# CHAPTER-2
# BIOLOGICAL MOLECULES

## 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. Hydration is yet another completely different process, involving the addition of water, but not breaking of bonds. Also do not assume that this breakdown releases energy, which is usually produced when the simpler substances are oxidized in respiration.

## Critical Thinking

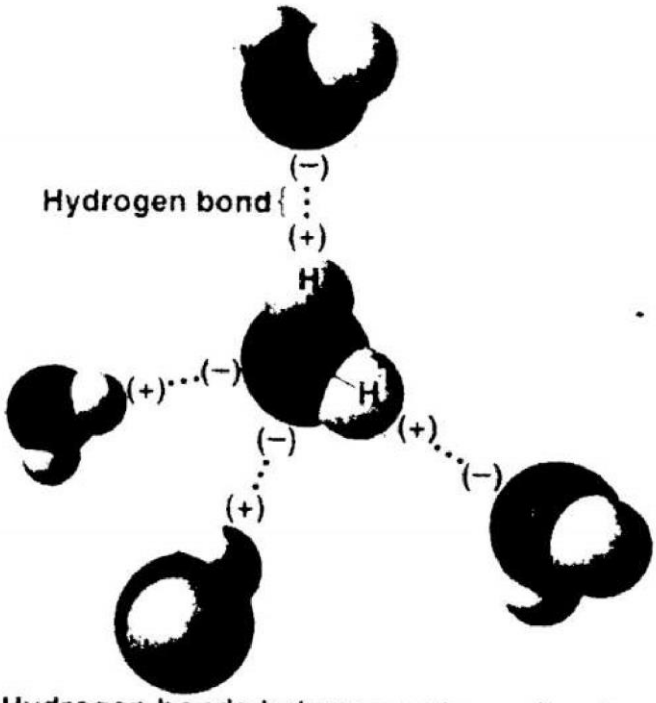
**When hydrogen gas combines with oxygen gas to form water, is the hydrogen reduced or oxidized?**

**Ans:** When hydrogen gas combines with oxygen gas to form water, the hydrogen is oxidized. When molecular **hydrogen** ($H_2$) and **oxygen** ($O_2$) are **combined** and allowed to react together, energy is released and the molecules of **hydrogen** and **oxygen** can **combine** to **form** either **water** or **hydrogen** peroxide.

## Skills: Analyzing, Interpreting and Communication

♦ **Draw model diagrams to describe the hydrogen bonding.**

**Solution:**




Hydrogen bonds between water molecules

♦ **Develop a table to align the properties of water with the benefits to life.**

**Solution:** **See Q#46 From (Extensive Questions)**

## Teacher's Point

Teacher would guide the students to develop a table to align the properties of water with the benefits.

## Science Titbits

Any carbohydrate which is capable 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.

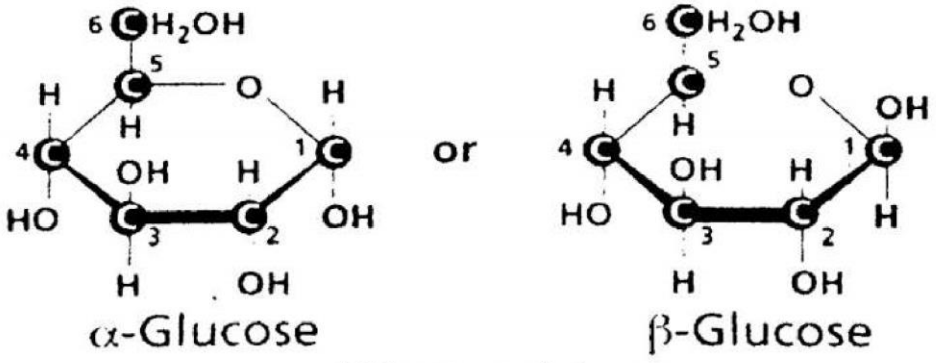
## Science Titbits

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.

## Skills: Analyzing, Interpreting and Communication

♦ **Draw the ring forms of alpha and beta glucose.**

**Solution:**




α and β isomers of glucose

♦ **Illustrate the formation and breakage of maltose, sucrose and lactose.**

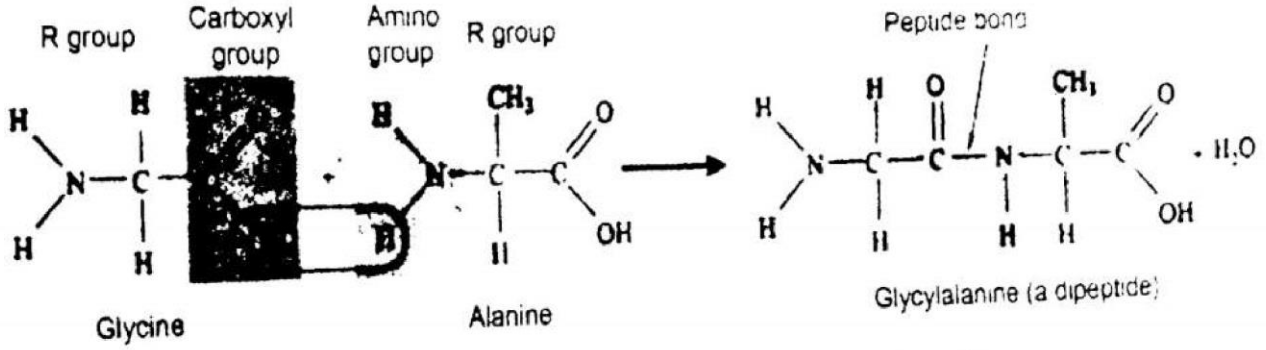
**Solution:** **See Q#19 From (Short Questions)**

**Q1. Explain the formation of dipeptides and polypeptides.**

**Ans: 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**.




**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.

## Skills: Analyzing, Interpreting and Communication

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

**Solution:** **See Q#55 From (Extensive Questions)**

## 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.

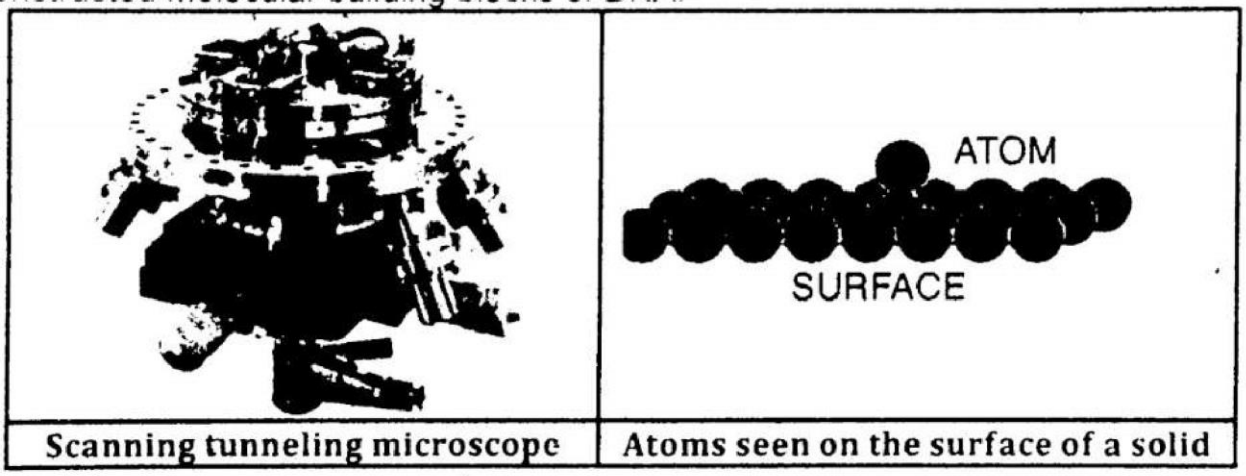
Aspirin is anti-inflammatory, analgesic, and antipyretic. Aspirin inhibit prostaglandin synthetase salicylate. This drug affects the metabolism of arachidonate via the lipoxygenase pathway by inhibiting the conversion of 12-hydroperoxy- to 12-hydroxy-5, 8, 10, 14-eicosatetraenoic acid.

## 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.

## 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 |
|---|---|

## Teacher's Point

Teachers would guide the students to hypothesize, which came first DNA or RNA.

## Science Titbits

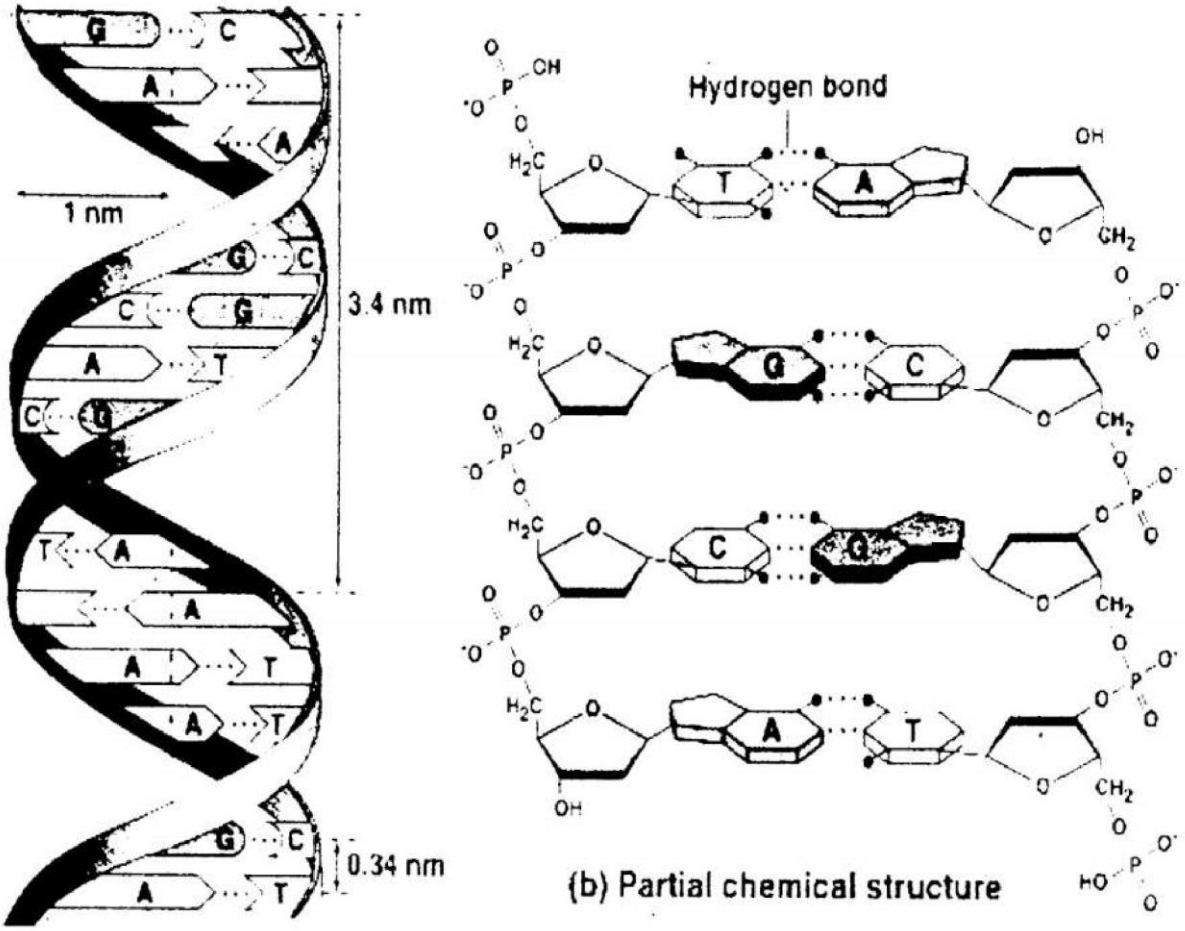
**Why do the nucleotides in DNA have a hydrogen atom at the 2' carbon instead of the hydroxyl group in ribose?**

**Ans:** 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**

**Solution:**




(a) Key features of double helix model of DNA (b) Partial chemical structure

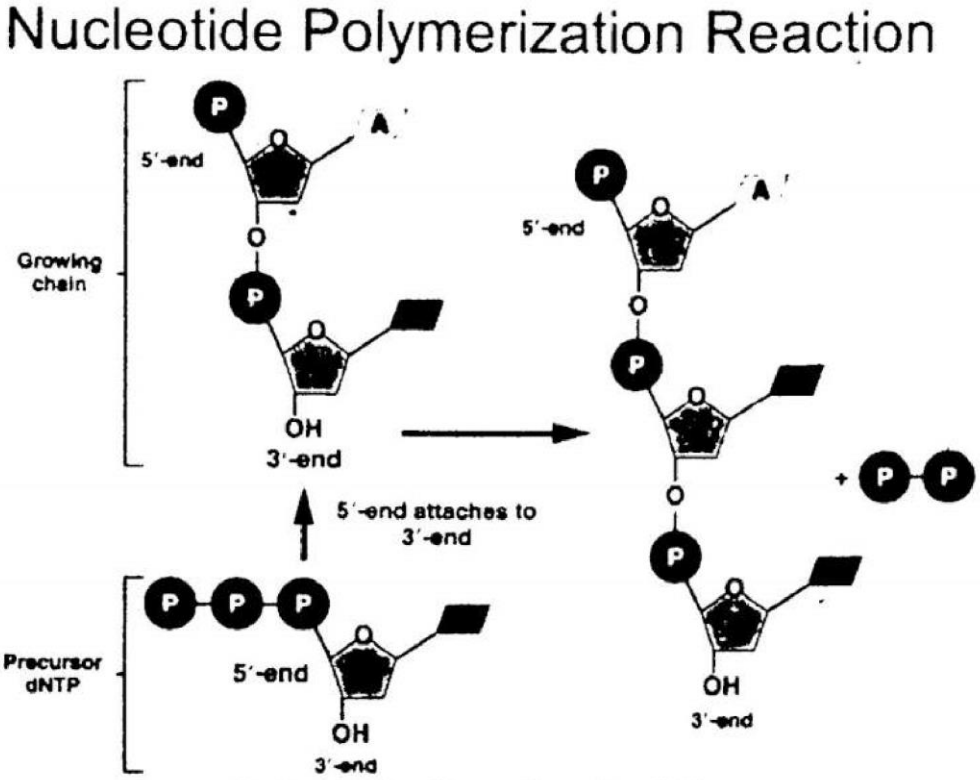
Watson and Crick model of DNA

♦ **Illustrate the formation of phosphodiester linkage**

**Solution:**

**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'.




**Polymerization of nucleotides**

## 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

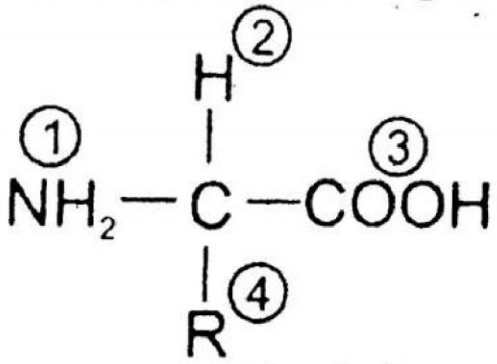
1. Performing Benedict's test for reducing sugars and confirmation of the presence of starch through iodine test
2. Confirmation of the presence of proteins through Biuret test
3. Confirmation of the presence of lipids through Emulsion test
4. Demonstration of the presence of nucleic acids in biological 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 different 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

## Answers

| | | | | |
|---|---|---|---|---|
| **(i) B** | **(ii) A** | **(iii) C** | **(iv) B** | **(v) D** |
| **(vi) A** | **(vii) A** | **(viii) B** | **(ix) B** | **(x) A** |
| **(xi) A** | **(xii) D** | **(xiii) A** | **(xiv) A** | **(xv) D** |

# SHORT QUESTIONS

**2. How would you describe biochemistry?**

**Ans: Biochemistry:**

**Biochemistry** is the branch of biology that deals with **Biological molecules** or **biomolecules**. It also deals with various chemical reactions (metabolism) of living beings. Biochemistry helps biologists to understand anatomy, physiology, pharmacology, biotechnology, bioinformatics etc.

**3. What are bioelements?**

**Ans: Bioelements:**

Approximately 25 elements out of 92 naturally occurring elements of earth are found in living beings. These are called **biogenic** or **bioelements**.

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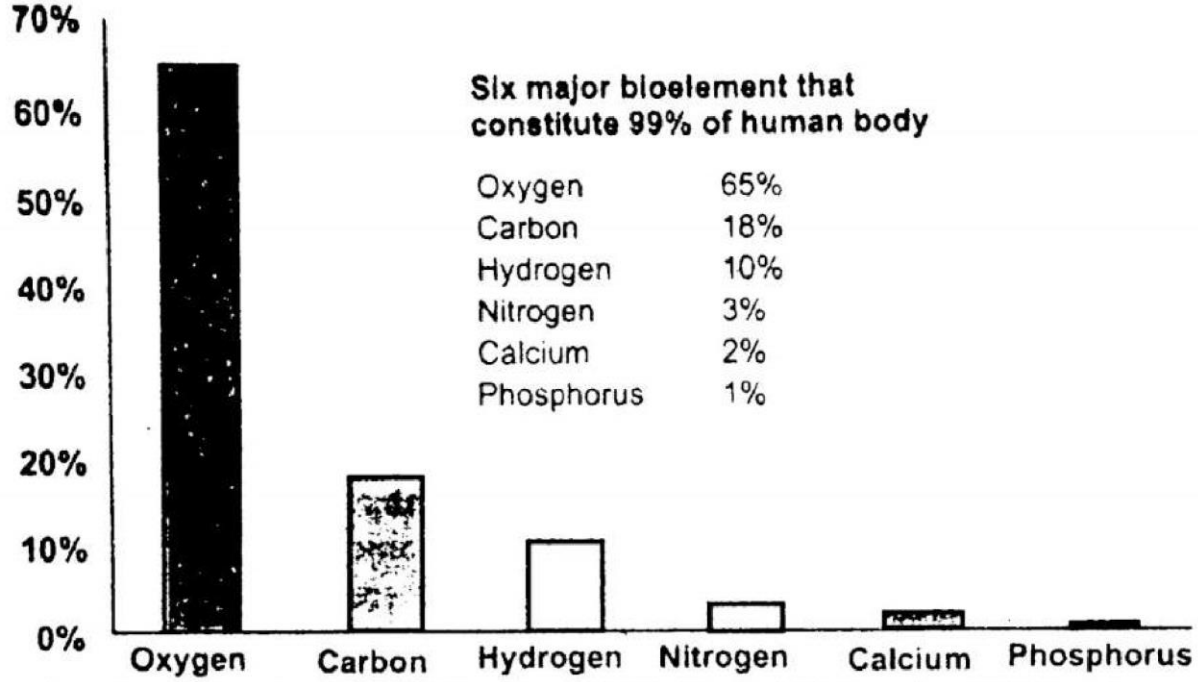
Approximately 25 elements out of 92 naturally occurring elements of earth are found in living beings. These are called **biogenic** or **bioelements**.

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




**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 and iodine

**Proportions of various bioelements in human body**

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: 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 ($Na^+$, $K^+$, $Ca^{++}$, $Mg^{++}$, $Cl^-$, $SO_4^-$) | 1% | 1% |

**4. Describe the chemical composition of protoplasm.**

**Ans: Chemical Composition of Protoplasm:**

Generally the protoplasm consists of oxygen, carbon, hydrogen and nitrogen. Approximately the oxygen is 62%, carbon 20%, hydrogen 10% and nitrogen 3%. The remainder of 5% part contains about thirty elements, of which calcium (Ca), iron (Fe), magnesium (Mg), chlorine (Cl), phosphorus (P), potassium (K), sulphur (S) etc., are important ones. In addition to these, boron (B), copper (Cu), fluorine (F), manganese (Mn) and silicon (Si) are found in small traces. In certain special cells alcohol, cobalt (Co) and zinc (Zn) are also found.

All these elements are found in ionic state or essentially found in adenosine triphosphate (ATP). All chemical reactions going on in the protoplasm obtain energy for their performance from ATP. The protoplasm contains 67-75% of water. Moreover, certain gases such as carbon-dioxide and oxygen remain dissolved in it.

The protoplasm of each cell contains several organic substances of which carbohydrates, fats, proteins, and nucleoproteins are important ones. These organic substances make protoplasm by molecular combination.

**5. What are the four fundamental kinds of biological molecules? Explain.**

**Ans:** The four fundamental kinds of biological molecules are carbohydrates, proteins, lipids and nucleic acids.

**i. Carbohydrates:**

**Carbohydrates** are present in the inclusions of the cells and provide fuel for the metabolic activities of the cell.

**ii. Proteins:**

**Proteins** are present in the membranes, ribosomes, cytoskeleton and enzymes of the cell.

**iii. Lipids:**

**Lipids** are present on the membranes of Golgi complex and inclusion of the cell. Lipids provide a reserved energy source, shape, protect and insulate the cells.

**iv. Nucleic Acid:**

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 transmits genetic information and takes part in protein synthesis.

**6. Why is the covalent bond in water polar?**

**Ans:** 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.

**7. Why water is regarded as universal solvent?**

**Ans:** 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

dissociates 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

**8. What is the importance of hydrogen bonding?**

**Ans: Importance of Hydrogen Bonding:**

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

**OR (Second Answer)**

**Importance of Hydrogen Bonding:**

Water is the best example of hydrogen bonding. We all know that how much water is important in our life. So hydrogen bonding is very important for sustaining life. Water is recognized as a natural solvent. Because without hydrogen bond water would not be formed. Hence hydrogen bonding is essential for sustaining life. Some of the important role of hydrogen bond is given below:

1. It is helpful in making wood fibers more rigid and hence for making wood article like furniture
2. It is used to determine the structure of various substances like protein.
3. Most of our food consists hydrogen bonding like carbohydrates, sugar
4. The fact that ice is less dense than liquid water is due to a crystal structure stabilized by hydrogen bonds.
5. High water solubility of many compounds such as ammonia is explained by hydrogen bonding with water molecules

**9. Why very large amount of heat can increase very little temperature in water?**

**Ans: High specific heat:**

**Heat capacity** can be defined as the amount of heat required for minimum increase (1°C or 1°K) 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°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.

**10. How water protects living things against sudden thermal change?**

**Ans:** 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.

**11. What is the importance of high heat of vapourization of water to animals?**

**Ans:** 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.

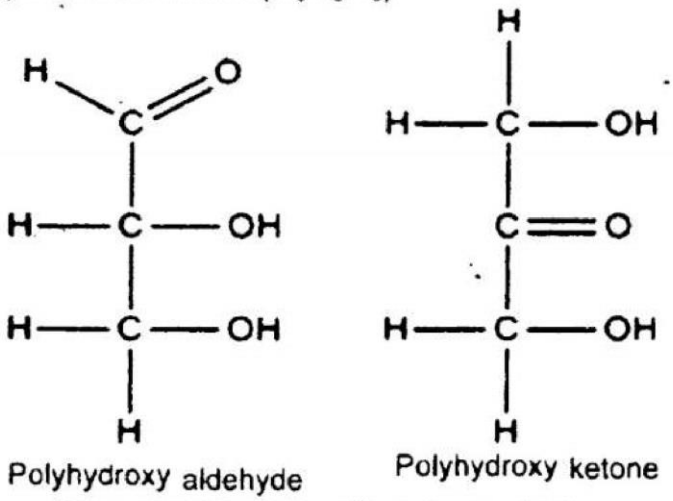
**12. What is the importance of ionization to the living organism?**

**Ans:** 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.

**13. Explain what carbohydrates are.**

**Ans: Carbohydrates:**

Carbohydrates are the compounds of carbon, hydrogen and oxygen. Literally word carbohydrate means "hydrates of carbon" i.e., a carbon associated with water or any compound composed of carbon, hydrogen and oxygen and in which hydrogen and oxygen are found in the same ratio as they are found in water (2:1), can be called carbohydrate. Although this definition is applied on many carbohydrates like glucose ($C_6H_{12}O_6$), sucrose ($C_{12}H_{22}O_{11}$), and the starches and cellulose $(C_6H_{10}O_5)n$ but some compounds containing hydrogen and oxygen in the same ratio as they are found in water (2:1), are actually not carbohydrates e.g., acetic acid ($C_2H_4O_2$) and lactic acid ($C_3H_6O_3$).




**Chemical nature of carbohydrates**

Moreover, there are also some carbohydrates, such as rhamnose $(C_6H_{12}O_5)_n$ which do not contain hydrogen and oxygen in the ratio of water. Hence the classical concept of carbohydrates as hydrates of carbon is now supposed to be incorrect and a more valid definition of these compounds is suggested as:

"Polyhydroxy aldehyde or polyhydroxy ketone or those compounds which upon hydrolysis yield such compounds (derivatives) are called carbohydrates".

**14. Describe classification of carbohydrates.**

**Ans: Classification of Carbohydrates:**

Carbohydrates are commonly known as **sugars** because more familiar carbohydrates have sweet taste. In Greek, "**sakcharon**" word is used for sugars, so the term saccharide is derived from this word. Therefore carbohydrates are also called **saccharides**. A polyhydroxy aldehyde or polyhydroxy ketone is supposed to be single saccharide units, whereas, the derivative carbohydrates are composed of more than one saccharide units.

Classification of carbohydrates is based upon number of saccharide units.

Carbohydrates are generally classified into three group i.e., monosaccharides, oligosaccharides and polysaccharides.

**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. |

**15. Describe the classification of monosaccharides?**

**Ans: 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).

**Examples and functions of monosaccharide:**

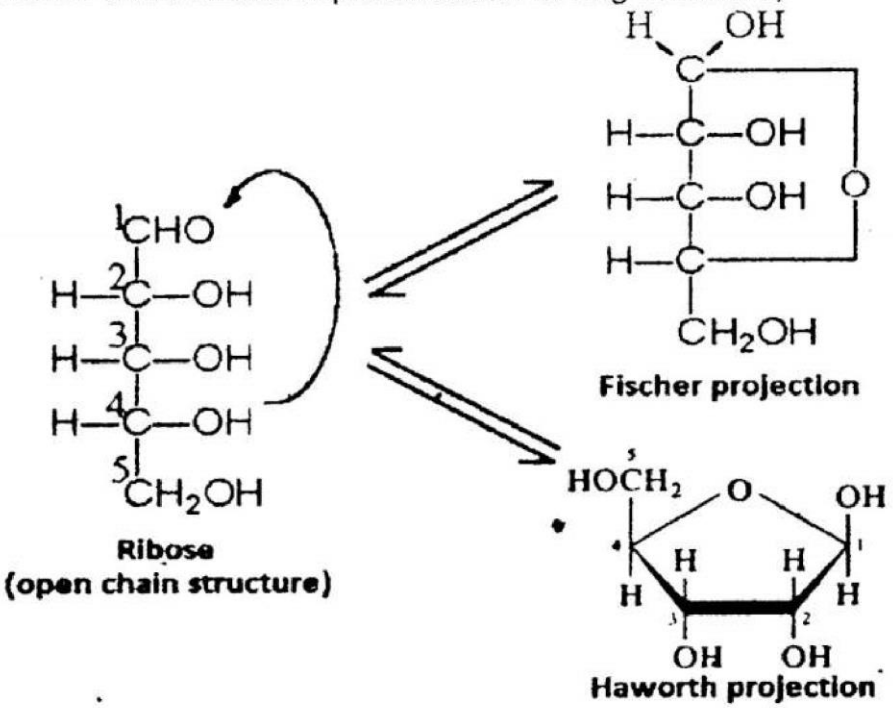
| Class | Formula | Aldoses | Ketoses | Function |
|---|---|---|---|---|
| Trioses (3C) | $C_3H_6O_3$ | Glyceraldehyde | Dihydroxy acetone | Intermediates in photosynthesis and cellular respiration. |
| Tetroses (4C) | $C_4H_8O_4$ | Erythrose | Erythrulose | Intermediates in bacterial photosynthesis. |
| 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 |

**16. Describe the conversion of open chain of ribose into ring chain.**

**Ans:** Let us understand it by taking ribose as an example. **Ribose** is an aldopentose, with the molecular formula $C_5H_{10}O_5$. It can exist in open chain structure in dried form but it exists in furanose ring in aqueous medium. When it is dissolved in water, the oxygen atom from aldehyde group reacts with penultimate carbon (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.

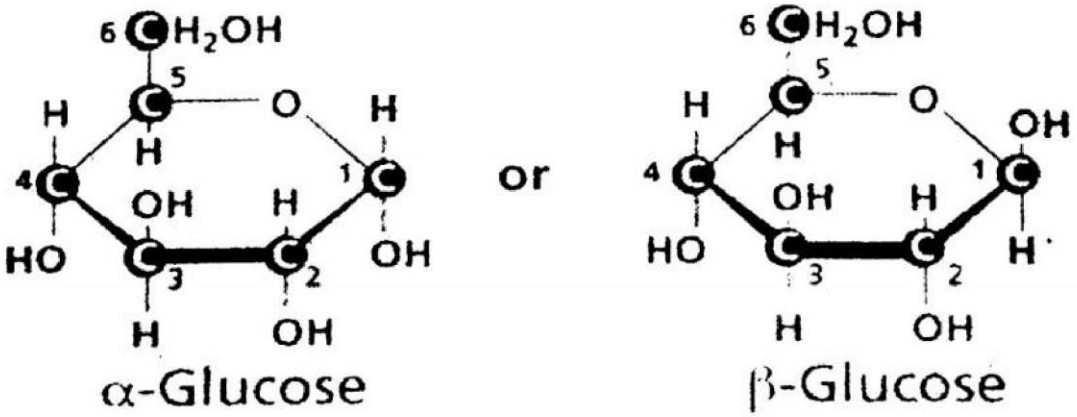
The ring structure demonstrated by Emil Fischer is called **Fischer projection** (a two dimensional representation of ring structure) while that represented by an English chemist Norman Haworth is called as **Haworth projection** (a three dimensional representation of ring structure)




Conversion of open chain into ring chain

**17. Draw and label the ring forms of alpha and beta glucose.**

**Ans:**

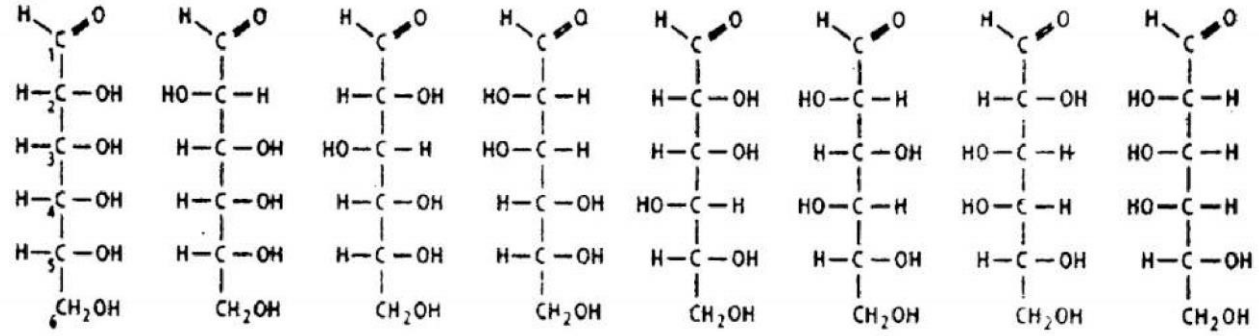



α and β isomers of glucose

**18. Justify that the laboratory-manufactured sweeteners are "left handed" sugars and cannot be metabolized by the "right handed" enzymes.**

**Ans: Laboratory Manufactured (Artificial) Sweeteners:**

Laboratory manufactured sugars such as tagatose, sucralose etc., are left-handed forms (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 particular enantiomers. 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 (sweetener) the enzyme must be left-handed.

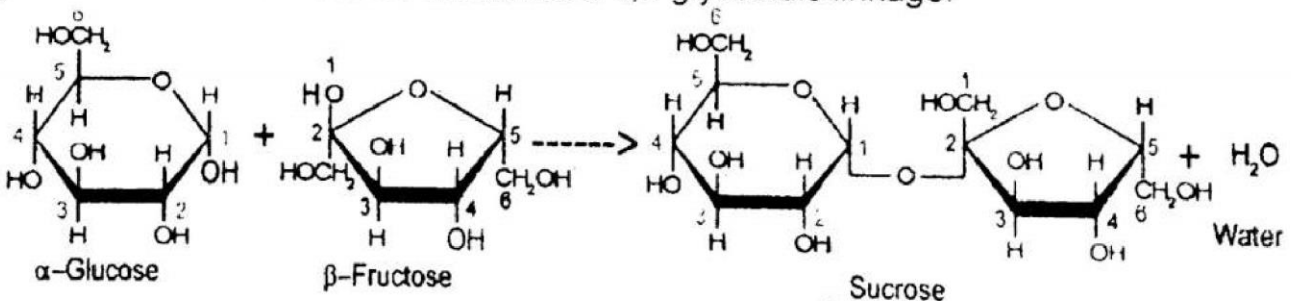



Stereoisomers of D-glucose

**19. Illustrate the formation and breakage of (a) sucrose (b) maltose (c) lactose.**

**Ans: (a) sucrose:**

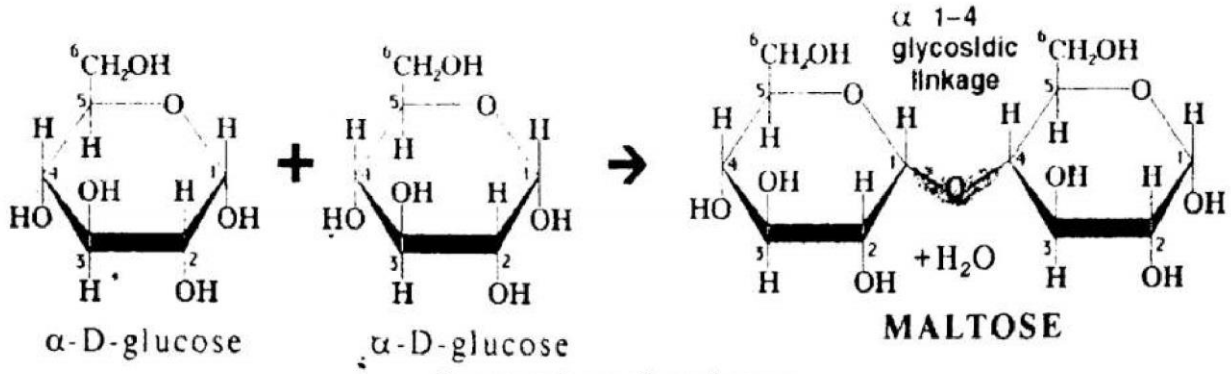
The sucrose is formed by the condensation of glucose and fructose. In this reaction, the –OH group at C-1 of glucose reacts with the –OH group at C-2 of fructose, liberating a water molecule and a linkage is formed between C-1 of glucose and C-2 of fructose known as α-1,2-glycosidic linkage.




Formation of sucrose

**(b) maltose:**

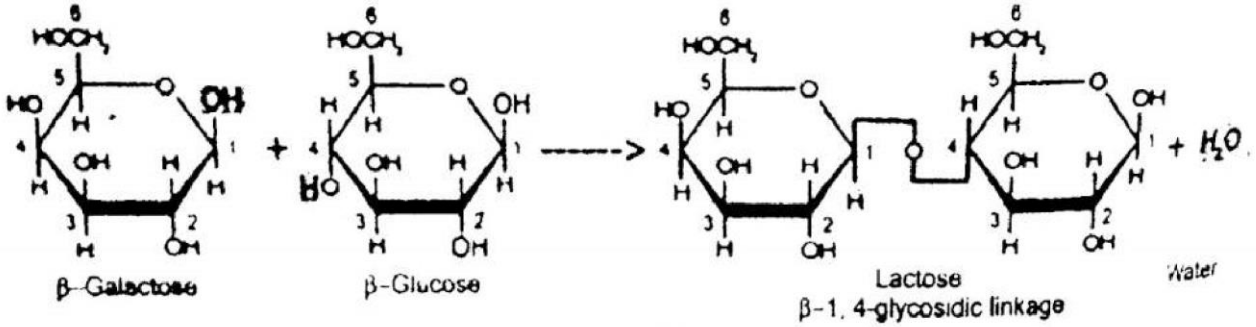
The maltose is formed by the condensation of α-glucoses. In this reaction, the –OH group at C-1 of one glucose reacts with the –OH group at C-4 of other glucose, liberating a water molecule and a linkage is formed between C-1 of one glucose and C-4 of other glucose, known as **α-1, 4-glycosidic linkage**.




Formation of maltose

**(c) lactose:**

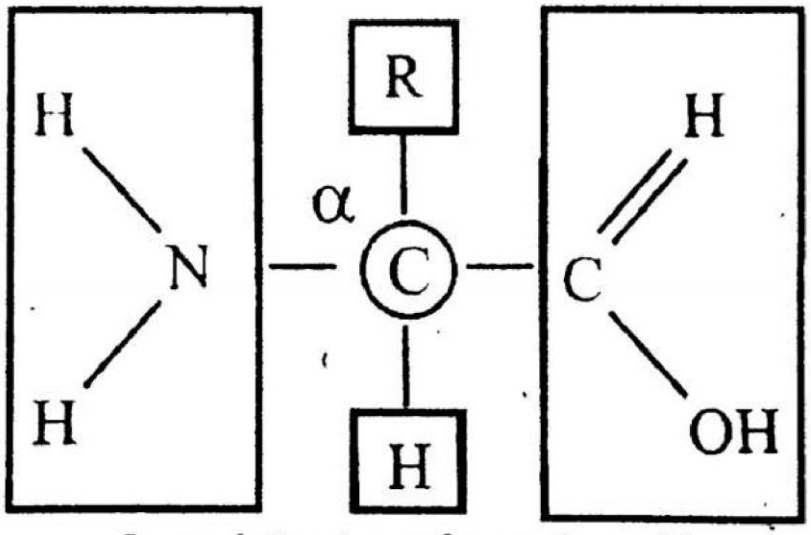
The lactose is formed by the condensation of β-galactose and β-glucose. In this reaction, the –OH group at C-1 of galactose reacts with the –OH group at C-4 of glucose, liberating a water molecule and a linkage is formed between C-1 of galactose and C-4 of glucose, known as ***β*-1, 4-glycosidic linkage**.




Formation of lactose

**20. Draw the structural formula of amino acid.**

**Ans:**




General structure of an amino acid

**21. Describe the synthesis of peptide bond**

**Ans:** The **peptide bond** is synthesized when the carboxyl group of one amino acid molecule reacts with the amino group of the other amino acid molecule, causing the release of a molecule of water ($H_2O$), hence the process is a dehydration **synthesis** reaction (also known as a condensation reaction), and usually occurs between amino acids.

**22. Describe the four types of structure of proteins.**

**Ans: Structural conformations in proteins:**

**i. Primary Structure:**

A linear polypeptide with a specific sequence and number of amino acid 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).

**ii. Secondary Structures:**

A helical **($\alpha$-helix)** or flattened sheets **($\beta$-pleated sheet)** like structures which are established by **H-bonding** between opposite charge bearing groups of different amino acids are called **secondary structures**.

**iii. Tertiary Structure:**

In some proteins the linear polypeptide is changed into $\alpha$-helix, then $\alpha$-helix fold again and again by **ionic bonds** and **disulfide bridges** to form a globular shaped structure the **tertiary structure**

**iv. Quaternary Structures:**

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**.

**23. What are the structural roles of proteins?**

**Ans: List of Structural Roles of 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. |

**24. What are the functional roles of proteins?**

**Ans: List of Functional Roles of 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. |

**25. Describe (a) globular proteins (b) fibrous protein.**

**Ans: (a) 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.

**(b) fibrous protein:**

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.

**26. Describe the classification of lipids.**

**Ans: Classification of Lipids:**

Lipids are broadly classified into simple, complex and derived, which are further subdivided into different groups.

**Simple Lipids:**

Simple lipids are esters of fatty acids with various alcohols e.g., acylglycerols (fats and oils) and waxes.

**Compound/Complex Lipids:**

The compound/complex lipids contain other groups in addition to an alcohol and a fatty acid e.g., phospholipids, glycolipids and lipoproteins.

**Derived Lipids:**

Derived lipids are the derivatives of simple and complex lipids e.g., terpenes, steroids, prostaglandins and cholesterols. Some examples such as acylglycerol, waxes, phospholipids, terpenes, prostaglandin and steroids are discussed here.

**27. What role do lipids play in living organisms?**

**Ans: 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), chemical messengers (steroid) and are also involved in protection, waterproofing, insulation and buoyancy.

**OR (Second Answer)**

**Lipids perform several biological functions.**

**Some of them are:**

i. Lipids such as triglycerides are storage compounds for the reserve energy of the body.

ii. Lipids are important component of the plasma membrane structure in eukaryotic cells and regulate membrane permeability.

iii. They serve as a source of fat soluble vitamins (A, D, E, and K)

iv. In nerve fibers, the myelin sheath contains lipids which act as electrical insulators

v. Lipids occur as components of some enzyme systems.

vi. Lipids are important as cellular metabolic regulators (Prostaglandins and steroid hormones).

vii. Cholesterol is found in the cell membrane of many organisms and in blood and bile.

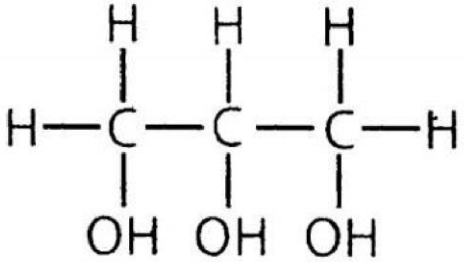
**28. Explain the structure of glycerol.**

**Ans:** **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.

**Formula of Glycerol:** $C_3H_8O_3$

**Structure of Glycerol:**




**29. What are the properties and types of fatty acids?**

**Ans: Properties 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.

**Types of Fatty Acids:**

**i. Saturated Fatty Acids:**

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).

**ii. Unsaturated Fatty Acids:**

**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.

**Common types of fatty acids:**

| Name | Typical source | No. of Carbon | Condensed Formula | Melting point (°C) |
|---|---|---|---|---|
| **Saturated** | | | | |
| **1. Laurie** | Coconut oil | 12 | $CH_3(CH_2)_{10}COOH$ | 44 |
| **2. Myristic** | Butter fat | 14 | $CH_3(CH_2)_{12}COOH$ | 58 |
| **3. Palmitic** | Most fats and oils | 16 | $CH_3(CH_2)_{14}COOH$ | 63 |
| **4. Stearic** | Most fats and oils | 18 | $CH_3(CH_2)_{16}COOH$ | 70 |
| **Unsaturated** | | | | |
| **5. Oleic** | Olive oil | 18 | $CH_3(CH_2)_7CH=CH(CH_2)_7COOH$ | 4 |
| **G. Linoleic** | Vegetable oils | 18 | $CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7COOH$ | -5 |
| **7. Linolenic** | Soybeans and canola oils | 18 | $CH_3CH_2CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_7CH_2OH$ | -11 |
| **8. Arachidonic** | Lard (present in chicken etc.) | 20 | $CH_3-(CH_2)_4-CH=CH-CH_2-CH=CH-CH_2-CH=CH-CH_2-CH=CH-(CH_2)_3-COOH$ | -50 |

**30. What is the function and uses of waxes?**

**Ans: Uses of Waxes:**

**Synthetic waxes** are generally derived from petroleum or polyethylene and consist of mixtures of long-chain hydrocarbons (alkanes), alcohols, aldehydes, ketones and fatty acids e.g., paraffin wax which is used to make candles, wax paper, lubricants, and sealing materials.

**31. Why phospholipids form a thin layer on the surface of an aqueous solution?**

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

**OR (Second Answer)**

Phospholipids have a hydrophilic head and two hydrophobic tails each. When phospholipids are exposed to water, they arrange themselves in a bi-layer sheet with the tails facing towards the center of the sheet, and away from the water.

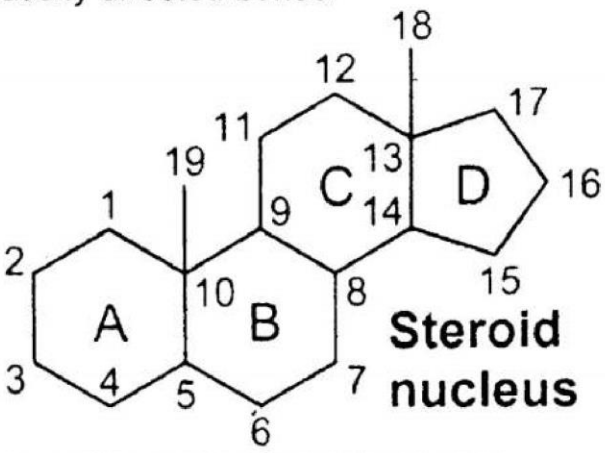
**32. What is isoprene unit? Explain.**

**Ans: Isoprene Unit:**

Terpenes are the types of derived lipids. 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**

**33. Describe a steroid nucleus.**

**Ans:** The **steroid nucleus** is a three-dimensional structure, and atoms or groups are attached to it by spatially directed bonds.




**34. What are the functions of prostaglandins?**

**Ans: Functions of Prostaglandins:**

Prostaglandins are derived from **arachidonic acid** (a tetra unsaturated 20C fatty 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. Those synthesized in the temperature-regulating centre of the hypothalamus cause fever. In fact, the ability of **aspirin** to reduce fever and decrease pain depends on the inhibition of prostaglandin synthesis.

**35. Describe the structure of a nucleotide.**

**Ans: Nucleotide Structure:**

The nucleotide in DNA consists of a sugar (deoxyribose), one of four bases (cytosine (C), thymine (T), adenine (A), guanine (G)), and a phosphate. Cytosine and thymine are pyrimidine bases, while adenine and guanine are purine bases. The sugar and the base together are called a nucleoside.

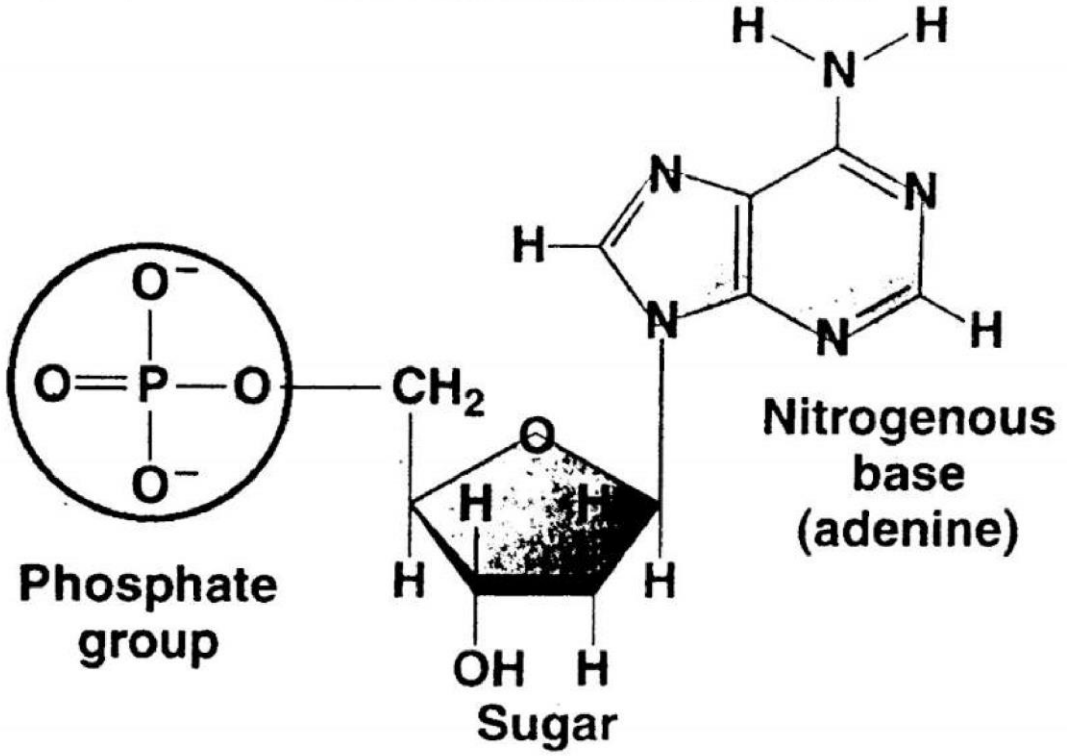
**Composition of a nucleotide:**

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 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 or 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).

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.**




Structure of a nucleotide

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.

**36. How might an error in the DNA of an organism affect protein function?**

**Ans:** Deoxyribonucleic acid (DNA) transcription occurs at a rate of around 1000x per second alone in a single-cell. Errors in these processes are typically checked and corrected by special enzymes. However errors in DNA transcription can result in protein synthesis with deleted amino acids which at best can be harmless. At worst, the deletion (or defective synthesis) of proteins can create fatal cancers through localized cell mutations.

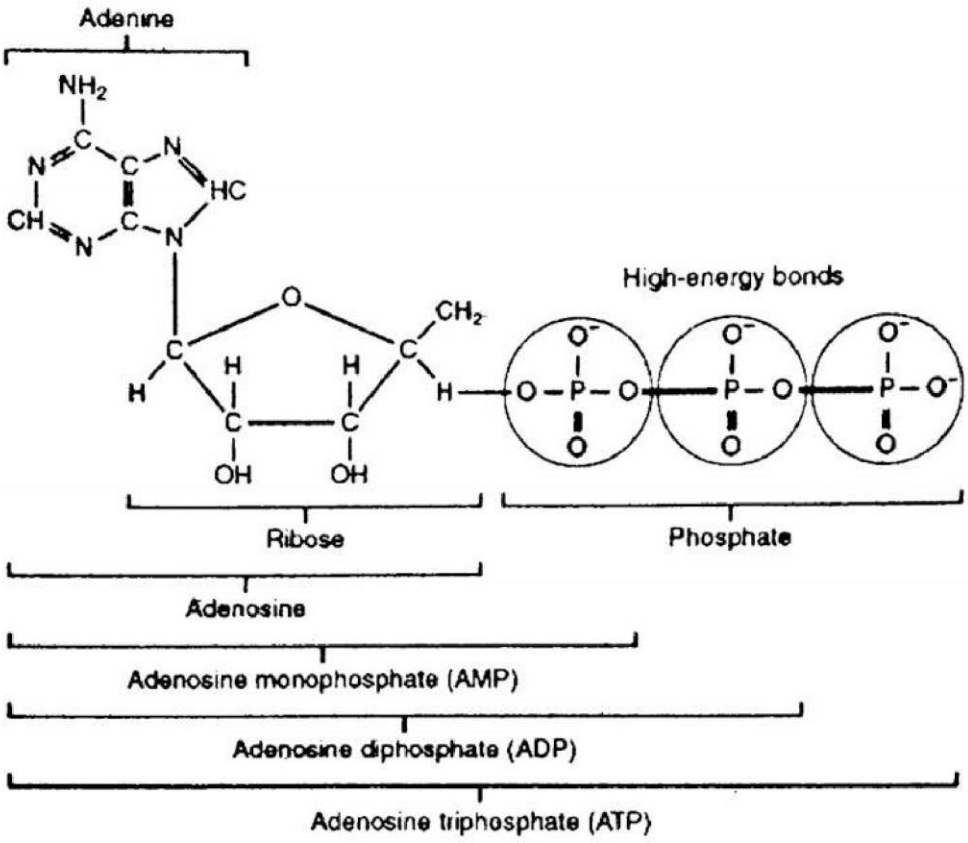
**37. Describe the structure of ATP.**

**Ans: Structure of ATP:**

**Adenosine triphosphate** (ATP) is a mononucleotide.

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**.

ATP is made from the oxidation of organic molecules during respiration. Since the energy to add the phosphate to ADP comes from oxidation, the process is known as **oxidative phosphorylation**. Most of the ATP in the cell is made in mitochondria.

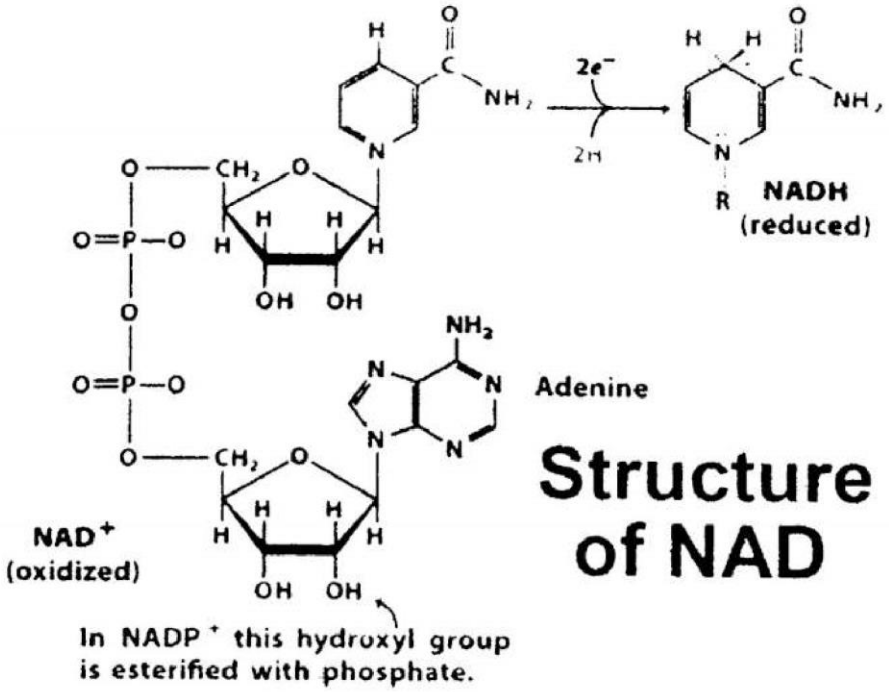



Structure of ATP

**38. Describe the structure of NAD.**

**Ans: Structure of NAD:**

**Nicotinamide adenine dinucleotide** (NAD) consists of two nucleotides. One nucleotide consists of base-nicotinamide, sugar and phosphate. Other nucleotide consists of base-adenine-sugar and phosphate. The two nucleotides are joined by their phosphate group forming a dinucleotide. NAD is a coenzyme. It works with dehydrogenases as oxidizing agent. Its reduced form is NADH+H ($NADH_2$).




Structure of NAD

**39. Define gene is a sequence of nucleotides as part of DNA, Which codes for the formational of a polypeptide.**

**Ans: 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. Genes possess the data to build and maintain cells and pass genetic information to offspring.

**OR (Second Answer)**

A gene can be defined as a piece of DNA sequence coding for a special polypeptide chain. Recall that in sickle cells Glutamic acid is replaced by valine at 6th position of polypeptide chain. The genetic code for glutamic acid is GAA (or GAG) If there is any change in the code it becomes GUA, then valine will be formed instead of glutamic acid, as a result the structure and function of the polypeptide chain is also changed. Thus gene is a sequence of nucleotides as part of DNA, which codes for the formation of a polypeptide.

**40. Define/Describe/Explain briefly:**
**carbohydrates, monosaccharides, oligosaccharides, starch, cellulose, stereoisomers, enantiomers, diastereisomers, epimers, proteins, amino acids, lipids, nucleic acids, nucleoside, nucleotides, peptide bond, phosphorylation, oxidative phosphorylation,**

**Ans: Carbohydrates:**

Carbohydrates are the compounds of carbon, hydrogen and oxygen. Literally word carbohydrate means "hydrates of carbon" i.e., a carbon associated with water or any compound composed of carbon, hydrogen and oxygen and in which hydrogen and oxygen are found in the same ratio as they are found in water (2:1), can be called carbohydrate.

Although this definition is applied on many carbohydrates like glucose ($C_6H_{12}O_6$), sucrose ($C_{12}H_{22}O_{11}$), and the starches and cellulose $(C_6H_{10}O_5)n$ but some compounds containing hydrogen and oxygen in the same ratio as they are found in water (2:1), are actually not carbohydrates e.g., acetic acid ($C_2H_4O_2$) and lactic acid ($C_3H_6O_3$). Moreover, there are also some carbohydrates, such as rhamnose $(C_6H_{12}O_5)_n$ which do not contain hydrogen and oxygen in the ratio of water.

Hence the classical concept of carbohydrates as hydrates of carbon is now supposed to be incorrect and a more valid definition of these compounds is suggested as:

"Polyhydroxy aldehyde or polyhydroxy ketone or those compounds which upon hydrolysis yield such compounds (derivatives) are called carbohydrates".

**Monosaccharides:**

Monosaccharides are true carbohydrates which are either polyhydroxy aldehydes or polyhydroxy ketones. The range of number of carbons in monosaccharide 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.

**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.

**Starch:**

Starch is a homopolysaccharides which is formed by the condensation of hundreds of **$\alpha$-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.

**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 **$\beta$-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. 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 **$\beta$-1, 4-glycosidic linkages** between glucose residues. Therefore, in a cellulose chain, the β-glucoses are alternatively arranged in upright and inverted manner.

**Stereoisomers:**

Those isomers in which –H and –OH groups are arranged in different pattern to the asymmetric carbon atoms are called **stereoisomers**.

An **asymmetric carbon** atom is that which makes bonds with four different atoms around it.

For example, in glucose, the C-2, C-3, C-4 and C-5 are asymmetric carbon atoms. In monosaccharide the number of stereoisomers; actually depends upon the number of asymmetric carbons in its structure and can be calculated by the formula 2n, where n is the number of asymmetric carbon atoms so glucose has 16 stereoisomers.

**OR (Second Answer)**

Stereoisomer molecules that have the same molecular formula, the same sequence of bonds, but different spatial arrangements. Geometric isomers and optical isomers are both types of stereoisomers.

**Enantiomers:**

Those stereoisomers which are non-superimposable mirror images of one another are called **enantiomers**. An example of an enantiomer is the D and L isomers of glucose.

**Diastereisomers:**

Those stereoisomers which have different arrangement of –H and –OH groups at more than one asymmetrical carbon atoms are called diastereoisomers. Unlike an enantiomer, diastereoisomers are not mirror images.

For example, the two carbohydrates that are diastereoisomers are **D – Glucose** and **D – Altrose**.

**Epimers:**

Those stereoisomers which have different arrangement of –H and –OH groups at only one asymmetrical carbon atom are called epimers. ***D – Glucose*** and ***D – Mannose*** are an example of an epimer.

**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.

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:**

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 (–OOH) 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.

**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), chemical messengers (steroid) and are also involved in protection, waterproofing, insulation and buoyancy.

**Nucleic acids:**

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. In 1920 the basic structure and chemical nature of nuclein was determined and was renamed as **nucleic acid** because of its acidic nature.

**Nucleoside:**

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.**

**Nucleotides:**

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**.

**Peptide bond:**

During the **translation** 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**.

**Phosphorylation:**

**Phosphorylation** is an important mechanism by which the activity of proteins can be altered after they are formed. A phosphate group ($PO_3^{-4}$) is added to a protein by specific enzymes called **kinases**. This phosphate group is usually provided by ATP, the energy carrier of the cell.

**Oxidative phosphorylation:**

Oxidative phosphorylation is the metabolic pathway in which cells use enzymes to oxidize nutrients, thereby releasing energy which is used to produce adenosine triphosphate (ATP). Almost all aerobic organisms carry out oxidative phosphorylation.

**OR (Second Answer)**

ATP is made from the oxidation of organic molecules during respiration. Since the energy to add the phosphate to ADP comes from oxidation, the process is known as **oxidative phosphorylation**.

**41. Write a brief notes on: Polarity of water molecules, Hydrogen bonding, High specific heat of water, High heat of vapourization of water, Cohesion and adhesion of water molecule, Hydrophobic exclusion, Ionization, Lower density of ice, Enantiomers, Diastereoisomers, Epimers, Sucrose, Maltose, Lactose, Starch, Glycogen, Cellulose, Chitin, Acylglycerol, Terpenes, Steroids, Prostaglandins, Composition of nucleotide, ATP, NAD, mRNA, tRNA, Sickle cell anaemia, Conjugated molecules.**

**Ans: (i) Polarity of water molecules:**

**Covalent Bonds:**

The bonds which are formed by the mutual sharing of electrons between two atoms are called **covalent bonds**.

**Nonpolar:**

Normally the sharing of electrons between two atoms is fairly equal and the covalent bond is **nonpolar**.

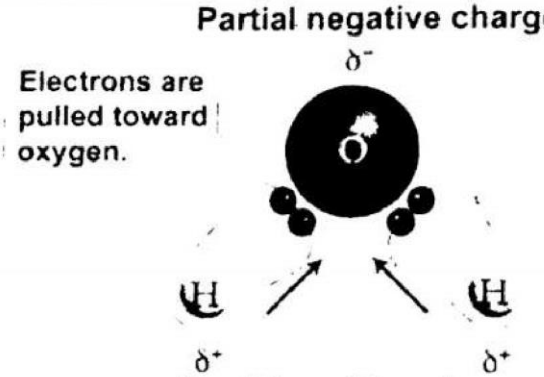
**Polar:**

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.

**Water Use as Universal Solvent:**

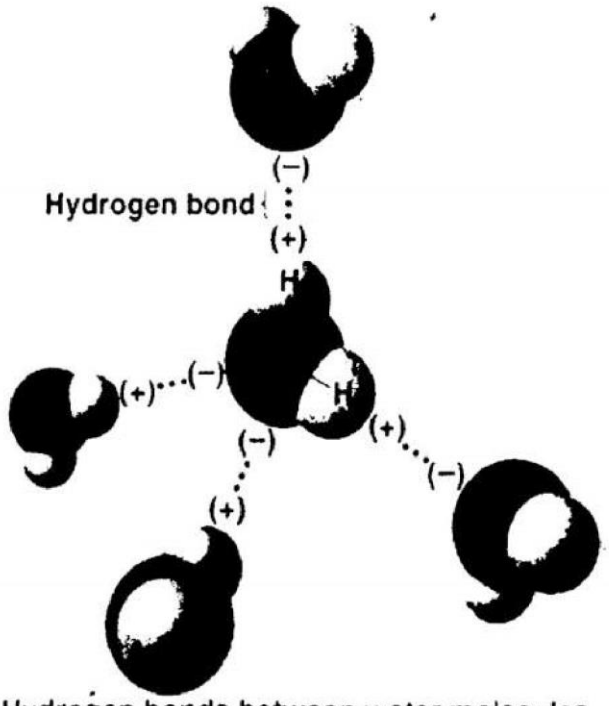
This is polarity of water molecules that makes it an excellent or **universal solvent** for polar substances. Ionic compound or electrolytes can be easily dissolved in water, non-polar substances having charged groups in their molecules can also be dissolved in water. Such compounds when dissolved in water, dissociates 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.




Polarity of water molecule

**(ii) 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.




Hydrogen bonds between water molecules

**Importance of Hydrogen bonding in Water:**

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.

### (iii) High specific heat of water:

**Heat capacity** can be defined as the amount of heat required for minimum increase (1°C or 1°K) 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°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.

### Importance of High Specific Heat:

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.

### (iv) High heat of vapourization of water:

**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.

### Importance of High Heat of Vapourization:

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.

### (v) Cohesion and adhesion of water molecule:

**Cohesion** is the attraction among the water molecules which enables the water molecules to stick together.

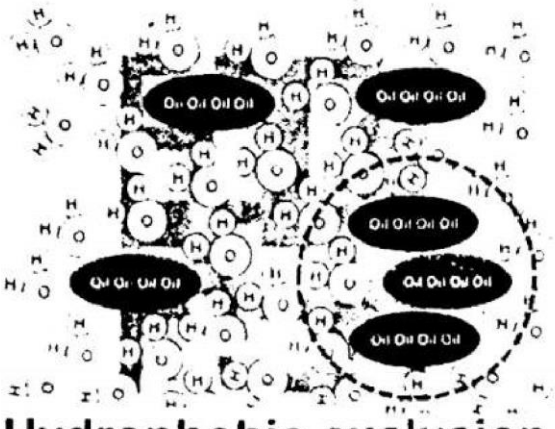
Water flows freely due to cohesion. Water molecules also have attraction to polar surfaces. This attraction is called **adhesion**.

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.

### (vi) 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 coalesce (to unite into one whole) into a single drop.



Hydrophobic exclusion

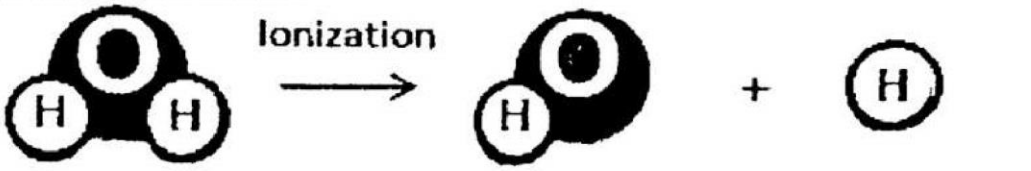
### Importance of Hydrophobic Exclusion:

Biologically, hydrophobic exclusion plays key roles in maintaining the integrity of lipid bilayer membranes.

**(vii) 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.

**Importance of Ionization:**




Water molecule $[H_2O]$ Hydroxyl ion $[OH^-]$ Hydrogen ion $[H^+]$

Ionization of water

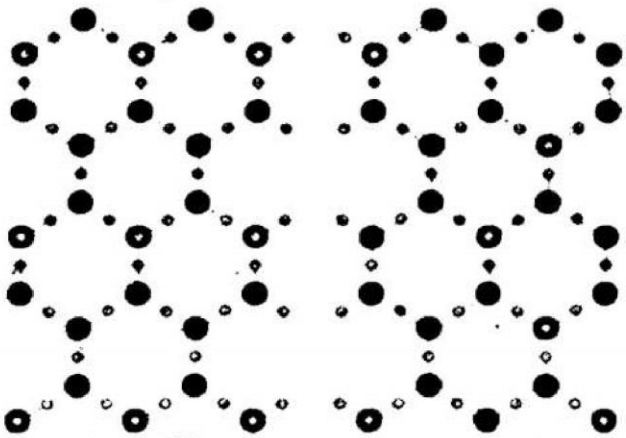
This reaction is reversible but equilibrium is maintained at 25°C. The $H^+$ and $OH^-$ ions affect and take part in many of the reactions that occur in cells, e.g., it helps to maintain or change the pH of the medium.

**(viii) 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.

**Importance of Lower Density of Ice:**

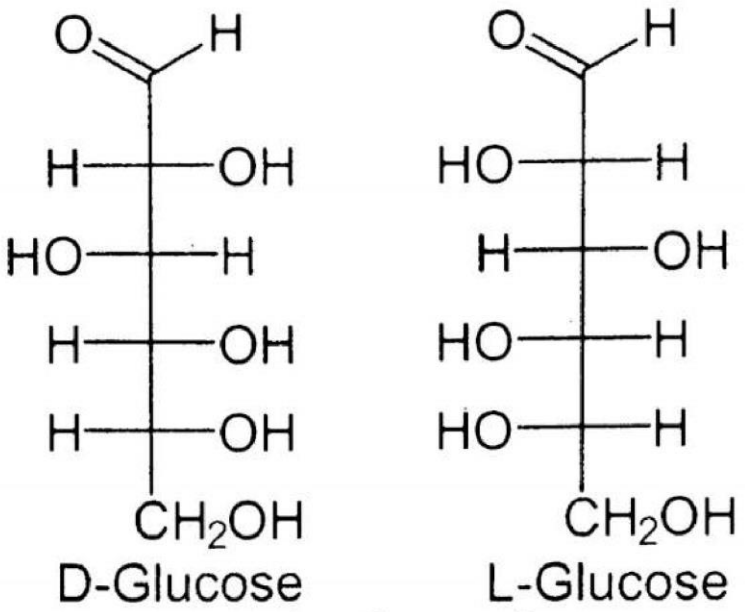
In freezing weather, ice forms on the surface of ponds and lakes forming an insulating layer above the water below. This provides a living environment for some organisms until the ice melts. Organisms can also live under the ice.



Lattice likes arrangement of water molecules in ice

**(ix) Enantiomers:**

Those stereoisomers which are non-superimposable mirror images of one another are called **enantiomers**. An example of an enantiomer is the D and L isomers of glucose, as shown in figure. In **D isomers** (also called right handed form) the asymmetric carbon atom farthest from aldehyde group (second last carbon or C-5 in case of glucose also called **penultimate carbon**) has –OH group on right side whereas in **L isomers** (also called left handed form), the –OH group is projected on left side at penultimate carbon atom. Out of 16 stereoisomers of glucose, 8 are enantiomers of other 8.




**An example of enantiomers**

**(x) Diastereoisomers:**

Those stereoisomers which have different arrangement of –H and –OH groups at more than one asymmetrical carbon atoms are called diastereoisomers. Unlike an enantiomer, diastereoisomers are not mirror images. For example, the two carbohydrates that are diastereoisomers are D-Glucose and D-Altrose.

**(xi) Epimers:**

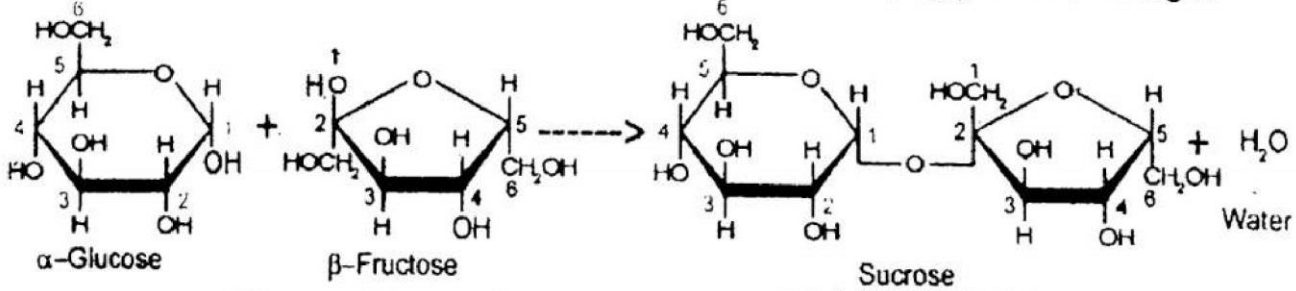
Those stereoisomers which have different arrangement of –H and –OH groups at only one asymmetrical carbon atom are called epimers. ***D – Glucose*** and ***D – Mannose*** are an example of an epimer.

**(xii) Sucrose:**

It is commonly known as cane sugar because it occurs abundantly in sugarcane beside it many other plants also have sucrose in considerable amount like sugar beet, pine apple, sorghum and all sweet fruits. 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. Upon hydrolysis sucrose yields a molecule of α-glucose and a molecule of β-fructose.

**Formation of Sucrose:**

Therefore, 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 and a linkage is formed between C-1 of glucose and C-2 of fructose known as α-1,2-glycosidic linkage.



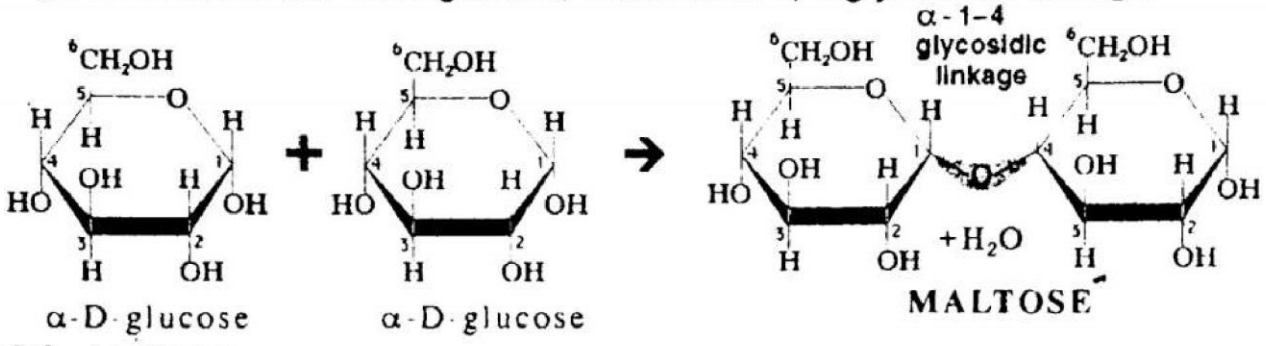

**Formation of sucrose**

### (xiii) 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. In brewing industry the maltose is produced from the breakdown of barley starch by the help of amylase enzyme. This process is known as **malting**. Upon hydrolysis it yields two molecules of α-glucoses.

### Formation of Maltose:

Therefore, the maltose is formed by the condensation of 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 and a linkage is formed between C-1 of one glucose and C-4 of other glucose, known as ***α*-1, 4-glycosidic linkage**.

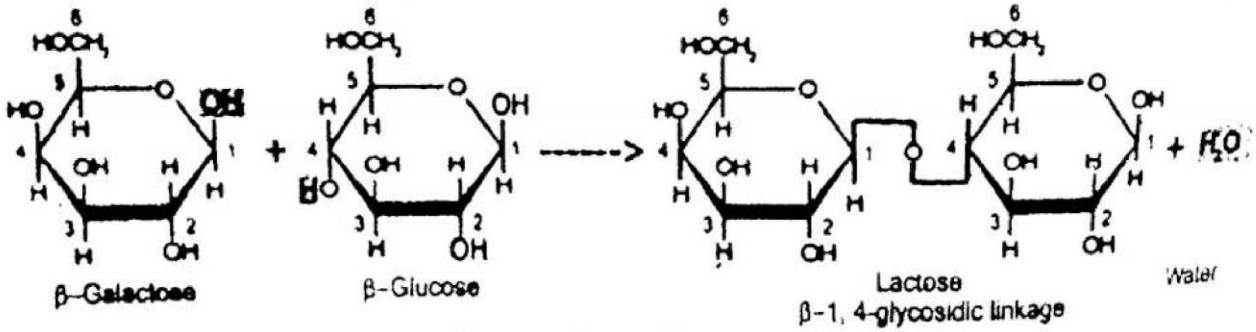



### (xiv) Lactose:

It is commonly known as milk sugar as it is found in milk of mammals i.e., 4-6% in cow's milk and 5-8% in human milk. It is also a byproduct in the manufacture of cheese. Upon hydrolysis it yields a molecule of β-galactose and a molecule of α-glucose.

### Formation of Lactose:

Therefore, 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 and a linkage is formed between C-1 of galactose and C-4 of glucose, known as ***β*-1, 4-glycosidic linkage**.




**Formation of lactose**

### (xv) Starch:

Starch is a homopolysaccharides which is formed by the condensation of hundreds of ***α*-glucoses**.

### Storage of Starch in Plants:

It is storage carbohydrate of plants. It is mainly stored in root, stem and seeds.

**Role of Starch:**

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.

**Types of Starch:**

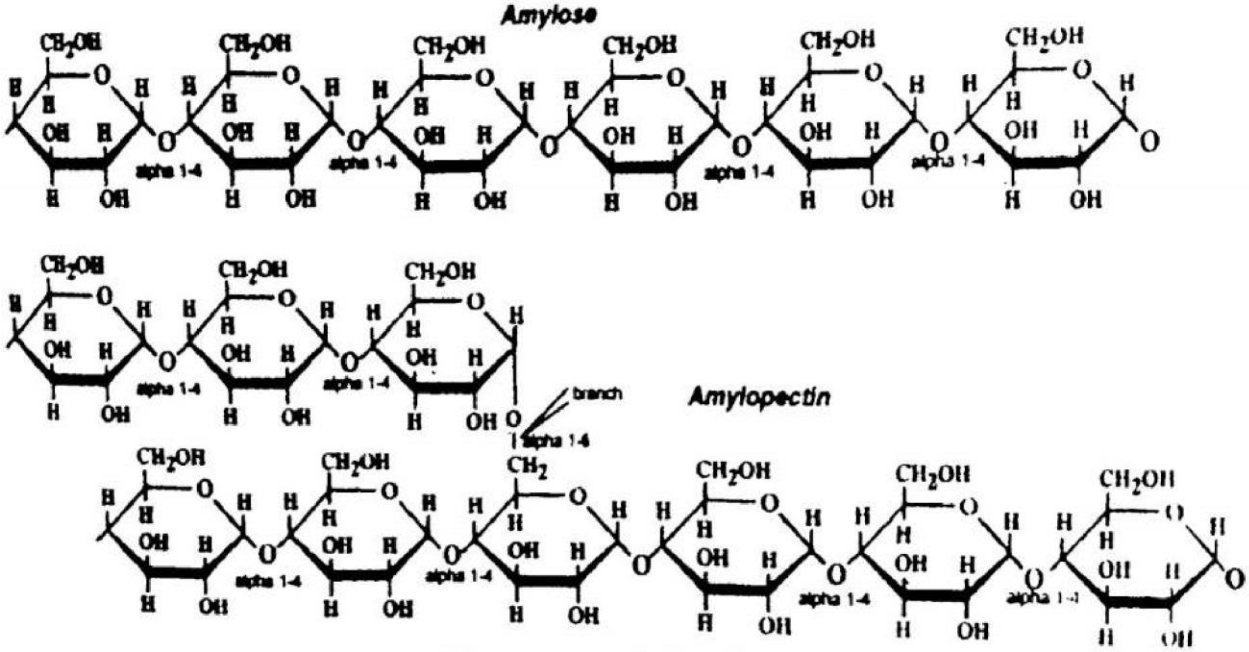
There are two types of starches i.e., amylose and amylopectin.

**Amylose:**

**Amylose** is un-branched i.e., a linear chain of glucoses in which glucoses are attached together by **$\alpha$-1, 4-glycosidic linkages**. It is soluble in hot water only.

**Amylopectin:**

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 **$\alpha$-1, 6-glycosidic linkages**. It is completely insoluble in water.




Structure of starches

**(xvi) Glycogen:**

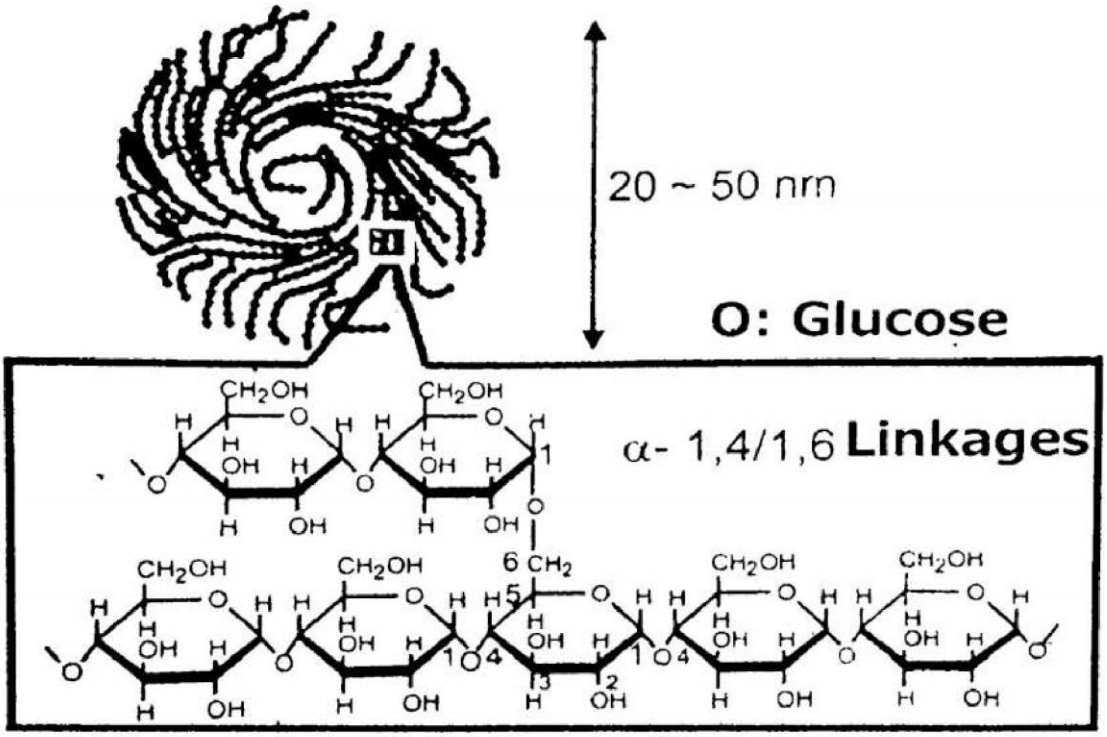
Like starch, glycogen is also a homopolysaccharides composed of **$\alpha$-glucoses**.

**Storage of Glycogen in Animals:**

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 also be confirmed by iodine test as it gives red colour with iodine solution.

**Structure of Glycogen:**

Structure of glycogen resembles with amylopectin starch but glycogen has much more branching than amylopectin.




**Glycogen (Highly branched unlike amylopectin)**

**Structure of glycogen**

### (xvii) Cellulose:

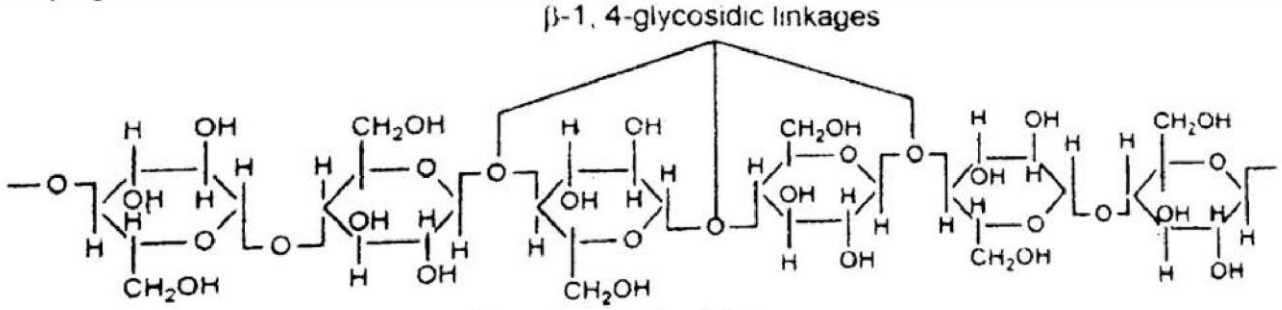
Cellulose is most abundant carbohydrate on earth. It is also a homopolysaccharides but unlike starch and glycogen it is formed by the condensation of hundreds of **β-glucoses**.

### Examples of Cellulose:

It is structural carbohydrate of plants as it is major constituent of plant cell wall. Cotton and paper are the pure forms of cellulose. Cellulose shows no colour with iodine solution.

### Structure of Cellulose:

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. Therefore, in a cellulose chain, the β-glucoses are alternatively arranged in upright and inverted manner.




**Structure of cellulose**

### (xviii) Chitin:

Chitin is the second most abundant organic molecule on earth.

### Role of Chitin:

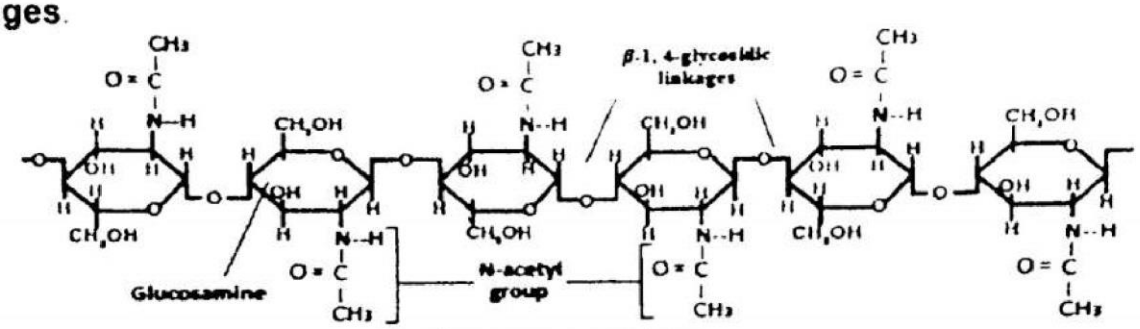
It is also a homopolysaccharides. It is a structural carbohydrate found in the cell walls of fungi and in the exoskeleton of arthropods. Due to the occurrence of chitin in fungal cell wall, it is also known as **fungal cellulose**.

**Formation of Chitin:**

Chitin is the derivative of **N-acetyl glucosamine** which is a modified form of glucose.

**Structure of Chitin:**

It has an un-branched structure like cellulose in which alternative upright and inverted N-acetyl glucosamine residues are linked together by **β-1, 4-glycosidic linkages**.




**Structure of chitin**

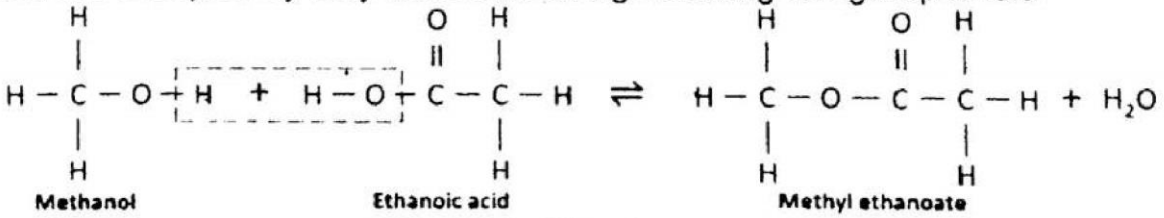
**(xix) Acylglycerol:**

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 2 Biological Molecules of a chemical reaction of an alcohol with acid and a water molecule is released such a reaction is called **esterification**.

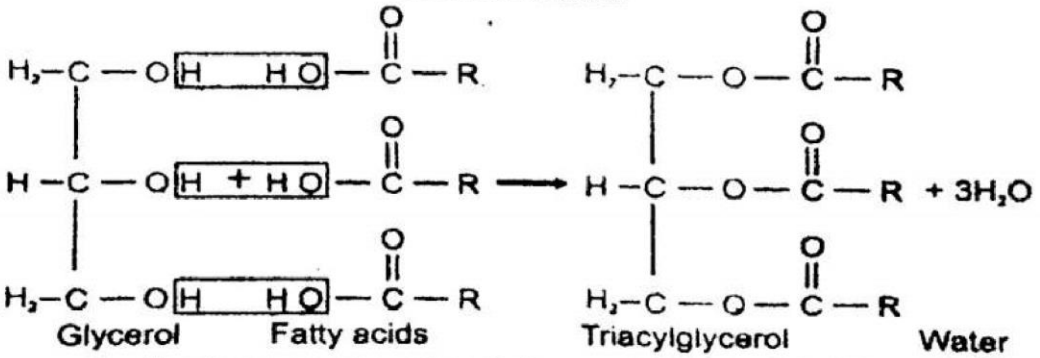
**Glycerol** is a trihydroxy alcohol which contains three carbons, each bears an OH group. A **fatty acid** is a type of organic acid containing one carboxylic acid group attached to a hydrocarbon. Fatty acids contain even number of carbons from 2 to 30. Each fatty acid is represented as R-COOH, where 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 charge bearing OH group is left.



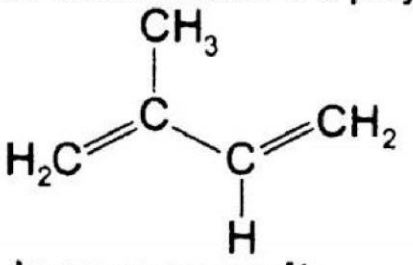

**Esterification**




**Formation of a triacylglycerol (neutral lipid)**

## (xx) Terpenes:

Terpenes are the types of derived lipids. 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**.




**Isoprene unit**

## (xxi) Steroids:

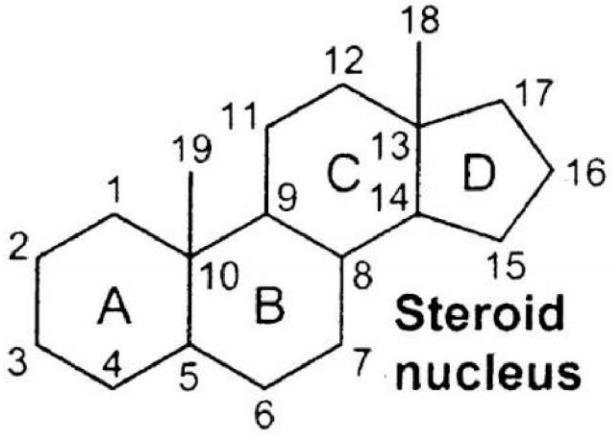
Steroids are lipids of high molecular weight which can be crystalline.

### Composition of steroid:

A steroid 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.

### Role of steroid in Living Organisms:

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.



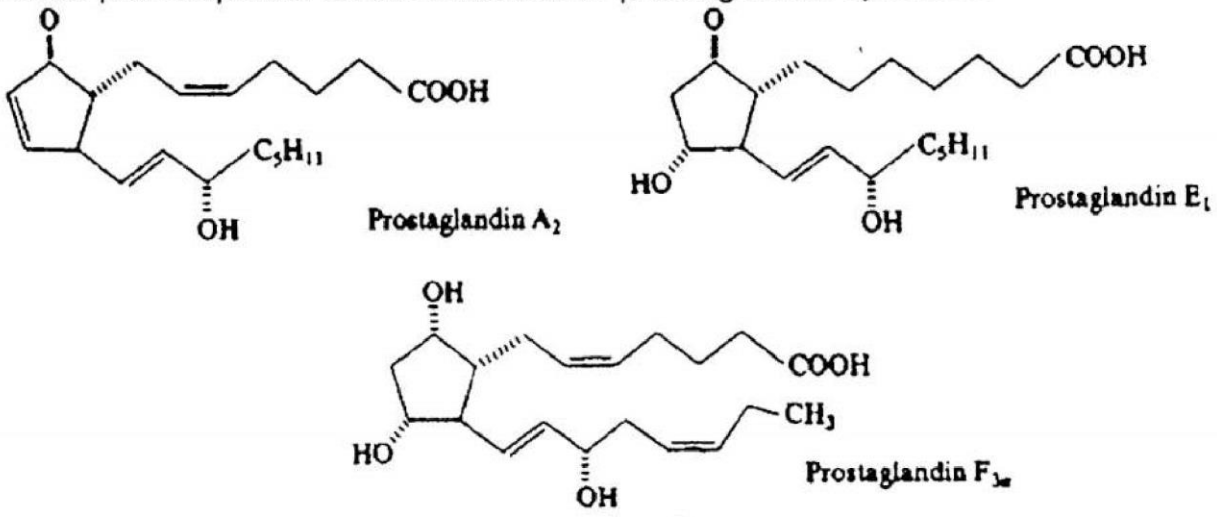

## (xxii) Prostaglandins:

Prostaglandins exist in virtually every mammalian tissue, acting as local hormones. Prostaglandins are derived from **arachidonic acid** (a tetra unsaturated 20C fatty acid).

### Role of Prostaglandins in Living Organisms:

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. Those synthesized in the temperature-regulating centre of the

hypothalamus cause fever. In fact, the ability of **aspirin** to reduce fever and decrease pain depends on the inhibition of prostaglandin synthesis.




**Prostaglandins**

**(xxiii) Composition of nucleotide:**

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.

**Pentose sugar:**

The **pentose sugar** in deoxyribonucleotides is deoxyribose and in ribonucleotides is ribose.

**Phosphoric acid:**

**Phosphoric acid** is a common component of both nucleotides which provides acidic properties to DNA and RNA.

**Nitrogenous bases:**

The nitrogen containing ring structures are called **bases** because of unshared pair of electron on nitrogen atoms, which can thus acquire a proton

**Classes of Nitrogenous Bases:**

There are two major classes of nitrogenous bases i.e., single ring **pyrimidine** and double ring **purines**.

**i. Pyrimidine bases:**

Pyrimidine bases are or 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.

**ii. Purine bases:**

On the other hand, the purine bases are also of two types i.e., adenine (A) and guanine (G).

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.

**(xxiv) ATP:**

**Adenosine triphosphate** (ATP) is a mononucleotide. 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. ATP is made from the oxidation of organic molecules during respiration. Since the energy to add the phosphate to ADP comes from oxidation, the process is known as **oxidative phosphorylation**. Most of the ATP in the cell is made in mitochondria.

**(xxv) NAD:**

**Nicotinamide adenine dinucleotide** (NAD) consists of two nucleotides One nucleotide consists of base-nicotinamide, sugar and phosphate. Other nucleotide consists of base-adenine-sugar and phosphate. The two nucleotides are joined by their phosphate group forming a dinucleotide. NAD is a coenzyme. It works with dehydrogenases as oxidizing agent. Its reduced form is NADH+H ($NADH_2$).

**(xxvi) 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. It is transcribed from DNA template i.e., the base of sequence of mRNA is according to the base sequence of DNA. It becomes attached to the ribosome. At ribosome, amino acids are attached one by one to form a polypeptide chain as per base sequence of mRNA. This process is known as **translation**.

**(xxvii) tRNA:**

It is the smallest of the RNA molecules that 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 always is the base sequence of ACC. Amino acid is attached to tRNA at this end. The nucleotide sequence of the rest of the molecule is variable. 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. For example, a tRNA that has anticodon GAA binds to the codon CUU and carries amino acid Leucine. 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

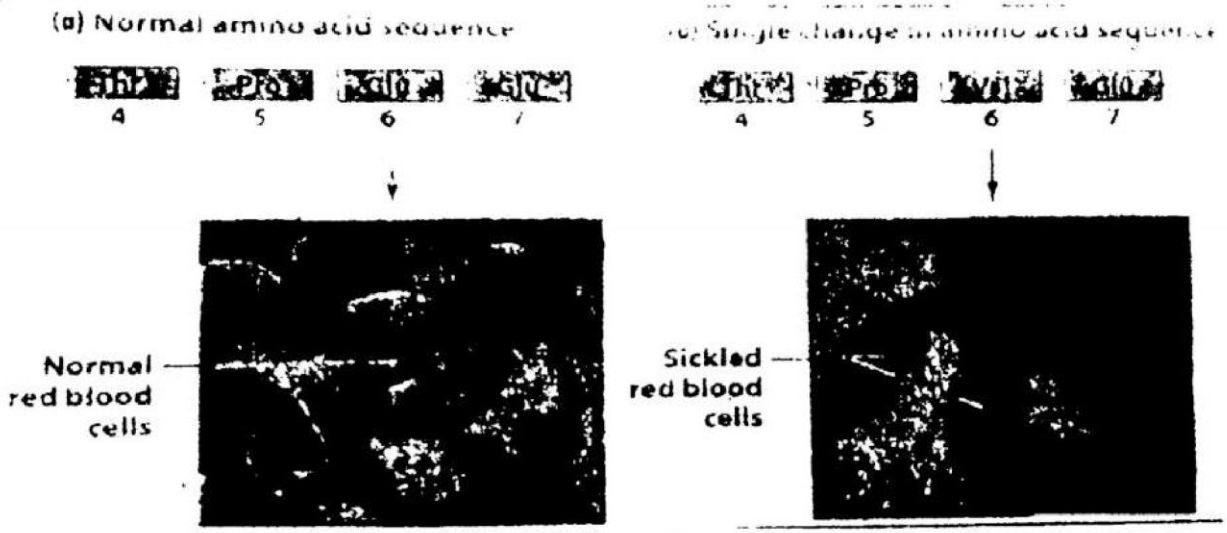
acids found in proteins. Sixty tRNA have been identified. However, human cells contain about 45 different kinds of tRNA molecules each transports a specific amino acid from cytoplasm to the surface of ribosome for protein synthesis.

**(xxviii) Sickle cell anaemia:**

**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 (HbS)**. 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.

**Causes of Sickle cell anemia:**

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 hemoglobin. Sickle cell haemoglobin (HbS) shows only one difference from HbA i.e., **glutamic acid** is replaced by **valine** at position number six in β-chain.




Difference in β-chain of HbA and HbS

**(xxix) Conjugated molecules:**

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

**42. 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) furanose and pyranose**
**(f) Fischer projection and Haworth projection**
**(g) alpha and beta glucose**
**(h) D-glucose and L-glucose**
**(i) enantiomers and diastereoisomers**
**(j) diastereoisomers and epimers**
**(k) amylase and amylopectin**

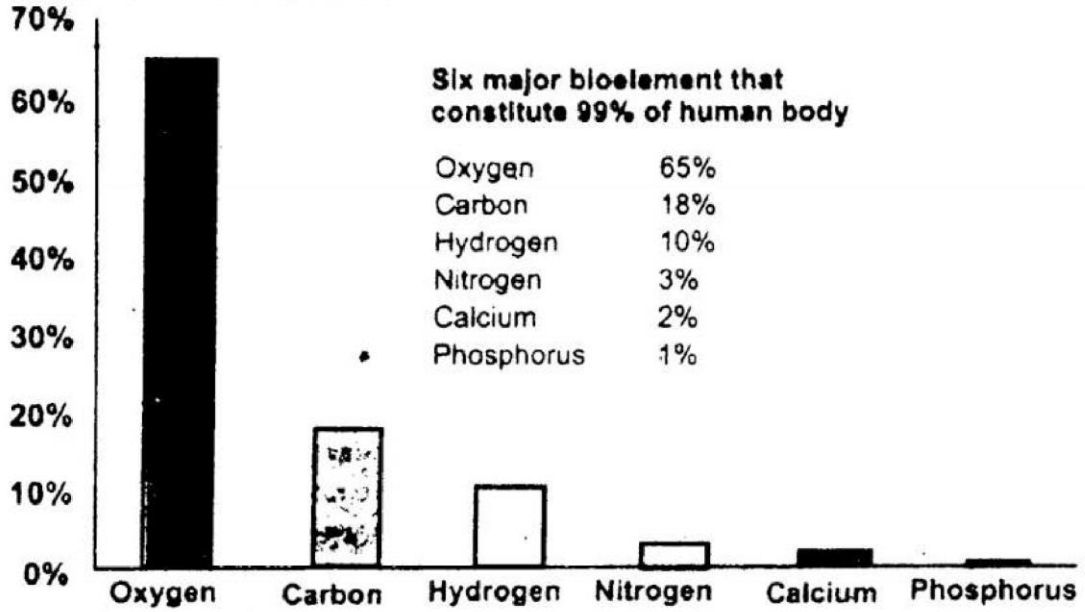
**(l) amylopectin and glycogen**
**(m) primary and secondary structure of proteins**
**(n) tertiary and quaternary structure of proteins**
**(o) purine and pyrimidine**
**(p) saturated and unsaturated fatty acids**
**(q) DNA and RNA**
**(r) oxidative phosphorylation and photophosphorylation**

**Ans: (a) major and minor bioelements:**

| Major Bioelements | Minor Bioelements |
|---|---|
| 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 elements are given in the figure.

Some trace elements such as iron are needed by all forms of life. Others are required only by certain species.




**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 and iodine

**OR (Second Answer)**

Chemical elements are divided up into two groups – major and minor

| Major Bioelements | Minor Bioelements |
|---|---|
| • Nitrogen (N)<br>• Phosphorus (P)<br>• Potassium (K)<br>• Sulphur (S)<br>• Calcium (Ca)<br>• Magnesium (Mg)<br>• Sodium (Na) | • Boron (B)<br>• Iron (Fe)<br>• Manganese (Mg)<br>• Copper (Cu)<br>• Zinc (Zn)<br>• Molybdenum (Mo)<br>• Chlorine (Cl)<br>• Cobalt (Co)<br>• Selenium (Se)<br>• Iodine (I) |

- The tissues of plants and animals are made up of Carbon (C), Hydrogen (H), and Oxygen (O) and about 15 mineral elements.
- The elements C, H and O along with Nitrogen (N), Phosphorus (P) and Sulphur (S) make up the living matter in plants and animals, with Calcium and Phosphorus forming animal skeletal bones
- The other elements are used in various body systems of plants and animals driven by enzymes and for nervous functions.
- An enzyme is a chemical used in a biological process but remains chemically unchanged.

**(b) dimer and polymer:**

| Dimer | Polymer |
|---|---|
| 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**. |

**OR (Second Answer)**

| Dimer | Polymer |
|---|---|
| A molecule consisting of two identical halves, formed by joining two identical molecules, sometimes with a single atom acting as a bridge. | A long or larger molecule consisting of a chain or network of many repeating units, formed by chemically bonding together many identical or similar small molecules called monomers. A polymer is formed by polymerization, the joining of many monomer molecules. |

**OR (Second Answer)**

A monomer is a non-repeating structure. A dimer is two monomers attached to each other. A polymer is many monomers attached to each other.

Think chain links. A single chain link is a monomer, two chain links hooked together is a dimer, and a 20 foot length of chain is a polymer.

**(c) polar and nonpolar covalent bond:**

| Polar Bond | Nonpolar Covalent Bond |
|---|---|
| Polar covalent bonding is a type of chemical bond where a pair of electrons is unequally shared between two atoms. | Nonpolar covalent bonds are a type of chemical bond where two atoms share a pair of electrons with each other. |

**OR (Second Answer)**

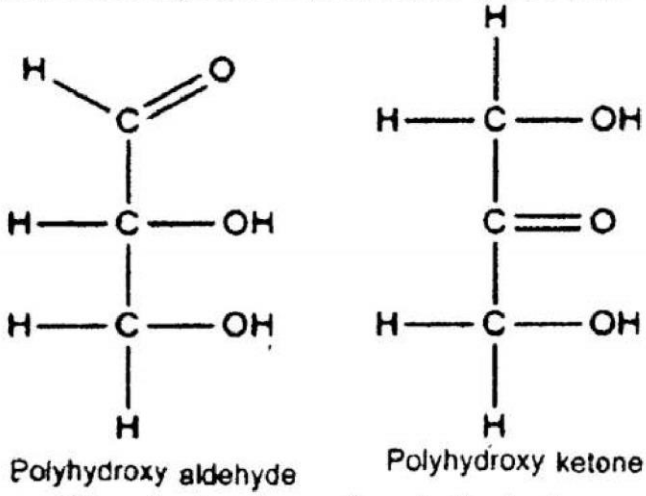
| | Polar | Non-Polar |
|---|---|---|
| **Definition** | Polar substances have a positive and a negative charge on the atom. | Non-Polar substances do not have large charges on the atom attached. |

| | | |
|---|---|---|
| **Movement** | They have electrical dipole movement. | They do not have any dipole movement. |
| **Charge separation** | There is charge separation. | There is no charge separation. |
| **Interaction** | They interact with other polar substances. | They do not interact with other polar substances. |
| **Example** | Water, alcohol and sulphur. | Oil. |

**(d) polyhydroxy aldehyde and polyhydroxy ketone:**

So **Polyhydroxy aldehydes** and **ketones** and their anhydrides describes carbohydrates, as molecules that contain an **aldehyde** or a **ketone** and have many OH groups and may be connected together with the removal of water Basically all of this is just a chemical way of saying "sugars" and "polysaccharides" (like starch)

"Polyhydroxy aldehyde or polyhydroxy ketone or those compounds which upon hydrolysis yield such compounds (derivatives) are called carbohydrates"

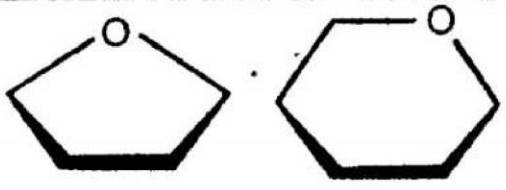



**Chemical nature of carbohydrates**

A polyhydroxy aldehyde or polyhydroxy ketone is supposed to be single saccharide units, whereas, the derivative carbohydrates are composed of more than one saccharide units.

**(e) furanose and pyranose:**

| Furanose | Pyranose |
|---|---|
| **Furanose** is a five membered ring in which one oxygen atom and four carbon atoms are found, oxygen atom is linked with C1 and C4. All pentoses and ketohexoses are converted into furanose ring. | **Pyranose** is a six membered ring in which one oxygen atom and five carbon atoms are found, oxygen atom is linked with C1 and C5. Only aldohexoses are converted into pyranose ring. |



Furanose ring Pyranose ring

**Types of rings in monosaccharides**

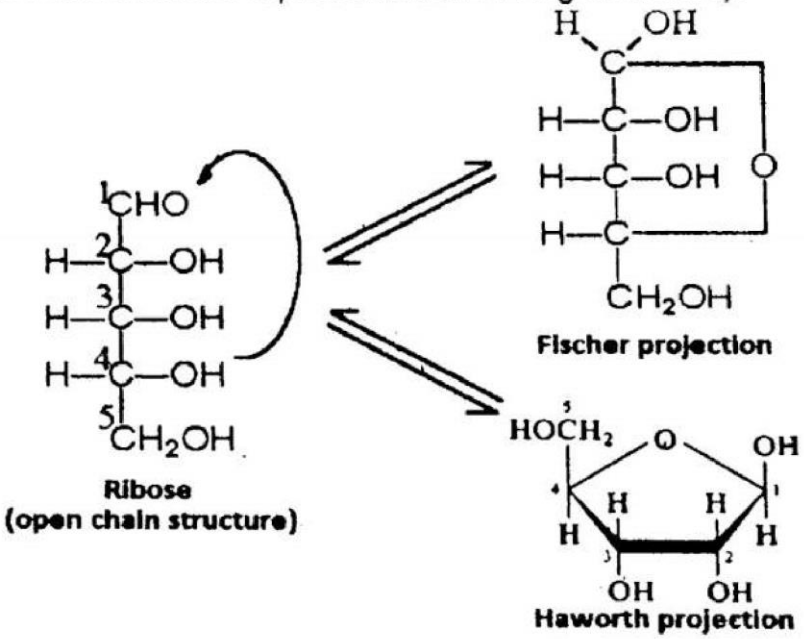
**OR (Second Answer)**

Pyranoses and furanoses are carbohydrates, but they are differ in their chemical structure i.e., pyranoses includes six membered ring consists of five carbon atoms and one oxygen atom. Furanoses includes five membered ring consists of four carbon atoms and one oxygen atoms.

## (f) Fischer projection and Haworth projection:

**Ribose** is an aldopentose, with the molecular formula $C_5H_{10}O_5$. It can exist in open chain structure in dried form but it exists in furanose ring in aqueous medium. When it is dissolved in water, the oxygen atom from aldehyde group reacts with penultimate carbon (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.

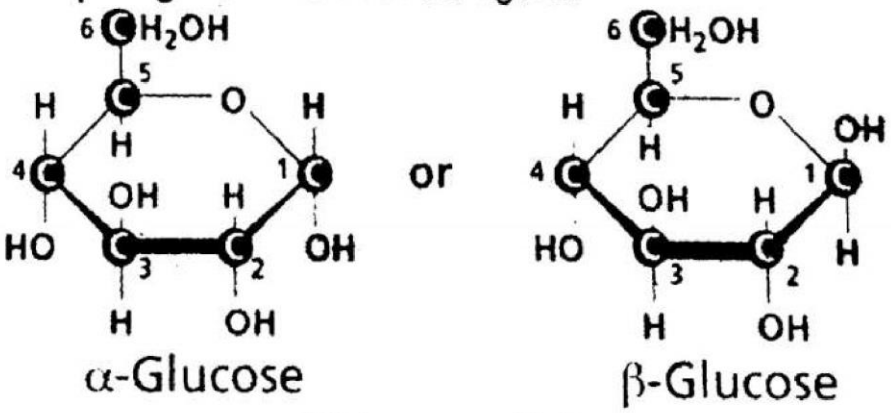
The ring structure demonstrated by Emil Fischer is called **Fischer projection** (a two dimensional representation of ring structure) while that represented by an English chemist Norman Haworth is called as **Haworth projection** (a three dimensional representation of ring structure).




**Conversion of open chain into ring chain**

## (g) alpha and beta glucose:

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 figure.



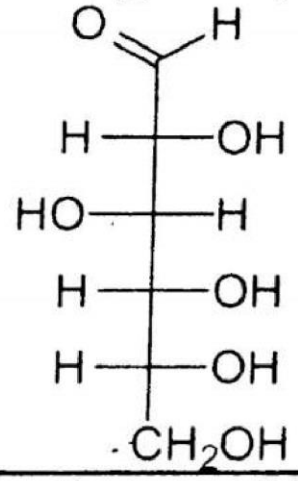
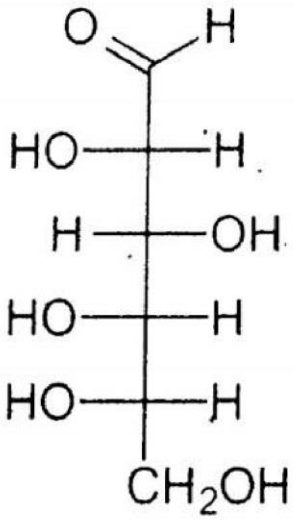

**α and β isomers of glucose**

**(h) D-glucose and L-glucose:**

**Differences between D-glucose and L-glucose:**

**Structure:**

D and L glucose molecules have the same atoms although they only differ in their structure. The structural difference between D and L glucose molecules can be best identified by observing their flat mirror images rather than the two-dimensional Fischer projections.

| D Glucose: | L Glucose: |
|---|---|
| In D-glucose, three hydroxyl groups and one hydrogen group are attached to the right. All the sugars derived from D-glyceraldehyde are D-sugars, including D-glucose and likewise L-glucose is derived from L-glyceraldehyde.  | In L-glucose, the three hydroxyl groups and one hydrogen group are oriented to the left  |

**(i) enantiomers and diastereoisomers:**

**(a) Enantiomers:**

Those stereoisomers which are non-superimposable mirror images of one another are called **enantiomers**. An example of an enantiomer is the D and L isomers of glucose. In **D isomers** (also called right handed form) the asymmetric carbon atom farthest from aldehyde group (second last carbon or C-5 in case of glucose also called **penultimate carbon**) has –OH group on right side whereas in **L isomers** (also called left handed form), the –OH group is projected on left side at penultimate carbon atom. Out of 16 stereoisomers of glucose, 8 are enantiomers of other 8.

**(b) Diastereoisomers:**

Those stereoisomers which have different arrangement of –H and –OH groups at more than one asymmetrical carbon atoms are called diastereoisomers. Unlike an enantiomer, diastereoisomers are not mirror images. For example, the two carbohydrates that are diastereoisomers are D-Glucose and D-Altrose.

**OR (Second Answer)**

**Differences between the enantiomers and the diastereomers:**

| Enantiomers | Diastereomers |
|---|---|
| They are mirror images of each other and are non-superimposable. | They are not mirror images of each other and are non-superimposable. |

| | |
|---|---|
| Their molecular structures often designed with R and S to distinguish them. | One molecule mimics the enantiomer structures whereas the other has the same configuration. So there is no need to use the naming to differentiate them. |
| Have the same chemical and physical properties but different optical properties. | Have different chemical and physical properties. |
| Have one or more stereocenter | Have two stereocenters |
| All enantiomers possess optical activity active although they rotate light in opposite directions. Those ones rotating light anti-clockwise are known as levorotary, and those rotating clockwise are known as dextrorotary. But when the other has the same dextrorotary and levorotary amounts of rotation, it is considered a race mixture and thus optically inactive. | Not all diastereomers possess optical activity. |

**(j) diastereoisomers and epimers:**

| Diastereoisomers | Epimers |
|---|---|
| Those stereoisomers which have different arrangement of –H and –OH groups at more than one asymmetrical carbon atoms are called diastereoisomers. Unlike an enantiomer, diastereoisomers are not mirror images. | Those stereoisomers which have different arrangement of –H and –OH groups at only one asymmetrical carbon atom are called epimers. |
| For example, the two carbohydrates that are diastereoisomers are D-Glucose and D-Altrose. | D-Glucose and D-Mannose are an example of an epimer. |

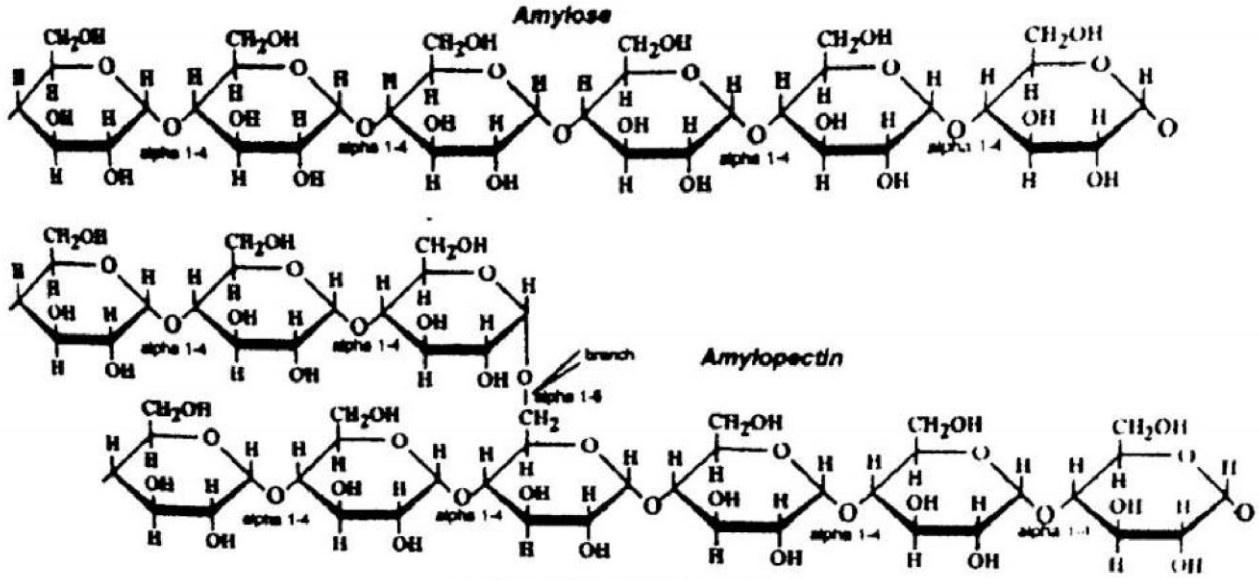
**(k) amylase and amylopectin:**

Amylose is a glucose polymer with long chain-like molecules, while amylopectin consists of larger highly branched molecules (1 to 6).

| Amylose | Amylopectin |
|---|---|
| It is a linear polymer of a-glucose. | It is a branched chain polymer of a-glucose. |
| It is water-soluble. | It is water-insoluble. |
| It constitutes about 10-20% of the starch. | It constitutes about 90-80% of the starch. |
| It forms blue color with iodine. | It forms red colour with iodine. |
| It has 60-300 glucose units. | It has 300-600 glucose units. |
| It forms by $C_1 - C_4$ glycosidic linkage. | It forms by $C_1 - C_6$ glycosidic linkage. |
| Soluble in hot water but does not form starch gel or paste. | Soluble in hot water with awelling. |

**(I) amylopectin and glycogen:**

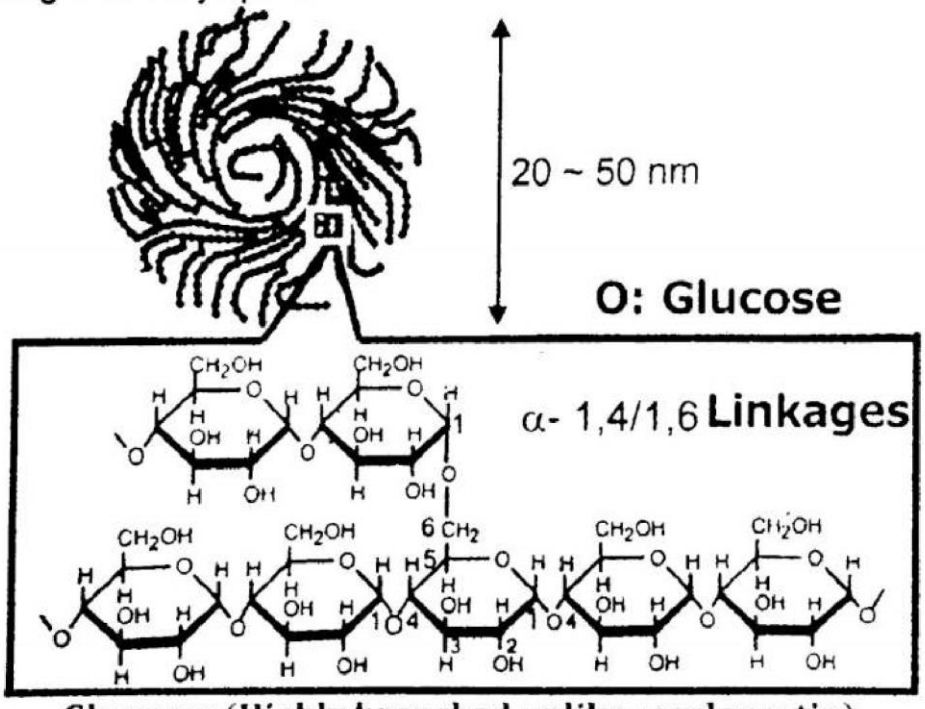
On the other hand, **amylopectin** has branched structure i.e., a linear chain of glucoses but more chains of glucoses in the form of branches are also attached by $\alpha$**-1, 6-glycosidic linkages**. It is completely insoluble in water.




**Structure of starches**

**Glycogen:**

Like starch, glycogen is also a homopolysaccharides composed of $\alpha$-**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 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.



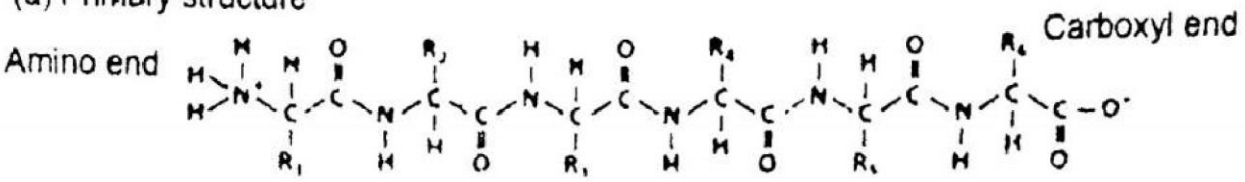

**Glycogen (Highly branched unlike amylopectin)**

**Structure of glycogen**

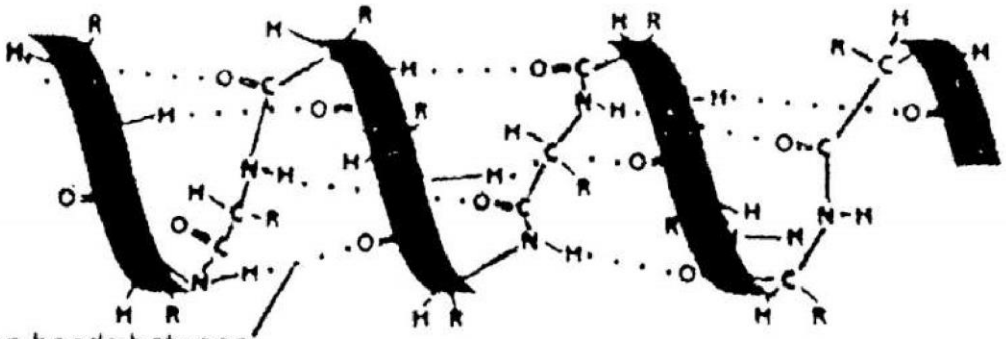
## (m) primary and secondary structure of proteins:

A linear polypeptide with a specific sequence and number of amino acid 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 **($\alpha$-helix)** or flattened sheets **($\beta$-pleated sheet)** like structures which are established by **H-bonding** between opposite charge bearing groups of different amino acids are called **secondary structures**.

(a) Primary structure

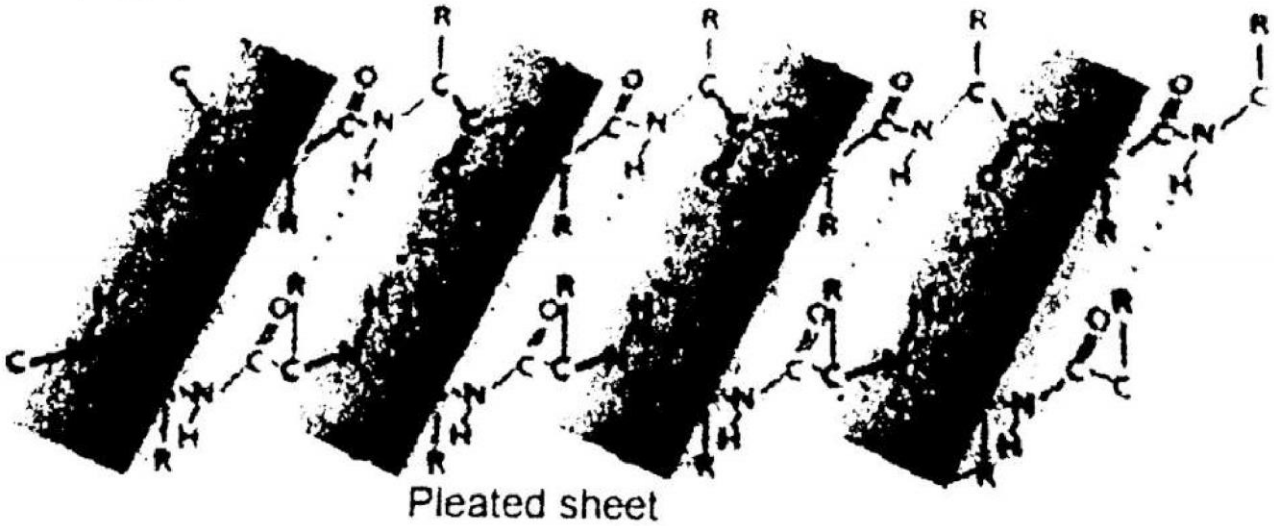



(b) Secondary structure



Hydrogen bonds between amino acids at different locations in polypeptide chain

α helix

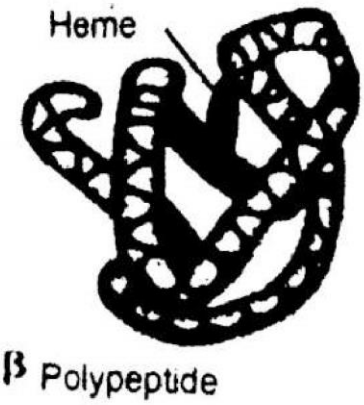


Pleated sheet

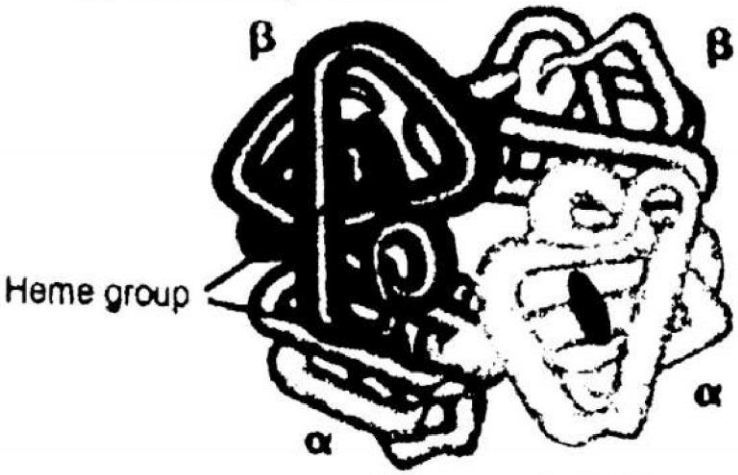
## (n) tertiary and quaternary structure of proteins:

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**.

(c) Tertiary structure




(d) Quaternary structure




(Haemoglobin)

Structural conformations in proteins

**(o) purine and pyrimidine:**

| Purine | Pyrimidine |
|---|---|
| Purines are heterocyclic aromatic organic compounds, consisting of a pyrimidine ring fused to an imidazole ring | Pyrimidines are heterocyclic aromatic organic compounds |
| Contain two carbon-nitrogen rings and four nitrogen atoms | Contain a single carbon-nitrogen ring and 2 nitrogen atoms |
| Contain comparatively high melting and boiling points | Contain comparatively low melting and boiling points |
| Synthesized by Traube Purine Synthesis | Synthesized by Biginelli Reaction |
| Catabolism produces uric acid | Catabolism produces beta amino acids, carbon dioxide, and ammonia |

**(p) saturated and unsaturated fatty acids:**

| Saturated Fatty Acids | Unsaturated Fatty Acids |
|---|---|
| Has only single bonds | Has both single bonds and double bonds |
| Not further dived into subcategories | Subdivided into two categories: monounsaturated & polyunsaturated |
| Have a solid consistency at room temperature | Have a liquid consistency at room temperature |
| Most animal-derived fats are considered to be saturated fats | Most plant-derived fats are considered to be unsaturated fats |
| Not susceptible to further oxidation and rancidity when exposed to the atmosphere | Susceptible to further oxidation and rancidity when exposed to the atmosphere |
| High amount of saturated fats can be harmful to health | Unsaturated fats are associated with various health benefits |

(q) **DNA and RNA:**

| | DNA | RNA |
|---|---|---|
| **Stands For** | DeoxyriboNucleicAcid. | RiboNucleicAcid. |
| **Definition** | A nucleic acid that contains the genetic instructions used in the development and functioning of all modern living organisms. DNA's genes are expressed, or manifested, through the proteins that its nucleotides produce with the help of RNA. | The information found in DNA determines which traits are to be created, activated, or deactivated, while the various forms of RNA do the work. |
| **Function** | The blueprint of biological guidelines that a living organism must follow to exist and remain functional. Medium of long-term, stable storage and transmission of genetic information. | Helps carry out DNA's blueprint guidelines. Transfers genetic code needed for the creation of proteins from the nucleus to the ribosome. |
| **Structure** | Double-stranded. It has two nucleotide strands which consist of its phosphate group, five-carbon sugar (the stable 2-deoxyribose), and four nitrogen-containing nucleobases: adenine, thymine, cytosine, and guanine. | Single-stranded. Like DNA, RNA is composed of its phosphate group, five-carbon sugar (the less stable ribose), and 4 nitrogen-containing nucleobases: adenine, uracil (not thymine), guanine, and cytosine. |
| **Base Pairing** | Adenine links to thymine (A-T) and cytosine links to guanine (C-G). | Adenine links to uracil (A-U) and cytosine links to guanine (C-G). |
| **Location** | DNA is found in the nucleus of a cell and in mitochondria. | Depending on the type of RNA, this molecule is found in a cell's nucleus, its cytoplasm, and its ribosome. |
| **Stability** | Deoxyribose sugar in DNA is less reactive because of C-H bonds. Stable in alkaline conditions. DNA has smaller grooves, which makes it harder for enzymes to "attack." | Ribose sugar is more reactive because of C-OH (hydroxyl) bonds. Not stable in alkaline conditions. RNA has larger grooves; which makes it easier to be "attacked" by enzymes. |
| **Propagation** | DNA is self-replicating. | RNA is synthesized from DNA when needed. |

| | | |
|---|---|---|
| **Unique Features** | The helix geometry of DNA is of B-Form. DNA is protected in the nucleus, as it is tightly packed. DNA can be damaged by exposure to ultra-violet rays. | The helix geometry of RNA is of A-Form. RNA strands are continually made, broken down and reused. RNA is more resistant to damage by Ultra-violet rays. |

**OR (Second Answer)**

**Differences between DNA and RNA:**

| Comparison | DNA | RNA |
|---|---|---|
| **Name** | DeoxyriboNucleic Acid | RiboNucleic Acid |
| **Function** | Long-term storage of genetic information; transmission of genetic information to make other cells and new organisms. | Used to transfer the genetic code from the nucleus to the ribosomes to make proteins. RNA is used to transmit genetic information in some organisms and may have been the molecule used to store genetic blueprints in primitive organisms. |
| **Structural Features** | B-form double helix. DNA is a double-stranded molecule consisting of a long chain of nucleotides. | A-form helix. RNA usually is a single-strand helix consisting of shorter chains of nucleotides. |
| **Composition of Bases and Sugars** | deoxyribose sugar<br>phosphate backbone<br>adenine, guanine, cytosine, thymine bases | ribose sugar<br>phosphate backbone<br>adenine, guanine, cytosine, uracil bases |
| **Propagation** | DNA is self-replicating. | RNA is synthesized from DNA on an as-needed basis. |
| **Base Pairing** | AT (adenine-thymine)<br>GC (guanine-cytosine) | AU (adenine-uracil)<br>GC (guanine-cytosine) |
| **Reactivity** | The C-H bonds in DNA make it fairly stable, plus the body destroys enzymes that would attack DNA. The small grooves in the helix also serve as protection, providing minimal space for enzymes to attach. | The O-H bond in the ribose of RNA makes the molecule more reactive, compared with DNA. RNA is not stable under alkaline conditions, plus the large grooves in the molecule make it susceptible to enzyme attack. RNA is constantly produced, used, degraded, and recycled |
| **Ultraviolet Damage** | DNA is susceptible to UV damage. | Compared with DNA, RNA is relatively resistant to UV damage. |

**(r) oxidative phosphorylation and photophosphorylation:**

| Oxidative Phosphorylation | Photophosphorylation |
|---|---|
| **1.** Occurs during respiration. | **1.** Occurs during photosynthesis. |
| **2.** Occurs inside mitochondria. | **2.** Occurs inside chloroplast. |
| **3.** Pigment systems are not involved. | **3.** Pigment systems {PS-I and PS-il) are involved. |
| **4.** ATP is produced from ADP and inorganic phosphate by utilizing energy released during electron transport. | **4.** Sunlight is the external energy source for photophosphorylation. |
| **5.** Molecular oxygen is required for terminal oxidation. | **5.** Molecular oxygen is not required for photophosphorylation. |
| **6.** The ATP molecules produced are released into the cytoplasm and this energy molecules are used to carry out various metabolic reactions of the cell. | **6.** The ATP molecules produced is used to fix $CO_2$ to carbohydrates in dark reaction. |

# EXTENSIVE QUESTIONS

**43. Describe the chemical composition of protoplasm.**

**Ans: Chemical Composition of Protoplasm:**

Generally the protoplasm consists of oxygen, carbon, hydrogen and nitrogen. Approximately the oxygen is 62%, carbon 20%, hydrogen 10% and nitrogen 3%. The remainder of 5% part contains about thirty elements, of which calcium (Ca), iron (Fe), magnesium (Mg), chlorine (Cl), phosphorus (P), potassium (K), sulphur (S), etc., are important ones. In addition to these, boron (B), copper (Cu), fluorine (F), manganese (Mn) and silicon (Si) are found in small traces. In certain special cells alcohol, cobalt (Co) and zinc (Zn) are also found.

All these elements are found in ionic state or essentially found in adenosine triphosphate (ATP). All chemical reactions going on in the protoplasm obtain energy for their performance from ATP The protoplasm contains 67-75% of water Moreover, certain gases such as carbon-dioxide and oxygen remain dissolved in it.

The protoplasm of each cell contains several organic substances of which carbohydrates, fats, proteins, and nucleoproteins are important ones. These organic substances make protoplasm by molecular combination.

**44. Distinguish carbohydrates, proteins, lipids and nucleic acids as the four fundamental kinds of biological molecules.**

**Ans:** The four fundamental kinds of biological molecules are carbohydrates, proteins, lipids and nucleic acids.

**i. Carbohydrates:**

**Carbohydrates** are present in the inclusions of the cells and provide fuel for the metabolic activities of the cell

**(r) oxidative phosphorylation and photophosphorylation:**

| Oxidative Phosphorylation | Photophosphorylation |
|---|---|
| **1.** Occurs during respiration. | **1.** Occurs during photosynthesis. |
| **2.** Occurs inside mitochondria. | **2.** Occurs inside chloroplast. |
| **3.** Pigment systems are not involved. | **3.** Pigment systems {PS-I and PS-il) are involved. |
| **4.** ATP is produced from ADP and inorganic phosphate by utilizing energy released during electron transport. | **4.** Sunlight is the external energy source for photophosphorylation. |
| **5.** Molecular oxygen is required for terminal oxidation. | **5.** Molecular oxygen is not required for photophosphorylation. |
| **6.** The ATP molecules produced are released into the cytoplasm and this energy molecules are used to carry out various metabolic reactions of the cell. | **6.** The ATP molecules produced is used to fix $CO_2$ to carbohydrates in dark reaction. |

# EXTENSIVE QUESTIONS

**43. Describe the chemical composition of protoplasm.**

**Ans: Chemical Composition of Protoplasm:**

Generally the protoplasm consists of oxygen, carbon, hydrogen and nitrogen. Approximately the oxygen is 62%, carbon 20%, hydrogen 10% and nitrogen 3%. The remainder of 5% part contains about thirty elements, of which calcium (Ca), iron (Fe), magnesium (Mg), chlorine (Cl), phosphorus (P), potassium (K), sulphur (S), etc., are important ones. In addition to these, boron (B), copper (Cu), fluorine (F), manganese (Mn) and silicon (Si) are found in small traces. In certain special cells alcohol, cobalt (Co) and zinc (Zn) are also found.

All these elements are found in ionic state or essentially found in adenosine triphosphate (ATP). All chemical reactions going on in the protoplasm obtain energy for their performance from ATP The protoplasm contains 67-75% of water Moreover, certain gases such as carbon-dioxide and oxygen remain dissolved in it.

The protoplasm of each cell contains several organic substances of which carbohydrates, fats, proteins, and nucleoproteins are important ones. These organic substances make protoplasm by molecular combination.

**44. Distinguish carbohydrates, proteins, lipids and nucleic acids as the four fundamental kinds of biological molecules.**

**Ans:** The four fundamental kinds of biological molecules are carbohydrates, proteins, lipids and nucleic acids.

**i. Carbohydrates:**

**Carbohydrates** are present in the inclusions of the cells and provide fuel for the metabolic activities of the cell

**ii. Proteins:**

**Proteins** are present in the membranes, ribosomes, cytoskeleton and enzymes of the cell.

**iii. Lipids:**

**Lipids** are present on the membranes of Golgi complex and inclusion of the cell. Lipids provide a reserved energy source, shape, protect and insulate the cells.

**iv. Nucleic Acid:**

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 transmits genetic information and takes part in protein synthesis.

**OR (Second Answer),**

**Biological Molecules:**

There are four basic kinds of biological macromolecules. They are carbohydrates, lipids, proteins and nucleic acids. These polymers are composed of different monomers and serve different functions.

- **Carbohydrates** - molecules composed of sugar monomers. They are necessary for energy storage. Carbohydrates are also called saccharides and their monomers are called monosaccharides. Glucose is an important monosaccharide that is broken down during cellular respiration to be used as an energy source. Starch is an example of a polysaccharide (many saccharides linked together) and is a form of stored glucose in plants.
- **Lipids** - water insoluble molecules that can be classified as fats, phospholipids, waxes, and steroids. Fatty acids are lipid monomers that consist of a hydrocarbon chain with a carboxyl group attached at the end. Fatty acids form complex polymers such as triglycerides, phospholipids, and waxes. Steroids are not considered true lipid polymers because their molecules do not form a fatty acid chain. Instead, steroids are composed of four fused carbon ring-like structures. Lipids help to store energy, cushion and protect organs, insulate the body, and form cell membranes.
- **Proteins** - biomolecules capable of forming complex structures. Proteins are composed of amino acid monomers and have a wide variety of functions including transportation of molecules and muscle movement. Collagen, hemoglobin, antibodies, and enzymes are examples of proteins.
- **Nucleic Acids** - molecules consisting of nucleotide monomers linked together to form polynucleotide chains. DNA and RNA are examples of nucleic acids. These molecules contain instructions for protein synthesis and allow organisms to transfer genetic information from one generation to the next.

**45. Describe and draw sketches of dehydration synthesis and hydrolysis reactions for making and breaking of macromolecule polymers.**

**Ans: Condensation and Hydrolysis:**

**Macromolecule:**

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

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.



Monomer and polymer

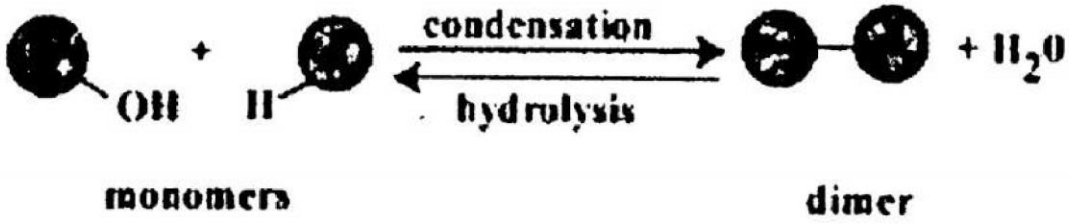
## Condensation:

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.

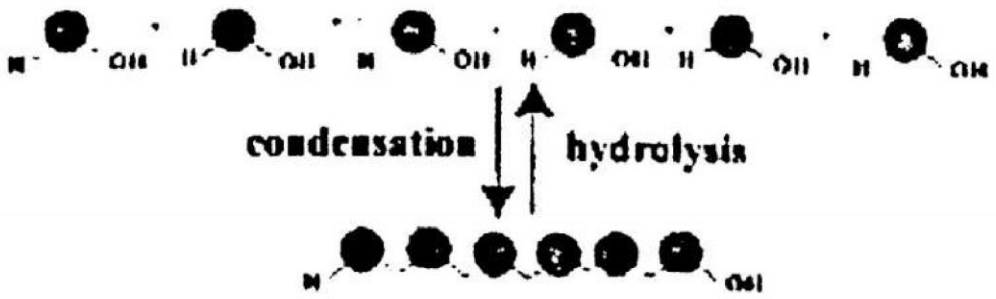
## Hydrolysis:

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 (food) digestion reactions are examples of hydrolysis, which are controlled by enzymes such as carbohydrases, proteases, lipases, nucleases.

**(1) Dimer**




**(2) Polymerisation**




Condensation and Hydrolysis

**46. How the properties of water make it the cradle of life?**

**Ans: 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).

**Properties of water:**

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

**1. High polarity:**

**Covalent Bonds:**

The bonds which are formed by the mutual sharing of electrons between two atoms are called **covalent bonds**.

**Nonpolar:**

Normally the sharing of electrons between two atoms is fairly equal and the covalent bond is **nonpolar**.

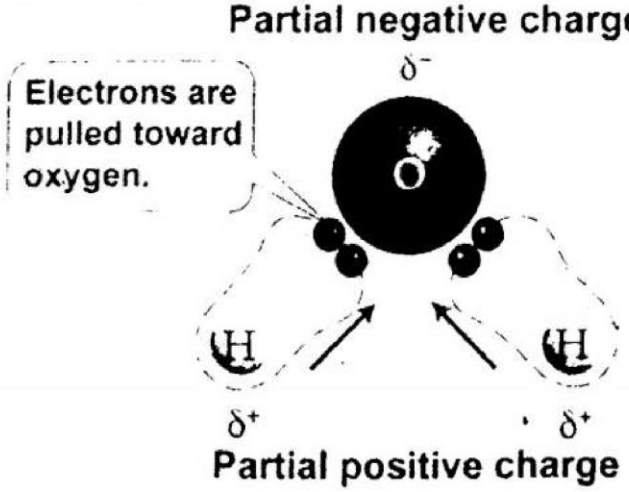
**Polar:**

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.

**Water Use as Universal Solvent:**

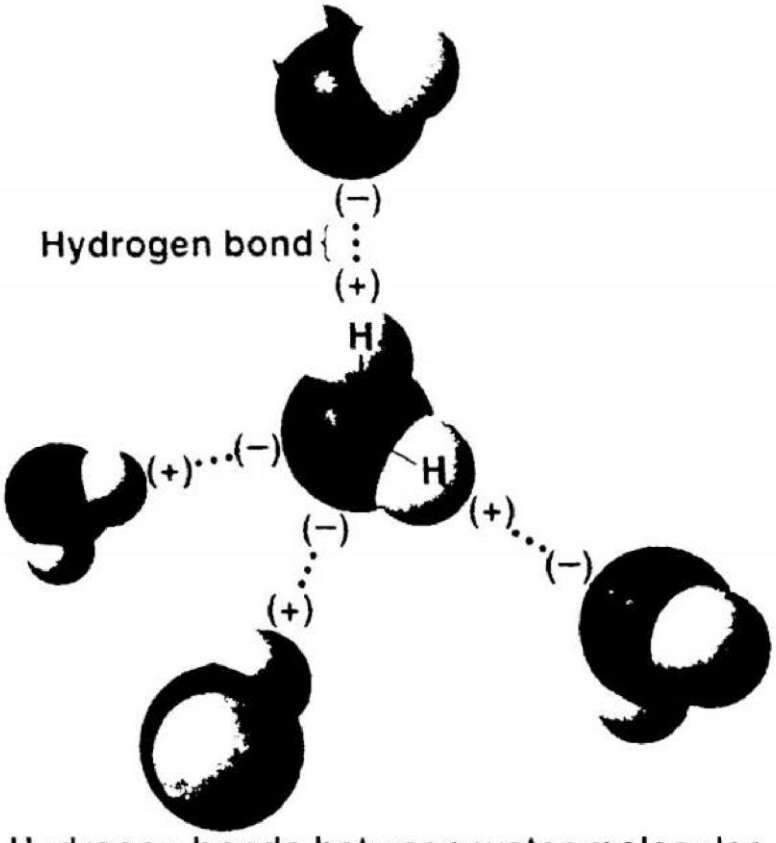
This is polarity of water molecules that makes it an excellent or **universal solvent** for polar substances. Ionic compound or electrolytes can be easily dissolved in water, non-polar substances having charged groups in their molecules can also be dissolved in water. Such compounds when dissolved in water, dissociates 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.




**Polarity of water molecule**

## 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




Hydrogen bonds between water molecules

### Importance of Hydrogen bonding in Water:

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:

**Heat capacity** can be defined as the amount of heat required for minimum increase (1°C or 1°K) 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°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.

**Importance of High Specific Heat:**

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.

**Importance of High Heat of Vapourization:**

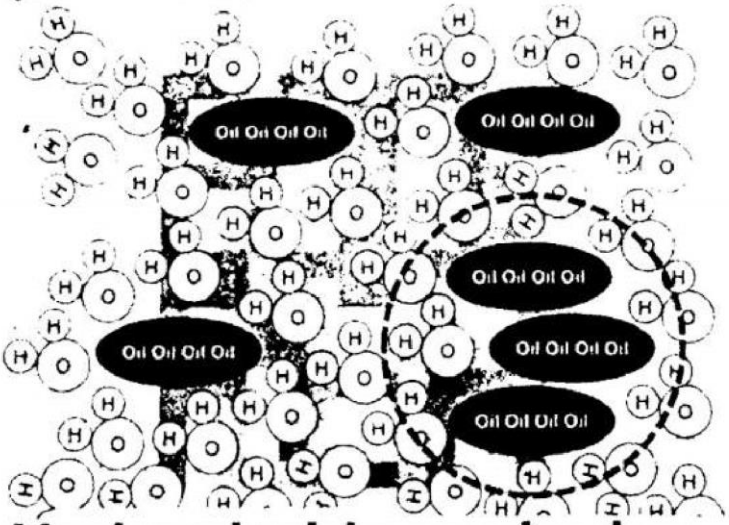
This is high heat of vapourization of water that gives animals an efficient way to release excess body heat in a hot environment. When an animal sweats, body heat is used to vapourize the sweat thus cooling the animal. Due to this property of water, evaporation of only 2 ml out of one litter of water 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 coalesce (to unite into one whole) into a single drop.

**Importance of Hydrophobic Exclusion:**

Biologically, hydrophobic exclusion plays key roles in maintaining the integrity of lipid bilayer membranes.



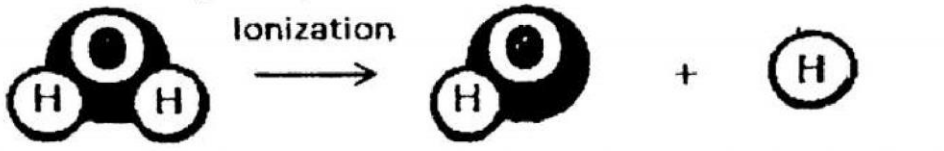

**Hydrophobic exclusion**

**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.

**Importance of Ionization:**

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.




Water molecule $[H_2O]$ | Hydroxyl ion $[OH^-]$ | Hydrogen ion $[H^+]$

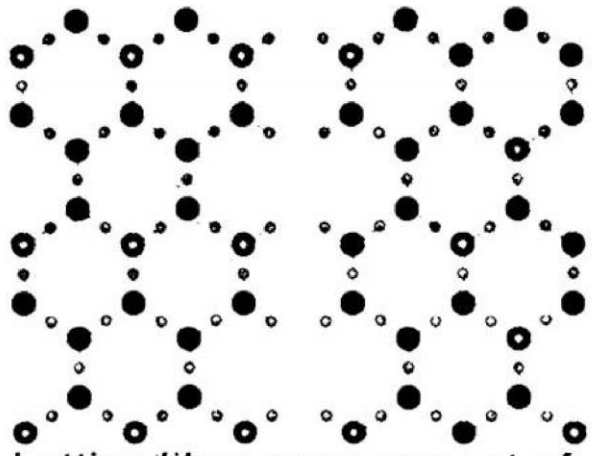
Ionization of water

**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.

**Importance of Lower Density of Ice:**

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.



Lattice likes arrangement of water molecules in ice

**47. Distinguish the properties and role of monosaccharides.**

**Ans: Monosaccharides:**

Monosaccharides are true carbohydrates which are either polyhydroxy aldehydes or polyhydroxy ketones. The range of number of carbons in monosaccharide 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.

**Table: Examples and functions of monosaccharide:**

| 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. |

**48. Write the emperical formula of monosaccharides and classify them.**

**Ans: Monosaccharides:**

Monosaccharides are the simplest carbohydrates in that they cannot be hydrolyzed to smaller carbohydrates. They are aldehydes or ketones with two or more hydroxyl groups.

**Emperical Formula of Monosaccharides:**

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).

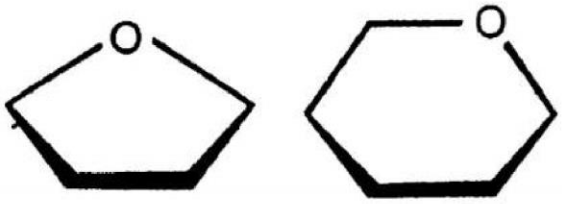
**Chemical structures of monosaccharides:**

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.

Two types of ring structures are found in monosaccharides i.e., furanose and pyranose.

**i. Furanose:**

**Furanose** is a five membered ring in which one oxygen atom and four carbon atoms are found, oxygen atom is linked with C1 and C4. All pentoses and ketohexoses are converted into furanose ring.



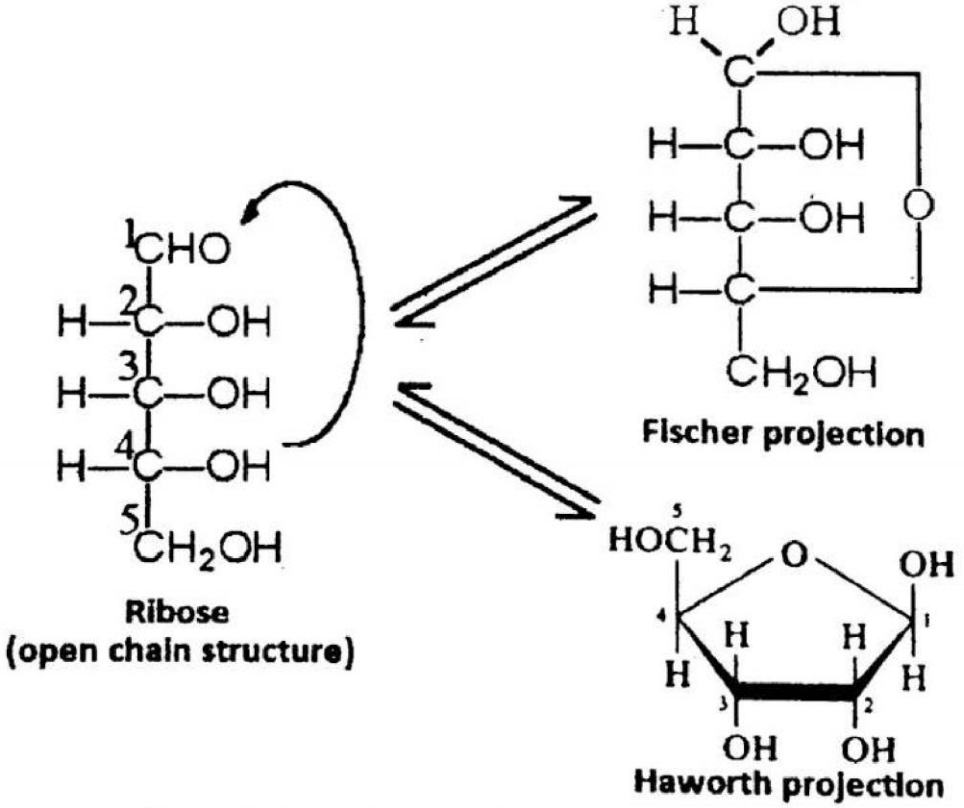
Furanose ring Pyranose ring

**Types of rings in monosaccharides**

**ii. Pyranose:**

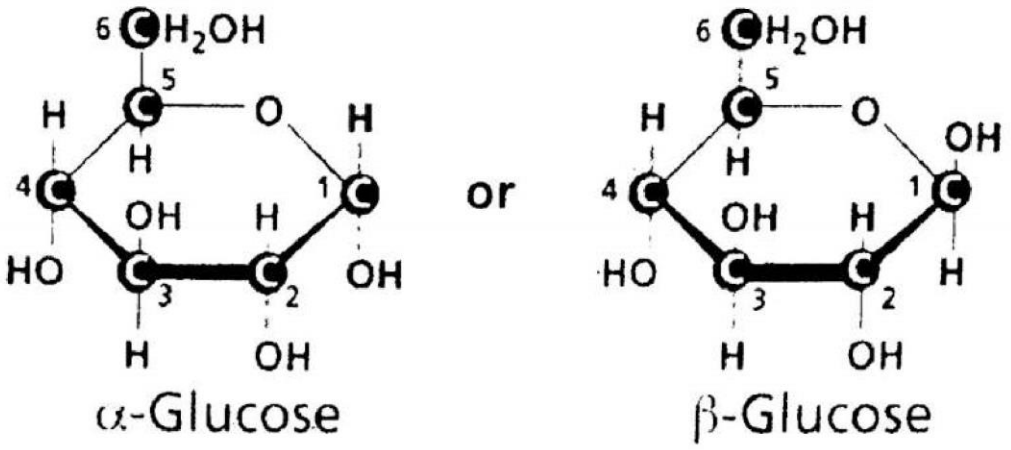
**Pyranose** is a six membered ring in which one oxygen atom and five carbon atoms are found, oxygen atom is linked with C1 and C5. Only aldohexoses are converted into pyranose ring.

Let us understand it by taking ribose as an example. **Ribose** is an aldopentose, with the molecular formula $C_5H_{10}O_5$. It can exist in open chain structure in dried form but it exists in furanose ring in aqueous medium. When it is dissolved in water, the oxygen atom from aldehyde group reacts with penultimate carbon (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. The ring structure demonstrated by Emil Fischer is called **Fischer projection** (a two dimensional representation of ring structure) while that represented by an English chemist Norman Haworth is called as **Haworth projection** (a three dimensional representation of ring structure).




**Conversion of open chain into ring chain**

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 figure.




**α and β isomers of glucose**

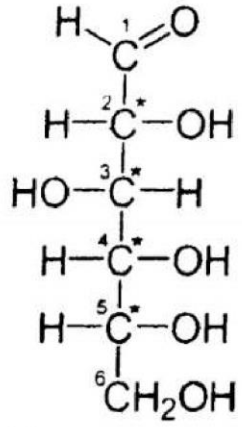
**49. Compare the isomers and stereoisomers of glucose.**

**Ans: Isomers:**

Isomers are molecules that have the same molecular formula, but have a different arrangement of the atoms in space. That excludes any different arrangements which are simply due to the molecule rotating as a whole, or rotating about particular bonds.

**Stereoisomerism in monosaccharides (Glucose):**

Those isomers in which –H and –OH groups are arranged in different pattern to the asymmetric carbon atoms are called **stereoisomers**. An **asymmetric carbon** atom is that which makes bonds with four different atoms around it. For example, in glucose, the C-2, C-3, C-4 and C-5 are asymmetric carbon atoms. In monosaccharide the number of stereoisomers; actually depends upon the number of asymmetric carbons in its structure and can be calculated by the formula 2n, where n is the number of asymmetric carbon atoms so glucose has 16 stereoisomers.



**Glucose: asymetric carbon are shown by sterics**

**Asymmetric carbons**

**Classification of Stereoisomerism:**

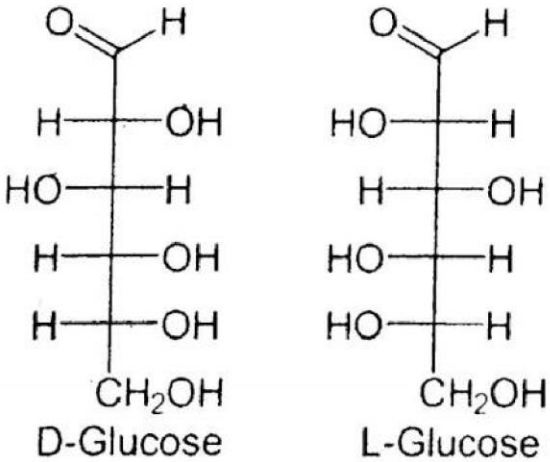
Stereoisomers can be classified in three groups:

**(i) Enantiomers:**

Those stereoisomers which are non-superimposable mirror images of one another are called **enantiomers**.

**Example:**

An example of an enantiomer is the D and L isomers of glucose, as shown in figure. In **D isomers** (also called right handed form) the asymmetric carbon atom farthest from aldehyde group (second last carbon or C-5 in case of glucose also called **penultimate carbon**) has –OH group on right side whereas in **L isomers** (also called left handed form), the –OH group is projected on left side at penultimate carbon atom. Out of 16 stereoisomers of glucose, 8 are enantiomers of other 8.




**An example of enantiomers**

**(ii) Diastereoisomers:**

Those stereoisomers which have different arrangement of –H and –OH groups at more than one asymmetrical carbon atoms are called diastereoisomers. Unlike an enantiomer, diastereoisomers are not mirror images.

**Example:**

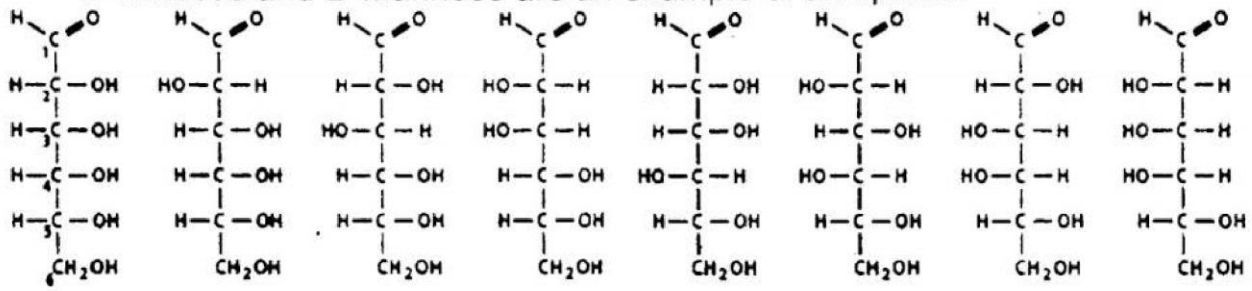
For example, the two carbohydrates that are diastereoisomers are D-Glucose and D-Altrose.

**(iii) Epimers:**

Those stereoisomers which have different arrangement of –H and –OH groups at only one asymmetrical carbon atom are called epimers.

**Example:**

D-Glucose and D-Mannose are an example of an epimer.




**Stereoisomers of D-glucose**

**50. Distinguish the properties and role of disaccharides.**

**Ans: Disaccharides:**

Two monosaccharides combine to form a disaccharide. It is a kind of oligosaccharides.

**Properties and role of disaccharides:**

Disaccharides are less sweet in taste and less soluble in water. These can be hydrolyzed to give monosaccharides.

**Examples are:** maltose, lactose, sucrose.

**General Formula of Disaccharide:**

The general formula of disaccharide is $C_{12} H_{22} O_{11}$.

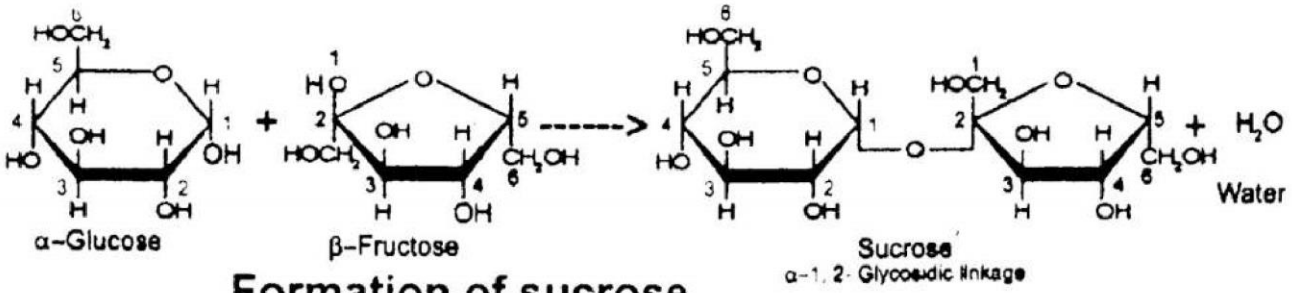
Some common disaccharides are as follows:

**Sucrose:**

It is commonly known as cane sugar because it occurs abundantly in sugarcane beside it many other plants also have sucrose in considerable amount like sugar beet, pine apple, sorghum and all sweet fruits. 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. Upon hydrolysis sucrose yields a molecule of α-glucose and a molecule of β-fructose.

**Formation of Sucrose:**

Therefore, 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 and a linkage is formed between C-1 of glucose and C-2 of fructose known as α-1,2-glycosidic linkage.



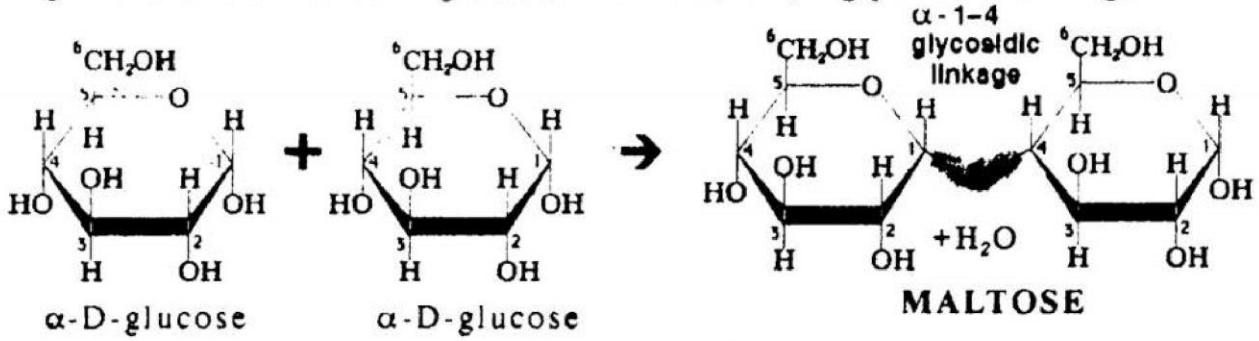

Formation of sucrose

**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 In brewing industry the maltose is produced from the breakdown of barley starch by the help of amylase enzyme. This process is known as **malting**. Upon hydrolysis it yields two molecules of α-glucoses.

**Formation of Maltose:**

Therefore, the maltose is formed by the condensation of 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 and a linkage is formed between C-1 of one glucose and C-4 of other glucose, known as ***α*-1, 4-glycosidic linkage**.



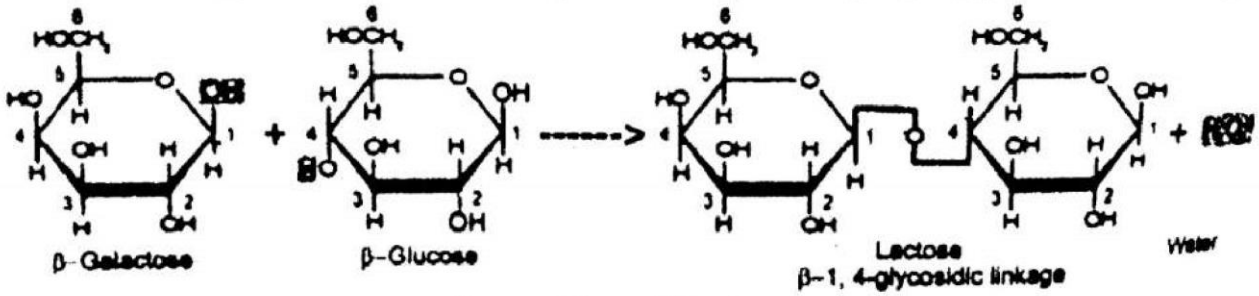

Formation of maltose

**Lactose:**

It is commonly known as milk sugar as it is found in milk of mammals i.e., 4-6% in cow's milk and 5-8% in human milk. It is also a byproduct in the manufacture of cheese. Upon hydrolysis it yields a molecule of β-galactose and a molecule of α-glucose.

**Formation of Lactose:**

Therefore, 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 and a linkage is formed between C-1 of galactose and C-4 of glucose, known as ***β*-1, 4-glycosidic linkage**.

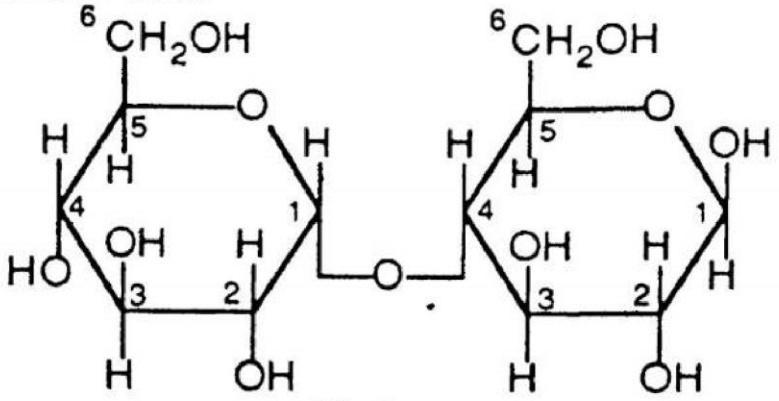



Formation of lactose

**51. Describe glycosidic bond in the transport of disaccharides.**

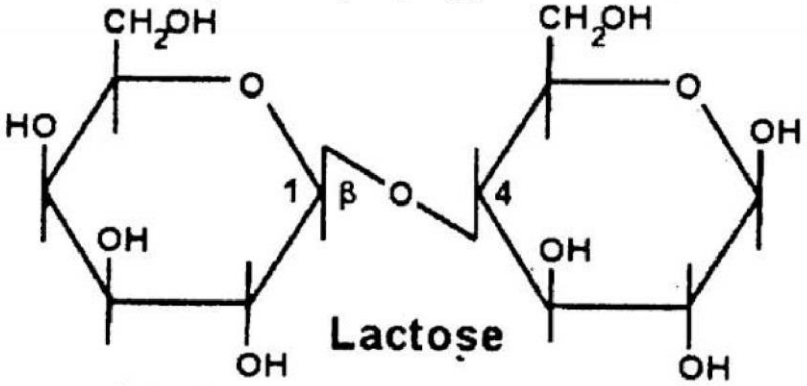
**Ans:** When 2 monomer bond together covalently, they for **disaccharides**. This is formed via a condensation reaction and a "bridge" is created. This "bridge" is called a **glycosidic bond**. Some of these disaccharies are maltose, lactose and sucrose.

**Maltose:** The glycosidic bond of maltose is formed between the OH of carbon 1 and carbon 4 of 2 glucose monomers. Thereforer, it forms an **$\alpha$-1, 4** glycosidic bond.



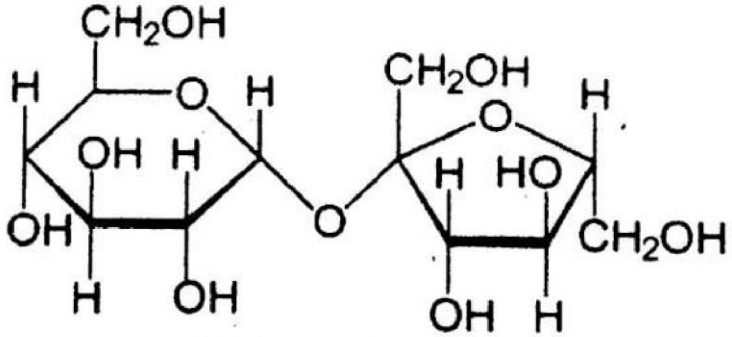
Maltose

**Lactose:** This is a milk sugar, composed of a glucose and a galactose monomer. They form a **$\beta$-1, 4** glycosidic bond.



Lactose

**Sucrose:** Sucrose links the anomeric hydroxyls of glucose and fructose to form an **$\alpha$-1,2** glycosidic bond.



**OR (Second Answer)**

**Disaccharides:**

Two monosaccharides combine to form a disaccharide. It is a kind of oligosaccharides.

**Properties and role of disaccharides:**

Disaccharides are less sweet in taste and less soluble in water. These can be hydrolyzed to give monosaccharides.

**Examples are:** maltose, lactose, sucrose.

**General Formula of Disaccharide:**

The general formula of disaccharide is $C_{12} H_{22} O_{11}$

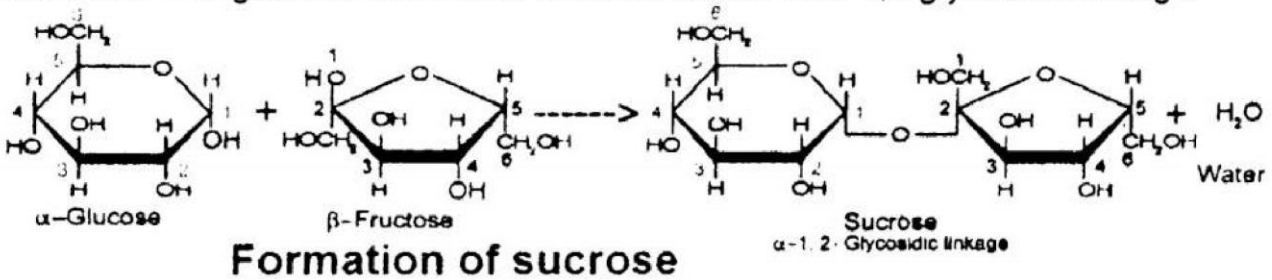
Some common disaccharides are as follows:

**Sucrose:**

It is commonly known as cane sugar because it occurs abundantly in sugarcane beside it many other plants also have sucrose in considerable amount like sugar beet, pine apple, sorghum and all sweet fruits. 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. Upon hydrolysis sucrose yields a molecule of α-glucose and a molecule of β-fructose.

**Formation of Sucrose:**

Therefore, 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 and a linkage is formed between C-1 of glucose and C-2 of fructose known as α-1,2-glycosidic linkage.



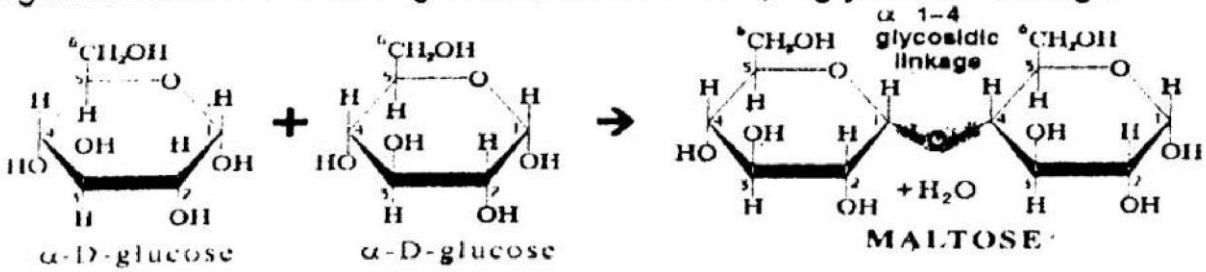

Formation of sucrose

**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. In brewing industry the maltose is produced from the breakdown of barley starch by the help of amylase enzyme. This process is known as **malting**. Upon hydrolysis it yields two molecules of α-glucoses.

**Formation of Maltose:**

Therefore, the maltose is formed by the condensation of 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 and a linkage is formed between C-1 of one glucose and C-4 of other glucose, known as **α-1, 4-glycosidic linkage**.



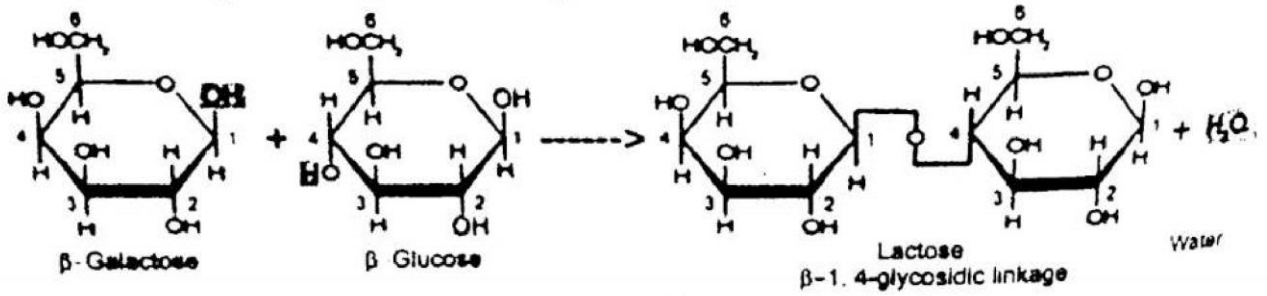

**Formation of maltose**

**Lactose:**

It is commonly known as milk sugar as it is found in milk of mammals i.e., 4-6% in cow's milk and 5-8% in human milk. It is also a byproduct in the manufacture of cheese. Upon hydrolysis it yields a molecule of β-galactose and a molecule of α-glucose.

**Formation of Lactose:**

Therefore, 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 and a linkage is formed between C-1 of galactose and C-4 of glucose, known as **β-1, 4-glycosidic linkage**.




Formation of lactose

**52. Distinguish the properties and role of polysaccharides.**

**Ans: Polysaccharides:**

Those carbohydrates which upon hydrolysis yield more than ten monosaccharide units are called polysaccharides. This is largest group of carbohydrates.

**Composition of Polysaccharides and their Types:**

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.

**Role of Polysaccharides:**

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.

**53. Describe the properties and roles of starch, glycogen, cellulose and chitin.**

**Ans: Starch:**

Starch is a homopolysaccharides which is formed by the condensation of hundreds of **α-glucoses**.

**Storage of Starch in Plants:**

It is storage carbohydrate of plants. It is mainly stored in root, stem and seeds.

**Role of Starch:**

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.

**Types of Starch:**

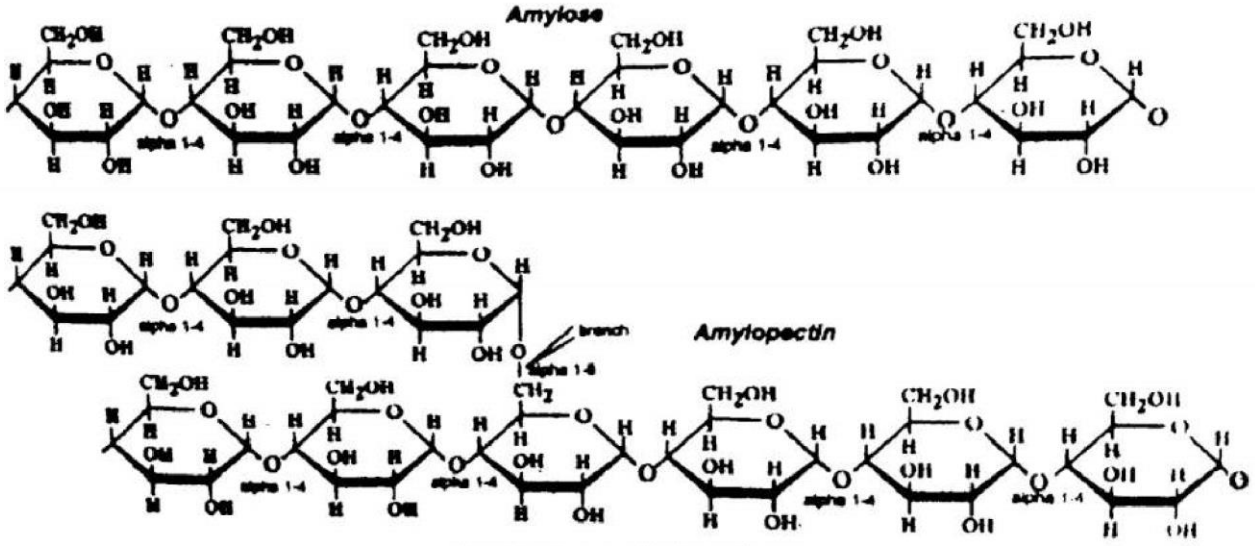
There are two types of starches i.e., amylose and amylopectin.

**Amylose:**

**Amylose** is un-branched i.e., a linear chain of glucoses in which glucoses are attached together by **$\alpha$-1, 4-glycosidic linkages**. It is soluble in hot water only.

**Amylopectin:**

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 **$\alpha$-1, 6-glycosidic linkages**. It is completely insoluble in water.




Structure of starches

**Glycogen:**

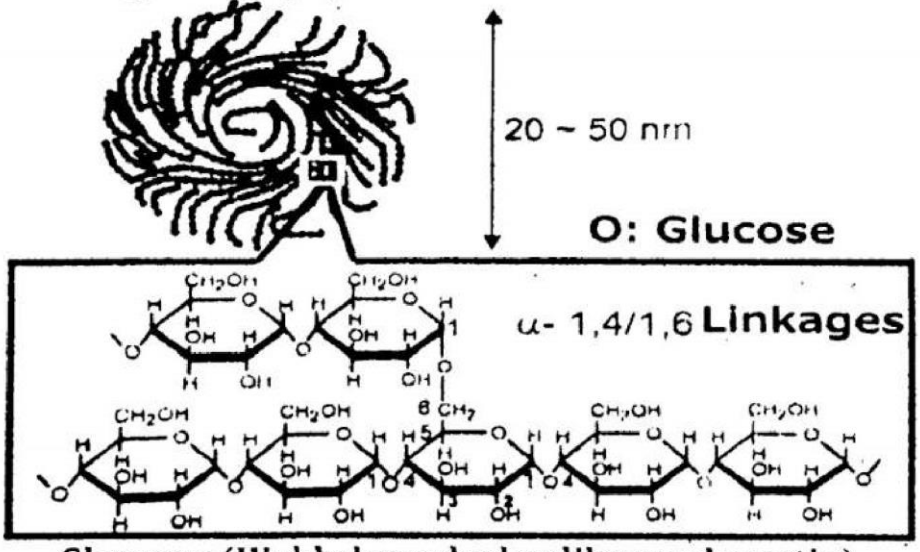
Like starch, glycogen is also a homopolysaccharides composed of **$\alpha$-glucoses**.

**Storage of Glycogen in Animals:**

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 also be confirmed by iodine test as it gives red colour with iodine solution.

**Structure of Glycogen:**

Structure of glycogen resembles with amylopectin starch but glycogen has much more branching than amylopectin.




Glycogen (Highly branched unlike amylopectin)

Structure of glycogen

**Cellulose:**

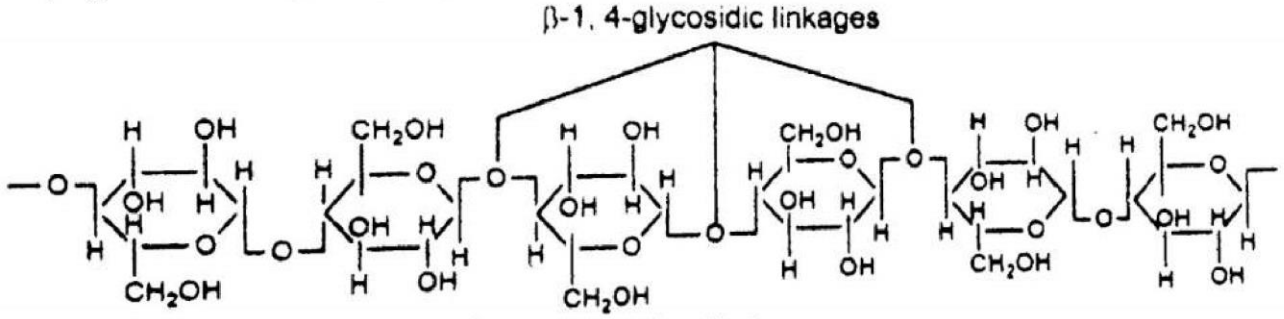
Cellulose is most abundant carbohydrate on earth. It is also a homopolysaccharides but unlike starch and glycogen it is formed by the condensation of hundreds of **β-glucoses**.

**Examples of Cellulose:**

It is structural carbohydrate of plants as it is major constituent of plant cell wall. Cotton and paper are the pure forms of cellulose. Cellulose shows no colour with iodine solution.

**Structure of Cellulose:**

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. Therefore, in a cellulose chain, the β-glucoses are alternatively arranged in upright and inverted manner.




Structure of cellulose

**Chitin:**

Chitin is the second most abundant organic molecule on earth.

**Role of Chitin:**

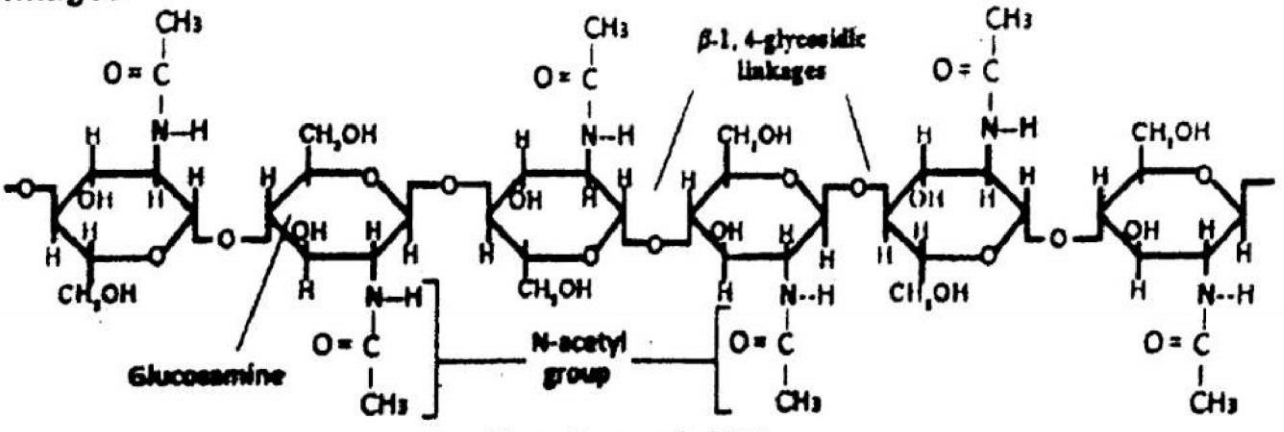
It is also a homopolysaccharides. It is a structural carbohydrate found in the cell walls of fungi and in the exoskeleton of arthropods. Due to the occurrence of chitin in fungal cell wall, it is also known as **fungal cellulose**.

**Formation of Chitin:**

Chitin is the derivative of **N-acetyl glucosamine** which is a modified form of glucose.

**Structure of Chitin:**

It has an un-branched structure like cellulose in which alternative upright and inverted N-acetyl glucosamine residues are linked together by **β-1, 4-glycosidic linkages**.




Structure of chitin

**54. Justify the significance of the sequence of amino acids through the example of sickle cell haemoglobin.**

**Ans: 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.

**Point Mutation:**

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.

**Haemoglobin ($Hb^A$):**

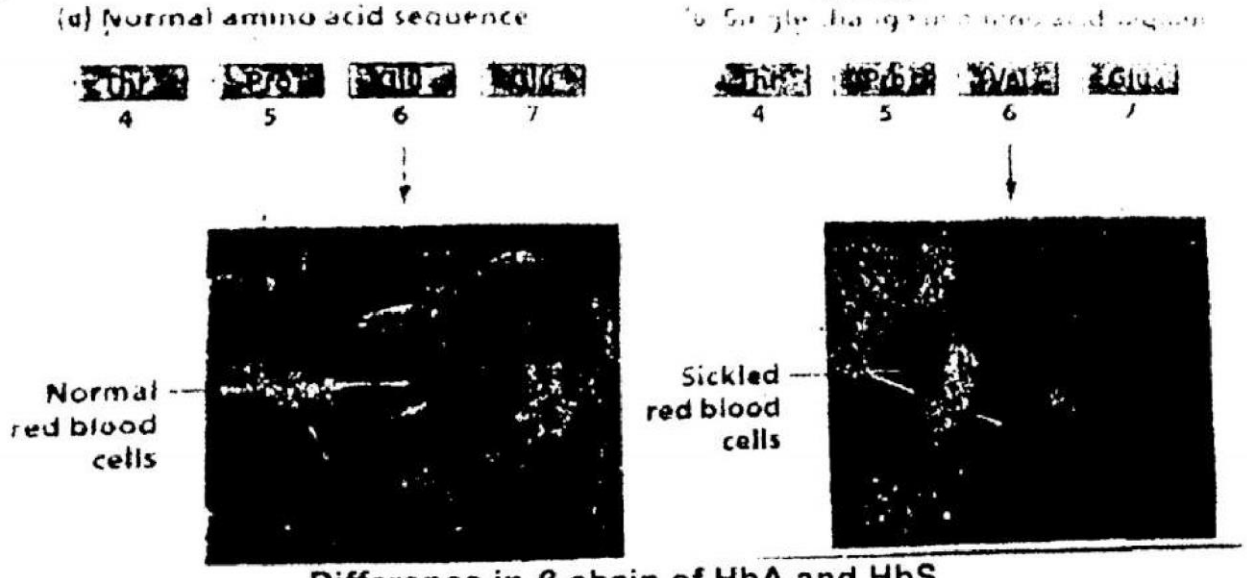
Normal red blood cells are disc-shaped and look like doughnuts without holes in the centre. They move easily through your blood vessels. Red blood cells contain an iron-rich protein called haemoglobin. This protein carries oxygen from the lungs to the rest of the body. **Normal haemoglobin ($Hb^A$)** 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:**

**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 (HbS)**. 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.

**Causes of Sickle cell anemia:**

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 hemoglobin. Sickle cell haemoglobin (HbS) shows only one difference from HbA i.e., **glutamic acid** is replaced by **valine** at position number six in β-chain.




**Difference in β-chain of HbA and HbS**

**55. List examples and the roles of structural and functional proteins.**

**Ans: 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 tables.

**Table: 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: 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. |

**56. Describe the properties and roles of:**

**(a) acylglycerol** **(b) phospholipids**

**(c) terpenes** **(d) waxes**

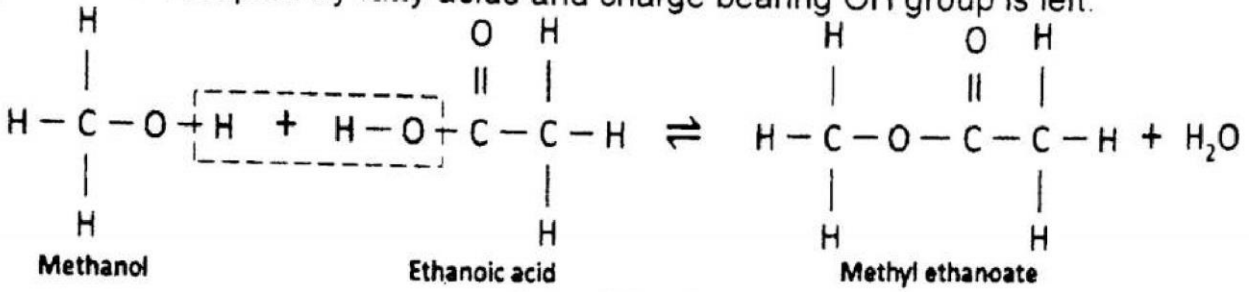
**Ans: (a) acylglycerol:**

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 2 Biological Molecules of a chemical reaction of an alcohol with acid and a water molecule is released such a reaction is called **esterification**.

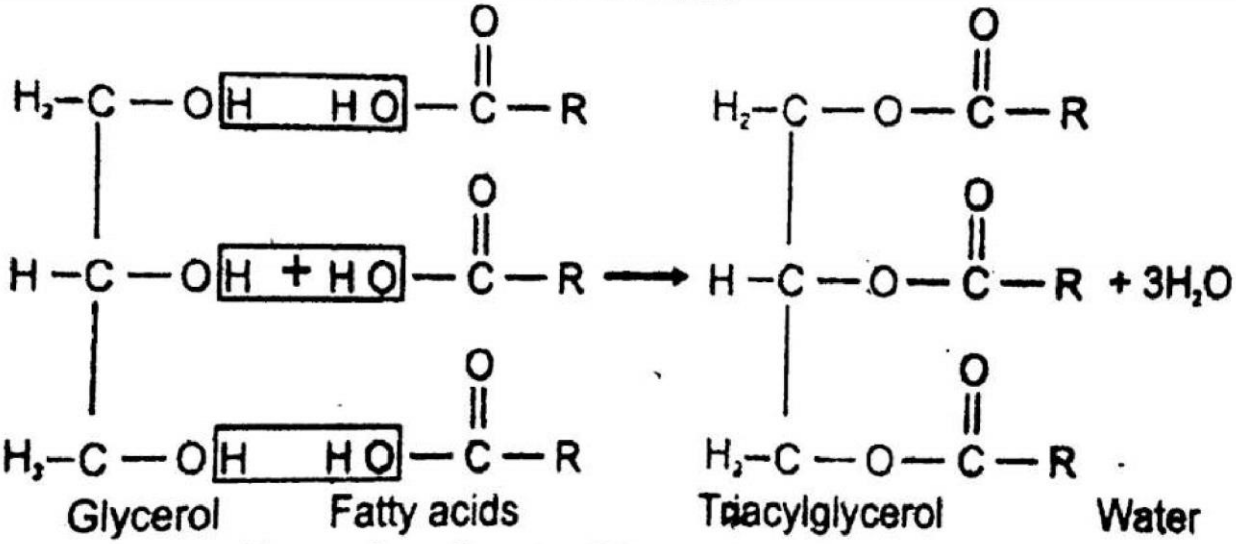
**Glycerol** is a trihydroxy alcohol which contains three carbons, each bears an OH group. A **fatty acid** is a type of organic acid containing one carboxylic acid group attached to a hydrocarbon. Fatty acids contain even number of carbons from 2 to 30. Each fatty acid is represented as R-COOH, where 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 charge bearing OH group is left.




Esterification




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. 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).

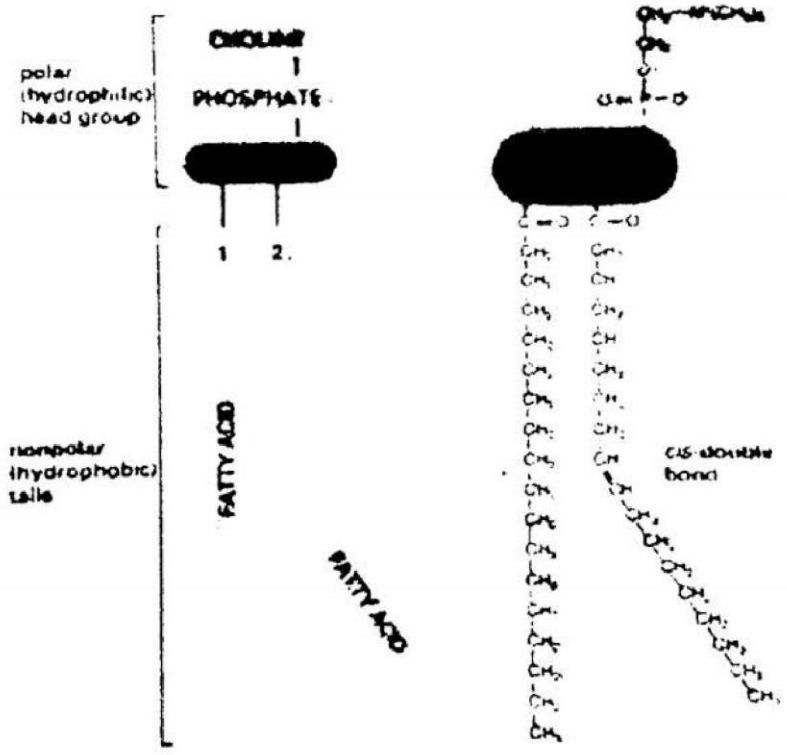
**Unsaturated fatty acids** have one or more pairs of carbon atoms joined by a double bond. They therefore are not fully saturated with hydrogen, e.g., oleic acid. Unsaturated fatty acids are liquid at room temperature (lower melting point) and are more common in plant lipids (oils). Triglycerides containing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

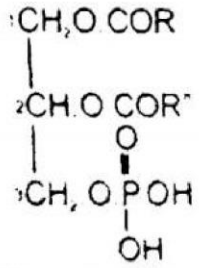
**Table: Common types of fatty acids:**

| Name | Typical source | No. of Carbon | Condensed Formula | Melting point (°C) |
|---|---|---|---|---|
| **Saturated** | | | | |
| 1. Laurie | Coconut oil | 12 | $CH_3(CH_2)_{10}COOH$ | 44 |
| 2. Myristic | Butter fat | 14 | $CH_3(CH_2)_{12}COOH$ | 58 |
| 3. Palmitic | Most fats and oils | 16 | $CH_3(CH_2)_{14}COOH$ | 63 |
| 4. Stearic | Most fats and oils | 18 | $CH_3(CH_2)_{16}COOH$ | 70 |
| **Unsaturated** | | | | |
| 5. Oleic | Olive oil | 18 | $CH_3(CH_2)_7CH=CH(CH_2)_7COOH$ | 4 |
| G. Linoleic | Vegetable oils | 18 | $CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7COOH$ | -5 |
| 7. Linolenic | Soybeans and canola oils | 18 | $CH_3CH_2CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_7CH_2OH$ | -11 |
| 8. Arachidonic | Lard (present in chicken etc.) | 20 | $CH_3-(CH_2)_4-CH=CH-CH_2-CH=CH-CH_2-CH=CH-CH_2-CH=CH-(CH_2)_3-COOH$ | -50 |

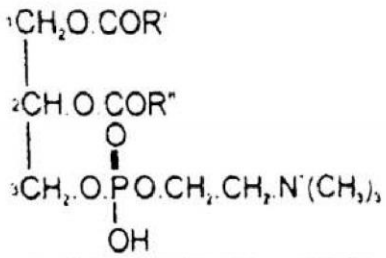
## (b) phospholipids:

Phospholipid is a type of compound/complex lipids. Commonly occurring 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 chains, is hydrophobic i.e., non-polar and insoluble in water. These phospholipids are major constituents of lipid bilayer of cell membrane.

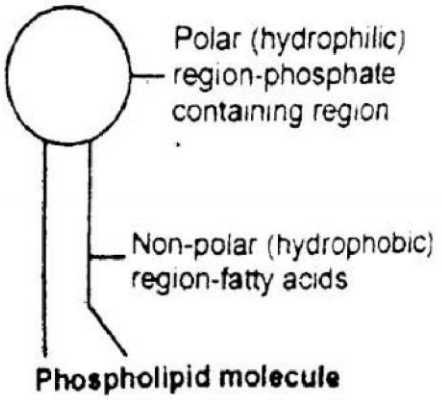





Phosphatidic acid



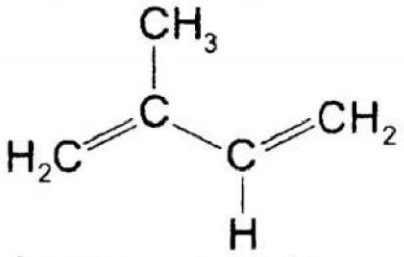

Phosphatidylcholine (Lecithin)




**Phosphatidylcholine (Lecithin)**

**(c) terpenes:**

Terpenes are the types of derived lipids. 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**.




**Isoprene unit**

**(d) waxes:**

Waxes are highly hydrophobic compounds.

**Types of Waxes:**

There are two types of waxes

**i. Natural 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), lanolin (obtained from sheep wool), cutin (on leaf surfaces of plants) and suberin (found in cell wall of endodermis of plant roots). These are chemically inert and resistant to atmospheric oxidation. Waxes have protective functions in plants and animals.

**ii. Synthetic waxes:**

**Synthetic waxes** are generally derived from petroleum or polyethylene and consist of mixtures of long-chain hydrocarbons (alkanes), alcohols, aldehydes, ketones and fatty acids e.g., paraffin wax which is used to make candles, wax paper, lubricants, and sealing materials.

**57. Illustrate the molecular structure (making and breaking) of:**

**(a) acylglycerol (b) phospholipids (c) terpenes**

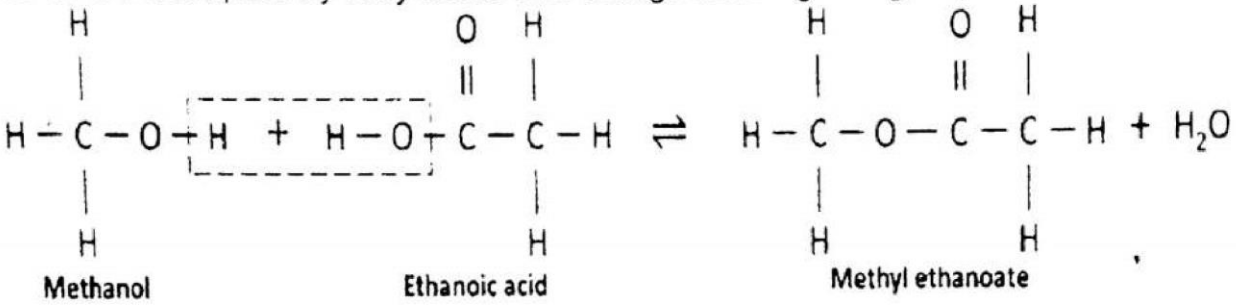
**Ans: (a) acylglycerol:**

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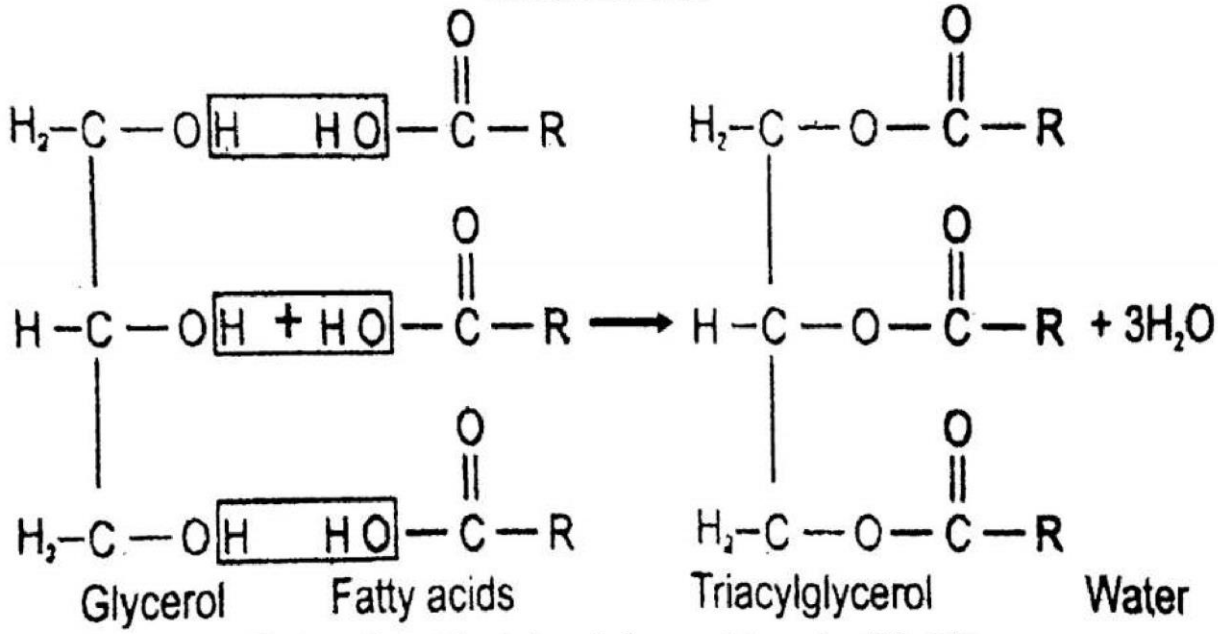
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Triacylglycerols are also called **neutral lipid** as all three OH groups of glycerol are occupied by fatty acids and charge bearing OH group is left



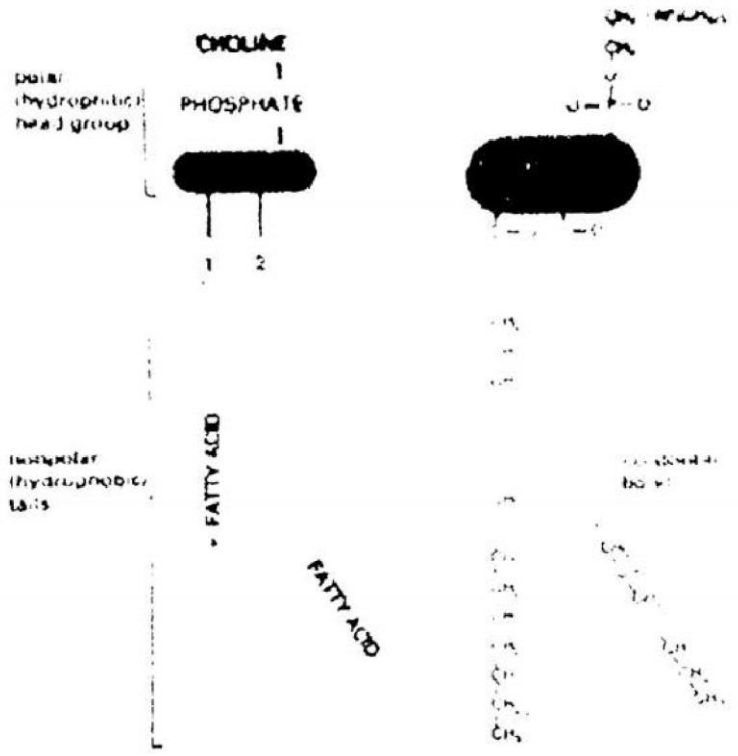

Esterification

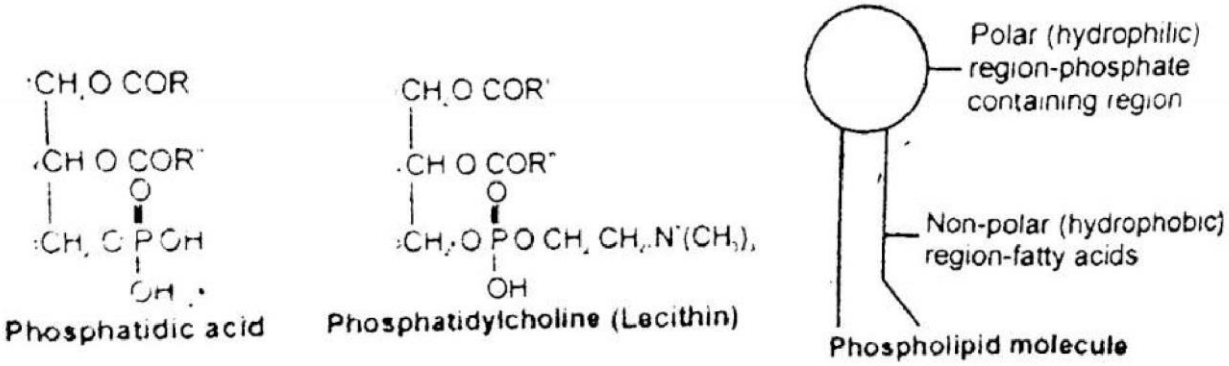



Formation of a triacylglycerol (neutral lipid)

**(b) phospholipids:**

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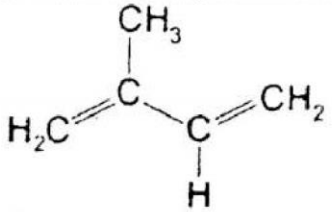



Phosphatidylcholine (Lecithin)

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**58. Evaluate the role of the following as important groups of lipids and describe their roles in living organism:**

**(a) steroid (b) prostaglandins**

**Ans: (a) steroid:**

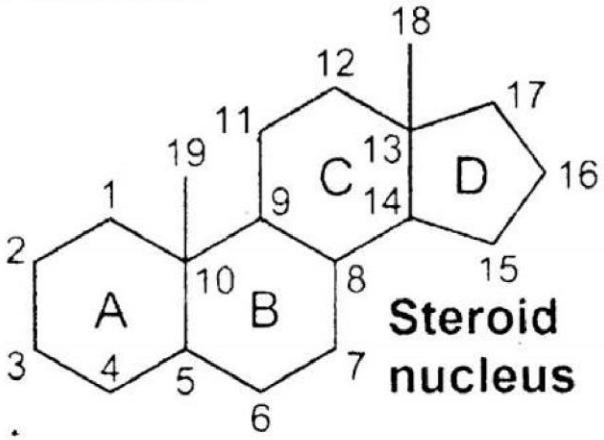
Steroids are lipids of high molecular weight which can be crystalline

**Composition of steroid:**

A steroid 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.

**Role of steroid in Living Organisms:**

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.

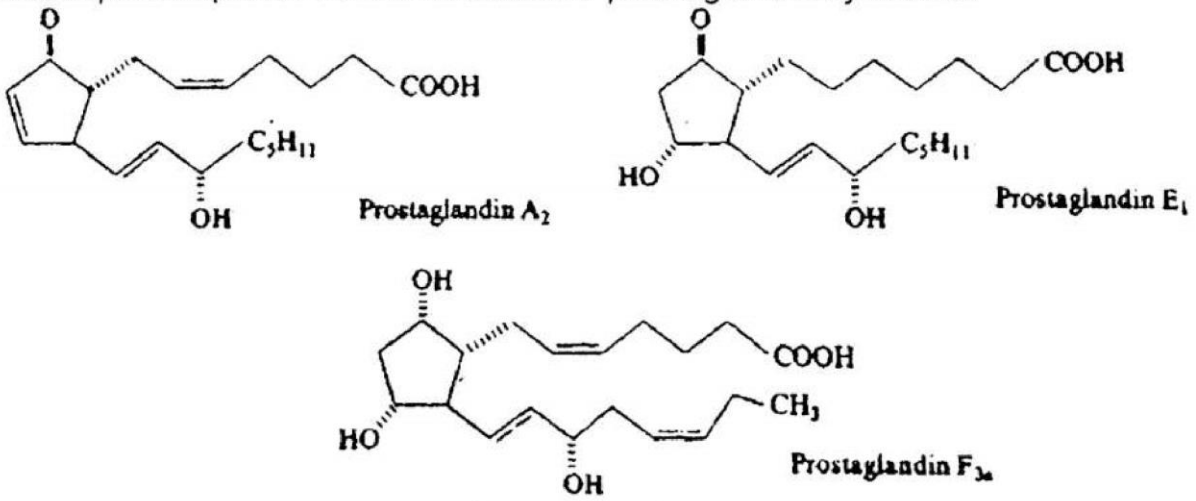



**(b) prostaglandins:**

Prostaglandins exist in virtually every mammalian tissue, acting as local hormones. Prostaglandins are derived from **arachidonic acid** (a tetra unsaturated 20C fatty acid).

**Role of Prostaglandins in Living Organisms:**

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. Those synthesized in the temperature-regulating centre of the hypothalamus cause fever. In fact, the ability of **aspirin** to reduce fever and decrease pain depends on the inhibition of prostaglandin synthesis.




Prostaglandins

**59. Describe the molecular level structure of nucleotides.**

**Ans: 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:**

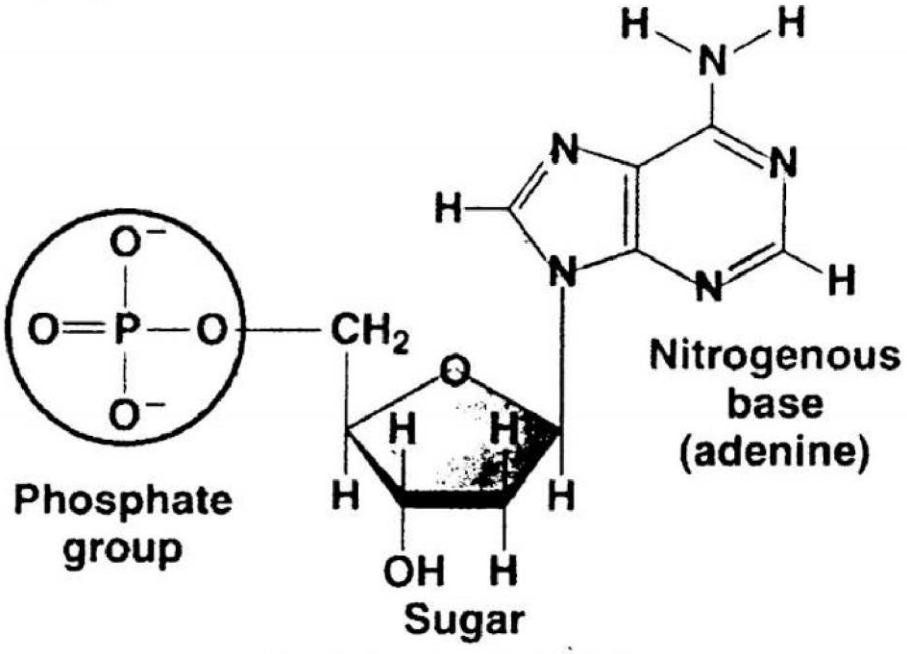
Nucleotides of DNA are called **deoxyribonucleotides** and of RNA are known as **ribonucleotides**. Each nucleotide consists of pentose sugar, a phosphate and a nitrogen containing ring structure called base.

**Pentose sugar:**

The **pentose sugar** in deoxyribonucleotides is deoxyribose and in ribonucleotides is ribose.

**Phosphoric acid:**

**Phosphoric acid** is a common component of both nucleotides which provides acidic properties to DNA and RNA.




Structure of a nucleotide

**Nitrogenous bases:**

The nitrogen containing ring structures are called **bases** because of unshared pair of electron on nitrogen atoms, which can thus acquire a proton.

**Classes of Nitrogenous Bases:**

There are two major classes of nitrogenous bases i.e., single ring **pyrimidine** and double ring **purines**

**i. Pyrimidine bases:**

Pyrimidine bases are or 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.

**ii. Purine bases:**

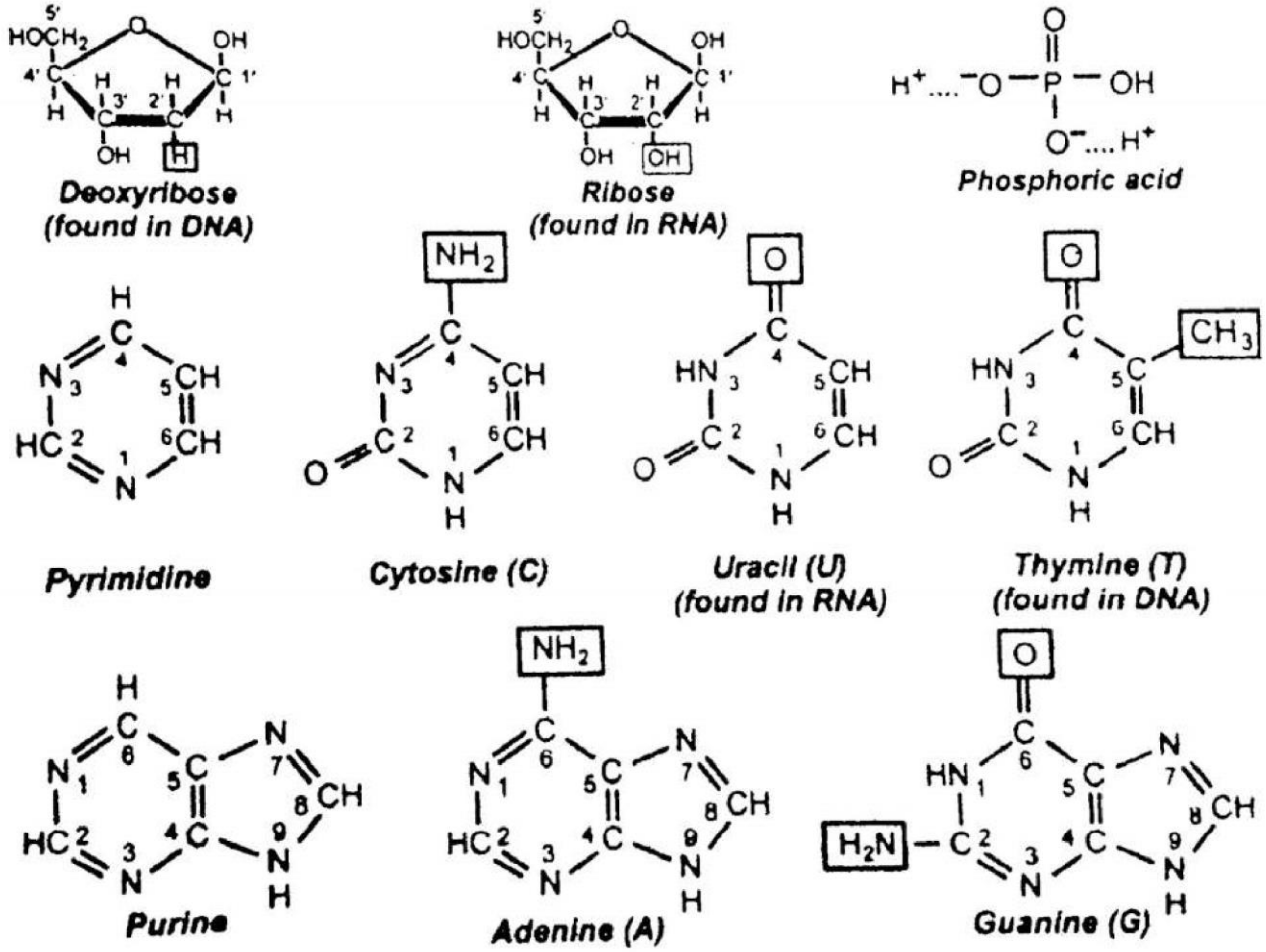
On the other hand, the purine bases are also of two types i.e., adenine (A) and guanine (G)

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

**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 |

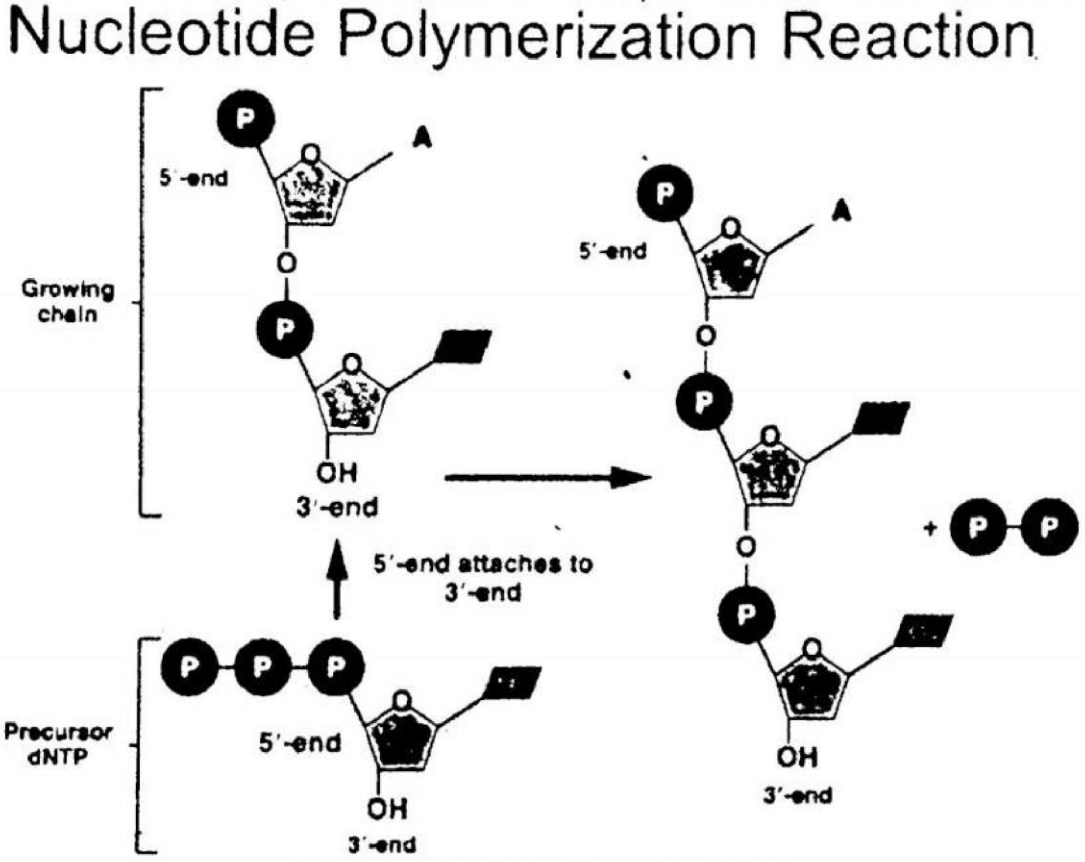



Components of nucleotides

**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'




Polymerization of nucleotides

**60. Distinguish among the nitrogenous bases found in the nucleotides of nucleic acids.**

**Ans: Nitrogenous bases:**

The nitrogen containing ring structures are called **bases** because of unshared pair of electron on nitrogen atoms, which can thus acquire a proton.

**Classes of Nitrogenous Bases:**

There are two major classes of nitrogenous bases i.e., single ring **pyrimidine** and double ring **purines**.

**i. Pyrimidine bases:**

Pyrimidine bases are or 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.

**ii. Purine bases:**

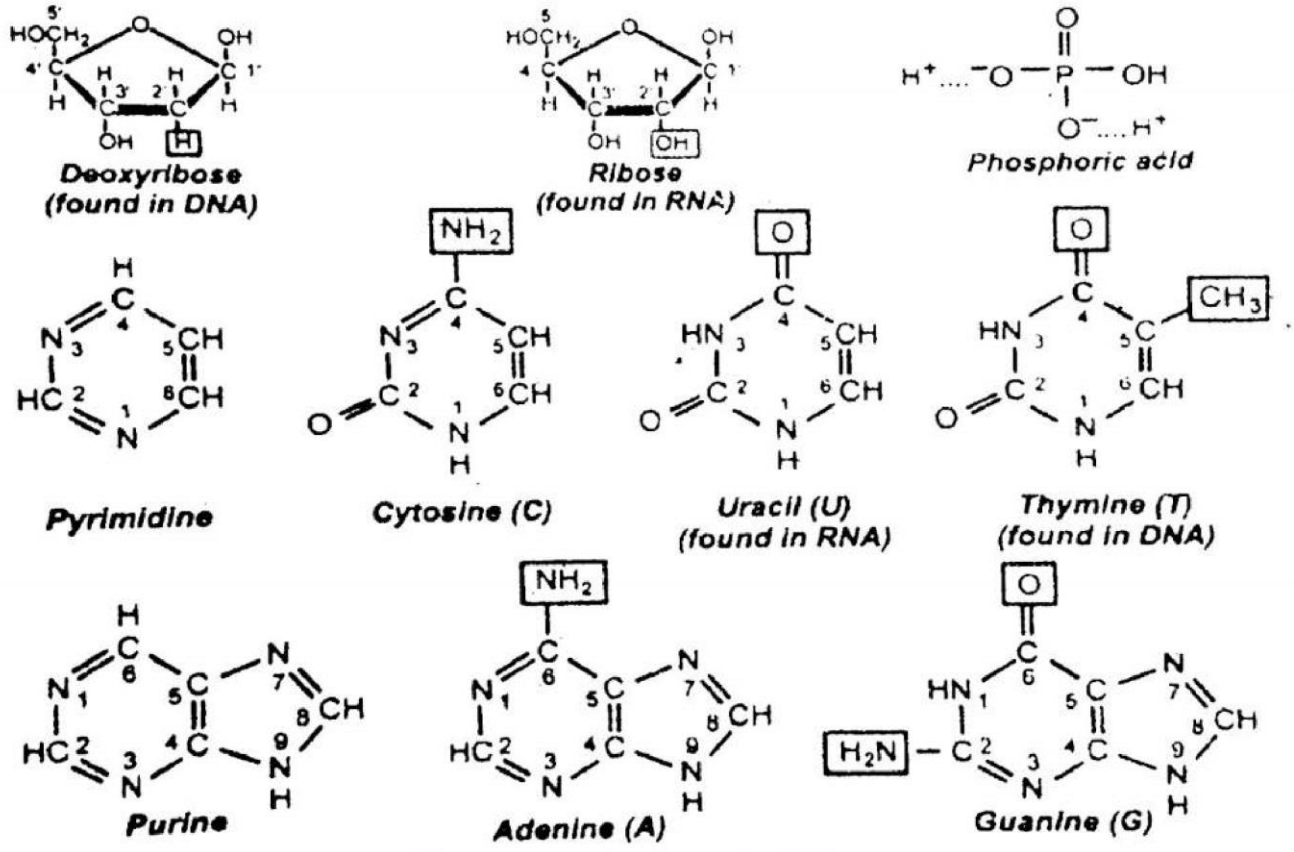
On the other hand, the purine bases are also of two types i.e., adenine (A) and guanine (G).

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

**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 |



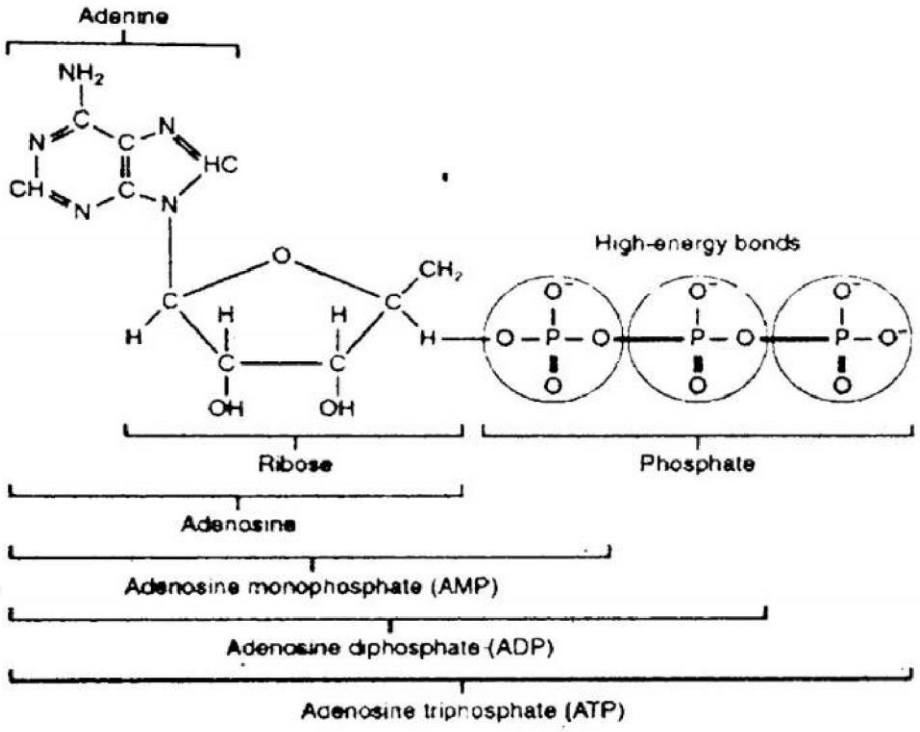

Components of nucleotides

**61. Describe the structure of a mononucleotide (ATP) and a dinucleotde (NAD).**

**Ans: Mononucleotide (ATP):**

**Adenosine triphosphate** (ATP) is a mononucleotide. 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

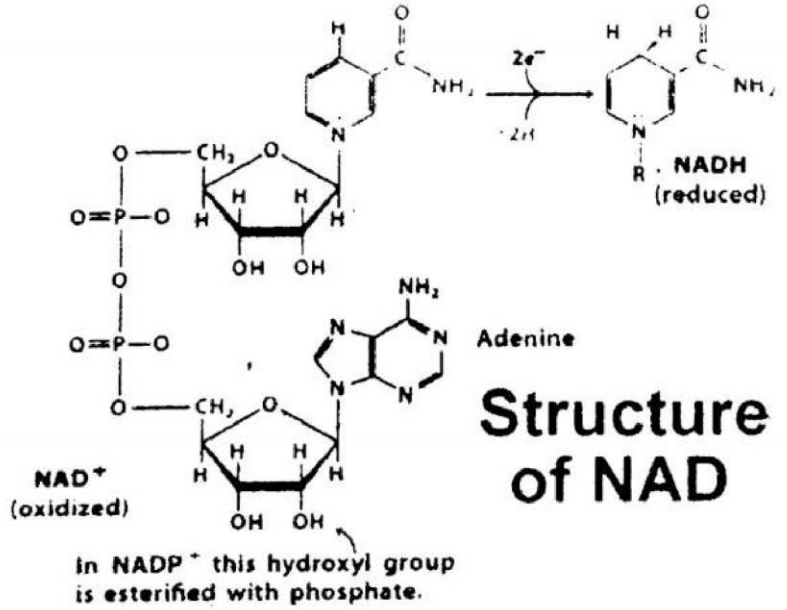
together are called **high-energy bonds**. ATP can be converted to ADP and inorganic phosphate (iP) by hydrolysis. ATP is known as the energy currency of cells. ATP is made from the oxidation of organic molecules during respiration. Since the energy to add the phosphate to ADP comes from oxidation, the process is known as **oxidative phosphorylation**. Most of the ATP in the cell is made in mitochondria.




Structure of ATP

## Chemical Nature and Role of NAD:

**Nicotinamide adenine dinucleotide** (NAD) consists of two nucleotides. One nucleotide consists of base-nicotinamide, sugar and phosphate. Other nucleotide consists of base-adenine-sugar and phosphate. The two nucleotides are joined by their phosphate group forming a dinucleotide. NAD is a coenzyme. It works with dehydrogenases as oxidizing agent. Its reduced form is NADH+H ($NADH_2$).




Structure of NAD

**62. Explain the formation of phosphodiester bond.**

**Ans: Phosphodiester Bond:**

A phosphodiester bond occurs when exactly two of the hydroxyl groups in phosphoric acid react with hydroxyl groups on other molecules to form two ester bonds.

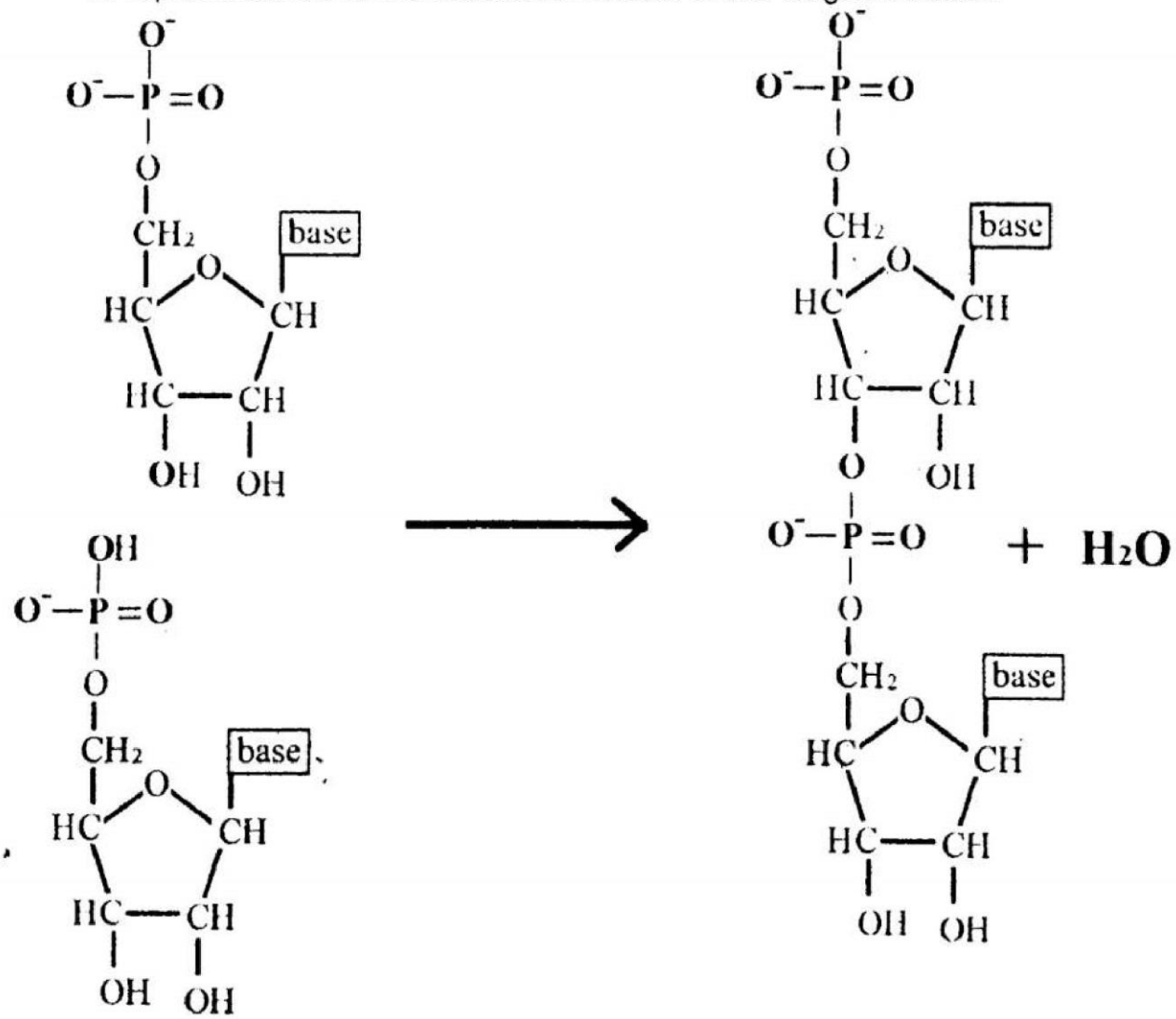
**Example:**

An example is found in the linking of two pentose (5 carbon sugar) rings to a phosphate group by strong, covalent ester bonds. Each ester bond is formed by a condensation reaction in which water is lost. This bond is a key structural feature of the backbone of DNA and RNA and links the 3′ carbon of one nucleotide to the 5′ carbon of another to produce the strands of DNA and RNA.

**Formation of Phosphodiester Bond:**

In phosphodiester formation, two hydroxyl (OH) groups on the phosphate molecule bind to the 3′ and 5′ carbons on two independent pentose sugars. These are two condensation reactions, so two molecules of water are produced. The phosphate is then bonded to the sugars by two ester bonds, hence the nomenclature of phosphodiester bond. This reaction is catalysed by ligases, such as DNA ligase during DNA replication.

A representation of the reaction is shown in the diagram below.



**63. Explain the double helical structure of DNA as proposed by Watson and Crick.**

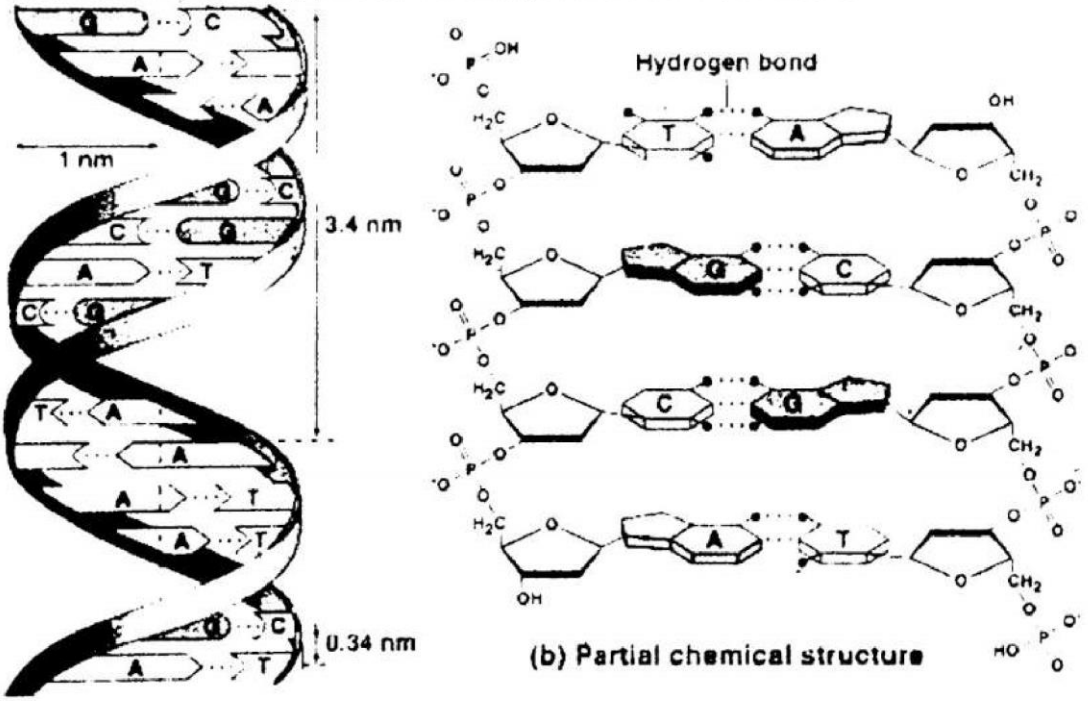
**Ans: Watson and Crick Model of DNA:**

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:

**i.** A DNA is made up of two polynucleotide chains which are attached together by base pairs.

**ii.** 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 from 5' to 3' upward. Both chains show a constant width of 2 ηm. Therefore, both chains are supposed be antiparallel to each other.




(a) Key features of DNA structure

(a) Key features of double helix model of DNA (b) Partial chemical structure

**Watson and Crick model of DNA**

**iii.** 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.

**iv.** There are three hydrogen bonds between Guanine and Cytosine and two hydrogen bonds between Adenine and Thymine. Therefore, the ratio of A: T and C: G is equal but the ratio of AT: CG is different.

v. 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.

**64. What is a gene? How gene codes for the formation of a polypeptide?**

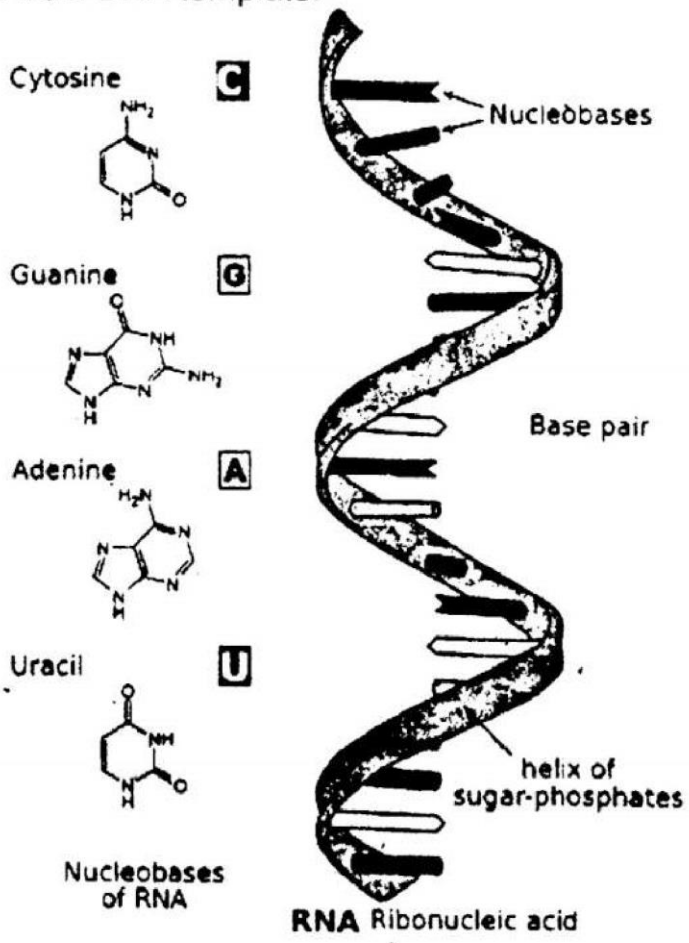
**Ans: Concept of Gene:**

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. Genes possess the data to build and maintain cells and pass genetic information to offspring.

**65. Explain general structure of RNA.**

**Ans: 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 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.



**66. Explain the structure and role of three types of RNA.**

**Ans: 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 RNA shows a secondary double stranded structure in their complementary regions.

**Types of RNA:**

There are three major classes of RNA each with a special function in protein synthesis. These RNA are transcribed from DNA template

i. Messenger RNA (mRNA)
ii. Ribosomal RNA (rRNA)
iii. Transfer RNA (tRNA)

**i. 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. It is transcribed from DNA template i.e., the base of sequence of mRNA is according to the base sequence of DNA. It becomes attached to the ribosome. At ribosome, amino acids are attached one by one to form a polypeptide chain as per base sequence of mRNA. This process is known as **translation**.

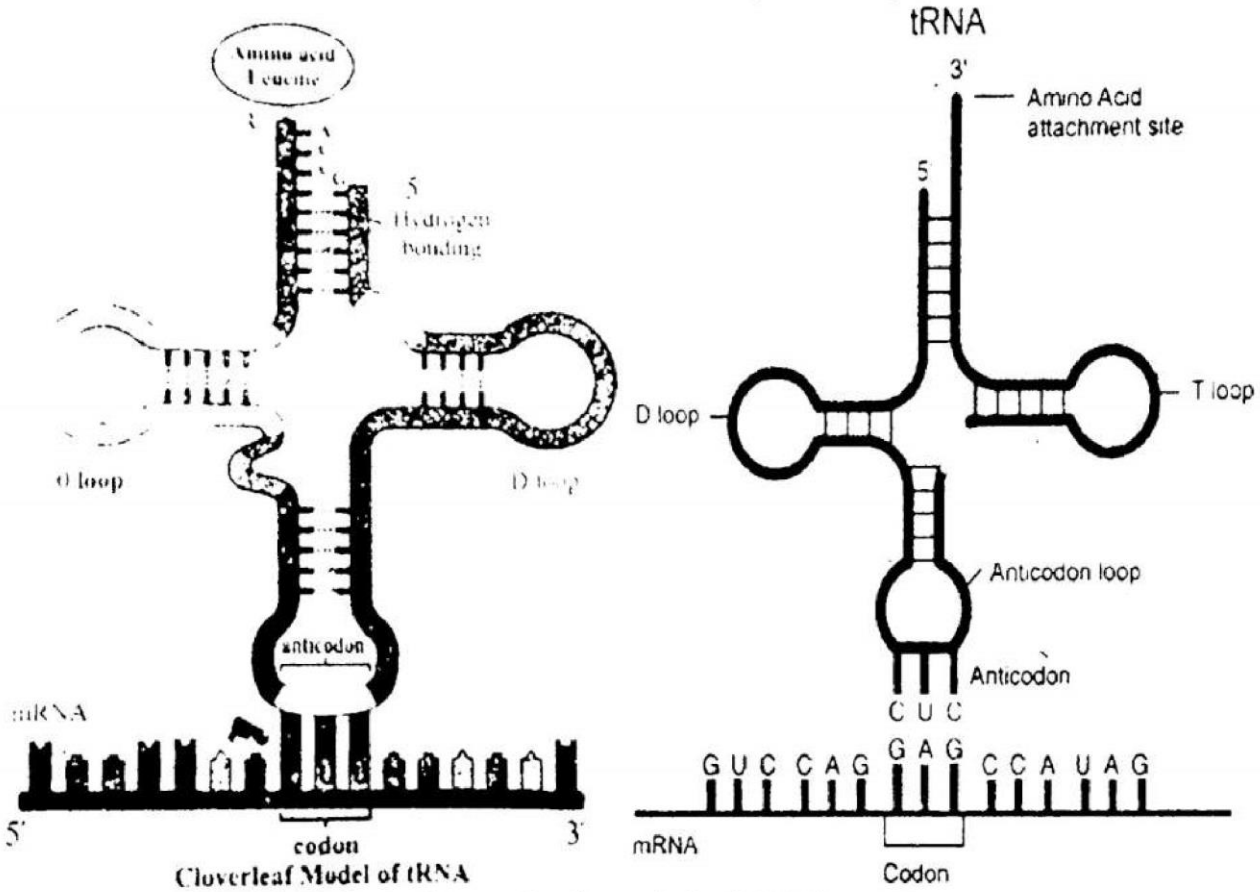
**ii. Ribosomal RNA (rRNA):**

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.

**iii. Transfer RNA (tRNA):**

It is the smallest of the RNA molecules that 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 always is the base sequence of ACC. Amino acid is attached to tRNA at this end. The nucleotide sequence of the rest of the molecule is variable. 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. For example, a tRNA that has anticodon GAA binds to the codon CUU and carries amino acid Leucine. 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.




Cloverleaf model of tRNA

**67. Describe the roles of the following conjugated molecules:**

**(a) glycolipids** **(b) glycoproteins**

**(c) lipoproteins** **(d) nucleoproteins**

**Ans: (a) glycolipids:**

**Glycolipids** are complex lipids containing one or more simple sugars in connection with long fatty acids or alcohol. The carbohydrates form the polar head to the molecule. Glycolipids are present in white matter of brain and myelin sheath of nerve fibres and chloroplast membrane.

**(b) glycoproteins:**

**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.

**(c) lipoproteins:**

**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.

**(d) nucleoproteins:**

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