CARBOHYDRATES

Carbohydrates are widely distributed in plants and animals; they have important structural and metabolic roles. In plants, glucose is synthesized from carbon dioxide and water by photosynthesis. Plants store reserve food as starch while animals as glycogen.

Carbohydrates are aldehyde or ketone darivatives of polyhydroxy alcohols and accordingly known as aldoses or ketoses. A carbohydrate is an organic compound which has the empirical formula $Cn(H_2O)n$; that is, consists only of carbon, hydrogen and oxygen, with a hydrogen: oxygen atom ratio of 2:1 (as in water). The general rule for carbohydrates is one carbon atom for each water molecule and therefore are called as carbohydrates (i.e. watered or hydrated carbon).

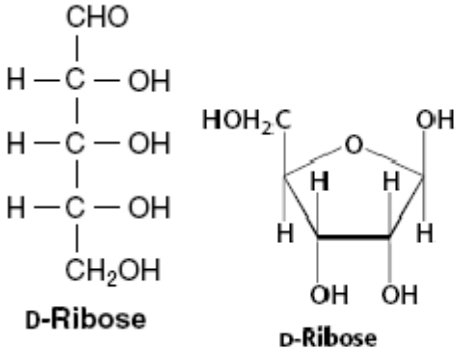
Classification of Carbohydrates

1. **Monosaccharides (2) Oligosaccharides (3) Polysaccharides**

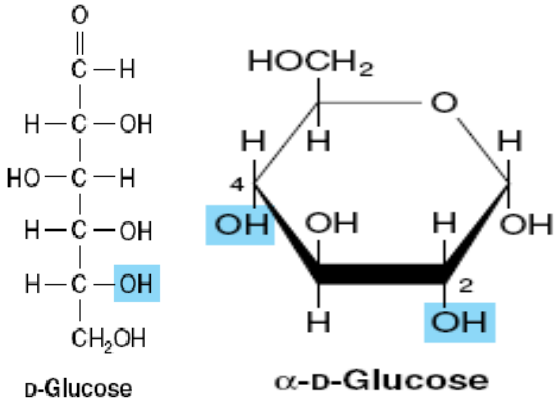
1. Monosaccharides: These are simple sugars. They cannot be hydrolyzed into simpler carbohydrates. Each saccharide or sugar molecule consists of a backbone of carbon atom linked together in a linear manner by single bond. Depending upon aldehyde (-CHO) or ketone (-C=O) group they are termed as aldoses or ketoses. Monosaccharides contains 3 to 7 carbon atoms accordingly they are classified as:

Trioses ($C_3H_6O_3$) - containing 3 carbon atoms in chain e.g. Glyceraldehyde.
Tetroses ($C_4H_8O_4$) - With 4 carbon atoms in chain e.g. Erythrose, Threoses.
Pentoses ($C_5H_{10}O_5$) - With 5 carbon atoms e.g. Ribose, Deoxyribose, Arabinose, Xylose, Xylulose, Lyxose.
Hexoses ($C_6H_{12}O_6$) - With 6 carbon atoms e.g. Glucose, Fructose, Galactose, Mannose, etc.
Heptoses ($C_7H_{14}O_7$) - With 7 carbon atoms e.g. Sedoheptulose.

Pentoses and hexoses occur in two forms i) Open chain form ii) Ring form.



Straight chain Ring form



Straight chain Ring form

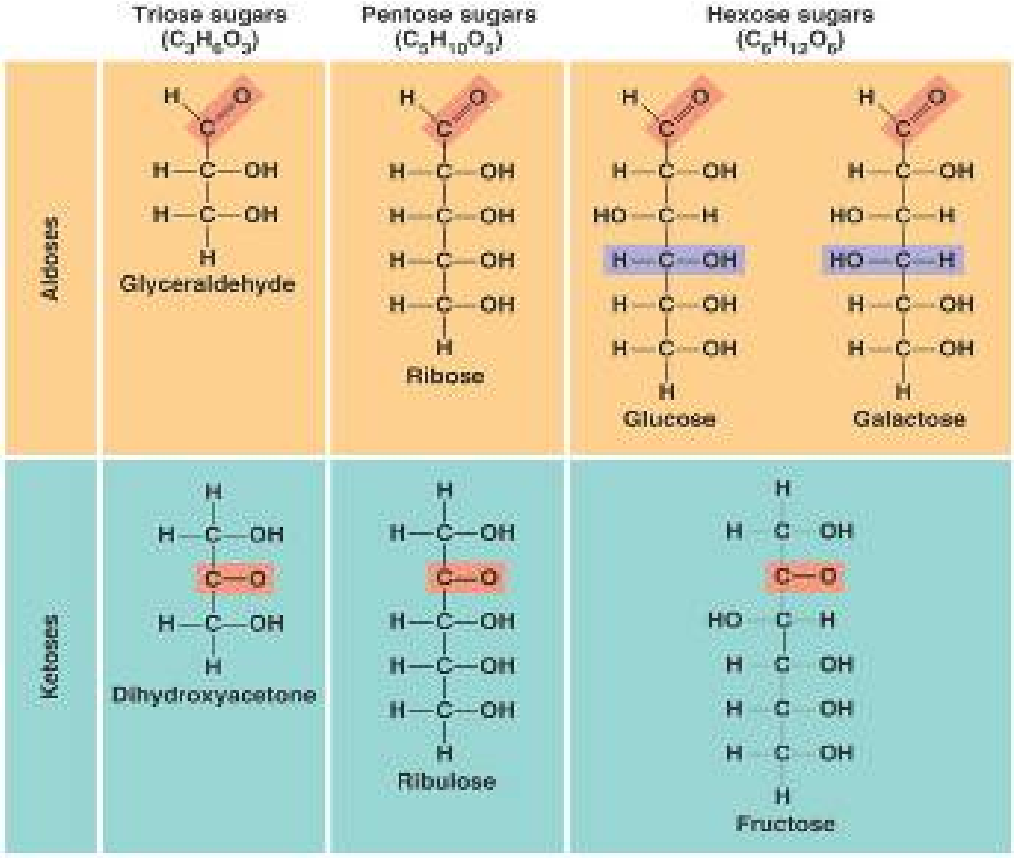
- **Derivatives of Monosaccharides:** Derivatives of Monosaccharides differ from aldoses and ketoses they are as follows:

i) Glycosides: OH on C-1 replaced by other radicals e.g. Methyl glucosides and galactosidases.

ii) Sugar phosphate: C-1 or C-6 of glucose reacts with phosphoric acid. E.g. Glucose-1-phosphate and Glucose-6-phosphate.

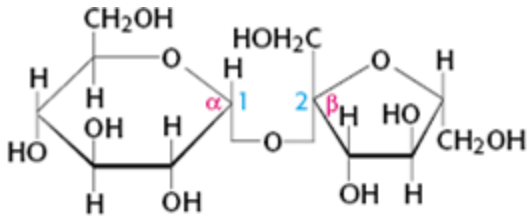
iii) Glucoronic acid: C-1 or C-6 glucose is oxidized.

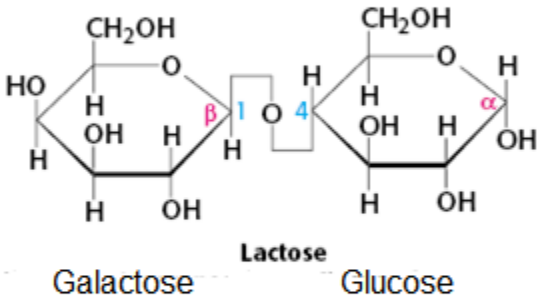
iv) Amino Sugars (Hexosamines) : Amino group is introduced in to hexoses e.g. Glycoproteins, Gangliosides, & Glycosaminoglycans, Neuraminic acid, Sialic acid etc.

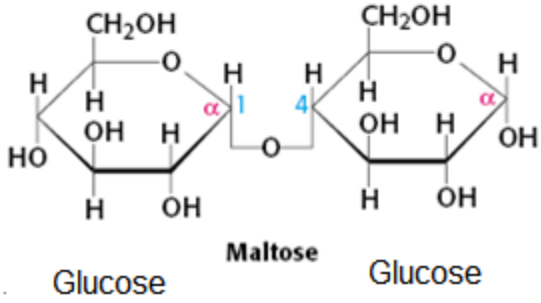


Properties of Monosaccharides:

1) Monosaccharides are sweet in test and colorless solids.
2) They are soluble in water and partially soluble in alcohols.
3) The presence of asymmetric carbon atoms also confers **optical activity** on the compound. When a beam of plane-polarized light is passed through a solution of these sugars (**optical isomer),** it will be rotated either to the right, dextrorotatory (D-); or to the left, levorotatory (L−).
4) These sugars undergo oxidation or reduction when treated with oxidizing or reducing agents.
5) Esterification of hydroxyl group is carried out by acetylating agents.







6) Glucose and fructose undergoes alcoholic fermentation by micro-organisms.

(2) Oligosaccharides: These are formed of two to nine monosaccharides i.e. a sugar molecule can combine with another identical or different type of sugar molecule. These are sweet, crystalline and soluble in water. Linkage between two molecules is the glycosidic linkage or glycosidic bond. A sugar molecule has several hydroxyl groups. The hydroxyl group of C-1 is known as glycosidic hydroxyl and forms glycosidic linkage with hydroxyl group of other sugar molecule. The process of formation of glycosidic bond is called condensation or dehydration during which one H^+ and one OH^- group are eliminated to form H_2O. On hydrolysis they dissociates in to monosaccharides.

<u>Oligosaccharides are of following types:</u>

Disaccharides : A *disaccharide* consists of two sugars joined by an *O*-glycosidic bond. Three abundant disaccharides are sucrose (cane sugar), lactose (milk sugar) and maltose (Malt sugar).

Trisaccharides : These have three monosaccharides e.g. Raffinose, Mannotriose, Rabinose, Rhaminose, Gentianose and Melezitose.

Tetrasaccharides: with four monosaccharide units e.g. Stachyose, Scorodose.

Pentasaccharides: With five monosaccharides e.g. Verbascose.

(3) Polysaccharides: These are polymers of ten or more than ten monosaccharide units. They may contain 10 to thousands of monosaccharide units and hence they have high molecular weight. They are insoluble in water and form branched or unbranched linear molecules.

Polysaccharides are named after their monosaccharide monomers by changing –ose to –an. E.g. Cellulose formed of glucose units is Glucan. Likewise fructose as fructane and pentose as pentane and so on.

Polysaccharides are of following types

A) Homopolysaccharides: They are formed of similar types of monosaccharides. They are as follows:

i) Starch: It is a homopolymer of glucose and forms α-glucosidic chain, called a glucosan or glucan. It is the most important storage form of carbohydrates in plants. It is abundant in carbohydrate in cereals (rice, wheat & corn), potatoes, legumes, banana and other vegetables. It is a end product of photosynthesis and stored as starch grains. The two main constituents are **amylose** (15–20%), which has a nonbranching helical structure and **amylopectin** (80–85%), which consists of branched chains composed of 24–30 glucose residues united by 1→4 linkages in the chains and by 1 →6 linkages at the branch points.

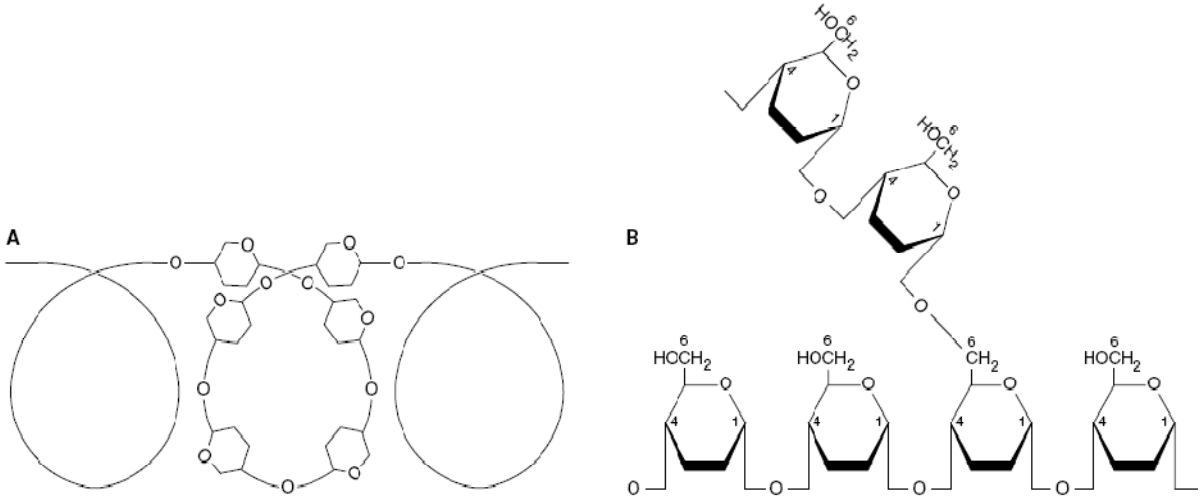


Figure 13–12. Structure of starch. **A:** Amylose, showing helical coil structure. **B:** Amylopectin, showing 1 → 6 branch point.

ii) Glycogen: It is major carbohydrate reserve in animals and therefore named as animal starch. It is a more highly branched structure than amylopectin and more soluble than starch. It is mainly stored in the liver cells and muscles. It is also present in fungi and yeast.

iii) Inulin: It is a polysaccharide of fructose (called as fructosan) found in tubers and roots of dahlias, artichokes, and dandelions. It is readily soluble in water.

iv) Cellulose: It is fibrous , tough and protective structural component of cell wall of plants. It is insoluble in water and consists of β-D-glucopyranose units linked by β(1→□4) bonds. The linear chain of cellulose forms long and highly tensile fibres that form bundles celled microfibrillae.

v) Pectins: Abundant in fruits, particularly in the rim of citrus fruits like orange and lemon.

vi) **Agar:** It is carbohydrate obtained from seaweeds. It is a galactan consisting of both D and L galactose.

B) Heteropolysaccharides: These are monosaccharides with amino-nitrogen, sulphuric acid or phosphoric acid or with proteins. They are:

i) **Neutral sugars:** These are polysaccharides of N-acetyl glucoseamine monosaccharides in which –OH group is replaced by $-NH_2$ group. They include hemicelluloses, gums, mucilage and pectic substances. Chitin is a structural polysaccharide in the exoskeleton of crustaceans and insects and also in mushrooms.

ii) **Acidic heteropolysccharides or mucopolysaccharides:** These are complex carbohydrates characterized by their content of amino sugars, uronic acids and their derivatives. Important of them are hyaluronic acid, chondroitin sulphate and heparin. They are found in the matrix of connective tissue, skin, synovial fluid of joints, blood, etc.

iii) **Muccoprotein and glycoprotein:** Acetyl glucosamine, monosaccharides and proteins combines to form heteropolysaccharides. They include gastric mucosa, serum and albumin.

Biological significance of carbohydrates:

1. Source of energy: Carbohydrates are storage substances of potential energy in mammals. Among the monosaccharides trioses, tetroses, pentoses hexoses and sedoheptulose are biologically important.
2. Glucose is the fuel of cell since it supplies immediate energy needed by the cells. It is sole form of energy for the brain and other nervous tissues. Glycogen is storage product of animals while starch is storage product of plants.
3. Structural component: Carbohydrates form important structural components of living organisms. Ribose sugar is the component of RNA and deoxyribose of DNA. Monosaccharides are important constituents of coenzymes, flavoproteins, lipids, conjugated proteins, etc. oligosaccharides are important in glycolipids and glycoproteins of plasma membrane. They help in cell to cell contact and also to surrounding.
4. Hyaluronic acid forms the viscous matrix of connective tissue. Heparin prevents clotting of blood. Chondroitin sulphates are found in cornea, cartilage, tendon, skin, heart valves and saliva.
5. Cellulose forms major component of cell wall of plants and polysaccharides in the capsule of bacteria.
6. Monosaccharides serves as monomers or building blocks of oligosaccharides and polysaccharides.
7. Metabolism: Degradation products of carbohydrates are utilized for synthesis of fatty acids, cholesterol, aminoacids, etc. Degradation products

also acts like catalysts. When there is deficiency of carbohydrates in diet fats and proteins are utilized for supplying energy.

8. Intermediate products of photosynthesis such as Glyceraldehyde, Ribulose and heptoses are involved in glucose synthesis.
9. Carbohydrates such as cellulose, hemicellulose and pectins are indigestible. Such fibers provides roughage to food and helps in peristaltic movement of intestine.
10. Intestinal bacteria growing on lactose synthesize B-complex vitamins.

PROTEINS

Introduction

Proteins occupy the first position among all organic compounds. They form two-third part of total dry weight of cell. *Proteins* are the most versatile macromolecules in living systems and carryout important functions in all biological processes. They function as catalysts, they transport and store other molecules such as oxygen, they provide mechanical support and immune protection, they generate movement, they transmit nerve impulses, and they control growth and differentiation.

Chemical nature

Proteins are composed of Carbon, Hydrogen, Oxygen and Nitrogen. Some protein also contain sulphur or phosphorus. Proteins are linear polymers having molecular weight from 12000 to several thousand daltos. Bacteria contain about 1000 to 2000 proteins while Human cells contain about 100,000 proteins.

Proteins are linear polymers composed of monomer units called amino acids. Amino acids are the building blocks of proteins. There are twenty different aminoacids, they are organic acids and amphoteric nature i.e. acidic as well as basic. An *amino acid* consists of a central carbon atom, called the *a-carbon,* linked to an amino group ($-NH_2$) which is basic, a carboxylic acid group (–COOH) which is acidic, a hydrogen atom, and a distinctive R group. The R group is often referred to as the *side chain.* With four different groups connected to the tetrahedral α-carbon atom hence α-amino acids are *chiral.*

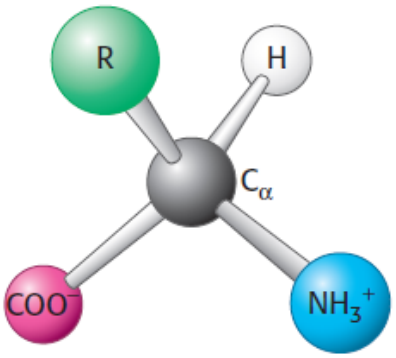
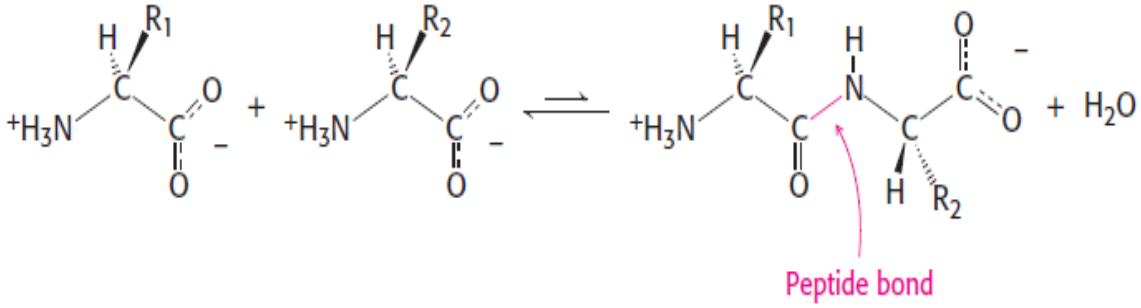


Fig. Amino acid

Linear polymers formed by linking the α-carboxyl group of one amino acid to the α-amino group of another amino acid with a *peptide bond* (also called an *amide bond*). The formation of a peptide from two amino acids involves liberation of a water molecule. The bond results from linkage between amino group (–NH_2) of first amino acid and carboxylic acid group (–COOH) of next amino acid. A series of amino acids joined by peptide bonds form a *polypeptide chain,* and each amino acid unit in a polypeptide is called a *residue. A polypeptide chain has polarity as its one* end amino group called as N-terminus and another end contains an carboxyl group at the other called as C-terminus.



Structural organization of protein-

Proteins shows different levels of organization:

Primery structure- Consist of sequence (chain) of amino acid.

Secondary structure- the α-helix (alpha helix) and the β-pleated sheets (beta pleated sheet).

Tirtiary structure- Proteins containing more than one polypeptide chain. Each polypeptide chain in such a protein is called a *subunit. Quaternary structure-* It refers to the spatial arrangement of subunits. Dimer is a quaternary consisting of two identical subunits.

Classification Of proteins:

On the basis of structure proteins are classified as Simple and conjugated proteins.

I Simple Proteins:

These proteins consists of only amino acids and their derivatives. On hydrolysis they yield only amino acids or their derivatives. These are Globular and Fibrous type.

A) Simple globular proteins: These are spherical or ovoid in shape, with definite molecular weight. Depending upon solubility they are again classified as water soluble and water insoluble proteins.

a) Water soluble:

i) Albumin- Found in both plant s and animal, coagulate on heating, they are water soluble and precipitated by dilute acid or alkali. E.g. Egg white albumin, Blood serum albumin, Leucin wheat protein, lactalbumin (milk protein) etc.

ii) Histones- These are rich in basic amio acids (e.g. Arginin and Lysin) and found associated with nucleic acid (DNA).
iii) Protamines- These are low molecular weight, basic and found in DNA of sperms of some fishes (e.g. Salmine in Salmon and Sturine in Sturgeons).
iv) Pseudoglobulin- Present in milk whey.

b) Water insoluble:

i) Gilobulins- These are water insoluble and soluble in strong acids and bases. E.g. Vitellin of egg yolk, Fibrinogen of blood plasma, Myogen and myosinogen of muscle, legumins of pods, tuberin of potato and edestein of wheat etc.
ii) Glutelins- Soluble in dilute acids or bases and found in plant seeds e.g. wheat.
iii) Prolamine- soluble in 70-80% alcohol. E.g. Gliadin of wheat, Zein of maize, Hordein of barley etc.

B) Simple fibrous protein: These long fibers and water insoluble proteins. These are found in animals and functions as structural and protective proteins.

a) Keratin: It is skin derives and indigestible and found in nails, hair, horns, wool, hoofs and feathers.
b) Collagen: It is present in skin and bones. Collagen also is present in connective tissues such as ligaments and tendons. It is converted into a tough substance when treated with tanic acid.
c) Elastin: It is yellow elastic fiber of connective tissue, tendons and arteries.
d) Myosin: Major protein of muscle.
e) Fibroin: Silk protein.

II Conjugated Proteins:

These are simple proteins (Apo-protein) combined with non-protein group (Prosthetic group) and forms Holoprotein. Groups are as follows.

A) Nucleoproteins- Here simple basic proteins such as protamine/histone combines with nucleic acids (prosthetic group) to give Nucleohistones.
B) Glycoproteins- Here protein combines with carbohydrates (amount of carbohydrate is less than 4%). E.g. plasma glycoprotein (Liver), Thyroglobin (Thyroid gland), Immunoglobulin (Plasma B Cell), etc.
C) Mucoproteins- Here protein combines with Mucopolysaccharides (amount of carbohydrate is more than 4%). E.g. Hyaluronic acid, Chondroitin sulphate.
D) Chromoprotein- Here proteins combine with colored pigments. E.g. respiratory pigments (Haemoglobin, haemocyanine, cytochormes, Rhodopsin (rods of eyes), catalase, peroxidase, etc.
E) Phosphoprotein- Here protein combines with phosphate containing radicals. E.g. Caesin of milk and ovovitellin of egg.

F) **Lipoprotein-** Here protein combines with lipid. E.g. Lecithin of egg and Cephalin of blood.

G) **Mettalloprotein-** Theay contain metal ions as prosthetic group. Several enzymes contain metal ions such as Fe, Co, Mn, Zn, Cu, Mg, etc. E.g. Ferritin contain Fe, Carbonic unhydrase (Zn) and ceruloplasmin (Cu).

- **Derived proteins:** These are products of simple or conjugated protein obtained as a result of hydrolysis or coagultion.

Metaprotein- Derived by hydrolysis by enzymes, acids or alkalies e.g. Proteoses, peptones.

Coagulated proteins- Coagulated or denatured proteins are obtained after heating of protein.

Biological significance of protein:

1. **Structural proteins:** Proteins are the building materials of the cells and tissues. It form structural component of plasma membrane along with lipids. They form connective tissue in the form of collagen, elastin and reticulin. They form Horney layer of skin, scales, feather, hoof etc. Microtubules form cilia, flagella and spindle fibers. Actin and myosin are proteins of muscles.
2. **Enzymes:** All enzymes are proteins which are biological catalyst which increase the rate of reaction. More than 2000 enzymes control physiological activities of cells and called functional proteins.
3. **Hormones:** Several hormones are proteins which regulates metabolic and reproductive functions.
4. **Defense mechanism:** Immunoglobulin or antibodies form first line of defense against bacterial or viral infections.
5. **Transport proteins:** Some proteins are carriers e.g. Haemoglobin of blood carry O_2 from lung to tissue and CO_2 from tissue to outside.
6. **Storage proteins** are present in milk, egg, seeds for nourishment of young once.
7. **Buffer action:** Proteins combine with acid and bases to maintain the pH. They also regulate the electrolyte and water balance.
8. **Visual pigments** Rhodopsin is present in rods and iodospin in cones.
9. **Receptor protein** present on cell membrane are essential for hormone action, pollination and recognition of signal.
10. **Toxins** such as snake venom, bacterial toxins, Blood clotting protein (thrombin and fibrinogen), regulators of gene expression all are protein in nature.

LIPIDS

These are very important group of organic compound found in both plants and animals. The lipids are a heterogeneous group of compounds, including fats, oils, steroids, waxes, and related compounds, which are greasy substances. (1) relatively **insoluble in water, (2) They are nonpolar (uncharged) biological molecules** and (3) **soluble in nonpolar solvents** such as ether, petroleum ether, benzene and chloroform etc. . They are important dietary constituents not only because of their high energy value but also because of the fat-soluble vitamins and the essential fatty
acids contained in the fat of natural foods.

- Chemically they are esters of different types of alcohols.

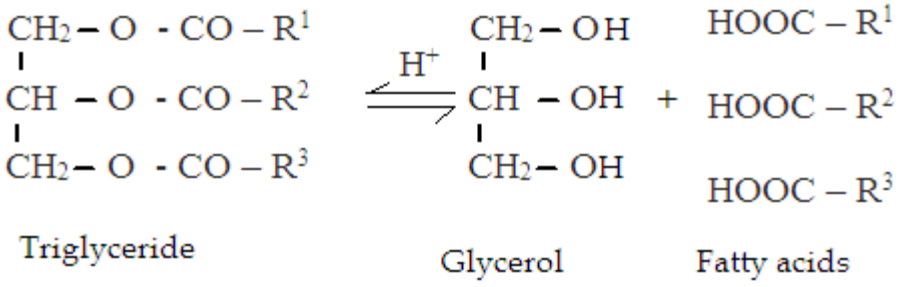
Lipids are compounds of Carbon, Hydrogen and oxygen in ratio 1:2:1. High proportion of Hydrogen in fat signifies that they are less oxidized than carbohydrates. Therefore they release more energy almost double than carbohydrates.

Classification of lipids

Lipids are classified as 1. Simple lipids 2. Compound lipids 3.Derived lipids

1. Simple lipids: Simple lipids are compounds of fatty acids and alcohols (i.e. Esters of fatty acids with various alcohols). Fatty acids are building blocks of lipids. Fatty acids are long unbranched hydrocarbon chain (-CH) having a single carboxyl group at one end. These are bipolar/amphipathic because of nonpolar (hydrophobic) hydrocarbon chain and polar (hydrophilic) carboxyl group.

E.g. Triglyceride- One molecule of glycerol (alcohol) combines with three fatty acid chains with **ester bond** and the process of bond formation is **esterification**. Its hydrolysis gives 3 fatty acids and glycerol.



Simple lipids are of two types

i) Neutral fats ii) Waxes

i) Neutral fats- These are esters of fatty acids with glycerol. They are lighter than water and exist in liquid state (called as Oils) as well as solid state (called as fats). When fatty acids of triglyceride are identical they are simple (e.g. tripalmitate) and when fatty acids are not identical they are mixed type (e.g. Butter). Fatty acids which form fat are classified as Saturated and Unsaturated fatty acids.

(1) In saturated fatty acids Carbon chain varies from 14-20 carbons, Each carbon atom is provided with two hydrogen atom and they without double bond.

E.g. Stearic acid

CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-$(CH_2)_7$-COOH

18 1

(2) Unsaturated fatty acids consists of odd or even number of carbon atoms, they may or may not provided with two hydrogen atoms and they consists of one or more double bonds in carbon atoms.

E.g. Oleic acid.

CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH =CH-$(CH_2)_7$-COOH

18 10 9 1

Saturated Fatty Acids		**Unsaturated Fatty Acids**
1.	All Carbon atoms are linked by single bond	At one more places carbon atoms are joined by double bond
2.	All carbon atoms bear two hydrogen except at end with –COOH group	Carbon atoms with double bond do not contain two hydrogen atoms
3.	Straight chain compounds	They have kink at double bond region
4.	Melting point is higher	Melting point is lower
5.	Solid at room temperature e.g. Animal Fat	Liquid at room temperature e.g. Plant oils

ii) Waxes: These are found in animal tissues. These are esters of fatty acids with higher molecular weight monohydric alcohols (Other than glycerol). They have fully reduced hydrocarbons. They are highly insoluble in water, chemically inert and resistant to atmospheric oxidation. E.g. Water resistant protective covering on insects, birds and furred animals (Linonin).Bee wax secreted by Honey bee. Spermaceti is a storage fat in sperm whale.

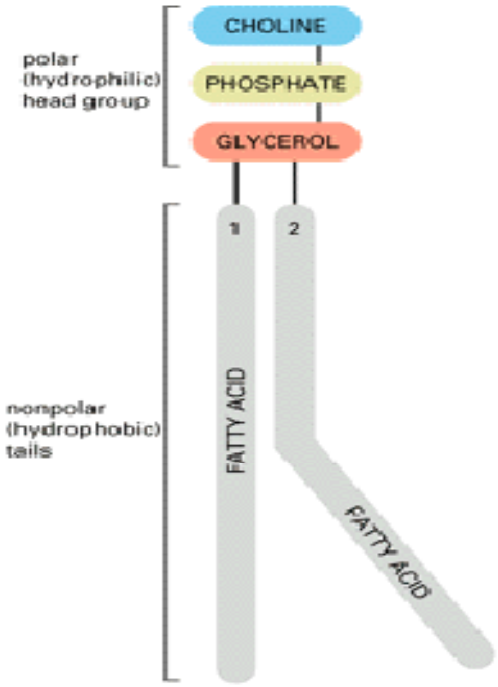
2. Complex lipids: These are esters of alcohol and fatty acid containing additional groups such as phosphate group or Carbohydrates or proteins. They are-

a. **Phospholipids (Phosphatides):** These are **l**ipids containing, in addition to fatty acids and an alcohol, a phosphoric acid residue.

i) **glycerophospholipids-** They have glycerol backbone, two fatty acids and phosphoric acid group. Parent compound is Phosphatidic acid which gives lecithin, Cephalin and Plasmalogen.

- Lecithin- They abundant in animal tissues. It consists of Cholin. Egg yolk is rich in lecithin which is important in permeability, osmotic tension and surface condition of cell.
- Cephalin- Cholin is replaced by Amino ethanol radical. It is a blood clotting factor.

- Plasmologen- It contains enol form of long chain aldehyde connected by ether-linkage.



i) **Sphingophospholipids-** Here **glycerol is replaced by** sphingosine. Ii is abundant in myelin sheath of nerve fibers.

b) Glycolipids (glycosphingolipids): Lipids containing a fatty acid, sphingosine (alcohol), and carbohydrate. E.g. Cerebrosides (conatins galactose) present in myelin sheath grey matter of brain) and gangliosides (Contains ceramide and acts as antigen).

c) Sulpolipids: These are sulphuric esters of sphingosine cerebronic acid and galactose.

d) Lipoproteins: These are complexes of lipid and proteins.

Fig. Phospholipid Molecule e.g. Lecithin.

3. Derived lipids: These derivatives of simple and complex lipids. These are cyclic forms. E.g. Sterols and Steroids.

- Sterols- Sterols are wax like solid found in animals. Cholesterol, an amphipathic lipid, is an important component of membranes. It is the parent molecule from which all other steroids in the body, including major hormones such as the adrenocortical and sex hormones, D vitamins, and bile acids, are synthesized.
- Steroids- Steroids are hormones e.g. androsteron, estrogen, progesteron.
- Prostaglandins- These derived fatty acids are found in seminal fluid, kidney, testis, placenta etc. These are local mediators of inflammation.
- Bile acids- These are catabolic products of cholesterol. E.g. Cholic acid, Deoxycolic acid and lipocholic acid.
- Terpenes- These are present in essential oils produced by plants. E.g. Camphor, Menthol, Eucaluptus and liminence.

Biological significance of lipids-

1. Lipids are energy rich which contains about twice the energy content of carbohydrates. Carbohydrates are short term and lipids are long energy sources.
2. Because of insolubility lipids are stored as a reserve food in body.
3. Fats deposited in the subcutaneous tissue acts as a insulator and conserve heat.
4. Along with proteins, lipids form structural component cell (Plasma membrane).
5. They acts as a solvent for fat soluble vitamin (Vit. A, D and E).
6. Cholesterol is a precursor for synthesis of steroid hormones e.g. Corticoids, Sex hormones and Cholic acid.
7. Phospholipids are essential in transport of fatty acids.
8. Fats from animals and plants are used in preparation of cosmetics, paints etc.