Chapter 9

Nutrients Important for Bone Health

Big Idea

Build peak bone mass during youth to preserve bone mass during aging.

Milk has been and will continue to be a key component in the diets of millions of people. During the agrarian age, people drank milk from the animals they raised. At the dawn of the twentieth century, nutritional science appeared on the scene and quickly acknowledged milk's importance as a part of a balanced diet. For over one hundred years, several US government nutrition programs have highlighted milk's value. How does milk get from a cow to your doorstep?

In the early nineteenth century raw milk was distributed in carelessly washed metal pails and was, at times, still warm from the cow when it reached its destination. If you got up too late to fetch your milk you received little of the coagulated cream on top. This distribution method did not suffice for the widespread delivery of fresh milk to the masses living in cities, thus milk and its preparation methods had to be changed in several ways. Consuming raw milk can be a potential health hazard as harmful bacteria such as Salmonella, E. coli, and Listeria may be present, all of which are known as culprits for many foodborne illnesses. Pasteurization, homogenization, fortification, and eventually packaging in plastic containers were developed to address distribution and food-safety issues.

In 1863, Louis Pasteur invented pasteurization. Pasteurization involves heating the milk to a high temperature (greater than 161 degrees Fahrenheit) for a short time (less than 20 seconds) and is an effective method of killing 99.999 percent of bacteria, molds, and yeast. Pasteurization was a welcome technology as it extended the shelf life of milk by about two to three weeks and destroyed infectious bacteria, such as those that caused diphtheria, typhoid fever, tuberculosis, and scarlet fever, thereby making milk safe to drink. Unfortunately, pasteurization also destroys vitamins, enzymes, and some beneficial bacteria. Milk may also be microfiltered, a process that pushes milk forcefully through ceramic filters that remove bacteria. Milk is homogenized so that it does not separate into butter-fat globules and milk

fluid. During homogenization milk is emulsified under intense pressure as it is pumped through narrow tubes. Fat globules are broken into smaller ones and they do not recoagulate. The homogenization process, however, does not have a negative effect on the milk's nutritional value or effectiveness.

Milk: An ever-changing product of the dairy industry.

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The dairy industry has gone through many changes to increase milk production, quality, and distribution. As a result of pasteurization and to meet the health needs of the American population, a public-policy decision was made in 1933 to fortify milk with vitamin D to prevent childhood bone disease. More recently, changes include expanding the number of cows per herd, increasing milk production per cow by over six-fold, improving dairy cow nutrition and herd management practices, and advancing technologies that increase storage time and decrease bacterial contamination. How did milk production increase six-fold per cow? Most cows are Holsteins, bred with optimum genetics for producing milk. They are provided with the best nutrition, a dietary pattern taken from many scientific studies that provides optimal nutrients specifically for cows to make milk. Some people are concerned about the changes that were brought about by controversial methods, such as injecting dairy cows with bovine growth hormone. This increases milk production by about 15 percent, but also increases the risk of udder infection in the cows. As a result, antibiotics are widely used in the dairy industry. There is evidence linking widespread antibiotic use with the increase in the resistance of bacteria. This practice also decreases the effectiveness of antibiotics in humans.

You Decide

How will you ensure that you are building strong bones and will be able to avoid detrimental bone loss in old age?

Osteoporosis is a childhood bone disease with old age consequences.

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It is estimated that every three seconds around the globe, an osteoporotic fracture occurs. Over two hundred million women worldwide suffer from this disease.Kanis, J. A. *WHO Technical Report*, (University of Sheffield, United Kingdom, 2007): 66. Statistics also show that one in three women and one in five men over sixty will experience an osteoporotic fracture.European Foundation for Osteoporosis and National Osteoporosis Foundation. "Who Are Candidates for Prevention and Treatment for Osteoporosis?" *Osteoporos Int* 7, no. 1 (1997):Melton 3rd, L. J. et al. "Perspective. How Many Women Have Osteoporosis?" *J Bone Miner Res* 7 (1992): 1005.Kanis, J. A. et al. "Long-Term Risk of Osteoporotic Fracture." *Malmo Osteoporos Int* 11 (2000): 669. How can you prepare yourself and fortify your bones against this disease? Milk is a ready and convenient source of calcium and vitamin D, but one glass of milk per day is not sufficient to provide adequate intake of these nutrients and many people have an allergy or intolerance to dairy products. Other good sources of calcium and vitamin D are soybeans, parsley, kale, salmon, broccoli, eggs, tuna, beans, and fortified products such as soymilk, rice milk, and almond milk. As you read this chapter you will learn the importance of building and preserving healthy bones through proper diet and exercise. Whatever you decide, know that your bone health will be affected by your dietary and lifestyle choices for years to come.

9.1 Bone Structure and Function

LEARNING OBJECTIVE

1. Explain the process of bone remodeling and explain why bones are living tissues.

Your bones are stronger than reinforced concrete. Bone tissue is a composite of fibrous **collagen**[1] strands that resemble the steel rebar in concrete and a hardened mineralized matrix that contains large amounts of calcium, just like concrete. But this is where the similarities end. Bone outperforms reinforced concrete by several orders of magnitude in compression and tension strength tests. Why? The microarchitecture of bone is complex and built to withstand extreme forces. Moreover, bone is a living tissue that is continuously breaking down and forming new bone to adapt to mechanical stresses.

Video Link 9.1

The Human Body: Bone Strength

This video is a dramatic demonstration of bone strength.

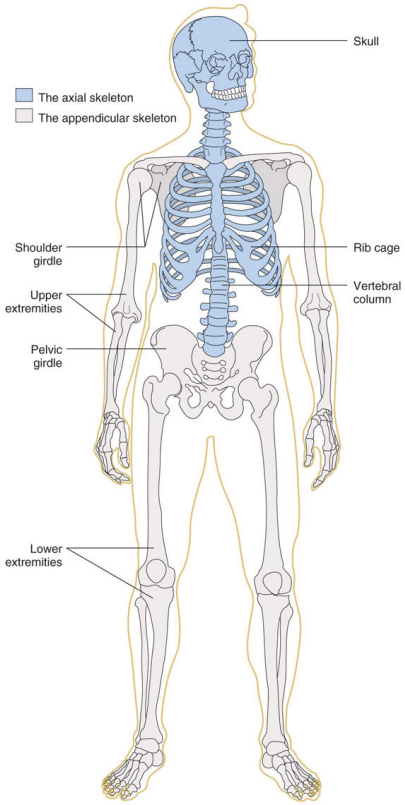
http://www.yourdiscovery.com/video/human-body-strength-bones/

Why Is the Skeletal System Important?

The human skeleton consists of 206 bones and other connective tissues called ligaments, tendons, and cartilage. Ligaments connect bones to other bones, tendons connect bones to muscles, and cartilage provides bones with more flexibility and acts as a cushion in the joints between bones. The skeleton's many bones and connective tissues allow for multiple types of **movement** such as typing and running. The skeleton provides **structural support** and **protection** for all the other organ systems in the body. The skull, or cranium, is like a helmet and protects the eyes, ears, and brain. The ribs form a cage that surrounds and protects the lungs and heart. In addition to aiding in movement, protecting organs, and providing

1. A strong, fibrous protein made up of mostly glycine and proline amino acids.

structural support, **red** and **white blood cells** and **platelets** are synthesized in bone marrow. Another vital function of bones is that they act as a **storage depot** for minerals such as calcium, phosphorous, and magnesium. Although bone tissue may look inactive at first glance, at the microscopic level you will find that bones are continuously breaking down and reforming. Bones also contain a complex network of canals, blood vessels, and nerves that allow for nutrient transport and communication with other organ systems.



The human skeleton contains 206 bones. It is divided into two main parts, the axial and appendicular.

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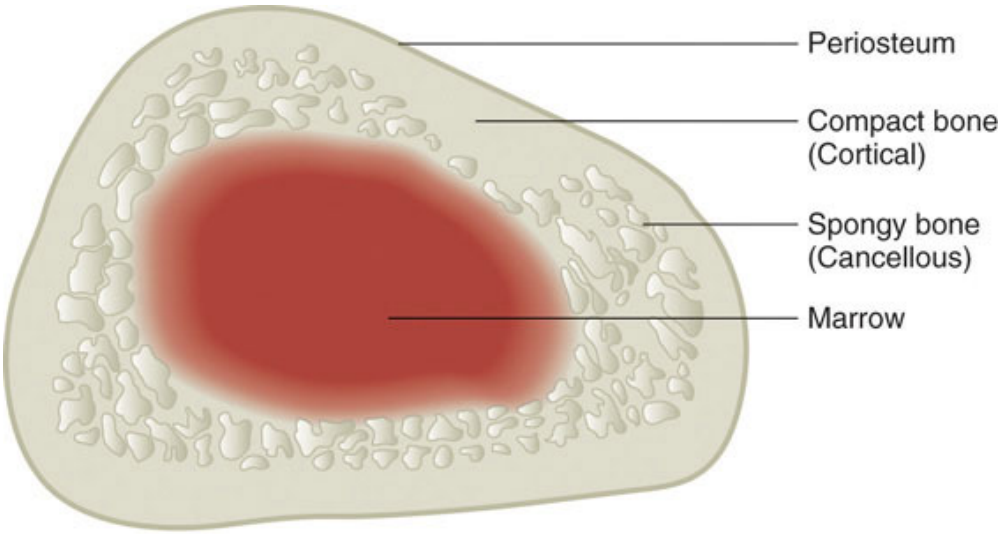
Bone Anatomy and Structure

To optimize bone health through nutrition, it is important to understand bone anatomy. The skeleton is composed of two main parts, the axial and the appendicular parts. The axial skeleton consists of the skull, vertebral column, and rib cage, and is composed of eighty bones. The appendicular skeleton consists of the shoulder girdle, pelvic girdle, and upper and lower extremities and is composed of 126 bones. Bones are also categorized by size and shape. There are four types of

bone: long bones, short bones, flat bones, and irregular bones. The longest bone in your body is the femur (or "thigh" bone), which extends from your hip to your knee. It is a long bone and functions to support your weight as you stand, walk, or run. Your wrist is composed of eight irregular-shaped bones, which allow for the intricate movements of your hands. Your twelve ribs on each side of your body are curved flat bones that protect your heart and lungs. Thus, the bones' different sizes and shapes allow for their different functions.

Figure 9.1 *The Arrangement of Bone Tissues*



Bone is composed of organized living tissues.

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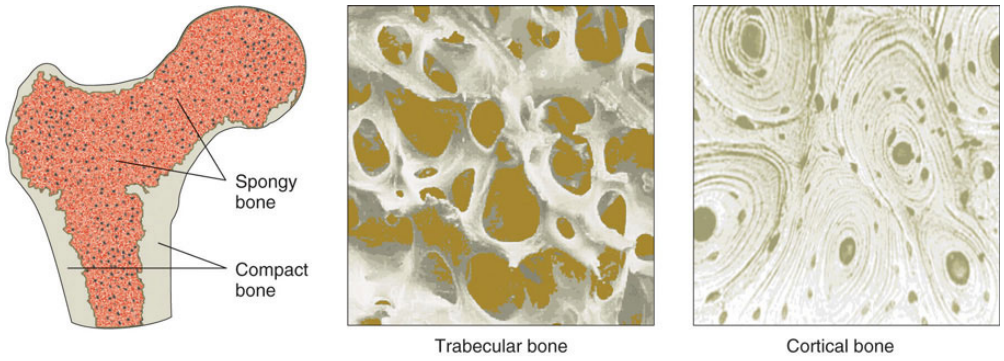
Bones are composed of approximately 65 percent inorganic material known as mineralized matrix. This mineralized matrix consists of mostly crystallized **hydroxyapatite**[2]. The bone's hard crystal matrix of bone tissue gives it its rigid structure. The other 35 percent of bone is organic material, most of which is the fibrous protein, collagen. The collagen fibers are networked throughout bone tissue and provide it with flexibility and strength. The bones' inorganic and organic materials are structured into two different tissue types. There is spongy bone, also called **trabecular or cancellous bone**[3], and compact bone, also called **cortical bone**[4] (Figure 9.1 "The Arrangement of Bone Tissues"). The two tissue types differ in their microarchitecture and porosity. Trabecular bone is 50 to 90 percent porous and appears as a lattice-like structure under the microscope. It is found at the ends of long bones, in the cores of vertebrae, and in the pelvis. Trabecular bone tissue makes up about 20 percent of the adult skeleton. The more dense cortical bone is

2. The primary crystal of bone formed from calcium and phosphorous.
3. Less dense bone with a lattice-like structure. Also called spongy bone.
4. Dense, strong bone that surrounds trabecular bone tissue. Also called compact bone.

about 10 percent porous and it looks like many concentric circles, similar to the rings in a tree trunk, sandwiched together (Figure 9.2). Cortical bone tissue makes up approximately 80 percent of the adult skeleton. It surrounds all trabecular tissue and is the only bone tissue in the shafts of long bones.

Figure 9.2



The two basic tissue types of bones are trabecular and cortical. Trabecular (spongy) and cortical (compact) bone tissues differ in their microarchitecture and porosity.

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Bone tissue is arranged in an organized manner. A thin membrane, called the periosteum, surrounds the bone. It contains connective tissue with many blood vessels and nerves. Lying below the periosteum is the cortical bone. In some bones, the cortical bone surrounds the less-dense trabecular bone and the bone marrow lies within the trabecular bone, but not all bones contain trabecular tissue or marrow.

Bone Tissues and Cells, Modeling and Remodeling

Bone tissue contains many different cell types that constantly resize and reshape bones throughout growth and adulthood. Bone tissue cells include osteoprogenitor cells, osteoblasts, osteoclasts, and osteocytes. The osteoprogenitor cells are cells that have not matured yet. Once they are stimulated, some will become **osteoblasts**[5], the bone builders, and others will become **osteoclasts**[6], the cells that break bone down. **Osteocytes**[7] are the most abundant cells in bone tissue. Osteocytes are star-shaped cells that are networked throughout the bone via their long cytoplasmic arms that allow for the exchange of nutrients and other factors from bones to the blood and lymph.

5. Cells that build new bone tissue.
6. Large cells that break down bone tissue.
7. Star-shaped cells that are the most abundant cell type in bone tissue.

Bone Modeling and Remodeling

Video 9.1

Bone Modification

(click to see video)

This video on bone remodeling demonstrates a bone's adaptability to mechanical stresses.

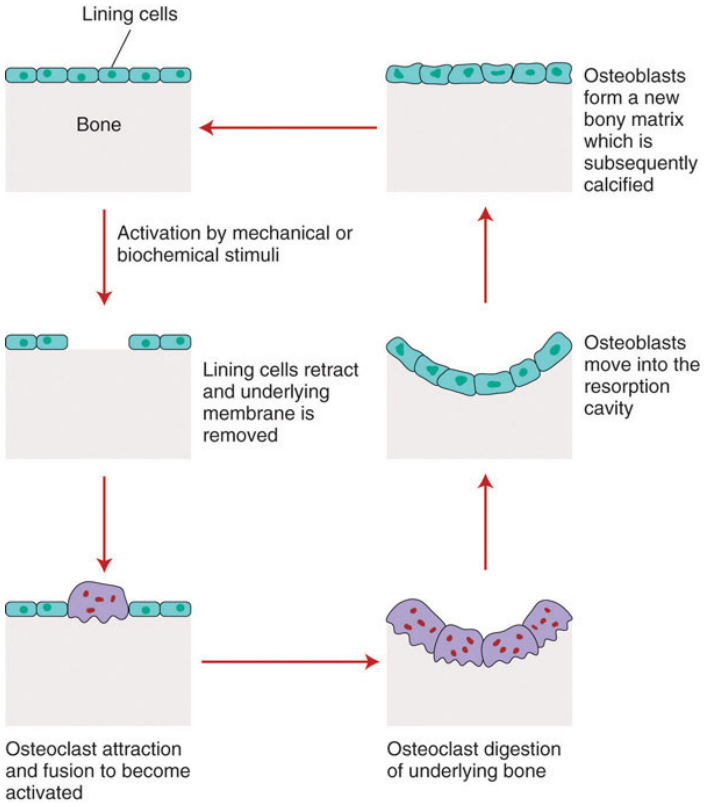
During infancy, childhood, and adolescence, bones are continuously growing and changing shape through two processes called growth (or ossification) and modeling. In fact, in the first year of life, almost 100 percent of the bone tissue in the skeleton is replaced. In the process of modeling, bone tissue is dismantled at one site and built up at a different site. In adulthood, our bones stop growing and modeling, but continue to go through a process of **bone remodeling**[8]. In the process of remodeling, bone tissue is degraded and built up at the same location. About 10 percent of bone tissue is remodeled each year in adults. As observed in Note 9.12 "Video 9.1", bones adapt their structure to the forces acting upon them, even in adulthood. This phenomenon is called **Wolff's law**, which states that bones will develop a structure that is best able to resist the forces acting upon them. This is why exercising, especially when it involves weight-bearing activities, increases bone strength.

The first step in bone remodeling is osteocyte activation (see Figure 9.3). Osteocytes detect changes in mechanical forces, calcium homeostasis, or hormone levels. In the second step, osteoclasts are recruited to the site of the degradation. Osteoclasts are large cells with a highly irregular ruffled membrane. These cells fuse tightly to the bone and secrete hydrogen ions, which acidify the local environment and dissolve the minerals in the bone tissue matrix. This process is called **bone resorption**[9] and resembles pit excavation. Our bodies excavate pits in our bone tissue because bones act as storehouses for calcium and other minerals. Bones supply these minerals to other body tissues as the demand arises. Bone tissue also remodels when it breaks so that it can repair itself. Moreover, if you decide to train to run a marathon your bones will restructure themselves by remodeling to better able sustain the forces of their new function.

8. Process in which bone tissue is broken down and then rebuilt at the same location.

9. Process in which osteoclasts secrete hydrogen ions, which acidify the local environment and dissolve the minerals in the bone tissue matrix.

Figure 9.3



Bone remodeling occurs in four steps: activation, osteoclast resorption, surface preparation, and building new bone tissue.

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After a certain amount of bone is excavated, the osteoclasts begin to die and bone resorption stops. In the third step of bone remodeling, the site is prepared for building. In this stage, sugars and proteins accumulate along the bone's surface, forming a cement line which acts to form a strong bond between the old bone and the new bone that will be made. These first three steps take approximately two to three weeks to complete. In the last step of bone remodeling, osteoblasts lay down new osteoid tissue that fills up the cavities that were excavated during the resorption process. **Osteoid**[10] is bone matrix tissue that is composed of proteins such as collagen and is not mineralized yet. To make collagen, vitamin C is required. A symptom of vitamin C deficiency (known as scurvy) is bone pain, which is caused by diminished bone remodeling. After the osteoid tissue is built up, the bone tissue begins to mineralize. The last step of bone remodeling continues for months, and for a much longer time afterward the mineralized bone is continuously packed in a more dense fashion.

10. Bone tissue that is not mineralized.

Thus, we can say that bone is a living tissue that continually adapts itself to mechanical stress through the process of remodeling. For bone tissue to remodel certain nutrients such as calcium, phosphorus, magnesium, fluoride, vitamin D, and vitamin K are required.

KEY TAKEAWAYS

- The skeletal system aids in movement, provides support for and protects organs, synthesizes platelets and red and white blood cells, and serves as a storage depot for minerals, such as calcium.
- The skeleton is composed of connective tissues including bones, cartilage, tendons, and ligaments.
- Bones are made up of a periosteum that surrounds compact bone, which in turn surrounds trabecular bone. Bone marrow resides within the trabecular bone.
- Bone tissue cells are osteoprogenitor cells, osteoblasts, osteoclasts, and osteocytes.
- Bone is a living tissue that adapts to mechanical stress via the remodeling process.
- Bone remodeling is a multifaceted process involving four steps: osteocyte activation, osteoclast-mediated bone resorption, surface preparation, and osteoblast-mediated bone building.
- The bone remodeling process requires certain nutrients such as calcium, phosphorus, magnesium, fluoride, vitamin D, and vitamin K.

DISCUSSION STARTERS

1. Analyze the shape of some of your bones. Recognize the varying structure of different bones that allows for the performance of multiple functions. With a classmate, compare the shape of hand bones (that allow for fine articulated movements) to the shape of foot bones and toe bones (that allow more awkward movement). If you designed a bone system to grasp a doorknob or hang upside down, what would it look like? For inspiration, go to the web and look at bat bones, monkey bones, and human bones.
2. Why do you think it hurts when you hit your funny bone? Why are there no bones to protect the nerves?

9.2 Bone Mineral Density Is an Indicator of Bone Health

LEARNING OBJECTIVE

1. Identify the tests used to measure bone mass.

Bone mineral density (BMD)[11] is a measurement of the amount of calcified tissue in grams per centimeter squared of bone tissue. BMD can be thought of as the total amount of bone mass in a defined area. When BMD is high, bone strength will be great. Similar to measuring blood pressure to predict the risk of stroke, a BMD measurement can help predict the risk of bone fracture. The most common tool used to measure BMD is called **dual energy X-ray absorptiometry (DEXA)**[12]. During this procedure, a person lies on their back and a DEXA scanner passes two X-ray beams through their body. The amount of X-ray energy that passes through the bone is measured for both beams. The total amount of the X-ray energy that passes through a person varies depending on their bone thickness. Using this information and a defined area of bone, the amount of calcified tissue in grams per unit area (cm^2) is calculated. Most often the DEXA scan focuses on measuring BMD in the hip and the spine. These measurements are then used as indicators of overall bone strength and health. DEXA is the cheapest and most accurate way to measure BMD. It also uses the lowest dose of radiation. Other methods of measuring BMD include quantitative computed tomography (QCT) and radiographic absorptiometry. People at risk for developing bone disease are advised to have a DEXA scan. We will discuss the many risk factors linked to an increased incidence of osteoporosis and the steps a person can take to prevent the disease from developing.

KEY TAKEAWAYS

- Bone-mineral density is a measurement of calcified bone tissue and positively correlates with overall bone health.
- DEXA is a clinical tool used to assess BMD.

11. Measurement of the amount of calcified tissue in grams per centimeter squared of bone tissue.
12. A procedure during which two X-ray beams pass through a person and calculate the amount of calcified tissue in grams per unit area of bone.

DISCUSSION STARTER

1. Evaluate the animation below that discusses the technology of the DEXA procedure. Form a hypothesis on why doctors recommend this procedure for women over age fifty. Discuss your findings.

   DEXA—Dual Energy X-Ray Absorptiometry

(click to see video)

9.3 Micronutrients Essential for Bone Health: Calcium and Vitamin D

LEARNING OBJECTIVES

1. List the four primary functions of calcium in the human body.
2. Identify the Dietary Reference Intake for calcium.

Calcium

The most abundant mineral in the body is **calcium**[13], and greater than 99 percent of it is stored in bone tissue. Although only 1 percent of the calcium in the human body is found in the blood and soft tissues, it is here that it performs the most critical functions. Blood calcium levels are rigorously controlled so that if blood levels drop the body will rapidly respond by stimulating bone resorption, thereby releasing stored calcium into the blood. (This is discussed in further detail shortly.) Thus, bone tissue sacrifices its stored calcium to maintain blood calcium levels. This is why bone health is dependent on the intake of dietary calcium and also why blood levels of calcium do not always correspond to dietary intake.

Calcium's Functional Roles

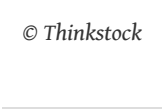
Calcium plays a role in a number of different functions in the body:

- **Bone and tooth formation.** The most well-known calcium function is to build and strengthen bones and teeth. Recall that when bone tissue first forms during the modeling or remodeling process, it is unhardened, protein-rich osteoid tissue. In the osteoblast-directed process of bone mineralization, calcium phosphates (salts) are deposited on the protein matrix. The calcium salts gradually crystallize into hydroxyapatite, which typically makes up about 65 percent of bone tissue. When your diet is calcium deficient, the mineral content of bone decreases causing it to become brittle and weak. Thus, increased

Calcium is an important mineral for multiple body functions. It is important to consume calcium-rich foods to sustain proper dietary intake of calcium.

13. The most abundant mineral in mineralized bone tissue. Good dietary sources of calcium are dairy products and many vegetables with low oxalate content, such as kale, collard greens, and okra.

calcium intake helps to increase the mineralized content of bone tissue. Greater mineralized bone tissue corresponds to a greater BMD, and to greater bone strength. The varying arrangements of the calcium-rich hydroxyapatite crystals on bone tissue's protein matrix contribute to bone's differing mechanical properties. In tooth enamel, hydroxyapatite crystals are densely packed, making it the most mineralized tissue (more than 95 percent) in the human body. Tooth enamel's densely packed crystal architecture provides it with its incredible strength and durability. The mineralized bone tissue in human teeth is so incredibly strong that back molars can withstand bite forces exceeding four hundred pounds of pressure.



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- **Nerve impulse transmission.** Calcium facilitates electrical impulse transmission from one nerve cell to another. Calcium binds to vesicles that contain neurotransmitters, causing a release into the neural synapses (junction between nerve cells). This allows the flow of ions in and out of nerve cells. If calcium is lacking, nerve-cell function will fail (see Note 9.30 "Interactive 9.1").
- **Muscle contraction.** The flow of calcium ions along the muscle cell's surface and the influx of calcium into the muscle cell are critical for muscle contraction. If calcium levels fall below a crucial range, the muscles can't relax after contracting. The muscles become stiff, and involuntary twitching may ensue in a condition known as tetany.
- **Clotting factors.** When a blood vessel is injured and bleeding starts, it must be stopped or death may result. Clotting factors and platelets are continuously circulating in the blood in case of such an emergency. When an injury occurs, the damaged tissue releases specific factors that activate the circulating clotting factors and platelets. Some of the clotting factors require calcium for activation. If clotting factors weren't activated blood clots would not form.

In addition to calcium's four primary functions calcium has several other minor functions that are also critical for maintaining normal physiology. For example, without calcium, the hormone insulin could not be released from cells in the pancreas and glycogen could not be broken down in muscle cells and used to provide energy for muscle contraction.

Maintaining Calcium Levels

Because calcium performs such vital functions in the body, blood calcium level is closely regulated by the hormones **parathyroid hormone (PTH)**[14], **calcitriol**[15], and **calcitonin**[16]. Calcitriol is the active hormone produced from vitamin D. Parathyroid hormone and calcitriol act in a concert to increase calcium levels in the blood, while

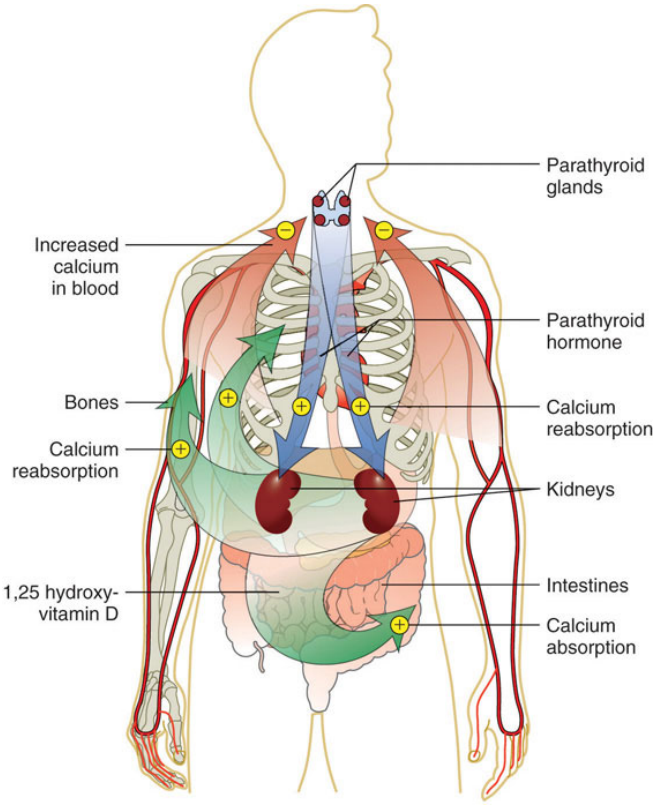
14. Parathyroid hormone acts to increase calcium levels in the blood.
15. The active hormone produced by vitamin D that also helps to increase and regulate blood calcium levels.
16. This hormone has the opposite effect of calcitriol and parathyroid hormone and aids in the maintenance of blood calcium levels by decreasing the calcium level as necessary.

calcitonin does the opposite and decreases blood calcium levels. These hormones maintain calcium levels in the blood in a range between 9 and 11 milligrams per deciliter.

Parathyroid Hormone

Four parathyroid glands, each the size of a grain of rice, can be found in the neck on the sides of the thyroid gland. PTH increases blood calcium levels via three different mechanisms (Figure 9.4). First, PTH stimulates the release of calcium stored in the bone. Second, PTH acts on kidney cells to increase calcium reabsorption and decrease its excretion in the urine. Third, PTH stimulates enzymes in the kidney that activate vitamin D to calcitriol. Calcitriol acts on intestinal cells and increases dietary calcium absorption. Thus, stored calcium is released, more calcium is absorbed from the diet, and less calcium is excreted, all of which increase calcium levels in the blood.

Figure 9.4



This is a typical negative feedback loop in which low calcium levels in the blood stimulate PTH release. PTH increases the movement of calcium from the bones, kidneys, and intestine to the blood with the help of activated vitamin D. The now higher calcium levels in the blood shut off further PTH release.

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Calcitriol (1,25 Hydroxy-Vitamin D)

Calcitriol functions as a second hand to PTH. It not only increases calcium release from bone tissue, but also it increases the absorption of calcium in the small intestine and increases calcium reabsorption by the kidneys. Neither hormone will work unless accompanied by the other. Vitamin D regulates PTH secretion and PTH regulates vitamin D activation to calcitriol. Adequate levels of vitamin D allow for a balance of the calcium between what is released by bone tissue and what is incorporated into bone tissue, so that bone health is not compromised. Calcitriol and PTH function together to maintain calcium homeostasis.

Calcitonin

Calcitonin is a hormone secreted by certain cells in the thyroid gland in response to high calcium levels in the blood. In comparison to PTH and calcitriol, calcitonin plays a small role in regulating calcium levels on a day-to-day basis. This is because as calcium levels rise in the blood, calcium feedback inhibits PTH release and effectively shuts off the actions of PTH and calcitriol. This route of feedback inhibition helps prevent calcium's further accumulation in the blood. At higher nonphysiological concentrations, calcitonin lowers blood calcium levels by increasing calcium excretion in the urine, preventing further absorption of calcium in the gut and by directly inhibiting bone resorption.

Other Health Benefits of Calcium in the Body

Besides forming and maintaining strong bones and teeth, calcium has been shown to have other health benefits for the body, including:

- **Cancer.** The National Cancer Institute reports that there is enough scientific evidence to conclude that higher intakes of calcium decrease colon cancer risk and may suppress the growth of polyps that often precipitate cancer. Although higher calcium consumption protects against colon cancer, some studies have looked at the relationship between calcium and prostate cancer and found higher intakes may increase the risk for prostate cancer; however the data is inconsistent and more studies are needed to confirm any negative association.
- **Blood pressure.** Multiple studies provide clear evidence that higher calcium consumption reduces blood pressure. A review of twenty-three observational studies concluded that for every 100 milligrams of

calcium consumed daily, systolic blood pressure is reduced 0.34 millimeters of mercury (mmHg) and diastolic blood pressure is decreased by 0.15 mmHg.Birkett, N. J. "Comments on a Meta-Analysis of the Relation between Dietary Calcium Intake and Blood Pressure." *Am J Epidemiol* 148, no. 3 (1998): 223–28. http://aje.oxfordjournals.org/content/148/3/223.long. There is emerging evidence that higher calcium intakes prevent against other risk factors for cardiovascular disease, such as high cholesterol and obesity, but the scientific evidence is weak or inconclusive.

- **Kidney stones.** Another health benefit of a high-calcium diet is that it blocks kidney stone formation. Calcium inhibits the absorption of oxalate, a chemical in plants such as parsley and spinach, which is associated with an increased risk for developing kidney stones. Calcium's protective effects on kidney stone formation occur only when you obtain calcium from dietary sources. Calcium supplements may actually increase the risk for kidney stones in susceptible people.

Calcium Needs, Sources, and Bioavailability

Dietary Reference Intake for Calcium

The recommended dietary allowances (RDA) for calcium are listed in Table 9.1 "Dietary Reference Intakes for Calcium". The RDA is elevated to 1,300 milligrams per day during adolescence because this is the life stage with accelerated bone growth. Studies have shown that a higher intake of calcium during puberty increases the total amount of bone tissue that accumulates in a person. For women above age fifty and men older than seventy-one, the RDAs are also a bit higher for several reasons including that as we age, calcium absorption in the gut decreases, vitamin D_3 activation is reduced, and maintaining adequate blood levels of calcium is important to prevent an acceleration of bone tissue loss (especially during menopause). Currently, the dietary intake of calcium for females above age nine is, on average, below the RDA for calcium. The Institute of Medicine (IOM) recommends that people do not consume over 2,500 milligrams per day of calcium as it may cause adverse effects in some people.

Table 9.1 Dietary Reference Intakes for Calcium

Age Group	RDA (mg/day)	UL (mg/day)
Infants (0–6 months)	200*	–
Infants (6–12 months)	260*	–
Children (1–3 years)	700	2,500
*** denotes Adequate Intake**		

Age Group	RDA (mg/day)	UL (mg/day)
Children (4–8 years)	1,000	2,500
Children (9–13 years)	1,300	2,500
Adolescents (14–18 years)	1,300	2,500
Adults (19–50 years)	1,000	2,500
Adult females (50–71 years)	1,200	2,500
Adults, male & female (> 71 years)	1,200	2,500
*** denotes Adequate Intake**		

Source: Ross, A. C. et al. "The 2011 Report on Dietary Reference Intakes for Calcium and Vitamin D from the Institute of Medicine: What Clinicians Need to Know." J Clin Endocrinol Metab 96, no. 1 (2011): 53–8. US National Library of Medicine. http://www.ncbi.nlm.nih.gov/pubmed/21118827.

Incorporate tofu, an excellent source of calcium, into your diet. Tofu kabobs make a delicious meal.

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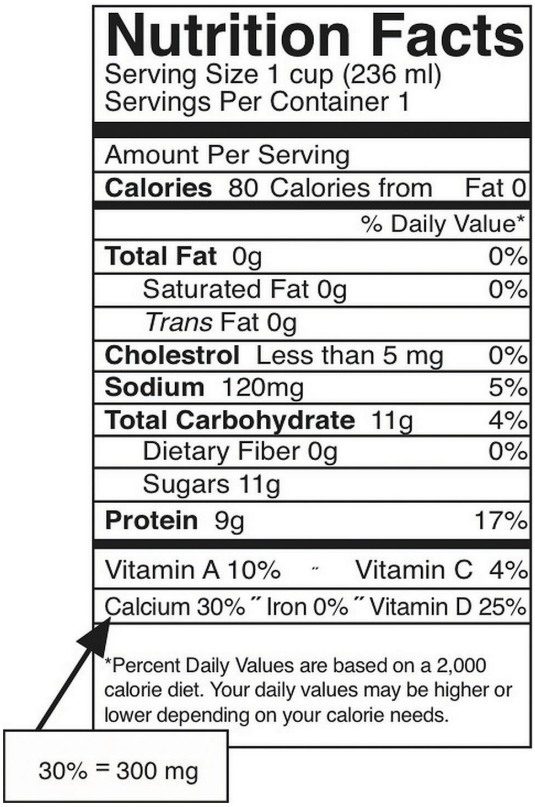
In the typical American diet, calcium is obtained mostly from dairy products, primarily cheese. A slice of cheddar or Swiss cheese contains just over 200 milligrams of calcium. One cup of nonfat milk contains approximately 300 milligrams of calcium, which is about a third of the RDA for calcium for most adults. Foods fortified with calcium such as cereals, soy milk, and orange juice also provide one third or greater of the calcium RDA. Although the typical American diet relies mostly on dairy products for obtaining calcium, there are many other good nondairy sources of calcium (see Note 9.28 "Tools for Change" in Section 9.3 "Micronutrients Essential for Bone Health: Calcium and Vitamin D" and Table 9.2 "Nondairy Dietary Sources of Calcium"). A food's calcium content can be calculated from the percent daily value (percent DV) displayed on the Nutrition Facts panel (Figure 9.5 "How to Calculate Calcium in Milligrams from the Nutrition Facts Panel"). Since the RDA for calcium used to calculate the daily value (DV) is 1,000 milligrams, you multiply the percent DV by ten to arrive at the calcium content in milligrams for a serving of a particular food. It is important to note that most processed foods offer a poor source for this vital mineral as the refinement process strips away the nutrients in the food.

Tools for Change

If you need to increase calcium intake, are a vegan, or have a food allergy to dairy products, it is helpful to know that there are several plant-based foods that are high in calcium. Broccoli, kale, mustard greens, and Brussel sprouts are excellent sources. One cup of these cooked vegetables provides between 100 and 180 milligrams of calcium. To increase the calcium content in your lunch and add some texture to your food, chop up some kale and put it on your sandwich or in your soup. For a list of nondairy sources that are high in calcium, see Table 9.2 "Nondairy Dietary Sources of Calcium". Additionally, you can find the calcium content for thousands of foods by visiting the USDA National Nutrient Database (http://www.nal.usda.gov/fnic/foodcomp/search/). When obtaining your calcium from a vegan diet, it is important to know that some plant-based foods significantly impair the absorption of calcium. These include spinach, Swiss chard, rhubarb, beets, cashews, and peanuts. With careful planning and good selections, you can ensure that you are getting enough calcium in your diet even if you do not drink milk or consume other dairy products.

Figure 9.5 How to Calculate Calcium in Milligrams from the Nutrition Facts Panel



The percent DV of calcium is given on the Nutrition Facts panel. To convert this to milligrams (mg), multiply this number by ten. This is the amount of calcium in milligrams in one serving. This can be done this easily ONLY for calcium and not for other nutrients because the DV for calcium, based on the RDA for adults between the ages of nineteen and fifty, is equal to 1,000 milligrams.

Table 9.2 Nondairy Dietary Sources of Calcium

Food, Standard Amount	Calcium (mg)	Calories
Fortified ready-to-eat cereals (various), 1 oz.	236–1043	88–106
Soy beverage, calcium fortified, 1 c.	368	98
Sardines, Atlantic, in oil, drained, 3 oz.	325	177
Tofu, firm, prepared with nigarib, ½ c.	253	88
Pink salmon, canned, with bone, 3 oz.	181	118
Collards, cooked from frozen, ½ c.	178	31

Food, Standard Amount	Calcium (mg)	Calories
Molasses, blackstrap, 1 Tbsp.	172	47
Soybeans, green, cooked, ½ c.	130	127
Turnip greens, cooked from frozen, ½ c.	124	24
Ocean perch, Atlantic, cooked, 3 oz.	116	103
Oatmeal, plain and flavored, instant, fortified, 1 packet prepared	99–110	97–157
Cowpeas, cooked, ½ c.	106	80
White beans, canned, ½ c.	96	153
Kale, cooked from frozen, ½ c.	90	20
Okra, cooked from frozen, ½ c.	88	26
Soybeans, mature, cooked, ½ c.	88	149
Blue crab, canned, 3 oz.	86	84
Beet greens, cooked from fresh, ½ c.	82	19
Pak-choi, Chinese cabbage, cooked from fresh, ½ c.	79	10
Clams, canned, 3 oz.	78	126
Dandelion greens, cooked from fresh, ½ c.	74	17
Rainbow trout, farmed, cooked, 3 oz.	73	144

Source: US Department of Agriculture. Appendix B-4, "Nondairy Food Sources of Calcium." *2005 Dietary Guidelines for Americans*. Updated July 9, 2008. http://www.health.gov/dietaryguidelines/dga2005/document/html/appendixb.htm.

Calcium Bioavailability

Bioavailability refers to the amount of a particular nutrient in foods that is actually absorbed in the intestine and not eliminated in the urine or feces. Simply put, the bioavailability of calcium is the amount that is on hand to perform its biological functions. In the small intestine, calcium absorption primarily takes place in the duodenum (first section of the small intestine) when intakes are low, but calcium is also absorbed passively in the jejunum and ileum (second and third sections of the small intestine), especially when intakes are higher. The body doesn't completely absorb all the calcium in food. About 30 percent of calcium is absorbed from milk and other dairy products. Interestingly, the calcium in some vegetables such as kale, Brussel sprouts, and bok choy, is better absorbed by the body than are dairy

products. The body absorbs approximately 50 percent of calcium from these plant-based sources.

Factors that Increase Calcium Bioavailability

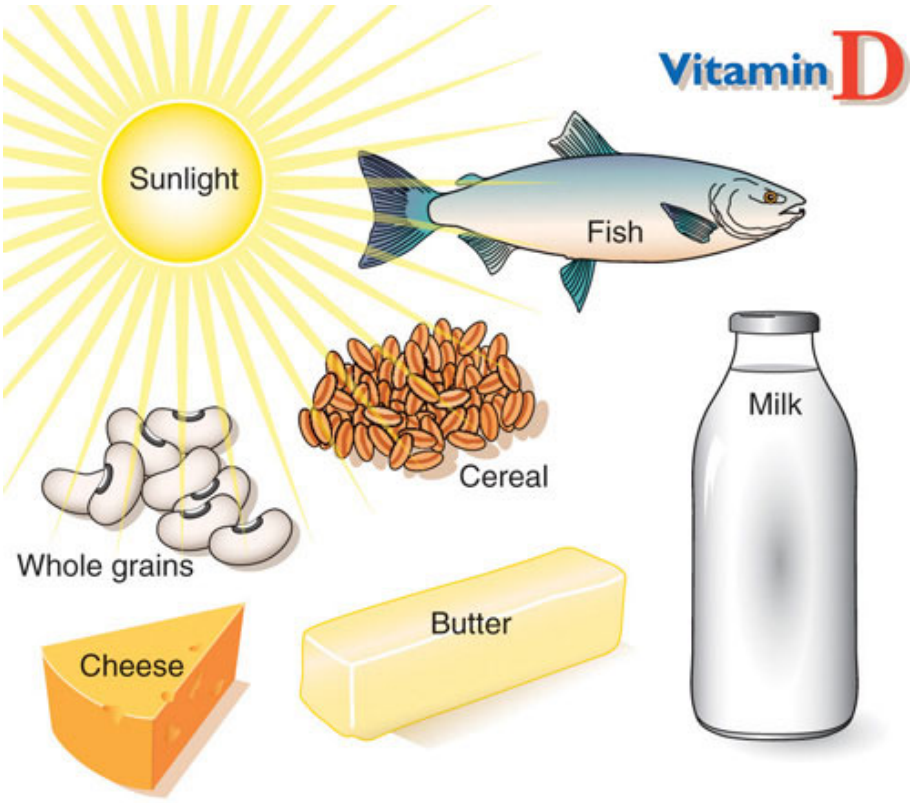
Stomach acid releases calcium from foods and ionizes it to Ca^{++}. Calcium must be in its ionized form to be absorbed in the small intestine. The greatest positive influence on calcium absorption comes from having an adequate intake of vitamin D. People deficient in vitamin D absorb less than 15 percent of calcium from the foods they eat. The hormone estrogen is another factor that enhances calcium bioavailability. Thus, as a woman ages and goes through menopause, during which estrogen levels fall, the amount of calcium absorbed decreases and the risk for bone disease increases. Some fibers, such as inulin, found in jicama, onions, and garlic, also promote calcium intestinal uptake.

Factors that Decrease Calcium Bioavailability

Chemicals that bind to calcium decrease its bioavailability. These negative effectors of calcium absorption include the oxalates in certain plants, the tannins in tea, phytates in nuts, seeds, and grains, and some fibers. Oxalates are found in high concentrations in spinach, parsley, cocoa, and beets. In general, the calcium bioavailability is inversely correlated to the oxalate content in foods. High-fiber, low-fat diets also decrease the amount of calcium absorbed, an effect likely related to how fiber and fat influence the amount of time food stays in the gut. Anything that causes diarrhea, including sicknesses, medications, and certain symptoms related to old age, decreases the transit time of calcium in the gut and therefore decreases calcium absorption. As we get older, stomach acidity sometimes decreases, diarrhea occurs more often, kidney function is impaired, and vitamin D absorption and activation is compromised, all of which contribute to a decrease in calcium bioavailability.

Vitamin D

Figure 9.6 Vitamin D Food Sources



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Vitamin D[17] refers to a group of fat-soluble vitamins derived from cholesterol. Vitamins D_2 and D_3 are the only ones known to have biological actions in the human body. Although vitamin D_3 is called a vitamin, the body can actually synthesize vitamin D_3. When exposed to sunlight, a cholesterol precursor in the skin is transformed into vitamin D_3. However, this is not the bioactive form of vitamin D. It first must be acted upon by enzymes in the liver and then transported to the kidney where vitamin D_3 is finally transformed into the active hormone, calcitriol (1,25-dihydroxy vitamin D_3) (Figure 9.7 "The Activation of Vitamin D to Calcitriol"). The skin synthesizes vitamin D when exposed to sunlight. In fact, for most people, more than 90 percent of their vitamin D_3 comes from the casual exposure to the UVB rays in sunlight. Anything that reduces your exposure to the sun's UVB rays decreases the amount of vitamin D_3 your skin synthesizes. That would include long winters, your home's altitude, whether you are wearing sunscreen, and the color of your skin (including tanned skin). Do you ever wonder

17. Both a vitamin and a hormone, vitamin D plays an essential role in maintaining calcium homeostasis. A deficiency in vitamin D compromises bone health.

about an increased risk for skin cancer by spending too much time in the sun? Do not fret. Less than thirty minutes of sun exposure to the arms and legs will increase blood levels of vitamin D_3 more than orally taking 10,000 IU (250 micrograms) of vitamin D_3. However, it important to remember that the skin production of vitamin D_3 is a regulated process, so too much sun does cause vitamin D toxicity.

Interactive 9.1

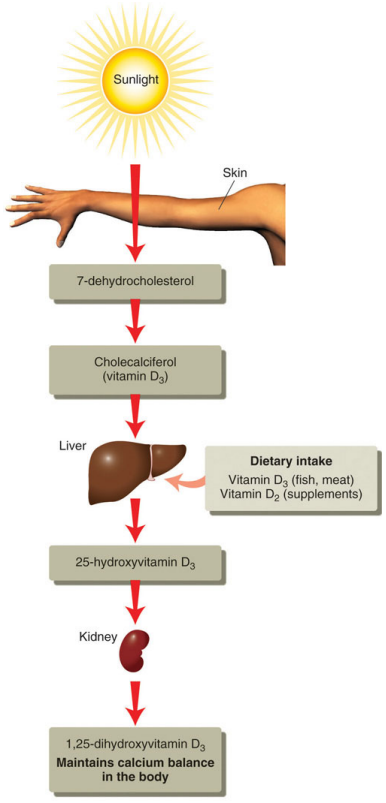
Vitamin D Production in the Body

Visit the University of North Carolina Gillings School of Global Public Health website to review the activation of vitamin D to calcitriol.

http://www.unc.edu/tlim/nutr240/?6

A person's vitamin D status is determined by measuring 25-hydroxy vitamin D_3 levels in the blood serum because it reflects both the vitamin D obtained from production in the skin and that from dietary sources. Measuring the active hormone, calcitriol, does not accurately reflect one's vitamin D status because of its short half-life (six to twelve hours). The vast majority of nutrition experts consider a concentration of 25-hydroxy vitamin D_3 in the blood serum less than 20 nanograms per millileter as an indicator of vitamin D deficiency. The IOM states that serum levels above 20 nanograms per milliliter are sufficient to maintain bone health in healthy individuals. Both nutrition experts and health advocates currently are debating what the optimal levels of vitamin D_3 should be to take full advantage of all of its health benefits. Some advocates propose that serum levels of vitamin D_3 above 40 nonograms per milliliter are optimal. To determine whether higher levels of vitamin D_3 provide advantages in fighting diseases such as cancer, a large clinical trial called VITAL (Vitamin D and Omega-3 Trial) has been initiated at Brigham and Women's Hospital and Harvard Medical School in Boston, Massachusetts. To remain updated on this trial, visit their website at http://www.vitalstudy.org/index.html.

Figure 9.7 The Activation of Vitamin D to Calcitriol



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Vitamin D's Functional Role

As previously discussed, activated vitamin D_3 (calcitriol) regulates blood calcium levels in concert with parathyroid hormone. In the absence of an adequate intake of vitamin D, less than 15 percent of calcium is absorbed from foods or supplements. The effects of calcitriol on calcium homeostasis are critical for bone health. A deficiency of vitamin D in children causes the bone disease **nutritional rickets**[18]. Rickets is very common among children in developing countries and is characterized by soft, weak, deformed bones that are exceptionally susceptible to fracture. In adults, vitamin D deficiency causes a similar disease called **osteomalacia**[19], which is characterized by low BMD. Osteomalacia has the same symptoms and consequences as osteoporosis and often coexists with osteoporosis. Vitamin D deficiency is common, especially in the elderly population, dark-skinned populations, and in the many people who live in the northern latitudes where sunlight exposure is much decreased during the long winter season.

18. A childhood bone disease caused by a lack of vitamin D. It is characterized by soft, weak bones that are susceptible to fracture.

19. Similar to nutritional rickets, in adults this disease involves softening and weakening of the bones due to a lack of vitamin D or a problem metabolizing the vitamin.

Observational studies have shown that people with low levels of vitamin D in their blood have lower BMD and an increased incidence of osteoporosis. In contrast, diets with high intakes of salmon, which contains a large amount of vitamin D, are linked with better bone health. A review of twelve clinical trials, published in the May 2005 issue of the *Journal of the American Medical Association*, concluded that oral vitamin D supplements at doses of 700–800 international units per day, with or without coadministration of calcium supplements, reduced the incidence of hip fracture by 26 percent and other nonvertebral fractures by 23 percent."Fracture Prevention with Vitamin D Supplementation: A Meta-Analysis of Randomized Controlled Trials." *JAMA* 293, no. 18 (2005): 2257–64. http://jama.ama-assn.org/content/293/18/2257.long. A reduction in fracture risk was not observed when people took vitamin D supplements at doses of 400 international units.

Vitamin D Needs and Sources

Dietary Reference Intake for Vitamin D

The Institute of Medicine RDAs for vitamin D for different age groups is listed in Table 9.3 "Dietary Reference Intakes for Vitamin D". For adults, the RDA is 600 international units, which is equivalent to 15 micrograms of vitamin D. The National Osteoporosis Foundation recommends slightly higher levels and that adults under age fifty get between 400 and 800 international units of vitamin D every day, and adults fifty and older get between 800 and 1,000 international units of vitamin D every day. According to the IOM, the tolerable upper intake level (UL) for vitamin D is 4,000 international units per day. Toxicity from excess vitamin D is rare, but certain diseases such as hyperparathyroidism, lymphoma, and tuberculosis make people more sensitive to the increases in calcium caused by high intakes of vitamin D.

Table 9.3 Dietary Reference Intakes for Vitamin D

Age Group	RDA (mcg/day)	UL (mcg/day)
Infant (0–6 months)	10*	25
Infants (6–12 months)	10*	25
Children (1–3 years)	15	50
Children (4–8 years)	15	50
Children (9–13 years)	15	50
Adolescents (14–18 years)	15	50
Adults (19–71 years)	15	50
*** denotes Adequate Intake**		

Age Group	RDA (mcg/day)	UL (mcg/day)
Adults (> 71 years)	20	50
*** denotes Adequate Intake**		

Source: Ross, A. C. et al. "The 2011 Report on Dietary Reference Intakes for Calcium and Vitamin D from the Institute of Medicine: What Clinicians Need to Know." J Clin Endocrinol Metab 96, no. 1 (2011): 53–8. http://www.ncbi.nlm.nih.gov/pubmed/21118827.

Vitamin D Bioavailability

There are few food sources of vitamin D. Oily fish, such as salmon, is one of the best. The amount of vitamin D obtained from one 3-ounce piece of salmon is greater than the recommended intake for one day. Many foods, including dairy products, orange juice, and cereals are now fortified with vitamin D. Most vitamin-D-fortified foods contain about 25 percent of the RDA for vitamin D per serving, but check the label. Many people are deficient in vitamin D as a result of the few dietary sources for this vitamin.

Other Health Benefits of Vitamin D in the Body

Many other health benefits have been linked to higher intakes of vitamin D, from decreased cardiovascular disease to the prevention of infection. Furthermore, evidence from laboratory studies conducted in cells, tissues, and animals suggest vitamin D prevents the growth of certain cancers, blocks inflammatory pathways, reverses atherosclerosis, increases insulin secretion, and blocks viral and bacterial infection and many other things. Vitamin D deficiency has been linked to an increased risk for autoimmune diseases. (Autoimmune diseases are those that result from an abnormal immune response targeted against the body's own tissues.) An increased prevalence of the autoimmune diseases, rheumatoid arthritis, multiple sclerosis, and Type 1 diabetes has been observed in populations with inadequate vitamin D levels. Additionally, vitamin D deficiency is linked to an increased incidence of hypertension. Until the results come out from the VITAL study (see Note 9.47 "Video 9.2"), the bulk of scientific evidence touting other health benefits of vitamin D is from laboratory and observational studies and requires confirmation in clinical intervention studies.

KEY TAKEAWAYS

- Calcium is the most abundant mineral in the body and has four primary functions: making bones strong and healthy, facilitating nerve-to-nerve communication, stimulating muscle contraction, and activating blood-clotting factors. Other benefits of calcium in the body include decreasing blood pressure and preventing colon cancer.
- Calcium blood-levels are rigorously controlled by three hormones: PTH, calcitriol, and calcitonin.
- The DRI for calcium intake for adults averages from 1,000–1,200 milligrams per day.
- Only some of the calcium in food is absorbed by the body. Vitamin D and estrogen enhance the bioavailability of calcium in the body. Alternately, diets high in oxalates, some types of fiber, and diets low in fat decrease the bioavailability of calcium in the body.
- Vitamin D is essential for maintaining calcium levels in the body. Once activated to calcitriol, it acts in concert with PTH to keep blood levels of calcium constant, especially by enhancing its intestinal absorption. High levels of vitamin D in the blood promote bone health.

DISCUSSION STARTERS

1. Talk about some of the vital functions of calcium and vitamin D in the body. Why are these nutrients so important to health? What can you do to increase these vitamins in your diet?

2. Watch the video below. List the pros and cons of consuming both raw and pasteurized milk. Develop an informed opinion based upon the history of milk and the scientific evidence about both types of milk consumption.

   Raw Milk

   (click to see video)

9.4 Other Essential Micronutrients for Bone Health: Phosphorous, Magnesium, Fluoride, and Vitamin K

LEARNING OBJECTIVES

1. Identify additional nutrients that are vital in maintaining bone health and state their primary role.
2. Identify food sources for each nutrient.

Bone tissue is greater than 70 percent inorganic material and as such, minerals are important for maintaining skeletal health. In addition to calcium, other minerals critical for bone health are phosphorus, magnesium, and fluoride. Vitamin K is also important to bone health. But that is not all—iron, copper, zinc, and vitamin C are also essential for the synthesis of collagen. Consuming too much or too little vitamin A affects bone health too, as it plays a role in osteoclast and osteoblast activities. The fact that there are many bone-friendly nutrients provides us with one more reason why it is better to eat a diet rich in many nutrients than take one particular supplement. In Table 9.4 "Micronutrients and Bone Health", notice the important nutrients for bone health and good food sources for each.

Table 9.4 Micronutrients and Bone Health

Micronutrient	Functional Role in Bone Health	Food Sources
Calcium	• Component of mineralized bone • Provides structure and microarchitecture	collards, mustard greens, kale, turnips, broccoli, beans, black molasses, and fortified juices, cereals, and milk.
Phosphorus	• Component of mineralized bone • Provides structure and microarchitecture	non-genetically-modified soy, legumes, whole grains, dairy, nuts, and seeds

Micronutrient	Functional Role in Bone Health	Food Sources
Magnesium	• Component of mineralized bone • Provides structure and microarchitecture	whole grains and legumes, almonds, cashews, hazelnuts, beets, collards, and kelp
Fluoride	• Component of mineralized bone • Provides structure and microarchitecture • Stimulates new bone growth	fluoridated water, foods prepared in fluoridated water, seafood (because the ocean contains natural sodium flouride)
Vitamin D	• Critical for maintaining calcium levels • Aids the absorption of calcium, promotes bone health	salmon, mackerel, tuna, sardines, mushrooms, cod liver oil, egg yolks, and fortified milk, yogurt, and cheese
Vitamin K	• Stimulates bone remodeling	kale, spinach, turnip, and other dark leafy vegetables
Boron	• May enhance calcium absorption and estrogen metabolism	avocado, nuts, peanut butter, green and orange vegetables, grapes, and raisins
Iron	• Helps enzymes and regulators function properly so the body	red meat, egg yolks, dark leafy vegetables, dried fruit, iron-fortified foods, beans, lentils, chick peas, liver, and artichoke

Micronutrient	Functional Role in Bone Health	Food Sources
	can form optimal bone structure for bone strength	
Vitamin C	• Helps enzymes and regulators to function properly so the body can form optimal bone structure for bone strength	citrus fruits, tomatoes and tomato juice, potatoes, Brussel sprouts, cauliflower, broccoli, strawberries, cabbage, and spinach
Zinc	• Helps enzymes and regulators to function properly so the body can form optimal bone structure for bone strength	oysters, wheat germ, pumpkin seeds, squash, watermelon seeds, beans, sesame seeds, tahini, beef, lamb

Phosphorus's Functional Role

Phosphorus[20] is the second most abundant mineral in the human body. Eighty-five percent of it is housed in the skeleton. In addition to serving as a primary mineral in the skeleton, phosphorus in the form of phosphate is a component of the backbones of RNA and DNA, the cellular energy storing molecule, adenosine triphosphate (ATP), and phospholipids. Because phosphorus is present with calcium in mineralized bone, it is somewhat regulated in parallel to calcium. PTH and calcitriol stimulate bone resorption, increasing not only blood levels of calcium, but also blood phosphate levels. However, in contrast to the effect of PTH on calcium reabsorption by the kidney, PTH stimulates the renal excretion of phosphate so that it does not accumulate to toxic levels.

20. A mineral that makes up a substantial part of mineralized bone tissue. The dietary sources are meat, fish, and dairy products, as well as processed foods, and cola beverages.

Dietary Reference Intake and Food Sources for Phosphorus

In comparison to calcium, most Americans are not at risk for having a phosphate deficiency. Phosphate is present in many foods popular in the American diet including meat, fish, dairy products, processed foods, and beverages. Phosphate is added to many foods because it acts as an emulsifying agent, prevents clumping, improves texture and taste, and extends shelf-life. The average intake of phosphorus in US adults ranges between 1,000 and 1,500 milligrams per day, well above the RDA of 700 milligrams per day. The UL set for phosphorous is 4,000 milligrams per day for adults and 3,000 milligrams per day for people over age seventy.

Table 9.5 Dietary Reference Intakes for Phosphorus

Age Group	RDA (mg/day)	UL (mg/day)
Infants (0–6 months)	100*	–
Infants (6–12 months)	275*	–
Children (1–3 years)	460	3,000
Children (4–8 years)	500	3,000
Children (9–13 years)	1,250	4,000
Adolescents (14–18 years)	1,250	4,000
Adults (19–70 years)	700	4,000
Adults (> 70 years)	700	3,000
*** denotes Adequate Intake**		

Table 9.6 Calcium and Phosphorus Contents in 100 Grams of Certain Foods

Foods	Calcium (mg)	Phosphorus (mg)
Dairy Products		
Buttermilk	116	89
Milk, nonfat	123	101
Milk, whole	207	158
Yogurt, low-fat	199	157
Yogurt, whole milk	121	95
Cottage cheese, low-fat	69	151

Foods	Calcium (mg)	Phosphorus (mg)
Swiss cheese	791	567
Meats		
Beef, round steak	7	199
Chicken	15	216
Crab	59	175
Oysters	62	159
Legumes/Nuts		
Macadamia nuts	85	188
Soybeans	145	158
Lentils	19	180
Lima beans	21	74
Vegetables		
Broccoli	47	66
Carrots	27	44
Lettuce, iceberg	19	20
Parsley	140	60
Cereals/Grains		
Barley	32	309
Wheat flour, white	15	108
Oat bran	10	119
Rice, brown	10	77
Rice, white	19	55
Processed Foods		
American cheese	712	923
Au gratin potatoes	83	95
Fish sticks	26	182
Fast food hamburger	46	97
Chocolate cake mix	150	270
Chocolate wafer cookies	31	32

Foods	Calcium (mg)	Phosphorus (mg)
Granola bar	105	230
Carbonated Beverages		
Cola	2	11
Clear soda	2	0

Source: Adapted from US Department of Agriculture National Nutrient Database. Last modified November 1, 2012. http://www.nal.usda.gov/fnic/foodcomp/search/.

Magnesium's Functional Role

Approximately 60 percent of **magnesium**[21] in the human body is stored in the skeleton, making up about 1 percent of mineralized bone tissue. Magnesium is not an integral part of the hydroxyapatite crystal, but it does reside on the surface of the crystal and helps maximize bone structure. Observational studies link magnesium deficiency with an increased risk for osteoporosis. A magnesium-deficient diet is associated with decreased levels of parathyroid hormone and the activation of vitamin D, which may lead to an impairment of bone remodeling. A study in nine hundred elderly women and men did show that higher dietary intakes of magnesium correlated to an increased BMD in the hip.Tucker, K. L. et al. "Potassium, Magnesium, and Fruit and Vegetable Intakes Are Associated with Greater Bone Mineral Density in Elderly Men and Women." *Am J ClinNutr* 69, no. 4 (1999): 727–36. Only a few clinical trials have evaluated the effects of magnesium supplements on bone health and their results suggest some modest benefits on BMD.

In addition to participating in bone maintenance, magnesium has several other functions in the body. In every reaction involving the cellular energy molecule, ATP, magnesium is required. More than three hundred enzymatic reactions require magnesium. Magnesium plays a role in the synthesis of DNA and RNA, carbohydrates, and lipids, and is essential for nerve conduction and muscle contraction. Another health benefit of magnesium is that it may decrease blood pressure.

21. A mineral that is part of mineralized bone tissue. The dietary sources are meat, fish, dairy products, whole grains, nuts, chocolate, and coffee.

Dietary Reference Intake and Food Sources for Magnesium

The RDAs for magnesium for adults between ages nineteen and thirty are 400 milligrams per day for males and 310 milligrams per day for females. For adults above age thirty, the RDA increases slightly to 420 milligrams per day for males and 320 milligrams for females.

For optimal magnesium intake, try consuming whole-grain breads and cereals.

© Thinkstock

Table 9.7 Dietary Reference Intakes for Magnesium

Age Group	RDA (mg/day)	UL (mg/day)
Infants (0–6 months)	30*	–
Infants (6–12 months)	75*	–
Children (1–3 years)	80	65
Children (4–8 years)	130	110
Children (9–13 years)	240	350
Adolescents (14–18 years)	410	350
Adults (19–30 years)	400	350
Adults (> 30 years)	420	350
*** denotes Adequate Intake**		

Source: National Institutes of Health, Office of Dietary Supplements. "Dietary Supplement Fact Sheet: Magnesium." Last reviewed July 13, 2009. http://ods.od.nih.gov/factsheets/Magnesium-HealthProfessional/.

Magnesium is part of the green pigment, chlorophyll, which is vital for photosynthesis in plants; therefore green leafy vegetables are a good dietary source for magnesium. Magnesium is also found in high concentrations in fish, dairy products, meats, whole grains, and nuts. Additionally chocolate, coffee, and hard water contain a good amount of magnesium. Most people in America do not fulfill the RDA for magnesium in their diets. Typically, Western diets lean toward a low fish intake and the unbalanced consumption of refined grains versus whole grains.

Fluoride's Functional Role

Fluoride[22] is known mostly as the mineral that combats tooth decay. It assists in tooth and bone development and maintenance. Fluoride combats tooth decay via three mechanisms:

1. Blocking acid formation by bacteria
2. Preventing demineralization of teeth
3. Enhancing remineralization of destroyed enamel

Fluoride was first added to drinking water in 1945 in Grand Rapids, Michigan; now over 60 percent of the US population consumes fluoridated drinking water. The Centers for Disease Control and Prevention (CDC) has reported that fluoridation of water prevents, on average, 27 percent of cavities in children and between 20 and 40 percent of cavities in adults. The CDC considers water fluoridation one of the ten great public health achievements in the twentieth century.Centers for Disease Control. "10 Great Public Health Achievements in the 20th Century." *Morbidity and Mortality Weekly Report* 48, no. 12 (April 2, 1999): 241–43. http://www.cdc.gov/about/history/tengpha.htm. The optimal fluoride concentration in water to prevent tooth decay ranges between 0.7–1.2 milligrams per liter. Exposure to fluoride at three to five times this concentration before the growth of permanent teeth can cause fluorosis, which is the mottling and discoloring of the teeth.

Fluoride's benefits to mineralized tissues of the teeth are well substantiated, but the effects of fluoride on bone are not as well known. Fluoride is currently being researched as a potential treatment for osteoporosis. The data are inconsistent on whether consuming fluoridated water reduces the incidence of osteoporosis and fracture risk. Fluoride does stimulate osteoblast bone building activity, and fluoride therapy in patients with osteoporosis has been shown to increase BMD. In general, it appears that at low doses, fluoride treatment increases BMD in people with osteoporosis and is more effective in increasing bone quality when the intakes of calcium and vitamin D are adequate. The Food and Drug Administration has not approved fluoride for the treatment of osteoporosis mainly because its benefits are not sufficiently known and it has several side effects including frequent stomach upset and joint pain. The doses of fluoride used to treat osteoporosis are much greater than that in fluoridated water.

Dietary Reference Intake and Food Sources for Fluoride

The IOM has given Adequate Intakes (AI) for fluoride, but has not yet developed RDAs. The AIs are based on the doses of fluoride shown to reduce the incidence of cavities, but not cause dental fluorosis. From infancy to adolescence, the AIs for

22. A mineral that blocks tooth decay and is part of mineralized bone tissue. The primary dietary source is fluoridated water.

fluoride increase from 0.01 milligrams per day for ages less than six months to 2 milligrams per day for those between the ages of fourteen and eighteen. In adulthood, the AI for males is 4 milligrams per day and for females is 3 milligrams per day. The UL for young children is set at 1.3 and 2.2 milligrams per day for girls and boys, respectively. For adults, the UL is set at 10 milligrams per day. Greater than 70 percent of a person's fluoride comes from drinking fluoridated water when they live in a community that fluoridates the drinking water. Other beverages with a high amount of fluoride include teas and grape juice. Solid foods do not contain a large amount of fluoride. Fluoride content in foods depends on whether it was grown in soils and water that contained fluoride or cooked with fluoridated water. Canned meats and fish that contain bones do contain some fluoride.

Table 9.8 Dietary Reference Intakes for Fluoride

Age Group	AI (mg/day)	UL (mg/day)
Infants (0–6 months)	0.01	0.7
Infants (6–12 months)	0.50	0.9
Children (1–3 years)	0.70	1.3
Children (4–8 years)	1.00	2.2
Children (9–13 years)	2.00	10.0
Adolescents (14–18 years)	3.00	10.0
Adult Males (> 19 years)	4.00	10.0
Adult Females (> 19 years)	3.00	10.0

Source: Institute of Medicine. *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride.* January 1, 1997. http://www.iom.edu/Reports/1997/Dietary-Reference-Intakes-for-Calcium-Phosphorus-Magnesium-Vitamin-D-and-Fluoride.aspx..

Vitamin K's Functional Role

Vitamin K[23] refers to a group of fat-soluble vitamins that are similar in chemical structure. They act as coenzymes and have long been known to play an essential role in blood coagulation. Without vitamin K, blood would not clot. Vitamin K is also required for maintaining bone health. It modifies the protein osteocalcin, which is involved in the bone remodeling process. All the functions of osteocalcin and the other vitamin K-dependent proteins in bone tissue are not well understood and are

23. A vitamin that acts as a coenzyme that modifies proteins important for bone health. The dietary sources are green vegetables such as broccoli, cabbage, kale, parsley, spinach, and lettuce.

under intense study. Some studies do show that people who have diets low in vitamin K also have an increased risk for bone fractures.

Dietary Reference Intake and Food Sources for Vitamin K

The AI of vitamin K for adult females is 75 micrograms per day, and for males it is 120 micrograms per day. A UL for vitamin K has not been set. Vitamin K is present in many foods. It is found in highest concentrations in green vegetables such as broccoli, cabbage, kale, parsley, spinach, and lettuce. Additionally, vitamin K can be synthesized via bacteria in the large intestine. The exact amount of vitamin K synthesized by bacteria that is actually absorbed in the lower intestine is not known, but likely contributes less than 10 percent of the recommended intake. Newborns have low vitamin K stores and it takes time for the sterile newborn gut to acquire the good bacteria it needs to produce vitamin K. So, it has become a routine practice to inject newborns with a single intramuscular dose of vitamin K. This practice has basically eliminated vitamin K-dependent bleeding disorders in babies.

Table 9.9 Dietary Reference Intakes for Vitamin K

Age Group	RDA (mcg/day)
Infants (0–6 months)	2.0*
Infants (6–12 months)	2.5*
Children (1–3 years)	30
Children (4–8 years)	55
Children (9–13 years)	60
Adolescents (14–18 years)	75
Adult Males (> 19 years)	120
Adult Females (> 19 years)	90
*** denotes Adequate Intake**	

Source: Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.* January 9, 2001. http://www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

KEY TAKEAWAYS

- Phosphorous is a primary mineral component of bone, is regulated in parallel with calcium, and in high amounts is detrimental to bone health.
- Magnesium helps keep bones strong. A deficiency in magnesium can compromise bone health.
- Fluoride combats tooth decay and benefits teeth and bones when present in the diet at the recommended intake.
- Vitamin K is a coenzyme that participates in the modification of proteins that act in bone tissues and promotes normal blood clotting.

DISCUSSION STARTERS

1. Discuss and plan a dinner menu that specifically contains bone-friendly foods. What are you going to serve? Be sure to include enough bone-friendly foods for the different types of vegetarians.
2. Discuss some of the functional roles that magnesium, phosphorous, fluoride, and vitamin K serve in the body. In the midst of a busy schedule, how can you ensure you are eating the right amount of foods to provide an adequate supply of these nutrients?

9.5 Osteoporosis

LEARNING OBJECTIVE

1. Describe osteoporosis, including its notable characteristics.

There are several factors that lead to loss of bone quality during aging, including a reduction in hormone levels, decreased calcium absorption, and increased muscle deterioration. It is comparable to being charged with the task of maintaining and repairing the structure of your home without having all of the necessary materials to do so. However, you will learn that there are many ways to maximize your bone health at any age.

Osteoporosis[24] is the excessive loss of bone over time. It leads to decreased bone strength and an increased susceptibility to bone fracture. The Office of the Surgeon General (OSG) reports that approximately ten million Americans over age fifty are living with osteoporosis, and an additional thirty-four million have **osteopenia**[25], which is lower-than-normal bone mineral density.Office of the Surgeon General. "Bone Health and Osteoporosis: A Report of the Surgeon General." October 2004. http://www.surgeongeneral.gov/library/bonehealth/chapter_1.html. Osteoporosis is a debilitating disease that markedly increases the risks of suffering from bone fractures. A fracture in the hip causes the most serious consequences—and approximately 20 percent of senior citizens who have one will die in the year after the injury. Osteoporosis affects more women than men, but men are also at risk for developing osteoporosis, especially after the age of seventy. These statistics may appear grim, but many organizations—including the National Osteoporosis Foundation and the OSG—are disseminating information to the public and to health-care professionals on ways to prevent the disease, while at the same time, science is advancing in the prevention and treatment of this disease.International Osteoporosis Foundation. "Facts and Statistics about Osteoporosis and Its Impact." © 2012 International Osteoporosis Foundation. Accessed http://www.iofbonehealth.org/facts-and-statistics.html.

As previously discussed, bones grow and mineralize predominately during infancy, childhood, and puberty. During this time, bone growth exceeds bone loss. By age twenty, bone growth is fairly complete and only a small amount (about 10 percent) of bone mass accumulates in the third decade of life. By age thirty, bone mass is at its greatest in both men and women and then gradually declines after age forty. Bone mass refers to the total weight of bone tissue in the human body. The greatest

24. Excessive bone loss over time.

25. Lower than normal bone mass.

quantity of bone tissue a person develops during his or her lifetime is called **peak bone mass**[26]. The decline in bone mass after age forty occurs because bone loss is greater than bone growth. On a cellular level, this means that the osteoclast-mediated bone degradation exceeds that of the bone building activity of osteoblasts. The increased bone degradation decreases the mineral content of bone tissue leading to a decrease in bone strength and increased fracture risk.

Osteoporosis is referred to as a silent disease, much like high blood pressure, because symptoms are rarely exhibited. A person with osteoporosis may not know he has the disease until he experiences a bone break or fracture. Detection and treatment of osteoporosis, before the occurrence of a fracture, can significantly improve the quality of life. To detect osteopenia or osteoporosis, BMD must be measured by the DEXA procedure. The results of a BMD scan are most often reported as T-scores. A **T-score**[27] compares a person's BMD to an averaged BMD of a healthy thirty-year-old population of the same sex. According to the World Health Organization, a T-score of –1.0 or above indicates normal BMD. A person with a T-score between –1.0 and –2.5 has a low BMD, which is a condition referred to as osteopenia. A person with a T-score of –2.5 or below is diagnosed with osteoporosis.National Osteoporosis Foundation. "Having A Bone Density Test." © 2011. http://www.nof.org/node/42 This classification of T-scores is based on studies of white postmenopausal women and does not apply to premenopausal women, nonwhite postmenopausal women, or men.

Osteoporosis is categorized into two types that differ by the age of onset and what type of bone tissue is most severely deteriorated. Type 1 osteoporosis, also called postmenopausal osteoporosis, most often develops in women between the ages of fifty and seventy. Between the ages of forty-five and fifty, women go through menopause and their ovaries stop producing estrogen. Because estrogen plays a role in maintaining bone mass, its rapid decline during menopause accelerates bone loss. This occurs mainly as a result of increased osteoclast activity. The trabecular tissue is more severely affected because it contains more osteoclasts cells than cortical tissue. Type 1 osteoporosis is commonly characterized by wrist and spine fractures. Type 2 osteoporosis is also called senile osteoporosis and typically occurs after the age of seventy. It affects women twice as much as men and is most often associated with hip and spine fractures. In Type 2 osteoporosis, both the trabecular and cortical bone tissues are significantly affected. Not everybody develops osteoporosis as they age. Other factors, which will be discussed in Section 9.6 "Risk Factors for Osteoporosis" of this chapter, also contribute to the risk or likelihood of developing the disease.

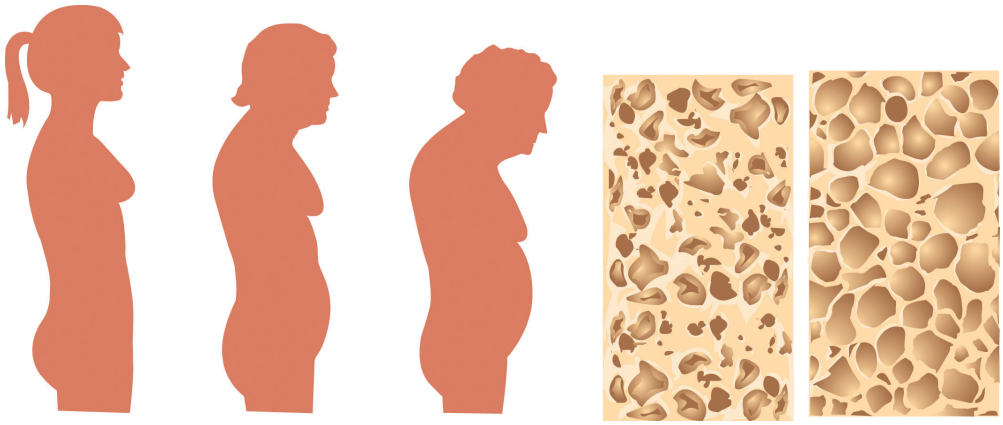
26. The greatest amount of bone mass that a person reaches during their lifetime.

27. Compares the patient's BMD to the averaged BMD of a healthy thirty-year-old population of the same sex.

During the course of both types of osteoporosis, BMD decreases and the bone tissue microarchitecture is compromised. Excessive bone resorption in the trabecular tissue increases the size of the holes in the lattice-like structure making it more

porous and weaker. A disproportionate amount of resorption of the strong cortical bone causes it to become thinner. The deterioration of one or both types of bone tissue causes bones to weaken and, consequently, become more susceptible to fractures. The American Academy of Orthopaedic Surgeons reports that one in two women and one in five men older than sixty-five will experience a bone fracture caused by osteoporosis.American Academy of Orthopaedic Surgeons. "Osteoporosis." © 1995–2012. Last reviewed August 2009. http://orthoinfo.aaos.org/topic.cfm?topic=a00232.

Figure 9.8 *Osteoporosis in Vertebrae*



Osteoporosis is characterized by a gradual weakening of the bones, which leads to poor skeletal formation.

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When the vertebral bone tissue is weakened, it can cause the spine to curve (Figure 9.8 "Osteoporosis in Vertebrae"). The increase in spine curvature not only causes pain, but also decreases a person's height. Curvature of the upper spine produces what is called Dowager's hump, also known as kyphosis. Severe upper-spine deformity can compress the chest cavity and cause difficulty breathing. It may also cause abdominal pain and loss of appetite because of the increased pressure on the abdomen.

Video 9.2

Osteoporosis Defined

(click to see video)

See this 3D medical animation about osteoporosis.

KEY TAKEAWAYS

- Bone mineral density (BMD) is an indicator of bone quality and correlates with bone strength.
- Excessive bone loss can lead to the development of osteopenia and eventually osteoporosis.
- Osteoporosis affects women more than men, but is a debilitating disease for either sex.
- Osteoporosis is often a silent disease that doesn't manifest itself until a fracture is sustained.

DISCUSSION STARTERS

1. Discuss how bone microarchitecture is changed in people with osteoporosis. How do these structural changes increase the risk of having a bone fracture?
2. Go back to Section 9.1 "Bone Structure and Function" and review that bone is a living tissue that adapts to changes in mechanical forces. How might weight training help prevent a fracture in someone with osteoporosis?

9.6 Risk Factors for Osteoporosis

LEARNING OBJECTIVE

1. Discuss risk factors for osteoporosis.

A **risk factor**[28] is defined as a variable that is linked to an increased probability of developing a disease or adverse outcome. Recall that advanced age and being female increase the likelihood for developing osteoporosis. These factors present risks that should signal doctors and individuals to focus more attention on bone health, especially when the risk factors exist in combination. This is because not all risk factors for osteoporosis are out of your control. Risk factors such as age, gender, and race are biological risk factors, and are based on genetics that cannot be changed. By contrast, there are other risk factors that can be modified, such as physical activity, alcohol intake, and diet. The changeable risk factors for osteoporosis provide a mechanism to improve bone health even though some people may be genetically predisposed to the disease.

Certain risk factors for developing osteoporosis are biological, such as being Caucasian or Asian and being over age forty. Other factors are related to lifestyle choices such as smoking.

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Nonmodifiable Risk Factors

Age, Sex, Body Type, and Heredity

As noted previously, after age forty, bone mass declines due to bone breakdown exceeding bone building. Therefore, any person over the age of forty has an increased probability of developing osteoporosis in comparison to a younger person. As noted, starting out with more bone (a high peak bone mass) enables you to lose more bone during the aging process and not develop osteoporosis. Females, on average, have a lower peak bone mass in comparison to males and therefore can sustain less bone tissue loss than males before developing a low BMD. Similarly, people with small frames are also at higher risk for osteoporosis. Being of advanced age, being a woman, and having a small frame are all biological risk factors for osteoporosis. Other biological risk factors that are linked to an increased likelihood of developing osteoporosis are having low estrogen levels, or another endocrine disorder such as hyperthyroidism, having a family member with osteoporosis, and being Caucasian or Asian.

28. A variable that is linked to an increased probability of developing a disease or adverse outcome.

Estrogen Level

Estrogen[29] is the primary female reproductive hormone and it stimulates osteoblast-mediated bone building and reduces osteoclast activity. Any condition in which estrogen levels are reduced throughout a woman's life decreases BMD and increases the risk for osteoporosis. By far the most profound effect on estrogen occurs during female menopause. Around the age of forty-five or fifty, women stop producing estrogen. The rapid decline in estrogen levels that occurs during menopause speeds up the bone resorptive process, and as a result the loss of bone tissue in menopausal women lasts for a period of five to ten years. Up to 3 percent of bone tissue is lost annually during menopause and therefore potentially 30 percent of peak bone mass can vanish during this time, leading to a substantial increase in risk for developing osteoporosis in postmenopausal women.

Medications

Some medications, most notably glucocorticoids (used to treat inflammatory disorders such as rheumatoid arthritis and asthma), are associated with an increased risk for osteoporosis. A side effect of glucocorticoids is that they stimulate bone resorption and decrease bone building. Other medications linked to an increased risk for osteoporosis are certain anticancer drugs, some antidiabetic drugs, and blood thinners.

Other Diseases

Diseases that predispose people to osteoporosis include those that disrupt nutrient absorption and retention, such as anorexia nervosa, chronic kidney disease, and Crohn's disease; diseases that influence bone remodeling such as hyperthyroidism and diabetes; and diseases that are characterized by chronic inflammatory responses such as cancer, chronic obstructive pulmonary disease, and rheumatoid arthritis.

Modifiable Risk Factors

Physical Inactivity

Bone is a living tissue, like muscle, that reacts to exercise by gaining strength. Physical inactivity lowers peak bone mass, decreases BMD at all ages, and is linked to an increase in fracture risk, especially in the elderly. Recall that mechanical stress increases bone remodeling and leads to increased bone strength and quality. Weight-bearing exercise puts mechanical stress on bones and therefore increases bone quality. The stimulation of new bone growth

29. Primary female reproductive hormone.

occurs when a person participates in weight-bearing or resistance activities that force the body to work against gravity. Research has shown that this is an excellent way to activate osteoblasts to build more new bone. Conversely, physical inactivity lowers peak bone mass, decreases BMD at all ages, and is linked to an increase in fracture risk, especially in the elderly.

Dancing is a form of weight-bearing activity that forces the body to move against gravity and therefore stimulates new bone growth.

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Being Underweight

Being underweight significantly increases the risk for developing osteoporosis. This is because people who are underweight often also have a smaller frame size and therefore have a lower peak bone mass. Maintaining a normal, healthy weight is important and acts as a form of weight-bearing exercise for the skeletal system as a person moves about. Additionally, inadequate nutrition negatively impacts peak bone mass and BMD. The most striking relationship between being underweight and bone health is seen in people with the psychiatric illness anorexia nervosa. Anorexia nervosa is strongly correlated with low peak bone mass and a low BMD. In fact, more than 50 percent of men and women who have this illness develop osteoporosis and sometimes it occurs very early in life.Mehler, P. S. and K. Weiner. "The Risk of Osteoporosis in Anorexia Nervosa." Reprinted from *Eating Disorders Recovery Today* 1, no. 5 (Summer 2003). © 2003 Gurze Books. http://www.eatingdisordersreview.com/nl/nl_edt_1_5_2.html Women with anorexia nervosa are especially at risk because they not only have inadequate nutrition and low body weight, but also the illness is also associated with estrogen deficiency.

Smoking, Alcohol, and Caffeine

Smoking cigarettes has long been connected to a decrease in BMD and an increased risk for osteoporosis and fractures. However, because people who smoke are more likely to be physically inactive and have poor diets, it is difficult to determine whether smoking itself causes osteoporosis. What is more, smoking is linked to earlier menopause and therefore the increased risk for developing osteoporosis among female smokers may also be attributed, at least in part, to having stopped estrogen production at an earlier age. A review of several studies, published in the *British Medical Journal* in 1997, reports that in postmenopausal women who smoked, BMD was decreased an additional 2 percent for every ten-year increase in age and that these women had a substantial increase in the incidence of hip fractures.Law, M. R. and A.K. Hackshaw. "A Meta-Analysis of Cigarette Smoking, Bone Mineral Density and Risk of Hip Fracture: Recognition of a Major Effect." *Br Med J* 315, no. 7112 (October 4, 1997): 841–6. http://www.ncbi.nlm.nih.gov/pubmed/9353503.

Alcohol intake's effect on bone health is less clear. In some studies, excessive alcohol consumption was found to be a risk factor for developing osteoporosis, but the results of other studies suggests consuming two drinks per day is actually associated with an increase in BMD and a decreased risk for developing osteoporosis. The International Osteoporosis Foundation states that consuming more than two alcoholic drinks per day is a risk factor for developing osteoporosis and sustaining a hip fracture in both men and women.International Osteoporosis Foundation. "New IOF Report Shows Smoking, Alcohol, Being Underweight, and Poor Nutrition Harm our Bones." Accessed October 2011. http://www.iofbonehealth.org/news/news-detail.html?newsID=193. Moreover, excessive alcohol intake during adolescence and young adulthood has a more profound effect on BMD and osteoporosis risk than drinking too much alcohol later in life.

Some studies have found that, similar to alcohol intake, excessive caffeine consumption has been correlated to decreased BMD, but in other studies moderate caffeine consumption actually improves BMD. Overall, the evidence that caffeine consumption poses a risk for developing osteoporosis is scant, especially when calcium intake is sufficient. Some evidence suggests that carbonated soft drinks negatively affect BMD and increase fracture risk. Their effects, if any, on bone health are not attributed to caffeine content or carbonation. It is probable that any effects of the excessive consumption of soft drinks, caffeinated or not, on bone health can be attributed to the displacement of milk as a dietary source of calcium.

Nutrition

Ensuring adequate nutrition is a key component in maintaining bone health. Having low dietary intakes of calcium and vitamin D are strong risk factors for developing osteoporosis. Another key nutrient for bone health is protein. Remember that the protein collagen comprises almost one third of bone tissue. A diet inadequate in protein is a risk factor for osteoporosis. Multiple large observational studies have shown that diets high in protein increase BMD and reduce fracture risk and that diets low in protein correlate to decreased BMD and increased fracture risk. There has been some debate over whether diets super high in animal protein decrease bone quality by stimulating bone resorption and increasing calcium excretion in the urine. A review in the May 2008 issue of the *American Journal of Clinical Nutrition* concludes that there is more evidence that diets adequate in protein play a role in maximizing bone health and there is little consistent evidence that suggests high protein diets negatively affect bone health when calcium intake is adequate.Heaney, R. P. and D.K. Layman. "Amount and Type of Protein Influences Bone Health." *Am J Clin Nutr* 87, no. 5 (2008): 1567S–70S. http://www.ajcn.org/content/87/5/1567S.long

KEY TAKEAWAYS

- Nonmodifiable risk factors for osteoporosis include: being female, being over age fifty, having a small frame, having an endocrine disorder, having a family member with the disease, and being Caucasian or Asian.
- The risk factors for osteoporosis that can be changed are: smoking, alcohol intake, physical inactivity, and poor nutrition.
- Dietary inadequacy, certain medications, and diseases increase the risk for developing osteoporosis.

DISCUSSION STARTER

1. Discuss why it is important for a person with more than one biological risk factor for osteoporosis to begin to manage their lifestyle early on to prevent the development of the disease.

9.7 Osteoporosis Prevention and Treatment

LEARNING OBJECTIVES

1. Explain why it is important to build peak bone mass when you are young.
2. Identify the tests used to measure bone mass.

Although the symptoms of osteoporosis do not occur until old age, osteoporosis is referred to as a childhood disease with old-age consequences. Thus, preventing osteoporosis in old age begins with building strong bones when you are growing. Remember, the more bone mass a person has to start with, the greater the loss a person can withstand without developing osteopenia or osteoporosis. Growing and maintaining healthy bones requires good nutrition, adequate intake of minerals and vitamins that are involved in maintaining bone health, and weight-bearing exercise.

An exercise group engages in weight-bearing activity, which is a primary way to prevent osteoporosis.

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Primary Prevention

Actions taken to avoid developing a disease before it starts are considered **primary prevention**[30]. Primary prevention of osteoporosis begins early on in life. About one half of mineralized bone is built during puberty and the requirements for calcium intake are higher at this time than at other times in life. Unfortunately, calcium intake in boys and girls during adolescence is usually below the recommended intake of 1,300 milligrams per day. To combat inadequate nutrition and physical inactivity in adolescents, the US Department of Health and Human Services launched the Best Bones Forever!™ campaign in 2009.US Department of Health and Human Services. *Best Bones Forever!* Last updated September 2009. http://www.bestbonesforever.gov/index.cfm This campaign is focused on promoting bone health, especially in girls, and reducing the incidence of osteoporosis in women.

30. Actions taken to avoid developing a disease before it starts.

Interactive 9.2

Visit the Best Bones Forever!™ website.

http://www.bestbonesforever.gov/index.cfm

An article in the October 2008 issue of *Food and Nutrition Research* concluded that there is extensive evidence that when girls and boys exercise they increase their peak bone mass and build a stronger skeleton. The greatest benefits to bone health were observed when exercise was combined with good nutrition.Karlsson, M. K., A. Nordqvist, and C. Karlsson. "Physical Activity Increases Bone Mass during Growth." *Food and Nutrition Research* 52 (Published online October 1, 2008). doi: 10.3402/fnr.v52i0.1871 Because there is such a strong correlation between peak bone mass and a decreased risk for developing osteoporosis, a main thrust of organizations that promote bone health, such as the National Osteoporosis Foundation, is to provide information on how to increase skeletal health early on in life, particularly during the time period of peak bone growth, which is puberty.

Primary prevention extends throughout life, and people with one or more risk factors for osteoporosis should have their BMD measured. The National Osteoporosis Foundation recommends the following groups of people get BMD screening:

- Women who are sixty-five or older
- Men who are seventy or older
- Women and men who break a bone after age fifty
- Women going through menopause with other risk factors
- Men fifty to sixty-nine years of age with risk factorsNational Osteoporosis Foundation. "National Osteoporosis Foundation on Bone Mineral Density Testing." http://www.nof.org/node/501

Primary Prevention Tactics
Nutrition: Eat Right for Your Bones

Eating a balanced diet throughout life is helpful in preventing the onset of osteoporosis and deleterious fractures in old age. There is ample scientific evidence to suggest that low intakes of calcium and vitamin D in adulthood are linked to an increased risk for developing osteoporosis. Therefore, it is essential to make sure

your diet contains adequate levels of these nutrients. The roles of calcium and vitamin D in maintaining bone health are discussed in detail in Section 9.3 "Micronutrients Essential for Bone Health: Calcium and Vitamin D" of this chapter.

Physical Activity: Use It or Lose It

Mechanical stress is one of the activation signals for bone remodeling and can increase bone strength. Exercises that apply forces to the bone increase BMD. The most helpful are weight-bearing exercises such as strength training with weights, and aerobic weight-bearing activities, such as walking, running, and stair climbing. Certain aerobic exercises such as biking and swimming do not build bones, although they are very good for cardiovascular fitness. The importance of weight-bearing exercise to bone health is seen most clearly in astronauts. Investigators who analyzed the BMD of astronauts found that typically it decreases by 1.8 percent every month in space. That means during a six-month stay at a space station an astronaut may lose greater than 10 percent of their bone mass. The lack of gravity, which tugs on the bones of people on Earth every day, is what causes bone mass loss in astronauts. NASA imposes a rigorous workout to prevent and to restore the loss of bone mass in astronauts. While in space, astronauts exercise two-and-a-half hours each day on a treadmill, and use a resistance-exercise device where they pull rubberband-like cords attached to pulleys. Then, when they return to Earth astronauts undergo weeks of rehabilitation to rebuild both bone and muscle tissue.

Video 9.3

Exercise Helps Keep Astronauts Healthy in Space

(click to see video)

This video from NASA explains the importance of exercise in maintaining the health of astronauts in space.

Fall Prevention

Reducing the number of falls a person has decreases the likelihood of sustaining a fracture. Fairly simple modifications to a person's environment, such as installing nightlights, railings on stairs, bars to hold onto in showers, and removing cords and throw rugs in walking paths can significantly reduce the likelihood of falling. Importantly, people at risk should have their vision and balance checked frequently.

Secondary Prevention

A person who has undergone a DEXA scan and been diagnosed with osteopenia or osteoporosis has multiple strategies available to reduce the chances of breaking a bone. These types of treatment strategies are referred to as **secondary prevention**[31]. The OSG reports that the primary goals in the prevention and treatment of osteoporosis are to maintain bone health by preventing its loss and by actually building new bone.Office of the Surgeon General. “Bone Health and Osteoporosis: A Report of the Surgeon General.” October, 2004 http://www.surgeongeneral.gov/library/bonehealth/chapter_9.html To accomplish these goals, the OSG recommends a pyramid approach. The base of the pyramid focuses on balancing nutrition, increasing physical activity, and preventing falls (primary prevention tactics). The second step in the pyramid is to determine if any underlying disorders or diseases are causing osteoporosis and to treat them. The third step is pharmacotherapy and involves administering medications. The second and third steps in the pyramid are secondary prevention tactics.

Secondary Prevention Tactics

We have noted that certain medications and diseases either cause or aggravate osteoporosis. Treating diseases such as hyperparathyroidism or discontinuing the use of or lowering the dose of medications such as prednisone, substantially reduces the risk of further deterioration of bone tissue and fracture. (In Section 9.3 "Micronutrients Essential for Bone Health: Calcium and Vitamin D" of this chapter, you learned the mechanics of how the parathyroid hormone regulates calcium homeostasis.) When parathyroid hormone is present at continuously high levels in the blood, it causes a marked elevation in calcium levels. It raises blood calcium levels by increasing osteoclast activity, thereby increasing bone breakdown and bone loss. Hyperparathyroidism is treated by the surgical removal of the parathyroid gland tumor. Chronic kidney disease and vitamin D deficiency can also cause an increase in parathyroid hormone levels. When the increase in parathyroid hormone is the result of disorders in other organs, the condition is referred to as secondary hyperparathyroidism.

Treating diseases such as chronic kidney disease and Crohn’s disease, which are associated with decreased activation of vitamin D, increased calcium excretion, or malabsorption, is important in people who have not developed osteoporosis yet in order to arrest further losses in BMD. If these types of conditions exist simultaneously with osteoporosis, it is recommended that both disorders be treated to prevent further bone deterioration.

31. Strategies focused on halting or reversing a disease after it has developed.

KEY TAKEAWAYS

- Osteoporosis is a childhood disease with old-age consequences. Primary prevention of osteoporosis begins early in life with proper diet and exercise.
- The strategies of secondary prevention that focus on treating osteoporosis aim to arrest further bone loss and reduce fracture risk.
- Osteoporosis prevention and treatment involves a three-tiered approach that incorporates lifestyle modifications, the assessment and treatment of underlying causes of the disease, and pharmacotherapy.

DISCUSSION STARTERS

1. Do you or any of your classmates have children? What could a parent of a teenager do to help their child achieve a high peak bone mass?
2. Discuss the tactics you might employ at your age to maximize your bone health and minimize your risk for developing osteoporosis.

9.8 Deficiency, Supplementation, and Choices

LEARNING OBJECTIVES

1. List the groups most at risk for calcium inadequacy and explain why they are at risk.
2. Understand the benefits and risks of calcium supplementation.

Despite the wealth of evidence supporting the many health benefits of calcium (particularly bone health), the average American diet falls short of achieving the recommended dietary intakes of calcium. In fact, in females older than nine years of age, the average daily intake of calcium is only about 70 percent of the recommended intake. Here we will take a closer look at particular groups of people who may require extra calcium intake.

Calcium inadequacy is most prevalent in adolescent girls and the elderly. Proper dietary intake of calcium is critical for proper bone health.

© Shutterstock

- **Adolescent teens.** A calcium-deficient diet is common in teenage girls as their dairy consumption often considerably drops during adolescence.
- **Amenorrheic women and the "female athlete triad."** Amenorrhea refers to the absence of a menstrual cycle. Women who fail to menstruate suffer from reduced estrogen levels, which can disrupt and have a negative impact on the calcium balance in their bodies. The "female athlete triad" is a combination of three conditions characterized by amenorrhea, disrupted eating patterns, and osteoporosis. Exercise-induced amenorrhea and anorexia nervosa-related amenorrhea can decrease bone mass.Drinkwater, B., B. Bruemner, and C. Chesnut. "Menstrual History As a Determinant of Current Bone Density in Young Athletes." *JAMA* 263, no. 4 (1990): 545–8. http://www.ncbi.nlm.nih.gov/pubmed/2294327?dopt=Abstract'Marcus, R. et al. "Menstrual Function and Bone Mass in Elite Women Distance Runners: Endocrine and Metabolic Features." *Ann Intern Med* 102, no. 2 (1985):158–63. http://www.ncbi.nlm.nih.gov/pubmed/3966752?dopt=Abstract In female athletes, as well as active women in the military, low BMD, menstrual irregularities, and individual dietary habits together with a

history of previous stress issues are related to an increased susceptibility to future stress fractures.Nattiv, A. “Stress Fractures and Bone Health in Track and Field Athletes.” *J Sci Med Sport* 3, no. 3 (2000): 268–79. http://www.ncbi.nlm.nih.gov/pubmed/11101266?dopt=Abstract.’Johnson, A.O., et al. “Correlation of Lactose Maldigestion, Lactose Intolerance, and Milk Intolerance.” *Am J Clin Nutr* 57, no. 3 (1993): 399–401. http://www.ncbi.nlm.nih.gov/pubmed/8438774?dopt=Abstract.

- **The elderly.** As people age, calcium bioavailability is reduced, the kidneys lose their capacity to convert vitamin D to its most active form, the kidneys are no longer efficient in retaining calcium, the skin is less effective at synthesizing vitamin D, there are changes in overall dietary patterns, and older people tend to get less exposure to sunlight. Thus the risk for calcium inadequacy is great.International Osteoporosis Foundation. “Calcium and Vitamin D in the Elderly.” © 2012. http://www.iofbonehealth.org/patients-public/about-osteoporosis/prevention /nutrition/calcium-and-vitamin-d-in-the-elderly.html.
- **Postmenopausal women.** Estrogen enhances calcium absorption. The decline in this hormone during and after menopause puts postmenopausal women especially at risk for calcium deficiency. Decreases in estrogen production are responsible for an increase in bone resorption and a decrease in calcium absorption. During the first years of menopause, annual decreases in bone mass range from 3–5 percent. After age sixty-five, decreases are typically less than 1 percent.Daniels, C. E. “Estrogen Therapy for Osteoporosis Prevention in Postmenopausal Women.” *National Institute of Health: Pharmacy Update* (March/April 2001).
- **Lactose-intolerant people.** Groups of people, such as those who are lactose intolerant, or who adhere to diets that avoid dairy products, may not have an adequate calcium intake.
- **Vegans.** Vegans typically absorb reduced amounts of calcium because their diets favor plant-based foods that contain oxalates and phytates.Food and Nutrition Board, Institute of Medicine. *Dietary Reference Intakes for Calcium and Vitamin D*. (Washington, DC: National Academy Press, 2010). In addition, because vegans avoid dairy products, their overall consumption of calcium-rich foods may be less.

If you are lactose intolerant, have a milk allergy, are a vegan, or you simply do not like dairy products, remember that there are many plant-based foods that have a good amount of calcium (see Note 9.28 "Tools for Change" in Section 9.3 "Micronutrients Essential for Bone Health: Calcium and Vitamin D" and Table 9.2 "Nondairy Dietary Sources of Calcium") and there are also some low-lactose and lactose-free dairy products on the market.

Calcium Supplements: Which One to Buy?

Getting informed about the risks and benefits of calcium supplementation is important.

© Dreamstime

Many people choose to fulfill their daily calcium requirements by taking calcium supplements. Calcium supplements are sold primarily as calcium carbonate, calcium citrate, calcium lactate, and calcium phosphate, with elemental calcium contents of about 200 milligrams per pill. It is important to note that calcium carbonate requires an acidic environment in the stomach to be used effectively. Although this is not a problem for most people, it may be for those on medication to reduce stomach-acid production or for the elderly who may have a reduced ability to secrete acid in the stomach. For these people, calcium citrate may be a better choice. Otherwise, calcium carbonate is the cheapest. The body is capable of absorbing approximately 30 percent of the calcium from these forms.

Beware of Lead

There is public health concern about the lead content of some brands of calcium supplements, as supplements derived from natural sources such as oyster shell, bone meal, and dolomite (a type of rock containing calcium magnesium carbonate) are known to contain high amounts of lead. In one study conducted on twenty-two brands of calcium supplements, it was proven that eight of the brands exceeded the acceptable limit for lead content. This was found to be the case in supplements derived from oyster shell and refined calcium carbonate. The same study also found that brands claiming to be lead-free did, in fact, show very low lead levels. Because lead levels in supplements are not disclosed on labels, it is important to know that products not derived from oyster shell or other natural substances are generally low in lead content. In addition, it was also found that one brand did not disintegrate as is necessary for absorption, and one brand contained only 77 percent of the stated calcium content.Ross, E. A., N. J. Szabo, and I. R. Tebbett. “Lead Content of Calcium Supplements.” *JAMA* 2000 Sep 20; 284 (2000): 1425–33.

Diet, Supplements, and Chelated Supplements

In general, calcium supplements perform to a lesser degree than dietary sources of calcium in providing many of the health benefits linked to higher calcium intake. This is partly attributed to the fact that dietary sources of calcium supply additional nutrients with health-promoting activities. It is reported that chelated forms of calcium supplements are easier to absorb as the chelation process protects the calcium from oxalates and phytates that may bind with the calcium in the

intestines. However, these are more expensive supplements and only increase calcium absorption up to 10 percent. In people with low dietary intakes of calcium, calcium supplements have a negligible benefit on bone health in the absence of a vitamin D supplement. However, when calcium supplements are taken along with vitamin D, there are many benefits to bone health: peak bone mass is increased in early adulthood, BMD is maintained throughout adulthood, the risk of developing osteoporosis is reduced, and the incidence of fractures is decreased in those who already had osteoporosis. Calcium and vitamin D pills do not have to be taken at the same time for effectiveness. But remember that vitamin D has to be activated and in the bloodstream to promote calcium absorption. Thus, it is important to maintain an adequate intake of vitamin D.

The Calcium Debate

A recent study published in the *British Medical Journal* reported that people who take calcium supplements at doses equal to or greater than 500 milligrams per day in the absence of a vitamin D supplement had a 30 percent greater risk for having a heart attack.Bolland, M. J. et al. "Effect of Calcium Supplements on Risk of Myocardial Infarction and Cardiovascular Events: Meta-Analysis." *Br Med J* 341, no. c3691 (July 29, 2010). Does this mean that calcium supplements are bad for you? If you look more closely at the study, you will find that 5.8 percent of people (143 people) who took calcium supplements had a heart attack, but so did 5.5 percent of the people (111) people who took the placebo. While this is one study, several other large studies have not shown that calcium supplementation increases the risk for cardiovascular disease. While the debate over this continues in the realm of science, we should focus on the things we do know:

1. There is overwhelming evidence that diets sufficient in calcium prevent osteoporosis and cardiovascular disease.
2. People with risk factors for osteoporosis are advised to take calcium supplements if they are unable to get enough calcium in their diet. The National Osteoporosis Foundation advises that adults age fifty and above consume 1,200 milligrams of calcium per day. This includes calcium both from dietary sources and supplements.
3. Consuming more calcium than is recommended is not better for your health and can prove to be detrimental. Consuming too much calcium at any one time, be it from diet or supplements, impairs not only the absorption of calcium itself, but also the absorption of other essential minerals, such as iron and zinc. Since the GI tract can only handle about 500 milligrams of calcium at one time, it is recommended to have split doses of calcium supplements rather than taking a few all at once to get the RDA of calcium.

Other Choices that Affect Bone Health

Too Much Soda

There are many proponents of low-phosphate diets for bone health. Scientific studies do provide evidence that diets consisting of a high intake of processed foods and cola beverages compromise bone health as well as increase the prevalence of obesity. Overall however, the data is inconsistent to show whether it is the phosphate content that is the culprit. The mechanism by which diets high in phosphate could cause a decrease in bone health is the following: a high dietary intake of phosphate leads to an increase in blood phosphate levels. High levels of phosphate in the blood stimulate the release of parathyroid hormone (PTH), which in turn stimulates bone resorption and calcium is lost from the bone. When calcium intake is adequate, it shuts off PTH release, but when calcium intake is inadequate and phosphate intake is high, bone health suffers. How much it suffers is under a considerable amount of debate in the scientific literature. It is a good idea to eat foods that are good sources for both calcium and phosphorus. Table 9.6 "Calcium and Phosphorus Contents in 100 Grams of Certain Foods" shows the calcium and phosphorus contents in certain foods.

Tools for Change

While the scientific community debates the effects of phosphate, we do know that carbonated cola beverages have negative effects on bone health. A study published in the *Archives of Pediatrics and Adolescent Medicine* reports that teenage girls who were physically active and drank carbonated cola beverages were five times more likely to break a bone than physically active girls who did not drink carbonated beverages.Wyshak, G. “Teenaged Girls, Carbonated Beverage Consumption, and Bone Fractures.” *Arch Pediatr Adolesc Med* 154 (2000): 610–13. http://archpedi.ama-assn.org/cgi/content/full/154/6/610?ijkey=d457e7f399850f63fdb8ee9ff3c3a61afcf3e352 The Beverage Guidance Panel, headed by Dr. Barry Popkin from the University of North Carolina, Chapel Hill, recommends drinking not more than one 8-ounce carbonated soft drink per day. A bone-healthy diet is one that does not replace milk and high calcium snacks with carbonated soft drinks and processed foods.

A Lactose-Free Diet

To decrease cola consumption try replacing sugary processed cola drinks with a nice cold glass of your favorite herbal tea.

© Thinkstock

Evidence has been uncovered recently indicating that lactose-free diets result in decreased calcium absorption because dietary lactose has been shown to actually enhance calcium absorption. Thus, lactose intolerance (and lactose-free diets) may predispose one to inadequate bone mineralization, an issue now correlated to many other disorders involving pediatric patients. Researchers are still working to clarify the effects of lactose-free diets in youth on long-term bone mineral content and the risks of osteoporosis and bone fractures with aging. Calcium homeostasis is also affected by protein intake, vitamin D status,Holick, MF. Ann Epidemiol. 2009 Feb;19(2):73–8. Epub 2008 Mar 10.NIH Public Access: "Vitamin D Status: Measurements, Interpretations, and Clinical Application." http://www.ncbi.nlm.nih.gov/pubmed/18329892. salt intake, and genetic and other factors, making long-term studies critical in determining the risks of each or all of these to bone health. Recent studies also indicate that in the future, genetic testing may be appropriate for spotting people who may be at a higher risk of lactase deficiency and subsequent decreased BMD. This may enable early intervention through dietary modification or supplementation.Heyman, M. B., MD, MPH. "Lactose Intolerance in Infants, Children, and Adolescents." *Pediatrics* 118, no. 3 (September 1, 2006): 1279–86. doi: 10.1542/peds.2006-1721.

Bone Health: A Firm Foundation

In your effort to maintain proper bone health, and prevent and treat osteoporosis, you will need to eat a balanced diet of foods that contain not only calcium and vitamin D, but also the other important bone-building nutrients. You will also need to employ physical exercise habits to encourage bone activity, such as remodeling. By consuming foods rich in bone-building materials on a daily basis, you can reduce your need for supplementation. However, if you cannot get the required amounts of calcium you need through diet alone, there are inexpensive, safe, and effective calcium supplements to choose from. As with anything you choose to consume or with any activity that you choose to undertake, supplementation, diet, and exercise should be uniquely tailored to your circumstances.

KEY TAKEAWAYS

- The groups of people who are most at risk for calcium inadequacy are adolescent teens, amenorrheic women, the female triad athlete, the elderly, lactose-intolerant people, those with milk allergies, and vegans.
- When taking calcium supplements, be sure to monitor vitamin D intake to ensure that the proper benefits are achieved. Split doses are more effective since the gastrointestinal tract can only absorb up to 500 milligrams at one time.
- There is need for caution when choosing different brands of calcium supplements. Oyster shell and other naturally derived brands tend to contain unusually high concentrations of lead. Other brands do not contain the stated amount of calcium as advertised.
- The best sources of calcium come from the diet. If you are considered at risk for inadequate calcium intake, then proper supplementation along with a good diet can produce positive results on bone health.

DISCUSSION STARTERS

1. Discuss the argument for and against calcium supplementation. Defend your personal view with scientific facts.

2. Visit the websites below and come up with your own opinion on whether carbonated cola beverages increase the risk of developing osteoporosis. Discuss with your classmates what evidence is lacking. What do you and your classmates think about the position of The Coca-Cola Company Beverage Institute? Do they make a good argument? Can you counter it with better scientific evidence?

   http://www.medpagetoday.com/Endocrinology/Osteoporosis/4247

   http://www.jacn.org/content/20/4/271.full

   http://www.beverageinstitute.org/en_US/pages/expert-beverages-and-bone-health-harmful-helpful-or-no-effect.html

9.9 End-of-Chapter Exercises

IT'S YOUR TURN

1. Calculate your daily calcium intake by visiting the website of the International Osteoporosis Foundation, http://www.livestrong.com/article/258803-how-to-calculate-calcium-intake/. Compare it to the RDA and UL for your age and sex.
2. Determine your risk factors for osteoporosis and plug them in the interactive tool at http://www.webmd.com/hw-popup/risk-of-osteoporosis to estimate your risk for osteoporosis.
3. Plan a dinner meal that contains at least one-third of the RDAs of calcium and vitamin D. To help you determine the calcium and vitamin D contents in foods, visit the USDA National Nutrient Database at http://www.nal.usda.gov/fnic/foodcomp/search/.

APPLY IT

1. Make a list of foods that increase calcium absorption and a list of foods that decrease calcium absorption. Based on your calculated calcium intake levels, determine which foods you should add or subtract from your diet. Now design a daily menu plan that incorporates the changes.
2. Go to the store and look at three calcium supplements. Record the brand names, type of calcium used in each brand, and amounts. Based on your daily calcium intake defend whether or not you need a calcium supplement. If you do decide you need a supplement, which brand would be your best choice?

EXPAND YOUR KNOWLEDGE

1. Draw a cartoon that contains the cells and the four steps involved in the bone remodeling process. Make a timeline on your cartoon that links the processes of bone remodeling with the length of time it takes a broken bone to heal.

2. Watch the following video on the DEXA technology. Then compose a hypothetical list of osteoporosis risk factors for a woman over the age of fifty and provide a recommendation on when she should start having her BMD monitored.

   DEXA—Dual Energy X-Ray Absorptiometry

   (click to see video)
3. Summarize in a written discussion why it is critical to achieve a high peak bone mass early in young adulthood to reduce the risk of developing osteoporosis later in life. Provide a graph of the bone-life cycle in men and women.

Chapter 10

Nutrients Important for Metabolism and Blood Function

Big Idea

Micronutrients come from many sources and some may surprise you; get them in the right amounts to support metabolism and blood health.

Video 10.1

How to Get Iron into Your Diet

(click to see video)

View this video for simple steps you can take to obtain and maintain healthy iron levels in your body.

Mmm, cornbread cooked in a cast iron skillet—the smell and taste of cooking on the range. Can this also be an iron-friendly meal?

© Shutterstock

In a small town in the Appalachian Mountains, Joseph Lodge founded Lodge Iron Cookware in 1896. Today it is still a family-run business that provides Americans with pioneer-style iron cookware. Iron cookware was, and still is, prized for its heat retention, even heating, and durability. In fact, many pans sold one hundred years ago are still in use today. Unbeknownst to the American pioneers, the cookware also leaches iron, an essential mineral, into foods as they are cooked in cast-iron hardware.

Iron has several vital functions in the body. Primarily it is the oxygen carrier of the protein hemoglobin, which is found in red blood cells. Oxygen is essential for cellular metabolism. A reduction in the oxygen-carrying capacity of red blood cells hampers the synthesis of energy and consequently cell function. Additionally, iron is required for energy production and enzymatic synthesis of RNA and DNA. Therefore cells that are rapidly dividing are acutely sensitive to an iron deficiency. Since red blood cells are under a constant state of

renewal in the body, low iron levels impede their synthesis, eventually causing anemia. A person with anemia experiences fatigue, shortness of breath, dizziness, muscle weakness, and pale skin. In infants and children iron-deficiency anemia can impair growth, motor control, mental functioning, behavior, and performance in school. Iron deficiency is the number-one nutritional deficiency in the world, and even in America it affects 10 percent of women of childbearing age and many infants, children, and adolescents.

Dietary sources of iron include red meats, poultry, leafy green vegetables, prunes, raisins, egg yolks, lentils, oysters, clams, artichokes, and enriched cereal grains. While there are many food sources of iron, only a small fraction of dietary iron is absorbed. One method of increasing dietary intake of iron is cooking foods in an iron skillet. Acidic foods high in moisture content, such as tomatoes, absorb more iron during cooking than nonacidic foods. For example, cooking spaghetti sauce in iron cookware can increase the iron content ten-fold. How much iron leaches into food is also dependent on cooking times; the longer food is in the pan the more iron is absorbed into the food. Stirring food more often increases contact time and thus more iron is absorbed from the cookware. The utility of iron cookware in increasing dietary intake of iron has prompted some international public health organizations to distribute iron cookware to high-risk populations in developing countries as a strategy to reduce the prevalence of iron-deficiency anemia worldwide.

You Decide

What are the different ways to build iron storehouses in your body without taking a pill?

In this chapter, we will discuss the importance of blood and its vital role in support of metabolism and pull together what we have learned about macronutrient metabolism. You will also learn the important roles micronutrients have in metabolism and how they support blood function and renewal. We will also consider food sources of these valuable nutrients. Read the facts, then decide the best way to supplement your diet with iron friendly eating and cooking.

10.1 Blood's Function in the Body and in Metabolism Support

LEARNING OBJECTIVE

1. List each component of blood and its major role.

You know you cannot live without blood, and that your heart pumps your blood over a vast network of veins and arteries within your body, carrying oxygen to your cells. However, beyond these basic facts, what do you know about your blood?

Blood is a connective tissue of the circulatory system, transporting absorbed nutrients to cells and waste products from cells. It supports cellular metabolism by transporting synthesized macromolecules and waste products. Additionally, it transports molecules, such as hormones, allowing for communication between organs. The volume of blood coursing throughout an adult human body is about 5 liters (1.3 gallons) and accounts for approximately 8 percent of human bodyweight.

What Makes Up Blood and How Do These Substances Support Blood Function?

Blood is about 78 percent water and 22 percent solids by volume. The liquid part of blood is called plasma and it is mostly water (95 percent), but also contains proteins, ions, glucose, lipids, vitamins, minerals, waste products, gases, enzymes, and hormones. You learned in Chapter 6 "Proteins" and Chapter 7 "Nutrients Important to Fluid and Electrolyte Balance" that the protein albumin is found in high concentrations in the blood. Albumin helps maintain fluid balance between blood and tissues, as well as helping to maintain a constant blood pH. In Chapter 7 "Nutrients Important to Fluid and Electrolyte Balance" we learned that the water component of blood is essential for its actions as a transport vehicle, and that the electrolytes carried in blood maintain fluid balance and a constant pH. Furthermore the high water content of blood helps maintain body temperature, and the constant flow of blood distributes heat throughout the body. Blood is exceptionally good at temperature control, so much so that the many small blood vessels in your nose are capable of warming frigid air to body temperature before it reaches the lungs.

The cellular components of blood include red blood cells, white blood cells, and platelets. **Red blood cells**[1] are the most numerous of the components. Each drop of blood contains millions of them. Red blood cells are red because they each contain approximately 270 million hemoglobin proteins, which contain the mineral iron,

1. The most numerous cells in blood, which transport oxygen to all cells in the body.

which when bound to oxygen turns red. The most vital duty of red blood cells is to transport oxygen from the lungs to all cells in the body so that they can make energy via aerobic metabolism. The **white blood cells**[2] that circulate in blood are part of the immune system and they survey the entire body looking for foreign invaders to destroy. They make up about 1 percent of blood volume. **Platelets**[3] are fragments of cells that are always circulating in the blood in case of an emergency. When blood vessels are injured platelets rush to the site of injury to plug the wound. Blood is under a constant state of renewal and is synthesized from stem cells residing in bone marrow. Red blood cells live for about 120 days, white blood cells live anywhere from eighteen hours to one year, or even longer, and platelets have a lifespan of about ten days.

Video 10.2

What Is Blood?

(click to see video)

Watch this brief animation on the importance of blood components.

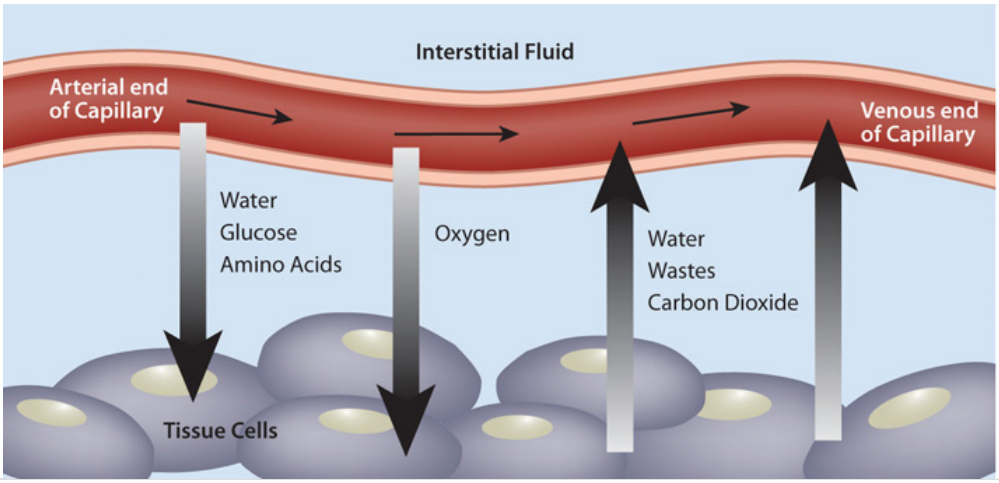
Nutrients In

Once absorbed from the small intestine, all nutrients require transport to cells in need of their support. Additionally, molecules manufactured in other cells sometimes require delivery to other organ systems. Blood is the conduit and blood vessels are the highway that support nutrient and molecule transport to all cells. Water-soluble molecules, such as some vitamins, minerals, sugars, and many proteins, move independently in blood. Fat-soluble vitamins, triglycerides, cholesterol, and other lipids are packaged into lipoproteins that allow for transport in the watery milieu of blood. Many proteins, drugs, and hormones are dependent on transport carriers, primarily albumin. In addition to transporting all of these molecules, blood must transfer the oxygen breathed in by the lungs to all cells in the body. As discussed, the iron-containing hemoglobin molecule in red blood cells accomplishes this.

2. Cells of the immune system that survey the entire body looking for foreign invaders to destroy.
3. Fragments of cells that, when stimulated by blood vessel injury, rush to plug up the wound.

Wastes Out

Figure 10.1 *The Capillary Exchange: Nutrients In and Wastes Out*



In the metabolism of macronutrients to energy, cells produce the waste products carbon dioxide and water. As blood travels through smaller and smaller vessels, the rate of blood flow is dramatically reduced allowing for efficient exchange of nutrients and oxygen for cellular waste products. The kidneys remove any excess water in the blood, and blood delivers the carbon dioxide to the lungs where it is exhaled. Also, the liver produces the waste product urea from the breakdown of amino acids, and detoxifies many harmful substances, all of which require transport in the blood to the kidneys for excretion.

All for One, One for All

We are not going to talk about the three musketeers, but we will talk about the way our bodies function and work harmoniously to sustain life. The eleven organ systems in the body completely depend on each other for continued survival as a complex organism. Blood allows for transport of nutrients, wastes, water, and heat, and is also a conduit of communication between organ systems. Blood's importance to the rest of the body is aptly presented in its role in glucose delivery, especially to the brain. The brain metabolizes, on average, 6 grams of glucose per hour. In order to avert confusion, coma, and death, glucose must be readily available to the brain at all times. To accomplish this task, cells in the pancreas sense glucose levels in the blood. If glucose levels are low, the hormone glucagon is released into the blood and is transported to the liver where it communicates the signal to ramp-up glycogen breakdown and glucose synthesis. The liver does just that, and glucose is released into the blood, which transports it to the brain. Concurrently, blood transports oxygen to support the metabolism of glucose to energy in the brain. Healthy blood conducts its duties rapidly, avoiding hypoglycemic coma and death. This is just one

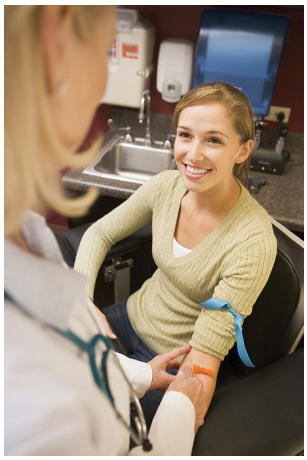
example of the body's survival mechanisms exemplifying life's mantra, "All for one, one for all."

What Makes Blood Healthy?

Maintaining healthy blood, including its continuous renewal, is essential to support its vast array of vital functions. Blood is healthy when it contains the appropriate amount of water and cellular components, and proper concentrations of dissolved substances, such as albumin and electrolytes. As with all other tissues, blood needs macro- and micronutrients to optimally function. In the bone marrow, where blood cells are made, amino acids are required to build the massive amount of hemoglobin packed within every red blood cell, along with all other enzymes and cellular organelles contained in each blood cell. Red blood cells, similar to the brain, use only glucose as fuel, and it must be in constant supply to support red-blood-cell metabolism. As with all other cells, the cells in the blood are surrounded by a plasma membrane, which is composed of mainly lipids. Blood health is also acutely sensitive to deficiencies in some vitamins and minerals more than others, a topic that will be explored in this chapter.

What Can Blood Tests Tell You About Your Health?

Since blood is the conduit of metabolic products and wastes, measuring the components of blood, and particular substances in blood, can reveal not only the health of blood, but also the health of other organ systems. In standard blood tests performed during an annual physical, the typical blood tests conducted can tell your physician about the functioning of a particular organ or about disease risk.



Blood tests are helpful tools in diagnosing disease and provide much information on overall health.

© Shutterstock

A **biomarker**[4] is defined as a measurable molecule or trait that is connected with a specific disease or health condition. The concentrations of biomarkers in blood are indicative of disease risk. Some biomarkers are cholesterol, triglycerides, glucose, and prostate-specific antigen. The results of a blood test give the concentrations of substances in a person's blood and display the normal ranges for a certain population group. Many factors, such as physical activity level, diet, alcohol intake, and medicine intake can influence a person's blood-test levels and cause them to fall outside the normal range, so results of blood tests outside the "normal" range are not always indicative of health problems. The assessment of

4. A measurable molecule or trait that is connected with a specific disease or health condition.

multiple blood parameters aid in the diagnosis of disease risk and are indicative of overall health status. See Table 10.1 "Blood Tests" for a partial list of substances measured in a typical blood test. This table notes only a few of the things that their levels tell us about health.

Table 10.1 Blood Tests

Substance Measured	Indicates
Red-blood-cell count	Oxygen-carrying capacity
Hematocrit (red-blood-cell volume)	Anemia risk
White-blood-cell count	Presence of infection
Platelet count	Bleeding disorders, atherosclerosis risk
pH	Metabolic, kidney, respiratory abnormalities
Albumin	Liver, kidney, and Crohn's disease, dehydration
Bilirubin	Liver-function abnormality
Oxygen/Carbon Dioxide	Respiratory or metabolic abnormality
Hemoglobin	Oxygen-carrying capacity
Iron	Anemia risk
Magnesium	Magnesium deficiency
Electrolytes (calcium, chloride, magnesium, potassium)	Many illnesses (kidney, metabolic, etc.)
Cholesterol	Cardiovascular disease risk
Triglycerides	Cardiovascular disease risk
Glucose	Diabetes risk
Hormones	Many illnesses (diabetes, reproductive abnormalities)

Source: National Heart Lung and Blood Institute. "Types of Blood Tests." January 6, 2012. http://www.nhlbi.nih.gov/health/health-topics/topics/bdt/types.html.

Interactive 10.1

Visit the websites of the National Heart, Lung, and Blood Institute and Lab Tests Online to find out more on what to expect on blood tests and how to interpret results.

http://www.nhlbi.nih.gov/health/dci/Diseases/bdt/bdt_whatdo.html

http://labtestsonline.org/

KEY TAKEAWAYS

- Blood is a connective tissue of the circulatory system, and the fluid in the body that transports absorbed nutrients to cells and waste products from cells.
- The fluid part of blood, plasma, makes up the largest amount of blood volume and contains proteins, ions, glucose, lipids, vitamins, minerals, waste products, gases, enzymes, and hormones. The cellular components of blood include red blood cells, white blood cells, and platelets. Blood is under a constant state of renewal and is synthesized from stem cells residing in bone marrow.
- As blood travels through smaller and smaller vessels the rate of blood flow is dramatically reduced, allowing for efficient exchange of nutrients and oxygen for cellular waste products.
- Blood is healthy when it contains the appropriate amount of water and cellular components, and proper concentrations of dissolved substances, such as albumin and electrolytes.
- The assessment of multiple blood parameters aid in the diagnosis of disease risk and are indicative of overall health status.

DISCUSSION STARTERS

1. Why does the heart pump blood at a faster rate during exercise?

2. Come up with an estimate on how often it is safe to donate blood. Get the facts on donating blood by visiting the website of the Red Cross.

   http://www.redcrossblood.org/donating-blood/eligibility-requirements

10.2 Metabolism Overview

LEARNING OBJECTIVES

1. Summarize how energy from the energy-yielding nutrients is obtained and used, and how and where it is stored in the body for later use.
2. Explain the role of energy in the process of building tissues and organs.

Throughout the various chapters in this text we have explored the metabolism of carbohydrates, lipids, and proteins. In this next section we will compile this information for a clear picture of the importance of metabolism in human nutrition.

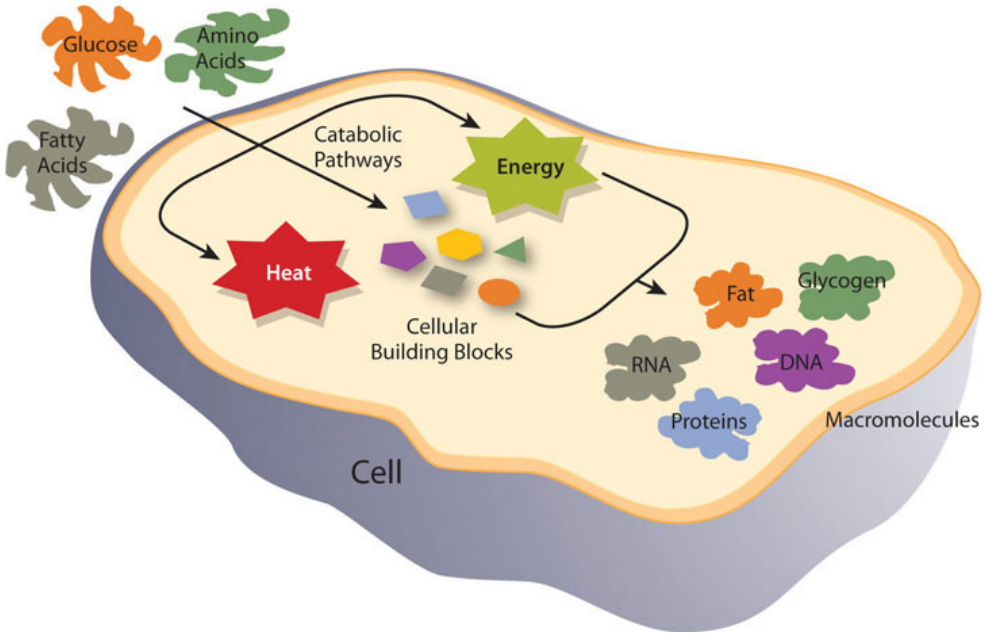
Metabolism[5] is defined as the sum of all chemical reactions required to support cellular function and hence the life of an organism. Metabolism is either categorized as **catabolism**[6], referring to all metabolic processes involved in molecule breakdown, or **anabolism**[7], which includes all metabolic processes involved in building bigger molecules. Generally, catabolic processes release energy and anabolic processes consume energy. The overall goals of metabolism are energy transfer and matter transport. Energy is transformed from food macronutrients into cellular energy, which is used to perform cellular work. Metabolism transforms the matter of macronutrients into substances a cell can use to grow and reproduce and also into waste products. In Chapter 6 "Proteins", you learned that enzymes are proteins and that their job is to catalyze chemical reactions. (Recall that the word catalyze means to speed-up a chemical reaction and reduce the energy required to complete the chemical reaction, without the catalyst being used up in the reaction.) Without enzymes, chemical reactions would not happen at a fast enough rate and would use up too much energy for life to exist. A metabolic pathway is a series of enzymatic reactions that transforms the starting material (known as a substrate) into intermediates, which are the substrates for the next enzymatic reactions in the pathway, until, finally, an endproduct is synthesized by the last enzymatic reaction in the pathway. Some metabolic pathways are complex and involve many enzymatic reactions, and others involve only a few chemical reactions.

To ensure cellular efficiency, the metabolic pathways involved in catabolism and anabolism are regulated in concert by energy status, hormones, and substrate and end-product levels. The concerted regulation of metabolic pathways prevents cells from inefficiently building a molecule when it is already available. Just as it would be inefficient to build a wall at the same time as it is being broken down, it is not

5. The sum of all chemical reactions required to support cellular function and hence the life of an organism.
6. All metabolic processes involved in molecule breakdown and the release of energy.
7. All metabolic processes involved in building bigger molecules, which consume energy.

metabolically efficient for a cell to synthesize fatty acids and break them down at the same time.

Catabolism of food molecules begins when food enters the mouth, as the enzyme salivary amylase initiates the breakdown of carbohydrates. The entire process of digestion converts the large polymers in food to monomers that can be absorbed. Carbohydrates are broken down to monosaccharides, lipids are broken down to fatty acids, and proteins are broken down to amino acids. These monomers are absorbed into the bloodstream either directly, as is the case with monosaccharides and amino acids, or repackaged in intestinal cells for transport by an indirect route through lymphatic vessels, as is the case with fatty acids and other fat-soluble molecules. Once absorbed, blood transports the nutrients to cells. Cells requiring energy or building blocks take up the nutrients from the blood and process them in either catabolic or anabolic pathways. The organ systems of the body require fuel and building blocks to perform the many fucntions of the body, such as digesting, absorbing, breathing, pumping blood, transporting nutrients in and wastes out, maintaining body temperature, and making new cells.



Metabolism is categorized into metabolic pathways that breakdown the molecules that release energy (catabolism) and the molecules that consume energy by building bigger molecules (anabolism).

Energy metabolism[8] refers more specifically to the metabolic pathways that release or store energy. Some of these are catabolic pathways, like glycolysis (the

8. The metabolic pathways that release or store energy.

splitting of glucose), β-oxidation (fatty-acid breakdown), and amino acid catabolism. Others are anabolic pathways, and include those involved in storing excess energy (such as glycogenisis), and synthesizing triglycerides (lipogenesis). Table 10.2 "Metabolic Pathways" summarizes some of the catabolic and anabolic pathways, and their functions in energy metabolism.

Table 10.2 Metabolic Pathways

Catabolic Pathways	Function	Anabolic Pathways	Function
Glycolysis	Glucose breakdown	Gluconeogenesis	Synthesize glucose
Glycogenolysis	Glycogen breakdown	Glycogenesis	Synthesize glycogen
β-oxidation	Fatty-acid breakdown	Lipogenesis	Synthesize triglycerides
Proteolysis	Protein breakdown to amino acids	Amino-acid synthesis	Synthesize amino acids

Catabolism: The Breakdown

All cells are in tune to their energy balance. When energy levels are high cells build molecules, and when energy levels are low catabolic pathways are initiated to make energy. Glucose is the preferred energy source by most tissues, but fatty acids and amino acids can also be catabolized to the cellular energy molecule, ATP. The catabolism of nutrients to energy can be separated into three stages, each containing individual metabolic pathways. The three stages of nutrient breakdown allow for cells to reassess their energy requirements, as endproducts of each pathway can either be further processed to energy or diverted to anabolic pathways. Additionally, intermediates of metabolic pathways can sometimes be diverted to anabolic pathways once cellular energy requirements have been met. The three stages of nutrient breakdown are the following:

- **Stage 1.** Glycolysis for glucose, β-oxidation for fatty acids, or amino-acid catabolism
- **Stage 2.** Citric Acid Cycle (or Kreb cycle)
- **Stage 3.** Electron Transport Chain and ATP synthesis

The breakdown of glucose begins with glycolysis, which is a ten-step metabolic pathway yielding two ATP per glucose molecule; glycolysis takes place in the cytosol and does not require oxygen. In addition to ATP, the end-products of glycolysis include two three-carbon molecules, called pyruvate. Pyruvate can either

be shuttled to the citric acid cycle to make more ATP or follow an anabolic pathway. If a cell is in negative-energy balance, pyruvate is transported to the mitochondria where it first gets one of its carbons chopped off, yielding acetyl-CoA. Acetyl-CoA, a two-carbon molecule common to glucose, lipid, and protein metabolism enters the second stage of energy metabolism, the citric acid cycle. The breakdown of fatty acids begins with the catabolic pathway, known as β-oxidation, which takes place in the mitochondria. In this catabolic pathway, four enzymatic steps sequentially remove two-carbon molecules from long chains of fatty acids, yielding acetyl-CoA molecules. In the case of amino acids, once the nitrogen is removed from the amino acid the remaining carbon skeleton can be enzymatically converted into acetyl-CoA or some other intermediate of the citric acid cycle.

In the citric acid cycle acetyl-CoA is joined to a four-carbon molecule. In this multistep pathway, two carbons are lost as two molecules of carbon dioxide. The energy obtained from the breaking of chemical bonds in the citric acid cycle is transformed into two more ATP molecules (or equivalents thereof) and high energy electrons that are carried by the molecules, nicotinamide adenine dinucleotide (NADH) and flavin adenine dinucleotide ($FADH_2$). NADH and $FADH_2$ carry the electrons to the inner membrane in the mitochondria where the third stage of energy synthesis takes place, in what is called the electron transport chain. In this metabolic pathway a sequential transfer of electrons between multiple proteins occurs and ATP is synthesized. The entire process of nutrient catabolism is chemically similar to burning, as carbon molecules are burnt producing carbon dioxide, water, and heat. However, the many chemical reactions in nutrient catabolism slow the breakdown of carbon molecules so that much of the energy can be captured and not transformed into heat and light. Complete nutrient catabolism is between 30 and 40 percent efficient, and some of the energy is therefore released as heat. Heat is a vital product of nutrient catabolism and is involved in maintaining body temperature. If cells were too efficient at transforming nutrient energy into ATP, humans would not last to the next meal, as they would die of hypothermia.

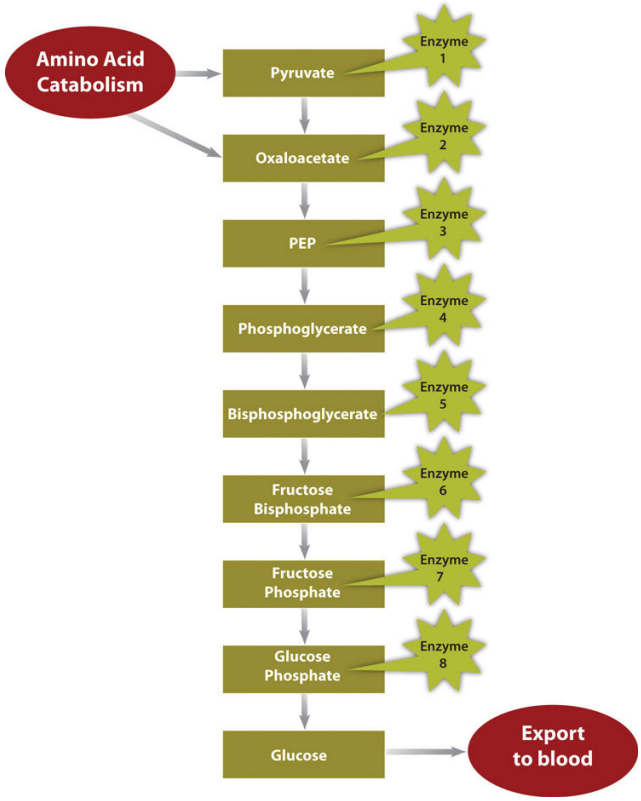
Anabolism: The Building

The energy released by catabolic pathways powers anabolic pathways in the building of macromolecules such as the proteins RNA and DNA, and even entire new cells and tissues. Anabolic pathways are required to build new tissue, such as muscle, after prolonged exercise or the remodeling of bone tissue, a process involving both catabolic and anabolic pathways. Anabolic pathways also build energy-storage molecules, such as glycogen and triglycerides. Intermediates in the catabolic pathways of energy metabolism are sometimes diverted from ATP production and used as building blocks instead. This happens when a cell is in positive-energy balance. For example, the citric-acid-cycle intermediate, α-ketoglutarate can be anabolically processed to the amino acids glutamate or

glutamine if they are required. Recall from Chapter 6 "Proteins" that the human body is capable of synthesizing eleven of the twenty amino acids that make up proteins. The metabolic pathways of amino acid synthesis are all inhibited by the specific amino acid that is the end-product of a given pathway. Thus, if a cell has enough glutamine it turns off its synthesis.

Anabolic pathways are regulated by their end-products, but even more so by the energy state of the cell. When there is ample energy, bigger molecules, such as protein, RNA and DNA, will be built as needed. Alternatively when energy is insufficient, proteins and other molecules will be destroyed and catabolized to release energy. A dramatic example of this is seen in children with Marasmus. These children have severely compromised bodily functions, often culminating in death by infection. Children with Marasmus are starving for calories and protein, which are required to make energy and build macromolecules. The negative-energy balance in children who have Marasmus results in the breakdown of muscle tissue and tissues of other organs in the body's attempt to survive. The large decrease in muscle tissue makes children with Marasmus look emaciated or "muscle-wasted."

Figure 10.2 *Metabolic Pathway of Gluconeogenesis*



In a much less severe example, a person is also in negative-energy balance between meals. During this time, blood-glucose levels start to drop. In order to restore blood-glucose levels to their normal range, the anabolic pathway, called gluconeogenesis, is stimulated. Gluconeogenesis is the process of building glucose molecules from certain amino acids and it occurs primarily in the liver (Figure 10.2 "Metabolic Pathway of Gluconeogenesis"). The liver exports the synthesized glucose into the blood for other tissues to use.

Energy Storage

In contrast, in the “fed” state (when energy levels are high), extra energy from nutrients will be stored. Glucose can be stored only in muscle and liver tissues. In these tissues it is stored as glycogen, a highly branched macromolecule consisting of thousands of glucose monomers held together by chemical bonds. The glucose monomers are joined together by an anabolic pathway called glycogenesis. For each molecule of glucose stored, one molecule of ATP is used. Therefore, it costs energy to store energy. Glycogen levels do not take long to reach their physiological limit and when this happens excess glucose will be converted to fat. A cell in positive-energy balance detects a high concentration of ATP as well as acetyl-CoA produced by catabolic pathways. In response, catabolism is shut off and the synthesis of triglycerides, which occurs by an anabolic pathway called lipogenesis, is turned on. The newly made triglycerides are transported to fat-storing cells called adipocytes. Fat is a better alternative to glycogen for energy storage as it is more compact (per unit of energy) and, unlike glycogen, the body does not store water along with fat. Water weighs a significant amount and increased glycogen stores, which are accompanied by water, would dramatically increase body weight. When the body is in positive-energy balance, excess carbohydrates, lipids, and protein are all metabolized to fat.

KEY TAKEAWAYS

- The overall goals of metabolism are energy transfer and matter transport. Metabolism is defined as the sum of all chemical reactions required to support cellular function and is either categorized as catabolism (referring to all metabolic processes involved in molecule breakdown) or anabolism (which includes all metabolic processes involved in building bigger molecules). Generally, catabolic processes release energy and anabolic processes consume energy.
- A metabolic pathway is a series of enzymatic steps that transforms a substrate (the starting material) into intermediates, which are substrates for the proceeding enzymatic reactions until finally an end-product is synthesized by the last enzymatic reaction in the pathway.
- The organ systems of the body require fuel and building blocks to digest, absorb, breathe, pump blood, transport nutrients in and wastes out, maintain body temperature, and make new cells amongst a multitude of other functions.
- When energy levels are high, cells build molecules, and when energy levels are low, catabolic pathways are stimulated to release energy.
- The energy released by catabolic pathways powers anabolic pathways in the building of bigger macromolecules.
- In the “fed” state (when energy levels are high), extra nutrient fuel will be stored as glycogen or triglycerides.

DISCUSSION STARTERS

1. Discuss the practicality of storing energy in early human civilizations and the consequences of these metabolic processes in today’s world. Refer back to the story of the Pima Indians in Chapter 1 "Nutrition and You" and the concept of the “thrifty gene.”
2. Can an overweight person blame their excess weight on having a slower metabolism?

10.3 Vitamins Important for Metabolism and for Blood Function and Renewal

LEARNING OBJECTIVES

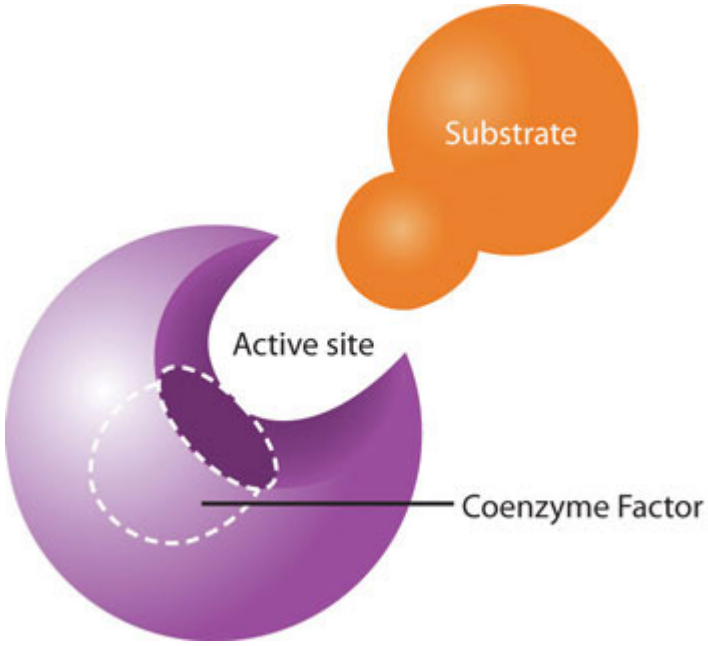
1. Summarize the role of the B vitamins in metabolism.
2. Explain how Vitamin K supports a life-saving function of blood.

While the macronutrients (carbohydrates, lipids, and proteins) and alcohol can be catabolized to release energy, vitamins and minerals play a different kind of role in energy metabolism; they are required as functional parts of enzymes involved in energy release and storage. Vitamins and minerals that make up part of enzymes are referred to as **coenzymes**[9] and **cofactors**[10], respectively. Coenzymes and cofactors are required by enzymes to catalyze a specific reaction. They assist in converting a substrate to an end-product (Figure 10.3). Coenzymes and cofactors are essential in catabolic pathways and play a role in many anabolic pathways too.

In addition to being essential for metabolism, many vitamins and minerals are required for blood renewal and function. At insufficient levels in the diet these vitamins and minerals impair the health of blood and consequently the delivery of nutrients in and wastes out, amongst its many other functions. In this section we will focus on the vitamins that take part in metabolism and blood function and renewal.

9. Vitamins that make up part of enzymes required for converting a substrate to an end-product.
10. Minerals that make up part of enzymes required for converting a substrate to an end-product.

Figure 10.3



Coenzymes and cofactors are the particular vitamin or mineral required for enzymes to catalyze a specific reaction.

Vitamins: Functions in Catabolic Pathways, Anabolic Pathways, and Blood

Thiamine (B_1)

Thiamine is especially important in glucose metabolism. It acts as a cofactor for enzymes that break down glucose for energy production (Figure 10.3). Additionally, thiamine plays a role in the synthesis of ribose from glucose and is therefore required for RNA, DNA, and ATP synthesis. The brain and heart are most affected by a deficiency in thiamine. Thiamine deficiency, also known as beriberi, can cause symptoms of fatigue, confusion, movement impairment, pain in the lower extremities, swelling, and heart failure. It is prevalent in societies whose main dietary staple is white rice. During the processing of white rice, the bran is removed, along with what were called in the early nineteenth century, "accessory factors," that are vital for metabolism. Dutch physician Dr. Christiaan Eijkman cured chickens of beriberi by feeding them unpolished rice bran in 1897. By 1912, Sir Frederick Gowland Hopkins determined from his experiments with animals that the "accessory factors," eventually renamed vitamins, are needed in the diet to support growth, since animals fed a diet of pure carbohydrates, proteins, fats, and minerals failed to grow.Encyclopedia Brittanica Blog. "Frederick Gowland Hopkins

and his “Accessory Food Factors.” Accessed October 1, 2011. http://www.britannica.com/blogs/2011/06/frederick-gowland-hopkins-accessory-food-factors/. Eijkman and Hopkins were awarded the Nobel Prize in Physiology (or Medicine) in 1929 for their discoveries in the emerging science of nutrition.

Riboflavin (B_2)

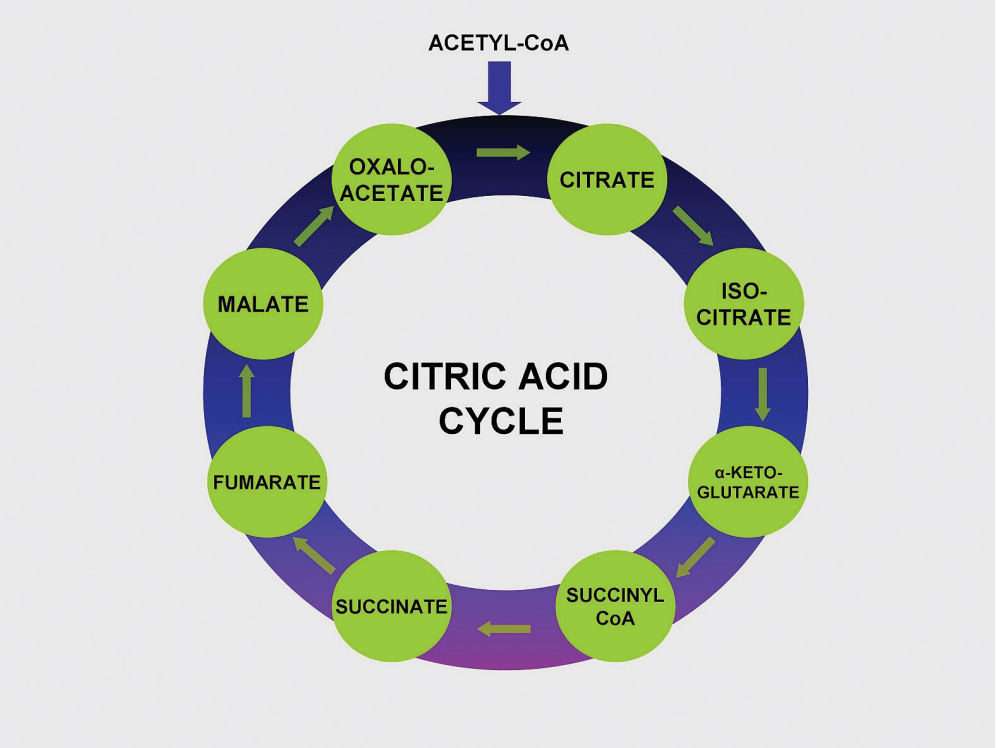
Riboflavin is an essential component of flavoproteins, which are coenzymes involved in many metabolic pathways of carbohydrate, lipid, and protein metabolism. Flavoproteins aid in the transfer of electrons in the electron transport chain. Furthermore, the functions of other B-vitamin coenzymes, such as vitamin B_6 and folate, are dependent on the actions of flavoproteins. The “flavin” portion of riboflavin gives a bright yellow color to riboflavin, an attribute that help lead to its discovery as a vitamin. Riboflavin deficiency, sometimes referred to as ariboflavinosis, is often accompanied by other dietary deficiencies (most notably protein) and can be common in people that suffer from alcoholism. Its signs and symptoms include dry, scaly skin, mouth inflammation and sores, sore throat, itchy eyes, and light sensitivity.

Niacin (B_3)

Niacin is a component of the coenzymes NADH and NADPH, which are involved in the catabolism and/or anabolism of carbohydrates, lipids, and proteins. NADH is the predominant electron carrier and transfers electrons to the electron-transport chain to make ATP. NADPH is also required for the anabolic pathways of fatty-acid and cholesterol synthesis. In contrast to other vitamins, niacin can be synthesized by humans from the amino acid tryptophan in an anabolic process requiring enzymes dependent on riboflavin, vitamin B_6, and iron. Niacin is made from tryptophan only after tryptophan has met all of its other needs in the body. The contribution of tryptophan-derived niacin to niacin needs in the body varies widely and a few scientific studies have demonstrated that diets high in tryptophan have very little effect on niacin deficiency. Niacin deficiency is commonly known as pellagra and is characterized by diarrhea, dermatitis, dementia, and sometimes death (see Note 10.24 "Video 10.3").

Pantothenic Acid (B_5)

Figure 10.4



Vitamin B_5 makes up coenzyme A, which carries the carbons of glucose, fatty acids, and amino acids into the citric acid cycle as Acetyl-CoA.

Pantothenic acid forms coenzyme A, which is the main carrier of carbon molecules in a cell. Acetyl-CoA is the carbon carrier of glucose, fatty acids, and amino acids into the citric acid cycle (Figure 10.4). Coenzyme A is also involved in the synthesis of lipids, cholesterol, and acetylcholine (a neurotransmitter). Vitamin B_5 deficiency is exceptionally rare. Signs and symptoms include fatigue, irritability, numbness, muscle pain, and cramps. You may have seen pantothenic acid on many ingredients lists for skin and hair care products; however there is no good scientific evidence that pantothenic acid improves human skin or hair.

Pyroxidine (B_6)

Pyroxidine is the coenzyme involved in nitrogen transfer between amino acids and therefore plays a role in amino-acid synthesis and catabolism. Also, it functions to release glucose from glycogen in the catabolic pathway of glycogenolysis and is required by enzymes for the synthesis of multiple neurotransmitters and

hemoglobin. A deficiency in vitamin B_6 can cause signs and symptoms of muscle weakness, dermatitis, mouth sores, fatigue, and confusion.

Vitamin B_6 is a required coenzyme for the synthesis of hemoglobin. A deficiency in vitamin B_6 can cause anemia, but it is of a different type than that caused by insufficient folate, cobalamin, or iron; although the symptoms are similar. The size of red blood cells is normal or somewhat smaller but the hemoglobin content is lower. This means each red blood cell has less capacity for carrying oxygen, resulting in muscle weakness, fatigue, and shortness of breath.

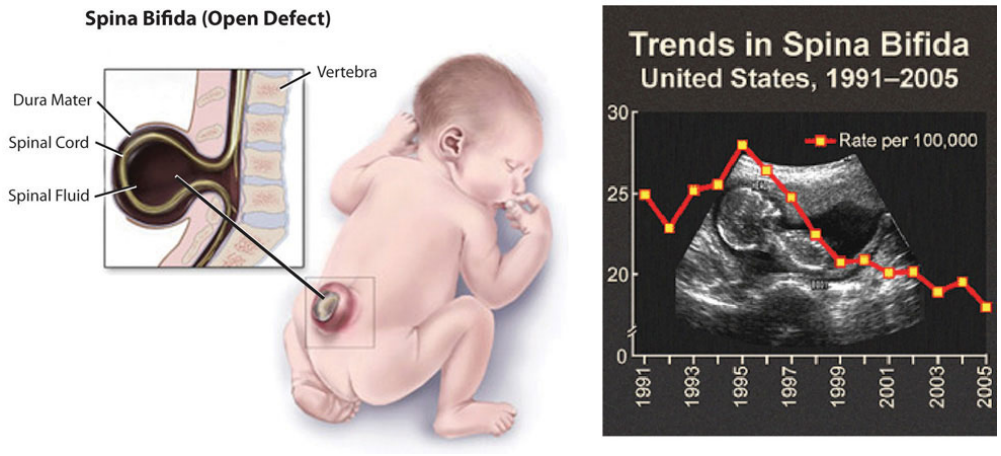
Biotin

Biotin is required as a coenzyme in the citric acid cycle and in lipid metabolism. It is also required as an enzyme in the synthesis of glucose and some nonessential amino acids. A specific enzyme, biotinidase, is required to release biotin from protein so that it can be absorbed in the gut. There is some bacterial synthesis of biotin that occurs in the colon; however this is not a significant source of biotin. Biotin deficiency is rare, but can be caused by eating large amounts of egg whites over an extended period of time. This is because a protein in egg whites tightly binds to biotin making it unavailable for absorption. A rare genetic disease-causing malfunction of the biotinidase enzyme also results in biotin deficiency. Symptoms of biotin deficiency are similar to those of other B vitamins, but may also include hair loss when severe.

Folate

Folate is a required coenzyme for the synthesis of the amino acid methionine, and for making RNA and DNA. Therefore, rapidly dividing cells are most affected by folate deficiency. Red blood cells, white blood cells, and platelets are continuously being synthesized in the bone marrow from dividing stem cells. A consequence of folate deficiency is macrocytic, also called megaloblastic, anemia. Macrocytic and megaloblastic mean “big cell,” and anemia refers to fewer red blood cells or red blood cells containing less hemoglobin. Macrocytic anemia is characterized by larger and fewer red blood cells. It is caused by red blood cells being unable to produce DNA and RNA fast enough—cells grow but do not divide, making them large in size.

Figure 10.5



Spina bifida is a neural-tube defect that can have severe health consequences.

Folate is especially essential for the growth and specialization of cells of the central nervous system. Children whose mothers were folate-deficient during pregnancy have a higher risk of neural-tube birth defects. Folate deficiency is causally linked to the development of spina bifida, a neural-tube defect that occurs when the spine does not completely enclose the spinal cord. Spina bifida can lead to many physical and mental disabilities (Figure 10.5). Observational studies show that the prevalence of neural-tube defects was decreased after the fortification of enriched cereal grain products with folate in 1996 in the United States (and 1998 in Canada) compared to before grain products were fortified with folate (Figure 10.5). Additionally, results of clinical trials have demonstrated that neural-tube defects are significantly decreased in the offspring of mothers who began taking folate supplements one month prior to becoming pregnant and throughout the pregnancy. In response to the scientific evidence, the Food and Nutrition Board of the Institute of Medicine (IOM) raised the RDA for folate to 600 micrograms per day for pregnant women. Some were concerned that higher folate intakes may cause colon cancer, however scientific studies refute this hypothesis.

Cobalamin (B_{12})

Cobalamin contains cobalt, making it the only vitamin that contains a metal ion. Cobalamin is an essential part of coenzymes. It is necessary for fat and protein catabolism, for folate coenzyme function, and for hemoglobin synthesis. An enzyme requiring cobalamin is needed by a folate-dependent enzyme to synthesize DNA. Thus, a deficiency in cobalamin has similar consequences to health as folate

deficiency. In children and adults cobalamin deficiency causes macrocytic anemia, and in babies born to cobalamin-deficient mothers there is an increased risk for neural-tube defects. In order for the human body to absorb cobalamin, the stomach, pancreas, and small intestine must be functioning properly. Cells in the stomach secrete a protein called intrinsic factor that is necessary for cobalamin absorption, which occurs in the small intestine. Impairment of secretion of this protein either caused by an autoimmune disease or by chronic inflammation of the stomach (such as that occurring in some people with H.pylori infection), can lead to the disease pernicious anemia, a type of macrocytic anemia. Vitamin B_{12} malabsorption is most common in the elderly, who may have impaired functioning of digestive organs, a normal consequence of aging. Pernicious anemia is treated by large oral doses of vitamin B_{12} or by putting the vitamin under the tongue, where it is absorbed into the blood stream without passing through the intestine. In patients that do not respond to oral or sublingual treatment vitamin B_{12} is given by injection.

A summary of the prominent functions of the B vitamins in metabolism and blood function, and their deficiency syndromes is given in Table 10.3 "B-Vitamin Functions in Metabolism and Blood, and Deficiency Syndromes".

Table 10.3 B-Vitamin Functions in Metabolism and Blood, and Deficiency Syndromes

B Vitamin	Function	Deficiency: Signs and Symptoms
B_1 (thiamine)	Coenzyme: assists in glucose metabolism, RNA, DNA, and ATP synthesis	Beriberi: fatigue, confusion, movement impairment, swelling, heart failure
B_2 (riboflavin)	Coenzyme: assists in glucose, fat and carbohydrate metabolism, electron carrier, other B vitamins are dependent on	Ariboflavinosis: dry scaly skin, mouth inflammation and sores, sore throat, itchy eyes, light sensitivity
B_3 (niacin)	Coenzyme: assists in glucose, fat, and protein metabolism, electron carrier	Pellagra: diarrhea, dermatitis, dementia, death
B_5 (pantothenic acid)	Coenzyme: assists in glucose, fat, and protein metabolism, cholesterol and neurotransmitter synthesis	Muscle numbness and pain, fatigue, irritability
B_6 (pyroxidine)	Coenzyme; assists in amino-acid synthesis, glycogneolysis, neurotransmitter and hemoglobin synthesis	Muscle weakness, dermatitis, mouth sores, fatigue, confusion

B Vitamin	Function	Deficiency: Signs and Symptoms
Biotin	Coenzyme; assists in glucose, fat, and protein metabolism, amino-acid synthesis	Muscle weakness, dermatitis, fatigue, hair loss
Folate	Coenzyme; amino acid synthesis, RNA, DNA, and red blood cell synthesis	Diarrhea, mouth sores, confusion, anemia, neural-tube defects
B_{12} (cobalamin)	Coenzyme; fat and protein catabolism, folate function, red-blood-cell synthesis	Muscle weakness, sore tongue, anemia, nerve damage, neural-tube defects

Do B-Vitamin Supplements Provide an Energy Boost?

Although some marketers claim taking a vitamin that contains one-thousand times the daily value of certain B vitamins boosts energy and performance, this is a myth that is not backed by science. The “feeling” of more energy from energy-boosting supplements stems from the high amount of added sugars, caffeine, and other herbal stimulants that accompany the high doses of B vitamins. As discussed, B vitamins are needed to support energy metabolism and growth, but taking in more than required does not supply you with more energy. A great analogy of this phenomenon is the gas in your car. Does it drive faster with a half-tank of gas or a full one? It does not matter; the car drives just as fast as long as it has gas. Similarly, depletion of B vitamins will cause problems in energy metabolism, but having more than is required to run metabolism does not speed it up. Buyers of B-vitamin supplements beware; B vitamins are not stored in the body and all excess will be flushed down the toilet along with the extra money spent.

B vitamins are naturally present in numerous foods, and many other foods are enriched with them. In the United States, B-vitamin deficiencies are rare; however in the nineteenth century some vitamin-B deficiencies plagued many people in North America. Remember the video in Chapter 1 "Nutrition and You" on niacin deficiency? Niacin deficiency, also known as pellagra, was prominent in poorer Americans whose main dietary staple was refined cornmeal (watch it again, Note 10.24 "Video 10.3"). Its symptoms were severe and included diarrhea, dermatitis, dementia, and even death. Some of the health consequences of pellagra are the result of niacin being in insufficient supply to support the body’s metabolic functions.

Video 10.3

Pellagra Video

(click to see video)

Review this video on how Dr. Joseph Goldberger discovered that pellagra was a diet-related illness.

Dietary Reference Intakes and Sources of B Vitamins

B vitamins are water-soluble and are not stored in significant amounts in the body. Therefore, they must be continuously obtained from the diet. Fortunately, B vitamins are generally well-absorbed in the gut. The Recommended Dietary Allowances (RDA) or Adequate Intakes (AI) set by the IOM, for the B vitamins are listed in Table 10.4 "Dietary Reference Intakes and Food Sources for B Vitamins", which also gives some dietary sources for these micronutrients. It should be noted that B vitamins are lost from foods during storage, processing, and cooking. To maximize B vitamin uptake, fruits and vegetables should not be stored for long periods of time, should be eaten more as whole foods, and vegetables should be steamed rather than boiled. Also, alcohol disrupts intestinal absorption of B vitamins. The US Department of Agriculture has reports of the nutrient contents in foods, including all B vitamins, available at their website. (See Note 10.25 "Interactive 10.2".)

Table 10.4 Dietary Reference Intakes and Food Sources for B Vitamins

B Vitamin	RDA (mg/day)	Food Sources
B_1 (thiamine)	1.2 (males)	Whole grains, enriched grains, orange juice, milk, peanuts, dried beans and seeds
	1.1 (females)	
B_2 (riboflavin)	1.3 (males)	Milk, yogurt, fortified breakfast cereals, organ meats, mushrooms, eggs, clams, spinach
	1.1 (females)	
B_3 (niacin)	16 (males)	Meat, poultry, fish, whole grains, fortified breakfast cereals, enriched grains, mushrooms, peanuts
	14 (females)	
*** denotes Adequate Intake**		

B Vitamin	RDA (mg/day)	Food Sources
B_5 (pantothenic acid)	5 (males)	Eggs, sunflower seeds, peanuts, meat, milk, vegetables
	5 (females)*	
B_6 (pyroxidine)	1.3 (males)	Meats, whole grains, potatoes, fortified breakfast cereals, bananas, avocados
	1.3 (females)	
Biotin	0.03 (males)	Egg yolks, peanuts, cheese
	0.03 (females)*	
Folate	0.4 (males)	Green leafy vegetables, legumes, fortified breakfast cereals, orange juice, sunflower seeds, liver
	0.4 (females)	
B_{12} (cobalamin)	0.0024 (males)	Animal derived foods, some soy milks, and fortified breakfast cereals
	0.0024 (females)	
*** denotes Adequate Intake**		

Source: Institute of Medicine. *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B_6, Folate, Vitamin B_{12}, Pantothenic Acid, Biotin, and Choline.* June 12, 2000. http://www.iom.edu/Reports/2000/Dietary-Reference-Intakes-for-Thiamin-Riboflavin-Niacin-Vitamin-B6-Folate-Vitamin-B12-Pantothenic-Acid-Biotin-and-Choline.aspx.

Interactive 10.2

The USDA has an interactive database of nutrient contents in food. To view reports of single nutrients simply click on the one you are interested in and view the report.

http://www.ars.usda.gov/Services/docs.htm?docid=20958

Dietary Sources Rich in Folate and Vitamin B_{12}

To assist you in getting all the vitamin B_{12} and folate you need to support metabolism and blood-cell synthesis look over Table 10.5 "Dietary Sources of Folate" and Table 10.6 "Dietary Sources of Vitamins B" for good dietary sources of these micronutrients.

Table 10.5 Dietary Sources of Folate

Food	Micrograms per Serving	Percent Daily Value
Liver	185 (3 oz.)	45
Calf liver	650 (3 oz.)	160
Fortified breakfast cereals	400 (¾ c.)	100
Spinach	100 (½ c., boiled)	25
Northern beans	100 (½ c., boiled)	25
Asparagus	85 (4 spears, boiled)	20
Vegetarian baked beans	60 (1 c.)	15
Broccoli	45 (2 spears)	10
Avocado	45 (½ c.)	10
Bread (enriched)	25 (1 slice)	6

Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Folate.” Last reviewed April 15, 2009. http://ods.od.nih.gov/factsheets/Folate-HealthProfessional/.

Table 10.6 Dietary Sources of Vitamins B_{12}

Food	Micrograms per Serving	Percent Daily Value
Liver	48 (1 slice)	800
Clams	34.2 (3 oz.)	570
Organic calf liver	31 (3 oz.)	520
Fortified breakfast cereals	6.0 (1 serving)	100
Trout (wild)	5.4 (3 oz.)	90
Trout (farmed)	3.5 (3 oz.)	58
Salmon (sockeye)	4.8 (3 oz.)	80
Cheeseburger	2.1	35
Yogurt (plain)	1.4 (1 c.)	23
Beef (top sirloin)	1.4 (3 oz.)	23
Milk	0.9 (1 c.)	15
Egg	0.6 (1 large)	10

Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Vitamin B_{12}.” Last reviewed June 24, 2011. http://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/.

Vitamin K: Functions in Metabolism and Blood

There is emerging evidence that vitamin K may play a role in energy metabolism, but currently the exact functions of vitamin K-dependent enzymes in energy metabolism remain elusive. Recall from Chapter 9 "Nutrients Important for Bone Health", vitamin K is required for optimal bone metabolism. Vitamin K is also critical for blood function. It is a coenzyme for enzymes involved in blood clotting. Blood-clotting proteins are continuously circulating in the blood. Upon injury to a blood vessel, platelets stick to the wound forming a plug. The clotting factors circulating close by respond in a series of protein-protein interactions resulting in the formation of the fibrous protein, fibrin, which reinforces the platelet plug (see Note 10.26 "Video 10.4" for an animation of the blood-clotting cascade of events).

Video 10.4

How Does Blood Clot?

(click to see video)

This video gives a brief description of the blood-clotting process.

A deficiency in vitamin K causes bleeding disorders. It is relatively rare, but people who have liver or pancreatic disease, celiac disease, or malabsorption conditions are at higher risk for vitamin K deficiency. Signs and symptoms include nosebleeds, easy bruising, broken blood vessels, bleeding gums, and heavy menstrual bleeding in women. The function of the anticoagulant drug warfarin is impaired by excess vitamin K intake from supplements. Calcium additionally plays a role in activation of blood-clotting proteins as discussed in the previous chapter.

Dietary Reference Intakes and Sources of Vitamin K

The RDA for vitamin K for adult males is 120 mcg/day and for adult females is 90 mcg/day. As discussed in Chapter 9 "Nutrients Important for Bone Health", vitamin K is present in many foods and most highly concentrated in green leafy vegetables. See Table 10.7 "Dietary Sources of Vitamin K" for a list of dietary sources of vitamin K.

Table 10.7 Dietary Sources of Vitamin K

Food	Micrograms per Serving	Percent Daily Value
Broccoli (½ c.)	160.0	133
Asparagus (4 spears)	34.0	28
Cabbage (½ c.)	56.0	47
Spinach (½ c.)	27.0	23
Green peas (½ c.)	16.0	13
Cheese (1 oz.)	10.0	8
Ham (3 oz.)	13.0	11
Ground beef (3 oz.)	6.0	5
Bread	1.1	<1
Orange	1.3	1

KEY TAKEAWAYS

- Vitamins and minerals play a different kind of role in energy metabolism; they are required as functional parts of enzymes involved in energy release and storage.
- The water-soluble B vitamins are involved as coenzymes in the breakdown of nutrients and in the building of macromolecules, such as protein, RNA, and DNA.
- B-vitamin deficiencies are relatively rare especially in developed countries; although the health consequences can be severe as with folate deficiency during pregnancy and the increased risk of neural-tube defects in offspring.
- The B vitamins, pyroxidine (B_6), folate, and cobalamin (B_{12}) are needed for blood-cell renewal and/or function.
- Vitamin K is necessary for blood clotting.

DISCUSSION STARTERS

1. Discuss how the actions of B vitamins are interdependent; meaning the level of one affects the function of another.
2. Have a classroom debate on whether it is prudent for the federal government to regulate claims on micronutrient supplements, such as those containing B vitamins.

10.4 Minerals Important for Metabolism and for Blood Function and Renewal

LEARNING OBJECTIVES

1. List the primary function of each of the minerals involved in metabolism.
2. Summarize the roles of minerals important in blood function and renewal.

Minerals: Functions in Catabolic Pathways, Anabolic Pathways, and Blood Renewal and Function

Magnesium

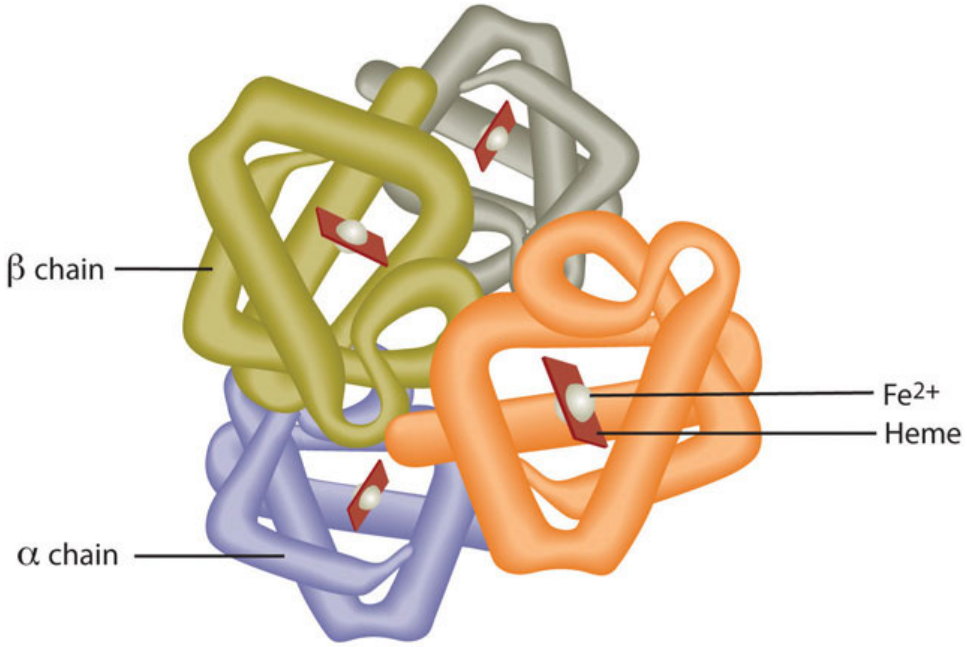
In a well-balanced diet, minerals are plentiful, and herbs are power-packed with minerals. Eat more plants, spice up your food, and drink herbal teas to obtain optimum mineral nutrition.

Magnesium is the eleventh most abundant element in the human body and is known to participate as a cofactor in hundreds of metabolic reactions. ATP exists as a complex with magnesium and therefore this mineral is involved in all reactions that synthesize or require ATP including carbohydrate, lipid, protein, RNA, and DNA synthesis. Many Americans do not get the recommended intake of magnesium from their diets. Some observational studies suggest mild magnesium deficiency is linked to increased risk for cardiovascular disease. Signs and symptoms of severe magnesium deficiency may include tremor, muscle spasms, loss of appetite, and nausea.

Iron

Red blood cells contain the oxygen-carrier protein hemoglobin. It is composed of four globular peptides, each containing a heme complex. In the center of each heme, lies iron (Figure 10.6). Iron is a key component of hundreds of metabolic enzymes. Many of the proteins of the electron-transport chain contain iron–sulfur clusters involved in the transfer of high-energy electrons and ultimately ATP synthesis. Iron is also involved in numerous metabolic reactions that take place mainly in the liver and detoxify harmful substances. Moreover, iron is required for DNA synthesis. The great majority of iron used in the body is that recycled from the continuous breakdown of red blood cells.

Figure 10.6



Hemoglobin is composed of four peptides. Each contains a heme group with iron in the center.

The iron in hemoglobin binds to oxygen in the capillaries of the lungs and transports it to cells where the oxygen is released (see Note 10.30 "Video 10.5"). If iron level is low hemoglobin is not synthesized in sufficient amounts and the oxygen-carrying capacity of red blood cells is reduced, resulting in anemia. When iron levels are low in the diet the small intestine more efficiently absorbs iron in an attempt to compensate for the low dietary intake, but this process cannot make up for the excessive loss of iron that occurs with chronic blood loss or low intake. When blood cells are decommissioned for use, the body recycles the iron back to the bone marrow where red blood cells are made. The body stores some iron in the bone marrow, liver, spleen, and skeletal muscle. A relatively small amount of iron is excreted when cells lining the small intestine and skin cells die and in blood loss, such as during menstrual bleeding. The lost iron must be replaced from dietary sources.

Video 10.5

Oxygen Transport

(click to see video)

Watch this video to view how hemoglobin in red blood cells transports oxygen to all cells in the body.

The bioavailability of iron is highly dependent on dietary sources. In animal-based foods about 60 percent of iron is bound to hemoglobin, and heme iron is more bioavailable than nonheme iron. The other 40 percent of iron in animal-based foods is nonheme, which is the only iron source in plant-based foods. Some plants contain chemicals (such as phytate, oxalates, tannins, and polyphenols) that inhibit iron absorption. Although, eating fruits and vegetables rich in vitamin C at the same time as iron-containing foods markedly increases iron absorption. A review in the *American Journal of Clinical Nutrition* reports that in developed countries iron bioavailability from mixed diets ranges between 14 and 18 percent, and that from vegetarian diets ranges between 5 and 12 percent.Centers for Disease Control and Prevention. "Iron and Iron Deficiency." Accessed October 2, 2011. http://www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html. Vegans are at higher risk for iron deficiency, but careful meal planning does prevent its development. Iron deficiency is the most common of all micronutrient deficiencies and will be explored in depth in Section 10.5 "Iron-Deficiency Anemia".

Zinc

Zinc is a cofactor for over two hundred enzymes in the human body and plays a direct role in RNA, DNA, and protein synthesis. Zinc also is a cofactor for enzymes involved in energy metabolism. As the result of its prominent roles in anabolic and energy metabolism, a zinc deficiency in infants and children blunts growth. The reliance of growth on adequate dietary zinc was discovered in the early 1960s in the Middle East where adolescent nutritional dwarfism was linked to diets containing high amounts of phytate. Cereal grains and some vegetables contain chemicals, one being phytate, which blocks the absorption of zinc and other minerals in the gut. It is estimated that half of the world's population has a zinc-deficient diet.Prasad, Ananda. "Zinc deficiency." BMJ 2003 February 22; 326(7386): 409–410. doi: 10.1136/bmj.326.7386.409. Accessed October 2, 2011. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1125304/?tool=pmcentrez. This is largely a consequence of the lack of red meat and seafood in the diet and reliance on cereal grains as the main dietary staple. In adults, severe zinc deficiency can cause hair loss, diarrhea, skin sores, loss of appetite, and weight loss. Zinc is a required cofactor for an enzyme that synthesizes the heme portion of hemoglobin and severely deficient zinc diets can result in anemia.

Iodine

Recall from Chapter 1 "Nutrition and You" the information about the discovery of iodine and its use as a means of preventing goiter, a gross enlargement of the thyroid gland in the neck. Iodine is essential for the synthesis of thyroid hormone,

which regulates **basal metabolism**[11], growth, and development. Low iodine levels and consequently hypothyroidism has many signs and symptoms including fatigue, sensitivity to cold, constipation, weight gain, depression, and dry, itchy skin and paleness. The development of goiter may often be the most visible sign of chronic iodine deficiency, but the consequences of low levels of thyroid hormone can be severe during infancy, childhood, and adolescence as it affects all stages of growth and development. Thyroid hormone plays a major role in brain development and growth and fetuses and infants with severe iodine deficiency develop a condition known as cretinism, in which physical and neurological impairment can be severe. The World Health Organization (WHO) estimates iodine deficiency affects over two billion people worldwide and it is the number-one cause of preventable brain damage worldwide.World Health Organization. "Iodine Status Worldwide." Accessed October 2, 2011. http://whqlibdoc.who.int/publications/2004/9241592001.pdf.

Selenium

Selenium is a cofactor of enzymes that release active thyroid hormone in cells and therefore low levels can cause similar signs and symptoms as iodine deficiency. The other important function of selenium is as an antioxidant, which was discussed in detail in Chapter 8 "Nutrients Important As Antioxidants".

Copper

Copper, like iron, assists in electron transfer in the electron-transport chain. Furthermore, copper is a cofactor of enzymes essential for iron absorption and transport. The other important function of copper is as an antioxidant, which was also discussed in Chapter 8 "Nutrients Important As Antioxidants". Symptoms of mild to moderate copper deficiency are rare. More severe copper deficiency can cause anemia from the lack of iron mobilization in the body for red blood cell synthesis. Other signs and symptoms include growth retardation in children and neurological problems, because copper is a cofactor for an enzyme that synthesizes myelin, which surrounds many nerves.

Manganese

Manganese is a cofactor for enzymes involved in glucose production (gluconeogenesis) and amino-acid catabolism in the liver. Manganese deficiency is uncommon.

11. Metabolic pathways necessary to support and maintain the basic functions of the body (e.g. breathing, heartbeat, liver, and kidney function) while at rest.

Chromium

The functioning of chromium in the body is less understood than that of most other minerals. It enhances the actions of insulin so plays a role in carbohydrate, fat, and protein metabolism. Currently, the results of scientific studies evaluating the usefulness of chromium supplementation in preventing and treating Type 2 diabetes are largely inconclusive. More research is needed to better determine if chromium is helpful in treating certain chronic diseases and, if so, at what doses.

A summary of the prominent functions of minerals in metabolism and their related deficiency syndromes is given in Table 10.8 "Mineral Functions in Metabolism and Blood and Deficiency Syndrome".

Table 10.8 Mineral Functions in Metabolism and Blood and Deficiency Syndrome

Mineral	Function	Deficiency: Signs and Symptoms
Macro		
Magnesium	ATP synthesis and utilization, carbohydrate, lipid, protein, RNA, and DNA synthesis	Tremor, muscle spasms, loss of appetite, nausea
Trace		
Iron	Assists in energy production, DNA synthesis required for red blood cell function	Anemia: fatigue, paleness, faster heart rate
Zinc	Assists in energy production, protein, RNA and DNA synthesis; required for hemoglobin synthesis	Growth retardation in children, hair loss, diarrhea, skin sores, loss of appetite, weight loss
Iodine	Making thyroid hormone, metabolism, growth and development	Goiter, cretinism, other signs and symptoms include fatigue, depression, weight gain, itchy skin, low heart-rate
Selenium	Essential for thyroid hormone activity	fatigue
Copper	Assists in energy production, iron metabolism	Anemia: fatigue, paleness, faster heart rate
Manganese	Glucose synthesis, amino-acid catabolism	Impaired growth, skeletal abnormalities, abnormal glucose metabolism
Chromium	Assists insulin in carbohydrate, lipid and protein metabolism	abnormal glucose metabolism

Dietary Reference Intakes for Minerals and Dietary Sources

The RDA set by the IOM for minerals involved in metabolism are listed for adults in Table 10.9 "Dietary Reference Intakes and Food Sources for Minerals Important for Metabolism". The table also lists dietary sources for these micronutrients. The mineral content of foods is greatly affected by the soil from which it grew, and thus geographic location is the primary determinant of the mineral content of foods. For instance, iodine comes mostly from seawater so the greater the distance from the sea the lesser the iodine content in the soil.

Table 10.9 Dietary Reference Intakes and Food Sources for Minerals Important for Metabolism

Mineral	RDA (mg/day)	Food Sources
Macro		
Magnesium	420.000 (males)	Nuts, vegetables, coffee and tea, cocoa
	320.000 (females)**	
Trace		
Iron	8.000 (males)	Animal products, fortified breakfast cereals, beans, spinach, peas
	18.000 (females)	
Zinc	11.000 (males)	Red meat, poultry, seafood, fortified breakfast cereals, beans, nuts, whole grains
	8.000 (females)	
Iodine	0.150 (males)	Seafood, dairy products
	0.150 (females)	
Selenium	0.055 (males)	Tuna, beef, chicken, nuts, dairy products
	0.055 (females)	
Copper	0.900 (males)	Whole grains, liver, legumes, seeds, cocoa
	0.900 (females)	
*** denotes Adequate Intake, **for ages 31–50 only**		

Mineral	RDA (mg/day)	Food Sources
Manganese	2.300 (males)	Whole grains, brown rice, spinach, nuts, tea
	1.800 (females)*	
Chromium	0.035 (males)	Egg yolks, whole grains, meats, organ meats, mushrooms, nuts, broccoli
	0.025 (females)*	
*** denotes Adequate Intake, **for ages 31–50 only**		

Source: Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.* January 9, 2001. http://www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

Bioavailability

Minerals are not as efficiently absorbed as most vitamins and so the bioavailability of minerals can be very low. Plant-based foods often contain factors, such as oxalate and phytate, that bind to minerals and inhibit their absorption. In general, minerals are better absorbed from animal-based foods. In most cases, if dietary intake of a particular mineral is increased, absorption will decrease. Some minerals influence the absorption of others. For instance, excess zinc in the diet can impair iron and copper absorption. Conversely, certain vitamins enhance mineral absorption. For example, vitamin C boosts iron absorption, and vitamin D boosts calcium and magnesium absorption. As is the case with vitamins, certain gastrointestinal disorders and diseases, such as Crohn's disease and kidney disease, as well as the aging process, impair mineral absorption, putting people with malabsorption conditions and the elderly at higher risk for mineral deficiencies.

KEY TAKEAWAYS

- Minerals cannot be broken down to release energy.
- Minerals are cofactors for hundreds of enzymes involved in metabolism.
- Iron especially, but also copper and zinc are critical for blood function and renewal.
- Minerals are not as efficiently absorbed as most vitamins and bioavailability can be very low.

DISCUSSION STARTERS

1. Discuss why "more is not always better," especially how this saying pertains to micronutrient intake.
2. Look up the chemical structure of phytate and explain how it inhibits the absorption of positively charged minerals.

10.5 Iron-Deficiency Anemia

LEARNING OBJECTIVE

1. Discuss why iron-deficiency anemia is the most prevalent nutritional deficiency worldwide, its impacts on human health, and possible solutions to combat it.

Iron-Deficiency Anemia: Signs, Symptoms, and Treatment

Iron-deficiency anemia[12] is a condition that develops from having insufficient iron levels in the body resulting in fewer and smaller red blood cells containing lower amounts of hemoglobin. Regardless of the cause (be it from low dietary intake of iron or via excessive blood loss), iron-deficiency anemia has the following signs and symptoms, which are linked to the essential functions of iron in energy metabolism and blood health:

- Fatigue
- Weakness
- Pale skin
- Shortness of breath
- Dizziness
- Swollen, sore tongue
- Abnormal heart rate

Iron-deficiency anemia is diagnosed from characteristic signs and symptoms and confirmed with simple blood tests that count red blood cells and determine hemoglobin and iron content in blood. Anemia is most often treated with iron supplements and increasing the consumption of foods that are higher in iron. See Table 10.10 "Dietary Sources of Iron" for good dietary sources of iron. Iron supplements have some adverse side effects including nausea, constipation, diarrhea, vomiting, and abdominal pain. Reducing the dose at first and then gradually increasing to the full dose often minimizes the side effects of iron supplements. Avoiding foods and beverages high in phytates and also tea (which contains tannic acid and polyphenols, both of which impair iron absorption), is important for people who have iron-deficiency anemia. Eating a dietary source of vitamin C at the same time as iron-containing foods improves absorption of nonheme iron in the gut. Additionally, unknown compounds that likely reside in muscle tissue of meat, poultry, and fish increase iron absorption from both heme

12. A condition that develops from having insufficient iron levels in the body, resulting in fewer and smaller red blood cells containing lower amounts of hemoglobin. Signs and symptoms include fatigue, weakness, pale skin, shortness of breath, dizziness, swollen and sore tongue, and abnormal heart rate.

and nonheme sources. See Table 10.11 "Enhancers and Inhibitors of Iron Absorption" for more enhancers and inhibitors for iron absorption.

Table 10.10 Dietary Sources of Iron

Food	Milligrams per serving	Percent RDA (males)	Percent RDA (females)
Oysters (3 oz.)	13.20	165	73
Beef liver (3 oz.)	7.50	94	42
Prune juice (½ c.)	5.20	65	29
Clams (2 oz.)	4.20	53	23
Walnuts (½ c.)	3.75	47	21
Chickpeas (½ c.)	3.00	38	19
Bran flakes (½ c.)	2.80	37	16
Pork roast (3 oz.)	2.70	34	15
Raisins (½ c.)	2.55	32	14
Roast beef (3 oz.)	1.80	23	10
Green peas (½ c.)	1.50	19	8
Peanuts (½ c.)	1.50	19	8
Green beans (½ c.)	1.00	13	6
Egg (1)	1.00	13	6

Source: University of Maryland Medical Center. “Iron.” © 2011 University of Maryland Medical Center (UMMC). All rights reserved. http://www.umm.edu/altmed/articles/iron-000309.htm#ixzz2BIykoCPs.

Table 10.11 Enhancers and Inhibitors of Iron Absorption

Enhancer	Inhibitor
Meat	Phosphate
Fish	Calcium
Poultry	Tea

Enhancer	Inhibitor
Seafood	Coffee
Stomach acid	Colas
	Soy protein
	High doses of minerals (antacids)
	Bran/fiber
	Phytates
	Oxalates
	Polyphenols

Iron Deficiency: A Worldwide Nutritional Health Problem

The Centers for Disease Control and Prevention reports that iron deficiency is the most common nutritional deficiency worldwide.Centers for Disease Control and Prevention. "Iron and Iron Deficiency." Accessed October 2, 2011. http://www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html. The WHO estimates that 80 percent of people are iron deficient and 30 percent of the world population has iron-deficiency anemia.The World Bank. "Anemia." Accessed October 2, 2011. http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTHEALTHNUTRITIONANDPOPULATION/EXTPHAAG/0,,contentMDK:20588506~menuPK:1314803~pagePK:64229817~piPK:64229743~theSitePK:672263,00.html. The main causes of iron deficiency worldwide are parasitic worm infections in the gut causing excessive blood loss, and malaria, a parasitic disease causing the destruction of red blood cells. In the developed world, iron deficiency is more the result of dietary insufficiency and/or excessive blood loss occurring during menstruation or child-birth.

At-Risk Populations

Infants, children, adolescents, and women are the populations most at risk worldwide for iron-deficiency anemia by all causes. Infants, children, and even teens require more iron because iron is essential for growth. In these populations, iron deficiency (and eventually iron-deficiency anemia) can also cause the following signs and symptoms: poor growth, failure to thrive, and poor performance in school, as well as mental, motor, and behavioral disorders. Women who experience heavy menstrual bleeding or who are pregnant require more iron in the diet. One more high-risk group is the elderly. Both elderly men and women have a high incidence of anemia and the most common causes are dietary iron deficiency and chronic disease such as ulcer, inflammatory diseases, and cancer. Additionally,

those who have recently suffered from traumatic blood loss, frequently donate blood, or take excessive antacids for heartburn need more iron in the diet.

Video 10.6

Iron Deficiency

(click to see video)

This video provides a brief overview on how good nutrition can prevent the development of iron-deficiency anemia.

Iron Toxicity

The body excretes little iron and therefore the potential for accumulation in tissues and organs is considerable. Iron accumulation in certain tissues and organs can cause a host of health problems in children and adults including extreme fatigue, arthritis, joint pain, and severe liver and heart toxicity. In children, death has occurred from ingesting as little as 200 mg of iron and therefore it is critical to keep iron supplements out of children's reach. The IOM has set tolerable upper intake levels of iron (Table 10.12 "Tolerable Upper Intake Levels of Iron"). Mostly a hereditary disease, hemochromatosis is the result of a genetic mutation that leads to abnormal iron metabolism and an accumulation of iron in certain tissues such as the liver, pancreas, and heart. The signs and symptoms of hemochromatosis are similar to those of iron overload in tissues caused by high dietary intake of iron or other nongenetic metabolic abnormalities, but are often increased in severity.

Table 10.12 Tolerable Upper Intake Levels of Iron

Age	Males (mg/day)	Females (mg/day)	Pregnancy (mg/day)	Lactation (mg/day)
7–12 months	40	40	N/A	N/A
1–13 years	40	40	N/A	N/A
14–18 years	45	45	45	45
19+ years	45	45	45	45

Source: Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.* January 9, 2001. http://www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

Preventing Iron-Deficiency Anemia

In young children iron-deficiency anemia can cause significant motor, mental, and behavior abnormalities that are long-lasting. In the United States, the high incidence of iron-deficiency anemia in infants and children was a major public-health problem prior to the early 1970s, but now the incidence has been greatly reduced. This achievement was accomplished by implementing the screening of infants for iron-deficiency anemia in the health sector as a common practice, advocating the fortification of infant formulas and cereals with iron, and distributing them in supplemental food programs, such as that within Women, Infants, and Children (WIC). Breastfeeding, iron supplementation, and delaying the introduction of cow's milk for at least the first twelve months of life were also encouraged. These practices were implemented across the socioeconomic spectrum and by the 1980s iron-deficiency anemia in infants had significantly declined. Other solutions had to be introduced in young children, who no longer were fed breastmilk or fortified formulas and were consuming cow's milk. The following solutions were introduced to parents: provide a diet rich in sources of iron and vitamin C, limit cow's milk consumption to less than twenty-four ounces per day, and a multivitamin containing iron.

In the third world, iron-deficiency anemia remains a significant public-health challenge. The World Bank claims that a million deaths occur every year from anemia and that the majority of those occur in Africa and Southeast Asia. The World Bank states five key interventions to combat anemia:The World Bank. "Anemia." Accessed October 2, 2011. http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTHEALTHNUTRITIONANDPOPULATION/EXTPHAAG/

While supplementation may be necessary in acute situations, the best way to boost your iron intake is through good eating habits.

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0,,contentMDK:20588506~menuPK:1314803~pagePK:64229817~piPK:64229743~theSitePK:672263,00.html

- Provide at-risk groups with iron supplements.
- Fortify staple foods with iron and other micronutrients whose deficiencies are linked with anemia.
- Prevent the spread of malaria and treat the hundreds of millions with the disease.
- Provide insecticide-treated bed netting to prevent parasitic infections.
- Treat parasitic-worm infestations in high-risk populations.

Also, there is ongoing investigation as to whether supplying iron cookware to at-risk populations is effective in preventing and treating iron-deficiency anemia.

KEY TAKEAWAYS

- Iron-deficiency anemia is a condition that develops from having insufficient iron levels in the body, resulting in fewer and smaller red blood cells containing lower amounts of hemoglobin. It is diagnosed from characteristic signs and symptoms and confirmed with simple blood tests that count red blood cells and determine hemoglobin and iron content in blood. Anemia is most often treated with iron supplements and increasing the consumption of foods that are higher in iron.
- The main causes of iron deficiency worldwide are parasitic-worm infections in the gut (causing excessive blood loss), malaria, a parasitic disease causing the destruction of red blood cells, and insufficient iron in the diet.
- Infants, children, adolescents, and women are the populations most at risk worldwide for iron-deficiency anemia by all causes.
- In America in the past, iron-deficiency anemia was prevalent in infants and young children. After the introduction of infant screening, fortification of formulas and foods, and educating parents on providing an iron-rich diet, iron-deficiency anemia significantly declined in this country.
- In the third world, iron-deficiency anemia remains a significant public-health challenge. Solutions to reduce the prevalence of iron-deficiency anemia in the developing world include providing supplements to target populations, fortifying foods with iron and other blood-healthy micronutrients, preventing the spread of malaria, treating parasitic infections, and giving iron cookware to high-risk populations.
- The body excretes little iron and therefore the potential for accumulation in tissues and organs is considerable. Iron accumulation in certain tissues and organs can cause a host of health problems in children and adults, including extreme fatigue, arthritis, joint pain, and severe liver and heart toxicity.

DISCUSSION STARTERS

1. Come up with a hypothesis or two on why it is vital that blood is continuously renewed.
2. Discuss the effectiveness and cost of some possible solutions for eliminating iron-deficiency anemia worldwide.

10.6 End-of-Chapter Exercises

IT'S YOUR TURN

1. Make a chart of the vitamins and minerals important for metabolism and list their main functions.
2. List four functions of blood.
3. With regard to the functions of iron in metabolism and blood health, describe how low iron levels lead to the characteristic signs and symptoms of iron-deficiency anemia.

APPLY IT

1. Draw a flow chart of the stages of nutrient catabolism and point out where the B vitamins are required.
2. Summarize in a paragraph why a pregnant woman requires more iron in the diet and why it is important for newborn babies to be screened for iron deficiency.
3. Plan a daily menu that meets the RDA for iron and iron-absorption enhancers.

EXPAND YOUR KNOWLEDGE

1. Read "Sir Frederick Hopkins—Nobel Lecture" on the history of the discovery of vitamins and summarize in a paragraph or two the importance of continuing scientific investigation to define the functions of vitamins in order to improve the health of humans. http://www.nobelprize.org/nobel_prizes/medicine/laureates/1929/hopkins-lecture.html
2. Go to the USDA database (http://www.ars.usda.gov/Services/docs.htm?docid=20958) and prepare a list of the top ten food sources of vitamin B_6 and vitamin B_{12}.
3. Why would having too many red blood cells decrease the amount of oxygen delivered to cells? To help answer this question visit the website of the National Heart, Lung, and Blood Institute (http://www.nhlbi.nih.gov/health/dci/Diseases/poly/poly_all.html).

Chapter 11

Energy Balance and Body Weight

Big Idea

The "obesogenic" environment in America is a societal hurdle that must be overcome to halt the climbing obesity rate of this country.

Video Link 11.1

The Obesity Epidemic

This video from the Centers for Disease Control and Prevention provides an overview of the burden of the obesity epidemic in the United States and its contributing causes.

http://www.cdc.gov/cdctv/ObesityEpidemic/

"Obesogenic" is a word that has sprung up in the language of public health professionals in the last two decades. The Centers for Disease Control and Prevention (CDC) defines obesogenic as "an environment that promotes increased food intake, nonhealthful foods, and physical inactivity." The CDC reports that in 2009 in the United States, 33 percent of adults and 16 percent of children were obese, a doubling and tripling of the numbers since 1980, respectively, while in Canada the obesity rate was 24.1 percent for 2007–2009. The health consequences of too much body fat are numerous, including increased risks for cardiovascular disease, Type 2 diabetes, and some cancers. The medical costs related to obesity are well over one hundred billion dollars and on the individual level, people who are obese spend $1,429 more per year for medical care than people of healthy weight.

Numerous obesogenic agents that contribute to this immense public health problem have become a part of everyday life in American society. The fast food industry has been growing for decades and continues to grow despite the latest economic slump. In America today there are over twelve thousand McDonald's restaurants, while in 1960 there was one. Food portions have been getting bigger since the 1960s, and in the 1990s North American society experienced the "super-size" marketing boon, which still endures. Between 1960 and 2000 more than 123 million vehicles were added to the American society. Escalators, elevators, and horizontal walkways now dominate shopping malls and office buildings, factory work has become increasingly mechanized and robotized, the typical American watches more than four hours of television daily, and in many work places the only tools required to conduct work are a chair and a computer. The list of all the societal obesogenic factors goes on and on. They are the result of modernization, industrialization, and urbanization continuing on without individuals, public health officials, or government adequately addressing the concurrent rise in overweight and obesity.

With obesity at epidemic proportions in America it is paramount that policies be implemented or reinforced at all levels of society including education, agriculture, industry, urban planning, health care, and government. Reversing and stopping obesity are two different things. The former will require much more societal change and change on the individual level than the latter. The following are some ideas for constructing an environment in America that promotes health and confronts the obesity epidemic:

- Individual Level
    - Purchase less prepared foods and eat more whole foods.
    - Decrease portion sizes when eating or serving food.
    - Eat out less, and when you do eat out choose low-calorie options.
    - Walk or bike to work. If this is not feasible, walk while you are at work.
    - Take the stairs when you come upon them or better yet, seek them out.
    - Walk your neighborhood and know your surroundings. This benefits both health and safety.
    - Watch less television.
- Community Level
    - Request that your college/workplace provides more access to healthy low-cost foods.
    - Support changes in school lunch programs—this is happening now in 2011.

    - Participate in cleaning up local green spaces and then enjoy them during your leisure time.
    - Patronize local farms and fruit-and-vegetable stands.
    - Talk to your grocer and ask for better whole-food choices and seafood at a decent price.
    - Ask the restaurants you frequent to serve more nutritious food and to accurately display calories of menu items.

- National Level

    - Support policies that increase the walkability of cities.
    - Support national campaigns addressing obesity, such as America on the Move.
    - Support policies that support local farmers and the increased access and affordability of healthy food.

Interactive 11.1

Visit the CDC website to see an animated map that shows the growing prevalence of obesity in the United States from 1985 to 2010.

http://www.cdc.gov/obesity/data/trends.html

Some scientists predict that the childhood obesity rate will reach 100 percent by 2044. It is critical for the nation's health to change our environment to one that promotes weight loss and/or weight maintenance. However, action is needed on multiple fronts to reverse the obesity epidemic trend within one generation.

You Decide

How can you assist in the American transition from an obesogenic environment to a healthier environment at the individual, community, and national levels?

In this chapter you will learn how to assess body weight and fatness. You will also learn that it is not only society and environment that play a role in body weight and

fatness, but also physiology, genetics, and behavior—and that all of them interact. We will also discuss the health risks of being underweight and overweight, learn evidence-based solutions to maintain body weight at the individual level, and assess the current state of affairs of combating the obesity epidemic in the United States.

"Thou seest I have more flesh than another man, and therefore more frailty."

- William Shakespeare (1564–1616)

11.1 Indicators of Health: Body Mass Index, Body Fat Content, and Fat Distribution

LEARNING OBJECTIVES

1. Calculate body mass index given a particular weight and height.
2. Name the factors that affect body fat composition and distribution.

Although the terms overweight and obese are often used interchangeably and considered as gradations of the same thing, they denote different things. The major physical factors contributing to body weight are water weight, lean tissue mass, bone tissue mass, and fat tissue mass. **Overweight**[1] refers to having more weight than normal for a particular height and may be the result of water weight, muscle weight, or fat mass. **Obese**[2] refers specifically to having excess body fat. In most cases people who are overweight also have excessive body fat and therefore body weight is an indicator of obesity in much of the population.

The "ideal" healthy body weight for a particular person is dependent on many things, such as frame size, sex, muscle mass, bone density, age, and height. The perception of the "ideal" body weight is additionally dependent on cultural factors and the mainstream societal advertisement of beauty.

To standardize the "ideal" body weight and relate it to health, scientists have devised mathematical formulas to better define a healthy weight. These mathematically derived measurements are used by health professionals to correlate disease risk with populations of people and at the individual level. A clinician will take two measurements, one of weight and one of fat mass, in order to diagnose obesity. Some measurements of weight and body fat that do not require using technical equipment can easily be calculated and help provide an individual with information on weight, fat mass, and distribution, and their relative risk of some chronic diseases.

1. Having more weight than normal for a particular height (BMI between 25 and 29.9).
2. Having excess body fat (BMI greater than 30).
3. A measurement that associates height and weight, and is a more comprehensive measurement of body fatness than weight alone.

Body Mass Index: How to Measure It and Its Limitations

Body mass index (BMI)[3] is calculated using height and weight measurements and is more predictive of body fatness than weight alone. BMI measurements are used to indicate whether an individual may be underweight (with a BMI less than 18.5), overweight (with a BMI over 25), or obese (with a BMI over 30). High BMI

measurements can be warning signs of health hazards ahead, such as cardiovascular disease, Type 2 diabetes, and other chronic diseases. BMI-associated health risks vary by race. Asians face greater health risks for the same BMI than Caucasians, and Caucasians face greater health risks for the same BMI than African Americans.

Calculating BMI

To calculate your BMI, multiply your weight in pounds by 703 (conversion factor for converting to metric units) and then divide the product by your height in inches, squared. Alternatively, see Note 11.9 "Interactive 11.2" for web-based calculators that provide a BMI in seconds.

$$\text{BMI} = [\text{weight (lb)} \times 703] \div \text{height (in)}^2$$

or

$$\text{BMI} = [\text{weight (kg)}] \div \text{height (m)}^2$$

Interactive 11.2

The National Heart, Lung, and Blood Institute and the CDC have automatic BMI calculators on their websites:

http://www.nhlbisupport.com/bmi/

http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/english_bmi_calculator/bmi_calculator.html

To see how your BMI indicates the weight category you are in, see Table 11.1 "BMI Categories" or use a chart of weight and height to figure out your BMI.

Table 11.1 BMI Categories

Categories	BMI
Underweight	< 18.5
Normal weight	18.5–24.9

Categories	BMI
Overweight	25–29.9
Obese	> 30.0

Source: National Heart, Lung, and Blood Institute. Accessed November 4, 2012. http://www.nhlbi.nih.gov.

BMI Limitations

A BMI is a fairly simple measurement and does not take into account fat mass or fat distribution in the body, both of which are additional predictors of disease risk. Body fat weighs less than muscle mass. Therefore, BMI can sometimes underestimate the amount of body fat in overweight or obese people and overestimate it in more muscular people. For instance, a muscular athlete will have more muscle mass (which is heavier than fat mass) than a couch potato of the same height. Based on their BMIs the muscular athlete would be less "ideal" and may be categorized as more overweight or obese than the couch potato; however this is an infrequent problem with BMI calculation. Additionally, an older person with osteoporosis (decreased bone mass) will have a lower BMI than an older person of the same height without osteoporosis, even though the person with osteoporosis may have more fat mass. A BMI is a useful inexpensive tool to categorize people and is highly correlative with disease risk, but other measurements are needed to diagnose obesity and more accurately assess disease risk.

Body Fat and Its Distribution

Next we'll discuss how to measure body fat, and why distribution of body fat is also important to consider when determining health.

Measuring Body Fat Content

Water, organs, bone tissue, fat, and muscle tissue make up a person's weight. Having more fat mass may be indicative of disease risk, but fat mass also varies with sex, age, and physical activity level. Females have more fat mass, which is needed for reproduction and, in part, is a consequence of different levels of hormones. The optimal fat content of a female is between 20 and 30 percent of her total weight and for a male is between 12 and 20 percent. Fat mass can be measured in a variety of ways. The simplest and lowest-cost way is the skin-fold test. A health professional uses a caliper to measure the thickness of skin on the back, arm, and other parts of the body and compares it to standards to assess body fatness. It is a noninvasive and fairly accurate method of measuring fat mass, but similar to BMI, is compared to

standards of mostly young to middle-aged adults. Other methods of measuring fat mass are more expensive and more technically challenging. They include:

- **Underwater weighing.** This technique requires a chamber full of water big enough for the whole body can fit in. First, a person is weighed outside the chamber and then weighed again while immersed in water. Bone and muscle weigh more than water, but fat does not—therefore a person with a higher muscle and bone mass will weigh more when in water than a person with less bone and muscle mass.
- **Bioelectric Impedance Analysis (BIA).** This device is based on the fact that fat slows down the passage of electricity through the body. When a small amount of electricity is passed through the body, the rate at which it travels is used to determine body composition. These devices are also sold for home use and commonly called body composition scales.
- **Dual-energy x-ray absorptiometry.** This technique was explained in detail in Chapter 9 "Nutrients Important for Bone Health", where we saw that it can be used to measure bone density. It also can determine fat content via the same method, which directs two low-dose x-ray beams through the body and determines the amount of the energy absorbed from the beams. The amount of energy absorbed is dependent on the body's content of bone, lean tissue mass, and fat mass. Using standard mathematical formulas, fat content can be accurately estimated.

Measuring Fat Distribution

Total body-fat mass is one predictor of health; another is how the fat is distributed in the body. You may have heard that fat on the hips is better than fat in the belly—this is true. Fat can be found in different areas in the body and it does not all act the same, meaning it differs physiologically based on location. Fat deposited in the abdominal cavity is called **visceral fat**[4] and it is a better predictor of disease risk than total fat mass. Visceral fat releases hormones and inflammatory factors that contribute to disease risk. The only tool required for measuring visceral fat is a measuring tape. The measurement (of waist circumference) is taken just above the belly button. Men with a waist circumference greater than 40 inches and women with a waist circumference greater than 35 inches are predicted to face greater health risks.

The **waist-to-hip ratio**[5] is often considered a better measurement than waist circumference alone in predicting disease risk. To calculate your waist-to-hip ratio, use a measuring tape to measure your waist circumference and then measure your hip circumference at its widest part. Next, divide the waist circumference by the

4. Fat deposited in the abdominal cavity.
5. Waist circumference divided by hip circumference.

hip circumference to arrive at the waist-to-hip ratio. Observational studies have demonstrated that people with "apple-shaped" bodies, (who carry more weight around the waist) have greater risks for chronic disease than those with "pear-shaped" bodies, (who carry more weight around the hips). A study published in the November 2005 issue of *Lancet* with more than twenty-seven thousand participants from fifty-two countries concluded that the waist-to-hip ratio is highly correlated with heart attack risk worldwide and is a better predictor of heart attacks than BMI.Yusuf, S. et al. "Obesity and the Risk of Myocardial Infarction in 27,000 Participants from 52 Countries: A Case-Control Study." *Lancet* 366, no. 9497 (2005): 1640–9. Accessed October 5, 2011. http://www.ncbi.nlm.nih.gov/pubmed/16271645?dopt=AbstractPlus. Abdominal obesity is defined by the World Health Organization (WHO) as having a waist-to-hip ratio above 0.90 for males and above 0.85 for females.

KEY TAKEAWAYS

- Most people who are overweight also have excessive body fat and therefore body weight is an indicator of obesity in much of the population.
- To standardize the "ideal" body weight and relate it to health, scientists have devised some computational measurements to better define a healthy ideal weight.
- Body weight in relation to height is called BMI and is correlated with disease risk.
- Total body fat mass is another predictor of disease risk; another is where the fat is distributed.
- Fat deposits in different areas in the body and do not all act the same, meaning it differs physiologically based on location. Visceral fat contributes more to disease risk, for example.

DISCUSSION STARTERS

1. Read the article, "Exercise Keeps Dangerous Visceral Fat Away a Year after Weight Loss, Study Finds," at http://www.sciencedaily.com/releases/2009/10/091029102740.htm. Then discuss the importance of exercise in eradicating excessive fat.
2. Based on what you learned, why would an individual with a high BMI have a decreased risk of osteoporosis?

11.2 Balancing Energy Input with Energy Output

LEARNING OBJECTIVES

1. Estimate your daily energy requirement.
2. Define basal metabolism and explain the factors that affect basal metabolic rate.
3. Summarize why the amount of food we eat (appetite) is not completely under our conscious control.

To Maintain Weight, Energy Intake Must Balance Energy Output

Recall that the macronutrients you consume are either converted to energy, stored, or used to synthesize macromolecules. A nutrient's metabolic path is dependent upon **energy balance**[6]. When you are in a positive energy balance the excess nutrient energy will be stored or used to grow (e.g., during childhood, pregnancy, and wound healing). When you are in negative energy balance you aren't taking in enough energy to meet your needs, so your body will need to use its stores to provide energy. Energy balance is achieved when intake of energy is equal to energy expended. Weight can be thought of as a whole body estimate of energy balance; body weight is maintained when the body is in energy balance, lost when it is in negative energy balance, and gained when it is in positive energy balance. In general, weight is a good predictor of energy balance, but many other factors play a role in energy intake and energy expenditure. Some of these factors are under your control and others are not. Let us begin with the basics on how to estimate energy intake, energy requirement, and energy output. Then we will consider the other factors that play a role in maintaining energy balance and hence, body weight.

Estimating Energy Requirement

To maintain body weight you have to balance the calories obtained from food and beverages with the calories expended every day. Here, we will discuss how to calculate your energy needs in kilocalories per day so that you can determine whether your caloric intake falls short, meets, or exceeds your energy needs. The Institute of Medicine has devised a formula for calculating your **Estimated Energy Requirement (EER)**[7]. It takes into account your age, sex, weight, height, and physical activity level (PA). The EER is a standardized mathematical prediction of a person's daily energy needs in kilocalories per day required to maintain weight. It is calculated via the following formulas:

6. When energy intake is equal to energy expended.
7. Energy intake values that have been established to preserve energy balance in healthy adults of a specific age, gender, weight, and height, and category of physical activity concurrent with good health.

Adult male: EER = 662 – [9.53 x age (y)] + PA X [15.91 x wt (kg) + 5.39.6 x ht (m)]

Adult female: EER = 354 – [6.91 x age (y)] + PA x [9.36 x wt (kg) + 726 x ht (m)]

Note: to convert pounds to kilograms, divide weight in pounds by 2.2.

To convert feet to meters, divide height in feet by 3.3.

Estimating Caloric Intake

In Chapter 3 "Nutrition and the Human Body" you learned how to calculate the number of calories in food. To determine your caloric intake per day requires that you conduct a dietary assessment and record the number of calories you eat. To help you accomplish this task see Note 11.17 "Interactive 11.3".

Interactive 11.3

To begin your dietary assessment, go to MyPlate, which is available on the US Department of Agriculture (USDA) website:

http://www.choosemyplate.gov/.

Table 11.2 Physical Activity (PA) Categories and Values

Activity Level	Men PA Value	Women PA Value	Description
Sedentary	1.00	1.00	No physical activity beyond that required for independent living
Low	1.11	1.12	Equivalent to walking 1.5 to 3 miles per day
Moderate	1.25	1.27	Equivalent to walking 3 to 10 miles per day
High	1.48	1.45	Equivalent to walking 10 or more miles per day
These values only apply to normal weight adults and not to children or pregnant or lactating women.			

Source: Health Canada. “Dietary Reference Intake Tables.” Last modified November 29, 2010. http://www.hc-sc.gc.ca/fn-an/nutrition/reference/table/index-eng.php#eeer.

The numbers within the equations for the EER were derived from measurements taken from a group of people of the same sex and age with similar body size and physical activity level. These standardized formulas are then applied to individuals whose measurements have not been taken, but who have similar characteristics in order to estimate their energy requirements. Thus, a person's EER is, as the name suggests, an estimate for an average person of similar characteristics. EER values are different for children, pregnant or lactating women, and for overweight and obese people. Also, remember the EER is calculated based on weight maintenance, not for weight loss or weight gain.

The *2010 Dietary Guidelines* provides a table (Table 11.3 "Estimated Daily Calorie Needs") that gives the estimated daily calorie needs for different age groups of males and females with various activity levels. The *2010 Dietary Guidelines* also states that while knowing the number of calories you need each day is useful, it is also pertinent to obtain your calories from nutrient-dense foods and consume the various macronutrients in their Acceptable Macronutrient Distribution Ranges (AMDRs) (Table 11.4 "Acceptable Macronutrient Distribution Ranges").

Table 11.3 Estimated Daily Calorie Needs

Sex	Age (years)	Sedentary	Moderately Active	Active
Child (female and male)	2–3	1,000–1,200	1,000–1,400	1,000–1,400
Female	4–8	1,200–1,400	1,400–1,600	1,400–1,800
	9–13	1,400–1,600	1,600–2,000	1,800–2,200
	14–18	1,800	2,000	2,400
	19–30	1,800–2,000	2,000–2,200	2,400
	31–50	1,800	2,000	2,200
	51+	1,600	1,800	2,000–2,200
Male	4–8	1,200–1,400	1400–1,600	1,600–2,000
	9–13	1,600–2,000	1,800–2,200	2,000–2,600
	14–18	2,000–2,400	2,400–2,800	2,800–3,200
	19–30	2,400–2,600	2,600–2,800	3,000
	31–50	2,200–2,400	2,400–2,600	2,800–3,000
	51+	2,000–2,200	2,200–2,400	2,400–2,800

Source: US Department of Agriculture. *2010 Dietary Guidelines for Americans.* 2010. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines2010.pdf.

Table 11.4 Acceptable Macronutrient Distribution Ranges

Age	Carbohydrates (% of Calories)	Protein (% of Calories)	Fat (% of Calories)
Young Children (1–3)	45–65	5–20	30–40
Older children/ adolescents (4–18)	45–65	10–30	25–35
Adults (19 and older)	45–65	10–35	20–35

Source: Institute of Medicine. "Dietary Reference Intakes: Macronutrients." *Dietary Reference Intakes for Energy, Carbohydrate. Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids.* September 5, 2002. http://www.iom.edu/~/media/Files/Activity%20Files/Nutrition/DRIs/DRI_Macronutrients.pdf

Total Energy Expenditure (Output)

The amount of energy you expend every day includes not only the calories you burn during physical activity, but also the calories you burn while at rest (basal metabolism), and the calories you burn when you digest food. The sum of caloric expenditure is referred to as **total energy expenditure (TEE)**[8]. **Basal metabolism**[9] refers to those metabolic pathways necessary to support and maintain the body's basic functions (e.g. breathing, heartbeat, liver and kidney function) while at rest. The basal metabolic rate (BMR) is the amount of energy required by the body to conduct its basic functions over a certain time period. The great majority of energy expended (between 50 and 70 percent) daily is from conducting life's basic processes. Of all the organs, the liver requires the most energy (see Table 11.5 "Energy Breakdown of Organs"). Unfortunately, you cannot tell your liver to ramp up its activity level to expend more energy so you can lose weight. BMR is dependent on body size, body composition, sex, age, nutritional status, and genetics. People with a larger frame size have a higher BMR simply because they have more mass. Muscle tissue burns more calories than fat tissue even while at rest and thus the more muscle mass a person has, the higher their BMR. Since females typically have less muscle mass and a smaller frame size than men, their BMRs are generally lower than men's. As we get older muscle mass declines and thus so does BMR. Nutritional status also affects basal metabolism. Caloric restriction, as occurs while dieting, for example, causes a decline in BMR. This is because the body attempts to maintain homeostasis and will adapt by slowing down its basic

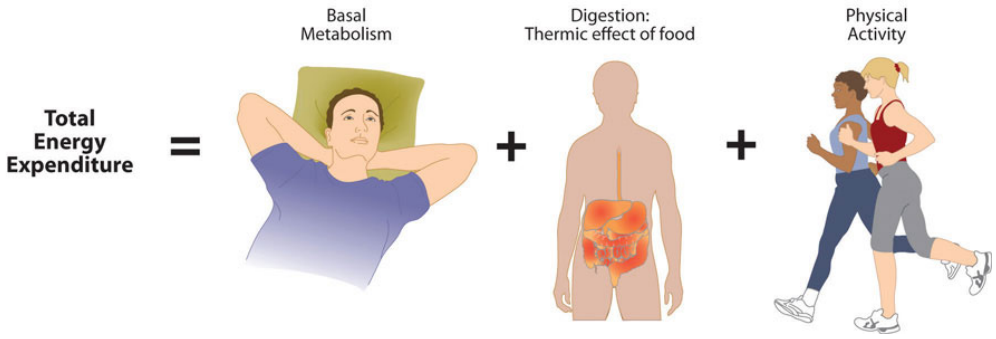
8. The sum of energy used for basal metabolism; energy required for food digestion and absorption and energy expended during physical activity.

9. The metabolic pathways necessary to support and maintain basic body functions (e.g. breathing, heartbeat, liver and kidney function) while at rest.

functions to offset the decrease in energy intake. Body temperature and thyroid hormone levels are additional determinants of BMR.

Table 11.5 Energy Breakdown of Organs

Organ	Percent of Energy Expended
Liver	27
Brain	19
Heart	7
Kidneys	10
Skeletal muscle (at rest)	18
Other organs	19



Total energy expenditure is the sum of energy expended at rest, during digestion, and during physical activity.

The energy required for all the enzymatic reactions that take place during food digestion and absorption of nutrients is called the "thermic effect of food" and accounts for about 10 percent of total energy expended per day. The other energy required during the day is for physical activity. Depending on lifestyle, the energy required for this ranges between 15 and 30 percent of total energy expended. The main control a person has over TEE is to increase physical activity.

How to Calculate Total Energy Expenditure

Calculating TEE can be tedious, but has been made easier as there are now calculators available on the Web (see Note 11.20 "Interactive 11.4"). TEE is dependent on age, sex, height, weight, and physical activity level. The equations are

based on standardized formulas produced from actual measurements on groups of people with similar characteristics. To get accurate results from web-based TEE calculators, it is necessary to record your daily activities and the time spent performing them. A spreadsheet for doing so is available online at http://www.health-calc.com/Calculate_daily_energy_expenditure.pdf.

Interactive 11.4

Health-calc.com offers an interactive TEE calculator.

http://www.health-calc.com/diet/energy-expenditure-advanced

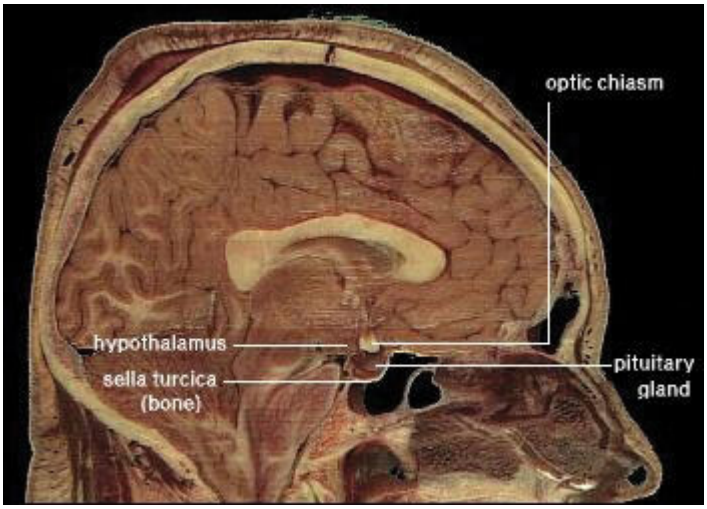
Factors Affecting Energy Intake

Physiology

In the last few decades scientific studies have revealed that how much we eat and what we eat is controlled not only by our own desires, but also is regulated physiologically and influenced by genetics. The hypothalamus in the brain is the main control point of appetite. It receives hormonal and neural signals, which determine if you feel hungry or full. **Hunger**[10] is an unpleasant sensation of feeling empty that is communicated to the brain by both mechanical and chemical signals from the periphery. Conversely, **satiety**[11] is the sensation of feeling full and it also is determined by mechanical and chemical signals relayed from the periphery. The hypothalamus contains distinct centers of neural circuits that regulate hunger and satiety (Figure 11.1).

10. An unpleasant sensation of feeling empty that is communicated from the periphery to the brain via both mechanical and chemical signals.
11. The sensation of feeling full; determined by mechanical and chemical signals relayed from the periphery.

Figure 11.1



This is a scan of a brain. The hypothalamus contains distinct centers of neural circuits that regulate hunger and satiety.

Source: Diabesity, Sixth Framework Programme. "Novel Molecular Targets for Obesity and Type 2 Diabetes." 2002-2006. http://www.diabesity.eu/.honours.htm.

Hunger pangs are real and so is a "growling" stomach. When the stomach is empty it contracts, producing the characteristic pang and "growl." The stomach's mechanical movements relay neural signals to the hypothalamus, which relays other neural signals to parts of the brain. This results in the conscious feeling of the need to eat. Alternatively, after you eat a meal the stomach stretches and sends a neural signal to the brain stimulating the sensation of satiety and relaying the message to stop eating. The stomach also sends out certain hormones when it is full and others when it is empty. These hormones communicate to the hypothalamus and other areas of the brain either to stop eating or to find some food.

Fat tissue also plays a role in regulating food intake. Fat tissue produces the hormone leptin, which communicates to the satiety center in the hypothalamus that the body is in positive energy balance. The discovery of leptin's functions sparked a craze in the research world and in the diet pill industry as it was hypothesized that if you give leptin to a person who is overweight, they will decrease their food intake. Alas, this is not the case. In several clinical trials it was found that people who are overweight or obese are actually resistant to the hormone, meaning their brain does not respond as well to it.Dardeno, T. A. et al. "Leptin in Human Physiology and Therapeutics." *Front Neuroendocrinol* 31, no. 3 (2010): 377–93. http://www.ncbi.nlm.nih.gov/pmc/articles/

PMC2916735/?tool=pubmed. Therefore, when you administer leptin to an overweight or obese person there is no sustained effect on food intake.

Nutrients themselves also play a role in influencing food intake. The hypothalamus senses nutrient levels in the blood. When they are low the hunger center is stimulated, and when they are high the satiety center is stimulated. Furthermore, cravings for salty and sweet foods have an underlying physiological basis. Both undernutrition and overnutrition affect hormone levels and the neural circuitry controlling appetite, which makes losing or gaining weight a substantial physiological hurdle.

Genetic Influences

Genetics certainly play a role in body fatness and weight and also affects food intake. Children who have been adopted typically are similar in weight and body fatness to their biological parents. Moreover, identical twins are twice as likely to be of similar weights as compared to fraternal twins. The scientific search for obesity genes is ongoing and a few have been identified, such as the gene that encodes for leptin. However, overweight and obesity that manifests in millions of people is not likely to be attributed to one or even a few genes, but to rather the interactions of hundreds of genes with the environment. In fact, when an individual has a mutated version of the gene coding for leptin, they are obese, but only a few dozen people around the world have been identified as having a completely defective leptin gene.

Psychological/Behavioral Influences

When your mouth waters in response to the smell of a roasting Thanksgiving turkey and steaming hot pies, you are experiencing a psychological influence on food intake. A person's perception of good-smelling and good-tasting food influences what they eat and how much they eat. Mood and emotions are associated with food intake. Depression, low self-esteem, compulsive disorders, and emotional trauma are sometimes linked with increased food intake and obesity.

Certain behaviors can be predictive of how much a person eats. Some of these are how much food a person heaps onto their plate, how often they snack on calorie-dense, salty foods, how often they watch television or sit at a computer, and how often they eat out. A study published in a 2008 issue of *Obesity* looked at characteristics of Chinese buffet patrons. The study found that those who chose to immediately eat before browsing the buffet, used larger plates, used a fork rather than chopsticks, and chewed less per bite of food, had higher BMIs than patrons who did not exhibit these behaviors.Levin, B. E. "Developmental Gene X

Environment Interactions Affecting Systems Regulating Energy Homeostasis and Obesity." *Front Neuroendocrinol* 3 (2010): 270–83. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2903638/?tool=pubmed. Of course many behaviors are reflective of what we have easy access to—a concept we will discuss next.

Societal Influences

It is without a doubt that the American society affects what and how much we eat. Portion sizes have increased dramatically in the past few decades. For example, a bagel is now more than twice the size it was in the 1960s. Today, American teenagers have access to a massive amount of calorie-dense foods and beverages, which is a large contributor to the recent rapid increase in overweight and obesity in adolescents in this country. Even different cultures within the United States have different eating habits. For instance, southern Americans, in general, consume more foods high in fat, which is a contributing factor to their higher incidences of overweight and obesity than Americans who live in the northern states. (Alaska is an exception because it also has a high incidence of overweight and obesity, which is also partly attributed to diet.)

The fast food industry in America not only supplies Americans with a large proportion of their diet, but because of its massive presence in society dominates the workings of the entire food system (Note 11.23 "Video 11.1"). To generalize, most fast food items have little nutritional merit as they are highly processed and rich in saturated fat, salt, and added sugars. Despite fast foods being a poor source of nourishment, Americans spend over one hundred billion dollars per year on fast food, up from six billion dollars in the early 1970s. The fast food business is likely to continue to grow in North America (and the rest of the world) and greatly affect the diets of whole populations. Because it is unrealistic to say that Americans should abruptly quit eating fast food to save their health (because they will not) society needs to come up with ideas that push nutrient-dense whole foods into the fast food industry. You may have observed that this largely consumer-driven push is having some effect on the foods the fast food industry serves (just watch a recent Subway commercial, or check the options now available in a McDonald's Happy Meal). Pushing the fast food industry to serve healthier foods is a realistic and positive way to improve the American diet.

Video 11.1

History, Structure, and Ethics of the Fast Food Industry

(click to see video)

A brief clip about the fast food industry and its effect on the United States.

Tools for Change

Support the consumer movement of pushing the fast food industry and your favorite local restaurants into serving more nutrient-dense foods. You can begin this task by starting simple, such as requesting extra tomatoes and lettuce on your burger and more nutrient-dense choices in the salad bar. Also, choose their low-calorie menu options and help support the emerging market of healthier choices in the fast food industry. In today's fast-paced society, it is difficult for most people to avoid fast food all the time. When you do need a quick bite on the run, choose the fast food restaurants that serve healthier foods. Also, start asking for caloric contents of foods so that the restaurant becomes more aware that their patrons are being calorie conscious.

Factors Affecting Energy Expenditure

Physiological and Genetic Influences

Why is it so difficult for some people to lose weight and for others to gain weight? One theory is that every person has a "set point" of energy balance. This set point can also be called a fat-stat or lipostat, meaning the brain senses body fatness and triggers changes in energy intake or expenditure to maintain body fatness within a target range. Some believe that this theory provides an explanation as to why after dieting, most people return to their original weight not long after stopping the diet. Another theory is referred to as the "settling" point system, which takes into account (more so than the "set-point" theory) the contribution of the obesogenic environment to weight gain. In this model, the reservoir of body fatness responds to energy intake or energy expenditure, such that if a person is exposed to a greater amount of food, body fatness increases, or if a person watches more television body fatness increases. A major problem with these theories is that they overgeneralize and do not take into account that not all individuals respond in the same way to changes in food intake or energy expenditure. This brings up the importance of the interactions of genes and the environment.

Not all individuals who take a weight-loss drug lose weight and not all people who smoke are thin. An explanation for these discrepancies is that each individual's genes respond differently to a specific environment. Alternatively, environmental factors can influence a person's gene profile, which is exemplified by the effects of the prenatal environment on body weight and fatness and disease incidence later in life. One of the first scientific investigations of prenatal control over energy balance was conducted in Germany. In this observational study, scientists found that offspring born to mothers who experienced famine were more likely to be obese in

adulthood than offspring born to mothers who were pregnant just after World War II who lived in the same geographical locations.Matthews, C. E. "Amount of Time Spent in Sedentary Behaviors in the United States, 2003–2004." *Am J Epidemiol* 167, no. 7 (2008): 875–81. doi: 10.1093/aje/kwm390. Other studies have shown that the offspring of women who were overweight during pregnancy have a greater propensity for being overweight and for developing Type 2 diabetes. Thus, undernutrition and overnutrition during pregnancy influence body weight and disease risk for offspring later in life. They do so by adapting energy metabolism to the early nutrient and hormonal environment in the womb.

Audio Link 11.1

Rethinking Thin: The Myths and Realities of Dieting

Listen to this broadcast for scientific information about why it is so difficult for some people to lose weight.

http://www.npr.org/player/v2/mediaPlayer.html?action=1&t=1&islist=false&id=10354959&m=10355662

Psychological/Behavioral Influence

Sedentary behavior[12] is defined as the participation in the pursuits in which energy expenditure is no more than one-and-one-half times the amount of energy expended while at rest and include sitting, reclining, or lying down while awake. Of course, the sedentary lifestyle of many North Americans contributes to their average energy expenditure in daily life. Simply put, the more you sit, the less energy you expend. A study published in a 2008 issue of the *American Journal of Epidemiology* reports that 55 percent of Americans spend 7.7 hours in sedentary behavior daily.Matthews, C. E. "Amount of Time Spent in Sedentary Behaviors in the United States, 2003–2004." *Am J Epidemiol* 167, no. 7 (2008): 875–81. doi: 10.1093/aje/kwm390. Fortunately, including only a small amount of low-level physical activity benefits weight control. A study published in the June 2001 issue of the *International Journal of Behavioral Nutrition and Physical Activity* reports that even breaking up sitting-time with frequent, but brief increased energy expenditure activities, such as walking for five minutes every hour, helps maintain weight and even aids in weight loss.Wu, Y. "Overweight and Obesity in China." *Br Med J* 333, no. 7564 (2006): 362. doi: 10.1136/bmj.333.7564.362. Americans partake in an excessive amount of screen time, which is a sedentary behavior that not only reduces energy

12. Activity during which energy expenditure is no more than one and one-half times the amount of energy expended while at rest (examples include sitting, reclining, or lying down while awake).

expenditure, but also contributes to weight gain because of the exposure to aggressive advertising campaigns for unhealthy foods.

Societal Influence

In the United States, many societal factors influence the number of calories burned in a day. Escalators, moving walkways, and elevators (not to mention cars!) are common modes of transportation that reduce average daily energy expenditure. Office work, high-stress jobs, and occupations requiring extended working hours are all societal pressures that reduce the time allotted for exercise of large populations of Americans. Even the remote controls that many have for various electronic devices in their homes contribute to the US society being less active. More "obesogenic" factors were discussed in the opening of this chapter.

Socioeconomic status has been found to be inversely proportional to weight gain. One reason for this relationship is that inhabitants of low-income neighborhoods have reduced access to safe streets and parks for walking. Another is that fitness clubs are expensive and few are found in lower-income neighborhoods. The recent and long-lasting economic crisis in this country is predicted to have profound effects on the average body weight of Americans. The number of homeless in this country is rising with many children and adults living in hotels and cars. As you can imagine neither of these "home spaces" has a kitchen, making it impossible to cook nutritious meals and resulting in increased economically-forced access to cheap, unhealthy foods, such as that at a nearby gas station.

KEY TAKEAWAYS

- Energy balance is achieved when energy intake is equal to energy expended. Energy balance is essential for maintaining weight.
- Knowing the number of calories you need each day is a useful reference point, but it is also important to obtain your calories from nutrient-dense foods and consume the macronutrients in their AMDRs.
- The amount of energy you expend every day includes not only the calories you burn during physical activity, but also the calories you burn at rest (basal metabolism), and the calories you burn when you digest food.
- Basal metabolic rate (BMR) is dependent on body size, body composition, sex, age, nutritional status, genetics, body temperature, and thyroid hormone levels.
- The great majority of energy expended (between 50 and 70 percent) daily comes from conducting life's basic processes.
- The main control a person has over TEE is to increase physical activity.
- Energy intake is regulated by complex physiological responses and is influenced by genetics, behavior, and society.
- Energy expenditure is also regulated by complex physiological responses and is influenced by genetics, behavior, and society.

DISCUSSION STARTERS

1. Some types of transportation are becoming economically unfeasible for obese people. Discuss whether or not it is acceptable that air carriers can enforce that obese people (or what they politely call "passengers of size" or "passengers requiring extra space") pay more for their seats.

2. Many people have a hard time understanding the difficulties of being too skinny. Discuss with your peers how to empathize with the weight problems of underweight people. Read the article to understand that being skinny does not mean a person necessarily has a lower risk of chronic disease.

   http://www.msnbc.msn.com/id/18594089/ns/health-fitness/t/thin-people-can-be-fat-inside/

11.3 Too Little or Too Much Weight: What Are the Health Risks?

LEARNING OBJECTIVE

1. Discern the differences in health risks associated with being underweight and being overweight.

The number of people considered overweight and obese in the world has now surpassed the number that are starving, with some officials estimating that the number of overweight people is nearly double the number of underweight people worldwide. Countries that have more recently modernized, industrialized, and urbanized are experiencing a surge in their overweight and obese populations. China, the most populous country in the world, now has more than 215 million people, approximately one-fifth of their population, that are considered overweight or obese.Wu, Yangfeng. "Overweight and obesity in China." BMJ. 2006 August 19; 333(7564): 362–363. doi: 10.1136/bmj.333.7564.362. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1550451/. The increase in China's waistline is partly attributed to changes in the traditional diet, more sedentary lives, and a massive increase in motor vehicle use. Moreover, China's recent famines in the 1950s, which affected the poor and lower classes to a greater extent than the upper class, has sanctioned lax social attitudes toward body fat and reinspired the age-old Chinese belief that excess body fat represents health and prosperity.

One of the worst statistics regarding overweight and obesity in China is that more than ten million adolescents between ages seventeen and eighteen were overweight in 2000, which is twenty-eight times the number that were overweight in 1985.Wu, Y. "Overweight and Obesity in China." *Br Med J* 333, no. 7564 (2006): 362. doi: 10.1136/bmj.333.7564.362. The associated diseases of overweight and obesity happen over many years and signs and symptoms commonly take decades to manifest. With China's younger population and other developed countries experiencing a dramatic weight increase, the associated chronic diseases will come about much earlier in life than in previous generations. This will put an even greater burden on society.

Video 11.2

Chinese Obesity

(click to see video)

Watch this video on the surge in Chinese obesity and how the country's rapid increase in modernization contributes to its obesity epidemic.

Health Risks of Being Overweight and Being Obese

The health consequences of obesity are great and are responsible for more than one hundred thousand deaths per year in the United States. According to the CDC, in the United States in 2007–2008:

- 34 percent of adults age twenty years and over are obese
- 34 percent of adults age twenty years and over are overweight (but not obese)
- 18 percent of adolescents age twelve to nineteen years are obese
- 20 percent of children age six to eleven years are obese
- 10 percent of children age two to five years are obeseThe Centers for Disease Control and Prevention. "Obesity and Overweight." Accessed October 8, 2011. http://www.cdc.gov/nchs/fastats/overwt.htm.

State Map of the Prevalence of Obesity in America

Visit www.cdc.gov/obesity/downloads/obesity_trends_2010.ppt to see the obesity trends from 1985 to 2010. As you will see, the percentages of obese adults are rising.

As BMIs increase over 25, the risks increase for heart disease, Type 2 diabetes, hypertension, endometrial cancer, postmenopausal breast cancer, colon cancer, stroke, osteoarthritis, liver disease, gallbladder disorders, and hormonal disorders. The WHO reports that overweight and obesity are the fifth leading cause for deaths globally, and estimates that more than 2.8 million adults die annually as a result of being overweight or obese.World Health Organization. "Obesity and Overweight." Accessed October 8, 2011. http://www.who.int/mediacentre/factsheets/fs311/en/. Moreover, overweight and obesity contribute to 44 percent of the Type 2 diabetes burden, 23 percent of the heart disease burden, and between 7 and 41 percent of the burden of certain cancers.World Health Organization. "Obesity and Overweight." Accessed October 8, 2011. http://www.who.int/mediacentre/factsheets/fs311/en/.

Similar to other public health organizations, the WHO states the main causes of the obesity epidemic worldwide are the increased intake of energy-dense food and decreased level of physical activity that is mainly associated with modernization,

industrialization, and urbanization. The environmental changes that contribute to the dietary and physical activity patterns of the world today are associated with the lack of policies that address the obesity epidemic in the health, urban planning, agriculture, food industry, and education sectors.

Health Risks of Being Underweight

The 2003–2006 National Health and Nutrition Examination Survey (NHANES) estimated that 1.8 percent of adults and 3.3 percent of children and adolescents in the United States are underweight.Centers for Disease Control and Prevention. "NCHS Health E-Stat. Prevalence of Underweight among Children and Adolescents: United States, 2003–2006." Accessed October 8, 2011. http://www.cdc.gov/nchs/data/hestat/underweight/underweight_children.htm. Being underweight is linked to nutritional deficiencies, especially iron-deficiency anemia, and to other problems such as delayed wound healing, hormonal abnormalities, increased susceptibility to infection, and increased risk of some chronic diseases such as osteoporosis. In children, being underweight can stunt growth. The most common underlying cause of underweight in America is inadequate nutrition. Other causes are wasting diseases, such as cancer, multiple sclerosis, tuberculosis, and eating disorders. People with wasting diseases are encouraged to seek nutritional counseling, as a healthy diet greatly affects survival and improves responses to disease treatments. Eating disorders that result in underweight affect about eight million Americans (seven million women and one million men).

Anorexia Nervosa

Anorexia nervosa[13], more often referred to as "anorexia," is a psychiatric illness in which a person obssesses about their weight and about food that they eat. Anorexia results in extreme nutrient inadequacy and eventually to organ malfunction. Anorexia is relatively rare—the National Institute of Mental Health (NIMH) reports that 0.9 percent of females and 0.3 percent of males will have anorexia at some point in their lifetime,The National Institute of Mental Health. "Eating Disorders among Adults: Anorexia Nervosa." Accessed October 8, 2011. http://mentalhealth.gov/statistics/1EAT_ADULT_ANX.shtml. but it is an extreme example of how an unbalanced diet can affect health. Anorexia frequently manifests during adolescence and it has the highest rate of mortality of all mental illnesses. People with anorexia consume, on average, fewer than 1,000 kilocalories per day and exercise excessively. They are in a tremendous caloric imbalance. Moreover, some may particpate in binge eating, self-induced vomiting, and purging with laxatives or enemas. The very first time a person starves him- or herself may trigger the onset of anorexia. The exact causes of anorexia are not completely known, but many things contribute to its development including economic status, as it is most prevalent in high-income families. It is a genetic disease and is often

13. A psychiatric illness in which a person obssesses over their weight and the food that they eat. Anorexia results in extreme nutrient inadequacy and, eventually, organ malfunction.

passed from one generation to the next. Pregnancy complications and abnormalities in the brain, endocrine system, and immune system may all contribute to the development of this illness.

The primary signs of anorexia are fear of being overweight, extreme dieting, an unusual perception of body image, and depression. The secondary signs and symptoms of anorexia are all related to the caloric and nutrient deficiencies of the unbalanced diet and include excessive weight loss, a multitude of skin abnormalities, diarrhea, cavities and tooth loss, osteoporosis, and liver, kidney, and heart failure. There is no physical test that can be used to diagnose anorexia and distinguish it from other mental illnesses. Therefore a correct diagnosis involves eliminating other mental illnesses, hormonal imbalances, and nervous system abnormalties. Eliminating these other possibilities involves numerous blood tests, urine tests, and x-rays. Coexisting organ malfunction is also examined. Treatment of any mental illness involves not only the individual, but also family, friends, and a psychiatric counselor. Treating anorexia also involves a dietitian, who helps to provide dietary solutions that often have to be adjusted over time. The goals of treatment for anorexia are to restore a healthy body weight and significantly reduce the behaviors associated with causing the eating disorder. Relapse to an unbalanced diet is high. Many people do recover from anorexia, however most continue to have a lower-than-normal bodyweight for the rest of their lives (see Note 11.33 "Video 11.3").

Video 11.3

What I Gained in Recovery from Anorexia

(click to see video)

On a more positive note, watch this personal account of what can be gained from anorexia recovery.

Bulimia

Bulimia[14], like anorexia, is a psychiatric illness that can have severe health consequences. The NIMH reports that 0.5 percent of females and 0.1 percent of males will have bulimia at some point in their lifetime.The National Institute of Mental Health. “Eating Disorders among Adults: Bulimia Nervosa.” Accessed October 8, 2011. http://mentalhealth.gov/statistics/1EAT_ADULT_RBUL.shtml. Bulimia is characterized by episodes of eating large amounts of food followed by purging, which is accomplished by vomiting and with the use of laxatives and diuretics. Unlike people with anorexia, those with bulimia often have a normal weight, making the disorder more difficult to detect and diagnose. The disorder is characterized by signs similar to anorexia such as fear of being overweight, extreme

14. A psychiatric illness characterized by frequent episodes of eating large amounts of food followed by purging.

dieting, and bouts of excessive exercise. Secondary signs and symptoms include gastric reflux, severe erosion of tooth enamel, dehydration, electrolyte imbalances, lacerations in the mouth from vomiting, and peptic ulcers. Repeated damage to the esophagus puts people with bulimia at an increased risk for esophageal cancer. The disorder is also highly genetic, linked to depression and anxiety disorders, and most commonly occurs in adolescent girls and young women. Treatment often involves antidepressant medications and, like anorexia, has better results when both the family and the individual with the disorder participate in nutritional and psychiatric counseling.

Binge-Eating Disorder

Similar to those who experience anorexia and bulimia, people who have a **binge-eating disorder**[15] have lost control over their eating. Binge-eating disorder is not currently diagnosed as a distinct psychiatric illness, although there is a proposal from the American Psychiatric Association to categorize it more specifically. People with binge-eating disorder will periodically overeat to the extreme, but their loss of control over eating is not followed by fasting, purging, or compulsive exercise. As a result, people with this disorder are often overweight or obese, and their chronic disease risks are those linked to having an abnormally high body weight such as hypertension, cardiovascular disease, and Type 2 diabetes. Additionally, they often experience guilt, shame, and depression. Binge-eating disorder is commonly associated with depression and anxiety disorders. According to the NIMH, binge-eating disorder is more prevalent than anorexia and bulimia, and affects 3.5 percent of females and 2.0 percent of males at some point during their lifetime.The National Institute of Mental Health. “Eating Disorders among Adults: Binge Eating Disorder.” Accessed October 8, 2011. http://www.nimh.nih.gov/statistics/1EAT_ADULT_RB.shtml. Treatment often involves antidepressant medication as well as nutritional and psychiatric counseling.

15. A nonpsychiatric disorder characterized by periodic losses of control over eating. The periods of excessive overeating are not followed by fasting or purging. People who have this disorder are often overweight or obese.

KEY TAKEAWAYS

- The number of people considered overweight and obese in the world has now surpassed the number that is starving.
- As BMIs increase over 25, the risks increase for heart disease, Type 2 diabetes, hypertension, endometrial cancer, breast cancer, colon cancer, stroke, osteoarthritis, liver disease, gallbladder disorders, and hormonal disorders.
- Being underweight is linked to nutritional deficiencies. These deficiencies cause iron-deficiency anemia and also delayed wound healing, hormonal abnormalities, increased susceptibility to infection, and increased risk of some chronic diseases such as osteoporosis. In children, being underweight can stunt growth.
- Eating disorders resulting in being underweight can have severe consequences to health. The eating disorder anorexia nervosa has the highest mortality rate of all mental illnesses.
- All underweight people do not have anorexia and all overweight people do not have an eating disorder.

DISCUSSION STARTERS

1. Visit the Food and Agriculture Organization of the United Nations website and discuss the impact of the rise in obesity in developing countries.

   http://www.fao.org/FOCUS/E/obesity/obes1.htm

2. Even as adults in this society we "profile" people with excess body fat as lazy and other disrespectful adjectives. Moreover, society commonly "profiles" people who are too skinny as being compulsive and vain. Propose ideas for improving body image during teenage years.

11.4 Dietary, Behavioral, and Physical Activity Recommendations for Weight Management

LEARNING OBJECTIVES

1. Explain the complementary actions of dietary changes and increased physical activity level on health.
2. Formulate an exercise plan that fits your lifestyle and that follows the *2008 Physical Activity Guidelines for Americans*.

We have just considered the gravity of the obesity problem in America and worldwide. How is America combating its weight problem on a national level and have the approaches been successful?

Successful weight loss is defined as individuals intentionally losing at least 10 percent of their body weight and keeping it off for at least one year.Wing, R. R. and J. O. Hill. "Successful Weight Loss Maintenance." *Annu Rev Nutr* 21 (2001): 323–41. Accessed October 8, 2011. http://www.ncbi.nlm.nih.gov/pubmed/11375440?dopt=Abstract. Results from lifestyle intervention studies suggest fewer than 20 percent of participants are successful at weight loss. An evaluation of successful weight loss, involving more than fourteen thousand participants published in the November 2011 issue of the *International Journal of Obesity* estimates that more than one in six Americans who were overweight or obese were successful in achieving long-term weight loss.Kraschnewski, J. L. et al. "Long-Term Weight Loss Maintenance in the United States." *Int J Obes* 34, no. 11 (2010): 1644–54. http://www.ncbi.nlm.nih.gov/pubmed/20479763. However, these numbers are on the high end because many similar studies report fewer than 10 percent of participants as successful in weight loss.

The National Weight Control Registry (NWCR) tracks over ten thousand people who have been successful in losing at least 30 pounds and maintaining this weight loss for at least one year. Their research findings are that 98 percent of participants in the registry modified their food intake and 94 percent increased their physical activity (mainly walking.)The National Weight Control Registry. "Research Findings." Accessed October 8, 2011. http://www.nwcr.ws/Research/default.htm. Although there are a great variety of approaches taken by NWCR members to achieve successful weight loss, most report that their approach involved adhering to a low-calorie, low-fat diet and doing high levels of activity (about one hour of exercise per day). Moreover, most members eat breakfast every day, watch fewer

than ten hours of television per week, and weigh themselves at least once per week. About half of them lost weight on their own and the other half used some type of weight-loss program. In most scientific studies successful weight loss is accomplished only by changing the diet *and* by increasing physical activity. Doing one without the other limits the amount of weight lost and the length of time that weight loss is sustained. On an individual level it is quite possible to achieve successful weight loss, as over ten thousand Americans can attest. Moreover, losing as little as 10 percent of your body weight can significantly improve health and reduce disease risk.National Heart, Lung, and Blood Institute. "Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report." *Obes Res* 6 supplement (1998): 51S–210S. http://www.ncbi.nlm.nih.gov/books/NBK2003/. You do not have to be overweight or obese to reap benefits from eating a healthier diet and increasing physical activity as both provide numerous benefits beyond weight loss and maintenance.

Evidence-Based Dietary Recommendations

The *2010 Dietary Guidelines for Americans* offers specific, evidence-based recommendations for dietary changes aimed at keeping calorie intake in balance with physical activity, which is key for weight management. These recommendations include:US Department of Agriculture. *2010 Dietary Guidelines for Americans*. 2010. Accessed October 7, 2011. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines 2010.pdf.

- **Increase intake of whole grains, vegetables, and fruits.** Scientific evidence demonstrates that adults who have a higher intake of whole grains, mainly those high in dietary fiber, have lower body weights compared to adults who eat a smaller amount of whole grains. Moreover diets incorporating more whole grains reduce chronic disease risk (see Chapter 4 "Carbohydrates"). A higher intake of fruits and vegetables is scientifically shown to protect against weight gain in adults and there is some evidence that this is also true for children and adolescents (see Chapter 8 "Nutrients Important As Antioxidants" for detailed information and the benefits to health of eating a variety of fruits and vegetables).
- **Reduce intake of sugar-sweetened beverages.** There is good evidence that reducing consumption of sugar-sweetened beverages, especially in children and adolescents, decreases body weight and reduces chronic disease risk (see Chapter 4 "Carbohydrates" for detailed information).
- **Monitor intake of 100 percent fruit juice for children and adolescents, especially those who are overweight or obese.** There is some evidence that increased intake of 100 percent juice exacerbates

weight problems in children and adolescents who are already overweight or obese.
- **Monitor calorie intake from alcoholic beverages for adults.** Drinking in moderation is not linked to weight gain; however, excessive intake of alcohol over time is associated with weight gain.

Evidence-Based Behavioral Recommendations

In addition to the dietary recommendations, the *2010 Dietary Guidelines for Americans* offers specific evidence-based recommendations that address behavioral changes aimed to keep calorie intake in balance with physical activity. The recommendations include:

- **Focus on the total number of calories consumed.** Reducing calorie intake improves health and aids in weight management.
- **Monitoring food and caloric intake.** Being more aware of the calories in foods and beverages by reading the Nutrition Facts panel is helpful for consumers to monitor intake. Vigilant monitoring of food and caloric intake assists in weight management.
- **When eating out, choose smaller portions or lower-calorie options.** As mentioned in an earlier section of this chapter, eating out more often, especially at fast food restaurants, contributes to weight gain. The *Dietary Guidelines* advise people that when they are eating out to order smaller portions, share meals when possible, or take home part of the meal.
- **Prepare, serve, and consume smaller portions of foods and beverages, especially those high in calories.** Having less on your plate helps you eat less.
- **Eat a nutrient-dense breakfast.** The old adage that "breakfast is the most important meal of the day" holds true when you consider that not eating breakfast is associated with higher body weights, especially among children and adolescents. Moreover, eating a nutrient-dense breakfast has in some scientific studies been shown to stimulate weight loss.
- **Limit screen time.** In children, adolescents, and adults, the sedentary activities of watching television and spending time on the computer are linked to increased overweight and obesity. The *Dietary Guidelines* recommend children and adolescents spend no more than one to two hours daily watching television, playing electronic games, or using the computer (other than for homework).US Department of Agriculture. *2010 Dietary Guidelines for Americans*. 2010. Accessed October 7, 2011. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines2010.pdf.

Evidence-Based Physical Activity Recommendations

The other part of the energy balance equation is physical activity. The *2010 Dietary Guidelines* are complemented by the *2008 Physical Activity Guidelines for Americans* issued by the Department of Health and Human Services in an effort to provide evidence-based guidelines for appropriate physical activity levels. The *2008 Physical Activity Guidelines* provide guidance to Americans aged six and older about how to improve health and reduce chronic disease risk through physical activity. Increased physical activity has been found in scientific studies to lower the risk of heart disease, stroke, high blood pressure, Type 2 diabetes, colon, breast, and lung cancer, falls and fractures, depression, and dying early. Increased physical activity not only reduces disease risk, but also improves overall health by increasing cardiovascular and muscular fitness, increasing bone density and strength, improving cognitive function, and assisting in weight loss and weight maintenance. The key guidelines for adults are the following (those for pregnant women, children, and older people will be given in Chapter 12 "Nutrition through the Life Cycle: From Pregnancy to the Toddler Years" and Chapter 13 "Nutrition through the Life Cycle: From Childhood to the Elderly Years"):US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans*. 2008. Accessed October 8, 2011. http://www.health.gov/paguidelines/guidelines/chapter2.aspx.

- Even small amounts of activity are beneficial to your health.
- More substantial health benefits are obtained by doing at least two hours and thirty minutes per week of moderate-intensity, or one hour and fifteen minutes per week of vigorous-intensity aerobic physical activity, or an equivalent combination thereof. Aerobic activity has better benefits if performed for at least ten minutes at a time, spread throughout the week.
- More extensive health benefits occur when moderate aerobic physical activity is increased to five hours per week of moderate-intensity, or to two hours and thirty minutes of vigorous-intensity aerobic physical activity, or a combination thereof. Additional health benefits are gained by going beyond these recommended amounts of physical activity.
- Muscle-strengthening activities at moderate or high intensity involving all major muscle groups two or more days per week provides additional health benefits to aerobic exercise.

The *2008 Physical Activity Guidelines* broadly classify moderate physical activities as those when “you can talk while you do them, but can’t sing” and vigorous activities as those when “you can only say a few words without stopping to catch your breath.”US Department of Health and Human Services. *2008 Physical Activity*

Guidelines for Americans. 2008. Accessed October 8, 2011. http://www.health.gov/paguidelines/guidelines/chapter2.aspx.

Table 11.6 Moderate and Vigorous Physical Activities

Moderate Activities	Vigorous Activities
Ballroom/line dancing	Aerobic dance
Biking on level ground	Biking (more than 10 miles per hour)
Canoeing	Heavy gardening (digging, hoeing)
Gardening	Hiking uphill
Baseball, softball, volleyball	Fast dancing
Tennis (doubles)	Jumping rope
Walking briskly	Martial arts (karate)
Water aerobics	Race walking
Using hand cyclers	Jogging or running
	Sports with running (basketball, hockey, soccer)
	Swimming laps
	Tennis (singles)
	Ice hockey

Source: US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans.* 2008. http://www.health.gov/paguidelines/.

Interactive 11.5

To get started on ramping up your physical activity or following a new exercise program use the toolkit, "Be Active Your Way" available from HHS:

http://www.health.gov/paguidelines/adultguide/activeguide.aspx.

Campaigns for a Healthy-Weight America

On a national level, strategies addressing overweight and obesity in the past have not been all that successful as obesity levels continue to climb. However, in the recent past (2007–2011) several newly created initiatives and organizations are actively reinforcing strategies aimed to meet the challenge of improving the health of all Americans.

In 2010 the national campaign to reduce obesity was reinforced when First Lady Michelle Obama launched the "Let's Move" initiative, which has the goal of "solving the challenge of childhood obesity within a generation so that children born today will reach adulthood at a healthy weight."The White House, Office of the First Lady. "First Lady Michelle Obama Launches Let's Move: America's Move to Raise a Healthier Generation of Kids." February 9, 2010. http://www.whitehouse.gov/the-press-office/first-lady-michelle-obama-launches -lets-move-americas-move-raise-a-healthier-genera. Another campaign, "Campaign to End Obesity," was recently established to try to enable more Americans to eat healthy and be active by bringing together leaders from academia and industry, as well as public-health policy-makers in order to create policies that will reverse the obesity trend and its associated diseases (Note 11.40 "Video Link 11.2"). It remains to be seen whether these new initiatives will finally help improve American health.

Video Link 11.2

Campaign to End Obesity

View this brief video on the Campaign to End Obesity.

http://www.obesitycampaign.org/

The "Small-Change" Approach

Currently, most people are not obese in this country. The gradual rise in overweight is happening because, on average, people consume slightly more calories daily than they expend, resulting in a gradual weight gain of one to two pounds a year. In 2003 the idea was first published that promoting small lifestyle changes to reduce weight gain occurring over time in all age groups may better reduce obesity rates in the American population.Hill, J. O. "Can a Small-Changes Approach Help Address the

Obesity Epidemic? A Report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council." *Am J Clin Nutr* 89, no. 2 (2009): 477–84. http://www.ajcn.org/content/89/2/477.long. Scientific studies have demonstrated that asking people to increase the number of steps they take each day while providing them with pedometers that count the steps they take each day successfully prevented weight gain. A "small-changes" study published in the October 2007 issue of *Pediatrics* evaluated whether families that made two small lifestyle changes, which were to walk an additional two thousand steps per day and to eliminate 100 kilocalories per day from their typical diet by replacing dietary sugar with a noncaloric sweetener, would prevent weight gain in overweight children.Rodearmel, S. J. et al. "Small Changes in Dietary Sugar and Physical Activity As an Approach to Preventing Excessive Weight Gain: The America on the Move Family Study." *Pediatrics* 120, no. 4 (2007): e869–79. http://pediatrics.aappublications.org/content/120/4/e869.long. The results of this study were that a higher percentage of children who made the small changes maintained or reduced their BMI in comparison to children of families given a pedometer but not asked to also make physical activity or dietary changes.Rodearmel, S. J. et al. "Small Changes in Dietary Sugar and Physical Activity As an Approach to Preventing Excessive Weight Gain: The America on the Move Family Study." *Pediatrics* 120, no. 4 (2007): e869–79. http://pediatrics.aappublications.org/content/120/4/e869.long. Several more studies funded by the National Institutes of Health and USDA are ongoing and are evaluating the effectiveness of the "small-changes" approach in reducing weight gain.

In 2009, a report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council proposed that the "small-changes" approach when supported at the community, industry, and governmental levels will be more effective than current strategies in gradually reducing the obesity rate in America.Hill, J. O. "Can a Small-Changes Approach Help Address the Obesity Epidemic? A Report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council." *Am J Clin Nutr* 89, no. 2 (2009): 477–84. http://www.ajcn.org/content/89/2/477.long. The HHS encouraged the approach and launched a "Small Step" website in 2008.

KEY TAKEAWAYS

- Successful weight loss is defined as when individuals intentionally lose at least 10 percent of their body weight and keep it off for at least one year.
- Although there is a great variety of approaches to achieve successful weight loss most report that it involves adhering to a low-calorie, low-fat diet and doing high levels of activity (about one hour of exercise per day).
- The *2010 Dietary Guidelines for Americans* recommendations are based upon scientific evidence.
- The other part of the energy balance equation is physical activity. The *2010 Dietary Guidelines* were complemented by the *2008 Physical Activity Guidelines for Americans* issued by the HHS in an effort to provide evidence-based guidelines for appropriate physical activity levels.
- On a national level, strategies addressing overweight and obesity in the past have not been all that successful as obesity levels continue to climb. However, in the recent past (2007–2011) several newly created initiatives and organizations are actively reinforcing strategies that aim to meet the challenge of improving the health of all Americans.

DISCUSSION STARTERS

1. Discuss ways to address the childhood obesity problem in your own community.
2. Calculate your EER by using the formula in this chapter and determine whether your average daily intake of calories falls below, meets, or exceeds your EER.

11.5 End-of-Chapter Exercises

IT'S YOUR TURN

1. Record in a dietary assessment diary the calories you consumed in one week. This can be done on your cell phone.
2. Calculate your EER by visiting http://www.health-calc.com/diet/energy-expenditure-advanced and determine whether your average daily intake of calories falls below, meets, or exceeds your EER.
3. Make a list of five strategies your local schools and community could implement to effectively address the childhood obesity problem.

APPLY IT

1. Calculate your BMI and waist-to-hip ratio. Make a list of five behavioral changes you can make to meet your goal of maintaining weight, reducing weight, or increasing weight.

2. Summarize in a paragraph or two why (with respect to reducing future chronic disease burden) it is of utmost importance to combat childhood obesity. Watch this video of First Lady Michelle Obama's unveiling of the initiative to combat childhood obesity to assist you in this assignment.

   US First Lady Michelle Obama Unveils Initiative to Battle Childhood Obesity

   (click to see video)
3. The CDC website provides a list of physical activities and categorizes them as moderate or vigorous (http://www.cdc.gov/nccdphp/dnpa/physical/pdf/PA_Intensity_table_2_1.pdf). Use this source to develop an exercise program that fits your lifestyle and follows the recommended amounts of physical activity.

EXPAND YOUR KNOWLEDGE

1. Make a daily log of your physical activities using the spreadsheet available at http://www.health-calc.com/Calculate_daily_energy_expenditure.pdf. Then calculate your EER by visiting http://www.health-calc.com/diet/energy-expenditure-advanced.
2. Harvard Health Publications has a document that lists the calories burned for various physical activities. It is available at http://www.health.harvard.edu/newsweek/Calories-burned-in-30-minutes-of-leisure-and -routine-activities.htm. Use it to develop a physical activity program that is attractive to you and follows the recommended physical activity guidelines.

Chapter 12

Nutrition through the Life Cycle: From Pregnancy to the Toddler Years

Big Idea

Breastfeeding promotion and support greatly influences infant health.

The choice to breastfeed is one that all new mothers face. Support from family members, friends, employers, and others can greatly help with both the decision-making process during pregnancy and the practice of breastfeeding after the baby's birth.

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The World Health Organization (WHO) recommends that infants should be given only breast milk for the first six months of life. Exclusive breastfeeding is one of the best ways a mother can support the growth and protect the health of her infant child. Breast milk contains all of the nutrients that a newborn requires and gives a child the best start to a healthy life. Many women want to breastfeed their babies. Unfortunately, a mother's intention alone may not be enough to make this practice possible. Around the world, less than 40 percent of infants under the age of six months are breastfed exclusively.World Health Organization. "10 Facts on Breastfeeding." Accessed February 21, 2012. http://www.who.int/features/factfiles/breastfeeding/en/. In the United States, about 75 percent of babies start out being breastfed. Yet by the age of six months, when solid foods should begin to be introduced into a child's diet along with breast milk, only 15 percent of infants in the United States were still breastfed exclusively, according to the Centers for Disease Control and Prevention (CDC).Centers for Disease Control and Prevention. "Breastfeeding: Promotion and Support." Last updated August 2, 2011. http://www.cdc.gov/breastfeeding/promotion/index.htm. However, the approval and assistance of family members, friends, employers, health-care providers, and policymakers can make an enormous difference and provide the needed promotion and support for mothers who wish to breastfeed their children.

Education about breastfeeding typically begins with health-care providers. During prenatal care and often soon after a woman has given birth, doctors, nurses, and other clinicians can explain the benefits of breastfeeding and describe the proper technique. Nearly all births in the United States and Canada occur in hospital settings, and hospital practices in labor, delivery, postpartum care, and discharge planning can inform and support women who want to breastfeed. Once a new mother has left the hospital for home, she needs access to a trained individual who can provide consistent information. International Board Certified Lactation Consultants (IBCLCs) are health-care professionals (often a registered nurse or registered dietitian) certified in breastfeeding management that work with new mothers to solve problems and educate families about the benefits of this practice. Research shows that breastfeeding rates are higher among women who had infants in hospitals that make IBCLCs available to new mothers, rather than those who gave birth in institutions without these professionals on staff.US Department of Health and Human Services, Office of the Surgeon General. "Executive Summary: The Surgeon General's Call to Action to Support Breastfeeding." January 20, 2011. http://www.surgeongeneral.gov/topics/breastfeeding/executivesummary.pdf. In addition, spouses, partners, and other family members can play critical roles in helping a pregnant woman make the decision to breastfeed and assisting with feeding after the baby is born.

Employment can also factor into a woman's decision to breastfeed or her ability to maintain the practice. Employed mothers have been less likely to initiate breastfeeding and tend to breastfeed for a shorter period of time than new mothers who are not employed or who have lengthy maternity leaves. In 2010 in the United States, the passage of the Affordable Care Act (ACA) called for employers to provide accommodations within the workplace for new mothers to pump breast milk. This law requires a private and clean space within the workplace, other than a restroom, along with adequate break time for a woman to express milk.US Department of Health and Human Services, Office of the Surgeon General. "Executive Summary: The Surgeon General's Call to Action to Support Breastfeeding." January 20, 2011. http://www.surgeongeneral.gov/topics/breastfeeding/executivesummary.pdf.

Members of a community can also promote and support breastfeeding. New mothers can join peer counseling groups or turn to other women within their community who have previous experience with breastfeeding. In addition, community-based programs can provide education and support. The US Department of Agriculture's Women, Infants, and Children program provides information on breastfeeding for low-income families. Launched in 2004, the Loving Support program combines peer counseling with breastfeeding promotion efforts to increase duration rates across the United States. La Leche League is an international program that provides mother-to-mother support, encouragement, and education about breastfeeding for women around the world.

You Decide

How can you help to promote and support breastfeeding practices in your community?

Although breastfeeding should be recommended and encouraged for almost all new mothers, it is important to remember that the decision to breastfeed is a personal choice and women should not be made to feel guilty if they cannot, or choose not, to breastfeed their infants. In some rare cases, a woman is unable to breastfeed or it is not in the baby's best interest.

Nutritional choices that parents make, such as the decision to breastfeed or bottle-feed, not only affect early childhood development, but also a child's health and wellness later in life. Therefore, it is imperative to promote and support the best practices for the well-being of infants and mothers alike. Throughout this chapter, we will examine how dietary choices—from daily caloric intake for pregnant women to serving sizes for toddlers—impact health and wellness during pregnancy and the early childhood years.

Video 12.1

Breastfeeding and Working

(click to see video)

This video from the Colorado Breastfeeding Coalition focuses on the importance of making workplace accommodations for employees who are breastfeeding their infants.

12.1 The Human Life Cycle

LEARNING OBJECTIVES

1. Identify and define the different stages of the human life cycle.
2. Explain how the human body develops from infancy through the toddler years.

According to the *American Journal of Clinical Nutrition*, the human life span, or the maximum length of time possible for human life, is 130 years.Ordovas, J. M. "Living Well to 100: Nutrition, Genetics, Inflammation." *Am J Clin Nutr* 83 (2006): 401S490S. Human bodies change significantly over time, and food is the fuel for those changes. People of all ages need the same basic nutrients—essential amino acids, carbohydrates, essential fatty acids, and twenty-eight vitamins and minerals—to sustain life and health. However, the amounts of nutrients needed differ. Throughout the **human life cycle**[1], the body constantly changes and goes through different periods known as stages. The major stages of the human life cycle are defined as follows:

- **Pregnancy.** The development of a zygote into an embryo and then into a fetus in preparation for childbirth.
- **Infancy.** The earliest part of childhood. It is the period from birth through age one.
- **Toddler years.** Occur during ages two and three and are the end of early childhood.
- **Childhood.** Takes place from ages four to eight.
- **Puberty.** The period from ages nine to thirteen, which is the beginning of adolescence.
- **Older adolescence.** The stage that takes place between ages fourteen and eighteen.
- **Adulthood.** The period from adolescence to the end of life and begins at age nineteen.
- **Middle age.** The period of adulthood that stretches from age thirty-one to fifty.
- **Senior years, or old age.** Extend from age fifty-one until the end of life.

1. The span of a human life, which consists of different stages, including childhood, adolescence, adulthood, and old age.

Changes during Pregnancy

This ultrasound image shows a four-month-old fetus.

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In this chapter, we will focus on the human life cycle from the prenatal period into early childhood. We begin with pregnancy, a developmental marathon that lasts about forty weeks. It begins with the first trimester (weeks one to week twelve), extends into the second trimester (weeks thirteen to week twenty-seven), and ends with the third trimester (week twenty-eight to birth). At conception, a sperm cell fertilizes an egg cell, creating a zygote. The zygote rapidly divides into multiple cells to become an embryo and implants itself in the uterine wall, where it develops into a fetus. Some of the major changes that occur include the branching of nerve cells to form primitive neural pathways at eight weeks. At the twenty-week mark, physicians typically perform an ultrasound to acquire information about the fetus and check for abnormalities. By this time, it is possible to know the sex of the baby. At twenty-eight weeks, the unborn baby begins to add body fat in preparation for life outside of the womb.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F.A. Davis Company, 2003), 81–82. Throughout this entire process, a pregnant woman's nutritional choices affect not only fetal development, but also her own health and the future health of her newborn.

Changes during Infancy

A number of major physiological changes occur during infancy. The trunk of the body grows faster than the arms and legs, while the head becomes less prominent in comparison to the limbs. Organs and organ systems grow at a rapid rate. Also during this period, countless new synapses form to link brain neurons. Two soft spots on the baby's skull, known as fontanels, allow the skull to accommodate rapid brain growth. The posterior fontanel closes first, by the age of eight weeks. The anterior fontanel closes about a year later, at eighteen months on average. Developmental milestones include sitting up without support, learning to walk, teething, and vocalizing among many, many others. All of these changes require adequate nutrition to ensure development at the appropriate rate.Beverly McMillan, *Illustrated Atlas of the Human Body* (Sydney, Australia: Weldon Owen, 2008), 248.

Changes during the Toddler Years

Major physiological changes continue into the toddler years. Unlike in infancy, the limbs grow much faster than the trunk, which gives the body a more proportionate appearance. By the end of the third year, a toddler is taller and more slender than an infant, with a more erect posture. As the child grows, bone density increases and bone tissue gradually replaces cartilage. This process known as ossification is not completed until puberty.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F.A. Davis Company, 2003), 108. Developmental milestones include running, drawing, toilet training, and self-feeding. How a toddler acts, speaks, learns, and eats offers important clues about their development.

Nutrition and Early Development

In this chapter and the next, we will explore how the dietary decisions we make affect our health and wellness throughout the life cycle. We begin by examining the developmental changes that occur during pregnancy, infancy, and the toddler years, and how nutritional choices affect those changes. From pregnancy through the toddler years, children are entirely dependent on parents or caregivers for nutrients. Parents also help to establish a child's eating habits and attitudes toward food. So, adults must be mindful of the choices they make and how those choices influence a young child's development, health, and overall well-being.

KEY TAKEAWAYS

- The human body constantly develops and changes throughout the human life cycle, and food provides the fuel for those changes.
- The major stages of the human life cycle include pregnancy, infancy, the toddler years, childhood, puberty, older adolescence, adulthood, middle age, and the senior years.
- Proper nutrition and exercise ensure health and wellness at each stage of the human life cycle.

DISCUSSION STARTER

1. In preparation for this chapter and the next, predict how you think nutrient needs might differ at the beginning of life compared to the end of life. Then, after reading this chapter and the one that follows, discuss if your predictions were correct or incorrect.

12.2 Pregnancy and Nutrition

LEARNING OBJECTIVES

1. Summarize prenatal nutritional requirements and dietary recommendations.
2. Discuss the most important nutritional concerns during pregnancy.
3. Explore the relationship between fetal development and nutritional choices.

It is crucial to consume healthy foods at every phase of life, beginning in the womb. Good nutrition is vital for any pregnancy and not only helps an expectant mother remain healthy, but also impacts the development of the fetus and ensures that the baby thrives in infancy and beyond. During pregnancy, a woman's needs increase for certain nutrients more than for others. If these nutritional needs are not met, infants could suffer from low birth weight (a birth weight less than 5.5 pounds, which is 2,500 grams), among other developmental problems. Therefore, it is crucial to make careful dietary choices.

The Early Days of Pregnancy

For medical purposes, pregnancy is measured from the first day of a woman's last menstrual period until childbirth, and typically lasts about forty weeks. Major changes begin to occur in the earliest days, often weeks before a woman even knows that she is pregnant. During this period, adequate nutrition supports cell division, tissue differentiation, and organ development. As each week passes, new milestones are reached. Therefore, women who are trying to conceive should make proper dietary choices to ensure the delivery of a healthy baby. Fathers-to-be should also consider their eating habits. A sedentary lifestyle and a diet low in fresh fruits and vegetables may affect male fertility. Men who drink too much alcohol may also damage the quantity and quality of their sperm.Mayo Clinic. "Healthy Sperm: Improving Your Fertility." © 1998–2012 Mayo Foundation for Medical Education and Research. Accessed February 21, 2012. http://www.mayoclinic.com/health/fertility/MC00023. For both men and women, adopting healthy habits also boosts general well-being and makes it possible to meet the demands of parenting.

Tools for Change

A pregnancy may happen unexpectedly. Therefore, it is important for all women of childbearing age to get 400 micrograms of folate per day prior to pregnancy and 600 micrograms per day during pregnancy. Folate, which is also known as folic acid, is crucial for the production of DNA and RNA and the synthesis of cells. A deficiency can cause megaloblastic anemia, or the development of abnormal red blood cells, in pregnant women. It can also have a profound affect on the unborn baby. Typically, folate intake has the greatest impact during the first eight weeks of pregnancy, when the neural tube closes. The neural tube develops into the fetus's brain, and adequate folate reduces the risk of brain abnormalities or neural tube defects, which occur in one in a thousand pregnancies in North America each year. This vital nutrient also supports the spinal cord and its protective coverings. Inadequate folic acid can result in birth defects, such as spina bifida, which is the failure of the spinal column to close. The name "folate" is derived from the Latin word *folium* for leaf, and leafy green vegetables such as spinach and kale are excellent sources of it. Folate is also found in legumes, liver, and oranges. Additionally, since 1998, food manufacturers have been required to add folate to cereals and other grain products.MedlinePlus, a service of the National Institutes of Health. "Folic Acid." © 1995–2012 Therapeutic Research Faculty, publishers of Natural Medicines Comprehensive Database, Prescriber's Letter, Pharmacist's Letter. Last reviewed August 7, 2011. http://www.nlm.nih.gov/medlineplus/druginfo/natural/1017.html.

Weight Gain during Pregnancy

During pregnancy, a mother's body changes in many ways. One of the most notable and significant changes is weight gain. If a pregnant woman does not gain enough weight, her unborn baby will be at risk. Poor weight gain, especially in the third trimester, could result not only in low birth weight, but also infant mortality and intellectual disabilities. Therefore, it is vital for a pregnant woman to maintain a healthy weight, and her weight prior to pregnancy has a major affect. Infant birth weight is one of the best indicators of a baby's future health. Pregnant women of normal weight should gain between 25 and 35 pounds in total through the entire pregnancy. The precise amount that a mother should gain usually depends on her beginning body mass index (BMI). See Table 12.1 "Body Mass Index and Pregnancy" for The Institute of Medicine (IOM) recommendations.

Table 12.1 Body Mass Index and Pregnancy

Prepregnancy BMI	Weight Category	Recommended Weight Gain
Below 18.5	Underweight	28–40 lbs.
18.5–24.9	Normal	25–35 lbs.
25.0–29.9	Overweight	15–25 lbs.
Above 30.0	Obese (all classes)	11–20 lbs.

Source: Institute of Medicine. "Weight Gain during Pregnancy: Reexamining the Guidelines." May 2009. http://www.iom.edu/~/media/Files/Report%20Files/2009/Weight-Gain-During-Pregnancy-Reexamining-the-Guidelines/Resource%20Page%20-%20Weight%20Gain%20During%20Pregnancy.pdf.

The weight an expectant mother gains during pregnancy is almost all lean tissue, including the placenta and fetus. Weight gain is not the only major change. A pregnant woman also will find that her breasts enlarge and that she has a tendency to retain water.

Source: Utah Department of Health, Baby Your Baby. "Weight Gain during Pregnancy." © 2012 Baby Your Baby. http://www.babyyourbaby.org/pregnancy/during.

Starting weight below or above the normal range can lead to different complications. Pregnant women with a prepregnancy BMI below twenty are at a higher risk of a preterm delivery and an underweight infant. Pregnant women with a prepregnancy BMI above thirty have an increased risk of the need for a cesarean section during delivery. Therefore, it is optimal to have a BMI in the normal range prior to pregnancy.

Generally, women gain 2 to 5 pounds in the first trimester. After that, it is best not to gain more than one pound per week. Some of the new weight is due to the growth of the fetus, while some is due to changes in the mother's body that support the pregnancy. Weight gain often breaks down in the following manner: 6 to 8 pounds of fetus, 1 to 2 pounds for the placenta (which supplies nutrients to the fetus and removes waste products), 2 to 3 pounds for the amniotic sac (which contains fluids that surround and cushion the fetus), 1 to 2 pounds in the breasts, 1 to 2 pounds in the uterus, 3 to 4 pounds of maternal blood, 3 to 4 pounds maternal fluids, and 8 to 10 pounds of extra maternal fat stores that will be needed for breastfeeding and delivery. Women who are pregnant with more than one fetus are advised to gain even more weight to ensure the health of their unborn babies.

The pace of weight gain is also important. If a woman puts on weight too slowly, her physician may recommend nutrition counseling. If she gains weight too quickly, especially in the third trimester, it may be the result of edema, or swelling due to excess fluid accumulation. Rapid weight gain may also result from increased calorie consumption or a lack of exercise.

Weight Loss after Pregnancy

During labor, new mothers lose some of the weight they gained during pregnancy with the delivery of their child. In the following weeks, they continue to shed weight as they lose accumulated fluids and their blood volume returns to normal. Some studies have hypothesized that breastfeeding also helps a new mother lose some of the extra weight, although research is ongoing.Stuebe, A. M., MD, MSc and J. W. Rich-Edwards, Sc. D. "The Reset Hypothesis: Lactation and Maternal Metabolism." © Thieme Medical Publishers, *Am J Perinatol* 26, no.1 (2009): 81–88. doi: 10.1055/s-0028-1103034. New mothers who gain a healthy amount of weight and participate in regular physical activity during their pregnancies also have an easier time shedding weight postpregnancy. However, women who gain more weight than needed for a pregnancy typically retain that excess weight as body fat. If those few pounds increase a new mother's BMI by a unit or more, that could lead to complications such as hypertension or Type 2 diabetes in future pregnancies or later in life.

Nutritional Requirements

As a mother's body changes, so do her nutritional needs. Pregnant women must consume more calories and nutrients in the second and third trimesters than other adult women. However, the average recommended daily caloric intake can vary depending on activity level and the mother's normal weight. Also, pregnant women should choose a high-quality, diverse diet, consume fresh foods, and prepare nutrient-rich meals. Steaming is the best way to cook vegetables. Vitamins are destroyed by overcooking, whereas uncooked vegetables and fruits have the highest vitamin content. It is also standard for pregnant women to take prenatal supplements to ensure adequate intake of the needed micronutrients.

Energy

During the first trimester, a pregnant woman has the same energy requirements as normal and should consume the same number of calories as usual—about 1,800 calories for a woman living a sedentary lifestyle, about 2,000 calories for a woman who is moderately active, and about 2,200 for a woman who is active. However, as the pregnancy progresses, a woman must increase her caloric intake. According to the IOM, she should consume an additional 340 calories per day during the second trimester, and an additional 450 calories per day during the third trimester. This is partly due to an increase in metabolism, which rises during pregnancy and contributes to increased energy needs. A woman can easily meet these increased needs by consuming more nutrient-dense foods. For example, an additional 340 calories could include a medium-sized banana (about 100 calories), a cup of nonfat yogurt with fruit on the bottom (about 140 calories), and a slice of whole-wheat toast (about 75 calories).

Carbohydrates

The recommended daily allowance, or RDA, of carbohydrates during pregnancy is about 175 to 265 grams per day to fuel fetal brain development. The best food sources for pregnant women include whole-grain breads and cereals, brown rice, root vegetables, legumes, and fruits. These and other unrefined carbohydrates provide nutrients, phytochemicals, antioxidants, and fiber. These foods also help to build the placenta and supply energy for the growth of the unborn baby. Refined carbohydrates, such as white bread, cookies and other baked desserts, pretzels, and chips are nutritionally deficient and should be kept to a minimum.

Protein

During pregnancy, extra protein is needed for the synthesis of new maternal and fetal tissues. Protein builds muscle and other tissues, enzymes, antibodies, and

hormones in both the mother and the unborn baby. Additional protein also supports increased blood volume and the production of amniotic fluid. The RDA of protein during pregnancy is 71 grams per day, which is 25 grams above the normal recommendation. However, in most instances, there is no need for a pregnant woman to make an effort to increase protein intake as long as she has a normal appetite, because even nonpregnant women in North America typically eat that much protein. Protein should be derived from healthy sources, such as lean red meat, white-meat poultry, legumes, nuts, seeds, eggs, and fish. Low-fat milk and other dairy products also provide protein, along with calcium and other nutrients.

Fat

There are no specific recommendations for fats in pregnancy, apart from following normal dietary guidelines. Fats should make up 25 to 35 percent of daily calories, and those calories should come from healthy fats, such as avocados. Foods with unhealthy fats, including French fries and other fast food, should be avoided. Also, it is not recommended for pregnant women to be on a very low-fat diet, since it would be hard to meet the needs of essential fatty acids and fat-soluble vitamins. Fatty acids are important during pregnancy because they support the baby's brain and eye development. In particular, the brain depends on omega-3 and omega-6 fatty acids, such as the kind found in salmon and sunflower or safflower oil, for function, structure, and growth. Fats can also help the placenta grow and may help to prevent premature birth and low birth weight.

Fiber

Ideally, a pregnant woman should eat 25 to 30 grams of dietary fiber per day. There are two types of fiber, and pregnant women should consume both. **Insoluble fiber**[2] acts as a natural laxative, which softens stools and speeds the elimination of waste material through the colon to avoid constipation. Sources of insoluble fiber include whole grains, fruits, vegetables, dried peas, and beans. **Soluble fiber**[3] has little effect on the intestines, however it helps to lower blood-cholesterol levels and regulate blood glucose. Sources of soluble fiber include fruits, vegetables, and beans, along with oats, barley, and other fiber-filled whole grains.

Fresh fruit and whole grains, such as a bowl of muesli, are

2. Fiber that is metabolically inert, which means it does not break down as it passes through the digestive system. Insoluble fiber absorbs water and adds bulk to stool, expediting the passage of food and waste.

3. Fiber that attracts water and turns to gel, which slows digestion. Soluble fiber is readily fermented in the colon by bacteria into gases and waste byproducts.

Fluids

excellent sources of fiber during a pregnancy.

© Thinkstock

Fluid intake must also be monitored. According to the IOM, pregnant women should drink 2.3 liters (about 10 cups) of liquids per day to provide enough fluid for blood production. It is also important to drink liquids during physical activity or when it is hot and humid outside, to replace fluids lost to perspiration. The combination of a high-fiber diet and lots of liquids also helps to eliminate waste.US Department of Health and Human Services, Office on Women's Health. "Pregnancy: Body Changes and Discomforts." Last updated September 27, 2010. http://www.womenshealth.gov/pregnancy/you-are-pregnant/body-changes -discomforts.cfm.

Vitamins and Minerals

Pregnancy requires certain **conditionally essential nutrients**[4], which are nutrients that are supplied only under special conditions, such as stress, illness, or aging. The daily requirements for nonpregnant women change with the onset of a pregnancy. Taking a daily prenatal supplement or multivitamin helps to meet many nutritional needs. However, most of these requirements should be fulfilled with a healthy diet. The following table compares the normal levels of required vitamins and minerals to the levels needed during pregnancy. For pregnant women, the RDA of nearly all vitamins and minerals increases.

Table 12.2 Recommended Nutrient Intakes during Pregnancy

Nutrient	Nonpregnant Women	Pregnant Women
Vitamin A (mcg)	700.0	770.0
Vitamin B_6 (mg)	1.5	1.9
Vitamin B_{12} (mcg)	2.4	2.6
Vitamin C (mg)	75.0	85.0
Vitamin D (mcg)	5.0	5.0
Vitamin E (mg)	15.0	15.0
Calcium (mg)	1,000.0	1,000.0
Folate (mcg)	400.0	600.0
Iron (mg)	18.0	27.0
Magnesium (mg)	320.0	360.0

4. Nutrients that are supplied only under special conditions or circumstances, such as pregnancy, stress, illness, or aging.

Nutrient	Nonpregnant Women	Pregnant Women
Niacin (B_3) (mg)	14.0	18.0
Phosphorus	700.0	700.0
Riboflavin (B_2) (mg)	1.1	1.4
Thiamine (B_1) (mg)	1.1	1.4
Zinc (mg)	8.0	11.0

Source: Institute of Medicine. "Nutrition during Pregnancy: Part I: Weight Gain, Part II: Nutrient Supplements." January 1, 1990. http://iom.edu/Reports/1990/Nutrition-During-Pregnancy-Part-I-Weight-Gain-Part-II-Nutrient-Supplements.aspx.

The micronutrients involved with building the skeleton—vitamin D, calcium, phosphorus, and magnesium—are crucial during pregnancy to support fetal bone development. Although the levels are the same as those for nonpregnant women, many women do not typically consume adequate amounts and should make an extra effort to meet those needs.

There is an increased need for all B vitamins during pregnancy. Adequate vitamin B_6 supports the metabolism of amino acids, while more vitamin B_{12} is needed for the synthesis of red blood cells and DNA. Additional zinc is crucial for cell development and protein synthesis. The need for vitamin A also increases, and extra iron intake is important because of the increase in blood supply during pregnancy and to support the fetus and placenta. Iron is the one micronutrient that is almost impossible to obtain in adequate amounts from food sources only. Therefore, even if a pregnant woman consumes a healthy diet, there still is a need to take an iron supplement, in the form of ferrous salts. Also remember that folate needs increase during pregnancy to 600 micrograms per day to prevent neural tube defects. This micronutrient is crucial for fetal development because it helps produce the extra blood a woman's body requires during pregnancy.

For most other minerals, recommended intakes are similar to those for nonpregnant women, although it is crucial for pregnant women to make sure to meet the RDAs to reduce the risk of birth defects. In addition, pregnant mothers should avoid exceeding any recommendations. Taking megadose supplements can lead to excessive amounts of certain micronutrients, such as vitamin A and zinc, which may produce toxic effects that can also result in birth defects.

Guide to Eating during Pregnancy

While pregnant women have an increased need for energy, vitamins, and minerals, energy increases are proportionally less than other macronutrient and micronutrient increases. So, nutrient-dense foods, which are higher in proportion of macronutrients and micronutrients relative to calories, are essential to a healthy diet. Examples of nutrient-dense foods include fruits, vegetables, whole grains, peas, beans, reduced-fat dairy, and lean meats. Pregnant women should be able to meet almost all of their increased needs via a healthy diet. However, expectant mothers should take a prenatal supplement to ensure an adequate intake of iron and folate. Here are some additional dietary guidelines for pregnant women:US Department of Health and Human Services, Office on Women's Health. "Healthy Pregnancy: Do's and Don'ts." Last updated March 5, 2009. http://www.womenshealth.gov/publications/our-publications/pregnancy-dos-donts.pdf.

- Eat iron-rich or iron-fortified foods, including meat or meat alternatives, breads, and cereals, to help satisfy increased need for iron and prevent anemia.
- Include vitamin C-rich foods, such as orange juice, broccoli, or strawberries, to enhance iron absorption.
- Eat a well-balanced diet, including fruits, vegetables, whole grains, calcium-rich foods, lean meats, and a variety of cooked seafood (excluding fish that are high in mercury, such as swordfish and shark).
- Drink additional fluids, water especially.

Foods to Avoid

A number of substances can harm a growing fetus. Therefore, it is vital for women to avoid them throughout a pregnancy. Some are so detrimental that a woman should avoid them even if she suspects that she might be pregnant. For example, consumption of alcoholic beverages results in a range of abnormalities that fall under the umbrella of fetal alcohol spectrum disorders. They include learning and attention deficits, heart defects, and abnormal facial features. Alcohol enters the unborn baby via the umbilical cord and can slow fetal growth, damage the brain, or even result in miscarriage. The effects of alcohol are most severe in the first trimester, when the organs are developing. As a result, there is no safe amount of alcohol that a pregnant woman can consume. Although pregnant women in the past may have participated in behavior that was not known to be risky at the time, such as drinking alcohol or smoking cigarettes, today we know that it is best to avoid those substances completely to protect the health of the unborn baby.

Pregnant women should also limit caffeine intake, which is found not only in coffee, but also tea, colas, cocoa, chocolate, and some over-the-counter painkillers. Some studies suggest that very high amounts of caffeine have been linked to babies born with low birth weights. The *American Journal of Obstetrics and Gynecology* released a report, which found that women who consume 200 milligrams or more of caffeine a day (which is the amount in 10 ounces of coffee or 25 ounces of tea) increase the risk of miscarriage.Weng X, Odouli R, and Li D-K. "Maternal caffeine consumption during pregnancy and the risk of miscarriage: a prospective cohort study." *Am J Obstet Gynecol* 2008;198:279.e1-279.e8. Consuming large quantities of caffeine affects the pregnant mother as well, leading to irritability, anxiety, and insomnia. Most experts agree that small amounts of caffeine each day are safe (about one 8-ounce cup of coffee a day or less).American Medical Association, *Complete Guide to Prevention and Wellness* (Hoboken, NJ: John Wiley & Sons, Inc., 2008), 495. However, that amount should not be exceeded.

Foodborne Illness

For both mother and child, foodborne illness can cause major health problems. For example, the foodborne illness caused by the bacteria *Listeria monocytogenes* can cause spontaneous abortion and fetal or newborn meningitis. According to the CDC, pregnant women are twenty times more likely to become infected with this disease, which is known as listeriosis, than nonpregnant, healthy adults. Symptoms include headaches, muscle aches, nausea, vomiting, and fever. If the infection spreads to the nervous system, it can result in a stiff neck, convulsions, or a feeling of disorientation.American Pregnancy Association. "Listeria and Pregnancy." © 2000–2012 American Pregnancy Association. http://www.americanpregnancy.org/pregnancycomplications/listeria.html.

Foods more likely to contain the bacteria are unpasteurized dairy products, especially soft cheeses, and also smoked seafood, hot dogs, paté, cold cuts, and uncooked meats. To avoid consuming contaminated foods, women who are pregnant or breastfeeding should take the following measures:

- Thoroughly rinse fruits and vegetables before eating them
- Keep cooked and ready-to-eat food separate from raw meat, poultry, and seafood
- Store food at 40° F (4° C) or below in the refrigerator and at 0° F (-18° C) in the freezer
- Refrigerate perishables, prepared food, or leftovers within two hours of preparation or eating
- Clean the refrigerator regularly and wipe up any spills right away
- Check the expiration dates of stored food once per week

You will learn more about foodborne illness and its consequences in Chapter 14 "Nutrition and Society: Food Politics and Perspectives" and Chapter 15 "Achieving Optimal Health: Wellness and Nutrition".

Food Contaminants

It is always important to avoid consuming contaminated food to prevent food poisoning. This is especially true during pregnancy. Heavy metal contaminants, particularly mercury, lead, and cadmium, pose risks to pregnant mothers. As a result, vegetables should be washed thoroughly or have their skins removed to avoid heavy metals.

Pregnant women can eat fish, ideally 8 to 12 ounces of different types each week. Expectant mothers are able to eat cooked shellfish such as shrimp, farm-raised fish such as salmon, and a maximum of 6 ounces of albacore, or white, tuna. However, they should avoid fish with high methyl mercury levels, such as shark, swordfish, tilefish, and king mackerel. Pregnant women should also avoid consuming raw shellfish to avoid foodborne illness. The Environmental Defense Fund eco-rates fish to provide guidelines to consumers about the safest and most environmentally friendly choices. You can find ratings for fish and seafood at http://www.edf.org.

Physical Activity during Pregnancy

For most pregnant women, physical activity is a must and is recommended in the *2010 Dietary Guidelines for Americans*. Regular exercise of moderate intensity, about thirty minutes per day most days of the week, keeps the heart and lungs healthy. It also helps to improve sleep and boosts mood and energy levels. In addition, women who exercise during pregnancy report fewer discomforts and may have an easier time losing excess weight after childbirth. Brisk walking, swimming, or an aerobics class geared toward expectant mothers are all great ways to get exercise during a pregnancy. Healthy women who already participate in vigorous activities, such as running, can continue doing so during pregnancy provided they discuss an exercise plan with their physicians.

Walking is an excellent way for an expectant mother to get moderate exercise.

© Thinkstock

However, pregnant women should avoid pastimes that could cause injury, such as soccer, football, and other contact sports, or activities that could lead to falls, such

as horseback riding and downhill skiing. It may be best for pregnant women not to participate in certain sports, such as tennis, that require you to jump or change direction quickly. Scuba diving should also be avoided because it might result in the fetus developing decompression sickness. This potentially fatal condition results from a rapid decrease in pressure when a diver ascends too quickly.National Institutes of Health, and Friends of the National Library of Medicine. "Should I Exercise During My Pregnancy?" *NIH Medline Plus* 3, no. 1 (Winter 2008): 26. http://www.nlm.nih.gov/medlineplus/magazine/issues/winter08/articles/winter08pg26.html.

Common Discomforts during Pregnancy

Pregnancy can lead to certain discomforts, from back strain to swollen ankles. Also, a pregnant woman is likely to experience constipation because increased hormone levels can slow digestion and relax muscles in the bowels. Constipation and pressure from growth of the uterus can result in hemorrhoids, which are another common discomfort.US Department of Health and Human Services, Office on Women's Health. "Pregnancy: Body Changes and Discomforts." Last updated September 27, 2010. http://www.womenshealth.gov/pregnancy/you-are-pregnant/body-changes -discomforts.cfm. Getting mild to moderate exercise and drinking enough fluids can help prevent both conditions. Also, eating a high-fiber diet softens the stools and reduces the pressure on hemorrhoids.

Heartburn can occur during the early months of pregnancy due to an increase in the hormone progesterone, and during the later months due to the expanding size of the fetus, which limits stomach contraction. Avoiding chocolate, mint, and greasy foods, and remaining upright for an hour after meals can help pregnant women avoid heartburn. In addition, it can be helpful to drink fluids between meals, instead of with food.

Other common complaints can include leg cramps and bloating. Regular exercise can help to alleviate these discomforts. A majority of pregnant women develop gastrointestinal issues, such as nausea and vomiting. Many also experience food cravings and aversions. All of these can impact a pregnant woman's nutritional intake and it is important to protect against adverse effects.

Nausea and Vomiting

Nausea and vomiting are gastrointestinal issues that strike many pregnant women, typically in the first trimester. Nausea tends to occur more frequently than vomiting. These conditions are often referred to as "morning sickness," although

that's something of a misnomer because nausea and vomiting can occur all day long, although it is often the worst in the first part of the day.

Increased levels of the pregnancy hormone human chorionic gonadotropin may cause nausea and vomiting, although that is speculative. Another major suspect is estrogen because levels of this hormone also rise and remain high during pregnancy. Given that a common side effect of estrogen-containing oral contraceptives is nausea this hormone likely has a role. Nausea usually subsides after sixteen weeks, possibly because the body becomes adjusted to higher estrogen levels.

It can be useful for pregnant women to keep a food diary to discover which foods trigger nausea, so they can avoid them in the future. Other tips to help avoid or treat nausea and vomiting include the following:

- Avoid spicy foods
- Avoid strong or unusual odors
- Eat dry cereal, toast, or crackers
- Eat frequent, small meals
- Consume more unrefined carbohydrates
- Get moderate aerobic exercise
- Drink ginger tea, which aids in stomach upset
- Seek fresh air when a bout of nausea comes on

A severe form of nausea and vomiting is a condition known as hyperemesis gravidarum. It is marked by prolonged vomiting, which can result in dehydration and require hospitalization. This disorder is relatively rare and impacts only 0.3 to 2 percent of all pregnant women.Eliakim, R., O. Abulafia, and D. M. Sherer. "Hyperemesis Gravidarum: A Current Review." *Am J Perinatol* 17, no. 4 (2000): 207–18.

Food Cravings and Aversions

Food aversions and cravings do not have a major impact unless food choices are extremely limited. The most common food aversions are milk, meats, pork, and liver. For most women, it is not harmful to indulge in the occasional craving, such as the desire for pickles and ice cream. However, a medical disorder known as pica is willingly consuming foods with little or no nutritive value, such as dirt, clay, and laundry starch. In some places this is a culturally accepted practice. However, it can be harmful if these substances take the place of nutritious foods or contain toxins.

Complications during Pregnancy

Expectant mothers may face different complications during the course of their pregnancy. They include certain medical conditions that could greatly impact a pregnancy if left untreated, such as gestational hypertension and gestational diabetes, which have diet and nutrition implications.

Gestational Hypertension

Gestational hypertension[5] is a condition of high blood pressure during the second half of pregnancy. Also referred to as pregnancy-induced hypertension, this condition affects about 6 to 8 percent of all pregnant women. First-time mothers are at a greater risk, along with women who have mothers or sisters who had gestational hypertension, women carrying multiple fetuses, women with a prior history of high blood pressure or kidney disease, and women who are overweight or obese when they become pregnant.

Hypertension can prevent the placenta from getting enough blood, which would result in the baby getting less oxygen and nutrients. This can result in low birth weight, although most women with gestational hypertension can still deliver a healthy baby if the condition is detected and treated early. Some risk factors can be controlled, such as diet, while others cannot, such as family history. If left untreated, gestational hypertension can lead to a serious complication called **preeclampsia**[6], which is sometimes referred to as toxemia. This disorder is marked by elevated blood pressure and protein in the urine and is associated with swelling. To prevent preeclampsia, the WHO recommends increasing calcium intake for women consuming diets low in that micronutrient, administering a low dosage of aspirin (75 milligrams), and increasing prenatal checkups.World Health Organization. "WHO Recommendations for Prevention and Treatment of Pre-eclampsia and Eclampsia." 2011. Accessed June 8, 2012. http://whqlibdoc.who.int/publications/2011/9789241548335_eng.pdf.

Video 12.2

Gestational Hypertension and Preeclampsia

(click to see video)

This video focuses on the signs and risk factors of gestational hypertension and preeclampsia.

5. A possible complication of pregnancy characterized by raised blood pressure levels.
6. A possible complication of pregnancy marked by elevated blood pressure and high levels of protein in the urine.

Gestational Diabetes

About 4 percent of pregnant women suffer from a condition known as **gestational diabetes**[7], which is abnormal glucose tolerance during pregnancy. The body becomes resistant to the hormone insulin, which enables cells to transport glucose from the blood. Gestational diabetes is usually diagnosed around twenty-four to twenty-six weeks, although it is possible for the condition to develop later into a pregnancy. Signs and symptoms of this disease include extreme hunger, thirst, or fatigue. If blood sugar levels are not properly monitored and treated, the baby might gain too much weight and require a cesarean delivery. Diet and regular physical activity can help to manage this condition. Most patients who suffer from gestational diabetes also require daily insulin injections to boost the absorption of glucose from the bloodsteam and promote the storage of glucose in the form of glycogen in liver and muscle cells. Gestational diabetes usually resolves after childbirth, although some women who suffer from this condition develop Type 2 diabetes later in life, particularly if they are overweight.

KEY TAKEAWAYS

- During pregnancy, it is imperative that a woman meet the nutritional needs both she and her unborn child require, which includes an increase in certain micronutrients, such as iron and folate.
- Starting BMI determines how much weight a woman needs to gain throughout her pregnancy. In an average pregnancy, a woman gains an extra 30 pounds.
- During the second and third trimesters, a woman's energy requirements increase by 340 calories per day for the second trimester and 450 calories per day for the third trimester.
- Common discomforts that can impact nutritional intake during pregnancy include nausea and vomiting, heartburn, and constipation.
- Gestational hypertension is a condition that impacts about 6 to 8 percent of pregnant women and results in a rise of blood pressure levels. This condition can lead to preeclampsia during a pregnancy.
- Gestational diabetes is a condition that impacts about 4 percent of pregnant women and results in a rise of blood glucose levels. This condition can lead to Type 2 diabetes later in life.

7. A possible complication of pregnancy characterized by elevated blood glucose levels.

DISCUSSION STARTER

1. Discuss the changing nutritional requirements for iron and vitamin A during pregnancy. Use what you know about each kind of micronutrient and its impact on the body to explain why the increase in RDA might be exponentially greater for one of these nutrients than for the other.

12.3 Infancy and Nutrition

LEARNING OBJECTIVES

1. Summarize nutritional requirements and dietary recommendations for infants.
2. Describe the physiologic basis for lactation and the specific components of breast milk.
3. Discuss the benefits and barriers related to breastfeeding.
4. Examine feeding problems that parents and caregivers may face with their infants.

Diet and nutrition have a major impact on a child's development from infancy into the adolescent years. A healthy diet not only affects growth, but also immunity, intellectual capabilities, and emotional well-being. One of the most important jobs of parenting is making sure that children receive an adequate amount of needed nutrients to provide a strong foundation for the rest of their lives.

Infancy (Birth to Age One)

The term infant is derived from the Latin word *infans*, which means "unable to speak." Healthy infants grow steadily, but not always at an even pace. For example, during the first year of life, height increases by 50 percent, while weight triples. Physicians and other health professionals can use growth charts to track a baby's development process. Because infants cannot stand, length is used instead of height to determine the rate of a child's growth. Other important developmental measurements include head circumference and weight. All of these must be tracked and compared against standard measurements for an infant's age. Nationally-accepted growth charts are based on data collected by the National Center for Health Statistics. These charts allow for tracking trends over time and comparing with other infants among percentiles within the United States. Growth charts may provide warnings that a child has a medical problem or is malnourished. Insufficient weight or height gain during infancy may indicate a condition known as **failure-to-thrive (FTT)**[8], which is characterized by poor growth. FTT can happen at any age, but in infancy, it typically occurs after six months. Some causes include poverty, lack of enough food, feeding inappropriate foods, and excessive intake of fruit juice.

8. A condition that is characterized by inadequate growth or weight gain due to any cause.

Nutritional Requirements

Requirements for macronutrients and micronutrients on a per-kilogram basis are higher during infancy than at any other stage in the human life cycle. These needs are affected by the rapid cell division that occurs during growth, which requires energy and protein, along with the nutrients that are involved in DNA synthesis. During this period, children are entirely dependent on their parents or other caregivers to meet these needs. For almost all infants six months or younger, breast milk is the best source to fulfill nutritional requirements. An infant may require feedings eight to twelve times a day or more in the beginning. After six months, infants can gradually begin to consume solid foods to help meet nutrient needs.

Energy

Energy needs relative to size are much greater in an infant than an adult. A baby's resting metabolic rate is two times that of an adult. The RDA to meet energy needs changes as an infant matures and puts on more weight. The IOM uses a set of equations to calculate the total energy expenditure and resulting energy needs. For example, the equation for the first three months of life is *(89 x weight [kg] -100) + 175 kcal*.

Based on these equations, the estimated energy requirement for infants from zero to six months of age is 472 to 645 kilocalories per day for boys and 438 to 593 kilocalories per day for girls. For infants ages six to twelve months, the estimated requirement is 645 to 844 kilocalories per day for boys and 593 to 768 kilocalories per day for girls. From the age one to age two, the estimated requirement rises to 844–1,050 kilocalories per day for boys and 768–997 kilocalories per day for girls.Food and Nutrition Board, Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*, Institute of Medicine of the National Academies (Washington, D.C.: The National Academies Press, 2005), 169–70. How often an infant wants to eat will also change over time due to growth spurts, which typically occur at about two weeks and six weeks of age, and again at about three months and six months of age.

Macronutrients

The dietary recommendations for infants are based on the nutritional content of human breast milk. Carbohydrates make up about 45 to 65 percent of the caloric content in breast milk, which amounts to a RDA of about 130 grams. Almost all of the carbohydrate in human milk is lactose, which infants digest and tolerate well. In fact, lactose intolerance is practically nonexistent in infants. Protein makes up about 5 to 20 percent of the caloric content of breast milk, which amounts to 13 grams per day. Infants have a high need for protein to support growth and

development, though excess protein (which is only a concern with bottle-feeding) can cause dehydration, diarrhea, fever, and acidosis in premature infants. About 30 to 40 percent of the caloric content in breast milk is made up of fat. A high-fat diet is necessary to encourage the development of neural pathways in the brain and other parts of the body. However, saturated fats and trans fatty acids inhibit this growth. Infants who are over the age of six months, which means they are no longer exclusively breastfed, should not consume foods that are high in these types of fats.

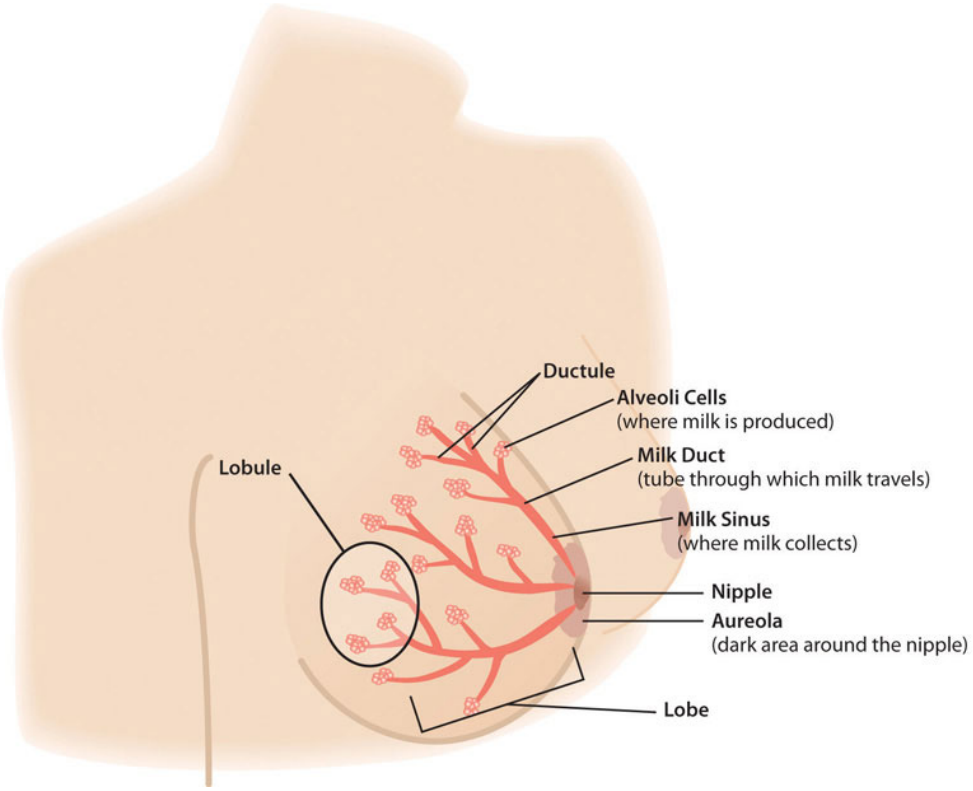
Micronutrients

Almost all of the nutrients that infants require can be met if they consume an adequate amount of breast milk. There are a few exceptions, though. Human milk is low in vitamin D, which is needed for calcium absorption and building bone, among other things. Therefore, breastfed children often need to take a vitamin D supplement in the form of drops. Infants at the highest risk for vitamin D deficiency are those with darker skin and no exposure to sunlight. Breast milk is also low in vitamin K, which is required for blood clotting, and deficits could lead to bleeding or hemorrhagic disease. Babies are born with limited vitamin K, so supplementation may be needed initially and some states require a vitamin K injection after birth. Also, breast milk is not high in iron, but the iron in breast milk is well absorbed by infants. After four to six months, however, an infant needs an additional source of iron other than breast milk.

Fluids

Infants have a high need for fluids, 1.5 milliliters per kilocalorie consumed compared to 1.0 milliliters per kilocalorie consumed for adults. This is because children have larger body surface area per unit of body weight and a reduced capacity for perspiration. Therefore, they are at greater risk of dehydration. However, parents or other caregivers can meet an infant's fluid needs with breast milk or formula. As solids are introduced, parents must make sure that young children continue to drink fluids throughout the day.

Breastfeeding



The alveoli cells produce milk. To secrete it, they contract and push milk into the ductules and the milk sinus, which collects the milk. When a nursing infant's gums press on the areola and nipple, the sinuses squeeze the milk into the baby's mouth. The nipple tissue becomes firmer with stimulation, which makes it more flexible and easier for the baby to grasp in the mouth.

After the birth of the baby, nutritional needs must be met to ensure that an infant not only survives, but thrives from infancy into childhood. Breastfeeding provides the fuel a newborn needs for rapid growth and development. As a result, the WHO recommends that breastfeeding be done exclusively for the first six months of an infant's life. New mothers must also pay careful consideration to their own nutritional requirements to help their bodies recover in the wake of the pregnancy. This is particularly true for women who breastfeed their babies, which calls for an increased need in certain nutrients.

Lactation

Lactation[9] is the process that makes breastfeeding possible, and is the synthesis and secretion of breast milk. Early in a woman's pregnancy, her mammary glands begin to prepare for milk production. Hormones play a major role in this, particularly during the second and third trimesters. At that point, levels of the

9. The medical term for the process of producing and secreting breast milk.

hormone prolactin increase to stimulate the growth of the milk duct system, which initiates and maintains milk production. Levels of the hormone oxytocin also rise to promote the release of breast milk when the infant suckles, which is known as the milk ejection reflex. However, levels of the hormone progesterone need to decrease for successful milk production, because progesterone inhibits milk secretion. Shortly after birth, the expulsion of the placenta triggers progesterone levels to fall, which activates lactation.King, J. "Contraception and Lactation: Physiology of Lactation." *Journal of Midwifery and Women's Health* 52, no. 6 (2007): 614–20. © 2007 Elsevier Science, Inc.

New mothers need to adjust their caloric and fluid intake to make breastfeeding possible. The RDA is 330 additional calories during the first six months of lactation and 400 additional calories during the second six months of lactation. The energy needed to support breastfeeding comes from both increased intake and from stored fat. For example, during the first six months after her baby is born, the daily caloric cost for a lactating mother is 500 calories, with 330 calories derived from increased intake and 170 calories derived from maternal fat stores. This helps explain why breastfeeding may promote weight loss in new mothers. Lactating women should also drink 3.1 liters of liquids per day (about 13 cups) to maintain milk production, according to the IOM. As is the case during pregnancy, the RDA of nearly all vitamins and minerals increases for women who are breastfeeding their babies. The following table compares the recommended vitamins and minerals for lactating women to the levels for nonpregnant and pregnant women from Table 12.2 "Recommended Nutrient Intakes during Pregnancy".

Table 12.3 Recommended Nutrient Intakes during Lactation

Nutrient	Nonpregnant Women	Pregnant Women	Lactating Women
Vitamin A (mcg)	700.0	770.0	1,300.0
Vitamin B_6 (mg)	1.5	1.9	2.0
Vitamin B_{12} (mcg)	2.4	2.6	2.8
Vitamin C (mg)	75.0	85.0	120.0
Vitamin D (mcg)	5.0	5.0	5.0
Vitamin E (mg)	15.0	15.0	19.0
Calcium (mg)	1,000.0	1,000.0	1,000.0
Folate (mcg)	400.0	600.0	500.0
Iron (mg)	18.0	27.0	9.0
Magnesium (mg)	320.0	360.0	310.0

Nutrient	Nonpregnant Women	Pregnant Women	Lactating Women
Niacin (B_3) (mg)	14.0	18.0	17.0
Phosphorus	700.0	700.0	700.0
Riboflavin (B_2) (mg)	1.1	1.4	1.6
Thiamine (B_1) (mg)	1.1	1.4	1.4
Zinc (mg)	8.0	11.0	12.0

Source: Institute of Medicine, http://www.iom.edu.

Calcium requirements do not change during breastfeeding because of more efficient absorption, which is the case during pregnancy, too. However, the reasons for this differ. During pregnancy, there is enhanced absorption within the gastrointestinal tract. During lactation, there is enhanced retention by the kidneys. The RDA for phosphorus, fluoride, and molybdenum also remains the same.

Components of Breast Milk

Human breast milk not only provides adequate nutrition for infants, it also helps to protect newborns from disease. In addition, breast milk is rich in cholesterol, which is needed for brain development. It is helpful to know the different types and components of breast milk, along with the nutrients they provide to enable an infant survive and thrive.

Colostrum

Colostrum[10] is produced immediately after birth, prior to the start of milk production, and lasts for several days after the arrival of the baby. Colostrum is thicker than breast milk, and is yellowish or creamy in color. This protein-rich liquid fulfills an infant's nutrient needs during those early days. Although low in volume, colostrum is packed with concentrated nutrition for newborns. This special milk is high in fat-soluble vitamins, minerals, and **immunoglobulins**[11] (antibodies) that pass from the mother to the baby. Immunoglobulins provide passive immunity for the newborn and protect the baby from bacterial and viral diseases.American Pregnancy Association. "Breastfeeding: Overview." Last updated January 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingoverview.htm.

10. A yellow fluid produced in a mother's breasts during the first few days after delivery, prior to milk production.

11. Proteins produced by plasma cells that function as antibodies. In infancy, immunoglobulins pass from mother to infant via breast milk and provide passive immunity for the baby.

Transitional Milk

Two to four days after birth, colostrum is replaced by transitional milk. Transitional milk is a creamy liquid that lasts for approximately two weeks and includes high levels of fat, lactose, and water-soluble vitamins. It also contains more calories than colostrum. After a new mother begins to produce transitional milk, she typically notices a change in the volume and type of liquid secreted and an increase in the weight and size of her breasts.American Pregnancy Association. "Breastfeeding: Overview." Last updated January 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingoverview.htm.

Mature Milk

Mature milk is the final fluid that a new mother produces. In most women, it begins to secrete at the end of the second week postchildbirth. There are two types of mature milk that appear during a feeding. Foremilk occurs at the beginning and includes water, vitamins, and protein. Hind-milk occurs after the initial release of milk and contains higher levels of fat, which is necessary for weight gain. Combined, these two types of milk ensure that a baby receives adequate nutrients to grow and develop properly.American Pregnancy Association. "Breastfeeding: Overview." Last updated January 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingoverview.htm.

About 90 percent of mature milk is water, which helps an infant remain hydrated. The other 10 percent contains carbohydrates, proteins, and fats, which support energy and growth. Similar to cow's milk, the main carbohydrate of mature breast milk is lactose. Breast milk contains vital fatty acids, such as docosahexaenoic acid (DHA) and arachidonic acid (ARA). In terms of protein, breast milk contains more whey than casein (which is the reverse of cow's milk). Whey is much easier for infants to digest than casein. Complete protein, which means all of the essential amino acids, is also present in breast milk. Complete protein includes lactoferrin, an iron-gathering compound that helps to absorb iron into an infant's bloodstream.

In addition, breast milk provides adequate vitamins and minerals. Although absolute amounts of some micronutrients are low, they are more efficiently absorbed by infants. Other essential components include digestive enzymes that help a baby digest the breast milk. Human milk also provides the hormones and growth factors that help a newborn to develop.

Diet and Milk Quality

A mother's diet can have a major impact on milk production and quality. As during pregnancy, lactating mothers should avoid illegal substances and cigarettes. Some legal drugs and herbal products can be harmful as well, so it is helpful to discuss them with a health-care provider. Some mothers may need to avoid certain things, such as spicy foods, that can produce gas in sensitive infants. Lactating women can drink alcohol, though they must avoid breastfeeding until the alcohol has completely cleared from their milk. Typically, this takes two to three hours for 12 ounces of beer, 5 ounces of wine, or 1.5 ounces of liquor, depending on a woman's body weight.Harms, R., MD. "Breast-Feeding and Alcohol: Is It Okay to Drink?" © 1998–2012 Mayo Foundation for Medical Education and Research. Accessed February 21, 2012. http://www.mayoclinic.com/health/breast-feeding-and-alcohol/AN02131. Precautions are necessary because exposure to alcohol can disrupt an infant's sleep schedule.

Benefits of Breastfeeding

Breastfeeding has a number of benefits, both for the mother and for the child. Breast milk contains immunoglobulins, enzymes, immune factors, and white blood cells. As a result, breastfeeding boosts the baby's immune system and lowers the incidence of diarrhea, along with respiratory diseases, gastrointestinal problems, and ear infections. Breastfed babies also are less likely to develop asthma and allergies, and breastfeeding lowers the risk of sudden infant death syndrome. In addition, human milk encourages the growth of healthy bacteria in an infant's intestinal tract. All of these benefits remain in place after an infant has been weaned from breast milk. Some studies suggest other possible long-term effects. For example, breast milk may improve an infant's intelligence and protect against Type 1 diabetes and obesity, although research is ongoing in these areas.Healthy Children.org. "Breastfeeding Benefits Your Baby's Immune System." © 2012 American Academy of Pediatrics. Accessed February 21, 2012. http://www.healthychildren.org/English/ages-stages/baby/breastfeeding/pages/Breastfeeding-Benefits-Your-Baby%27s-Immune-System.aspx.

Breastfeeding has a number of other important benefits. It is easier for babies to digest breast milk than bottle formula, which contains proteins made from cow's milk that require an adjustment period for infant digestive systems. Breastfed infants are sick less often than bottle-fed infants. Breastfeeding is more sustainable and results in less plastic waste and other trash. Breastfeeding can also save families money because it does not incur the same cost as purchasing formula. Other benefits include that breast milk is always ready. It does not have to be mixed, heated, or prepared. Also, breast milk is sterile and is always at the right temperature.

In addition, the skin-to-skin contact of breastfeeding promotes a close bond between mother and baby, which is an important emotional and psychological benefit. The practice also provides health benefits for the mother. Breastfeeding helps a woman's bones stay strong, which protects against fractures later in life. Studies have also shown that breastfeeding reduces the risk of breast and ovarian cancers.National Cancer Institute. "Reproductive History and Breast Cancer Risk." Accessed February 6, 2012. http://www.cancer.gov/cancertopics/factsheet/Risk/reproductive-history.

The Baby-Friendly Hospital Initiative

In 1991, the WHO and UNICEF launched the Baby-Friendly Hospital Initiative (BFHI), which works to ensure that all maternities, including hospitals and free-standing facilities, become centers of breastfeeding support. A maternity can be denoted as "baby-friendly" when it does not accept substitutes to human breast milk and has implemented ten steps to support breastfeeding. These steps include having a written policy on breastfeeding communicated to health-care staff on a routine basis, informing all new mothers about the benefits and management of breastfeeding, showing new mothers how to breastfeed their infants, and how to maintain lactation, and giving newborns no food or drink other than breast milk, unless medically indicated. Since the BFHI began, more than fifteen thousand facilities in 134 countries, from Benin to Bangladesh, have been deemed "baby friendly." As a result, more mothers are breastfeeding their newborns and infant health has improved, in both the developed world and in developing nations.United Nations Children's Fund. "The Baby-Friendly Hospital Initiative." Accessed June 8, 2012. http://www.unicef.org/programme/breastfeeding/baby.htm.

Barriers to Breastfeeding

Although breast milk is ideal for almost all infants, there are some challenges that nursing mothers may face when starting and continuing to breastfeed their infants. These obstacles include painful engorgement or fullness in the breasts, sore and tender nipples, lack of comfort or confidence in public, and lack of accommodation to breastfeed or express milk in the workplace.

One of the first challenges nursing mothers face is learning the correct technique. It may take a little time for a new mother to help her baby properly latch on to her nipples. Improper latching can result in inadequate intake, which could slow

growth and development. However, International Board Certified Lactation Consultants (IBCLCs), OB nurses, and registered dietitians are all trained to help new mothers learn the proper technique. Education, the length of maternity leave, and laws to protect public breastfeeding, among other measures, can all help to facilitate breastfeeding for many lactating women and their newborns.

Contraindications to Breastfeeding

Although there are numerous benefits to breastfeeding, in some cases there are also risks that must be considered. In the developed world, a new mother with HIV should not breastfeed, because the infection can be transmitted through breast milk. These women typically have access to bottle formula that is safe, and can be used as a replacement for breast milk. However, in developing nations where HIV infection rates are high and acceptable infant formula can be difficult to come by, many newborns would be deprived of the nutrients they need to develop and grow. Also, inappropriate or contaminated bottle formulas cause 1.5 million infant deaths each year. As a result, the WHO recommends that women infected with HIV in the developing world should nurse their infants while taking antiretroviral medications to lower the risk of transmission.World Health Organization. "Infant and Young Child Feeding." July 2010. http://www.who.int/mediacentre/factsheets/fs342/en/index.html

Breastfeeding also is not recommended for women undergoing radiation or chemotherapy treatment for cancer. Additionally, if an infant is diagnosed with galactosemia, meaning an inability to process the simple sugar galactose, the child must be on a galactose-free diet, which excludes breast milk. This genetic disorder is a very rare condition, however, and only affects 1 in thirty- to sixty thousand newborns.Genetics Home Reference, a service of the US National Library of Medicine. "Galactosemia." July 9, 2012. http://ghr.nlm.nih.gov/condition/galactosemia. When breastfeeding is contraindicated for any reason, feeding a baby formula enables parents and caregivers to meet their newborn's nutritional needs.

Bottle-Feeding

Most women can and should breastfeed when given sufficient education and support. However, as discussed, a small percentage of women are unable to breastfeed their infants, while others choose not to. For parents who choose to bottle-feed, infant formula provides a balance of nutrients. However, not all formulas are the same and there are important considerations that parents and caregivers must weigh. Standard formulas use cow's milk as a base. They have 20 calories per fluid ounce, similar to breast milk, with vitamins and minerals added. Soy-based formulas are usually given to infants who develop diarrhea, constipation, vomiting, colic, or abdominal pain, or to infants with a cow's milk protein allergy.

Hypoallergenic protein hydrolysate formulas are usually given to infants who are allergic to cow's milk and soy protein. This type of formula uses hydrolyzed protein, meaning that the protein is broken down into amino acids and small peptides, which makes it easier to digest. Preterm infant formulas are given to low birth weight infants, if breast milk is unavailable. Preterm infant formulas have 24 calories per fluid ounce and are given until the infant reaches a desired weight.

Infant formula comes in three basic types:

1. Powder that requires mixing with water. This is the least expensive type of formula.
2. Concentrates, which are liquids that must be diluted with water. This type is slightly more expensive.
3. Ready-to-use liquids that can be poured directly into bottles. This is the most expensive type of formula. However, it requires the least amount of preparation. Ready-to-use formulas are also convenient for traveling.

Most babies need about 2.5 ounces of formula per pound of body weight each day. Therefore, the average infant should consume about 24 fluid ounces of breast milk or formula per day. When preparing formula, parents and caregivers should carefully follow the safety guidelines, since an infant has an immature immune system. All equipment used in formula preparation should be sterilized. Prepared, unused formula should be refrigerated to prevent bacterial growth. Parents should make sure not to use contaminated water to mix formula in order to prevent foodborne illnesses. Follow the instructions for powdered and concentrated formula carefully—formula that is overdiluted would not provide adequate calories and protein, while overconcentrated formula provides too much protein and too little water which can impair kidney function.

It is important to note again that both the American Academy of Pediatrics and the WHO state that breast milk is far superior to infant formula. This table compares the advantages of giving a child breast milk to the disadvantages of using bottle formula.

Table 12.4 Breast Milk versus Bottle Formula

Breast Milk	Bottle Formula
Antibodies and lactoferrin in breast milk protect infants.	Formula does not contain immunoprotective factors.

Breast Milk	Bottle Formula
The iron in breast milk is absorbed more easily.	Formula contains more iron than breast milk, but it is not absorbed as easily.
The feces that babies produce do not smell because breastfed infants have different bacteria in the gut.	The feces that bottle-fed infants produce tends to have a foul-smelling odor.
Breast milk is always available and is always at the correct temperature.	Formula must be prepared, refrigerated for storage, and warmed before it is given to an infant.
Breastfed infants are less likely to have constipation.	Bottle-fed infants are more likely to have constipation.
Breastfeeding ostensibly is free, though purchasing a pump and bottles to express milk does require some expense.	Formula must be purchased and is expensive.
Breast milk contains the fatty acids DHA and ARA, which are vital for brain and vision development.	Some formulas contain DHA and ALA.

Source: American Pregnancy Association. "Breastfeeding versus Bottle Feeding." November 5, 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingandbottle.html.

Video 12.3

Breastfeeding Mothers—La Leche League Canada

(click to see video)

This video explains the benefits of breastfeeding for both mothers and infants.

Introducing Solid Foods

Infants should be breastfed or bottle-fed exclusively for the first six months of life according to the WHO. (The American Academy of Pediatrics recommends breast milk or bottle formula exclusively for at least the first four months, but ideally for six months.) Infants should not consume solid foods prior to six months because solids do not contain the right nutrient mix that infants need. Also, eating solids may mean drinking less breast milk or bottle formula. If that occurs, an infant may not consume the right quantities of various nutrients. If parents try to feed an infant who is too young or is not ready, their tongue will push the food out, which is called an **extrusion reflex**[12]. After six months, the suck-swallow reflexes are not as

12. An involuntary reflex that causes infants to push food out of their mouths with their tongues.

strong, and infants can hold up their heads and move them around, both of which make eating solid foods more feasible.

Solid baby foods can be bought commercially or prepared from regular food using a food processor, blender, food mill, or grinder at home. Usually, an infant cereal can be offered from a spoon between four to six months. By nine months to a year, infants are able to chew soft foods and can eat solids that are well chopped or mashed.

Infants who are fed solid foods too soon are susceptible to developing food allergies. Therefore, as parents and caregivers introduce solids, they should feed their child only one new food at a time (starting with rice cereal, followed by fruits or vegetables), to help identify allergic responses or food intolerances. An iron supplement or iron-fortified cereal is also recommended at this time.

Learning to Self-Feed

With the introduction of solid foods, young children begin to learn how to handle food and how to feed themselves. At six to seven months, infants can use their whole hand to pick up items (this is known as the **palmer grasp**[13]). They can lift larger items, but picking up smaller pieces of food is difficult. At eight months, a child might be able to use a **pincer grasp**[14], which uses fingers to pick up objects. After the age of one, children slowly begin to use utensils to handle their food. Unbreakable dishes and cups are essential, since very young children may play with them or throw them when they become bored with their food.

Feeding Problems during Infancy

Parents and caregivers should be mindful of certain diet-related problems that may arise during infancy. Certain foods are choking hazards, including foods with skins or foods that are very small, such as grapes. Other examples of potential choking hazards include raw carrots and apples, raisins, and hard candy. Parents should also avoid adding salt or seasonings to an infant's food.

Heating an infant's food presents a risk of accidental injury or burns, which may occur if the food is heated unevenly or excessively. Keep in mind that an infant cannot communicate that the food is too hot. Also, parents and caregivers should never leave a baby alone at mealtime, because an infant can accidentally choke on pieces of food that are too big or have not been adequately chewed. Raw honey and corn syrup both contain spores of *Clostridium botulinum*. They produce a poisonous toxin in a baby's intestines, which can cause the foodborne illness botulism. After the age of one, it is safe to give an infant honey or corn syrup. However, honey as an

13. A grip that involves picking up an object with the whole hand.

14. A grip that involves picking up an object with the fingers.

ingredient in food, such as in cereal, is safe for all ages because it has been adequately heat treated.

Overnutrition

Overnutrition during infancy is a growing problem. Overfed infants may develop dietary habits and metabolic characteristics that last a lifetime. According to the *American Journal of Clinical Nutrition*, the consequences of overnutrition and growth acceleration in infancy include long-term obesity, along with Type 2 diabetes and cardiovascular disease later in life.Singhal, A. et al. "Nutrition in Infancy and Long-Term Risk of Obesity: Evidence from Two Randomized Control Trials." *Am J Clin Nutr* 92 (2010): 1133–44. Therefore, parents and other caregivers should restrain from overfeeding, and ideally give their infants breast milk to promote health and well-being.

Food Allergies

Food allergies impact four to six percent of young children in America. Common food allergens that can appear just before or after the first year include peanut butter, egg whites, wheat, cow's milk, and nuts. For infants, even a small amount of a dangerous food can prove to be life-threatening. If there is a family history of food allergies, it is a good idea to delay giving a child dairy products until one year of age, eggs until two years of age, and shellfish, fish, and nuts until three years of age.

However, lactating women should not make any changes to their diets. Research shows that nursing mothers who attempt to ward off allergies in their infants by eliminating certain foods may do more harm than good. According to the American Academy of Allergy, Asthma, and Immunology, mothers who avoided certain dairy products showed decreased levels in their breast milk of an immunoglobulin specific to cow's milk. This antibody is thought to protect against the development of allergies in children. Even when an infant is at higher risk for food allergies, there is no evidence that alterations in a mother's diet make a difference.Gever, J. "Nursing Mom's Diet No Guard Against Baby Allergies." Medpage Today. © 2012 Everyday Health, Inc. March 7, 2012. http://www.medpagetoday.com/MeetingCoverage/AAAAIMeeting/31527?utm_content=&utm_medium=email&utm_campaign=DailyHeadlines&utm_source=WC&eun=g330425d0r&userid=330425&email=mzimmerman@cox.net&mu_id=.

Early Childhood Caries

Primary teeth are at risk for a disorder known as **early childhood caries**[15] from breast milk, formula, juice, or other drinks fed through a bottle. Liquids can build

15. A dental disorder characterized by decay within the primary teeth.

up in a baby's mouth, and the natural or added sugars lead to decay. Early childhood caries is caused not only by the kinds of liquids given to an infant, but also by the frequency and length of time that fluids are given. Giving a child a bottle of juice or other sweet liquids several times each day, or letting a baby suck on a bottle longer than a mealtime, either when awake or asleep, can also cause early childhood caries. In addition, this practice affects the development and position of the teeth and the jaw. The risk of early childhood caries continues into the toddler years as children begin to consume more foods with a high sugar content. Therefore, parents should avoid giving their children sugary snacks and beverages.

Gastroesophageal Reflux

Small amounts of spitting up during a feeding is normal. However, there is cause for concern if it is too difficult to feed an infant due to **gastroesophageal reflux**[16]. This condition occurs when stomach muscles open at the wrong times and allow milk or food to back up into the esophagus. Symptoms of gastroesophagel reflux in infants include severe spitting up, projectile vomiting, arching of the back as though in pain, refusal to eat or pulling away from the breast during feedings, gagging or problems with swallowing, and slow weight gain. For most infants, making adjustments in feeding practices addresses the issue. For example, a parent can feed their baby in an upright position, wait at least an hour after eating for play time, burp more often, or give a child smaller, more frequent feedings.

Diarrhea and Constipation

Diarrhea is often caused by a gastrointestinal infection and can dehydrate an infant. It is characterized by stool frequency and consistency that deviates substantially from the norm. If an infant has had several bouts of this condition, they will need to replace lost fluids and electrolytes. A common recommendation is to give a child an oral rehydration solution. Because of the immunoprotective factors in breast milk, breastfed infants are less likely to contract gastrointestinal viral illness and experience diarrhea.

Infant constipation—which is the passage of hard, dry bowel movements, but not necessarily the absence of daily bowel movements—is another common problem. This condition frequently begins when a baby transitions from breast milk to formula or begins eating solid foods. Pediatricians can provide the best guidance for handling the problem. Common recommendations include applying a small amount of water-based lubricant to an infant's anus to ease the passage of hard stools, and feeding an infant on solid foods pureed pears or prunes, or providing barley cereal in place of rice cereal.Mayo Clinic. "Infant and Toddler Health." March 16, 2011. © 1998–2012 Mayo Foundation for Medical Education and Research. http://www.mayoclinic.com/health/infant-and-toddler-health/MY00362. Parents

16. A disorder that occurs when stomach acid rises into the esophagus. In infancy, it is characterized by coughing, choking, or vomiting after feeding.

can also offer their child a little more water in between feedings to help alleviate the condition.

Colic

Colic is a common problem during infancy, characterized by crankiness and crying jags. It is defined as crying that lasts longer than three hours per day for at least three days per week and for at least three weeks (which is commonly known as the "rule of 3's"), and is not caused by a medical problem. About one-fifth of all infants develop colic, usually between the second and third weeks. Crying spells can occur around the clock, but often worsen in the early evening. Also, colicky babies may have stomachs that are enlarged or distended with gas.

There is no definitive explanation for colic. Often, colic occurs when a child is unusually sensitive to stimulation. In breastfeeding babies, colic can be a sign of sensitivity to the mother's diet. Lactating mothers can try to eliminate caffeine, chocolate, and any other potentially irritating foods from their meals.Medline Plus, a service of the US National Library of Medicine. "Colic and Crying." Last updated August 2, 2011. http://www.nlm.nih.gov/medlineplus/ency/article/000978.htm. However, since colic usually subsides over time, any improvement that occurs with food elimination may conincide with the natural healing process.

Parents and caregivers who are feeding bottle formula to colicky babies should talk with pediatricians about replacing it with a protein hydrolysate formula.American Academy of Pediatrics. "Colic." HealthyChildren.org. © American Academy of Pediatrics. Last updated May 12, 2011. http://www.healthychildren.org/English/ages-stages/baby/crying-colic/pages/Colic.aspx. Whether breastfeeding or bottle-feeding, it is also important not to overfeed infants, which could make them uncomfortable and more likely to have crying fits. In general, it is best to wait between two and three hours from the start of one feeding to the start of the next. If food sensitivity is the cause, colic should cease within a few days of making changes. Eventually, the problem goes away. Symptoms usually begin to dissipate after six weeks and are gone by twelve weeks.Medline Plus, a service of the US National Library of Medicine. "Colic and Crying." Last updated August 2, 2011. http://www.nlm.nih.gov/medlineplus/ency/article/000978.htm.

Newborn Jaundice

Yellowing skin is one sign of newborn jaundice.

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Newborn jaundice[17] is another potential problem during infancy. This condition can occur within a few days of birth and is characterized by yellowed skin or yellowing in the whites of the eyes, which can be harder to detect in dark-skinned babies. Jaundice typically appears on the face first, followed by the chest, abdomen, arms, and legs. This disorder is caused by elevated levels of bilirubin in a baby's bloodstream. Bilirubin is a substance created by the breakdown of red blood cells and is removed by the liver. Jaundice develops when a newborn's liver does not efficiently remove bilirubin from the blood. There are several types of jaundice associated with newborns:

- **Physiologic jaundice.** The most common type of newborn jaundice and can affect up to 60 percent of full-term babies in the first week of life.
- **Breast-milk jaundice.** The name for a condition that persists after physiologic jaundice subsides in otherwise healthy babies and can last for three to twelve weeks after birth. Breast-milk jaundice tends to be genetic and there is no known cause, although it may be linked to a substance in the breast milk that blocks the breakdown of bilirubin. However, that does not mean breastfeeding should be stopped. As long as bilirubin levels are monitored, the disorder rarely leads to serious complications.
- **Breastfeeding jaundice.** Occurs when an infant does not get enough milk. This may happen because a newborn does not get a good start breastfeeding, does not latch on to the mother's breast properly, or is given other substances that interfere with breastfeeding (such as juice). Treatment includes increased feedings, with help from a lactation consultant to ensure that the baby takes in adequate amounts.

Newborn jaundice is more common in a breastfed baby and tends to last a bit longer. If jaundice is suspected, a pediatrician will run blood tests to measure the amount of bilirubin in an infant's blood. Treatment often involves increasing the number of feedings to increase bowel movements, which helps to excrete bilirubin. Within a few weeks, as the baby begins to mature and red blood cell levels diminish, jaundice typically subsides with no lingering effects.American Pregnancy Association. "Breastfeeding and Jaundice." © 2000–2012 American Pregnancy

17. A condition that can occur within a few days of birth and is characterized by yellowed skin or yellowing in the whites of the eyes.

Association. Accessed February 21, 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingandjaundice.htm.

KEY TAKEAWAYS

- Parents and other caregivers should use growth charts to track an infant's development and determine how to best meet their child's nutritional needs.
- For the first four to six months of life, children should consume breast milk exclusively. For the next six months, solid foods should be introduced gradually into an infant's diet as parents and caregivers continue to provide breast milk.
- Breast milk is ideal for infants and provides all of the nutrients they need to grow and develop.
- Breastfeeding provides a number of benefits for both a mother and her infant. For babies, breast milk boosts the immune system to protect against disease. For mothers, breastfeeding has several health benefits, such as reducing the risk of breast cancer and ovarian cancer. For both, breastfeeding promotes an emotional bond between mother and child.
- Some problems related to food and nutrition that may occur during infancy include overnutrition, early childhood caries, gastroesophageal reflux, diarrhea, constipation, and colic.

DISCUSSION STARTER

1. Why do some women choose to breastfeed their infants? Why do others decline to breastfeed? Discuss this crucial decision that parents make in the first stages of an infant's life and the possible consequences of each choice.

12.4 Nutrition in the Toddler Years

LEARNING OBJECTIVES

1. Summarize nutritional requirements and dietary recommendations for toddlers.
2. Explore the introduction of solid foods into a toddler's diet.
3. Examine feeding problems that parents and caregivers may face with their toddlers.

By the age of two, children have advanced from infancy and are on their way to becoming school-aged children. Their physical growth and motor development slows compared to the progress they made as infants. However, toddlers experience enormous intellectual, emotional, and social changes. Of course, food and nutrition continue to play an important role in a child's development. During this stage, the diet completely shifts from breastfeeding or bottle-feeding to solid foods along with healthy juices and other liquids. Parents of toddlers also need to be mindful of certain nutrition-related issues that may crop up during this stage of the human life cycle. For example, fluid requirements relative to body size are higher in toddlers than in adults because children are at greater risk of dehydration. Toddlers should drink about 1.3 liters of fluids per day, ideally liquids that are low in sugar.

The Toddler Years (Ages Two to Three)

During this phase of human development, children are mobile and grow more slowly than infants, but are much more active. The toddler years pose interesting challenges for parents or other caregivers, as children learn how to eat on their own and begin to develop personal preferences. However, with the proper diet and guidance, toddlers can continue to grow and develop at a healthy rate.

Nutritional Requirements

MyPlate may be used as a guide for the toddler's diet (http://www.choosemyplate.gov/preschoolers.html). A toddler's serving sizes should be approximately one-quarter that of an adult's. One way to estimate serving sizes for young children is one tablespoon for each year of life. For example, a two-year-old child would be served 2 tablespoons of fruits or vegetables at a meal, while a four-year-old would be given 4 tablespoons, or a quarter cup. Here is an example of a toddler-sized meal:

- 1 ounce of meat or chicken, or 2 to 3 tablespoons of beans
- One-quarter slice of whole-grain bread
- 1 to 2 tablespoons of cooked vegetable
- 1 to 2 tablespoons of fruit

Energy

The energy requirements for ages two to three are about 1,000 to 1,400 calories a day. In general, a toddler needs to consume about 40 calories for every inch of height. For example, a young child who measures 32 inches should take in an average of 1,300 calories a day. However, the recommended caloric intake varies with each child's level of activity. Toddlers require small, frequent, nutritious snacks and meals to satisfy energy requirements. The amount of food a toddler needs from each food group depends on daily calorie needs. See Table 12.5 "Serving Sizes for Toddlers" for some examples.

Table 12.5 Serving Sizes for Toddlers

Food Group	Daily Serving	Examples
Grains	About 3 ounces of grains per day, ideally whole grains	• 3 slices of bread • 1 slice of bread, plus ⅓ cup of cereal, and ¼ cup of cooked whole-grain rice or pasta
Proteins	2 ounces of meat, poultry, fish, eggs, or legumes	• 1 ounce of lean meat or chicken, plus one egg • 1 ounce of fish, plus ¼ cup of cooked beans
Fruits	1 cup of fresh, frozen, canned, and/or dried fruits, or 100 percent fruit juice	• 1 small apple cut into slices • 1 cup of sliced or cubed fruit • 1 large banana

Food Group	Daily Serving	Examples
Vegetables	1 cup of raw and/or cooked vegetables	• 1 cup of pureed, mashed, or finely chopped vegetables (such as mashed potatoes, chopped broccoli, or tomato sauce)
Dairy Products	2 cups per day	• 2 cups of fat-free or low-fat milk • 1 cup of fat-free or low-fat milk, plus 2 slices of cheese • 1 cup of fat-free or low-fat milk, plus 1 cup of yogurt

Source: Academy of Nutrition and Dietetics. "It's about Eating Right: Size-Wise Nutrition for Toddlers." © 1995–2012, Academy of Nutrition and Dietetics, all rights reserved. http://www.eatright.org/public/content.aspx?id=8055.

Macronutrients

For carbohydrate intake, the Acceptable Macronutrient Distribution Range (AMDR) is 45 to 65 percent of daily calories (113 to 163 grams for 1,000 daily calories). Toddlers' needs increase to support their body and brain development. Brightly-colored unrefined carbohydrates, such as peas, orange slices, tomatoes, and bananas are not only nutrient-dense, they also make a plate look more appetizing and appealing to a young child. The RDA of protein is 5 to 20 percent of daily calories (13 to 50 grams for 1,000 daily calories). The AMDR for fat for toddlers is 30 to 40 percent of daily calories (33 to 44 grams for 1,000 daily calories). Essential fatty acids are vital for the development of the eyes, along with nerve and other types of tissue. However, toddlers should not consume foods with high amounts of trans fats and saturated fats. Instead, young children require the equivalent of 3 teaspoons of healthy oils, such as canola oil, each day.

Micronutrients

As a child grows bigger, the demands for micronutrients increase. These needs for vitamins and minerals can be met with a balanced diet, with a few exceptions.

According to the American Academy of Pediatrics, toddlers and children of all ages need 600 international units of vitamin D per day. Vitamin D-fortified milk and cereals can help to meet this need. However, toddlers who do not get enough of this micronutrient should receive a supplement. Pediatricians may also prescribe a fluoride supplement for toddlers who live in areas with fluoride-poor water. Iron deficiency is also a major concern for children between the ages of two and three. You will learn about iron-deficiency anemia later in this section.

Learning How to Handle Food

As toddlers mature, they become more comfortable handling dishes and utensils.

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As children grow older, they enjoy taking care of themselves, which includes self-feeding. During this phase, it is important to offer children foods that they can handle on their own and that help them avoid choking and other hazards. Examples include fresh fruits that have been sliced into pieces, orange or grapefruit sections, peas or potatoes that have been mashed for safety, a cup of yogurt, and whole-grain bread or bagels cut into pieces. Even with careful preparation and training, the learning process can be messy. As a result, parents and other caregivers can help children learn how to feed themselves by providing the following:

- small utensils that fit a young child's hand
- small cups that will not tip over easily
- plates with edges to prevent food from falling off
- small servings on a plate
- high chairs, booster seats, or cushions to reach a table

Feeding Problems in the Toddler Years

During the toddler years, parents may face a number of problems related to food and nutrition. Possible obstacles include difficulty helping a young child overcome a fear of new foods, or fights over messy habits at the dinner table. Even in the face of problems and confrontations, parents and other caregivers must make sure their preschooler has nutritious choices at every meal. For example, even if a child stubbornly resists eating vegetables, parents should continue to provide them. Before long, the child may change their mind, and develop a taste for foods once abhorred. It is important to remember this is the time to establish or reinforce healthy habits.

Nutritionist Ellyn Satter states that feeding is a responsibility that is split between parent and child. According to Satter, parents are responsible for *what* their infants eat, while infants are responsible for *how much* they eat. In the toddler years and beyond, parents are responsible for *what* children eat, *when* they eat, and *where* they eat, while children are responsible for *how much* food they eat and *whether* they eat. Satter states that the role of a parent or a caregiver in feeding includes the following:

- selecting and preparing food
- providing regular meals and snacks
- making mealtimes pleasant
- showing children what they must learn about mealtime behavior
- avoiding letting children eat in between meal- or snack-timesEllyn Satter Associates. "Ellyn Satter's Division of Responsibility in Feeding." © 2012 by Ellyn Satter. http://www.ellynsatter.com/ellyn-satters-division-of-responsibility -in-feeding-i-80.html.

High-Risk Choking Foods

Certain foods are difficult for toddlers to manage and pose a high risk of choking. Big chunks of food should not be given to children under the age of four. Also, globs of peanut butter can stick to a younger child's palate and choke them. Popcorn and nuts should be avoided as well, because toddlers are not able to grind food and reduce it to a consistency that is safe for swallowing. Certain raw vegetables, such as baby carrots, whole cherry tomatoes, whole green beans, and celery are also serious choking hazards. However, there is no reason that a toddler cannot enjoy well-cooked vegetables cut into bite-size pieces.

Picky Eaters

The parents of toddlers are likely to notice a sharp drop in their child's appetite. Children at this stage are often picky about what they want to eat. They may turn their heads away after eating just a few bites. Or, they may resist coming to the table at mealtimes. They also can be unpredictable about what they want to consume for specific meals or at particular times of the day. Although it may seem as if toddlers should increase their food intake to match their level of activity, there is a good reason for picky eating. A child's growth rate slows after infancy, and toddlers ages two and three do not require as much food.

Food Jags

For weeks, toddlers may go on a **food jag**[18] and eat one or two preferred foods—and nothing else. It is important to understand that preferences will be inconsistent as a toddler develops eating habits. This is one way that young children can assert their individuality and independence. However, parents and caregivers should be concerned if the same food jag persists for several months, instead of several weeks. Options for addressing this problem include rotating acceptable foods while continuing to offer diverse foods, remaining low-key to avoid exacerbating the problem, and discussing the issue with a pediatrician. Also, children should not be forced to eat foods that they do not want. It is important to remember that food jags do not have a long-term effect on a toddler's health, and are usually temporary situations that will resolve themselves.

Toddler Obesity

Another potential problem during the early childhood years is toddler obesity. According to the US Department of Health and Human Services, in the past thirty years, obesity rates have more than doubled for all children, including infants and toddlers.Head Start, US Department of Health and Human Services. "Prevention of Overweight and Obesity in Infants and Toddlers." 2005. Accessed February 21, 2012. http://eclkc.ohs.acf.hhs.gov/hslc/tta-system/family Almost 10 percent of infants and toddlers weigh more than they should considering their length, and slightly more than 20 percent of children ages two to five are overweight or obese.Institute of Medicine of the National Academies. "Early Childhood Obesity Prevention Policies." June 23, 2011. http://www.iom.edu/Reports/2011/Early-Childhood -Obesity-Prevention-Policies.aspx Obesity during early childhood tends to linger as a child matures and cause health problems later in life.

There are a number of reasons for this growing problem. One is a lack of time. Parents and other caregivers who are constantly on the go may find it difficult to fit home-cooked meals into a busy schedule and may turn to fast food and other conveniences that are quick and easy, but not nutritionally sound. Another contributing factor is a lack of access to fresh fruits and vegetables. This is a problem particularly in low-income neighborhoods where local stores and markets may not stock fresh produce or may have limited options. Physical inactivity is also a factor, as toddlers who live a sedentary lifestyle are more likely to be overweight or obese. Another contributor is a lack of breastfeeding support. Children who were breastfed as infants show lower rates of obesity than children who were bottle-fed.

To prevent or address toddler obesity parents and caregivers can do the following:

18. A behavior exhibited by a young child who insists upon eating the same foods over and over again.

- Eat at the kitchen table instead of in front of a television to monitor what and how much a child eats.
- Offer a child healthy portions. The size of a toddler's fist is an appropriate serving size.
- Plan time for physical activity, about sixty minutes or more per day. Toddlers should have no more than sixty minutes of sedentary activity, such as watching television, per day.

Early Childhood Caries

Early childhood caries remains a potential problem during the toddler years. The risk of early childhood caries continues as children begin to consume more foods with a high sugar content. According to the National Health and Nutrition Examinaton Survey, children between ages of two and five consume about 200 calories of added sugar per day.US Department of Health and Human Services. "Consumption of Added Sugar among US Children and Adolescents." *NCHS Data Brief*, No. 87 (March 2012). Therefore, parents with toddlers should avoid processed foods, such as snacks from vending machines, and sugary beverages, such as soda. Parents also need to instruct a child on brushing their teeth at this time to help a toddler develop healthy habits and avoid tooth decay.

Iron-Deficiency Anemia

An infant who switches to solid foods, but does not eat enough iron-rich foods, can develop **iron-deficiency anemia**[19]. This condition occurs when an iron-deprived body cannot produce enough hemoglobin, a protein in red blood cells that transports oxygen throughout the body. The inadequate supply of hemoglobin for new blood cells results in anemia. Iron-deficiency anemia causes a number of problems including weakness, pale skin, shortness of breath, and irritability. It can also result in intellectual, behavioral, or motor problems. In infants and toddlers, iron-deficiency anemia can occur as young children are weaned from iron-rich foods, such as breast milk and iron-fortified formula. They begin to eat solid foods that may not provide enough of this nutrient. As a result, their iron stores become diminished at a time when this nutrient is critical for brain growth and development.

There are steps that parents and caregivers can take to prevent iron-deficiency anemia, such as adding more iron-rich foods to a child's diet, including lean meats, fish, poultry, eggs, legumes, and iron-enriched whole-grain breads and cereals. A toddler's diet should provide 7 to 10 milligrams of iron daily. Although milk is critical for the bone-building calcium that it provides, intake should not exceed the RDA to avoid displacing foods rich with iron. Children may also be given a daily supplement, using infant vitamin drops with iron or ferrous sulfate drops. If iron-

19. A condition characterized by inadequate hemoglobin in the blood due to low iron levels.

deficiency anemia does occur, treatment includes a dosage of 3 milligrams per kilogram once daily before breakfast, usually in the form of a ferrous sulfate syrup. Consuming vitamin C, such as orange juice, can also help to improve iron absorption.Kazal Jr., L. A., MD. "Prevention of Iron Deficiency in Infants and Toddlers." *American Academy of Family Physicians* 66, no. 7 (October 1, 2002): 1217—25. http://www.aafp.org/afp/2002/1001/p1217.html.

Toddler Diarrhea

As with adults, a variety of conditions or circumstances may give a toddler diarrhea. Possible causes include bacterial or viral infections, food allergies, or lactose intolerance, among other medical conditions. Excessive fruit juice consumption (more than one 6-ounce cup per day) can also lead to diarrhea.American Academy of Pediatrics, Committee on Nutrition 1999–2000. "The Use and Misuse of Fruit Juice in Pediatrics." *Pediatrics* 119, no. 2 (February 2007): 405. doi:10.1542/peds.2006-3222. Diarrhea presents a special concern in young children because their small size makes them more vulnerable to dehydration. Parents should contact a pediatrician if a toddler has had diarrhea for more than twenty-four hours, if a child is also vomiting, or if they exhibit signs of dehydration, such as a dry mouth or tongue, or sunken eyes, cheeks, or abdomen. Preventing or treating dehydration in toddlers includes the replacement of lost fluids and electrolytes (sodium and potassium). Oral rehydration therapy, or giving special fluids by mouth, is the most effective measure.

Developing Habits

Eating habits develop early in life. They are typically formed within the first few years and it is believed that they persist for years, if not for life. So it is important for parents and other caregivers to help children establish healthy habits and avoid problematic ones. Children begin expressing their preferences at an early age. Parents must find a balance between providing a child with an opportunity for self-expression, helping a child develop healthy habits, and making sure that a child meets all of their nutritional needs. Following Ellyn Satter's division of responsibility in feeding (see above) can help a child eat the right amount of food, learn mealtime behavior, and grow at a healthy and predictable rate.

Bad habits and poor nutrition have an accrual effect. The foods you consume in your younger years will impact your health as you age, from childhood into the later stages of life. As a result, good nutrition today means optimal health tomorrow. In the next chapter, you will learn about how nutritional needs change from the later childhood years, through adolescence and adulthood, and into old age. The choices that you make at every age accumulate over time and greatly impact your health into the golden years.

Video 12.4

Introducing Your Toddler to New Foods

(click to see video)

This video focuses on ways to encourage toddlers to try new foods.

KEY TAKEAWAYS

- By the toddler years, young children are able to self-feed and begin to develop eating habits and preferences.
- The energy requirements for ages two to three are about 1,000 to 1,400 calories per day, and in general, a toddler needs to consume about 40 calories for every inch of height.
- Growth slows during the toddler years, but children are more active at this stage and undergo a great deal of intellectual, emotional, and social development.
- Some food- and nutrition-related problems that can occur during the toddler years include choking, picky eating, food jags, early childhood caries, iron-deficiency anemia, and toddler diarrhea.

DISCUSSION STARTER

1. How do the nutritional needs of a child change from infancy into the toddler years? Discuss the changing needs for energy, macronutrients, and micronutrients as young children mature.

12.5 End-of-Chapter Exercises

IT'S YOUR TURN

1. Plan a day's worth of meals for a pregnant woman that contain the RDA of vitamin C. To help determine the vitamin C content in foods, visit the USDA National Nutrient Database: http://www.nal.usda.gov/fnic/foodcomp/search.
2. Create a brochure or plan a peer-to-peer campaign that encourages pregnant women to breastfeed their newborns and includes the major benefits of this practice.
3. After watching the video, which recommends snacks for adults and older children, use these ideas and what you have learned to create a list of toddler-friendly healthy snacks for parents. Take into account potential problems for young children, such as foods that are choking hazards.

   Eating Healthy Snacks

   (click to see video)

APPLY IT

1. Create a chart that compares the energy requirements and fluid recommendations for the following phases: the second trimester of pregnancy, the third trimester of pregnancy, the first six months of lactation, and the second six months of lactation.
2. Visit a store and study the labels of three different brands of infant formula. Record the nutrition facts for each brand, such as the calories, amount of carbohydrates, amount of protein, and so on.
3. Research ways to adjust the behavior of picky eaters at this website: http://www.healthychildren.org. Then, create a list of four to five tips for parents of toddlers. Apply Ellyn Satter's division of responsibility as you create your suggestions.

EXPAND YOUR KNOWLEDGE

1. How might statistics regarding unplanned pregnancies relate to the recommendation that all women should regularly take a multivitamin with folic acid? Use your knowledge of the impact of folate to explain your response.
2. Write a short speech that you would give to local government officials to recommend ways that they can promote and support the practice of breastfeeding in your community. Or prepare an email or letter to explain to a friend or family member why you have made the choice to breastfeed your child or to support your partner in the practice of breastfeeding.
3. Visit http://www.healthychildren.org and research ways to introduce solid foods into an infant's diet. Then create an eating plan to help parents gradually introduce solids to their babies, beginning at the age of six months.