Biological Molecules

CHAPTER – 2

BIOCHEMISRTY

Biochemistry is a branch of biology, which deals with the study of chemical components and chemical processes in living organisms.

WATER (H2O)

MAIN CHARACTERISTICS OF WATER

- Chemically it is "Dihydrogen oxide"
- It is the most abundant component in living cell.
- Its amount varies approximately from 70 to 90% and life activities occur in the cell due to the presence of water.
- It is a polar molecule, means that it has a very slightly negative end (the oxygen atom) and a very slightly positive end (the hydrogen atom).

- Due to its polarity, H2O molecules form hydrogen bonds.

IMPORTANT BIOLOGICAL PROPERTIES OF WATER

(1) BEST SOLVENT

- Water is an excellent solvent for polar substances, when ionic substances dissolved in water, dissociate into positive and negative ions.
- Non-ionic substances, having charged groups in their molecules, are dispersed in water.
- Because of solvent property of water, almost all reactions in cells occur in aqueous media.

(2) HIGH HEAT CAPACITY

- Water has great ability of absorbing heat due to its high specific heat capacity.
- The specific heat capacity of water is the number of calories required to raise the temperature of 1g water through 1ºC.
- The thermal stability plays an important role in water based protoplasm of individual's metabolic activities.

(3) HIGH HEAT OF VAPORIZATION

- Liquid water requires higher amount of heat energy to change into vapours due to hydrogen bonding which holds the water molecules together.
- It provides cooling effect to plants when water is transpired, or to animals when water is respired.

(4) ACT AS AMPHOTERIC MOLECULE

- Water molecule acts both as acid and a base. As acid, it gives up electron to form H+ ion, while as a base, it gains electron to form OH ions.
- $H_2O \leftrightarrow H^+ + OH^-$
- It acts as buffer and prevents changes in the pH of living body.

(5) PROTECTION

- Water is an effective lubricant that provides protection against damage resulting from friction.

- It also forms a fluid cushion around organs that helps to protect them from trauma.

(6) AS REAGENT /TURGIDITY

- Water acts as a reagent in many processes such as photosynthesis and hydrolysis reactions.
- It also provides turgidity to the cells.

ORGANIC COMPOUNDS

Those compounds containing carbon (other than carbonates) are called organic compounds. E.g: carbohydrates, Proteins, Lipids and Nucleic acid.

INORGANIC COMPOUNDS

Those compounds, which are without carbon, are called inorganic compounds. E.g: water, carbondioxide, acids , bases and salts.

MACROMOLECULES

Huge and highly organized molecules which form the structure and carry out the activities of cells are called "Macromolecules" Macromolecules can be divided into four major groups.

- Proteins
- Carbohydrates
- Lipids
- Nucleic acids.

MONOMERS

Macromolecules are composed of large number of low molecular weight building blocks or subunits called "Monomers" E.g: Amino-acids (Protein).

CONDENSATION

The process by which two monomers are joined is called "Condensation".

In this process two monomers join together when a hydroxyl(OH) group is removed from one monomer and a hydrogen (-H) is removed from other monomer.

This type of condensation is called "Dehydration Synthesis"

because water is removed (dehydration) and a bond is made (synthesis).

HYDROLYSIS

A process during which polymers are broken dawn into their subunits (monomers) by the addition of H2O called "Hydrolysis ". It is just reverse of the condensation.

FUNCTIONAL GROUPS

These are particular group of atoms that behave as a unit and give organic molecules their physical, chemical properties and solubility in aqueous solution. E.g

- Methyl group (CH3-)
- Hydroxyl or Alcohol group (OH-)
- Carboxylic acid or Organic-acid group (COOH-)
- Amino or Amine group (NH2-)
- Carbonyl group (CO=)
- Sulfhydryl group (SH-)

PROTEINS

These are the complex organic compounds having C, H,O and N as elements but sometimes they contain P and S also. Due the presence of N they are called "Nitrogenous Compounds" Proteins constitute more than 50% of dry weight of cell. They are present in all types of cells and in all parts of the cell.

CHEMICAL COMPOSITION OF PROTEINS

Proteins are polymers of amino-acids and number of amino-acids varies from a few to 3000 or even more in different proteins.

These amino-acids are linked together by specialized bond or linkage called "peptide linkage"

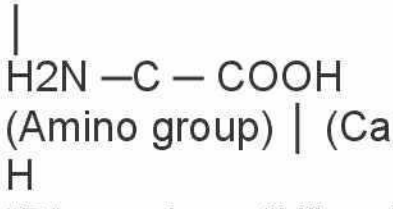
Each proteins has a unique sequence of amino-acids that gives the unique properties to molecules.

AMINO ACID

It is the basic structural unit of proteins and all amino-acids have an "Amino group (NH2-) and a "Carboxyl group (COOH-)" attached to the same carbon atom, also known as

"Alpha carbon". The have the general formula as:

1. A hydrogen atom.
2. An amino (NH2) group.
3. A carboxyl group (COOH)
4. "Something else" this is the "R" group.



"R" may be a "H" as in glycine, or CH3 as in alanine, or any other group. So amino acids mainly differ in the R-group.

POLYPEPTIDES

Amino Acids are linked together to from polypeptides of proteins. The amino group of one amino acids may react with the carboxyl group of another releasing a molecule of water. E.g: Glycine and analine may combine to form a dipeptiede

PEPTIDE LINKAGE/ BOND

The linkage between the hydroxyle group of carboxyl group of one amino-acid and the hydrogen of amino-group of another amino-acid release H2O and C-N link to form a bond called "Peptide bond".

TYPES OF PROTEINS ON THE BASIS OF STRUCTURE

There are four basic structural levels of proteins.

(A) PRIMARY STRUCTURE

- A polypeptide chain having a linear sequence of amino-acids.
- Disulphide (S-S) bond is other important characteristic of the primary protein.

E.g: Insulin Polypeptide chain.

B) SECONDARY STRUCTURE

- In this type polypeptide chain of amino-acids become spirally coiled.

- This coiling results in the formation of a rigid and tubular structure called "Helix"

C) TERTIARY STRUCTURE

- Polypeptide chain bends and folds upon it self forming a globular shape.
- It is maintained by three types of bonds. Namely ionic, hydrogen and disulfide (S-S).

(D) QUATERNARY STRUCTURE

- This type is usually present in highly complex proteins in which polypeptide tertiary chains are aggregated and held together by hydrophobic interactions, hydrogen and ionic bonds.

E.g: Haemoglobin molecule.

FUNCTIONS OF PROTEIN

- They Build many Structures of the cell E.G: Plasma Membrane.
- All enzymes are proteins and in this way they control the whole metabolism of the cell.
- Skin, nails, hair, feather, horn etc. contain portion called keratin.
- Casein is the milk portion and ovalbumin is the egg white protein.
- Collagen present in bones, cartilage, etc. is the most abundant protein in higher vertebrates.
- Protein acts as antibodies, antigens and fibrin etc.

CARBOHYDRATES

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 thus called "Hydrated carbons" They are found about 1% by weight and generally called Sugars or saccharides" due to their sweet taste except polysaccharides.

CLASSIFICATION OF CARBOHYDRATES

The carbohydrates can be classified into following groups on the basis of number of monomers.

1. Monosaccharide
2. Oligosaccharides
3. Polysaccharides.

(1) MONOSACCHARIDES

- These are called "Simple Sugars", because they can not be hydrolysed further into simple sugars.
- Their general formula is "Cn H2n On
- They are white crystalline solids with sweet taste and soluble in water.
- They are present in various fruits and vegetables.

E.g: Glucose, Galactose, Fructose and Ribose etc.
Monosaccharide can be sub-classified according to umber of carbon atom present in each molecule. They may be triose, (Glycerose), tetrose (erythrose), pentose (ribose), hexone (glucose) or heptose (Glucoheptose) having 3,4,5 ,6 and 7 carbon atoms respectively.

(2) OLIGOSACCHARIDES

- These carbohydrates yield 2to 10 monosaccharides mnolecules on hydrolysis
- Disaccharides are the most common and abundant carbohydrates of oligosaccharides.
- These sugars are comparatively less sweet in taste, and less soluble in water.

E.g: Maltose, Sucrose and lactose etc.

(3) POLYSACCHARIDES

- These are the most complex and most abundant carbohydrates in nature.
- They are of high molecular weight carbohydrate which on hydrolysis yield mainly monosaccarides or products related to monosaccharide.
- These sugars are formed by the condensation of hundreds of thousands of monosaccharide units.
- They are tasteless and only sparingly souble in H2O.

E.g: Strach, cellulose Glycogen , Dextrin Agar, pectin and Chitin etc.

FUNCTIONS OF CARBOHYDRATES

- Carbohydrates are the potential source of energy.
- They act as storage food molecules and also work as an excellent building, protective and supporting structure.
- They also form complex conjugated molecules.
- They are needed to synthesize lubricants and are also needed to prepare the nectar in some flowers.

LIPIDS

These are naturally occurring compounds, which are insoluble in water but soluble in organic solvents. They contain carbon, hydrogen and oxygen like carbohydrates rate but in much lesser ratio of oxygen than carbohydrates. These biomolecules are widely distributed among plants and animals.

CLASSIFICATION OF LIPIDS

Following are the important groups of lipids.

1. Acylglycerol (fats and oil)
2. Waxes
3. Phospholipids.
4. Terpenoids.

(1) ACYLGLYCEROL (FATS AND OIL)

- These are found in animals and plants, provide energy for different metabolic activates and are very rich in chemical energy.
- They are composed of glycerol and fatty acids. The most widely spread acylglycerol is triacyl glycerol, also called triglycerides or natural lipids.

There are two types of acylgycerol

(A) SATURATED ACYLGLYCEROL

- They contain no double bond.
- They melt at higher temperature than unsatured acylglycerols.
- Lipids containing saturated acylgycerol are solid and known as Saturated lipids.

E.g: Butter and Animal fat. etc.

(B) UNSATURATED ACYLGLYCEROL

- 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 found in cotton seeds etc.

(2) WAXES

- Chemically waxes are mixtures of long chain alkanes and alcohols. Ketones and esters of long chain fathy acids
- Waxes are widespread as protective coatings of fruits and leaves some insects also secrete wax.
- Waxes protect plants form water loss and abrasive damage.
- They also provide water barrier for insects, birds and animals etc.

(3) PHOSPHOLIPIDS

- It is most important class of lipids from biological point of view and is similar to acylglycerol or an oil except that one fatty acid is replaced by phosphate group.
- The molecule of phospholipids consist of two ends, which are called hydrophilic (water loving end (head) and hydrophobic (water fearing)end (Tail).
- These are frequently associated with membranes and are related to vital functions such as regulation of cell permeability and transport process.

(4) TERPENOIDS

- It is large and important class of lipids containing "Isoprenoid " unit (C5H8).
- They help in oxidation reduction process, act as components of essential oils of plants and also found in cell membrances as "cholesterol

SUB-CLASSES OF LIPIDS

1. Terpenes
2. Steroids.
3. Carotenoids.

(1) TERPENES

- This group based only on "Isoprenoid" unit and they are usually volatile in nature produce special fragrance.
- Derivatives of this group are found in vitamin A and are also important constituents of chlorophyll and cholesterol biosynthesis.
- They are utilized in synthesis of "Rubber" and "Latex", and some of these are used in perfumes.

(2) STEROIDS

- This group of Terpenoids contains 17 carbon atoms ring called "steroid nucleus".

(3) CAROTENOIDS

- They consist of fatty acid like carbon chain and usually found in plants, for example carotene, xanthophylls etc.

NUCLEIC ACIDS

Nucleic Acids Were First Isolated In 1870 By an Austrian Physician Fridrich Micscher from the nuclei of pus cells. These bio molecules are acidic in nature and present in the nucleus.

TYPES OF NUCLEIC ACIDS

Nucleic acids are of two types.

1. Deoxyribonucleic acid or DNA
2. Ribonucleic acid or RNA

CHEMICAL NATURE OF NUCLEIC ACID

Nucleic acids are complex substances. They are polymers of units called nucleotides. DNA is made up of deoxyribonucleotides, while RNA is composed of ribo nucleotides.

STRUCTURE OF NUCLEOTIDE

Each nucleotide is made of three subunits

a) 5-carbon monosaccharide (a pentose sugar)

b) Nitrogen containing base.
c) Phosphoric acid.

(A) PENTOSE SUGAR

Pentose sugar in RNA is ribose, while in DNA it is deoxyribose.

(B) NITROGENOUS BASE

Nitrogenous bases are of two types

(I) PYRIMIDINES (SINGLE RINGED): These are cytosine (abbreviated as C), thymine (abbreviated as T), and uracil (abbreviated as U).

(II) PURINES (DOUBLE RINGED): These are adenine (abbreviated as A) and guanine(abbreviated as G).

C) PHOSPHORIC ACID

Phosphoric acid (H3PO4) has the ability to develop ester linkage with OH group of pentose sugar.

FORMATION OF NUCLEOTIDE

Formation of nucleotide takes place in two steps. First the mitrogenous base combines with pentose sugar at its first carbon to form a "Nucleoside" In second step the phosphoric acid combines with the 5th carbon of pentose sugar to form a "Nucleotide".

(A) MONONUCLEOTIDES

- They exist singly in the cell or as a part of other molecules.
- These are not the part of DNA or RNA and some of these have extra phosphate groups e.g ATP.

B) DINCULEOTIDES

- These nucleotides are covalently bounded together and usually act as co-enzymes

E.g NAD (Nicotinamide dinucleotide).

(C) POLYNUCLEOTIDES

- Nucleotides are found in the nucleic acid as "Polynucleotide" and they have a variety of role in living organisms.