2

BIOLOGICAL MOLECULES

After completing this lesson, you will be able to

- Introduce biochemistry and describe the approximate chemical composition of protoplasm.
- Distinguish carbohydrates, proteins, lipids and nucleic acids as the four fundamental kinds of biological molecules.
- Describe and draw sketches of the dehydration-synthesis and hydrolysis reactions for the making and breaking of macromolecule polymers.
- Explain the following properties of water that make it the cradle of life.
  high polarity,
  hydrogen bonding,
  high specific heat
  high heat of vaporization
  cohesion,
  hydrophobic exclusion
  ionization
  lower density of ice
- Define carbohydrates and classify them.
- Distinguish the properties and roles of monosaccharides, write their empirical formula and classify them.
- Compare the isomers and stereoisomers of glucose.
- Distinguish the properties and roles of disaccharides and describe glycosidic bond in the transport disaccharides.
- Distinguish the properties and roles of polysaccharides and relate them with the molecular structures of starch, glycogen, cellulose and chitin.
- Justify that the laboratory-manufactured sweeteners are "left-handed" sugars and cannot be metabolized by the "right-handed" enzymes.
- Define proteins and amino acids and draw the structural formula of amino acid.
- Outline the synthesis and breakage of peptide linkages.
- Justify the significance of the sequence of amino acids through the example of sickle cell hemoglobin.
- Classify proteins as globular and fibrous proteins.
- List examples and the roles of structural and functional proteins.
- Define lipids and describe the properties and roles of acylglycerols, phospholipids, terpenes and waxes.
- Illustrate the molecular structure (making and breaking) of an acylglycerol, a phospholipid and a terpene.

- Evaluate steroids and prostaglandins as important groups of lipids and describe their roles in living organisms.
- Define nucleic acids and nucleotides.
- Describe the molecular level structure of nucleotide.
- Distinguish among the nitrogenous bases found in the nucleotides of nucleic acids.
- Outline the examples of a mononucleotide (ATP) and a dinucleotide (NAD).
- Explain the double helical structure of DNA as proposed by Watson and Crick.
- Define gene is a sequence of nucleotides as part of DNA, which codes for the formation of a polypeptide.
- Explain the general structure of RNA.
- Distinguish in term of structures and roles, the three types of RNA.
- Define conjugated molecules and describe the roles of common conjugated molecules i.e. glycolipids, glycoproteins, lipoproteins and nucleoproteins.

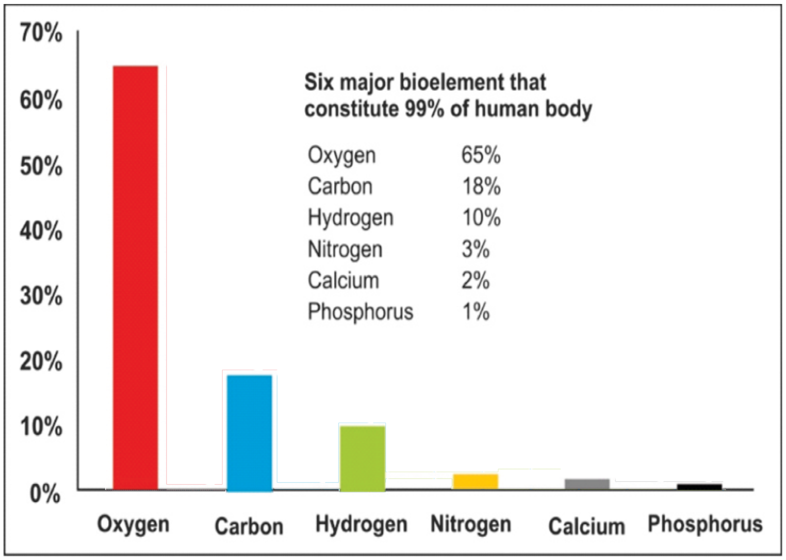
You have got a very brief introduction about biological molecules in IX-X biology course. This chapter caters the detailed study of carbohydrates, proteins, lipids and nucleic acid as well as the importance of water and the role of conjugated molecules.

2.1 BIOLOGICAL MOLECULES IN PROTOPLASM

Biological molecules are different chemical compounds of living beings. **Biochemistry** is the branch of biology that deals with such molecules. It also deals with various chemical reactions (metabolism) of living beings.

2.1.1 Chemical Composition of Protoplasm

Approximately 25 elements out of 92 naturally occurring elements of earth are found in living beings. These are called **bioelements**. However, human body is composed of only 16 of these bioelements. These elements can be classified on the basis of their proportions in organisms. The six commonest bioelements that constitute 99% of protoplasm are called **major** bioelements. **Minor** bioelements are those that are found as less than 1% whereas those that are found as less than 0.01% of the protoplasm are called **trace elements**. The proportions of these



Minor elements include: potassium (0.35%), sulphur (0.25%), chlorine (0.15%), sodium (0.15%) and magnesium (0.05%). **Trace elements** include iron, copper, manganese, zinc

Fig. 2.1: Proportions of various bioelements in human body

elements are given in the fig: 2.1. Some trace elements such as iron are needed by all forms of life. Others are required only by certain species.

The bioelements are combined with each other and can form thousands of different biomolecules which may be **inorganic** (water and minerals) and **organic** (carbohydrates, lipids, proteins and nucleic acids). The proportions of these biomolecules are given in the table.

Table 2.1: Proportions of various biomolecules in bacterial and mammalian cells

Biomolecules	Bacterial cell	Mammalian cell
Water	70%	70%
Protein	15%	18%
Carbohydrates	3%	4%
Lipids	2%	3%
DNA	1%	0.25%
RNA	6%	1.1%
Other organic molecules (enzymes, hormones, metabilites)	2%	2%
Inorganic ions (Na^+, K^+, Ca^{++}, Mg++, Cl^-, $SO4^{--}$)	1%	1%

The four fundamental kinds of biological molecules are carbohydrates, proteins, lipids and nucleic acids. **Carbohydrates** are present in the cytoplasm of the cells and provide fuel for the metabolic activities of the cell. **Proteins** are present in the membranes, ribosomes, cytoskeleton and enzymes of the cell. **Lipids** are present in the membranes and cytoplasm of the cell. Lipids provide a reserved energy source, shape, protect and insulate the cells. The **nucleic acid** DNA is present in the chromosome. It controls the cell activity. The nucleic acid RNA is present in the nucleoplasm and cytoplasm. It takes genetic information from DNA and play role in protein synthesis.

2.1.2 Condensation and Hydrolysis

A **macromolecule** is high molecular weight compound which is made from many repeating units. Molecules built like this are also known as **polymers**.

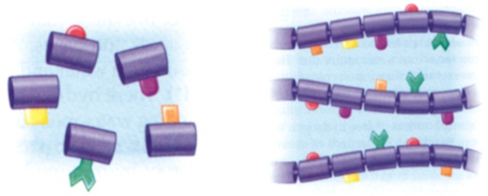


Fig: 2.2: Monomer and polymer

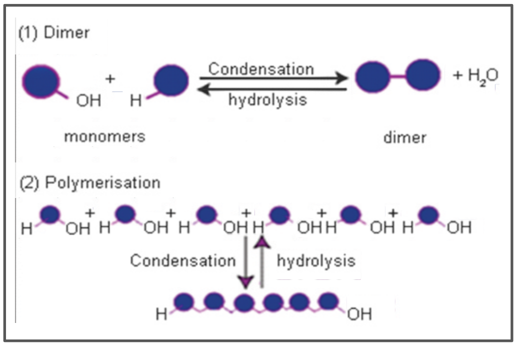


Fig. 2.3: Condensation and Hydrolysis

The individual units of polymers are **micromolecules** which are also known as **monomers**. The interconversions of these molecules are carried out by condensation and hydrolysis.

During **condensation**, when two monomers join, a hydroxyl (–OH) group is removed from one monomer and a hydrogen (–H) is removed from the other to make water and as a result a bond is synthesized between the monomers. The product of such reaction is called a

dimer. If the same reaction is repeated several times the resulting molecule will be a **polymer**. Condensation is also called **dehydration synthesis** because water is removed (dehydration) and bond is made (synthesis). Condensation does not take place unless the proper enzyme is present and the monomers are in an activated energy- rich form.

The **hydrolysis** is essentially the reverse of condensation i.e., the breakdown of a polymer into its monomers by the addition of water. During hydrolysis, an (–OH) group from water is attached to one monomer and (–H) is attached to the other monomer. Actually all digestion reactions are examples of hydrolysis, which are controlled by enzymes such as carbohydrases, proteases, lipases, nucleases.

Science Titbits

Do not confuse involvement of water in hydrolysis with making a solution, in which the role of water is to act as a solvent, rather than taking part in a chemical reaction. Also do not assume that this breakdown releases energy, which is usually produced when the simpler substances are oxidized in respiration. Hydration is yet another completely different process, involving the addition of water, but not breaking of bonds.

2.2 IMPORTANCE OF WATER

Water is one of the main constituents on earth. More than two thirds of the earth is covered by water. Approximately 70 percent of the any organism is formed of water. Water is the most abundant component in any organism, the lowest is 20% in seeds and bones and highest is 85-90% in brain cells. Jellyfish has exceptionally large amount of water i.e., 99% (hence the body shows transparency).

Critical Thinking

When hydrogen gas combines with oxygen gas to form water, is the hydrogen reduced or oxidized?

2.2.1. Properties of water

The properties of water that make it the cradle of life are:

1. High polarity

The bonds which are formed by the mutual sharing of electrons between two atoms are called **covalent bonds**. Normally the sharing of electrons between two atoms is fairly equal and the covalent bond is **nonpolar**. In the case of water, however the sharing of electrons between oxygen and hydrogen is not completely equal so the covalent bond is **polar**. A polar covalent bond is a chemical bond in which shared electrons are pulled closer to the more electronegative atom, making it partially negative and the other atom partially positive. Thus, in H_2O, the O atom actually has a slight negative charge and each H atom has a slight positive charge, even though H_2O as a whole is neutral. Because of its polar covalent bonds, water is a polar molecule i.e., it has a slightly negative pole and two slightly positive ones.

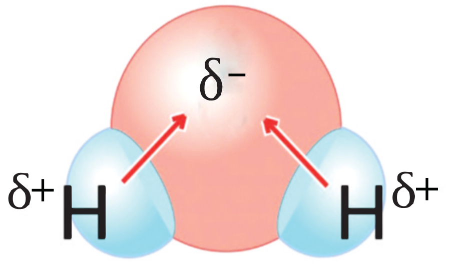


Fig: 2.4: Polarity of water molecule

This is polarity of water molecules that makes it an excellent or **universal solvent** for polar substances. Ionic compound or electrolytes can be easily dissolved in water, non-polar substances having charged groups in their molecules can also be dissolved in water. Such compounds when dissolved in water, disassociates into positive and negative ions and are in more favourable state to react with other molecules and ions. This is the reason why all chemical reactions in living beings occur in aqueous medium.

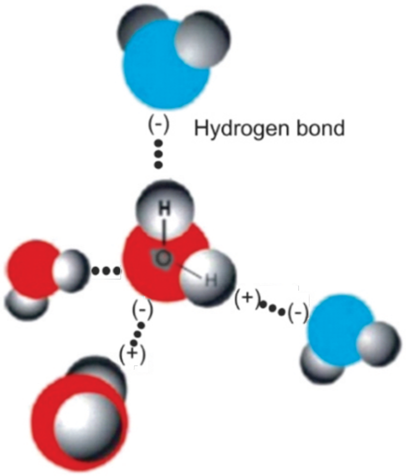


Fig: 2.5 Hydrogen bonds between water molecules

2. Hydrogen bonding

The polarity of water molecules makes them interact with each other. The charged regions on each molecule are attracted to oppositely charged regions on neighbouring molecules, forming weak bonds. Since the positively charged region in this special type of bond is always an H atom, the bond is called a **hydrogen bond**. This bond is often represented by a dotted line because a hydrogen bond is easily broken.

Because of hydrogen bonding, water is a liquid at temperatures suitable for life. The high cohesion and adhesion force of water is due to the presence of hydrogen bonds in water, which in turns makes water as transport medium.

3. Cohesion and adhesion

Cohesion is the attraction among the water molecules which enables the water molecules to stick together. Water flows freely due to cohesion. Water molecules also have attraction to polar surfaces. This attraction is called **adhesion**. Both cohesion and adhesion are due to hydrogen bonds among water molecules. These properties of water enable it to circulate in living bodies and to act as transport medium.

4. High specific heat capacity

Heat capacity can be defined as the amount of heat required for minimum increase in temperature of a substance. The specific heat capacity of water can be represented as number of calories required to raise the temperature of 1g of water up to $1^{o}C$ i.e., **1 Calorie (4.18 Joules)**. Water has relatively a very high heat capacity than any other substance due to its hydrogen bonding, because much of the heat absorbed by water is utilized in the breakdown of hydrogen bonding therefore it does not manifest itself to raise the temperature of water. Hence, very large amount of heat can increase very little in temperature in water. Due to its high heat capacity water works as **temperature stabilizer** or regulator for organisms in the hot environment and hence protects the living material against sudden thermal changes.

5. High heat of vapourization

Heat of vapourization is the amount of heat required to convert a unit mass of a liquid into gaseous form. Heat of vapourization of water is represented as number of calories absorbed per gram vapourized. Water has high heat of vapourization i.e., **574 calories per gram**. The high heat of vapourization means that a large amount of heat can be lost with minimal loss of water from the body. This is high heat of vapourization of water that gives animals an efficient way to release excess body heat in a hot environment. When an animal sweats, body heat is used to vapourize the sweat thus cooling the animal. Due to this property of water, evaporation of only 2 ml out of one litter of water lowers the temperature of the remaining 998 ml water by 1°C.

6. Hydrophobic exclusion

Hydrophobic exclusion can be defined as reduction of the contact area between water and hydrophobic substances which are placed in water. For example, if you place few drops of oil on the surface of a water solution, the oil drops will tend to join into a single drop. Biologically, hydrophobic exclusion plays key roles in maintaining the integrity of lipid bilayer membranes.

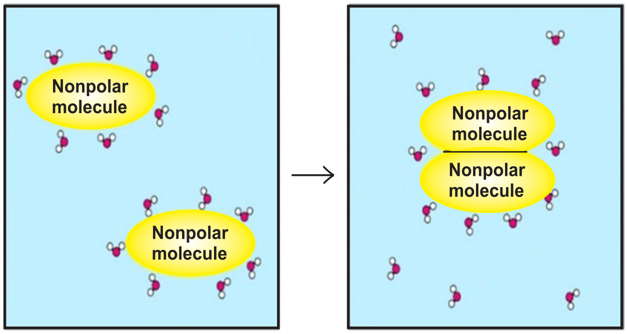


Fig: 2.6: Hydrophobic exclusion

7. Ionization

The dissociation of a molecule into ions is called **ionization**. When water molecule ionizes, it releases an equal number of positive hydrogen and negative hydroxyl ions.

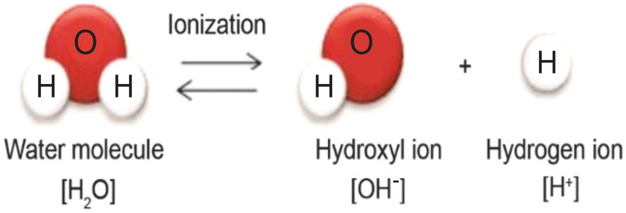


Fig: 2.7: Ionization of water

This reaction is reversible but equilibrium is maintained at 25°C. The H^+ and OH^- ions affect and take part in many of the reactions that occur in cells, e.g., it helps to maintain or change the pH of the medium.

8. Lower density of ice

Ice floats on water. This is because ice is less dense than water. The reason is that ice has a giant structure and show maximum number of hydrogen bonding among water molecules; hence, they are arranged like a lattice. In freezing weather, ice forms on the surface of ponds and lakes forming an insulating layer above the water below. This provides a living environment for some organisms until the ice melts. Organisms can also live under the ice.

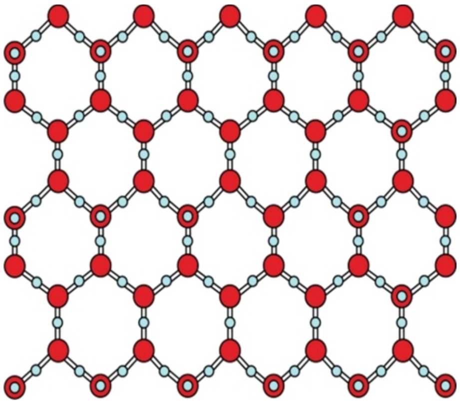


Fig: 2.8: Lattice likes arrangement of water molecules in ice

Skills: Analyzing, Interpreting and Communication

- Draw model diagrams to describe the hydrogen bonding.

2.3 CARBOHYDRATES

Carbohydrates are the compounds of carbon, hydrogen and oxygen. Literally word carbohydrate means “hydrates of carbon” i.e., a carbon associated with water. Chemically carbohydrates are:

"Organic compounds that are polyhydroxy aldehydes or polyhydroxy ketones, or change to such substances on simple chemical transformations, as hydrolysis, oxidation, or reduction."

2.3.1 Classification of Carbohydrates

Carbohydrates are commonly known as **sugars** or **saccharides** because more familiar carbohydrates have sweet taste. Classification of carbohydrates is based upon number of saccharide units. Carbohydrates are generally classified into three group i.e., monosaccharides, oligosaccharides and polysaccharides.

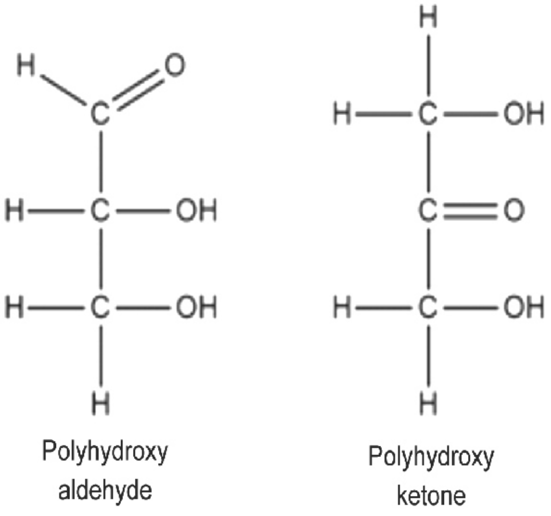


Fig: 2.9: Chemical nature of carbohydrates

Table: 2.2: Comparison of characteristics of carbohydrates

Monosaccharides	Oligosaccharides	Polysaccharides
They consist of single saccharide unit.	They are composed of 2 to 10 saccharide units.	They are composed of more than 10 saccharide units.
They are simplest carbohydrates; therefore, they cannot be further hydrolyzed.	They have less complex structure, so upon hydrolysis they yield at least 2 and maximum 10 monosaccharides.	They have highly complex structure, so upon hydrolysis they yield at least 11 monosaccharides.
They are highly soluble in water.	They are less soluble in water.	They are generally insoluble in water.
They are sweetest among all carbohydrates.	They are less sweet in taste.	They are tasteless.

2.3.2 Monosaccharides

Monosaccharides are true carbohydrates which are either polyhydroxy aldehydes or polyhydroxy ketones. The range of number of carbons in monosaccharides is 3 to 7. All the carbon atoms in a monosaccharide except one, have a hydroxyl group (-OH) while the remaining carbon atom is either the part of aldehyde or ketone. The general formula for the representation of monosaccharides is $C_nH_{2n}O_n$, where, n is the number of carbon atoms in monosaccharides.

Classification of monosaccharides

Classification of monosaccharides is based upon functional group and number of carbon atoms. On the basis of functional group, the monosaccharides containing aldehyde are called **aldoses** while those containing ketone are called **ketoses**. On the other hand monosaccharides are classified into five groups based upon number of carbon atoms i.e., **trioses** (3C), **tetroses** (4C), **pentoses** (5C), **hexoses** (6C) and **heptoses** (7C).

Table: 2.3: Examples and functions of monosaccharides

Class	Formula	Aldoses	Ketoses	Function
Trioses (3C)	$C_3H_6O_3$	Glyceraldehyde	Dihydroxy acetone	Intermediates in photosynthesis and cellular respiration.
Tetroses (4C)	$C_4H_8O_4$	Erythrose	Erythrulose	Intermediates in bacterial photosynthesis.
Pentoses (5C)	$C_5H_{10}O_5$	Ribose, Deoxyribose ($C_5H_{10}O_4$)	Ribulose	Ribose and deoxyribose are components of RNA and DNA respectively. Ribulose is an intermediates in photosynthesis.
Hexoses (6C)	$C_6H_{12}O_6$	Glucose, Galactose	Fructose	Glucose is respiratory fuel (initial substrate) Fructose is an intermediate in respiration. Galactose is the component of milk sugar.
Heptoses (7C)	$C_7H_{14}O_7$	Glucoheptose	Sedoheptulose	Intermediates in photosynthesis.

Chemical structures of monosaccharides

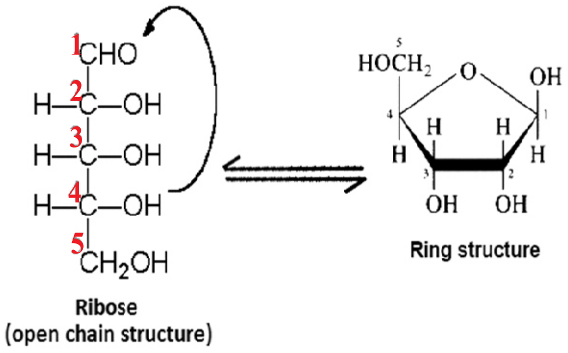


Fig: 2.10: Conversion of open chain into ring chain

Monosaccharides are usually found in open chain structure in crystalline form but when they are dissolved in water most of them (pentoses and hexoses) are converted into ring chain structure.

Let us understand it by taking ribose ($C_5H_{10}O_5$) as an example. It can exist in open chain structure in dried form but it exists in ring structure in aqueous medium. When it is dissolved in water, the oxygen atom from aldehyde group reacts with second last carbon i.e., C4 in case of ribose. In this way oxygen atom forms a link between C1 and C4 while the OH group of C4 is shifted to C1. After this modification ring structure of ribose is formed.

Each pentose or hexose molecule in ring structure exists in either α or β form depending upon the position of –H and –OH group on C-1. If –OH group is found downward on C-1 then it is called **α sugar** and if –OH is present upward on C-1 then it is known as **β sugar** as shown in the fig: 2.12.

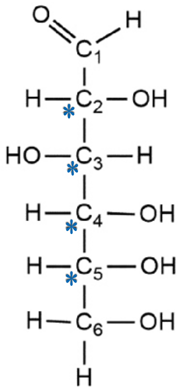


Fig: 2.11: Glucose open chain structure

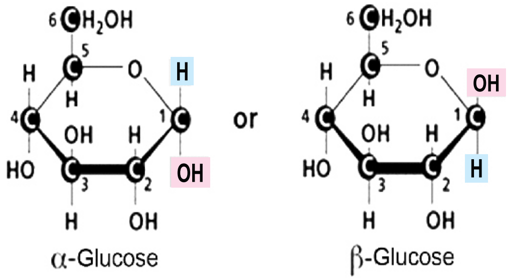


Fig: 2.12: *α* and *β* isomers of glucose

Stereoisomerism in Glucose

Stereoisomers are molecules that have the same molecular formula and differ only in how atoms are arranged in 3D space. Enantiomers is a type of stereoisomers in which molecules are nonsuperimposable mirror-images. This means that the molecules are mirror image but they cannot be placed on top of one another to give the same molecule. An example of enantiomer is D and L glucose. D sugars are right handed and L sugars are left handed molecules.

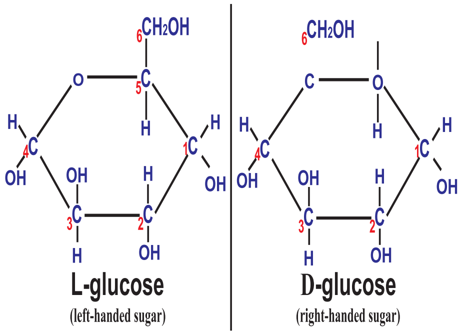


Fig: 2.13: An example of enantiomers

Laboratory Manufactured (Artificial) Sweeteners

Laboratory manufactured sugars are L sugars. On the other hand the naturally occurring sugars in bodies are D sugars. Proteins and cell receptors are designed to react only with D sugars. For example the enzymes in your stomach can digest only right-handed sugars. Likewise left-handed sugars cannot be metabolized by right-handed enzymes. Just as the glove fits only on the proper hand, a right-handed enzyme cannot fit on or react with a left-handed substrate. The substrate must fit on the proper active site of the enzyme. So for the left handed substrate (artificial sweetener) the enzyme must be left-handed.

2.3.3 Oligosaccharides

This group consists of derivatives of monosaccharides. Those carbohydrates which upon hydrolysis yield 2 to 10 saccharide units are called oligosaccharides. On the basis of number of saccharide units, the oligosaccharides are classified into **disaccharides**, **trisaccharides, tetrasaccharides** and so on. The most common among these are disaccharides.

Disaccharides

Two monosaccharides combine to form a disaccharide. It is a kind of oligosaccharides. Disaccharides are less sweet in taste and less soluble in water. These can be hydrolyzed to give monosaccharides. Examples are: maltose, lactose, sucrose. The general formula of disaccharide is: $C_{12}H_{22}O_{11}$. Some common disaccharides are as follows:

Sucrose: It is commonly known as cane sugar. It is widely used as sweetener at homes for making sweet dishes. In plants sucrose is also called **transport disaccharide** as prepared food in plants is transported in the form of sucrose. It is very soluble and can therefore be moved efficiently in high concentration in plants. It is also relatively unreactive chemically. The sucrose is formed by the condensation of glucose and fructose. In this reaction, the –OH group at C-1 of glucose reacts with the –OH group at C-2 of fructose, liberating a water molecule forming **α-1,2-glycosidic linkage**.

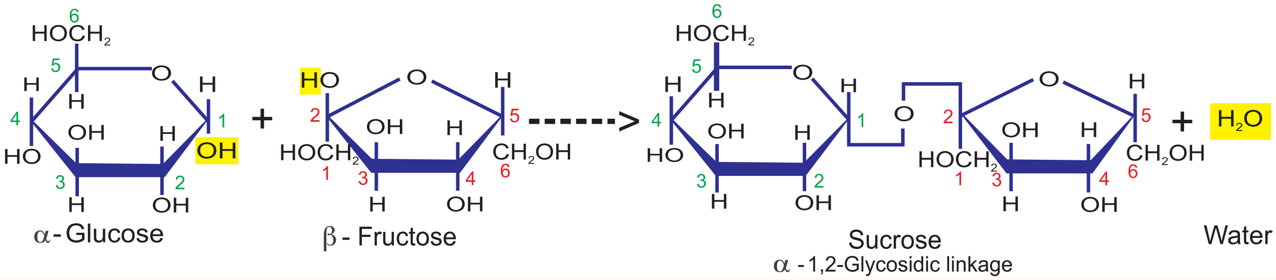


Fig: 2.14: Formation of sucrose

Maltose: It is commonly known as malt sugar. It is an intermediate disaccharide produced during the breakdown of starch and glycogen. Maltose is generally found in germinating seeds. The maltose is formed by the condensation of two α-glucoses. In this reaction, the –OH group at C-1 of one glucose reacts with the –OH group at C-4 of other glucose, liberating a water molecule forming **α-1, 4-glycosidic linkage**.

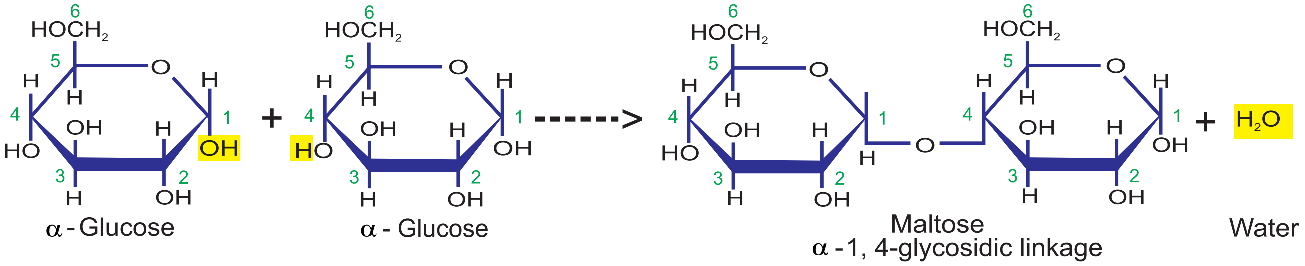


Fig: 2.15: Formation of maltose

Lactose: It is commonly known as milk sugar. The lactose is formed by the condensation of β-galactose and β-glucose. In this reaction, the –OH group at C-1 of galactose reacts with the –OH group at C-4 of glucose, liberating a water molecule forming **β-1, 4-glycosidic linkage**.

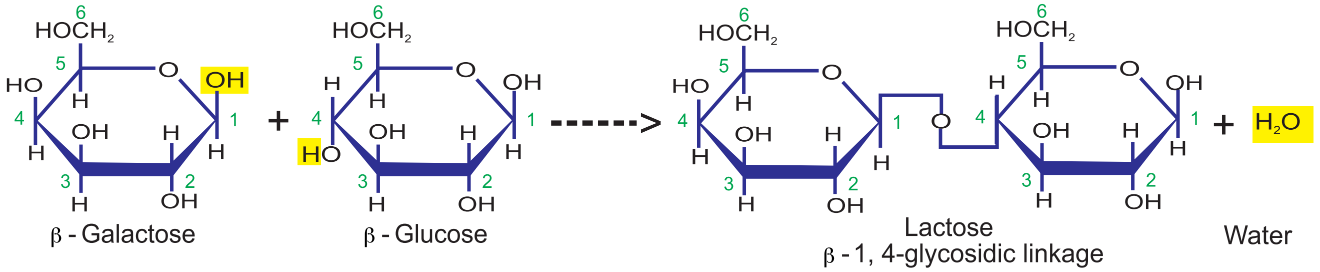


Fig: 2.16: Formation of lactose

Science Titbits

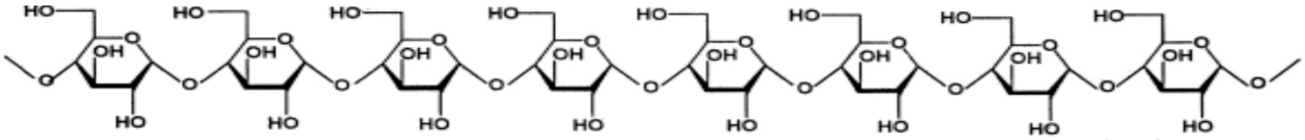
Any carbohydrate which is capable of being oxidized and causes the reduction of other substances without having to be hydrolyzed first is known as **reducing sugar**, but those which are unable to be oxidized and do not reduce the other substances are known as **non-reducing sugars.** All monosaccharides and two of three types of disaccharides (maltose and lactose) have the open chemical structure needed to act as reducing agents. The third type of disaccharides, sucrose, and polysaccharides are non-reducing sugars.

2.3.4 Polysaccharides

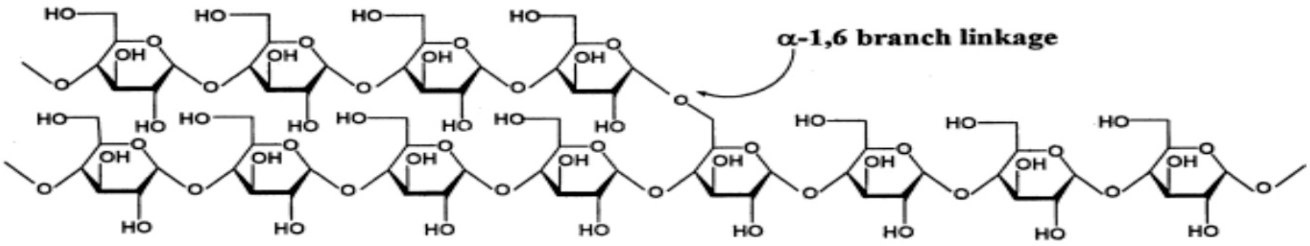
Those carbohydrates which upon hydrolysis yield more than ten monosaccharide units are called polysaccharides. This is largest group of carbohydrates. The polysaccharides which are composed by the condensation of only one kind of monosaccharides are called **homopolysaccharides** e.g., starch, glycogen, cellulose, chitin; whereas the polysaccharide which are composed by the condensation of different kind of monosaccharides are called **heteropolysaccharides** e.g., agar, pectin, peptidoglycan. Polysaccharides function chiefly as food and energy stores, e.g., starch, glycogen, and structural material, e.g., cellulose and chitin. They are convenient storage molecule for several reasons. Their large size makes them more or less insoluble in water, so they exert no osmotic or chemical influence in the cell; they fold into compact shapes and they are easily converted to sugars by hydrolysis when required. Some common polysaccharides e.g., starch, cellulose, and chitin are being discussed here.

Starch

Starch is a homopolysaccharides which is formed by the condensation of hundreds of **α-glucoses**. It is storage carbohydrate of plants. It is mainly stored in root, stem and seeds. Cereal grains and potato tubers are rich sources of starch in human diet. Starch is digested in oral cavity and in small intestine by the enzyme amylase. Upon hydrolysis it yields maltose first and then maltose is further digested by maltase enzyme and yields glucoses. The presence of starch in a given sample can be confirmed by iodine test as it gives blue colour with iodine solution. There are two types of starches i.e., amylose and amylopectin.



Segment of an amylose molecule



Segment of an amylopectin molecule, showing one α-1,6 branch linkage

Fig: 2.17: Structure of starches

Amylose is un-branched i.e., a linear chain of glucoses in which glucoses are attached together by **α-1, 4-glycosidic linkages**. It is soluble in hot water only. On the other hand, **amylopectin** has branched structure i.e., a linear chain of glucoses but more chains of glucoses in the form of branches are also attached by **α-1, 6-glycosidic linkages**. It is completely insoluble in water.

Glycogen

Like starch, glycogen is also a homopolysaccharides composed of **α-glucoses**. It is storage carbohydrate of animals. It is mainly stored in liver and muscles. Therefore it is also known as **animal's starch**. The digestion of glycogen is also quite similar to that of starch. The presence of glycogen in a given sample can

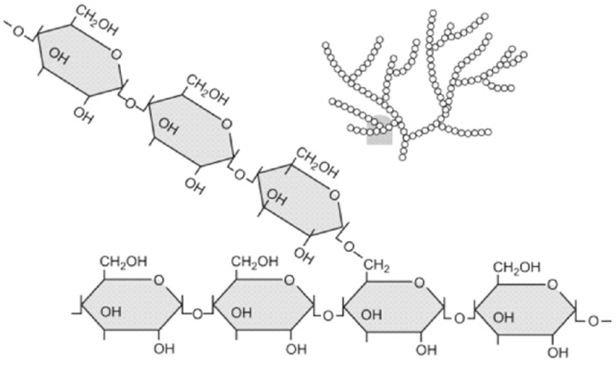


Fig: 2.18: Structure of glycogen

also be confirmed by iodine test as it gives red colour with iodine solution. Structure of glycogen resembles with amylopectin starch but glycogen has much more branching than amylopectin.

Cellulose

Cellulose is most abundant carbohydrate on earth. It is also a homopolysaccharides but unlike starch and glycogen it is formed by the condensation of hundreds of **β-glucoses**. It is structural carbohydrate of plants as it is major constituent of plant cell wall. Cotton and paper are the pure forms of cellulose.

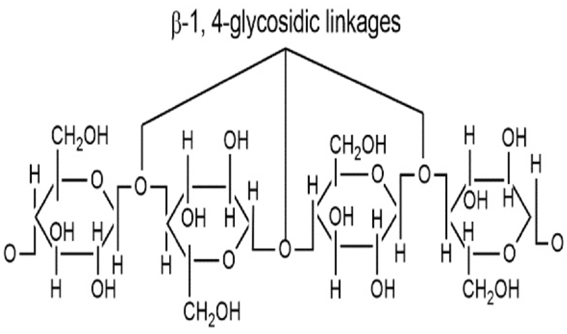


Fig: 2.19: Structure of cellulose

Cellulose shows no colour with iodine solution. Structure of cellulose resembles with amylose starch in such a way that it has un-branched structure but it has **β-1, 4-glycosidic linkages** between glucose residues.

Science Titbits

Cellulose cannot be digested by human body but it has to be taken into diet because it works as roughage or fibre so it prevents abnormal absorption of food in intestine. However, herbivore animals have some symbiotic bacteria that secrete **cellulase** enzyme for its digestion. Upon hydrolysis it first yields a disaccharide, the **cellubiose** and then cellubiose is further digested into glucoses.

Chitin

Chitin is the second most abundant organic molecule on earth. It is also a homopolysaccharides. It is a structural carbohydrate found in the cell walls of fungi and in the exoskeleton of arthropods. Due to the occurrence of chitin in fungal cell wall, it is also known as **fungal cellulose**. Chitin is the derivative of **N-acetyl glucosamine** monomers which is a modified form of glucose. It has an un-branched structure and its monomers are linked together by **β-1, 4-glycosidic linkages**.

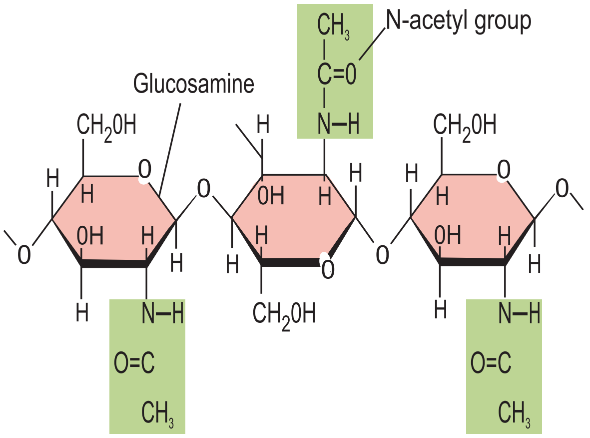


Fig: 2.20: Structure of chitin

2.4. PROTEINS

Proteins are the main structural components of the cell. All proteins contain C, H, O and N, while some contains P, S. Few proteins have Fe, I and Mg incorporated into the molecule.

2.4.1 Structure of Proteins

Chemically proteins can be defined as **polymers of amino acids** or **polypeptide chains**. A protein may consist of a single polypeptide or more than one polypeptide.

Amino acids

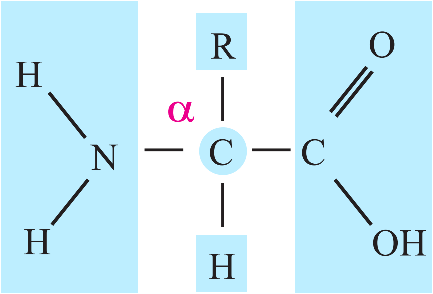


Fig: 2.21 General structure of an amino acid

Amino acids are the building blocks of proteins. There are many amino acids known to occur, but only 20 are commonly found in proteins. The amino acids are built on a common plan. Each contains a carbon atom. It is called α (alpha) carbon to this a hydrogen atom, an amino group (–NH2), a carboxyl group (–COOH) and a variable group known as –R group are attached. The R group has a different structure in each of the 20 biologically important amino acids and determines their individual chemical properties. Two simplest amino acids i.e., glycine and alanine are shown in figure 2.21.

Dipeptides and Polypeptides

Dipeptides and polypeptides are formed by the condensation of amino acids on the ribosome under the instructions of mRNA which takes these instructions from DNA. This process is known as **translation**. During this process, when an amino acid reacts with another amino acid, the –OH from carboxylic acid group of one amino acid and –H from amino group of other amino acid are liberated and form a water molecule, as a result a bond is established between C of carboxylic acid group and N of amino group of two amino acids called **peptide bond**. Hence, a product of two amino acids is formed which is known as **dipeptide**.

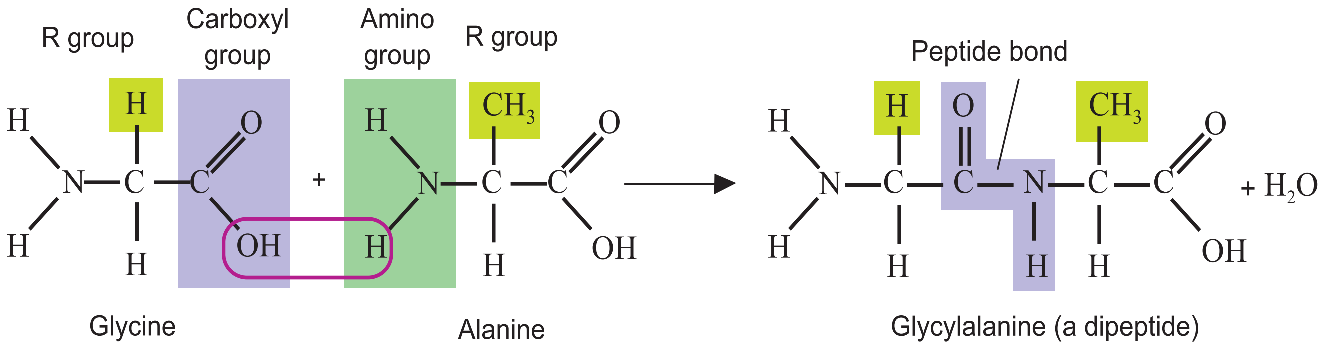


Fig: 2.22: Formation of a dipeptide and peptide bond

A dipeptide has two ends; one is called amino or **–N terminal** end while other is called carboxylic acid or **–C terminal** end. A new amino acid can be added in this chain from its carboxylic acid or –C terminal end in the same way. Thus, a **tripeptide** (a product of three amino acids) is formed and another water molecule is also released. Similarly, when several amino acids are linked together by many peptide bonds, the **polypeptide** chain is formed.

Structural conformations in proteins

A linear polypeptide with a specific sequence and number of amino acids is called **primary structure**. It is shown by all proteins at the time of their synthesis on ribosomal surface. After synthesis a protein does not remain in its primary structure but can be changed into some other structural conformations (particular form, shape or structure).

A helical **(α-helix)** or flattened sheets **(β-pleated sheet)** like structures which are established by **H-bonding** between opposite charge bearing groups of different amino acids are called **secondary structures**. In some proteins the linear polypeptide is changed into α-helix, then α-helix fold again and again by **ionic bonds** and **disulfide bridges** to form a globular shaped structure, the **tertiary structure**. Some proteins exist in very complex structure in which more than one globule is attached together by **hydrophobic interaction**. Such structures are called **quaternary structures**.

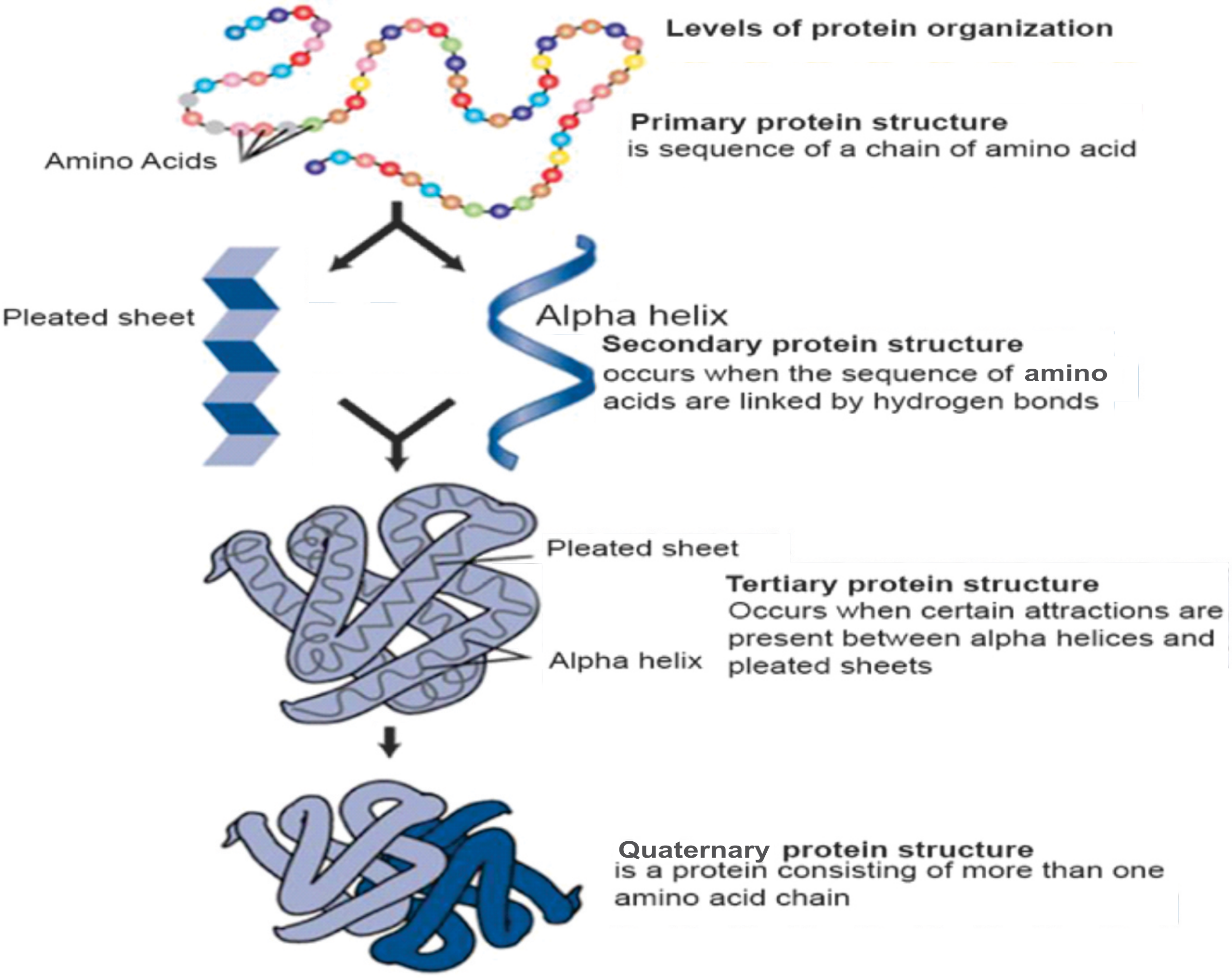


Fig: 2.23: Structural conformations in proteins

2.4.2 Significance of Amino Acid Sequence

Sequence of amino acid in a polypeptide is a characteristic feature of primary structure of protein which is responsible for proper functioning of protein. It is determined by the sequence of nucleotide in DNA. Even due to **point mutation** (change of single or few nucleotides in DNA) the sequence of amino acid in a particular protein (polypeptide) may be disturbed which causes severe defects in the body as it happens in sickle cell anemia, a hereditary disease.

Normal red blood cells are disc-shaped and look like doughnuts without holes in the centre. They move easily through your blood vessels. Red blood cells contain an iron-rich protein called haemoglobin. This protein carries oxygen from the lungs to the rest of the body. **Normal haemoglobin (Hb^A)** contains four polypeptides i.e. two α-chains which consist of 141 amino acids each and two β-chains which consist of 146 amino acids each.

Sickle cell anemia is a serious disorder in which the body makes sickle or crescent shaped red blood cells. Sickle cells contain abnormal hemoglobin called **sickle haemoglobin (Hb^S)**. Sickle haemoglobin causes the cells to develop a sickle, or crescent, shape. Sickle cells are stiff and sticky. They tend to block blood flow in the blood vessels of the limbs and organs. Blocked blood flow can cause pain and organ damage. Sickle cell anemia is caused by a point mutation in β-globin gene in which only one nucleotide is replaced by another which causes a change in amino acid sequence of β-chain of haemoglobin. Sickle cell haemoglobin (Hb^S) shows only one difference from Hb^A i.e., **glutamic acid** is replaced by **valine** at position number six in β-chain.

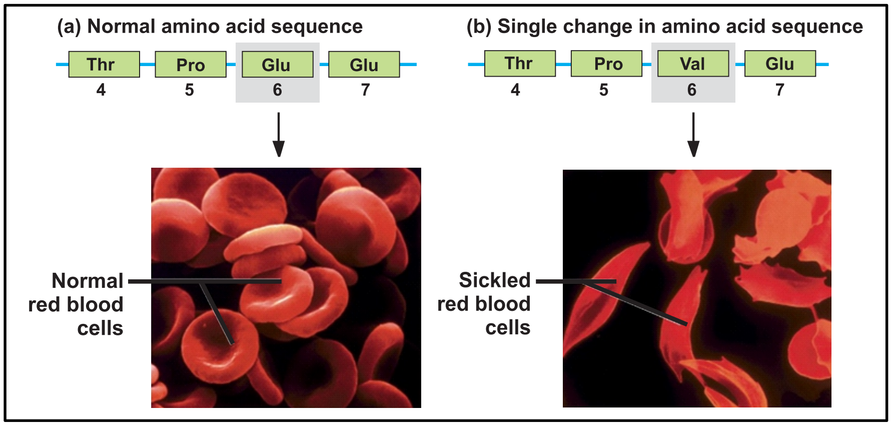


Fig: 2.24: Difference in *β*-chain of Hb^A and Hb^S

2.4.3 Classification of Proteins

Based upon structure and shape proteins can be classified into two groups i.e., fibrous and globular.

Fibrous proteins

These proteins have fibre or filament like shape. Therefore, they exist in secondary structure during function. These proteins are insoluble in aqueous medium, elastic in nature and cannot be crystalized. Examples are: collagen, fibrinogen, actin, myosin and keratin.

Globular proteins

These proteins have spherical or globules like shape. Therefore, they exist in tertiary or quaternary structure during function. These proteins are soluble in aqueous medium, inelastic in nature and can be crystalized. Examples are: enzymes, hormones, antibodies, channel proteins.

2.4.4 Role of Proteins

Proteins are very important molecules in our cells. They are involved in virtually all cell functions. Each protein within the body has a specific function. Some proteins are involved in support or composition of body parts i.e., structural roles, while others are involved in various physiological activities like bodily movement or in defence against germs i.e., functional roles. A list of several types of proteins and their functions is given in table 2.4 and 2.5.

Table: 2.4: List of structural proteins

Types	Roles of proteins
Collagen	It establishes the matrix of bone and cartilages.
Elastin	Elastin provides support for connective tissues such as tendons and ligaments.
Keratin	It strengthens protective coverings such as hair, nails, quills, feathers, horns, and beaks.
Histone	It arranges the DNA into the chromosome.

Table: 2.5 List of functional proteins

Types	Roles of proteins
Enzymes	The most of enzymes are protein which control metabolism i.e., they speed up the biochemical reactions.
Hormones	Some hormones are protein in nature which are involved in the regulation of physiological activities such as regulation of glucose level, calcium level, digestion, blood pressure etc.
Antibodies	These proteins are produced by WBCs in response to antigen (a foreign particle) and provide immunity.
Haemoglobin	It is found in RBCs and is involved in the transport of oxygen mainly and carbon dioxide to some extent.
Fibrinogen	It is found in blood plasma and is involved in blood clotting process.
Ovalbumin and Casein	Ovalbumin is found in egg whites and casein is a milk-based protein. Both of them are involved in the storage of amino acids.

Skills: Analyzing, Interpreting and Communication

- Draw table to illustrate different structural and functional proteins with roles of each.

2.5 LIPIDS

Lipid is the collective name for variety of organic compounds such as fats, oils, waxes and fat-like molecules (steroids) found in the body. Therefore, it is defined as a heterogeneous group of organic compounds which are insoluble in water (hydrophobic) but soluble in organic solvent such as acetone, alcohol, and ether etc. Lipids are composed of carbon, hydrogen and oxygen as carbohydrates. However, they have relatively less oxygen in proportion to carbon and hydrogen than do carbohydrates. For instance, **tristearin** is a simple lipid which shows molecular formula as $C_{57}H_{110}O_6$. Due to high contents of carbon and hydrogen, they contain double amount of energy than carbohydrates.

In general lipids are components of cell membranes (phospholipids and cholesterol), act as energy stores (triglycerides), steroid hormones and are also involved in protection, waterproofing, insulation and buoyancy.

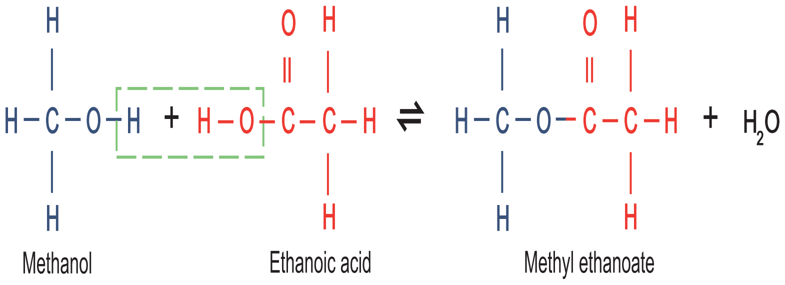


Fig: 2.25: Esterification

Some common lipids are acylglycerol, waxes, phospholipids, terpenes, prostaglandin and steroids.

Acylglycerol

The most abundant lipids in living things are acylglycerol. Chemically, acylglycerols can be defined as esters of glycerol and fatty acids. An **ester** is the compound produced as the result of a chemical reaction of an alcohol with acid and a water molecule is released such a reaction is called **esterification**.

Glycerol is a trihydroxy alcohol which contains three carbons, each bears an OH group. A **fatty acid** is a type of organic acid containing one carboxylic acid group attached to a hydrocarbon. Fatty acids contain even number of carbons from 2 to 30. Each fatty acid is represented as R-COOH, where R is a hydrocarbon tail. When a glycerol molecule combines chemically with one fatty acid, a **monoacylglycerol** (monoglyceride) is formed. When two fatty acids combine with a glycerol a **diacylglycerol** (diglyceride) is formed and when three fatty acids combine with one glycerol molecule a **triacylglycerol** (triglyceride) is formed. Triacylglycerols are also called **neutral lipid** as all three OH groups of glycerol are occupied by fatty acids and no charge bearing OH group is left.

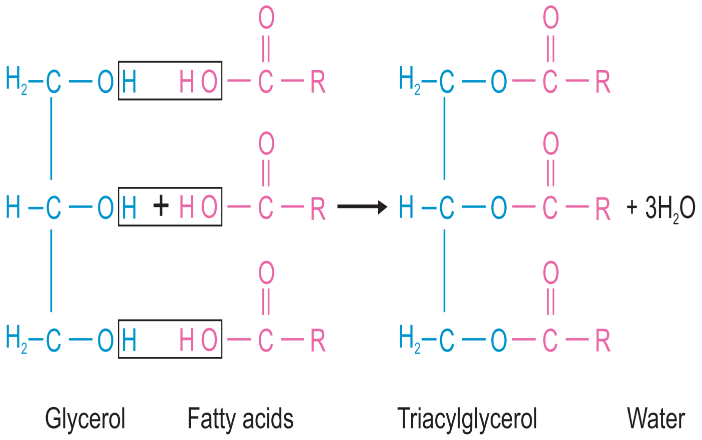


Fig: 2.26: Formation of a triacylglycerol (neutral lipid)

Properties and types of fatty acids

About 30 different fatty acids are found. Fatty acids vary in length. Acetic acid (2C) and butyric acid (4C) are simplest fatty acid, whereas palmitic acid (16C) and stearic acid (18C) are most common fatty acids. Some properties of fatty acid are increased with an increase in number of carbon atoms, such as melting point, solubility in organic solvent and hydrophobic nature. Some common fatty acids are given in the table 2.6. Fatty acids are either saturated or unsaturated. Fatty acids in which all of the internal carbon atoms possess hydrogen side groups are said to be **saturated fatty acids** because they contain the maximum number of hydrogen atoms that are possible, e.g., palmitic acid. Saturated fatty acids tend to be solid at room temperature (higher melting point) and are more common in animal lipids (fats).

Unsaturated fatty acids have one or more pairs of carbon atoms joined by a double bond. They therefore are not fully saturated with hydrogen, e.g., oleic acid. Unsaturated fatty acids are liquid at room temperature (lower melting point) and are more common in plant lipids (oils). Triglycerides containing hydrocarbon chains melt at a low temperature. This is useful for living things.

Table: 2.6: Common types of fatty acids

Name	Typical source	No. of Carbon	Condensed Formula	Melting point (°C)
Saturated				
1.Palmitic	**Most fats and oils**	**16**	$CH_3^- (CH_2)_{14}^- COOH$	**63**
2.Stearic	**Most fats and oils**	**18**	$CH_3 \ (CH_2)_{16} \ COOH$	**70**
Unsaturated				
3.Oleic	**Olive oil**	**18**	$CH_3^-(CH_2)_7^-CH{=}CH^-(CH_2)_7^-COOH$	**4**
4.Linoleic	**Vegetable oils**	**18**	$CH_3^-(CH_2)_4CH{=}CHCH_2CH{=}CH^-(CH_2)_7^-COOH$	**-5**

Waxes

Waxes are highly hydrophobic compounds. There are two types of waxes. **Natural waxes** are simple lipids. They are typically esters of long chain fatty acids and long chain alcohols, such as bee's wax (found in honeycomb) and cutin (on leaf surfaces of plants). These are chemically inert and resistant to atmospheric oxidation. Waxes have protective functions in plants and animals.

Synthetic waxes are generally derived from petroleum or polyethylene e.g. paraffin wax which is used to make candles.

Phospholipids

Phospholipids are derived from **phosphatidic acid**. A phospholipid is formed when phosphatidic acid combines with one of the four organic compounds such as **choline** (a nitrogenous base), **ethanolamine** (an amino alcohol), **inositol** (an amino alcohol) and **serine** (an amino acid). A phosphatidic acid molecule is most similar to diglyceride that it contains a glycerol, two fatty acids esterified with first and second OH groups of glycerol and a phosphate group esterified with third OH group of glycerol. Most common type of phospholipid is **phosphatidylcholine** also called **lecithin** in which choline is attached to phosphate group of phosphatidic acid. One end of the phospholipid molecule, containing the phosphate group and additional compound is hydrophilic i.e., polar and readily soluble in water. The other end, containing the fatty acid side

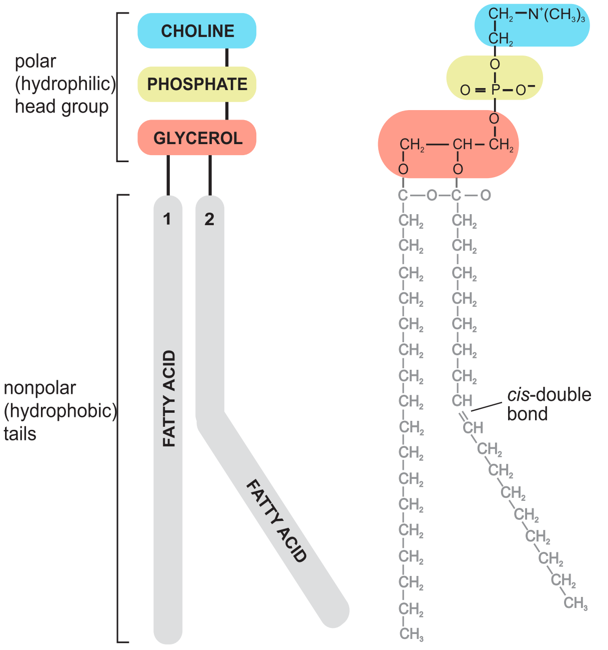


Fig. 2.27: Phosphatidylcholine (Lecithin)

chains, is hydrophobic i.e., non-polar and insoluble in water. These phospholipids are major constituents of lipid bilayer of cell membrane.

Terpenes

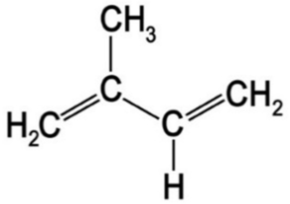


Fig. 2.28 Isoprene unit

All the terpenes are synthesized from a five-carbon building block known as **isoprene unit**. This unit condenses in different ways to form many compounds. Two isoprene units form a **monoterpene** e.g., menthol, four form a **diterpene** e.g., vitamin A, phytol (chlorophyll tail) and six form a **triterpene** e.g., ambrein. Natural rubber is a **polyterpene**.

Steroids

Steroids are lipids of high molecular weight which can be crystalline. A steroid nucleus consists of 17 carbon atoms arranged in four attached rings, three of the rings contain six carbon atoms, and the fourth contains five. The length and structure of the side chains that extend from these rings distinguish one steroid from other steroids. These structures are synthesized from isoprene units.

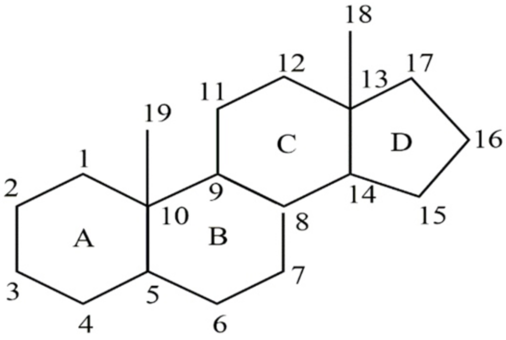


Fig. 2.29 Steroid nucleus

Cholesterol is a structural component of cell membrane. Cholesterol is the precursor of a large number of equally important steroids which include the bile acids, male sex hormone testosterone, female sex hormone progesterone and estrogen etc. Bile salts which emulsify fats and Vitamin D, which helps to regulate calcium metabolism are also steroid.

Prostaglandins

Prostaglandins exist in virtually every mammalian tissue, acting as local hormones. Prostaglandins are derived from **arachidonic acid**. Their functions vary widely depending on the tissue. Some reduce blood pressure, whereas others raise it. In the immune system, various prostaglandins help to induce fever and inflammation and also intensify the sensation of pain. They also help to regulate the aggregation of platelets an early step in the formation of blood clots. In fact, the ability of **aspirin** to reduce fever and decrease pain depends on the inhibition of prostaglandin synthesis.

Science, Technology and Society Connections

- **Relate the role of prostaglandin in inflammation with the inhibition of prostaglandin synthesis through aspirin.**

Prostaglandins play a pivotal role in inflammation a process characterized by redness (*rubor*), heat (*calor*), pain (*dolor*), and swelling (*tumor*). The changes associated with inflammation are due to dilation of local blood vessels that permits increased blood flow to the affected area. The blood vessels also become more permeable, leading to the escape of white blood cells (leukocytes) from the blood into the inflamed tissues.

Aspirin is anti-inflammatory, analgesic, and antipyretic. Aspirin inhibits prostaglandin synthetase salicylate. This drug affects the metabolism of arachidonate via the lipoxygenase pathway by inhibiting the conversion of 12-hydroperoxy- to 12-hydroxy-5, 8, 10, 14-eicosatetraenoic acid.

2.6 NUCLEIC ACID

Nucleic acids were first reported (in 1869) by a Swiss physician when he isolated a new compound from the nuclei of pus cells (white blood cells). This compound was neither a protein nor lipid nor a carbohydrate; therefore, it was a novel type of biological molecule. He named this molecule as **nuclein**, because it was located in the nucleus. The basic structure and chemical nature of nuclein was determined (in 1920) and was renamed as **nucleic acid** because of its acidic nature.

2.6.1 Chemical Structure of Nucleic Acids

Now it has been cleared that nucleic acids are of two types i.e., **deoxyribo nucleic acid (DNA)** and **ribo nucleic acid (RNA)**. Both nucleic acids are linear un-branched polymers. The monomers of the nucleic acid are called **nucleotides**.

Composition of a nucleotide

Nucleotides of DNA are called **deoxyribonucleotides** and of RNA are known as **ribonucleotides**. Each nucleotide consists of pentose sugar, a phosphate and a nitrogen containing ring structure called base. The **pentose sugar** in deoxyribonucleotides is

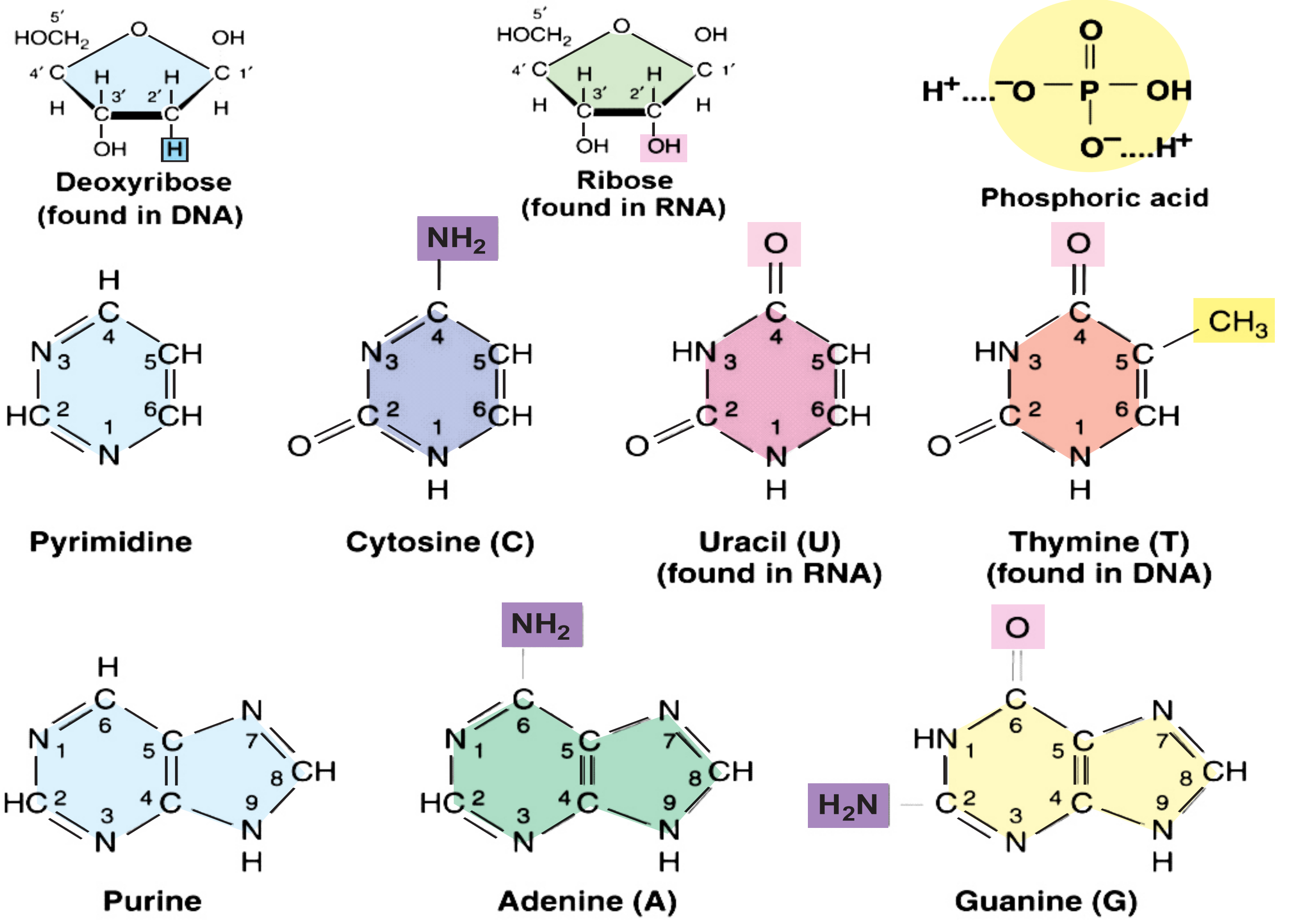

Deoxyribose (found in DNA)
Ribose (found in RNA)
Phosphoric acid
Pyrimidine
Cytosine (C)
Uracil (U) (found in RNA)
Thymine (T) (found in DNA)
Purine
Adenine (A)
Guanine (G)

Fig. 2.30: Components of nucleotides

deoxyribose and in ribonucleotides is ribose. **Phosphoric acid** is a common component of both nucleotides which provides acidic properties to DNA and RNA. The nitrogen containing ring structures are called **bases** because of unshared pair of electron on nitrogen atoms, which can thus acquire a proton.

There are two major classes of nitrogenous bases i.e., single ring **pyrimidine** and double ring **purines**. Pyrimidine bases are of three types i.e., cytosine (C), thymine (T) and uracil (U). Thymine is only found in DNA while the uracil is only found in RNA. On the other hand, the purine bases are also of two types i.e., adenine (A) and guanine (G).

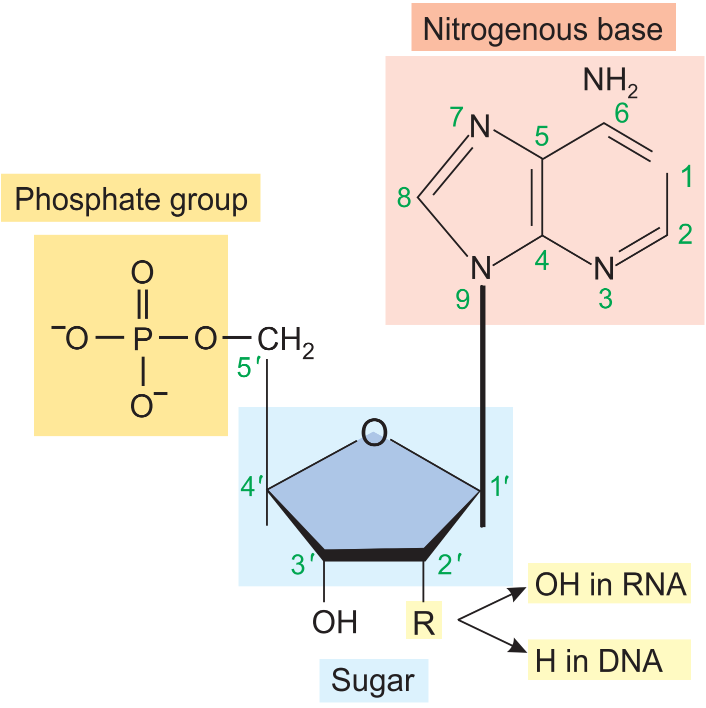


Fig. 2.31: Structure of a nucleotide

During the formation of a nucleotide, first nitrogenous base is linked with 1′ carbon of pentose sugar. Such combination is called **nucleoside**. When a phosphoric acid is linked with 5′ carbon of pentose sugar of a nucleoside, the nucleotide is formed. A nucleotide with one phosphoric acid is called **nucleoside monophosphate** with two phosphoric acids is called **nucleoside diphosphate** and with three phosphoric acids is called **nucleoside triphosphate.**

The nucleotides which take part in the formation of DNA or RNA must contain three phosphates but during their incorporation into DNA or RNA polymer each nucleotide losses its two terminal phosphates. Different terms used for nucleosides and nucleotides are given in the table 2.7.

Table: 2.7: Different types of nucleosides and nucleotides of RNA and DNA

Nitrogenous base	RNA		DNA	
	Ribonucleosides (Ribose + Base)	Ribonucleotides (Ribose+Base+ Phosphate)	Deoxyribonucleosides (Deoxyribose + Base)	Deoxyribonucleotides (Deoxyribose+Base+ Phosphate)
Adenine	Adenosine	AMP, ADP, ATP	d-Adenosine	dAMP, dADP, dATP
Guanine	Guanosine	GMP, GDP, GTP	d-Guanosine	dGMP, dGDP, dGTP
Cytosine	Cytidine	CMP, CDP, CTP	d-Cytidine	dCMP, dCDP, dCTP
Uracil/ Thymine	Uredine	UMP, UDP, UTP	d-Thymidine	dTMP, dTDP, dTTP

Polymerization of nucleotides (Formation of polynucleotide)

Nucleotides are also joined together by a condensation reaction like other biomolecules. Unlike proteins, carbohydrates, and lipids, however, the molecule that is released is not water but pyrophosphate (two phosphate groups bound together). When pyrophosphate is cleaved by the addition of water, a great deal of free energy is released which derives the process. In this way nucleotides begin to link by phosphodiester bonds and a polymer of nucleotides (polynucleotide) is formed. Polynucleotides have a free 5' phosphate group at one end and a free 3' hydroxyl group at the other end. By convention, these sequences are named from 5' to 3'.

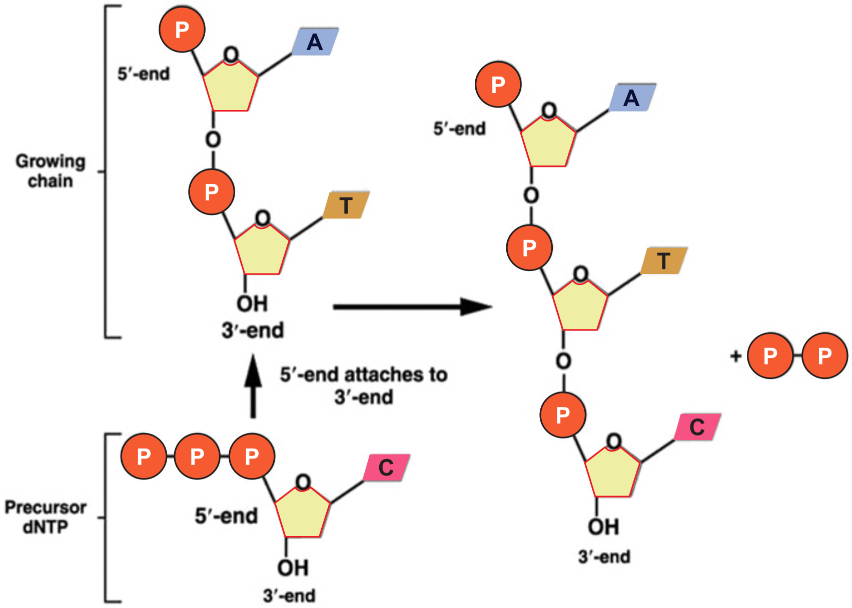


Fig. 2.32 Polymerization of nucleotides

2.6.2 Chemical Nature and Role of ATP and NAD

Adenosine triphosphate (ATP) is a mononucleotide. As shown in fig. 2.32 ATP has three parts, connected by covalent bonds: (a) adenine, a nitrogen base, (b) ribose, a five carbon sugar, (c) three phosphates. The two covalent bonds linking the three phosphates together are called **high-energy bonds**. ATP can be converted to ADP and inorganic phosphate (iP) by hydrolysis. ATP is known as the energy currency of cells.

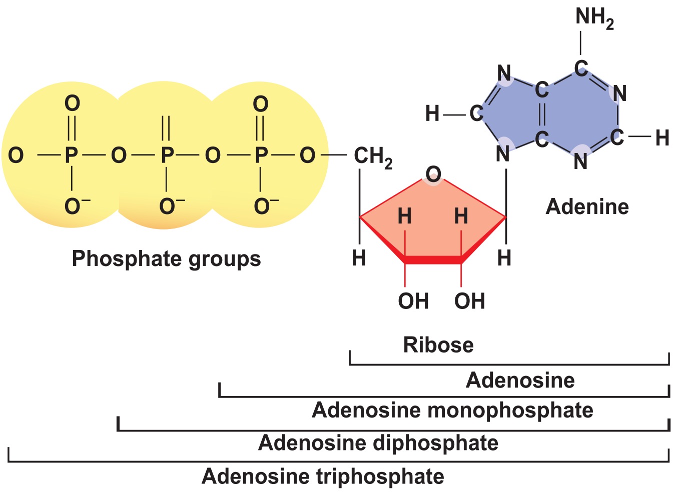


Fig. 2.33 Structure of ATP

Nicotinamide adenine dinucleotide (NAD) consists of two nucleotides. One

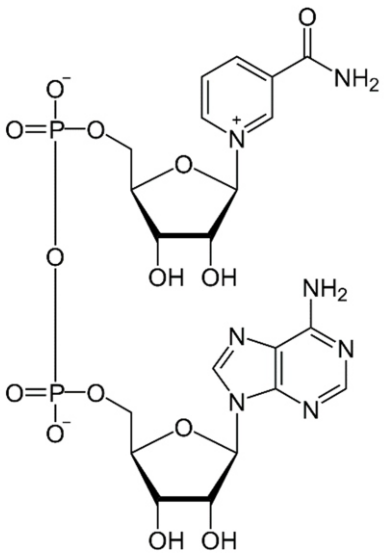


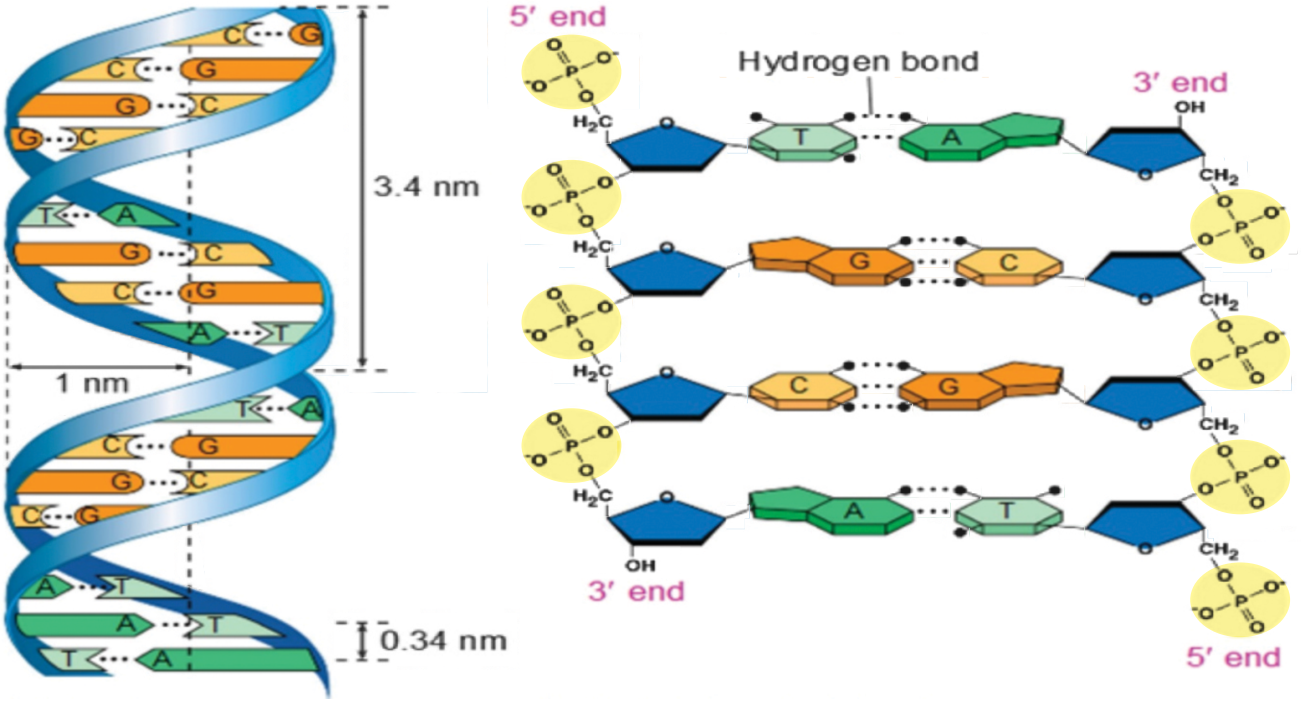
Fig. 2.34 Structure of NAD

nucleotide consists of nicotinamide, sugar and phosphate. Other nucleotide consists of adenine-sugar and phosphate. The two nucleotides are joined by their phosphate group forming a dinucleotide. NAD is a coenzyme.

2.6.3 Watson and Crick Model of DNA

In 1951, **Erwin Chargaff** found that the nitrogenous bases in a DNA show specific ratios. He observed that amount of adenine is always equal to the amount of thymine and amount of guanine is always equal to the amount of cytosine in DNA. This implies that the total purines and total pyrimidines are in 1:1 in any DNA. This conclusion is known as **Chargaff's rule**. In those days the **X-ray diffraction analysis** of DNA by **Maurice Wilkins** and **Rosalind Franklin** was published. They first time claimed that DNA is a duplex (double helix) molecule. The width of duplex is 2ηm while the length of each turn is 3.4ηm. In 1953, on the basis of these observations a graduate student **Francis Crick** and a research fellow **James Watson** of Cambridge University proposed a physical model of DNA which is now called **Watson and Crick Model of DNA**.

According to this model a DNA is made up of two polynucleotide chains which are attached together by base pairs. In order to make base pairing the two polynucleotide chains are opposite in direction i.e., one chain runs from 5′ to 3′ downward and the other chain runs



(a) Key features of double helix model

(b) Partial chemical structure

Fig. 2.35 Watson and Crick model of DNA from 5′ to 3′ upward. Both chains show a constant width of 2 ηm. Therefore, both chains are supposed be antiparallel to each other. The base pairing is very specific i.e., Adenine makes the pair with Thymine and Guanine with Cytosine. The base pairs are held together by the hydrogen bond. There are three hydrogen bonds between Guanine and Cytosine and two hydrogen bonds between Adenine and Thymine. Each turn of the duplex consist of 10 base pairs. Both polynucleotide chains are complementary to each other. There is no restriction of the sequence of nucleotides along the length of a DNA strand. The sequence can vary in countless ways. The sequence is specific for different species, organisms and even individuals.

Science Titbits

Watson and Crick assembled the molecular model and published their two-page article on their molecular model of DNA in the journal *"Nature"* in April 1953. Few milestones in the history of biology have as broad an impact as their double helix. They were awarded Nobel Prize in 1962 for their model of DNA.

2.6.4 Concept of Gene

A gene is region of DNA which is made up of nucleotides. It is the physical and functional unit of heredity. Each gene contains the information required to build specific proteins needed in an organism, such as they contain the instructions for our individual characteristics – like eye and hair colour. In order to make proteins, the gene from the DNA is copied into messenger RNA. The mRNA moves out of the nucleus and uses ribosomes to form the polypeptide that finally folds and configures to form the protein.

2.6.5 Ribonucleic Acid (RNA)

RNA is also a polymer of nucleotides. Its detailed chemical nature has already been discussed in previous topics. Unlike DNA, the RNA is generally single stranded and does not form a double helix like DNA. However, some regions of RNA shows a secondary double stranded structure in their complementary regions. There are three major classes of RNA each with a special function in protein synthesis. These RNA are transcribed from DNA template.

Messenger RNA (mRNA)

mRNA 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 message. For example, for a protein molecule consisting of 100 amino acids, the mRNA will have the length of 300 nucleotides. Actually every three nucleotides in mRNA encode a specific amino acid, such triplets of nucleotides along the length of mRNA are called **codons** of **genetic codes**. mRNA is about 3 to 4% of the total RNA in the cell. mRNA takes the genetic message from the nucleus to the ribosome in the cytoplasm to form particular protein. This process is known as **translation**.

Ribosomal RNA (rRNA)

Ribosome consists of rRNA and protein. rRNA is transcribed by the genes present on the DNA of the several chromosomes. It is called rRNA because it eventually becomes part of ribosome. The rRNA is packaged with a variety of proteins into ribosomal subunits. The base sequence of rRNA is similar from bacteria to higher plants and animals. rRNA have largest size among the RNA. Approximately, 80% of total RNA contents of a cell are rRNA. It is a part of ribosome where protein synthesis takes place. In other words rRNA provides a platform for protein synthesis.

Transfer RNA (tRNA)

It is the smallest of the RNA molecules and it consists of 75 to 90 nucleotides. A tRNA is a single stranded molecule but it shows a duplex appearance at its some regions where complementary bases are bonded to one another. It shows a flat cloverleaf shape in two dimensional views. Its 5′ end always terminates in Guanine base while the 3′ end is always terminated with base sequence of CCA. Amino acid is attached to tRNA at this end. The nucleotide sequence of the rest of the molecule is variable.

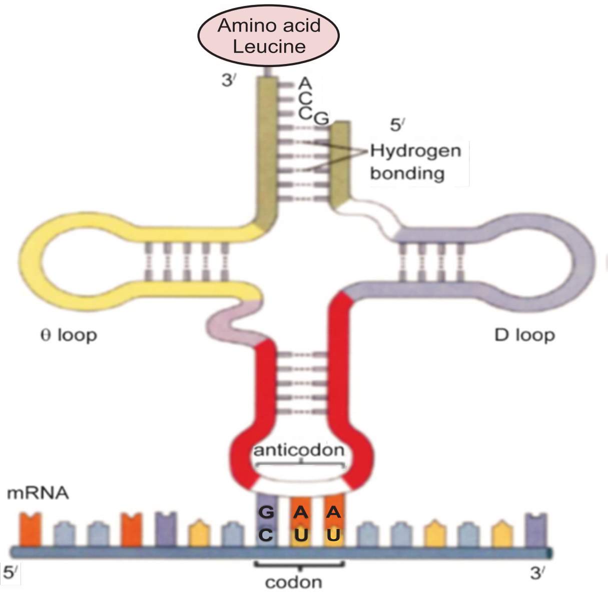


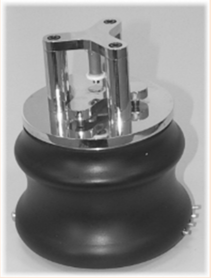
Fig: 2.36: Cloverleaf model of tRNA

tRNA has three loops. The middle loop in all the tRNA is composed of 7 bases, the middle three of which form the **anticodon**; it is complementary to specific **codon** of mRNA. The D loop recognizes the activation enzyme. Theta (θ) loop recognizes the specific place on the ribosome for binding during protein synthesis. There is at least one tRNA molecule for each of the 20 amino acids found in proteins. Sixty tRNA have been identified. However, human cells contain about 45 different kinds of tRNA molecules, each transports a specific amino acid from cytoplasm to the surface of ribosome for protein synthesis.

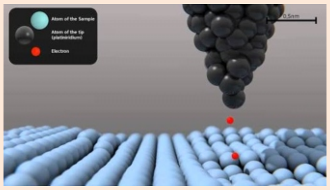
Science, Technology and Society Connections

- **Correlate the scanning tunnelling microscope as the latest advancement for seeing the atoms of DNA.**

The Scanning tunneling microscope was invented in 1980. It can allow scientists to view atoms on the surface of a solid. It is a very powerful tool that can be used to resolve features less than a nanometer. The microscope's inventors, Gerd Binnig and Heinrich Rohrer were awarded Nobel Prize in Physics in 1986. Seeman's group worked on the DNA nanotechnology. They constructed molecular building blocks of DNA.



Scanning tunneling microscope



Atoms seen on the surface of a solid

2.7 CONJUGATED MOLECUELS

Molecules when joined by other kinds of molecules are called conjugated molecules. The examples are glyocolipids, glycoproteins, lipoproteins and nucleoproteins.

Glycolipids are complex lipids containing one or more simple sugars in connection with long fatty acids or alcohol. Glycolipids are present in white matter of brain and myelin sheath of nerve fibres and chloroplast membrane.

Glycoproteins are formed when proteins are covalently attached to carbohydrates. Glycoproteins are widely distributed in the cells. They function as hormones, transport proteins, structured proteins and receptors. The blood group antigens contain glycoproteins, which also play an important role in blood grouping.

Lipoproteins are formed by the combination of protein with phospholipids. Phospholipid protein complexes are widely distributed in plant and animal material. They occur in milk, blood, cell nucleus, egg yolk membrane and chloroplasts of plants.

Nucleoproteins consist of simple basic protein and nucleic acid. They are found in chromosomes and ribosomes.

Science Titbits

Why do the nucleotides in DNA have a hydrogen atom at the 2' carbon instead of the hydroxyl group in ribose? The answer is that a hydroxyl group at the 2' position can participate in a reaction that cleaves the phosphodiester bond. Thus, DNA can act as a stable long-term repository for genetic information. RNA is usually degraded within your cells in 30 minutes.

Skills: Analyzing, Interpreting, and Communication

- Draw the Watson—Crick model of DNA
- Illustrate the formation of phosphodiester linkage

Science Technology and Society Connections

- **List the career opportunities in the field of biochemistry.**

Biochemistry, the study of chemical processes that take place in living organisms, is a broad field that offers a wide range of career options. Biochemists can pursue stem cell or genetic research that has the potential to result in dramatic medical or scientific breakthroughs. Some biochemists study the body's immune response to germs and allergens or the effectiveness of drugs in treating a wide array of afflictions. Other biochemists work in the commercial food or agricultural field looking for ways to improve products and crops. The many and diverse applications of biochemistry include pharmacology, genetics, immunology, bioinformatics, environmental science, forensics, toxicological studies and food science. The career options are nearly endless, and still unfolding, as new applications for this exciting field of study continue to evolve.

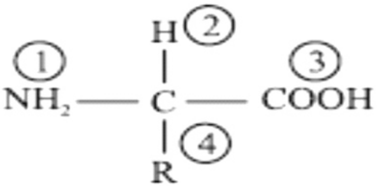
Activity

1. Performing Benedict's test for reducing sugars and confirmation of the presence of starch through Iodine test
2. Confirmation of the presence of proteins through Biuret test
3. Confirmation of the presence of lipids through Emulsion test
4. Demonstration of the presence of nucleic acids in biological materials e.g., onion

Exercise

MCQs

1. Select the correct answer



(i) An amino acid molecule has the following structure:

Which two of the groups combine to form a peptide link between two amino acids?

(A) 1 and 2 (B) 1 and 3 (C) 2 and 3 (D) 2 and 4

(ii) Which class of molecule is the major component of cell membrane

(A) phospholipid (B) cellulose (C) wax (D) triglyceride

(iii) Glycerol is the backbone molecule for

(A) ATP (B) terpenes (C) neutral lipids (D) steroids

(iv) A fatty acid is unsaturated if it

(A) contains hydrogen (B) contains double bonds

(C) contains an acid group (D) all of them

(v) In RNA the nitrogen base that takes the place of thymine is

(A) adenine (B) cytosine (C) guanine (D) uracil

(vi) The ending—ose means a substance is a

(A) sugar (B) lipid (C) protein (D) nucleic acid

(vii) Glycolipids and lipoprotein are important components of

(A) cellular membrane (B) cell wall (C) both of them (D) none of them

(viii) When two amino acids are linked to form peptide linkage .... is removed

(A) hydroxyl (B) water (C) carbon (D) nitrogen

(ix) What is the theoretical number of chemically different dipeptides that may be assembled from two amino acids?

(A) one (B) two (C) three (D) four

(x) A polar molecule is ………………. in water

(A) soluble (B) insoluble (C) reactive (D) innert

(xi) Which statement correctly describes a property of water?

(A) a relatively large amount of heat is needed to increase its temperature

(B) at normal room temperature, its molecules are bound together by ionic bonds

(C) the highest density of water occurs below its freezing point

(D) water acts as solvent for nonpolar molecules

(xii) Estrogen, vitamin-D and cholesterol are all examples of

(A) glycolipids (B) lipoproteins (C) terpenes (D) steroids

(xiii) Which term includes all others?

(A) carbohydrate (B) starch (C) monosaccharide (D) polysaccharide

(xiv) Choose the pair of terms that correctly completes this sentence: Nucleotide are to ------as --------are to proteins.

(A) nucleic acids; amino acids (B) amino acids; polypeptides

(C) glycosidic linkages; polypeptide linkages (D) polymers; polypeptides

(xv) The enantiomer of D-glucose is

(A) D-galactose (B) L-galactose (C) both of them (D) none of them

Short Questions

2. How would you describe biochemistry?
3. What are bioelements?
4. Describe the chemical composition of protoplasm.
5. What are the four fundamental kinds of biological molecules? Explain.
6. Why is the covalent bond in water polar?
7. Why water is regarded as universal solvent?
8. What is the importance of hydrogen bonding?
9. Why very large amount of heat can increase very little temperature in water?
10. How water protects living things against sudden thermal change?
11. What is the importance of high heat of vapourization of water to animals?
12. Describe classification of carbohydrates.
13. Describe the classification of monosaccharides?
14. Describe the conversion of open chain of ribose into ring chain.
15. Draw and label the ring forms of alpha and beta glucose.
16. Justify that the laboratory-manufactured sweeteners are “left handed” sugars and cannot be metabolized by the “right handed” enzymes.

17. Illustrate the formation and breakage of (a) sucrose (b) maltose (c) lactose.
18. Draw the structural formula of amino acid.
19. Describe the synthesis of peptide bond
20. Describe the four types of structure of proteins.
21. Describe (a) globular proteins (b) fibrous proteins.
22. Describe the classification of lipids
23. What role do lipids play in living organisms?
24. Why phospholipids form a thin layer on the surface of an aqueous solution?
25. What is isoprene unit? Explain.
26. Describe a steroid nucleus.
27. How might an error in the DNA of an organism effect protein function?
28. Define gene is a sequence of nucleotides as part of DNA, which codes for the formation of a polypeptide.
29. Write the differences between:

(a) major and minor bioelements
(b) dimer and polymer
(c) polar and nonpolar covalent bond
(d) polyhydroxy aldehyde and polyhydroxy ketone
(e) alpha and beta glucose
(f) D-glucose and L-glucose
(g) amylase and amylopectin
(h) amylopectin and glycogen
(i) primary and secondary structure of proteins
(j) tertiary and quaternary structure of proteins
(k) purine and pyrimidine
(l) saturated and unsaturated fatty acids
(m) DNA and RNA

Extensive Questions

30. Describe the chemical composition of protoplasm.
31. Distinguish carbohydrates, proteins, lipids and nucleic acids as the four fundamental kinds of biological molecules.
32. Describe and draw sketches of dehydration synthesis and hydrolysis reactions for making and breaking of macromolecule polymers.

33. How the properties of water make it the cradle of life?
34. Distinguish the properties and role of monosaccharides.
35. Write the emperical formula of monosaccharides and classify them.
36. Compare the stereoisomers of glucose.
37. Distinguish the properties and role of disaccharides.
38. Describe glycoside bond in the transport of disaccharides.
39. Distinguish the properties and role of polysaccharides.
40. Describe the properties and roles of starch, glycogen, cellulose and chitin.
41. Justify the significance of the sequence of amino acids through the example of sickle cell haemoglobin.
42. List examples and the roles of structural and functional proteins.
43. Describe the properties and roles of:
    (a) acylglycerol
    (b) phospholipids
    (c) terpenes
    (d) waxes
44. Evaluate the role of the following as important groups of lipids and describe their roles in living organism:
    (a) steroid
    (b) prostaglandins
45. Describe the molecular level structure of nucleotides.
46. Distinguish among the nitrogenous bases found in the nucleotides of nucleic acids.
47. Describe the structure of a mononucleotide (ATP) and a dinucleotide (NAD).
48. Explain the formation of phosphodiester bond.
49. Explain the double helical strucutre of DNA as proposed by Watson and Crick.
50. What is a gene? How gene codes for the formation of a polypeptide?
51. Explain general strucutre of RNA.
52. Explain the structure and role of three types of RNA.
53. Describe the roles of the following conjugated molecules:
    (a) glycolipids
    (b) glycoproteins
    (c) lipoproteins
    (d) nucleoproteins