FOOD NUTRIENTS

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I. INTRODUCTION

Foods are complex substances composed of chemical constituents called nutrients. Six general kinds of nutrients are carbohydrates, fats, proteins, vitamins, minerals and water. These constituents give foods their structure, texture, colour, flavour and nutritive value. The nutrients derived from plant sources are called phytonutrients. Examples of phytonutrients are carotenoids, Lutein, Lycopene, Flavanols, Prebiotics/probiotics etc.

Antioxidants protects the body by repairing damaged cells, transforming free radicals into less dangerous compounds, protects immune system and body cells. That is why some vitamins are considered to be antioxidants.The brief description of various nutrients is as under:

II. CARBOHYDRATES

These are the prime source of energy that helps in utilizing proteins and fats. Our body's main requirement of energy (70%) has been fulfilled by carbohydrates. This energy can be generated by utilizing O_2 (4 kcal/g edible portion) from animal cells by the oxidation of carbohydrates. The required minimum amount of carbohydrates is 100 g/day to ensure efficient oxidation of fat. Excess consumption of carbohydratesis converted into fats which were to be utilized when required.

The main sources of carbohydrates in the diet are starch (cereals grains and tubers) and sugar (fruits and sugarcane).

The general formula for carbohydrates is $C_x(H_2O)_y$.

Previously, the carbohydrates were defined as hydrates (i.e. water) of carbon, but there are many carbohydrates which do not fit to this general formula.Therefore, according to modern definition, carbohydrates are polyhydroxy (-OH group) aldehydes (-CHO group) or ketones (-CO group) and their derivatives.

All carbohydrates contain C, H and O. They are formed from units known as saccharide groups. Monosaccharides (like glucose, galactose, fructose, mannose etc.) have one saccharide group, disaccharide (like sucrose, lactose maltose etc.) has two and polysaccharide (like starches, glycogen etc.) has many groups.

1. **Monosaccharides:** These are the simple sugars having one aldehydic or ketonic group consisting of short chains of C-atom. Each of the remaining C atom is having a hydroxyl

(-OH) group. Glucose (also called dextrin), galactose, fructose and mannose have same empirical formula $C_6H_{12}O_6$ but varied in the arrangement of groupings about the C-atom and are distinctive in their physical properties like solubility, sweetness etc.

Substances having dissimilar structural formulas but similar molecular formulas are called as **structural isomers**.

Glucose (Fig. 1), galactose and mannose are aldohexoses (because they possess an aldehyde group), whereas fructose is ketohexose (because it has ketone group). Galactose is not found free in nature; it is only formed from the hydrolysis of lactose (milk sugar). Glucose (present in grapes, berries, oranges, sweet corn, hydrolysis of sucrose) is less sweet than cane sugar. Fructose (present in honey, ripe fruits, some vegetables) is much sweet than cane sugar, highly soluble and don't readily crystalize.

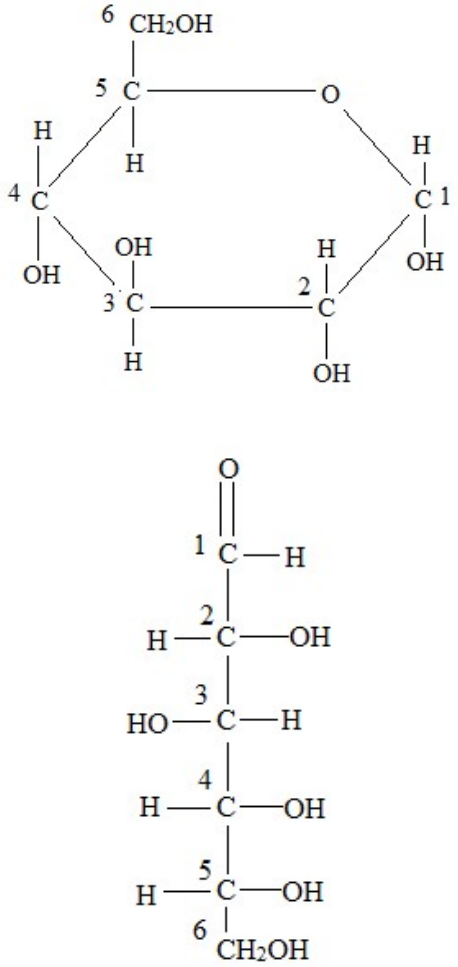

Figure 1: Structure of Glucose

Glucose in stored in the body as adipose tissue and as glycogen. If the level of glucose is low in the body, it affects the proper functioning of nervous system of our body.

Ribose, xylose and arabinose are three pentoses (5 Carbon sugars) that don't occur free in nature but are constituents of pentosans in fruits and the nucleic acids in meats. Ribose is of great physiologic importance as a constituent of Riboflavin and is rapidly utilized by the body and is not a essential dietary constituent.

2. **Disaccharides:** Disaccharides ($C_{12}H_{22}O_{11}$) are formed when two hexoses are merged while losing one water molecule. They are soluble in water and crystalline in nature and their level of sweetness varies among different disaccharides. They break down to simple sugars when digestive enzymesact upon them and by acid hydrolysis. Following are some of the examples:

   - Sucrose (table sugar): Merging of glucose and fructose.
   - Lactose (milk sugar): Merging of glucose and galactose.
   - Lactose is $1/6^{th}$ as sweet as compared to sucrose.
   - Maltose (or malt sugar) is combination of two glucose molecules and is the product of starch hydrolysis. The solubility of different types of sugars is due to the hydroxyl groups present in them.

     Reducing and Non-reducing sugars: The reducing sugars have a free aldehyde (-CHO) orketone (-C=0) group. Examples are maltose and lactose. The non-reducing sugars don't have a free aldehyde (-CHO) orketone (-C=0) group.Example is sucrose.

3. **Polysaccharides:** Polysaccharides $(C_6H_{10}O_5)_n$ are complex compounds having high molecular weight, amorphous nature and insoluble in water etc. Starches, glycogens, dextrins and various indigestible carbohydrates are having nutritional significance.

Starch (a polysaccharide) is formed by the combination of a large number of glucose residues. It occurs in the form of particles called granules. The characteristics of the starch molecule depend upon the way in which the 2000 or so glucose units that make up the molecules are linked. Amylose (15-30%) and amylopectin(70-85%) are the main components of starch.

- **Amylose** consists of several linear and un-branched chains of hundreds of glucose units by a glycosidic linkage between their C-1 and C-4 carbon atoms. The number of glucose units in one molecule of amylose may vary from about 500 to 5000 with different starches. Amylose is soluble in hot water, the solution on cooling sets to a gel due to precipitation of amylose (Process is known as Retrogradation). Amylose (Fig. 2) gives a blue colour with iodine.

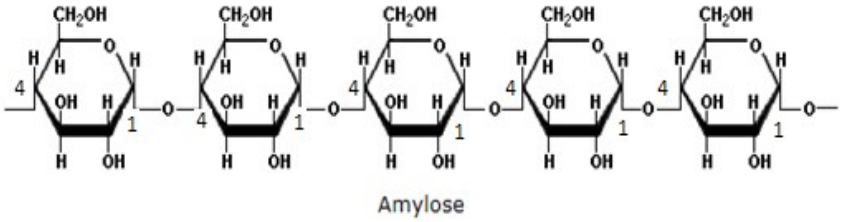

Figure 2: Structure of Amylose

- **Amylopectin**(Fig. 3) varies from amylose as it is highly branched. It consists of a number of small chains containing 20 to 30 glucose units joined by 1,4 linkages (glycosidic bond), interconnected by 1,6 bond. Amylopectin has larger molecular weight than amylose. One molecule of amylopectin may contain 5000 – 50,000 glucose molecules. It is soluble in water, but forms a thick paste, which does not set to a gel. It gives a reddish colour with iodine.

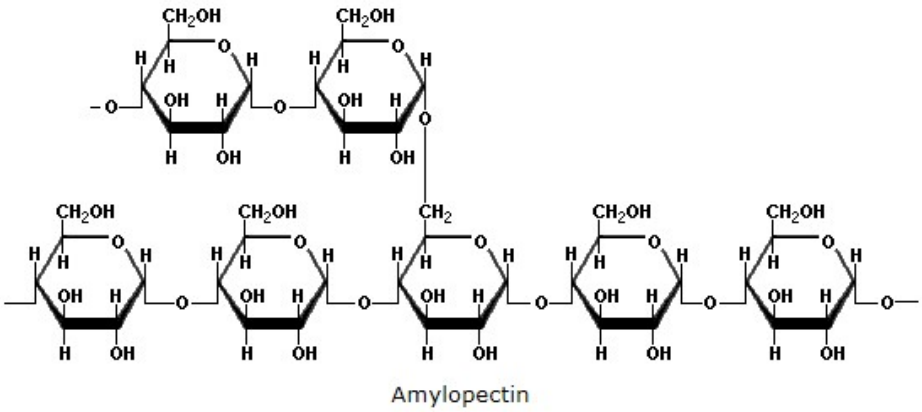

Figure 3: Structure of Amylopectin

Dextrin comprises of shorter chains of glucose units and are the products of starch hydrolysis.

- **Glycogen** (so called animal starch)is similar in structure to the amylopectin, but contains many more branched chains of glucose. It is rapidly synthesized from glucose in the liver and muscle. Glycogen is broken back into glucose when energy is required (known as glycogenolysis).

4. Non-starch polysaccharides

- **Cellulose:** The constitutional portions of edible plants, coating of seeds and skin of fruits are the only forms of cellulose and hemicellulose having importance with nutrition. The cellulose and hemicellulose cannot be hydrolyzed by enzymes of the human digestive tract. Therefore, they yield no energy, and are excreted in the faeces. Several indigestible polysaccharides have useful properties in food processing. Pectin (found in mature fruits) has the potential to absorb water and forming gels. Agar is obtained from seaweed and is useful for its gelling properties. Carrageenan (Irish moss) and alginates from seaweed are often used to enhance the smoothness of foods, such as ice cream and evaporated milk.
- **Gum Arabic** acquired from Acacia bark is a fusion of polysaccharides, is utilized as an emulsifier and stabilizer in bakery products.
- **Guar gum** is utilized as a thickening agent, stabilizer in ice creams and salad dressings.
- **Xanthan gum**is a polysaccharide that is utilized as thickening agent in canned foods, salad dressings etc.

- **Dextran** is utilized as a thickening and stabilizer in confectionary and bakery products.

III. PROTEINS

Protein is obtained from Greek word "Proteius" means "primary". No form of life can exist without proteins. These are the prime constituent of all living cells yielding 4.1 kcal energy/g. Proteins occurring in animal and plant tissues are called **native proteins**. The proteins are complex nitrogenous substances having on average 16% nitrogen.

% Protein = Nitrogen content x 6.25

Proteins are larger organic compounds made of α-amino acids (more precisely L-α aminocarboxylic acids) ordered in a linear pattern and linked by peptide bonds between the carboxy (COOH) and amino (NH_2) groups of adjacent amino acid residues. The amino acids are the building blocks of protein or structural units or smallest units of protein.

Amino acids (Fig. 4) constitute of the elements like carbon, hydrogen, oxygen and nitrogen and in some cases Sulphur. Most proteins also comprise P,Fe, Cuand other inorganic elements.

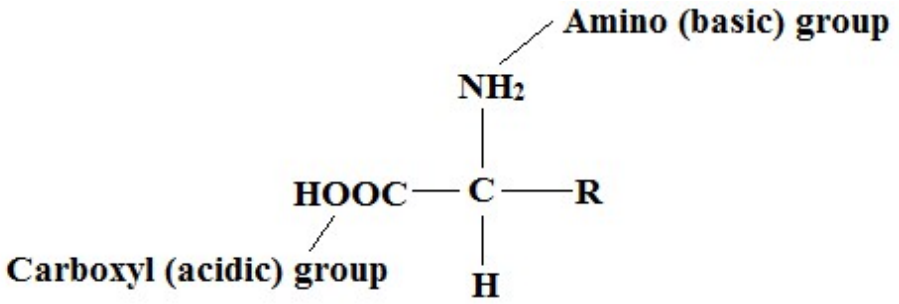

Figure 4: Amino acid

The NH_2 group can usually be found on the C-atom adjacent to the carboxyl group; and that is why the term α-amino acid is used. The amino acids found in protein have some common features like:

- They all are 'α' (i.e. amino group is on the C-atom next to the Carboxyl group)
- They all are of L-configuration (i.e. linear configuration) except glycine having asymmetric C-atoms.

The amino acids comprise of a basic (Amino i.e. NH_2) group and an acid (carboxyl i.e. COOH) group in their molecules linked by peptide bonds (Fig. 5). The existence of these groups (amino and carboxylic) is accountable for amphoteric nature of proteins. Therefore, proteins are called ampholytes. Due to their amphoteric nature, amino acids (i.e. proteins) prevent a sudden change of pH in the body. They are soluble both in strong acids and alkalis.

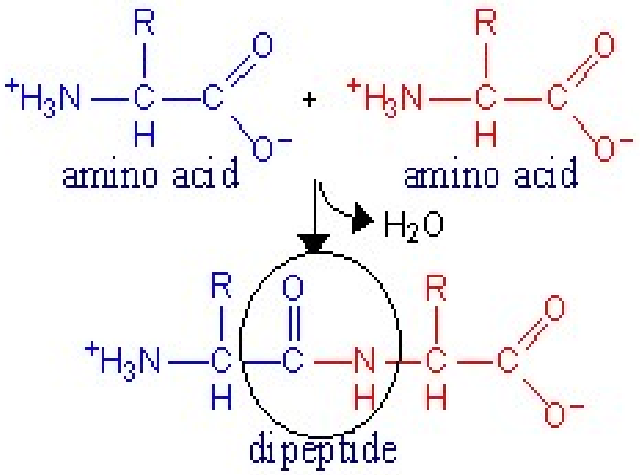

Figure 5: Peptide Bond

The functional group -C(=O) NH- is called an amide group or peptide group.

Different amino acids are joined by peptide linkages to form an infinite number of proteins. The variation in different proteins is based on the number, the kind, the amount and arrangement of amino acids present. Proteins produced by each species of animal and plant are unique for that species.

There are 20 naturally occurring amino acids. Out of 20 amino acids, 8 (for adults) or 10 (for infants) amino acids are essential (or indispensable) amino acids. **The essential amino acids** are those that must be obtained in the diet and are necessary for growth and health of a growing animal, because by lacking any one of the amino acids, synthesis of protein won't happen as it is the main requirement for growth. Examples of essential amino acids are Histidine, Phenylalanine, Arginine, Isoleucine,Methionine, Leucine, Lysine, Threonine, Tryptophan and Valine.

The protein which consists of adequate dosage of all essential amino acids to support human body tissues and regulate normal development and growth is known as **complete proteins. Incomplete proteins**are unable to satisfy all the requirements fulfill by complete proteins. Egg proteins contain all essential amino acids in adequate amounts and possess highest nutritive value among dietary proteins.

Non-essential (or dispensable) amino acids are those amino acids which the body is able to synthesize at the rate needed. Examples of non-essential amino acids are Alanine, Aspartic Acid, Asparagine and Glutamic Acid. Examples of conditional Amino Acidsare Glycine, Glutamine, Cysteine, Tyrosine, Serine and Proline.

1. **Classification of proteins based on conformation**

- **Globular Proteins:** It consists of polypeptides chain that is tightly folded into globular shape. It includes most of enzymes, hormones, and antibodies.
- **Fibrous Proteins:** The polypeptide chains are arranged in parallel fashion along a single axis to give the long sheets. eg. α-keratin of hair, elastin of elastic tissues, collagen of tendon.

2. **Classification of proteins on the basis of specific function**

- **Storage Proteins:** It stores nutrients that the organism needs. E.g. Protein in grain, casein in milk.
- **Structural Proteins:** The protein that hold the living system together. E.g. Collagen, α -keratin (hairs).
- **Contractile proteins:** They are responsible for muscular movement. E.g. Actin and myosin.
- **Transport proteins:** These are the proteins that carry molecules or ions from one place to another in the living system. E.g. Hemoglobin (carries O_2 in blood), myoglobin (carries O_2 in muscles).
- **Protective proteins:** these are the proteins that destroy foreign substances released in living system e.g. Antibodies.
- **Toxins:** these are the poisonous proteins e.g. Clostridium botulinum toxin.

3. **Classification of proteins based on composition**

- **Simple Proteins:** These proteins yield will give amino acids or their derivatives on hydrolysis and they constitute of only amino acids linked by peptide bonds.

  - **Albumins:** The water soluble-proteins that are generally coagulated by heat and found in blood stream and almost all body cells. Examples are egg albumin,lactalbumin found in milk etc.
  - **Globulins:** The proteins that are solubilizein dilute salt solutions of strong acids and bases but insoluble in water. Examples are serum globulin (blood), tuberin (potato), myosin and actin in meat.
  - **Glutelins:** These proteins exist in plant materials and are solubilize in alkalis and dilute acids. Examples areoryzenin (rice) andglutenin (wheat) etc.
  - **Prolamins:** The proteins that are solubilize in 70-80% alcohol and exist in plant materials and are. Examples are gliadin (wheat)and zein (corn).
  - **Scleroproteins or Fibrous Proteins**: These proteins form long protein filaments, which are shaped like rods or wires. These proteins are characteristic of skeletal structures of animals and also of the external protective tissues, such as skin, hairs etc. These proteins are insoluble in acids and alkalis and exist in connective tissues and in hair and nails. Examples are keratin, collagen, elastin.
  - **Histones:** These proteins are solubilized in water and insoluble in very dilute ammonia.Examples are the globin of hemoglobin.
  - **Protamine:** They are rich in arginine and are strong basic proteins with low MW (4000-8000 daltons), solubilize in water and not coagulated by heat. Example issalmine (in salmon).

- **Conjugated Proteins:** When protein molecules are combined with some non-protein group, they are known as conjugated proteins. The non-protein groups are known as prosthetic groups or **cofactors**. Examples of this group are mentioned as follows:

  - **Nucleoproteins:** These are the compounds of protein with nucleic acid.
  - **Glycoproteins:** Protein molecules combined with a carbohydrate group. Example is Mucin.
  - **Phosphoproteins:** Protein molecules combined with a phosphate group. Examples are casein (milk) and ovo vitelline(egg yolk).
  - **Chromoproteins:** Protein molecules combined with a prosthetic group (pigment). Examples are haemoglobin and hemocyanin etc.
  - **Lecithoproteins:** Protein molecules combined with lecithin or related substances.
  - **Lipoproteins:** Protein molecules combined with a lipid group.Examples are high density lipoproteins (HDL), low density lipoproteins (VLDL) and chylomicrons.
  - **Metalloproteins:** Protein molecules combined with metal ions (not a member of prosthetic group).Examples are caeruloplasmin, an enzyme with oxidase activity etc.

- **Derived proteins:** These proteins are obtained from simple proteins by the action of enzymes and chemical agents, X- raysetc. eg. Peptides, peptones, proteoses.

  - **Casein and lactalbumin are proteins of milk.**
  - **The chief protein of wheat is gluten (combination of glutelin and gliadin).**
  - **Gelatin is formed when collagen (protein in connective tissues and bones) is heated with** water. The solution of gelatin on cooling sets to a gel.

4. **Structure of Proteins:** This can be clearly justified in four different categories as under.

- **Primary Structure:** It is thelinear sequenceof covalently linked (peptide bond) amino acids.
- **Secondary Structure (due to hydrogen bonds):**The section of polypeptides fold into structures that are stabilized by hydrogen bonding eg. $\alpha-$helices and β - pleated sheets. Secondary structure of proteins are presented in Fig. 6 as under.

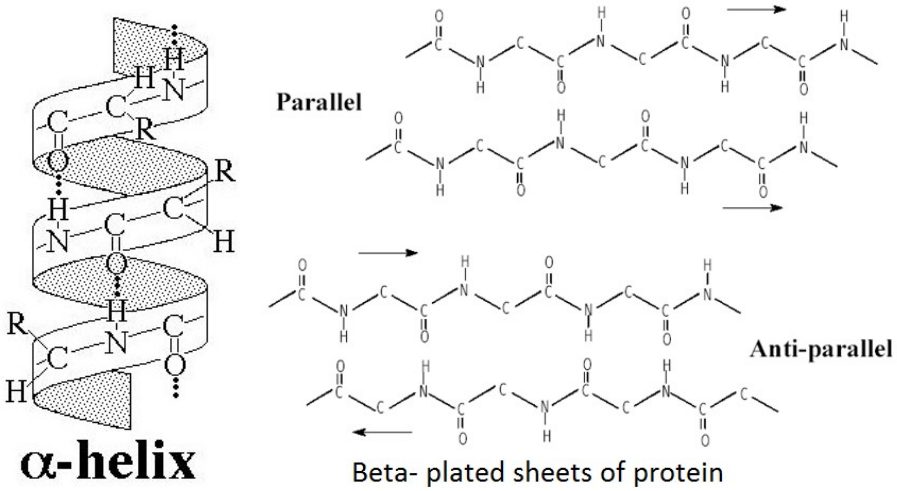

Figure 6: Secondary structure of proteins

- **Tertiary Structure (due to hydrophilic, hydrophobic disulphide bonds):**Tertiary protein structure refers to the complete 3D structure of a protein formed by large number of non-covalent interactions between amino acids. The comparison of primary, secondary and tertiary structure is presented in Fig. 7 as under.
- **Quaternary Structure:** It means the systematicinterconnection of two or more polypeptide chains by forming a complex. This structure is unstable due to lose interconnection between surface residues within a complex.

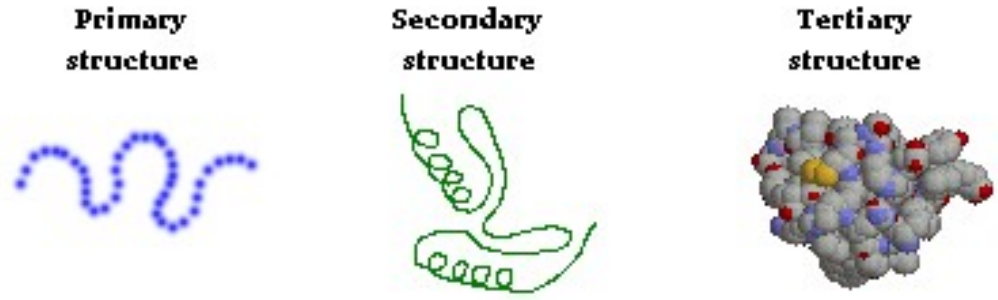

Figure 7: Comparison of Primary, secondary and tertiary structure

5. Some Properties of Proteins

- **Isoelectric Point:** It is the pH at which both positive and negative charges on the proteins molecules are equal. At isoelectric point, the **Zwitter ion (Fig. 8)** exists as a neutral ion.

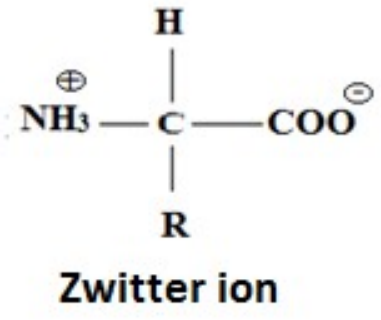

Figure 8: Zwitter ion

At isoelectric point, the protein is least soluble. The amino acids have least solubility at isoelectric point which helps in separation of proteins.

- **Denaturation of Proteins:** It is a process that changes the molecular structure without breaking any of the peptide bonds of protein. This may be due to the action of heat, pH, salts, surface effects etc. eg. Denaturation of whey proteins for production of milk powder.
- **Maillard Reaction:** When proteins react with sugars, they form brown nitrogenous polymers.

6. **Effects of Protein Deficiency:** Protein deficiency may result in weight loss, easy fatigue, muscular weakness, diarrhea, discoloration of skin etc. Nutrition edema is the condition of collection of fluid in the tissues due to decrease in osmotic pressure of the blood. This may decrease the level of plasma proteins (due to protein deficiency). The severe deficiency of protein may lead to kwashiorkor. Protein calorie deficiency leads to disease known as nutritional marasmus. The protein rich foods are meat, fish, egg, milk, cereal and pulses.

IV. LIPIDS

These are the chemical compounds that are insoluble in water but soluble in organic (i.e. non-polar) solvents like chloroform, benzene, carbon disulphide, ether etc. These include monoglycerides, diglycerides, triglycerides, phosphatides, sterols etc. Lipids does not exist in free state in foods but they mingled with proteins (lipoproteins) and carbohydrates (glycolipids).

Lipids are insoluble in water is due to the existenceof one or more fatty acids. Fats are present in major amounts in both plants and animal materials. Nuts, such as groundnuts, are rich sources of fats.

1. Biological Functions of Lipids

- The lipids supply energy and heat to the body (9 kcal of energy per gram of edible portion). This helps to keep the body at the correct temperature (37^{o} C).
- Triglycerides provide energy storage in adipocytes.
- They actas a carrier of fat-soluble vitamins into cells of small intestine.
- They act as important structural components of the brain and cell membranes.

Like carbohydrates, lipids contain the elements C, H and O, but the resemblance ends there. Fats are most concentrated form of energy in food. It produces twice the energy than carbohydrates (because fat contains less % of O and more of H and Cas compared to carbohydrates.The term fat is normally applicable to all triglycerides {formed by combining glycerol (alcohol) and fatty acids}.
Fats are Glycerides.
The Glycerides are Esters.
Therefore, Fats are Esters.

2. **Esters:** An ester is the condensation product of an alcohol and a carboxylic acid.

$$R\text{-}OH + R'\text{-}COOH \rightarrow R\text{-}COO\text{-}R' + H_2O$$

$$\text{Alcohal} + \text{Carboxylic acid} \rightarrow \text{Ester} + \text{Water}$$

In fat, alcohol part is always Glycerol $\left[C_3H_5(OH)_3\right]$ and the acid part may be any of the fatty acids. The Glycerol is a 3-carbon alcohol with 3 hydroxyl (i.e. -OH) groups, each of which can combine with a fatty acid (Fig. 9).

The acid part may be any number of acids having an even numbered C-atoms. The reason that only even numbered acids are found in fat is that, the body builds these acids entirely by Acetyl CoA (Acetyl co-enzyme A) and therefore puts the C in two at a time.

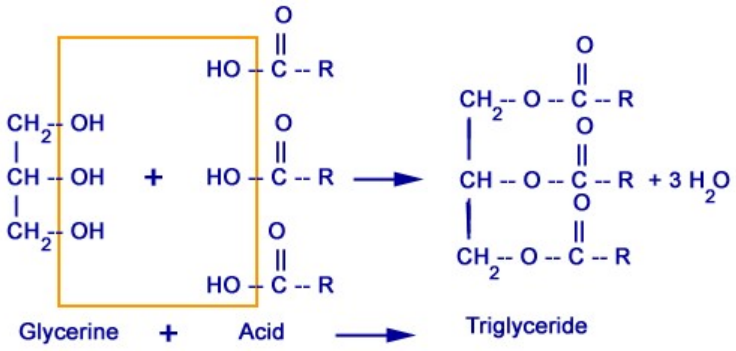

Figure 9: Triglyceride

3. **Fatty acids:** A fatty acid is a long chain (no branching) carboxylic acid having the formula $CH_3\ (CH_2)_n\ COOH$. They are called fatty acid, because they are used in the formation of fat. Most natural fatty acid contains an **even** number of C atom due to their mode of biosynthesis, but odd-numbered fatty acids do occur naturally.

- **Saturated and Unsaturated Fatty Acids:** The saturated fatty acids have only the single bonds (present in solid fats) and the unsaturated fatty acids have the double or triple bonds (present in oils). Examples of saturated fatty acids are lauric, myristic, palmitic and stearic. Unsaturated fatty acids may have one, two or even up to 6 double bonds. Examples areoleic acid, linolenic acid, linoleic acid. Generally, straight chain saturated fatty acids C_2 to C_{20} (or more precisely C_{16} to C_{18}) are found in most animal and vegetable fats. If the substance is a liquid at 20°C it is called oil; if it is solid at 20°C, it is called fat.

By Hydrogenation process, H is added into oils to convert into solid fat(Fig. 10).

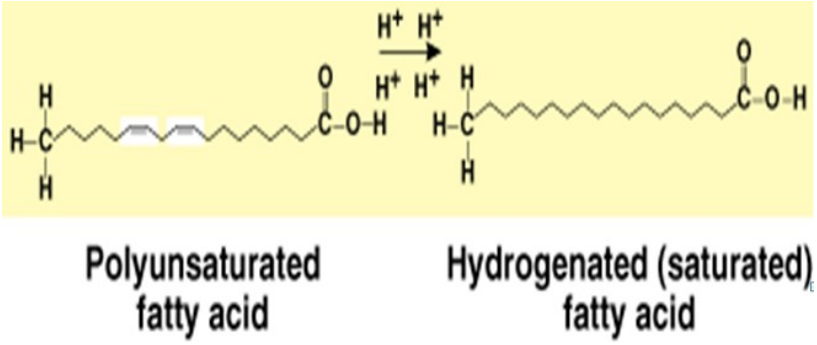

Figure 10: Saturated Fatty acid

- **Nomenclature of Fatty Acids:** Fatty acids are straight chain hydrocarbons possessing a carboxyl (COOH) group at one end. The carbon next to the carboxylate (-COOH) is known as α, the next carbon β, the next carbon γ and so forth. The last position is labelled as a "ω" (Fig. 11), the last letter in the Greek alphabet.

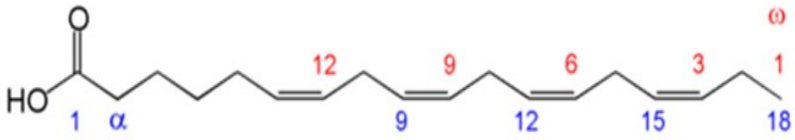

Figure 11: Omega fatty acid

Linoleic acid (Fig. 12) is an $\omega-6$ fatty acid because it has a double bond six carbons away from the "ω" carbon. The ω-6 type includes γ-linolenic acid (Fig. 12) and arachidonic acid.

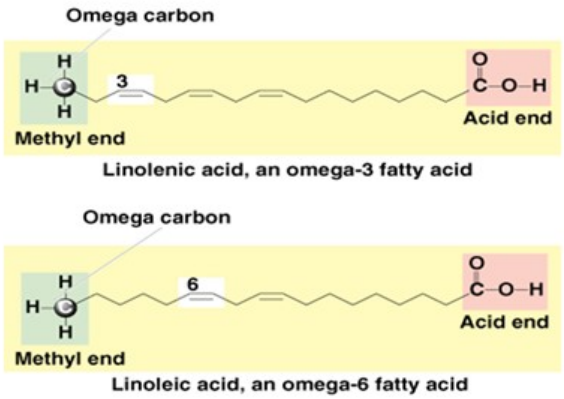

Figure 12: Linolenic acidand Linoleic acid

- **Difference of cis and trans configuration:** The two carbon atoms in the chain that are bound next to either side of the double bond can occur in a cis(Fig. 13) (hydrogen atoms are present on same side of double bond) or trans configuration (Fig. 14) (hydrogen atoms are present on opposite side of double bond).

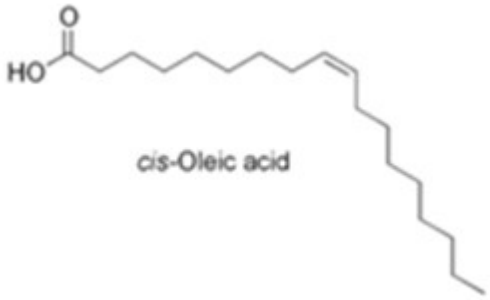

Figure 13: Cis configuration

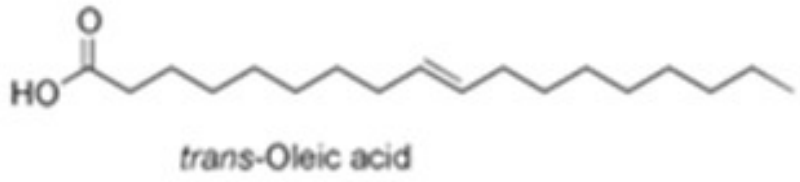

Figure14: Trans configuration

The various saturated and fatty acids are presented in Table 1 and Table 2 as under:

Table 1: Saturated fatty acids

SATURATED FATTY ACIDS					
Common Name	**Scientific name**	**Formula**			
Butyric Acid	Butanoic acid	C_3H_5COOH	-70°C, Soluble	Liquid at RT	Butter fat
Caproic Acid	Hexanoic acid	$C_5H_{11}COOH$	Slightly soluble	Liquid at RT	Butter fat
Caprylic Acid	Octanoic acid	$C_7H_{15}COOH$	Insoluble	Liquid at RT	coconut oil
Capric Acid	Decanoic acid	$C_9H_{19}COOH$	32°C Insoluble	Solid at RT	coconut oil
Lauric acid	Dodecanoic acid	$C_{11}H_{23}COOH$	44°C	Solid at RT	coconut oil
Myristic acid	Tetradecanoic acid	$C_{13}H_{27}COOH$	54°C	Solid at RT	palm kernel oil
Palmitic acid	Hexadecanoic acid	$C_{15}H_{31}COOH$	63°C	Solid at RT	palm oil
Stearic acid	Octadecanoic acid	$C_{17}H_{35}COOH$	70°C	Solid at RT	animal fats
Arachidic acid	Eicosanoic acid	$C_{17}H_{39}COOH$	77°C; Insoluble	Solid at RT	peanut, fish oil

Table 2. Various Unsaturated fatty acids

UNSATURATED FATTY ACIDS				
Name		**Formula**		**Animal fats**
Palmitoleic acid	9-hexadecenoic acid	$C_{15}H_{29}COOH$	0°C	olive oil
Oleic acid (Soft fat) (2H atoms less).	9-octadecenoic acid	$C_{17}H_{33}COOH$ $C_nH_{2n-2}COOH$	16°C	castor oil
Ricinoleic acid	12-hydroxy-9-octadecenoic acid	18		Butter fat
Vaccenic Acid	11-octadecenoic acid	18		grape seed oil
Linoleic acid (4H atoms less) (Linoleic Series)	9,12-octadecadienoic acid	$C_{17}H_{31}COOH$ $C_nH_{2n-4}COOH$	5°C	flaxseed (linseed) oil
α - Linolenic acid	9,12,15-octadecatrienoic acid;	$C_{17}H_{29}COOH$	-11°C	borage oil
γ - Linolenic acid	6,9,12-octadecatrienoic acid	$C_{17}H_{29}COOH$		liver fats
Arachidonic acid	5,8,11,14-eicosatetraenoic acid	$C_{19}H_{39}COOH$	-50°C	fish oil
Gadoleic Acid	9-eicosenoic acid	20 Carbon atoms		Fish oil
Eicosapentaenoic acid (EPA)	5,8,11,14,17-eicosapentaenoic	20 carbons		

The short chain fatty acids (with <14 C-atoms) occur as triglyceride constituent in milk fat, coconut and palm seeds.

- **Essential Fatty Acids:** Theseare those polyunsaturated fatty acids which cannot be made in the body and must be provided in food diet because the human metabolism cannot create them from other fatty acids. They are required for biological processes, and not those that only act as fuel.The essential fatty acids linoleic acid (an ω -6 fatty acid). and α -linolenic acid (an ω -3 fatty acid)start with the short chain polyunsaturated fatty acids. They form the starting point for the creation of longer and more desaturated fatty acids, which are also referred to as long-chain polyunsaturated fatty acids.

  - **ω-3 fatty acids:**
    Eicosapentaenoic acid
    Docosahexaenoic acid
  - **ω-6 fatty acids:**
    Gamma-linolenic acid
    Dihomo-gamma-linolenic acid
    Arachidonic acid

- **Fat as an Energy Source:** Before fats can be utilized as an energy source, they must be broken down into glycerol and fatty acids. The fatty acid segments are converted into acetyl coenzyme A, which can then be oxidized in the citric acid cycle.

- **Functions of Essential Fatty Acids in the Human Body**
  - Regulation of blood pressure, blood clotting, blood lipid levels etc.
  - Preventing deposition of cholesterol in arteries and veins.
  - Their deficiency results in eczema and loss of weight in children.

- **Classification of Lipids**
  Lipids are broadly categorized into the following types:

  - **Simple lipids:** Naturally occurring oils, fats and waxes are collectively known as **"simple lipids** or **natural lipids".** These are the esters of long chain fatty acids with alcohols.

    A **monoglyceride** is formed by combining a fatty acid with one of the hydroxyl group of the glycerol molecule.

    Diglycerides contain two fatty acids;**triglycerides**comprise of three fatty acids.

    Waxesare esters of **long chainfatty acids** with **long chainor cyclic monohydroxy alcohols (other than glycerol).** This group includes the esters of cholesterol, vitamin A, and vitamin D. Examples of waxes include: Carnauba, from Brazilian wax palm, Beeswax

  - **Compound Lipids or Complex lipids or Conjugated Lipids:** These are the esters of glycerol with two saturated or unsaturated fatty acids and some other

compound such as carbohydrate, amino acids, phosphoric acid or protein etc. The compound lipids include phosphoglycerides (phospholipids or phosphatides), steroids, carotenoids and lipids functioning as vitamins or hormones.

- **Derived Lipids:** They are obtained from simple or compound lipids and have general properties of lipids.These are alcohols of high molecular weight and are in un-saponifiable portion of fats. These include fatty acids, mono and diglycerides, steroids etc.

  Cholesterol ($C_{27}H_{45}OH$) is a Sterol (Solid alcohols) in milk. cholesterol is soluble in water. One of its form is 7-dehydro cholesterol is a precursor of Vitamin D being activated by irradiation with UV rays.These include fatty acids, alcohols (glycerols and sterols), the fat-soluble vitamins.

V. VITAMINS

Vitamins are the low molecular weight organic substances required for normal functioning, growth and maintenance of good health. These are the cofactors [Coenzymes (partners) with enzymes in reactions] and cannot be made by our own bodies.
Vitamins play following important roles in our body:

- They act as a constituent of enzymes that play a prime role in several biological reactions in the body.
- They help in the regulating several body processes along with minerals.
  The vitamins Riboflavin, niacin, vitamin B_6, vitamin B_{12}, vitamin $B_5$are all indulged in utilizing carbohydrates, fats and proteins. The vitamins are of two kinds: water soluble and fat soluble.
- **Water-soluble vitamins:** These vitamins are solubilize in water and are not stored and excess amounts are eliminated along with waste products.
- **Fat-soluble vitamins:** These vitamins are conveyed and absorbed by fat. Excess amount of these vitamins isreserved by the body for later usage. These vitamins are stored in mediumamounts in several body tissues.

1. **Fat soluble vitamins:** Fat soluble vitamins are vitamins A (Retinol), D (Calciferol), E (α Tocopherol) and K (Phylloquinone, menaquinones). Vitamin A and D excess can be harmful; E and K usually not.

- **Vitamin A (Retinol):** Vitamin A is popularly known as retinol due to its predominant role in the retina of the eye. The main functions of this vitamin are:
  - Required for night vision.
  - Supports the epithelial cells of skin and membranes.
  - Required for proper wellbeing of skeletal and soft tissues.
  - Essential for the nurturing of tooth enamel and healthy gums.

  Sources: Meat, milk, fish etc.
  Deficiency: Rough, scaly skin, nightblindness, corneal ulceration etc.

- **Vitamin D (Calciferol):** Vitamin D is known as calciferol when isolated in crystalline form. It is the stable vitamins that can be stored in the body.The main role of this vitamin are:
  - Regulates the absorption of calcium and phosphorus.
  - Boosting the nourishment of bones and teeth.

  Sources: Fish liver oil, butter, liver, egg yolk etc.
  Deficiency: Rickets (in children)and Osteomalacia (in adults).

- **Vitamin E (Tocopherol):** Vitamin E is an antioxidant that prevents the oxidation of vitamin A and polyunsaturated fatty acids. The main functions of this vitamin are:
  - Shielding the cell membranes from deterioration created by peroxides.
  - Protecting cell membranes fromdeterioration created byfree radicals during oxidation of fats.

  Sources: Wheat germ oil, butter, meat, nuts and vegetable oils etc.

- **Vitamin K:** This vitamin is an anti-haemorrhagic vitamin that exist in two forms: Phylloquinone (Vitamin K_1) and Menaquinone (Vitamin K_2). The main function of this vitamin is:
  - Required for regulation of prothrombin, which plays major role in blood clotting.

  Sources: Green leafy vegetables (spinach, cabbage and lettuce etc.), fruits, cereals, dairy products etc.
  Deficiency: Internal hemorrhage and uncontrolled bleeding.

2. **Water soluble vitamins:** Vitamins belong to this groupare Vitamin C (Ascorbic acid) and B complex. These vitamins are carried in bloodstream and are not stored in body. Excess dosage of these vitamins may cause extra work on kidneys.

   Vitamin B complexvitamins coexist together in nature; hence they are grouped in same group. These group of vitamins are required for normal functioning of body cells. Vitamin B complex contains:
   - Thiamine (B_1)
   - Riboflavin (B_2)
   - Folic acid (Folacin) (B_9)
   - Niacin (B_3)
   - Pantothenic acid (B_5)
   - Biotin (B_7)
   - Cyanocobalamin (B_{12})
   - Choline
   - Inositol
   - Pyridoxine (B_6)

   - **Ascorbic Acid (Vitamin C):** It is considered as one of the most unstable vitamins and is soluble in water, crystalline in nature and colorless. It is very sensitive to heat and oxidized smoothly but stable in acid medium. The main functions of this vitamin are:
     - Maintenance of healthy capillaries, bones, skin, and teeth.
     - Healing of fractures and wounds.
     - Fighting against bacterial infections in the body.
     - Assists in the functioning of the adrenal gland.

- Promotes the absorption of iron.
- Acts as an antioxidant.

  Sources: Amla, citrus fruits, oranges, sweetlime, grapefruit, berries, guava, capsicum and green leafy vegetables.

  Deficiency: Prolonged deficiency of this vitamin results in scurvy.

- **Vitamin B_1 (Thiamine):** It is one of the least stable vitaminsand is also destroyed by oxidation and reduction. Certain processing techniques and storage also results in loss of this vitamin in meat, fruits and vegetables.The predominant functions of this vitamin are:
  - It is part of the coenzyme needed for oxidation of carbohydrates and in synthesis of ribose.
  - It is required throughout the journey of life for letting go energy from fuel molecules.

    Sources: Nuts,cereal grain (particularly wheat) germ layers, pulses (peas, beans),fish etc.

    Deficiency: Beriberi (disturbance in gastrointestinal tract, neuro and cardiovascular system), fatigue, appetite loss etc.

- **Riboflavin (Vitamin B_2):** It is a very heat sensitive vitamin that is orange yellow in colour. It is less soluble in water. The main functions of this vitamin are:
  - Required for maintaining good vision.
  - Essential for building body tissues and energy metabolism.
  - Required for oxidation of glucose and fatty acids as a part of coenzyme.
  - Essential for cellular growth.

    Sources: Dairy products, broccoli, turnip greens, asparagus, spinach etc.

- **Niacin (Nicotinic Acid):** It is among one of the stablest vitaminsthat is not affected byheat, light, acids and alkalis. The main functions of this vitamin are:
  - Requiredfor proper digestion,energy metabolism and healthy nervous system.
  - Important component of coenzymes required for the oxidation of glucose.
  - Predominant role in the synthesis of proteins, fats, and nucleic acids.

    Sources: Lean meat, whole grain cereals, yeast, fish, pulses poultry etc.

    Deficiency: Pellagra, diarrhea, depression, indigestion, weakness etc.

- **Pyridoxine (B_6):** This vitaminis stable to heat and strong alkali or acid and is sensitive to light, especially ultraviolet light and when present in alkaline solutions. It is very unstable to light. The important functions of this vitamin are:
  - It acts as coenzyme that assists in metabolism of carbohydrate, fat and protein.
  - It is involved as cofactor in converting tryptophan to niacin.

    Sources: Vegetables, meat, especially liver and cereals with bran.

    Deficiency: Depression, confusion and convulsions in adults. Weight loss, vomiting in infants.

- **Folic acid (Folacin):** This is one of the most important vitamins that play vital role in human life mentioned as follows:
  - Coenzyme needed for metabolism of certain amino acids.
  - Required for synthesis of DNA.

- Essential for production of normal red blood cells.
- Preventing birth defects that damage the brain and spinal cord.

  Sources: Green leafy vegetableslike asparagus, broccoli etc., liver, kidney, whole wheat bread, dried beans etc.

  Deficiency: Poor growth, anemia, blood disorders, gastrointestinal tract disturbance.

- **Biotin (B_7):** It is a water soluble, sulphur containing vitaminthat is very stable to heat and light and essential for the wellbeing of individuals and widely distributed in nature.The main functions of this vitamin are:
  - Coenzyme needed for metabolism of amino acids and fatty acids.
  - Required for the regulation of nucleic acids.
  - Predominant role in the metabolism of carbohydrates and fats.

    Sources: Vegetables, groundnut, liver, kidney, egg yolk etc.

    Deficiency: Nausea, depression vomiting and dry scaly dermatitis.

- **Pantothenic Acid (B_5):** It is synthesized by intestinal microflora. It is more stable in solution than in the dry form. It is stable in the pH range 4-7. It is decomposed by alkali and dry heat. It is stable in moist heat in neutral solution.The main functions of this vitamin are:
  - Being an important component of coenzyme A, it is needed for the oxidation of carbohydrates and fats.

    Sources: Pulses, animal tissues, pulses, whole grain cereals etc.

    Deficiency: Fatigue, insomnia, depression, irritability etc.

- **Cobalamin or Cyanocobalamin (Vitamin B_{12}):** This vitamin is heat stable and water soluble and particularly known as cobalamin as it is found as a co-ordination complex cobalt. The main functions of this vitamin are as follows:
  - Essential for proper functioning in the metabolism of all cells.
  - Vital for growth and development of body.
  - Required for the metabolism of carbohydrates.
  - Coenzyme for the regulation of nucleic acids.

    Sources: Liver, kidney, cheese, eggs, milk, muscle meat, and sea foods etc.

    Deficiency: Vitamin B_{12} deficiency is not usually dietary in origin, but results due to a lack of its absorption in intestine.

- **Other factors listed among B-complex vitamins**
- **Choline:** It is essential for the transmission of nerve impulses. Egg yolk is especially rich in choline, but legumes, organ meats, milk, muscle meat etc. are also good sources.
- **Inositol:** It is water soluble, sweet tasting substance distributed in fruits, vegetables, whole grains, meats and milk. It possesses lipotropic activity (prevents the deposit of fat in the body).
- **Lipoic acid:** It is a sulphur containing fat soluble substance. Strictly speaking, it is not a vitamin because it is not necessary in the diet of animals. It functions in the same manner as do many of the B-complex vitamins.

VI. MINERALS

The minerals are the inorganic components of food that leave ash as residue when burned. Depending upon the dosage in the body, the minerals are categorized as macronutrients (present >0.005%of body weight) and micronutrients (present <0.005% of body weight). Examples of macronutrients are Calcium, Phosphorus, Magnesium, Sodium, Potassium, Chloride etc.Microminerals (or trace elements) are chemical elements essential in the amountof less than 20 mg/day.Examples are Iron, Manganese, Copper, Iodine, Zinc, Fluoride, and Selenium. Each mineral has a particular role in human body. The minerals cannot be destroyed by heat. About 5% of the body weight is constitute of minerals. The major functions of minerals are mentioned as follows

- Catalysts for many biological reactions within the body.
- Main role in building of bones and other structural parts of the body.
- Assists in muscular contraction.
- Better utilization of nutrients in food.

1. Macrominerals or Macronutrients

- **Calcium (Ca):** It is one of the most plentiful minerals in the human body and fluids. The requirement of calcium varies from puberty to maturity. The main functions of this mineral are:

  - Regulate the contractions of blood vessels and muscles.
  - Required for bone and teeth structure.
  - Vital for contraction of muscle fibres, conduction of nerve impulses.
  - Predominant role in activating certain enzymes.
    Sources: Milk and milk products, and leafy green vegetables.
    Deficiency: Osteoporosis is a condition caused by calcium deficiency due to which the bones become porous, weak, fragile.

- **Sodium (Na):** It is generally consumed as table salt. The requirement of sodium may vary from person to person; For example: energeticindividuals in suffocating climates who sweat extensively may require more sodium than the normal intake. The main functions of this mineral are:
  - Regulation of osmotic pressure of extracellular fluids and water movement.
  - Essential for muscle contraction.
  - Required for conduction of nerve impulses.
  - Assists in the transportation of substances across the cell membranes.
    Sources**:** Sweet potato, broccoli, pumpkin seeds, eggs, milk etc.

- **Phosphorous (P):** It is the second most plentiful mineral in the human body that is concentrated maximum in the connective tissues and combines with calcium in the bones and teeth. The main functions of this mineral are:
  - Essential for bone and teeth structure.
  - Vital constituent of many proteins, vitamins, nucleic acids etc.
  - Essential component of DNA, RNA, bones, teeth etc.
  - Essential for energy metabolism of the cells.

- Promotes proper functioning of kidneys, heart and nervous system.
- Repairing body tissues and assists muscle contractions.
- Sources: Meat, milk, poultry, eggs, fish, nuts, dairy products, whole grains, and soft drinks. **Deficiency:** Weakness in body, loss of appetite, bone pain and fractures etc.

- **Fluorine:** Most of the body's fluorine is concentrated in bones and teeth. The main functions of this mineral are:
- It hardens tooth enamel and preventing dental caries.
  Source: Drinking water.

- **Magnesium (Mg):** It is essential for the production of ATP.The main functions of this mineral are:
  - Essential for the contraction and relaxation of muscles.
  - Vital role in the breakdown of ATP to ADP.
  - Involved in the synthesis of protein.
    Sources: Milk, dairy products, legumes, nuts, and leafy green vegetables which are rich in chlorophyll.

- **Potassium (K):** The main functions of this mineral are:
  - Maintaining intercellular osmotic pressure.
  - Regulation of pH.
  - Essential for muscle contraction.
  - Required for nerve impulse conduction.
  - Maintaining fluid volume inside and outside of cells.
    Sources: Fruits and vegetables, dairy products, dried peas, meat etc.

- **Sulfur (S):** It is the vital component of several amino acids, thiamine, insulin, biotin etc.
  Sources: Meat, milk, eggs, and legumes.

- **Chlorine (Cl):** It is required for maintaining osmotic pressure of extracellular fluids, regulating pH, and sustains electrolyte balance; formation of hydrochloric acid; assists in transportation of carbon dioxide by red blood cells.
  Sources of chlorine are same as for sodium.

2. Micronutrients (trace elements)

- **Iron (Fe):** Iron is part of the hemoglobin that catalyzes the formation of Vitamin A.
  Sources: Liver, lean meats, dried apricots, legumes, and molasses etc.
  Deficiency: Anemia. Some signs of anemia in body are feeling tired, weak, shortage of breath, pale face etc.

- **Molybdenum:** This mineral is a component of coenzymes that is required for the activity of xanthine oxidase, sulfite oxidase and aldehyde oxidase.
  Sources: Legumes such as lentils, beans, and peas etc.

- **Iodine (I):** Iodine is essential component for the synthesis of two thyroid hormones, namely thyroxine and triiodothyronine. The main functions of this mineral are:
  - Iodine nurtures healthy hair, nails, skin and teeth.
  - Controls growth and body weight.

  Sources: Sea foods, iodized salt, milk and foods that are grown in iodine-rich places.

  Deficiency: Goiter (enlargement of thyroid gland).

- **Manganese (Mn):** Manganese occurs in enzymes needed for synthesis of fatty acids, and cholesterol. The main functions of this mineral are:
  - Required for healthy bone structure.
  - Essential component of various enzyme systems.
  - Vital for the proper functioning of nervous system.

  Sources: Nuts, green leafy vegetables, whole-grain cereals, fruits etc.

- **Copper (Cu):** Copper is an essential trace mineral that plays an important role in the formation of connective tissues. The main functions of copper are:
  - Assists in the proper functioning of muscles.
  - Required for healthy body and growth.
  - Predominant role in functioning of arteries and heart.

  Sources: Vegetables, legumes, beans, nuts and legume seeds, mushrooms, liver, shellfish (especially cooked oysters), crab meat, avocado and whole grain cereals.

- **Selenium (Se)**: It is a part of the enzymes that deiodinate thyroid hormones. Normally, it works as an antioxidant along with vitamin E.
  Sources: Poultry, meat, fish, and nuts.

- **Zinc (Zn):** Zinc is generally concentrated in bones, teeth, hair, skin, liver, muscles etc. The main functions of this mineral are:
  - Essential for nourishing the skin's integrity.
  - Required for healing wounds.
  - Vital constituent of several hundred enzymes involved in digestion, respiration, bone metabolism, and liver metabolism.

  Sources: Oysters and cereals.

- **Cobalt (Co):** Cobalt is component of cyanocobalamin (Vitamin B_{12}) and is required for the synthesis of several enzymes.
  Sources: Liver, lean meats, and milk.

  - **Fluorine (F):** It is essential part of bone and tooth structure and required to prevent tooth decay and strengthen bones.

    Sources: Fluoridated water.
  - **Chromium (Cr):** It is essential for the use of carbohydrates. In the absence of chromium, there is unbalanced glucose mechanism in the body.

    Sources: Liver, lean meat, spices and wine.
  - **Electrolytes (Sodium, Chloride, Potassium):** The minerals that manage and stabilizes the flow of fluid in and out of the cells are known as electrolyte minerals. Examples are sodium, chloride, and potassium. They are known as

electrolyte minerals because they form electrolytes, which attract the fluidsand keep body cells from bursting

VII. WATER

Water is the prime constituent required by the human body after oxygen. It makes up a part of every cell, tissue and organ. It accounts for about 60% of body weight and is considered as an essential medium for conveying dissolved nutrients and waste in the entire body. Some foods contain a very excessive percentage of water.

Functions of Water

- It is the prime constituent of all body fluids.
- It assists in:
  - Regulation of nerve impulses
  - Muscle contractions
  - Nutrient transport
  - Regulate body temperature
  - Excretion of waste products
- It helps dissolve foods and aids digestion.
- It is a medium of dissolved minerals like calcium, flourine etc.
- It retains the body fluids liquid so that they may pass easily.

