Chapter 9

Nutrients Essential to Healthy Tissues

Table 9.1: Nutrients for Healthy Tissues

Nutrient	Recommended Intake
Iron	RDA for 19 to 50 years of age: Women 18 mg/day Men = 8 mg/day
Zinc	RDA for 19 to 50 years of age: Women = 8 mg/day Men = 11 mg/day
Copper	RDA for 19 to 50 years of age: 90 μg/day
Vitamin B6 (pyridoxine)	RDA for 19 to 50 years of age: 1.3 mg/day RDA for 51 years of age and older: Women 1.5 mg/day Men 1.7 mg/day
Folate (folic acid)	RDA for 19 years of age and older: 400 μg/day
Vitamin B12 (cobalamin)	RDA for 19 years of age and older: 2.4 μg/day
Vitamin K	Al for 19 to 50 years of age: Women = 90 μg/day Men 120 μg/day
Vitamin C	RDA for 19 years of age and older. Women 75 mg/day Men 90 mg/day Smokers = 35 mg more per day than RDA
Calcium	RDA for 19 to 50 years of age: 1,000 mg/day Women 51 years of age and older = 1,200 mg/day Men 51 to 70 years of age = 1,000 mg/day; 70 years of age and older = 1,200 mg/day
Phosphorus	RDA for 19 years of age and older. 700 mg/day
Magnesium	RDA for 19 to 30 years of age: Women = 310 mg/day Men = 400 mg/day RDA for 31 years of age and older: Women = 320 mg/day Men = 420 mg/day
Fluoride	RDA for 19 years of age and older: Women = 3 mg/day Men = 4 mg/day
Vitamin D	RDA for 19 to 70 years of age:* 600 IU/day RDA for 71 years of age and older: 800 IU/day

To see the full profile of all micronutrients, turn to the In Depth essay following Chapter 6, Vitamins and Minerals: Micronutrients with Macro Powers (pages 211–221).

*Based on the assumption that a person does not get adequate sun exposure.

9.1 Components of the Blood

- **Erythrocytes** – red blood cells
- **Leukocytes** – white blood cells; key to our immune function
- **Platelets** – cell fragments that assist in the formation of blood clots
- **Plasma** – the watery matrix of blood in which the cells and platelets flow

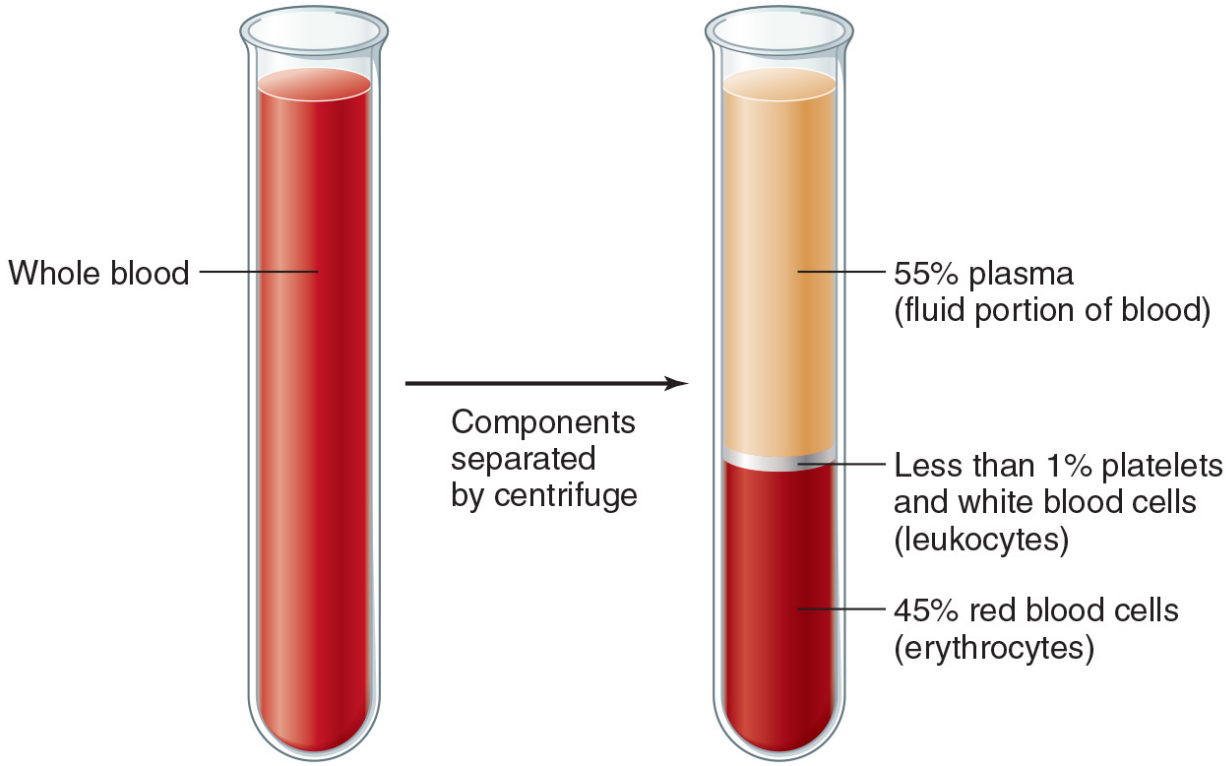

Figure 9.1: Components of the Blood

9.2 Iron

- Iron is a component of numerous proteins in the body
  - Approximately two-thirds of the body's iron is found in the hemoglobin, the oxygen-carrying protein, of the red blood cells
  - Iron can also be found in myoglobin, which is similar to hemoglobin but is found in the muscle cells

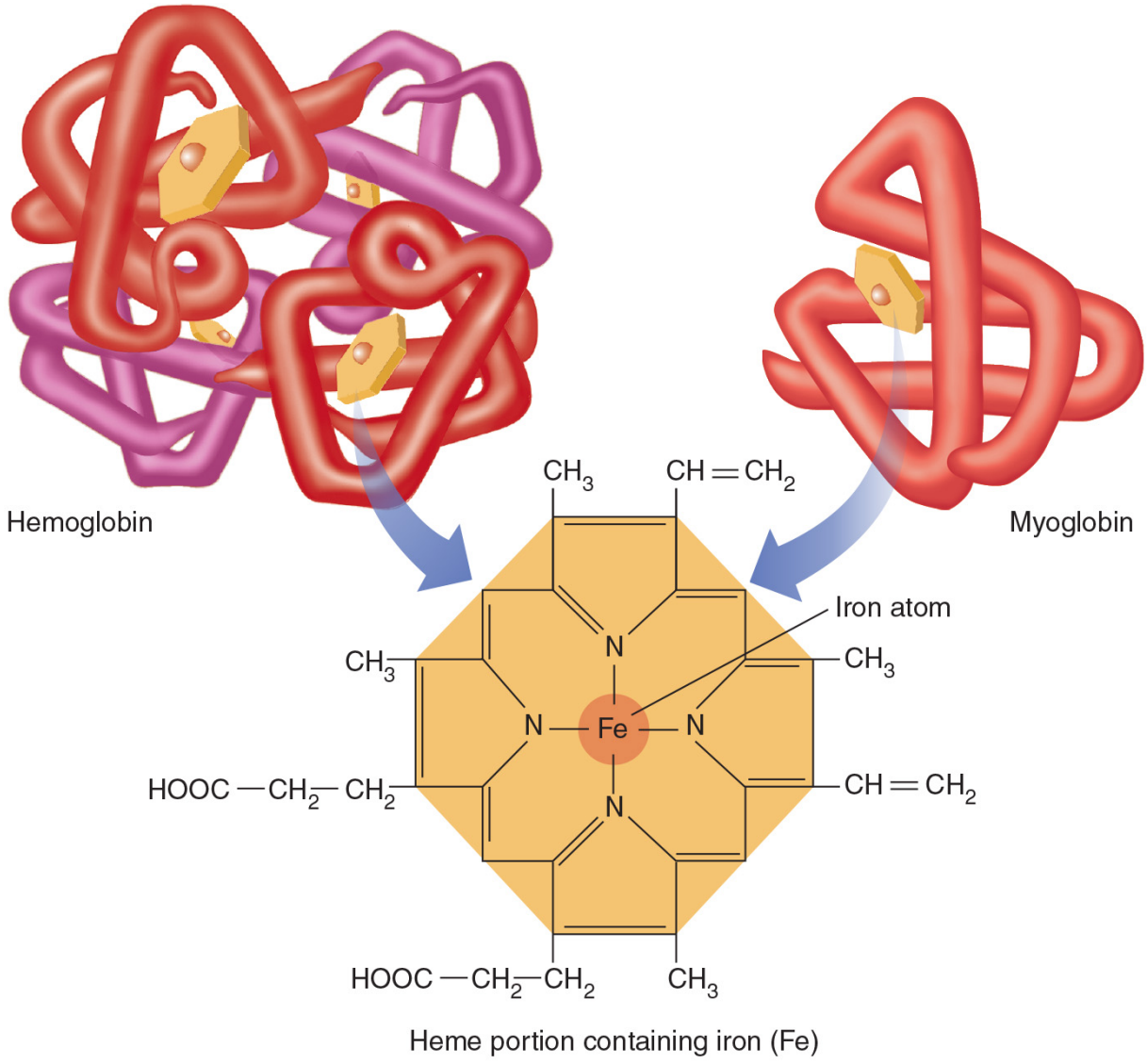

Figure 9.2: Iron

9.3 Iron Storage and Recycling

- Extra iron can be stored in the liver, intestinal mucosa, bone marrow, and spleen
- As red blood cells break down their iron is released and can be recycled
  - The liver and spleen are responsible for iron-recycling, which decreases our need for dietary iron

9.4 Iron Absorption

- The body's ability to absorb iron are influenced by:

  - Iron status
  - Stomach acid
  - Iron content in the diet
  - Type of iron consumed
  - Other dietary factors; phytates, polyphenols, and other minerals
- Sources: Beef, oysters, clams, turkey, chicken, pork, beans, lentils, spinach, tomatoes

Table 9.2: Circumstances Affecting Iron Status

Circumstances That Improve Iron Status	Circumstances That Diminish Iron Status
• Use of oral contraceptives-reduces menstrual blood loss in women. • Breastfeeding-delays resumption of menstruation in new mothers and thereby reduces menstrual blood loss. It is therefore an important health measure, especially in developing nations. • Consumption of iron-containing foods and supplements.	• Use of hormone replacement therapy–can cause uterine bleeding. • Eating a vegetarian diet–reduces or eliminates sources of heme iron. • Intestinal parasitic infection–causes intestinal bleeding. Iron-deficiency anemia is common in people with intestinal parasitic infection. • Blood donation–reduces iron stores; people who donate frequently, particularly premenopausal women, may require iron supplementation. • Intense endurance exercise training–appears to increase risk for inflammation, suboptimal iron intake, increased iron loss due to rupture of red blood cells, and losses in sweat and feces.

Source: Data from Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc © 2002 by the National Academy of Sciences, National Academies Press.

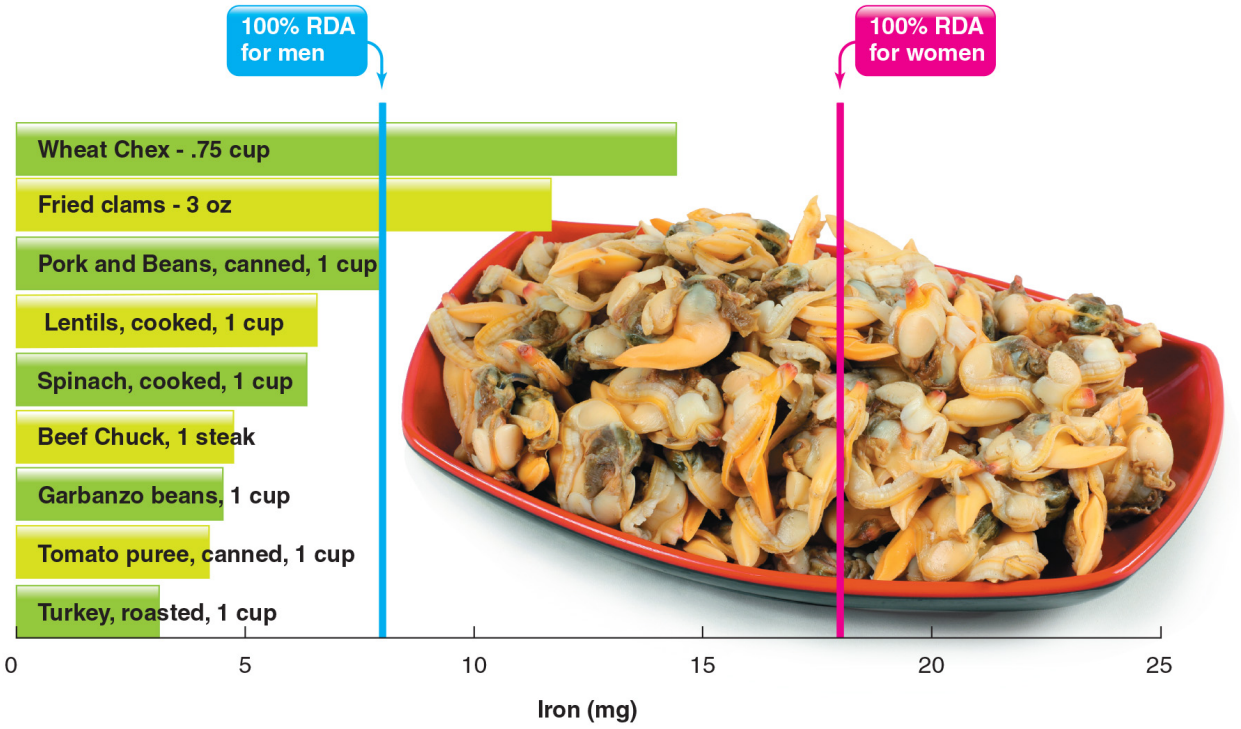

Figure 9.3: Common Food Sources of Iron

- Iron toxicity
  - In the U.S. accidental iron overdose is the leading cause of death in children under 6
  - Can cause nausea and constipation in mild cases
- Iron deficiency
  - Iron deficiency anemia causes the red blood cells to be smaller and paler than normal

9.5 Zinc

- Functions of zinc include
  - Enzymatic functions–over 300 enzymes in the human body use zinc
  - Structural functions–helps to stabilize proteins so that they function properly
  - Regulatory functions–helps to regulate gene expression

  Only 10–35% of dietary zinc is absorbed Factors decreasing absorption include:
  - Non-heme iron intake
  - Phytates

  - Fiber

- Sources
  - Oysters
  - Beef
  - Crab
  - Lobster
  - Pork
  - Cashews
  - Garbanzo beans
  - Cheese
  - Yogurt
- Toxicity is rare, but is mainly seen with over consumption of zinc supplements
- Deficiency is rare in the U.S. but can be seen in other countries where diets are predominantly bread or grain based
  - Symptoms include growth retardation, delayed sexual maturation, and increased risk of infections

9.6 Copper

- Trace mineral that is crucial for blood health
  - Component of ceruloplasmin
    - Protein used in iron transport
  - Energy metabolism
  - Building of connective tissues
- Sources:
  - Oysters
  - Lobster
  - Nuts
  - Seeds
  - Pork
  - Spinach
- Toxicity is not well studied in humans

- Deficiencies are rare but can lead to
  - Inhibition of hemoglobin synthesis
  - Inadequate iron utilization
  - Microcytic anemia

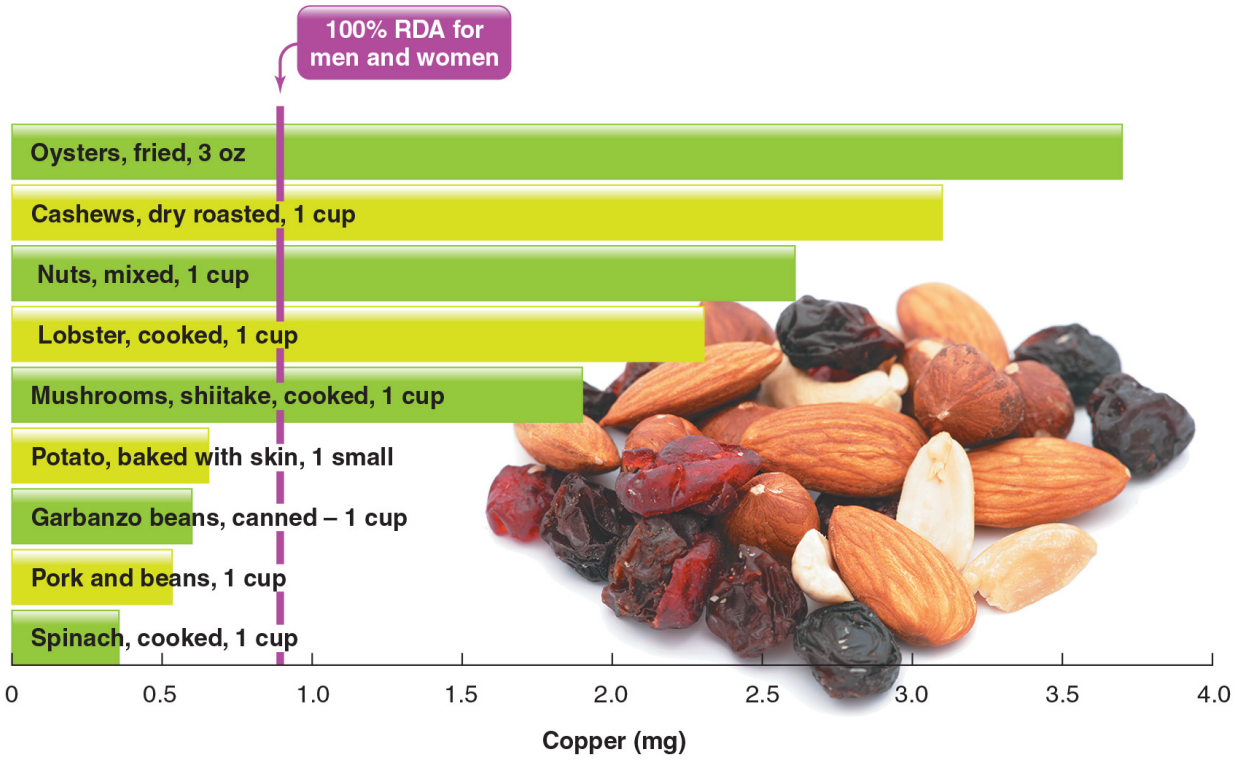

Figure 9.4: Copper

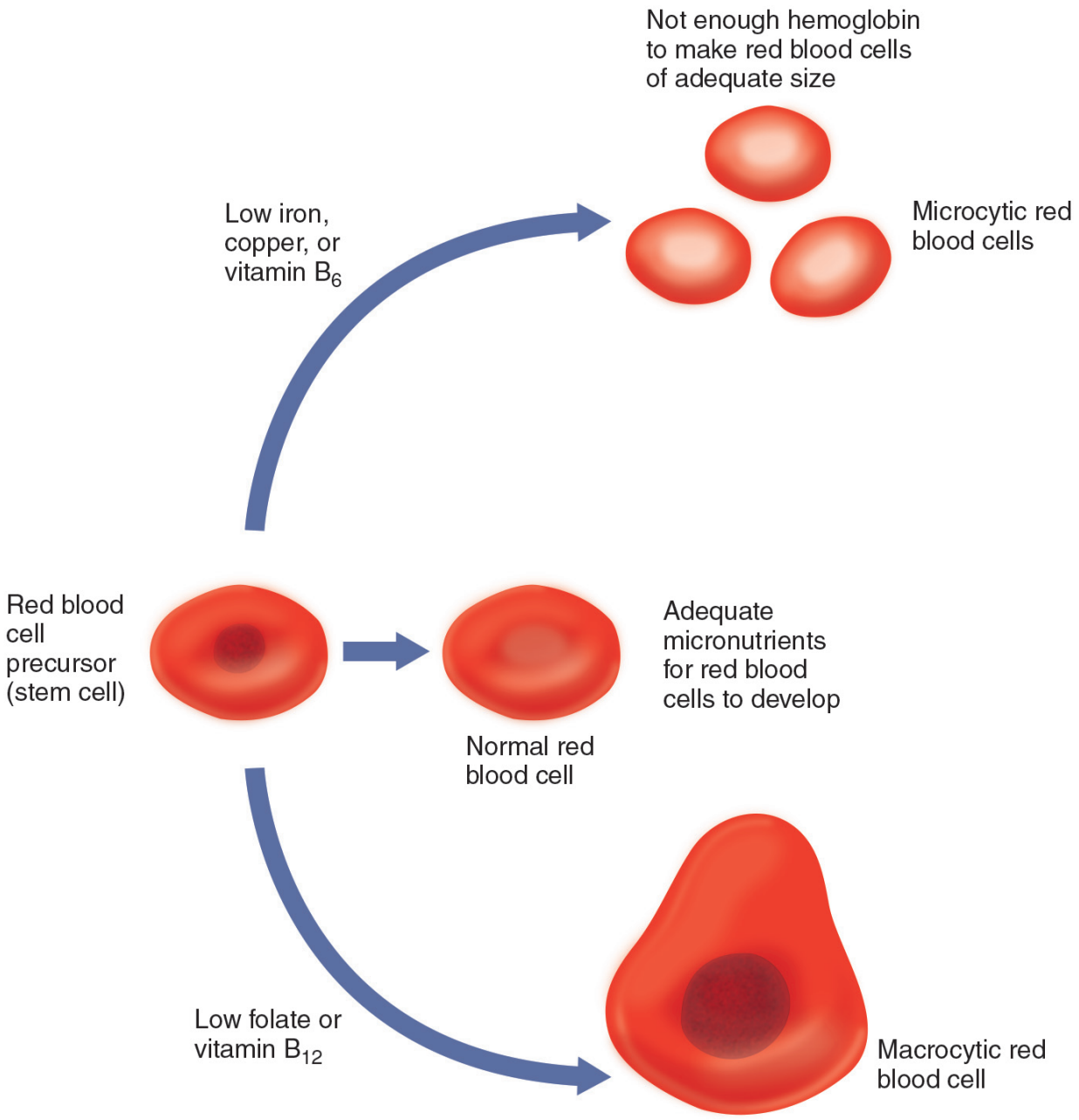

Figure 9.5: Vitamin Roles in Blood Formation

9.7 Vitamin K

- Fat-soluble vitamin
- Stored primarily in the liver

- Types:
  - **Phylloquinone** – plant form of vitamin K
  - **Menaquinone** – form of vitamin K produced by bacteria in the large intestine
- Functions of vitamin K
  - Blood clotting (prothrombin synthesis)
  - Bone metabolism (osteocalcin synthesis)
- Recommended intake
  - There is no RDA for vitamin K
  - AI values are 120 μg/day for men and 90 μg/day for women
- Sources of vitamin K
  - Green leafy vegetables, vegetable oils
- What if you consume too much vitamin K?
  - No side effects from large quantities
- What if you don't consume enough vitamin K?
  - Reduced blood clotting, excessive bleeding
  - Occurs with diseases that limit absorption of fat in the small intestine

9.8 Vitamin C

- Vitamin C helps to produce and maintain healthy collagen
  - Collagen is a fibrous protein found in the bone, teeth, tendons, blood vessels, and gum tissue
- Assists in the synthesis of
  - DNA
  - Bile
  - Serotonine
  - Carnitine
- Recommended intake
  - 90 mg/day for men; 75 mg/day for women
  - Smokers need an extra 35 mg/day

  - UL is 2,000 mg/day for adults

- Sources of vitamin C
  - Fresh fruits and vegetables
  - Heat destroys vitamin C
  - Cooking foods lowers their vitamin C content

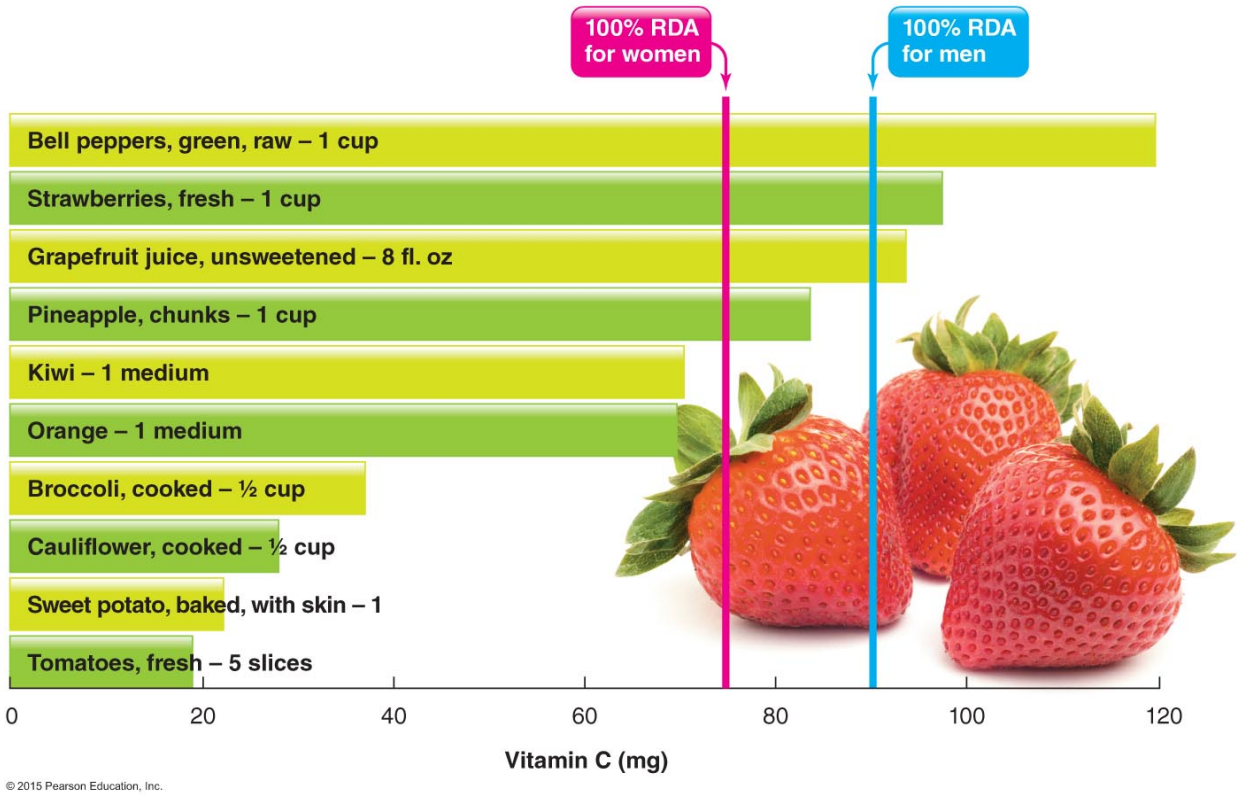

Figure 9.6: Common Food Sources of Vitamin C

- What if you consume too much vitamin C?
  - Megadoses (ten times or more of the recommended intake) of vitamin C can cause nausea, diarrhea, nosebleeds, and abdominal cramps
  - Can cause iron toxicity in people with hemochromatosis
  - Can lead to kidney stone formation in people with kidney disease

- What if you don't consume enough vitamin C?
  - Scurvy is the most common vitamin C deficiency disease
    * Bleeding gums, loose teeth, wounds that fail to heal, swollen ankles and wrists, bone pain and fractures, diarrhea, weakness, and depression

- Anemia can also result from vitamin C deficiency

Figure 9.7: Scurvy

9.9 Bone Health

- Bone structure
  - Provides strength to support the body
  - Allows for flexibility
  - Contains about 65% minerals, providing the hardness of bone
  - Contains 35% organic structures for strength, durability, and flexibility
  - **Collagen** – fibrous protein in bone tissue

Table 9.3: Functions of Bone in the Human Body

Functions Related to Structure and Support	Functions Related to Metabolic Processes
• Bones provide physical support for organs and body segments. • Bones protect vital organs; for example, the rib cage protects the lungs, the skull protects the brain, and the vertebrae of the spine protect the spinal cord. • Bones work with muscles and tendons to allow movement-muscles to attach to bones via tendons, and their contraction produces movement at the body's joints.	• Bone tissue acts as a storage reservoir for many minerals, including calcium, phosphorus, and fluoride. The body draws upon such deposits when these minerals are needed for various body processes; however, this can reduce bone mass. • Most blood cells are produced in the bone marrow.

- Two types of bone tissue
  - **Cortical bone (compact bone)** – very dense tissue making up 80% of the skeleton
    - Outer surface of all bones
    - Many of the small bones (wrists, hands, feet)
  - **Trabecular bone (spongy bone)** – "scaffolding" on the inside of bones; supports cortical bone and makes up 20% of the skeleton
    - Faster turnover rate

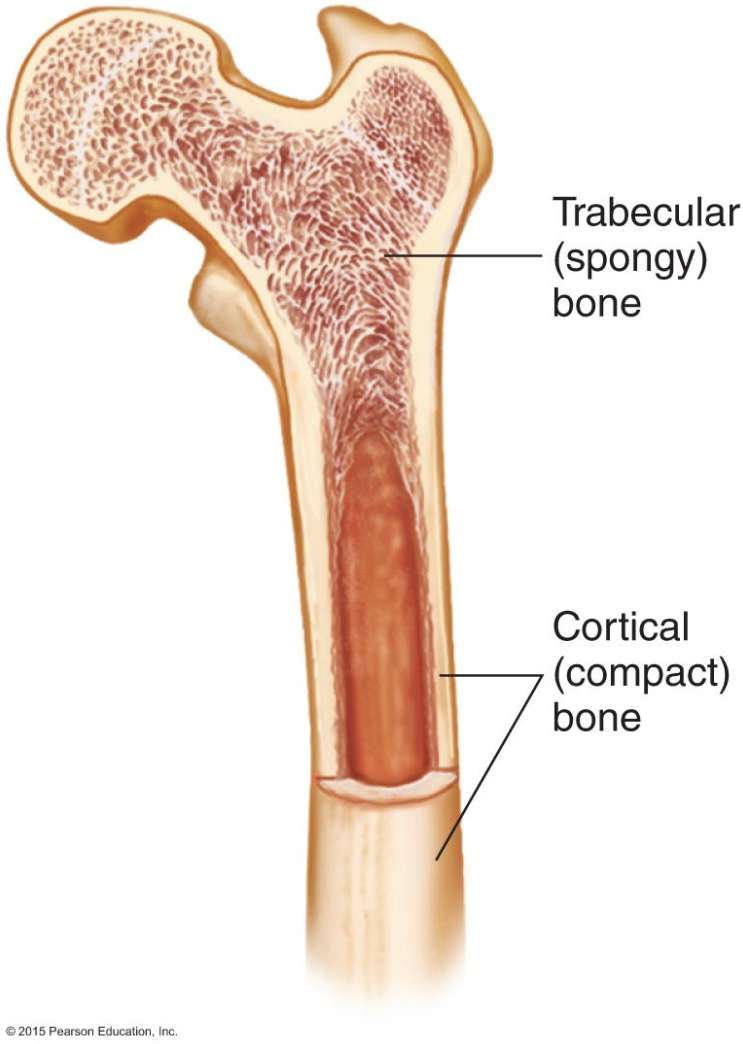

Figure 9.8: Bone Structure

- Bones develop through three processes

  Bone growth increase in bone size

  Bone modeling shaping of bone

  - Size and shape do not change significantly after puberty
  - **Bone density** – degree of compactness of bone tissue; continues to develop into early adulthood

  Bone remodeling reshaping of bone; occurs throughout life

  - Bone remodeling involves
    - **Resorption** – surface of bones is broken down by osteoclasts
      - **Osteoclasts** – cells that erode the surface of bones
    - Formation of new bone by cells called osteoblasts
      - Osteoblasts produce the collagen-containing component of bone

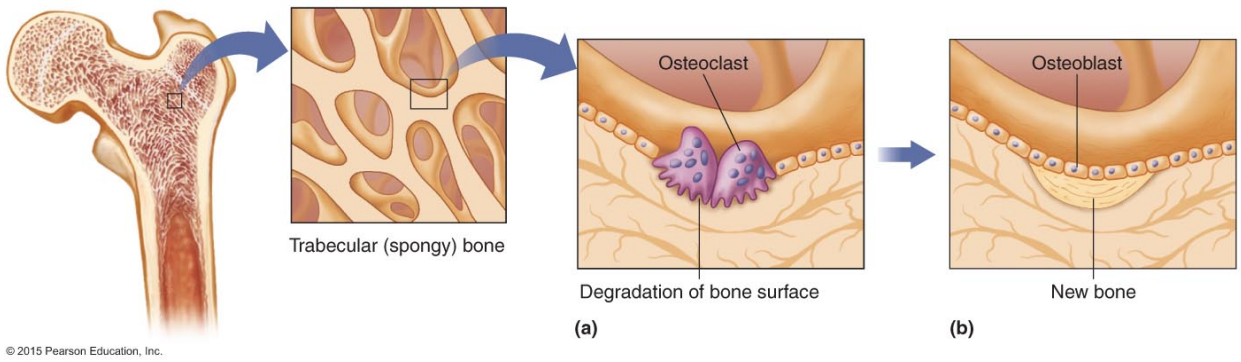

Figure 9.9: Bone Remodeling

9.10 Assessing Bone Health

- Dual-energy x-ray absorptiometry (DXA or DEXA)
  - Measures bone density
  - Uses very-low-level x-ray energy
  - Provides a full body scan or can be used to scan peripheral regions (hip, wrist, heel)
  - Is a noninvasive procedure
  - Recommended for postmenopausal women
  - A T-score is obtained, which compares bone density to that of a healthy 30-year-old

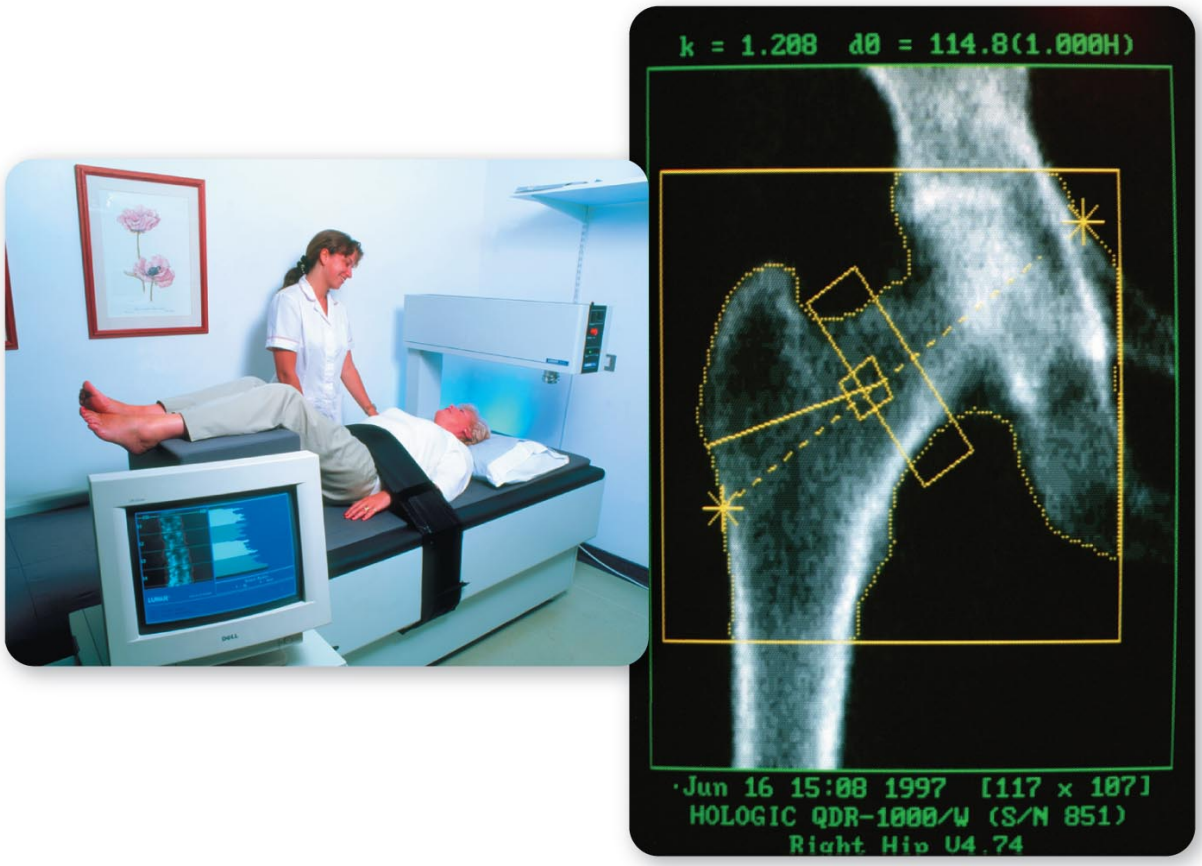

Figure 9.10: DXA

9.11 Calcium

- The most abundant major mineral in the body
  - 99% of body calcium is found in bone
  - 1% is found in blood and soft tissues
- Functions of calcium
  - Forms and maintains bones and teeth
  - Assists with acid–base balance
  - Critical for normal transmission of nerve impulses
  - Assists in muscle contraction
- Blood calcium level is tightly controlled
- Low calcium level
  - Parathyroid hormone (PTH) is released

  - PTH stimulates activation of vitamin D
  - PTH and vitamin D cause
    * Kidneys to retain more calcium
    * Osteoclasts to break down bone and release calcium
    * Stimulation of calcium absorption from intestines

- High calcium level
  - Thyroid gland releases calcitonin
  - Calcitonin functions to
    * Prevent calcium reabsorption from kidneys
    * Limit calcium absorption from intestines
    * Inhibit osteoclasts from breaking down bone

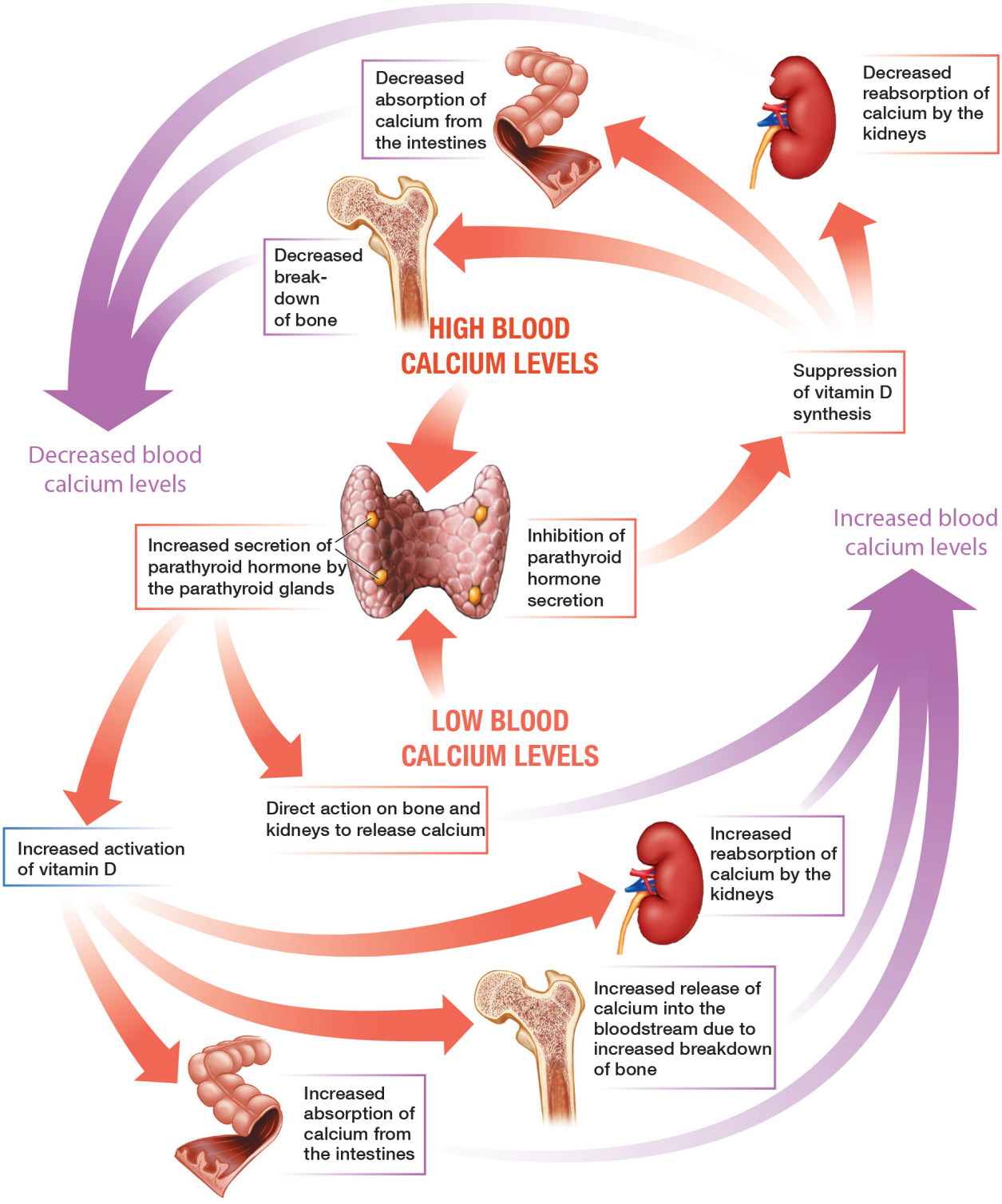

Figure 9.11: Regulation of Blood Calcium Levels

- Sources:
  - Dairy

  - Collard greens
  - Sardines
  - Kale
  - Tofu

- Bioavailability: degree to which a nutrient is absorbed
- Calcium bioavailability depends on need and age
  - Infants, children, and adolescents can absorb more than 60%
  - Pregnant and lactating women can absorb 50%
  - Healthy adults typically absorb 30%
  - Older adults absorb less
  - Bodies cannot absorb over 500 mg at one time
  - Numerous factors in food influence absorption

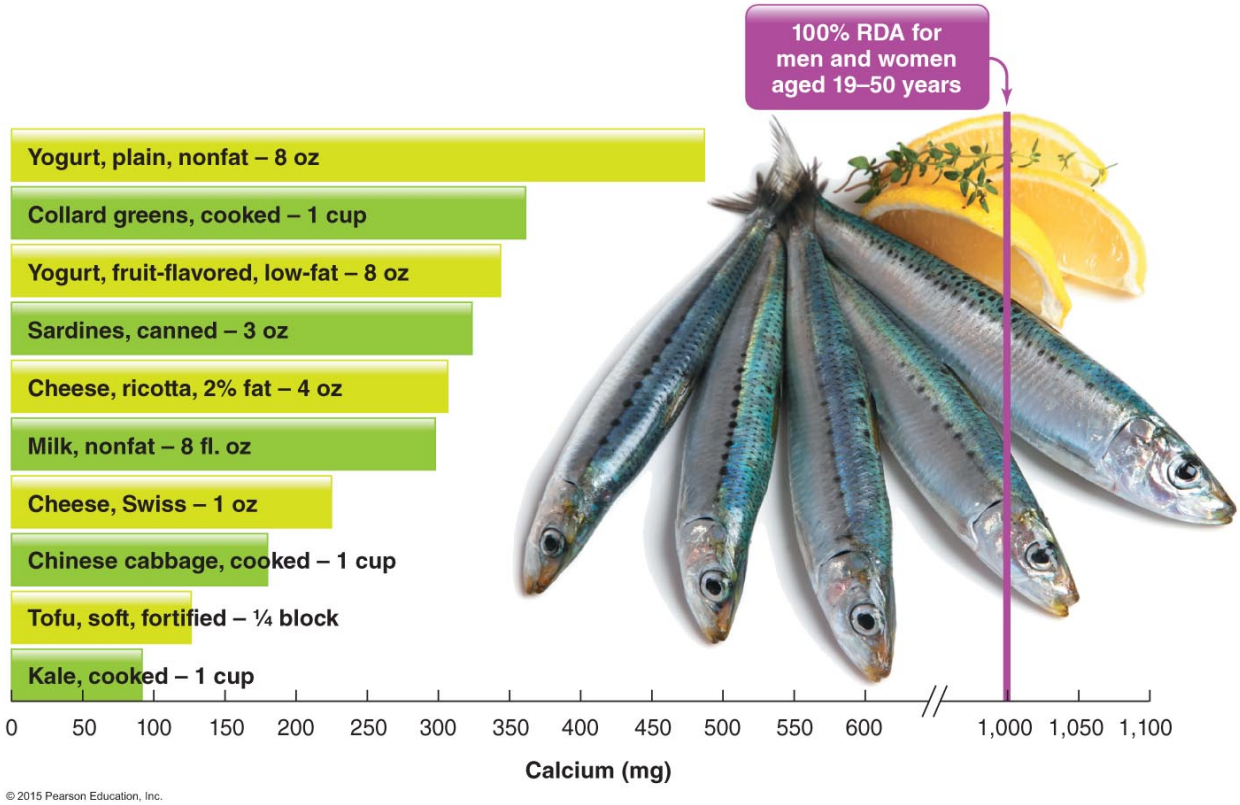

Figure 9.12: Common Food Sources of Calcium

- What if you consume too much calcium?
  - Excess calcium is excreted from the body

  - Calcium supplements can lead to mineral imbalances
  - Hypercalcemia (high blood calcium) can be caused by cancer and overproduction of PTH

- What if you don't consume enough calcium?
  - Hypocalcemia (low blood calcium) can be caused by kidney disease or vitamin D deficiency

9.12 Phosphorus

- Phosphorus (as phosphate) is the primary intracellular negatively charged electrolyte
- Functions of phosphorus
  - Critical to mineral composition of bone
  - Required for proper fluid balance
  - Component of lipoproteins, cell membranes, DNA and RNA, and several energy molecules
- Recommended intake
  - RDA for phosphorus is 700 mg/day
- Sources of phosphorus
  - High in protein-containing foods such as milk, meats, and eggs
  - In processed foods as a food additive
  - In soft drinks as phosphoric acid
- What if you consume too much phosphorus?
  - Kidney disease and excessive vitamin D supplements or consumption of too many phosphorus-containing antacids can cause elevated phosphorus levels, muscle spasms, and convulsions
- What if you don't consume enough phosphorus?
  - Deficiencies are rare in healthy adults
  - Malnutrition, critical illness

9.13 Magnesium

- The bones contain 50–60% of the body's magnesium
- Functions of magnesium
  - A mineral found in bone structure
  - Cofactor for over 300 enzyme systems
  - Required for the production of ATP
  - Plays an important role in DNA and protein synthesis and repair
- Recommended intake
  - RDA varies based on age and gender
  - 310 mg/day for women aged 19–30
  - 400 mg/day for men aged 19–30
- Sources of magnesium
  - Green leafy vegetables, whole grains, seeds, nuts, seafood, beans, some dairy products

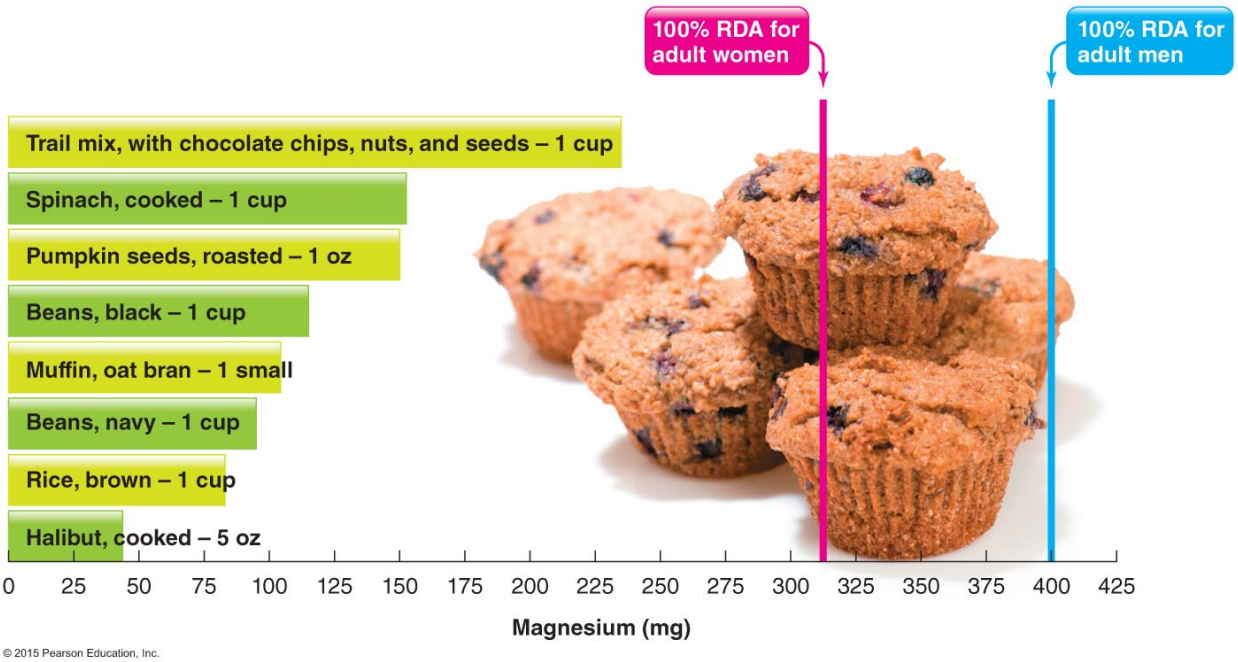

Figure 9.13: Common Food Sources of Magnesium

- What if you consume too much magnesium?
  - No toxicity from magnesium in food

  - Magnesium supplements can cause diarrhea, nausea, cramps, dehydration, and cardiac arrest
  - **Hypermagnesemia** – high blood magnesium levels
- What if you don't consume enough magnesium?
  - Hypomagnesemia can result in low blood calcium and osteoporosis
  - Other symptoms include muscle cramps, spasms, nausea, weakness, and confusion

9.14 Fluoride

- Fluoride is a trace mineral
  - 99% of the body's fluoride is stored in teeth and bones
- Functions of fluoride
  - Development and maintenance of teeth and bones
  - Combines with calcium and phosphorus to make tooth enamel stronger, which protects teeth from dental caries (cavities)
- Recommended intake
  - RDA for women is 3 mg/day
  - RDA for men is 4 mg/day
- Sources of fluoride
  - Fluoridated dental products
  - Fluoridated water
- What if you consume too much fluoride?
  - **Fluorosis (excess fluoride)** – creates porous tooth enamel; teeth become stained and pitted
- What if you don't consume enough fluoride?
  - Dental caries (cavities)

Figure 9.14: Fluorosis

9.15 Vitamin D

- Fat-soluble vitamin
- Excess is stored in liver and fat tissue
- Can be synthesized by the body by exposure to UV light from the sun
- Is considered a hormone because it is synthesized in one location and acts in other locations

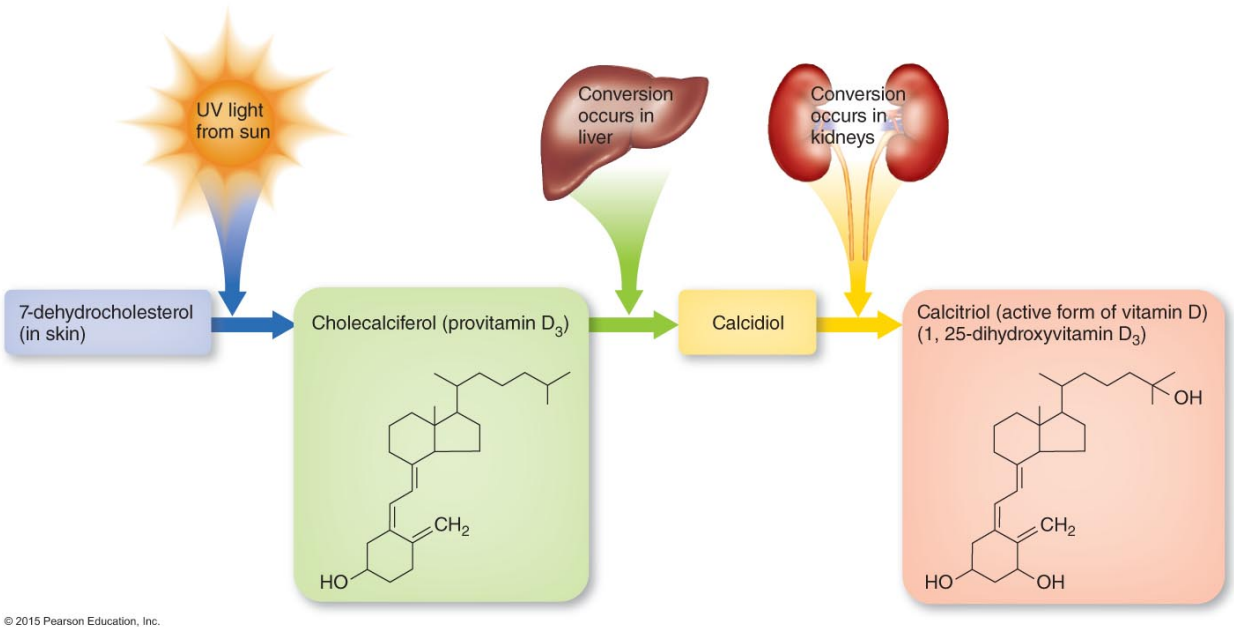

Figure 9.15: Conversion of Sunlight into Vitamin D

Figure 9.16: Vitamin D and Sunlight in North America

- Functions of vitamin D
  - Required for calcium and phosphorus absorption
  - Regulates blood calcium levels
  - Stimulates osteoclasts
  - Necessary for calcification of bone
- Sources of vitamin D

  - Most foods naturally contain very little vitamin D
    - Vitamin D_2 or ergocalciferol is found in plant foods
    - Vitamin D_3 or cholecalciferol is found in animal foods

- Most vitamin D is obtained from fortified foods such as milk and cereal products
- Vegetarians not consuming dairy foods receive vitamin D from the sun, fortified soy products, or supplements

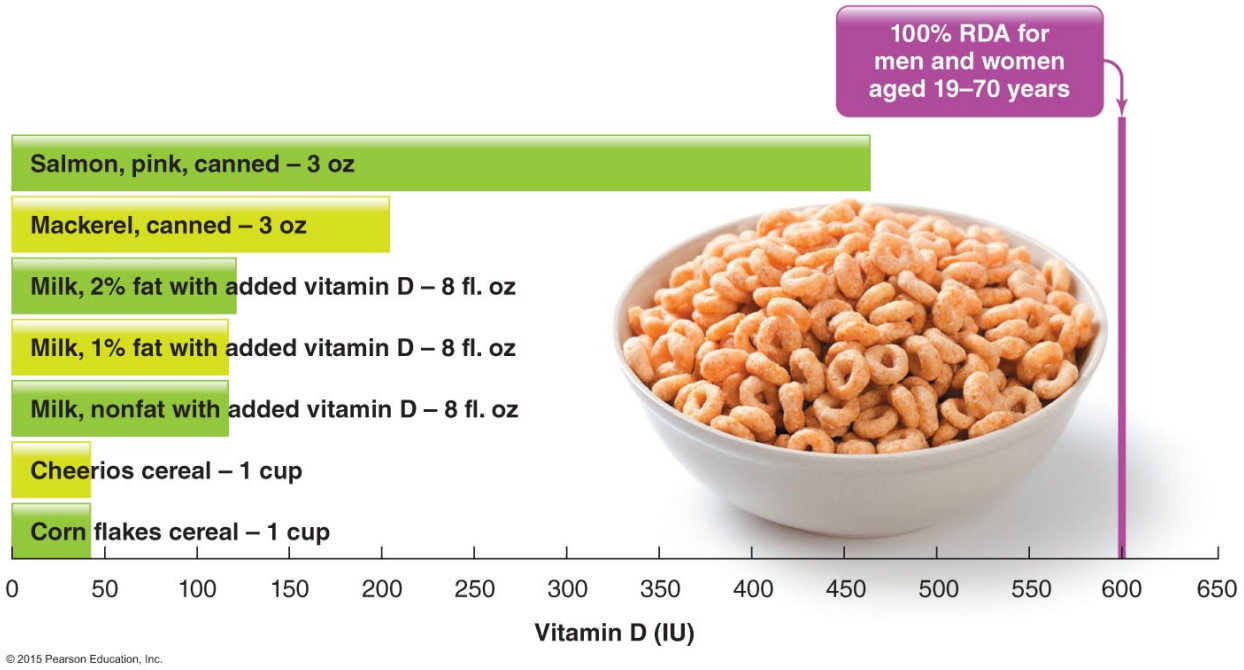

Figure 9.17: Common Food Sources of Vitamin D

- What if you consume too much vitamin D?
  - Occurs with vitamin supplements, *not* excessive exposure to sunlight
  - Results in **hypercalcemia** – high blood calcium
- What if you don't consume enough vitamin D?
  - Occurs with diseases that reduce intestinal absorption of fat and limited exposure to sunlight
  - **Rickets** – inadequate mineralization or demineralization of bones; occurs in children
  - **Osteomalacia** – loss of bone mass in adults

9.16 In Depth: Osteoporosis

- Osteoporosis is a disease characterized by
  - Low bone mass
  - Deterioration of bone tissue
  - Fragile bones, leading to bone fractures
  - Compaction of bone; decreased height
  - Shortening and hunching of the spine: dowager's hump

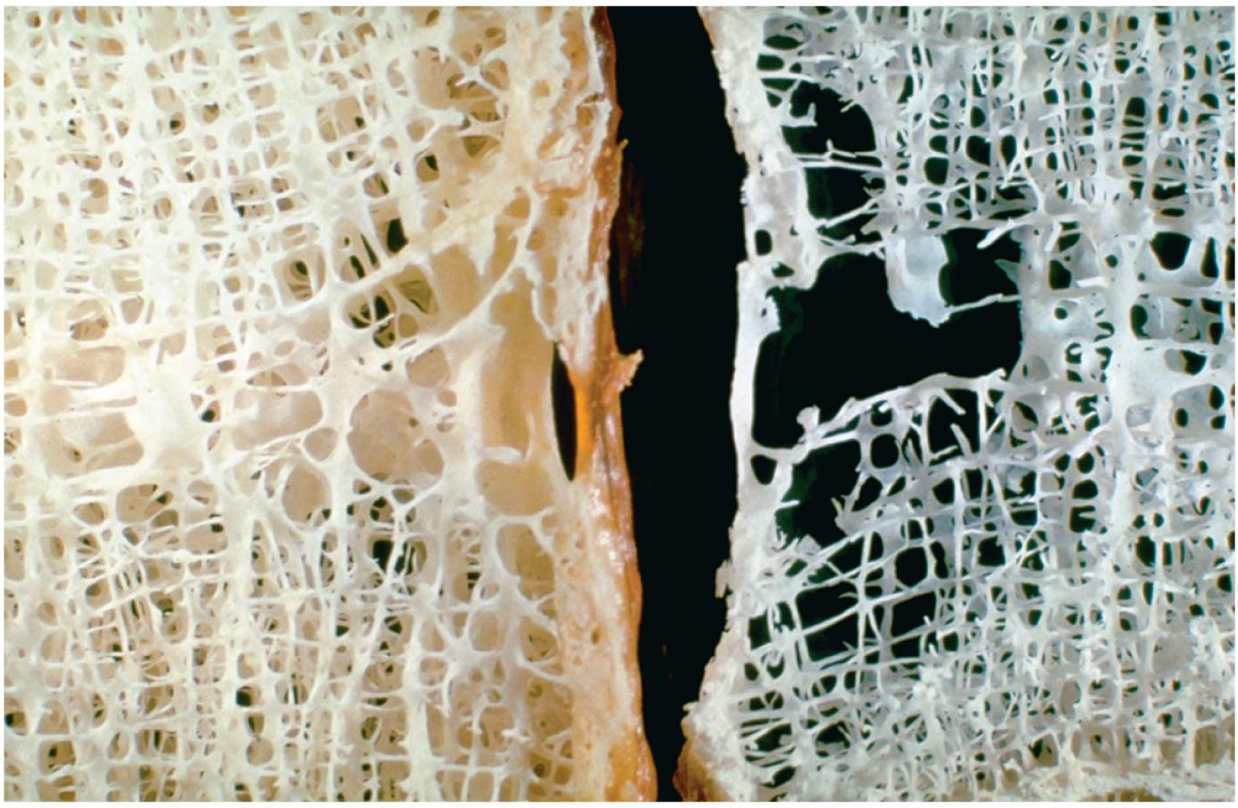

Figure 9.18: Osteoporosis

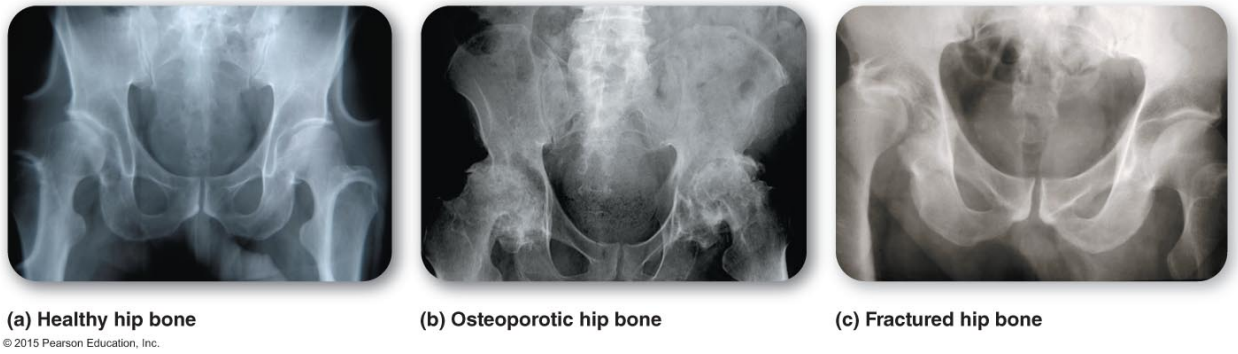

Figure 9.19: Osteoporosis

- Factors influencing the risk of osteoporosis include
  - Age
  - Gender
  - Genetics
  - Tobacco, alcohol, and caffeine use
  - Nutrition
  - Physical activity
  - History of amenorrhea (loss of menstrual function)

Table 9.4: Risk Factors for Osteoporosis

Modifiable Risk Factors	**Nonmodifiable Risk Factors**
Smoking	Older age (elderly)
Low body weight	Caucasian or Asian race
Low calcium intake	History of fractures as an adult
Low sun exposure	Family history of osteoporosis
Alcohol abuse	Gender (female)
History of amenorrhea (failure to menstruate) in women with inadequate nutrition	History of amenorrhea (failure to menstruate) in women with no recognizable cause
Estrogen deficiency (females)	
Testosterone deficiency (males)	
Repeated falls	
Sedentary lifestyle	

Source: Information adapted from the National Osteoporosis Society. 2014. Factors that increase your risk of osteoporosis and fracture. https://www.nos.org.uk/healthy-bones-and-risks/are-you-at-risk

- Age is a factor for osteoporosis because

  - Bone mass decreases with age
  - Age-related hormonal changes influence bone density (reduced estrogen and testosterone production)
  - Older adults are less able to absorb vitamin D

- Gender is a risk factor for osteoporosis
  - 80% of Americans with osteoporosis are women
  - Women have lower bone density than men
  - Estrogen loss in postmenopausal women causes increased bone loss
  - Women live longer than men
  - Social pressure on girls to be thin leads some to harmful dieting when bone mass is still building

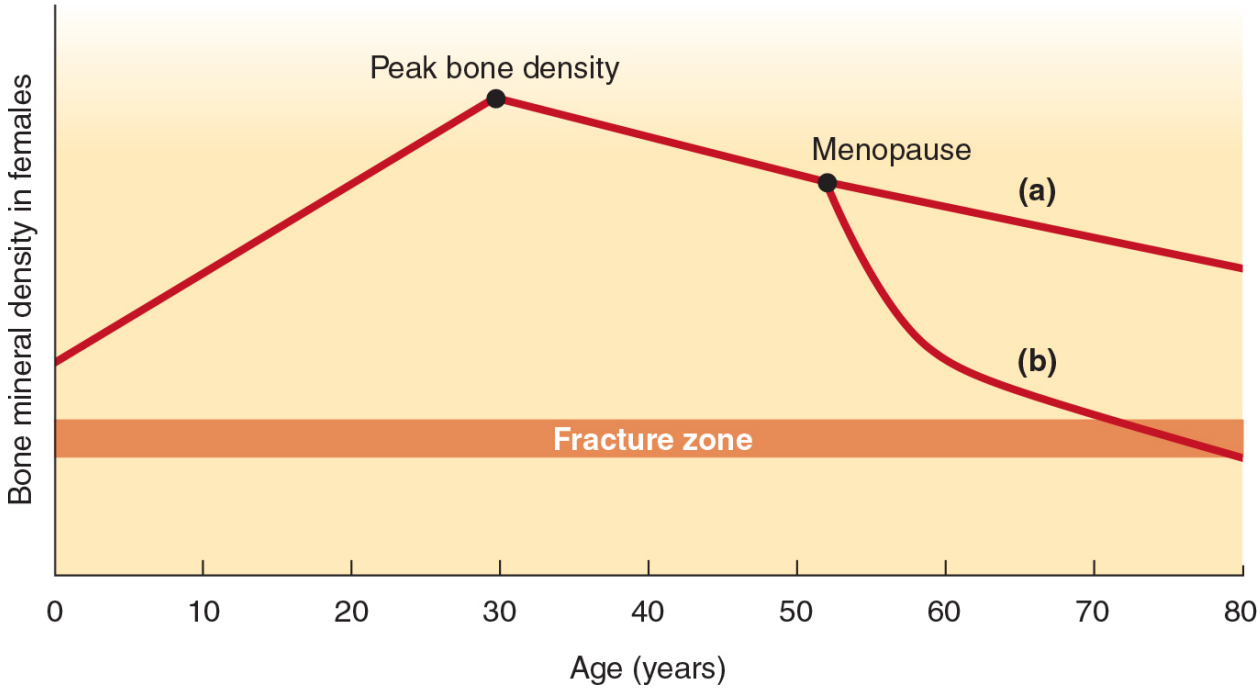

Figure 9.20: Osteoporosis

- Tobacco, alcohol, and caffeine use
  - Cigarette smoking decreases bone density due to its effects on hormones that influence bone formation and resorption
- Alcohol consumption beyond 1–2 drinks per day is associated with a higher risk of fractures
- Caffeine increases calcium loss in the urine

- Nutritional factors influence risk
  - Diets high in fruits and vegetables are associated with improved bone health
- Physical activity influences risk
  - Regular exercise causes stress to bones, leading to increased bone mass
  - Weight-bearing activities (walking, jogging) are especially helpful in increasing bone mass
- There is no cure for osteoporosis
- The progression of osteoporosis may be slowed by
  - Adequate calcium and vitamin D intake
  - Regular exercise
  - Some medications, including hormone replacement therapy (HRT)