**Chapter**

**Food Nutrients**

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1. **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.

The Antioxidants are the substances that protect body cells and the immune system from damage by harmful chemicals in air and foods. Some vitamins protect body cells and the immune system by either transforming harmful free radicals into less damaging compounds or repairing damaged cells.That is why some vitamins are considered to be antioxidants. The brief description of various nutrients is as under:

1. **Carbohydrates**

Carbohydrates make bulk of the diet and are chief source of energy. About 70% of the energy requirements for all body functions are obtained from carbohydrates. Energy is produced by the oxidation of carbohydrates in the animal cells using O2 (at the rate of 4 kcal/g edible portion). Carbohydrates also help in utilization of proteins and fats. The required minimum amount of carbohydrates is 100 g/day to ensure efficient oxidation of fat. Carbohydrates when consumed in excess are converted into fats (some glycogens also) to be used when needed.

The main sources of carbohydrates in the diet are starch and sugar. The sources of starch are mainly cereal grains (wheat, rice etc.) or tubers (potatoes, sweet potatoes, cassava). The sources of sugar are sugarcane and fruits.

The general formula for carbohydrates is Cx(H2O)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**

 Monosaccharides are compounds that cannot be hydrolyzed to simpler compounds. These are the simple sugars containing short chains of C-atom with one aldehydic or ketonic group. Each of the remaining C atom bearing a hydroxyl (-OH) group. Glucose (also called dextrin), galactose, fructose and mannose have same empirical formula C6H12O6. They differ in the arrangement of groupings about the C-atom and are distinctive in their physical properties like solubility, sweetness etc.

Substances which have identical molecular formulas but different structural formulas are known 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 and is soluble in hot or cold water. Fructose (present in honey, ripe fruits, some vegetables) is much sweet than cane sugar, highly soluble and don’t readily crystalize.





**Fig 1. Structure of Glucose**

Excess of Glucose is stored as glycogen in the liver and muscles. It is also stored as adipose tissue. If less than required amount of carbohydrate is consumed, the body first burns its own fats and then its tissue proteins for heat and energy. A temporary drop in the glucose concentration may impair nervous system functioning because the neurons depend upon a continuous supply of glucose for survival. Any decrease in the normal amount required will have an effect on the person’s neurological state.

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 (a B complex vitamin), Ribonucleic acid (RNA) and Deoxyribonucleic acid (DNA). It is rapidly synthesized by the body and is not a dietary essential.

* 1. **Disaccharides**

Disaccharides (C12H22O11) are formed when two hexoses are combined with the loss of one molecule of water. They are water soluble, diffusible and crystallizable. They vary widely in their sweetness. They split to simple sugars by acid hydrolysis or by digestive enzymes.

Sucrose (table sugar) is the combination of glucose and fructose. Lactose (milk sugar) is combination of glucose and galactose. Lactose is 1/6th as sweet as sucrose and dissolves poorly in cold water. Maltose (or malt sugar) is combination of two glucose molecules and is the immediate product in the hydrolysis of starch. Maltose is produced in malting and fermentation of grains and is present in beer and malted breakfast cereals. All sugars are very soluble in water because of their many hydroxyl groups.

**Reducing and Non-reducing sugars**

The reducing sugars have a free aldehyde (-CHO) orketone (-C=0) group. All common monosaccharides are reducing sugars. The disaccharides maltose and lactose are reducing sugars. The non-reducing sugars don’t have a free aldehyde (-CHO) orketone (-C=0) group. The disaccharide sucrose is a non-reducing sugar.

* 1. **Polysaccharides**

Polysaccharides (C6H10O5)n are complex compounds with a relatively high molecular weight. They are amorphous rather than crystalline, are not sweet, are insoluble in water, and are digested with varying degrees of completeness. Starches, dextrins, glycogens, and several indigestible carbohydrates are of nutritional interest.

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. The starch consists of two components viz. Amylose and Amylopectin. The amylose forms about 15-30% and amylopectin about 70-85% of starch.

* **Amylose** consists of linear, un-branched chains of several hundred glucose residues (units). The glucose residues are linked by a glycosidic bond between their C-1 and C-4 carbon atoms. The number of glucose units present 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.



 **Fig. 2 Structure of Amylose**

* **Amylopectin** (Fig. 3) differs from amylose in being 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 linkage. 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.



**Fig. 3. Structure of Amylopectin**

Dextrin is intermediate products in the hydrolysis of starch and consists of shorter chains of glucose units.

* **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. Animals store excess glucose by polymerizing it to form glycogen. Glycogen is broken back down into glucose when energy is needed (a process calledglycogenolysis).

**2.4 Non-starch polysaccharides**

1. **Cellulose**

The skins of fruits, the covering of seeds and the structural parts of edible plants 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 ripe fruits) has the ability to absorb water and to form 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.

1. **Gum Arabic** obtained from the bark of Acacia trees is a mixture of polysaccharides, is used as an emulsifier and stabilizer in baked products.
2. **Guar gum** is used as a thickening agent and a stabilizer in salad dressings and ice creams.
3. **Xanthan gum** is a polysaccharide is used as thickening agent in canned foods, salad dressings and instant puddings and jellies.
4. **Dextran** is used as a thickening and stabilizing agent in bakery and confectionary products.
5. **Proteins**

The word protein is derived from Greek word “Proteius” means “to be first or primary”. Proteins are the principal components of all living cells and are important in practically all aspects of cell structure and functions. They are vital parts of nucleus and protoplasm of every cell. No form of life can exist without proteins. Protein is the most abundant component in the body. Proteins yield 4.1 kcal of energy per gram.

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 (having high molecular weight ranging from 13,700 to 1,60,000 or more) made of α-amino acids (more precisely L-α aminocarboxylic acids) arranged in a linear chain and joined together by peptide bonds between the carboxy (COOH) and amino (NH2) 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) are made up of the elements carbon, hydrogen, oxygen and nitrogen and with few exceptions, Sulphur. Most proteins also contain P, and some specialized proteins contain very small amounts of Fe, Cu and other inorganic elements.

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## Fig. 4. Amino acid

## The NH2 group can usually be found on the C-atom next 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) with exception of glycine which has asymmetric C-atoms.

The amino acids contain a basic (Amino i.e. NH2) group and an acid (carboxyl i.e. COOH) group in their molecules. The presence of these acidic and basic groups in the constituent amino acid is responsible for amphoteric nature of proteins. The 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 alkalies. The main type of linkage between amino acids in the protein is the peptide bonds (Fig. 5). The peptide linkage between two amino acids is



**Fig. 5 Peptide Bond**

The functional group -C(=O) NH- is called an amide group or (in the context of proteins) a peptide group.

Different amino acids can combine 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. Therefore, a protein is a polypeptide, a linear polymer of many amino acids, linked by peptide bonds.

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 as the body either cannot manufacture them in sufficient quantities or are unable to produce them at all. The essential amino acids are necessary for growth and health of a growing animal, because if one of the amino acids is missing, then protein synthesis cannot take place. Protein synthesis is the backbone for growth.

**Essential Amino Acids**

* + 1. Histidine (essential in children, not in adults)
		2. Arginine (essential in children, not in adults)
		3. Isoleucine
		4. Leucine
		5. Lysine
		6. Methionine
		7. Phenylalanine
		8. Threonine
		9. Tryptophan, and
		10. Valine.

The protein which contains adequate amounts of the essential amino acids to maintain human body tissues and promote normal growth and development is called complete proteins. Incomplete proteins are unable, by themselves, to maintain human tissues or to support normal growth and development. 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.

**Nonessential Amino Acids**

1. Alanine,

2. Asparagine,

3. Aspartic Acid,

4. Glutamic Acid.

**Conditional Amino Acids**

1. Cysteine
2. Glutamine
3. Glycine
4. Proline
5. Serine, and
6. Tyrosine.

The nutritive value of protein is determined by many parameters. Some are protein efficiency ratio (PER); digestibility coefficient; biological value; net protein utilization; net chemical ratio; chemical score etc.

**3.1Classification of proteins based on conformation**

1. **Globular Proteins:** It consists of polypeptides chain that is tightly folded into globular shape. It includes most of enzymes, hormones, and antibodies.
2. **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.
	1. **Classification of proteins on the basis of specific function**
3. **Storage Proteins:** It stores nutrients that the organism needs. E.g. Protein in grain, casein in milk.
4. **Structural Proteins:** The protein that hold the living system together. E.g. Collagen, -keratin (hairs).
5. **Contractile proteins:** They are responsible for muscular movement. E.g. Actin and myosin.
6. **Transport proteins:** These are the proteins that carry molecules or ions from one place to another in the living system. E.g. Hemoglobin (carries O2 in blood), myoglobin (carries O2 in muscles).
7. **Protective proteins:** these are the proteins that destroy foreign substances released in living system e.g. Antibodies.
8. **Toxins:** these are the poisonous proteins e.g. Clostridium botulinum toxin.
	1. **Classification of proteins based on composition**
		1. **Simple proteins**

The simple proteins are those which are made of amino acid units only, joined by peptide bond. These proteins yield only amino acids or their derivatives on hydrolysis.

1. **Albumins:** These are water soluble-proteins found in all body cells and also in the blood stream. These are coagulated by heat. Examples are lactalbumin found in milk, Egg albumin and serum albumin found in blood.
2. **Globulins:** These are insoluble in water but are soluble in dilute salt solutions of strong acids and bases. Examples of globulins are lactoglobulin found in milk, Serum globulin (blood), tuberin (potato), myosin and actin in meat.
3. **Glutelins:** These are soluble in dilute acids and alkalis. E.g. protein glutenin from wheat, oryzenin (rice). They occur only in plant material.
4. **Prolamins:** These are soluble in 70-80% alcohol. They include gliadin from wheat and zein from corn. They are found only in plant material.
5. **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. Scleroproteins are insoluble in all neutral solvents and in dilute alkalis and acids. They are found in connective tissues and in hair and nails. E.g. Keratin (found in the cornified layers of the skin, cortex of hair and nails); collagen, elastin.
6. **Histones:** Soluble in water and insoluble in very dilute ammonia. On hydrolysis, they yield several amino acids, among which the basic (alkaline) ones are predominate. They have high content of lysine and arginine. The important members of this group are histones, and the globin of hemoglobin.
7. **Protamine:** They are rich in arginine. Strongly basic proteins with low MW (4000-8000 daltons), soluble in water, not coagulated by heat, on hydrolysis yield large amounts of basic (alkaline) amino acids. eg. salmine (in salmon).
	* 1. **Conjugated proteins**

These consist of simple proteins in combination with some non-protein component. The non-protein groups are called prosthetic groups or **cofactors**. Conjugated protein includes the following group.

1. **Nucleoproteins:** These are the Compounds of protein with nucleic acid.
2. **Glycoproteins:** Protein molecules combined with a carbohydrate group. Eg. Mucin;
3. **Phosphoproteins:** Phosphoproteins are proteins in combination with a phosphate-containing radical other than a nucleic acid or a phospholipid. Examples of phosphoproteins are casein of milk and ovo vitelline in egg yolk.
4. **Chromoproteins:** These are proteins in combination with a prosthetic group that is a pigment. Examples are the respiratory pigments haemoglobin and hemocyanin, visual purple or rhodopsin found in the rods of the eye, flavoproteins and cytochromes.
5. **Lecithoproteins:** Protein molecules combined with lecithin or related substances.
6. **Lipoproteins:** These are proteins conjugated with lipids. There are four types of lipoproteins, high density lipoproteins (HDL) or a-lipoproteins, low density lipoproteins (VLDL) or pre-β lipoproteins and chylomicrons.
7. **Metalloproteins:** These are proteins conjugated to metal ion (s) which are not part of the prosthetic group. They include caeruloplasmin, an enzyme with oxidase activity that may transport copper in plasma, and siderophilin that is found to iron.
	* 1. **Derived proteins**

These are not naturally occurring proteins and are obtained from simple proteins by the action of enzymes and chemical agents, heat, X- rays, UV rays etc. eg. Peptides, peptones, proteoses.

* Casein and lactalbumin are proteins of milk.
* The chief protein of wheat is gluten (a mixture of two proteins namely 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.

**3.4 Structure of proteins**

Structural features of proteins are usually described at four levels of complexity

* + 1. **Primary structure:** It is the sequence (linear arrangement) of covalently linked (peptide bond) amino acids.
		2. **Secondary structure (due to hydrogen bonds):** Segments of polypeptides often fold locally into stable structures. The structures are stabilized by hydrogen bonding eg. helices and - pleated sheets. Secondary structure of proteins are presented in Fig. 6 as under.



**Fig. 6 Secondary structure of proteins**

* + 1. **Tertiary structure (due to hydrophilic, hydrophobic disulphide bonds):** Tertiary protein structure refers to the complete 3D structure of a protein, which results from a large number of non-covalent interactions between amino acids. The comparison of primary, secondary and tertiary structure is presented in Fig. 7 as under.
		2. **Quaternary structure:** It refers to the regular association of two or more polypeptide chains to form a complex. This structure tends to be stabilized mainly by weak interactions between residues exposed on surfaces polypeptides within a complex.

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**Fig. 7 Comparison of Primary, secondary and tertiary structure**

**3.5 Some properties of proteins**

1. **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.

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**Fig. 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.

1. **Denaturation of Proteins**

It is a process that changes the molecular structure without breaking any of the peptide bonds of protein. It can be brought by variety of agents like heat, pH, salts, surface effects etc. eg. Denaturation of whey proteins for production of milk powder.

1. **Maillard reaction**

When proteins react with sugars, they form brown nitrogenous polymers.

**3.6 Effects of Protein deficiency**

Protein deficiency may result in weight loss, reduced resistance to infection, impaired healing of wounds, hepatic insufficiency, nutritional edema, easy fatigue, muscular weakness, diarrhea, discoloration of skin. Nutrition edema is the condition of collection of fluid in the tissues due to decrease in osmotic pressure of the blood. The decrease in osmotic pressure of blood 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.

1. **Lipids**

Lipids consist of numerous fatlike chemical compounds that are insoluble in water but soluble in organic (i.e. non-polar) solvents like chloroform, benzene, carbon disulphide, ether etc. Lipid compounds include monoglycerides, diglycerides, triglycerides, phosphatides, cerebrosides, sterols, terpenes, fatty alcohols, and fatty acids.

The characteristic insolubility of lipids in water, in several cases, is due to the presence in them one or more fatty acids. Fats are abundant in both plants and animal materials. The fat content of fruits (except avocado and olive) is poor. Fat up to about 15% is present in the germ of cereals. Nuts, such as groundnuts, are rich sources of fats. Milk is an important source of fat. The adipose tissue of animals consists mainly of fats. The lipids rarely occur in an organism in Free State, but are more usually combined with proteins (lipoproteins) or carbohydrates (lipopolysaccharides or glycolipids).

**4.1 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 (37o C).
* The Triglycerides provide energy storage in adipocytes.
* Phosphoglycerides, sphingolipids, and steroids are structural components of cell membranes.
* Steroid hormones are critical intercellular messengers.
* Dietary fat acts as a carrier of lipid-soluble vitamins (vitamins A, D, E and K) into cells of small intestine.
* The lipids provide shock absorption to the delicate organs such as the kidneys and nerves. A layer of fat surrounds them.
* The lipids provide the insulation to the body eg. A layer of fat under the skin prevents heat loss from the body.
* Lipids are a source of antioxidants and bioactive compounds.
* Lipids are also incorporated as structural components of the brain and cell membranes.

Like carbohydrates, lipids contain the elements C, H and O, but the resemblance ends there. Fats have a much smaller proportion of O than do the carbohydrates and differ importantly in their structure and properties. Some lipids also contain carbohydrates, phosphates, or nitrogenous compounds.

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 C as compared to carbohydrates; and consequently, on oxidation yield more energy). Generally, about 30% of human energy requirement are met by fats. When excess energy is supplied to the body, it is stored as fat.

The term fat is generally applied to all triglycerides {formed by combination of glycerol (alcohol) and fatty acids}. The nature of the fat or oil depends on the kind of fatty acids linked the glycerol. The hardness, melting point and flavor of fat is related to the length of C-chain and the level of saturation of fatty acids.

Fats are Glycerides.

The Glycerides are Esters.

Therefore, Fats are Esters.

**4.2 Esters**

An ester is the condensation product of an alcohol and a carboxylic acid.



In fat, alcohol part is always Glycerol  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.



**Fig. 9. Triglyceride**

Cyclic esters are called lactones, regardless of whether they are derived from an organic or an inorganic acid.

**4.3 Fatty acids (carboxylic acids)**

A fatty acid is a long chain (no branching) carboxylic acid having the formula CH3 (CH2)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. The fatty acids with ODD numbered C atoms are found in animal and vegetable fats but they seldom exceed 1-2% of total fat.

**4.3.1 Saturated and unsaturated Fatty acids**

The saturated fatty acids have only the single bonds and the unsaturated fatty acids have the double or triple bonds. Saturated fatty acids are found in solid fats, whereas most of the oils contain unsaturated fatty acids (having double bonds). The unsaturated fatty acids may have one, two or even up to 6 double bonds. Generally, straight chain saturated fatty acids C2 to C20 (or more precisely C16 to C18) are found in most animal and vegetable fats.

Saturated fatty acids (having only single bonds) with more than 24 Carbon atoms seldom occur in food triglycerides, but do so in waxes. The lower members C4-C10 occur mainly in milk fat. Those of chain length C12-C24 are found in most animal, vegetable fats. The triglycerides from animal source contain a higher percentage of saturated fatty acids and are normally solid at room temperature and are known as fat. The most commonly encountered saturated fatty acids are lauric, myristic, palmitic and stearic. The triglycerides from plant source are rich in unsaturated fatty acids, are generally liquids at room temperature and are called oils. The unsaturated fatty acids may have one, two or even up to 6 double bonds. The most commonly encountered un-saturated fatty acids are oleic acid, linolenic acid, linoleic acid.
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). In UNSFs, the double bonds carry a slightly negative charge and readily accept charged hydrogen atoms, creating a saturated fatty acid (Fig. 10).



**Fig. 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 and so forth. The last position is labelled as a "ω", the last letter in the Greek alphabet. The physiological properties of unsaturated fatty acids largely depend on the position of the first unsaturation relative to the end position and not the carboxylate. That is why the USFAs are designated by the position of first double bond from the end (omega) position. For example, the term ω-3 (Fig. 11) signifies that the first double bond exists as the third carbon-carbon bond from the terminal CH3 end of the carbon chain.



**Fig. 11 Omega fatty acid**

Linoleic acid (Fig. 12) is an  fatty acid because it has a double bond six carbons away from the "" carbon. Linoleic acid plays an important role in lowering cholesterol levels. linolenic acid is an  fatty acid because it has a double bond three carbons away from the "" carbon. Arachidonic acid is an fatty acid and the oleic acid which is an fatty acid. ω-3 (- linolenic acid type), ω-6 (linoleic acid type) and ω-9 (oleic acid type) are USFAs. The ω-6 type includes -linolenic acid (Fig. 12) and arachidonic acid (found in meat, liver, lard and lipids of chicken eggs). Erucic acid found only in mustard family of seeds belongs to ω-9 group.



**Fig. 12. Linolenic acid and Linoleic acid**

In these simplified structural formulas of unsaturated fatty acids, each angle represents a carbon atom. All the double bonds have the Cis configuration.

**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) or trans configuration.

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**Fig. 13 Cis configuration**

A cis configuration means that **adjacent hydrogen atoms are on the same side of the double bond.** The rigidity of the double bond freezes its conformation and restricts the conformational freedom of the fatty acid. More the number of double bonds the chain in *cis* configuration, the less will be the flexibility.

A trans configuration (Fig. 14), **two hydrogen atoms are bound to opposite sides of the double bond.** As a result, they do not cause the chain to bend much, and their shape is similar to straight saturated fatty acids.

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**Fig. 14 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 | C3H5COOH | -70°C, Soluble | Liquid at RT | Butter fat |
| Caproic Acid | Hexanoic acid | C5H11COOH | Slightly soluble | Liquid at RT | Butter fat |
| Caprylic Acid | Octanoic acid | C7H15COOH | Insoluble | Liquid at RT | coconut oil |
| Capric Acid | Decanoic acid | C9H19COOH | 32°C Insoluble | Solid at RT | coconut oil |
| Lauric acid | Dodecanoic acid | C11H23COOH | 44°C | Solid at RT | coconut oil |
| Maristic acid | Tetradecanoic acid | C13H27COOH | 54°C | Solid at RT | palm kernel oil |
| Palmitic acid | Hexadecanoic acid | C15H31COOH | 63°C | Solid at RT | palm oil |
| Stearic acid  | Octadecanoic acid | C17H35COOH | 70°C | Solid at RT | animal fats |
| Arachidic acid | Eicosanoic acid | C17H39COOH | 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 | C15H29COOH | 0°C | olive oil |  |
| Oleic acid (Soft fat) (2H atoms less).  | 9-octadecenoic acid | C17H33COOHCnH2n-2COOH | 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 | C17H31COOHCnH2n-4COOH | 5°C | flaxseed (linseed)oil |  |
| - Linolenic acid | 9,12,15-octadecatrienoic acid; | C17H29COOH | -11°C | borage oil |  |
| - Linolenic acid | 6,9,12-octadecatrienoic acid | C17H29COOH |  | liver fats |  |
| Arachidonic acid | 5,8,11,14-eicosatetraenoic acid | C19H39COOH | -50°C | fish oil |  |
| Gadoleic Acid | 9-eicosenoic acid | 20 Carbon atoms |  | Fish oil |  |
| Eicosapentaenoic acid (EPA) | 5,8,11,14,17-eicosapentaenoic | 1. carbons
 |  |  |  |

The short chain fatty acids (with <14 C-atoms) occur as triglyceride constituent in milk fat, coconut and palm seeds. They also occur in free form or esters of low MW alcohols in foods processed with microorganisms and contribute to the aroma of such foods.

* Oleic acid is found in almost all fats. It is a dominant compound of olive oil in which it is present up to a concentration of 75%.
* Linoleic acid is present in high concentration in many fats and oils. It is present to the extent of 60-80% in safflower seed oil.
* Linolenic acid comprises 50-60% of the fatty acid in linseed oil.
* Arachidonic acid is found primarily in animal sources.

**4.3.2 Essential fatty acids**

The essential fatty acids are those polyunsaturated fatty acids which cannot be made in the body from other substrates. They must be supplied 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 mammals lack the ability to introduce double bonds in fatty acids beyond carbons 9 and 10. Hence linoleic acid and -linolenic acid are essential fatty acids for humans. The linoleic acid and -linolenic acid are the parent compounds of the -6 and -3 fatty acid series, respectively. The linoleic acid (an *ω* -6 fatty acid). and -linolenic acid (an *ω* -3 fatty acid), are widely distributed in plant oils. In addition, fish oils contain the longer-chain -3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Other "conditionally essential" fatty acids include γ-linolenic acid (an *ω* -6 fatty acid), lauric acid (a saturated fatty acid), and palmitoleic acid (a monounsaturated fatty acid).

The humans can easily make saturated fatty acids or monounsaturated fatty acids with a double bond at the -9 position, but do not have the enzymes necessary to introduce a double bond at the -3 position or -6 position. Excessive amounts of -6 polyunsaturated fatty acids and a very high  ratio have been linked with pathogenesis of many diseases, including cardiovascular disease, cancer, and inflammatory and autoimmune diseases.

The ratio of -6 to -3 in modern diets is approximately 15:1, whereas ratios of 2:1 to 4:1 have been associated with reduced mortality from cardiovascular disease, suppressed inflammation in patients with rheumatoid arthritis, and decreased risk of breast cancer.

Some researchers have suggested that it may be better to increase the consumption of omega-3 fatty acids rather than decrease the consumption of omega-6 fatty acids because a reduction of polyunsaturated fats in the diet would increase the incidence of cardiovascular disease.

The essential fatty acids linoleic acid (an *ω* -6 fatty acid). and -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

**4.3.3 Fat as an energy source**

Before fats can be used 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. In the body, the liver converts fatty acids from one form to another. The liver also controls the total amount of circulating lipids and cholesterol that is released into the blood.

* + 1. **Functions of essential fatty acids in the human body**
1. Essential fatty acids are primarily used to produce hormone-like substances that regulate a wide range of functions, including blood pressure, blood clotting, blood lipid levels, the immune response, and the inflammation response to injury infection.
2. They prevent deposition of cholesterol in arteries and veins.
3. Their deficiency results loss of weight in children.
4. Their deficiency results in the development of eczema.
	* 1. **Classification of Lipids**

Lipids are broadly classified into the following groups :

* + - 1. **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.

**Natural fats and oils** are the Esters of glycerol with long chain carboxylic acid (12 to 20 carbon atoms). These are known as triglycerides (or triacylglycerols).

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** (also referred to as **neutral fats**) contain three fatty acids.

A **“simple triglyceride”** is one in which the 3 fatty acids are the same. A **“mixed triglyceride”** is one in which at least two fatty acids are different. Mixed triglycerides account for 98% of fats in foods and over 90% of fat in the body.

**Waxes**

The waxes are esters of **long chain** **fatty acids** with **long chain** **or 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

**4.3.5.2 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 acid or amine derivative, phosphoric acid or protein etc. The compound lipids include phosphoglycerides (phospholipids or phosphatides), steroids, carotenoids and lipids functioning as vitamins or hormones. The phospholipid containing Choline is called Lecithin. Lecithin is a very good emulsifier. Egg yolk is rich in Lecithin and is used in the preparation of emulsions. Example: lecithin, cephalins, sphingomyelins etc.

**4.3.5.3 Derived Lipids**

Derived lipids are the substances derived from neutral (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, fatty alcohols, mono and diglycerides, steroids, terpenes and carotenoids.

Cholesterol (C27H45OH) 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); carotenoids; and the fat-soluble vitamins A, D, E and K.

Antioxidants are used to stabilize fats and oils. An antioxidant is a substance that is added to fats or fat containing foods to retard the oxidative breakdown of fats and thus prevent the spoilage of foods. Naturally, an antioxidant should be fat soluble and should not contribute any objectionable flavour, odour, colour to the fat or foods in which it is used. These include butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), alpha-tocopherol (Vitamin E) and propyl gallate (PG).

1. **Vitamins**

The word "vitamin" comes from vita, the Latin for “life”. Vitamins are low molecular weight organic (carbon containing) substances needed for normal function, growth and maintenance of good health. The vitamins are “accessory nutrients”. Vitamins together with minerals are involved in small quantities in the regulation of the body processes. They are constituents of enzymes, which function as catalyst for many biological reactions within the body. Vitamins are cofactors [Coenzymes (partners) with enzymes in reactions], they don’t do anything by themselves. They are not a source of energy. They cannot be made by our own bodies. Vitamins are found in plant and animal tissues. Vegetables and fruits are good sources of vitamins. Wheat is an excellent source of B vitamins.

The vitamins Riboflavin, niacin, vitamin B6, vitamin B12, vitamin B5, and biotin have some common functions in the body. They are all involved in using carbohydrates, proteins, and fats. The vitamins may be soluble in water or fat. Water-soluble vitamins dissolve in water and are carried in the bloodstream; they are not stored, and excess amounts are eliminated with waste products. Fat-soluble vitamins are absorbed and transported by fat; excess amounts are stored by the body for later use. The fat-soluble vitamins are stored in moderate quantities in various tissues and are fairly resistant to the effects of heat.

**5.1 Fat soluble vitamins**

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

1. **Vitamin A (Retinol)**

Vitamin A has been named as retinol because of its specific function in the retina of the eye. It is essential for night vision. It maintains the epithelial cells of skin and membranes. It is also essential for the growth and development of skeletal and soft tissues. It is also required for the proper formation and maintenance of tooth enamel and healthy gums.

Vitamin A is found in animal materials like meat, milk, fish etc. especially in the liver. Plants do not contain vitamin A, but contain its precursors, the carotenoids, which are converted to vitamin A after absorption by the ingesting animal. Prolonged deficiency of vitamin A may result in rough, scaly skin, night blindness, corneal ulceration, infections in the respiratory tract and other areas of the body.

1. **Vitamin D (Calciferol)**

Vitamin D isolated in crystalline form is known as Calciferol. Most foods are low in vitamin D, although it is found in small quantities in butter, cream, egg yolk and liver. Milk is a poor source of vitamin D. The best food sources of vitamin D are fish liver oils. There are at least 10 sterols which are provitamins D. Two major sterols that are converted into vitamin D by the action of UV light are the plant sterol, ergosterol and 7-dehydrocholestrol from animal tissues. Vitamin D is remarkably stable. It can be stored in the body to large extent.

Vitamin D promotes the absorption of calcium and phosphorus as well as promotes the development of teeth and bones. The deficiency of vitamin D in children during the period of active skeletal growth causes rickets, which results from the defective mineralization of the ends of the growing bones. Osteomalacia is a disease caused by a lack of vitamin D in adults.

1. **Vitamin E (Tocopherol)**

Vitamin E is an antioxidant. It prevents oxidation of vitamin A and polyunsaturated fatty acids. It appears to protect the cell membranes from deterioration caused by peroxides and free radicals formed from fats. Good sources of Vitamin E are oils from cereal seeds, salad oils, margarine, shortenings, fruits, nuts, and vegetables. Wheat germ oil is the richest source of the vitamin. It is also present in other cereals, green plants, egg-yolk, milk fat, butter, meat, nuts and vegetable oils (soyabean, corn, cottonseed).

**iv. Vitamin K**

Two forms of vitamin K occur naturally – vitamin K1 (Phylloquinone) in green plants and vitamin K2 (Menaquinone) which is formed as a result of bacterial action in the intestinal tract. The best sources of vitamin K are green leafy vegetables, especially spinach, cabbage and lettuce. Fruits, cereals, dairy products and meat provide lesser amounts.

Vitamin K is needed for synthesis of prothrombin, which functions in blood clotting i.e. this vitamin is an anti-haemorrhagic vitamin. Vitamin K deficiency prolongs blood clotting time which may lead to internal hemorrhage and uncontrolled bleeding.

**5.2 Water soluble vitamins**

Water soluble vitamins are Vitamin C (Ascorbic acid) and B complex group. The water-soluble vitamins are carried in bloodstream and are not stored in body. Excess amounts of these vitamins may cause extra work on kidneys.

**Vitamin B complex** is several compounds that are essential for normal cellular metabolism that often occur together in foods. Vitamin B complex contains:

* 1. Thiamine (B1)
	2. Riboflavin (B2)
	3. Folic acid (Folacin) (B9)
	4. Niacin (B3)
	5. Pantothenic acid (B5)
	6. Biotin (B7)
	7. Cyanocobalamin (B12)
	8. Choline
	9. Inositol
	10. Pyridoxine (B6)
1. **Ascorbic Acid (Vitamin C)**

It closely resembles glucose in structure. It is a white, crystalline, colorless compound readily soluble in water. It is a strong reducing agent, comparatively stable in an acid medium but is destroyed by the action of heat. It is most unstable of all known vitamins. In solution it easily gets oxidized, especially on exposure to heat.

Its excellent sources are citrus fruits, oranges, sweetlime, grapefruit, berries, guava, capsicum and green leafy vegetables. Amla is one of the richest sources of ascorbic acid containing about 600 mg ascorbic acid per 100 g of the fruit. Leafy vegetables such as drumstick leaves, amaranth, and cabbage contain less quantity of ascorbic acid. Canned or frozen citrus fruits and tomatoes are also good sources. Milk, eggs, meat and poultry contain little or no ascorbic acid.

Vitamin C helps to maintain healthy capillaries, bones, skin, and teeth. It helps in healing of wounds, fractures and resist bacterial infections in the body. It also plays an important role in the normal metabolism of the amino acid (viz. tyrosine), and in the functioning of the adrenal gland. It aids in the absorption of iron and works as an antioxidant. It plays a role in caring for collagen that gives structure to bones, cartilage, muscle, and blood vessels.

Many species of animals are able to synthesize ascorbic acid and do not require it in the diet. Prolonged deficiency of this vitamin results in scurvy.

1. **Vitamin B1 (Thiamine)**

It is part of the coenzyme needed for oxidation of carbohydrates and in a coenzyme needed in synthesis of ribose. It is necessary throughout the life for release of energy from fuel molecules. The best sources of this vitamin are cereal grain (particularly wheat) germ layers, pulses (peas, beans), nuts, liver lean meats, poultry egg yolk and fish. It is one of the least stable vitamins. Thermal destruction of thiamine in many products may leads to the formation of a characteristic odour which is involved in the development of “meaty flavor” in cooked products. Thiamine is also destroyed by oxidation and reduction. Extensive losses occur in cereals as a result of cooking or baking. Processing operations and storage also results in loss of this vitamin in meats, fruits and vegetables.

Mild thiamine deficiency may result in fatigue, emotional instability, depression, irritability, retarded normal growth, loss of appetite and lethargy. Severe thiamine deficiency of long duration causes beriberi which is characterized by disturbances of neurological and cardiovascular systems and of gastrointestinal tract.

1. **Riboflavin (Vitamin B2)**

Riboflavin ispart of enzymes and coenzymes needed for oxidation of glucose and fatty acids as well as needed for cellular growth. It is orange yellow in colour. It is less soluble in water than thiamine (Vitamin B1) but is more stable to heat in acid and neutral media. It is destroyed by heating in alkaline solution. Riboflavin is found in dairy products, lean meats, poultry, fish, grains, broccoli, turnip greens, asparagus, spinach, and enriched food products. Riboflavin is needed for energy metabolism, building tissue, and helps maintain good vision.

1. **Niacin (Nicotinic Acid)**

It is part of coenzymes needed for oxidation of glucose and synthesis of proteins, fats, and nucleic acids. It is one of the stablest vitamins, being relatively resistant to heat, light, acids and alkalis. Niacin is needed for energy metabolism, proper digestion, and healthy nervous system.

Good sources of the niacin are lean meat, yeast, fish, poultry, groundnuts, pulses and whole grain cereals. Fruits and vegetables poor sources of niacin. Niacin can be synthesized by the bacteria of the intestinal flora and is formed in the tissues from the amino acid tryptophan.

Deficiency of niacin results in weakness and indigestion followed by ulcerated mouth and tongue. Prolonged deficiency leads to pellagra, and this result in dermatitis, diarrhea and depression or dementia.

1. **Pyridoxine (B6)**

The vitamin is widely distributed throughout the plant and animal kingdom. The best sources are meat, especially liver, some vegetables and grain cereals with bran. The vitamin is stable to heat and strong alkali or acid; it is sensitive to light, especially ultraviolet light and when present in alkaline solutions. It is very unstable to light.

It is found in cells in active form. This is the coenzyme of many enzymes involved in carbohydrate, fat protein metabolism. It is involved as cofactor in the conversion of tryptophan to niacin, the essential fatty acid linoleic acid to arachidonic acid and the release of glucose from glycogen.

Deficiency of B6 in infants may result in epileptic form of convulsions, loss of weight and abdominal distress, vomiting and hyperirritability. In adults, deficiency may cause depression, confusion and convulsions.

1. **Folic acid (Folacin)**

It is a coenzyme needed for metabolism of certain amino acids and for synthesis of DNA as well as production of normal red blood cells. It prevents birth defects that damage the brain and spinal cord. Its rich sources are yeast, kidney, liver and green leafy vegetables, especially spinach, asparagus and broccoli. Dried beans and whole wheat bread are good sources of the vitamin. The folic acid content of processed milk, highly milled cereals, eggs, root vegetables and most fruits is low. Folacin deficiency in man results in poor growth, anemia, blood disorders, gastrointestinal tract disturbance.

1. **Biotin (B7)**

It is a coenzyme needed for metabolism of amino acids and fatty acids and for synthesis of nucleic acids. It is a sulphur containing vitamin widely distributed in nature and is essential for the health. Its good sources are liver, kidney, egg yolk, groundnuts and some vegetables. Cereal grains, fruits and meats are regarded as poor sources. Biotin of maize and soybean meal is completely available, whereas the biotin of wheat is almost unavailable. It is a water-soluble. It is stable to heat and light but unstable in strong acid or alkali.

The biotin deficiency in the human beings may be due consumption of large amounts of raw egg white (having biotin binding protein, avidin, present in raw egg-white). Symptoms of biotin deficiency in man include anorexia, nausea, vomiting, mental depression and dry scaly dermatitis. The vitamin plays an extremely important role in the metabolism of both carbohydrates and fats.

1. **Pantothenic acid (B5)**

It is part of coenzyme A needed for oxidation of carbohydrates and fats. It is widely distributed in foods and is particularly abundant in animal tissues, whole grain cereals and pulses. It also occurs in lesser amounts in milk, vegetable and fruits. 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.

As the vitamin is widely distributed in foods, a deficiency disease due to lack of it has not been observed in man. Deficiency symptoms have been produced by the administration of metabolic antagonists (omega methyl pantothenic acid). Symptoms of a vitamin B5 deficiency may include fatigue, insomnia, depression, irritability, vomiting, stomach pains, burning feet, and upper respiratory infections.

1. **Cobalamin or Cyanocobalamin** **(Vitamin B12)**

It is part of coenzyme needed for synthesis of nucleic acids and for the metabolism of carbohydrates; plays a role in myelin synthesis. It is known by the cobalamin since it is found as a co-ordination complex cobalt. It is present in animal protein foods. Liver and kidney are excellent sources of this vitamin. Milk, muscle meat, cheese, eggs and sea foods are good sources of this vitamin. There is no vitamin B12 in plant products such as grains, vegetables and fruits. Strict vegetarians may not get sufficient vitamin B12 from their dietary source. However, human requirements are very low and this met by intestinal bacterial synthesis.

It is water soluble and heat stable. Approximately 70% of vitamin activity is retained during cooking. It is necessary for normal functioning in the metabolism of all cells, especially for those of the gastrointestinal tract, bone marrow and nervous tissue and for growth. Vitamin B12 deficiency is not usually dietary in origin, but results due to a lack of its absorption in intestine.

1. **Other factors listed among B-complex vitamins**
* **Choline**

It is known as a lipotropic factor because it prevents the deposit of fat in the liver. It is essential for the transmission of nerve impulses. Egg yolk is especially rich in choline, but legumes, organ meats, milk, muscle meats, and whole grain cereals 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.

1. **Minerals**

The minerals are inorganic components of food that leave ash as residue when burned. They occur in foods and tissues as inorganic salts in combination with organic compounds and chiefly in their ionic form. About 5% of the body weight is made up of minerals. Minerals also act as catalysts for many biological reactions within the body. Their other functions include the building of bones and other structural parts of the body, muscular contraction, transmission of messages through the nervous system, and the digestion and utilization of nutrients in food.

The human body requires about 20 mineral elements. Each has a specific function and is found in certain foods. The minerals cannot be destroyed by heat. Minerals are lost into the water during cooking. Minerals are found in foods from animal and plant sources. Dietary minerals may be present in inorganic salts, or as part of carbon-containing organic compounds. For example, magnesium is present in chlorophyll, the pigment that makes plants green.

Depending upon their amounts in the adult’s body, the mineral are classified as macronutrient and micronutrient elements. The macronutrients are present in the amounts greater than 0.005% of the body weight, while the micronutrients are present in less than 0.005% of body weight. The macro mineral (macronutrients) group is made up of Calcium, Phosphorus, Magnesium, Sodium, Potassium, Chloride, and Sulfur. The macrominerals are required in the adult human diet in amounts of over 100 mg/day.

Micro minerals (also known as trace elements) are chemical elements required in the amounts of less than 20 mg/day. Trace minerals includes Iron, Manganese, Copper, Iodine, Zinc, Fluoride, and Selenium.

* 1. **Macrominerals or macronutrients**
1. **Calcium (Ca)**

It is the most abundant mineral in the human body. More than 99% of total body calcium is stored in the bones and teeth. Calcium is also found in body fluids where its function is to regulate contractions of blood vessels and muscles. It is important for bone and teeth structure; is essential for nerve impulse conduction, muscle fiber contraction, and blood coagulation; increases the permeability of cell membranes; and activates certain enzymes. The requirement for calcium is greatest from puberty to maturity, when the body grows very quickly. Good source of Calciumare milk, milk products, and leafy green vegetables. Osteoporosis is a condition caused by calcium deficiency due to which the bones become porous, weak, fragile.

1. **Sodium (Na)**

It is usually consumed as table salt. The adequate intake of 1.5 grams per day with an upper limit of 2.3 grams per day is calculated to meet the needs for sweat losses for individuals 8 years or older engaged in recommended levels of physical activity. Active people in humid climates who sweat excessively may need more than the Adequate Intake. The upper limit applies to healthy individuals without hypertension, but may be too high for persons with hypertension. It helps to maintain osmotic pressure of extracellular fluids and regulate water movement; needed for conduction of nerve impulses and contractions of muscle fibers; aids in regulation of pH and in transport of substances across cell membranes.

1. **Phosphorous (P)**

It is important for bone and teeth structure; is a component in nearly all metabolic reactions; is a constituent of nucleic acids, many proteins, some enzymes, and some vitamins; and occurs in cell membranes, ATP, and phosphates of the body fluids. Recommended Dietary Allowances (RDA): adults, 800 mg; young adults and pregnant women, 1200 mg. Phosphorus is the second most plentiful "essential mineral" in the body and is a key component of DNA, RNA, bones, and teeth, and many other compounds required for life. It is present in many foods, especially in milk. It combines with calcium in the bones and teeth. It plays an important role in energy metabolism of the cells, affecting carbohydrates, lipids and proteins. Like calcium, phosphorus is essential for bone formation and maintenance; more than 75% of phosphorus is contained in the skeletal structure and connective tissues. Phosphorus also stimulates muscle contraction and contributes to tissue growth and repair, energy production, nerve-impulse transmission, central nervous system health, and proper heart and kidney function.

Phosphorus exists to some degree in nearly all foods, especially meats, poultry, eggs, fish, nuts, dairy products, whole grains, and soft drinks. Deficiency is rare. The deficiency may be induced by long term use of antacids or anticonvulsant drugs that contain aluminum hydroxide. Symptoms of phosphorus deficiency include general weakness, loss of appetite, bone pain, and increased susceptibility to bone fractures. Excess phosphorus in the bloodstream promotes calcium loss, which may weaken bones. Extreme phosphorus toxicity is very rare, except in the event of kidney disease.

1. **Fluorine**

Most of the body's fluorine is contained in bones and teeth. The main source of fluoride is drinking water. Fluorine hardens tooth enamel and effectively prevents dental caries. Excessive fluorine in drinking water can accumulate in teeth and bones, causing fluorosis.

1. **Magnesium (Mg)**

It is needed in metabolic reactions that occur in mitochondria and are associated with the production of ATP; plays a role in the breakdown of ATP to ADP. Magnesium has several important metabolic functions in the production and transport of energy. It is also important for the contraction and relaxation of muscles. It is involved in the synthesis of protein, and it assists in the functioning of some enzymes. Good source of Magnesium are milk, dairy products, legumes, nuts, and leafy green vegetables which are rich in chlorophyll.

1. **Potassium (K)**

It helps to maintain intercellular osmotic pressure and regulate pH; promotes metabolism; is needed for nerve impulse conduction and muscle fiber contraction. Potassium maintains fluid volume inside and outside of cells, and acts to blunt the rise of blood pressure in response to excess sodium intake. The adequate intake of potassium is 4.5 grams per day for children 9 to 13 years old and 4.7 grams per day for older persons. It is generally found in fruits and vegetables, dried peas, dairy products, meats, and nuts. Potassium from supplements or salt substitutes can result in hyperkalemia and possibly sudden death if excess is consumed by individuals with chronic renal insufficiency (kidney disease) or diabetes.

1. **Sulfur (S)**

It is an essential part of various amino acids, thiamine, insulin, biotin, and mucopolysaccharides. Good source of Sulfur are meats, milk, eggs, and legumes.

1. **Chlorine (Cl)**

It helps maintain osmotic pressure of extracellular fluids, regulates pH, and maintains electrolyte balance; is essential in the formation of hydrochloric acid; aids transport of carbon dioxide by red blood cells. Good source of Chlorine are same as for sodium.

* 1. **Micronutrients (trace elements)**
1. **Iron (Fe)**

Iron is part of the hemoglobin, myoglobin molecules, catalyzes formation of Vitamin A; is incorporated into a number of enzymes. Good sources of Iron are liver, lean meats, dried apricots, raisins, enriched whole-grain cereals, legumes, and molasses. Meat products are the best sources of dietary iron. Iron deficiency, which can cause anemia, is the most common nutritional deficiency in the world. Some signs of iron-deficiency anemia in body are feeling tired, weak, short of breath, pale, and cold. Pica is a condition linked to iron deficiency which causes unusual appetite for ice, clay, and other nonfood items. Excess iron is toxic and may damage the intestines and other organs, as well as cause vomiting and diarrhea.

1. **Molybdenum**

Molybdenum is a component of coenzymes necessary for the activity of xanthine oxidase, sulfite oxidase (necessary for the metabolism of sulfur-containing amino acids, such as cysteine), and aldehyde oxidase. Legumes such as lentils, beans, and peas are good sources of molybdenum. The RDA for adult men and women is . The tolerable upper intake level is 2 mg/day.

1. **Iodine (I)**

Iodine is essential component for the synthesis of two thyroid hormones, namely thyroxine and triiodothyronine. In adults, about 80% of the iodide absorbed is trapped by the thyroid gland. Most environmental iodine occurs in seawater. People living far from the sea are at particular risk of deficiency. Salt fortified with iodide helps ensure adequate intake. In mild or moderate deficiency results in goiter which is an enlargement of the thyroid gland visible as a swelling of the front of the neck.

1. **Manganese (Mn)**

Manganese occurs in enzymes needed for synthesis of fatty acids, and cholesterol, formation of urea, and normal functions of the nervous system. It is necessary for healthy bone structure and is a component of several enzyme systems. The adequate intake of manganese is 2 to 5 mg/day. Good source of Manganese are nuts, legumes, whole-grain cereals, leafy green vegetables and fruits.

 **v. Copper (Cu)**

Copper is essential trace mineral, which plays a role in the formation of connective tissue, and in the normal functioning of muscles, the nervous system and the immune system. The human body requires copper for normal growth and health. Copper, along with iron, is a critical component in the formation of red blood cells. Copper also influences the functioning of the heart and arteries, helps prevent bone defects such as osteoporosis and osteoarthritis, and promotes healthy connective tissues. Good food sources include vegetables, legumes, beans, nuts and legume seeds, mushrooms, liver, shellfish (especially cooked oysters), crab meat, avocado and whole grain cereals.

Copper deficiency is rare, but can occur in people who are severely undernourished or who have chronic diarrhoea. Disorders that impair nutrient absorption, such as Crohn's disease, can also lead to copper deficiency, as can high dietary intakes of iron or zinc. Signs of deficiency include bleeding under the skin, damaged blood vessels, hair loss, pale skin, and an enlarged heart. Symptoms include fatigue.

**vi. Selenium (Se)**

It is a part of the enzyme which metabolizes hydroperoxides formed from PUFAs. It is also a part of the enzymes that deiodinate thyroid hormones. Generally, selenium acts as an antioxidant that works with vitamin E. Deficiency of selenium causes Keshan disease which is a form of congestive cardiomyopathy. The RDA for selenium is 70  . Selenium is found in poultry, meats, fish, and nuts.

**vii. Zinc (Zn)**

It is a constituent of several hundred enzymes involved in digestion, respiration, bone metabolism, and liver metabolism; is necessary for normal wound healing and maintaining the integrity of the skin. It is contained mainly in bones, teeth, hair, skin, liver, muscle, leukocytes, and testes. The RDA of zinc is 11 milligrams for men, and 8 milligrams for women. Good dietary sources of zinc are oysters, and cereals.

**viii. Cobalt (Co)**

Cobalt is component of cyanocobalamin (Vitamin B12) and is needed for the synthesis of several enzymes. Cobalt is present in liver, lean meats, and milk.

1. **Fluorine** (F)

It is a component of bone and tooth structure. Good source of Fluorine is fluoridated water. The fluoride is needed in the diet to prevent tooth decay and strengthen bones. A total intake of 1.5 to 4 mg per day is safe and adequate for adults. Chromic fluoride toxicity, fluorosis, is seen in persons consuming more than 20 mg per day over an extended period.

1. **Chromium** (*Cr*)

It is essential for the use of carbohydrates. In the absence of chromium, there is disturbed glucose mechanism in the body. A chromium intake of 50-200 microgram per day is recommended for adults. Good source of Chromium are liver, lean meats, spices and wine.

1. **Electrolytes (Sodium, Chloride, Potassium)**

The minerals which control and balance fluid flow in and out of cells are called Electrolyte minerals. Sodium, chloride, and potassium called electrolyte minerals because they form chemical particles called electrolytes, which attract fluids. Cells move electrolytes through cell walls as needed to balance fluids and keep cells from collapsing or bursting.

1. **Water**

Water (a most essential nutrient) is second only to oxygen in importance for the body. It is an ideal medium for transporting dissolved nutrients and wastes throughout the body. It makes up part of every cell, tissue, organ. It accounts for about 60% of body weight.Some foods contain a high percentage of water. Apart from this, oxidation of carbohydrates, fats and proteins in the body yields water.

* 1. **Functions of Water**
* It is the chief component 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 source of dissolved minerals such as flourine and calcium.
* It keeps the body fluids liquid so that they may flow easily.