CHAPTER 2

INTRODUCTION TO BIOCHEMISTRY

Q.1: Define biochemistry give its importance.
➔ Define biochemistry and write its significance / role in biology.
➔ Define Metabolism and differentiate between anabolism and catabolism.

Ans: BIOCHEMISTRY

> **Q: What is Biochemistry.**
> **(GUJ-G1), (GUJ-G2), (FBD-G1)-15**

Definition

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

Significance/role of Biochemistry

A basic knowledge of biochemistry is essential for understanding anatomy and physiology, because all of the structures of an organism have biochemical organization and different processes e.g. photosynthesis, respiration, digestion and muscle contraction can all be describe in biochemical terms.

Chemical Compounds of Living Organisms

All living things are made of certain chemical compounds, which are generally classified as organic and inorganic compounds.

- Most **organic compounds** in living organisms are carbohydrates, proteins, lipids and nucleic acids.
- **Inorganic substances** are water, carbon dioxide, bases and salts.

Typically an animal and a bacterial cell consist of chemicals as shown in following table.

S.No.	Chemical Components	% 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.	RNA	6	1.1
7.	Other organic molecules (enzymes, hormones, metabolites)	2	2
8.	Inorganic ions (Na^+, K^+, Mg^{++}, Cl^-, SO_4^- etc.)	1	1

Importance of Chemicals

The survival of an organism depends upon its ability to take some chemicals from its environment and use them to make chemicals of its living matter. Life of an organism depends upon the ceaseless chemical activities in its cells.

METABOLISM

Definition

"All the chemical reactions taking place in a cell are collectively called as metabolism".

Types

There are two types of metabolism:

(i) Anabolic Reactions

Reactions in which simpler substances are combined to form complex substances are called anabolic reactions.

★ Anabolic reactions need energy e.g. photosynthesis.

(ii) Catabolic Reactions

Reactions in which larger substances are broken down into simpler substances are called catabolic reactions.

★ Energy is released during these reactions e.g. respiration.

Coordinated Catabolic and Anabolic Activities

Anabolic and catabolic reactions go hand in hand in the living cells. Complex molecules are broken down and the resulting smaller molecules are reused to form new complex molecules.

Inter conversions of carbohydrates, proteins and lipids that occur continuously in living cells are examples of coordinated catabolic and anabolic activities.

IMPORTANCE OF CARBON

Q.2: Write a note on importance of carbon.

→ What are the effects of carbon bonding on structure and give importance of carbon containing compounds.

Ans. INTRODUCTION:

Carbon is the basic element of organic compounds. Due to its unique properties, carbon occupies the centr position in the skeleton of life.

Q: Why carbon occupies central position in the skeleton of life.
(RWP-GI-2015: MTN-GI-16)

Q: Give importance of carbon skeleton of life. (DGK-GII-2016)

Features of Carbon

(i) Carbon is a **tetravalent**.

(ii) Carbon mostly forms **organic compounds**.

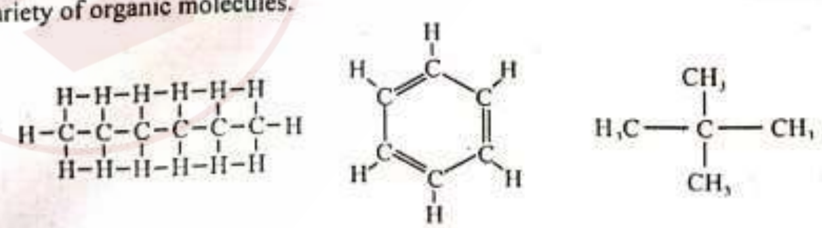
(iii) Carbon usually forms covalent bond with other elements, which stores large amount of energy.

Effect of Carbon Bonding on Structure:

★ When a carbon atom combines with four atoms or radicals, the four bonds are arranged symmetrically in a **tetrahedron** and result to give a sta configuration.

★ **Stability** of carbon due to tetravalency makes it a favourable element for the synthesis of complica cellular structures.

★ Carbon also forms branched or unbranced **chains or rings**. C-C bonds from different types of skele in a variety of organic molecules.



Unbranched Chain **Ringed Structure** **Branched Chain**

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

Combination of Carbon with Other Elements:

Carbon combines commonly with H, O, N, P and S. Combinations with these and other elements contribute to the large variety of organic compounds.

- ★ Carbon and hydrogen bond **(C-H bond)** is the potential source of chemical energy for cellular activities.
- ★ Carbon-oxygen **(C-O bond)** association in glycosidic linkages provides stability to the complex carbohydrate molecules.
- ★ Carbon combines with nitrogen **(C-N bond)** in amino acid linkages to form peptide bonds and form proteins, which are very important due to their diversity in structure and function.

Importance of Carbon-Containing (Organic) Compounds:

Large organic molecules (macromolecules) such as cellulose, fats, proteins, etc. are generally insoluble in water, hence, they form structures of cells. They serve as storage of smaller molecules like glucose, which in turn are responsible for providing energy to the body.

Small molecules (micro-molecules) such as glucose, amino acids, fatty acids etc.

- Serve as a source of energy
- Serve as subunits to build macromolecules
- Some being unstable are immediately broken down to release energy e.g. ATP. These are immediate source of energy for cellular metabolism.

IMPORTANCE OF WATER

Q.3: Describe the importance of water for life.

→ Differentiate between heat capacity and heat of vaporization.

Ans. INTRODUCTION

Water is the medium of life. It is most abundant compound in all organisms. It varies from **65 to 89%** in different organisms. Human tissues contain about **20%** water in **bone cells** and 85% in **brain cells**.

Importance

(i) Almost all the reactions of a cell occur in presence of water. It takes part in many **biochemical reactions** such as hydrolysis of macromolecules.

(ii) It is used as **raw material** in photosynthesis.

SOME OTHER PROPERTIES

1- UNIVERSAL SOLVENT

- ★ Due to its polarity, water is a universal solvent for **polar substance**.
- ★ **Ionic-substances** when dissolved in water, dissociate into positive and negative ions.
- ★ **Non-ionic** substances having charged groups in their molecules are dispersed in water.

(i) When in solution, ions and molecules move randomly to react with other molecules and ions.

(ii) Water is necessary for all the biochemical reactions in living organisms.

(iii) All chemical reactions are catalyzed by enzymes, which work in aqueous environment.

(iv) Non-polar organic molecules such as fats are insoluble in water and help to maintain membranes, which make compartment in the cell.

> **Q: Describe importance of water in living organisms / life.**
> **(FBD-2013: RWP-14: LHR-14GI, 15GII: GUJ, DGK-15GI)**
> **Q: Discuss water as medium of life. Also give its importance.**
> **(SWL-GI-2015: SGD-GI-16)**
> **Q: Give the Biological importance of water. (GUJ-2014GI, 15GII)**
> **Q: Describe any four properties of water. (LHR-GI-2015)**

2- HEAT CAPACITY:

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. Specific heat capacity of water is **1 cal/g-C or 4.184 J/g-C.** This is because much of energy is used to break hydrogen bond.

> **Q: What is the heat capacity of water. (LHR-G2)-16**

Importance

Water has great ability of absorbing heat with minimum of change in its own temperature. Thus it works as **temperature stabilizer** for organisms in the environment and hence protects living material against sudden thermal changes.

3- HEAT OF VAPORIZATION:

Definition

Amount of heat required to convert a substance from its liquid to gaseous state without change in temperature is called heat of vaporization.

- ★ It is expressed in calories per gram or kilocalories per kilogram.
- ★ The specific heat of vaporization of water is **574 Kcal/kg.**

Importance

(i) It plays an important role in **regulation of heat** produced by oxidation.

(ii) It provides **cooling effects** to plants when water is transpired or to animals when water is perspired.

Evaporation of only 2 ml out of one liter of water lowers the temperature of the remaining 998 ml by 1°C.

4- IONIZATION OF WATER:

Water molecules ionize to form H^+ and OH^- ions.

$$H_2 \rightleftharpoons H^+ + OH^-$$

This reaction is reversible but equilibrium is maintained. At 25°C the concentration of each of H^+ and OH^- ions in pure water is about 10^{-7} mole/liter.

Importance:

The ions affect and take part in many of the reactions that occur in cells.

5- 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.
- ★ It forms a ***fluid cushion*** around organs that helps to protect them from trauma.

6- TURGIDITY:

- ★ Water provides turgidity to the cells, turgidity is very important especially in plants.
- ★ It provides support in baby plants and herbaceous stems.

CARBOHYDRATES

Q.4: Write a note on carbohydrates.

➔ Write a note on classification of carbohydrates.

➔ How can we differentiate cellulose, starch and glycogen on the basis of iodine test?

➔ Give function of carbohydrate.

➔ Make ring formulae of ribofuranose and glucopyranose.

➔ Describe what you know about polysaccharides.

Ans. INTRODUCTION

Carbohydrates occur abundantly in living organisms. They are found in all organisms and in almost all parts of the cell.

Meaning

The word carbohydrate literally means **"hydrated carbon"**.They are composed of carbon, hydrogen and oxygen and the ratio of hydrogen and oxygen is the same as in water. Their general formula is $C_x(H_2O)_y$, where x and y are the whole number from three to many thousands.

Definition

Chemically carbohydrates are defined as polyhydroxy aldehydes or ketones or complex substances, which on hydrolysis yield polyhydroxy aldehyde or ketone subunits.

Source

The source of carbohydrates is green plants. These are the primary products of photosynthesis. Other compounds of plants are produced from carbohydrates by various chemical changes.

Cellulose of wood, cotton, paper, starches present in cereals, root tubers, cane sugar and milk sugar are all examples of carbohydrates.

Conjugated Molecules of Carbohydrates

Carbohydrates in cell combine with:

★ Protein forming **glycoproteins**

★ Lipids forming **glycolipids**

• Glycoproteins and glycolipids have structural role in the extracellular matrix of animals and bacterial cell wall. Both these conjugated molecules are components of biological membranes.

CLASSIFICATION OF CARBOPHYDRATES

Carbohydrates are also called **'saccharides'** (derived from Greek word 'saccharon' meaning sugar) and are classified into three groups:

(i) Monosaccharides

(ii) Oligosaccharides

(iii) Polysaccharides

Q: Write a detailed note on monosaccharides. (GUJ-2014)

Q: Write down the characteristics of Monosaccharides and Oligosaccharides. (SWL-2013)

Q: Compare monosaccharide with oligosaccharide. (GUJ-2010)

Q: What is Polysaccharide? Describe its two different types. (BWP-2015: GUJ-13: LHR-14)

Q: Write a note on Oligosaccharides. (AJK-GI-2015)

Q: What are polysaccharides? Describe its two different types. (BWP-2015GI: LHR-GII, GUJ-GI-15)

Q: What are monosaccharides? Explain. (BWP-GI-2016)

Q: Explain polysaccharides with examples. (DGK-GI-2016)

(i) MONOSACCHARIDES

These are simple sugars:

Features

(i) They are sweet in taste

(ii) They are easily soluble in water

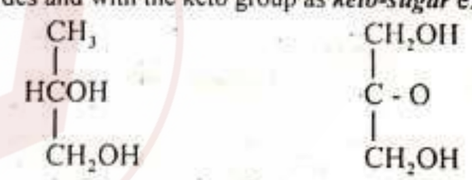
(iii) They cannot be hydrolyzed into simple sugars.

Composition

Chemically they are either polyhydroxy aldehydes or ketones.

All carbon atoms in monosaccharides except one have a hydroxyl group.

The remaining carbon atom is either a part of aldehyde group or a keto group. The sugar with aldehyde group is called ***aldo-sugar*** e.g. glyceraldehydes and with the keto group as ***keto-sugar*** e.g. dihydroxyacetone.

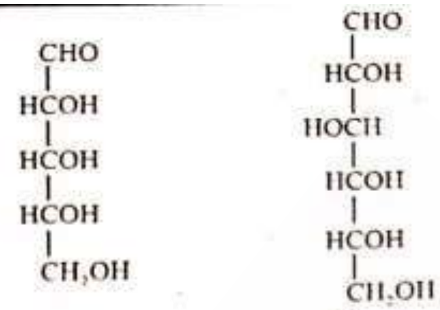


Aldehyde form **Keto form**

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

Types

In nature monosaccharides with 3 to 7 carbon atoms are found. They are called trioses (3C), **tetroses** (4C), **pentoses** (5C), **hexoses** (6C) and **heptoses** (7C). They have general formula $(CH_2O)_n$. Where "**n**" is the whole number from three to many thousands.



Ribose
(A pentose sugar)

Glucose
(A hexose sugar)

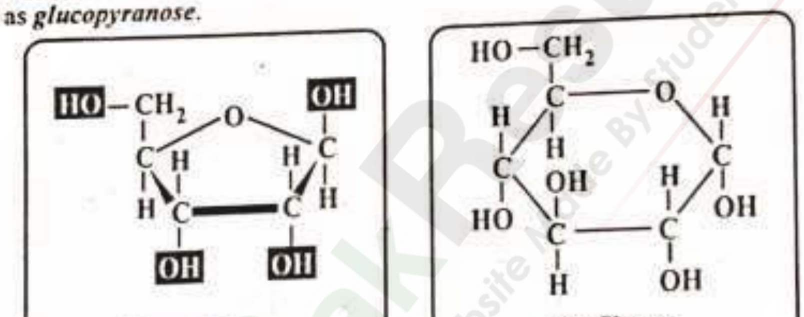
Fig: Structure of Ribose and Glucose

Examples

- ★ Two trioses mentioned above i.e. glyceraldehydes & dihydroxyacetone, are intermediates in respiration and photosynthesis.
- ★ Tetroses are rare in nature and occur in some bacteria.
- ★ Pentones and hexoses are most common. Most important hexose is glucose, which is an aldose sugar.

Ring formation

Most of the monosaccharides form a ring structure when in solution. For example ***ribose*** will form a five-cornered ring known as ***glucopyranose***.



(a) Ribose
Ribofuranose (D-Ribose)

(b) Glucose
Glucopyranose (D-glucose)

Fig. Ribose and glucose form ring shaped structures.

Glucose-Common Example

- ★ Glucose is naturally produced in green plants, which take carbon dioxide from the air and water from the soil to synthesize glucose.

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Energy is consumed in this process, which is provided by sunlight. So this process is called photosynthesis. For synthesis of 10 g of glucose 717.6 Kcal of solar energy is used. This energy is stored in the glucose molecules as chemical energy and becomes available in all organisms when it is oxidized in the body.

- ★ In free state, glucose is present in all fruits, being abundant in grapes, figs and dates.
- ★ Our body normally contains 0.08% glucose.
- ★ In combined form, it is found in many disaccharides and polysaccharides. Starch, cellulose and glycogen yield glucose on complete hydrolysis.

(ii) OLIGOSACCHARIDES

Features

- (i) These are less sweet in taste.
- (ii) These are less soluble in water.
- (iii) On hydrolysis, they yield from two to ten monosaccharides.
- (iv) The covalent bond between two monosaccharides formed by the removal of H_2O molecule is called **Glycosidic linkage**.

Types

- ★ Those yielding two monosaccharides on hydrolysis are called disaccharides.
- ★ Those yielding three are known as trisaccharides and so on.

Examples

- ★ Physiologically important disaccharides are maltose, sucrose and lactose.
- ★ Most familiar disaccharide is sucrose (cane sugar), which on hydrolysis yields glucose and fructose, both of which are reducing sugars. Its molecular formula is $C_{12}H_{22}O_{11}$.

Glucose + Galactose $\longrightarrow$ Lactose

Glucose + Glucose $\longrightarrow$ Maltose

Glucose + Fructose $\longrightarrow$ Sucrose

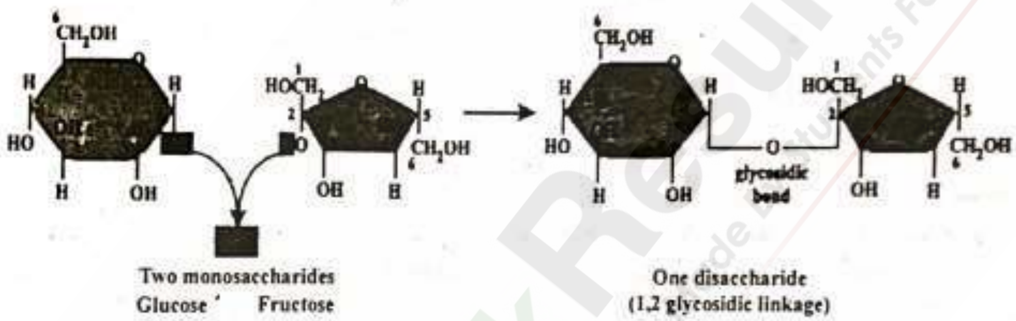


Fig: A disaccharide. Note carefully the glycosidic linkages between the two monosaccharides.

EFFECT OF HYDROLYSIS ON OLIGOSACCHARIDES

On hydrosylsis oligosaccharides yields from two to ten monosaccharides the ones yielding two monosaccharide are known as disaccharides those yield three are trisaccharides and so on.

> **Q: What is the effect of hydrolysis on Oligosaccharides.**

(iii) POLYSACCHARIDES

Polysaccharides are the most complex and most abundant carbohydrates in nature.

Features

- (i) They are usually branched and tasteless.
- (ii) They are formed by several monosaccharide units linked by glycosidic bonds.
- (iii) They have high molecular weights.
- (iv) They are sparingly soluble in water.

Examples

Some biological important polysaccharides are starch, glycogen, cellulose, dextrin's, agar, pectin and chitin etc.

(1) Starch

- (i) It is found in fruits, grains, seeds and tubers.
- (ii) It is the main source of carbohydrates for animals.
- (iii) On hydrolysis, it yields glucose molecules.
- (iv) It gives blue colour with iodine.
- (v) It occurs in two types:

★ **Amylose** starches have unbranched chains of glucose and are soluble in hot water.

★ Amylopectin starches have branched chains and are insoluble in hot or cold water.

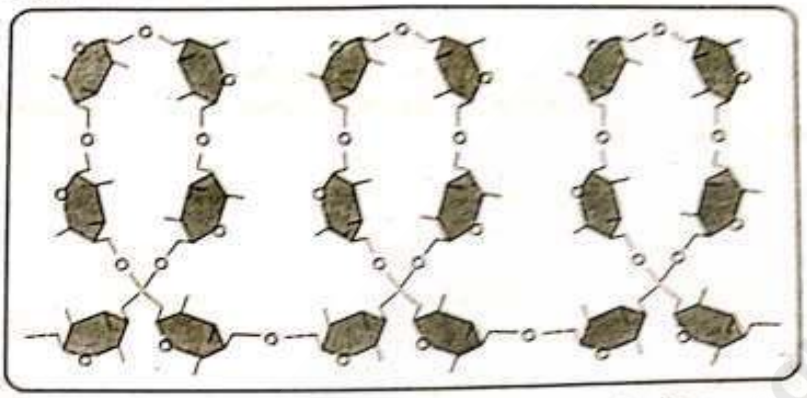


Fig. Polysaccharides are polymers of monosaccharides.

(2) Glycogen

(i) It is also called animal starch because it is found in animal bodies.

(ii) In animals, it is most abundantly found in liver and muscles, though found in all animal cells.

(iii) It is insoluble in water.

(iv) It gives red colour with iodine.

(v) It yields glucose on hydrolysis.

(3) Cellulose

(i) It is the most abundant carbohydrate in nature.

(ii) It is the main constituent of plant cell walls and highly insoluble in water. Cotton is the pure form of cellulose.

(iii) On hydrolysis, it yields glucose molecules.

(iv) It gives no colour to iodine.

(v) It is not digested by human digestive tract. In the herbivores, it is digested because of micro-organisms (bacteria, yeasts, protozoa) in their digestive tract. These micro-organisms secrete an enzyme called cellulose for its digestion.

LIPIDS

Q.5: Write a note on lipids.

→ Give classification of lipids

→ What is an ester, explain with insulation?

→ Give function of lipids.

Ans. INTRODUCTION:

The lipids are a heterogeneous group of compounds related to fatty acids. They are insoluble in water but soluble in organic solvents such as ether, alcohol, chloroform and benzene. Lipids include fats, oils, waxes, cholesterol and related compounds.

Functions:

(i) Lipids as hydrophobic compounds are **components of cellular membranes**.

(ii) They also store energy. Because of higher proportion of C-H bonds and very low proportion of oxygen, lipids store double the amount of energy as compared to the same amount of any carbohydrate.

(iii) Some lipids provide **insulation** for atmospheric heat and cold and also act as water proof material.

(iv) They also provide mechanical protection from abrasive damage.

(v) Waxes, in the exoskeleton of insects and cutin, are an additional protective layer on the cuticle of epidermis of some plant organs. Leaves, fruits and seeds are some of main examples.

Q: Write a note on Phospholipids. (SWL-2014)

Q: Write a note on Acylglycerols. (LHR, GUJ, MTN-2014)

Q: Describe acylglycerols in detail. (GUJ-2014GI: LHR-15GII: SGD-16GI)

Q: Write down about the acylglycerols. (MTN-GI-2015)

Q: What are phospholipids? (GUJ-GI-2015: DGK-GI-16)

CLASSIFICATION

Lipids have been classified as:

(1) Acylglycerols (2) Waxes

(3) Phospholipids (4) Terpenoids-lipids including carotenoids and steroids.

- Glycolipids and Sphingolipids are also important groups of lipids.

The structure of some of them is given below:

(1) ACYLGLYCEROLS

It is one of the most important groups of lipids.

Chemical Composition

Acylglycerols are composed of **glycerol** and **fatty acids**. They are esters. An ester is the compound produced as the result of a chemical reaction of an alcohol with an acid and a water molecule is released as shown below:

$$\underset{alcohol}{C_2H_5OH} + \underset{acetic\ acid}{HOOCCH_3} \longrightarrow \underset{an\ ester}{C_2H_5OCOCH_3} + \underset{water}{H_2O}$$

Example:

The most widely spread acylglycerol is ***triacyl glycerol***, also called triglycerides or neutral lipids.

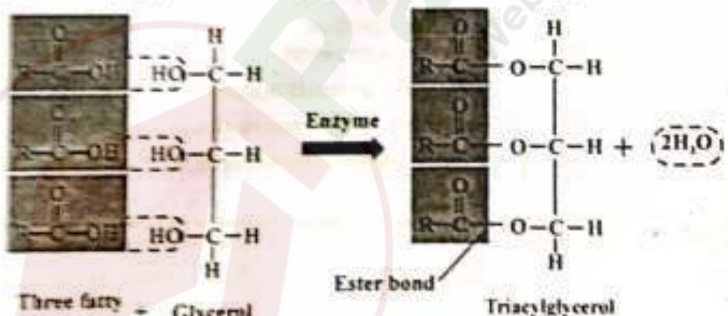


Fig: Triacylglycerol is composed of one glycerol and three fatty acids molecules.

Fatty Acids:

- Fatty acids are one of the most important components of triglycerides.
- They contain even number of carbon atoms in straight chains ranging from 2-30, attached with hydrogen and having an acidic group COOH (carboxylic group).
- There may be two types of fatty acids i.e.
  - (i) ***Saturated*** fatty acids which contain no double bonds.
  - (ii) ***Unsaturated*** fatty acids, which contain upto 6 double bonds.

- ★ In animals, fatty acids are straight chains.
- ★ In plants, they may be branched or ringed.
- ★ Solubility of fatty acids in organic solvents and their melting points increase with increasing number of carbon atoms in chain.

For example, palmitic acid (C_{16}) with melting point 63.1°C is much more soluble in organic solvents than butyric acid (C_4) with melting point – 8°C.

In this reaction, OH is released from alcohol and H from an acid, H and OH combine and form a water molecule.

$\overset{2}{C}H_3.\overset{1}{C}OOH$ **Acetic Acid (C_2)**

$\overset{4}{C}H_3.\overset{3}{C}H_2.\overset{2}{C}H_2.\overset{1}{C}OOH$ **Butyric Acid (C_4)**

$\overset{16}{C}H_3.\overset{15}{C}H_2.\overset{14}{C}H_2.\overset{13}{C}H_2.\overset{12}{C}H_2.\overset{11}{C}H_2.\overset{10}{C}H_2.\overset{9}{C}H_2.\overset{8}{C}H_2.\overset{7}{C}H_2.$

$\overset{6}{C}H_2.\overset{5}{C}H_2.\overset{4}{C}H_2.\overset{3}{C}H_2.\overset{2}{C}H_2.\overset{1}{C}OOH$ **Palmitic Acid (C_{16})**

$\overset{18}{C}H_3.\overset{17}{C}H_2.\overset{16}{C}H_2.\overset{15}{C}H_2.\overset{14}{C}H_2.\overset{13}{C}H_2.\overset{12}{C}H_2.\overset{11}{C}H_2.\overset{10}{C}H_2.\overset{9}{C}H_2.$

$\overset{8}{C}H_2.\overset{7}{C}H_2.\overset{6}{C}H_2.\overset{5}{C}H_2.\overset{4}{C}H_2.\overset{3}{C}H_2.\overset{2}{C}H_2.\overset{1}{C}OOH_2$ **Oleic Acid (C_{18})**

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.

Fats are considered as high energy molecules or compounds because of highs proportion of C – H bonds and very low proportion of oxygen lipids stare the double amount of energy as compared to the same amount of any carbohydrate.

Types of Fats

- ★ Fats containing unsaturated fatty acids are usually liquid at room temperature and are said to be *oils*. They are mostly obtained from plants e.g. soyabean oil, canola oil, sunflower oil etc.
- ★ Fats containing saturated fatty acids are solid at room temperature and are simply said as *fats*. They are mostly obtained from animals e.g. desighee, butter, cheese etc.

Fats and oils are lighter than water and have a specific gravity of about ***0.8***. They are not crystalline but some can be crystallized under specific conditions.

Q: Classify Proteins according to their structure. **(BWP, MTN-2014: LHR-2010)**

Q: Give secondary and tertiary structure of protein. (MTN-2012GII)

Q: Describe Primary and Secondary structure levels of protein organization. (SGD-2014GI, 15GII: MTN-2010: AJK-16GI)

Q: Compare alpha helix structure with beta-pleated sheet in protein. (GUJ-2011)

Q: What function are performed by proteins in the bodies of living organisms? (SGD-GI-2015: RWP-GI-16)

Q: Classify proteins according to their structure. (BWP-G1-2014)

Q: Write a note primary structure of protein. (FBD-GI-2016)

Q: Why are fats considered as high energy compounds. (MTN-G1)-16

(2) WAXES

Chemical Composition

Chemically, waxes are mixtures of long chain alkanes (with odd number of carbons ranging from C_{25} to C_{35}) and alcohols, ketons and esters of long chain fatty acids.

Characteristics

(i) Waxes are widespread as protective coatings on fruits and leaves.

(ii) Some insects also secrete wax.

(iii) They protect plants from water loss and abrasive damage.

(iv) They provide water barrier for insects, birds and animals such as sheep.

Q: Write down any eight functions of proteins.

Q: What are waxes? (RWP-G1)-15

Q: Describe fibrous and globular proteins. (SWL-GI-2016)

Q: Give the importance of proteins. (LHR-GI-2016)

(3) PHOSPHOLIPIDS

They are widespread in bacteria, animal and plant cells and are frequently associated with membranes.

Chemical Composition

Phospholipids are derivatives of **phosphatidic acid,** which are composed of glycerol, fatty acids and phosphoric acid. Nitrogenous bases such as choline, ethanolamine and serine are important components of phospholipids.

Example

Phosphatidylcholine is one of the common phospholipids.

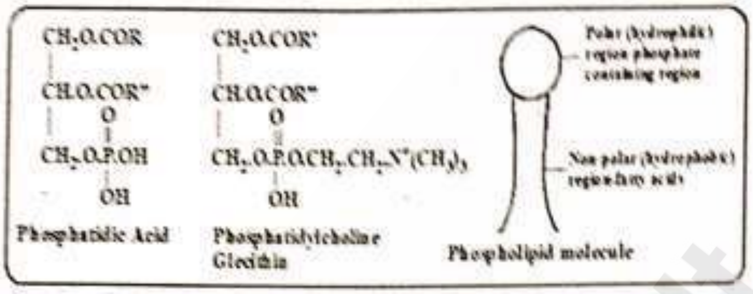
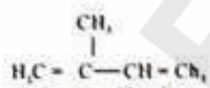


Fig: Phospahditic acid is composed of glycerol, 2 fatty acids (on C1 and C2), and a phosphoric acid on C3 of glycerol. In phospholipid a nitrogenous base (e.g. choline) is attached to phosphoric acid in phosphatidic acid.

(4) TERPENOIDS

Terpenoids is a very large and important group of compounds, which are made up of a simple repeating units called **isoprenoid unit.**

Isoprenoid units by condensation, in different ways, give rise to compounds such as rubber, carotenoids, steroids, terpenes etc.



Isoprenoid unit

PROTEINS

Q.6: Write a note on proteins.

➔ What are the functions of protein?

➔ Discuss different structures of proteins with example.

➔ Write a short note on amino acids.

Ans. INTRODUCTION

Proteins are the most abundant organic compounds to be found in cells and comprise over **50 %** of their total dry weight. They are present in all types of cells and in all parts of the cell.

FUNCTION

Proteins perform many functions. Some of their important functions are;

(i) They **build many structures** to the cell.

(ii) All **enzymes** are proteins and in this way they control the whole metabolism of the cell.

(iii) **Hormones** are also proteinous and regulate metabolic processes.

(iv) Some proteins e.g. **hemoglobin** work as carrier and transport specific substances such as oxygen, lipid, metal ions etc.

(v) Some proteins called antibodies defend the body against pathogens.

(vi) **Blood clotting** proteins prevent the loss of blood from the body after any injury.

(vii) **Movement** of organs and organisms and movement of chromosomes during anaphase of cell division are caused by proteins.

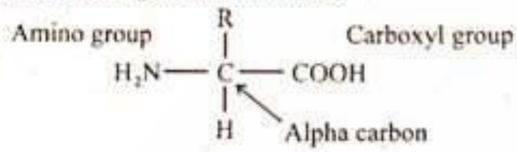
AMINOACIDS AS UNITS OF PROTEIN

Proteins are polymers of amino acids, the compounds containing carbon, nitrogen, oxygen and hydrogen. The number of amino acids varies from a few to 3000 or even more in different proteins.

- About 170 types of amino acids have been found to occur in cells and tissues.
- Out of 170, 25 are constituents of proteins.
- Most of the proteins however are made of 20 types of amino acids.

CHEMICAL COMPOSITION OF AMINO ACIDS

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



R may be

- Hydrogen atom as in glycine or
- NH_3 as in alanine

So amino acids mainly differ due to the type or nature of R group.

LINKAGE BETWEEN AMINO ACIDS

Amino acids are linked together to form polypeptide **proteins.** The amino group of one amino acid may react with the carboxyl group of another, releasing a molecule of water.

The linkage between the hydroxyl group of carboxyl group of one amino acid and the hydrogen of amino group of another amino acid release H_2O and C-N link to form a bond called **peptide bond.**

Example

Glyeine and alanine may combine to form glycylalanine. It has two amino acid subunits and is a dipeptide

A dipeptide has an amino group at one end and a carboxyl group at the other end of the molecule. So both reactive parts are again available for further peptide bonds to produce tripeptides, tetrapeptides and pentapeptide etc, leading to polypeptide chains.

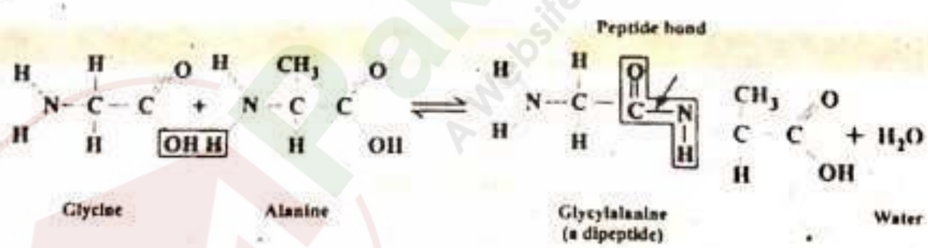


Fig: Peptide linkage- formation of peptide bond.

ARRANGEMENT OF AMINO ACIDS IN PROTEINS

There are over 10,000 proteins in the human body, which are composed of unique and specific arrangement of 20 types of amino acids.

The sequence is determined by the order of nucleotides in the DNA.

The arrangement of amino acids in a protein molecule is highly specific for its proper functioning. If any amino acid is not at its normal place, the protein fails to carry on its normal function.

Example

The best example is **sickle cell hemoglobin.** In this case only one amino acid in each beta chain out of the 574 amino acids do not occupy the normal place in the proteins and the hemoglobin fails to carry any or sufficient oxygen, hence leading to death of the patient.

SIZE OF PROTEINS

The size of protein molecules is determined by the **type of amino acid** and the **number of amino acids** comprising the particular protein molecule.

STRUCTURE OF PROTEINS

Q.7: Describe primary and secondary structure of protein.

- ➔ **What function are performed by proteins in the bodies of living organisms?**
- ➔ **Classify proteins according to their structure.**
- ➔ **Write down any eight functions of proteins.**
- ➔ **Describe fibrous and globular proteins.**
- ➔ **Give the importance of proteins.**

Ans. STRUCTURE OF PROTEIN

Each protein has specific properties, which are determined by the number and the specific sequence of amino acids in a molecule and upon the shape, which the molecule assumes as the chain folds into its final, compact form.

There are the four levels of organization, which are described below.

(1) Primary Structure of Proteins

Prime structure comprises the **number and sequence of amino acids** in a protein molecule. **F. Sanger** was the first scientist who determined the sequence of amino acids in a protein molecule.

Fig: Polypeptide chains in keratin (fibrous protein) and in hemoglobin (globular protein) are held together to form respective function proteins.

Example

F. Sanger concluded that **insulin** is composed of 51 amino acids in two chains. One of the chains has 21 amino acids and the other has 30 amino acids and they are held together by disulphide bridges.

Hemoglobin is composed of four chains, two alpha and two beta chains. Each alpha chain contains 141 amino acids while each beta chain contains 146 amino acids. So, total amino acids in HB are 574.

(2) Secondary Structure Proteins

Secondary structure tells us about the **helix structure of other regular configuration** of polypeptide chains do not lie flat. They usually coil into a helix or into some other regular configuration.

Example

One of the common secondary structures is the **α-helix.** It involves a spiral formation of the basic polypeptide chain. The α-helix is a very uniform geometric structure with 3.6 amino acids in each turn of the helix.

The helical structure is kept by the formation of hydrogen bonds among amino acid molecules in successive turns of the spiral.

β- pleated sheet is formed by fold backs of the polypeptide.

(3) Tertiary Structure

Usually a polypeptide chain bends and folds upon itself **form a globular shape.** Tertiary structure tells us about **shape of protein after bending and folding.**

Tertiary structure is maintained by three types of bonds, named ionic, hydrogen and disulphide (-S-S).

Example

In aqueous environment, the most stable tertiary structure (conformation) is that in which hydrophobic amino acids are buried inside with hydrophilic amino acids are on the surface of the molecule.

(4) **Quaternary Structure**

In many highly complex proteins, polypeptide tertiary chains are **aggregated** and held together by hydrophobic interactions, hydrogen and ionic bonds. This specific arrangement is the quaternary structure.

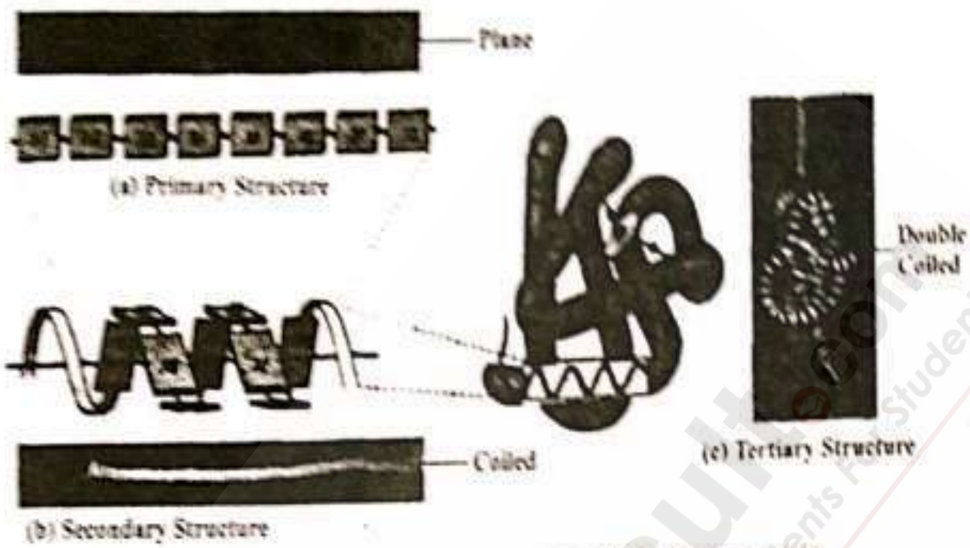


Fig. Three levels of protein structures compared with a telephone wire

Example

Hemoglobin, the oxygen carrying protein of red blood cells, which exhibits such a structure.

CLASSIFICATION OF PROTEINS

Because of complexity of structure and diversity in their function, it is very difficult to classify proteins in a single well-defined fashion. However, according to their structure, proteins classified as follows.

(1) **Fibrous Proteins**

- They consist of molecules having one or more polypeptide chains in the form of **fibrils.**
- **Secondary structure** is most important in them.
- They are **insoluble in aqueous media.**
- They are **non- crystalline and elastic** in nature.
- They perform **structural role** in cells and organism.

Example

Examples are silk fiber (from silk worm and spiders, web), myosin (in muscles cells), fibrin (of blood clot) and keratin (of nails and hair).

(2) **Globular Proteins**

- They are **spherical or ellipsoidal** due to multiple folding of polypeptide chains.
- **Tertiary structure** is most important in them.
- They are **soluble in aqueous media** such as salt solution, solution of acids and bases or aqueous alcohol.
- They can be **crystallized.**
- They disorganize with changes in the physical and physiological environment.

Example

Examples are enzymes, antibodies, hormones and hemoglobin.

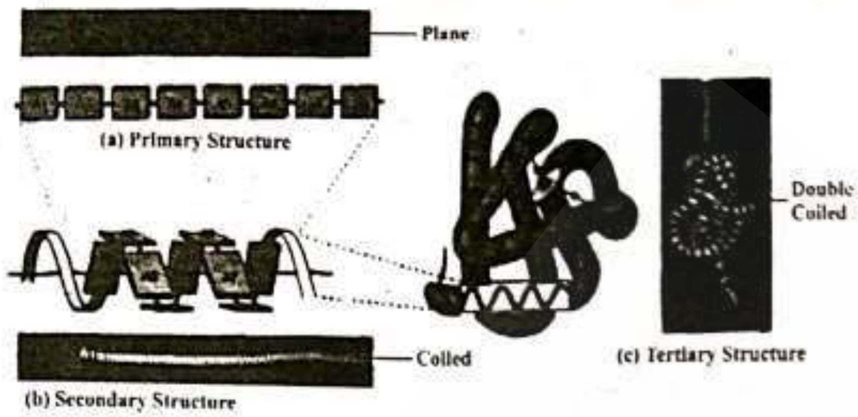


Fig: Three levels of protein structures compared with a telephone wire

NUCLEIC ACIDS (DNA and RNA)

Q.8: Write a note on Nucleic acid.

➔ **Discuss types of nucleic acids?**

➔ **Explain conjugated molecule and give example.**

➔ **What is an RNA give different types of RNA.**

Ans. NUCLEIC ACID

Nucleic acids are important component of cells, which control all the activities of cell.

DISCOVERY

Nucleic acids were first isolated in 1870 by **F. Miescher** from the nuclei of pus cells. Due to their isolation from nuclei and their acidic nature, they were named as nucleic acids.

TYPES OF NUCLEIC ACIDS

There are two main types of nucleic acids i.e

(i) Ribonucleic acid (RNA)

(ii) Deoxyribonucleic acid (DNA)

There chemical composition is described as follows:-

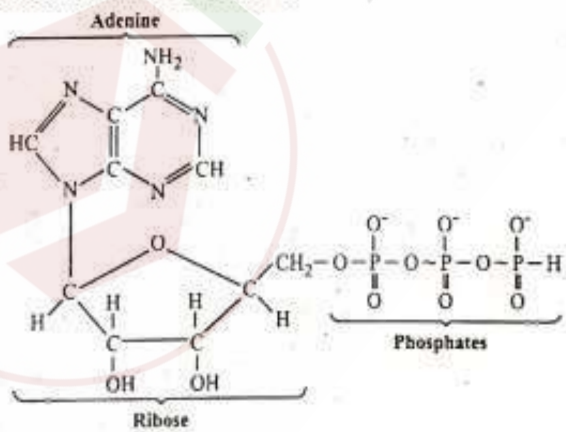


Fig: Structural Formula of ATP (a nucleotide)

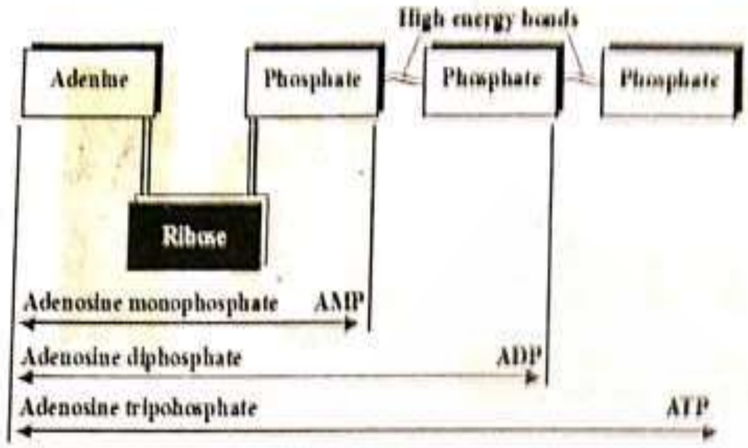


Fig: Components of ATP (a nucleotide)

NUCLEOTIDE

Nucleotides are units of nucleic acids, which are linked to each other by ester linkage to form polynucleotide chains:

- ★ DNA is made of deoxyribonucleotides.
- ★ RNA is made of ribonucleotides.

CHEMICAL COMPOSITION OF NUCLEOTIDE:

Typically a nucleotide is composed of three components i.e.

(i) Pentose sugar (ii) Nitrogenous base (iii) Phosphoric acid

(1) Pentose Sugar:

- ★ Pentose sugar is RNA is **ribose**.
- ★ Pentose sugar in DNA is **dexyribose**.

(2) Nitrogenous Bases:

Nitrogenous bases are of two types:

(i) Single-ringed pyrimidines, which include cytosine (C), thymine (T) and uracil (U).

(ii) Double-ringed purines, which include ademnine (A) and guanine (G).

(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 nitrogenous base is attached to position 1 of pentose sugar while phosphoric acid is attached to position 3 of pentose sugar in front and position 5 of pentose sugar behind it.

Since phosphate forms a double ester linkage with pentose sugar, the linkage is known as ***phosphodiester linkage***.

FORMATION OF A NUCLEODTIDE:

A compound, nucleoside is formed by combination of a base and a pentose sugar. A nucleoside and a phosphoric acid combine to form a nucleotide.

As we know pentose sugar is RNA is ribose while in DNA is deoxyribose. Deoxybribose is formed from ribose by removing one oxygen from OH group at carbon number 2.

Q: Describe RNA and types of RNA.
(LHR-2011, 13: MTN-13: BWP-13, 14: SWL-14GII: FBD-14: DGK-16)

Q: Compare DNA with RNA.
(FBD-GI-2016)

Q: What is RNA? Give the functions of its various types.
(DGK-GII-2015)

Q: What is RNA? Explain different types of RNA. **(FBD-GI-2014)**

Q: Describe the types of RNA.
(BWP-GI-2014)

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

DEOXYRIBONUCLEIC ACID (DNA)

DNA is heredity material. It controls the properties and potential activities of a cell.

LOCATION IN CELL:

DNA occurs in chromosomes, in the nuclei of the cells and in much lesser amounts in mitochondria and chloroplast.

CHEMICAL COMPOSITION OF DNA:

DNA is made of four kinds of ***nucleotides*** namely:

- ★ d-adenosine monophosphate (d-AMP)
- ★ d-guanosine monophosphate (d-GMP)
- ★ d-cytidine monophosphate (d-CMP)
- ★ d-thymidinemonophosphyate (d-TMP)

List of ribonucleotides and deoxyribonucleotides

RNA			DNA	
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

These nucleotides are united with one another through phosphodiester linkages in a specific sequence to form long chains.

Q: What is NAD. (SWL-G1)-16

Two nucleotides joint to form dinucleotide e.g. Nicotinamide adenine dinucleotide (NAD), which is important coenzyme in several oxidation-reduction reactions in the cells.

Three nucleotides join to form trinucleotide.

RATIO OF BASES IN DNA:

In 1951, Erwin Chargaff provided data about the ratios of different bases present in DNA. This data suggested that adenine and thymine are equal in ratio and so guanine and cytosine.

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

PHYSICAL STRUCTURE OF DNA:

Maurice Wilkins and Rosalind Franklin used the technique of X-ray diffraction to determine the structure of DNA. At the same time James D. Watson and Francis Crick built the scale to determine the structure of DNA.

- All the data thus obtained strongly suggested that DNA is made of two polynucleotide chains or strands. The two strands are coiled round each other in the form of double helix.
- Coiling of two strands is opposite i.e. they are coiled antiparallel to each other.
- The two chains are held together by weak hydrogen bonds.
- Adenine is opposite to thymine and there are two hydrogen bonds between them.
- Guanine is opposite to cytosine and there are three hydrogen bonds between them.
- The two strands are wound around each other so that there are 10 base pairs in each turn of about 34 Angstrom units (one Angstrom = 10^{-10} = 1/1,000,000,000 or 100-millionth of a centimeter).

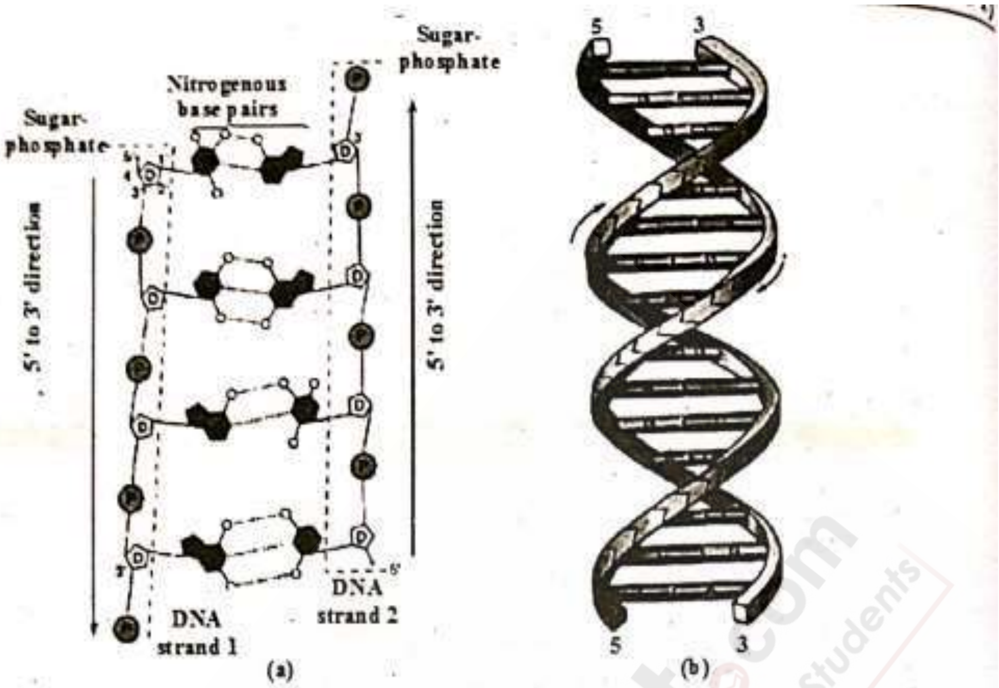


Fig: Model of DNA. Double helical structure of DNA proposed by Watson and Crick (b).A hypothetical sequence of nucleotides (on left side) shows hydrogen bonding between the complementary bases. Note the double bond between A and T and triple bond between C and G (A).

Model of DNA:

Double helical structure of DNA proposed by Watson & Crick (b). A hypothetical sequence of nucleotide (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).

AMOUNT OF DNA:

Amount of DNA is fixed for a particular species as it depends upon number of chromosomes. The amount of DNA in germ line cells (sperms and ova) is almost half to that of somatic cells.

Type of cell	Amount of DNA/nucleus (in pictogram)	
	Chicken	Carp
Red Blood Cells	2.3	3.3
Liver Cells	2.4	3.3
Kidney Cells	2.4	3.3
Sperm Cells	1.3	1.6

Table: Amount of DNA/nucleus in different types of cells of a chicken (bird and a carp (fish)

RIBONUCLEIC ACID (RNA)

RNA is also a polymer of ribonucleotides.

(1) LOCATION IN CELL:

RNA is present in the nucleolus, in the ribosomes, in the cytosole and in smaller amounts in other parts of the cell.

Structure:

(i) The RNA molecules occur as single strand, which may be folded back on it, to give double helical characteristics.

(ii) Nitrogenous bases, which are involved, are adenine (A), guanine (G), cytosine (C) and uracil (U).

(iii) RNA is synthesized by DNA in a process known as transcription.

Types of RNA:

There are three main types of RNA i.e.

(1) Messenger RNA (mRNA)

(2) Transfer RNA (tRNA)

(3) Ribosomal RNA (rRNA)

All these three types of RNA are synthesized from DNA in the nucleus and then are moved out in cytoplasm to perform their specific functions.

(3) Messenger RNA (m RNA)

- ★ It takes genetic message from the nucleus to the ribosomes in the cytoplasm to perform particular proteins. They carry the genetic information from DNA to ribosomes, where amino acids are arranged according to the information in mRNA to form specific protein molecules.
- ★ 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 nucleotides.
- ★ mRNA is about 3-4% of the total RNA in the cell.

(4) Transfer RNA (tRNA)

- ★ It transfers amino acid molecules to the site where peptide chains are being synthesized. There is one specific tRNA for each amino acid. So the cell will have at least 20 kinds of tRNA molecules. It picks up amino acids and transfers them to ribosomes, where they are linked to each other to form proteins.
- ★ Their molecules are small, each with a chain length of 75 to 90 nucleotides.
- ★ It comprises about 10-20% of the cellular RNA.

Q: What is function of rRNA (FBD-G2)-15

(5) Ribosomal RNA (rRNA)

- ★ It acts as machinery for the synthesis of proteins. On the surface of the ribosomes the mRNA and rRNA molecules interact to translate the information from genes into a specific protein.
- ★ It is strongly associated with the ribosomal protein where 40-5% of it is present.
- ★ It is the major portion of RNA in the cell, and may be upto 80% of the total RNA.

CONJUGATED MOLECULES

Definition

Two different molecules belonging to different categories usually combine to form conjugated molecules.

Q: What are conjugated molecules. (AJK-G1), (DGK-G1), (SGD-G1)-16, (MTN-G2)-17

Examples with their Role

- ★ Carbohydrates may combine with proteins to form glycoproteins or with lipids to form glycolipids. Most of the cellular secretions are glycoprotein in nature. Both glycoproteins and glycolipids are integral structural components of plasma membrane.
- ★ Lipids and proteins combine to form lipoproteins which are basic structural framework of all types of membranes in the cells.
- ★ Nucleic acids have special affinity for basic affinity for basic proteins. They are combines together to form proteins are not only of structural but also are of functional significance. They play an important role in regulation of gene expression.

Remember:

- All the information for the structure and functioning of cell is stored in DNA.
- For example, in the chromosome of the bacterium *E. coli*, each of the paired strand of DNA contains about 5 million bases arranged in a particular linear order, the information in these bases is divided into units of several hundred bases each. Each unit is a gene (a unit of biological inheritance).
- The *E. coli* genome consists of **4,639,221** base pairs which code for at least 4288 proteins.
- **Haemophilus influenza** is the first microbe to have the genome completely sequenced and this was published in July 28, 1995.