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Minerals and Trace Elements

Biochemistry

Classification, sources, functions and clinical importance of calcium, phosphorus, iron, iodine, sodium, potassium, magnesium, zinc and other essential minerals.

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CHAPTER 07

Minerals and Trace Elements

Macrominerals, trace elements, sources, roles and clinical significance

1. Definition and classification

Minerals are inorganic nutrients required for structural, enzymatic and regulatory functions. Macrominerals are required in relatively larger amounts; trace elements in smaller amounts. They do not provide calories.

Macromineral	Sources and functions	Deficiency / abnormality
Calcium	Milk, ragi, fortified foods; bones, contraction, clotting, signalling	Low calcium: tetany, paraesthesia; high: constipation, confusion
Phosphorus	Dairy, legumes, meat; ATP, nucleic acids, bone and buffers	Low phosphate: weakness, respiratory muscle impairment; excess in CKD
Magnesium	Nuts, seeds, grains; ATP-dependent reactions, neuromuscular function	Tremors, arrhythmias, refractory low potassium; excess can depress reflexes
Sodium	Salt and processed foods; major extracellular cation, fluid balance	Low/high serum sodium may cause neurological symptoms
Potassium	Legumes, fruit, vegetables; major intracellular cation, membrane potential	Low/high levels may cause dangerous arrhythmias
Chloride	Salt; extracellular anion, acid-base balance, gastric HCl	Loss with vomiting may contribute to alkalosis
Sulfur	Sulfur-containing amino acids; proteins and glutathione	Isolated dietary deficiency uncommon with adequate protein

2. Trace elements

Element	Sources and functions	Deficiency / excess
Iron	Meat, legumes, fortified foods; haemoglobin, myoglobin, enzymes	Microcytic anaemia; overload damages organs
Iodine	Iodized salt, seafood; thyroid hormones	Goitre, hypothyroidism, impaired fetal neurodevelopment; excess can disrupt thyroid function
Zinc	Meat, dairy, legumes, nuts; enzyme function, immunity, healing	Poor growth, dermatitis, impaired taste; excess may cause copper deficiency

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Copper	Nuts, seeds, shellfish; iron metabolism, connective tissue enzymes	Anaemia, neuropathy; accumulation in Wilson disease
Selenium	Fish, eggs, cereals; antioxidant enzymes and thyroid hormone metabolism	Deficiency may affect muscle and thyroid function; excess causes hair/nail changes
Manganese	Whole grains, nuts; enzyme cofactor	Deficiency rare; excess exposure may cause neurotoxicity
Fluoride	Water, tea; strengthens dental enamel	Low exposure increases caries risk; excess causes fluorosis

Element	Sources and functions	Deficiency / excess
Molybdenum	Legumes, grains; sulfite oxidase and other enzymes	Deficiency rare

3. Selected adult Indian dietary references

ICMR-NIN 2020/FSSAI summary [1]: calcium 1000 mg/day, phosphorus 1000 mg/day; magnesium 440 mg (men) and 370 mg (women); iron 19/29 mg; zinc 17/13.2 mg; iodine 140 microg both. Sodium 2000 mg and potassium 3500 mg are cited adult references in the summary; these are not fluid prescriptions or advice for kidney failure. Sodium reduction and adequate dietary potassium may support cardiovascular health in suitable patients.

4. Mineral homeostasis

PTH increases serum calcium, promotes renal phosphate excretion and stimulates calcitriol production. Calcitriol increases intestinal calcium and phosphate absorption. Aldosterone promotes renal sodium reabsorption and potassium secretion. Hepcidin reduces intestinal iron transfer and release from macrophages through ferroportin; inflammation can increase hepcidin. Vitamin C supports non-haem iron absorption, while phytates may reduce absorption.

5. Iron absorption, transport and storage

Dietary iron occurs as haem and non-haem iron. Absorption takes place mainly in the duodenum and proximal small intestine. Iron enters the circulation through ferroportin and binds transferrin; ferritin is a major intracellular storage protein. Hepcidin regulates iron availability by limiting ferroportin-mediated export. Inflammation may increase ferritin and reduce circulating iron availability, so ferritin must be interpreted in context.

Test	Meaning
Serum ferritin	Reflects iron stores but can rise with inflammation
Transferrin saturation	Proportion of iron-binding sites occupied
Serum iron	Circulating iron; variable with clinical conditions
Total iron-binding capacity	Indirect estimate of transferrin binding capacity

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6. Calcium and phosphorus relationship

Calcium is stored predominantly in bone as mineral associated with phosphate. Circulating calcium exists as ionized calcium, protein-bound calcium and complexed calcium. Ionized calcium is the biologically active fraction. Low albumin may reduce total calcium without reducing ionized calcium. Phosphate is also essential for ATP, phospholipids, nucleic acids and intracellular buffering.

7. Iodine, zinc and other trace minerals

Iodide is taken up by thyroid follicular cells and incorporated into thyroid hormone precursors. Adequate iodine is important for fetal brain development. Zinc is involved in many enzymes and wound repair; excessive prolonged supplementation can impair copper absorption. Fluoride helps protect tooth enamel but sustained excess can cause dental or skeletal fluorosis.

8. Nursing applications

Monitor electrolyte trends and ECG when indicated. Assess dietary intake, diarrhoea, vomiting, renal function and relevant medications. Explain prescribed iron and mineral supplementation, avoiding unnecessary supplementation. Abnormal potassium or symptomatic calcium disturbances require prompt clinical review. Never administer potassium chloride by direct IV push.

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9. Important Examination Questions

Long Answer Questions

1. 1. Classify minerals and describe functions, sources and deficiency conditions.
2. 2. Describe calcium and phosphorus regulation and its clinical significance.
3. 3. Explain iron absorption, transport, storage and regulation.

Short Answer Questions

1. 1. Write a short note on Iron metabolism.
2. 2. Write a short note on calcium regulation.
3. 3. Write a short note on iodine deficiency.

Very Short Answer Questions

1. 1. Which hormone regulates systemic iron availability? - Hepcidin.
2. 2. Which mineral is central to haemoglobin? - Iron.
3. 3. Which trace element is a cofactor in glutathione peroxidases? - Selenium.
4. 4. What is the active circulating calcium fraction? - Ionized calcium.

Additional objective question

Which is the main intracellular cation? - Potassium.

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10. Quick Revision

- Sodium is the major extracellular cation; potassium is the major intracellular cation.
- Calcium and phosphate are major bone mineral components.
- Iron is transported by transferrin and stored mainly in ferritin.
- Iodine is essential for thyroid hormone synthesis.

Conclusion

Minerals maintain structural integrity, enzyme activity, oxygen transport and electrolyte homeostasis, making their assessment important in nursing care.

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Practice questions

Choose one best answer. The answer key and explanations follow the questions.

1. Which mineral is the major intracellular cation?

A. Potassium
B. Sodium
C. Calcium
D. Magnesium

2. Which plasma protein transports circulating iron?

A. Albumin
B. Transferrin
C. Ferritin
D. Fibrinogen

3. Which trace element is required for thyroid hormone synthesis?

A. Zinc
B. Copper
C. Iodine
D. Fluoride

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Answer key and explanations

1. A - Potassium

Potassium is the principal intracellular cation.

2. B - Transferrin

Iron binds transferrin in circulation; ferritin mainly stores iron.

3. C - Iodine

Iodine is a constituent of thyroid hormones.

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