Section II

UNITY OF LIFE

Despite the existence of great diversity that is observed among living things, they all share features like cells, cellular organelles, chemicals, etc. What does it suggest? They all have a Creator - Allah, Who is the only one and none shares His authority.

Chapter 2

BIOLOGICAL MOLECULES

Chemical substances which are supposed to be non-living, when incorporated in living protoplasm become a live and then they behave in a coordinated fashion. What turns them into life in living protoplasm?

2.1 INTRODUCTION OF BIOCHEMISTRY

The branch of biology which explains the biochemical basis of life is called **biochemistry.** It is one of the most important branch of biology especially now a days It has much excitement and activity in It due to several reasons some are given below.

Firstly, it provides information about all the processes carried out in the living organism, from construction of body structures to flow of information from the nucleus, especially DNA for enzyme (Protein) synthesis and control of all the mechanisms.

Secondly, it provides information about abnormal mechanisms which lead to diseases, ultimately opening the doors to the development of medicines and medical equipments to elucidate these abnormalities.

Thirdly, recent biochemical concepts and powerful techniques have enabled us to investigate and understand some most challenging and fundamental problems in biology and medicine e.g how does a fertilised egg give rise to different types of cells such as muscles, brain and liver etc.? How do cells find each other to form a complex organ? How is the growth of cells controlled? What are the causes of cancer? What is the mechanism of memory? These questions are satisfactorily answered by biochemistry.

To understand all these, it is important to keep in mind that most organisms are composed of organs, these organs are made up of tissues, these tissues are the group of cells, finally the cells are made up of molecules and the molecules are chemically bonded atoms. It means that fundamentally living things or organisms are made up of chemicals i.e. structure and function are dependent upon chemicals.

Therefore, it is appropriate for us to study chemical principles and structure of molecules involved in the cells to understand the structure and mechanism of living organisms.

2.1.1 Chemical Composition of Cell:

We know that all living bodies are structurally composed of cells and living cell contains a living material called **protoplasm.** The actual chemical composition of protoplasm is still not known perfectly. However, chemically it contains 70 to 90% of H_2O. If the water is evaporated, the remaining mass is called dry weight of the cell, which consists of mainly carbon containing molecules, these molecules are termed as organic molecules. As chemists synthesized these molecules in laboratory, the mystry associated with organic compounds disappeared. Now, the compounds produced by living organisms are called **biochemicals.**

Only six elements, carbon, hydrogen, nitrogen, oxygen, phosphorous and sulphur make up most (about 98%) of the bioehemlcals, which ultimately make up the body weight of organism. Following are some properties and functions of these elements.

Table 2.1

Element	Atomic No / Weight	Molecular form of utilization	Function	Percentage by weight in human body
Carbon	6/12	CO_2	Basic element of organic compounds, fixed during photosynthesis.	18.5
Hydrogen	1/1	H_2O	During photosynthesis, used as reducing agent.	9.5
Oxygen	8/16	O_2	Used in anaerobic respiration.	6.5
Nitrogen	7/14	NO_3^{-1}, NH_4^{+1}	Used in aminoacid for protein synthesis, nucleic acids, hormones, co-enzymes.	3.3
Phosphorus	15/31	$H_2PO_4^-$, HPO_4^{-2}	Component of nucleic acid, ATP, phospholipids, co-enzymes NAD, NADP etc.	1.0
Sulphure	16/32	SO_4^{-2}	Component of proteins and co-enzymes.	0.3

2.1.2 Relationship between structure and function of molecules;

Biomolecules can be divided into following groups according to variability of their chemical structures and functions.

1. Proteins
2. Carbohydrate
3. Lipids
4. Nucleic acids
5. Conjugated molecules

There is a variation found in literature about the percentage of biomolecules present in the cell. It is because different cells within the same body have different amount of biomolecules. Therefore, these values are always taken as average value. Approximate percentage of chemical composition of a typical bacterial and a typical mammalian cell is given in table 2.2.

Table 2.2 Chemical composition of cells (in %)

Molecules	Bacterial Cell	Mammalian Cell
Water	70	70
Protein	15	18
Carbohydrate	3	4
Lipids	2	3
DNA	1	0.25
RNA	6	1.10

Other Organic compounds	2	2
Inorganic ions	1	1

WATER

Water is the most abundant component in living cell. It's amount varies approximately from 70 to 90%. Life activities occur in a cell due to the presence of water.
The ability of water to play its wide variety of roles, and the reasons for its importance in biological systems is due to the basic chemistry of the molecule. The chemical formula of water is H_2O which tells us that two atoms of hydrogen are joined to one atom of oxygen to make up each water molecule.
Water is a polar molecule, it means that it has a very slightly negative end—the oxygen atom and a very slightly positive end—the hydrogen atoms. This separation of electrical charge is called a **dipole**, which gives the water molecule its very important properties. One of the most important properties of this charge separation is the tendency of H_2O molecule to form hydrogen bonds.

2.2.1 Biologically important Properties of water:

Water has variety of properties which are also important in biological system. Some of the important ones are given below.

i) Behave as best solvent:

Due to polar nature of water molecules, many polar substances (solute), particularly ionic substances dissociate in ions and dissolve in water.
Water can also act as a solvent to many non-polar substances. As all the chemical reactions that go on within the cell takes place in aqueous solution, the ability of water to act as a solvent is vitally important for the process of life. Ions or molecules are dissolved in water, these ions move and collide to perform the chemical reaction.

ii) Slow to absorb and release heat (High specific heat capacity):

The specific heat capacity of a substance is a measure of the amount of energy needed to raise the temperature of 1 gm of that substance by 1°C. The specific heat capacity of water is high, it takes a lot of energy to warm up. This thermal stability plays an important role in water-based protoplasm of individual cell to allow the biochemistry of life carried at fairly constant rate.

iii) High heat of vapourization:

Due to hydrogen bonding which holds the water molecules together, liquid water requires higher amount of heat energy to change into vapours. It also gives stability to water molecules. Therefore water needs to lose a lot of energy to form ice, due to this reason the content of cell are unlikely to freeze.

iv) An amphoteric molecule:

Water molecule is amphoteric because it acts both as an acid and a base. As acid, it gives up electron to form H^+ ion. As base, it gains electron to form OH^- ions.
This ability of water molecules means that it is a perfect medium for the biochemical reactions occurring in cells. It acts as buffer. A buffer helps to prevent changes in the pH of a solution when an acid or an alkali is added. Thus water in the cells minimises any change in pH which prevent any interference in the metabolism of the cell.

v) Co-hesive force in water molecules:

Force of attraction between similar molecules is called co-hesive force. Due to polar nature water molecules attract each other to form a chain. This chain of water molecules do not break apart which help it to flow freely. They remain together because of hydrogen bonding. Water molecules also adhere to the surface. It can fill a tubular vessel and still flow so that dissolved and suspended molecules are evenly distributed throughout a system. Therefore, water is an excellent transport and matrix medium both outside and inside the cell.

2.3 ORGANIC MOLECULES

Chemists classify molecules as organic or inorganic molecules. The word organic originally meant that these molecules could only be synthesized within the living organisms. Today, however, organic chemists can synthesize many of these molecules in the laboratory. Therefore, the modern definition of organic molecule is modified as the molecules containing Carbon as basic element bounded covalently with Hydrogen atom. Most organic molecules are large, with complex structure. On the other hand inorganic molecules are those which do not contain carbon as basic element or in which hydrogen is not directly bonded with carbon as CO_2, CO and H_2O etc.

2.3.1 Synthesis of large Molecules by Condensation:

The molecules which form the structure and carry out activities of the cells are huge and highly organised molecules called **macromolecules**. These macromolecules are composed of large numbers of low molecular weight building blocks or subunits called **monomers** (for example amino acids). The macromers are called **polymers** (Poly = many; mers = molecules). Macromolecules can be divided into four major categories, proteins, polysaccharides, lipids and nucleic acids. Proteins are composed of subunits called amino acids; polysaccharides are composed of monosaccharides; fatty acid and glycerol are the subunits of fats and the nucleotides are the subunits of nucleic acid.

Macromolecules are constructed from monomers by a process that resembles coupling rail cars onto a train. The basic structure and function of each family of macromolecule is very simillar in all organisms, from bacteria to human beings. Two monomers join together when a hydroxyl (—OH) group is removed from one monomer and a hydrogen (—H) is removed from other monomer. The joining of two monomers is called **condensation**. This type of condensation is called **dehydration synthesis** because water is removed (dehydration) and a bond is made (synthesis). Condensation always takes place by proper enzyme and energy expense.

2.3.2 Breaking of large Molecules by Hydrolysis:

Another process, which is just reverse of the condensation is called **hydrolysis.** (Hydro = water, lysis = breaking). A process during which polymers are broken down into their subunits (monomers) by the addition of H_2O is called hydrolysis. During this process a water molecule breaks into H^+ and OH^- ions with the help of enzyme, whereas—OH group attaches to one monomer and —H attaches to the other. When a bond is broken, energy is released and made available.

During metabolism, macromolecules are either formed or broken down in the cell, when each cell rebuilds many of it's parts. In heterotrophic organism during digestion especially, macromolecules are broken into monomers by the process of hydrolysis with the help of hydrolytic enzymes and again, these monomers when reach to the cells form macromolecules or polymers by the process of condensation. In autotrophic organism, cell produces monomers from simple inorganic molecules like CO_2, H_2O. nitrates, sulphates etc. These monomers later on assemble to form macromolecules in source or sink cells by the process of condensation while the other cells when require these molecules either for building purpose or to produce energy, these molecules break into monomers by the process of hydrolysis.

2.4 CARBON

Chemistry of living world is the chemistry of carbon, which is called Organic Chemistry. Carbon is a unique element in a sense that it forms unlimited number of compounds which vary widely in their properties and adaptation. Therefore organic compounds are well adapted with the requirement of living processes. Now, question arises why only carbon does it, why not other elements? Carbon is a light element and has atomic number 6. It contains $4e^-$ (electron) in its outer most shell and requires 4 more e^- (electron) to complete its outer-most shell. For this purpose, it forms 4 covalent bonds with other atoms i.e. It is tetravalent in nature (4 valency).

Loosing, gaining and sharing electrons between the atoms result in forces called **chemical bonds** that hold atoms together in molecules. There are two major types of chemical bonds, ionic and covalent bonds. The chemical bonds which are formed due to loos and gain of e- are called ionic bonds. While the chemical bonds which are formed due to shairing of e- are called covalent bonds. In organic compounds elements are held together by covalent bonds. Covalent bond stores large amount of energy.

Carbon can form four covalent bonds with other carbon atoms. This property allows the formation of skeleton and the fundamental frame work of carbon around which organic molecules are constructed. Carbon containing back bone may be linear, branched or cyclic e.g.
Carbon can be linked with other carbon either by single covalent bond as shown above or it can form double or triple covalent bond between two carbon atoms as shown below.

Biological molecules:
Biological molecules can be divided into following four main classes.

i) Proteins ii) Carbohydrates
ii) Lipids iv) Nucleic acids

1. Proteins (Gr; Proteios means 'First Rank')
Proteins can be defined as the polymers of amino acids, where specific amino acids link to gether in a definite manner to perform a particular function. Proteins are the most important organic compounds of the cell which carry out virtually all of the cell's activities. They constitute more than 50% of dry weight of a cell. The name protein was suggested by Berzelius in 1838 and a Dutch Chemist G.J. Murlder in 1883 recognised the importance of protein as a vital compound.
Proteins are the complex organic compounds having C, H, O and N as elements but sometimes they contain P and S also. Due to the presence of N they are called nitrogenous compounds. Proteins are the building blocks of tissues. Many common parts of the living body such as hair, skin, nails and feathers are also protein. Whereas egg, meat, fish, milk and pulses are the major sources of protein.

A) Amino acid as a building block of protein:
Proteins are macromolecules or polymers of **amino acid** monomers. These amino acids are linked together by specialised bond or linkage called **peptide linkage**. Each protein has a unique sequence of amino acids that gives the unique properties to molecules. Many of the chemical properties of a protein are based upon chemical properties of it's constituent amino acids. There are twenty basic amino acids, which are commonly found in proteins of the living organisms ranging from virus to human being.
Amino acids are organic compounds which contain at least one basic amino group ($—NH_2$) and one acidic carboxylic group ($—COOH$), bounded to the same carbon atom called α- carbon having following general structural formula.
Where R is the radical group, it shows the great variety of structures e.g in glycine R is H, in serine R is CH_2OH and in alanine R is CH_3 etc.

B) Linkage of Amino Acids:

During the process of protein synthesis, each amino acid become joined to two other amino acids forming a long, continuous, unbranched polymer called **poly peptide** chain. In polypeptide chain these amino acids are linked together by condensation process.

The proteins are polypeptides with usually more than 100 amino acids, but some proteins are small in size having less number of amino acids. The sequence of amino acids in the peptide chain is specific for each protein and potentially capable of great diversity. Protein may differ in number of peptide chain per protein molecules.

C) Structure of Proteins:

There are four basic structural levels of proteins:

i) **Primary Structure:** A polypeptide chain having a linear sequence of amino acids due to peptide bonds is called **Primary structure** e.g. insulin.

ii) **Secondary Structure:** When a polypeptide chain of amino acids become spirally coiled this structure is called **Secondary structure** of protein. It results in the formation of a rigid and tubular structure called helix.The hydrogen and sulphide bonds are involved to hold the protein chain in spiral manner e.g. hairs, spider's webs.

iii) **Tertiary Structure**: The term **Tertiary structure** refers to the arrangement of secondary structure into the three dimensional (fold or super fold) structure having peptide, hydrogen, ionic and disulphide bond e.g. Lysozyme.

iv) **Quaternary Structure:** The association of two or more sub-units (polypeptide chains) into large-sized molecules is called quaternary structure, e.g Haemoglobin.

High temperature or various chemical treatments will denature a protein, causing it to lose its conformation and ability to function. If the denatured protein remains dissolved, it may renature when the environment is restored to normal.

In quaternary structure the participating units may be similar or dissimilar, if they have similar units called homogenous quaternary structure and if dissimilar called heterogenous quaternary structure.

D) Functions of Protein:

Proteins have a wide variety of structures, therefore, they perform variable notions. Proteins are the molecules which carry out the cell-activities and form the main structure of cell. It is estimated that the typical mammalian cell may have as many as, 10,000 different proteins having a diverse array of function. As structural cables, proteins provide mechanical support both within the cell and outside their perimeter. As enzymes, proteins vastly accelerate the rate of metabolic reactions. As hormones, growth factors and gene activators, proteins perform a wide variety of regulatory functions. As membrane receptors and transporters, proteins determine what type of substances should enter or leave the cells. Protein act as antibodies, antigens, fibrine etc.

2. Carbohydrate (CARBO = Carbon, HYDRATE = Water):

It is a group of organic compounds having carbon, oxygen and hydrogen, in which hydrogen and oxygen are mostly found in the same ratio as in water i.e. 2:1 and are thus called hydrated carbons.

Carbohydrates are found to occur in all living cells both as building material and as storage substances. They are found about 1% by weight and generally called sugar or saccharides due to their sweet taste except polysaccharide.

The carbohydrate can be classified into following groups on the basis of number of monomers. These are Monosaccharides, Oligosaccharide and Polysaccharides.

A) Monosaccharides (Gr; mono = One. Sakcharon = Sugar):
These are also called simple sugars because they can not be hydrolysed further into simpler sugars. Their general formula is $C_n H_{2n} O_n$. e.g Glucose, galactose, fructose ($C_6 H_{12} O_6$) and ribose ($C_5 H_{10} O_5$) etc.
All monosaccharides are white crystalline solids with sweet taste and are soluble in water.
Monosaccharides can be classified according to number of carbon atoms present in each molecule. They may be triose, tetrose, pentose, hexose and heptose having 3, 4, 5, 6 and 7 carbon atoms respectively. Some important examples are given in table below:

Class	Formula	Example
Triose	$C_3H_6O_3$	Glycerose(glyceraldehyde), Dihydroacetone
Tetrose	$C_4H_8O_4$	Erythrose, Erythrulose
Pentose	$C_5H_{10}O_5$	Ribose, Ribulose
Hexose	$C_6H_{12}O_6$	Glucose, Fructose, Galactose
Heptose	$C_7H_{14}O_7$	Glucoheptose

Monosaccharides are found in various friuts and vegetables, most of them are found in combined state e.g. sucrose.
Glucose is found in ripe friut, sweet corn and honey. On the other hand it is also found in starch. In sugar-cane it is associated with fructose.
Fructose most abundant hexose found in nature generally called fruit sugar.
Galactose is found largely in combined state in lactose (milk) disaccharide.

B) Oligosaccharide (Gr; Oligo - few; Sakcharon = sugar)
The carbohydrate molecule which yield 2 to 10 monosaccharide molecules on hydrolysis are oligosaccharide. The most common and abundant carbohydrates of oligosaccharides are disaccharides. The oligosaccharide which contains 3 to 10 monosaccharide are commonly called **Dextrin**.
The sugars which are composed of two monomers are disaccharides i.e. On hydrolysis they produce two monosaccharide sub-units. They are usually formed when two hexose sugar molecules unite by condensation. Following are some examples of disaccharide molecules.
Sucrose (Cane sugar) is found in most plants. It is stored in large amount in sugar cane and beet root. Lactose (milk sugar) is found solely in milk. Maltose (malt sugar) does not occur abundantly in nature. It can be extracted from malt, which is prepared from sprouting barley.

C) Polysaccharides (Gr; Poly = many; sakcharon = sugar):
Polysaccharides: They are of high molecular weight carbohydrates, which on hydrolysis yield mainly monosaccharides or products related to monosaccharides. These are formed by the condensation of hundreds to thousands of monosaccharide units e.g. Starch, Glycogen and Cellulose.
Starch: It is the most important reserve food material of higher plants, found in cereals, legumes, potatoes and other vegetables. It is made up of many glucose molecules joined together in straight chain, amylose and a branched chain, amylopectin. It is insoluble in water. Starch is converted into simple sugars by

hydrolysis and then oxidised to produce energy to be used in metabolism of other biomolecules.

Human diet use only about 12 species of plants as food sources. Three of these are cereals, rice, corn and wheat. A grain of wheat contains a seed and fruit both of them are fused in insepreable manner. Seed occupies most of its volume and consist of 3 parts. Endosperm (stored food), embryonic plant, seed coat alongwith protective layers. Embryonic plant is wheat grain, which is high in vitamins. The starchy endosperm is used to produce the flour from which our white breads are made. The seed coat is bran, composed mostly of cellulose, which can not be digested by humans. For this reason, bran is an excellent roughage substance that adds bulk to the diet.

Cellulose: Cellulose is a glucose polymer produced by plants. The glucose units are joined in straight chain and no branching in the cellulose molecule is Indicated. It is the main constituent of plant cell-wall and most abundant carbohydrate in nature.

Glycogen: It is also a reserve polysaccharide found mainly in bacteria, fungi, liver and muscle tissues of animal. It is commonly known as animal starch. It is insoluble in water and is stored in granular form. Its structure is smillar to starch.

Cellulose is an unbranched polysaccharide. Parallel cellulose molecules are held together by hydrogen bonds. About 80 cellulose molecules chains associate to form a microfibril, the main architectural unit of the plant cell-wall.

D) Functions of Carbohydrate:

Carbohydrates are the potential source of energy. This energy is utilized in body metabolism. Carbohydrates also act as storage food molecules. In plants excess glucose is converted into starch and in animals into glycogen. Carbohydrates also work as an excellent building, protective and supporting structure e.g Cellulose is the major component of cell-wall. In animals chitin forms the exoskeleton of arthropods. They also form complex conjugated molecules.

3. LIPIDS

Lipids are the important diverse group of biological molecules widely distributed among plants and animals.
Bloor in 1943 proposed the term lipid for those naturally occuring compounds which are insoluble in water but soluble in organic solvent These are also the compounds containing carbon, hydrogen and oxygen like carbohydrate but contain much lesser ratio of oxygen than carbohydrates.
Following are the important groups oi lipids.

i) Acylglycerol (fats and oil)
ii) Waxes
iii) Phospholipids
iv) Terpenoids

i) Acylglycerol (Fats and Oil):

These are found both in animals and plants, provide energy for different metabolic activities and are very rich in chemical energy. When compared an equal amount of acylglycerol contains over twice the energy content than carbohydrate. It is estimated that a person of average size contains approximately 16 Kg of fat which is equivalent to 144000 K Cal of energy which takes a very long time to deplete.
Acylglycerol consists of a glycerol molecule linked to three fatty acids. This condensed molecule is also called a Triacylglycerol (Triglyceride).
There are two types of acylglycerol:

(a) Saturated acylglycerol (Fats): They contain saturated fatty acids i.e. they do not contain any double bond between carbon atom. They are solid at ordinary temperature, mostly found in animals, e.g Stearin ($C_{57} H_{110} O_6$) found in beef and mutton.

(b) Unsaturated acylglycerol (Oils): They contain unsaturated fatty acids i.e. They contain one or more than one- double bond between carbon atom (— C = C —). They are liquid at ordinary temperature. They are found in plant also called oil. e.g Linolin ($C_{57} H_{104} O_6$) found in cotton seed contains linoleic acid.

ii) Waxes:

Waxes are simple lipids having one molecule of fatty acid forming ester bond with one molecule of long chain alcohol e.g Bee's Wax.

$CH_3 (CH_2)_4 COO (CH_2)_{29} CH_3$

Waxes are found as protective coating on stems, stalks, leaves, petals, fruit, skins, animal skins, fur and feathers etc. Waxes are water repellant and non-reactive.

Wax esters are of considerable commercial importance because they act as superior machine lubricants. For many years, sperm whales were the principle source of these wax but now a unique plant that grows primarily in desert areas, Simmondsia chinesis or Jojoba, may serve as superior substitute because it synthesize large amounts of oxygen wax esters as storage lipids in its seed.

iii) Phospholipids:

Phospholipid is the most important class of lipids from biological point of view. A phospholipid is similar to Triacylgrycerol of an oil, except that one fatty acid is replaced by phosphate group. The phospholipid molecule consists of two ends, which are called hydrophillic (water loving) end (head) and hydrophobic (water fearing) end (tail).

Phospholipids are present in all living cells frequently associated with membranes and are related to vital functions such as regulation of cell permeability and transport processes. Properties of cell membrane depend on it phospholipid component. The function of these molecules will be discussed in chapter-4 in connection with plasma membrane.

iv) Terpenoids:

Terpenoid is a large and important class of lipids, built up of isoprenoid ($C_5 H_8$) units. Steroids. Carotenoids and terpens are the important classes of it. They help in oxidation reduction processes as terpens, some are components of essential oils of plants e.g Menthal, camphor, mint etc. They are also found in cell-membrane as Cholesterol. Plant pigments like Carotene, Xanthophylls are also the form of terpenoides.

(a) Terpenes:

The group of lipids based only on isoprenoid unit ($C_5 H_8$). Small size terpenes are volatile in nature; produce special fragrence. Some of these are used in perfumes e.g. Myrcene from oil of bay, Geranoil from rose, Limonene from lemon oil and Menthol from peppermint oil. Derivates of some terpenes are found in Vitamin A_1 and A_2. They are also important constituents of chlorophyll molecules .as well as intermediate compound for cholesterol biosynthesis. In nature they are utilized in the synthesis of rubber and latex.

(b) Steroids:

Steroids consist of three 6-membered carbon rings (A, B. C) and one 5-membered carbon ring (D). These rings are fused together as shown in fig: 2.8 with total 17 carbon atoms called steroid nucleus.
One of the most important steriod is Cholesterol, a component of animal cell membrane and a precursor for the synthesis of a number of steriods, sex hormones such as testosterone, progesterone and estrogenes.

(c) Carotenoids:

Carotenoids consist of fatty acid like carbon chain, which are conjugated by double bonds carrying 6-membered carbon ring at each end.
These compounds are pigment producing red, orange, yellow, cream and brown colours in plants. Some important carotenoids are caroten, xanthophyll etc.
Another group of pigmented compounds areTetrapyrrol which are present as an important part of familiar chlorophyll and cytochromes plgments.

4. NUCLEIC ACID

A 22-years old Swiss physician and chemist, Friedrich Miescher isolated a substance from the nuclei of pus cells, which was quite different from other biomolecules and named it as 'nuclein'. Later, it was found that the nuclein had acidic properties land hence it was renamed as nucleic acid.
Nucleic acids are present in all living things, from virus to man. These macromolecules are present either in the free-state or bound to proteins as nucleoproteins. Like proteins, the nucleic acids are biopolymers of high molecular weight with mononucleotide as their sub-units (monomers). The nucleic acids are the long chains of polynucleotide in which mononucleotides are linked to each other.
There are two kinds of nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). DNA is found mainly in the chromatin of the cell nucleus whereas most of the RNA (90%) is present in the cell cytoplasm and a little (10%) in the nucleolus.
As we now know that nucleic acid is a polymer of nucleotide, a question arises here what is nucleotide? Nucleotide is a molecule which consists of following three parts.

i) Pentose sugar (5 carbon)
ii) Phosphoric acid (H_3PO_4)
iii) Nitrogenous base (Organic base)

Pentose sugar found in nucleotide is either Ribose ($C_5H_{10}O_5$) or Deoxyribose ($C_6H_{10}O_4$).
Ribose is found in RNA nucleotides while Deoxyribose sugar is found in DNA nucleotides, both of them are distinguished primarily on the basis of this pentose sugar. This sugar behave as basic skeleton.
Phosphoric acid is common in all nucleotides. It is attached with 5th carbon of pentose sugar in each nucleotide.
There are two basic types of nitrogenous bases i.e. Purine and Pyiimidine. Purine includes two nitrogenous bases named Adenine (A) and Guanine (G) while pyrimidine includes three nitrogenous bases cytosine (C), thymine (T) and uracil (U). The nucleotides differ on the basis of their nitrogenous bases.
Formation of nucleotide takes place in two steps. At first step the nitrogenous base combines with pentose sugar at its first carbon to form a **nucleoside**. At the second step the phosphoric acid combines with the 5th carbon of pentose sugar to form a **nucleotide**.

A) Mononucleotide:

Generally, nucleotides are found in the nucleic acid as polynucleotide but they are also found as mononucleotide and dinucleotide. Mononucleotides exsist singly in the cell or as a part of other molecules. These are not the part of DNA or RNA. Some of these have extra phosphate groups e.g ATP (Adenosine triphosphate). It

is the most important among these nucleotide. It is an unstable molecule and carries energy from place to place within a cell. It is synthesized from ADP (Adenosine diphosphate) and inorganic phosphate by capturing energy during photosynthesis. This energy is utilized to derive energy demanding reactions such as in synthesis of proteins, lipids, carbohydrates, mechanical energy for cyclosis, contractility, cell-division, movement of flagella, active transport etc.
ATP consists of Adenosine (Adenine and ribose sugar) and three phosphate; among them two are energy rich phosphate bond. During conversion of ATP into ADP the tee energy releases which is considerable large i.e. 31.81 Kj or 7.3 K.Cal/ mole energy.

B) Dinucleotide:
Some times two nucleotides are covalently bounded together, to form compounds are called dinucleotide. One ofthe well-known dinucleotide is Nicotinamide adenine dinucleotide (NAD).
Nicotinamide is a vitamin constituent The two nucleotides are linked by phosphate of one another.
NAD is a co-enzyme [co-enzymes are the organic molecules (non-protein) which bind to enzyme (protein) and serve as a carrier for chemical groups or electrons] that carries electron and work with dehydrogenase enzyme. It removes two hydrogen atom (2e- + 2H+) from its substrate, both electrons, but only one hydrogen ion is passed to NAD which reduces it to NADH.

C) Polynucleotide (Nucleic acids as informational macromolecules):
As we have already discussed that the nucleic adds are the polynucleotides. They have a variety ofrole in living organisms. Inspite of all, the unique and premiere service of nucleic acid is as repositories (store house) and transmitters of genetic information. They make it possible for cells to function according to specific patterns and give rise to new cells that either function similarly or develop new functions, according to plans encoded in the nucleic acid.
Genetic information is encoded in a nucleic acid molecule in a particular and simple fashion. Four different nucleotides make up each informational nucleic acid molecule. They are three letters in a genetic code. The nucleic acid molecule is some what linear and the units (nucleotides) like letters on a printed page or digital magnetic signals on a computer tape. In the proper machinery, these codes (nucleotides) can be interpreted. The cell interpretes the information present in many nucleic acid molecules an sequence of amino acid in protein and peptide molecules. The synthesis of proteins with definite sequences of amino acid and controlled amounts of protein is observed as the expression of heredity of an organism which generally give the physical appearance of that particular character.
Dna and RNA are basically similar structure because both of these are poly nucleotide chains but the nucleotide of both are different in following ways.
i) DNA contains deoxyribose sugar ($C_5H_{10}O_4$) while RNA contains ribose sugar ($C_5H_{10}O_5$) in their nucleotides.
ii) DNA contains Adenine, Guanine, Cytosine and Thymine containing nucleotides where as RNA contain Adenine, Guanine, Cytosine and Uracil containing nucleotide.
iii) DNA is double stranded helical structure while RNA is mainly a single stranded structure except rRNA.
iv) DNA is of just one kind while RNA is of three kinds rRNA, tRNA and mRNA (r = ribosomal, t = transfer m = messenger).

D) DNA as Hereditary material!
Transformation of one type of bacteria into another type and infection of bacteria by bacteriophage provides first evidence that DNA is the hereditary malarial. Griffith discovered that living bacteria can acquire genetic material from dead

bacteria and transform live bacteria from non-virulent to virulent. Avery and his colleagues showed that the genes taken up living bacteria during transformation were composed of DNA.

A bacteriophage consists solely of DNA and protein. When it infects a bacterium, the phage injects its DNA only into the bacterium, where it directs the synthesis of more phages Hershey and Chase thus experimentally confirmed that DNA must be the genetic material.

Now, a new question arises how the DNA behaves as genetic material? As we have discussed earlier that DNA is a polynucleotide chain in which nucleotides are are arranged in a specific manner. In all nucleotides of DNA, phosphate and deoxyribose sugars are always common but the nitrogenous bases are different. In other words, we can say that each **DNA has specific sequences of nitrogenous bases.** These sequences of bases in DNA can encode vast amount of information. Since the nitrogenous bases are of four type, it is amazing that how just four different types of bases in DNA encode all of the information needed to produce thousands of proteins each with various combinations of 20 amino acids. The four different types of bases can be arranged in any linear order along a strand of DNA. Each sequence of bases represents a unique set of genetic instructions e.g. a piece of DNA with 10 nucleotide can exist in over a million different possible sequences of four bases. An average chromosome of plant and animal has millions to billions of nucleotides in a DNA molecule, thus encode a huge amount of information in the form of genetic codes.

E) RNA as a carrier of Information:

In Eukaryotic cells DNA is located in the nucleus while most of the synthesis and metabolic functions occur in the cytoplasm under the instruction of DNA. Therefore, DNA requires some intermediate molecules that cany informations from DNA to the cytoplasm. These molecules are ribonucleic acids or RNA's.

Genetic information flows in a cell from DNA to mRNA than to cytoplasm in a two step process for the synthesis of protein.

1. Transcription:

In this step information contained in a specific segment of DNA is copied into RNA. The RNA which perform this process is called the **messenger RNA (mRNA)**. It carries information from the nucleus to the ribsomes.

2. Translation:

In this step two other types of RNA; transfer RNA (tRNA) and ribosomal RNA (rRNA) translate the information of messenger RNA into the specific sequence of amino acids which help to synthesize the protein.

2.6 CONJUGATED MOLECULES

Conjugated molecules are formed when biomolecules of two different groups combine with each other acting as unit molecule. When a molecule of carbohydrate combines with protein molecules, they form glycoprotein. Following are the types of conjugated molecules.

i) Glycolipids or cerebrosides:

These are conjugate of lipids and carbohydrates also contain some nitrogenous compound. Glycolipids are also called cerebrosides because, it is important constituent of brain. Glycolipids and sulpholipids are also the example of glycolipids found commonly in chloroplast.

ii) Glycoproteins or Mucoids:

Glycoproteins are formed when a molecule of carbohydrate combine with a protein molecules. Most of the oligo and polysaccharides in the animals and plants cells are linked covalently to protein molecules and are called glycoproteins. It contains small amount of carbohydrate i.e less than 4% e.g egg albumin, gonadotrophic hormone etc. The cell membrane also possesses some amount of glycoproteins.

iii) Nucleoproteins:
These are found in the nucleus conjugated with nucleic acid. On hydrolysis nucleoproteins give rise to simple proteins and nucleic acids. These are weakly acidic and soluble in water.

iv) Lipoproteins:
They are conjugates of lipids and proteins. The prosthetic groups of these are lipids such as lecithin and cholesterol. Lipoproteins help in the transportation of lipid in the blood plasma as low density protein or free fatty acid. They also occur as component of membrane ofmitochondria, endoplasmic reticulum and nucleus. The electron transport system in mitochondria appears to contain large amount of lipoproteins. Lamellar lipoprotein system occur in the myelin sheath of nerves, photoreceptive structures, chloroplast and the membranes of bacteria.

KEY POINTS

- Branch of Biology deals with the study of biochemical and chemical process in living organism is called biochemistry.
- Protoplasm is mainly consist of H_2O, proteins, carbohydrates, lipids, nucleic acids and conjugated molecules.
- Water is most abundant and important component in living cell.
- Complex biomolecules are polymers synthesize by the process ofcondensation while decompose into monomers by hydrolysis.
- Proteins are the polymers of amino acid, most important biomolecule of the cell, carry out all cell activities as enzymes.
- Proteins are found in four basic structures, primary, secondary, tertiary and quaternary.
- Carbohydrate are the hydrated carbon, these are the immediate source of energy.
- Carbohydrates molecules are found as monosaccharide, oligosaccharide and • polysaccharide.
- Lipids are the important diverse group of non-polar bio-molecules, found as acyglycerol (fats and oils), waxes, phospholipids and terpenoids.
- Lipids provide, fats, hormones, protective layers, precursors of vitamins and aroma to bodies.
- Nucleic acids are the acidic compounds derived from nucleus found in two forms as DNA and RNA.
- Nucleotide is the basic unit of nucleic acid consist of a molecule of pentose sugar bonded with phosphate and nitrogenous base.
- ATP is a mononucleotide found in free state as energy rich molecules.
- DNA is the hereditary material; having specific sequence of nitrogenous bases which encode vast amount of information as genetic code.
- RNA behave as carrier of information from DNA to ribosome for protein synthesis.
- Two different group of biomolecules combine together to form conjugated molecule. Like glycolipids, glycoprotein, nucleoprotein and lipoprotein.

EXERCISE

1. Encircle the correct choice:

(i) Which of the following terms includes all others in the lists?
(a) Monosaccharide (b) Disaccharide
(c) Starch (d) Carbohydrate

(ii) Which of the following statement concerning unsaturated fats is correct?
(a) They are more common in animals than plants.
(b) They have double bonds in the carbon chains of their fatty acids.
(c) They generally solidify at room temperature.
(d) They have fewer fatty acid molecules per fat molecules.

(iii) Human sex hormones are classified as:
(a) Protein (b) Triglyceride
(c) Steroids (d) Carbohydrate

(iv) Which of these terms includes all others in the list:
(a) Nucleic acid (b) Purine
(c) Nucleotide (e) Nitrogenous base

(v) The difference between one amino acid and other is found in:
(a) Amino group (b) Carboxyl group
(c) R-group (d) Peptide bond.

(vi) Nucleic acid and proteins combine to form:
(a) Glycoprotein (b) Glycolipid
(c) lipoprotein (d) Nucleoprotein

(vii) The process of mRNA directed polypeptide synthesis by ribosomes is called:
(a) Transcription (b) Transpiration
(c) Transforomation (d) Transportation

(viii) Nitrogenous base not present in RNA:
(a) Adenine (b) Guanine
(c) Uracil (d) Thymine

(ix) A kinds of lipids utilized in synthesis of rubber is:
(a) Acylglycerol (b) Waxes
. (c) Phospholipids (d) Terpenes

(x) Type of polynucleotide acting as messenger:
(a) ADP (b) ATP
(c) NAD (d) mRNA

2. Write detailed answers of the following questions:

(i) Name several molecules of monosaccharides, disaccharides and polysaccharids and give function and sources of each.

(ii) Describe the four basic structures of protein with examples?

(iii) Define protein.

3. Write short answers of the following questions:

(i) Many birds must store large amounts of energy to power flight during migration. Which type of organic molecules would be the most advantageous for energy storage. Why?

(ii) Why butter solidify at room temperature but not mustured oil?

(iii) How DNA is different from RNA?

(iv) Do mononucleotides work independently as heredity material? Why?

4. Define the followin terms.

(a)	Amino acid	(b)	Triglycerides	(c)	Oligosaccharides
(d)	Nucleotides	(e)	Secondary proteins	(f)	Terpenoid