

Water and the Major Minerals: Fluids and Electrolytes Balance, Minerals and Trace Minerals In Diets

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WATER

FLUIDS AND ELECTROLYTES IN THE BODY

- A **body fluid** is a substance, usually a liquid, that is produced by the body and consists of water and dissolved solutes. In lean adults, body fluids constitute between 55% and 60% of total body mass in females and males, respectively.
- **Electrolytes** are the positive and negative ions present in body fluids.
 - ✓ **Electrolytes** are chemicals that dissolve in water and dissociate into ions; most are **inorganic**.
 - ✓ Electrolytes some of them are involved in maintenance of normal pH in body fluids.
 - ✓ These ions have specific functions and a range of the amount in each fluid needed for homeostasis.

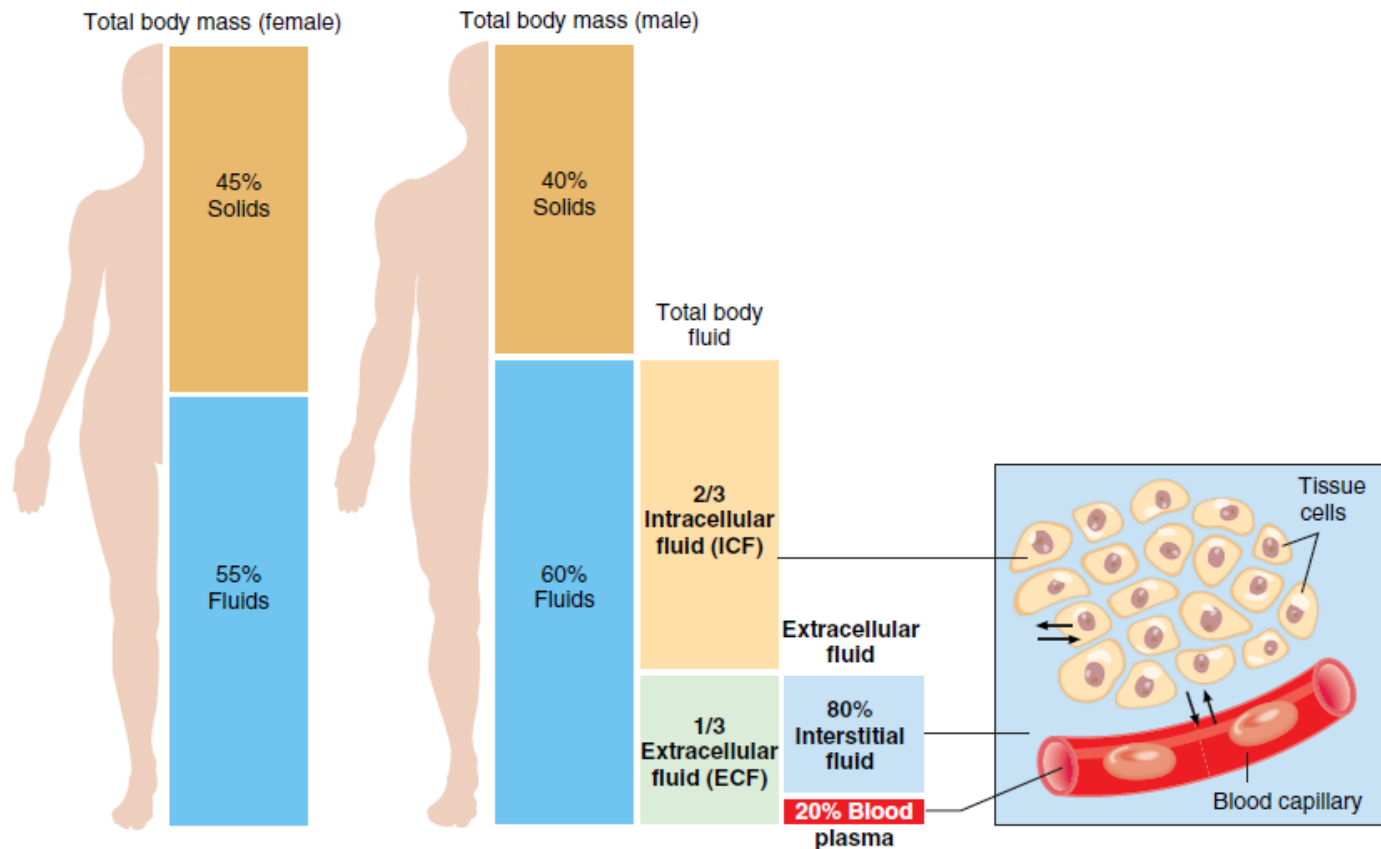
Question: What other names are appropriate for most electrolytes?

Answer:

Most electrolytes are minerals, or salts, and many may also be called trace elements.

Body fluid compartments.

The term body fluid refers to body water and its dissolved substances.



(a) Distribution of body solids and fluids in average lean adult female and male

(b) Exchange of water among body fluid compartments

Water compartments

- The fluid sites in the body are called [Water compartments](#).
- Intracellular fluid (ICF) – water within cells; about two-thirds of total body water.
- Extracellular fluid (ECF) – water outside cells. This includes:
 1. Tissue fluid
 2. Plasma
 3. Lymph
 4. Specialized fluids → include cerebrospinal fluid, aqueous humor, synovial fluid, urine, and digestive fluids such as bile.



Water compartments (continued)

Water is always moving from one compartment to another by processes of filtration and osmosis

- ✓ **Osmosis** is regulated by the concentration of electrolytes in body fluids (osmolarity).
- ✓ In osmosis water will **diffuse** through membranes to an area of greater electrolyte concentration.
- ✓ Water and electrolytes are constantly moving between compartments, their concentrations remain constant.
- ✓ Maintaining their homeostasis is essential for life
- ✓ **Edema= imbalance**

Water Balance and Recommended Intakes

Water intake/ input

1. Liquids – 1600 mL (average per 24 hours).
 2. Foods – 700 mL.
 3. Metabolic water – 200 mL → comes from cell respiration, specifically the cytochrome (electron) transport system (the third stage).
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Water output

1. Urine – 1500 mL (average per 24 hours).
 2. Sweat – 500 mL.
 3. Exhaled water vapor – 300 mL.
 4. Feces – 200 mL.
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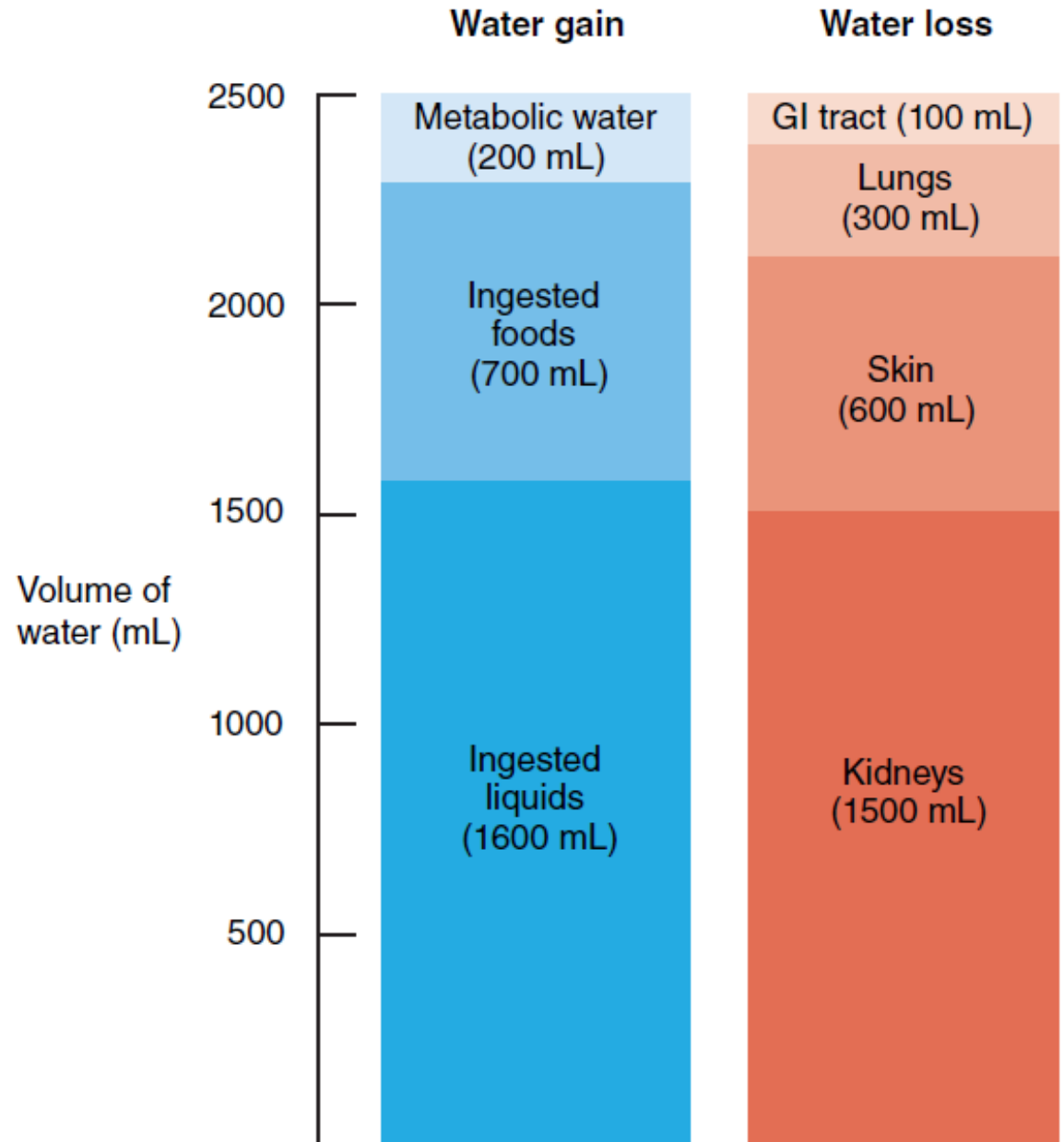
✓ Total water input/output per 24 hours is about 2.5 liters.

✓ Variations are possible.

Sources of daily water gain and loss under normal conditions.

→ Numbers are average volumes for adults.

→ Normally, daily water loss equals daily water gain.



Water Balance and Recommended Intakes

Water Intake:

- **Thirst and satiety influence water intake, apparently in response** to changes sensed by the mouth.
- The **hypothalamus is a brain center that controls** activities such as maintenance of water balance, regulation of body temperature, and control of appetite.
- **Dehydration develops** When too much water is lost from the body and not replaced.
- **The symptoms of dehydration** may progress rapidly from thirst to weakness, exhaustion, and delirium—and end in death if not corrected . Dehydration may easily develop with either water deprivation or excessive water losses.

→ **Several other factors cause water loss**

- ✓ Examples: Excessive sweating, Hemorrhage, Diarrhea, Vomiting, Severe burns, Fever

TABLE 12-1 Signs of Dehydration

Body Weight
Lost (%)

Symptoms

1-2

Thirst, fatigue, weakness, vague discomfort, loss of appetite

3-4

Impaired physical performance, dry mouth, reduction in urine, flushed skin, impatience, apathy

5-6

Difficulty concentrating, headache, irritability, sleepiness, impaired temperature regulation, increased respiratory rate

7-10

Dizziness, spastic muscles, loss of balance, delirium, exhaustion, collapse

NOTE: The onset and severity of symptoms at various percentages of body weight lost depend on the activity, fitness level, degree of acclimation, temperature, and humidity. If not corrected, dehydration can lead to death.

Water Balance and Recommended Intakes (continued-1)

Overhydration/ Water intoxication → too much water.

- The symptoms may include confusion, convulsions, and even death in extreme cases.
- Excessive water ingestion (10 to 20 liters) within a few hours dilutes the sodium concentration of the blood and contributes to a dangerous condition known as **hyponatremia**.
- For this reason, guidelines suggest limiting fluid intake during times of heavy sweating to between 1 and 1.5 liters per hour.

ANP – is a hormone involved in correcting overhydration

Summary of Factors That Maintain Body Water Balance

FACTOR	MECHANISM	EFFECT
Thirst center in hypothalamus	Stimulates desire to drink fluids.	Water gained if thirst is quenched.
Antidiuretic hormone (ADH) , also known as <i>Vasopressin</i>	Promotes insertion of water-channel proteins (aquaporin-2) into apical membranes of principal cells in collecting ducts of kidneys. As a result, water permeability of these cells increases and more water is reabsorbed.	Reduces loss of water in urine.
Aldosterone	By promoting urinary reabsorption of Na ⁺ , increases water reabsorption via osmosis.	Reduces loss of water in urine.
Atrial natriuretic peptide (ANP)	Promotes natriuresis , elevated urinary excretion of Na ⁺ , accompanied by water.	Increases loss of water in urine.

Water Balance and Recommended Intakes (continued-2)

Water Recommendations

- *Water needs vary depending on diet, activity, environmental temperature, and humidity.*
- Recommendations are sometimes expressed in **proportion to the amount of energy expended under average environmental conditions.**
 - The recommended water intake for a person who expends 2000 kcalories a day, for example, is 2 to 3 liters of water (about 8 to 12 cups).
 - Total water includes not only drinking water, but water in other beverages and in foods as well.

Water Balance and Recommended Intakes (continued-3)

Water Recommendations

- 1.0 to 1.5 mL/kcal expended (adults)
- 1.5 mL/kcal expended (infants and athletes)

Conversion factors:

- 125 mL $\approx$ ½ c

Easy estimation: ½ c per 100 kcal expended

Adequate Intake for *total water*:

- ✓ Men: 3.7 L/day
- ✓ Women: 2.7 L/day

Water Balance and Recommended Intakes (continued-4)

Health Effects of Water

- Drinking plenty of water may protect against urinary stones and constipation.
- Even mild dehydration seems to interfere with daily tasks involving concentration, alertness, and short-term memory.

Water Balance and Recommended Intakes (continued-5)

Soft water

- ✓ Water that is free from dissolved salts of such metals as calcium, iron, or magnesium, which form insoluble deposits such as appear as scale in boilers or soap curds in bathtubs and laundry equipment
- ✓ More easily dissolves certain contaminant minerals, such as cadmium and lead, from old plumbing pipes.
- ✓ These contaminant minerals harm the body by displacing the nutrient minerals from their normal sites of action.
- ✓ People who live in buildings with old plumbing should run the cold water tap a minute or two to flush out harmful minerals whenever the water faucet has been off for more than six hours.

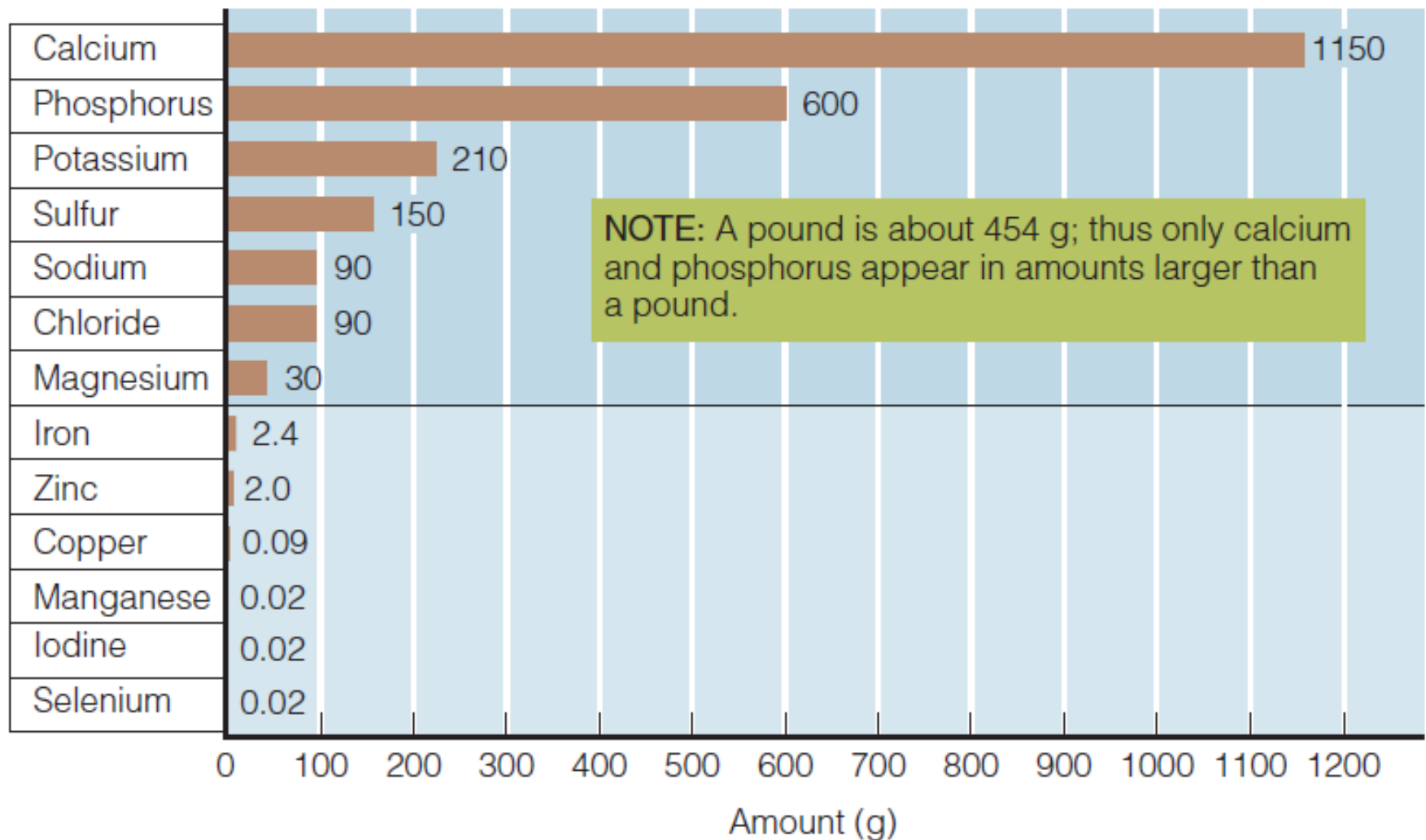
THE MAJOR MINERALS

THE MINERALS—AN OVERVIEW

- The distinction between the major and **trace/minor** minerals does not mean that one group is more important than the other—all minerals are vital.
- The major minerals are so named because they are present, and needed, in larger amounts in the body, whereas the trace minerals occur in smaller amounts.
- Although, minerals are inorganic elements that retain their chemical identities, they usually receive **special handling** and regulation in the body:
 - They may bind with other substances
 - They may interact with other minerals, thus limiting their absorption.

FIGURE 12-9 Minerals in a 60-kilogram (132-pound) Human Body

Not only are the major minerals needed by the body in larger amounts, but they are also present in the body in larger amounts than the trace minerals.



Variable Bioavailability and Interactions

- Some foods contain **binders that combine chemically with minerals**, preventing their absorption and carrying them out of the body with other wastes.
- Examples of **binders** include phytates, which are found primarily in legumes and grains, and oxalates, which are present in rhubarb and spinach, among other foods.
 - These foods contain more minerals than the body actually receives for use.
- Presence or absence of one mineral can affect another's absorption, metabolism, and excretion.

EXAMPLES

- The interactions between **sodium and calcium**, cause both to be excreted when sodium intakes are high.
- **Phosphorus** binds with **magnesium** in the GI tract, so magnesium absorption is limited when phosphorus intakes are high.

The Major Minerals

Mineral and Chief Functions

Deficiency Symptoms

Toxicity Symptoms

Significant Sources

Sodium

Maintains normal fluid and electrolyte balance; assists in nerve impulse transmission and muscle contraction

Muscle cramps, mental apathy, loss of appetite

Edema, acute hypertension

Table salt, soy sauce; moderate amounts in meats, milks, breads, and vegetables; large amounts in processed foods

Chloride

Maintains normal fluid and electrolyte balance; part of hydrochloric acid found in the stomach, necessary for proper digestion

Do not occur under normal circumstances

Vomiting

Table salt, soy sauce; moderate amounts in meats, milks, eggs; large amounts in processed foods

Potassium

Maintains normal fluid and electrolyte balance; facilitates many reactions; supports cell integrity; assists in nerve impulse transmission and muscle contractions

Irregular heartbeat, muscular weakness, glucose intolerance

Muscular weakness; vomiting; if given into a vein, can stop the heart

All whole foods; meats, milks, fruits, vegetables, grains, legumes

Calcium Mineralization of bones and teeth; also involved in muscle contraction and relaxation, nerve functioning, blood clotting, and blood pressure	Stunted growth in children; bone loss (osteoporosis) in adults	Constipation; increased risk of urinary stone formation and kidney dysfunction; interference with absorption of other minerals	Milk and milk products, small fish (with bones), tofu, greens (bok choy, broccoli, chard), legumes
Phosphorus Mineralization of bones and teeth; part of every cell; important in genetic material, part of phospholipids, used in energy transfer and in buffer systems that maintain acid-base balance	Muscular weakness, bone pain ^a	Calcification of nonskeletal tissues, particularly the kidneys	All animal tissues (meat, fish, poultry, eggs, milk)
Magnesium Bone mineralization, building of protein, enzyme action, normal muscle contraction, nerve impulse transmission, maintenance of teeth, and functioning of immune system	Weakness; confusion; if extreme, convulsions, bizarre muscle movements (especially of eye and face muscles), hallucinations, and difficulty in swallowing; in children, growth failure ^b	From nonfood sources only; diarrhea, alkalosis, dehydration	Nuts, legumes, whole grains, dark green vegetables, seafood, chocolate, cocoa
Sulfate As part of proteins, stabilizes their shape by forming disulfide bridges; part of the vitamins biotin and thiamin and the hormone insulin	None known; protein deficiency would occur first	Toxicity would occur only if sulfur-containing amino acids were eaten in excess; this (in animals) suppresses growth	All protein-containing foods (meats, fish, poultry, eggs, milk, legumes, nuts)

^aDietary deficiency rarely occurs, but some drugs can bind with phosphorus making it unavailable and resulting in bone loss that is characterized by weakness and pain.

^bA still more severe deficiency causes tetany, an extreme, prolonged contraction of the muscles similar to that caused by low blood calcium.

Special notes on **CALCIUM**

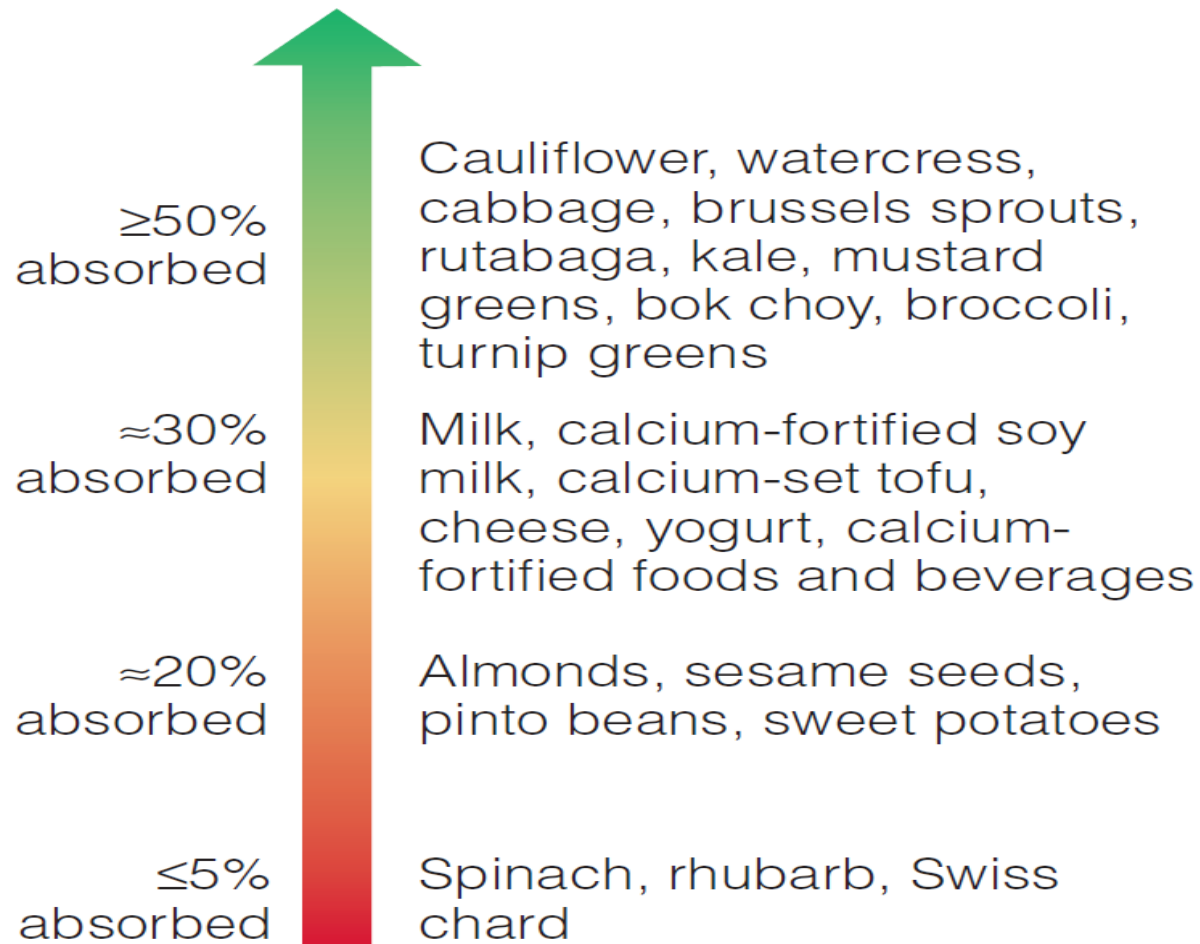
Factors that *enhance calcium absorption*:

- Stomach acid
- Vitamin D
- Lactose (in infants only)

Factors that *inhibit calcium absorption*:

- Lack of stomach acid
- Vitamin D deficiency
- High phosphorus intake
- Phytates (in seeds, nuts, grains)
- Oxalates (in beet greens, rhubarb, spinach, sweet potatoes)

FIGURE 12-15 Bioavailability of Calcium from Selected Foods



THE TRACE MINERALS

The Trace Minerals—An Overview

- Essential mineral nutrients the human body requires in relatively small amounts (less than 100 milligrams per day); sometimes called ***microminerals***.
- They are no less important than the major minerals or any of the other nutrients.
- Each of the trace minerals performs a vital role.
- A deficiency of any of them may be fatal, and an excess of many is equally deadly.
- Remarkably, people's diets normally supply just enough of these minerals to maintain health.
 - The trace mineral contents of foods depend on soil and water composition and on how foods are processed.
 - Many factors in the diet and within the body affect the minerals' bioavailability.
 - A wide variety of foods sources for each of the trace minerals

The Trace Minerals—An Overview

(DEFICIENCIES)

Severe deficiencies → *Better-known* minerals are easy to recognize.

→ Deficiencies of the *others* may be harder to diagnose, and for all minerals.

Mild deficiencies are easy to **overlook**.

- Because the minerals are active in many body systems—digestive, cardiovascular, circulatory, muscular, skeletal, and nervous—*deficiencies can have wide-reaching effects and can affect people of all ages.*
- The most common result of a deficiency in children is failure to grow and thrive.

The Trace Minerals—An Overview

(TOXICITIES)

- Most of the trace minerals are toxic at intakes only two and a half to seven times above the estimated requirements.
- It is important not to habitually exceed the Upper Level (UL) of recommended intakes.
- By law, the Food and Drug Administration (FDA) has **no authority to limit the amounts** of trace minerals in supplements.
- It would be easier and safer to meet nutrient needs by selecting a variety of foods than by combining an assortment of supplements.

The Trace Minerals—An Overview

(INTERACTIONS)

Interactions among the trace minerals are **common** and often well coordinated to meet the body's needs.

→ For example, several of the trace minerals support insulin's work (magnesium, zinc, and chromium), influencing its synthesis, storage, release, and action. At other times, interactions lead to nutrient imbalances.

An excess of one may **cause a deficiency of another.**

→ (A slight manganese overload, for example, may aggravate an iron deficiency.)

A deficiency of one may **interfere with the work of another.**

→ (A selenium deficiency halts the activation of the iodine-containing thyroid hormones.)

The Trace Minerals—An Overview

(INTERACTIONS - continued)

A deficiency of a trace mineral may even open the way for a contaminant mineral to **cause a toxic reaction.**

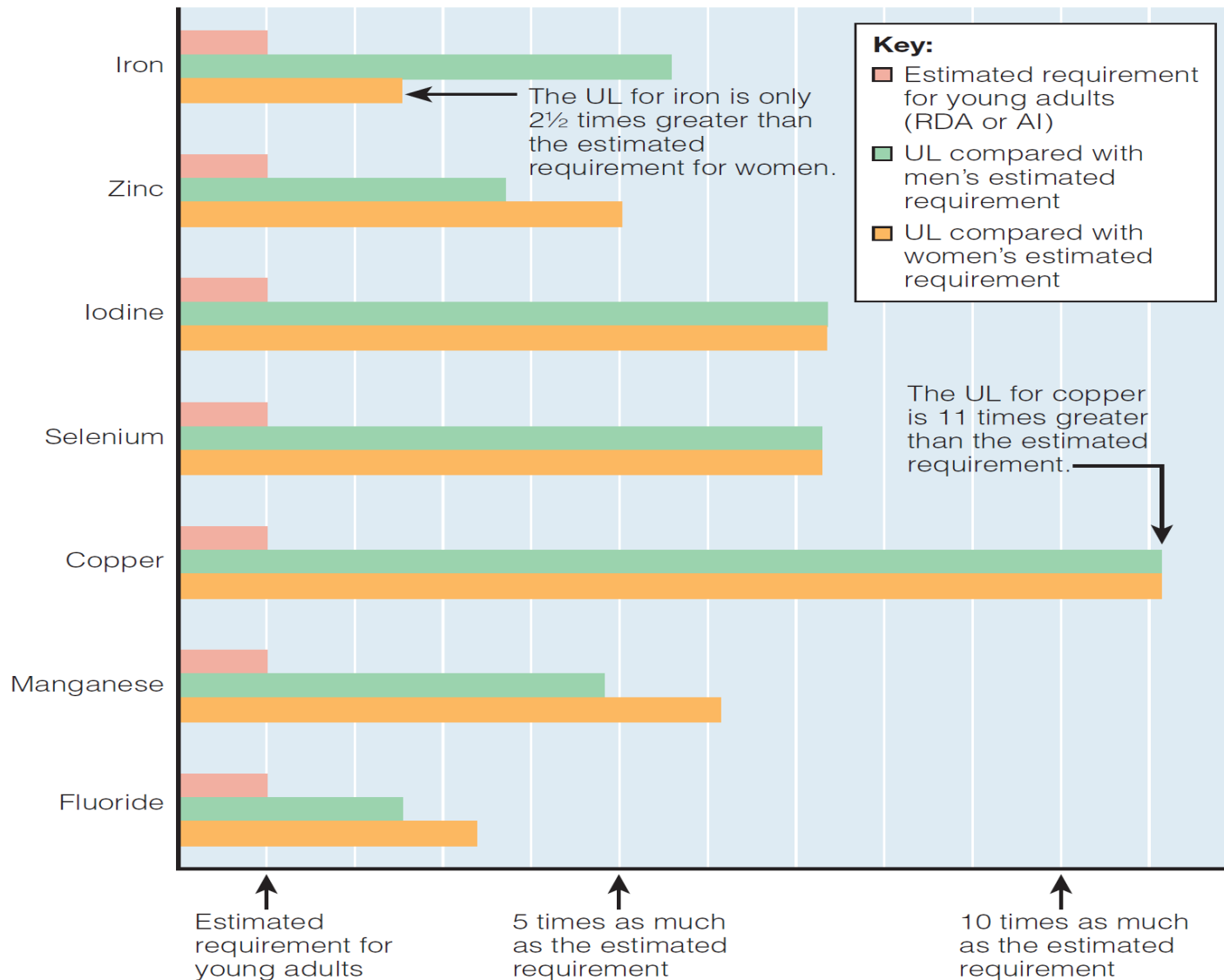
→ (Iron deficiency, for example, makes the body more vulnerable to lead poisoning.)

A good food source of one nutrient may be a poor food source of another, and factors that enhance the action of some trace minerals may interfere with others.

→ (Vitamin C enhances the absorption of iron but hinders that of copper.)

These examples reinforce the need to balance intakes and to use supplements wisely, if at all.

FIGURE 13-1 Estimated Requirements and UL Compared for Selected Trace Minerals



IRON Roles in the Body

1- Can serve as a **cofactor** to enzymes involved in oxidation-reduction reactions.

Iron's two ionic states:

→ Ferrous iron (reduced): Fe^{++}

→ Ferric iron (oxidized): Fe^{+++}

2- Iron forms a part of the **electron carriers** that participate in the electron transport chain

3- Most of the body's iron is found in two proteins: **hemoglobin** in the red blood cells and **myoglobin** in the muscle cells. In both, **iron helps accept, carry, and then release oxygen.**

→ **Myoglobin: the oxygen-holding protein of the muscle cells.**

Iron Absorption and Metabolism

Iron Absorption

Special proteins help the body absorb iron from food:

- ***Ferritin: the iron-storage protein***, captures iron from food and stores it in the cells of the small intestine.
- When the body needs iron, ferritin releases some iron to an iron transport protein called ***Transferrin (the iron transport protein)***.

Iron Absorption and Metabolism (continued)

Heme and Nonheme Iron

Iron absorption depends in part on its dietary source. Iron occurs in two forms in foods:

- **Heme iron:** the iron in foods that is bound to the hemoglobin and myoglobin proteins; found only in meat, fish, and poultry.
- **Nonheme iron:** the iron in foods that is not bound to proteins; found in both plant-derived and animal-derived foods.

NOTES:

- **About 40% of the iron** in meat, fish, and poultry is bound into **heme**; the other **60% is nonheme iron**.
- **All** of the iron in **plant** foods is nonheme iron.

Iron Absorption and Metabolism (continued)

Factors that **enhance** *nonheme iron absorption*:

- **MFP factor**: a peptide released during the digestion of meat, fish, and poultry that enhances nonheme iron absorption.
- **Vitamin C (ascorbic acid)** → enhances nonheme iron absorption from foods eaten in the same meal by capturing the iron and keeping it in the reduced ferrous form, ready for absorption.

Iron Absorption and Metabolism (continued)

Factors that *inhibit nonheme iron absorption*:

- Phytates (legumes, grains, and rice)
- Vegetable proteins (soybeans, legumes, nuts)
- Calcium (milk)
- Tannic acid (and other polyphenols in tea and coffee)

Iron Deficiency

High risk for iron deficiency:

- Women in their reproductive years
- Pregnant women
- Infants and young children
- Teenagers

Stages of iron deficiency:

- Iron stores diminish
 - Transport iron decreases
 - Hemoglobin production declines.
-
- **Symptoms include fatigue and anemia.**

Iron Deficiency and Behavior

- Many of the symptoms associated with iron deficiency are easily mistaken for behavioral or motivational problems.
- When investigating a behavioral problem, check the adequacy of the diet and seek a routine physical examination before undertaking more expensive, and possibly more harmful, treatment options.
- Treatment with long-term, low-dose iron supplements may improve cognitive skills and physical development

Iron Deficiency and Pica

PICA

Geophagia → when referring to eating clay, baby powder, chalk, ash, ceramics, paper, paint chips, or charcoal.

Pagophagia → when referring to eating large quantities of ice.

Amylophagia → when referring to eating uncooked starch (flour, laundry starch, or raw rice).

10- OTHER TRACE MINERALS

- **Nickel** may serve as a cofactor for certain enzymes.
- **Silicon** is involved in the formation of bones and collagen.
- **Vanadium**, too, is necessary for growth and bone development and for normal reproduction.
- **Cobalt** is a key mineral in the large vitamin B12 molecule, but it is not an essential nutrient and no recommendation has been established.
- **Boron** may play a key role in bone health, brain activities, and immune response.
- **Arsenic**—famous as a poison used by murderers and known to be a carcinogen- carcinogen—may turn out to be essential for human beings in tiny quantities. It has already proved useful in the treatment of some types of leukemia.

11- CONTAMINANT MINERALS

- Contaminant minerals include the **heavy metals** LEAD, MERCURY, and CADMIUM that enter the food supply by way of soil, water, and air pollution.
- **LEAD:**
- Chemically similar to nutrient minerals like iron, calcium, and zinc (cations with two positive charges), lead displaces them from some of the metabolic sites they normally occupy but is then unable to perform their roles.

LEAD POISONING

- Lead competes with iron in heme, but it cannot carry oxygen.
- Lead competes with calcium in the brain, but it cannot signal messages from nerve cells.
- Excess lead in the blood also deranges the structure of red blood cell membranes, making them leaky and fragile.
- Lead interacts with **white** blood cells, too, impairing their ability to fight infection, and it binds to antibodies, thwarting their effort to resist disease.

IN SUMMARY The Trace Minerals

Mineral and Chief Functions	Deficiency Symptoms	Toxicity Symptoms ^a	Significant Sources
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Iron			
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Part of the protein hemoglobin, which carries oxygen in the blood; part of the protein myoglobin in muscles, which makes oxygen available for muscle contraction; necessary for energy metabolism			
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	Deficiency Symptoms		
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Anemia: weakness, fatigue, headaches; impaired work performance; impaired immunity; pale skin, nail beds, mucous membranes, and palm creases; concave nails; inability to regulate body temperature; pica			
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		Toxicity Symptoms^a	
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		GI distress; iron overload: infections, fatigue, joint pain, skin pigmentation, organ damage	
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			Significant Sources
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			Red meats, fish, poultry, shellfish, eggs, legumes, dried fruits
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Zinc			
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Part of insulin and many enzymes; involved in making genetic material and proteins, immune reactions, transport of vitamin A, taste perception, wound healing, the making of sperm, and normal fetal development			
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Growth retardation, delayed sexual maturation, impaired immune function, hair loss, eye and skin lesions, loss of appetite			
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		Loss of appetite, impaired immunity, low HDL, copper and iron deficiencies	
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			Protein-containing foods: red meats, fish, shellfish, poultry, whole grains; fortified cereals
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Iodine			
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A component of the thyroid hormones that help to regulate growth, development, and metabolic rate			
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Underactive thyroid gland, goiter, mental and physical retardation (cretinism)			
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		Underactive thyroid gland, elevated TSH, goiter	
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			Iodized salt; seafood; plants grown in iodine-rich soil and animals fed those plants
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Selenium			
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Part of an enzyme that defends against oxidation; regulates thyroid hormone			
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Associated with Keshan disease			
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		Nail and hair brittleness and loss; fatigue, irritability, and nervous system disorders, skin rash, garlic breath odor	
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			Seafoods, organ meats; other meats, whole grains, fruits, and vegetables (depending on soil content)
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Mineral and Chief Functions	Deficiency Symptoms	Toxicity Symptoms ^a	Significant Sources
Copper Helps form hemoglobin; part of several enzymes	Anemia, bone abnormalities	Liver damage	Seafood, nuts, legumes, whole grains, seeds
Manganese Cofactor for several enzymes; bone formation	Rare	Nervous symptom disorders	Nuts, whole grains, leafy vegetables, tea
Fluoride Maintains health of bones and teeth; confers decay resistance on teeth	Susceptibility to tooth decay	Fluorosis (pitting and discoloration) of teeth	Drinking water (if fluoridated), tea, seafood
Chromium Enhances insulin action, may improve glucose intolerance	Diabetes-like condition	None reported	Meats (liver), whole grains, brewer's yeast
Molybdenum Cofactor for several enzymes	Unknown	None reported	Legumes, cereals, nuts

^aAcute toxicities of many minerals cause abdominal pain, nausea, vomiting, and diarrhea.

Causes of Vitamin and Mineral Deficiency

Cause	Mechanism	Examples
Inadequate Intake	Poor dietary diversity or insufficient food supply.	Lack of fruits leading to Vitamin C deficiency (scurvy).
Impaired Absorption	Gastrointestinal disorders like celiac disease impair nutrient absorption.	Fat malabsorption reducing Vitamin D levels.
Increased Demand	Growth, pregnancy, or illness increases micronutrient requirements.	Folate deficiency during pregnancy causing neural tube defects.
Excessive Loss	Loss of nutrients through blood, urine, or diarrhea.	Chronic diarrhea depleting potassium and water-soluble vitamins.

Mechanisms of Specific Vitamin Deficiencies

Vitamin	Mechanism	Clinical Manifestation
Vitamin A	Inadequate intake or impaired conversion of beta-carotene.	Night blindness, xerophthalmia, immune dysfunction.
Vitamin B12	Reduced gastric acid or intrinsic factor (pernicious anemia).	Fatigue, neurological symptoms, megaloblastic anemia.
Vitamin D	Lack of sunlight, impaired skin synthesis, or kidney failure.	Rickets (children), osteomalacia (adults).
Vitamin C	Prolonged dietary insufficiency.	Scurvy (bleeding gums, impaired wound healing).

Mechanisms of Specific Mineral Deficiencies

Mineral	Mechanism	Clinical Manifestation
Iron	Poor intake, chronic blood loss, or increased demand (pregnancy).	Anemia, fatigue, pallor.
Calcium	Impaired absorption (low Vitamin D) or renal losses.	Osteopenia, muscle cramps.
Zinc	Poor intake or excessive loss through diarrhea.	Delayed wound healing, impaired immunity.
Magnesium	Renal losses (e.g., diuretics).	Muscle weakness, arrhythmias.

Drug-Nutrient Interactions Leading to Deficiency

Drug	Nutrient Affected	Mechanism
Proton Pump Inhibitors (PPIs)	Calcium, Iron, Vitamin B12	Reduced gastric acid decreases absorption.
Metformin	Vitamin B12	Impairs absorption through intestinal interference.
Phenytoin	Folate	Increases folate metabolism, leading to deficiency.

Management of Deficiency

Deficiency	Treatment	Examples of Interventions
Vitamin B12	Parenteral injection or high-dose oral.	Hydroxocobalamin injection for severe deficiency.
Iron	Oral or IV iron supplementation.	Ferrous sulfate for iron-deficiency anemia.
Vitamin D	Oral supplementation or UV exposure.	Cholecalciferol (Vitamin D3) supplementation.
Zinc	Oral zinc sulfate or dietary changes.	Fortified cereals or supplements for deficiency.