Chapter 2

BIOLOGICAL MOLECULES

Q.1a ***Define the following basic terms:***

(i) Biochemistry ***(ii) Organic Compounds***
(iii) Inorganic Compounds ***(iv) Carbohydrates***
(v) Lipids ***(vi) Proteins***
(vii) Nucleic Acids

Ans. **BASIC TERMS**

(i) **Biochemistry:** The study of the chemicals of living organisms is called biochemistry.

(ii) **Organic Compounds:** Those compounds in which C and H atoms are necessary with other atoms and carbon is central and basic element.

(iii) **Inorganic Compounds:** H_2O, HCl, H_2SO_4, NaCl, NaOH, Na_2CO_3 like compounds in which both C and H in same molecules are not essential.

(iv) **Carbohydrates:** *Polyhydroxy aldehydes or ketones are called carbohydrates.*

(v) **Lipids:** The organic compounds which are heterogenous, hydrophobic and sparingly solube in water are called lipids.

(vi) **Proteins:** The organic molecules in which polypeptide chains are formed by the peptide linkages of amino acids are called proteins.

(vii) **Nucleic Acids:** The acids in which ***pentose sugar***, ***purine*** or ***pyrimidine*** and ***phosphoric acid*** are components. e.g. DNA and RNA.

Q.1b ***Define the following key terms:***

(i) Metabolism ***(iv) Micromolecules***
(ii) Catabolism ***(v) Macromolecules***
(iii) Anabolism ***(vi) ATP***

Ans. **KEY TERMS**

(i) **Metabolism:** The *making and breaking* of molecules in *biochemical reactions* is called metabolism.

(ii) **Catabolism:** The breaking of large molecules into small molecules during metabolism is called catabolism.

(iii) **Anabolism:** The making of large molecules from small molecules in biochemical reactions is called anabolism.

(iv) **Micromolecules:** The small molecules which have lower molecular weight.

(v) **Macromolecules:** Large organic molecules which have polymeric chain structure. e.g. Proteins, polysaccharides.

(vi) **ATP** (Adenosine triphosphate) the energy currency in the organism which becomes the source of different activities.

Q.1 What is Biochemistry? Discuss the chemical composition of protoplasm.

Ans. **BIOCHEMISTRY**

"The branch of biology which deals with the chemical components and biochemical reactions in living organisms is known as biochemistry".

Relationship of Biochemistry: It is an important branch of biology and is directly related with some other branches of biology such as physiology, anatomy etc. All organisms are composed of either organic or inorganic molecules.

Organic Compounds: The living matter i.e. protoplasm consists of organic compounds such as proteins, lipids carbohydrates and nucleic acids.

Inorganic Compounds: Inorganic compounds may include water, CO_2, acids, bases and salts.

Comparison of Chemical Composition of a Bacterial and a Mammalian Cell:

	Compounds	Total Cell Weight (%)	
		Bacterial cell	Mammalian cell
1.	Water	70	70
2.	Proteins	15	18
3.	Carbohydrates	3	4
4.	Lipids	2	3
5.	DNA	1	0.25
6.	Other organic molecules	2	2
7.	Inorganic ions	1	1

	Na^+, K^+, Ca^{++}, Cl^-, SO^{-4}		
8.	RNA	6	1.1

Q.2 What do you mean by metabolism? Briefly discuss its types.

Ans. **METABOLISM**

"The making and breaking of molecules during chemical reactions in living bodies are called metabolism".

The survival of any animal or plant depends upon its ability to take some chemical from the environment, to make its protoplasm. For this, the cells of every organism are constantly taking a new substances and using them to from new cellular materials and obtaining energy for their needs.

Categories of Metabolism:

The process of metabolism may be divided into two categories.

(a) **Anabolism:** "The type of metabolism in which simpler substances are combined to form ***complex substances*** is called metabolism".

(b) **Catabolism:** "The type of metabolism in which ***complex substances are broken down*** to simple and smaller molecules by the action of energy is called catabolism".

Example: ***Interconversion of organic molecules:*** Proteins, lipids and carbohydrates are commonly interconverted in living cells. These interconversions are example of metabolism.

Q.3 What is the role of carbon in biochemicals?

Ans. **ROLE OF CARBON**

(1) **Valency of Carbon:** Carbon has 4 valency. It makes covalent bonds. It is also known as ***tetravalent***.

(2) **Skeleton of Organic Compounds:** Carbon is skeleton of organic compounds. Carbon is basic element of organic compound. It is ***central element*** of organic compounds.

(3) **Tetrahedron:** The arrangement of carbon to ***four bonds*** symmetrically with four atoms is called tetrahedron.

(4) Stability: Carbon is suitable element for the synthesis of cellular structures due to having *stable configuration.*

(5) Rings and Branches: Ringed and branched structures are easily and comfortably formed by carbons.

(6) Combinations: C generally combines with H, O, N, P and S for the formations of different organic compounds.

(7) C-H Bonds: Carbon and hydrogen bonding is a *good source of energy* for cellular activity.

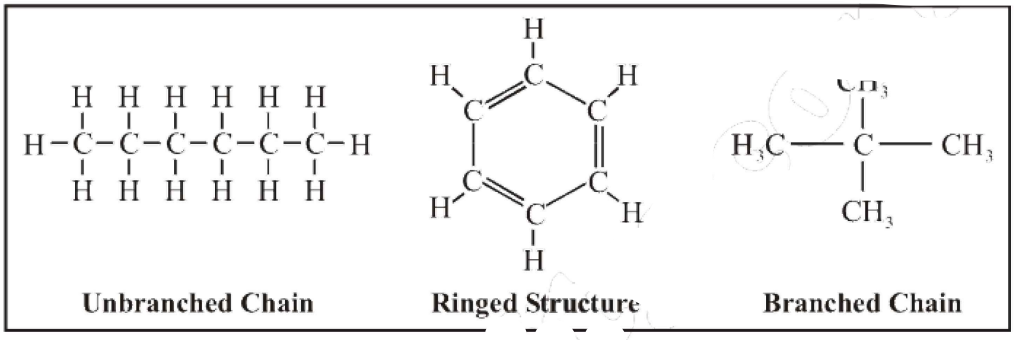


Fig. Unbranched and branched chains, and ring structures formed by C-C bonds.

(8) Glycosidic Linkage (*C-O association*): In carbohydrates, carbon and oxygen linkage provides stability to molecules. The C-O association in carbohydrates is called glycosidic linkage. When two monosaccharides combine, they linked by glcosidic bonding.

(9) Peptide Bonds: The linkage of C-N between the amino acids in protein is known as peptide linkage or peptide bonding.

(10) Macromolecules: ***Proteins, polysaccharides*** *and* ***fats*** *etc. are macromolecules.* They are generally insoluble in water. They form structure of cells In these long and ring structures molecules carbon play an important role of skeleton stability.

(11) Small Molecules: ***Glucose, amino acids*** *and* ***fatty acids*** *are small molecules.* These are sub units of polysaccharides, proteins and lipids respectively. These are unstable. Due to immediately break down, they release energy i.e. ATP. So they provide immediate source of energy for metabolism.

Q.4 What is the importance of H_2O in metabolism? (OR) Describe the importance of H_2O in life. (OR) How is water effective for metabolic processes?

Ans. **IMPORTANCE OF WATER**

(1) Medium of Life: It is found 65 to 90% in different cells of different organisms. It is most abundant in all cells or organisms. All reactions take place in H_2O of cells.

It is 20% in bone cells of man and 85% in human brain cells. Active tissues have more water than inactive ones.

(2) Raw Material: It is raw material of photosynthesis.

(3) Best Solvent: Water acts as solvent for metabolic reactants. It is known as the best solvent. More substances dissolve in it than any other solvent.

Water is *polar*, so it dissociates the ionic substances into +ve and –ve ions. But non-polar organic molecules are insoluble in water. While in case of ionic substances, water molecules behave like dipoles. Water is oriented toward both +ve and –ve ions, this is the *property* ability of water to act as a solvent. Positive and negative ions in a crystal lattice can be approached by dipolar water molecules and brought into solution.

(4) Heat Capacity: Water absorbs heat. When it absorbs heat, very minute temperature of water is changed. So water provides stability to the temperature of an organism in its environment. Water *protects* living material against temperature change. ***H_2O keeps the temperature of an organism relatively constant.***

Actually, water works as ***"Temperature Stablizer"*** for energy is used to break hydrogen bonds.

"The specific heat capacity of water is the number of calories required to raise the temperature of 1 g of water from 15 to 16°C 1.0". It is due to much of energy is used to break hydrogen bonds.

(5) Heat of Vaporization: Water absorbs much heat as it changes from liquid to gas.

Heat of vaporization is expressed as calories absorbed per gram vaporized. The specific heat of ***vaporization of water is 574 Kcal/kg***, which plays an important role in the regulation of heat produced by oxidation. It also provides ***cooling effect*** to plants when water is transpired, or to animals when water is respired.

Evaporation of only two ml out of one liter of water, lowers the temperature of the remaining 998 ml by 1°C.

(6) Ionization of Water: The water molecules ionize to form H^+ and OH^- ions.

$$H_2O \rightleftharpoons H^+ + OH^-$$

This reaction is reversible but an equilibrium is maintained. At 25°C the concentration of each of H^+ and OH^- ions in pure water is about 10^{-7} mole/litre. The H^+ and OH^- ions affect, and take part in many of the reactions that occur in cells.

(7) Protection: Water is effective ***lubricant*** that provides ***protection against damage*** resulting from friction. For example, tears protect the surface of eye from the rubbing of eyelids, water also forms a fluid cushion around organs that helps to protect them from trauma (shock).

Q.5 What are carbohydrates? Give their types in detail.

Ans. **CARBOHYDRATES**

Definition: "Carbohydrates are the organic compounds which are composed of carbon, hydrogen and oxygen".

Chemically: "Carbohydrates are defined as *polyhyaroxy aldehydes or ketones which on hydrolysis produce* polyhydroxy aldehyde or ketone subunits."

General Formula: Their general formula is $C_x(H_2O)_r$, where x=3 to many thousands.

Presence: Carbohydrates are found abundantly in

CLASSIFICATION OF CARBOHYDRATES:

Carbohydrates are also known as "**saccharides**" (drived from Greek word "sakcharon" means "sugar".)

They are classified into following three groups:

(1) Monosaccharides

(2) Oligosaccharides

(3) Polysaccharides.

**mono means one.*
**oligo means few.*
**poly means many.*
**saccharide means sugars.*

(a) **MONOSACCHARIDES**

(1) These are *simplest sugars.*

(2) They are sweet in taste and soluble in water.

(3) They *cannot be hydrolysed* into *simpler sugars.*

(4) All carbon atoms in a monosaccharides except one have a *hydroxy group.*

(5) The sugar with aldehyde group is called aldo sugar and with the *keto group* is keto sugar.

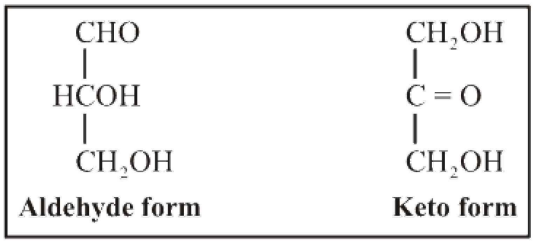


Fig. Structure of glyceraldehydes, a 3C Sugar ($C_3H_6O_3$). The aldehyde form is glyceraldehyde, whereas ketonic form is dihydroxyacetone.

(6) The aldehyde form is glyceraldehydes, whereas ketonic form is dihydroxyacetone.

(7) The number of carbon atom varies from "3" to "1 in monosaccharides. They are called trioses (3C), tetroses (4C), pentoses (5C), hexoses (6C) and heptoses (7C).

(8) They have the general formula $(CH_2O)_n$. *Tetroses are rare in nature and occur in some bacteria. However, pentoses and hexoses are most common.*

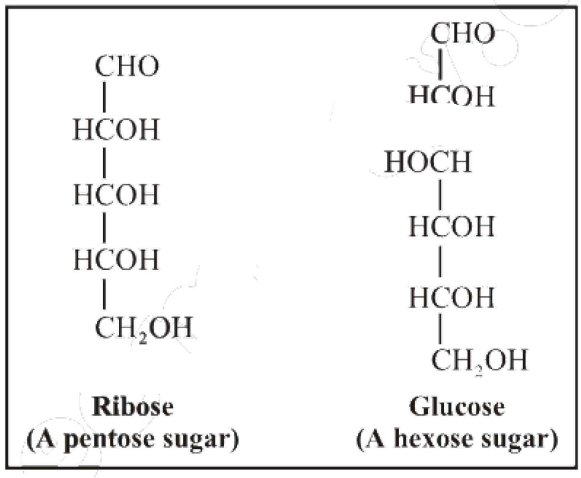


Fig. Structure of Ribose and Glucose

(9) Monosaccharides also form ringed structures e.g. ribose will form a five corner rings known as ***ribofuranose*** where as glucose will form six corner ring known as ***glucopyranose***.

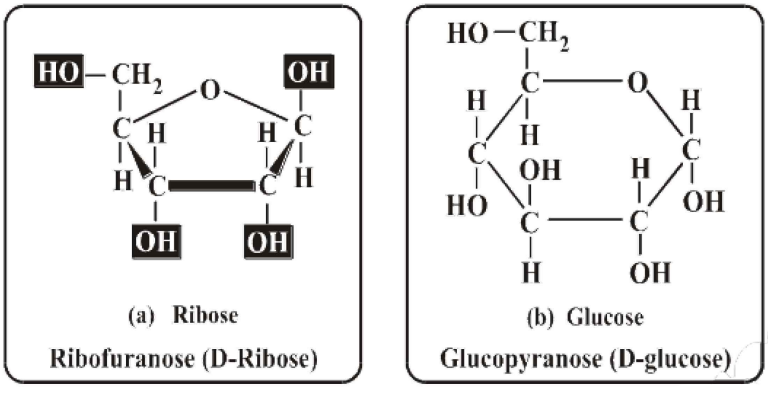


Fig. Ribose and glucose form ring shaped structure

(10) Glucose is present in all fruits e.g. grapes, figs and dates. Our blood normally contains 0.08% glucose. As a result of photosynthesis, glucose is synthesized in all green plants.

Sunlight

$$6CO_2 + 12H_2O \longrightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Chlorophyll Glucose)

(b) OLIGOSACCHARIDES

(1) The oligosaccharides *yiled 2-10 monosaccharides* on hydrolysis.

(2) These are ***less sweet*** in taste and less ***soluble in water***.

(3) The oligosaccharides, which yield two monosaccharides are known as *disaccharides,* those vielding three are known as *trisaccharides* and so on.

(4) The *covalent* bond between two monosaccharides is called ***"glycosidic bond"***. Maltose, sucrose and lactose are examples of disaccharides.

(5) The common table sugar i.e. sucrose on hydrolysis yield glucose and fructose.

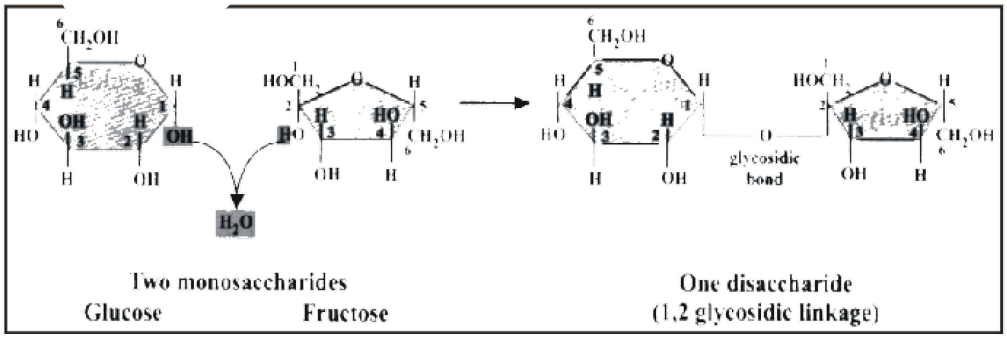


Fig. A disaccharide. Note carefully the between two monosaccharides glycosidic linkages

POLYSACCHARIDES

He carbohydrates which are *formed by* ***several monosaccharides*** units linked by glycosidic bonds are known as polysaccharides":

(1) They have higher molecular weights and are ***sparingly soluble in water*** e.g. starch, glycogen, cellulose, pectin and chitin.

(2) These are normally ***branched*** and ***tasteless***.

(a) STARCH

It is found in *seeds, grains tubers and fruits*. It is one of the main source of carbohydrates for animals. It yields glucose, molecules on hydrolysis. *It gives blue colour with iodine.*

Types of Starches: There are two types of starches:

(i) Amylose: They have ***unbranched chains*** of glucose and are ***soluble in hot water*** only.

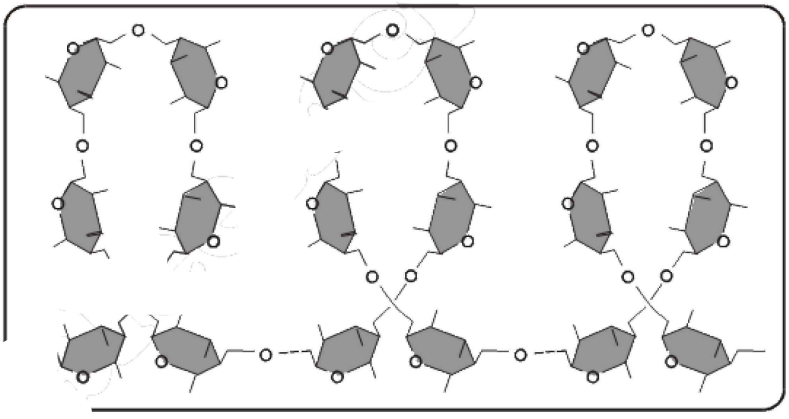


Fig. Polysaccharides are polymers of monosaccharides

(ii) Amylopectin: They have ***branched chains*** and are ***insoluble in water***.

(b) GLYCOGEN

(1) It is the chief form of carbohydrates stored in animal bodies and that is why it is also called ***animal starch***.

(2) Mostly it is found ***in liver and muscular cells***.

(3) It also ***yields glucose*** units on hydrolysis.

(4) It is ***insoluble*** in water.

(5) And gives ***red color with iodine***.

(c) CELLULOSE

(1) It is the most abundant carbohydrates in nature because it is the *major* ***constituent of cell walls*** in plants.

(2) On hydrolysis, it also yields glucose units e.g. cotton is insoluble in water.

(3) It is ***insoluble*** in water.

(4) It is *not digested in human* digestive tract.

(5) In herbivores it is digested because of microorganisms (bacteria, yeast and protozoa) and enzyme ***cellulase in*** their digestive tract.

(6) *Cellulose gives* ***no color with iodine.***

Q.6 Define lipids. Give the details its kinds with examples.

Ans. LIPIDS

"Lipids are hydrophobic compounds and are the basic components of cellular membranes". They store energy because of C-H linkage in them. *These are also related to fatty acids*. They are *insoluble* in water but *soluble in organic solvents* such as ether, alcohol, chloroform and benzene.

Examples: Examples of lipids are fats, oils, waxes etc.

CLASSIFICATION OF LIPIDS:

Lipids can be classified into following groups:

(i) Acylglycerol	(ii) Waxes	(iii) Sphingolipids
(iv) Phospholipids	(v) Glycolipids	(vi) Terpenoids

(i) Acylglycerol:

They are composed of glycerol and fatty acids. The most commonly used acylglycerol is "**triacylglycerol**". It is also known as neutral lipids or triglyceride. On chemical basis the acylglycerol can be defined as "**the esters of fatty acids and alcohols**". An acid is produced by the action of acetic acid and ethanol i.e.

$$C_2H_5OH + CH_3COOH \longrightarrow C_2H_5COOCH_3 + H_2O$$

(ethyl alcohol) (acetic acid) (ethyl methyl ester)

The fatty acids are of the most important compounds of triglycerides. *They contain 4-30 carbon atoms in their straight chains.* They may contain *no double bond* (saturated fatty acids) or up to 6 double bonds (unsaturated fatty acids). *In animals the fatty acids may be unbranched while in plants these may be branched or ringed.*

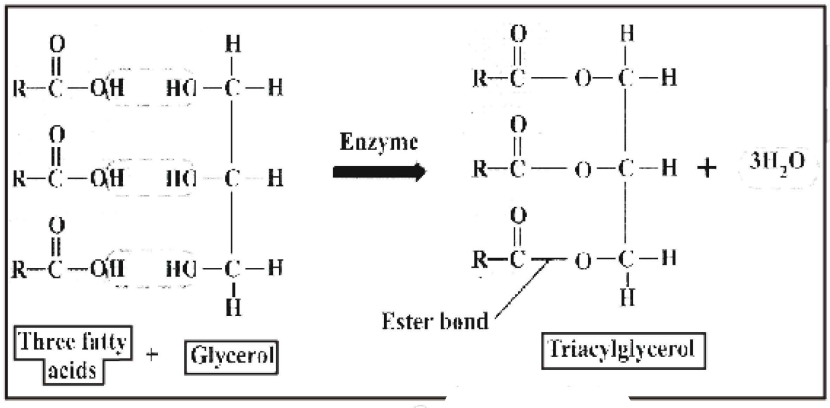


Fig. Triacylglycerol is composed of one glycerol and three fatty acids molecules

The solubility of fatty acids and their melting points in organic solvents increase with increasing number of carbon atoms in chain e.g. palmitic acid, C_{16}(63.1°C) is more soluble inorganic solvents than butyric acid, C_4(-8°C).

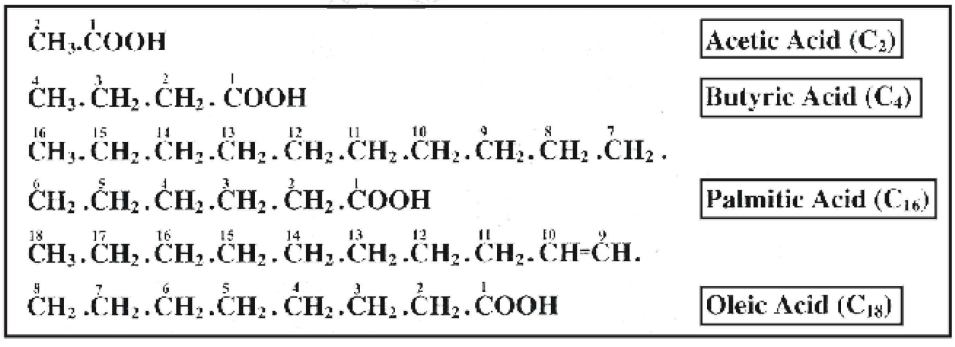


Fig. Some fatty acids with carbon numbers 2-18 are shown. Oleic acid is an unsaturated fatty acid (note a double bond between C_9 and C_{10}) other fatty acids are saturated.

One thing is very important that higher fat contents causes slower movement of feces through the alimentary canal. Thus, the bacteria present in the food convert the fat into "**Cancer causing compounds".** There are two broad types of fatty acids i.e.

(a) Oils:

Fats containing unsaturated fatty acids are usually liquids at room temperature and are said to be oils.

(b) Solids:

Fats containing saturated fatty acids are solids. Animal fats are solid at room temperature whereas, most of the plant fats are liquids. They have specific gravity of about 0.8. Normally, they are not crystalline but can be made crystalline under specific conditions.

(ii) Waxes:

Waxes are mixtures of long chain alkanes and alcohols, ketones and esters of long chain fatty acids. The carbon atoms in the chain are always in odd number ranging from C_{25} to C_{35}.

Functions:

(1) They are wide spread as **protective coatings** on fruits and leaves. Some insects also secrete wax.

(2) They protect plants form water loss and abrasive damage.

(3) They also provide **water barrier** for insects, birds and animals like sheep.

(iii) Phospholipids:

These are composed of glycerol, fatty acids and phosphoric acid linked with nitrogenous bases such as ***choline, ethanolamine*** and ***serine***. In other words, the phospholipids are derivatives of phosphatidic acid. Phosphatidicholine is one of the common phospholipids. They are wide spread in bacteria, animal and plant cells.

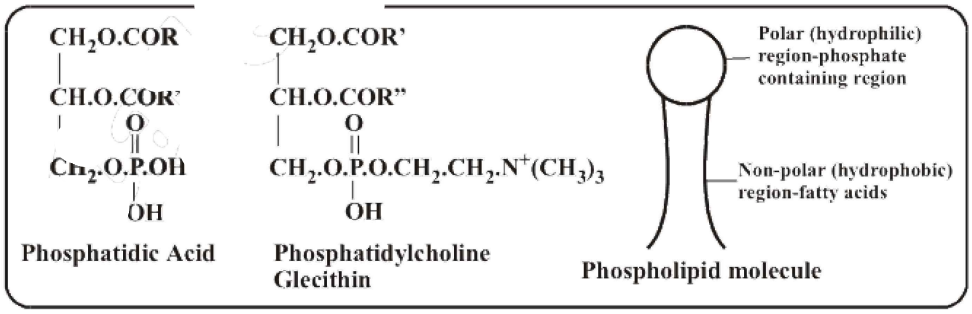


Fig. Phosphatidic acid is composed of glycerol, 2 fatty acids (on C1 and C2), and a phosphoric acid on C3 of glycerol. In phospholipids a nitrogenous base (e.g. choline) is attached to phosphoric acid in phosphatidic acid.

(v) Terpenoids:

They are important compounds and are wide spread. They are made up of simple repeating units called "**isoprenoid unit**". ***Rubber, carotenoids, steroids*** and ***terpenes*** are examples of terpenoids.

HELP LINE

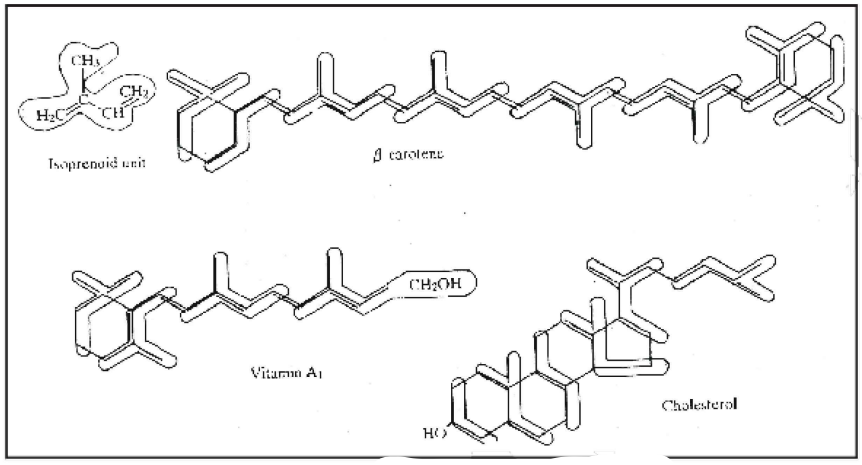


Fig. Some terpenoids formed by condensation of isoprenoid units

Q.7 What are proteins? Describe their important functions.

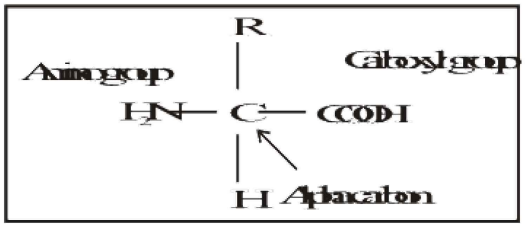
Ans. **PROTEINS** ***Consult Q.10***

Q.8 What are the amino acids? Describe its general formula and its role in protein.

Ans. **AMINO ACIDS**

"Amino acid has an amino group (**-NH₂**) and a carboxylic group (**-COOH**) attached to the same carbon, also known as alpha carbon".

General Formula: Following is the general formula of an amino acid:



Where "R" may be a hydrogen atom as in glycine or CH_3 in alanine. The amino acid differ due to the R-group. (i.e., alkyl group).

Role of Amino Acid in Protein:

About 170 amino acids have been found to occur in cells and tissues of these, about 25 are constituents of proteins. However, most of the proteins are made up of 20 types of amino acids. The amino acids are linked to form polypeptide proteins by peptide bonds. The amino group of an amino acid may react with the carboxyl group of another releasing a molecule of water.

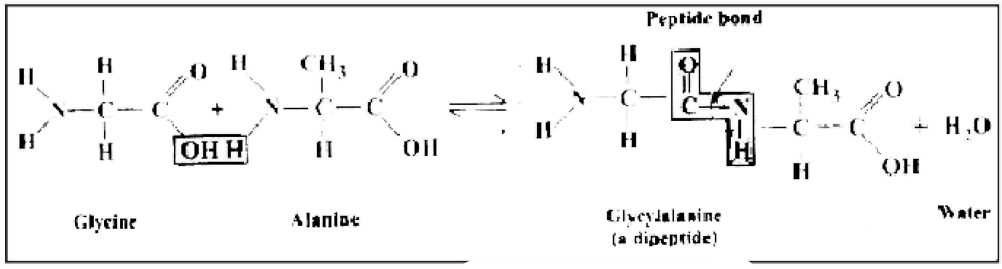


Fig. Peptide linkage-formation of peptide bond

Q.9 Classify p`roteins into major categories. (GRW-06)

Ans. **CLASSIFICATION OF PROTEIN**

Protein classification is rather difficult due to complexity in structure. However, following 2 categories can be diversified:

(a) FIBROUS PROTEINS:

They show following characters.

(i) Polypeptide Chains: They consists of polypeptide chains in the form of fibrils.

(ii) Insoluble: They are insoluble in aqueous media.

(iii) Non-Crystalline: They are non crystalline and are elastic in nature.

(iv) Structural Roles: They play structural roles in cells and organisms. For example, the secondary structure of protein, silk fibers, ***myocin, fibrin*** and ***keratin*** etc.

(b) GLOBULAR PROTEINS:

They have following main characters:

(i) ***Folding of Polypeptide:*** They are spherical or ellipsoidal due to multiple folding of polypeptide chains.

(ii) ***Soluble:*** They are soluble in aqueous media such as salt solution, acids, bases or alcohols.

(iii) ***Crystallized:*** They can be crystallized and disorganized in the physical environment.

For Example: Protein tertiary structures, enzymes, antibodies, hormones, haemoglobin etc.

Q.10 ***(a) Define protein, amino acid.***

(b) What types of elements are found in proteins?

(c) Discuss function of proteins.

(d) Describe structural kinds of proteins.

Ans. (a) (i) PROTEIN

"The organic compound in which polypeptide chains are formed by the peptide linkage among the amino acids is called protein".

(ii) AMINO ACID

Amino Acids are the basic units of protein in which **carboxyl group** and **amino group** are essential components.

(b) ELEMENTS OF PROTEINS

All proteins contain *carbon, hydrogen, oxygen, nitrogen,* and usually sulfur and some have *phosphorus*. Proteins are made up of chain of amino acids. They amino acids of a protein are united to one another by their respective amino carboxyl groups, forming peptide bonds.

(c) FUNCTIONS OF PROTEIN

"Protein is the structural and functional unit of the cell".

(i) As Enzyme: All enzymes are proteins. Enzymes speed up the chemical reactions. e.g. ***Pepsin, lipase, amylase*** etc.

(ii) As Hormones: Those proteins which regular and control the metabolic process are considered as hormone. e.g. ***Insulin*** etc.

(iii) O_2 Carrier: ***Haemoglobin*** is the protein which transports oxygen.

(iv) Antibodies: These are proteins which defend against the disease causing organisms.

(v) Blood Clotting: ***Fibrinogen*** is a blood clotting protein. It prevents the loss of blood in case of injury.

(vi) Contraction and Relaxation: Muscles have ***Myosin*** and ***actin*** which are contracting and relaxing bonds

(vii) Structure of Chromosome: ***Histone*** protein forms the structure of chromosome.

(viii) Structure of Cell Membranes: The membranes of cells and organelles are formed by (lipid and) proteins.

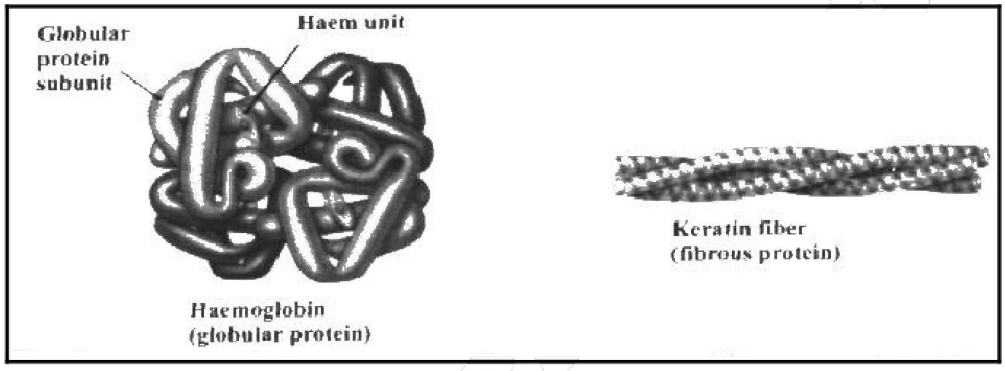


Fig. Polypeptide chains in keratin (fibrous protein) and in hemoglobia (globular protein) are held together to form respective functional proteins.

Q.11 Differentiate between Glycosidic linkage and peptide bonding.

Ans. Glycosidic Linkage takes place among the monosaccharides for the *preparation of oligosaccharides and polysaccharides of carbohydrates*. Glycosidic linkage (bonding) has two kinds E.g. *(1-4) glycosidic linkage and (1-6) glycosidic linkage.*

In case of 1-4 glycosidic linkage unbranched chains of carbohydrates are formed. While 1-6 glycosidic linkage form a branch on linear chain.

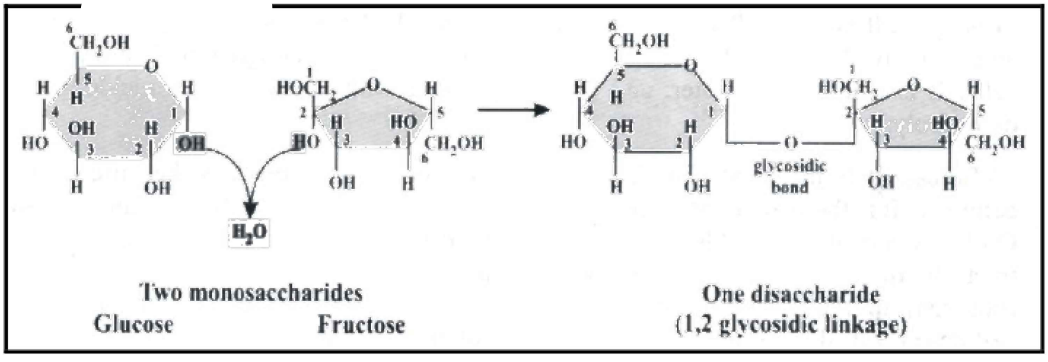


Fig. A disaccharide. Note carefully the glycosidic linkages between the two monosaccharides.

PEPTIDE LINKAGE: The bond which is formed ***between amino group and carboxyl group*** of two amino acids is called peptide linkage or peptide bonding. In this case, bond is formed between C and N of carboxyl group and amino group. Peptide linkages form the ***polypeptide chains*** of proteins.

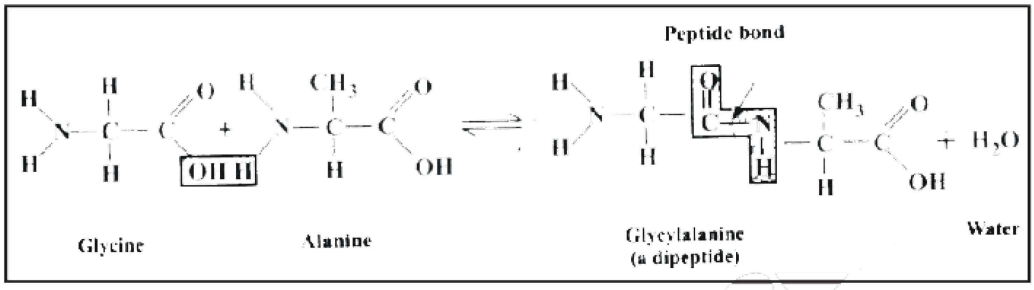


Fig. Peptide linkage-formation of peptide bond

Q.12 Define the followings

Ans.

(a) Fatty Acids: The organic compounds with *monocarboxylic acid* and straight chain of 4 to 30 carbons are called fatty acids.

Fatty acid = Monocarboxylic acid + 4 to 30 carbon chain

(b) Waxes: The organic compound in which *C_{25} to C_{35} long chain alkanes* with odd carbon numbers have oxygenated derivatives such as secondary alcohols and ketones, are called waxes.

(c) Phospholipid: The kind of lipids in which key components i.e. ***glycerols, fatty acids and nitrogenous base*** also have phosphorus atom is called phospholipid.

(d) Glycolipids: The association of lipids with carbohydrates is called glycolipids.

(e) Sphingolipids: The kind of lipid in which *central compound is 4-sphingenine,* these lipids are closely associated with animal membranes and nerve tissues.

(f) Terpenoids: The organic compounds of lipid company which *have repeating isoprenoid units.*

CONCEPTIONAL VIEW

Q.13 What do you know about bonding of amino acids in proteins?

Ans. BONDS INVOLVE IN PROTEINS:

(1) Covalent Bond:

Each amino acid has central carbon which is attached to $-NH_2$, -COOH and –H with three sides by covalent bond. These (atoms or) molecules have covalent linkage to each other or itself. In amino acid, the only fourth position is variable. It is R group. R group of amino acid is called variable group.

(2) Peptide Bond:

A covalent bond between $-NH_2$ and –COOH of two different amino acid is called peptide bond. The elimination of H_2O by the bonding of $-NH_2$ and -COOH is called condensation.

(3) Ionic Bond:

Acidic and basic (R) groups exist in an charged state at different pH. Acidic R is +vely charged while basic R is –vely charged. When acidic R and basic R meets the ionic bonding occurs. In aqueous environment, ionic bonds are weaker due to this reason they may be broken by pH changes.

(4) Disulfide:

These bonds make the molecules fold into a particular shape. These are strong. Disulphide forms between different chains or in the same chain. In this case, R group has –SH (sulphidryl) group. So two molecules of –SH group line up (oxidized) and form disulphide bond.

(5) Hydrogen Bonding

Hydrogen bonding is weaker. But H bonding present frequently. It produces helix structure in polypeptide chain. In it, hydrogen is attracted towards a neighboring electronegative O or N. H bonding provides stability to structure.

-O---H……O

---O---H……N

---O---H……O

---O---H……N

H-bonds

(6) Hydrophobic Interactions:

Some R group of amino acids are non polar, so they are hydrophobics. Hydrophobics means water hating. In chain, the hydrophobic groups tend to point inwards towards the center of molecule in aqueous medium. While hydrophilic groups

(H_2O loving) face outwards into the aqueous medium.

(d) KINDS OF STRUCTURE OF PROTEINS

Primary Structure:

"The sequence of amino acids in a polypeptide chain is called primary structure".

F. Sanger was first worker who described the sequence of amino acids in protein. proteins have ***specific arrangements*** of amino acids along its chains. today, one hundred thousand protein primary structures are known.

There are thousands of different proteins in the human body. These proteins have different arrangements of 20 amino acids. Total kinds of amino acids are 20 which form proteins. But each protein has specific kinds, particular arrangement and certain number of amino acids. Alteration of a single amino acid from its specific position becomes the reason of abnormal function.

For example, haemoglobin protein has ***574 amino acids***. If a single amino acid is replaced from its normal place the function of hemoglobin is disturbed. Hemoglobin carries oxygen. So ***sickle cell anaemia*** occurs if only one amino acid is replaced from its proper place in hemoglobin.

Concept of Primary Structure:

(i) "It is defined as the linear sequence of amino acids in the polypeptide chain".

(ii) "No other forces or bonds are indicated by the term "primary structure".

Secondary Structure·

The term "secondary structure" refers to ***regular folding patterns of contiguous portions of polypeptide chain***. This structure includes coil into helix. In other words α-helix and the β-pleated sheets are formed and bonds occur.

α-helix means chain rotates clock wise.

α-helix has 3.6 amino acids per turn.

β-pleated sheets represent hydrogen bonding.

So β-pleated sheets structure, like the α-helix, allow to maximum amount of H-bonding.

O
||

In this consideration, ***H-bonding*** occur between –C– and NH–. So the stable and rigid structure is called β-pleated sheet.

Tertiary Structure:

This term refers to ***three dimensional structure***. The bonds between the amino acids are distant from each other in polypeptide chain.

Usually the chain bends and folds extensively, forming a compact globular shape.

This structure is maintained by four types of bonds, ***ionic, hydrogen, disulphide bonds and hydrophobic interactions***. In aqueous surrounding ***hydrophilic*** amino acids side chain exposes, while hydrophobic amino acids side chain buried inside.

This is the proteins Tertiary Conformation. The term "conformation" refers to the secondary and tertiary structure jointly.

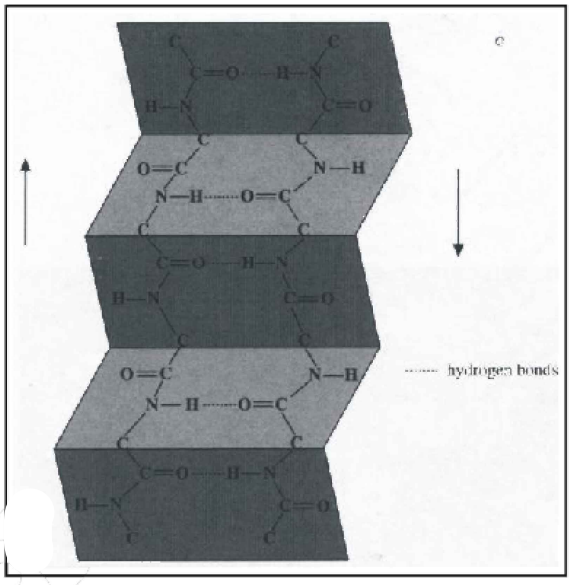


Fig. β-pleated sheet. The chains are held parallel to each other by the hydrogen bonds that form between the NH and CO groups. The side groups (R) are not shown but would project above and below the plane of the sheet.

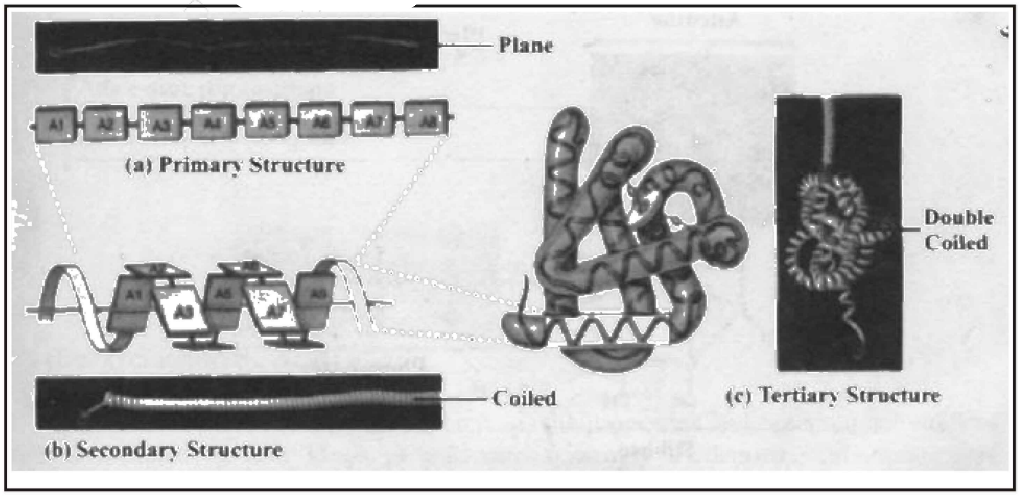


Fig. Three levels of protein structures compared with a telephone wire.

ITEMS FOR SPECIAL ATTENTION

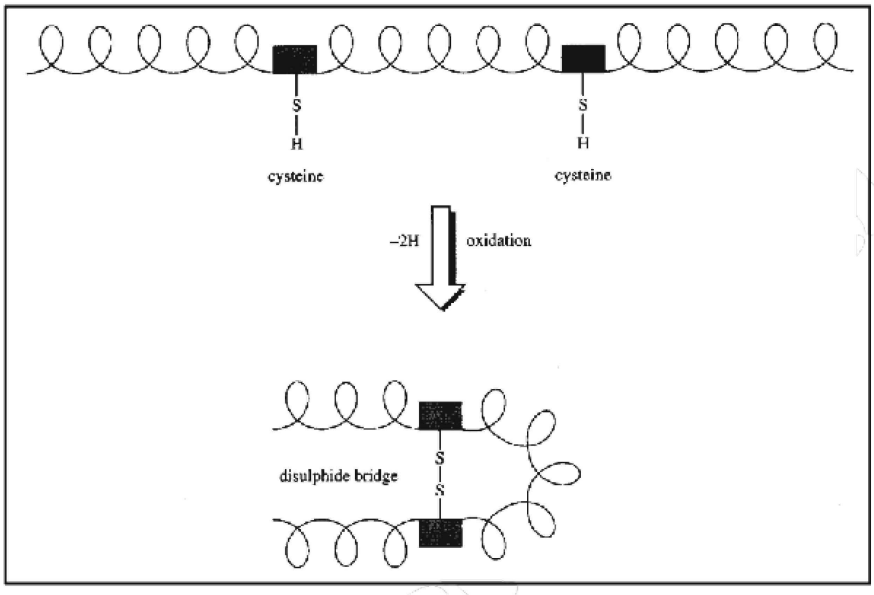
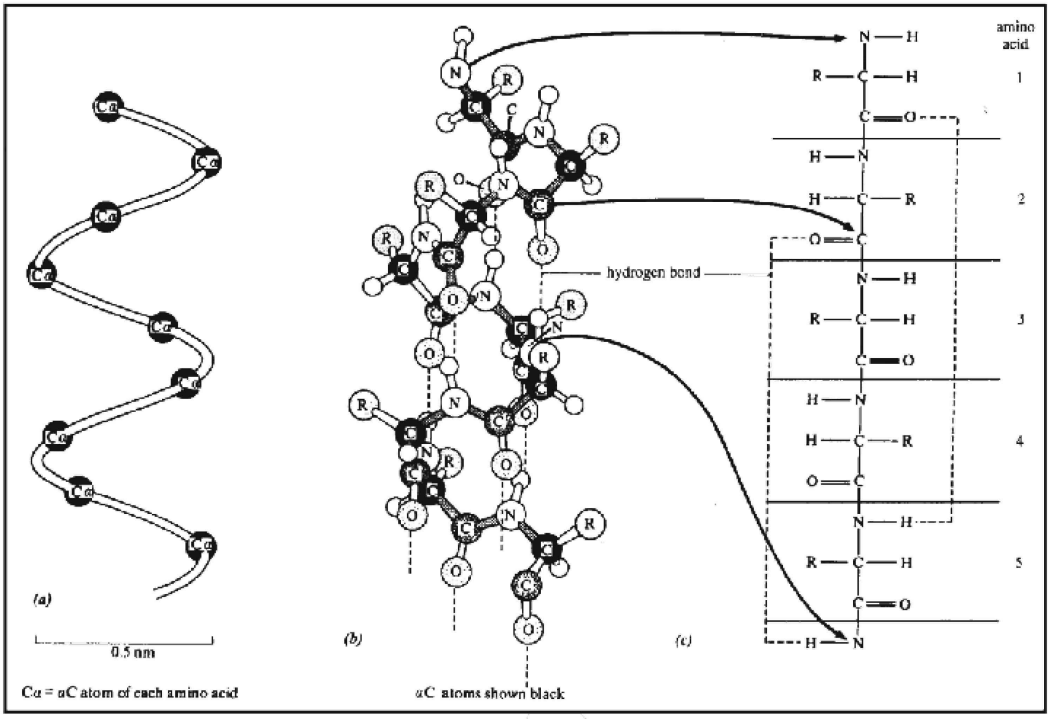


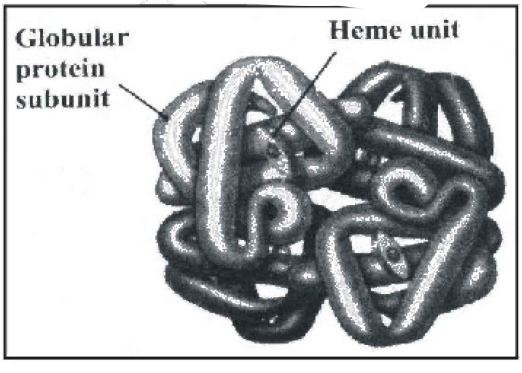
Fig. Formation of a disulphide bond between the sulphydryl groups of two cysteines.



Quarternary Structure:

"The separate chains are held togetner by hydrophobic interactions, ionic ***bonds and hydrogen bonds*** is known as quarternary structure".

Hemoglobin having quarternary structure, consisting of two identical and chains and two identical β chains.



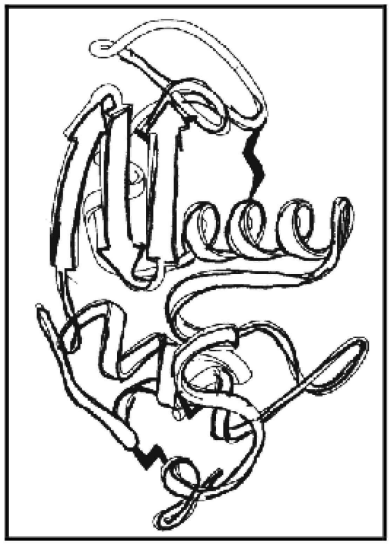


Fig. Tertiary structure of lysozyme. The arrows represent a region of β sheet. α helices are shown as regular coils. The rest of the molecule is represented as a ribbon and the four disulphide bridges as black zig-zags (compare fig.)

Carbohydrates:

(1) The skeleton carbons of carbohydrates have (H-C-OH) polyhydroxy groups. OR-All contain several hydroxyl groups.

(2). All carbohydrates are (C=O) aldehyde H or (C=O) ketones |

(3) It contains C, H and O. General formula is $C_nH_2O_n$.

Structure of a haemoglobin. The molecule consists of four chains and two b chains. Each chain carries a haem to which one molecule of oxygen binds. The assembly of a protein from separate polypeptide chains is an example of quaternary structure.

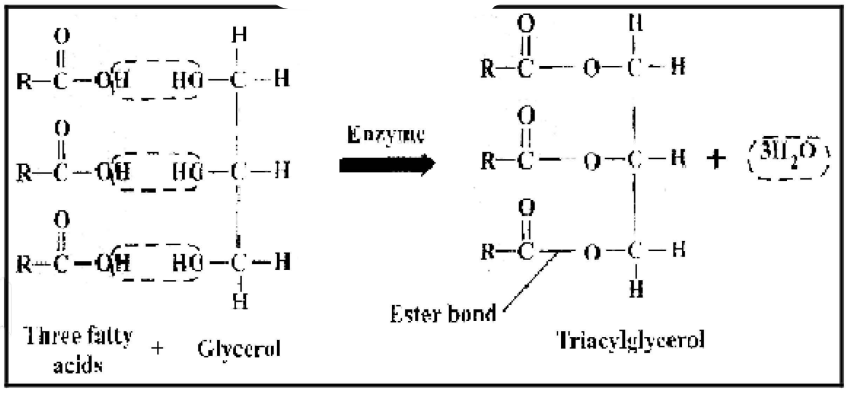
Lipids:

(1) True lipids are formed by condensation reactions between fatty acids and alcohols.

(2) Carbohydrates, phosphate group, alkanes. alkenes etc may be additional component.

Q.15 What are the key components of lipids?

Ans. ***Fatty acids, glycerols*** and ***estrification*** are key components of lipids.



Q.16 What are the key components of carbohydrates and proteins?

Ans. The key components of carbohydrates are ***polyhydroxy, aldehydes*** or ***ketones***.

The key components of proteins are ***amino acids*** while amino acids have carboxyl group. ***Amino group*** and H with ***alpha carbon*** are as key component.

Q.17 Define the Followings: **HELP LINE**

Ans. Amino Acids:

The basic units of proteins in which alpha carbon (central) is always attached to _COOH carboxyl group, Amino (-NH_2) group and hydrogen (-H) are called amino acids.

Condensation:

Elimination of water between amino group and carboxyl group of amino acids is called condensation.

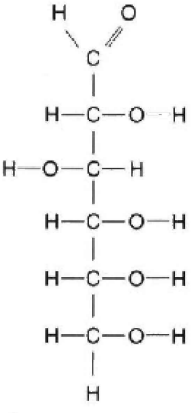
Peptide Bond:

The covalent bond between amino group (-NH_2) of one amino acid and carboxyl (-COOH) of another amino acid is called peptide bond or peptide linkage.

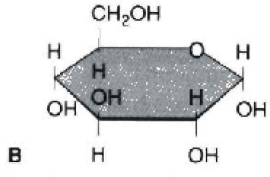
FOR CONCEPT ONLY

Q.18 Write any five examples of carbohydrates with structural formulae:

Ans. Structural formula shows the actual places of atoms and arrangement of molecule.

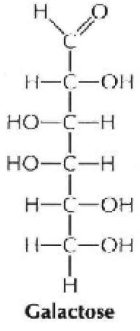


A

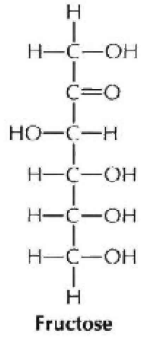


B

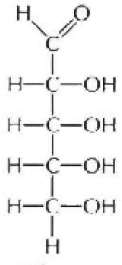
Two ways of depicting the structural formula of the simple sugar glucose. In **A**, the carbon atoms are shown in open-chain form. When dissolved in water, glucose tends to assume a ring form as in **B**. In this ring model the carbon atoms located at each turn in the ring are usually not shown.



Galactose

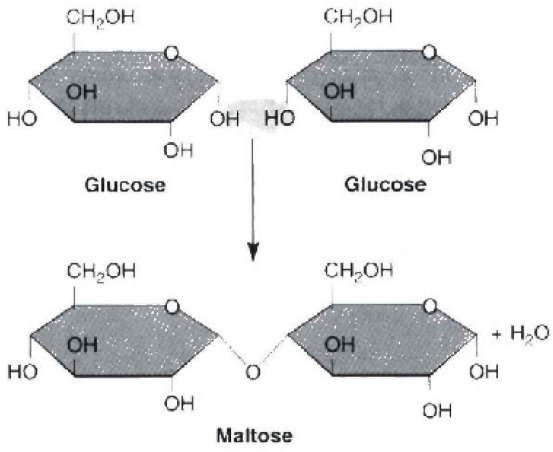


Fructose



Ribose

These two hexoses and a pentose are common monosaccharides. Galactose and ribose are aldehyde sugars; fructose is a ketone sugar.



Formation of a double sugar (disaccharide maltose) from two glucose molecules with the removal of one molecule of water. This type of reaction is a condensation reaction. The reverse reaction, adding a molecule of water to maltose and forming two glucose molecules, is a hydrolytic reaction.

Q.19 What are nucleic acids? Differentiate between RNA and DNA.

Ans. **NUCLEIC ACID (DNA & RNA)**

"The macromolecules which are essential contributors in reproduction, genetic control, biosynthesis are called nucleic acid".

F.Miecher in 1870 discovered "nucleic acid" from the nuclei of PUS cells, for the first time in history. Due to their isolation from nuclei and other acidic nature, they were named as 'Nucleic Acids'

Types of Nucleic Acids

There are following two types of Nucleic acids"

(i) DNA (ii) RNA

(i) DNA stands for (Deoxyrido Nucleic Acid).

(ii) RNA stands for (Ribonucleic Acid).

DNA	RNA
(1) DNA occurs ***in chromosomes***, in the nuclei of cells, in ***mitochondria*** and ***chloroplasts***.	(1) RNA is present in the *nucleolus*, in the ***ribosomes***, in the ***cytosol*** and in smaller in other parts of cell.
(2) It is made up of deoxyribo nucleotides.	(2) It is composed of *ribonucleotides*.

(3) It contains ***deoxyribose sugar***.	(3) It contains ***ribose sugar***.
(4) DNA has ***double helical chain*** of nucleotides.	(4) RNA has ***single chain*** of nucleotides.
(5) It contains adenine, guanine, cytosine and ***thymine*** as nitrogen bases.	(5) It has ***uracil*** in place of thymine.

Q.20 Describe chemical composition of nucleic acids.

Ans. ***Nucleic acids*** are complex substances. They are polymers of nucleotides. Each nucleotide is made up of following three sub units:

(1) 5-Carbon monosaccharides (a "pentose" sugar).

(2) A 'nitrogen' base.

(i) ***Adenine*** [A]

(ii) ***Guanine*** [G] Larger units (purines)

(iii) ***Cytocine*** [C]

(iv) ***Thymine*** [T] or ***Uracil***) Smaller units (pyrimidines)

(3) Phosphoric Acid:

Phosphoric acid (H_3PO_4) has the ability to develop ***ester linkage with OH group*** of pentose sugar.

In a typical nucleotide, the nitrogen base is attached to position '1' of pentose sugar, while phosphoric acid is attached to carbon ***at position 3 of pentose*** sugar.

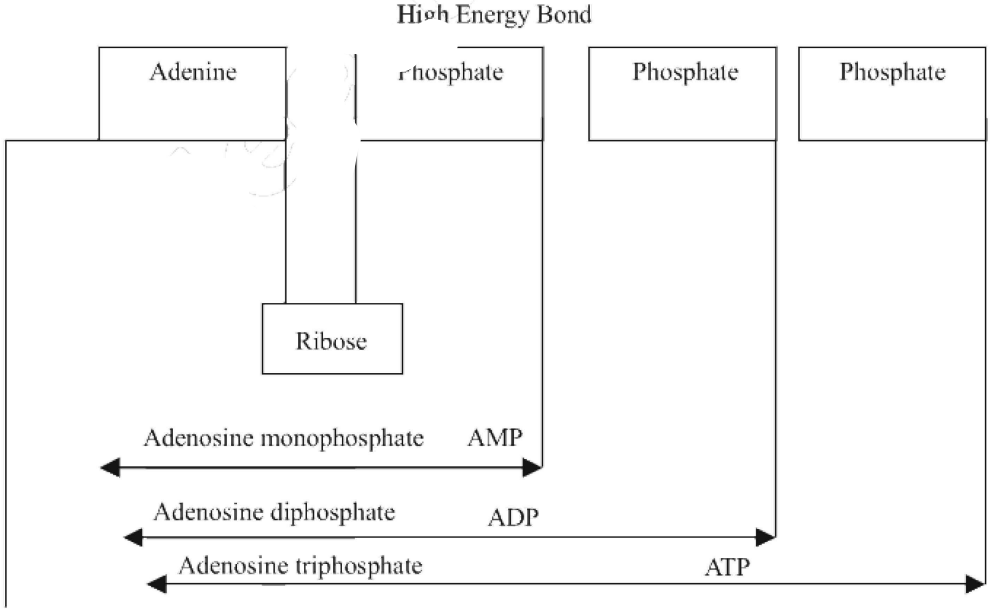


Fig. Showing Components of "ATP"

Nucleoside and Nucleotide:

The compound formed by a base and a pentose sugar is called ***nucleoside***.

A nucleoside and phosphoric acid combine to form a ***'nucleotide'***.

There are following four nucleotides, depending on the nitrogen bases:

Adenine + Sugar + Phospheric acid ⟶ Adenine nucleotide
Guanine + Sugar + Phosphoric acid ⟶ Guanine nucleotide
Cytosine + Sugar + Phosphoric acid ⟶ Cytosine nucleotide
Thymine + Sugar + Phosphoric acid ⟶ Thymine nucleotide

ATP is also an important nucleotide used as energy currency by cell.

Q.21 Write note on DNA. Also discuss various molecules of its structure.

Ans. **DNA (DEOXYRIBONUCLEIC ACID)**

DNA is the hereditary material and is transferred from parents to off springs.

It controls the activities of a cell.

DNA is made of following four nucleotides:

(i) d-adenosine monophosphate (d-AMP)

(ii) d-guanosine monophosphate (d-GMP)

(iii) d-cytidine monophosphate (d-CMP)

(iv) d-thymidine monophosphate (d-TMP)

Phosphodi-este[illegible]ges:

These nucleotides are united with one another through phosphodiester linkages.

NAD (Nicotinamide adenine dinucleotide) is an excellent example of ***dinucleotide***.

This is an important coenzyme in several oxidation-radiation reactions in the cell.

MODELS OF DNA STRUCTURES

(a) Chargaff's DATA: (*Ratio of Bases*)

Erwin chargaff in 1951 provided data about the ratios of different bases present in DNA molecule. The data suggested that adenine and thymine are equal in ratio and so are guanine and cytosine.

(b) Wilkins and Franklin's Technique: (*Structure*)

In 1995, Maurice Wilkins and Rosalind Franklin used the ***technique of 'x-rays diffraction'*** to determine the structure of DNA.

List of ribonucleotides and deoxyribonucleotides

		RNA		DNA
Nitrogenous base	Nucleosides (ribose + nitrogenous base)	Nucleotides (ribose + nitrogenous base + phosphoric acid)	Nucleosides (deoxyribose + nitrogenous base)	Nucleotides (deoxyribose + nitrogenous base + phosphoric acid)
Adenine	***Adenosine***	AMP, ADP, ATP	***d-Adenosine***	dAMP, dADP, dATP
Uracil	***Uridine***	UMP, UDP, UTP		
Guanine	***Guanosine***	GMP, GDP, DTP	***d-Guanosine***	dGMP, dGDP, dGTP
Cytosine	***Cytidine***	CMP, CDP, CTP	***d-Cytidine***	dCMP, dCDP, dCTP
Thymine			***d-Thymidine***	dTMP, dTDP, dTTP

Relative amounts of bases in DNA from various organisms (on percentage basis).

Source of DNA	Adenine	Guanine	Thymine	Cytosine
Man	30.9	19.9	29.4	19.8
Sheep	29.3	21.4	28.3	21.0
Wheat	27.3	22.7	27.1	22.8
Yeast	31.3	18.7	32.9	17.1

WATSON AND CRICK'S MODEL

In 1956, James D. Watson and Francis Crick built the scale model of DNA. Following are the important points of their model:

(1) 2-Polynucleotide Chains: DNA is made up of two polynucleotide chains or ***strands***.

(2) Antiparallel Coiling: The two strands are coiled round each other in the form of ***double helix***. This ***coiling is antiparallel***.

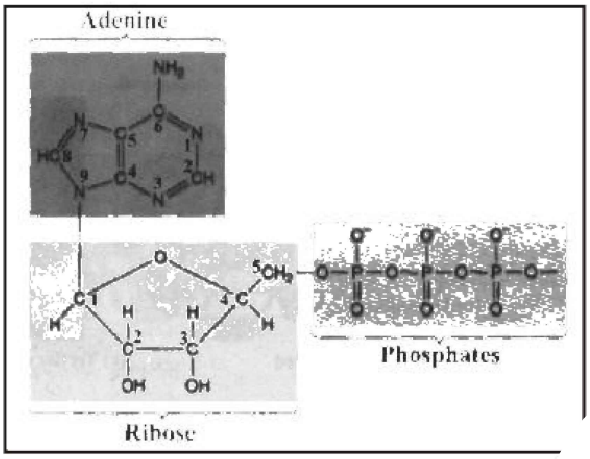


Fig. Structural formula of ATP (a nucleotide)

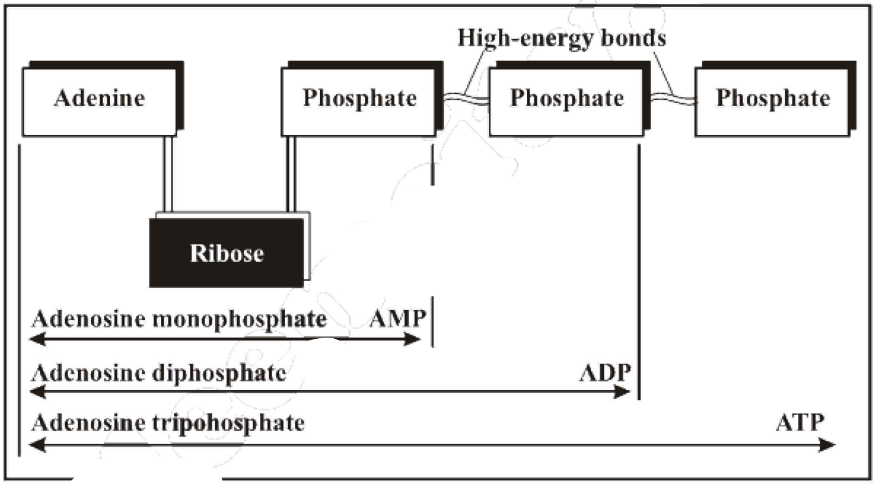


Fig. Components of ATP, nucleotide

(3) Hydrogen Bonding: The two chains are held together by weak bonds i.e. hydrogen bonds.

(4) Complements: Adenine (A) is always opposite to thymine (T), guanine (G) and cytosine (C) are opposite to each other.

(5) Specific H-bonding: There are two hydrogen bonds between 'A' and 'T' pair **A = T** and three hydrogen bonds between 'G' and 'C' pair **G ≡ C**.

(6) 10 Base Pairs in Each Turn: The two strands are coiled around each other so that there are 10 base pairs in each turn of about 34 Angstrom units (A°). One A° = one 100 millionth of a centimeter.

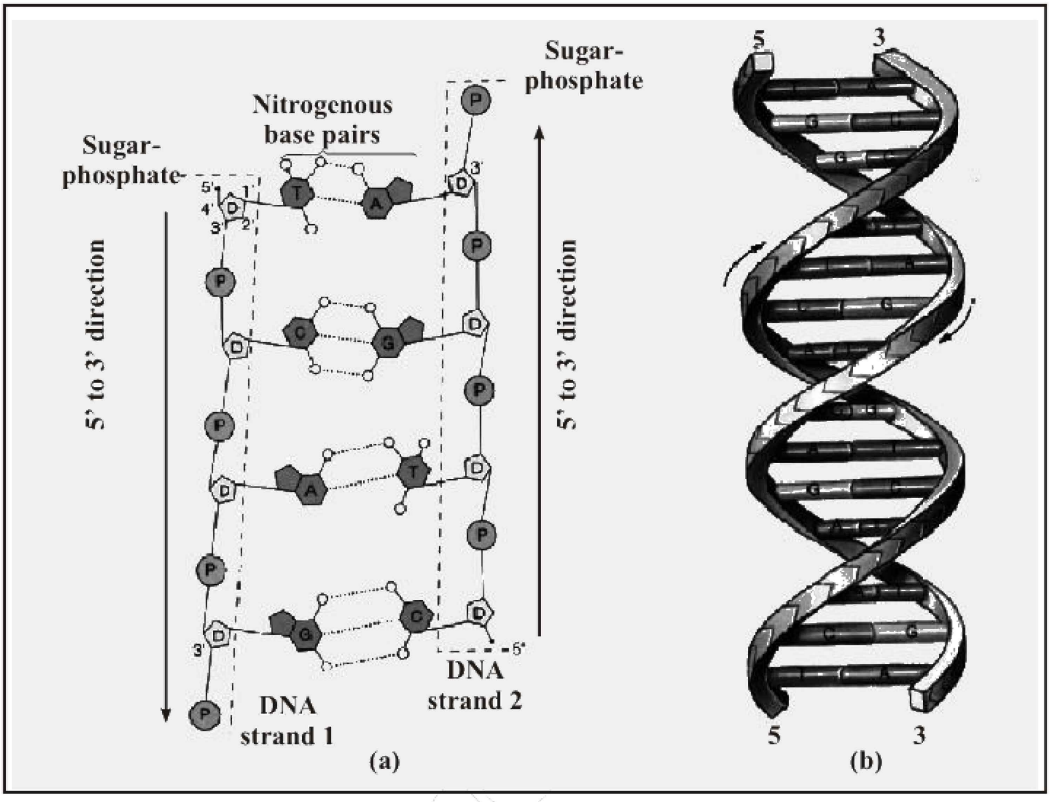


Fig. Model of DNA. Double helical structure of DNA proposed by Watson and Crick (b). A hypothetical sequence of nucleotides (on the left side) shows hydrogen bonding between the complementary bases. Note a double bond between. A and T, and triple bond between C and G (a)

Q.22 (a) What are the basic types of RNA and their role in protein synthesis?

Ans. **RNA (RIBONUCLEIC ACID)**

The molecules of RNA occur as single strand. This can be folded to give double helical characters. RNA is synthesized by DNA in a process known as "**transcription**".

Types of RNA:

Following are three different types of RNA:

(i) Messenger RNA (mRNA)

(ii) Transfer RNA (tRNA)

(iii) Ribosomal RNA (rRNA)

(i) mRNA (3-4%):

It takes the genetic message from the nucleus to the ribosomes in the cytoplasm to form particular proteins. This type of RNA consists of a single strand of variable length. Its length depends upon the size of the gene as well as the protein for which it is taking the message.

For Example:

For a protein molecule of 1,000 amino acids, mRNA will have the length of 3,000 nucleolides. mRNA is the most important type of RNA and is *about* ***3-4%*** of the total RNA in the cell.

(ii) tRNA (10-20%):

It transfers amino acid molecules to the site where peptide chains are being synthesized. The 'tRNA' *comprises about* ***10-20%*** of the cellular RNA. Its molecules are small, each with a chain length of 75-90 length nucleotides. Its main function is to pick up amino acids from cytoplasm and to transfer them to ribosomes.

(iii) rRNA (80%):

It is about ***80%*** of the total cellular RNA. It is mainly associated with the ***ribosomal protein***. It acts as ***bio-machinery*** for the synthesis of proteins.

Q.22 (b) Describe the conjugating molecules.

Ans. **CONJUGATING MOLECULES**

Two different molecules, belonging to different categories, usually combine together to form conjugating molecules:

(i) **Carbohydrates:** Carbohydrates may combine with proteins to form glycoprotein or with lipids to form glycolipids.

(ii) Most of the cellular secretions are ***glycoprotein*** in nature.

(iii) Both ***glycoprotein*** and ***glycolipids*** are integral structural components of ***plasma membrane***

(iv) Lipoprotein formed by combination of lipids and proteins are basic ***structural frame work*** of all types of membrane in the cell.

NUCLEIC ACID:

(i) Nucleic acids have special affinity for basic proteins.

(ii) They are combined together to form ***nucleoprotein***.

(iii) The nucleohistones are present in chromosomes.

(iv) These conjugated proteins are not only of ***structural*** but also are of functional significance. They play an important role in ***regulation of gene expression.***

SHORT QUESTIONS

Q.1 What are the amphoteric molecules? Give an example.

Ans. **Amphoteric Molecules**

A molecule which *contains both an acid and a basic part* are described as amphoteric molecule.

Example: Amino acid.

Q.2 How many bonds are used in protein structure?

Ans. **Bonds in Proteins**

Generally five types of bonds are used in the structure of proteins:

- Amino acids combine to form proteins.
- Amino acids are joined together by a type of bond known as Peptide Bond.
- After peptide bonding, the protein folds into a particular shape due to four other types bonds, namely:
  - (i) Ionic bonds
  - (ii) Disulphide bonds
  - (iii) Hydrogen bonds
  - (iv) Hydrophobic interactions.

Q.3 What are amino acids? How many amino acids are known?

Ans. **Amino Acids**

Amino acids are the basic units from which proteins are made by ***peptide linkages***.

Over ***170 amino acids are known*** in cells or tissue.

Only ***20 are commonly found in proteins***.

Q.4 Write the names of any five amino acids. ***(for concept only)***

Ans. **Names of Amino Acids**

(i)	Glycine	(ii)	Alanine	(iii)	Phenyl alanine
(iv)	Arginine	(v)	Lysine	(vi)	Leucine
(vii)	Tyrosine	(viii)	Serine	(ix)	Valine

Q.5 What is quaternary protein?

Ans. More than one polypeptide chains held together by hydrophobic interactions and hydrogen and ionic bonds a complex protein form is called quaternary protein.

Q.6 What do you know about β-pleated sheet?

Ans. **β-Pleated Sheet:** All NH_2 and C=O groups are involved in hydrogen bonding, so the structure is very stable and rigid. The whole structure is known as **β-pleated sheet.**

Q.7 Define tertiary structure of protein.

Ans. Bending and folding of polypeptide chains into compact globular shape, which is maintained by bonds like ***ionic, hydrogen*** and ***disulphide*** bonds as well as ***hydrophobic*** interactions known as tertiary structure.

Q.8 How can you briefly describe about secondary structure of protein.

Ans. Spiral spring like structure which is maintained by hydrogen bonding between C=O and NH_2 called as secondary structure

Q.9 Shortly describe about structural protein with few examples.

Ans. **Structural Proteins**

Keratin is structural protein, it is found in skin, feathers, nails, hairs and horn.

Elastic is also structural protein found in elastic connective tissues (ligament).

Collagen is structural protein which is component of bones, cartilage and tendons.

Q.10 What are reducing sugars? Give an example of non-reducing sugar.

Ans. **Reducing Sugars**

"Those sugars which carry out ***reduction reactions*** are called reducing sugars".

(i) ***All monosacchardies are reducing sugars.***

(ii) Some disaccharides i.e. ***maltose*** and ***lactose*** are reducing sugars.

(iii) Bendict test and Fehling test are common test for reducing sugars.

Sucrose is the only common non reducing sugar.

TERMS TO REMEMBER

Q.11 Define Oxidation, Reduction, Oxidation-reduction reaction, ATP, Fermentation, Respiration.

Ans. **Oxidation:** Oxidation means accept of O_2 or donate electrons.

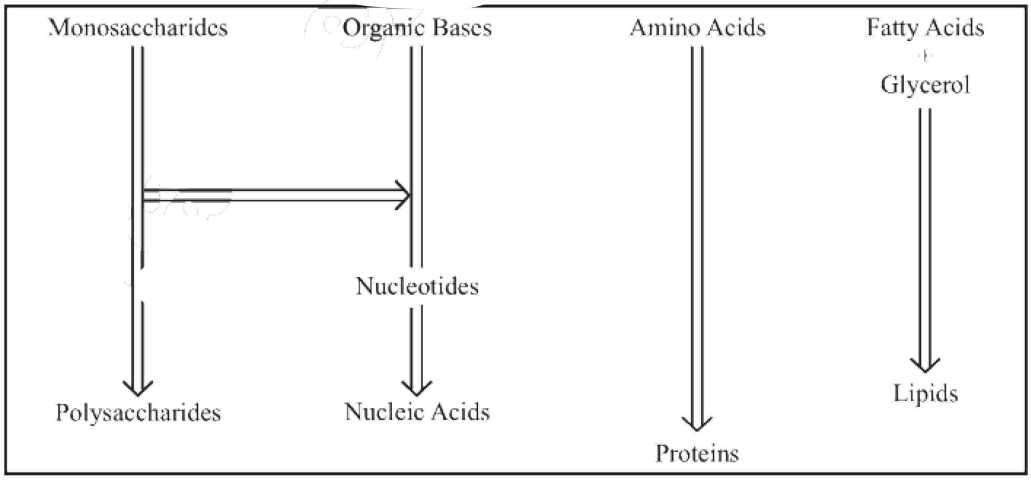
Reduction: Reduction means donate O_2 or accept electrons.

Oxidation-Reduction Reaction: A process in which electrons are transferred from an electron donor (oxidizing agent) to an electron acceptor (reducing agent), it is major energy supplying reaction in animals and plants.

Adenosine Triphosphate (ATP): A major energy transferring molecule in biological reactions in which adenosine is linked with three phosphates is called ATP.

Fermentation: The process or reaction in which energy is obtained from glucose in the absence of free oxygen.

Respiration: The oxidative breakdown of food substances within the cells of an organism and energy is likerated for processes of life or activities.



MAKE SHORTS QUESTIONS & ANSWERS

Table Organic Compounds Associated with Living Things

Macromolecule	Monomer	Function
Proteins	Amino acids	Enzymes speed up chemical reactions; structural components (e.g., muscle proteins)
Carbohydrates		
Starch	Glucose	Energy storage in plants
Glycogen	Glucose	Energy storage in animals
Cellulose	Glucose	Plant cell walls
Lipids		
Fats and Oils	Glycerol, 3 fatty acids	Long-term energy storage
Phospholipids	Glycerol, 2 fatty acids, phosphate group	Plasma membrane structure
Nucleic Acids		
DNA	Nucleotides with deoxyribose sugar	Genetic material
RNA	Nucleotides with ribose sugar	Protein synthesis

DIFFICULT WORD MEANINGS

Words	Meanings	Words	Meanings
Specific	مخصوص	Lipids	چکنائیاں
Describe	بیان کرنا	Mono	ایک
Arrangement	ترتیب	Di	دو
Kinds (types)	قسمیں	Tri	تین
Alternation	تبدیلی	Poly	کئی/بے شمار
Abnormal	صحیح نہ ہونا	Oligo	چند
Sequence	ترتیب	Soluble	حل پذیر
Linear	ایک لائن میں	Insoluble	ناحل پذیر
Sickle cell Anaemia	آکسیجن کی کمی کی وجہ سے سیل کی شکل خراب ہونا	Peptide bond	امائنو ایسڈز کے درمیان تعلق کیمیائی داری
Haemoglobin	آکسیجن سپلائی کرنے والی پروٹین	Saturated	بغیر ڈبل باٹڈ
Helix	بل کھانا (رسی کی طرح)	Unsaturated	ڈبل باٹڈ کے ساتھ
Bond (linkage)	کیمیائی جوڑ	Fibres	دھاگہ نما
Glycosidic	کاربوہائیڈریٹس کے درمیان کے باٹڈ	Globular	گلوب/بلڈز کی
Tetrahedron	چارکونے/جوڑ	Crystallised	قلمی شکل کی
Association	تعلق	Contraction	سکڑنا
Stability	استحکام	Relaxation	پھیلنا
Respectively	بالترتیب	Hydrophobic	پانی سے نفرت کرنے والے
Dipolar	دو پول/اور + چارج	Hydrophilic	پانی سے محبت کرنے والا
Product	تیار کردہ مال/شے		

Q.1 Fill in blanks:

(i) The sum of all the chemical reactions taking place within a cell is called ————.

(ii) ———— is the basic element of organic compounds.

(iii) All the amino acids have an amino group and carboxyl group attached to the same ———— atom.

(iv) ———— is the most abundant carbohydrate in nature

(v) Adenine and guanine are double ringed bases and are called ————.

ANSWERS:

(i) Metabolism (ii) Carbon (iii) Carbon

(iv) Cellulose (v) Purines

Q.2 Write whether the statement is 'true' or 'false' and write the correct statement if it is false:

	STATEMENT	T/F	CORRECT STATEMENT
(i)	A small proportion of water molecules are in ionized form	T	
(ii)	The covalent bond among two monosaccharides is called a peptide bond	F	The covalent bond among two monosaccharides is called a glycosidic.
(iii)	Glycogen is also called plant starch.	F	Glycogen is also called animal's stored poly saccharide
(iv)	Adenine is always opposite to guanine cytosine and thymine or opposite to each other in DNA molecule.	F	Adenine is always opposite to thymine, cytosine and guanine are opposite to each other in DNA molecule.
(v)	DNA molecule is made of two polynucleotide strands.	T	

Q.3 Each question has four options. Encircle the correct answer:

(i) Animals obtain carbohydrates mainly from:

(a) Glucose (b) Starch

(c) Sucrose (d) Glycogen

(ii) Peptide bond is a:

(a) C – N link (b) C – O link

(c) C – H link (d) C – H link

(iii) Globular proteins differ from fibrous proteins in:

(a) Having amino acids

(b) Their repeating units joined by peptide bond

(c) Being soluble in aqueous medium

(d) Being non-crystalline

(iv) Which of the following amounts of bases are more likely to be found in an organism?

(a) Adenine 30.9% and Cytosine 30.7%

(b) Guanine 27.5% and Adenine 27.8%

(c) Cytosine 19.8% and thymine 20.0%

(d) Adenine 32% and Thymine 31.9%

(vi) Amino acids are arranged in proper sequence during protein systhesis according to the instructions transcribed on:

ANSWERS:

(i) (d) (ii) (a) (iii) (c) (iv) (d) (v) (c)

Q.4 Short Questions:

(i) Name the carbohydrates suitable as food for man.

Ans. Glucose, fructose, sucrose, lactose and starch.

(ii) Why are fats considered as high energy compounds?

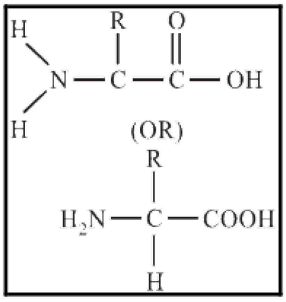
Ans. Because fats contain high proportion of C – H bonds and low proportion of oxygen 50 energy stored in fats is twice as compared to carbohydrates.

(iii) What is the function of mRNA?

Ans. It carries the genetic message from nucleus to ribosome in cytoplasm to form a particular type or protein.

(iv) What is the general formula for amino acid?

Ans. Formula of amino acid.

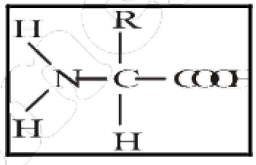


R group is different in different amino acids.

(v) Write a short note on amino acids.

Ans. **Amino Acids:** About 170 types of amino acids have been found to occur in cells and tissues. Of these, about 25 are constituents of proteins. Most of the proteins are however, made of 20 types of amino acids.

Structure of an Amino Acid: All the amino acids have an amino group (- NH_2) and a carboxyl group (- COOH) attached to the same carbon atom, also known as ***alpha carbon***. They have the general formula as:



R may be a hydrogen atom as in glycine, or CH_3 of as in alanine, or any other group. So amino acids mainly differ due to the type or nature R group.

(vi) How many bonds are found in quaternary structure of protein which hold the chains?

Ans. (i) Hydrophobic interactions (ii) Hydrogen bonding

(iii) Ionic bonds