MINERALS

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Minerals

Macronutrients

Micronutrients

> 100 mg/day <

1. Calcium
2. Phosphorus
3. Magnesium
4. Sodium
5. Potassium
6. Chlorine
7. Sulphur

1. Iron
2. Iodine
3. Copper
4. Zinc
5. Cobalt
6. Manganese
7. Molybdenum
8. Chromium
9. Selenium
10. Fluorine

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MACRONUTRIENTS

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Calcium

- Calcium is the most abundant mineral in human beings.
- Total calcium in an average adult is about 1,000 gm of which nearly 99% is present in bones and teeth
- The rest (about 10 gm) is distributed in various tissues and body fluids

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- **Muscles and nerves have relatively more calcium than other tissues.**

- **Calcium is present in bones mainly in the form of calcium phosphate.**

- **Small amounts of carbonate, hydroxide, fluoride, citrate and other salts of calcium are also present**

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- **Calcium phosphate is first deposited in an amorphous form which is later converted into crystalline form.**

- **The crystalline form is known as hydroxyapatite, and its rough composition is Ca10(PO4)6(OH)2**

- **The crystals are rod-shaped**

- **There is a continuous exchange of calcium between bones and extracellular fluid**

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- **Concentration of calcium in intracellular and extracellular fluids is delicately regulated.**

- **The concentration of calcium in plasma (or serum) is 9 -11 mg/dl (4.5-5.5 mEq/L).**

- **About 50% of this is bound to proteins, and can not diffuse through capillaries (protein bound or non-diffusible calcium)**

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Blood Calcium – 10mgs/100 mls	Diet
Non diffusible - 3.5 mgs Albumin bound - 2.8 Globulin bound - 0.7 Diffusible - 6.5 mgs Ionized - 5 mgs Complexed - 1.5 mgs	Dietary calcium Milk and dairy products , vegetables, egg etc.

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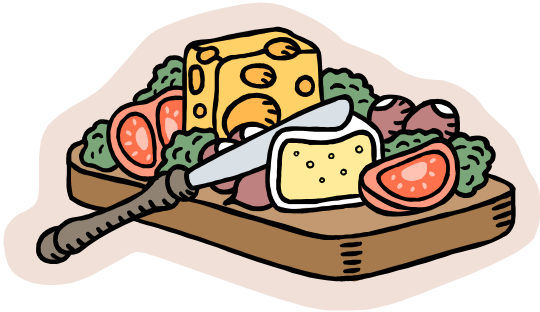
Dietary requirements



- **Dietary requirements:**
  - Adult : 800 mg/day;
  - Women during pregnancy, lactation and post-menopause: 1.5 g/day;
  - Children (1-18 yrs): 0.8-1.2 g/ day;
  - Infants: (< 1 year): 300-500 mg /day
- **Food Sources:**
  - Best sources: milk and milk product;
  - Good sources: beans, leafy vegetables, fish, cabbage, egg yolk.

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Functions

- Formation of bones and teeth
- Excitability and conductivity of nerves
- Neuromuscular transmission
- Excitability and contractility of myocardium
- Coagulation of blood
- Action of hormones

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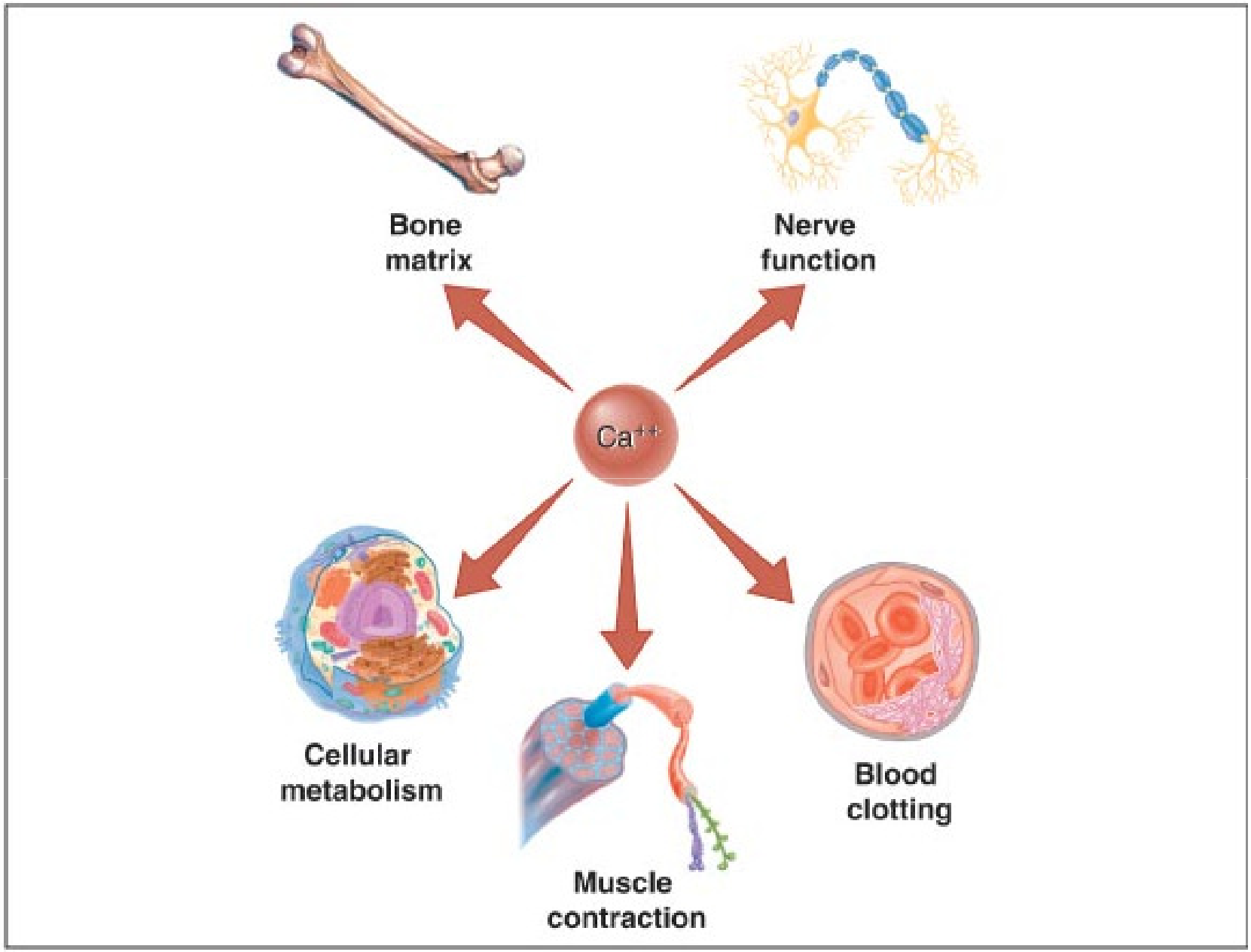

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Formation of bones and teeth

- A major function of calcium is to form bones and teeth

- Calcium phosphate is deposited around collagen fibres in the zone of ossification in an amorphous form which changes later into hydroxyapatite crystals

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- **Osteoblasts mineralise the bones and osteoclasts remove calcium phosphate from the bones**

- **During growing age, osteoblastic activity is more than the osteoclastic activity leading to skeletal growth**

- **In adults, the activities are balanced leading to a continuous remodelling of the bones**

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Excitability and conductivity of nerves

- **Excitability of nerves depends upon a number of cations including Ca++**

- **A raised plasma Ca++ level decreases, and a lowered plasma Ca++ level increases the excitability of nerves**

- **Transmission of impulses across synapses occurs due to release of neurotransmitters which requires Ca++**

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- **Neurotransmitters are present in the cell inside synaptic vesicles**

- **There are two pools of synaptic vesicles, reserve pool and releasable pool**

- **In the reserve pool, a synaptic vesicle is bound to actin filaments through a protein, synapsin I (dephosphorylated)**

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- **Release of Ca++ activates calmodulin (CaM) kinase II which phosphorylates synapsin I**

- **This leads to dissociation of the synaptic vesicle from actin filaments**

- **Synaptic vesicle moves to releasable pool from where it releases the neurotransmitter molecules by exocytosis**

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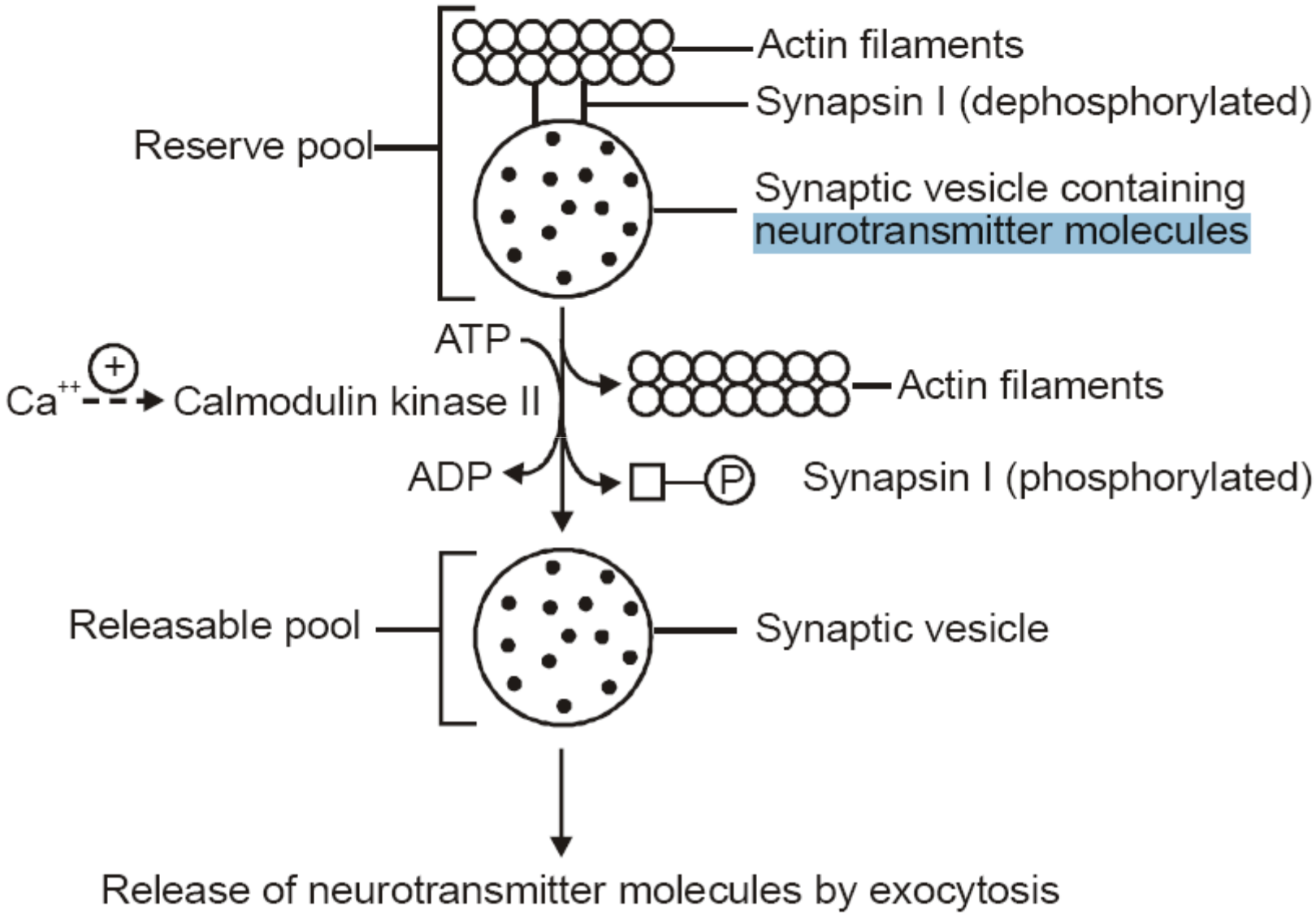

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Excitability and contractility of myocardium

- **The rhythmic generation of impulses in heart and contraction of heart muscle also require calcium ions**

- **An increase in the concentration of ionised calcium increases cardiac contractility and vice versa**

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Coagulation of blood

- Ionised calcium is one of the coagulation factors
- Coagulation of blood occurs by a cascade of reactions
- Calcium ions are required in most of these reactions
- Many of the anticoagulants which are used to prevent in vitro coagulation of blood, e.g. oxalate,citrate, EDTA etc, act by binding calcium ions

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Action of hormones

- Ionised calcium acts as a second messenger for some of the hormones

- Moreover, the secretion of hormones which are stored in granular form also requires the presence of calcium ions

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Absorption

- **Absorption of calcium occurs by an active uptake system in the upper part of small intestine**

- **Normally, 10-20% of the dietary calcium is absorbed**

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Calcium Absorption (0.4-1.5 g/d)	Mechanisms of GI Calcium Absorption
Absorption-20% Fecal excretion – 60% Urination – 20% *Dr. M. K. Ahmad* *Department of Biochemistry*	Vitamin D dependent Duodenum > jejunum > ileum Active transport across cells calcium binding proteins (e.g., calbindins)

The absorption is affected by the following factors:

- **pH**
- **Calcium : phosphorus ratio**
- **Proteins**
- **Vitamin D and parathormone**

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pH

- **A relatively low pH increases the solubility of calcium salts and favours calcium absorption**

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Calcium : phosphorus ratio

- Since calcium and phosphorus are absorbed together, they must be present in the diet in a proper ratio

- The ideal ratio is 1:1 but absorption can occur satisfactorily as long as the ratio lies between 1:2 and 2:1

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Vitamin D and parathormone

- **Vitamin D and parathormone play an important role in the metabolism of calcium**

- **Cholecalciferol is converted into its active metabolite, 1,25-dihydroxychole calciferol with the help of parathormone**

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- **1,25–Dihydroxycholecalciferol induces the synthesis of calcium-binding protein, calcium-dependent ATPase and alkaline phosphatase in the intestinal mucosa**

- **These are required for the active absorption of calcium**

- **As calcium is absorbed, plasma calcium level rises**

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- **When plasma calcium rises above the normal range, it causes feedback inhibition of parathormone secretion**

- **This switches off the series of reactions responsible for raising the plasma calcium level**

- **Thus, vitamin D and parathormone act in concert to regulate calcium absorption and the plasma calcium level**

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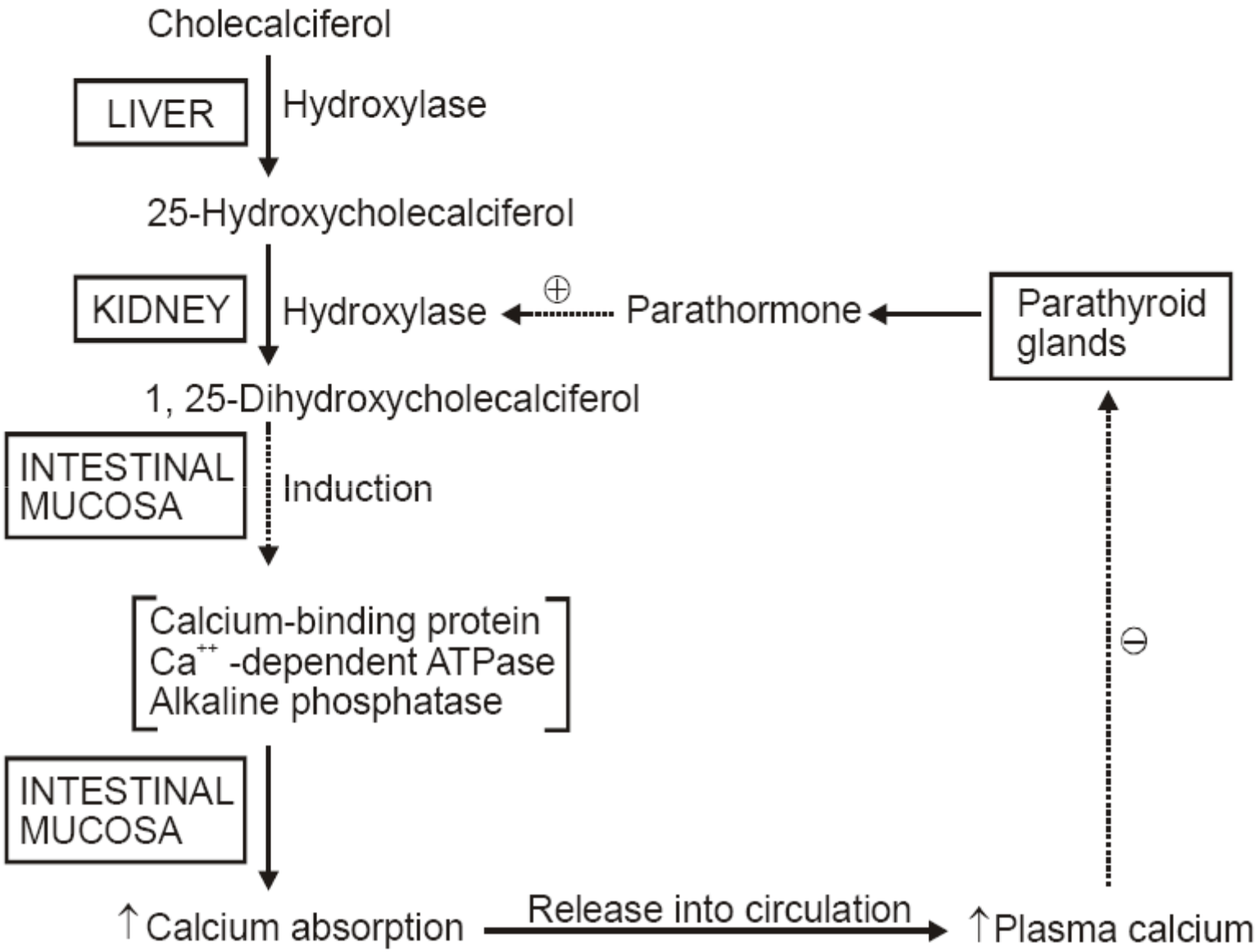

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Abnormal serum calcium levels

- **Serum calcium level may rise or fall in some pathological conditions**

- **A rise in serum calcium level (hypercalcaemia) occurs in hyperparathyroidism, hypervitaminosis D, bone cancer, multiple myeloma, leukaemia, polycythaemia, milk-alkali syndrome, sarcoidosis, idiopathic infertile hypercalcaemia etc**

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- **A decrease in serum calcium level (hypocalcaemia) is seen in hypoparathyroidism, rickets, osteomalacia, steatorrhoea, chronic renal failure, nephrotic syndrome etc**

- **If serum calcium level remains elevated over a long period, calcium may get deposited in soft tissues such as kidneys, liver, arteries etc**

- **A sudden decrease in serum calcium may cause tetany (involuntary contraction of skeletal muscles)**

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Hypercalcemic Disorders

A. Endocrine Disorders Associated with Hypercalcemia

1. Endocrine Disorders with Excess PTH Production
   - Primary Sporadic hyperparathyroidism
   - Primary Familial Hyperparathyroidism
     - MEN I
     - MEN IIA

2. Endocrine Disorders without Excess PTH Production
   - Hyperthyroidism
   - Hypoadrenalism

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Hypercalcemic Disorders

B. Malignancy-Associated Hypercalcemia (MAH)

1. MAH with Elevated PTHrP
   - Humoral Hypercalcemia of Malignancy
   - Solid Tumors with Skeletal Metastases
   - Hematologic Malignancies

2. MAH with Elevation of Other Systemic Factors
   - MAH with Elevated 1,25(OH)2D3
   - MAH with Elevated Cytokines
   - Ectopic Hyperparathyroidism
   - Multiple Myeloma

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Treatment

- **Treatment of primary diseases**

- **Bisphosphonates : Chronic treatment of hypercalcemia includes administration of bisphosphonates. It inhibit bone resorption leading to decrease in plasma calcium.**

- **Calcitonin : It effectively reduces plasma calcium levels by inhibiting bone resorption.**

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Osteoporosis

- **After the age of 40-50, calcium absorption is reduced and calcium excretion is increased**

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Treatment

- **Severe symptomatic hypocalcemia: In the presence of tetany, intravenous administration of calcium gluconate is indicated**

- **Asymptomatic hypocalcemia : If the hypocalcemia is asymptomatic, oral calcium (calcium carbonate) and vitamin D preparation are used.**

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Phosphorus

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- **Next to calcium, phosphorus is the most abundant mineral in human beings**
- **About 800 gm of phosphorus is present in the body of an average adult**
- **Nearly 80% of it is present in bones and teeth**
- **The remainder is distributed all over the body**

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- **Nerves and muscles are particularly rich in phosphorus**

- **Phosphorus is mainly an intracellular mineral**

- **Serum inorganic phosphorus level is 2.5 - 4.0 mg/dl in adults and 4 - 7 mg/dl in children**

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Functions

- Formation of bones and teeth
- Formation of high-energy compounds
- Role in metabolism
- Formation of nucleic acids
- Formation of membranes
- Formation of nervous tissue
- Maintenance of pH

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Formation of high-energy compounds

Phosphorus is a constituent of most of the high energy compounds in our body e.g. ATP, creatine phosphate, phosphoenol pyruvate etc

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Role in metabolism

- **Phosphorus is a constituent of many coenzymes e.g. FMN, FAD, NAD, NADP, thiamin pyrophosphate, pyridoxal phosphate and coenzyme A**

- **Phosphorus plays an important role in metabolic reactions in the form of these coenzymes**

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- **Carbohydrates have to be phosphorylated before they can enter any metabolic pathway**

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Formation of nucleic acids

Phosphorus is required for the formation of nucleotides which, in turn, form nucleic acids

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Formation of membranes

Phosphorus participates in the formation of biomembranes in the form of phospholipids

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Formation of nervous tissue

Phosphorus also takes part in the formation of nervous tissue in the form of phospholipids

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MAINTENANCE OF PH

- **Inorganic phosphorus exists as $HPO4^{--}$ and H_2PO4^{-} which constitute a buffer pair and help in the maintenance of pH**

- **Phosphate buffer is more abundant in intracellular fluid**

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ABSORPTION

- **Phosphorus is absorbed from the small intestine along with calcium**

- **If calcium absorption is normal, so will be that of phosphorus**

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REQUIREMENT

Infants	**: 250-400 mg/day**
Children	**: 800 mg/day**
Adolescents	**: 1200 mg/day**
Adults	**: 800 mg/day**
Pregnant and lactating women	**: 1200 mg/day**

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DIETARY SOURCES

- **Phosphorus is widely distributed in foodstuffs**
- **If calorie and protein intakes are sufficient, a dietary deficiency of phosphorus is unlikely to occur**
- **Milk, cheese, eggs, meat, nuts and beans are particularly good sources of phosphorus**

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Abnormal serum phosphorus levels

- A rise in serum inorganic phosphorus level (hyperphosphataemia) occurs in chronic renal failure, hypoparathyroidism, hypervitaminosis D, acromegaly, diabetes mellitus etc

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- **A low serum inorganic phosphorus level (hypophosphataemia) is seen in rickets, osteomalacia, hyperparathyroidism, steatorrhoea, Fanconi syndrome and familial hypophosphataemic rickets (renal rickets or vitamin D-resistant rickets)**

- **Renal rickets is an inherited disorder (X-linked dominant) in which renal tubular reabsorption of phosphate is greatly decreased**

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Magnesium

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- **The total magnesium in an average adult is about 25 gm**
- **Bones contain about 70% of the total body magnesium**
- **The remainder is present in other tissues and body fluids e.g. muscles, blood, CSF etc**

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- **Serum magnesium level is 2 - 3 mg/dl**

- **Concentration of magnesium in the intracellular compartment is higher than that in the extracellular compartment**

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Functions

- Magnesium is involved in excitability of nerves
- Magnesium is a cofactor for some enzymes

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Excitability of nerves

- Together with some other cations, magnesium ions also affect the excitability of nerves

- A low magnesium level increases the excitability, and a high magnesium level decreases the excitability

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Cofactor for enzymes

- **Enzymes involved in the metabolism of carbohydrates, lipids, amino acids, purines and pyrimidines e.g. hexokinase, phosphofructokinase, pyruvate kinase, thiokinase, mevalonate kinase, squalene synthetase, glutamine synthetase, carbamoyl phosphate synthetase, PRPP synthetase etc**

- **Some other enzymes requiring Mg++ as a cofactor are enolase, glucose-6-phosphate dehydrogenase, transketolase etc**

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Absorption

- Magnesium is absorbed from the small intestine
- On an average diet, about half of the ingested magnesium is absorbed
- The regulation of magnesium balance is the function of kidneys
- A high aldosterone level decreases the tubular reabsorption of magnesium

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Requirement

Infants	: 60-70 mg/day
Children	: 150-250 mg/day
Adult men	: 350 mg/day
Adult women	: 300 mg/day
Pregnant and lactating women	: 450 mg/day

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Dietary sources

- Nuts, beans, wheat, milk, eggs, orange and spinach are good sources of magnesium

- Almond is particularly rich in magnesium

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Abnormal serum magnesium levels

- Serum magnesium level is decreased (hypomagnesaemia) in chronic alcoholism, chronic diarrhoea, hyperparathyroidism and aldosteronism

- A high serum magnesium level (hypermagnesaemia) is commonly seen in renal failure

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SODIUM

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- **Total amount of sodium in an average adult is about 60 gm**
- **About 20 gm is present in bones**
- **The rest is distributed in other tissues**

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- **Sodium is the major cation of the extracellular fluids**
- **Plasma sodium level is 310-340 mg/dl or 136-145 mEq/L**
- **Other extracellular fluids are also rich in sodium**
- **The intracellular fluid contains only about 10 mEq/L**

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Functions

- Maintenance of osmotic pressure
- Maintenance of pH
- Nerve excitability and conduction
- Active transport

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Maintenance of osmotic pressure

- Being the major cation of extracellular fluids, sodium plays on important role in maintaining the osmotic pressure of body fluids

- Osmotic pressure depends upon the number of solute particles and not on their size

- Sodium ions outnumber all the other solute particles in extracellular fluids

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Maintenance of Ph

- In the form of sodium bicarbonate, it is a component of the bicarbonate-carbonic acid buffer which is a major buffer of the extracellular fluids.

- Renal excretion of hydrogen ions in exchange for sodium ions is also important in maintaining the pH of body fluids.

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Nerve excitability and conduction

- Maintenance of normal excitability of nerves and conduction of nerve impulses are also important functions of sodium
- Cations and anions are so distributed across the cell membrane of nerve fibres that the exterior of the membrane is slightly electropositive in relation to the interior.
- This potential difference is known as the resting potential.

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- When a stimulus is applied to the nerve, the stimulated area immediately becomes permeable to sodium ions which move into the interior of the nerve fibre.
- The interior becomes electropositive in relation to the exterior.
- Thus, a nerve impulse is generated.
- Transmission of the nerve impulse also occurs due to influx of sodium ions along the entire length of the nerve fibre.

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Active transport

- Several compounds enter the cells against their concentration gradient by active absorption.

- Sodium pump, which ejects sodium ions from the interior of the cell to the exterior, is linked with the active absorption of glucose, galactose and some amino acids.

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Absorption

- Sodium enters gastrointestinal tract through ingested food and through digestive secretions.
- The latter is a far more abundant source as compared to dietary intake.
- Almost all the sodium is absorbed from the gastrointestinal tract.
- The absorption occurs from the entire length of the small and large intestines.

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- **As the concentration of sodium in intestinal lumen is far greater than that inside the mucosal cells, sodium diffuses from the lumen into the cells.**

- **The intracellular sodium is actively transported into blood by the sodium pump.**

- **This keeps the intracellular concentration of sodium in the mucosal cells at a low level so that more sodium can diffuse from the intestinal lumen into the mucosal cells.**

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Requirement

- There has been considerable controversy about the daily requirement of sodium.

- The requirement depends upon daily loss of sodium from the body which depends upon climate.

- In a tropical country like India, a daily intake of 4-6 gm of elemental sodium or 10-15 gm of sodium chloride is sufficient to maintain sodium balance.

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- **In recent years, a direct relationship between excessive sodium intake and prevalence of hypertension has been shown.**

- **As far as sodium nutrition is concerned, the problem is really one of preventing excessive intake rather than one of guarding against a dietary deficiency.**

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Dietary sources

- Table salt (sodium chloride) is one of the chief sources of sodium in our daily diet.
- Baking powder (sodium bicarbonate) can also contribute significant amounts.
- Meat, fish, fowl, eggs, milk, cheese and cereals are rich in sodium.
- Carrot, radish, cauliflower, spinach, turnip, legumes and nuts are also good sources of sodium.

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Abnormal serum sodium levels

- **Hyponatraemia (low serum sodium) occurs in adrenocortical insufficiency, severe diarrhoea, chronic renal disease, excessive sweating etc.**
- **Hyponatraemia may also occur due to dilution of plasma when dehydrated patients are rehydrated with salt-free fluids.**

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- **Hypernatraemia (high serum sodium) occurs in adrenocortical hyperactivity, prolonged steroid therapy and dehydration.**
- **In dehydration, hypernatraemia occurs due to haemoconcentration.**

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POTASSIUM

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- **Total amount of potassium in an average adult is about 140 gm.**

- **Potassium is the chief cation of the intracellular compartment, and is present in all cells.**

- **The potassium content of intracellular fluid is about 140 mEq/L while that of extracellular fluid is only about 5 mEq/L.**

- **Serum potassium level is 3.5-5 mEq/L**

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Functions

- Maintenance of osmotic pressure
- Maintenance of Ph
- Nerve excitability and conduction
- Cofactor for enzymes
- Active transport

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Maintenance of osmotic pressure

- **Potassium is involved in the maintenance of osmotic pressure within the cells in the same way as sodium does in extracellular compartment.**

- **Nearly half the osmolarity of intracellular fluid is due to potassium.**

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Maintenance of pH

- **Potassium, in the form of KH_2PO_4 and K_2HPO_4, helps to maintain the pH of intracellular fluid.**

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Nerve excitability and conduction

- Together with sodium, potassium plays a role in maintaining the normal excitability of nerves and in the conduction of nerve impulses.
- It also affects the excitability and contractility of muscles, particularly heart muscles.
- Marked alterations in serum potassium level often cause serious abnormalities in the functioning of the heart.

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Cofactor for enzymes

- **Potassium functions as a cofactor for some enzymes e.g. pyruvate kinase.**

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Active transport

- **Along with sodium, potassium is also involved in active transport.**

- **The sodium pump, involved in active transport of glucose, galactose, amino acids etc, is really a sodium-potassium pump as it causes energy dependent efflux of sodium and influx of potassium.**

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Absorption

- **Potassium absorption occurs down the concentration gradient from small intestine as well as large intestine.**

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Requirement

- The exact potassium requirement is not known with certainty.
- A daily intake of 4 gm is sufficient to maintain potassium balance.

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Dietary sources

- **Potassium is very widely distributed in foodstuffs.**

- **Meat, fish, fowl, cereals, vegetables, apricots, peaches, oranges and pineapples are rich is potassium.**

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Abnormal serum potassium levels

- **Hypokalaemia (low serum potassium) occurs in adrenocortical hyperactivity, prolonged steroid therapy, diarrhoea, wasting diseases, metabolic alkalosis, familial periodic paralysis and after insulin injection.**

- **Hypokalaemia may also be caused by prolonged use of thiazide diuretics which promote urinary excretion of potassium.**

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- **Hyperkalaemia (high serum potassium) is seen in adrenocortical insufficiency, renal failure, dehydration etc.**

- **Indiscriminate intravenous potassium therapy may also cause hyperkalaemia.**

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CHLORINE

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- **The total amount of chlorine in an average adult is about 80 gm.**
- **Chlorine, in the form of chloride ions, is the chief anion of extracellular compartment.**
- **Normal serum chloride level is 100-106 mEq/L (355-375 mg/dl).**
- **The chloride content of cerebrospinal fluid is 120 to 130 mEq/L.**
- **The interstitial fluid contains about 110 mEq/L.**
- **The intracellular fluid contains only about 4 mEq/L.**

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Functions

- Maintenance of osmotic pressure
- Maintenance of Ph
- Formation of hydrochloric acid

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Maintenance of osmotic pressure

- **Alongside sodium, chloride ions play an important role in maintaining the osmotic pressure of extracellular fluids as they are present in a high concentration in extracellular fluids.**

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Maintenance of pH

- **Chloride ions help in maintaining the pH of blood by the mechanism of chloride shift.**

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Formation of hydrochloric acid

- **Hydrochloric acid is an important constituent of gastric juice.**

- **Chloride ions are necessary for its formation**

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Absorption

- Chloride ions are absorbed passively down the concentration gradient in the upper portion of the small intestine.

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Requirement

- Chloride is commonly present in food as sodium chloride.
- Therefore, sodium and chloride intakes are parallel.
- If daily requirement of sodium is met, so will be that of chloride.

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Dietary sources

- Table salt is the most abundant source of chloride in our daily diet.

- Foods that provide sodium also provide chloride e.g. meat, fish, fowl, eggs, milk, cheese, cereals etc.

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Abnormal serum chloride levels

- With a few exceptions, changes in serum chloride level are parallel to those in serum sodium level.
- Serum chloride level is raised (hyperchloraemia) in dehydration, respiratory alkalosis, metabolic acidosis (e.g. renal failure and diarrhoea) and adrenocortical hyperactivity.
- Serum chloride level is lowered (hypochloraemia) in severe vomiting, prolonged gastric suction, respiratory acidosis, metabolic alkalosis and Addison's disease.

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Sulphur

- About 100 gm of sulphur is present in an average adult
- Inorganic sulphur, in the form of sulphate ions, is present in very small amounts
- Organic sulphur is the predominant form of sulphur in the body

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FUNCTIONS

- Component of proteins
- Component of mucopolysaccharides
- Constituent of many vitamins
- Detoxification of many harmful substances

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- **Sulphur is a component of most of the proteins in the form of cysteine and methionine.**

- **The sulphydryl (–SH) groups of cysteine residues not only stabilise the structure of proteins by forming disulphide bonds but are also essential for the biological activity of many proteins, particularly the enzymes.**

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- **Several mucopolysaccharides, e.g. heparin, chondroitin sulphate and keratan sulphate, contain sulphur.**

- **Sulphur is a constituent of many vitamins e.g. thiamin, biotin, lipoic acid etc.**

- **Active form of pantothenic acid, i.e. coenzyme A and acyl carrier protein, also contain sulphur.**

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- **Detoxification of many harmful substances is done in the liver by conjugating them with sulphate.**

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ABSORPTION

- **Sulphur is absorbed from the intestine mainly in the form of sulphur-containing amino acids**

- **Absorption of inorganic sulphate is very poor**

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REQUIREMENT

- **The daily excretion of sulphur is about 5 gm in average adults**
- **Most of it is derived from proteins**

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DIETARY SOURCES

- **It is the sulphur of the proteins that meets our sulphur requirements.**

- **Therefore, protein-rich foods, e.g. eggs, milk, cheese, meat, fish, nuts and legumes, are the main sources of sulphur in our daily diet.**

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