Chapter 1

STRUCTURE AND FUNCTIONS OF BIOMOLECULES

Syllabus:
Structure and function of biomolecules: Carbohydrates, Lipids, Proteins and Nucleic acid

CARBOHYDRATES

Carbohydrates are polyhydroxy aldehydes or ketones. Carbohydrates are sugars and their polymers. They are composed of carbon, hydrogen and oxygen. The word carbohydrates literally mean **hydrated carbons.** The ratio of hydrogen and oxygen is the same, as in water, i.e. 2:1. Their general formula is $C_n(H_2O)_n$. The number of carbons may be from three to many thousands. Sources of carbohydrates are green plants. Carbohydrates are primary products of photosynthesis. Other compounds of plants are produced from carbohydrates by different chemical changes.

Carbohydrates occur abundantly in living organisms. They have following importance:

1. They form different structures, like cellulose of wood, cotton, and papers.
2. They are found in all organisms. They are present in all parts of the cells.
3. They act as storage compounds like **starch** and **glycogen**.
4. Carbohydrates are also present in cane sugar and milk sugar.
5. They are the main source of energy in cell.
6. Some carbohydrates like cellulose, chitin form cell wall in plants and microorganisms.
7. Carbohydrate combines with proteins and lipids to form **glycoproteins** and **glycolipids**. These are called **conjugate**

compounds. Conjugate compounds play important role in the cell.

Classification of Carbohydrates

Carbohydrates are also called '**saccharides**'. The word saccharide is derived from a Greek word '**sakcharon**'. It means sugar. Saccharide is taken as unit (monomer) of carbohydrates. Carbohydrates are classified in to three groups:

(a) Monosaccharides

Monosaccharides are simple sugars. Mono means single and sacchar means sugar. They are composed of single sugar unit. Their formula is multiple of CH_2O. They generally contain carbon number from 3 to 7. They show following characters:

1. They are sweet in taste.
2. They are easily soluble in water. They cannot be hydrolyzed into simple sugars.
3. Except one carbon, all other carbon atoms in a monosaccharide have hydroxyl group (OH). The carbon without OH group has **carbonyl carbon**. It forms aldehyde or ketone group.
4. The sugars with aldehyde groups are called **aldo-sugar** and with the sugar with keto groups are called **keto-sugars**. The example of aldo sugar is glucose and example of keto sugar is fructose.
5. Most of monosaccharides differ in spatial arrangements of their parts around asymmetric carbon. Asymmetric carbon is attached four different types of covalent partners. For example, glucose and galactose different in arrangement of parts around one asymmetric carbon (carbon no. 3).
6. In aqueous solutions, most monosaccharides form rings.
7. Monosaccharides are major nutrients of cells. They are broken down during cellular respiration to release energy. During respiration many smaller monosaccharides are produced. These smaller monosaccharides like glyceraldehyde, dihydroxy acetone phosphate acts as precursor for the synthesis of many new compounds like amino acids, fatty acids..

Types of Monosaccharides

Monosaccharide with 3 to 7 carbon atoms are found in nature. They are called trioses (3C), tetroses (4C), pentoses (5C), hexoses (6C) and heptoses (7C). Their have general formula $(CH_2O)_n$. There are following types of monosaccharide:

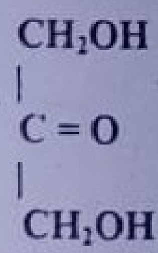
(a) Trioses: They have three carbons. Two trioses are aldehyde (glyceraldehydes) and **ketones** (dihydroxyacetone). These are produced as intermediate compounds during respiration and photosynthesis.

(b) Tetroses: They have four carbons. Tetroses are rare in nature. They occur in some bacteria.

(c) Pentoses: They have five carbons. Ribose sugar is a common pentose. It is an aldo sugar. It gives five cornered ring structure in solution form. This ring is called **ribofuranose.** It is present in ribonucleic acids RNA. **Deoxyribose** is also a pentose sugar. It is found in DNA.

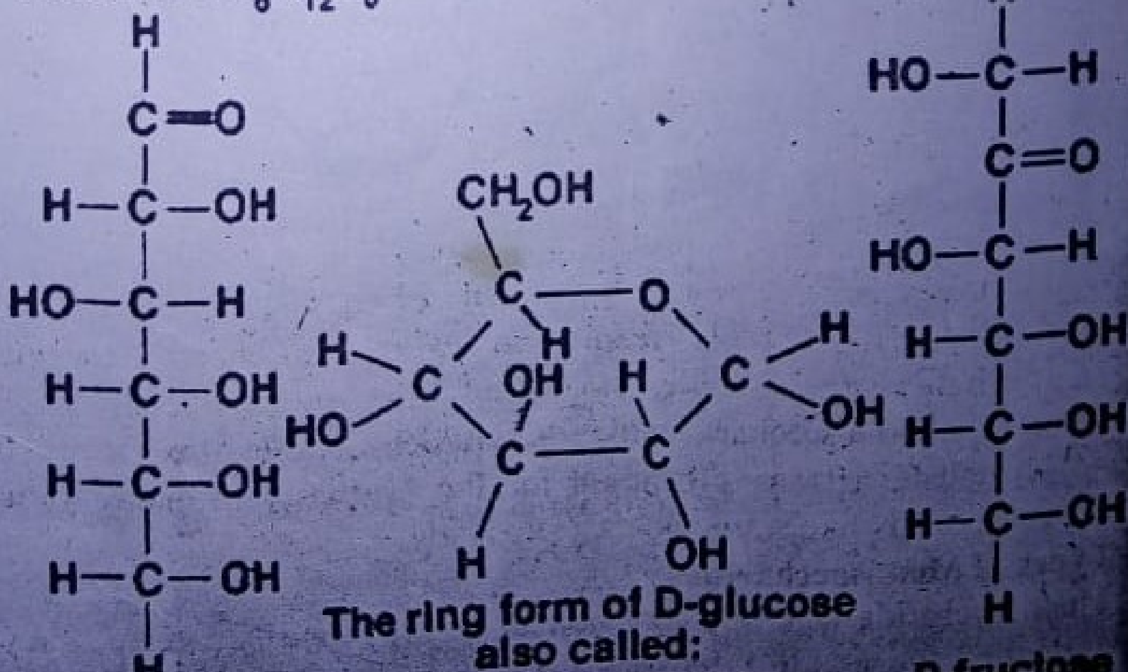
(d) Hexoses: They have six carbons. For example, glucose, galactose, fructose, mannose.

Aldehyde form



Keto form

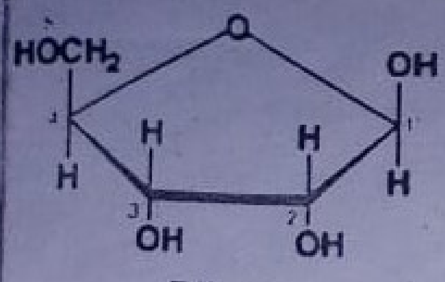
Hexose = $C_6H_{12}O_6$



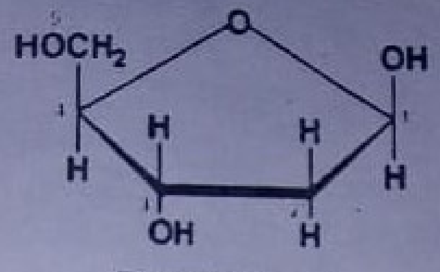
D-glucose

The ring form of D-glucose also called: α-D-glucopyranose

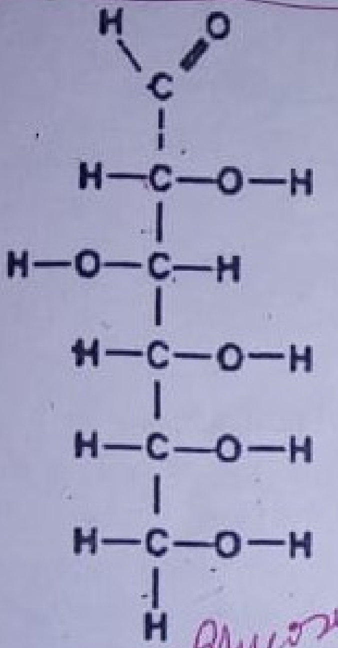
D-fructose

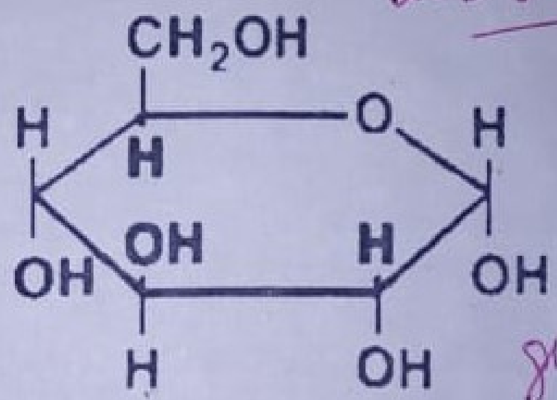


Ribose



Deoxyribose





(b) Disaccharides (Double sugars)

The sugars composed of two monosaccharides are called disaccharides. These sugars are linked by glycosidic linkage:

1. Their general formula is $C_{12}H_{22}O_{11}$.
2. These are less sweet in taste.
3. These are less soluble in water.
4. They yield 2 monosaccharides on hydrolysis.
5. There are three important disaccharides:

a) **Sucrose (table sugar):** It is a disaccharide formed by linking a molecule of glucose to a molecule of fructose.

b) **Lactose:** A glucose molecule bonds to another monosaccharide, galactose and it forms disaccharide lactose (commonly called milk sugar).

c) **Maltose:** It is formed by the joining of glucose subunits. It gives beer seeds a sweet taste. Beer brewers ferment barley into alcohol.

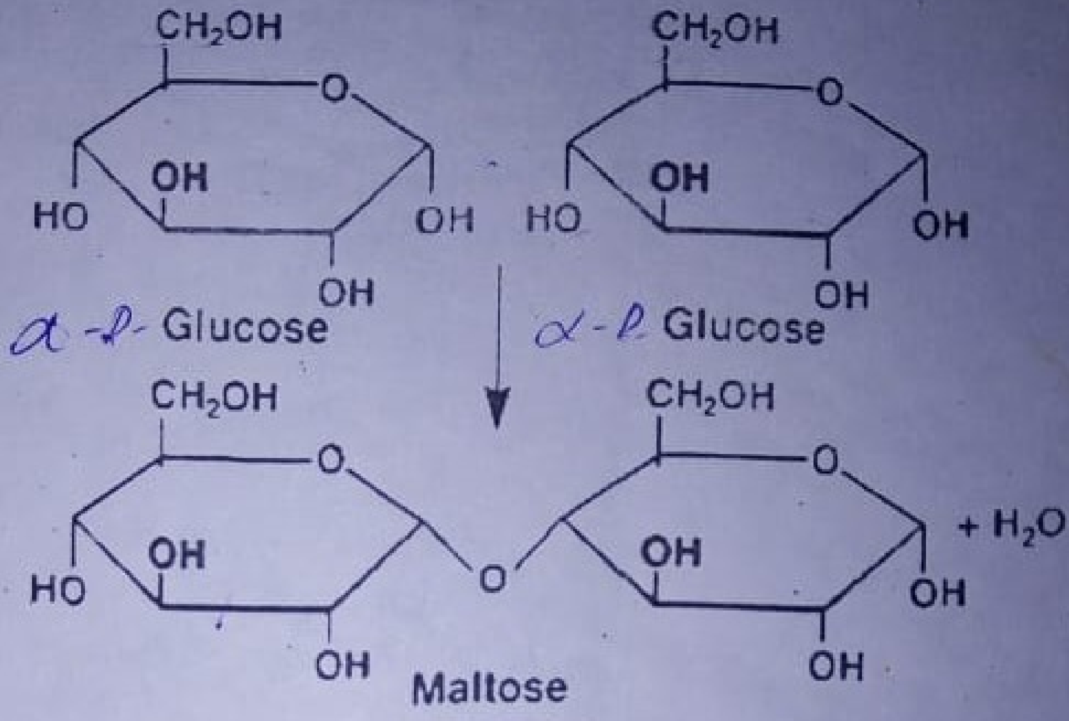
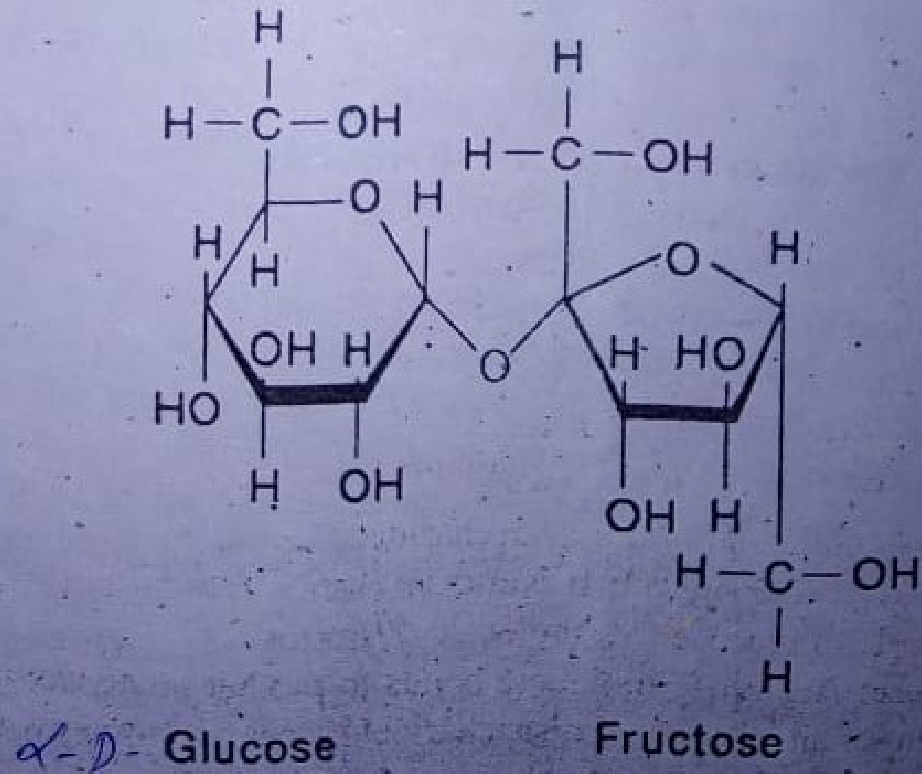
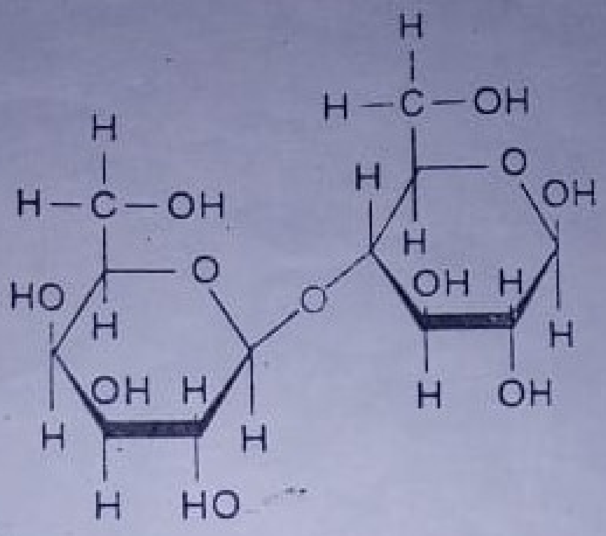


Fig: Formation of disaccharide



Sucrose



Galactose β-D-Glucose

Lactose

(C) Polysaccharides

The polymer of many monosaccharides is called polysaccharides. Polysaccharides are macromolecules. Polysaccharides show following characters:

1. In polysaccharide, few hundred to a few thousand monosaccharides are linked together. Several monosaccharides linked by glycosidic linkage and form polysaccharides.
2. They are tasteless and sparingly soluble in water.
3. They are most abundant in nature.
4. They are usually branched or unbranched.
5. Some polysaccharides like starch acts as storage material. Some polysaccharides like chitin, cellulose acts as building material.
6. Some biologically important polysaccharides are starch, glycogen, cellulose, dextrin, agar, pectin, and chitin.

Starch

It is found in fruits, grains, seeds, tuberous roots and potato tubers. It is the major storage compound in most of the plants. Plants store. The monomers are linked by 1-4 linkage in starch. Starch gives blue colour with iodine. Starch has two types:

(a) **Amylose starch:** It is a simple form of starch. Amylose have unbranched chain of glucose. It is soluble in hot water.

(b) **Amylopectin:** It is most complex form of starch. It has branched chains. It is insoluble in hot or cold water.

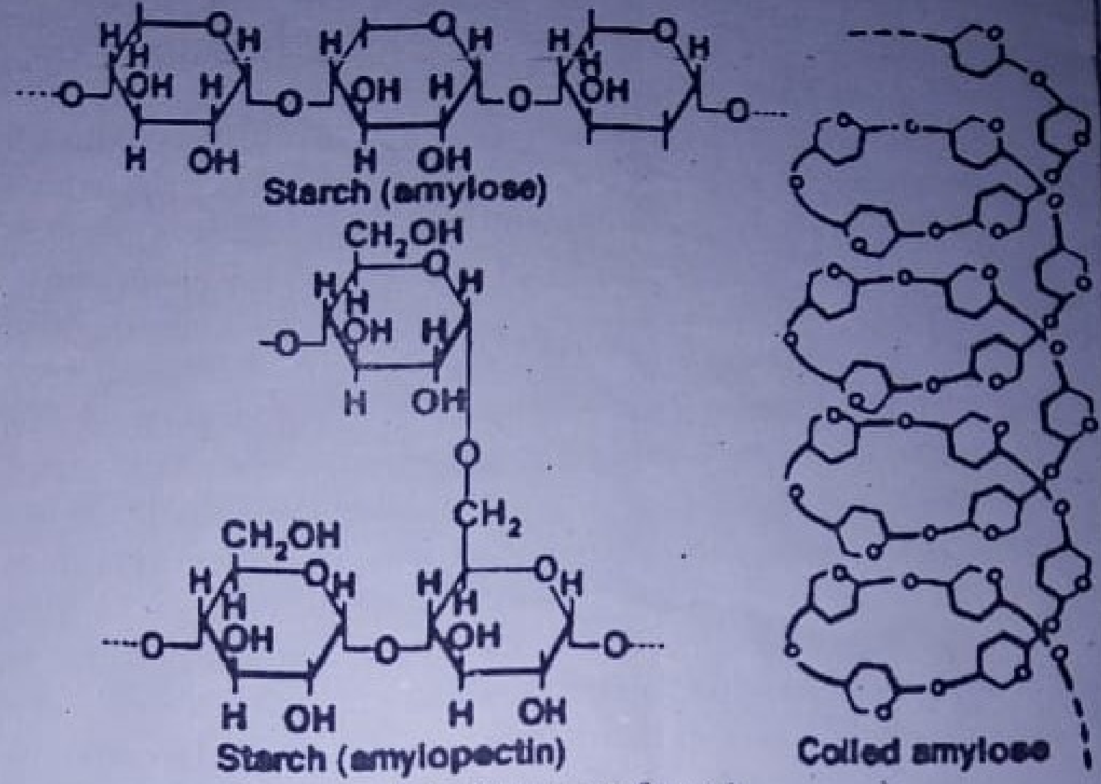


Fig: Structure of starch

Glycogen

Glycogen is a polymer of glucose. It is more extensively branched than the amylopectin of plants. It is also called **animal starch.** It is a chief storage compound of animals. It is found in liver and muscles. It is also found in all animal cells. It is insoluble in water. It gives red colour with iodine. It gives glucose on hydrolysis.

Cellulose

It is the most abundant carbohydrate in nature. Cellulose is also a polymer of glucose. But its glycosidic linkages are different from the starch. The glucose molecules of cellulose are in β configuration. The molecules of glucose in starch are held by hydrogen bonding to form **microfibrils.** Several intertwined microfibrils molecules form a cellulose fibril. Cellulose is the main constituents of cell walls of plants. Cotton is pure form of cellulose. It is insoluble in water. It yields glucose molecules on hydrolysis. Cellulose gives no colour with iodine. The enzyme for starch digestion acts only on α bond. It cannot act on β glycosidic bond. Therefore, this enzyme cannot digest cellulose. Some bacteria and other microorganisms live in the intestine of herbivores. They produce **cellulase** enzyme. Cellulase can break β glycosidic bond and digest it.

Chitin

Chitin is another structural polysaccharide. Chitin is found in cel wall of fungi. It also forms exoskeleton of Arthropods. Chitin has amino sugars in its molecules.

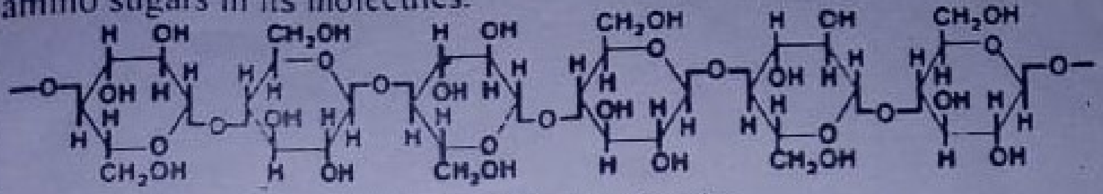


Fig: Cellulose molecule

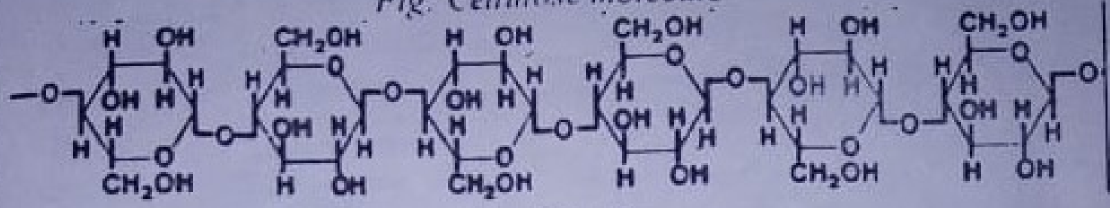


Fig: Starch

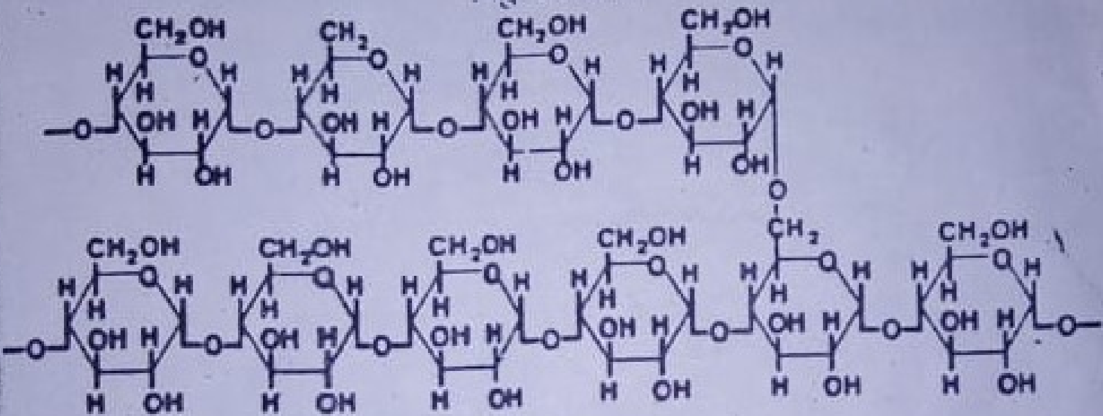


Fig: Glycogen

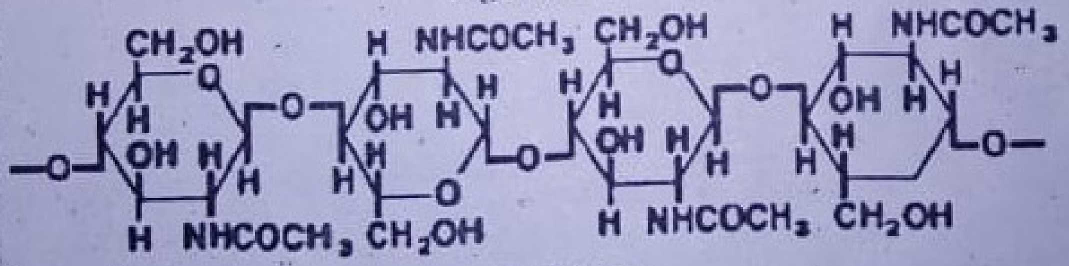


Fig: Chitin

LIPIDS

Lipids are nonpolar organic molecules that are insoluble in polar water but soluble in nonpolar organic solvents like ether, alcohol, and chloroform. Lipids show hydrophobic behavior. The behaviour is associated with the chemical structures of lipids. Lipids have high proportion of C-H bonds. C-H is non-polar in character. Phospholipids and cholesterol are lipids. They are important constituents of cell membranes. The most common lipids in plants and animals are fats.

(a) Fats (Oils)

Fats are esters of fatty acids and glycerol. Fats build cell parts and supply energy for cellular activities. Fats have following properties:

1. Fats molecules are composed primarily of carbon, hydrogen, and oxygen atoms. Some fats also contain small amounts of phosphorus and nitrogen. They contain a much smaller proportion of oxygen than carbohydrates. For example the formula of the fat tristearin is $C_{57}H_{110}O_6$. $C_{57}H_{110}O_6$
2. The building blocks of fat molecules are fatty acids and glycerol. **Fatty acids contain long hydrocarbon chains bonded to carboxyl (COOH) groups.** Glycerol is a three-carbon alcohol, with each carbon bearing a hydroxyl (OH) group. Three fatty acid molecules combine with one glycerol molecule. They are attached to the three carbon atoms in the glycerol backbone.
3. The fats with three fatty acids are called **triglyceride neutral fat or triacylglycerol.** The glycerol portion of every fat molecule is the same. But there are many kinds of fatty acids. Therefore, there are many kinds of fats. Fatty acid molecules differ in the length of their carbon chains and in the ways the carbon atoms combine. The most common are even-numbered chains of 14 to 20 carbons.

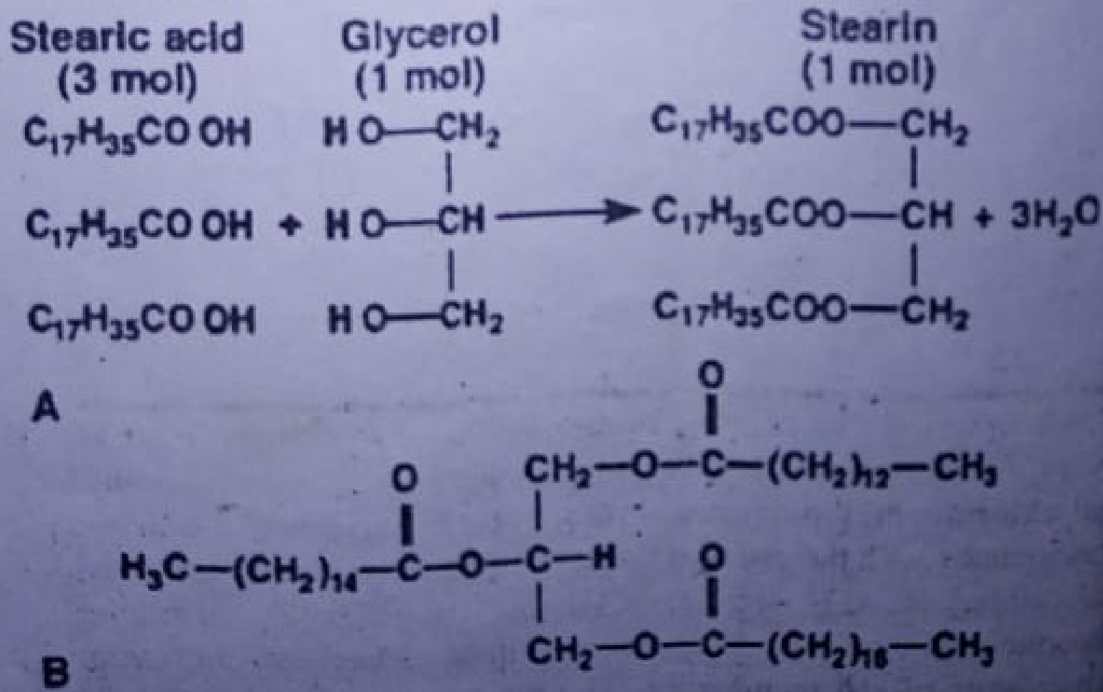
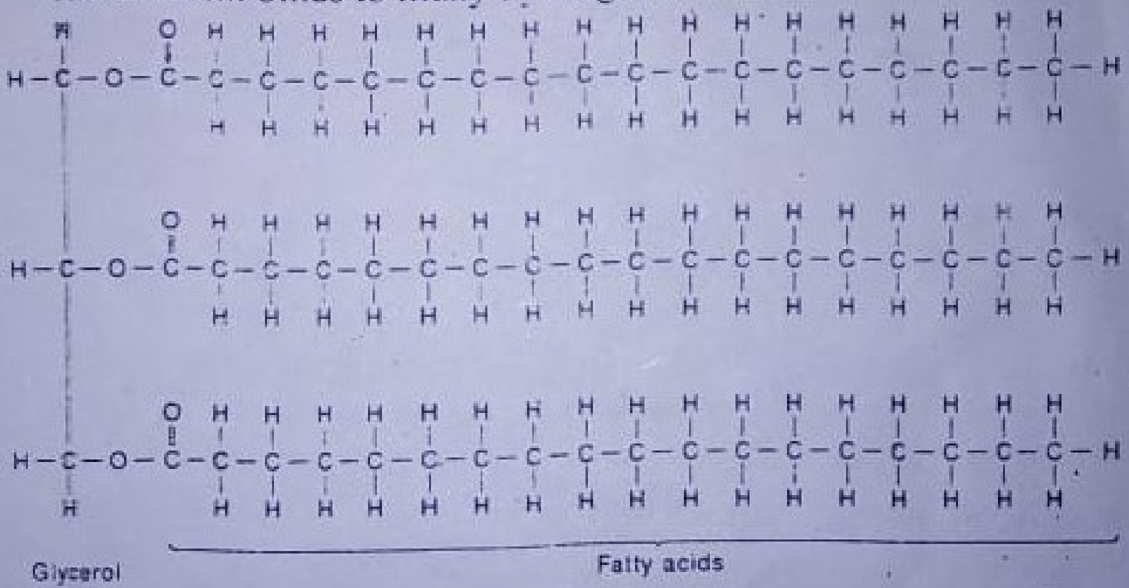


Fig: Formation of lipids

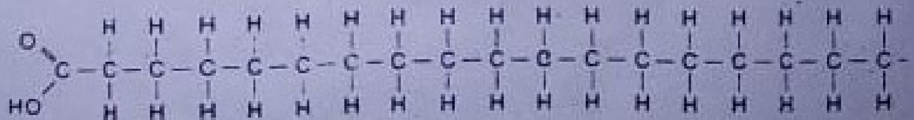
Types of fats

There are two types of fats:

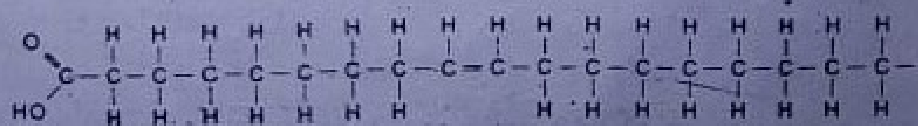
- **Unsaturated fats:** They have double bonds. Their chains bend at the double bonds. So the fat molecules cannot align closely with one another. Therefore, they have low melting points. Thus the fat may be fluid at room temperature. **A liquid fat is called oil.** Most plant fats are unsaturated. Fatty acids with one double bond are monounsaturated. They fatty acids with numerous double bonds are polyunsaturated.
- **Saturated fatty acids:** They do not have double bonds. Animal fats are often saturated. They occur as hard or solid fats. In this case, the carbon atoms join by single carbon-carbon bonds. Each carbon atom binds to many hydrogen atoms.



(a) Stearic acid



(b) Oleic acid



(b) Phospholipids

A phospholipids molecule is similar to a fat molecule. It contains a glycerol portion and fatty acid chains. But phospholipids have only two fatty acid chains. The nitrogen containing groups replace the third chain. There are two parts of phospholipids:

- **Head:** The polar phosphate and nitrogen groups are soluble in water (hydrophilic). They form the "head" of the molecule.

- **Tail:** The insoluble (nonpolar, hydrophobic) fatty acid portion forms the "tail."

Phospholipids have double tendency. They are soluble at one end and insoluble at the other end. So they are the major structural components of cell membranes.

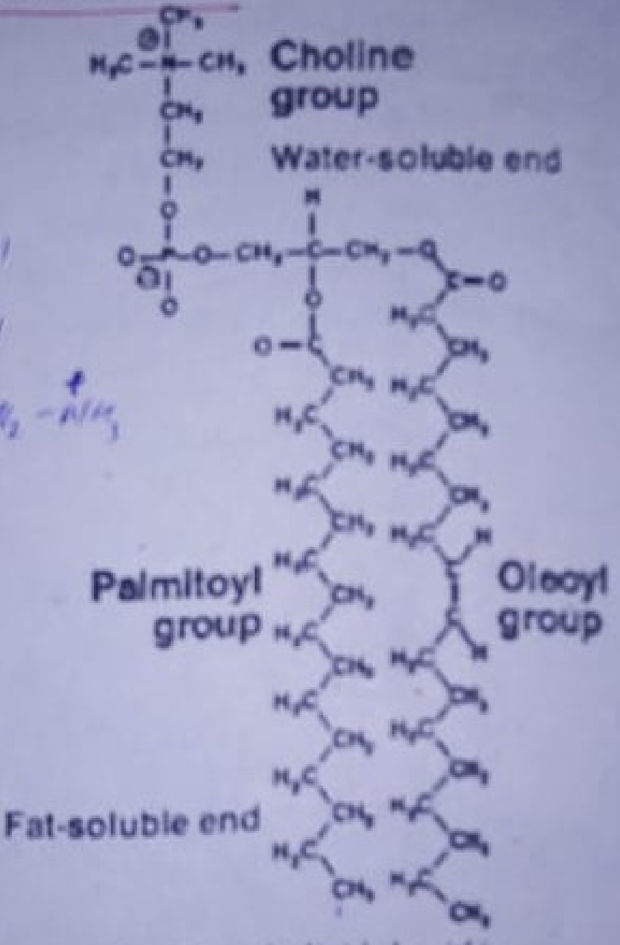
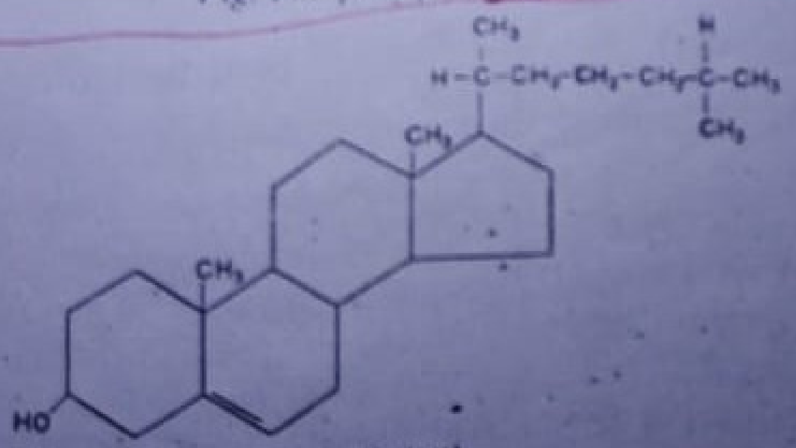


Fig. Phospholipid: Lecithin



Cholesterol

(c) Steroids

They are naturally occurring, lipid-soluble molecules. They are composed of four fused carbon rings. It forms a rigid structure. Three of the rings are six-sided. The fourth is five-sided. The four rings contain a total of 17 carbons. Cholesterol is an important biologically active steroid. Similarly vitamin D is also an important steroid.

(d) Waxes

The mixture of long chain alkanes (with odd number of carbon from C_{25} to C_{35}), alcohols, ketones, and esters of long chain fatty acids is called waxes, e.g. cutin. Waxes form protective coating on fruits and leaves. Waxes protect plants from water loss and abrasive damages. The xerophytic plants a thick layer of waxes. It reduces transpiration in these plants.

Functions of lipids

Lipids perform following functions:

1. Lipids are hydrophobic compounds. Therefore, they form components of the cell membrane.
2. Lipids act as storage compounds like fats.
3. They have high proportion of **C - H bonds** and low proportion of oxygen. Thus lipids store double amount of energy as compared to carbohydrates.
4. Some lipids provide insulation against atmospheric heat and cold. They also act as water proof material. For example, waxes in the exoskeleton of insects. A wax **cutin** forms an additional protective layer on the cuticle of epidermis of some plant organs like leaves, fruits, seeds etc.
5. Some lipids like **steroids**, **cholesterol** performs important functions in the bodies of plants and animals.

PROTEINS

Proteins are polymers of amino acids. The name of proteins is derived from the Greek word called ***proteios***. It means first place. Proteins always contain atoms of carbon, hydrogen, nitrogen, oxygen, and sometimes sulfur. Proteins are composed of more than 50% of the dry weight of most cells.

Prime importance

Amino Acids

Amino acids are the building blocks of proteins. Amino acids contain an amino group (NH_2), a carboxyl group (COOH), a hydrogen atom, and a functional group R. They all are bonded to a central carbon atom called α carbon. The α carbon is an asymmetric carbon. It is attached with four different covalent partners.

The nature of the R group determines the chemical properties of each amino acid. R group is called **side chain**. It may be single hydrogen atom as in glycine. Or it may be carbon skeleton with various functional groups like glutamic acid. Amino acids are divided into two groups on the basis of properties of R group:

(a) **Hydrophobic amino acids:** These amino acids contain non-polar side chain.

(b) **Hydrophilic amino acids:** These amino acids have polar side chains. There are two types of hydrophobic amino acids

- **Acidic amino acids:** Their side chain is generally negative in charge.
- **Basic amino acids:** Their side chains are generally positive in charge.

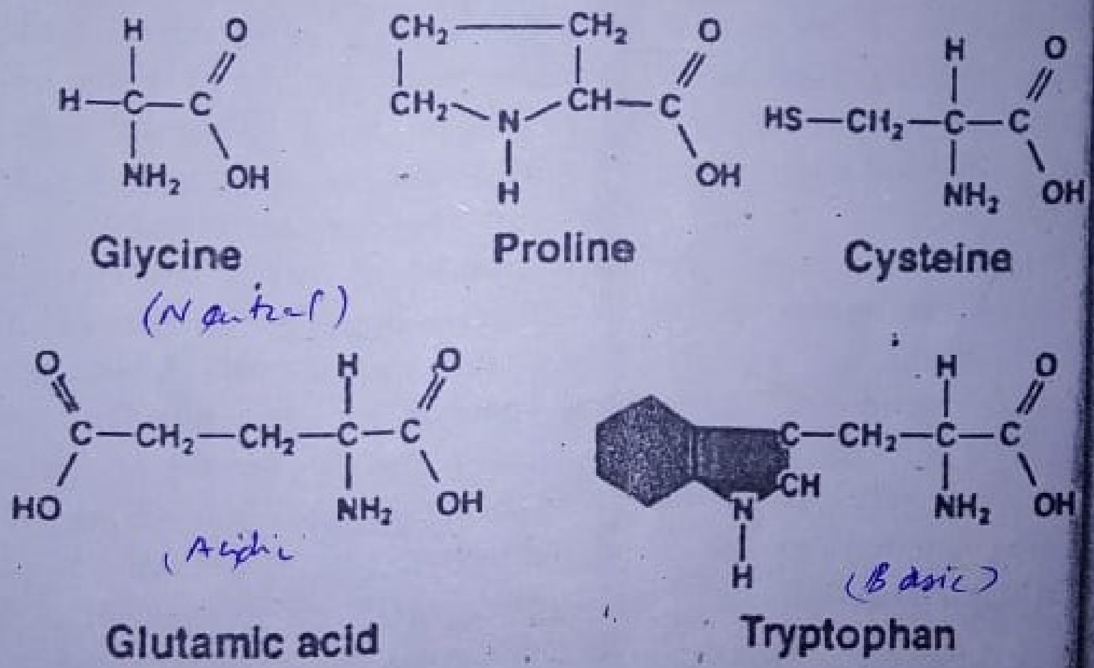
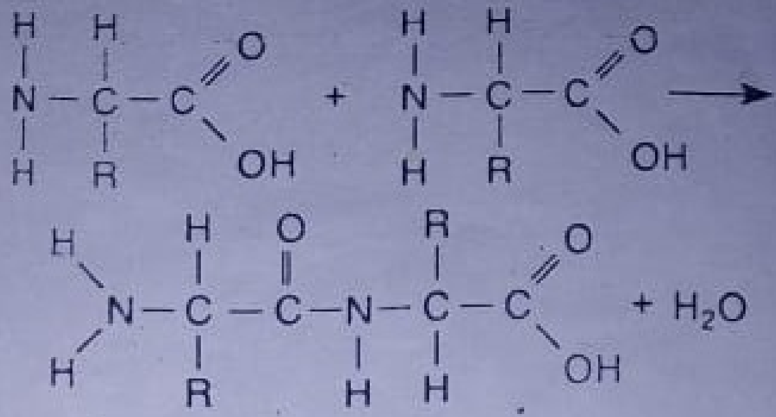


Fig: Different amino acids

Peptide bond formation

Twenty different amino acids commonly occur in animals. Peptide bonds join amino acids in chains. Peptide bonds are covalent bonds. The carboxyl group of one amino acid bonds to the amino group of another amino acid in peptide bond. One molecule of water is released. The chain of amino acids can vary from fewer than 50 to more than 2,000 amino acids in different proteins.

- Two amino acids bond to form **dipeptide.**
- Three bonded amino acids form a **tripeptide.**
- Many amino acids bond to form a chain called a **polypeptide.**



Protein conformation

A protein consists of one or more polypeptide chains. These chains are twisted, wound and folded upon themselves to form macromolecule. This macromolecule has definite three dimensional shapes called **conformation**. The function of protein depends upon its conformation. Form example enzyme can perform its function by key and lock mechanism. This mechanism is possible only due to conformation of protein of an enzyme. Many proteins are globular. Some are fibrous.

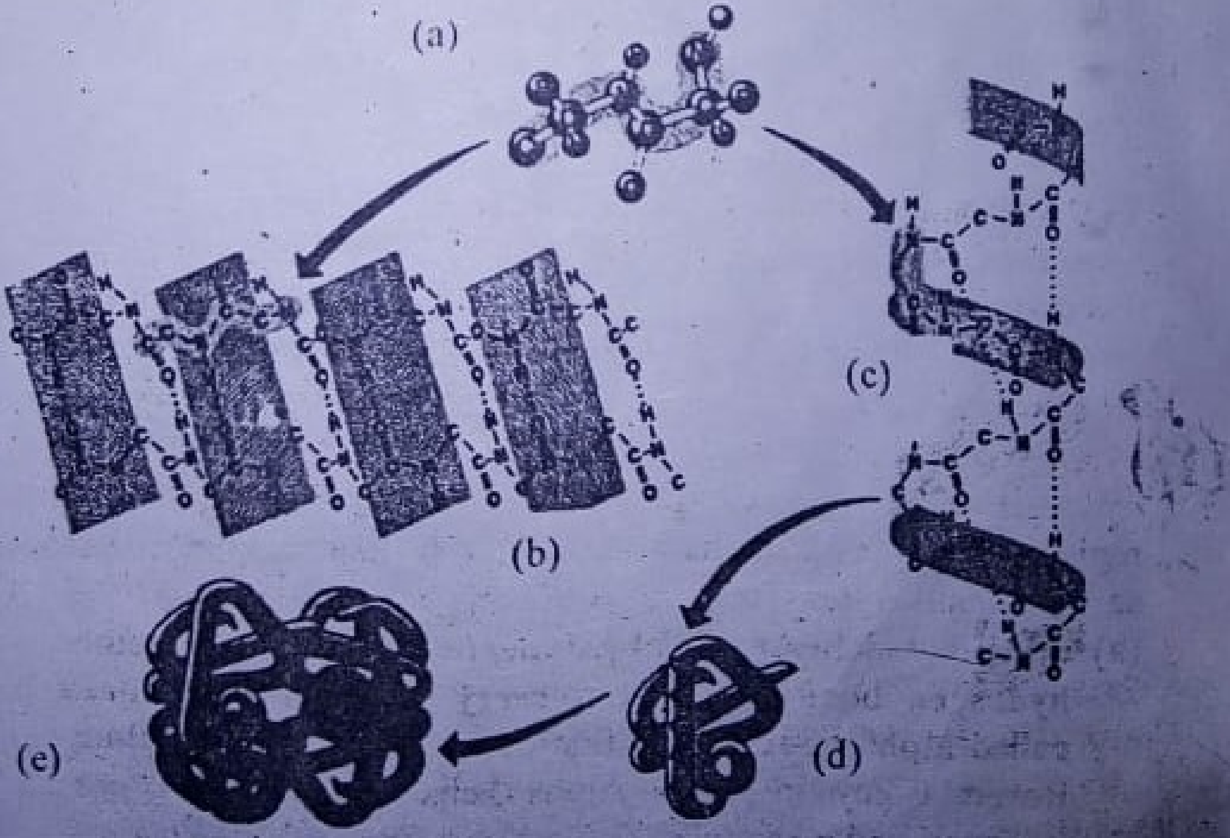


Fig: Three levels of protein structures (a) Primary structure (b) Beta pleated sheet, (c) Alpha helix, (d) Tertiary structure, (e) Quaternary structure

Levels of Protein Structures

Each type of protein contains a specific number and kind of amino acids. These amino acids are arranged in a particular sequence. The protein molecule may be coiled and folded. They may interact with other protein molecules and form a unique three dimensional structure. Different kinds of protein molecules have different shapes. Their shapes are related to their particular functions in life processes. A protein molecule has several different levels of structure.

1. Primary structure

The linear sequence of amino acids in the polypeptide chains is called primary structure. For example **lysozyme** is an antibacterial enzyme. It is present in tears, saliva and other body secretions. Lysozyme is a small protein. It is only composed of 129 amino acids. The primary structure is like order of letters of very long word. The sequence of amino acids in protein is specific. Slight change in primary structure can affect protein conformation and ability to function. Its example is sickle cell anemia. In this case, only one amino acid is not in its proper position. It is unable to perform its function normally. First primary structure was determined by Frederick Sanger. He determined the sequence of insulin hormone.

2. Secondary structure

The structure formed by folding or coiling of polypeptide chain with the help of hydrogen bonding is called secondary structure. The secondary structure of a protein is formed by a repeating pattern of bonds (hydrogen bonds) between amino acids. The hydrogen atom attached to nitrogen develops weak electronegative charge. This hydrogen develops affinity for nearby peptide bond. Thus a weak hydrogen bond is formed. Many such bonds are repeated over long region of polypeptide chain. Such bonds can support particular secondary structures. These structures are:

(a) **α helix: A delicate coil of polypeptide chain held together by hydrogen bonding between every fourth peptide bond is called alpha helix.** It was first described by Linus Pauling and Robert Corey in 1951. Alpha helix is formed in enzyme lysozyme and α keratin.

(b) **Pleated sheet: A sheet of polypeptide chain formed by the folding back and forth of the polypeptide chain is called β pleated sheet.** In this case, two regions of the chain lie parallel to each other. Hydrogen bonds between the two regions hold the structure together. The β sheet forms dense core of many globular proteins. Most of the fibrous proteins have β pleated sheet in their secondary structure. The examples of fibrous proteins are silk and fibroin.

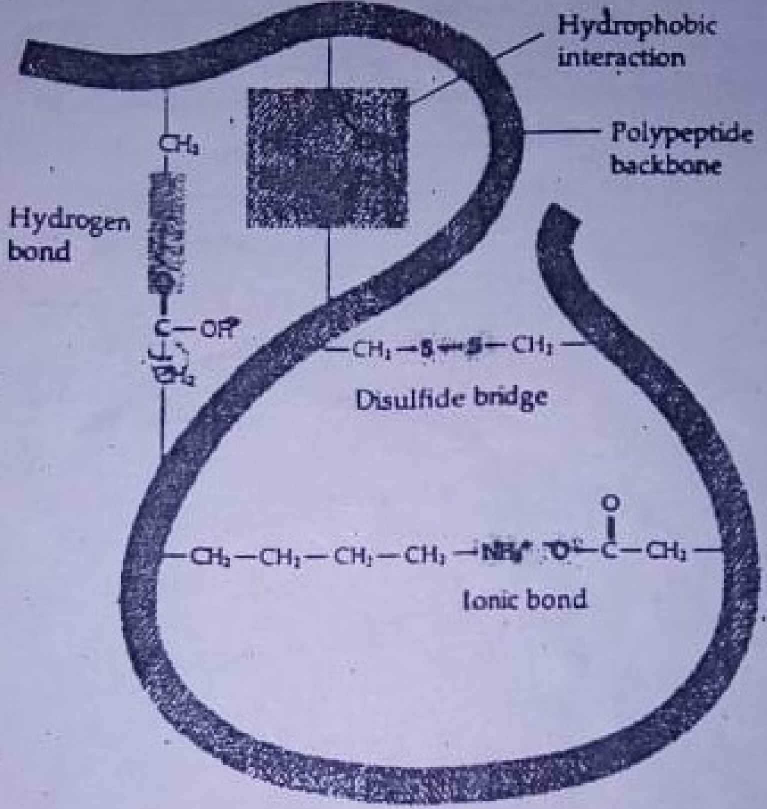


Fig: Formation of disulphide bridge

3. **Tertiary structure**

The structure of protein formed by folding of helix or sheet into a three dimensional shape is called tertiary structure. In this case, irregular bonding occurs between side chains of amino acids. Two types of forces are involved in the formation of tertiary structure of protein:

(a) **Hydrophobic interactions:** The most important bonding occurs due to hydrophobic interactions. Hydrophobic interactions are caused by behavior of water molecules. The amino acids of polypeptide with hydrophobic side chains collected at the core of protein. They are now out of contact with the water. These side chains form clusters and weak hydrogen bonds are formed between them. The groups of such large number of hydrogen bonds keep the structure intact.

(b) **Disulphide bridge:** Disulphide bridge is formed between two **cysteine** amino acids of polypeptide chain. The amino acids with sulfhydryl groups on their side-chains are called cysteine amino acids. The sulfur of one cysteine bonds to the sulfur of second cysteine and disulphide bridge is formed.

4. **Quaternary structure**

The structure formed by the aggregation of two or more polypeptide chains is called quaternary structure. The aggregation of such polypeptide chain forms one functional macromolecule. Each polypeptide chain is called **subunit** of protein. These subunits give rises to quaternary structure. The example of ~~tertiary~~ structure is collagen and hemoglobin.

(a) **Collagen:** Collagen is a fibrous protein. It has helical subunits. These subunits supercoil into a large triple helix. It forms a rope like structure. It gives the fiber great strength.

(b) **Hemoglobin:** The quaternary structure of hemoglobin is composed of four subunits. The subunits are composed of two kinds of polypeptide chains: Two α chains and two β chains.

Types of protein

Proteins are classified into two categories on the basis of their structures. These are globular proteins and fibrous proteins

(a) **Globular protein**

Globular proteins or **spheroproteins** are one of the two main protein classes. It is composed of globelike proteins that are more or less soluble in aqueous solutions. They form colloidal solutions in water. The spherical structure is induced by the proteins' primary structure. The non-polar groups are bounded towards the interior of the molecule. But the polar ones are bounded outwards. It allows dipole-dipole interactions with the solvent. It causes solubility their water. Globular proteins can act as:

1. Enzymes.
2. Messengers, by transmitting messages to regulate biological processes. This function is done by hormones, i.e. insulin etc.
3. Transporters of other molecules throughout membranes.
4. Stocks of amino acids.
5. Among the most known globular proteins is hemoglobin. It belongs to member of the globin protein family.
6. Immunoglobulins (IgA, IgD, IgE, IgG and IgM), and alpha, beta and gamma globulins.

(b) **Fibrous proteins**

Fibrous proteins are also called **scleroproteins**. These are long filamentous protein molecules that form one of the two main classes of tertiary structure protein. Fibrous proteins are only found in animals.

Fibrous proteins form rod or wire like shapes. These are usually structural or storage proteins. They are water-insoluble. These are found as an aggregate due to hydrophobic R-groups. The amino acid sequences are not repeated in them. These can form unusual secondary structures, e.g. collagen triple helix. The structures often contain cross-links between chains, for example disulfide bonds between keratin chains. Fibrous proteins are used to construct connective tissues, tendons, bone matrix and muscle fiber. Examples of fibrous proteins include keratins, collagens and elastins.

(a)

Collagen, a fibrous protein

(b)

Myoglobin, a globular protein

Functions of protein

Proteins have following physiological functions:

1. **Proteins as structural material:** Proteins are structural material for the animals and plants. Proteins form the major part of the dry weight of animals and plants. Proteins are major part of the all the membranous system of cell.
2. **Energy source:** Although proteins does not acts as fuel for body but still proteins provide energy to body. Protein is broken down into amino acids during digestion. Then deamination of these amino acids takes place. Ammonia is released and different compounds are formed. These compounds enter into respiratory pathways (Glycolysis and Krebs cycle) at different points.

4. **Defense of body:** Proteins are used against disease in higher animals. Antibodies and interferon are proteins in nature. They defend the body from the attack of bacteria and viruses.
5. **Proteins as chemical messengers:** Proteins act as chemical messengers (hormones). Some of the hormones like insufin and glucagons are protein in nature.
6. **Receptors on cells membrane:** Proteins combine with glucose to form glycoprotein. These glycoproteins are attached on the cell membrane. They act as receptors on cell membranes.
7. **Enzymes** Some proteins act as enzymes. Enzymes play important roles in metabolic reactions. They enter and speed up specific chemical reactions.
8. **Reserve food:** Most part of the fruits and vegetable is composed of proteins. Thus proteins act as storage compounds. **Albumin** is stored in egg white. It is major source of amino acids for developing embryo. **Casein** is present in milk. It is source of amino acids for baby mammals.
9. **Structural fibers:** Most of the structural fibers of plants and animals are protein in nature.
10. **Contractility:** Most proteins are involved in contractility. For example **dynein** in cilia and flagella, **tublin** in spindle fibers, actin and myosin in muscles.

NUCLEIC ACID

Nucleic acid is polymer of nucleotides.

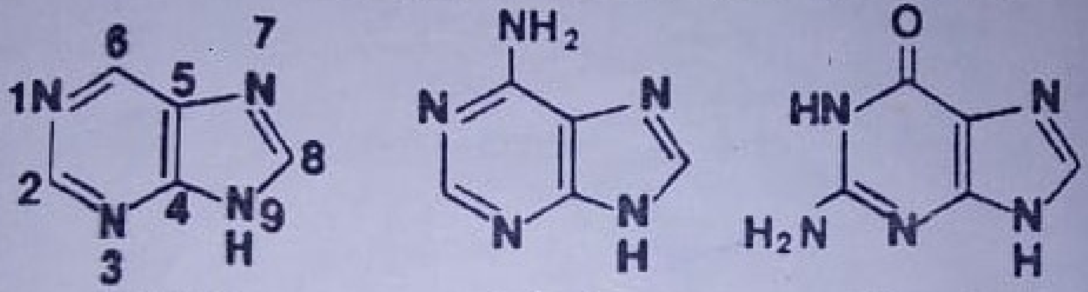
Discovery

A German Chemist, Friedrich Miescher, discovered Nucleic in 1869. He discovered DNA only four years after the publication of Mendel's work. Miescher extracted a white substance from the nuclei of human cells and fish sperm. He called this substance **nuclein** as it was associated with the nucleus. The nuclein was acidic in character. So the nuclein was called nucleic acid.

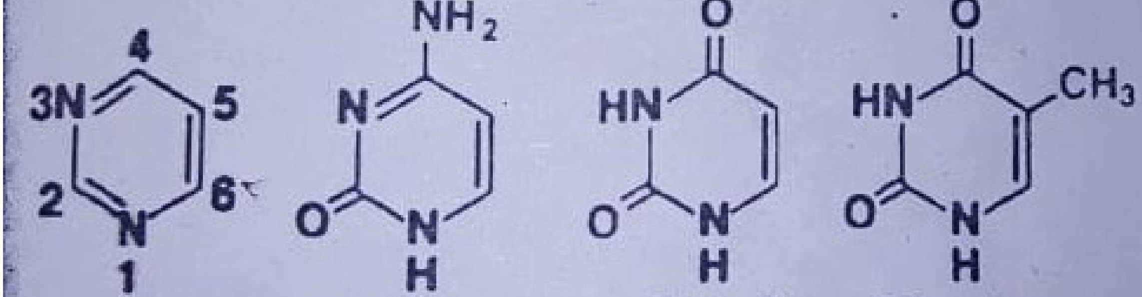
Research revealed its significance in the last half of the 20th cent. RNA was first made by laboratory synthesis in 1955. In 1965 the nucleotide sequence of tRNA was determined. In 1967 the synthesis of biologically active DNA was achieved. The amount of RNA varies from cell to cell. But the amount of DNA is normally constant for all typical cells of a given species of plant or animal.

Significance

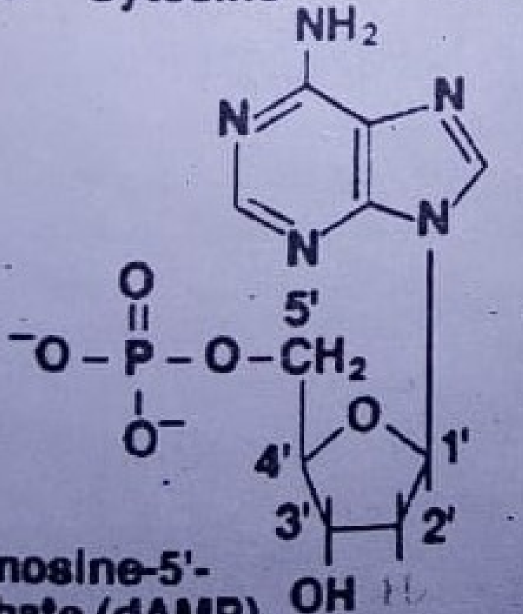
... found in the chromosomes of living cells and iruses. They play a central role in the storage and replication of hereditary information and in the expression of this information hrough protein synthesis. In most organisms, nucleic acids occur in ombination with proteins. The combined substances are called ucleoproteins. Nucleic acid molecules are complex chains of arying length. The two chief types of nucleic acids are DNA deoxyribonucleic acid). DNA carries the hereditary information rom generation to generation. RNA (ribonucleic acid) delivers the nstructions to the cell's protein manufacturing sites (ribosome).



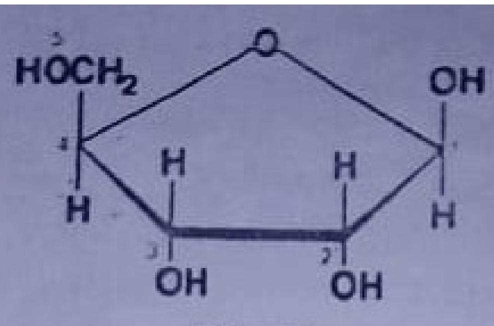
Purine Adenine Guanine



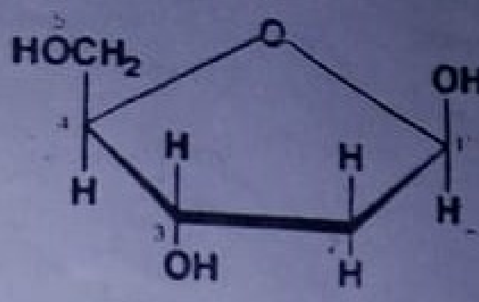
Pyrimidine Cytosine Uracil Thymine



Deoxyadenosine-5'-
onophosphate (dAMP)



Ribose



Deoxyribose

Chemical composition

P.A. Levene determined the basic structure of nucleus acid in 1920's. Nucleic acid molecules are made of repeating units calle **nucleotide**. He found that nucleotide contains three mai components:

(a) Phosphate (PO_4 groups)

(b) Five carbon sugars: ribose and deoxyribose

(c) Nitrogen containing bases. There are two types of bases:

- **Purines:** These are adenine, A, and guanine, G
- **Pyrimidines:** These are thymine, T and cytosine, C, RN contains uracil, U instead of T.

Erwin Chargaff proved that the amount of adenine in DN always equals the amount of thymine. Similarly amount c guanine always equals the amount of cytosine. Thus there always equal proportion of purine (A+G) and pyrimidine (C+T).

Bonding in Nucleic acid

Nitrogen base is attached to carbon number 1 of a pentose sugar nucleotide. Phosphate group is attached to carbon number 5 of th sugar. A free hydroxyl (OH) group is attached to the 3' carbon ator The 5' phosphate and 3 hydroxyl groups react chemically with eac other. A covalent bond is formed between them. It links tw nucleotides. This reaction releases a water molecule. So it is calle **dehydration reaction**. It allows DNA and RNA to form long chai of nucleotides. The phosphate group is linked to the two sugars by pair of ester (P-O-C) bonds. Thus the linkage between tw nucleotides is called a **phosphodiester bond**. The two unit polym of this reaction still has a free 5' phosphate group at one end and free 3' hydroxyl group at the other. Thus it can link to oth nucleotides. In this way, many thousands of nucleotides join togeth in long chains. Linear strands of DNA or RNA always have a free 5' phosphate group at one end and a free 3' hydroxyl group at the other.

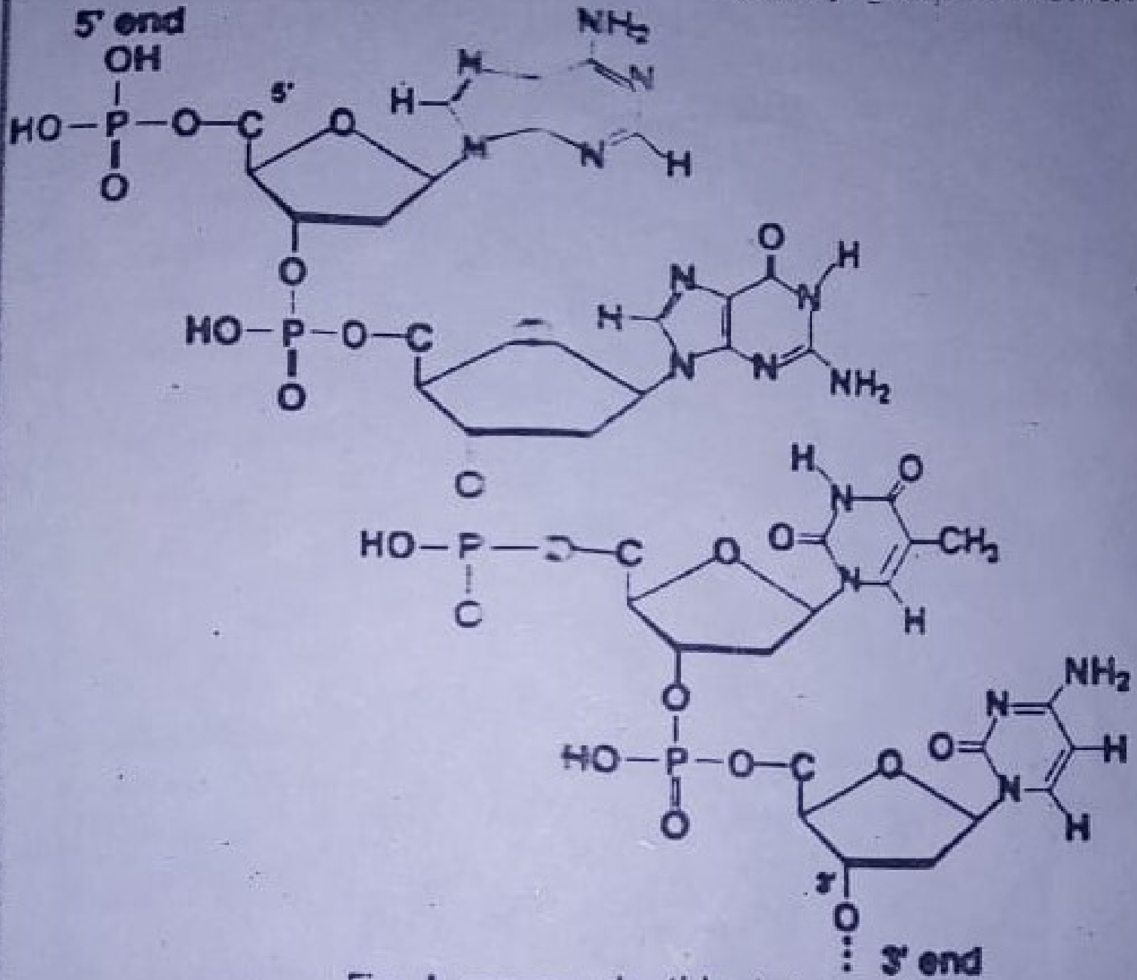


Fig: A polynucleotide chain

Types of nucleic acids

There are two types of nucleic acids: DNA and RNA

DNA (DEOXYRIBONUCLEIC ACID)

The nucleic acid polymer of deoxyribonucleotides is called DNA. DNA is hereditary material. It is present in nucleus. A small amount of DNA is also present in mitochondria and chloroplasts. DNA has following four important characteristics:

1. It is a genetic material. It codes for the sequence of amino acids in proteins and control protein synthesis.
2. It replicates itself before cell division.
3. It is present in the nucleus of eukaryotic cells.
4. It can change over time for evolutionary changes.

Chemical composition of DNA

DNA is polymer of deoxyribonucleotides. It contains four nitrogen bases: Adenine, guanine, thymine and cytosine. Uracil is absent in it.

Similarly it contains deoxyribose. Deoxyribose is deficient in on oxygen atom at carbon number 2. DNA is composed of tw polynucleotide chains. DNA contains genes. Each gene contro specific characteristics. DNA is composed of four types of nucleotides:

(i) d-adenosine monophosphate (**d-AMP**).
(ii) d-guanosine monophosphate (**d-GMP**).
(iii) d-cytidine monophosphate (**d-CMP**).
(iv) d-thymidine monophosphate (**d-TMP**).

The nucleotides are linked with one another by **phosphodieste** bonds and form a long chain. This chain is called **Polynucleotid chain.** This chain has a specific sequence. There may be differe lengths of nucleotide chain. **Erwin Chargaff** provided a data abo the ratio of different bases of DNA molecule. It shows that adenin and Thymine have equal ratio and guanine and cytosine have equ ratio.

Function of DNA: The information carried by a given gene is code in the sequence of nucleotides. These nucleotide sequence determine the sequences of amino acids in the polypeptide chain o the protein. There are long portions of DNA called **satellite DN** between the genes of DNA of higher organisms. Satellite DNA co no proteins. Sometimes junk DNA occurs within a gene. In this cas the coding portions are called **exons** and the noncoding (jun portions are called **introns**. Junk DNA makes up 97% of the DNA the human genome. Little is known of its purpose.

Double helix model of DNA (Watson and Crick model)

It was discovered in 1950s that covalent bonds are present in nucleic acid. The scientists started work on discovery of the thre dimensional structure of DNA. **Watson and Crick** proposed th model of DNA:

1. The DNA is helical in shape. It is made up of two strands.
2. The helix has a uniform width of 2 nm.
3. Its nitrogenous bases are 0.34 nm apart. Ten layers of base pai are present on each turn of the helix.
4. The phosphate groups were present outside the helix. But th nitrogenous bases are present in the interior of the double helix.
5. The double helix is a ladder like. It has rigid rungs. Its ladd twists in a spiral fashion. The side ropes are the equivale sugar—phosphate backbones. The rungs are pairs of nitrogeno

bases.

6. Franklin's X-ray data indicate that the helix makes one full turn after every 3.4 nm of its length.
7. The pairing of the nitrogenous bases is complement. Adenine pair with thymine (T) and guanine (C) with cytosine. Adenine and Guanine are larger bases. They have two ringed structures. They are called **purine** base. On the other hand, the cytosine and thymine are **pyrimidine** bases. They have single ring. In this way one purine and one pyrimidine combination keep the diameter of the DNA uniform.
8. Both strands of the DNA are anti parallel. One strand is in 5 – 3 direction. The other strand is in 3 – 5 strands.
9. The helix of DNA has two grooves. One is major groove and the other minor groove. Both These grooves alternate with each other.

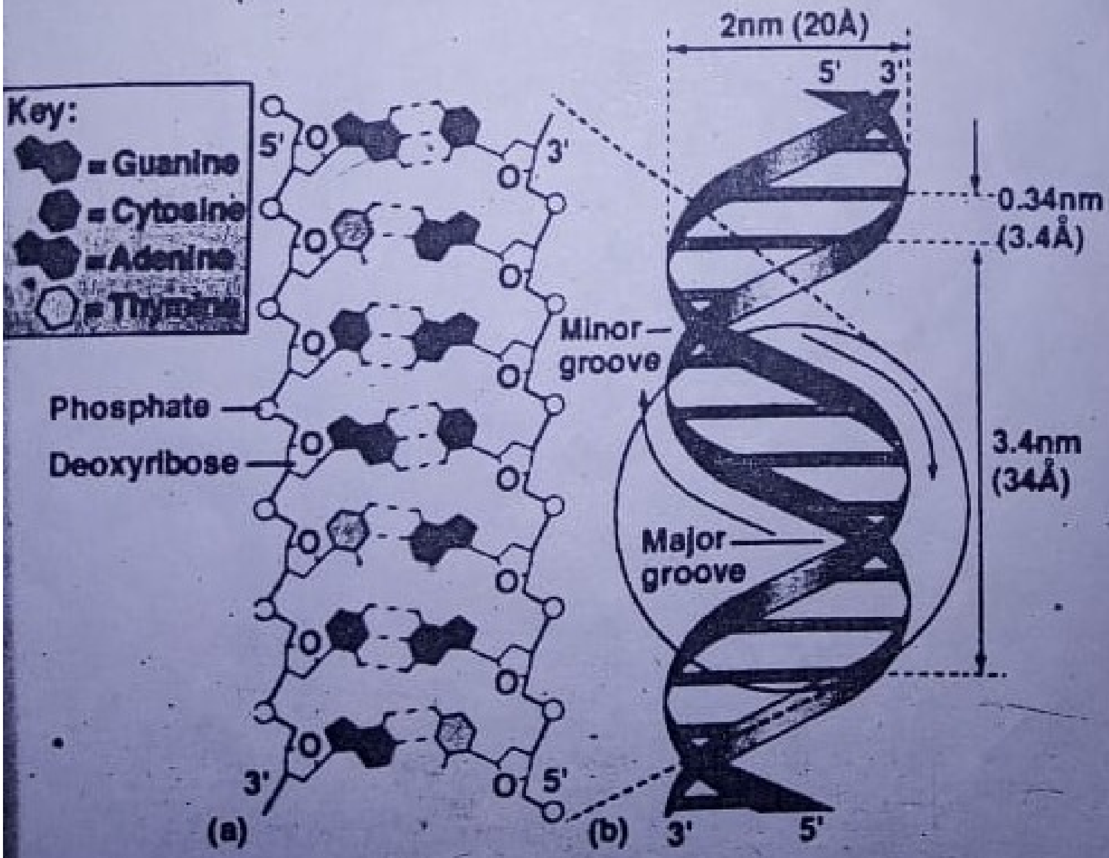
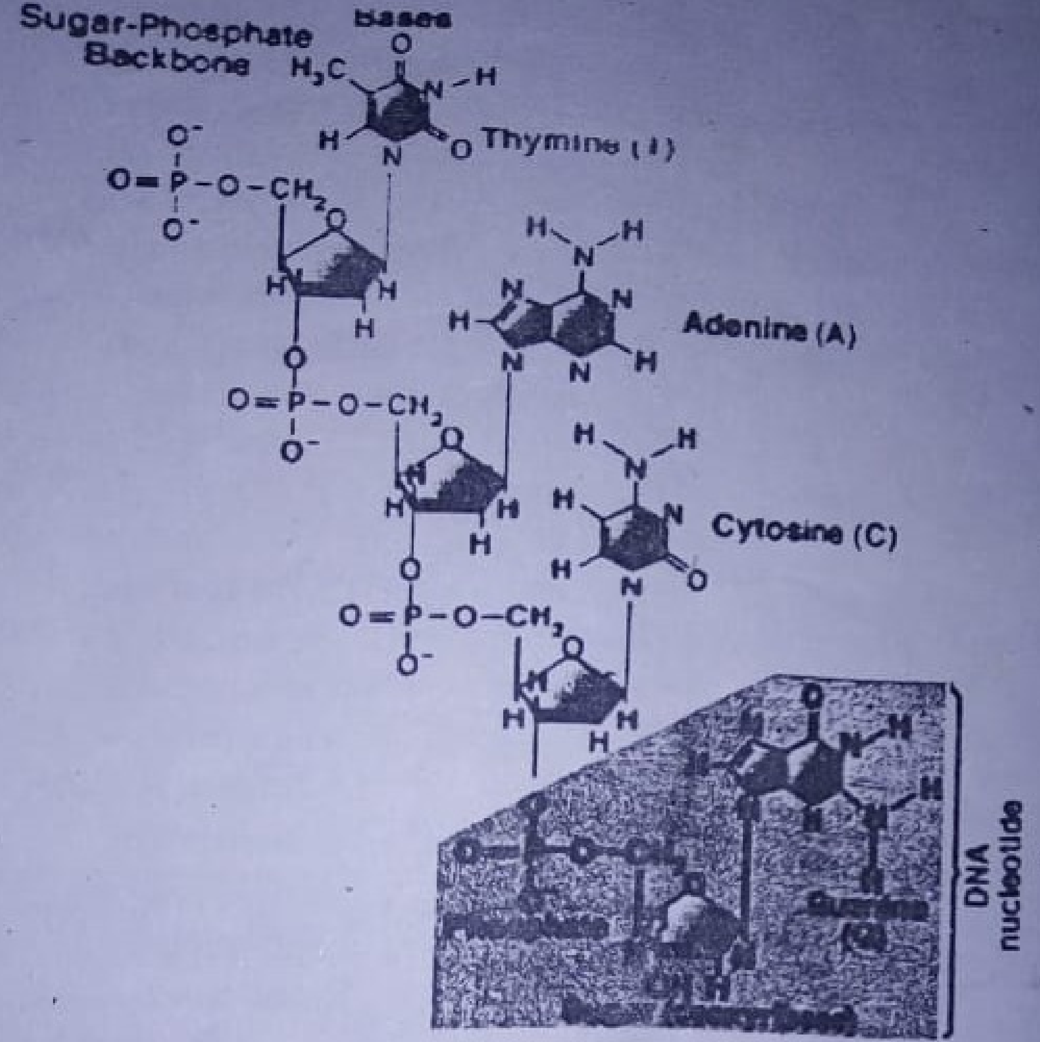


Fig: Watson and Crick model of DNA



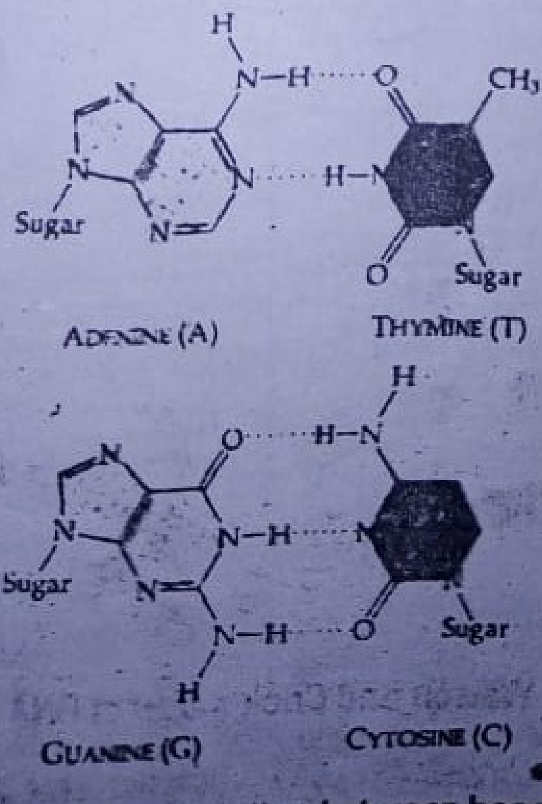


Fig: Hydrogen bonding between base pairs

RNA (RIBONUCLEIC ACID)

The polymers of ribonucleotides are called RNA. The RNA molecule has single strand. Sometimes, this strand may fold back to give double helical characteristics. The nitrogenous bases form complementary pairings. RNA have nitrogenous base Uracil in place of Thymine. Cytosine (C) forms pair with Guanine (G) and Uracil (U) forms pair with Adenine (A). DNA synthesizes RNA. **The process of synthesis of RNA from DNA is called transcription.**

Types of RNA

There are three main types of RNA. These are messenger RNA (mRNA), transfer RNA (tRNA) and ribosomal RNA (rRNA). All three types of RNA are synthesized from DNA in nucleus. After their synthesis they are transferred to cytoplasm. All three RNA (mRNA, tRNA and rRNA) interact with each other. They synthesize proteins from the genetic information (gene).

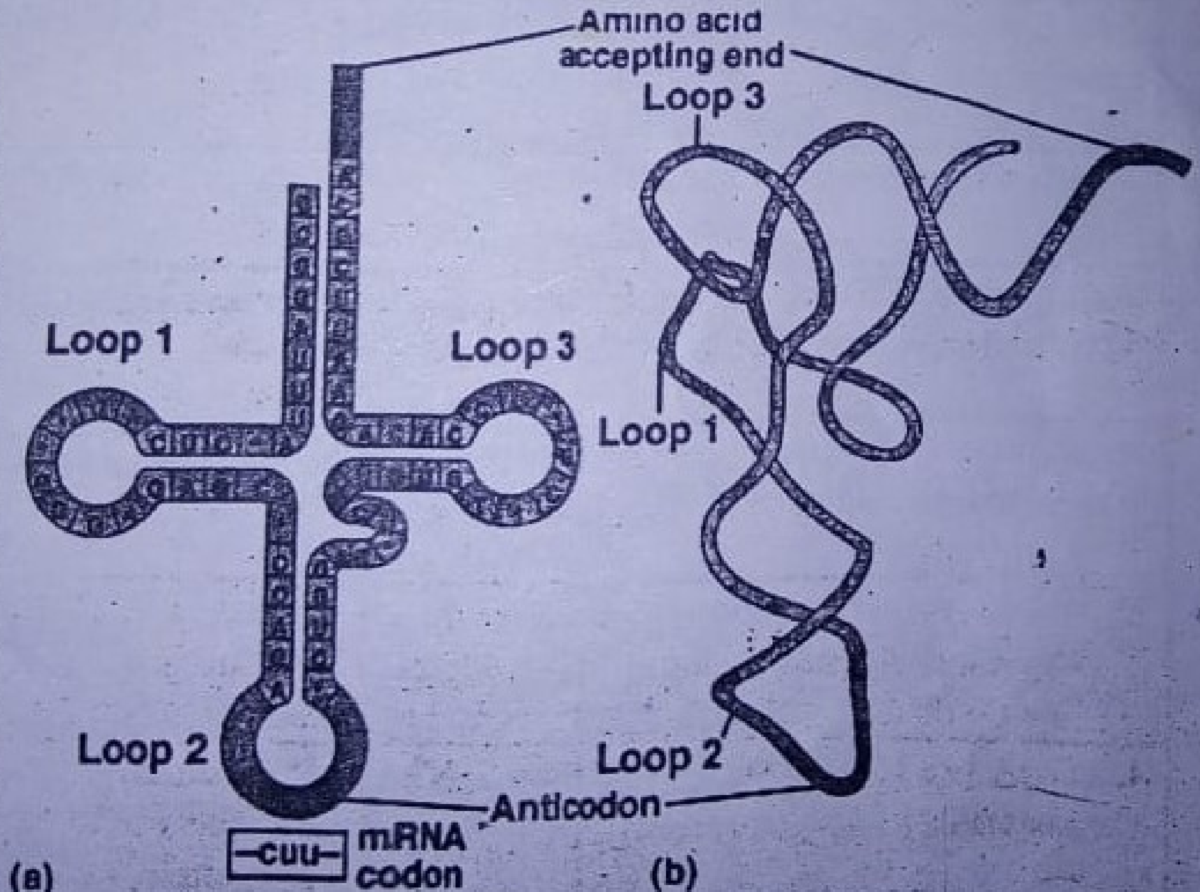


Fig: Structure of tRNA

(a) Messenger RNA (mRNA)

The mRNA brings genetic message from nucleus to the ribosome. The mRNA is about **3 to 4%** of the total RNA in the cell. The ribosomes are present in the cytoplasm for the synthesis of the particular protein. DNA transfers its genetic information to mRNA.

Now, this mRNA has genetic information for the synthesis c specific protein. This mRNA; attaches with the ribosome fc synthesis of protein. The mRNA consists of single strand of variabl length. Its size depends on size of gene (on DNA) for the specifi protein. For example, the mRNA has 3,000 nucleotides for a protei of 1,000 amino acids.

(b) Transfer RNA (tRNA)

The tRNA reads message (code) on mRNA and transfer specif amino acid to the ribosome. It has clover leaf like structure. It h: anticodes. These amino acids are linked to form polypeptide chain the protein. There is one specific tRNA for each amino acid. So tl cell contains 20 types of tRNA. It forms about **10 to 20%** of the tot cellular RNA. The tRNA has small size. Its chain is composed of to 90 nucleotides.

(c) Ribosomal RNA (rRNA)

The rRNA combines with ribosomal proteins and forr ribosome. Ribosome is made up of rRNA and protein. The rRN forms 50 % of the ribosome. It forms a large part, about **80 %**, total RNA. It acts as machine for the synthesis of protein.

Difference between DNA and RNA

DNA	RNA
1. DNA is composed of double strand	1. RNA is composed of singl strand
2. The pentose sugar is deoxyribose	2. The pentose sugar is ribose
3. The nitrogen bases are Thymine, Adenine guanine and cytosine	3. The nitrogen bases are Uracil , Adenine guanine and cytosine
4. DNA is a hereditary material	4. RNA is not hereditary material. It is used in the synthesis of protein.
5. It is present in nucleus	5. It is present in nucleus and cytoplasm.
6. The synthesis of DNA is called replication.	6. The synthesis of DNA is called transcription.