CHAPTER

5 The Skeletal System

A colored X-ray of a foot on tiptoe.

CURRENT ISSUE

A Black Market in Human Bones?

Alistair Cooke, famed host of the PBS series *Masterpiece Theatre*, died in 2004 at the age of 95. His body lay in a New York City funeral parlor for a few days awaiting cremation. But before Cooke's body was cremated, it was secretly carved up in a back room and his bones were removed. Authorities allege that his bones were then sold for a substantial profit, to be transplanted into patients in desperate need of tissue grafts.

Cooke's family, who had not given permission for his body parts to be donated, knew nothing of this until police contacted them after the funeral. Understandably, they were appalled. But there is an even more horrifying side to this story: Cooke died of lung cancer that had spread to his bones. Could his deadly cancer have been transmitted to the people who received his bone tissue? It's unlikely since bone products generally are sterilized (see below), but the answer may not be known for decades.

Recycling Body Parts: A Legitimate Industry

The processing of tissues taken from human corpses into products that can be transplanted into other people is a legitimate industry that serves urgent medical needs. The industry has evolved over the past several decades as harvesting and transplantation

Alistair Cooke, long-time host of *Masterpiece Theatre*. Cooke's body was subjected to secret, illegal bone harvesting after he died.

Donated bones are cleaned, sterilized, and shaped into bone products.

techniques have improved. Bones are used to repair fractures and replace cancerous bone. Bone pins and powdered bone are used in dental surgery; bone paste plugs holes. Tendons and ligaments are used to repair joints and tissues damaged by sports injuries, transplanted vertebrae relieve back pain, and veins and heart valves are used in heart surgeries. The bones, tendons, veins, and heart valves from just one corpse can be worth over $200,000 to surgeons, hospitals, and recipients.

Under federal law it is illegal to sell human body parts for a profit—they can only be donated, either by the patient while he or she is still alive or by the family after death. Several hundred licensed nonprofit tissue banks in the United States receive donated tissues and test them for infectious diseases such as HIV, syphilis, and the viruses that cause hepatitis (inflammation of the liver). To reduce the chances of tissue products transmitting disease, authorities impose strict guidelines that specify what types of tissues may be harvested, from whom they may be harvested, and how they must be processed. For instance, to prevent any risk of transmitting cancer, federal guidelines prohibit the use of bones from cancer patients for tissue implants.

After donation, bone tissue is shaped into usable forms, such as pins, plates, and powders. The final products are sterilized and shipped to hospitals and surgeons all over the country, where they are used in more than 600,000 surgical procedures every year. The patient pays all fees incurred in the handling, processing, testing, and shipping of the products, but the tissue banks themselves do not make a profit.

Illegal Body Parts Enter the Supply Chain

In the Alistair Cooke case, prosecutors alleged that Michael Mastromarino, an oral surgeon who had lost his license, arranged for a Brooklyn funeral parlor to deliver bodies to a secret operating room. There, Mastromarino and his accomplices removed body parts before the bodies were buried or cremated. Authorities say that the men paid the funeral parlor up to $1,000 per body and then sold the harvested tissues for up to $7,000 per body to a legitimate but unsuspecting tissue-processing company.

In some cases Mastromarino and his accomplices falsified records indicating the deceased's age and cause of death. Mr. Cooke died of cancer at the age of 95, but his records were falsified to indicate that he died at age 85 of a heart attack. They also allegedly looted body parts from a 43-year-old woman who had died of ovarian cancer; they then forged a signature on a consent form and listed the cause of death as a head injury. When investigators examined the corpse of one grandmother, they found that her leg bones had been removed and replaced with PVC pipes. Prosecutors eventually identified over a thousand corpses from which body parts were taken without permission between 2001 and 2005.

In 2008 Mr. Mastromarino pled guilty in a plea bargain that could reduce his jail time in exchange for providing information about others who were involved. He is expected to spend at least 18 years in prison. An accomplice and seven funeral home directors received lesser sentences.

Human bones and bone products ready for shipment to hospitals.

The Alistair Cooke case is not the first such incident, and it is not likely to be the last. In 1999 the University of California at Irvine discovered that the director of its Willed Body Program was selling human spines to a Phoenix hospital for $5,000 apiece. And in 2008 the director of UCLA's Willed Body Program was sentenced to 4 years in prison for selling more than a million dollars worth of body parts. Regulators say that abuses such as these are most likely to occur when relatively poorly paid directors (including funeral home directors) have access to valuable body parts and when oversight is lax. UC Irvine and UCLA have both tightened their oversight procedures as a result of the scandals.

Only 22,000 cadavers are donated annually for body parts—not enough to supply the growing demand for human body parts and tissues. Done properly, the donation of a single cadaver to a nonprofit tissue-processing company can benefit several dozen patients. Patients should only have to pay the legitimate costs associated with the body parts processing industry—not the added fees paid to traffickers in illegal body parts. Safeguards need to be put in place to prevent abuses so that we can be assured of the legitimacy and the safety of the supply of human body parts.

THE FACTS...

- **It is illegal to buy or sell human body parts for a profit. Patients or their families can donate body parts only to nonprofit tissue banks.**
- **Legitimately donated tissues are tested, sterilized, processed, and transplanted into patients who urgently need them.**
- **Only 22,000 cadavers are donated annually for body parts—not enough to meet the growing legitimate demand for human tissues and tissue products.**
- **The supply/demand imbalance may be contributing to a black market in body parts harvested illegally from cadavers.**

QUESTIONS TO CONSIDER

1 Do you approve of human bones being harvested from cadavers for processing into bone-based products for patients, provided the bones are legally obtained?

2 What steps do you think should be taken to curb abuses in the human body parts industry?

KEY CONCEPTS

- **The skeletal system is composed of bones, ligaments, and cartilage.** The skeletal system supports and protects the other organ systems of the body and provides a structure that enables movement.
- **Bones consist of living cells surrounded by extracellular deposits of calcium minerals.** Bone tissue undergoes constant replacement, remodeling, and repair.
- **Bones store minerals and produce the cellular components of blood** (red blood cells, white blood cells, and platelets).
- **Ligaments comprised of connective tissue hold bones together.** When damaged, ligaments are slow to heal because they have very few living cells and a poor blood supply.
- **Joints are the points of contact between bones.** In a movable joint, bone surfaces are covered by a layer of smooth cartilage and lubricated with fluid to reduce friction and wear.

The human body is capable of an awesome array of physical activities. With training, some individuals can run a mile in less than four minutes or lift more than their own weight. Exquisitely sensitive motor skills allow us to thread a needle, turn our head to focus on a single star, and throw a baseball into the strike zone. Considered individually, any one of these activities may not seem amazing, but for a single structure (the human body) to be capable of all of them is remarkable indeed. From an engineering standpoint it would be like designing a bulldozer that is strong enough to flatten a building, yet delicate enough to pick up a dime.

This chapter describes the skeletal system, the organ system for support, protection, and movement. We examine the structure and development of bones, and the way they remodel and repair themselves; review how the bones fit together to make the skeleton; and take a look at how joints enable bones and muscles to work together. Finally, we consider what can go wrong with the skeletal system.

5.1 The skeletal system consists of connective tissue

The skeletal system comprises three types of connective tissue—bones, ligaments, and cartilage. *Bones* are the hard elements of the skeleton with which we are most familiar. *Ligaments* consist of dense fibrous connective tissue—they bind the bones to each other. *Cartilage* is a specialized connective tissue consisting primarily of fibers of collagen and elastic in a gel-like fluid called *ground substance*. Cartilage has several functions, including reducing friction in joints.

Bones are the hard elements of the skeleton

Most of the mass of **bones** consists of nonliving extracellular crystals of calcium minerals that give bones their hard, rigid appearance and feel. But bone is actually a living tissue that contains several types of living cells involved in bone formation and remodeling, plus nerves and blood vessels. Indeed, bones bleed when cut during orthopedic surgery or when they break.

Bones perform five important functions. The first three—*support, protection*, and *movement*—are the same as the functions of the skeleton overall, which is, after all, primarily bone. The rigid support structure of bones is what allows us to sit and to stand upright. The bones of the skeleton also support, surround, and protect many of our soft internal organs, such as the lungs, liver, and spleen. The attachment of bones to muscles makes it possible for our bodies to move.

The fourth and fifth functions of bones—*blood cell formation* and *mineral storage*—are harder to remember, but they are just as important. Cells in certain bones are the only source of new red and white blood cells and platelets for blood. Without this ability to produce new blood cells we would die within months. Bones also serve as an important long-term storage depot for two important minerals, calcium and phosphate. These two minerals can be drawn from bone when necessary, though excessive withdrawal may have consequences for bone composition and strength.

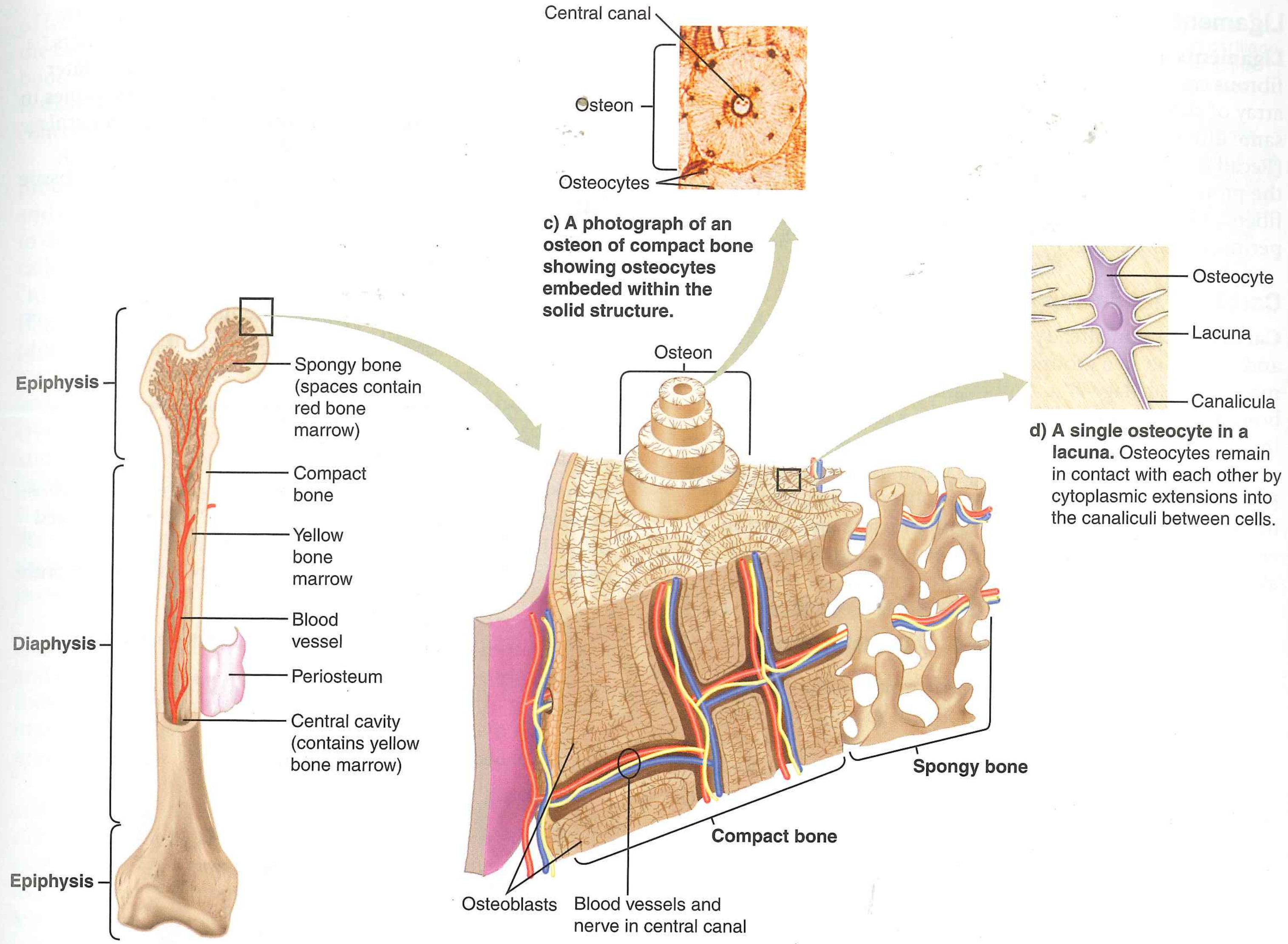
Bone contains living cells

A typical long bone, so called because it is longer than it is wide, consists of a cylindrical shaft (called the *diathesis*) with an enlarged knob called an *epiphysis* at each end (Figure 5.1a). Dense **compact bone** forms the shaft and covers each end. A central cavity in the shaft is filled with *yellow bone marrow*. Yellow bone marrow is primarily fat that can be utilized for energy.

The outer surface of the bone is covered by a tough layer of connective tissue, the *eriostemon*, which contains specialized bone-forming cells. If an epiphysis of a long bone forms a movable joint with another bone, the joint surface is covered by a smooth layer of cartilage that reduces friction.

Inside each epiphysis is **spongy bone** (Figure 5.1b). Spongy bone is less dense than compact bone, allowing the bones to be light but strong. Spongy bone is a latticework of hard, relatively strong *trabeculae* (from Latin, meaning "little beams") composed of calcium minerals and living cells. In certain long bones, most notably the long bones of the upper arms and legs (humerus and femur, respectively), the spaces between the trabeculae are filled with *red bone marrow*. Special cells called *stem cells* in the red bone marrow are responsible for the production of red and white blood cells and platelets.

Taking a closer look (Figure 5.1c), we see that compact bone is made up largely of extracellular deposits of calcium phosphate enclosing and surrounding living cells called **osteocytes** (from the Greek words for "bone" and "cells").



a) A partial cut through a long bone.

b) A closer view of a section of bone. Compact bone is a nearly solid structure with central canals for the blood vessels and nerves.

Figure 5.1 Structure of bone.

Osteocytes are arranged in rings in cylindrical structures called **osteons** (sometimes called *Haversian systems*). Osteocytes nearest the center of an osteon receive nutrients by diffusion from blood vessels that pass through a **central canal** (Haversian canal).

As bone develops and becomes hard, the osteocytes become trapped in hollow chambers called *lacunae* (Figure 5.1d). However, the osteocytes remain in direct contact with each other via thin canals called *canaliculi*. Within the canaliculi, extensions of the cell cytoplasm of adjacent osteocytes are joined together by gap junctions. (Gap junctions, as you may already know, are channels that permit the movement of ions, water, and other molecules between two adjacent cells.) By exchanging nutrients across these gap junctions, all the osteocytes can be supplied with nutrients even though most osteocytes are not located near a blood vessel. Waste products produced by the osteocytes are exchanged in the opposite direction and are removed from the bone by the blood vessels.

In spongy bone, osteocytes do not need to rely on central canals for nutrients and waste removal. The slender trabecular structure of spongy bone gives each osteocyte access to nearby blood vessels in red bone marrow.

✓ **Quick Check** *If osteocytes did not have gap junctions in their cell membranes, would they be able to survive? Explain.* ■

Answers to ✓ questions can be found in Appendix A.

Ligaments hold bones together

Ligaments attach bone to bone. Ligaments consist of dense fibrous connective tissue, meaning that they are a regular array of closely packed collagen fibers all oriented in the same direction, with just a few fibroblasts in between. (Recall that fibroblasts are cells that produce and secrete the proteins that compose collagen, elastic, and reticular fibers.) Ligaments confer strength to certain joints while still permitting movement of the bones in relation to each other.

Cartilage lends support

Cartilage, as you already know, contains fibers of collagen and/or elastin in a ground substance of water and other materials. Cartilage is smoother and more flexible than bone. Cartilage is found where support under pressure is important and where some movement is necessary.

There are three types of cartilage in the human skeleton. *Fibrocartilage* consists primarily of collagen fibers arranged in thick bundles. It withstands both pressure and tension well. The intervertebral disks between the vertebrae, and also certain disk-like supportive structures in the knee joint called *menisci*, are made of fibrocartilage. *Hyaline cartilage* is a smooth, almost glassy cartilage of thin collagen fibers. Hyaline cartilage forms the embryonic structures that later become the bones. It also covers the ends of mature bones in joints, creating a smooth, low-friction surface. *Elastic cartilage* is mostly elastin fibers, so it is highly flexible. It lends structure to the outer ear and to the epiglottis, a flap of tissue that covers the larynx during swallowing.

Recap Bones contribute to support, movement, and protection. Bones also produce the blood cells and store minerals. Ligaments hold bones together, and cartilage provides support.

5.2 Bone development begins in the embryo

In the earliest stages of fetal development, even before organs develop, the rudimentary models of future bones are created out of hyaline cartilage by cartilage-forming cells called **chondroblasts** (Figure 5.2a). After about two to three months

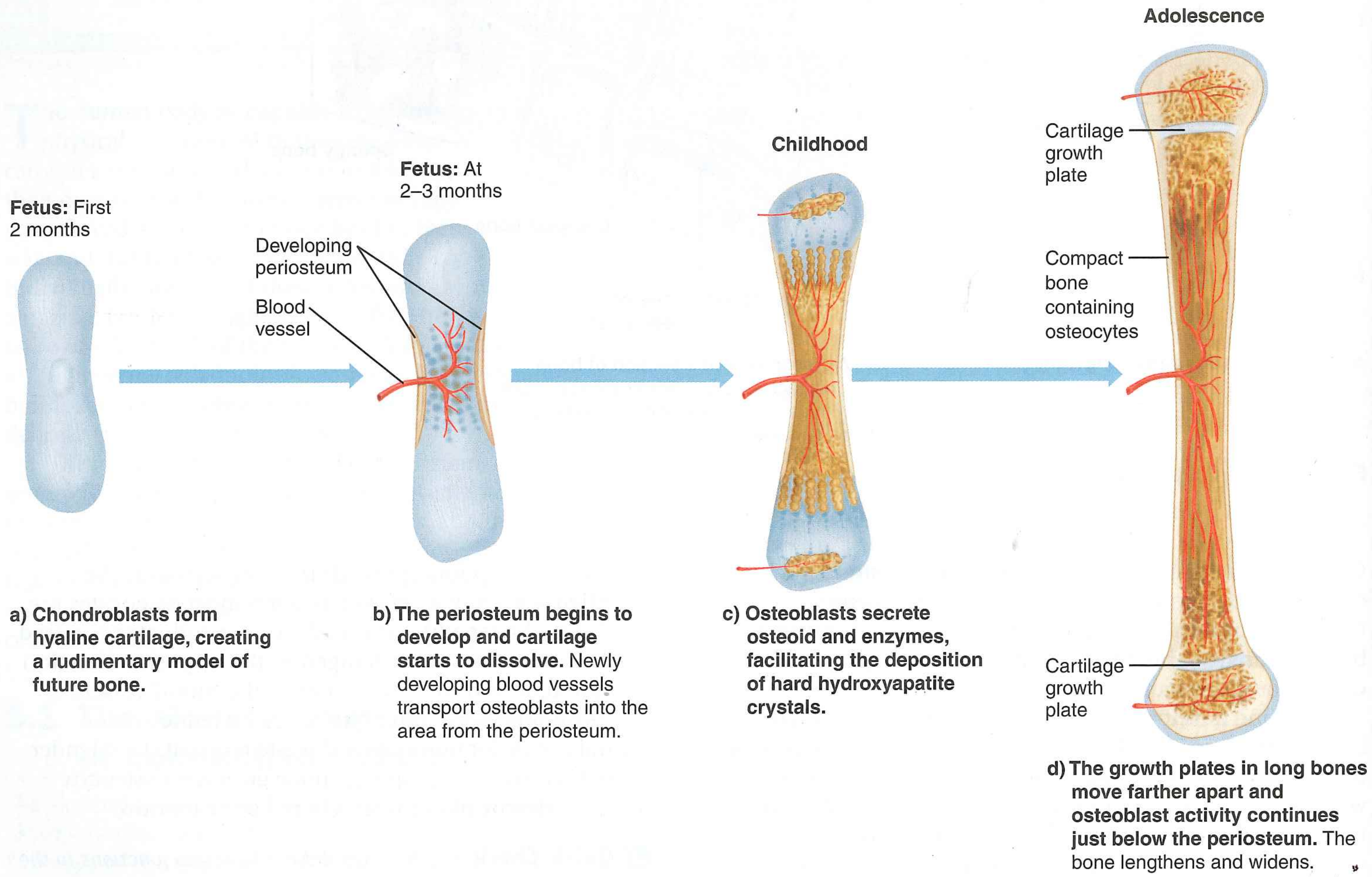


Figure 5.2 How bone develops. The first two phases of bone development occur in the fetus. Bones continue to grow longer throughout childhood and adolescence because of growth at the growth plates.

of fetal development, the chondroblasts slowly die out and the cartilage models begin to dissolve and are replaced by bone. This process is called *ossification*. Although ossification is slightly different for flat bones and long bones, we will concentrate on the process for long bones.

After the chondroblasts die, the cartilage models they produced gradually break down inside the future shaft and epiphysis of the bone, making room for blood vessels to develop. The blood vessels carry bone-forming cells called **osteoblasts** (from the Greek words for "bone" and "to build") into the area from the developing eriostemon (Figure 5.2b). The osteoblasts secrete a mixture of proteins (including collagen) called *osteoid*, which forms a matrix that provides internal structure and strength to bone. Osteoblasts also secrete enzymes that facilitate the crystallization of hard mineral salts of calcium phosphate, known as *hydroxyapatite*, around and between the osteoid matrix (Figure 5.2c). As more and more hydroxyapatite is deposited, the osteoblasts become embedded in the hardening bone tissue. In mature compact bone, approximately one-third of the structure is osteoid and two-thirds is crystals of hydroxyapatite.

Eventually the rate at which osteoblasts produce the osteoid matrix and stimulate the mineral deposits declines, and osteoblasts become mature osteocytes embedded in their individual lacunae. Mature osteocytes continue to maintain the bone matrix, however. Without them the matrix would slowly disintegrate.

Bones continue to lengthen throughout childhood and adolescence. This is because a narrow strip of cartilage called the **growth plate** (or *epiphyseal plate*) remains in each epiphysis (Figure 5.2d). Chondroblast activity (and hence the development of new cartilage as a model for the lengthening bone) is concentrated on the outside of the plate, whereas the conversion of the cartilage model to bone by osteoblasts is concentrated on the inside of the plate (Figure 5.3). In effect, the bone lengthens as the two growth plates migrate farther and farther apart. Bones also grow in width as osteoblasts lay down more bone on the outer surface just below the eriostemon.

The bone development process is controlled by hormones, chemicals secreted by the endocrine glands. The most important hormone in preadolescents is growth hormone, which stimulates the bone-lengthening activity of the growth plate. During puberty the sex hormones (testosterone and estrogen) also stimulate the growth plate, at least initially. But at about age 18 in females and 21 in males these same sex hormones signal the growth plates to stop growing, and the cartilage is replaced by bone tissue. At this point the bones can no longer lengthen, though they can continue to grow in width.

Recap **Bone-forming cells called *osteoblasts* produce a protein mixture (including collagen) that becomes bone's structural framework. They also secrete an enzyme that facilitates mineral deposition.** ■

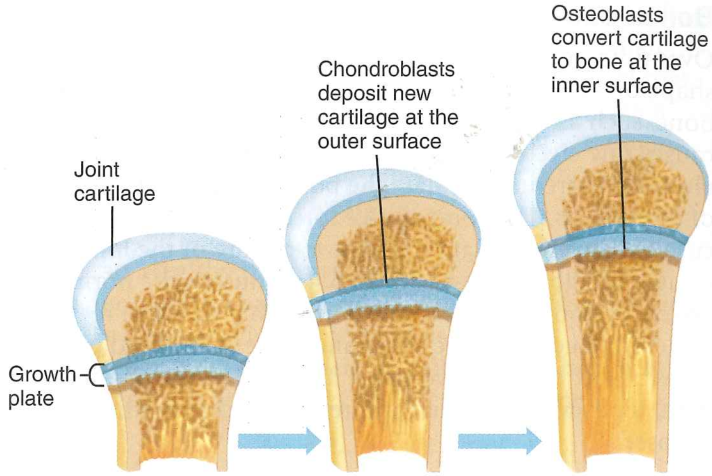


Figure 5.3 How long bones increase in length.

✓ *Mark the place(s) in this bone where osteoblasts are most active, and name the crystal that they are producing.*

5.3 Mature bone undergoes remodeling and repair

Even though bones stop growing longer, they do not remain the same throughout life. Bone is a dynamic tissue that undergoes constant replacement, remodeling, and repair. Remodeling may be so extensive that there is a noticeable change in bone shape over time, even in adults.

Bone remodeling and repair are in part due to a third type of bone cell called an **osteoclast** (from the Greek words for "bone" and "to break"). Osteoclasts cut through mature bone tissue, dissolving the hydroxyapatite and digesting the osteoid matrix in their path. The released calcium and phosphate ions enter the blood. The areas from which bone has been removed attract new osteoblasts, which lay down new osteoid matrixes and stimulate the deposition of new hydroxyapatite crystals.

Table 5.1 summarizes the four types of cells that contribute to bone development and maintenance.

Table 5.1 Cells involved in bone development and maintenance

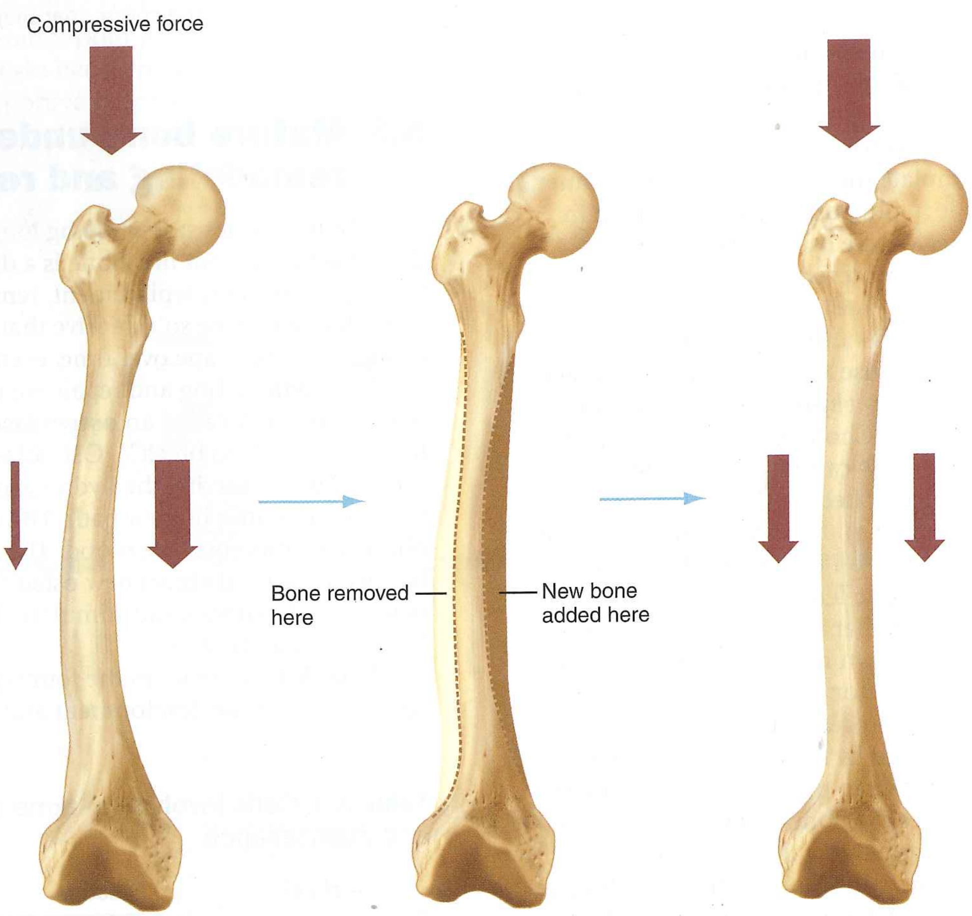
Type of cell	Function
Chondroblasts	Cartilage-forming cells that build a model of the future bone
Osteoblasts	Young bone-forming cells that cause the hard extracellular matrix of bone to develop
Osteocytes	Mature bone cells that maintain the structure of bone
Osteoclasts	Bone-dissolving cells

Bones can change in shape, size, and strength

Over time, constant remodeling can actually change the shape of a bone. The key is that compression stress on a bone, such as the force of repeated jogging on the legs, causes tiny electrical currents within the bone. These electrical currents stimulate the bone-forming activity of osteoblasts. The compressive forces and the electric currents are greatest at the inside curvature of the long bone undergoing stress (Figure 5.4). Thus, in the normal course of bone turnover, new bone is laid down in regions under high compressive stress and bone is resorbed in areas of low compressive stress. The final shape of a bone, then, tends to match the compressive forces to which it is exposed.

Weight-bearing exercise increases overall bone mass and strength. The effect is pronounced enough that the bones of trained athletes may be visibly thicker and heavier than those of nonathletes. You don't have to be a professional athlete to get this benefit, however. If you begin a regular program of any weight-bearing exercise, such as jogging or weight lifting, your bones will become denser and stronger as your osteoblasts produce more bone tissue.

The maintenance of homeostasis of bone structure depends on the precise balance of the activities of osteoclasts and osteoblasts. **Osteoporosis** is a common condition in which bones lose a great deal of mass (seemingly becoming "porous") because of an imbalance over many years in the rates of activities of these two types of bone cells.



a) The application of force to a slightly bent bone produces a greater compressive force on the inside curvature. Compressive force produces weak electrical currents, which stimulate osteoblasts.

b) Over time, bone is deposited on the inside curvature and removed from the outside curvature.

c) The final result is a bone matched to the compressive force to which it is exposed.

Figure 5.4 Bone remodeling.

Quick Check *Swimming is considered good exercise for muscle mass and overall cardiorespiratory fitness. How would you expect swimming to affect bone mass and density?* ■

Bone cells are regulated by hormones

Like bone growth, the rates of activities of osteoblasts and osteoclasts in adulthood are regulated by hormones that function to maintain calcium homeostasis. When blood levels of calcium fall below a given point, *parathyroid hormone* (*PTH*) stimulates the osteoclasts to secrete more bone-dissolving enzymes. The increased activity of osteoclasts causes more bone to be dissolved, releasing calcium and phosphate into the bloodstream. If calcium levels rise, then another hormone called *calcitonin* stimulates osteoblast activity, causing calcium and phosphate to be removed from blood and deposited in bone. Although the total bone mass of young adults doesn't change much, it's estimated that almost 10% of their bones may be remodeled and replaced each year. We'll review the regulation of blood calcium concentration in more detail when we discuss the endocrine system.

Quick Check *Suppose a man is not getting sufficient calcium in his diet, such that his blood calcium level is chronically low. Would his PTH levels and calcitonin levels be low, normal, or high? Explain.* ■

Bones undergo repair

When you break (fracture) a bone, the blood vessels supplying the bone bleed into the area, producing a mass of clotted blood called a *hematoma*. Inflammation, swelling, and pain generally accompany the hematoma in the days immediately after a fracture. The repair process begins within days as fibroblasts migrate to the area. Some of the fibroblasts become chondroblasts, and together they produce a tough fibrocartilage bond called a *callus* between the two broken ends of the bone. A callus can be felt as a hard, raised ring at the point of the break. Then osteoclasts arrive and begin to remove dead fragments of the original bone and the blood cells of the hematoma. Finally, osteoblasts arrive to deposit osteoid matrix and encourage the crystallization of calcium phosphate minerals, converting the callus into bone. Eventually the temporary union becomes dense and hard again. Bones rarely break in the same place twice because the repaired union remains slightly thicker than the original bone.

BlogInFocus (MB)

What is *Gaucher disease*, and more importantly, why does the drug to treat it cost a whopping $300,000 a year? To find out, visit MJ's blog in the Study Area in MasteringBiology and look under "Gaucher disease."

The repair process can take weeks to months, depending on your age and the bone involved. In general, the repair process slows with age. Recently it has been discovered that the application of weak electrical currents to the area of a broken bone can increase the rate of healing. It is thought that electrical current works by attracting osteoclasts and osteoblasts to the area under repair.

Recap **Healthy bone replacement and remodeling depend on the balance of activities of bone-resorbing osteoclasts and bone-forming osteoblasts. When a bone breaks, a fibrocartilage callus forms between the broken ends and is later replaced with bone.** ■

5.4 The skeleton protects, supports, and permits movement

Now that we have reviewed the dynamic nature of bone tissue, we turn to how all of those bones are classified and organized. Bones can be classified into four types based on shape: long, short, flat, and irregular. So far we have discussed *long bones*, which include the bones of the limbs and fingers. *Short bones* (the bones of the wrists) are approximately as wide as they are long. *Flat bones* (including the cranial bones, the sternum, and the ribs) are thin, flattened, and sometimes curved, with only a small amount of spongy bone sandwiched between two layers of compact bone. *Irregular bones* such as the coxal (hip) bones and the vertebrae include a variety of shapes that don't fit into the other categories. A few flat and irregular bones, including the sternum and the hip bones, contain red bone marrow that produces blood cells.

The 206 bones of the human body and the various connective tissues that hold them together make up the **skeleton** (Figure 5.5). The skeleton has three important functions. First, it serves as a structural framework for support of the soft organs. Second, it protects certain organs from physical injury. The brain, for example, is enclosed within the bones of the skull, and the heart and lungs are protected by a bony cage consisting of ribs, the sternum, and vertebrae. Third, because of the way that the bony elements of the skeleton are joined together at joints, the presence of the skeleton permits flexible movement of most parts of the body. This is particularly true of the hands, feet, legs, and arms.

The skeleton is organized into the *axial skeleton* and the *appendicular skeleton*.

The axial skeleton forms the midline of the body

The **axial skeleton** consists of the skull (including the maxilla and mandible), sternum, ribs, and vertebral column (including the sacrum) (see Figure 5.5).

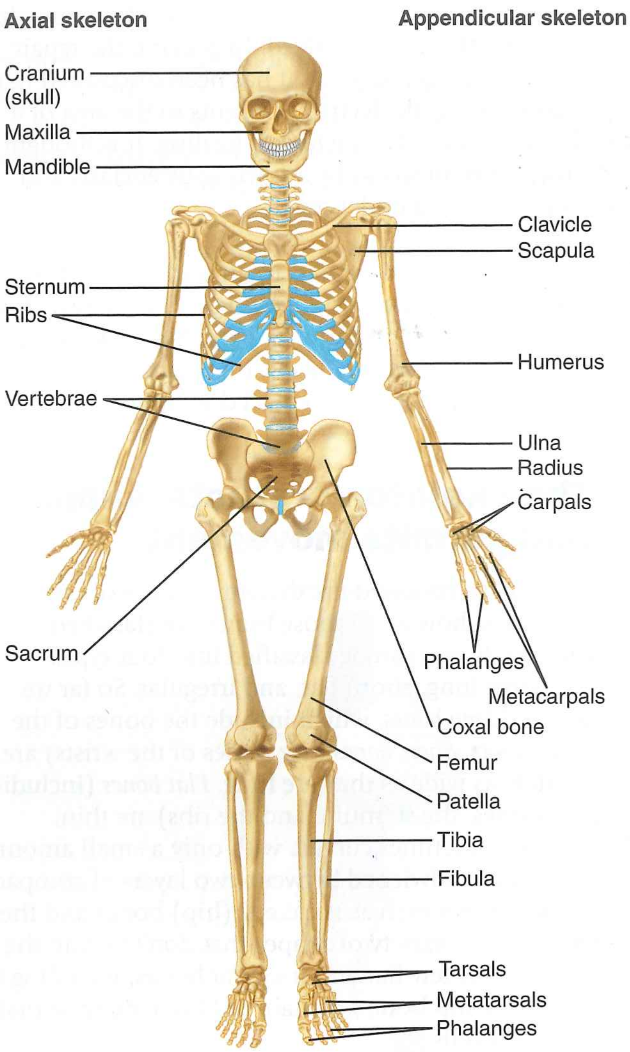


Figure 5.5 The human skeleton.

✓ *On this and subsequent figures, find the anatomical terms corresponding to the following common names: breastbone, collarbone, shoulder blade, hip bone, thighbone, shinbone.*

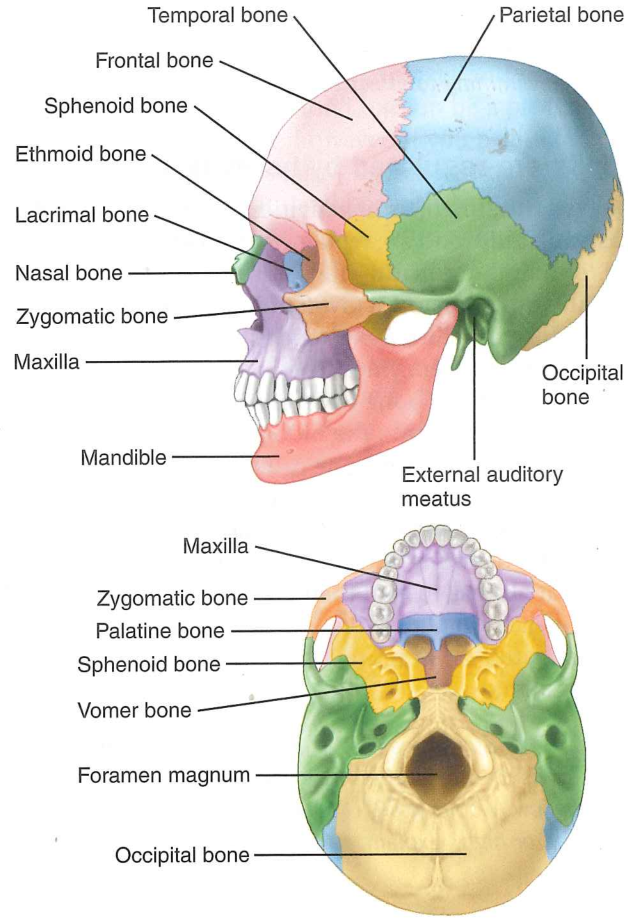


Figure 5.6 The human skull. Except for the mandible, which has a hinged joint with the temporal bone, the bones of the skull are joined tightly together. Their function is protection, not movement.

The skull: Cranial and facial bones The human **skull** (cranium) comprises over two dozen bones that protect the brain and form the structure of the face. Figure 5.6 illustrates some of the more important bones of the skull.

The *cranial bones* are flat bones in the skull that enclose and protect the brain. Starting at the front of the skull, the *frontal bone* comprises the forehead and the upper ridges of the eye sockets. At the upper left and right sides of the skull are the two *parietal bones*, and forming the lower left and right sides are the two *temporal bones*. Each temporal bone is pierced by an opening into the ear canal that allows sounds to travel to the eardrum. Between the frontal bone and the temporal bones is the *sphenoid bone*, which forms the back of both eye sockets. The *ethmoid bone* contributes to the eye sockets and also helps support the nose.

The two small, narrow *nasal bones* underlie only the upper bridge of the nose; the rest of the fleshy protuberance called the nose is made up of cartilage and other connective tissue. Part of the space formed by the maxillary and nasal bones is the nasal cavity. The small *lacrimal bones*, at the inner eye sockets, are pierced by a tiny opening through which the tear ducts drain tears from the eye sockets into the nasal cavity.

The *mandible*, or lower jaw, contains the sockets that house the lower row of teeth. All the bones of the skull are joined tightly together except for the mandible, which attaches to the temporal bone by a joint that, because it permits a substantial range of motion, allows us to speak and chew.

Curving underneath to form the back and base of the skull is the *occipital bone*. Near the base of the occipital bone is a large opening called the *foramen magnum* (Latin for "great opening"). This is where the vertebral column connects to the skull and the spinal cord enters the skull to communicate with the brain.

The *facial bones* compose the front of the skull. On either side of the nose are the two *maxilla* (maxillary) bones, which form part of the eye sockets and contain the sockets that anchor the upper row of teeth. The hard palate (the "roof" of the mouth) is formed by the maxilla bones and the two *palatine bones*. Behind the palatine bones is the *vomer bone*, which is part of the nasal septum that divides the nose into left and right halves. The two *zygomatic bones* form the cheekbones and the outer portion of the eye sockets.

Several of the cranial and facial bones contain air spaces called **sinuses**, which make the skull lighter and give the human voice its characteristic tone and resonance. Each sinus is lined with tissue that secretes mucus, a thick, sticky fluid that helps trap foreign particles in incoming air. The sinuses connect to the nasal cavity via small passageways through which the mucus normally drains. However, if you develop a cold or respiratory infection, the tissue lining your sinuses can become inflamed and block these passages. Sinus inflammation is called *sinusitis.* If fluid accumulates inside the sinuses, the resulting sensation of pressure may give you a "sinus headache."

The hyoid bone The **hyoid** bone (Figure 5.7) does not make direct contact with the other bones of the axial skeleton; it is attached to the temporal bone only by ligaments. It serves as a point of attachment for muscles of the tongue, the larynx, and the pharynx. Because of its position it is rarely broken by accidental injury. In cases of suspected homicide, however, a broken hyoid bone is considered to be a strong indication of deliberate strangulation.

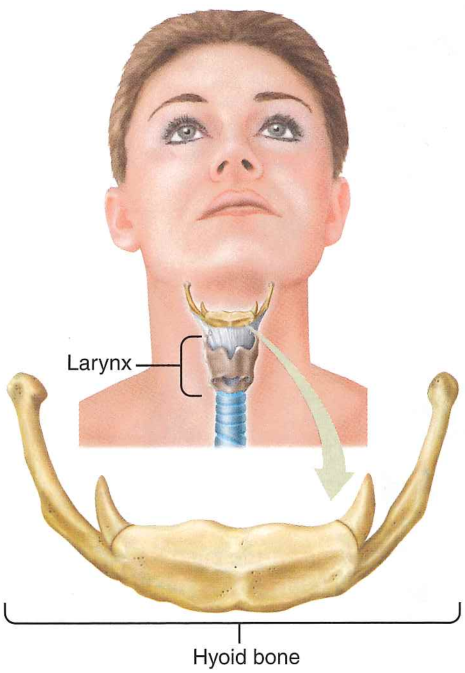


Figure 5.7 **The hyoid bone.**

The vertebral column: The body's main axis The **vertebral column** (the backbone or spine) is the main axis of the body (Figure 5.8). It supports the head, protects the spinal cord, and serves as the site of attachment for the four limbs and various muscles. It consists of a column of 33 irregular bones called *vertebrae* (singular: *vertebra*) that extend from the skull to the pelvis. When viewed from the side the vertebral column is somewhat curved, reflecting slight differences in structure and size of vertebrae in the various regions.

We classify the vertebral column into five anatomical regions:

- Cervical (neck)—7 vertebrae.
- Thoracic (the chest or thorax)—12 vertebrae.

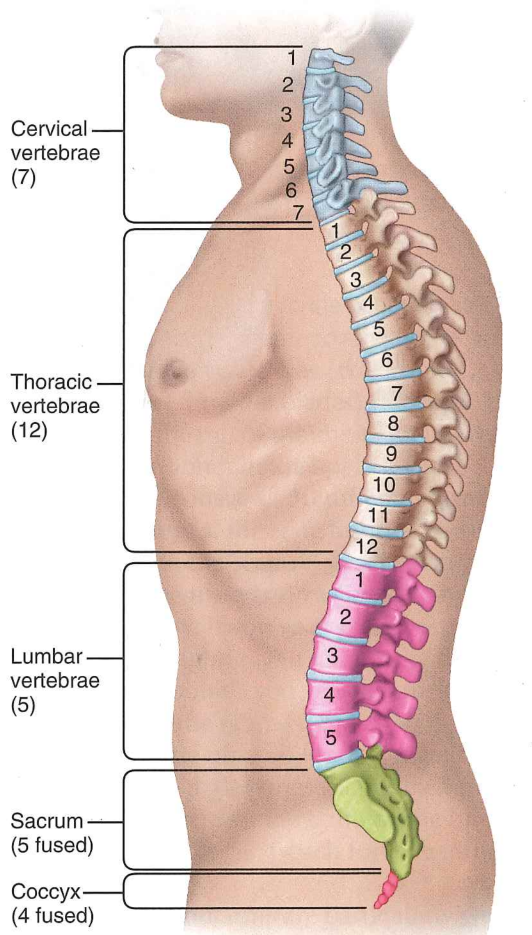


Figure 5.8 **The vertebral column.** Vertebrae are named and numbered according to their location. The vertebral column is moderately flexible because of the presence of joints and intervertebral disks.