Minerals

Minerals

At the end of this topic, the student should be able to:

- Explain the criteria of classification of minerals
- List the main major and trace minerals
- Explain the main functions of minerals
- Outline the main natural sources and the dietary required quantity of minerals.
- Outline the disorders related to minerals' deficiency/toxicity.

Minerals

Minerals are the inorganic substances the human body needs to survive and carry out daily physiological functions and processes. They are essential nutrients.

Minerals must be supplied in the diet (food and fluids) and vary from grams per day through milligrams to micrograms per day.

Minerals

Mineral supply depends not only on the intake in food but primarily on the bioavailability, which is essentially related to the composition of the food.

A series of food constituents, e. g., proteins, peptides, amino acids, polysaccharides, sugars, and organic acids, bind minerals and enhance or inhibit their absorption.

Classification of minerals

There are 2 main classes of minerals:

- major minerals (macrominerals)
- trace minerals (microminerals)

These 2 classes of minerals are equally important, but major minerals are needed in big amounts than trace minerals which are needed in smaller amounts.

Classification of minerals

The macrominerals are needed for the human body in ***amounts >50 mg/day*** *while* the microminerals are needed in **amounts <50 mg/day.**

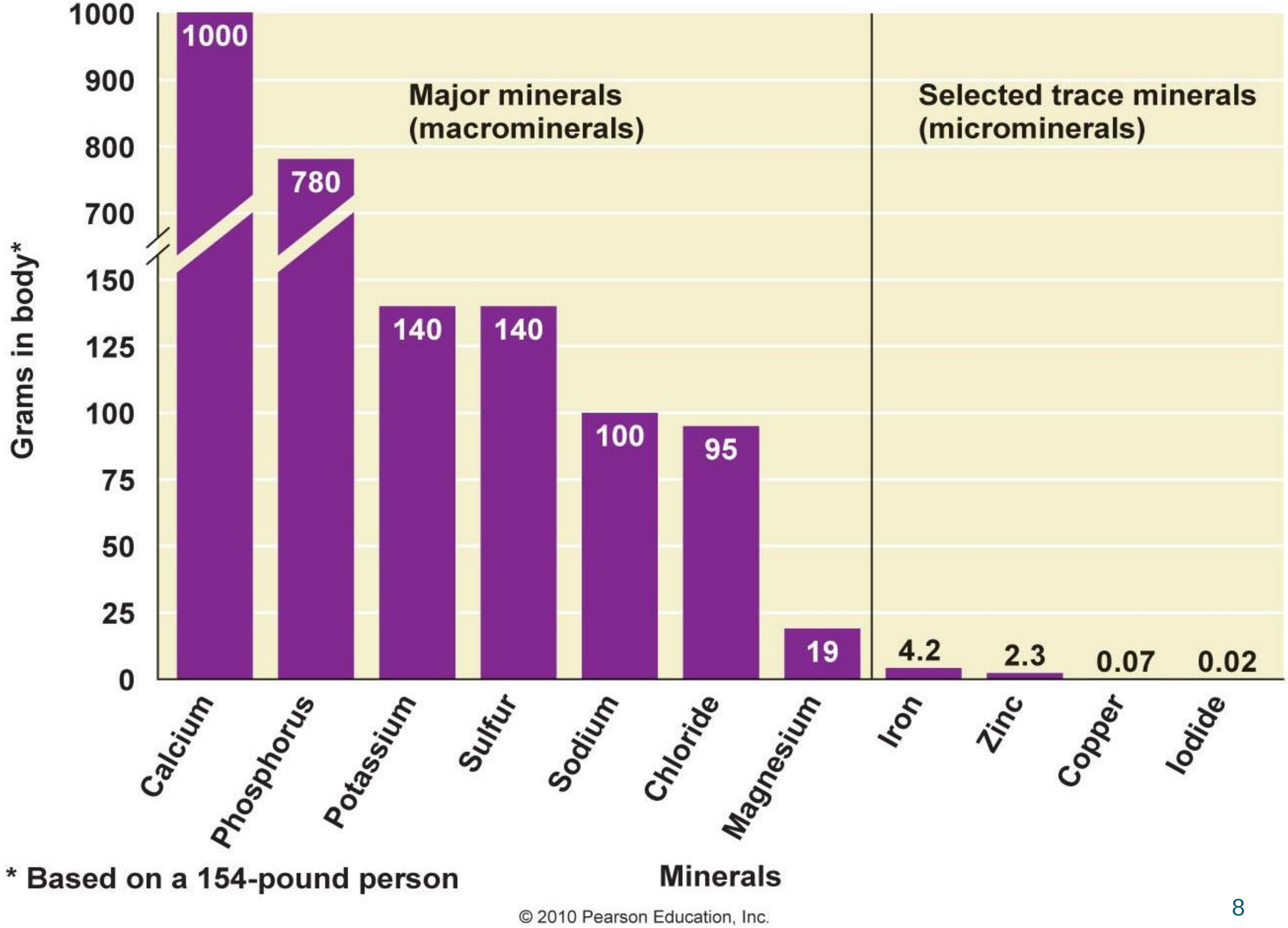
N.B. The amounts needed in the body are not an indication of their importance.

Macrominerals

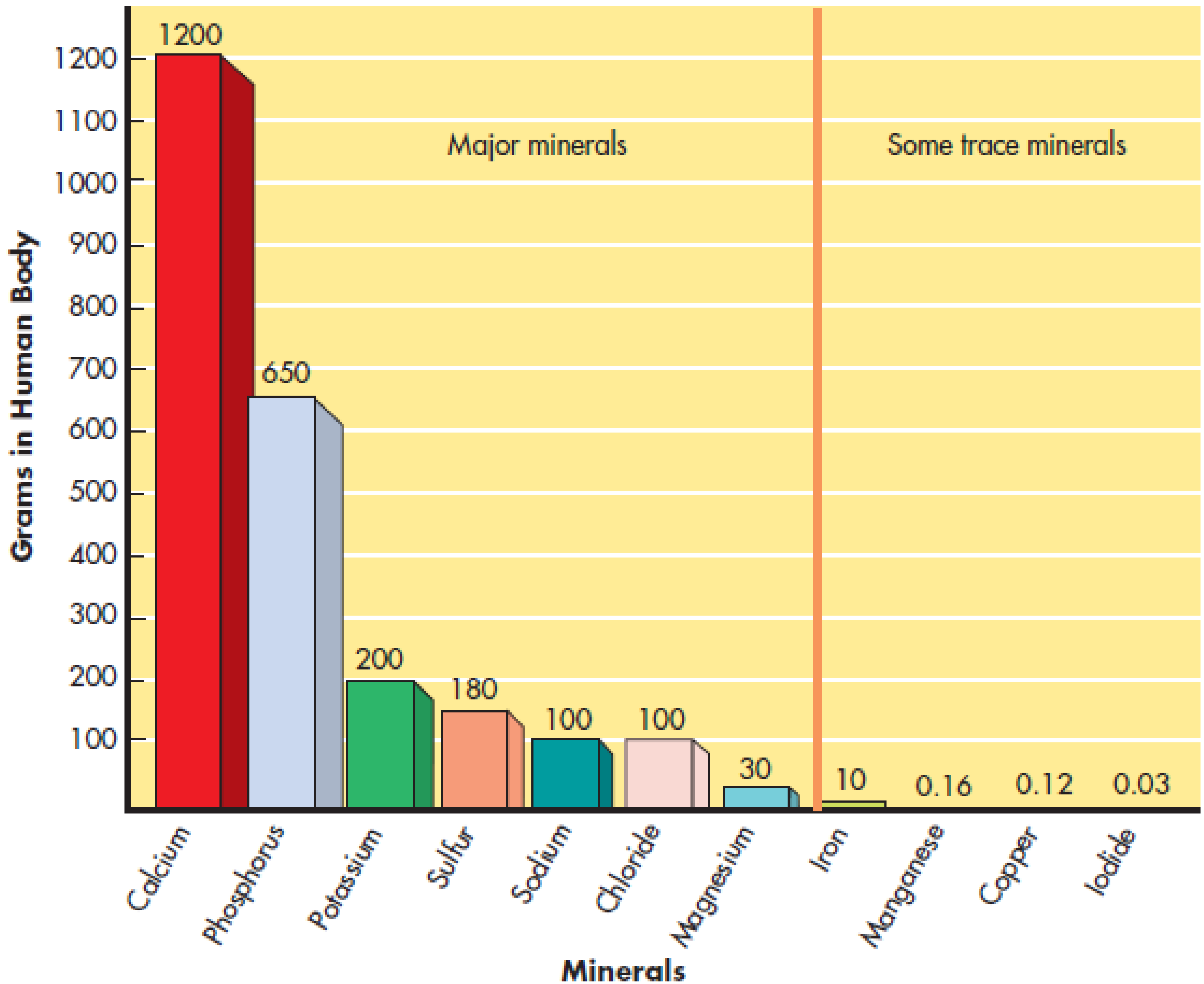
The main macrominerals are: Sodium, Potassium, Magnesium, Calcium, Chloride, Phosphorus, Sulfur.

Sulfur also belongs to this group. However, it will not be discussed here because sulfur requirements are met by the intake of sulfur-containing amino acids.

Classification of minerals



Classification of minerals



Functions of minerals

Like vitamins, minerals help the human body to grow, develop and stay healthy.

The human body uses minerals to perform many different functions (from building strong bones to transmitting nerve impulses). Some minerals are even used to make hormones or maintain a normal heart beat.

Functions of minerals

One of the key tasks of major minerals is to maintain the proper balance of water in the body: Sodium, chloride and potassium take the lead in doing this. The three other major minerals (calcium, phosphorus, magnesium) are important for healthy bones.

Functions of minerals

Minerals play several key roles in overall health and well being, help the chemical reactions taking place in cells and help muscles to contract and keep the heart beating.

Major mineral	Main function	Related disorder
Sodium	Major positive ions of extracellular fluid and maintaining its osmotic pressure Water balance Used in conduction of nerve impulse.	➢ Muscle cramps ➢ nervous depression ➢ loss of Na+ in urine dehydration
Potassium	Major positive ions of intracellular fluid and used in osmotic balance Muscle contraction Nerve impulse conduction or transmission Water balance	➢ Irregular heart beat beat ➢ Muscle cramps leading to paralysis. ➢ Loss of appetite
Calcium	• Bones and tooth structure, used in blood clotting, muscle contraction, hardening of bones and conduction of nerve impulse from presynaptic to postsynaptic region	➢ Increased risk osteoporosis ➢ Loss of muscle coordination. ➢ Rickets and tetany

Magnesium	Development and maintenance of bones aids enzyme function by cofactor for enzyme (e.g.: hexokinase) Aids nerve and heart function	➢ Weakness, muscle pain ➢ Dilated blood pressure ➢ Poor heart function (Heart and vascular irregularities)
Phosphorus	Major ion of intracellular fluid Bones and tooth strength Part of various metabolic compounds Production of high energy phosphate compounds such as ATP, CTP, etc It is important in production of coenzyme Acid/base balance	➢ Possibility of poor bone maintenance ➢ Rickets and osteomalacis ➢ osteoporosis
Chloride	Major negative ions of extracellular fluid Participates in acid production in stomach Aids nerve impulse transmission Water balance, acid-base balance regulate the osmotic pressure within the cell and electrolyte balance.	➢ Convulsions in infants ➢ Vomiting and ➢ hypochlorenic alkalosis
Sulfur	Parts of vitamins and amino acids Component of enzymes and coenzymes. insulin production Aids in drug detoxification Acid/base balance	➢ Stress, ➢ Pain, ➢ Cancer, ➢ Fatigue

Trace mineral	Main function	Related disorder
Iron	Component of hemoglobin and other key compounds used in respiration, cofactor of catalase enzyme Immune function, cognitive development	➢ Fatigue, anemia ➢ Skin problem ➢ Low blood hemoglobin values
Zinc	Required for nearly 200 enzymes Growth, immunity, alcohol metabolism Sexual development and reproduction Antioxidant protection Vitamin A metabolism	➢ Diarrhea, hair loss, poor growth and development, reduced respiration, ➢ poor wound healing, decreased appetite and sense of taste, ➢ Dermatitis
Fluoride	Maintains dental enamel and prevent dental caries.	➢ Increase risk of dental caries
Iodide	Component of thyroid hormones Promote normal functioning of thyroid	➢ Goiter, mental retardation, ➢ poor growth in infancy when mother is iodide deficient during pregnancy

Trace mineral	Main function	Related disorder
Selenium	Part of an antioxidant system Assist vitamin E	➢ Muscle pain and weakness ➢ Form of heart diseases
Molybdenum	Aids in action of some enzyme and cofactor for nitrogenase enzyme and involved in of sulfur amino-acids, purines and purimidines	➢ None observed in health human
Copper	Aids in iron metabolism and necessary for iron absorption Works with many antioxidant enzymes and cofactor for enzyme (oxydase, tyrosinase) Involves with enzymes of protein metabolism and hormone synthesis Increases the level of high density lipo-proteins and protects the heart	Anemia low white blood cell count Poor growth
Cobalt	Component of vitamin B12.	Pernicious anemia

Trace mineral	Main function	Related disorder
Chromium	Enhances insulin action Catabolic metabolism	High blood glucose after eating Irregularities of catabolism and ATP production.
Manganese	Cofactor of some enzymes (those involved in carbohydrate metabolism), works with some antioxidant systems Help in normal reproductive functions	Reproductive failure, Menstrual irregularities
Cobalt		
Nickel		
Silicon		
Vanadium		

Sources of major minerals

Mineral	source
Sodium	Table salt, soy sauce; large amounts in processed foods; small amounts in milk, breads, vegetables, and unprocessed meats
Chloride	Table salt, soy sauce; large amounts in processed foods; small amounts in milk, meats, breads, and vegetables
Potassium	Meats, milk, fresh fruits and vegetables, whole grains, legumes
Calcium	Milk and milk products; canned fish with bones (salmon, sardines); fortified tofu and fortified soy milk; greens (broccoli, mustard greens); legumes.
Phosphorus	Meat, fish, poultry, eggs, milk, processed foods (including soda pop)
Magnesium	Nuts and seeds; legumes; leafy, green vegetables; seafood; chocolate; artichokes; "hard" drinking water
Sulfur	Occurs in foods as part of protein: meats, poultry, fish, eggs, milk, legumes, nuts

Sources of trace minerals

Mineral	source
Iron	Organ meats; red meats; fish; poultry; shellfish (especially clams); egg yolks; legumes; dried fruits; dark, leafy greens; iron-enriched breads and cereals; and fortified cereals
Zinc	Meats, fish, poultry, leavened whole grains, vegetables
Iodine	Seafood, foods grown in iodine-rich soil, iodized salt, bread, dairy products
Fluoride	
Iodide	Legumes, nuts and seeds, whole grains, organ meats, drinking water
Selenium	Widespread in foods, especially plant foods
Molybdenum	Drinking water (either fluoridated or naturally containing fluoride), fish, and most teas

Sources of trace minerals

Mineral	source
Copper	Organ meats; red meats; fish; poultry; shellfish (especially clams); egg yolks; legumes; dried fruits; dark, leafy greens; iron-enriched breads and cereals; and fortified cereals
Cobalt	Meats, fish, poultry, leavened whole grains, vegetables
Chromium	Seafood, foods grown in iodine-rich soil, iodized salt, bread, dairy products
Manganese	
	Legumes, nuts and seeds, whole grains, organ meats, drinking water
	Widespread in foods, especially plant foods
	Drinking water (either fluoridated or naturally containing fluoride), fish, and most teas

Sources of trace minerals

Mineral	source
Chromium	Organ meats; red meats; fish; poultry; shellfish (especially clams); egg yolks; legumes; dried fruits; dark, leafy greens; iron-enriched breads and cereals; and fortified cereals
Molybdenum	Meats, fish, poultry, leavened whole grains, vegetables
	Seafood, foods grown in iodine-rich soil, iodized salt, bread, dairy products
	Meats, seafood, grains
	Legumes, nuts and seeds, whole grains, organ meats, drinking water
	Widespread in foods, especially plant foods
	Drinking water (either fluoridated or naturally containing fluoride), fish, and most teas

Functions of microminerals

Mineral		Sources
Chromium		Unrefined foods, especially liver, brewer's yeast, whole grains, nuts, cheeses
Molybdenum		Legumes; breads and grains; leafy greens; leafy, green vegetables; milk; liver

Other trace minerals known to be essential in tiny amounts include nickel, silicon, vanadium, and cobalt.

Sodium & Chloride

The sodium content of the body is 1.4 g/kg. Sodium is present mostly as an extracellular constituent and maintains the osmotic pressure of the extracellular fluid. The intake of too little or too much sodium can result in serious disorders.

From a nutritional standpoint, only the excessive intake of sodium is of importance because it can lead to hypertension.

Sodium & Chloride

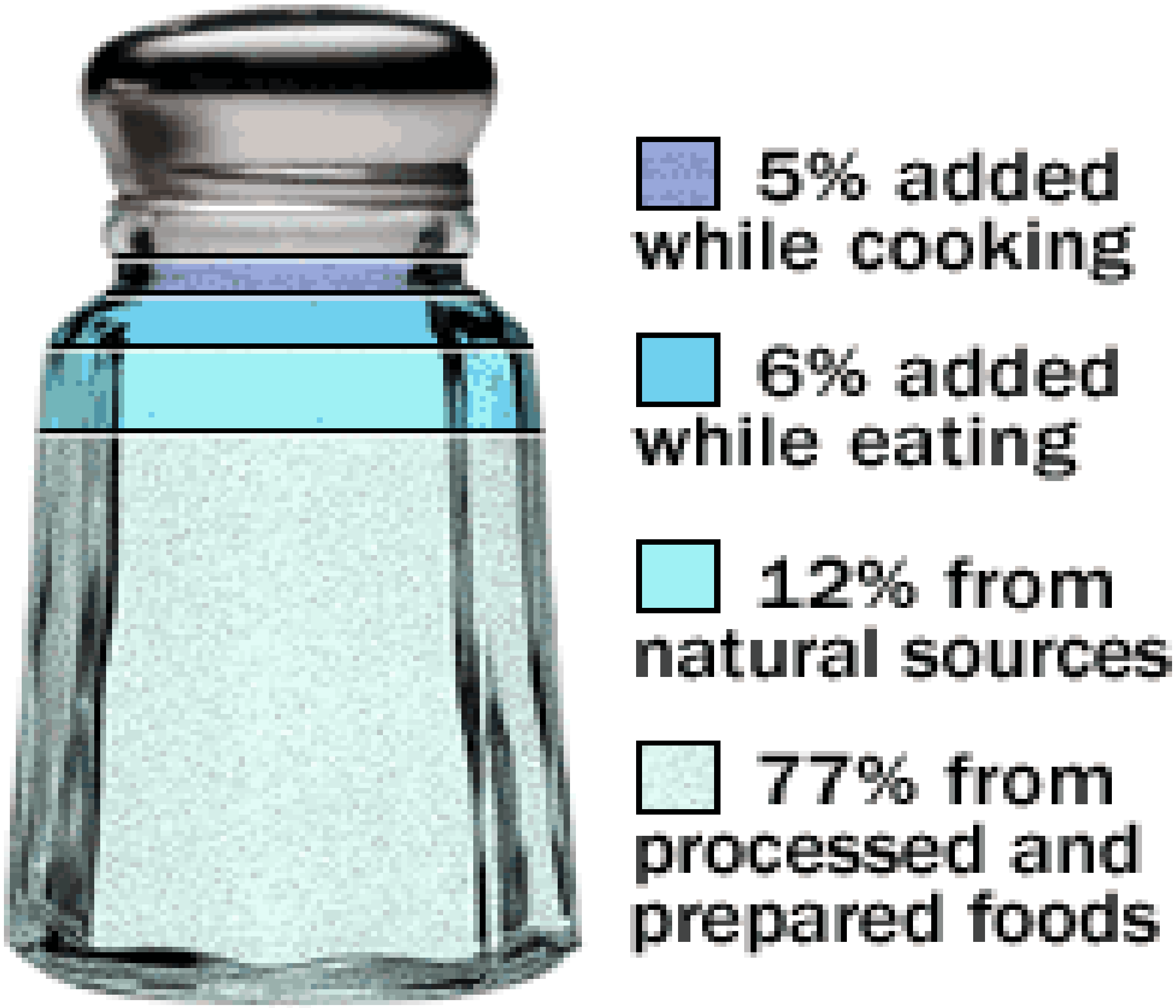
Although there is a wide variety of sodium salts, sodium chloride(NaCl) is the major source of sodium in foods.
As sodium and chloride intakes in humans are so closely matched, both will be considered together.

Sodium & Chloride

The human beings have special taste and salt appetite systems, which led to special culinary uses for salt and made it a much sought-after commodity.

salt is used widely to modify flavor, to alter the texture and consistency of food, and to control microbial growth.

Sources of sodium



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Sodium & Chloride

Absorption and tissue distribution

Sodium is the major extracellular electrolyte and exists as the fully water-soluble cation.

Chloride is also mainly found in Extracellular fluid (ECF) and is fully water soluble as the chloride anion.

Both ions are readily absorbed from the digestive tract.

Sodium & Chloride

Absorption and tissue distribution

The main excretory route for both sodium and chloride is the urine. Sweat loss of these ions tends to be very low except with severe exertion in hot climates. Fecal losses are also low in healthy individuals.

Sodium & Chloride

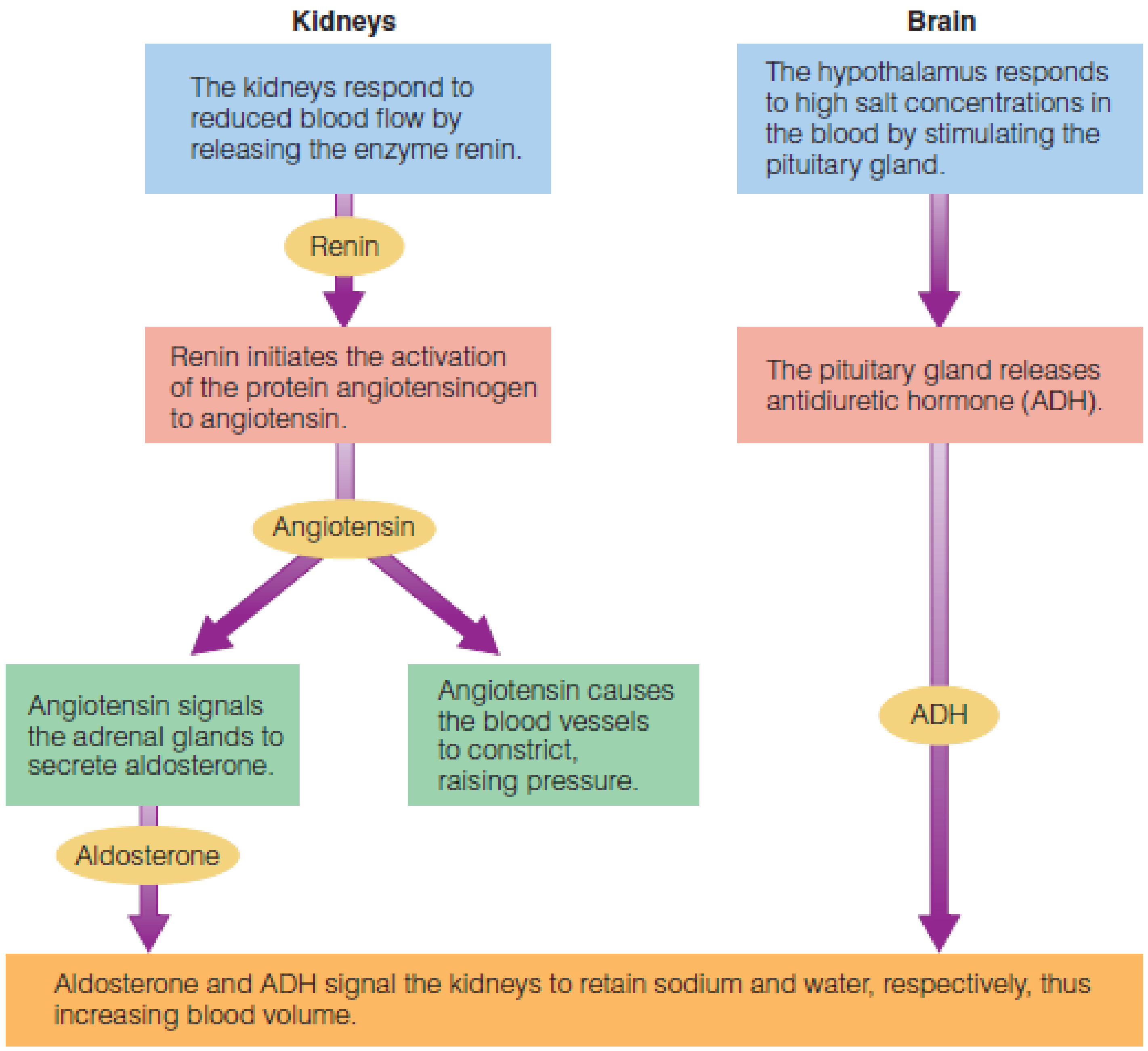
Plasma sodium regulation

Angiotensin and aldosterone both act to conserve sodium by increasing sodium reabsorption by the kidney.

Sodium depletion stimulates the renal production of renin, which generates active angiotensin in the circulation.

Sodium & Chloride

Sodium stimulates vasoconstriction, which increases blood pressure, decreases water loss, and stimulates aldosterone release from the adrenal cortex. Atrial natriuretic hormone counter acts the sodium retention mechanisms by suppressing renin and aldosterone release and by inducing water and sodium excretion. It also decreases blood pressure and antagonizes angiotensin.


Kidneys
The kidneys respond to reduced blood flow by releasing the enzyme renin.
Renin
Renin initiates the activation of the protein angiotensinogen to angiotensin.
Angiotensin
Angiotensin signals the adrenal glands to secrete aldosterone.
Angiotensin causes the blood vessels to constrict, raising pressure.
Aldosterone
Brain
The hypothalamus responds to high salt concentrations in the blood by stimulating the pituitary gland.
The pituitary gland releases antidiuretic hormone (ADH).
ADH
Aldosterone and ADH signal the kidneys to retain sodium and water, respectively, thus increasing blood volume.

Sodium & Chloride

Metabolic function:

The sodium cation is an active participant in the regulation of osmotic and electrolyte balances, whereas the chloride anion is a passive participant in this regulatory system.

Each ion, however, has other functions within the body.

Sodium & Chloride

Metabolic function

Sodium is involved in nerve conduction, active cellular transport and the formation of mineral apatite of bone. Central to its role in water balance, nerve conduction, and active transport is the plasma membrane enzyme sodium–potassium-ATPase (Na+/K+- ATPase).

Apatite: A common complex mineral consisting of calcium fluoride phosphate or calcium chloride

Sodium & Chloride

The Na+/K+-ATPase pump

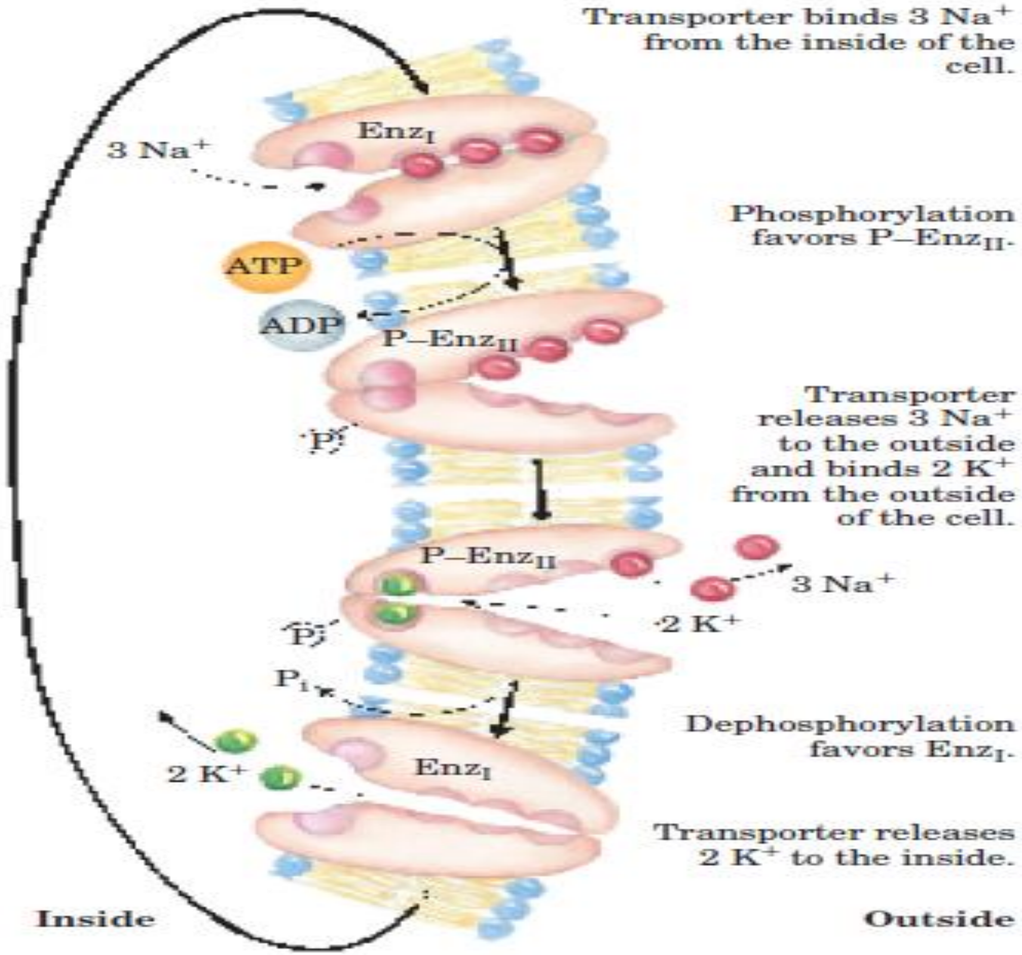
This the plasma membrane enzyme sodium–potassium-ATPase (Na+/K+-ATPase) pumps sodium out of the cell and at the same time returns potassium to the intracellular environment while ATP is hydrolyzed.

Sodium & Chloride

The Na+/K+-ATPase pump

Signal transmission along nerve cells, active transport of nutrients into the enterocyte and muscle contraction/ relaxation all depend on the Na+/K+-ATPase pump.

Sodium & Chloride



Postulated mechanism of Na^+ and K^+ transport by the Na^+K^+ ATPase.

Sodium & Chloride

Deficiency symptoms

Obligatory losses of sodium are very low, and low plasma sodium or chloride depletion is difficult to induce.

Low plasma sodium or chloride is not diet related but rather caused by a variety of clinical conditions, including major trauma and overuse of diuretics.

Sodium & Chloride

Deficiency symptoms

Loss of sodium can also ensue as a result of excessive water intake, liver disease, congestive heart failure with edema, and severe infection and diarrhea. Acute diarrhea is the most common cause of sodium deficiency.

Vomiting, chronic renal disease, renal failure, and chronic respiratory acidosis can result in chloride depletion.

Sodium & Chloride: Toxicity

Excessive salt intakes are usually excreted efficiently in healthy individuals.

High plasma sodium and chloride are commonly caused by dehydration through either excessive sweating or deficient water intake.

Excessive salt intake may have roles in the degenerative diseases of coronary heart disease, stroke, gastric cancer, osteoporosis, and bronchial hyperactivity.

Sodium & Chloride: Toxicity

There are accumulating data from epidemiological studies and controlled clinical trials to indicate an adverse effect of sodium intake on blood pressure, and that most people are sodium sensitive.

Clinical studies indicate that a high-sodium diet increases calcium excretion and measures of bone resorption, thereby suggesting a possible role for high salt intakes in osteoporosis.

Sodium & Chloride: Toxicity

Cross-cultural epidemiology suggests that high salt intakes are associated with gastric cancer, whereas a low-salt diet is regarded as having a potentially favorable effect in asthma patients.

Sodium & Chloride:
Requirements and dietary sources

Average requirements for sodium and chloride are estimated to be about 500 and 750 mg/day, respectively.

Normal sodium (mostly from salt) intake varies from about 2 g/day to 14 g/day, with chloride (mostly from salt) intakes generally slightly in excess of sodium.

Snack and processed foods have more added salt than unprocessed foods.

Sodium & Chloride:
Micronutrient interactions

The major interactions between sodium (and chloride) and other micronutrients are with respect to potassium and calcium. There is evidence, from clinical studies, to suggest that the sodium to potassium ratio correlates more strongly with blood pressure than does either nutrient alone.

Sodium & Chloride:
Micronutrient interactions

As indicated previously, the metabolism of sodium, chloride, and potassium is closely related, and sodium and calcium ions have a close metabolic relationship within cells.

Potassium

The concentration of potassium in the body is 2 g/*kg.* Potassium is localized mostly within the cells. It regulates the osmotic pressure within the cell, it is involved in cell membrane transport and also in the activation of a number of glycolytic and respiratory enzymes.

Potassium

Potassium, sodium, and chloride make up the principal electrolytes within the body. In contrast to sodium and chloride, nutritional concerns with potassium are mainly concerned with the possibility of underconsumption.

Potassium:

Absorption, transport, and tissue distribution

Potassium is the major intracellular electrolyte and exists as the fully water-soluble cation. More than 90% of dietary potassium is absorbed from the digestive tract. Almost all of the body potassium is exchangeable, intracellular concentration being more than 30 times the concentration of the ECF.

Potassium:

Absorption, transport, and tissue distribution

Potassium is distributed within the body in response to energy dependent sodium redistribution.

Various hormonal and other factors regulate potassium homeostasis, both within cells and with the external environment.

Potassium: Plasma potassium regulation

Hyperkalemia (too much potassium in the ECF) stimulates insulin, aldosterone, and epinephrine (adrenaline) secretions, which promote the uptake of potassium by body cells. The aldosterone hormone also stimulates potassium excretion by the kidney and, at the same time, conserves sodium.

Potassium: Plasma potassium regulation

Hypokalemia has opposite effects, such that more potassium is released from cells. As with sodium, the kidney regulates potassium balance. Urine is the major excretory route in healthy people, with only small amounts lost in the feces and minimal amounts in sweat.

Potassium: Metabolic function

Potassium, sodium, and chloride are the major determinants of osmotic pressure and electrolyte balance.
The concentration difference of potassium and sodium across cell membranes is maintained by the Na+/K+-ATPase pump and is critical for nerve transmission and muscle function.

Potassium: Metabolic function

The physiological importance of potassium in the body covers many systems including cardiovascular, respiratory, digestive, renal, and endocrine.
In addition, potassium is a cofactor for enzymes involved in among other things, energy metabolism, and cellular growth and division.

Potassium: Deficiency symptoms

The low concentration of potassium in plasma is tightly regulated. Low potassium intakes are unlikely to lead to clinical potassium depletion and hypokalemia except during starvation and anorexia nervosa.

Potassium: Deficiency symptoms

Hypokalemia, however, can result from either excessive uptake of potassium by cells or potassium depletion from the body. Diarrhea, vomiting, and laxative abuse can result in hypokalemia.

The activity of nerves and muscles is affected in potassium depletion, and other clinical consequences involve cardiac, renal, and metabolic alterations.

Potassium: Toxicity

Hyperkalemia, as a result of either a shift of potassium from cells to the ECF or excessive potassium retention, can be caused by major trauma and infection, metabolic acidosis, Addison's disease (aldosterone insufficiency) and chronic renal failure.

Potassium: Toxicity

Overuse of potassium supplements can also result in potassium excess. As with potassium depletion, the most important clinical consequence of potassium excess is cardiac arrest.

Potassium: Requirement and dietary sources

Adult requirements for potassium are estimated to be about 2 g/day. Because of potential beneficial antagonistic effects against high salt intakes, higher intakes (around 3.5 g/day) of potassium are considered to be optimal.

Potassium: Requirement and dietary sources

Food processing (through leaching) may decrease potassium content as well as increasing salt content.

Major vegetable sources : potatoes and spinach. Rich sources of potassium :legumes, nuts, dried fruit, and fresh fruit, especially bananas, and avocados.

Other sources: cereal and dairy products

Potassium: Micronutrient interactions

Potassium appears to have positive effects on calcium balance by regulating the acid–base balance and ameliorating any effects of sodium on calcium depletion.

Sodium & Potassium sources

Sodium and potassium content of various foods (mg/100 g edible portion)

Food	Na	K
Legumes		
Red kidney beans	18	1370
Soyabeans	5	1730
Lentils	12	940
Dried fruit		
Raisins	60	1020
Fruit and vegetables		
Banana	1	400
Melon	5–32	100–210
Potato	11	320
Spinach	140	500
Meat and fish		
Beef, veal, lamb	52–110	230–260
Chicken	81	320
Miscellaneous		
Cow's milk	55	140
Chocolate	11	300

Magnesium

Magnesium was first shown to be an essential dietary component for rats in 1932 and later for humans.
This essentiality is a reflection of the role that magnesium plays in the stabilization of ATP and other molecules. Since then, nutritionists have come to realize that magnesium deficiency is rare and that it only occurs in clinical settings as a secondary consequence of another disease.

Magnesium

More recently, moderate or marginal deficiency has been proposed as a risk factor for chronic diseases such as osteoporosis, cardiovascular disease, and diabetes. These associations are controversial.

Magnesium: Tissue distribution

Magnesium is the second most common cation found in the body (about 25 g). It is evenly distributed between the skeleton (50–60% of total) and the soft tissues (40–50% of total). In the skeleton, about one third of the magnesium is on the surface of bone.

Magnesium: Tissue distribution

This magnesium pool is thought to be exchangeable and thus may serve to maintain serum or soft-tissue magnesium concentrations in times of need.

Body magnesium is most closely associated with cells; only 1% of total body magnesium is extracellular. Within the cell, magnesium is found in all of the compartiments.

Magnesium: **Absorption & transport**

Magnesium homeostasis is maintained by controlling the efficiency of intestinal absorption and magnesium losses through the urine.

Magnesium absorption is presumed to occur throughout the **small intestine** of humans. In normal, healthy individuals, magnesium absorption is between 20% and 70% of magnesium in a meal.

Magnesium: Absorption & transport

Magnesium crosses the intestinal epithelium by three different mechanisms: passive diffusion, solvent drag (i.e., following water movement) and active transport. Regulation of intestinal nutrient absorption is generally thought to occur only for the active component of absorption. The mechanisms controlling intestinal magnesium absorption are not yet clear .

Magnesium: homeostasis

The kidney is the principal organ involved in magnesium homeostasis. The renal handling of magnesium in humans is a filtration–reabsorption process. Approximately 70% of serum magnesium is ultrafiltrable, and the normal healthy kidney reabsorbs about 95% of filtered magnesium.

Magnesium: homeostasis

When an individual is fed a low-magnesium diet, renal output of magnesium is reduced. Excessive magnesium loss via urine is a clinical condition contributing to magnesium depletion in patients with renal dysfunction.

Magnesium: Metabolic function

Magnesium is essential for a wide range of fundamental cellular reactions, and is involved in at least 300 enzymic steps in intermediary metabolism.
Magnesium plays an important role in the development and maintenance of bone; about 60% of total body magnesium is present in bone.

Magnesium: food sources

Foods with a high magnesium content : include whole grains, legumes, green leafy vegetables, and tofu.
Foods with an intermediate magnesium content : meat, fruits, and dairy products.

Magnesium: food sources

Although high levels of calcium, phosphate, or fiber may lead to reduced bioavailability of magnesium, differences in bioavailability of magnesium from various food sources does not appear to be a significant barrier to achieving adequate magnesium status.

Magnesium: Micronutrient interactions

As mentioned above, phosphorus as phosphate, may decrease intestinal magnesium absorption. In general, calcium intake in the usual dietary range does not affect magnesium absorption, but calcium intakes in excess of 2.6 g have been reported to reduce magnesium balance. Magnesium intake in the usual dietary range does not appear to alter calcium balance.

Magnesium: Deficiency symptoms

Magnesium homeostasis can be maintained over a wide range of intakes in normal, healthy individuals.
Thus, magnesium deficiency does not appear to be a problem in healthy people.

Magnesium: Deficiency symptoms

Magnesium deficiency is only seen in humans under two conditions: as a secondary complication of a primary disease state (diseases of cardiovascular and neuromuscular function, endocrine disorders, malabsorption syndromes, muscle wasting) and resulting from rare genetic abnormalities of magnesium homeostasis.

Magnesium: Deficiency symptoms

-Symptoms of magnesium deficiency:

● progressive reduction in plasma magnesium (10–30% below controls) and red blood cell magnesium (slower and less extreme than the fall in plasma magnesium)

● hypocalcemia

● hypokalemia resulting from excess potassium excretion

Magnesium: *Toxicity*

Magnesium, when ingested as a naturally occurring substance in foods, has not been demonstrated to exert any adverse effects in people with normal renal function. However, adverse effects of excess magnesium intake (e.g., diarrhea, nausea, abdominal cramping) have been observed with intakes from nonfood sources such as various magnesium salts used for pharmacological purposes.

Magnesium:*Toxicity*

Magnesium, when ingested as a naturally occurring substance in foods, has not been demonstrated to exert any adverse effects in people with normal renal function. However, adverse effects of excess magnesium intake (e.g., diarrhea, nausea, abdominal cramping) have been observed with intakes from nonfood sources such as various magnesium salts used for pharmacological purposes.

Calcium

Calcium was among the first materials known to be essential in the diet. All foods of vegetable origin contain small but useful amounts of calcium.

The total amount of calcium in the body is about 1500 g. Because of the large amounts of calcium all over the body, it is one of the most important minerals. It is abundant in the skeleton and in some body tissues.

Calcium

Calcium is an essential nutrient because it is involved in the structure of the muscular system and controls essential processes like muscle contraction (locomotor system, heartbeat) and blood clotting.

Calcium: tissue distribution

The adult human body contains about 1200 g of calcium, which amounts to about 1–2% of body weight. Of this, 99% is found in mineralized tissues, such as bones and teeth, where it is present as calcium phosphate (together with a small component of calcium carbonate), providing rigidity and structure.

Calcium: tissue distribution

The remaining 1% is found in blood, extracellular fluid (ECF), muscle, and other tissues. Calcium is under close homeostatic control, with processes such as absorption, excretion and secretion, and storage in bone being involved in maintaining the concentration of ionized calcium in the plasma within a tightly regulated range.

Calcium: *Homeostatic control*

The tight regulation of plasma calcium concentration is achieved through a complex physiological system comprising the interaction of the parathyroid hormone (PTH), 1,25-dihydroxycholecalciferol [1,25(OH)2D3] and calcitonin, that serve to increase or to decrease the entry of calcium into the extracellular space (plasma).

Calcium: *Homeostatic control*

When the circulating ionized calcium concentration declines acutely, PTH synthesis and release increases. PTH acts on three target organs. At the kidney, PTH promotes the reabsorption of calcium in the distal tubule. PTH affects the intestine indirectly by stimulating the production of 1,25(OH)2D3 (in the kidney), which, in turn, leads to increased calcium absorption. PTH also induces bone resorption, thereby releasing calcium into blood.

Calcium: *Homeostatic control*

Owing to the action of PTH and 1,25(OH)2D3 on the target tissues, plasma calcium concentrations are restored within minutes to hours. Only in extreme circumstances, such as severe malnutrition or yperparathyroidism, is the serum ionized calcium concentration below or above the normal range.

Calcium: *Homeostatic control*

The secretion of these hormones is governed wholly, or in part, by the plasma concentration of ionized calcium.

PTH and 1,25(OH)2D3 are secreted when plasma calcium is low, whereas calcitonin is secreted when plasma calcium is high.

Calcium: absorption

Calcium must be released in a soluble, and probably ionized, form before it can be absorbed. Calcium is absorbed in the intestine by two routes, transcellular and paracellular.The transcellular route involves active transport of calcium by the mucosal calcium transport protein, calbindin, and is saturable and subject to physiological and nutritional regulation via vitamin D.

Calcium: absorption

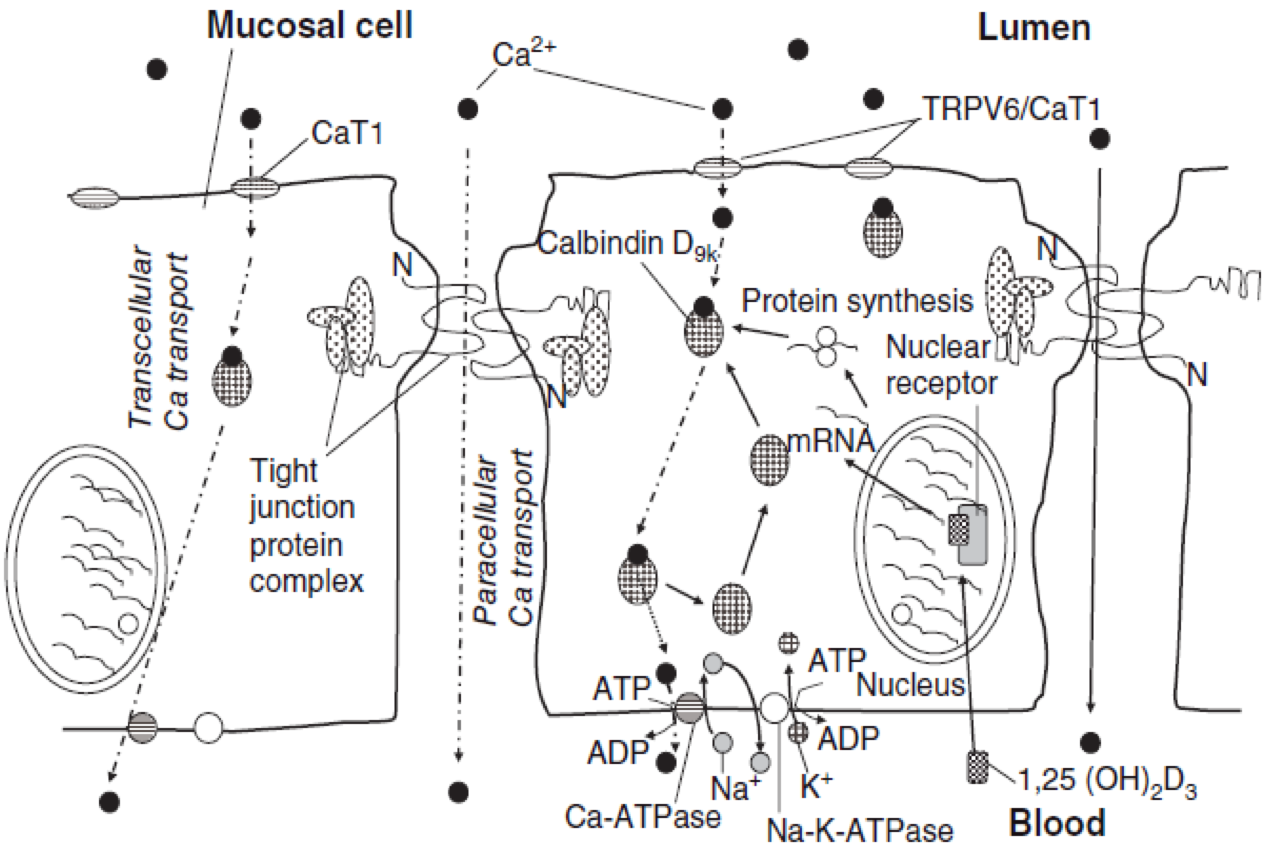
The paracellular route involves passive calcium transport through the tight junctions between mucosal cells; it is nonsaturable, essentially independent of nutritional and physiological regulation, and concentration dependent.

Most calcium absorption in humans occurs in the small intestine, but there is some evidence for a small colonic component.

Calcium: regulation of intestinal absorption

Transcellular calcium absorption responds to calcium needs, as reflected by changes in plasma calcium concentration, by hormone mediated up- or down-regulation of calbindin in
mucosal cells. for example, reduced plasma calcium evokes a PTH-mediated increase in plasma 1,25(OH)2D3, which stimulates increased calbindin synthesis in intestinal mucosal cells.

Calcium



Calcium transport across the intestinal mucosal lining: paracellular calcium transport (between mucosal cells) and transcellular calcium transport (across the mucosal cell).

Calcium: Metabolic function

Calcium is required for normal growth and development of the skeleton. During skeletal growth and maturation, i.e., until the early twenties in humans, calcium accumulates in the skeleton at an average rate of 150 mg/day. Extraskeletal calcium (representing around 1% of total body calcium) plays a role in mediating vascular contraction and vasodilatation, muscle contraction, nerve transmission, glandular secretion, and as an important second messenger molecule.

Calcium: Deficiency symptoms

Because of the small metabolic pool of calcium (less than 0.1% in the ECF compartment) relative to the large skeletal reserve, for all practical purposes metabolic calcium deficiency probably never exists, at least not as a nutritional disorder.

Calcium: consequence of a continual inadequate intake

If there is a continual inadequate intake or poor intestinal absorption of calcium (e.g., because of vitamin D deficiency), circulating calcium concentration is maintained largely at the expense of skeletal mass, that is, from an increased rate of bone resorption.

Calcium: consequence of a continual inadequate intake

This PTH-mediated increase in bone resorption is one of several important causes of reduced bone mass and osteoporosis. Prolonged inadequate calcium intake in younger people reduces the rate of accretion of the skeleton. This may increase the risk of osteoporosis in later life.

Calcium: Toxicity

The available data on the adverse effects of high calcium intakes in humans are primarily from the intake of calcium from nutrient supplements.

The three most widely studied and biologically important are:

- kidney stone formation (nephrolithiasis)
- the syndrome of hypercalcemia and renal insufficiency

Calcium: Dietary sources

The most important dietary sources : milk and milk products
Other sources : cereal products, fruits and vegetables (significant contribution due to high level of consumption)
Development and maintenance of bone is the major determinant of calcium needs.

Calcium: Dietary sources

Thus, unlike other nutrients, the requirement for calcium is considered to relate not to the maintenance of the metabolic function of the nutrient but to the maintenance of an optimal reserve and the support of the reserve's function (i.e., bone integrity).

Calcium: requirements

Throughout an individual's life, Calcium requirements vary, birth to 6 months (0*.4), 6 to 12 months* (0*.6), 1 to 5 years (0.8), 6 to 10 years (0.8–1.2),* 11 to 24 years and pregnant women (1*.2 to 1.5*)*,* 25 to 65 years (1*.0) and above 65 years (1.5).*

Calcium: requirements

Because of their effects on urinary calcium losses, high intakes of both sodium and protein increase dietary calcium requirements.

There is considerable disagreement over human calcium requirements, and this is reflected in the wide variation in estimates of daily calcium requirements made by different expert authorities.

Phosphorus

Phosphorus is most commonly found in nature form in combination with oxygen as phosphate (PO_4^{3-}).
Phosphorus, plays an important role in metabolism and, as such, is an essential nutrient. The organic forms of phosphorus in food are cleaved by intestinal phosphatases and, thereby, absorption occurs mostly in the form of inorganic phosphate.

Phosphorus: Absorption, transport, and tissue distribution

Phosphorus makes up about 0.65–1.1% of the adult body (~600 g). In the adult body 85% of phosphorus is in bone and the remaining 15% is distributed in soft tissues. Phosphorus in blood is in the phospholipids of erythrocytes and plasma lipoproteins, with a small part present as inorganic phosphate.

Phosphorus: Absorption, transport, and tissue distribution

This inorganic phosphate is located mainly in the blood and ECF.
It is into the inorganic compartment that phosphate is inserted on absorption from the diet and resorption from bone, and from this compartment that most urinary phosphorus and hydroxy apatite mineral phosphorus are derived.

Phosphorus

This compartment is also the primary source from which the cells of all tissues derive both structural and high-energy phosphate. Food phosphorus is a mixture of inorganic and organic forms.

On a mixed diet, absorption of total phosphorus ranges from 55% to 70% in adults. There is no evidence that this absorption varies with dietary intake.

Phosphorus: Metabolic function

Structurally, phosphorus occurs in calcified tissues and as phospholipids, which are a major component of most biological membranes, and as nucleotides and nucleic acid. Other functional roles of phosphorus include:

- the temporary storage and transfer of the energy derived from metabolic fuels
- phosphorylation, and hence activation of many catalytic proteins.

Phosphorus: Metabolic function

As phosphorus is not irreversibly consumed in these processes and can be recycled indefinitely, the actual functions of dietary phosphorus are first to support tissue growth (either during individual development or through pregnancy and lactation), and second to replace excretory and dermal levels.

Phosphorus: Deficiency symptoms

Phosphorus is so ubiquitous in various foods that near total starvation is required to produce dietary phosphorus deficiency. Inadequate phosphorus intake is expressed as hypophosphatemia.
Only limited quantities of phosphate are stored within cells, and most tissues depend on ECF inorganic phosphate for their metabolic phosphate.

Phosphorus: Deficiency symptoms

When ECF inorganic phosphate levels are low (below 0.3 mmol/l.) , cellular dysfunction follows. At a whole organism level, the effects of hypophosphatemia include muscle weakness, bone pain, rickets and osteomalacia, increased susceptibility to infection, confusion, and even death.

Phosphorus: *Toxicity*

Serum inorganic phosphate rises as total phosphorus intake increases. Excess phosphorus intake from any source is expressed as hyperphosphatemia .

The 3 principal effects that have been attributed to hyperphosphatemia are:

1.Calcification of nonskeletal tissues, particularly the kidneys

2. in some animal models, increased porosity of the skeleton

Phosphorus: *Toxicity*

3. a suggestion that high phosphorus intakes could decrease calcium absorption by complexing calcium in the chyme. Concern about high phosphorus intake has been raised in recent years because of a probable population level increase in phosphorus intake through such sources as cola beverages and food phosphate additives.

Phosphorus: Dietary sources

Phosphates are found in foods as naturally occurring components of biological molecules and as food additives in the form of various phosphate salts. The phosphorus density of cow’s milk and other dairy products is higher than that of most other foods in a typical diet.

Phosphorus: ***Micronutrient interactions***

It has been reported that intakes of polyphosphates, such as are found in food additives, can interfere with the absorption of iron, copper, and zinc.

Trace minerals

The main trace minerals are: Iron, Copper, Zinc, Manganese, Cobalt, Chromium, Iodine, Selenium, Molybdenum, Nickel, Fluorine.

The above trace minerals are essential in concentrations of **<50 mg/day**; their biochemical actions have been elucidated.

Iron

Iron deficiency is probably the most frequent deficiency disorder in the world. In biological systems, Iron occurs primarily as the ferrous (Fe^{2+}) and ferric (Fe^{3+}) forms.

Iron: *Absorption & tissue distribution*

Special proteins help the body absorb and transport iron :

- Mucosal ferritin, receives iron from food and stores it in
the mucosal cells of the small intestine.
When the body needs iron, mucosal ferritin releases some iron to another protein, called mucosal transferrin.
-

Iron: ***Absorption & tissue distribution***

Mucosal transferrin transfers the iron to another protein, blood transferrin, which transports the iron to the rest of the body. If the body does not need iron, it is carried out when the intestinal cells are shed and excreted in the feces. By holding iron temporarily, these cells control iron absorption by either delivering iron when the day's intake falls short or disposing of it when intakes exceed needs.

Iron: Absorption, transport & tissue distribution

The body has three unique mechanisms for maintaining iron balance and preventing iron deficiency and iron overload:

(1) storage of iron (with ferritin being an important reversible storage protein for iron),

(2) reutilization of iron (especially of iron in erythrocytes)

Iron: Absorption, transport & tissue distribution

(3) regulation of iron absorption.

In theory, therefore, when the body needs more iron, absorption is increased, and when the body is iron sufficient, absorption is restricted.

Iron: Metabolic function & essentiality

- In hemoglobin, iron is required for the transport of oxygen, critical for cell respiration.
- In myoglobin, iron is required for oxygen storage in muscle.
- Iron is also a component of various tissue enzymes, that are critical for energy production, and enzymes necessary for immune system functioning.

Iron: Deficiency anemia

The functional effects of iron deficiency anemia result from both a reduction in circulating hemoglobin and a reduction in iron-containing enzymes and myoglobin. Both factors presumably play a role in the fatigue, restlessness, and impaired work performance associated with iron deficiency anemia. Other functional defects include disturbances in normal thermoregulation and impairment of certain key steps in the immune response.

Iron: *Toxicity*

The very effective regulation of iron absorption prevents overload of the tissues by iron from a normal diet, except in individuals with genetic defects.

Excess iron via overuse of iron supplements could pose a possible health risk.

Iron: *Toxicity*

The mechanism of cellular and tissue injury resulting from excess iron is not fully understood.

Individuals taking iron at high levels (>45 mg/day) may encounter gastrointestinal side-effects (constipation, nausea, vomiting, and diarrhea).

Iron: requirements

An average adult man needs to absorb only 1 mg of iron from the diet on a daily basis.
Adult women need 1.4 mg (90%) to 2.4 mg (10%) to compensate for their menstrual losses. Pregnant women (especially during the second and third trimesters) need a daily requirements of 4–6 mg.
Growing children and adolescents require 0.5 mg iron/day in excess of body losses to support growth.

Iron: Dietary sources

Iron is widely distributed in meat, eggs, vegetables, and cereals, but the concentrations in milk, fruit, and vegetables are low.

Iron

Factors affecting (a) heme and (b) nonheme iron absorption

Increased absorption	Decreased absorption
(a) Heme	
Physiological factors	
Low iron status	High iron status
Dietary factors	
Low heme iron intake	High heme iron intake
Meat	Calcium
(b) Nonheme	
Physiological factors	
Depleted iron status	Replete iron status
Pregnancy	Achlorhydria (low gastric acid)
Disease states (aplastic anemia, hemolytic anemia, hemochromatosis)	
Dietary factors	
Ascorbic acid	Phytate
Meat, fish, seafood	Iron-binding phenolic compounds
Certain organic acids	Calcium

Iron: *Micronutrient interactions*

The fact that serum copper has been found to be low in some cases of iron deficiency anemia suggests that iron status has an effect on copper metabolism. Interactions between iron and copper seem to be owing to impaired utilization of one in the absence of the other. Calcium can inhibit iron absorption under certain circumstances.

Copper

The amount of copper in the body is 80–100 mg. Copper is a component of a number of oxidoreductase enzymes.

In blood plasma, it is bound to ceruloplasmin, which catalyzes the oxidation of Fe^{2+} to Fe^{3+} . This reaction is of great significance since it is only the Fe^{3+} form in blood which is transported by the transferrin protein to the
iron pool in the liver.

The daily copper requirement is 1–1*.5 mg and it is supplied in a normal* diet.

Copper

Absorption, transport & tissue distribution

About 50–75% of dietary copper is absorbed, mostly via the intestinal mucosa, from a typical diet.

The amount of dietary copper appears to be the primary factor influencing absorption, with decreases in the percentage absorption as the amount of copper ingested increases.

Copper

Absorption, transport & tissue distribution

High intakes of several nutrients can also influence copper bioavailability. These include antagonistic effects of zinc, iron, molybdenum, ascorbic acid, sucrose, and fructose, although evidence for some of these is mainly from animal studies.

Although high intakes of sulfur amino acids can limit copper absorption, absorption of copper is promoted from high-protein diets.

Copper: Metabolic functions and essentiality

Copper is a component of several enzymes, cofactors, and proteins in the body. These include a requirement for copper in the proper functioning of the immune, nervous and cardiovascular systems, for bone health, for iron metabolism and formation of red blood cells, and in the regulation of mitochondrial and other gene expression.

Copper: absorption regulation

Regulation of absorption at low levels of copper intake is probably by a saturable active transport mechanism, while passive diffusion plays a role at high levels of copper intake. The major regulator of copper elimination from the body, is biliary excretion. Most biliary copper is not reabsorbed and is eliminated in the feces. Little copper is lost from the urine, skin, nails, and hair.

Copper: *Deficiency symptoms*

Owing to remarkable homeostatic mechanisms, clinical symptoms of copper deficiency occur in humans only under exceptional circumstances.

Among the predisposing factors of copper deficiency are prematurity, low birth weight, and malnutrition, especially when combined with feeding practices such as cow’s milk or total parenteral nutrition.

Copper: *Deficiency symptoms*

The most frequent symptoms of copper deficiency are anemia, neutropenia, and bone fractures, while less frequent symptoms are impaired growth, increased incidence of infections, and abnormalities of glucose and cholesterol metabolism.

Copper: Toxicity

Acute copper toxicity in humans is rare and usually occurs from contamination of drinking water, beverages, and foodstuffs from copper pipes or containers. Symptoms include vomiting, diarrhea, hemolytic anemia, renal and liver damage, sometimes (at about 100 g or more) followed by coma and death.

Copper: Toxicity

Clinical symptoms of chronic copper toxicity appear when the capacity for protective copper binding in the liver is exceeded. These symptoms include hepatitis, liver cirrhosis, and jaundice.

Copper: Requirements & dietary sources

Current estimates suggest that the requirements for copper for the great majority of adults are below about 1.5 mg copper/day. Particularly rich food sources of copper include offal (brain, liver,…), nuts, seeds, legumes, wholegrain cereals, and chocolate. Milk and dairy products are very low in copper and infants are at risk of copper deficiency if they are fed exclusively on cow’s milk.

Copper: Micronutrient interactions

High intakes of zinc and iron can restrict copper utilization in infants and adults.

Zinc

The total zinc content in adult human tissue is 2–4 g.
Zinc is a versatile trace element required as a cofactor by more than 100 enzymes.
Virtually all cells contain zinc, but the highest concentrations are found in muscle and bone.

Zinc: roles in the body

- Regulation of gene expression
- Assists in immune function
- Participates in the synthesis, storage, and release of the hormone insulin in the pancreas.
- Interacts with platelets in blood clotting, affects thyroid hormone function
- Influences behavior and learning performance.
- Is needed to produce the active form of vitamin A (retinal) in visual pigments.

Manganese

The body contains a total of 10–40 mg of manganese.

The daily requirement, 2–5 mg, is met by the normal daily food intake (2–48 mg manganese/*day).* Relatively high concentrations of manganese have been reported in cereals (, brown bread, nuts, ginger, and tea.

Manganese

Manganese is the metal activator for pyruvate carboxylase and, like some other divalent metal ions, it activates various enzymes, such as amino peptidase and lecithinase.

Manganese, even in higher amounts, is relatively nontoxic.

Cobalt

The total cobalt content of the body is 1–2 mg. Since it was discovered that vitamin B12 contains cobalt as its central atom, the nutritional importance of cobalt has been emphasized and it has been assigned the status of an essential element.

in higher amounts, is relatively nontoxic.

Chromium

The chromium content of the body varies considerably depending on the region; the range is 6– 12 mg.

The daily intake also varies greatly from 5 to 200 µg. Significant Sources are meats (especially liver) and whole grains.

Chromium helps maintain glucose homeostasis by enhancing the activity of the hormone insulin.

Chromium

When chromium is lacking, a diabetes-like condition may develop with elevated blood glucose and impaired glucose tolerance, insulin response, and glucagon response. In spite of these relationships, research findings suggest that chromium supplements do not effectively improve glucose or insulin responses in diabetes.

Selenium

The selenium content in humans is 10–15 mg, while the daily intake is 0*.05–0.1 mg. Depending* on the region, it can vary greatly because of the varying content of selenium in the soil.

Selenium is one of the body’s antioxidant nutrients, working primarily as a part of proteins—most notably, the enzyme glutathione peroxidase.

Selenium

Another enzyme that converts the thyroid hormone to its active form also contains selenium.

For adults, an adequate intake is estimated at 30– 70 µg Se/*day.*

Significant Sources are Seafood, meat, whole grains, fruits, and vegetables (depending on soil content)

Molybdenum

Molybdenum acts as a working part of several metalloenzymes.
Dietary deficiencies of molybdenum are unknown because the amounts needed are minuscule—as little as 0.1 part per million parts of body tissue.
Legumes, breads and other grain products, leafy green vegetables, milk, and liver are molybdenum-rich foods.

Fluoride

Fluoride is present in small but widely varying concentrations in practically all soils, water supplies, plants and animals, and is a constituent of all diets.

During the mineralization of bones and teeth, calcium and phosphorus form crystals called hydroxyapatite.

Fluoride

Then fluoride replaces the hydroxyl (OH) portions of the hydroxyapatite crystal, forming fluorapatite, which makes the bones stronger and the teeth more resistant to decay.

About 99% of the body's fluoride is found in calcified tissues (bone and teeth), to which it is strongly but not irreversibly bound ilk, and liver are molybdenum-rich foods.

Fluoride: Toxicity

The primary adverse effects associated with chronic, excessive fluoride intake are enamel and skeletal fluorosis.

Enamel fluorosis is a dose-related effect caused by fluoride ingestion during tooth development and cannot be reversed. Moderate and severe forms of enamel fluorosis are generally characterized by esthetically objectionable changes in tooth color and surface irregularities.

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Iodine

There is little iodine in most food. Good sources are milk, eggs and, above all, seafood.
The thyroid gland actively accumulates and traps iodine from the bloodstream to support thyroid hormone synthesis.
Thyroid hormones are synthesized using iodide and the amino acid, tyrosine.
These hormones help regulate metabolic rate and promote growth and development throughout the body, including the brain.

Iodine

If a person's iodide intake is insufficient, the thyroid gland enlarges as it attempts to take up more iodide from the bloodstream. This eventually leads to goiter. Regular consumption of excessive amounts of foods that contain an antithyroid substance (goitrogen) may lead to goiter.

Iodine

Examples of goitrogen-containing foods:

- Cabbage, spinach, radishes, rutabagas
- Soybeans, peanuts
- Peaches, strawberries

To avoid diseases caused by low iodine supply, some countries with iodine-deficient districts employ prophylactic measures to combat the deficiency symptoms.

Iodine: Deficiency symptoms

A deficiency of iodine causes a wide spectrum of disorders from mild goiter (a larger thyroid gland than normal) to the most severe forms of endemic congenital hypothyroidism (cretinism: severe, irreversible mental, and growth retardation). Collectively, these manifestations of iodine deficiency are termed
iodine deficiency disorders (IDDs) and symptoms differ depending on the life stage at which iodine deficiency occurs.

Ultra-trace minerals

The ultra-trace minerals are: *Tin, Aluminum, Boron, Silicon & Arsenic.*

In addition to the essential elements discussed above, other elements in the periodic table may emerge as being essential for human nutrition.

Their suspected essentiality is based on :

- evidence from data emanating from animal models
- essential functions in lower forms of life
- biochemical actions consistent with a biological role or beneficial action in humans.