The lipids which can be saponified like fats, oils and waxes are called saponifiable lipids.

Unsaponifiable lipids: The lipids which cannot be saponified like steroids and terpenes are called unsaponifiable lipids.

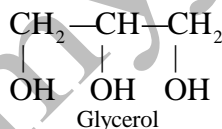
Classification of Lipids

There are three major classes of lipids.

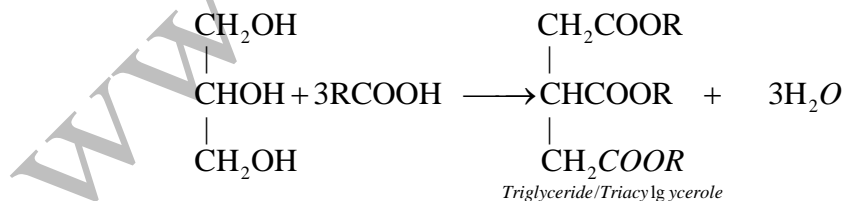
1. Simple lipids

These are the esters of fatty acids with different types of alcohols. These may further be fats, oils and waxes.

- Fats and oils:** These are the esters of fatty acids with trihydroxy alcohol called glycerol.



Fat is solid at room temperature while oil is liquid at room temperature oil contains more unsaturation in the alkyl part of fatty acids than fats. They are also known as triglycerides or triglycerols.



Fatty acids are long chain carboxylic acids containing usually 12-18 carbon atoms per molecule.

- Waxes:** These are the esters of fatty acids with high molecular weight monohydric alcohols. For example, bees wax carnauba wax etc.

2. Compound lipids

These are the esters of fatty acids with alcohols containing some additional groups as well. These are further divided into the following classes.

- i. Phospholipids:** These are also called phosphatide. These lipids contain fatty acids, phosphoric acids, nitrogenous bases along with some other constituents.
- ii. Glycolipids:** These contain fatty acids, alcohols and carbohydrates. These are present in large amount in the white matter of the brain and in myelin sheaths of nerves.
- iii. Sulpholipids:** These contain a sulphate group in addition to fatty acids, alcohols and carbohydrates.
- iv. Lipo-proteins:** These are the complexes of lipids with proteins.

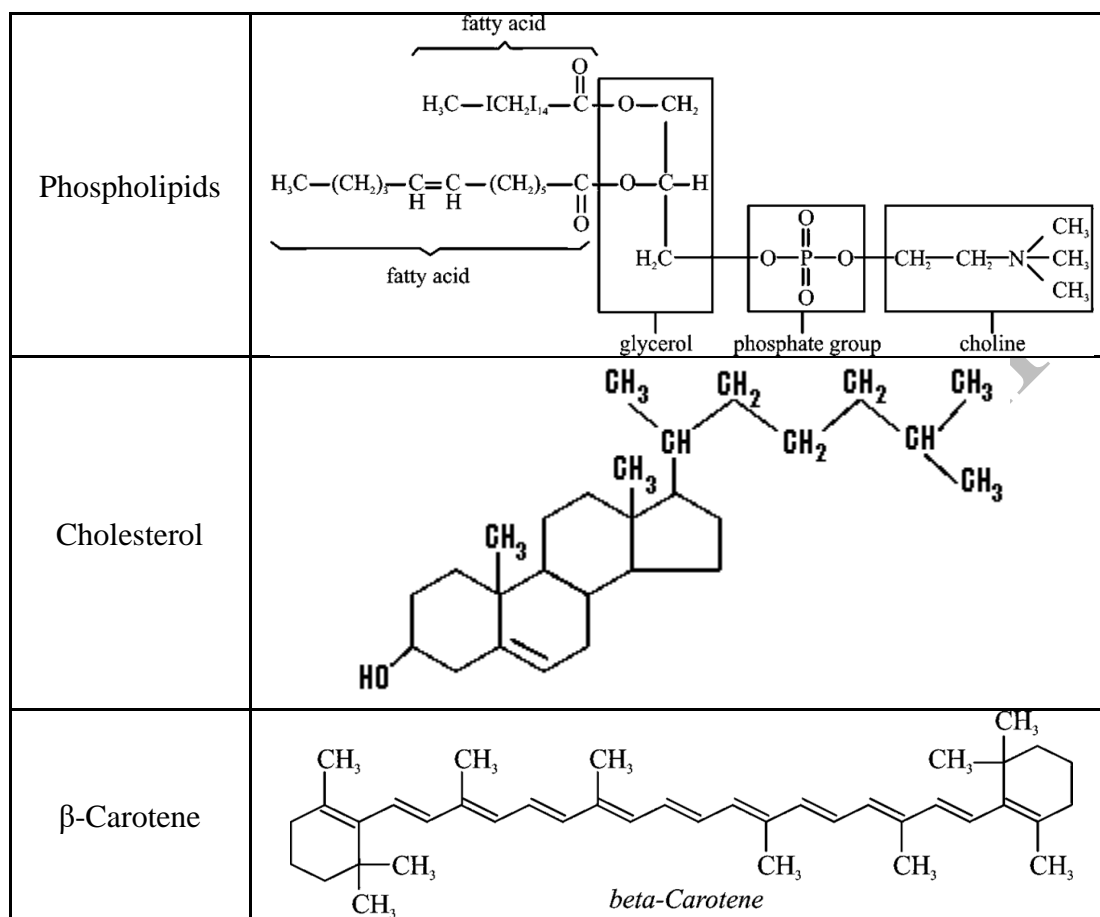
3. Derived lipids

These are the substances derived by the hydrolysis of simple and compound lipids. These include fatty acids, alcohols, mono and triglycerides, steroids, terpenes and arthenoids.

Structure

Lipid has no common structure. The most common occurring lipids are triglycerides and phospholipids. Triglycerides are fats and oils. These have a glycerol backbone bonded to three fatty acids. If the three fatty acids are similar, the fats are called simple triglycerides. If the fatty acids are not similar, these are known as mixed triglycerides. Phospholipids are found in cell membrane of animals and plants. These contain glycerol and fatty acids as well as phosphoric acid and low molecular weight alcohol. Some lipids and their structures are given below.

Name of Lipid/ Fatty acids	Structure
Stearic acid	$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$ (Saturated)
Oleic acid	$\begin{array}{c} \text{CH}_3(\text{CH}_2)_7 \quad \quad \quad (\text{CH}_2)_7\text{COOH} \\ \quad \quad \quad \diagdown \quad \quad \quad / \\ \quad \quad \quad \text{C} = \text{C} \\ \quad \quad \quad / \quad \quad \quad \diagdown \\ \text{H} \quad \quad \quad \quad \quad \quad \text{H} \end{array}$
Wax (From bee hive)	$\text{CH}_3(\text{CH}_2)_{28}\text{CH}_2 - \text{O} - \overset{\text{O}}{\parallel}{\text{C}}(\text{CH}_2)_{14}\text{CH}_3$
Name of Lipid/ Fatty acids	Structure

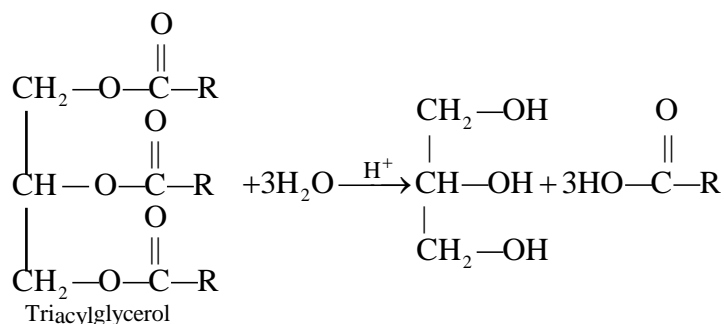


Properties of Lipids

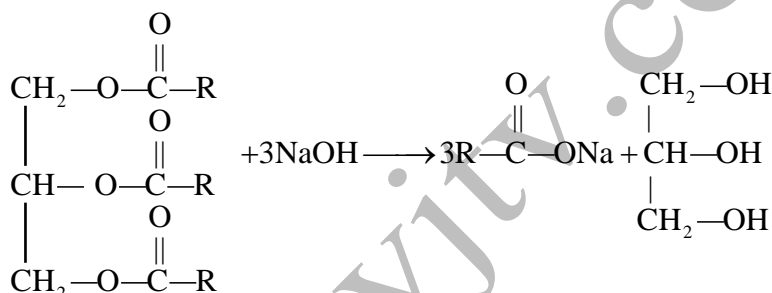
1. Oil and fats are either liquids or non crystalline solids at room temperature.
2. Natural fats are colourless, odourless and tasteless.
3. These are insoluble in water but soluble in organic solvents.
4. These have well defined melting and solidifying points.
5. These have low specific gravity and floats on the surface of water.
6. These readily form emulsion when agitated with H_2O in the presence of soap or other emulsifier.
7. These are poor conductor of heat and electricity and therefore serve as excellent insulator for the animal body.

Chemical Properties

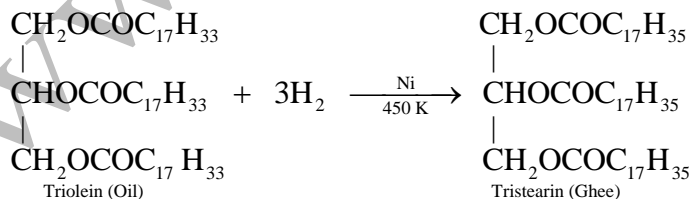
1. **Hydrolysis:** Natural fats undergo hydrolysis with acids or bases in boiling water and produce fatty acids and glycerol.



2. Saponification: In case of base hydrolysis, the base reacts with fats and produce salts of fatty acids called soap. This reaction is known as saponification or soap formation.



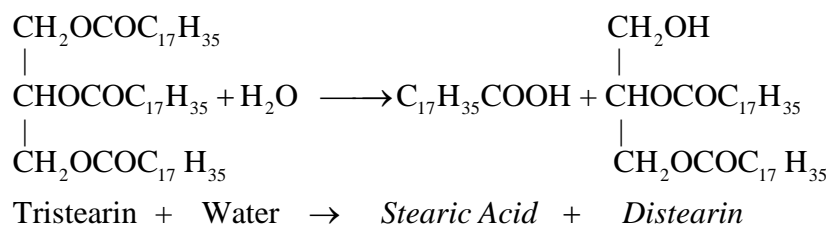
3. Addition reactions: Unsaturated fatty acids of fats and oil undergo addition reactions at the point of unsaturation and produce addition products. The oil which contains more unsaturation are hydrogenated to produce solid ghee. By this method inedible and cheap oil such as cotton seed oils are hydrogenated and converted in to solid and edible ghee.



4. Oxidation: Fats rich in unsaturated fatty acids (linseed oil) undergo spontaneous oxidation at their double bonds and produce aldehydes, ketones and resins. These form thin transparent coating on the surface to which the oil is applied. These are known as drying oils. These are used in the manufacturing of paints and varnishes.

5. Rancidification: The spoilage of fats and oils to give bad odour is called rancidification. Natural and especially animal fats contains lipase enzyme. By the action of atmospheric oxygen, in the presence of lipase the fats undergo partial

hydrolysis and oxidation and produce volatile fatty acids and carbonyl compounds of sour taste and unpleasant smell. This process is called rancidification and the fat is said to have become rancid.

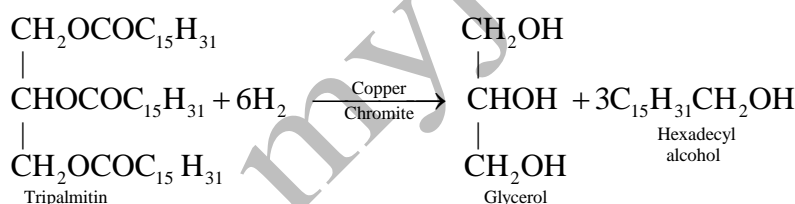


It may be hydrolytic or oxidative rancidification.

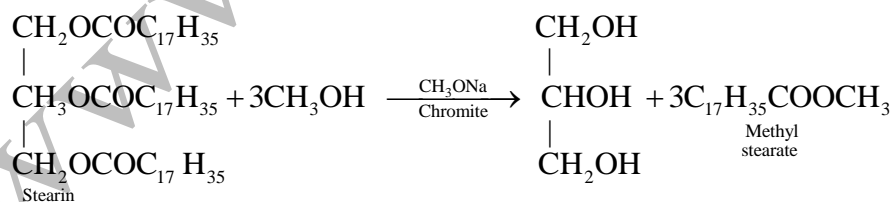
Hydrolytic rancidification: It involves the hydrolysis of ester linkages of a glyceride to original fatty acids.

Oxidative rancidification: In this case the attack of atmospheric oxygen on the C-C double bond in the unsaturated side chain of the glyceride occurs and small chain carboxylic acids and aldehydes are formed.

6. Hydrogenolysis: If hydrogen gas is passed in excess through a fat or oil at high temperature and under high pressure, glycerol and long chain aliphatic alcohols are obtained.



7. Trans-esterification: Simple esters can be prepared by treating oils or fats with lower alcohols in the presence of sod. alkoxides



Nutritional and Biological Importance of Lipids

Different functions of lipids in living organisms are given below.

1. Lipids provide food which is highly rich in calorific value. One gram of lipid on complete oxidation produces 9.3 kcal of heat which is about double the amount produced by carbohydrates and proteins.
2. Lipids are insoluble in water and, therefore, they can be stored easily in the body as food reserves. These food reserves are then used by the organisms

- during hibernation periods.
3. Lipids in association with different proteins form the important constituents of cell membranes.
 4. Fats have high insulating capacity. Great quantities of fats are deposited in the sub-cutaneous layers in aquatic mammals such as whale and in animals of cold climates. These fat deposits protect these animals from severe cold and severe temperature changes.
 5. Some lipids especially phospholipids play a key role in the absorption and transportation of fatty acids in the body.
 6. Sex hormones, adrenocorticoids, cholic acids are synthesized from a steroidal lipid known as cholesterol.
 7. Lipids serve as carrier of fat soluble vitamins such as vitamin A, D and E in the body.
 8. Squalene, a steroid present in the blood of shark has antibiotic and antifungal properties. This explains why sharks rarely contract infections and almost never get cancer.

Acid value: It is defined as the no. of milligrams of potassium hydroxide required to neutralize one gram of oil or fat. It indicates the amount of free fatty acid present in an oil or fat. A high acid value indicates a stale oil.

Saponification value: It is defined as the no. of milligram of potassium hydroxide required to saponify one gram of fat or oil completely. The saponification value gives us an estimate of the molecular mass of the fat or oil, the smaller the saponification value, higher the molecular weight.

Iodine value or iodine number: It is the no. of grams of iodine that combine with 100 g of oil or fat. It gives a measure of unsaturation in an oil or fat.

Saponification number: It is the number of milligrams of KOH required to saponify one gram of fat and oil.

Acid number: It is the number of milligrams of KOH required to neutralize one gram of fat.

Reichert-Meissl Value (R.M. Value): It is the number of millilitre of N/10 potassium hydroxide solution required to neutralize the distillate of 5 g of hydrolyzed fat or oil.

Nucleic Acids

Nucleic acids are large polymeric biomolecules made of monomers called Nucleotides. A 25 years old Swiss Chemist isolated nuclei from pus cells (WBCs). He found that these nuclei contained an unknown phosphate rich substance, he named it as nuclein. This newly discovered substance was quite different in properties from carbohydrates, proteins and fats. He also isolated a nucleoprotein complex from ripe

salmon sperm. It was a basic protein which he named protamine. Altmann for the first time used the word nucleic acid in 1889. He also discovered the existence of two different types of nucleic acids, DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). Later on Watson and Crick determined the structure of nucleic acids. These are present in every living organisms as well as in viruses. These are the essential substances of the genes. These contain in their structure the blueprints for the normal growth and development of each and every organism. These are responsible for storing, expressing and transmitting genetic information and mutation in living organisms.

Types of Nucleic Acids

Nucleic acids are divided in two types.

- (1) DNA (Deoxyribonucleic acid). It is present in nuclei and in some viruses. It is the main constituent of chromosomes.
- (2) RNA (Ribonucleic acid) is present in cytoplasm and in some viruses.

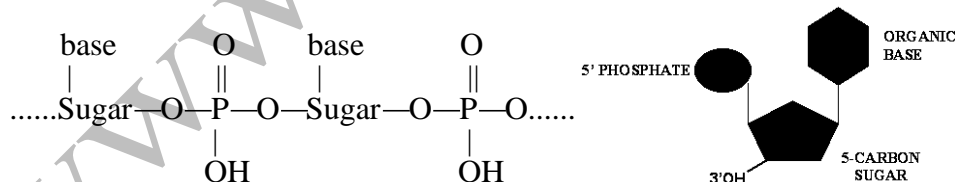
Structural Components of DNA and RNA

Both DNA and RNA are formed by the polymerization of large number of small units known as nucleotides, that's why DNA and RNA are polynucleotides.

Nucleotide: Nucleotide is a molecule composed of three components. Nitrogenous base, a sugar (pentose) and a phosphate group.

Nucleotide = Nitrogenous base + Sugar + Phosphoric acid

In a typical nucleotide the nitrogenous base is attached to carbon No.1 of pentose sugar while phosphate group is attached to carbon No.5 of the pentose sugar. The bond formed between the phosphate group and -OH of pentose sugar is called ester linkage



Nucleotides are classified as mono, di and polynucleotides.

1. Mononucleotides: It exists as a single nucleotide unit. Examples are adenosine monophosphate (AMP), adenosine diphosphate (ADP) and adenosine triphosphate (ATP). ATP consists of three phosphate groups, pentose sugar and adenine. Adenine base and pentose sugar form adenosine which combine with a phosphate group and form adenosine monophosphate (AMP). When AMP combine with other phosphate group then adenosine diphosphate (ADP) is formed. When ADP combine with third phosphate group it form adenosine triphosphate (ATP).

2. Dinucleotides: When two nucleotides are linked together, a dinucleotide is

formed. If it contains adenine as a base then it is called as adenine dinucleotide.

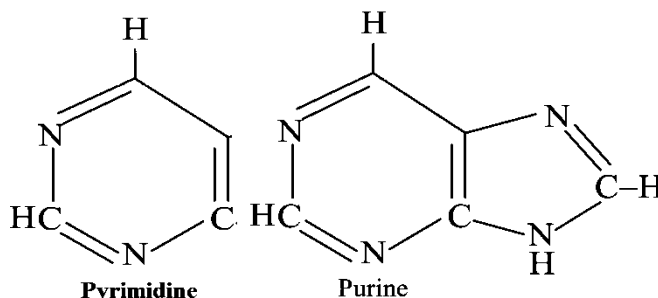
3. Polynucleotides: When many nucleotides are linked together they form polynucleotide. DNA and RNA are polynucleotides.

Types of nucleic acids: Nucleic acids are of two types.

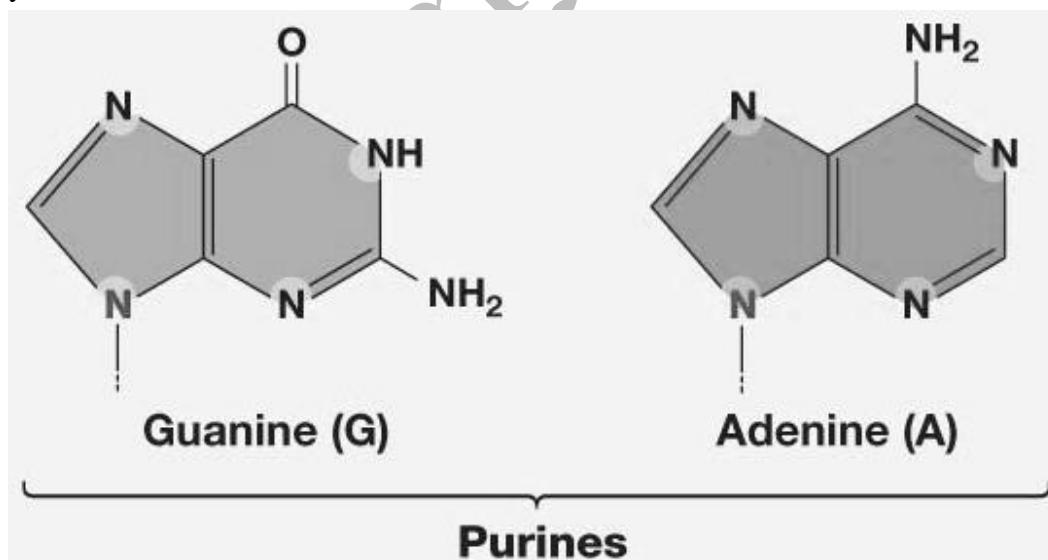
DNA: Deoxyribonucleic acid, which is made up of deoxiribonucleotides.

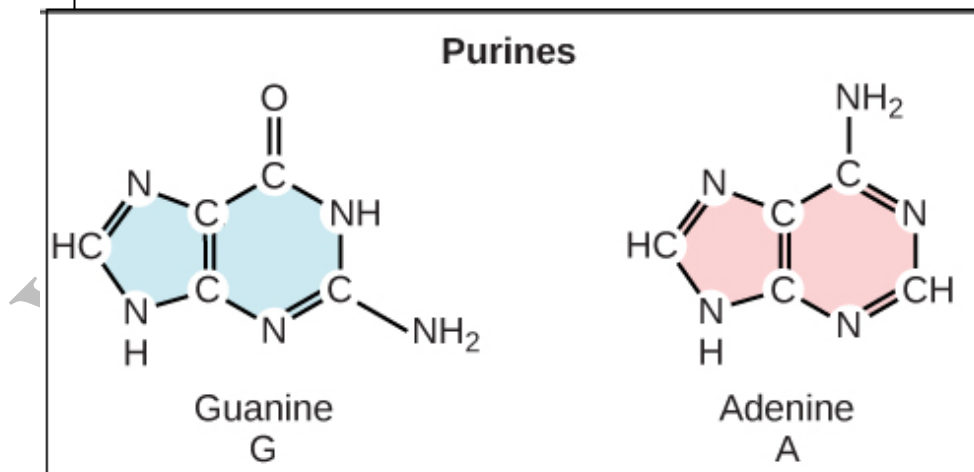
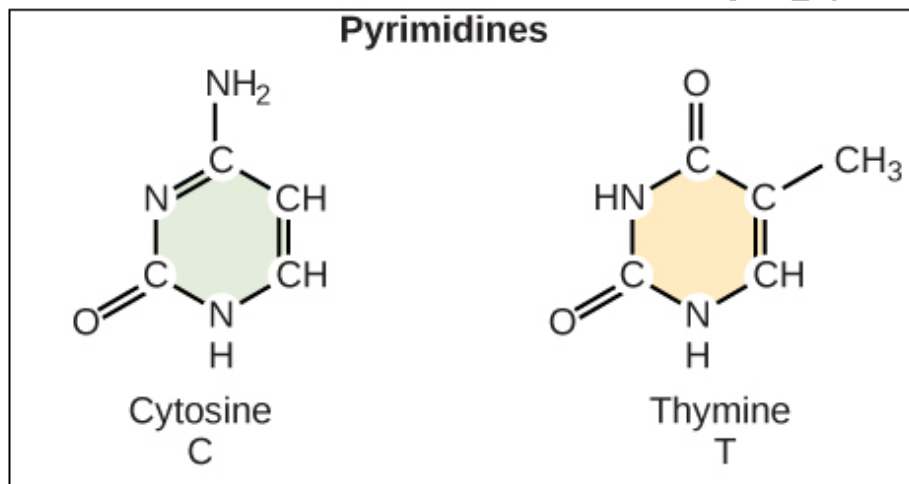
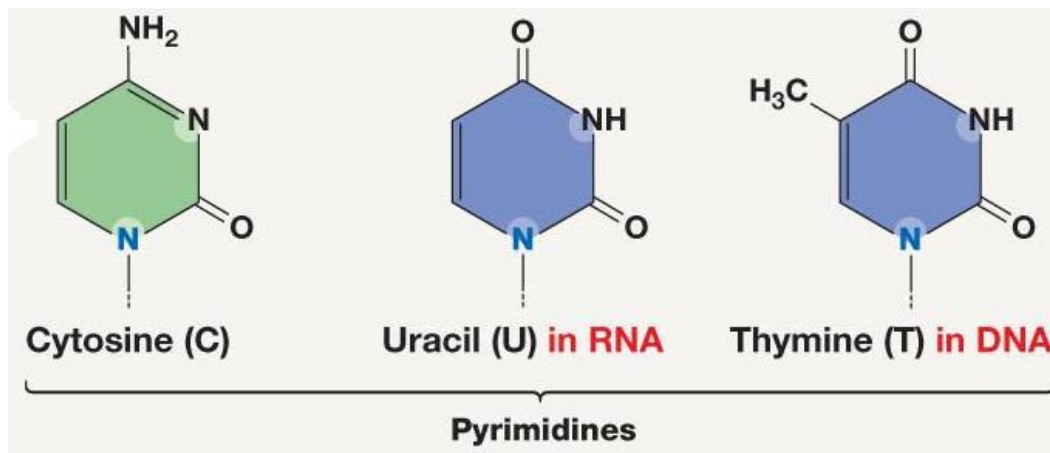
RNA: Ribonucleic acid, which is made up of ribonucleotides.

Types of nitrogenous bases: The nitrogenous bases are of two types, pyrimidine and purine. Pyrimidines are single ring compounds while purines are double ring compounds.

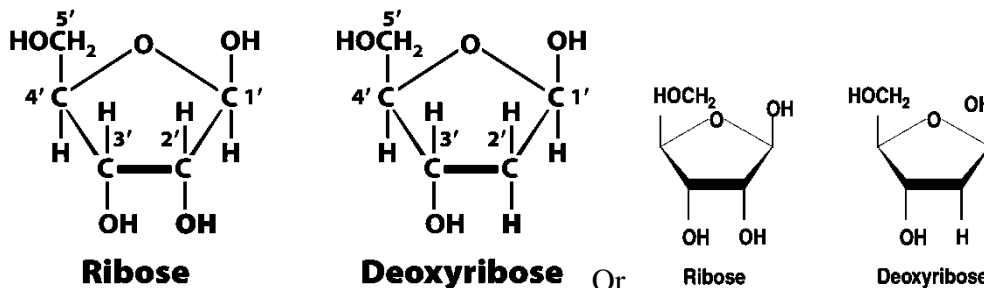


There are two different types of purine derivatives. These are adenine and guanine. Similarly there are three derivatives of pyrimidine. These are cytosine, thymine and uracil.

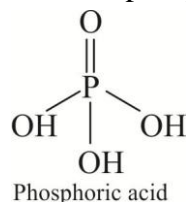




Both DNA and RNA are polynucleotide molecules. DNA and RNA contain two different types of sugars, one is deoxyribose and the other is ribose sugar. Both these sugars are in cyclic form as shown below.

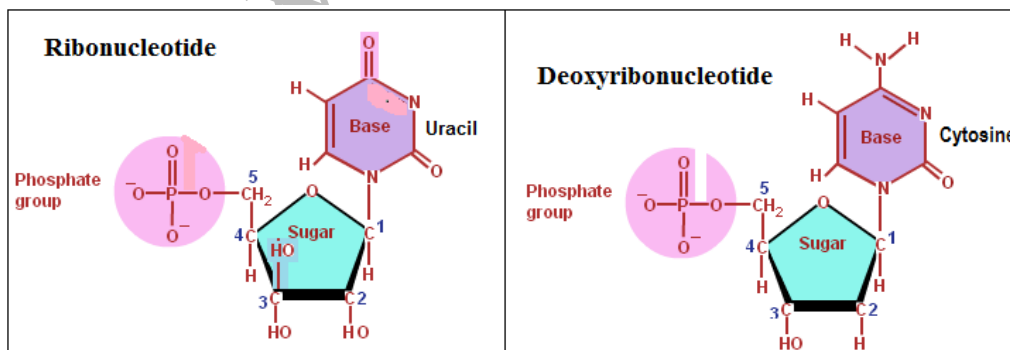


The third component of nucleic acid is phosphoric acid.



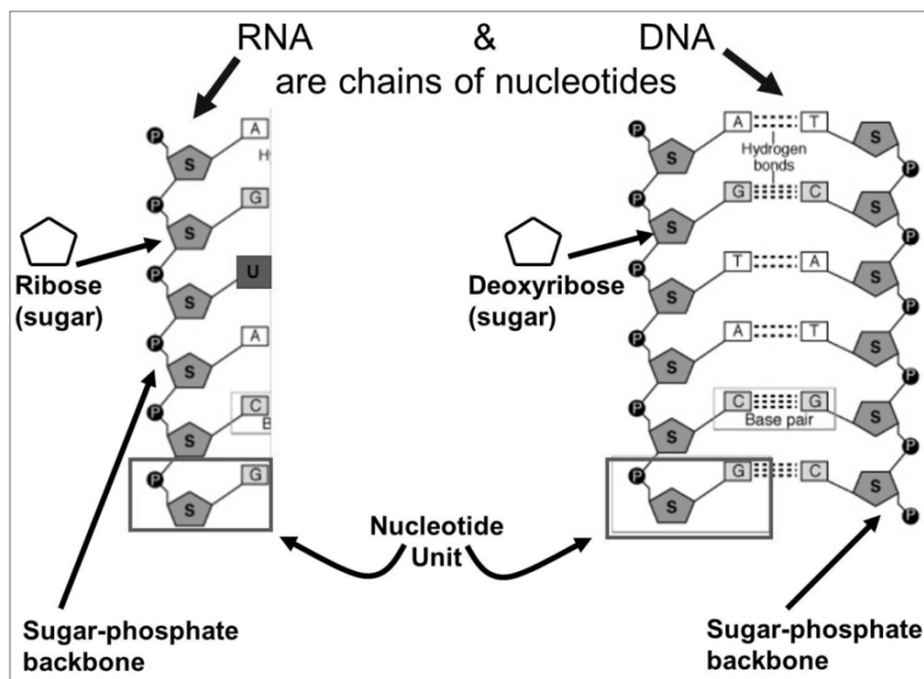
Difference between DNA and RNA

Both the DNA and RNA contain the same types of purine bases called adenine and guanine, but the DNA differs from RNA in the sense that the pyrimidine bases of DNA are cytosine and thymine while the pyrimidine bases of RNA are cytosine and urasil. The pentose sugar of DNA is deoxyribose while that of RNA is ribose. DNA is made up of repeating units of deoxyribonucleotides while RNA is a polyribonucleotide. DNA is double stranded while RNA is single stranded molecule. DNA is present in the nucleus while RNA is present in the cytoplasm. DNA is not directly involved in the protein synthesis while RNA is directly involved in the protein synthesis. DNA is hereditary material while RNA is not.



Structure of DNA: The DNA molecule is formed by two antiparallel long poly deoxoribonucleotide chains which wind on each other. These two chains are held together throughout the whole length by hydrogen bondings present between their nitrogenous bases. Adenine joins only to thymine while guanine joins only to

cytosine. Adenine joins to thymine by two while cytosine joins to guanine by three hydrogen bondings. This pairing of bases is highly specific. Adenine will never join cytosine and guanine will never joins thymine.



Storage of Genetic Information

DNA is the ultimate carrier of heredity in all living organisms. Genes are composed of DNA which contains genetic information in the form of codes. A sequence of three nitrogenous bases on DNA strands contains codes for one amino acid synthesis of proteins which occurs inside ribosomes present in the cytoplasm of living cells. The information stored in the form of genes which are parts of DNA are transmitted to the cytoplasm in the form of messenger RNA (mRNA). There is another type of RNA called transfer RNA (tRNA) which reads out the message of mRNA and brings the amino acids to the ribosome in the form of amino acid tRNA complexes. Then these amino acids are incorporated into the peptide chain. This process is called translation.

Minerals of Biological Significance

Sources of important minerals

Minerals essential for life are the inorganic nutrients, which are needed by the living organisms for vital functions but they cannot synthesize them. These are naturally present in the soil and river water. Plants take up minerals from the soil. Animals get these minerals in drinking water and eating plants as food. We receive

these inorganic substances from both animals and plants in our diet. Sometimes drinking water also supplies appreciable quantities of these minerals. Purified salt such as NaCl is used in food preparation is also good source of minerals for human consumption.

Types of Minerals

1. **Macronutrients:** Nutrients which are required in large amount to the body are called macronutrients like Calcium, phosphorous, magnesium and sulphur.
2. **Micronutrients:** Nutrients which are required in small amount to the body are called micronutrients like iron, zinc, iodine, copper and magnesium.

1. Biological significance of iron

Iron is an important mineral because it is part of the haemoglobin, a carrier of oxygen in the body.

Required amount: An adult man requires about 10mg of iron in his daily diet. Growing children, pregnant and lactating women require greater concentrations of iron due to the loss of blood in menstruation.

Sources: Liver, heart, kidney, egg yolk, green leafy vegetables, wheat etc are the good sources of iron.

The daily synthesis of haemoglobin requires about 27mg of iron but the same quantity of iron is liberated by the breakdown of body haemoglobin, therefore only a small quantity of iron is required unless there is a loss of blood from the body. About 30mg of iron is transferred to the fetus in uterus. Since there is no loss by excretion so this amount is sufficient during uterine life.

ProblemsAssociated: The lack of iron in the diet or a deficiency in its absorption by the body produces a disease known as anemia. Excess of iron is stored in the form of hemosiderin in the skin, pancreas, liver, spleen etc. this leads to bronzed appearance of the skin, diabetes mellitus and cirrhosis. This state is called hemochromatosis or hemosiderosis.

2. Biological significance of calcium

Calcium is the main constituent of teeth and bones. About one kilogram of calcium is present in man, 99% of which is present in bones in the form of hydroxyapatite crystals. Small amount of calcium is also present in the blood.

Sources: The main sources of calcium are milk and milk products, egg yolks, legumes, nuts and green leafy vegetables.

Importance: Calcium is required for the regulation of a large number of cellular activities, muscles and nerve functions, hormonal action, blood coagulation and cell motility.

ProblemsAssociated: Increase in the concentration of calcium in plasma leads to a

condition known as hyperparathyroidism. Decrease in plasma calcium level leads to a condition known as hypocalcaemia.

3. Biological significance of phosphorous

Phosphorous is also the major constituent of bones and teeth. It is present in all body cells in association with proteins, lipids and carbohydrates, phospholipids and similar compounds. It has a unique role in storage and transformation of energy in the body.

Required amount: An adult requires about 800mg per day of phosphorous.

Sources: It is present in association with calcium in its sources. Proteins of food also provide good amount of phosphorous to the body.

ProblemsAssociated: An increase in the plasma phosphate level due to a decrease in excretion leads to kidney dysfunction. A decrease in the plasma phosphate level due to an increase in its excretion leads to renal rickets.

4. Biological significance of Zinc

Zinc is an important element for the normal growth, reproduction and longevity of animals. Human body contains about 2g of zinc which is next only to iron (about 4 g). It is a constituent of several types of enzymes such as alkaline phosphatase, carbonic anhydrase etc. It also forms a complex with insulin and helps in its storage and release according to the need of the body. It is also required for maintaining the plasma concentration of vitamin A. Some of the zinc-containing enzymes play an important role in the digestion of proteins by animals. Besides this, zinc enzymes are also involved in the energy release processes, sugar metabolism and metabolism of alcohol in the human body.

Sources: Meat, liver, eggs, fish, milk and cereals are the sources of zinc.

Deficiency: The deficiency of zinc results in delayed wound healing and impairment of acuity of taste.

EXERCISE

Q.I. Choose the Correct Option for each statement.

- (1) The most abundant carbohydrate in nature is
 - (a)✓ Cellulose
 - (b) Glycogen
 - (c) Pectin
 - (d) Chitin
- (2) The glycosidic linkage is present between the molecules of
 - (a)✓ Glucose
 - (b) Glycine
 - (c) Fatty acid
 - (d) None of these
- (3) Steroids belong to family of
 - (a) Carbohydrates
 - (b) Protein
 - (c)✓ Lipid
 - (d) Enzymes

- (4) Protein present in haemoglobin has the structure known as _____ structure.
- (a) Primary (b) Secondary
(c) Tertiary (d)✓ Quaternary
- (5) The optimum p^H of pepsin is
- (a) 1.5 (b) 1
(c) 2.5 (d)✓ 2.0
- (6) Which carbohydrates does not conform the general formula $C_n(H_2O)_n$.
- (a)✓ Deoxyribose (b) Ribose
(c) Glucose (d) Fructose
- (7) Ethanol is produced from starch by the process of
- (a) Hydrolysis (b) Hydrogenation
(c) Decomposition (d)✓ Fermentation
- (8) Human are unable to digest
- (a) Glucose (b)✓ Cellulose
(c) Starch (d) Denatured protein
- (9) Which one of the following term is not related to term aldohexose?
- (a) Aldehyde (b)✓ Ketone
(c) Six (d) Sugar
- (10) Synthesis of DNA is also known as
- (a) Transcription (b)✓ Replication
(c) Translation (d) Transmutation
- (11) RNA is primarily seen in
- (a) Nucleus (b)✓ Cytoplasm
(c) Cell wall (d) Cell membrane
- (12) Specificity of enzymes depend upon
- (a)✓ Active site (b) Linear sequence
(c) Turn over number (d) None of these
- (13) The best source of iron is
- (a) Organ meat (b)✓ Milk
(c) Tomato (d) Potato
- (14) In which the following disaccharides both the basic structural units are the same?
- (a)✓ Maltose (b) Lactose
(c) Sucrose (d) All of these
- (15) In competitive inhibition, the inhibitor
- (a) Competes with enzyme (b) Irreversibly binds with the enzyme

- (c) Bind with substrate (d)✓ Competes with substrate
- (16) In DNA, adenine forms a complementary pair with what other nitrogen base?
- (a) Uracil (b) Cytosin
(c)✓ Thymine (d) Guanine
- (17) The primary structure of protein represents
- (a)✓ Linear sequence of amino acids joined together by peptide bonds
(b) 3-dimensional structure of protein
(c) Helical structure of protein
(d) Sub units structure of protein
- (18) Liquid forms of triglycerides at room temperature are called
- (a)✓ Oils (b) Fats
(c) Solid (d) None of these

SHORT QUESTIONS

Q.II.Short Questions:

(1) **Why vegetable oil is sensitive to rancidity?**

Ans. When vegetable oil comes in contact with oxygen, it undergoes partial hydrolysis or oxidation which develops sour taste and unpleasant smell and the process is called rancidity. Naturally occurring fats and oil contain an active enzyme known as lipase due to which they are very sensitive to rancidity. Also if the oil has greater unsaturation it will become more rancid and will be sensitive to rancidity. Exposure to heat and light also cause rancidification.

(2) **Give brief reason why melting point of saturated fatty acid is higher than unsaturated fatty acid.**

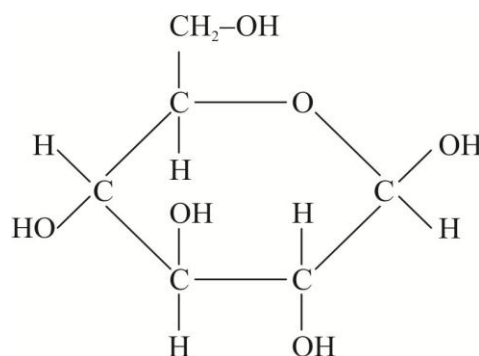
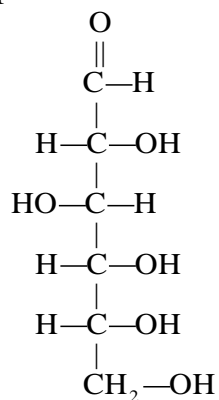
Ans. In case of saturated fatty acids the molecules are as a whole linear due to the SP^3 hybridization of carbon atoms. The linear molecules are much closer to one another and attractive forces will be strong so their melting points will be higher. In case of unsaturated fatty acids some of the carbon atoms are sp^2 hybridized and there is a twist in geometry of the molecules, the attractive forces are not that much strong and hence the melting points of unsaturated fatty acids are lower.

(3) **Draw the open and cyclic structure of the following compounds**

- (a) **Glucose** (b) **Fructose**
(c) **Mannose** (d) **Galactose**
-

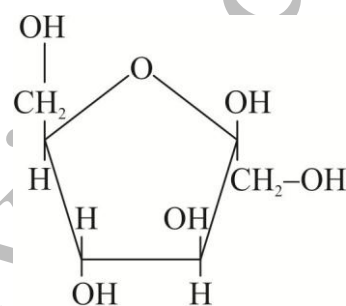
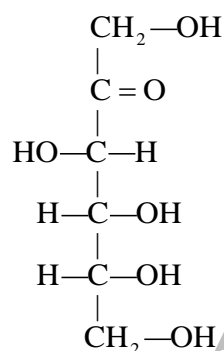
Ans. (a) Glucose

Open Chain Structure



Closed Chain Glucose

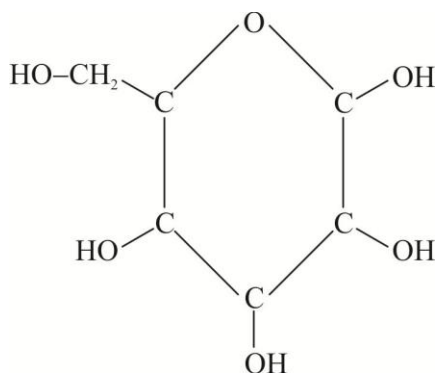
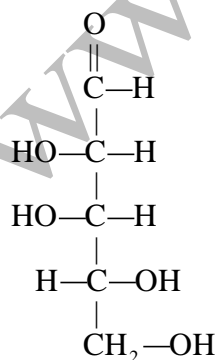
(b) Fructose



Closed Chain Fructose

Open Chain Fructose

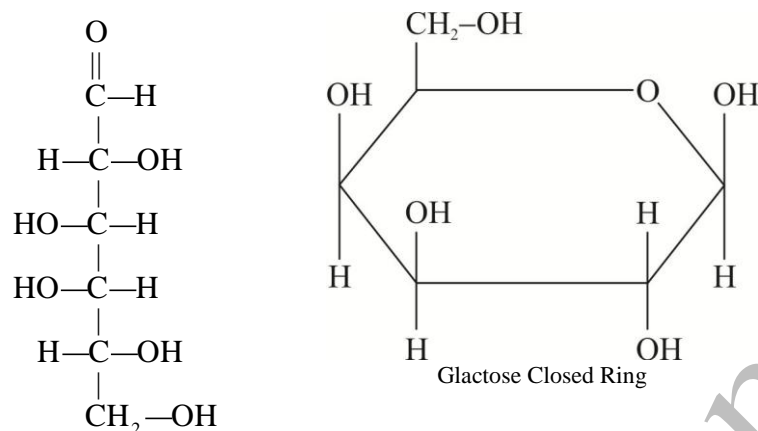
(c) Mannose



Open Structure

Closed Ring Structure

(d) Galactose



- (4) **Differentiation between**
- Aldose and ketose**
 - Homopoly saccharides and heteropoly saccharides**
 - Sugar and non sugar**
 - Competitive and non-competitive inhibition.**
 - DNA and RNA**

Ans. (a) Aldose and ketose

Aldose	Ketose
★ Polyhydroxy aldehydes are called aldose.	★ Polyhydroxy ketones are called ketose.
★ In aldoses the carbonyl group is at position 1.	★ In ketoses the carbonyl group is at position 2.
★ Aldose gives Fehling solution test.	★ Ketose donot give Fehling solution test.
★ Example: Glucose	★ Example: Fructose

- (b) Homopoly-saccharides and heteropoly-saccharides

Homopolysaccharides	Heteropolysaccharides
★ Polymers of carbohydrates formed by the combination of same monosaccharides.	★ Polymers of carbohydrates formed by the combination of different monosaccharides.
★ In these carbohydrates same monosaccharides are present.	★ In these carbohydrates different monosaccharides are present.
Examples:	Examples:
★ Cellulose	★ Glycolipids
★ Starch	★ Glycoproteins
★ Glycogen	★ Lignin

- (c) Sugar and non sugar

Sugar	Non Sugar
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<ul style="list-style-type: none"> ★ The monosacharides and oligosaccharides. ★ These are crystalline solids. ★ These are sweet in taste. <p>Examples: Glucose, Sucrose, Fructose, maltose</p>	<ul style="list-style-type: none"> ★ Polysacharides. ★ These are amorphous. ★ These are tasteless. <p>Examples: Starch, Cellulose, glycogen</p>
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(d) Competitive and non-competitive inhibition.

Competitive Inhibition	Non-Competitive Inhibition
<ul style="list-style-type: none"> ★ When inhibitor is in competition with substrate for active site is called competitive inhibition. ★ In competitive inhibition the inhibitor resemble with substrate. ★ Blocking of active sites of enzyme depends upon reactivity of substrate & inhibitor. 	<ul style="list-style-type: none"> ★ When inhibitor is not in competition with substrate for active site is called non-competitive inhibition. ★ In non competitive inhibition the substrate and inhibitor are different. ★ No competition so inhibitor blocks the active sites while substrate attach at other site.

(e) Difference between DNA & RNA.

Ans: Given in the theory.

(5) What is meant by the term “fuel of life”.

Ans. Carbohydrates, proteins, lipids, vitamins etc. are known to be the fuel of life specially the carbohydrates because they provide energy for the different functions of the body. That’s why these are known as the fuel of life.

(6) What happens when protein is denatured?

Ans. Denaturing is a process in which proteins and nucleic acids loss their tertiary structure by application of some external stress or chemicals or heat. If proteins in a living cell are denatured this results in the death of the cell. Most biological active substances loss their biological function when denatured. A common example of denaturing of protein comes from egg white.

(7) What are chemical entities that compose the nucleic acid?

Ans. A nucleic acid consists of

1. Polynucleotides which contain purines and pyrimidine as nitrogenous bases.
2. A sugar molecule (deoxyribose and ribose sugar)
3. A phosphate group.

(8) Describe briefly the primary, secondary, Tertiary and quaternary structure of protein.

Ans. Given in the theory.

(9) What is the importance of protein in our daily life?

Ans. Given in the theory.

(10) Why zinc is important for human being?

Ans. Given in the theory.

(11) State the medical problem that may relate to calcium and phosphorus.

Ans. Given in the theory.

LONG QUESTIONS

Q.III.Long Questions:

- (1) (a) What are the carbohydrate? Describe the properties of each kind of carbohydrates with example.**
(b) Explain the role and nutritional importance of carbohydrates.

Ans. Given in the theory.

- (2) (a) Describe various classes of protein along with examples.**
(b) Enlist the properties of proteins.

Ans. Given in the theory.

- (3) (a) What are lipids? Describe the classification and role in human body.**
(b) Write down at least three chemical properties of lipids.

Ans. Given in the theory.

- (4) (a) Define enzymes. Describe the role of enzymes in digestion of fat, carbohydrates and protein.**
(b) What are the factors affecting enzyme activity?

Ans. Given in the theory.

- (5) Write notes on**
(a) Nucleic acid (b) Biological significance of minerals

Ans. Given in the theory.