Chapter 7

Minerals

Complex organic compounds like carbohydrates, fats proteins, vitamins provide energy, support growth and development and also perform protective and regulatory functions. A set of inorganic elements called minerals are also required by the body.

Minerals are defined as those elements which largely remain as ash when plant or animal tissues are completely burnt.

Like vitamins minerals are micro nutrients which perform regulatory and protective functions. The total mineral content of the body is however, small and accounts for only 4 - 6 percent of the total body weight.

Human body contains about 24 minerals. All of which much be supplied by the diet. Thee include calcium, phosphorous, potassium, sodium, chlorine, magnesium, iron, manganese, copper, iodine, cobalt, zinc, aluminium, arsenic, etc. These minerals are necessary for the following functions.

1. As constituents of bone and teeth. E.g. Calcium and phosphorous.
2. As constituents of body cells of soft tissues such as muscles, liver etc. e.g. Phosphorous.
3. As soluble salts, which give to the body fluids and cell contents, their composition and stability which are both essential for life, eg, Sodium, potassium chloride and phosphorous.
4. Some minerals are required in small quantities for specific functions.
   (a) Iron and copper :- formation of haemoglobin.
   (b) Iodine :- formation of thyroxine.
   (c) Zinc :- constituent of an enzyme(carbonic anhydrase) and a hormone (insulin)
   (d) Cobalt :- constituent of vitamin.e.g Vitamin B_{12} and
   (e) Some other elements which are essential for activity of various enzymes.

Some of the important minerals found in our body include calcium phosphorous, iron, iodine, sodium, potassium, zinc and chloride. All of these minerals are of course, derived from the food, we eat.

Of the minerals we have just mentioned some are required in larger amounts and others in much smaller amounts, as you will learn in this chapter. However the total amount of minerals required by the body is small, each mineral has to be seen in detail, with reference to the role they play, their food sources, their absorption and utilization in the body.

7.1 Calcium

Among the different minerals, calcium, occurs in the highest amounts in the body. About 99% of the calcium is present in the skeleton and the remaining 1% in soft tissues. The body of the infant at birth contains about 27.5 g of calcium while the adult human body contains about 1000 - 1200 g. All this calcium is deposited in the bones during the growth of the body.

7.1.1 Functions of Calcium

The important physiological functions of calcium are:

1. It is essential for the formation of bone and teeth.
2. It is essential for the clotting of blood.
3. It regulates the permeability of capillary walls.
4. It is essential for the contraction of heart and muscles.
5. It regulates the excitabily of nerve fibres and nerve centres.

7.1.2 Calcium Balance

Dietary calcium which is not absorbed in the intestines is excreted in the faeces. A small part of the absorbed calcium is excreted in urine. The calcium balance i.e. the difference between the quantity of calcium ingested and that excreted in urine and the faeces, is positive during growth, pregnancy, lactation and in normal adults. The excretion of calcium continues on a calcium deficient diet when the body will be in negative calcium balance.

7.1.3 Factors affecting calcium absorption

The various factors affecting calcium absorption from the diets are discussed below:

1. Vitamin D :- Vitamin D is essential for the absorption of calcium.
2. Phosphorous and Phytic acid :- Excess of phosphates lowers calcium absorption. Phytic acid forms insoluble calcium salts and interferes with the absorption of calcium.
3. Reaction of intestinal contents :- Calcium is well absorbed at the normal p^H of the intestines. If the contents become alkaline, calcium absorption is lowered due to the formation of insoluble tricalcium phosphate.
4. Fats and fatty acids :- Faulty absorption of fats leading to the presence of large amounts of fatty acids in the stools interferes with calcium absorption, as insoluble calcium salts of fatty acids are formed and excreted in the faeces.
5. Proteins :- Higher levels of proteins in the diet help to increase the absorption of calcium.
6. Fibre :- Presence of excess fibre in the diet interferes with the absorption of calcium.
7. Oxalic acid :- Oxalic acid present in certain food stuffs forms insoluble calcium oxalate which is excreted in the faeces, thus lowering calcium absorption.
8. Citric acid :- Even though citric acid and citrates have beneficial effect in rickets, affects calcium absorption.
9. Lactose :- Lactose increases the absorption of calcium. The beneficial effect of lactose is due to increased acidity(lactic acid), of the intestinal contents which leads to increased calcium absorption

7.1.4 Calcium Absorption and Retention in Humans

. The absorption and retention of calcium in human subjects depends on:

1. Calcium intake.
2. Presence of interfering substances.
3. Presence of vitamin D.

On normal intake of calcium, the retention varies from 10 to 30 % depending on the diet and the age of the subject.

7.1.5 Calcium and Parathyroid

The parathyroid regulates calcium level in blood and calcium metabolism in the bone. It acts directly on the bone releasing calcium from it and thus raising the plasma calcium level. It also increases the excretion of phosphates by the kidney. In hyperthyroidism, the serum calcium level may fall to a low level of 4 - 8 mg/100 ml and tetany may result. The symptoms of tetany can be relieved temporarily by injecting parathyroid hormones. In hyperthyroidism, the calcium level in serum may increase from the normal level of 9 - 11 mg to 16 - 20 mg. Rarefraction of the bones and spontaneous fracture may occur.

7.1.6 Effect of Calcium Deficiency

Young Animals and Children

The effects of deficiency are :

(a). Decreased rate of growth.

(b). Negative Calcium balance.

(c). Loss of calcium from bone leading to the development of osteoporosis.

(d). Hyperplasia(a diffuse overgrowth) of parathyroid glands, and

(e). Hyper irritability and tetany leading to death.

Adults

1. In adults deficiency of calcium causes a condition known as osteoporosis. Osteoporosis is the de calcification of bones. Osteoporosis results in:
   (a) Fractures of the brittle bones occur even after minor accidents.
   (b) Pain due to fractures of vertebrae may radiate round the trunk to the buttocks or down the legs.
   (c) Healing of fractures is not impaired.
2. Premature reduction in strength of teeth.

The treatment consists of giving a well balanced diet containing about 1 to 1.5 g calcium along with vitamin D.

7.1.7 Calcium Content of Blood

The calcium content of blood serum is fairly constant ranging from 9 - 11 mg per 100 ml. This level is maintained constant in healthy subjects by the following factors:

1. The calcium absorbed from food through the intestines and
2. The rate of secretion of parathyroid hormones which controls the level of calcium in blood.

7.1.8 Important Dietary Sources of Calcium

The important sources of Calcium in the diet are :

1. Milk and milk Products :- Milk is the best natural source and skimmed milk powder is the very rich source(1.37%) of calcium. Other sources are cheese and Khoa
2. Cereals, oil seeds, nuts etc. :- Ragi is the cheapest natural source of calcium containing about 0.3 to 0.36%. Sesame seeds are rich in calcium(1.45%), but the major part is situated in the husks.

3. Green leafy vegetables :- They are one of the cheapest natural sources of calcium containing about 0.44 to 1.13 %. They are also very rich sources of carotene and ascorbic acid. Other examples are Sesbania leaves, Carrot leaves, Amaranth leaves and drumstick leaves.

4. Fish :- Small fish eaten with bones is an excellent source of calcium.

7.1.9 Requirements

Surveys have shown that a large majority of the population in the developing countries consume diets providing 300 - 500 mg of calcium. Metabolic studies have shown that they maintain positive calcium balance. The FAO/WHO expert group suggested that this will be adequate to meet the needs of different age groups.

7.2 Phosphorous

An adult human body contains about 400 - 700 g of phosphorous as phosphates. A greater part of this is present in the bone and teeth and the rest in other tissues. Phosphorous is present in the body in two types:

1. As inorganic salts of phosphoric acid.

2. In combination with organic compounds.

Inorganic Phosphates

Phosphorous is present as calcium phosphate in bones and teeth and as phosphates of sodium and potassium in soft tissues and body fluids.

Organic Phosphates

The important organic compounds containing phosphorus are the following:

1. Phospholipids e.g lecithin, cephalin.

2. Nucleo proteins and nucleic acids

3. Creatine phosphate, ATP, ADP, co enzymes etc.

4. Hexose phosphates, triose phosphates, glycerophosphates.

7.2.1 Food Sources

The important food sources are:

1. Milk, eggs, meat, and fish.

2. Vegetables are fair sources.

3. Cereals, pulses, nuts and oilseeds(in the form of phytic acid and phytin)

Phytic acid is compound of inositol and phosphoric acid where as phytin is Ca, Mg, salts of phytic acid.

7.2.2 Functions of Phosphorus

The important functions of phosphorus are:

1. Phosphorous is necessary for the formation of bone and teeth.

2. It is necessary for the formation of phospholipids-lecithin and cephalin which are integral arts of cell structure and also act as intermediates in fat transport and metabolism.

3. It is essential for carbohydrate metabolism as phophorylation of glycogen requires inorganic phosphorus and phosphoric acid esters like adenylic acid, adenylpyrophosphate and creatine phosphate.

4. It is a constituent in certain co enzymes,. e.g.. Co-enzyme I and co-carboxylase which take part in the enzyme systems concerned in the oxidation of carbohydrates, fats and protein.

5. It is and essential constituent of nucleic acid and nucleo proteins which are integral part of the cells.

7.2.3 Metabolism

Phosphorus is absorbed in the small intestines as inorganic phosphates. Phosphorus present in organic combination like phytic acid should be hydrolysed to inorganic phosphates before absorption. Since the enzyme - phytase - is not present in humans digestive juices, phytin phosphorus is absorbed only to a very slight extent in human beings. Phosphorus present in animal food such as milk, meat and eggs is absorbed to a greater extent than that present in cereals and legumes as the latter exists mostly in the form Phytic acid. The kidney is the major pathway of excretion of the phosphorus absorbed. The retention of phosphorus in children on different diets has been reported to vary from 10-40%. The retention of phosphorus depend upon the following factors:

1. The quantity of phosphorus ingested.

2. The calcium content of the diet.

3. The form in which phosphorus exists in the diet.

4. Vitamin D intake.

7.2.4 Phosphorus content of blood serum

The inorganic phosphorus content of blood serum in normal human adults ranges from 2.5 to 4.0 mg/100ml and in children 4.0 to 5.0 mg/100ml. In rickets, the level of phosphorus is reduced to less than 3mg/100ml.

7.2.5 Requirements

Phosphorus requirements depends on the availability of phosphorous present in the diets. Phosphorus present in cereals and legumes are available to a lesser extent(as it is present in the form of phytic acid)than that present in milk, meat, eggs, and fish. So phosphorous requirements of persons consuming predominantly cereal based diets, will be greater than those consuming large quantities of milk, meat, eggs, and fish.

The optimal Ca:P ratio for infants and children is 1:1 and for adults it is 1:2. Metabolism studies conducted on these diets have shown that those subjects maintained a positive calcium and phosphorus balance. N.R.C(USA) has recommended an allowance for phosphorous equal to that of calcium for all age groups and for infants it is 1:1.5.

7.3 Iron

The total iron content of the normal adult man (70 kg) is estimated to be about 4 - 5 g. A greater part of the iron in the body is present as haemoglobin. Most of the body iron exists in complex forms bound to protein either as porphyrin or haeme compounds or as ferritin and transferrin. Free inorganic iron occurs in the body only in very small amounts, The haemo protein and flavo-protein enzymes also contain iron.

7.3.1 Utilization of Iron in the Body

The compounds containing iron which biological importance are the following.

1. Iron porphyrin compounds : Blood haemoglobin, Myoglobin(in muscle).
2. Haeme enzymes : Cytochromes, catalase, peroxidase.
3. Flavin-enzymes : Succinic dehydrogenase. Xanthine oxidase, DPNH-cytochrome C reductase, Iron chelate enzyme aconitase and
4. Transport and storage of iron : Transferrin(2-Fe+lobulin), Ferritin[(4-$FeOOH)_n$+globulin], Hemosiderin (Ferric hydroxide+non nitrogenous compound).

7.3.2 Iron Metabolism

In monogastric species, it is known that iron is absorbed principally in the ferrous state in the duodenum. In the rat and dog, ferric salts have been shown to be as well utilised as ferrous salts indicating that gastrointestinal conditions in those animals are favourable to reduction of ferric iron. In man, on the other hand ferrous salts have been shown to be more effective for haemoglobin formation than ferric salts. The rate of absorption of iron is also affected by the magnitude of iron reserve in the body and the rate erythropoiesis. About 2 - 20 % of an oral dose of radioactive iron absorbed in normal subjects, compared with 20 - 60% in iron deficiency anaemia, the percentage absorption falling as the intake is increased.

7.3.3 Factors Affecting Absorption

The different factors that affect absorption of Iron are the following:

1. Iron is absorbed form the intestines in the form of ferric state. Iron in the ferric form will have to be reduced to ferrous state before absorption.
2. Vitamin C enhances the absorption of iron in the intestinal tract.
3. Excess of calcium interferes with the absorption of iron.
4. Excess of phosphates and phytates lowers the absorption of iron by forming insoluble iron salt.
5. Oxalic acid present in some foods interferes in the absorption of iron by forming insoluble oxalate.

7.3.4 Effect of Iron Deficiency

Iron deficiency anaemia is widely prevalent among children, adolescent girls, and expectant and nursing mothers in all developing countries.

Signs and symptoms of anaemia: The clinical features are the results of diminished oxygen carrying power of the blood due to low haemoglobin content.

Women of child bearing age: The clinical features are general fatigue and lassitude, breathlessness on exertion, giddiness and pallor of the skin. In severe cases, there may be some oedema of the ankles. The haemoglobin levels commonly range between 5 and 9 g/100 ml blood(normal 13 - 15 g/100 ml) and the RBC count (3 - 4.5 million per cubic mm).

Weaned infants and young children: Iron deficiency anaemia is widely prevalent among weaned infants and young children in India and other developing countries. The haemoglobin levels in severe and moderately severe cases, may range from 5 to 9 g/100 ml. The children are dull, inactive and show pallor of the skin. The appetite is poor and growth and development of children are retarded due to low food intake. There is a tendency for children below 3 years to eat mud.

Treatment: Anaemic women should get ferrous sulphate tablets(0.2 g) 3 times a day For a child of below 12 months a mixture containing 0.2g ferrous ammonium citrate sweetened with sugar three

times a day and for children 1 - 5 years 0.4 to 0.9 g of ferrous ammonium citrate in the form of mixture will be effective in curing anaemia. The treatment should be continued for a few months till the haemoglobin is restored to normal level.

7.3.5 Dietary Sources

The important sources of iron are :

1. Cereals are the most important sources in developing countries.
2. Other important sources are legumes, green leafy vegetables, and jaggery.
3. Meat, fish, and eggs are the important sources in advanced countries,
4. Milk is a poor source of iron.

7.3.6 Requirements

Iron requirements are influenced by the availability of iron present in foods. Iron present in cereals, legumes and green leafy vegetables is available to a lesser extent than that present in meat, fish and eggs. So iron requirements of persons consuming a predominantly cereal based diet, will be greater than those consuming large quantities of meat and eggs.

7.4 Iodine

Iodine is a constituent of thyroxine, the active principle of the thyroid gland. The thyroid gland, weighing about 25 g in a normal adult, contains only about 10 mg of iodine. The adult body as a whole contains about 50 mg of iodine. The thyroid gland plays an important part in energy metabolism and in the growth of the body.

7.4.1 Food Sources of Iodine

Iodine is present only in small amounts in common foods, the quantity of iodine present depending on the iodine content of the soil. The soil of mountainous regions usually contains less iodine than the soil of the plains near the sea. Crude common salt prepared from sea water and sea fish are good sources of iodine.

7.4.2 Iodine requirements

Iodine requirements for adults are about 0.15 to 0.2 mg and for infants and children 0.05 to 0.10 mg daily. This is normally supplied by an ordinary well balanced diet and by drinking water except in mountainous regions where the food and water are deficient in iodine.

7.4.3 Iodine Deficiency in Human Beings

If sufficient iodine is not taken in the diet, enlargement of the thyroid takes place, resulting in the disease called goitre. The thyroid gland of the adult which normally weighs about 25 g may weigh as much as 200 to 500 g or even more in goitre. Histological examination shows diffuse overgrowth of the glandular tissue, known as general hyperplasia of the glands. The vesicles contain little or no colloid. If treatment with iodine is started very early the thyroid may become normal. But if treatment is delayed the enlargement of the gland persists, In children, severe iodine deficiency may result in serious retardation of growth. This condition is known as cretinism.

7.4.4 Incidence and Prevention of Goitre

A survey of the incidence of the goitre in different parts of the world shows that the disease is related to deficiency of iodine in the water and the food. Goitre commonly occurs among people living in mountainous regions. In India, goitre occurs in the hilly districts along the foot of the Himalayas, e.g. in Kashmir, Kangra valley, etc. Goitre can be prevented by the regular use of iodised salt (1 g sodium iodate being added to 100,000 g of common salt). By the use of iodised salt, goitre has been prevented in countries such as Switzerland, USA, India, etc.

7.4.5 Goitrogenic Substances in Foods

There is evidence indicating many foods such as cabbage, cauliflower and radish contain substances which react with the iodine present in th food and make it unavailable. These substances are known as 'goitrogenic' substances. Consumption of large quantities of these foods leads to the development of goitre by making the iodine present in the food not available to the body.

7.5 Copper

The first conclusive evidence, that copper is an essential element for the formation of haemoglobin in rats suffering from iron deficiency anaemia emerged from the studies of Hart and co-workers in 1928. Later studies have indicated that copper is a constituent of several enzymes and is found as a complex with some proteins in blood.

7.5.1 Distribution of copper in the Body

The healthy human adult body contains about 100 - 150 mg of copper. Copper present in the blood exists in the form of copper protein complex-heamocuprin in red blood cells and ceruloplasmin in plasma.

7.5.2 Effects of Copper Deficiency

a. Animals :- A wide variety of clinical disorders have been associated with a dietary deficiency of copper in animals. These include anaemia, decreased growth, bone disorders, de pigmentation of hair or wool, abnormal wool growth, neonatal ataxia and impaired reproductive performance.

b. Human beings :- In human beings the only condition observed is anaemia due to copper deficiency.

7.5.3 Copper in Human Nutrition

Anaemia produced in infants fed exclusively on milk can be cured only by giving copper salts along with iron. The estimates of average daily intakes in adult diets range from 2 - 3 mg in diets. The high intake in Indian diets as compared with 4.5 to 5.8 mg on diets. The high intake of Indian diets may be due to contamination of copper from brass vessels used in cooking. Copper deficiency is likely to occur only in infants fed exclusively on milk diet.

7.5.4 Copper Requirements

The copper requirements for different categories of human subjects are as follows:

Copper requirements per day	
Adults	2 mg
Pregnancy	3 mg
Lactation	3 mg
Infants(below 1 year)	0.5 - 1.0 mg
Children	2 mg
Adolescent	3 mg

7.6 Fluorine

The importance of fluorine in nutrition was proved with the discovery of endemic fluorosis in man and farm animals in 1931.

7.6.1 Fluorine and Dental Caries

The incidence of dental caries in animals is high on a fluorine deficient diet and incorporation of fluorine at a level of 1 - 2 ppm. in the diet prevented the disease. Surveys carried out on the incidence of dental caries in human beings have yielded the following results:

1. The incidence of dental carries in children is high in areas where the drinking water contained less than 0.5 ppm fluorine and was low in areas where the water contained 1 - 2 ppm, of fluorine.

2. Addition of fluorine to drinking water at a level of 1 ppm brought about a significant reduction in the incidence of dental caries.

7.6.2 Toxic Effects of Excess Fluorine in Human Beings

Dental fluorosis(Mottled enamel): In many parts of the world where the drinking water contains excessive amounts of the fluorine (3 -5 ppm) signs and symptoms of dental fluorosis have been observed. The enamel of the teeth loses its lustre and becomes rough. Chalky white patched with a secondary infiltration of yellow or brown staining are found irregularly over the surface of the teeth, The enamel is structurally weak of yellow or brown staining are found irregularly over the surface of the teeth. The enamel is structurally weak and in severe cases, there is marked loss of enamel accompanied by 'pitting' which gives the tooth surface a corroded appearance.

Skeletal fluorosis: Chronic fluorine intoxication through drinking water containing excessive amounts of fluorine(over 10 ppm) or among workers handling fluoride containing minerals results in pathological changes in bones. There is increased density and hypercalcification of the bone of the spine(sclerosis), pelvis, and limbs. In addition, the ligaments of the spine become calcified, producing a 'poker back'. It is possible that collagen in the bone is calcified. There may also been ossification of the tendinous insertions of muscles. Neurological disturbances secondary to the changes in the vertebral column are common. Such persons are crippled and cannot perform simple daily tasks, such as bending squatting, etc., as the joints become stiff.

7.6.3 Prevention of Toxic Fluorosis

Toxic fluorosis can be prevented only by removing fluorine from the water supplies by treatment with activated carbon or by some other suitable adsorbents.

7.6.4 Requirements

Fluorine is found in small amounts in normal bones and teeth. Since water containing 1-2 ppm. prevents dental caries and does not do any harm, the fluorine requirements of the body are met by the quantity normally present in drinking water (1 - 2 ppm) in most of the regions.