Unit 3: Micronutrients

1. Introduction to Micronutrients

Micronutrients are those nutrients that are required by the body in **very small amounts**, usually in milligrams or micrograms, yet their importance is enormous. Unlike carbohydrates, proteins, and fats, micronutrients do not provide energy directly. They do not yield calories, nor do they form the major bulk of the diet. However, without them, the body cannot properly utilize macronutrients, maintain normal growth, regulate metabolism, preserve tissue integrity, or protect itself from disease.

For a beginner, the concept of micronutrients may appear paradoxical: they are needed only in minute quantities, but deficiency of even a single micronutrient can produce serious disorders. This is because micronutrients act as regulators, catalysts, cofactors, structural elements, antioxidants, and protective factors in innumerable physiological processes. Enzyme systems, nerve conduction, immunity, blood formation, bone mineralization, vision, hormone synthesis, cell division, and reproductive functions all depend on them.

Micronutrients include two major groups:

1. **Vitamins**
2. **Minerals**

The body cannot synthesize most of them in sufficient quantities. Therefore, they must be obtained regularly through a varied and balanced diet. If the intake is inadequate, or if absorption/utilization is impaired, deficiency diseases gradually develop. On the other hand, excessive intake of some micronutrients, especially through indiscriminate supplementation, may also be harmful. Thus, micronutrient nutrition is a matter of **adequacy and balance**, not merely abundance.

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2. Meaning and Characteristics of Micronutrients

Micronutrients are essential nutrients required in small quantities for normal growth, development, metabolism, and maintenance of health. Their main characteristics may be understood as follows:

- They are required in **small amounts**, unlike macronutrients which are needed in gram quantities.
- They **do not provide energy**, but they help the body release and use energy from carbohydrates, proteins, and fats.
- They are vital for the **proper functioning of enzymes, hormones, blood, bones, nerves, muscles, and immune mechanisms**.
- Deficiency may lead to specific clinical disorders, reduced work capacity, poor immunity, growth failure, and long-term health consequences.
- Some micronutrients are stored in the body to varying extents, while others must be supplied more regularly.

Micronutrients therefore serve as the **fine regulators of body function**. If macronutrients are the bricks and fuel of the body, micronutrients may be compared to the tools, switches, and control systems that allow the structure to function properly.

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3. Classification of Micronutrients

Micronutrients are broadly classified into:

3.1 Vitamins

These are organic compounds required in small amounts for various metabolic and protective functions. Vitamins are

further divided into:

- **Fat-soluble vitamins**: A, D, E, K
- **Water-soluble vitamins**: Vitamin C and the B-complex vitamins

3.2 Minerals

These are inorganic elements essential for body structure and physiological regulation. They are commonly divided into:

- **Major minerals (macro-minerals)**: calcium, phosphorus, sodium, potassium, magnesium, chloride
- **Trace elements (micro-minerals)**: iron, iodine, zinc, copper, selenium, fluoride, manganese, chromium, and others

This classification is useful because it reflects both chemical nature and nutritional behavior, especially in relation to absorption, storage, excretion, and deficiency patterns.

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4. Vitamins

4.1 Introduction to Vitamins

Vitamins are organic substances that are required in minute quantities for normal metabolic functions, growth, maintenance, and health. They usually do not serve as building materials or sources of energy, but they are indispensable in enabling the body to use nutrients efficiently.

Vitamins often function as components of coenzymes, antioxidants, hormone-like substances, or regulators of specific biochemical reactions. The absence of a vitamin may disrupt a metabolic pathway and produce characteristic clinical symptoms.

Since vitamins differ in their solubility, storage, and mode of action, they are studied under two main categories: fat-soluble and water-soluble vitamins.

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5. Fat-Soluble Vitamins

Fat-soluble vitamins are absorbed along with dietary fat and are usually stored in the liver and fatty tissues. Because they are stored, deficiency may take time to appear. At the same time, excessive intake can sometimes lead to toxicity.

These include:

- Vitamin A
- Vitamin D
- Vitamin E
- Vitamin K

5.1 Vitamin A

Vitamin A is one of the most important vitamins for vision, epithelial integrity, growth, reproduction, and immune function. It exists in two major forms:

- **Preformed vitamin A (retinol)** from animal sources
- **Provitamin A carotenoids** from plant sources, especially beta-carotene

Functions of Vitamin A

Vitamin A is essential for the formation of visual pigments in the retina, especially for vision in dim light. It also maintains the health of epithelial tissues lining the skin, respiratory tract, gastrointestinal tract, and genitourinary tract. In addition, it supports immunity, growth, and reproduction.

Sources

Animal sources include liver, fish liver oils, milk, butter, egg yolk, and other dairy products. Plant sources rich in carotene include green leafy vegetables, carrots, pumpkin, mango, papaya, and other yellow-orange fruits and vegetables.

Deficiency

Vitamin A deficiency commonly affects the eyes and epithelial tissues. The earliest symptom is usually **night blindness**. More severe deficiency may produce xerophthalmia, Bitot's spots, corneal dryness, keratomalacia, and eventual blindness. It also increases susceptibility to infections.

Excess

Excessive intake of vitamin A supplements may cause toxicity, manifesting as headache, nausea, liver abnormalities, skin changes, and bone pain.

5.2 Vitamin D

Vitamin D is unique among vitamins because it behaves partly like a hormone. It is essential for calcium and phosphorus metabolism and for the formation and maintenance of healthy bones and teeth.

The body can synthesize vitamin D in the skin when exposed to sunlight. However, dietary intake remains important, especially when sunlight exposure is insufficient.

Functions of Vitamin D

Vitamin D promotes intestinal absorption of calcium and phosphorus, helps maintain their blood levels, and supports bone mineralization. It also influences immune and muscular function.

Sources

Sunlight is the primary natural source. Dietary sources include fish liver oils, fatty fish, egg yolk, butter, fortified milk, and fortified foods.

Deficiency

In children, vitamin D deficiency leads to **rickets**, characterized by defective bone mineralization, bowed legs, delayed dentition, and skeletal deformities. In adults, it causes **osteomalacia**, with bone pain, muscle weakness, and increased fracture risk.

Excess

Excess supplementation can lead to hypercalcemia, nausea, kidney damage, and soft tissue calcification.

5.3 Vitamin E

Vitamin E is primarily known for its antioxidant role. It protects cell membranes from oxidative damage by neutralizing free radicals.

Functions of Vitamin E

Its main function is to prevent oxidation of unsaturated fatty acids in cell membranes. It also contributes to immune function and protects red blood cells and tissues from oxidative stress.

Sources

Vegetable oils, nuts, seeds, whole grains, and green leafy vegetables are good sources.

Deficiency

Deficiency is uncommon in healthy individuals but may occur in fat malabsorption states. It can result in neuromuscular problems, hemolytic anemia, and nerve dysfunction.

Excess

Toxicity is uncommon from food sources but very high supplemental intake may interfere with blood clotting.

5.4 Vitamin K

Vitamin K is essential for the synthesis of clotting factors and therefore plays a major role in blood coagulation.

Functions of Vitamin K

It is required for the formation of prothrombin and several other clotting proteins. It also plays a role in bone metabolism.

Sources

Green leafy vegetables, cabbage, broccoli, liver, and intestinal bacterial synthesis contribute to vitamin K supply.

Deficiency

Deficiency may cause delayed blood clotting and bleeding tendencies. It is more likely in newborns, prolonged antibiotic use, or fat malabsorption states.

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6. Water-Soluble Vitamins

Water-soluble vitamins are not stored in large amounts in the body, with a few exceptions such as vitamin B12. Therefore, they usually need more regular dietary supply. Excess amounts are often excreted in urine, so toxicity is generally less common compared to fat-soluble vitamins.

These include:

- Vitamin C
- B-complex vitamins

6.1 Vitamin C (Ascorbic Acid)

Vitamin C is an important antioxidant and is essential for collagen synthesis, wound healing, iron absorption, and immunity.

Functions of Vitamin C

It is necessary for the formation of connective tissue, maintenance of gums and skin, healing of wounds, and strengthening of blood vessels. It also enhances absorption of non-heme iron and supports resistance to infection.

Sources

Fresh fruits and vegetables are major sources, especially amla, citrus fruits, guava, tomato, green chilies, cabbage, and sprouted pulses.

Deficiency

Deficiency causes **scurvy**, characterized by bleeding gums, fragile capillaries, poor wound healing, bone pain, and general weakness.

Excess

Very high intakes may cause gastrointestinal discomfort in some individuals.

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7. B-Complex Vitamins

The B-complex group contains several vitamins that act mainly as coenzymes in energy metabolism, nerve function, cell division, and blood formation.

7.1 Thiamine (Vitamin B1)

Thiamine is essential for carbohydrate metabolism and nerve function.

Sources

Whole cereals, pulses, nuts, seeds, yeast, and pork are good sources.

Deficiency

Deficiency causes **beriberi**, which may be dry (neurological symptoms) or wet (cardiovascular symptoms). Severe deficiency may also lead to Wernicke-like neurological syndromes.

7.2 Riboflavin (Vitamin B2)

Riboflavin is involved in oxidation-reduction reactions and energy release.

Sources

Milk, eggs, liver, green leafy vegetables, and cereals.

Deficiency

Deficiency may produce cheilosis, angular stomatitis, glossitis, and dermatitis.

7.3 Niacin (Vitamin B3)

Niacin participates in energy metabolism through coenzymes NAD and NADP.

Sources

Meat, fish, groundnuts, cereals, pulses, and whole grains. It may also be synthesized in small amounts from tryptophan.

Deficiency

Deficiency causes **pellagra**, classically associated with the “three Ds”: dermatitis, diarrhea, and dementia.

7.4 Pyridoxine (Vitamin B6)

Vitamin B6 plays a major role in amino acid metabolism and nervous system function.

Sources

Whole grains, pulses, nuts, meat, banana, and vegetables.

Deficiency

Deficiency may cause anemia, dermatitis, irritability, and neuropathic symptoms.

7.5 Folate (Folic Acid)

Folate is essential for DNA synthesis, cell division, and blood formation.

Sources

Green leafy vegetables, legumes, liver, and fortified cereals.

Deficiency

Deficiency leads to **megaloblastic anemia** and is especially important in pregnancy because inadequate folate increases the risk of neural tube defects in the fetus.

7.6 Vitamin B12 (Cobalamin)

Vitamin B12 is required for blood formation, nerve health, and DNA synthesis.

Sources

It is found mainly in animal foods such as meat, fish, eggs, milk, and liver.

Deficiency

Deficiency causes megaloblastic anemia and neurological disturbances. It is more common in strict vegetarians if intake is poor over long periods, and in absorption disorders.

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8. General Functions of Vitamins

Though each vitamin has specific functions, their broader roles may be summarized as follows:

- assisting metabolic reactions as coenzymes
- maintaining healthy skin, nerves, vision, and blood
- promoting bone growth and mineralization
- supporting immunity and resistance to infection
- protecting tissues from oxidative damage
- helping in blood clotting and wound healing
- aiding normal growth and reproduction

Thus, vitamins are indispensable for the smooth and efficient operation of body metabolism.

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9. Minerals

9.1 Introduction to Minerals

Minerals are inorganic substances required by the body for structural functions, fluid balance, enzyme activity, nerve conduction, muscle contraction, oxygen transport, and hormonal regulation. Unlike vitamins, minerals are elements and cannot be destroyed by heat, air, or cooking in the same way organic vitamins can be. However, they may be lost in processing, washing, or cooking water.

Minerals are required in varying amounts. Some are needed in relatively larger quantities, while others are needed only in traces. Despite this difference, all are essential for health.

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10. Major Minerals

10.1 Calcium

Calcium is the most abundant mineral in the human body. Most of it is present in bones and teeth.

Functions

It is essential for bone and tooth formation, muscle contraction, nerve transmission, blood clotting, and enzyme activity.

Sources

Milk and milk products are rich sources. Other sources include ragi, green leafy vegetables, sesame seeds, and small fish eaten with bones.

Deficiency

Deficiency may lead to poor bone development, rickets in children, osteomalacia, osteoporosis, muscle spasms, and defective teeth.

10.2 Phosphorus

Phosphorus works closely with calcium in bone formation and is also essential for energy metabolism.

Functions

It is a component of bones, teeth, ATP, nucleic acids, and cell membranes.

Sources

Milk, meat, fish, eggs, pulses, cereals, and nuts.

Deficiency

Deficiency is uncommon but may affect bones and energy metabolism.

10.3 Magnesium

Magnesium is involved in numerous enzymatic reactions and neuromuscular function.

Sources

Whole grains, nuts, seeds, legumes, and green leafy vegetables.

Functions

It helps in muscle and nerve function, energy metabolism, and bone structure.

Deficiency

Deficiency may cause muscle cramps, irritability, and neuromuscular symptoms.

10.4 Sodium, Potassium, and Chloride

These are electrolyte minerals and are essential for water balance, nerve conduction, and muscle activity.

Sodium

Important for extracellular fluid balance, nerve impulses, and blood pressure regulation.

Potassium

Essential for intracellular fluid balance, heart rhythm, nerve transmission, and muscle contraction.

Chloride

Helps maintain fluid balance and forms part of hydrochloric acid in gastric juice.

Deficiency or imbalance of these electrolytes may produce weakness, cramps, altered blood pressure, or severe physiological disturbances.

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11. Trace Elements

11.1 Iron

Iron is one of the most nutritionally significant minerals because of its central role in blood formation and oxygen transport.

Functions

It is a key component of hemoglobin and myoglobin and is necessary for cellular respiration.

Sources

Liver, meat, egg yolk, green leafy vegetables, pulses, jaggery, whole grains, and fortified foods. Vitamin C improves absorption of plant-based iron.

Deficiency

Iron deficiency causes **anemia**, with symptoms such as pallor, fatigue, weakness, poor concentration, and reduced immunity. It is particularly common among women, children, and adolescents.

11.2 Iodine

Iodine is essential for the synthesis of thyroid hormones.

Functions

It regulates growth, metabolism, and development through thyroid hormone production.

Sources

Iodized salt, seafood, and foods grown in iodine-rich soil.

Deficiency

Deficiency may cause **goiter**, hypothyroidism, mental retardation in severe fetal deficiency, and impaired growth.

11.3 Zinc

Zinc is important for growth, immunity, wound healing, and enzyme activity.

Sources

Meat, eggs, legumes, nuts, whole grains, and seeds.

Deficiency

Deficiency may cause growth retardation, delayed wound healing, poor appetite, skin lesions, and reduced immunity.

11.4 Copper

Copper helps in iron metabolism and enzyme systems.

Sources

Nuts, seeds, legumes, whole grains, and organ meats.

Deficiency

Deficiency may cause anemia and connective tissue abnormalities, though it is relatively uncommon.

11.5 Selenium

Selenium functions as an antioxidant and supports thyroid function.

Sources

Cereals, nuts, seafood, eggs, and meat.

Deficiency

Deficiency may impair antioxidant defenses and certain metabolic processes.

11.6 Fluoride

Fluoride is mainly associated with tooth health.

Functions

It helps strengthen tooth enamel and reduce dental caries.

Sources

Fluoridated water, tea, seafood, and some groundwater sources.

Deficiency and Excess

Deficiency may increase risk of dental caries, while excess intake causes fluorosis.

12. General Functions of Minerals

The overall functions of minerals may be summarized under the following major categories:

12.1 Structural functions

Minerals such as calcium, phosphorus, and magnesium help form bones and teeth.

12.2 Regulatory functions

Electrolytes such as sodium, potassium, and chloride regulate water balance, osmotic pressure, and acid-base equilibrium.

12.3 Functional roles in metabolism

Minerals act as cofactors for enzymes and are essential in many biochemical reactions.

12.4 Nerve and muscle function

Calcium, sodium, potassium, and magnesium are necessary for normal nerve impulse transmission and muscle contraction.

12.5 Blood formation and oxygen transport

Iron, copper, and cobalt-related systems contribute to blood health.

12.6 Hormonal and glandular roles

Iodine is necessary for thyroid hormones, and several trace elements influence endocrine functions.

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13. Micronutrient Deficiency Disorders

Micronutrient deficiency remains one of the major public health challenges worldwide. Since these nutrients are needed only in small quantities, deficiency may not always be recognized early, but its long-term effects can be serious.

Some important deficiency disorders include:

Micronutrient	Deficiency Disorder
Vitamin A	Night blindness, xerophthalmia
Vitamin D	Rickets, osteomalacia
Vitamin C	Scurvy
Thiamine	Beriberi
Niacin	Pellagra
Folate / B12	Megaloblastic anemia
Iron	Iron deficiency anemia
Iodine	Goiter, developmental disorders
Calcium	Weak bones, osteoporosis

These conditions illustrate why even “small nutrients” have major physiological significance.

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14. Hidden Hunger and Public Health Importance

A person may consume enough calories and still suffer from micronutrient deficiency. This condition is often called **hidden hunger**. It is especially common in diets dominated by polished cereals, refined foods, poor dietary variety, and low intake of fruits, vegetables, pulses, milk, and animal products.

Micronutrient deficiencies affect:

- child growth and development
- school performance
- maternal health
- immunity
- work productivity
- pregnancy outcomes
- overall quality of life

For this reason, public health programs often emphasize:

- dietary diversification
- food fortification
- supplementation where needed
- nutrition education
- maternal and child nutrition services

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15. Balanced Diet and Micronutrient Adequacy

The best way to obtain micronutrients is through a balanced and varied diet. No single food contains all vitamins and minerals in adequate amounts. Therefore, daily meals should include a diversity of food groups such as:

- cereals and millets
- pulses and legumes
- milk or equivalent foods
- green leafy vegetables
- other vegetables
- seasonal fruits
- nuts and seeds
- eggs, fish, or meat where acceptable

A diversified diet not only supplies vitamins and minerals but also improves bioavailability and overall dietary quality.

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16. Important Practical Points for Students

When studying micronutrients, beginners should remember some practical principles:

- Deficiency does not always appear suddenly; it often develops gradually.
- Cooking methods influence vitamin retention, especially water-soluble vitamins.
- Excessive polishing, peeling, washing, or overcooking may reduce nutrient content.
- A diet rich in variety is usually better than dependence on supplements alone.
- Micronutrients work together; for example, vitamin C improves iron absorption, and vitamin D supports calcium utilization.
- Deficiency can arise not only from poor intake but also from infections, poor absorption, chronic disease, and increased physiological need.

These applied points are very useful in meal planning and nutrition counseling.

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17. Summary of the Unit

Micronutrients are essential nutrients required in small amounts but are indispensable for life and health. They include vitamins and minerals. Vitamins are organic compounds needed for metabolic regulation, tissue maintenance, immunity, blood formation, bone health, and protection from oxidative damage. They are divided into fat-soluble and water-soluble groups. Minerals are inorganic substances that support skeletal structure, fluid balance, enzyme systems, nerve function, muscle contraction, oxygen transport, and hormone production. Deficiency of micronutrients may lead to specific disorders such as anemia, rickets, scurvy, pellagra, goiter, and night blindness. A balanced and varied diet remains the most effective way to ensure adequate micronutrient intake and prevent hidden hunger.

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18. Review Questions

1. Define micronutrients and explain their importance in human nutrition.
2. Classify vitamins and describe the characteristics of fat-soluble and water-soluble vitamins.
3. Write a detailed note on vitamin A, including its functions, sources, and deficiency manifestations.
4. Explain the role of vitamin D in the body and discuss its deficiency.
5. Describe the functions and deficiency manifestations of vitamin C.
6. Write short explanatory notes on thiamine, riboflavin, niacin, folate, and vitamin B12.

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7. Define minerals and classify them into major and trace elements.
8. Discuss the importance of calcium, iron, and iodine in human health.
9. What is hidden hunger? Explain its significance in public health.
10. Explain how a balanced diet helps in meeting micronutrient needs.