### 3. Ribosomal RNA

It is the most abundant type of RNA. rRNA has a complex irregular structure. It provides the site where polypeptide chains are assembled.

### Differences between DNA and RNA

1. DNA is double stranded molecule while RNA is a single stranded molecule.
2. DNA consists of A, T, G and C and absence of U, while RNA consists of A,U, G and C and absence of T
3. Sugar molecule in RNA is ribose, while in DNA it is deoxyribose.

### Nucleotides other than those found in nucleic acids

ATP, $NAD^+$, $NADP^+$, FAD

**Functions of ATP**

- Universal energy carrier

**Functions of $NAD^+$**

- Act as a coenzyme
- Act as an electron carrier
- Function as an oxidizing agent during respiration

**Functions of $NADP^+$**

- Act as coenzymes
- Act as an electron carrier
- $NADP^+$ act as an oxidizing agent in photosynthesis

**Functions of FAD**

- Act as a coenzyme
- Act as an electron carrier
- Act as an oxidizing agent

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# Chemical Basis

## Unit 02

## INTRODUCTION TO BIOLOGY

## Resource Book

Sampath Lankadheera

https://advanceonlineclass.com

# 02

## Chemical and cellular basis of life

### Elemental composition of living matter

There are ninety two elements recognized in nature. Of which, about 20-25% elements are essential to continue healthy life and reproduction. (about 25-elements are essential for humans and about 17 for plants).

Oxygen (O), Carbon (C), Hydrogen (H), and Nitrogen (N) make up 96% of living matter.

Calcium (Ca), Phosphorous (P), potassium (K) and sulphur (S)- make up most of the remaining 4% of the mass of the organism. In addition to these, Na, Cl ,Mg, B, Co, Cu, Cr, F, I and Fe are also found in minute amounts in living matter.

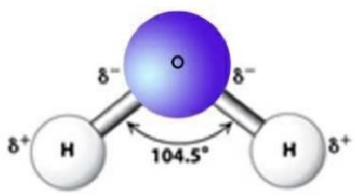
### Physical and chemical properties of water important for life

Water is a vital inorganic molecule; life could not exist on this planet without water. It is important due to following reasons,

1. Vital chemical constituent of living cell
2. Provides a biological medium for all organisms

Physical and chemical properties of water molecule provide the ability to render the vitality.

**Chemical nature of water molecule**




δ+ partial positive

δ-partial negative

*Fig 2.1: Chemical structure of the water molecule*

Water molecule is a small, polar and angular molecule.Polarity is an uneven charge distribution within a molecule. In water molecule, oxygen atom is slightly negative and hydrogen atom is slightly positive. Weak attractions between the slightly polar hydrogen atom of one water molecule and the slightly polar oxygen atom of adjacent water molecule are known as hydrogen bonds.These hydrogen bonds play a major role in maintaining all the properties of water.

### Functions of DNA

- Store and transmit genetic information from one generation to the next generation
- Store the genetic information for protein synthesis

### Structure of RNA

This is normally a single stranded nucleic acid composed of ribo-nucleotides containing bases, Uracil (U), Cytosine (C ), Guanine (G), Adenine (A). Complementary base pairing between two RNA molecules or within the same molecule may occur in some. Complementary base pairing facilitates three dimensional shapes essential for their functioning. Adenine binds with Uracil with two hydrogen bonds and Guanine binds with Cytosine with three hydrogen bonds. There are three types of RNA present in cells,

1. Messenger RNA (mRNA)
2. Transfer RNA (tRNA)
3. Ribosomal RNA (rRNA)

**1. Messenger RNA**

Messenger RNA is a linear molecule and is the least abundant type of RNA in a cells comparatively. There are two functions;

- Copies the genetic information stored in DNA molecule as a sequence of nitrogenous bases
- Transports genetic information from nucleoplasm to the site of protein synthesis (ribosome) through nucleopores

**2. Transfer RNA (tRNA)**

Smallest RNA molecule. Linear, but forms three- looped structure as shown in the diagram.

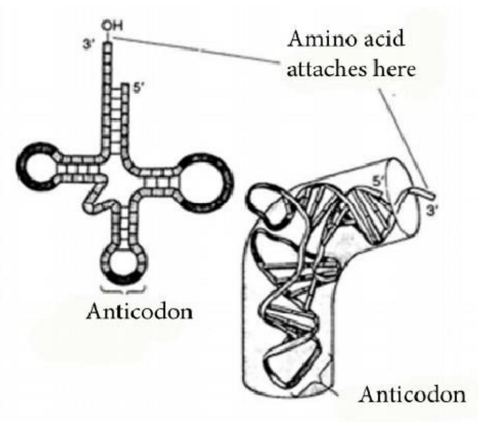



*Fig 2.17: Structure of the tRNA molecule*

**Formation of nucleic acids**

Millions of nucleotides join by phospho-di-ester bond to form polynucleotide chains by condensation between the –OH group of the phosphate of one nucleotide and the –OH attached to 3rd carbon of pentose sugar of the other. These bonds result in a backbone with a repeating pattern of sugar phosphate units. Nucleic acids are linear polymers of nucleotides. There are two kinds of nucleic acids depending on the type of the sugar molecules involved. If the sugar molecule in the nucleotide is deoxyribose,the nucleic acid is (DNA). If the pentose sugar is ribose, then the nucleic acid is RNA. DNA contains Adenine, Thymine, Guanine and Cytosine and RNA contains Adenine, Guanine, Cytosine and Uracil.

**Structure of DNA molecule (Watson and Crick model)**

DNA molecules have two anti-parallel polynucleotide chains that spiral around an imaginary axis, forming a double helix. The two sugar-phosphate backbones run in opposite directions from each other, and the arrangement is referred to as anti-parallel. The sugar phosphate backbones are on the outside of the helix, and the nitrogenous bases are paired in the interior of the helix. The two strands are held together by hydrogen bonds between the paired nitrogen bases.

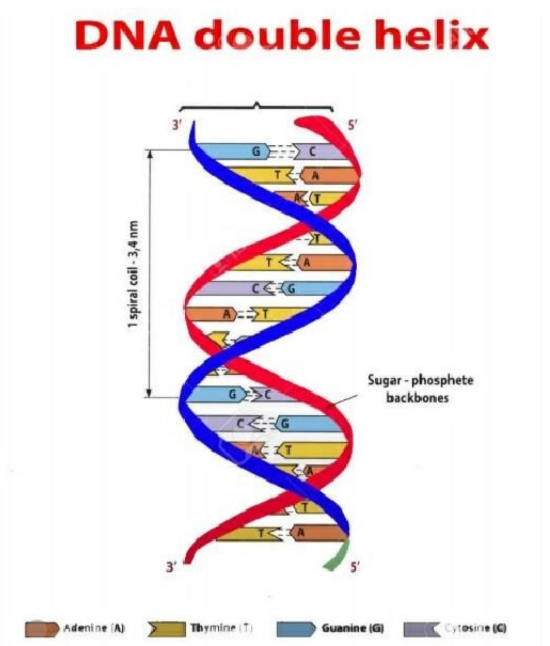
**Base pair rule**

Always a purine base, pairs with a specific,pyrimidine base,

A=T (2 hydrogen bonds)

G≡C (3 hydrogen bonds)

Hence, the strands of the DNA are said to be complementary to each other. These pairs are known as complementary base pairs.In this original double helical structure, one complete turn consists of ten base pairs as shown in the diagram.



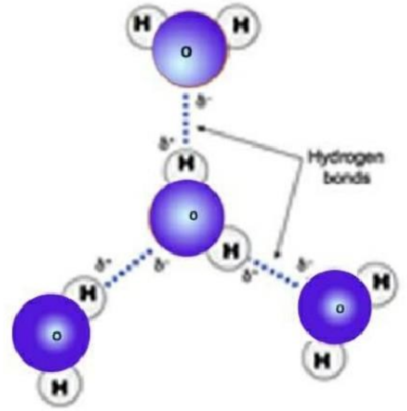




*Fig 2.2: Hydrogen bonding in water*

The properties of water arise due to the hydrogen bonds between different water molecules. When the water is in liquid form its H bonds are very fragile. H bonds form, break and reform with great frequency.

**Physical properties of water**

Four major properties of water to maintain life on earth

- Cohesive behavior
- Ability to moderate temperature
- Expansion upon freezing
- Versatility as a solvent

**Properties of water related to functions**

**1. Cohesive behavior**

Attraction between water molecules due to hydrogen bonding is known as cohesion. Attraction between water molecules and other substances are known as adhesion. Both of the above properties of water allow it to act as a transport medium.

Due to cohesion between water molecules, water and dissolved substances such as minerals are transported as a continuous column through xylem against gravity.

Adhesion between water molecules and cell walls also helps in conduction of water and dissolved substances.

Water has a high surface tension. This ability is given to water molecules, due to cohesion between the water molecules. Therefore, in an aquatic system, upper surface water molecules are attracted by lower surface molecules and it forms a water film. Small insects e.g. water skaters can walk on the surface of a pond.

**2. Ability to moderate temperature**

Water can absorb or release a relatively high amount of heat energy by a slight change in its own temperature.

Due to the high specific heat, water will function as thermal buffer in living system and aquatic bodies during the temperature fluctuations on earth.

Due to the high heat of vaporization, with the minimum loss of water an organism can release much heat energy. This helps the organisms to cool their body surface.

e.g. Prevent from overheating.

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e.g. Prevent from overheating.

Evaporation of sweat from human skin helps to maintain the body temperature at constant level.

Transpiration in plants helps to cool the plant body surface and prevent from becoming too warm in the sunlight.

**3. Expansion upon freezing**

Generally, in an increase in temperature of any substances, reduces their density and on the other hand, in a decrease in temperature increases their density. When the temperature of water falls below 4 ˚C, it begins to freeze and forms a crystalline lattice called ice cubes. Water has the maximum density at 4˚C. Hence, ice floats on the surface of water bodies. It is an important property of water in polar regions, where, organisms in aquatic bodies can survive during the winter.

**4. Versatility as a solvent**

This ability is given to water due to their polarity. Polar molecules (e.g. Glucose), ionic compounds (e.g. NaCl), molecules with both polar and ionic regions (e.g. lysozymes) can dissolve in water. Water molecules surround each of the solute molecules and form hydrogen bonds with them. Therefore, solubility of the solutes depends on polarity and not in their ionic nature.

## Chemical Nature and Functions of Main Organic Compounds of Organisms

### Carbohydrates

Most abundant group of organic compound on earth is carbohydrates. Major elemental composition is C, H, and O. Hydrates of carbon contain the same proportion of H: O which equals to 2:1 as in water. General formula is $C_x(H_2O)_y$ . Three major groups of carbohydrates are monosaccharides, disaccharides and polysaccharides.

Generally carbohydrates include sugars (monosaccharides and disaccharides) and polysaccharides.

### Nucleic acids

Nucleic acids are Polymers exist as polynucleotides made up of monomers called nucleotides. They contain C, H, O, N and P. Nucleic acids are macromolecules, biopolymers. There are two types of Nucleic acids: DNA (Deoxyribo nucleic acids) and RNA (Ribonucleic acids).

### Structure of nucleotides

Nucleotides have 3 components; namely pentose sugar, nitrogenous base and a phosphate group

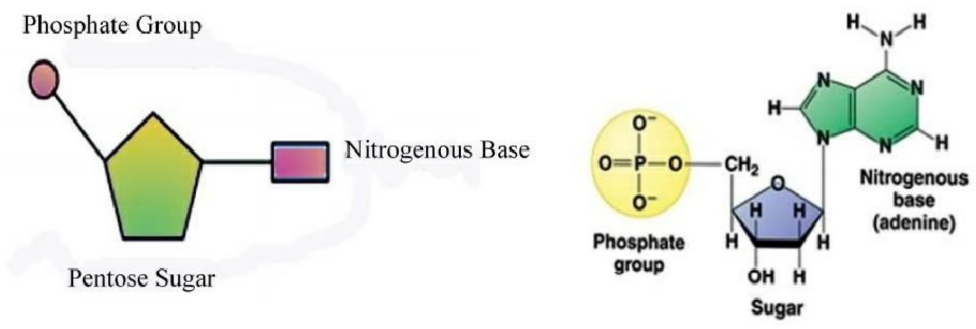



*Fig 2.15: Structure of nucleotides (no need to memorize chemical structures)*

A nucleotide without a phosphate group is called a nucleoside.e.g. Adenosine, Guanosine

### Pentose sugar

Pentose sugars are two types; namely Deoxy ribose and ribose (in deoxyribose one oxygen atom is less than in ribose)

### Nitrogenous bases

There are two major groups of nitrogenous bases:

1. Purines- larger in size with two rings
2. Pyrimidines- smaller in size with a single ring

In purines there are two types; namely Adenine, Guanine. In pyrimidens there are three types, Thyamine, Uracil and Cytocine. Bases are commonly represented by letters A, G, T, U and C respectively.

### Phosphate group

It gives the nucleic acids the acidic nature.

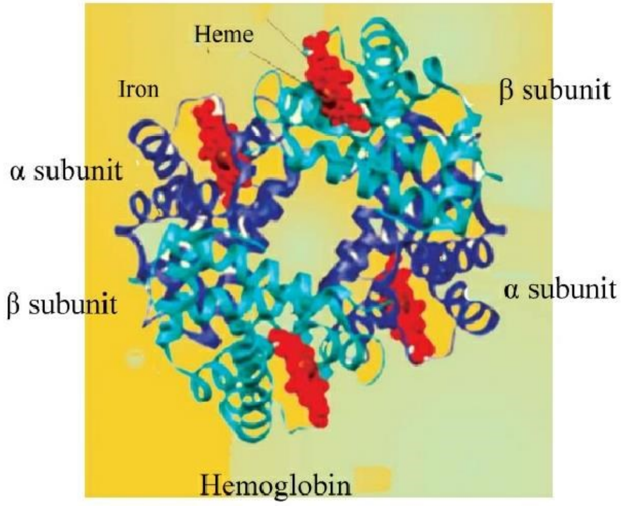



*Fig 2.14: structure of the hemoglobin molecule*

### Denaturation of proteins

Denaturation of protein is the loss of specific three dimensional shape due to the alteration of weak chemical bonds and interactions.

### Agents affecting denaturation

1. High temperature and high energy radiation
2. Strong acids, alkaline and high concentrations of salts
3. Heavy metals
4. Organic solvents and detergents

### Functions of the proteins

**Table 2.2 Functions of Proteins**

| Type of protein | Example | Functions |
|---|---|---|
| Catalytic protein | Pepsin, Amylase | Catalyze biochemical reaction |
| Structural protein | Keratin, | Prevent desiccation |
| | Collagen | Provide strength and support |
| Storage | Ovalbumin | Storage protein in egg |
| | Casein | Storage protein in milk |
| Transport | Haemoglobin | Transport $O_2$ and $CO_2$ |
| | Serum albumin | Transport fatty acids |
| Hormones | Insulin | Regulate blood glucose level |
| | Glucagon | |
| Contractile/ Motor | Actin/Myosin | Contraction of muscle fibres |
| Defensive | Immunoglobulins | Neutralizes foreign bodies |

### Monosaccharides

The simplest form of carbohydrates having general molecular formula as $(CH_2O)_n$ are monosaccharide. The number of C atoms varies from 3-7. All monosaccharide are reducing sugars, water soluble and occur in crystalline form.

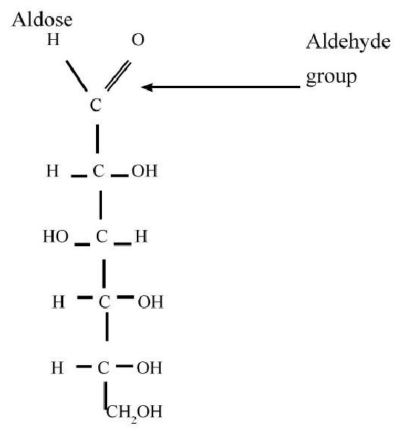
According to the number of carbon atoms, they are named as;

- 3C- Triose e.g. Glyceraldehydes (Phosphoglyceraldehyde is a derivative of Triose)
- 4C- Tetroses. e.g. Erythrose (rare in nature)
- 5C- Pentoses. e.g. Ribose, Deoxyribose, Ribulose (RUBP is a derivative of ribulose)
- 6C- Hexoses e.g. Glucose, Fructose, Galactose

According to the type of carbonyl (Keto, aldo) group, they are classified as;

a. Aldoses-glucose, galactose

b. Ketoses-fructose



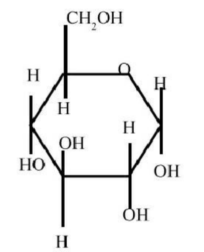
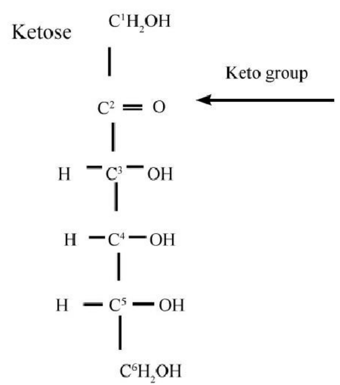



*Fig 2.3: Solid form of glucose*  *Fig 2.4: Aqueous form of Glucose molecule*



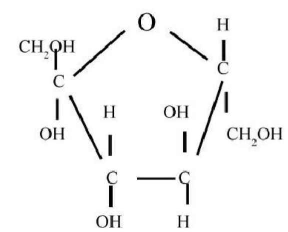



*Fig 2.5: Solid form of fructose*  *Fig 2.6: Aqueous form of fructose*

In aqueous media some monosaccharides are in ring form (No need to memorize the chemical structures)

**Disaccharides**

They are sugars formed by joining two monosaccharides by a glycosidic bond.

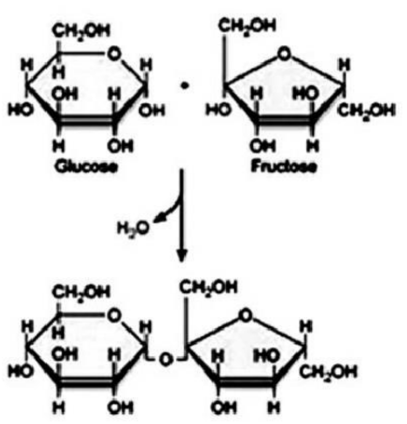



*Fig 2.7: Formation of sucrose*

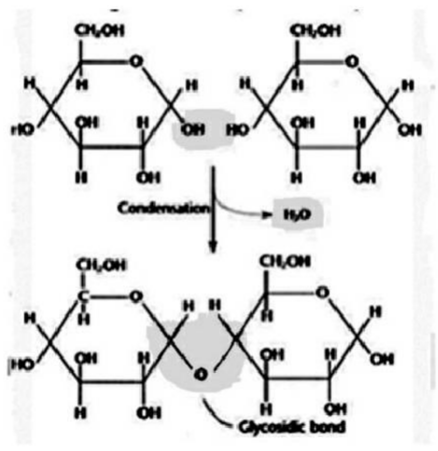



*Fig 2.8: Formation of maltose*

(no need to memorize the chemical structures)

Glycosidic bond is formed by removal of a water molecule from two adjacent monosaccharides by a condensation reaction. Water molecule is formed from OH group of one monosaccharide molecule and H from adjoining monosaccharide molecule.

Glucose + Glucose $\xrightarrow{\text{Condensation}}$ Maltose + $H_20$

Glucose + fructose $\xrightarrow{\text{Condensation}}$ Sucrose + $H_20$

Glucose + Galactose $\xrightarrow{\text{Condensation}}$ Lactose + $H_20$

Maltose and lactose are reducing sugars and sucrose is a non reducing sugar.

**Polysaccharides**

They are macromolecules and biopolymers. Polysaccharides are made up of few hundred to a few thousand monosaccharide subunits

They are non crystalline, water insoluble, and not considered as sugars.

Some polysaccharides act as storage components where others contribute to the structure of living organisms. Based on their function they are categorized as storage polysaccharides and structural polysaccharides.

- Storage- Starch, Glycogen
- Structural- Cellulose, Hemicellulose, Pectin

Based on their architecture they are categorized as

- Linear forms- Cellulose, Amylose
- Branched forms- Glycogen, Amylopectin, Hemicellulose

**a) Primary structure**

The unique sequence of linearly arranged amino acids linked by peptide bonds is the primary structure of proteins.

**b). Secondary structure**

The primary structure of a single polypeptide chain coils and folds, as a result of intra molecular hydrogen bonds between the oxygen atoms of the carboxyl groups and the hydrogen atoms of the amino groups, of the same polypeptide chain backbone, to form the secondary structure. There are two types of secondary structures.

- Alpha helix- e.g.Keratin.
- β pleated sheet e.g.spider's silk fiber

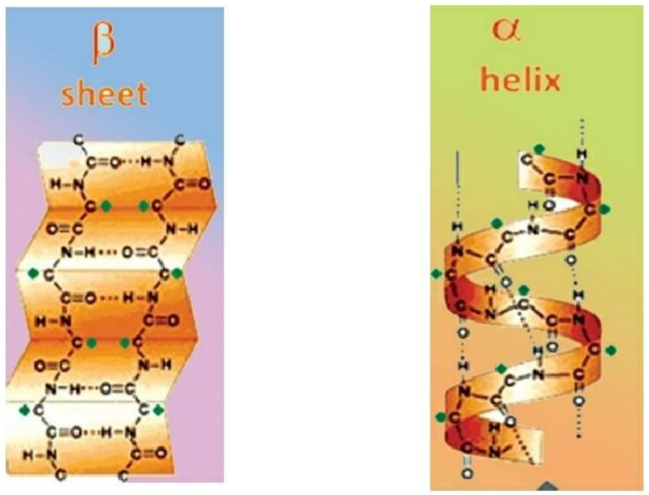



*Fig 2.13: beta pleated sheet and alpha helix of secondary structures of proteins*

**b) Tertiary structure**

Usually the secondary polypeptide chain bends and folds extensively forming a precise compact unique, functional and three-dimensional shape resulting from following interactions between the side chain/ R-group of amino acids;

- H bonds
- Disulphide bonds
- Ionic bonds
- Hydrophobic interactions and Van der Waals interactions

e.g.most of the enzymes, myoglobin, albumin

**c) Quaternary structure**

Aggregation of two or more polypeptide chains involve in the formation of one functional protein. Separate chains are called protein subunits which were held together by inter and intra-molecular interactions.

e.g.Haemoglobin, Collagen

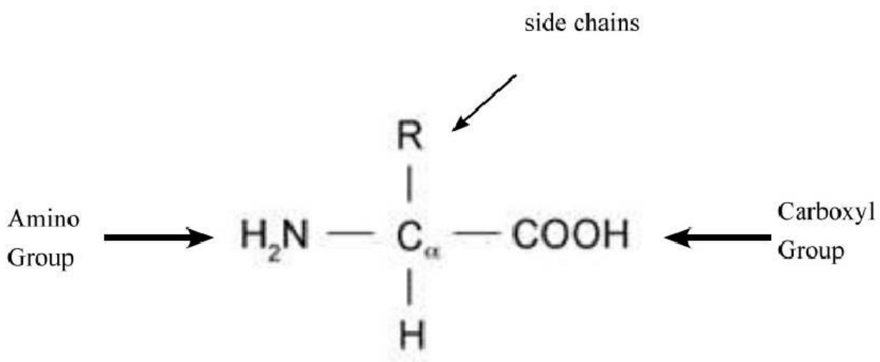



*Fig 2.11: Structure of an Amino acid molecule*

Amino acids may have one or more carboxyl groups and amino groups. Amino group has alkaline nature and carboxyl group has acidic nature. When both characteristics are found in one molecule they are known as amphoteric molecules. Therefore, amino acids are amphoteric.

Two Amino acids undergo condensation reaction by removing a water molecule, and result a bond known as peptide bond; OH from one amino acid and H from the other amino acid forms the water molecule.

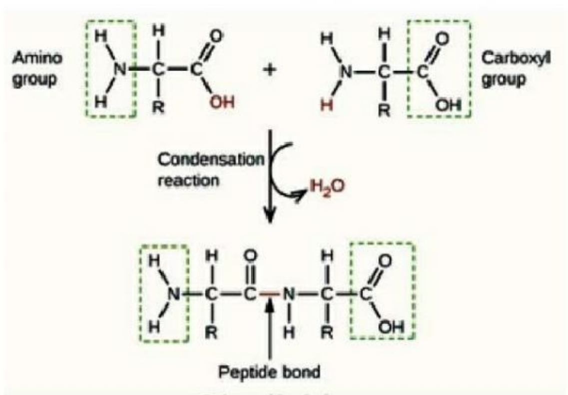



*Fig 2.12: Formation of peptide bond*

Protein is composed of one or more polypeptide chains which are composed of amino acids.

**Levels of protein structures**

There are four levels of structure which play important roles in their functions;

a) Primary
b) Secondary
c) Tertiary
d) Quaternary

*Table 2.1: Major polysaccharides, their monomers and functions*

| Polysaccharide | Monomer | Functions |
|---|---|---|
| Starch | Glucose | Stored in plants |
| Glycogen | Glucose | Stored in animals and fungi |
| Cellulose | Glucose | Component of Cell wall |
| Inuline | Fructose | Stored in tubers of Dhalia |
| Pectin | Galacturonic acid | Component of Middle lamella of plant cell wall |
| Hemicellulose | Pentose and Hexoses | Component of Plant cell walls |
| Chitin (nitrogen containing polysaccharide) | Glucosamine | Component of Fungal cell walls and exoskeleton of Arthropods |

## Functions of carbohydrates

**Monosaccharides**

- Energy source
- Building blocks of disaccharides and polysaccharides (disaccharides such as maltose, sucrose and polysaccharides such as starch, glycogen)
- Components of nucleotides (DNA, RNA)

**Disaccharides**

- Storage sugar in milk- Lactose
- Translocation in phloem –Sucrose
- Storage sugar in sugarcane- Sucrose

**Polysaccharides**

a.) Storage polysaccharides-

- starch stores glucose as energy source in plants and chlorophytes
- glycogen stores glucose as energy source in animals and fungi
- inulin stores fructose as energy source in Dahlia tubers

b.) structural polysaccharides-

- Cellulose in the cell walls of plants and chlorophytes
- Pectin in the middle lamella of plant tissues.
- Hemicellulose in cell walls of plants.
- Chitin in the cell walls of fungi and in exoskeleton in Arthropods.

**Lipids**

- Diverse group of hydrophobic molecules
- Large biological molecules but not considered as polymers or macromolecules.
- Consist of C, H, O and H:O ratio is not 2:1. Comparatively more H than O are present.
- Biologically important types of lipids: Fats, Phospholipids and Steroids.

**Fats**

Fats are made up of glycerol and fatty acids; Glycerol belongs to alcohol group having 3 carbons where each of them bear single hydroxyl group. Fatty acids are hydrocarbon chains with long (usually 16-18) carbon skeleton with a carboxyl group at its one terminal.

Fatty acid molecules bind to each hydroxyl group of glycerol by ester bond. Resulting fat molecules are called as triacylglycerol (triglycerides).

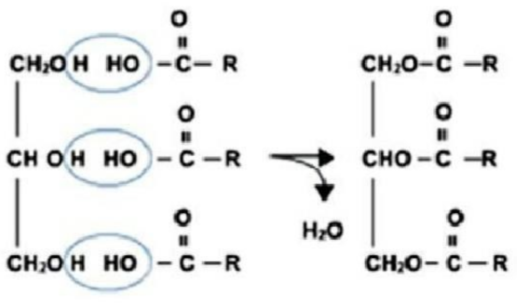


*Fig 2.9: Formation of Triacylglycerol*

Hydrocarbon chains of fatty acids contribute to the hydrophobic nature of the fats. Based on the nature of hydrocarbon chains of fatty acids, they are categorized as

a) Saturated fats- made up of saturated fatty acids with hydrocarbon chains having no double bonds. Usually animal fats come under this category. They are mostly solid at room temperature. e.g: butter

b) Unsaturated fats- made up of unsaturated fatty acids with hydrocarbon chains having one or more double bonds. Usually plant fats come under

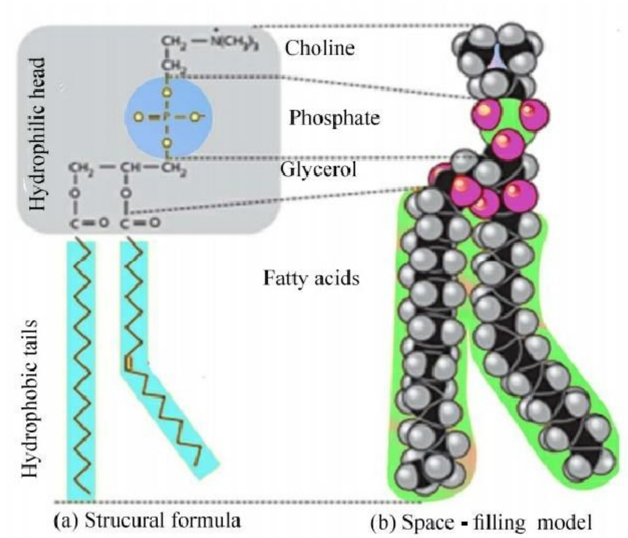
this category. They are mostly liquid in room temperature. e.g: vegetable oils. Unsaturated fats are classified based on the nature of their double bonds. a) *Cis* unsaturated fat b) *Trans* unsaturated fat

Consumption of excess saturated fats and trans unsaturated fats contribute arthrosclerosis.

**Phospholipids**

Phospholipids are major components of the cell membranes. They are composed of two fatty acids and one phosphate group attached to one glycerol molecule. The phosphate group gives the negative electrical charge to the phospholipid molecule. Typically an additional polar molecule or small charged molecule is also linked to the phosphate group e.g. choline.

The two ends of the phospholipids show different behavior. The hydrocarbon tails are hydrophobic while phosphate group and its attachment (head) are hydrophilic.




(no need to memorize the structure)

*Fig 2.10: structure of the phospholipid molecule*

## Functions of Lipids

- food reserve as energy source (triacylglycerols such as fats and oils)
- maintain the fluidity of plasma membrane (phospholipids, cholestrol)
- act as signaling molecules (eg. Hormones) that travel through the body
- found as components of cell membranes (phospholipids, cholesterol)

## Proteins

Proteins are made up of amino acids. Twenty different amino acids are involved in the formation of proteins. Elemental composition is C, H,O,N and S. At the centre of the amino acid there is an asymmetric carbon atom except in glycine. In addition to this, each amino acid is composed of an amino group, a carboxyl group, a hydrogen atom and a variable group symbolized by R. In the case of glycine R is replaced by H atom. The R group also called the 'side chain' differs with each amino acid where as the other groups are in the ' back bone' (including the H atom).