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كلية العلوم

BCH 445
Biochemistry of nutrition
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Minerals

Minerals:

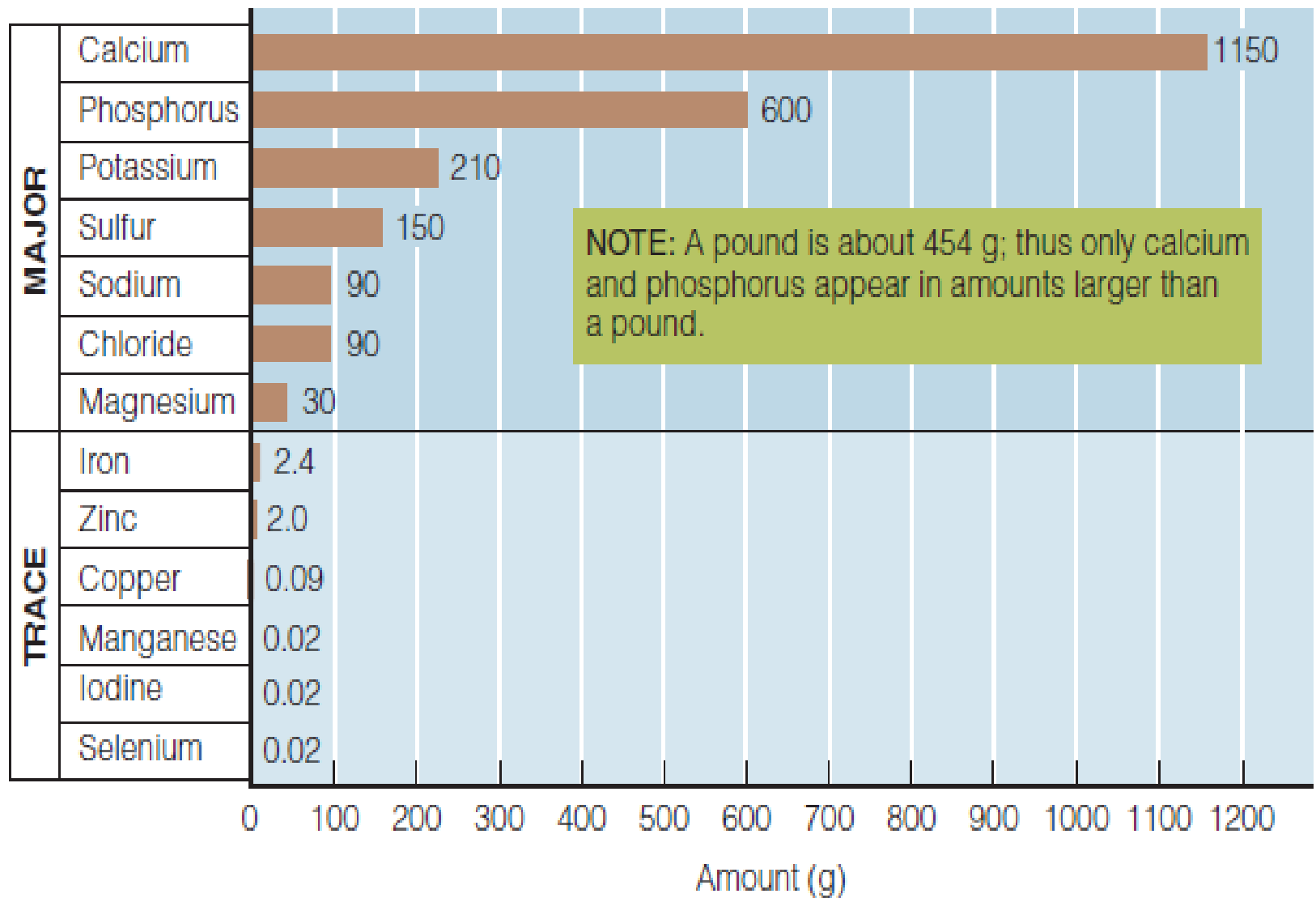
- Small, naturally occurring, inorganic, chemical elements.
- More than 25 have been isolated
- Minerals make up about 4 to 5% of body
- weight (for a 70 kg individual: 2.8 kg)
- Serve as structural components

Major minerals: essential mineral nutrients the human body requires in relatively large amounts (greater than 100 milligrams per day); sometimes called macrominerals.

Trace minerals: essential mineral nutrients the human body requires in relatively small amounts (less than 100 milligrams per day); sometimes called microminerals.

Minerals in 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.

Binders: chemical compounds in foods that combine with nutrients (especially minerals) to form complexes the body cannot absorb. Examples include phytates and oxalates.



Sodium

Sodium is the main cation outside cells and one of the primary electrolytes responsible for maintaining fluid balance. Dietary deficiency is unlikely, and excesses raise blood pressure in many people. For this reason, health professionals advise a diet moderate in salt and sodium.

Sodium

Sodium

Adequate Intake (AI)

Adults: 1500 mg/day (19–50 yr)
1300 mg/day (51–70 yr)
1200 mg/day (>70 yr)

Upper Level

Adults: 2300 mg/day

Chief Functions in the Body

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

Deficiency Symptoms

Not from inadequate intakes
Hyponatremia from excessive losses

Toxicity Symptoms

Edema, acute hypertension

Significant Sources

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

Chloride

The element chlorine (Cl_2) is a poisonous gas. When chlorine reacts with sodium or hydrogen, however, it forms the negative chloride ion (Cl^-). Chloride, an essential nutrient, is required in the diet. Chloride is the major anion outside cells, and it associates closely with sodium. In addition to its role in fluid balance, chloride is part of the stomach's hydrochloric acid.

Chloride

Adequate Intake (AI)

Adults: 2300 mg/day (19–50 yr)
2000 mg/day (51–70 yr)
1800 mg/day (>70 yr)

Upper Level

Adults: 3600 mg/day

Chief Functions in the Body

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

Deficiency Symptoms

Do not occur under normal circumstances

Toxicity Symptoms

Vomiting

Significant Sources

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

Potassium

Like sodium, potassium is a positively charged ion. In contrast to sodium, potassium is the body's principal intracellular cation, inside the body cells.

Potassium plays an important role in maintaining fluid balance. Fresh foods, notably fruits and vegetables, are its best sources.

Potassium

Potassium

Adequate Intake (AI)

Adults: 4700 mg/day

Chief Functions in the Body

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

Deficiency Symptoms^a

Irregular heartbeat, muscular weakness, glucose intolerance

^aDeficiency accompanies dehydration.

Toxicity Symptoms

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

Significant Sources

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

Calcium

The most abundant mineral in the body; found primarily in the body's bones and teeth.

Two important roles:

- **Integral part of bone structure**
- **Serves as a bank that can release calcium to the body fluids if the slightest drop in blood concentration occurs**

Only about 1% of the body's calcium is in the fluids plays these major roles:

- **Essential for muscle contraction**
- **Essential for nerve function**
- **Plays a role in blood clotting**
- **Activates cellular enzymes**
- **Regulates the transport of ions**
- **Helps maintain blood pressure, Allows for secretion of hormones, digestive enzymes, and neurotransmitters**

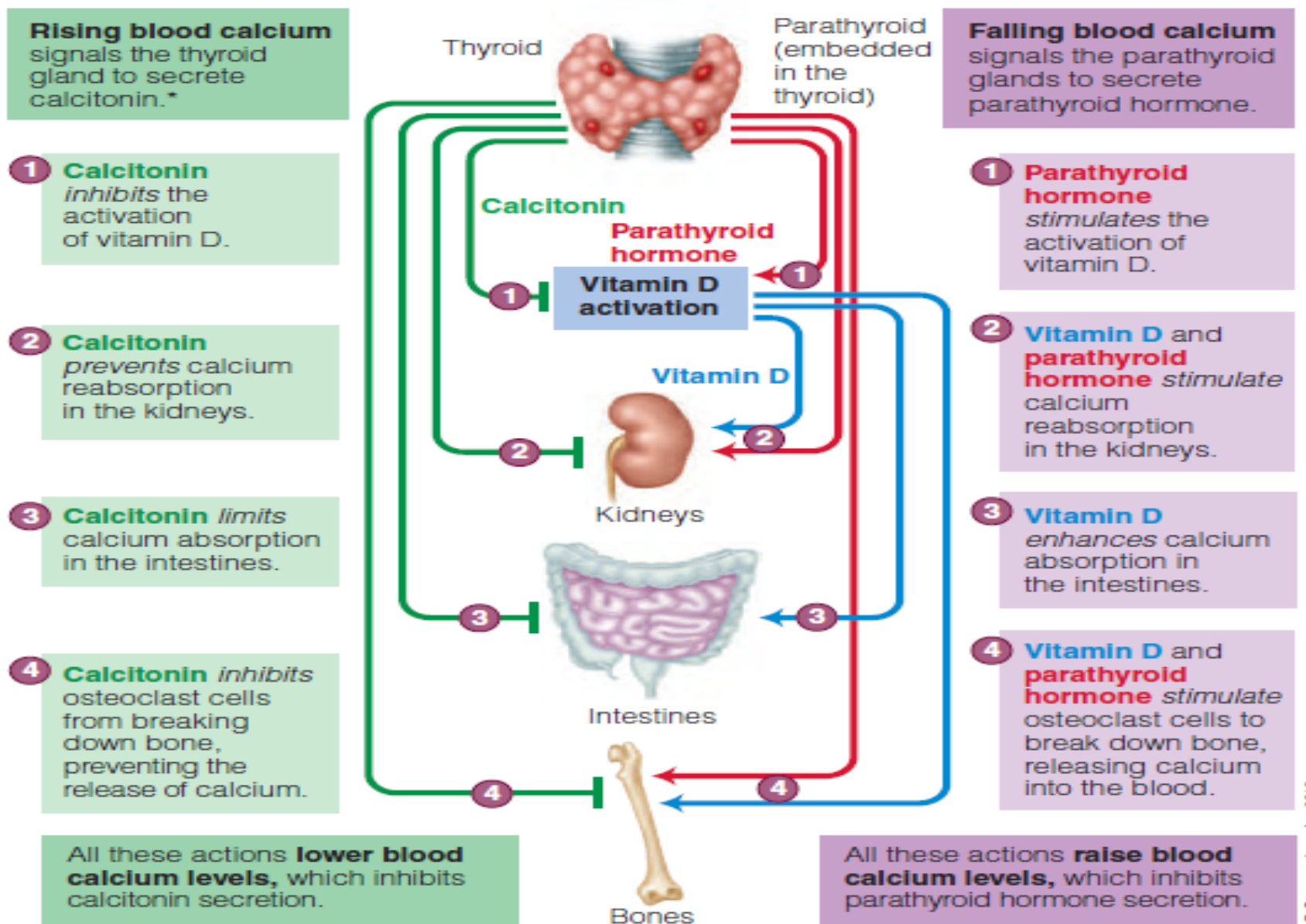
Hydroxyapatite: crystals made of calcium and phosphorus.

Mineralization: the process in which calcium, phosphorus, and other minerals crystallize on the collagen matrix of a growing bone, hardening the bone.

Calmodulin: a calcium-binding protein that regulates such cell activities as muscle contractions.

Parathyroid hormone: a hormone from the parathyroid glands that regulates blood calcium by raising it when levels fall too low; also known as parathormone.

Calcitonin: a hormone secreted by the thyroid gland that regulates blood calcium by lowering it when levels rise too high.





With an adequate intake of calcium-rich food, blood calcium remains normal



With a dietary deficiency, blood calcium still remains normal



. . . and bones deposit calcium. The result is strong, dense bones.



. . . because bones give up calcium to the blood. The result is weak, osteoporotic bones.

Calcium

2011 RDA

Adults: 1000 mg/day (adults, 19–50 yr)
1000 mg/day (men, 51–70 yr)
1200 mg/day (men, ≥71 yr)
1200 mg/day (women, ≥51 yr)

Upper Level

Adults: 2500 mg/day (adults, 19–50 yr)
2000 mg/day (adults, ≥51 yr)

Chief Functions in the Body

Mineralization of bones and teeth; also involved in muscle contraction and relaxation, nerve functioning, blood clotting, blood pressure

Deficiency Symptoms

Stunted growth in children; bone loss (osteoporosis) in adults

Toxicity Symptoms

Constipation; increased risk of urinary stone formation and kidney dysfunction; interference with absorption of other minerals

Significant Sources

Milk and milk products, small fish (with bones), calcium-set tofu (bean curd), greens (bok choy, broccoli, chard, kale), legumes

Phosphorus

- **Phosphorus is the second most abundant mineral in the body. About 85 percent of it is found combined with calcium in the hydroxyapatite crystals of bones and teeth.**
- **Phosphorus accompanies calcium both in many foods such as milk.**
- **Phosphorus is also important in energy metabolism as part of ATP, in lipid transport as part of phospholipids, and in genetic materials as part of DNA and RNA.**

RDA

Adults: 700 mg/day

Upper Level

Adults (19–70 yr): 4000 mg/day

Chief Functions in the Body

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

Deficiency Symptoms

Muscular weakness, bone pain^a

Toxicity Symptoms

Calcification of nonskeletal tissues, particularly the kidneys

Significant Sources

Foods derived from animals (meat, fish, poultry, eggs, milk)

Magnesium

- **Like calcium and phosphorus, magnesium supports bone mineralization. Magnesium is also involved in numerous enzyme systems and in heart function. It is found abundantly in legumes and dark green, leafy vegetables and, in some areas, in water.**
- **Magnesium toxicity is rare, but it can be fatal.**

RDA

Men (19–30 yr): 400 mg/day

Women (19–30 yr): 310 mg/day

Upper Level

Adults: 350 mg nonfood magnesium/day

Chief Functions in the Body

Bone mineralization, building of protein, enzyme action, normal muscle contraction, nerve impulse transmission, maintenance of teeth, and functioning of immune system

Deficiency Symptoms

Weakness; confusion; if extreme, convulsions, bizarre muscle movements (especially of eye and face muscles), hallucinations, and difficulty in swallowing; in children, growth failure^a

Toxicity Symptoms

From nonfood sources only; diarrhea, alkalosis, dehydration

Significant Sources

Nuts, legumes, whole grains, dark green vegetables, seafood, chocolate, cocoa

Sulfate

- **Sulfate is the oxidized form of the mineral sulfur, as it exists in food and water.**
- **The body's need for sulfate is easily met by a variety of foods and beverages. In addition, the body receives sulfate from the amino acids methionine and cysteine.**
- **The sulfur-containing side chains in cysteine molecules can link to each other via disulfide bridges, which stabilize the protein structure.**

- **Skin, hair, and nails contain some of the body's more rigid proteins, which have a high sulfur content.**
- **Because the body's sulfate needs are easily met with normal protein intakes, there is no recommended intake for sulfate.**
- **Deficiencies do not occur when diets contain protein. Only when people lack protein to the point of severe deficiency will they lack the sulfur-containing amino acids.**

The Major minerals

| 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 injected 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.

Trace minerals

- Essential mineral nutrients the human body requires in relatively small amounts (less than 100 milligrams per day); sometimes called microminerals.
- The trace mineral contents of foods depend on soil and water composition and on how foods are processed. Furthermore, many factors in the diet and within the body affect the minerals' bioavailability.

bioavailability: the rate at and the extent to which a nutrient is absorbed and used.

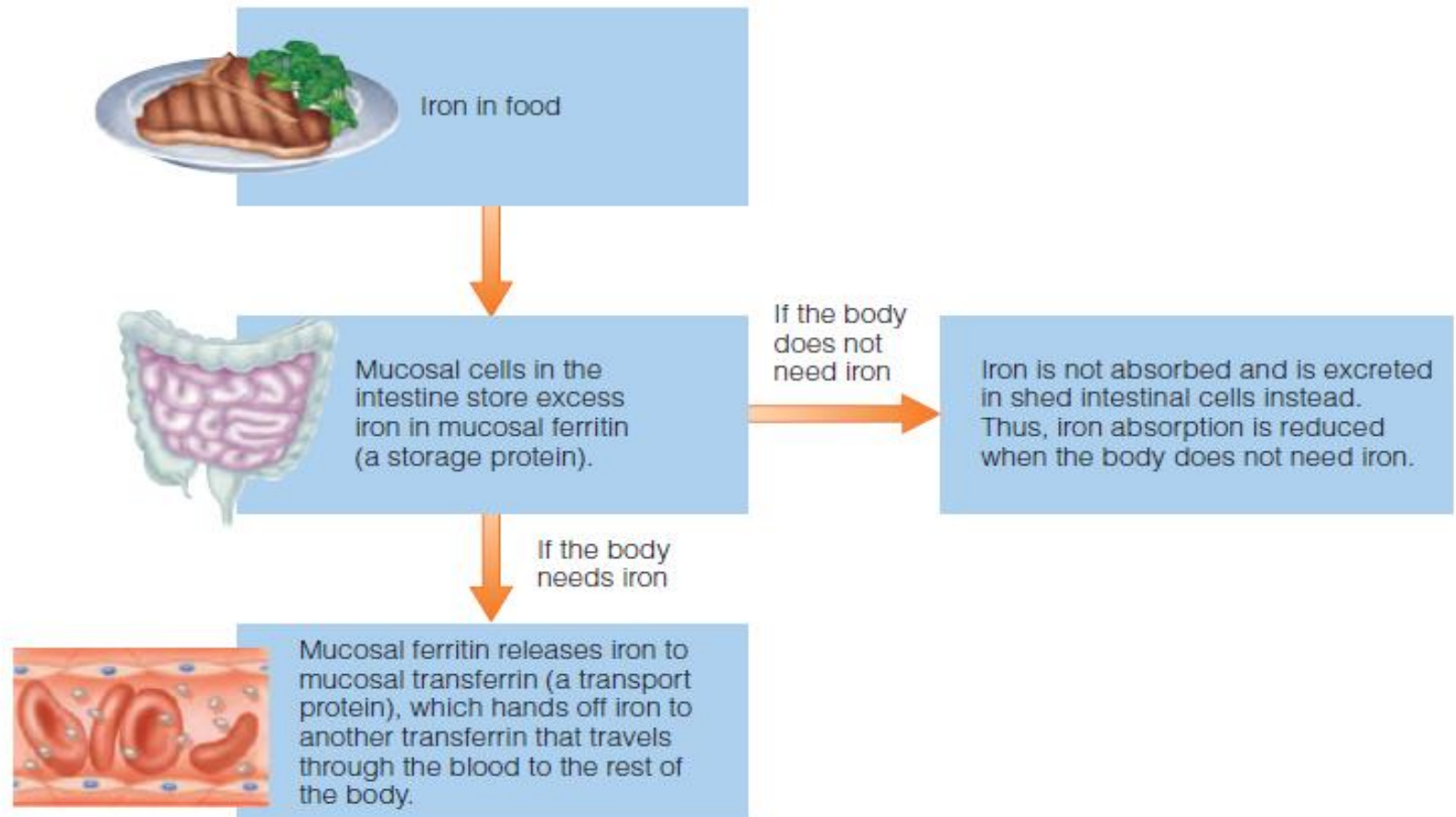
Iron

- **Iron is an essential nutrient, vital to many of the cells' activities, but it poses a problem for millions of people. Some people simply don't eat enough iron-containing foods to support their health optimally, whereas others absorb so much iron that it threatens their health.**
- **Iron exemplifies the principle that both too little and too much of a nutrient in the body can be harmful. The body has several ways to maintain iron balance, protecting against both deficiency and toxicity.**

- **Most of the body's iron is in hemoglobin and myoglobin, where it carries oxygen for use in energy metabolism; some iron is also required for enzymes involved in a variety of reactions.**
- **Special proteins assist with iron absorption, transport, and storage, all helping to maintain an appropriate balance—because both too little and too much iron can be damaging.**
- **Iron deficiency is most common among infants and young children, teenagers, women of childbearing age, and pregnant women.**

- **Heme iron, which is found only in meat, fish, and poultry, is better absorbed than nonheme iron, which occurs in most foods. Nonheme iron absorption is improved by eating iron-containing foods with foods containing the MFP factor and vitamin C; absorption is limited by phytates and oxalates.**

Iron absorption:

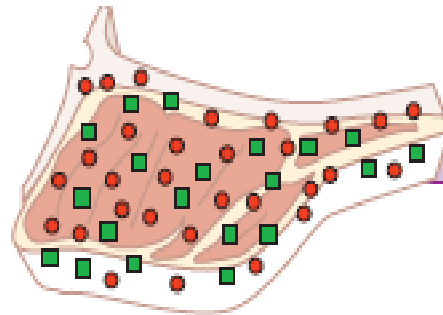


Heme and nonheme iron in foods

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

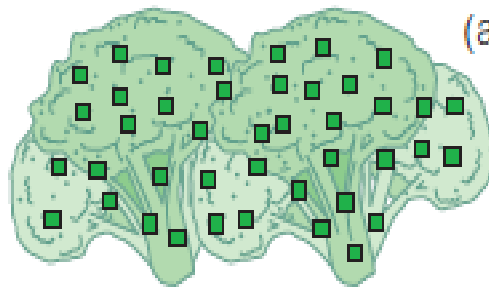
Key:

- Heme
- Nonheme

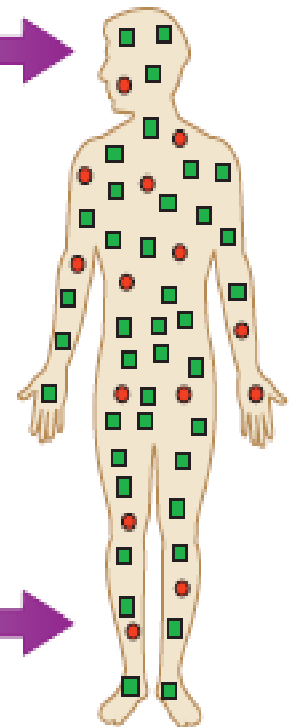


Heme accounts for about 10% of the average daily iron intake, but it is well absorbed (about 25%).

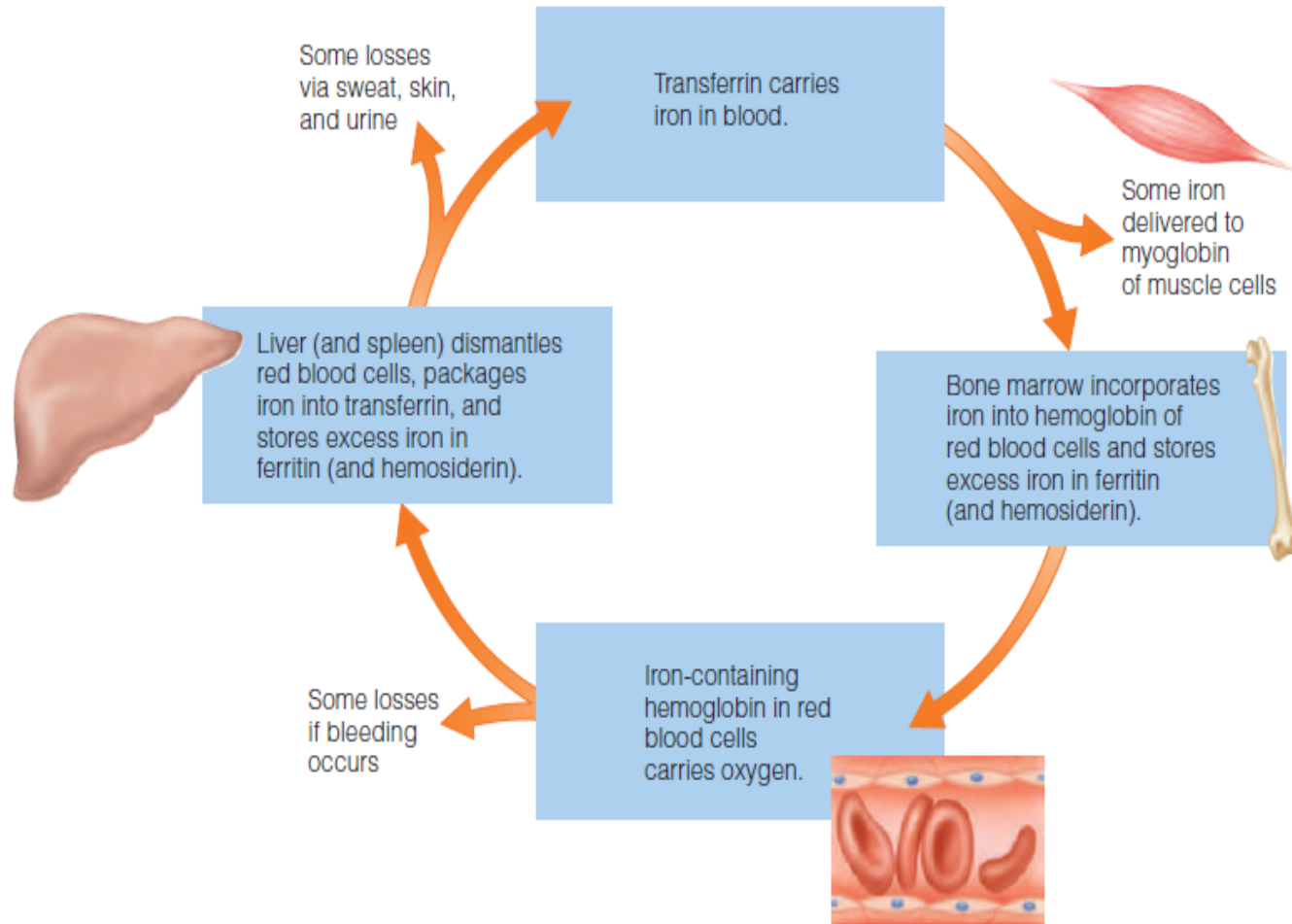
Nonheme iron accounts for the remaining 90%, but it is less well absorbed (about 17%).



All of the iron in foods derived from plants is nonheme iron.



Iron recycled in the body



RDA

Men: 8 mg/day

Women: 18 mg/day (19–50 yr)
8 mg/day (51+)

Upper Level

Adults: 45 mg/day

Chief Functions in the Body

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 the utilization of energy as part of the cells' metabolic machinery

Significant Sources

Red meats, fish, poultry, shellfish, eggs, legumes, dried fruits

Deficiency Symptoms

Anemia: weakness, fatigue, headaches; impaired work performance and cognitive function; impaired immunity; pale skin, nail beds, mucous membranes, and palm creases; concave nails; inability to regulate body temperature; pica

Toxicity Symptoms

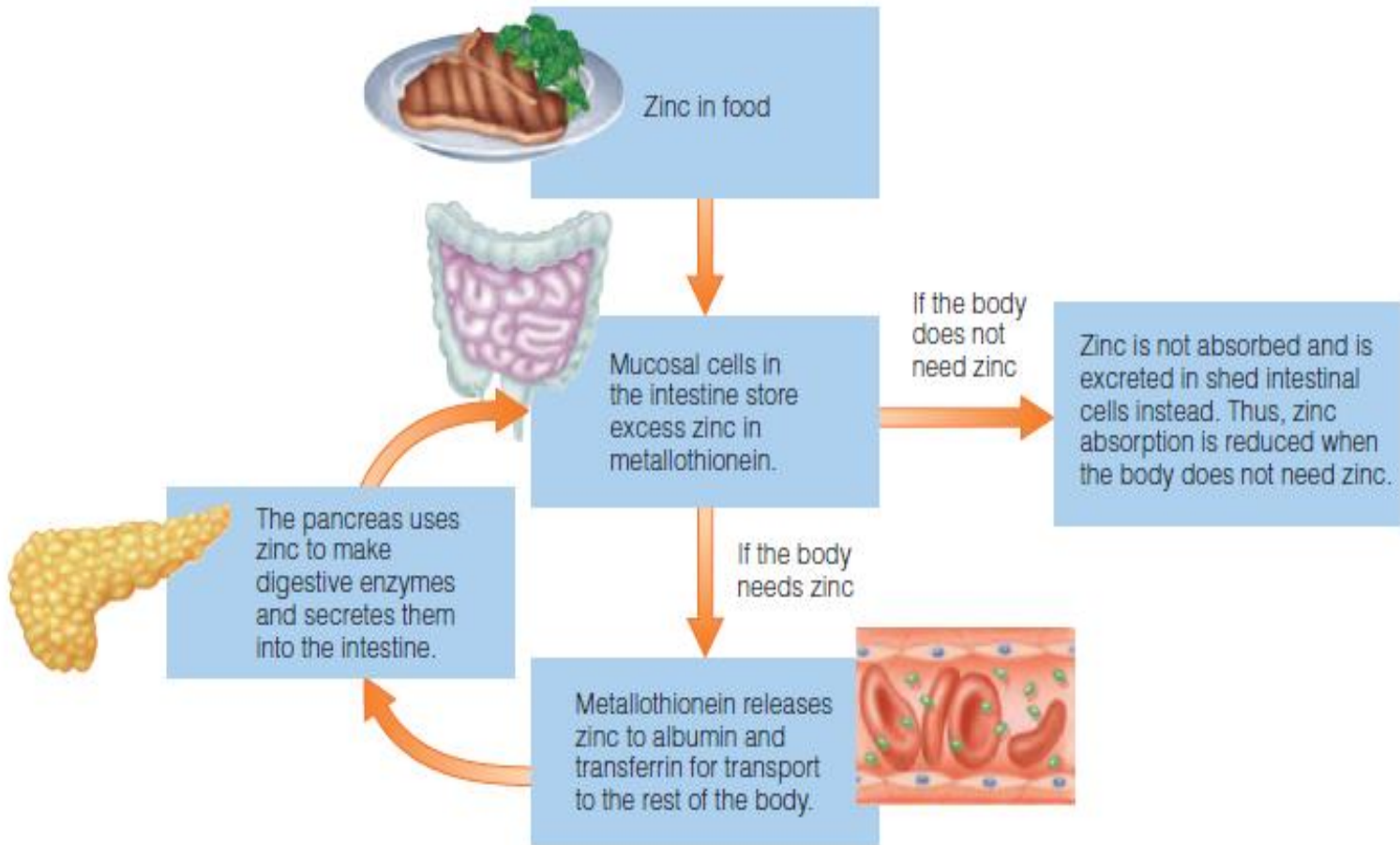
GI distress

Iron overload: infections, fatigue, joint pain, skin pigmentation, organ damage

Zinc

- **Zinc-requiring enzymes participate in a multitude of reactions affecting growth, vitamin A activity, and pancreatic digestive enzyme synthesis, among others.**
- **After a meal, both dietary zinc and zinc-rich pancreatic secretions (via enteropancreatic circulation) are absorbed.**
- **Absorption is regulated by a special binding protein (metallothionein) in the small intestine. Protein-rich foods derived from animals are the best sources of bioavailable zinc. Fiber and phytates in cereals bind zinc, limiting absorption.**

Enteropancreatic circulation of zinc



RDA

Men: 11 mg/day

Women: 8 mg/day

Upper Level

Adults: 40 mg/day

Chief Functions in the Body

Part of many enzymes; associated with the hormone insulin; involved in making genetic material and proteins, immune reactions, transport of vitamin A, taste perception, wound healing, the making of sperm, and the normal development of the fetus

Significant Sources

Protein-containing foods: red meats, shellfish, whole grains; some fortified cereals

Deficiency Symptoms^a

Growth retardation, delayed sexual maturation, impaired immune function, hair loss, eye and skin lesions, loss of appetite

Toxicity Symptoms

Loss of appetite, impaired immunity, low HDL, copper and iron deficiencies

Iodide

The ion of the mineral iodine, is an essential component of the thyroid hormones. An iodine deficiency can lead to simple goiter (enlargement of the thyroid gland) and can impair fetal development, causing cretinism. Iodization of salt has largely eliminated iodine deficiency.

Iodine

RDA

Adults: 150 µg/day

Upper Level

1100 µg/day

Chief Functions in the Body

A component of two thyroid hormones that help to regulate growth, development, and metabolic rate

Significant Sources

Iodized salt, seafood, bread, dairy products, plants grown in iodine-rich soil and animals fed those plants

Deficiency Disease

Simple goiter, cretinism

Deficiency Symptoms

Underactive thyroid gland, goiter, mental and physical retardation in infants (cretinism)

Toxicity Symptoms

Underactive thyroid gland, elevated TSH, goiter

Selenium

- **Selenium is an antioxidant nutrient that works closely with the glutathione peroxidase enzyme and vitamin E.**
- **Selenium is found in association with protein in foods.**
- **Deficiencies are associated with a predisposition to a type of heart abnormality known as Keshan disease.**

Selenium

RDA

Adults: 55 µg/day

Upper Level

Adults: 400 µg/day

Chief Functions in the Body

Defends against oxidation; regulates thyroid hormone

Significant Sources

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

Deficiency Symptoms

Predisposition to heart disease characterized by cardiac tissue becoming fibrous (Keshan disease)

Toxicity Symptoms

Loss and brittleness of hair and nails; skin rash, fatigue, irritability, and nervous system disorders; garlic breath odor

Copper

- **Copper is a component of several enzymes, all of which are involved in some way with oxygen or oxidation. Some act as antioxidants; others are essential to iron metabolism.**
- **Legumes, whole grains, and shellfish are good sources of copper.**

Copper

RDA

Adults: 900 µg/day

Upper Level

Adults: 10,000 µg/day (10 mg/day)

Chief Functions in the Body

Necessary for the absorption and use of iron in the formation of hemoglobin; part of several enzymes

Significant Sources

Seafood, nuts, whole grains, seeds, legumes

Deficiency Symptoms

Anemia, bone abnormalities

Toxicity Symptoms

Liver damage

Manganese

- **Manganese-dependent enzymes are involved in bone formation and various metabolic processes. Because manganese is widespread in plant foods, deficiencies are rare, although regular use of calcium and iron supplements may limit manganese absorption.**

Manganese

AI

Men: 2.3 mg/day

Women: 1.8 mg/day

Upper Level

Adults: 11 mg/day

Chief Functions in the Body

Cofactor for several enzymes; bone formation

Significant Sources

Nuts, whole grains, leafy vegetables, tea

Deficiency Symptoms

Rare

Toxicity Symptoms

Nervous system disorders

Fluoride

- **Fluoride makes teeth stronger and more resistant to decay. Fluoridation of public water supplies can significantly reduce the incidence of dental caries, but excess fluoride during tooth development can cause fluorosis—discolored and pitted tooth enamel.**

Fluoride

AI

Men: 4 mg/day

Women: 3 mg/day

Upper Level

Adults: 10 mg/day

Chief Functions in the Body

Strengthens teeth; helps to make teeth resistant to decay

Significant Sources

Drinking water (if fluoride containing or fluoridated), tea, seafood

Deficiency Symptoms

Susceptibility to tooth decay

Toxicity Symptoms

Fluorosis (pitting and discoloration of teeth)

Chromium

Chromium enhances insulin's action. A deficiency can impair glucose homeostasis. Chromium is widely available in unrefined foods including brewer's yeast, whole grains, and liver.

Chromium

AI

Men: 35 µg/day

Women: 25 µg/day

Chief Functions in the Body

Enhances insulin action and may improve glucose tolerance

Significant Sources

Meats (especially liver), whole grains, brewer's yeast

Deficiency Symptoms

Diabetes-like condition

Toxicity Symptoms

None reported

Molybdenum

Molybdenum is found in a variety of foods and participates in several metabolic reactions.

Molybdenum

RDA

Adult: 45 µg/day

Upper Level

Adults: 2 mg/day

Chief Functions in the Body

Cofactor for several enzymes

Significant Sources

Legumes, cereals, nuts

Deficiency Symptoms

Unknown

Toxicity Symptoms

None reported; reproductive effects in animals

| Mineral and Chief Functions | Deficiency Symptoms | Toxicity Symptoms^a | Significant Sources |
|---|---|--|--|
| Iron 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 | 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 | GI distress; iron overload: infections, fatigue, joint pain, skin pigmentation, organ damage | Red meats, fish, poultry, shellfish, eggs, legumes, dried fruits |
| Zinc 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 | Growth retardation, delayed sexual maturation, impaired immune function, hair loss, eye and skin lesions, loss of appetite | Loss of appetite, impaired immunity, low HDL, copper and iron deficiencies | Protein-containing foods: red meats, fish, shellfish, poultry, whole grains; fortified cereals |
| Iodine A component of the thyroid hormones that help to regulate growth, development, and metabolic rate | Underactive thyroid gland, goiter, mental and physical retardation (cretinism) | Underactive thyroid gland, elevated TSH, goiter | Iodized salt; seafood; plants grown in iodine-rich soil and animals fed those plants |
| Selenium Part of an enzyme that defends against oxidation; regulates thyroid hormone | Associated with Keshan disease | Nail and hair brittleness and loss; fatigue, irritability, and nervous system disorders, skin rash, garlic breath odor | Seafoods, organ meats; other meats, whole grains, fruits, and vegetables (depending on soil content) |

| | | | |
|--|--------------------------------|--|--|
| Selenium Part of an enzyme that defends against oxidation; regulates thyroid hormone | Associated with Keshan disease | Nail and hair brittleness and loss; fatigue, irritability, and nervous system disorders, skin rash, garlic breath odor | Seafoods, organ meats; other meats, whole grains, fruits, and vegetables (depending on soil content) |
| 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 |