CHAPTER

4 The Skeletal System

HOSA Event Prep

Do you participate in any sports? Being active in sports is a healthy way to get the exercise your body needs. Basketball, softball, hockey, lacrosse, soccer...all of these and more are good sources of exercise. However, if you play sports long enough, sooner or later, you will experience an injury.

Sports medicine is the healthcare field that specializes in treating injuries caused by playing various sports. HOSA's *Sports Medicine* event highlights the knowledge and skills required for patient care in a sports medical setting. This event concentrates on sports-related musculoskeletal injuries and how they are treated.

If sports medicine interests you, you may want to go to the HOSA website at https://hosa.org/guidelines/ to find out more about HOSA's *Sports Medicine* event. What is involved in this event? Is it a written or practical (skills assessment) event, or both? What information presented in this chapter may help you prepare for this event? If you decide you want to participate in this event, check with your HOSA advisor for more information about guidelines and procedures.

Why are bones considered "living tissue"?

People tend to think of bone as a hard, dried-up chunk of mineral that a dog would enjoy chewing. While this is true of dead bone, the living bones inside the human body are made up of amazing, complex living tissues. Bones are not only hydrated (containing water), but also very dynamic, continually changing in size, shape, and strength over time.

How and why do these processes of change occur? This chapter explores the characteristics of living bone and describes the well-tailored functionality of the major bones and joints in the human skeleton. It also discusses some of the common injuries and disorders of the bones and joints, how these problems tend to occur, and how their likelihood can be reduced.

Building Your Portfolio

Take digital photographs of the models and projects you create as you work through this chapter. Create a document called "The Skeletal System" and insert the photographs, along with written descriptions of what the models show and your reasons for creating them using the materials and forms you choose. Add this document to your personal portfolio.

Chapter 4 Outline

Chapter-opening image: Life science/Shutterstock.com

LESSON 4.1 Bone as a Living Tissue

Before You Read

Try to answer the following questions before you read this lesson.

- Do all bones have the same internal structure?
- When and why do bones stop growing?
- What practices can make bones stronger or weaker?

Learning Outcomes

4.1-1 Describe the functions of the skeletal system.

4.1-2 Describe the anatomical structure of the various types of bones.

4.1-3 Discuss bone remodeling, including the cells responsible and the practices and environments that can dramatically influence remodeling.

Key Terms

articular cartilage	medullary cavity
bone marrow	ossification
cortical bone	osteoblasts
diaphysis	osteoclasts
endosteum	osteocytes
epiphyseal plate	osteon
epiphysis	perforating (Volkmann's) canals
Haversian canals	periosteum
Haversian system	remodeling
hematopoiesis	trabecular bone
lacunae	

The approximately 206 individual bones comprising the human skeleton come in many different sizes and shapes, each uniquely well designed to serve a particular function. This lesson describes the structure and function of human bones, as well as their development and maintenance throughout a person's lifetime.

4.1-1 Functions of the Skeletal System

The skeletal system performs several important functions. These functions are summarized in this section.

Support

It is hard to imagine humans without bones because, like the wooden framework of a house, bones form the internal support system that provides shape and structural support to the body's trunk and limbs. The bones in your legs enable you to stand upright, and your ribs support your chest cavity.

Protection

Bones surround and support the body's delicate internal organs. For example, the ribs serve as bony protectors of critical organs such as the heart and lungs nestled in the thoracic cavity. Equally important, the skull provides protection for the brain, and the vertebral column surrounds and protects the delicate spinal cord.

Movement

What produces human movement? Movement is generated by muscles, which attach to bones. When muscles contract or shorten, they pull on the attached bones, causing movement.

The design of the skeletal system, with bones able to rotate or glide in certain ways around joints, is extraordinarily functional. This amazing design enables walking, running, jumping, pushing, pulling, and throwing, as well as all of the routine activities that people take for granted every day.

A joint such as the shoulder allows movement in multiple directions, while movement at the knee is largely constrained to one direction. These movement capabilities are favorably designed for the ways in which humans move. You will learn more about the muscles and how they work in the next chapter.

Storage

Bones also serve as a storage repository for minerals, notably phosphorus and calcium. Phosphorus plays a vital role in the development and maintenance of healthy bones and teeth, and it also plays a role in the chemical reactions that release energy from stored fat in the body. Calcium is essential for normal functioning of the neuromuscular system, as well as for blood clotting. Through a chemical balancing procedure known as homeostasis (hoh-mee-oh-STAY-sis), discussed in Chapter 1, the body can draw upon the stored phosphorus or calcium in bone if the levels of these minerals in the bloodstream fall below normal. This process is under hormonal control. See Chapter 8 for more information about hormonal control of calcium.

Another storage site in the skeletal system is the **medullary** (MEHD-yoo-lair-ee) **cavity**, a central hollow space inside most of the long bones, such as those of the arms and legs. The medullary cavity is also known as the *marrow cavity* because it stores **bone marrow**, a flexible tissue found inside bones.

There are two types of bone marrow—yellow and red. Both types contain a rich blood supply. Yellow marrow, found within the medullary cavity, is a major storehouse for fat in the body. Red marrow is found in the cavities of many bones, including flat and short bones, bodies of the vertebrae, sternum, ribs, and articulating ends of long bones.

Blood Cell Formation

It is in the red marrow that the critically important function of **hematopoiesis** (hee-ma-toh-poy-EE-sis), or blood cell formation, occurs. As you will discover in Chapters 10 and 11, blood cells deliver oxygen to tissues throughout the body and also transport waste in the form of carbon dioxide to the lungs, where it can be breathed out.

Check Your Understanding

1. List the five functions of the skeletal system.
2. What are two functions of bone marrow?

4.1-2 Structures and Classification of Bones

The composition and structure of bone make it remarkably strong and resilient, given its relatively light weight. Beyond this, bones assume specialized shapes in accordance with their specific functions.

Composition of Bones

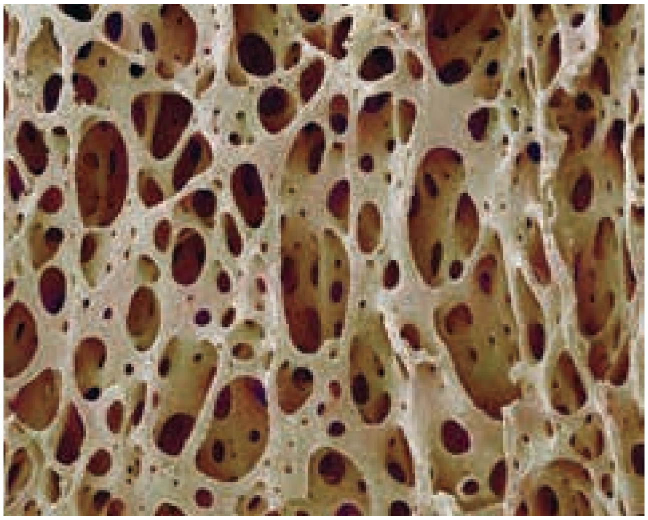
Cells are the structural building blocks of bone, as they are in other kinds of tissues in the body. **Osteocytes** are mature bone cells.

Bones have both organic and inorganic content. One factor that distinguishes bone from other tissues is that 60%–70% of a bone's mass comes from its mineral, or inorganic, content—primarily calcium carbonate and calcium phosphate. The remaining 30%–40% of bone mass comes from water and collagen, a protein that provides the bone with flexibility. Collagens and other proteins in bone are considered organic content. Both the mineral and water content contribute to bone strength. The bones of children tend to be more flexible than the bones of adults due to higher collagen and water content.

Organization of Bones

Bone is structurally organized into two different types of tissue—cortical (compact) and trabecular (cancellous) bone. **Cortical** (KOR-ti-kal) **bone** tissue, also known as *compact bone*, is relatively dense. **Trabecular** (tra-BEHK-yoo-lar) **bone** tissue, also known as *spongy bone*, is relatively porous, with a honeycomb structure (**Figure 4.1**). Cortical bone is stiffer due to its higher mineral content, so it is generally stronger than trabecular bone. Trabecular bone, with its spongy structure, is more flexible than cortical bone.

Most bones include both cortical and trabecular tissue. The function of a given bone determines whether it is composed mostly of cortical or trabecular bone. The outer layer of a bone is always composed of hard, protective cortical bone, with spongy trabecular bone present to varying degrees in the interior.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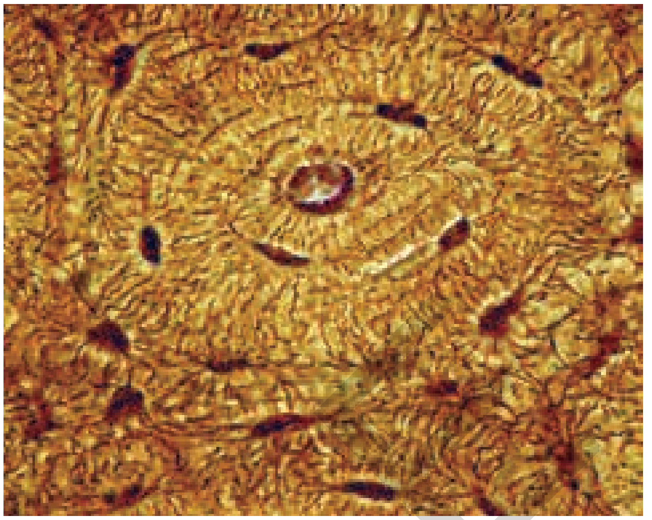
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Susumu Nishinaga/Science Source, Jose Luis Calvo/Shutterstock.com

Figure 4.1 A—A micrograph of trabecular bone tissue. B—Cortical bone tissue. *How would you describe the difference between trabecular and cortical bone to someone who knew nothing about these two types of bone tissue?*

The long bones in the arms and legs are primarily composed of strong cortical bone tissue, although there is trabecular bone inside the ends. The bones in the spinal column contain a large amount of trabecular bone inside their cortical encasings, giving them a certain amount of shock-absorbing capability. **Figure 4.2** compares the properties of these two types of bone tissue.

MEMORY TIP

The word *cortical* (coming from *cortex*) pertains to the outer layer of something. For example, the outer layer of the brain is known as the *cerebral cortex*. The outer layer of many structures and objects, including a plant stem or even a rock, is also known as its *cortex*. The type of bone tissue forming the outer layer of bone is therefore called *cortical* bone.

Shape Categories of Bones

Because of the large variety of sizes and shapes of the bones in the human skeleton, for purposes of discussion bones are traditionally divided into five categories (**Figure 4.3**):

- *Long bones* have a long, somewhat round shaft made of cortical bone, with bulbous knobs of trabecular bone encased in cortical bone at both ends. The shafts enclose the central hollow medullary cavity or canal. The major bones of the arms and legs are long bones.
- *Short bones* are shaped like a cube and are composed mainly of trabecular bone. The bones of the wrists and ankles are short bones.

Properties of the Two Types of Bone Tissue

	Cortical Bone	Trabecular Bone
Structure	dense	porous (honeycomb structure)
Mineral content	relatively high	relatively low
Strength	relatively high	low
Flexibility	low	relatively more
Shock-absorbing ability	low	relatively more
Primary locations	outer surface of all bones, long bones of limbs	interior of vertebrae, femoral neck, wrist, and ankle bones

Figure 4.2

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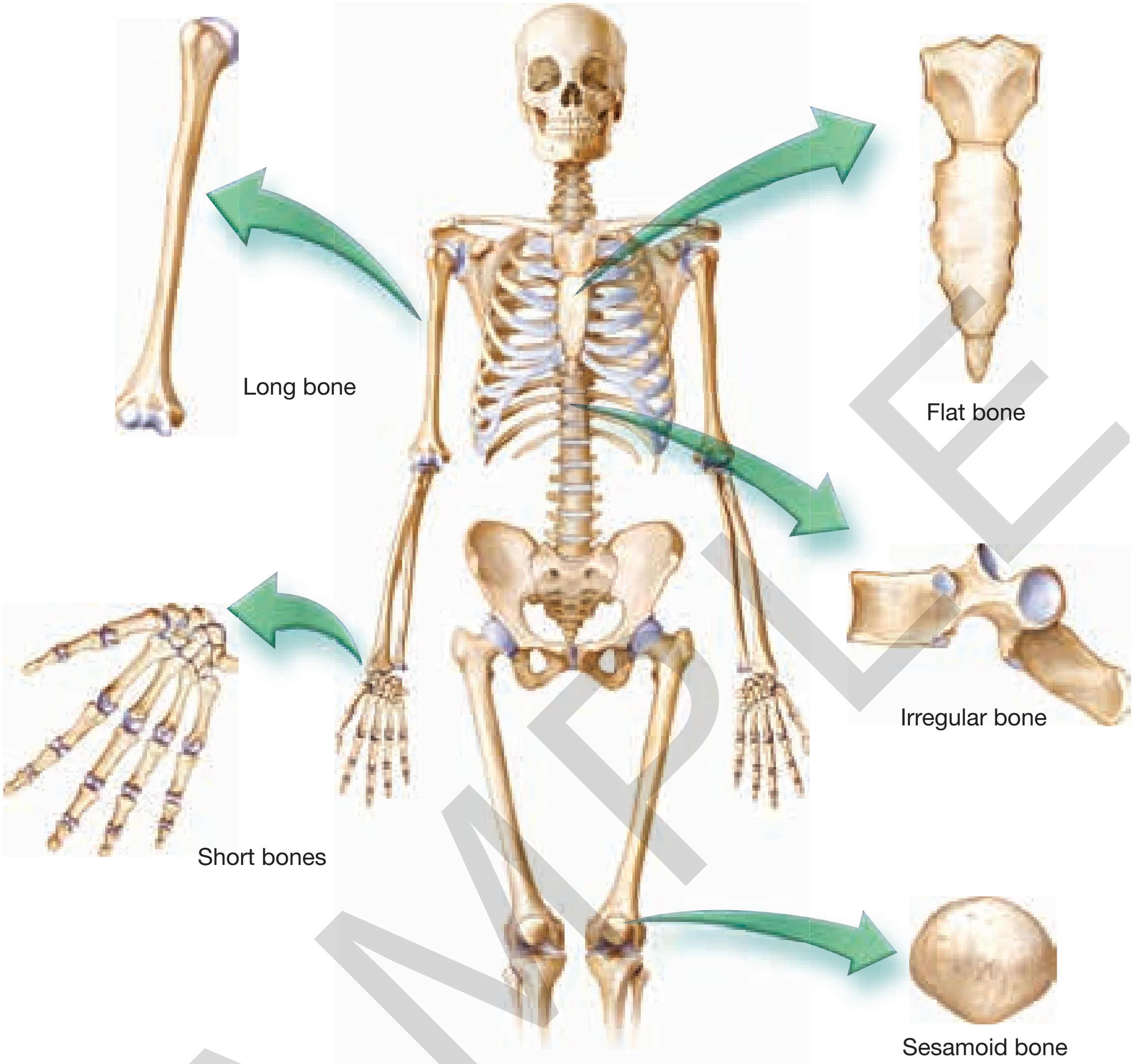


Figure 4.3 The five categories of bones.

- *Flat bones* are thin, relatively large in surface area, and generally curved to some extent. Structurally, they consist of two thin layers of cortical bone with a layer of trabecular bone in between. These bones protect underlying organs and also provide large areas for muscle attachments. The scapula and the bones of the skull are considered flat bones.
- *Sesamoid bones* are bones that are formed within tendons. The patella (at the front of the knee) is an example of a sesamoid bone.
- *Irregular bones* are all those bones that do not fit into one of the preceding categories. They have individualized shapes to fulfill specific functions. The bones of the spinal column and hip girdle are in this category.

Check Your Understanding

1. What percentage of bone mass comes from its mineral content?
2. What is collagen?
3. Where is cortical bone typically found?
4. Where is trabecular bone typically found?
5. List the five shape categories of bone.

Anatomical Structure of Long Bones

The **diaphysis** (digh-AF-i-sis) of a long bone is the hollow shaft of the bone composed of cortical bone (**Figure 4.4**). A fibrous connective tissue membrane called the **periosteum** (per-ee-AHS-tee-um) surrounds and protects the diaphysis. The periosteum contains blood and lymph vessels,

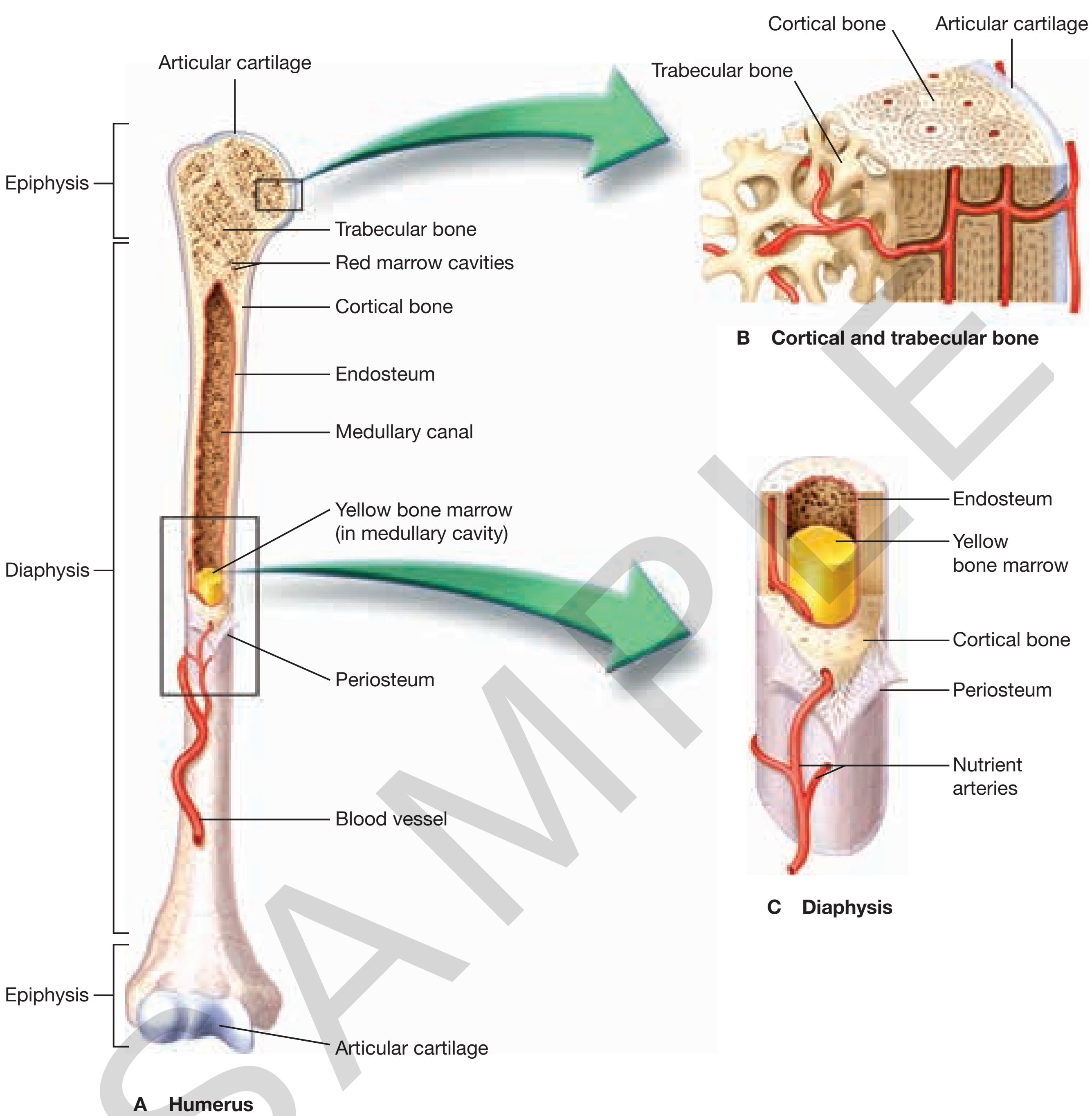


Figure 4.4 The anatomical structure of a long bone. A—Anterior view of the humerus with the interior of the top half exposed. B—Cortical and trabecular bone of the epiphysis. C—Enlargement of the diaphysis.

as well as nerves. It is involved in bone growth, repair, and nutrition.

The hollow center of the diaphysis is the medullary cavity, or canal. Beginning when a person is about five years old, this cavity is filled with yellow bone marrow, which has a rich supply of blood vessels and is a storehouse for fat. The medullary cavity is lined by a membrane known as the **endosteum** (ehn-DAHS-tee-um).

The bulbous endings of the long bones are known as **epiphyses** (eh-PIF-i-seez). These regions are composed of trabecular bone that contains red marrow, which participates in the formation of red blood cells, or erythrocytes (e-RITH-roh-sights), and some white blood cells, or leukocytes (LOO-koh-sights). Each epiphysis is surrounded by a protective covering of **articular** (ar-TIK-yoo-lar) **cartilage**. You may have noticed the shiny white

LIFE SPAN DEVELOPMENT: Bones

Over the course of the life span from birth through old age, some parts of the human body grow, while others tend to shrink. Knowledge of the processes by which bones grow and develop is key to understanding why these phenomena occur.

Osteoblasts and Osteoclasts

Specialized immature bone cells called **osteoblasts** (AHS-tee-oh-blasts) carry out the work of building new bone tissue. In this process, the osteoblasts secrete a collagen matrix and calcium salts. The area surrounding the osteoblast then calcifies and the osteoblast becomes trapped. The osteoblast then matures into an osteocyte. When there is a need to resorb or eliminate weakened or damaged bone tissue, that work is accomplished by other specialized cells called **osteoclasts** (AHS-tee-oh-klasts).

Bone growth clearly involves more osteoblast activity than osteoclast activity. However, both osteoblasts and osteoclasts remain extremely busy over the course of a normal person's life. In healthy adult bone, the activity of osteoblasts and osteoclasts is balanced.

MEMORY TIP

Osteoblast and *osteoclast* are similar-sounding names for these specialized bone cells. An easy way to avoid confusing them is to remember the "b" in *osteoblast* is the same as the "b" in *build*. Similarly, the "cl" in *osteoclast* is the same as the "cl" in *clear*. Osteoblasts *b*uild bone and osteoclasts *cl*ear away old or damaged bone.

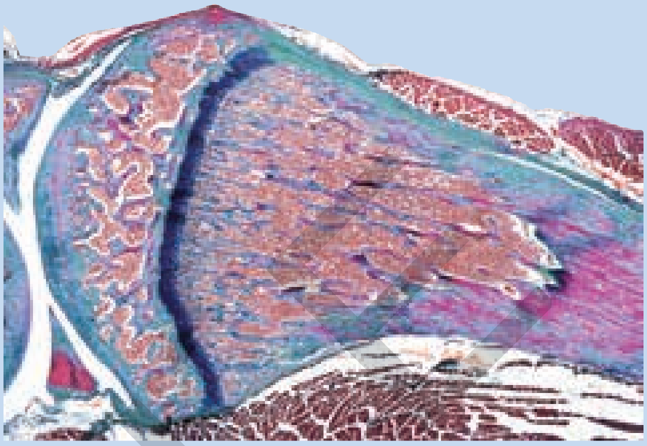
Bone Formation

Bone modeling is the process in which new bone is created through osteoblast activity during the formation and growth of immature bones. The skeleton of early-developing embryos is composed mainly of a flexible tissue called *hyaline cartilage*. By the end of the eighth week there is a rapid replacement of cartilage with bone in the developing fetus.

The process of bone formation is called **ossification** (ahs-i-fi-KAY-shun). Before birth, this occurs in two phases. During the first phase, a bone matrix shell covers the hyaline cartilage through the activity of osteoblasts. Next, osteoclasts resorb the enclosed hyaline cartilage, creating a medullary cavity within the bony superstructure.

Longitudinal Growth

Bones grow in length at the **epiphyseal** (ehp-i-FIZ-ee-al) **plates**, located close to the ends of long bones (**Figure 4.5**).



MicroScape/Science Source

Figure 4.5 Bones grow in length at the epiphyseal plates (the dark blue area). *When will this plate dissolve?*

During childhood growth, osteoblasts on the central side of the epiphyseal plate produce new bone cells, resulting in an increase in bone length. At the end of the growth period, occurring during or shortly after adolescence, the plate dissolves and the bone on either side of the plate fuses, ending the longitudinal growth of the bone.

Circumferential Growth

Although most bone growth occurs during childhood, bones actually grow in diameter, or width, throughout most of life (**Figure 4.6**). Osteoblasts in the internal layer of the periosteum build concentric layers of new bone on top of existing ones. To understand the process, it helps to visualize the way in which the rings on a cross-cut tree stump reveal the tree's growth.

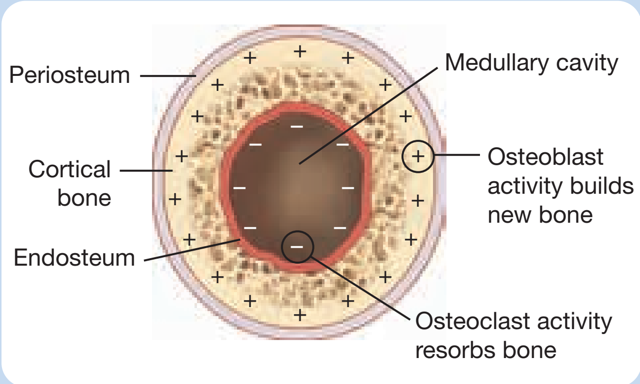


Figure 4.6 Cross section of a long bone showing normal bone throughout life. *Is it the circumference or the length of bones that continues to grow throughout life?*

(continued)

At the same time that the osteoblasts are doing their work, the osteoclasts resorb layers of bone inside the medullary cavity, causing the diameter of the cavity to be progressively enlarged. This beautifully engineered process occurs in such a way that a healthy bone remains optimally functional, lightweight, and strong enough to resist daily stresses.

Adult Bone Development

As people age, there is a progressive loss of collagen and a subsequent increase in bone brittleness. This means that children are often able to sustain falls and other accidents without harm, while older adults tend to be increasingly vulnerable to bone fractures.

Bone mineral normally peaks in women at about 25 to 28 years of age and in men at about 30 to 35 years of age. Thereafter, bone mass is progressively lost. Because women tend to have smaller bones than men, the loss of bone mass and bone mineral density is generally more problematic for women.

Life Span Review

1. During which parts of life are osteoblasts and osteoclasts active?
2. How and why is the medullary cavity in bone enlarged?
3. What is the importance of the epiphyseal plate?
4. Why are elderly individuals more prone to bone fractures?
5. What is the role of osteocytes in bone growth and repair?

covering of articular cartilage over the ends of the bone in chicken drumsticks.

How does living bone receive nourishment and get rid of waste products? Bone has what you might think of as its own subway system. An intricate array of passageways exists at a microscopic level inside the mineralized part of bone. Blood vessels and nerves course through these tiny tunnels (**Figure 4.7**). Major passageways running lengthwise through the bone are called **Haversian** (ha-VER-zhen) **canals**. Tiny cavities called **lacunae** (la-KOO-nee) are

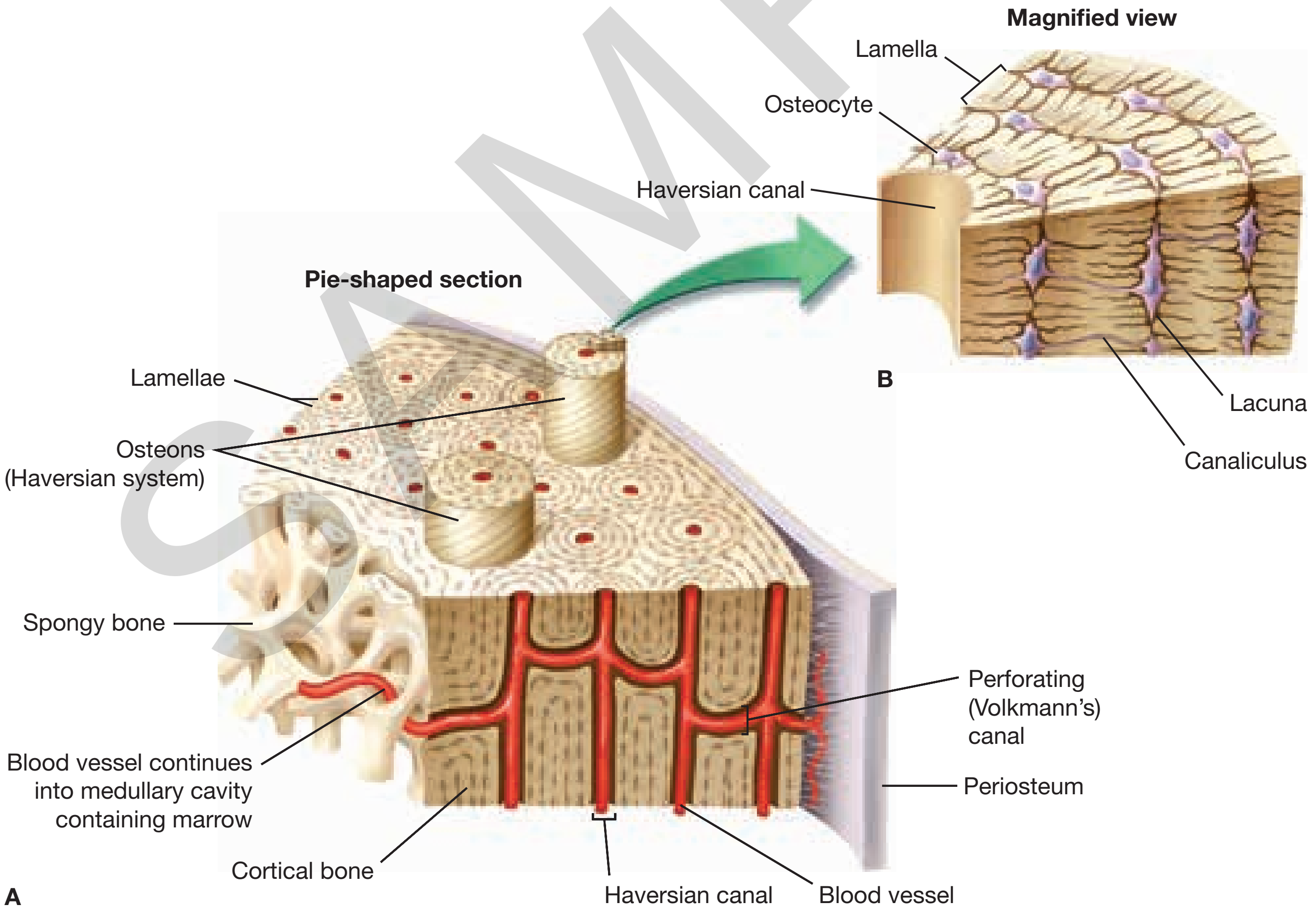


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Figure 4.7 A—A microscopic view of the inside of bone tissue. B—An even more magnified view. *Why might someone compare the inside of living bone to a subway system?*

What Research Tells Us

...about Physical Activity and Bones

There are many documented examples of bone remodeling, and hypertrophy (enlargement), in response to regular physical activity. Sports that require repeated, forceful use of a certain limb promote not only muscle hypertrophy, but also bone hypertrophy, in the stressed area. For example, clinical case studies have shown increased bone mass, circumference, and mineralization in the dominant forearm of professional tennis players and in the dominant upper arm of baseball players.

It also appears that the larger the forces habitually encountered, the more dramatic the effect. In one interesting study, researchers measured the density of the femur among 64 nationally ranked athletes from different sports. The densest femurs were those of the weight lifters, followed by hammer and discus throwers, runners, soccer players, and swimmers. As you might expect from this research, the size of the regularly acting forces on the body is one factor that appears to be related directly to bone mass.

The other important factor contributing to increased bone mineral density is absorption of repeated impacts, such as those routinely encountered during running and landings from jumps (**Figure 4.8**). In an investigation involving collegiate female athletes, those participating in high-impact sports (basketball and volleyball) were found to have much higher bone mineral densities than the swimmers, with the soccer and track athletes having intermediate values. Another study compared the bone mineral densities of trained runners and cyclists to those of sedentary individuals of the same age. Not surprisingly, the runners were found to have increased bone density, but the cyclists did not.

On the whole, the evidence suggests that physical activity involving impact forces is necessary for maintaining or increasing bone mass. One need not be an athlete, however, to exercise for bone health—even vigorous walking generates bone-building impact forces.

Competitive swimmers, who spend a lot of time in the water where the buoyant force counteracts gravity, may have even less bone mineral density than sedentary individuals. It is important for competitive swimmers to also participate in activities such as weight training and running to maintain normal bone density.

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Figure 4.8 *Why is running especially good for bones?*

Taking It Further

1. Explain in your own words the relationship between physical activity, bone remodeling, and hypertrophy.
2. Create a continuum, placing activities that negatively impact bone mass, such as swimming, on one end and those that increase bone mass (for example, basketball and volleyball) on the other end. Plot your daily activities on the continuum. Could you change your routine in a way that would increase your ability to build bone mass?

laid out in concentric circles called *lamellae* (la-MEHL-ee) around the Haversian canals, and it is the lacunae that house the osteocytes.

Each Haversian canal, with its surrounding layers of lacunae, forms a structural unit called an **osteon**, or **Haversian system**. Within the system are tiny sideways canals called *canaliculi* (kan-ah-LIK-yoo-ligh). The canaliculi connect with the lacunae, forming a comprehensive transportation matrix for supply of nutrients and removal of waste products throughout the Haversian system. The multiple Haversian systems are joined by **perforating (Volkmann's) canals**, also running sideways, that connect the Haversian canals.

Check Your Understanding

1. What is the periosteum? Name at least three functions of the periosteum.
2. Where is the endosteum found? Is it inside or outside the periosteum?
3. What covers the ends of long bones?
4. Describe the functions of osteoblasts and osteoclasts.
5. Describe and analyze the effects of less elasticity on the body as people age.

4.1-3 Remodeling of Bones

Living adult bone is a very active tissue, always changing at a microscopic level in bone mineral content (and thereby strength) and sometimes in size or shape. This occurs through osteoblast and osteoclast activity during a process called **remodeling**.

Forces, such as gravitational force, muscle forces, forces received when you push or pull on something, and impact forces when you bump into something, all influence bones. The remodeling process converts the size and direction of the forces acting on bone to changes in bone mineral density. (Refer to Chapter 1 for more information about the effects of forces on the body.) In some circumstances, the remodeling process also causes changes in the size or shape of bone.

Hypertrophy of Bones

Generally, when bone is subjected to larger (stronger) forces, it tends to *hypertrophy* (high-PER-troh-fee), with increases in density and growth at the sites of force application (often muscle attachments). As a result, the bones of people who are physically active are usually denser and stronger than the bones of people who are sedentary.

Because gravity is also a force that continuously acts on bones, people who are heavier tend to have greater bone mass and density than people who are lightweight for their height. Dynamic activities such as running and jumping involve landing impacts, which cause motion of fluid within the bone matrix. This motion is particularly effective at triggering the actions of osteoblasts to build bone.

Altogether, bones account for only about 15% of body weight. This tends to be true whether a person is underweight, of average weight, or overweight. No one is overweight because of heavy bones, however. Being overweight is almost always the result of carrying excess body fat.

Atrophy of Bones

People who are subject to reduced forces are prone to bone *atrophy*, or loss of bone mineral density and strength. This has been observed, for example, in individuals who are bedridden for long periods of time.

Somewhat surprisingly, bone atrophy has also been observed in elite swimmers who spend hours a day training in a swimming pool. Swimming involves a large amount of muscle activity, but the buoyancy of the water counteracts much of the force of gravity. So, while swimmers are in the water, their bones are subjected to greatly reduced stresses.

Loss of bone mass and strength is an even more significant problem for astronauts, who spend time completely out of the earth's gravitational field. The loss of bone in astronauts in space is so rapid that it is currently one of the major factors preventing a manned space mission to Mars.

Check Your Understanding

1. What factors can cause bone to hypertrophy, increasing mass, density, and sometimes circumference?
2. What factors can cause bone to atrophy, losing mass and mineralization?

LESSON 4.1 Review and Assessment

Mini Glossary

Make sure that you know the meaning of each key term.

articular cartilage dense, white, connective tissue that covers the articulating surfaces of bones at joints

bone marrow material with a rich blood supply found within the marrow cavity of long bones; yellow marrow stores fat, and red marrow is active in producing blood cells

cortical bone dense, solid bone that covers the outer surface of all bones and is the main form of bone tissue in the long bones

diaphysis the shaft of a long bone

endosteum membrane lining the medullary cavity

epiphyseal plate growth plate near the ends of long bones where osteoblast activity increases bone length

epiphysis the bulbous end of a long bone

Haversian canals major passageways running in the direction of the length of long bones, providing paths for blood vessels

Haversian system a single Haversian canal along with its multiple canaliculi, which branch out to join with lacunae, forming a comprehensive transportation matrix for supply of nutrients and removal of waste products; also called an *osteon*

hematopoiesis process of blood cell formation

lacunae tiny cavities laid out in concentric circles around the Haversian canals

medullary cavity central hollow in the long bones

ossification process of bone formation

osteoblasts specialized bone cells that build new bone tissue

osteoclasts specialized bone cells that resorb bone tissue

osteocytes mature bone cells

osteon a Haversian system

perforating (Volkmann's) canals large canals that connect the Haversian canals; also known as *perforating canals*; oriented across bones and perpendicular to Haversian canals

periosteum fibrous connective tissue membrane that surrounds and protects the shaft (diaphysis) of long bones

remodeling process through which adult bone can change in density, strength, and sometimes shape

trabecular bone interior, spongy bone with a porous, honeycomb structure

Know and Understand

1. List each of the five functions of the skeletal system and describe how they benefit the body. (LO 4.1-1)
2. Explain the differences between cortical bone and trabecular bone. (LO 4.1-2)
3. Describe where the diaphysis of a long bone is in relation to the epiphysis, and where the periosteum is in relation to the endosteum. (LO 4.1-2)
4. Briefly describe the process of remodeling. (LO 4.1-3)

Analyze and Apply

1. Compare and contrast osteoblasts and osteoclasts and explain how they work together to reshape and remodel bones. (LO 4.1-2)
2. Explain why a physician might be worried about a child who broke a long bone close to the epiphyseal plate. (LO 4.1-2)
3. Keeping in mind the properties of cortical and trabecular bone tissue, describe the structure of a bone and why the two bone tissue types are found where they are in bones (outside or inside). (LO 4.1-2)
4. An elderly woman and her young granddaughter are involved in an automobile accident. The woman sustained several broken ribs, but her granddaughter did not have any injuries. In terms of bone mineralization, why might the older woman have sustained injuries, while her granddaughter did not? (LO 4.1-2)
5. Explain why someone whose job involves manual labor, such as construction, roofing, or carpentry, would have noticeably larger and stronger upper body bones than someone who has a different occupation. (LO 4.1-2)
6. Find out the difference between intramembranous and endochondral ossification. Name your sources. (LO 4.1-2)

IN THE LAB

1. Before reading further in this chapter, make labels for all the bones that you can name. Quickly research the bones identified on your labels. Taking turns with your classmates, place your labels on the correct bones of the classroom skeleton and tell what category (long, short, flat, sesamoid, irregular) each bone belongs to. (LO 4.1-2)
2. Draw or trace a cross-section picture of a long bone. Label the outside parts: epiphysis, diaphysis, and articular cartilage. Using different colors, draw and label the inside parts: trabecular bone, endosteum, yellow bone marrow, medullary cavity, and red marrow. On a separate piece of paper, describe each part that you have labeled. (LO 4.1-2)

LESSON **4.2**

The Axial Skeleton

Before You Read

Try to answer the following questions before you read this lesson.

- Why is the skull composed of multiple bones?
- Why is the spine curved instead of straight?

Learning Outcomes

4.2-1 Identify the bones of the skull and describe their locations.

4.2-2 Describe the structure of a typical vertebra and explain how the atlas, axis, and other cervical, thoracic, and lumbar vertebrae are specialized for their specific functions.

4.2-3 Discuss the structure and functional importance of the thoracic cage.

Key Terms

atlas	maxillary bones
axial skeleton	process
axis	sacrum
cervical region	skull
coccyx	sternum
cranium	sutures
facial bones	thoracic cage
fontanel	thoracic region
intervertebral discs	vertebrae
lumbar region	vomer
mandible	

Anatomists divide the body into the axis, consisting of the head and trunk, and the appendages—the arms and legs (**Figure 4.9**). Consequently, the major bones of the axis are known as the **axial skeleton**, which includes three major parts—the skull, vertebral (spinal) column, and thoracic cage. The axial skeleton is designed to provide stability to the core of the body. This lesson discusses the axial skeleton. Lesson 4.3 describes the appendicular skeleton.

4.2-1 The Skull

The 22 bones of the **skull** are divided into two groups: the cranial and the facial bones (**Figure 4.10**). The thin, curved bones of the **cranium** surround and protect the delicate brain. The round shape of the cranium is structurally strong in resisting impact forces and tends to absorb less force than if it were composed of flat surfaces. The **facial bones** protect the front of the head, give people's faces their individual shapes, protect and orient the eyes, and allow chewing of food.

Most of the bones of the skull and face are joined together by irregularly shaped, interlocking, and immovable joints called **sutures**. A suture is a joint in which bones of the skull are bound together by strong, tiny fibers. The sutures permit a very small amount of movement, which contributes to the compliance (ability to change size and shape in response to force) and elasticity of the skull. The one exception is the mandible, or jawbone, which is attached to the skull by a movable joint (for obvious reasons!).

The skull of a newborn infant is quite different from the adult skull. Compared to adults, babies have big heads relative to the size of their bodies. Whereas the skull of an adult accounts for about one-eighth of total body height, the skull of a newborn represents about one-fourth of body height.

As previously discussed, the skeletal system of children includes regions of hyaline cartilage. The sutures of the skull in infants are composed of this soft, connective tissue, which will ossify (turn to bone) in early childhood. In regions of the infant skull where several bones join together, there are openings connected only by pockets of fibrous membranes. Because the baby's pulse can be felt through these "soft spots," they have been given the name **fontanel** (fahn-ta-NEHL), which is French for "little fountain."

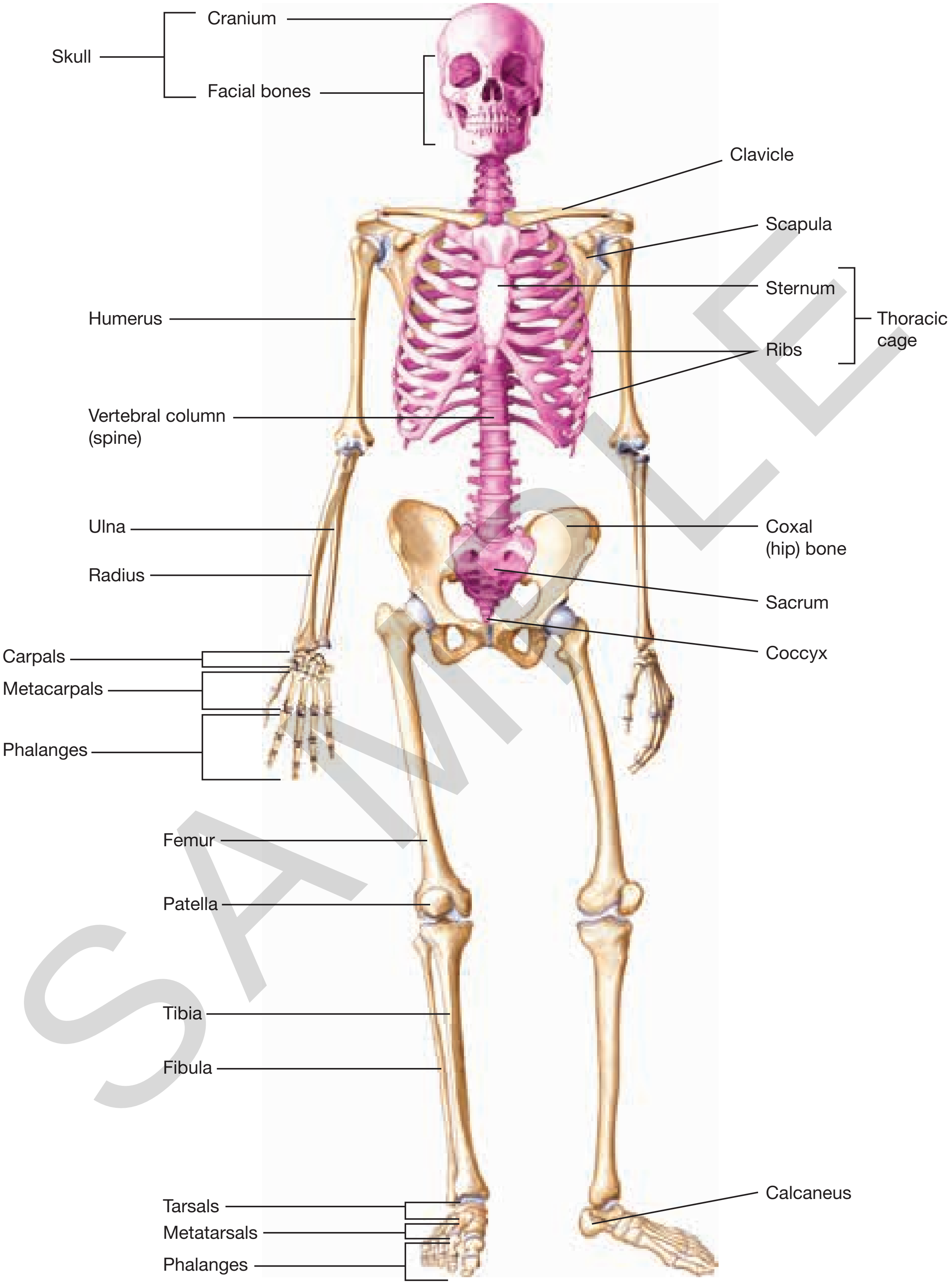

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Figure 4.9 The axial skeleton (shown in a reddish color) and the appendicular skeleton.

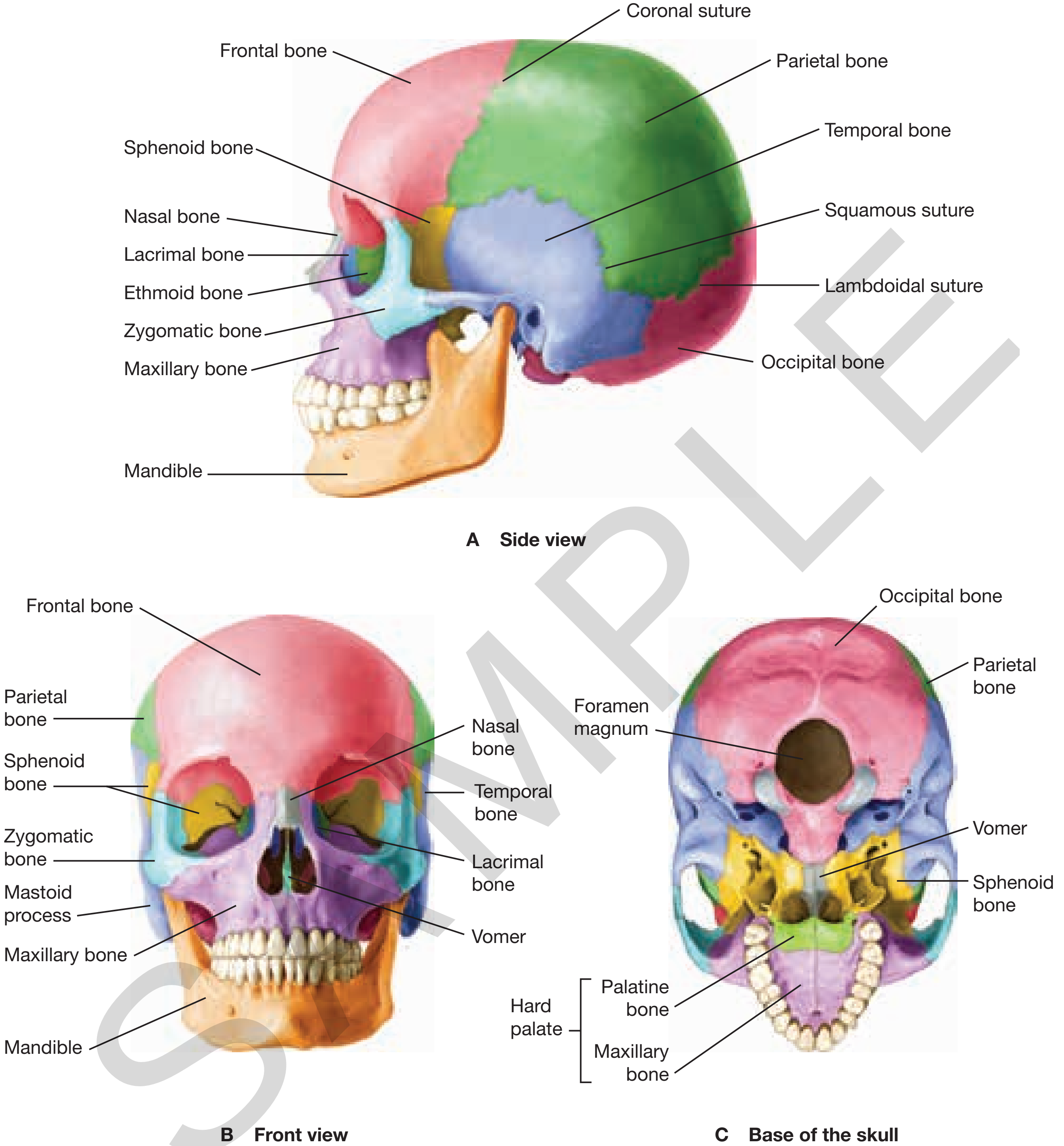

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Figure 4.10 Bones of the skull. *How many bones go together to make up the skull? What type of joints hold these bones together?*

The soft sutures and fontanels serve two important functions. They enable some compression of the skull (the largest part of the body) during birth. Equally important, they enable brain growth during late pregnancy and early infancy. The fontanels ossify to bone by 22 to 24 months following birth.

The Cranium

The cranium includes eight bones. There are two sets of paired (left and right side) bones; the rest are single bones. The bones that make up the cranium include:

- the *frontal bone*, which forms the forehead
- the two paired *parietal* (pah-RIGH-eh-tal) *bones*, which form the majority of the top and sides of the skull
- the two paired *temporal* (TEHM-poh-ral) *bones*, which surround the ears
- the *occipital* (ahk-SIP-i-tal) *bone*, which forms the base and lower back portions of the skull
- the *ethmoid* (EHTH-moyd) *bone*, which forms part of the nasal septum
- the *sphenoid* (SFEE-noyd) *bone*, which is butterfly shaped and centrally located within the skull. The sphenoid bone supports part of the base of the brain, forms part of the orbits of the eyes, and is connected to all of the other bones of the skull.

The Facial Bones

A total of fourteen bones form the face, including the mandible (MAN-di-buhl), vomer (VOH-mer), and six pairs (left and right) of bones. The facial bones include:

- the two fused **maxillary** (MAK-si-lair-ee) **bones**, which form the upper jaw, house the upper teeth, and connect to all other bones of the face, with the exception of the mandible
- the two *palatine* (PAL-a-tighn) *bones*, which form the posterior part of the hard palate, or roof of the mouth
- the two *zygomatic* (zigh-goh-MAT-ik) *bones*, or cheekbones, which also form much of the sides of the orbits, or eye sockets
- the two *lacrimal* (LAK-ri-mal) *bones*, tiny bones connecting to the orbits and surrounding the tear ducts
- the two *nasal bones*, forming the bridge of the nose
- the **vomer** (plow-shaped) bone, comprising most of the bony nasal septum
- the two *inferior concha* (KAHN-ka) *bones*, forming the sides of the nasal cavity
- the **mandible**, or lower jawbone, which is the largest facial bone, as well as the only movable facial bone.

Check Your Understanding

1. Scientists often divide the human skeleton into two parts. What are these parts called?
2. What holds the bones of the skull together? Is movement possible at these joints? Why is this important?
3. List the two functions of the fontanels in a baby's skull.
4. List the eight cranial bones and tell where each is found.
5. List the fourteen facial bones and tell where each is found.

4.2-2 The Vertebral Column

Although the word *spine* suggests a straight, rigid bar, the human spine, or vertebral column, is anything but straight and rigid. The human vertebral column is well designed to perform its functions of protecting the extremely delicate spinal cord, while supporting the weight of the trunk and allowing flexibility in multiple directions.

Thirty-three stacked, individual bones called **vertebrae** (VER-teh-bray) comprise the spine. The vertebrae differ in size and shape in the different regions of the spine to best fulfill their respective functions (**Figure 4.11**).

Regions of the Spine

There are five named sections of the spine:

- The **cervical** (SER-vi-kal) **region** (neck) includes the upper seven vertebrae that enable nodding the head up and down, as well as rotation to the right and left. The first cervical vertebra, the **atlas**, is specialized to provide the connection between the occipital bone of the skull and the spinal column (**Figure 4.12**). The second cervical vertebra, the **axis**, is also specialized, with an upward projection called the *odontoid process*, on which the atlas rotates.
- The **thoracic** (thoh-RAS-ik) **region** encompasses the next 12 vertebrae, which extend through the chest region and articulate (connect) with the ribs.

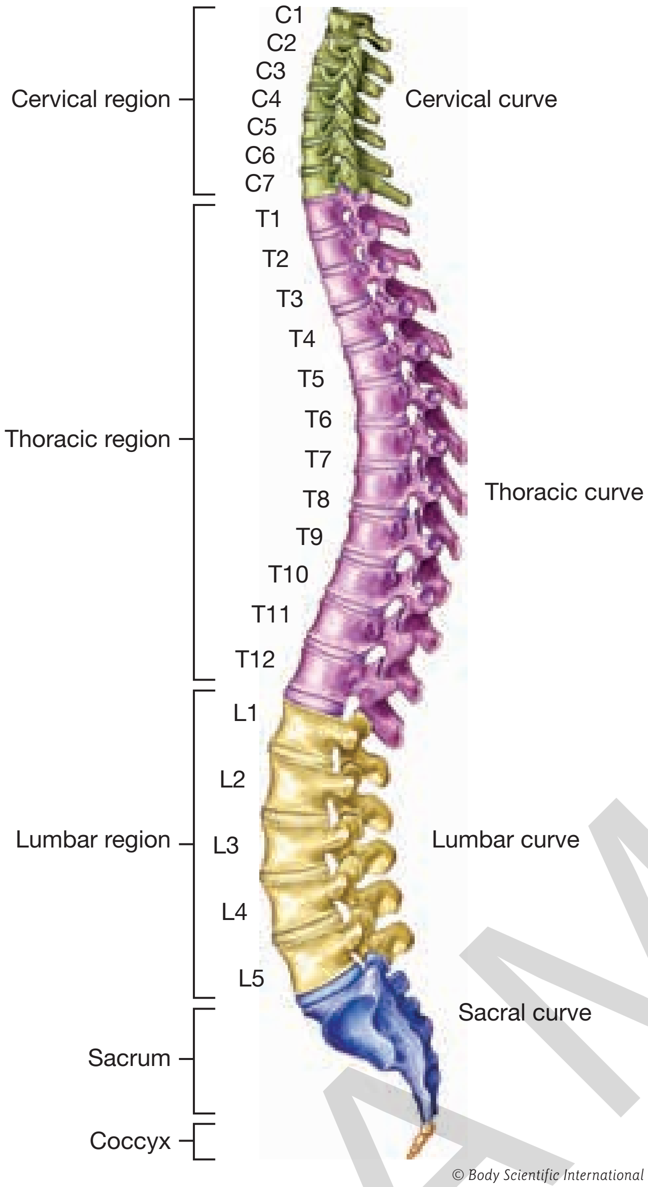


Figure 4.11 The vertebral column (spine). *How many bones make up the sacrum? The coccyx? How do these bones differ from the bones of the other three regions of the vertebral column?*

- The **lumbar** (LUM-bar) **region** includes the five vertebrae found in the lower back.
- The **sacrum** (SAY-krum) consists of five fused vertebrae that form the posterior portion of the pelvic girdle.
- The **coccyx** (KAHK-siks), or tailbone, located at the bottom of the spine, includes four fused vertebrae.

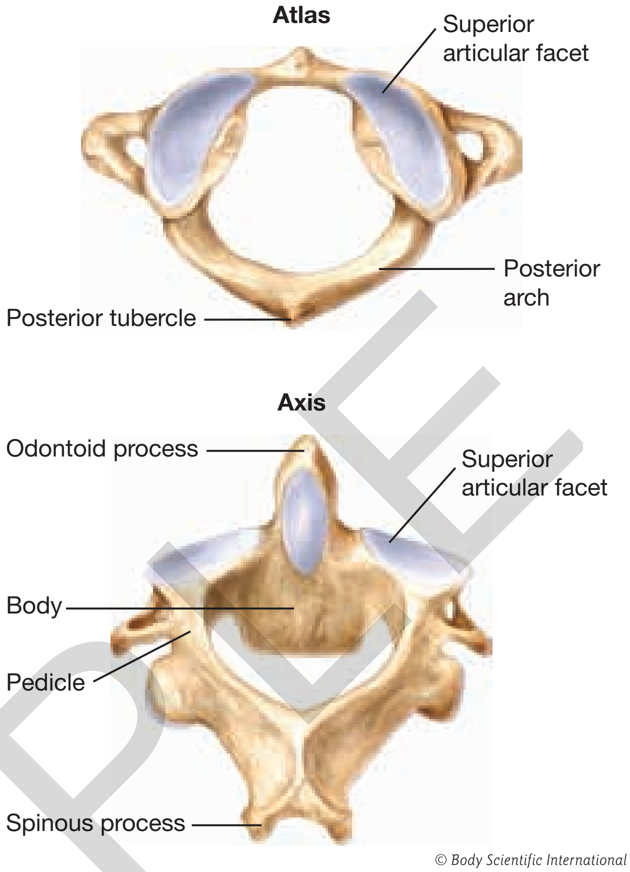


Figure 4.12 The first and second cervical vertebrae, the atlas and the axis.

Structures of the Vertebrae

Although no two vertebrae are exactly alike, most of the vertebrae have several structural features in common (**Figure 4.13**):

- The *vertebral body* is the thick, disc-shaped portion that bears weight and forms the anterior portion of the vertebra.
- The *vertebral arch* is the round projection of bone on the posterior aspect of the vertebra. It surrounds a hole known as the *vertebral foramen* (foh-RAY-mehn), through which the spinal cord passes.
- The *transverse processes* are bony projections on the lateral sides of the vertebral arch. In anatomy, a **process** is a projection on a bone or other tissue.
- The *spinous process* is a bony projection that extends posteriorly.

- The *superior* and *inferior articular processes* are indentations or facets where a vertebra articulates, or joins, with the vertebrae immediately above and below. These articulations are called *facet* (FAS-eht) *joints*.

Vertebral size increases progressively from the cervical region down through the lumbar region (**Figure 4.14**). This gradual size increase serves a functional purpose.

When the body is in an upright position, each vertebra must support the weight of all of the body parts positioned above it. Think about what this means. While a cervical vertebra supports only the weight of the head and neck, a lumbar vertebra supports the weight of the head, neck, arms, and all of the trunk positioned above that vertebra.

The size and angulation of the vertebral processes also vary throughout the spinal column. This changes the orientation of the facet joints, which connect the vertebrae and limit range of motion in the different spinal regions.

The Spinal Curves

The characteristic shapes of the vertebrae in the different spinal regions also form the normal spinal curves. As **Figure 4.11** shows, the cervical and lumbar curves are posteriorly concave, while the thoracic, sacral, and coccyx curvatures are anteriorly concave. These alternating curves make the spine stronger and better able to resist potentially injurious forces than if it were straight.

The thoracic and sacral curves are known as *primary spinal curves* because they are present at birth. The lumbar and cervical curves are referred to as *secondary spinal curves*. They develop after the baby begins to raise the head, sit, and stand, as increased muscular strength enables the young child to shift body weight to the spine.

Abnormal spinal curvatures can develop due to genetic or congenital abnormalities or when the spine is habitually subjected to asymmetrical forces (**Figure 4.15**). Exaggeration of the lumbar curve is termed *lordosis* (lor-DOH-sis), accentuation of the thoracic curve is called *kyphosis* (kigh-FOH-sis), and any lateral deviation of the spine is known as *scoliosis* (skoh-lee-OH-sis).

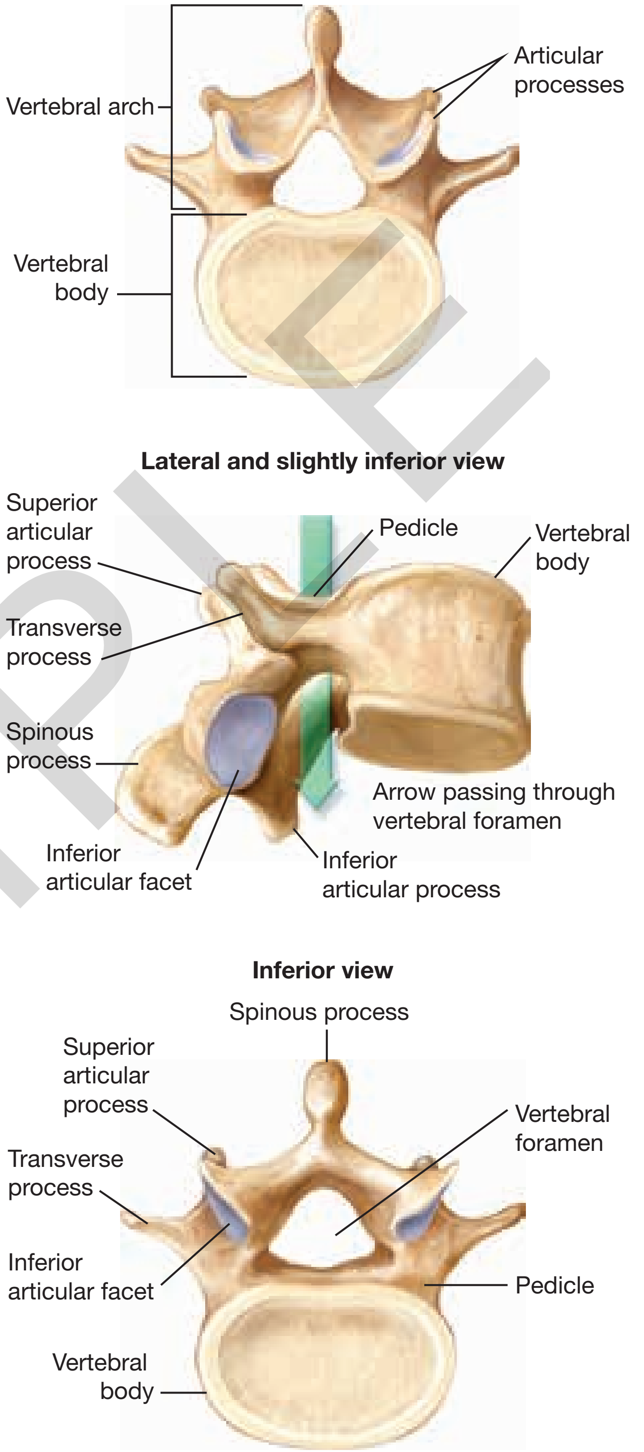


Figure 4.13 Three views of a typical vertebra. *What are the names of the indentations on the articular processes?*

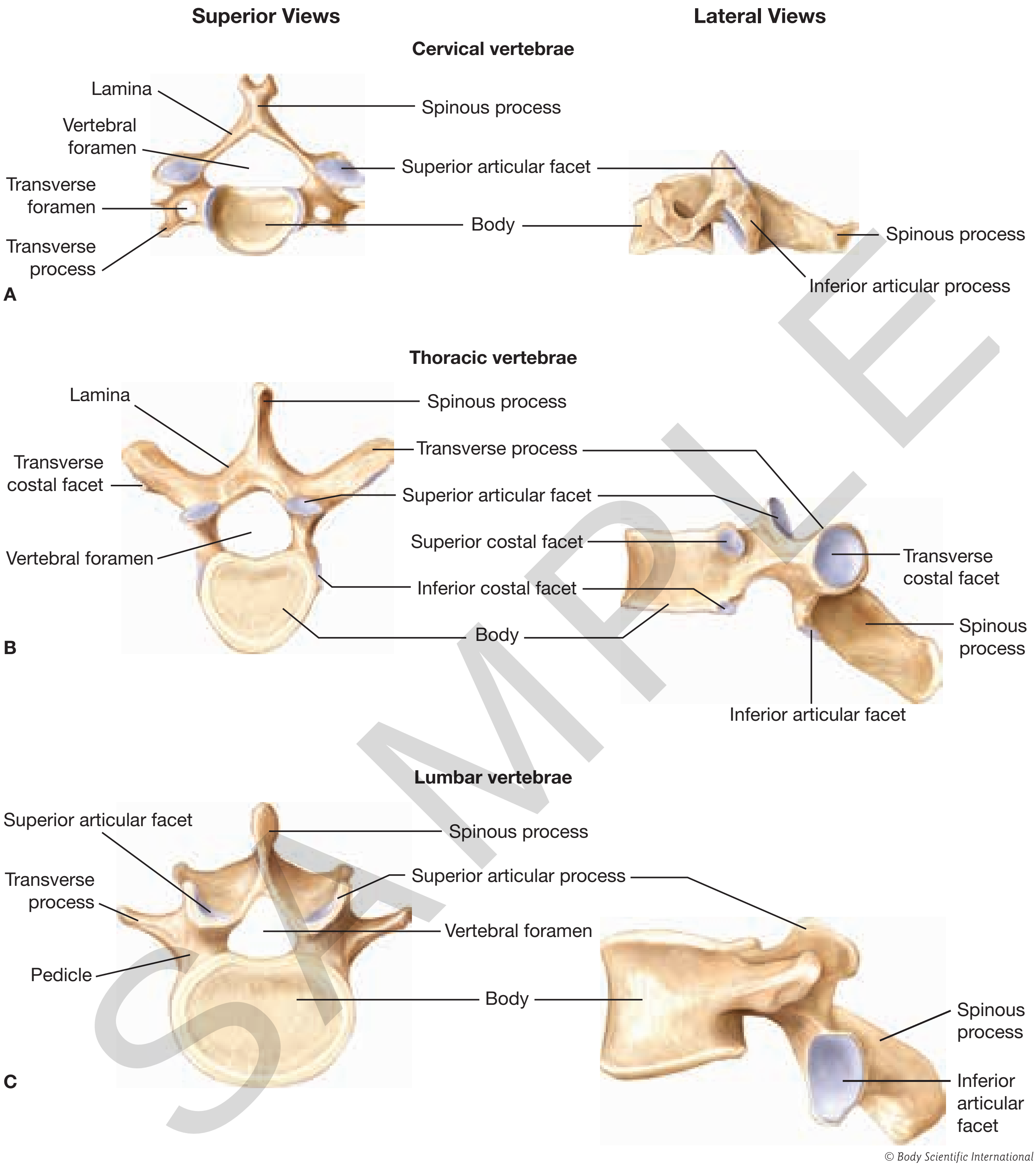


Figure 4.14 Superior and left lateral views of typical vertebrae. A—cervical vertebra. B—thoracic vertebra. C—lumbar vertebra.

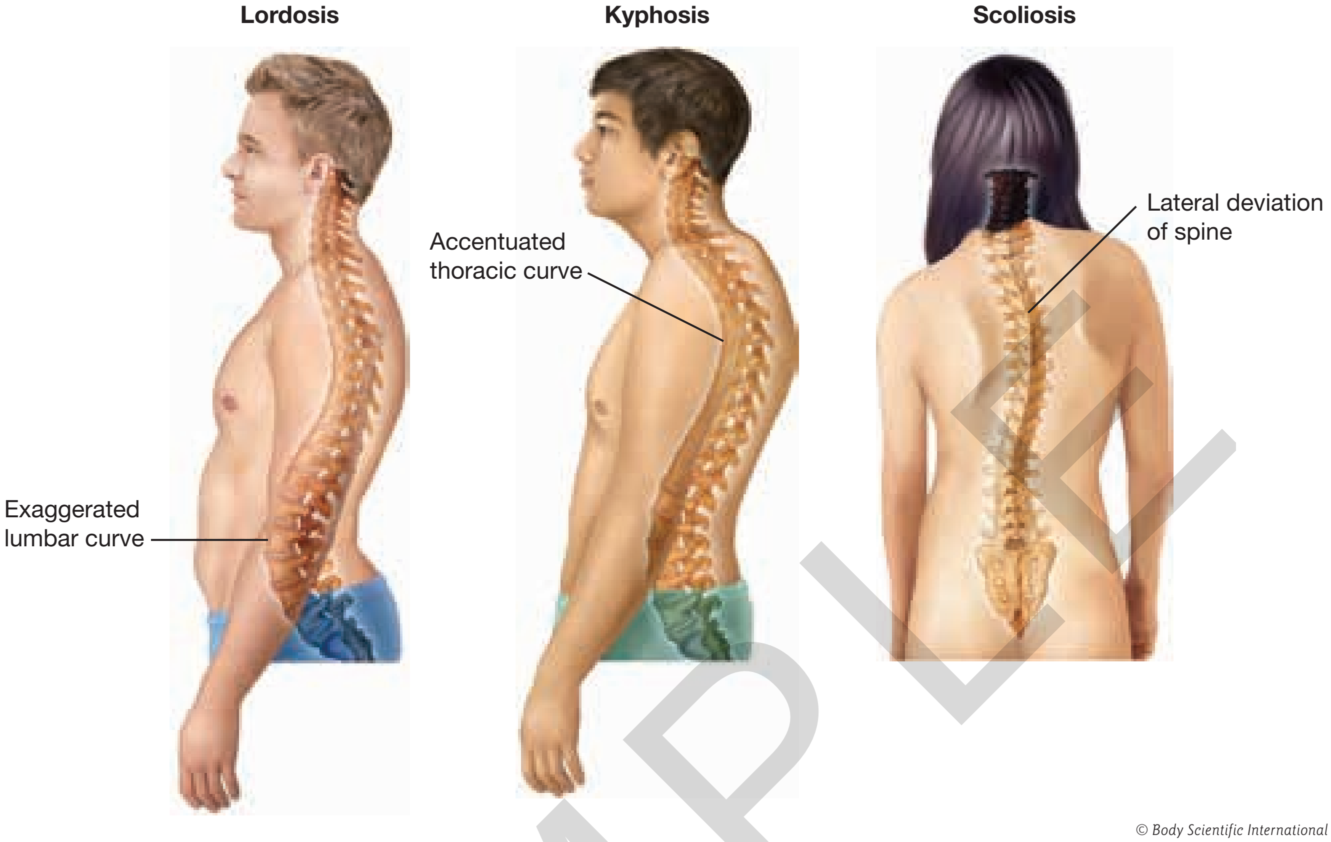


Figure 4.15 Three types of abnormal spinal curvature. *What are some causes of abnormal curvature?*

The Intervertebral Discs

Intervertebral (in-ter-VER-teh-bral) **discs** composed of fibrocartilage provide cushioning between all of the articulating vertebral bodies except those that are fused. These discs serve as shock absorbers and allow the spine to bend. The differences in the anterior and posterior thicknesses of these discs produce the normal cervical, thoracic, and lumbar curves.

In a normal adult, the discs account for approximately one-quarter of the height of the spine. When a person is lying in bed during overnight sleep, the discs absorb water and expand slightly. During periods of upright standing and sitting, when the discs are bearing weight, they lose a small amount of fluid and are compressed. For this reason, people are as much as three-fourths of an inch taller when they first arise in the morning. Injury and progressive aging reduce the water retention capability of the discs, accounting for diminished standing height in elderly individuals.

Because the discs receive no blood supply, they must rely upon changes in posture and body position to produce a pumping action that brings in nutrients and flushes out metabolic waste products with an influx and outflow of fluid. Because maintaining a fixed body position curtails this pumping action, sitting in one position for a long period of time can negatively affect disc health.

The Hyoid Bone

Technically not part of the cranium, spine, or thoracic cage, the hyoid bone is considered part of the axial skeleton. It is located at the base of the mandible and helps with movements of the tongue, larynx, and pharynx.

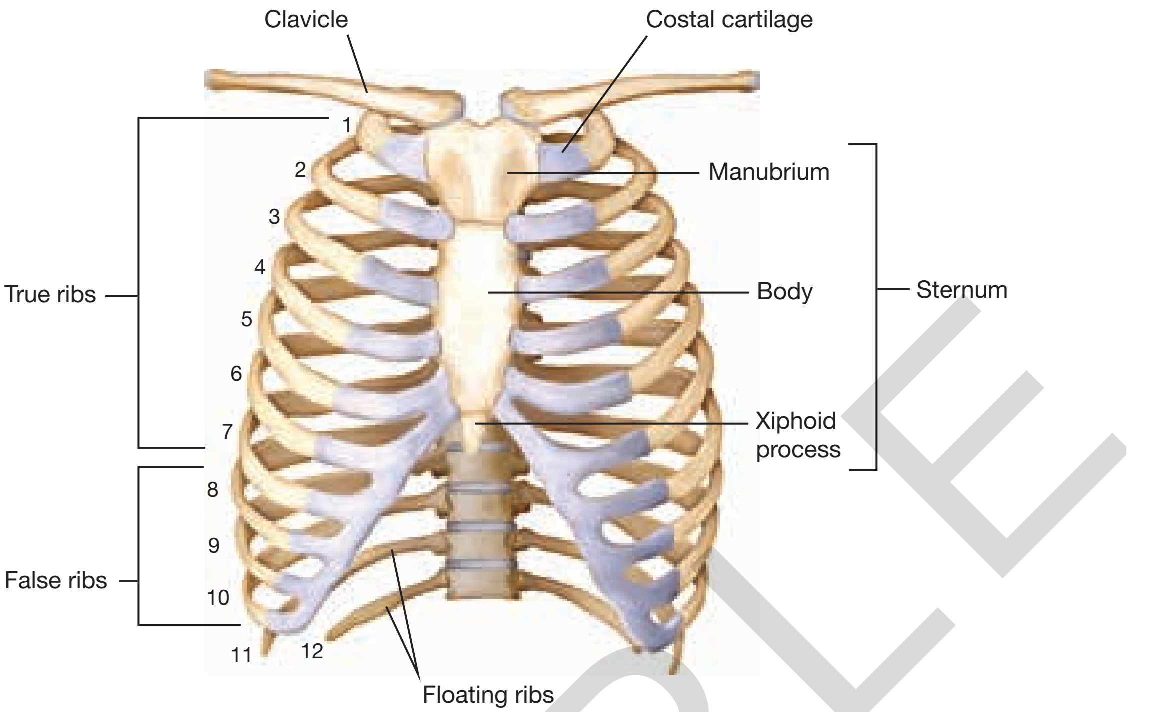


Figure 4.16 The thoracic cage. *Why are the false ribs called false ribs?*

Check Your Understanding

1. List the five regions of the vertebral column, from upper to lower.
2. What is the functional purpose of the vertebrae increasing in size from the cervical region down to the lumbar region?
3. What is the function of the intervertebral discs?

4.2-3 The Thoracic Cage

The ribs, sternum, and thoracic vertebrae are collectively known as the **thoracic cage**, or *bony thorax*. Why are these bones given this name? It is because together they form a protective, bony "cage" that surrounds the heart and lungs in the thoracic cavity, as shown in **Figure 4.16**. The **sternum** (STER-num), or breastbone, includes three regions:

- The *manubrium* (ma-NOO-bree-um) is the upper portion of the sternum. It has articulations to the left and right bones of the clavicle, or collarbone, as well as to the first and second ribs.
- The remainder of the bony portion of the sternum is the body of the sternum.
- At the lower end of the sternum is a projection called the *xiphoid* (ZIGH-foyd) *process*.

There are 12 pairs of ribs in the thoracic cage, as shown in **Figure 4.16**.

- The first seven pairs (1–7) attach directly to the sternum and are, therefore, called *true ribs*.
- The next three pairs of ribs (8–10) are called *false ribs* because they have cartilaginous (kar-ti-LAJ-i-nuhs) attachments to the cartilage of the seventh rib, rather than attaching directly to the sternum.
- The lowest two pairs of ribs (11–12) are known as *floating ribs*, because they do not attach to bone or cartilage in front of the body.

Check Your Understanding

1. Which bones make up the thoracic cage?
2. List the three regions of the sternum.
3. How many pairs of ribs are in the thoracic cage?

LESSON 4.2 Review and Assessment

Mini Glossary

Make sure that you know the meaning of each key term.

atlas the first cervical vertebra; specialized to provide the connection between the occipital bone of the skull and the spinal column

axial skeleton central, stable portion of the skeletal system, consisting of the skull, spinal column, and thoracic cage

axis the second cervical vertebra; specialized with an upward projection called the *odontoid process*, on which the atlas rotates

cervical region the first seven vertebrae, comprising the neck

coccyx four fused vertebrae at the base of the spine forming the tailbone

cranium fused, flat bones surrounding the back of the head

facial bones bones of the face

fontanel openings in the infant skull through which a baby's pulse can be felt; these openings enable compression of the skull during birth and brain growth during late pregnancy and early infancy

intervertebral discs fibrocartilaginous cushions between vertebral bodies that allow bending of the spine and help to create the normal spinal curves

lumbar region low back region of the spine composed of five vertebrae

mandible jawbone

maxillary bones two fused bones that form the upper jaw, house the upper teeth, and connect to all other bones of the face, with the exception of the mandible

process an outgrowth or projection on a bone or other body tissue

sacrum five fused vertebrae that form the posterior of the pelvic girdle

skull the part of the skeleton composed of all of the bones of the head

sternum breastbone

sutures joints in which irregularly grooved, articulating bone sheets join closely and are tightly connected by fibrous tissues

thoracic cage bony structure surrounding the heart and lungs in the thoracic cavity; composed of the ribs, sternum, and thoracic vertebrae

thoracic region the 12 vertebrae in the middle of the back

vertebrae the bones making up the spinal column

vomer a plow-shaped bone that comprises most of the bony nasal septum

Know and Understand

1. Explain the function of the axial skeleton and which parts of the skeleton are included in it. (LO 4.2-1)
2. The bones of the skull are often divided into two groups. Name those two groups. (LO 4.2-1)
3. Which bone of the skull is freely movable? (LO 4.2-1)
4. Describe how sutures and fontanels relate to each other. (LO 4.2-1)
5. List the five named sections of the spine and tell how many vertebrae are included in each of these sections. (LO 4.2-2)
6. Name five structural features common to most vertebrae. (LO 4.2-2)

Analyze and Apply

1. Why is it important to protect and cradle a baby's head when you are holding the baby? (LO 4.2-2)
2. Compare and contrast the conditions of lordosis, kyphosis, and scoliosis. (LO 4.2-2)
3. How does the structure of an intervertebral disc (made of fibrocartilage) relate to its function? (LO 4.2-2)
4. What are the primary and secondary spinal curves? Explain why and distinguish between them. (LO 4.2-2)
5. Explain the different ways in which ribs are attached to the sternum. (LO 4.2-3)

IN THE LAB

1. Using different colors of clay, construct a model of the axial skeleton. Be sure to label all of the bones included. You will add to this skeleton in a later lesson in this chapter. (LO 4.2-1)
2. Work with a team of one or two classmates. On a Styrofoam mannequin head, draw in all of the sutures of the skull and outline them in black marker. Draw in all of the bones of the cranium and face and color each a different color using markers or crayons. Label each suture and bone with a number and then create a key listing the name of each suture and bone to correspond with the number label. (LO 4.2-1)

LESSON 4.3 The Appendicular Skeleton

Before You Read

Try to answer the following questions before you read this lesson.

- Why are there two bones in the forearm?
- What are the best and worst design features of the hip joint?

Learning Outcomes

4.3-1 Discuss the bones of the upper extremity, including the pectoral girdle, arms, wrists, and hands, and explain their functions.

4.3-2 Identify the bones of the lower extremity, including the pelvis, legs, ankles, and feet, and explain their functions.

Key Terms

appendicular skeleton	pectoral girdle
carpal bones	pelvis
clavicle	phalanges
femur	radius
fibula	scapula
humerus	tarsal bones
lower extremity	tibia
metacarpal bones	ulna
metatarsal bones	upper extremity
patella	

The **appendicular skeleton**, as the name suggests, includes the body's appendages. These include both the bones of the **upper extremity** (the shoulder complex, arms, wrists, and hands) and those of the **lower extremity** (the pelvic girdle, legs, ankles, and feet). Altogether, there are approximately 126 bones in the appendicular skeleton. The appendicular skeleton is built for motion.

4.3-1 The Upper Extremity

The upper extremity is well designed for all of the tasks that people routinely ask it to perform. The muscles, bones, and joints of the upper extremity enable movements as diverse as carrying a load, throwing a ball, and threading a needle. The different movements of hammering a nail, texting on a smartphone, and performing a handspring are also made possible by this unique design.

The Pectoral Girdle

The bones surrounding the shoulder are referred to as the **pectoral** (PEHK-toh-ral) **girdle**, or *shoulder girdle*, and include a left and right **clavicle**, or collarbone, and a left and right **scapula** (SKAP-yoo-la, plural *scapulae*), or shoulder blade (**Figure 4.17**). These bones serve as sites for attachment of the numerous muscles that enable motion of the arms at the shoulders in so many different directions.

As **Figure 4.18** shows, there are two bony projections on the scapula, known as the *acromion* (a-KROH-mee-ahn) and the *coracoid* (KOR-a-koyd) *process*. The lateral end of the clavicle attaches to the acromion process to form the *acromioclavicular* (a-kroh-mee-oh-kla-VIK-yoo-lar) *joint* (**Figure 4.17**). The medial end of the clavicle attaches to the sternum to form the *sternoclavicular* (ster-noh-kla-VIK-yoo-lar) *joint*.

The acromioclavicular joint primarily allows you to raise your arm so that you can perform movements overhead. The sternoclavicular joint enables you to move your clavicle and scapula for motions such as shrugging the shoulders, raising your arms, and swimming.

The clavicle serves as a brace for positioning the shoulder laterally away from the trunk. Although there are no bony articulations between the scapulae and the posterior aspect of the trunk, the region between each scapula and the underlying tissues is sometimes referred to as the *scapulothoracic* (skap-yoo-loh-thoh-RAS-ik) *joint*.

The *glenoid* (GLEE-noyd) *fossa* of the scapula is a relatively shallow indentation that articulates, or joins, with the head of the **humerus** (HYOO-mer-us), the bone in the upper arm, to form the *glenohumeral joint*, or shoulder joint. Because the glenoid fossa (socket) is less curved than the humeral head, the humerus is

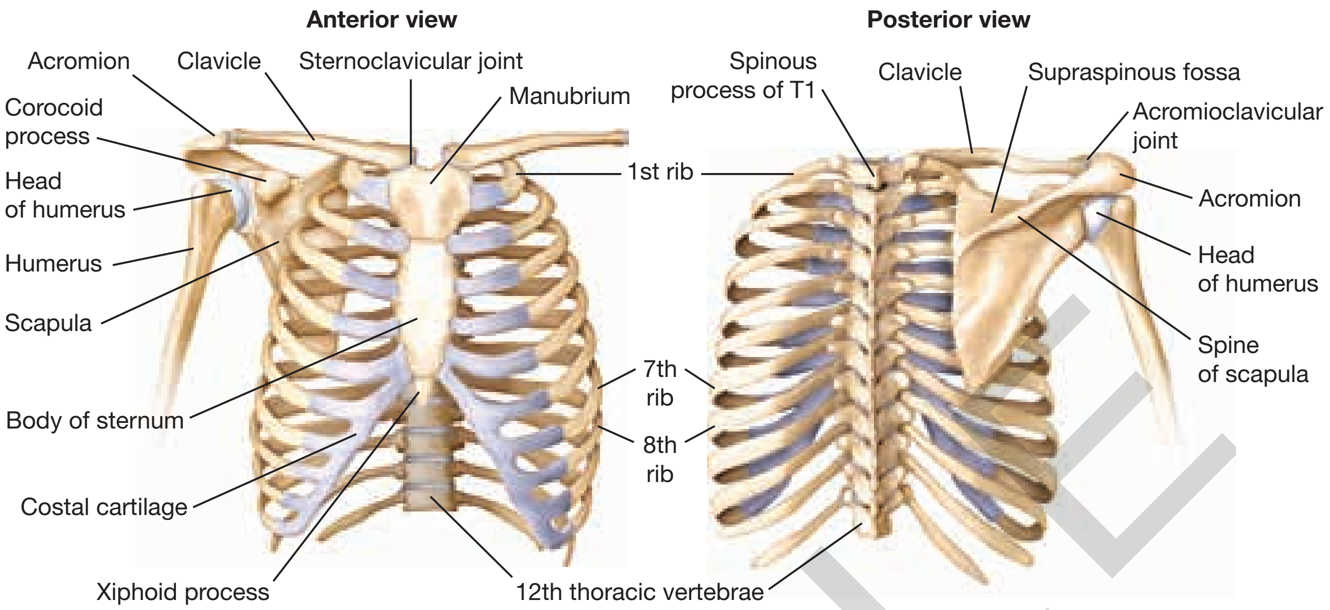


Figure 4.17 Anterior and posterior views of the pectoral girdle, ribs, and humerus.

able to glide against the glenoid fossa, in addition to rotating. As a result, the glenohumeral joint allows motion in more directions than any other joint in the body.

The glenohumeral joint, along with the bones and joints of the pectoral girdle, are referred to as the *shoulder complex*. Together these joints provide the significant range of motion present in a healthy shoulder. This large degree of mobility, however, comes at the cost of instability: the shoulder is one of the most frequently dislocated joints in the human body. **Figure 4.19** summarizes the joints of the shoulder complex.

The Arm

The single bone of the upper arm is the humerus (**Figure 4.20**). The humerus is a large, strong bone, second in size only to the major bone of the

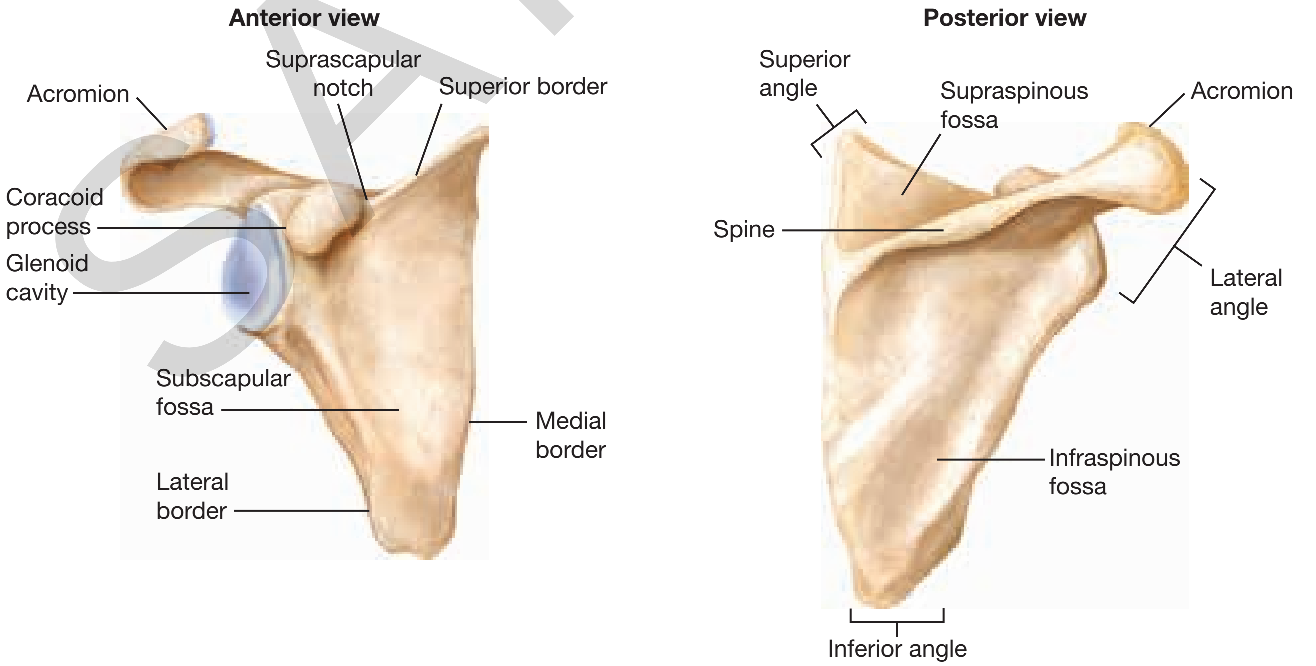


Figure 4.18 Anterior and posterior views of the scapula.

Articulating Bones of the Shoulder Complex

Joint	Notched Bone	Joining Bone or Region
acromioclavicular joint	acromion of the scapula	clavicle
sternoclavicular joint	sternum	clavicle
scapulothoracic joint	scapula	thorax
glenohumeral joint	glenoid fossa of the scapula	humerus

Figure 4.19

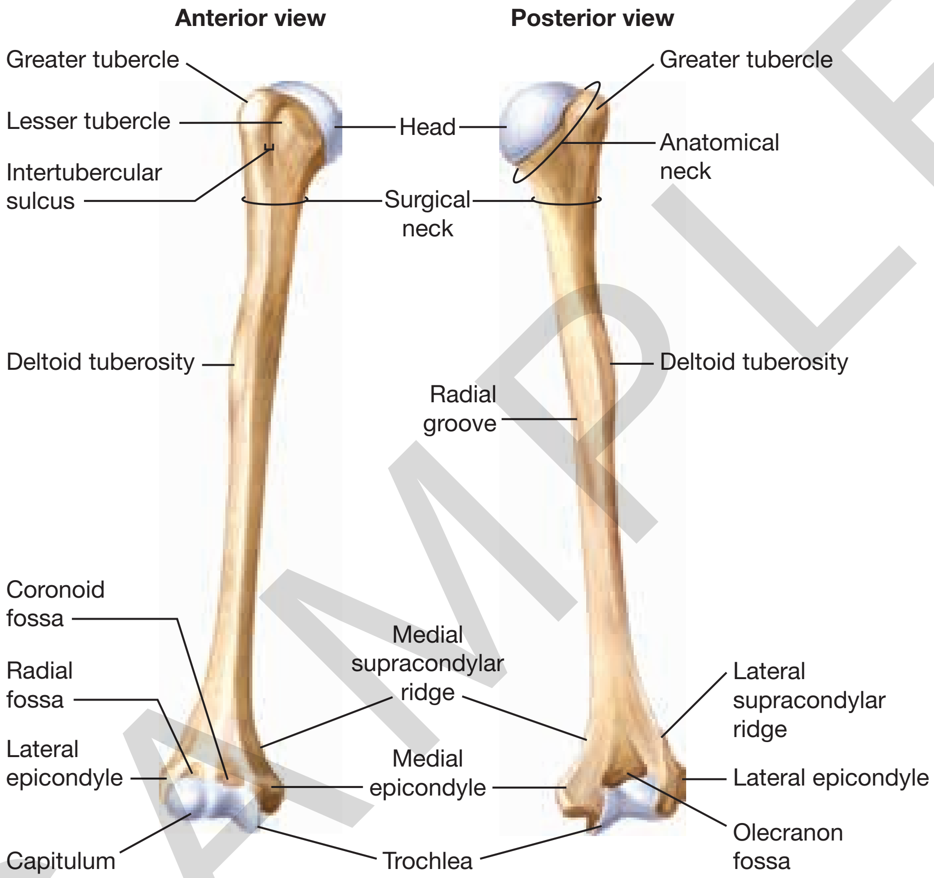


Figure 4.20 Anterior and posterior views of the humerus.

upper leg. The upper end of the humerus forms a rounded head, which, as mentioned, articulates with the glenoid fossa of the scapula to form the glenohumeral joint.

As **Figure 4.21** shows, the framework for the forearm consists of two bones—the **radius** (RAY-dee-us) and **ulna** (UHL-nuh). The radius is the bone that articulates with the wrist on the thumb side. The name *radius* comes from the ability of this bone to "radially" rotate around the ulna. This radial rotation is the familiar motion that enables the forearm and hand to rotate freely.

The ulna is larger and stronger than the radius, and it articulates with the humerus at the humeroulnar (hyoo-mer-oh-UHL-ner) joint at the elbow. The ulna attaches to the wrist on the "little finger" side. The bony projection at the upper end of the ulna, called the *olecranon* (oh-LEHK-ra-nahn) *process*, is what people refer to as the *elbow*.

The radius and ulna are connected along their entire lengths by an *interosseus* (in-ter-AHS-ee-us) *membrane*. The two bones articulate at both ends, and these joints are known as the *proximal* and *distal radioulnar* (ray-dee-oh-UHL-nar) *joints*.

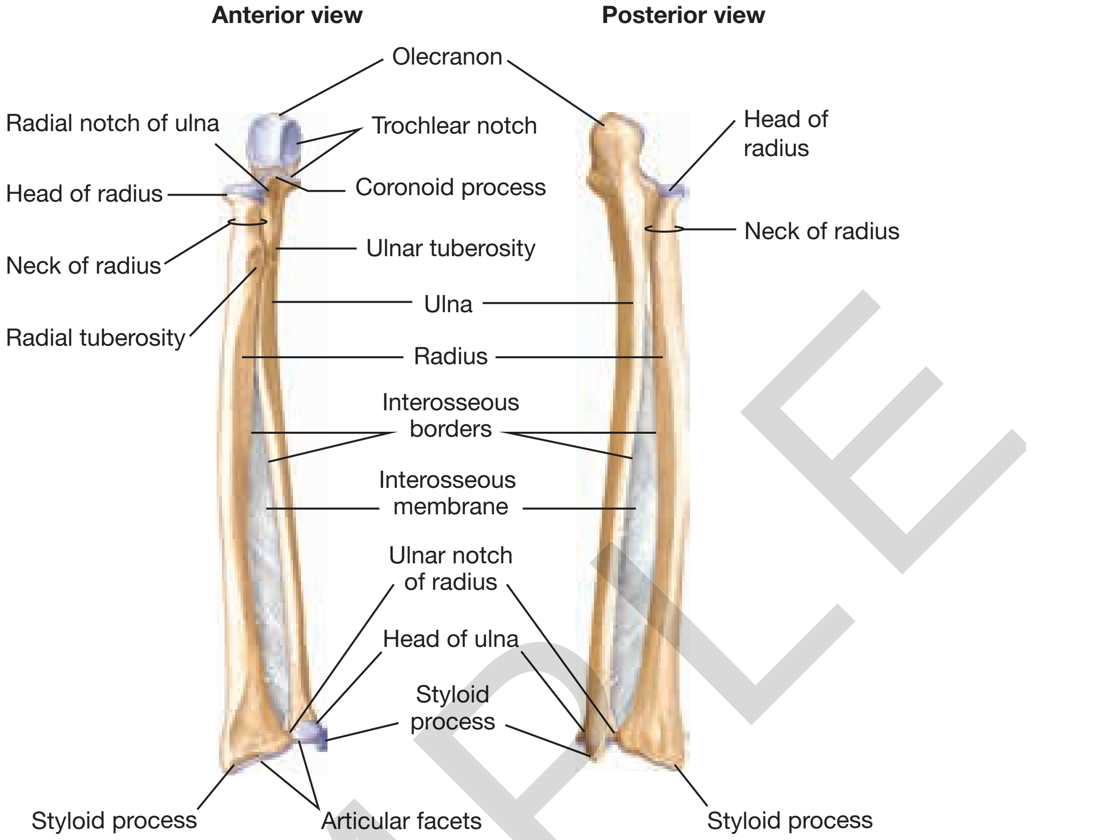


Figure 4.21 Anterior and posterior views of the radius and ulna. *Which of these two bones allows your forearm and hand to rotate freely?*

At the distal (lower) ends of both the radius and ulna are *styloid* (STIGH-loyd) *processes* that are easy to see and feel with your fingers. The distal end of the radius unites with several of the carpal bones of the wrist to form the *radiocarpal* (ray-dee-oh-KAR-pal) *joint* (**Figure 4.22**).

The Wrist and Hand

Collectively, the wrists and hands contain 54 bones—27 on the left and 27 on the right. This large number of bones enables a wide range of precise movements, along with the important ability to grasp objects.

The wrist includes eight **carpal** (KAR-pal) **bones** that are roughly arranged in two rows (**Figure 4.23**). The carpal bones are bound together by ligaments that allow a small amount of gliding motion at the intercarpal joints. However, the main function of the carpals is to provide a base for the bones of the hand.

Five **metacarpal** (meht-a-KAR-pal) **bones** in each hand articulate with the carpal bones in each wrist. There are 14 **phalanges** (fa-LAN-jeez)—the bones in the fingers. Each of the four fingers has proximal, medial, and distal phalanges, but the thumb has only two.

Articulating Bones of the Arm and Wrist

Joint	Notched Bone	Joining Bone
humeroulnar (elbow) joint	humerus	ulna
radioulnar joints (proximal and distal)	radius	ulna
radiocarpal (wrist) joint	radius	three carpal bones

Figure 4.22 Goodheart-Willcox Publisher

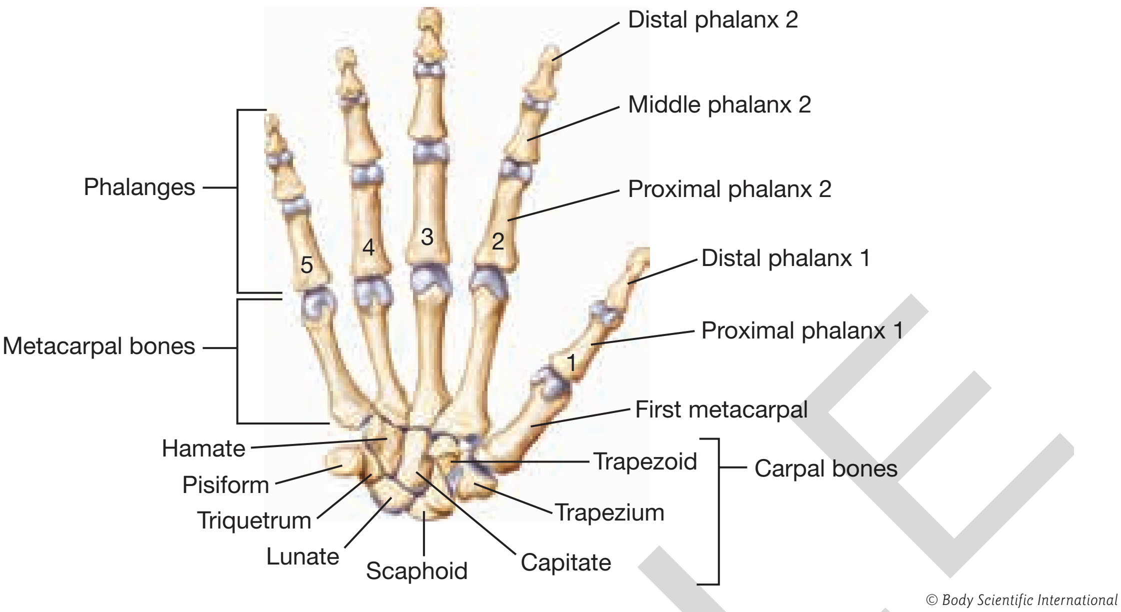


Figure 4.23 Anterior view of the bones of the right hand.

Whereas the joints of the fingers permit motion in only one plane, the thumb has the ability to freely rotate and to stretch across the palm of the hand. This capability, known as an *opposable thumb*, is shared only by humans and other primates.

Check Your Understanding

1. Which bones make up the appendicular skeleton?
2. Which bones are included in the shoulder complex?
3. Which forearm bone enables rotation of the hand around the longitudinal axis of the arm?
4. How many bones are in each wrist and hand?

4.3-2 The Lower Extremity

The lower extremity is well designed for its functions of weight bearing and gait, including walking and running. During sporting activities, the muscles, bones, and joints of the lower extremity also enable movements involved in jumping, skating, surfing, skiing, and dancing, for example.

The Pelvic Girdle

As the name suggests, the pelvic girdle is a bony encasement of the pelvic region that shelters the reproductive organs, bladder, and part of the large intestine. It is formed by two large, strong *coxal* (KAHK-sal) *bones* (hip bones, also known as the *os coxa*) and the sacrum (**Figure 4.24**). These three bones, with the addition of the coccyx, comprise the **pelvis**. The female pelvis is wider than the male pelvis to enable pregnancy and childbirth. The pelvis is one of the hallmark differences that allows classification of a skeleton as male or female.

Each coxal bone is formed by the fusion of the ilium, ischium, and pubis. During childhood these are three separate bones.

The *ilium* (IL-ee-um) comprises most of each coxal bone, connecting posteriorly to the sacrum at the *sacroiliac* (sa-kroh-IL-ee-ak) *joint*. The prominent upper edge of the ilium, which can usually be palpated (examined or felt by touch), is called the *iliac crest*.

The *ischium* (IS-kee-um), which forms the inferior portion of each coxal bone, is the bone that supports the weight of the upper body during sitting. Within each coxal bone lies an *acetabulum* (as-eh-TAB-yoo-lum): a deep, bony socket that receives the head of the thigh bone.

The *pubis* (PYOO-bis) is the anterior portion of each coxal bone. The two pubic bones fuse in the center front of the body at the *pubic symphysis* (PYOO-bik SIM-fi-sis), where the bones are joined by a disc of hyaline cartilage.

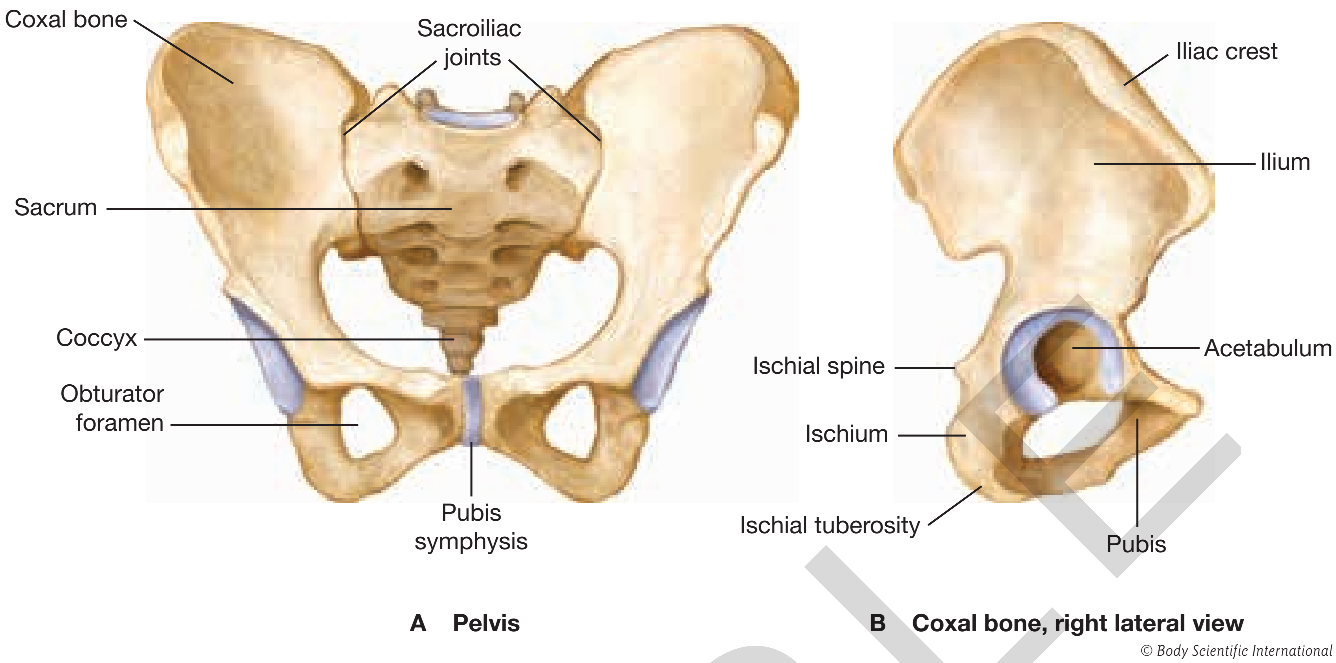


Figure 4.24 Bones of the pelvis. *Why are these bones important when classifying skeletons?*

The Leg

The single bone of the upper leg, or thigh, is the **femur** (FEE-mer), which is the longest and strongest bone in the body. **Figure 4.25** shows the anatomical features of the femur. The head of the femur fits snugly into the acetabulum of the hip, making the joint extremely stable. The most vulnerable part of the femur is the neck, which is the site where most hip fractures occur.

The lower leg has two bones: the tibia and fibula (**Figure 4.26**). The thick, strong **tibia** (TIB-ee-a)—or shinbone—is the bone that bears most of the weight of the body above it.

Unlike the radius in the forearm, the **fibula** (FIB-yoo-la) has no special motion capability and serves primarily as a site for muscle attachments. The fibula is not part of the articulation with the femur at the knee joint, but the distal end of the fibula has a bony prominence called the *lateral malleolus* (mal-LEE-oh-lus), which you can readily touch and feel on the lateral (outer) side of the ankle.

Like the radius and ulna in the forearm, the tibia and fibula are connected along their lengths by an interosseous membrane, and they articulate at both ends of the fibula. The **patella** (pa-TEHL-a), or kneecap, is a small, flat, triangular-shaped bone that protects the front of the knee. The articulations of the bones of the leg and ankle are summarized in **Figure 4.27**.

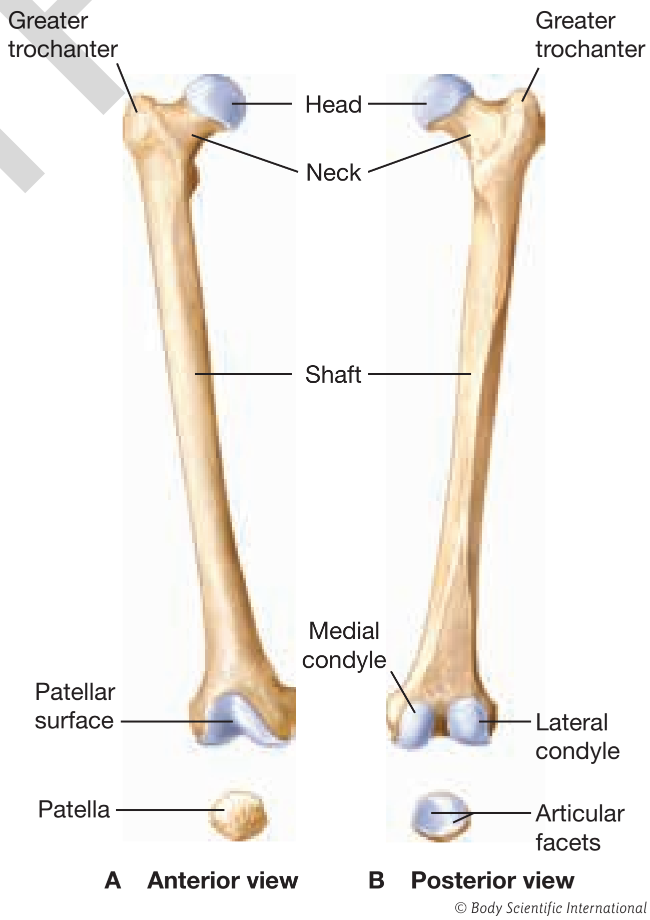


Figure 4.25 The right femur and the patella. *Although the femur is the strongest bone in the body, one part is vulnerable to fracture. What is the most vulnerable part of the femur?*

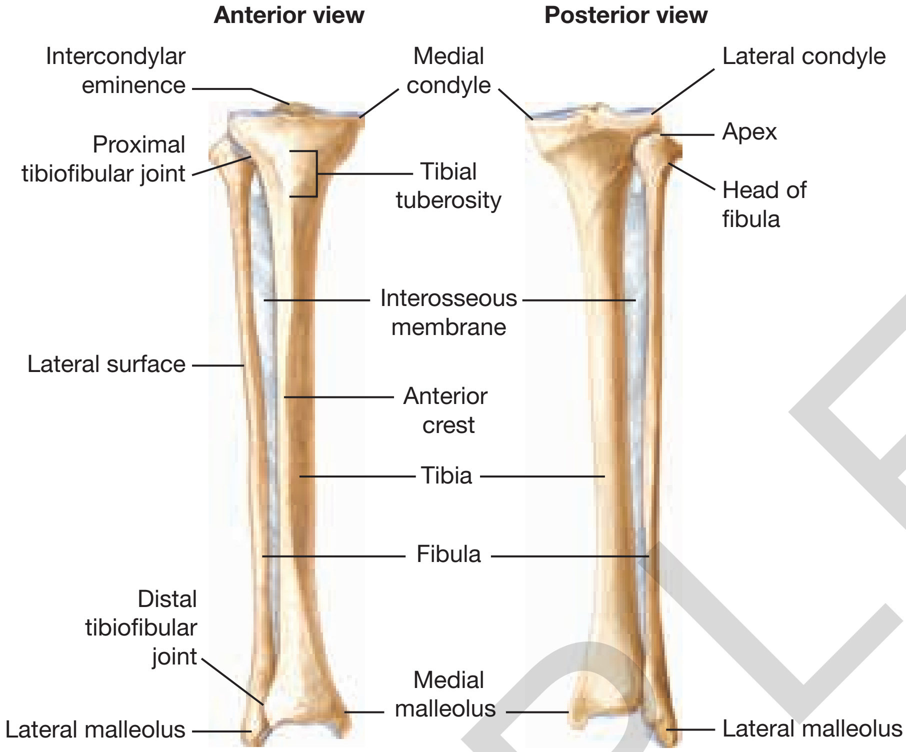


Figure 4.26 The right tibia and fibula, anterior and posterior views.

Articulating Bones of the Leg and Ankle

Joint	Notched Bone or Socket	Joining Bone or Region
iliofemoral (hip) joint	acetabulum	femur
tibiofemoral (knee) joint	tibia	femur
patellofemoral joint	patella	anterior knee
tibiofibular joints (proximal and distal)	tibia	fibula

Figure 4.27

The Ankle and Foot

The ankle and foot serve the critically important functions of supporting body weight and enabling locomotion. The foot is so well designed that it assists with walking and running by acting like a spring that stores and releases energy.

The hindfoot is constructed of **tarsal** (TAR-sal) **bones**, with the two largest, the *talus* (TAY-lus) and *calcaneus* (kal-KAY-nee-us)—or heel bone—bearing most of the weight of the body (**Figure 4.28**). The five **metatarsal** (meht-a-TAR-sal) **bones** that support the midfoot region are similar to the metacarpals of the hand. Like the fingers, each toe is comprised of three phalanges, and like the thumb, the big toe has only two phalanges. The toes function by increasing the area of the foot during weight-bearing activities such as walking and running—thereby increasing body stability.

The configuration of the metatarsal bones forms two important arches (**Figure 4.29**). The *longitudinal arch* runs lengthwise from the calcaneus to the heads of the metatarsals. The *transverse arch* runs sideways (perpendicular to the longitudinal arch), and in most people causes

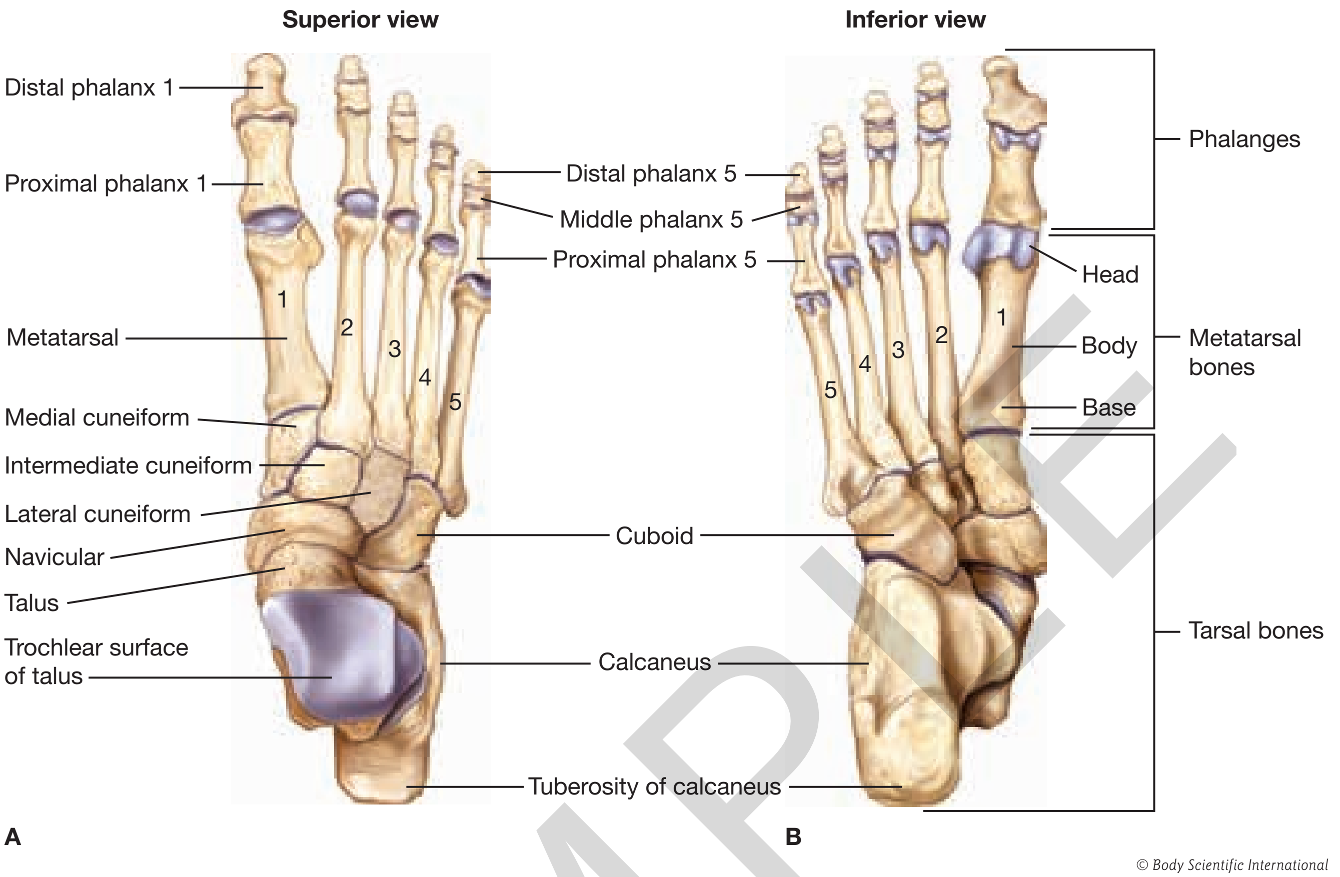


Figure 4.28 Superior (A) and inferior (B) views of the bones of the right foot.

the medial center of the bottom of the foot to be slightly elevated. It is these arches that compress somewhat during the weight-bearing phase of your gait, but then act as springs when they rebound to their original shape during the propulsive (push-off) phase of the gait.

Check Your Understanding

1. Which bones make up the pelvic girdle?
2. Which three bones fuse to form each coxal bone?
3. What is the longest and strongest bone in the body?
4. Although relatively small bones, the bones of the toes serve what important function?
5. What is the purpose of the two arches formed by the metatarsal bones?

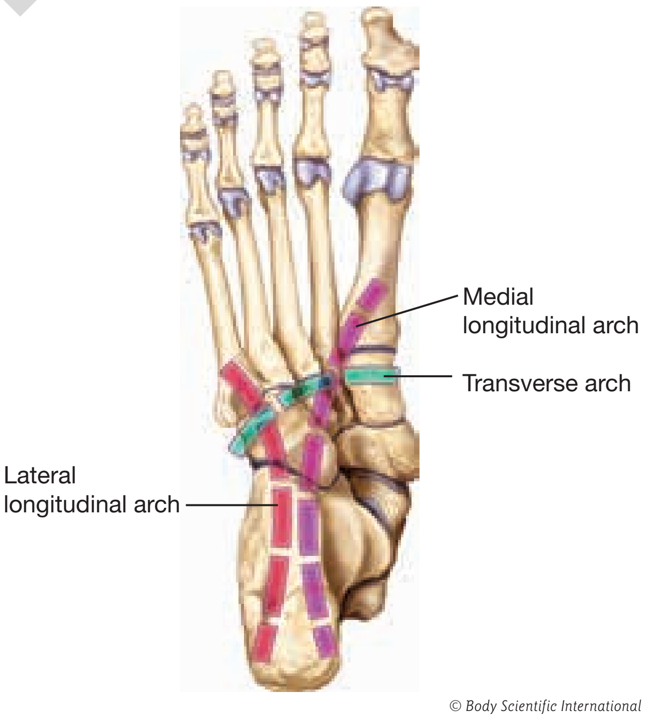


Figure 4.29 Arches of the foot, inferior view. *How do these arches contribute to the ability to walk with a smooth, easy gait?*

LESSON 4.3 Review and Assessment

Mini Glossary

Make sure that you know the meaning of each key term.

appendicular skeleton the bones of the body's appendages; the arms and legs

carpal bones bones of the wrist

clavicle doubly curved long bone that forms part of the shoulder girdle; the collarbone

femur thigh bone

fibula bone of the lower leg; does not bear weight

humerus major bone of the upper arm

lower extremity bones of the hips, legs, and feet

metacarpal bones the five interior bones of the hand, connecting the carpals in the wrist to the phalanges in the fingers

metatarsal bones small bones of the ankle

patella kneecap

pectoral girdle bones surrounding the shoulder, including the clavicle and scapula

pelvis bones of the pelvic girdle and the coccyx at the base of the spine

phalanges bones of the fingers

radius smaller of the two bones in the forearm; rotates around the ulna

scapula shoulder blade

tarsal bones bones of the ankle

tibia major weight-bearing bone of the lower leg

ulna larger bone of the lower arm

upper extremity bones of the shoulders, arms, and hands

Know and Understand

1. Explain how the bones of the pectoral girdle, along with various muscles and joints, allow movement in many different directions. (LO 4.3-1)
2. Which bone of the forearm is larger and stronger than the other? (LO 4.3-1)
3. What is the common name for the olecranon process? (LO 4.3-1)
4. How many bones are present in your left wrist and hand? (LO 4.3-1)
5. Why is the pelvis of a female wider than the pelvis of a male? (LO 4.3-2)
6. What is the name of the part of the coxal bone that receives the head of the femur? (LO 4.3-2)
7. Which bone of the lower leg is the stronger bone that bears most of the weight of the body above it? (LO 4.3-2)
8. What is the anatomical name for the heel bone? (LO 4.3-2)
9. What is the purpose of the two arches in the foot? (LO 4.3-2)

Analyze and Apply

1. Compare the motions allowed by the sternoclavicular joint with those allowed by the acromioclavicular joint. Explain how both joints contribute to the motions needed at the shoulder. (LO 4.3-1)
2. Functionally, why does the pectoral girdle have much more range of motion than the pelvic girdle? (LO 4.3-1, LO 4.3-2)
3. Why are there two bones in the forearm rather than just one? (LO 4.3-1)
4. The finger joints allow movement in only one plane, but the thumb can rotate freely. How is this beneficial in everyday life? (LO 4.3-1)
5. Why would you not be able to walk properly if you had a fracture in one of the metatarsals or phalanges? (LO 4.3-2)
6. Why are there two bones in the lower leg rather than just one? Explain how those two bones work together. (LO 4.3-2)

IN THE LAB

1. Using different colors of clay, construct a model of the appendicular skeleton, labeling all of the bones included. Attach your appendicular skeleton to the axial skeleton you constructed in Lesson 4.2. When you have finished, analyze the strengths and weaknesses of your model. Does it adequately represent the human skeleton? What are the limitations of the model? (LO 4.3-1, LO 4.3-2)
2. Using clay, construct models of a male pelvis and a female pelvis. Research the normal size of each coxal bone in each gender and write a short report detailing the size differences in the male and female models. Further explain how this information is helpful to forensic scientists. (LO 4.3-2)

LESSON 4.4

Joints

Before You Read

Try to answer the following questions before you read this lesson.

- Some joints permit little to no movement; what is the purpose of these joints?
- What prevents damage to joints from frictional wear over time?

Learning Outcomes

4.4-1 Describe the general structures and functions of the three major categories of joints.

4.4-2 Explain the functions of articular tissues such as cartilage, tendons, and ligaments.

Key Terms

amphiarthrosis	pivot joint
articular fibrocartilage	saddle joint
ball-and-socket joint	symphysis
bursae	synarthrosis
condyloid joint	synchondrosis
diarthrosis	syndesmosis
gliding joint	synovial joint
hinge joint	tendon
ligaments	tendon sheaths

The joints of the human body govern the extent and directions of movement of the bones that articulate (come together) at the joint. Although the range of motion at a given joint is affected by the tightness of the soft tissues crossing that joint, it is the structure of the bony articulation that determines the directions of motion permitted.

4.4-1 Types of Joints

Anatomists classify joints in different ways based on joint complexity, the number of axes present, joint structure, and joint function. Joint function determines movement capability and is the most easily remembered; therefore, this classification is used in this lesson.

There are three main categories of joints with regard to function: the immovable joints, the slightly movable joints, and the freely movable joints. Most of the joints of the body appendages are freely movable, because moving is the function of the arms, hands, legs, and feet. The joints of the axial skeleton are primarily immovable or slightly movable, because stability and protection of vital organs are their functions.

Immovable Joints

The immovable joints are called **synarthroses** (sin-ar-THROH-seez). The prefix *syn-* means "together" and the root word *arthron* means "joint." Synarthroses are fibrous joints that can absorb shock but permit little or no movement of the articulating bones. The two types of immovable joints are sutures and syndesmoses.

Sutures, which you read about earlier in this chapter, are joints in which irregularly grooved, articulating bone sheets join closely and are tightly connected by fibrous tissues. The fibers begin to ossify (turn to bone) in early adulthood and are eventually replaced completely by bone. The only sutures in the human body are the sutures of the skull.

Syndesmoses (sin-dehz-MOH-seez), meaning "held by bands," are joints in which dense, fibrous tissue binds the bones together, permitting extremely limited movement. Examples include the coracoacromial (kor-a-koh-a-KROH-mee-al) joint and the distal tibiofibular (tib-ee-oh-FIB-yoo-lar) joints.

Slightly Movable Joints

The **amphiarthroses** (am-fee-ar-THROH-seez)—the prefix *amphi-* means "on both sides"—are gliding joints that permit only slight motion. These cartilaginous joints allow more motion of the adjacent bones than do the synarthrodial joints and are therefore somewhat better able to absorb shock. The two types of amphiarthroses are synchondroses and symphyses.

Synchondroses (sin-kahn-DROH-seez), meaning "held by cartilage," are joints in which the articulating bones are held together by a thin layer of hyaline cartilage. Examples include the sternocostal joints (between the sternum and the ribs) and the epiphyseal plates in the long bones.

Symphyses (SIM-fi-seez) are joints in which thin plates of hyaline cartilage separate a disc of fibrocartilage from the bones. Examples include the vertebral joints and the pubic symphysis.

Freely Movable Joints

Freely movable joints are called **diarthroses** (digh-ar-THROH-seez). They are also referred to as **synovial** (si-NOH-vee-al) **joints** because each joint is surrounded by an articular capsule with a synovial membrane lining that secretes a lubricant known as *synovial fluid* (**Figure 4.30**). Each of the six different types of diarthroses is structured to permit different types of motion (**Figure 4.31**).

At **gliding joints** the articulating bone surfaces are nearly flat. The only movement permitted is gliding.

In **hinge joints**, one articulating bone surface is convex (curved outward), and the other is concave (curved inward). Strong ligaments restrict movement to a planar, hingelike motion, similar to the hinge on a door.

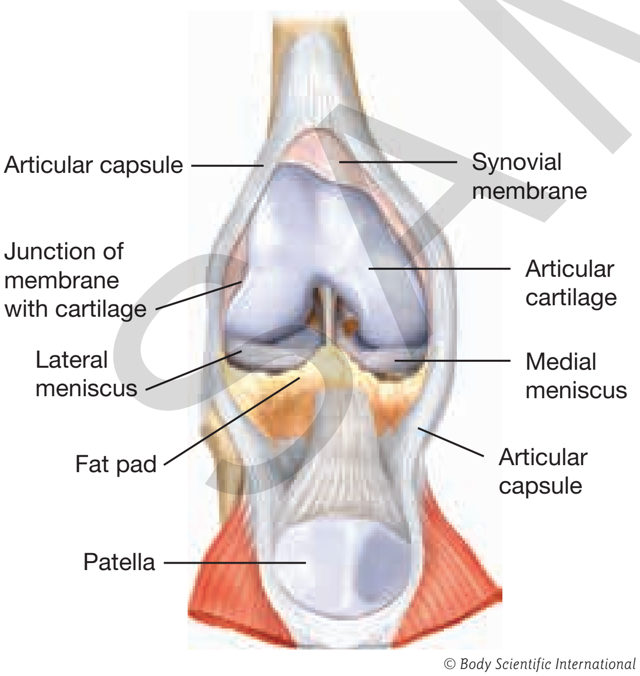


Figure 4.30 Anterior view of the knee, which is a synovial joint.

Pivot joints permit rotation around only one axis. (Think about moving around your stationary pivot foot in basketball.)

At **condyloid** (KAHN-di-loyd) **joints**, one articulating bone surface is an oval, convex shape, and the other is a reciprocally shaped concave surface. Flexion, extension, abduction, adduction, and circumduction are permitted.

Saddle joints are so named because their articulating bone surfaces are both shaped like the seat of a riding saddle. Movement capability is the same as that of the condyloid joint but greater range of movement is allowed.

Ball-and-socket joints are the most freely movable joints in the body. In these joints the surfaces of the articulating bones are reciprocally convex and concave, with one bone end shaped like a "ball" and the other like a "socket." Rotation is permitted in all three planes of movement. In cases in which the joint socket is relatively shallow, such as in the shoulder, a large range of motion is permitted, but at the sacrifice of joint stability. Alternatively, the deep socket of the hip joint maximizes stability but allows much less of a range of motion than at the shoulder.

Two structures often associated with diarthrodial joints are bursae and tendon sheaths. **Bursae** (BER-see) are small capsules lined with synovial membranes and filled with synovial fluid that cushion the structures they separate. Most bursae separate tendons from bone, reducing the friction on the tendons during joint motion.

Tendon sheaths are double-layered synovial structures surrounding tendons that are subject to friction because they are close to bones. These sheaths secrete synovial fluid to promote free motion of the tendon during joint movement. Many long muscle tendons crossing the wrist and finger joints are protected by tendon sheaths.

Check Your Understanding

1. Which types of joints are most prevalent in the axial skeleton? Why?
2. What are the two main types of synarthroses?
3. What are the two main types of amphiarthroses?

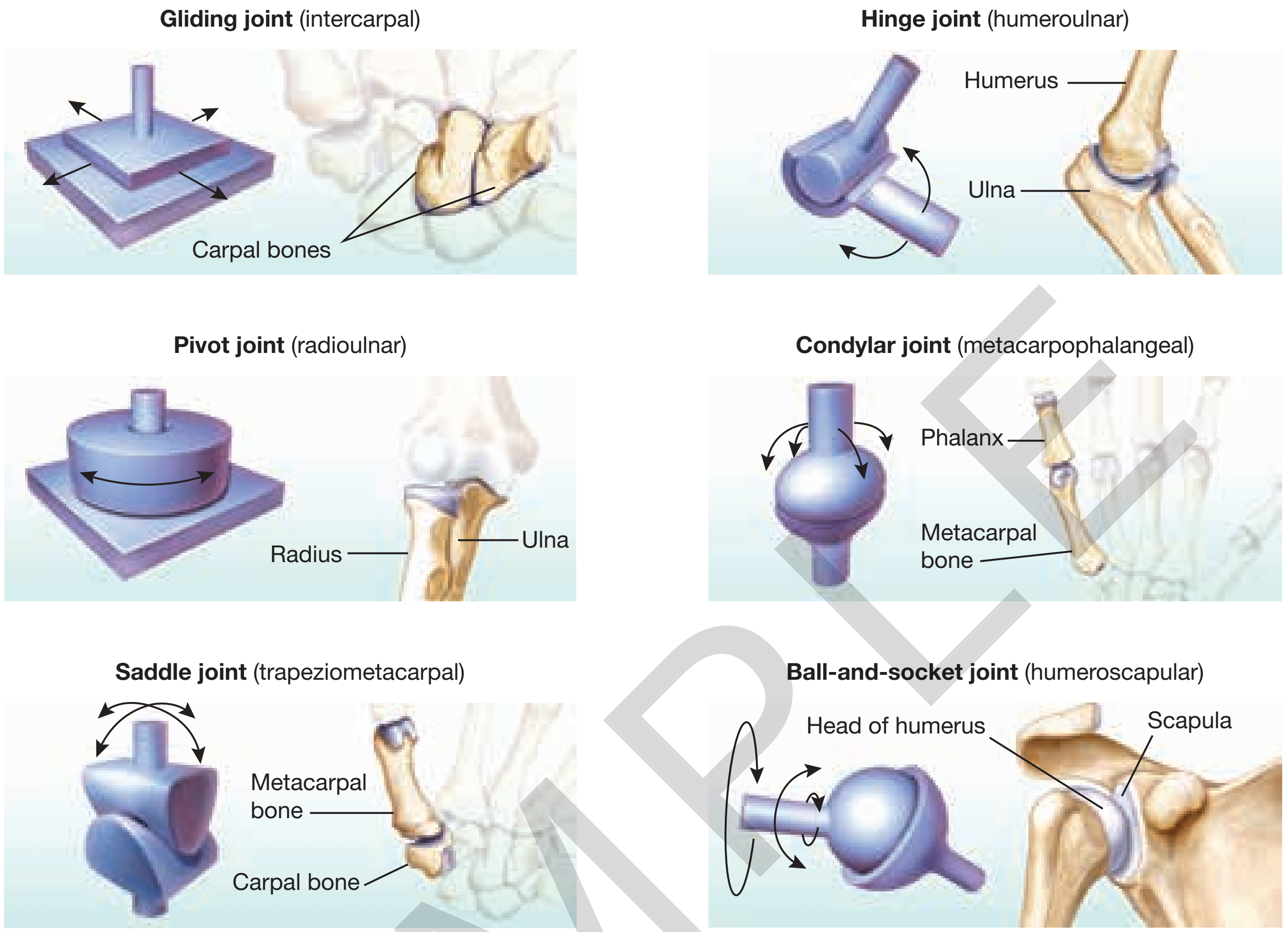


Figure 4.31 Examples of the six different types of diarthroses. *Which of these six types of joints is the most freely movable?*

4.4-2 Articular Tissues

The joints of any mechanical device must be properly lubricated if the movable parts are to move freely and not wear against each other. In the human body, articular cartilage covers the ends of bones at diarthrodial joints and provides a protective lubrication. Articular cartilage cushions the joint and reduces friction and wear.

At some joints, **articular fibrocartilage**, shaped like a disc or a partial disc called a *meniscus*, is also present between the articulating bones. The intervertebral discs and the menisci of the knee are examples. These discs and menisci help to distribute forces evenly over the joint surfaces and absorb shock at the joint.

Tendons, which connect muscles to bones, and **ligaments**, which connect bones to other bones, are also present at the diarthrodial joints. Composed of collagen and elastic fibers, these tissues are slightly elastic and will return to their original length after being stretched, unless overstretched to the point of injury. The tendons and ligaments crossing a joint play an important role in joint stability. The hip joints, in particular, are crossed by a number of large, strong tendons and ligaments.

Check Your Understanding

1. What is the purpose of articular fibrocartilage?
2. In functional terms, what is the difference between a tendon and a ligament?

LESSON 4.4 Review and Assessment

Mini Glossary

Make sure that you know the meaning of each key term.

amphiarthrosis joint type that permits only slight motions

articular fibrocartilage tissue shaped like a disc or partial disc called a *meniscus* that provides cushioning at a joint

ball-and-socket joint synovial joint formed between one bone end shaped roughly like a ball and the receiving bone reciprocally shaped like a socket

bursae small capsules lined with synovial membranes and filled with synovial fluid; they cushion the structures they separate

condyloid joint type of diarthrosis in which one articulating bone surface is an oval, convex shape, and the other is a reciprocally shaped concave surface

diarthrosis freely movable joints; also known as *synovial joints*

gliding joint type of diarthrosis that allows only sliding motion of the articulating bones

hinge joint type of diarthrosis that allows only hingelike movements in forward and backward directions

ligaments bands composed of collagen and elastic fibers that connect bones to other bones

pivot joint type of diarthrosis that permits rotation around only one axis

saddle joint type of diarthrosis in which the articulating bone surfaces are both shaped like the seat of a riding saddle

symphysis type of amphiarthrosis joint in which a thin plate of hyaline cartilage separates a disc of fibrocartilage from the bones

synarthrosis fibrous joint that can absorb shock, but permits little or no movement of the articulating bones

synchondrosis type of amphiarthrosis joint in which the articulating bones are held together by a thin layer of hyaline cartilage

syndesmosis joint at which dense, fibrous tissue binds the bones together, permitting extremely limited movement

synovial joint a diarthrodial joint

tendon tissue band composed of collagen and elastic fibers that connects a muscle to a bone

tendon sheaths double-layered synovial structures surrounding tendons subject to friction given their position close to bones; secrete synovial fluid to promote free motion of the tendons during joint movement

Know and Understand

1. What does it mean to say that bones articulate with each other? (LO 4.4-1, LO 4.4-2)
2. Give two examples of immovable joints and where they are found in the body. (LO 4.4-1)
3. Give two examples of slightly movable joints and where they are found in the body. (LO 4.4-1)
4. Give six examples of freely movable joints and where they are found in the body. (LO 4.4-1)
5. What is the purpose of articular fibrocartilage? (LO 4.4-2)

Analyze and Apply

1. Why is it important to have a layer of cartilage between bones that articulate with each other? (LO 4.4-1, LO 4.4-2)
2. Why do people need joints that permit little or no skeletal movement? (LO 4.4-1)
3. Why does the human skeleton need freely movable joints? (LO 4.4-1)
4. What happens when articular cartilage begins to erode from excessive wear and stress on a joint? (LO 4.4-2)
5. Functionally, how does a torn meniscus change the knee joint? (LO 4.4-2)

IN THE LAB

1. Obtain (or draw) a picture of a skeleton. Label the areas on the skeleton where these types of joints are located: sutures, syndesmoses, synchondroses, symphyses, gliding, hinge, pivot, condyloid, saddle, and ball-and-socket. Be prepared to explain to the class the kind of movement that each type of joint allows. (LO 4.4-1)
2. Obtain a model of a skeleton, or use the clay skeleton you made earlier in this chapter. Pick two each of the immovable joints, slightly movable joints, and freely movable joints, and find them on the skeleton model. Explain to the class why those joints are found where they are, relating structure to function. (LO 4.4-1)

LESSON 4.5

Common Injuries and Disorders of the Skeletal System

Before You Read

Try to answer the following questions before you read this lesson.

- What is the female athlete triad, and why is it potentially deadly?
- What is osteoarthritis, and how might it possibly be prevented?

Learning Outcomes

4.5-1 Identify the different types of bone and epiphyseal injuries, and in each case explain the types of forces that can cause these injuries.

4.5-2 Discuss osteoporosis, including contributing factors, groups at risk, consequences, and prevention strategies.

4.5-3 Describe the common types of joint injuries, including the structures affected and symptoms.

4.5-4 Describe specific types of arthritis, including symptoms.

Key Terms

amenorrhea	female athlete triad
anorexia nervosa	fracture
apophysis	osteoarthritis
arthritis	osteopenia
avulsion	osteoporosis
bulimia nervosa	rheumatoid arthritis
bursitis	sprain
dislocation	stress fracture

CLINICAL CASE STUDY

Joan is an outside hitter on her high school varsity volleyball team. Recently the shoulder of her hitting arm has been stiff and somewhat achy when she first wakes up in the morning. After a long, hard team practice the shoulder is quite painful. Joan does not recall having done or experienced anything unusual to injure her shoulder. As you read this section, try to determine which of the following conditions Joan most likely has:

A. Stress fracture
B. Sprain
C. Bursitis
D. Arthritis

Injuries and disorders of the skeletal system include problems with bones, joints, and the articular tissues. This lesson discusses many of the most common disorders.

4.5-1 Common Bone Injuries

Considering all of the important functions performed by bone, bone health is a vital part of general health. Bone health can be diminished by injuries and pathologies. The etiology, strategies for prevention, pathology, diagnosis, and common treatments for these common bone injuries and disorders are summarized in **Figure 4.32** and are discussed further in this lesson.

Fractures

A **fracture** is a break or a crack in a bone. The nature of a fracture depends on the size, direction, and duration of the injurious force, as well as the health and maturity of the bone.

Fractures are classified as *simple* when the bone ends remain within the surrounding soft tissues, and *compound* when one or both bone ends protrude from the skin. When the bone is splintered, the fracture is classified as *comminuted*. See **Figure 4.33**.

An **avulsion** is a fracture caused when a tendon or ligament pulls away from its attachment to a bone, taking a small chip of bone with it. Explosive throwing and jumping movements may cause avulsion fractures of the medial epicondyle (ehp-i-KAHN-dighl) of the humerus and the calcaneus.

Forceful bending and twisting movements can produce spiral fractures of the long bones. A common example occurs during downhill skiing. When a ski is planted in one direction, and the skier rotates while falling in a different direction, a spiral fracture of the tibia can result.

Common Bone Injuries and Disorders

	Etiology	Prevention	Pathology	Diagnosis	Treatment
Fractures	a force strong enough to cause a partial or complete break in a bone	Be careful!	swelling, tenderness, bruising, deformity, bone protrudes through skin if a compound fracture	physical exam, X-ray	cast immobilization, functional cast or brace, traction, external fixation
Stress fractures	repetitive activity that overwhelms a bone's ability to self-repair	avoid dramatic increase in activity, running or landing on a hard surface, and poorly cushioned shoes	pain with activity	X-ray, CT scan, MRI	cease the activity that caused the stress fracture until healing occurs
Osteochondrosis (Osgood-Schlatter disease)	overuse of the quadriceps in adolescent athletes	avoid excessive, repetitive physical activity involving the quadriceps	pain and swelling over the anterior tibial growth plate that worsens with physical activity	physical exam, X-ray	cease the activity that caused the injury, stretching exercises, medication
Osteoporosis	abnormally low bone mineralization and strength due to aging or the female athlete triad	regular weight-bearing exercise, adequate intake of calcium and vitamin D; avoid excessively low body weight	daily activity results in bone fractures, with associated pain and deformity	physical exam, X-rays, bone densitometry, specialized laboratory tests	estrogen replacement therapy, prescribed medications to increase bone mass
Herniated disc	rupture in an intervertebral disc	regular exercise, healthy weight, good posture	arm or leg pain, numbness, weakness	physical exam, imaging, nerve tests	exercise, medication, physical therapy

Figure 4.32

Goodheart-Willcox Publisher

The bones of children contain relatively larger amounts of collagen than do the bones of adults. For this reason, children's bones are more flexible and are generally less likely to fracture than adult bones. Consequently, greenstick fractures, or incomplete fractures, are more common in children than in adults. A greenstick fracture is an incomplete fracture caused when a bone bends or twists but does not break all the way through.

A A *greenstick fracture* is incomplete. The break occurs on the convex surface of the bend in the bone.

B A *stress fracture* involves an incomplete break.

C A *comminuted fracture* is complete and splinters the bone.

D A *spiral fracture* is caused by twisting a bone excessively.

© Body Scientific International

Figure 4.33 Types of fractures.

Bone fractures are diagnosed and treated as appropriate for the nature of the injury. Symptoms of a simple fracture typically include swelling and tenderness around the fracture site. There may also be bruising, and in the case of a complete fracture, the limb may look deformed or out of place. A compound fracture, with a bone fragment protruding through the skin, is accompanied by bleeding and extreme pain. The most common treatment is application of a plaster or fiberglass cast to completely immobilize the fracture after the doctor has properly aligned the bone.

Avulsions and incomplete fractures may be treated with a functional cast or brace, such as a walking boot. If the doctor cannot readily align the bone ends, traction may be applied to gently pull on opposite ends of the fractured bone to achieve proper realignment. With more serious, complicated fractures the doctor may elect to use external fixation. This is a surgical procedure in which metal pins or screws are placed into the broken bone above and below the fracture site. The pins or screws are connected to a metal bar outside the skin to hold the bones in the proper position while they heal. **Figure 4.34** displays a variety of bone fractures.

Stress fractures are tiny, painful cracks in bone that result from overuse. Under normal circumstances, bone responds to stress-related injury by remodeling. Osteoclasts resorb the damaged tissue, and osteoblasts deposit new bone at the site, resulting in repair of the injury. However, with repeated overuse, the remodeling process cannot keep up with the damage being done by the overuse. When this happens, the condition progresses to a stress fracture.

Runners and athletes in sports such as soccer, basketball, gymnastics, and tennis are prone to stress fractures, particularly in the tibia and the metatarsals. Common causes are increasing running mileage or playing time too abruptly, running or repetitive landing on a hard surface, and wearing shoes with inadequate cushioning.

Diagnosis of stress fractures is not always as straightforward as diagnosis of other types of fractures. The primary symptom is pain with activity. X-rays are the first tool for diagnosing a stress fracture. However, very small stress fractures may only be visible with a computed tomography (CT) scan or magnetic resonance imaging (MRI). The treatment for a stress fracture is rest. Resuming activity too soon can prevent healing.

Puwadol Jaturawutthichai/Shutterstock.com

Figure 4.34 X-rays are an important diagnostic tool for finding bone fractures.

Epiphyseal Injuries

Epiphyseal injuries include injuries to the epiphyseal plate, articular cartilage, and apophysis. An **apophysis** (a-PAHF-i-sis) is a site where a tendon attaches to a bone. Both acute and overuse-related injuries can damage the growth plate, potentially resulting in premature closure of the epiphyseal junction and termination of bone growth.

Osteochondrosis (ahs-tee-oh-kahn-DROH-sis), also known as *Osgood-Schlatter disease*, is inflammation of the apophysis and growth plate at the superior end of the tibia. This apophysis is the site where the powerful quadriceps muscle group on the front of the thigh attaches to the tibia through a tendon extending down from the patella. The apophysis is positioned over the tibial growth plate. When the quadriceps is used a lot in running, jumping, and other sports activities during the adolescent growth spurt, the tibial growth plate and apophysis can become inflamed, swollen, and painful.

Osteochondrosis is common in adolescents who play soccer, basketball, and volleyball, and who participate in gymnastics, with more boys affected than girls. The primary symptom is a painful region of swelling at the muscle attachment site, which can occur on one or both legs, as shown in **Figure 4.35**. The pain worsens with physical activity.

A physical exam and X-ray can confirm the diagnosis of osteochondrosis. The primary treatment is cessation of the activity believed to have been the cause. Stretching exercises for the thigh muscles can also help to relieve the strain on the tibial apophysis. Oral anti-inflammatory drugs can be prescribed to help address the pain and swelling. In severe cases, a physician may apply a cast to ensure complete rest of the knee.

Homeostatic Calcium Imbalances

Calcium not only provides structural integrity to bone, but also plays a role in nerve function, as well as the functions of the muscular, cardiovascular, and digestive systems. The skeletal, endocrine, digestive, and urinary systems work together to maintain a homeostatic balance of calcium circulating in the blood. When one or more of these homeostatic mechanisms fail, hypo- or hypercalcemia results.

Hypocalcemia, involving abnormally low levels of calcium, can negatively affect tooth health, heart function, the ability of the blood to coagulate, nerve impulse conduction, and contraction of the smooth and skeletal muscles. It can also cause the bones to become brittle and more susceptible to fracture. Both hormonal imbalances and a diet low in calcium can cause the condition.

sutisakphoto14's portfolio/Shutterstock.com

Figure 4.35 Note the prominent swelling below the knee. This is characteristic of Osgood-Schlatter disease.

Symptoms of hypercalcemia, or abnormally high levels of calcium, include slowed reflexes, loss of appetite, constipation, and confusion. Severe cases can trigger coma. Treatments for these conditions vary with the cause.

Check Your Understanding

1. List and describe the following types of fractures: simple, compound, comminuted, avulsion, spiral, greenstick, and stress.
2. Explain osteochondrosis.
3. Why is it important for children to avoid activities that could cause damage to an epiphyseal plate?
4. What health issues may be caused if the calcium concentration in the blood becomes abnormally low?

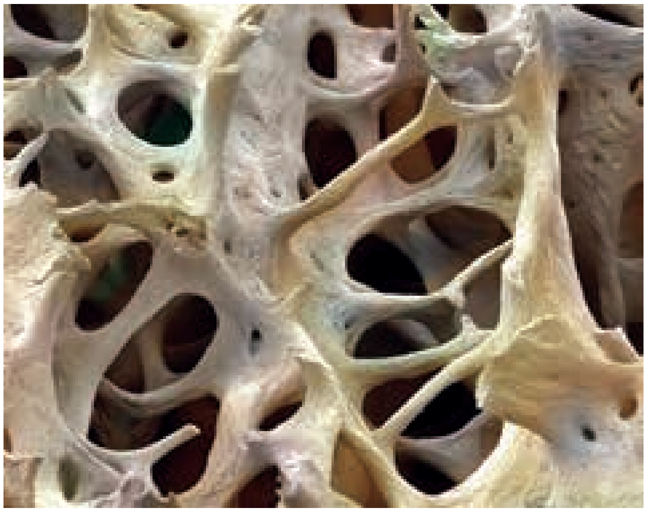
4.5-2 Osteoporosis

Osteoporosis (ahs-tee-oh-poh-ROH-sis) is a condition in which bone mineralization and strength are so abnormally low that regular, daily activities can result in painful fractures. With its honeycomb structure, trabecular bone is most commonly the site of osteoporotic fractures (**Figure 4.36**).

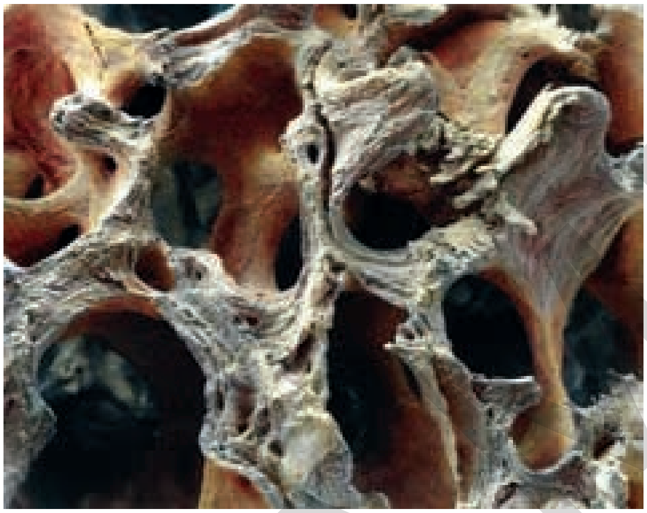
Age-Related Osteoporosis

Osteoporosis occurs in most elderly individuals, with earlier onset in women. The condition begins as **osteopenia** (ahs-tee-oh-PEE-nee-a), reduced bone mass without the presence of a fracture. The osteopenia often progresses to osteoporosis, with fractures present. Although once regarded as primarily a health issue for women, with the increasing age of the population, osteoporosis is now also becoming a concern for older men.

With type I osteoporosis, also known as *postmenopausal osteoporosis*, fractures usually begin to occur about 15 years post-menopause; the femoral neck, vertebrae, and wrist bones are the most common fracture sites. Type II osteoporosis, also called *age-associated osteoporosis*, affects most women and also affects men over 70 years old. After 60 years of age, the majority of fractures in both men and women are osteoporosis-related. In the elderly population, fractures of the femoral neck, in particular, often trigger a downward health spiral that leads to death.



A



B

Steve Gschmeissner/Science Source, Dee Breger/Science Source

Figure 4.36 Compare the normal trabecular bone (A) with the brittle, degraded bone (B) characteristic of osteoporosis. The yellowish, underlying tissue in B is visible because the surface of the bone (orange colored) has worn away. As the bone becomes more brittle, it is more likely to fracture. *Which groups of people are most likely to suffer from osteoporosis?*

The most common symptom of osteoporosis, however, is back pain derived from crush-type fractures of the weakened trabecular bone of the vertebrae. These fractures can be caused by activities as simple as picking up a bag of groceries or a bag of trash. These vertebral crush fractures frequently cause reduction of body height and tend to accentuate the kyphotic curve in the thoracic region of the spine. This disabling deformity is known as *dowager's hump*.

A diagnosis of osteoporosis is confirmed with X-rays, bone densitometry, and specialized laboratory tests. Treatments can include estrogen replacement therapy and prescribed medications to increase bone mass.

The Female Athlete Triad

Unfortunately, osteoporosis is not confined to the elderly population. It can also occur in female athletes at the high school and collegiate levels who strive to maintain an excessively low body weight.

In females, striving for an extremely low weight can cause a dangerous condition known as the **female athlete triad**. This condition involves a combination of disordered eating, **amenorrhea** (ah-men-oh-REE-a)—having no period or menses—and osteoporosis. Because this triad can cause negative health consequences ranging from irreversible bone loss to death, friends, parents, coaches, and physicians need to be alert to the signs.

Female athletes participating in endurance or appearance-related sports are most likely to be affected by the female athlete triad. Disordered eating can take the form of anorexia nervosa or bulimia nervosa.

Symptoms of **anorexia nervosa** in girls and women include a body weight that is 15% or more below the minimal normal weight range, extreme fear of gaining weight, an unrealistic body image, and amenorrhea. **Bulimia nervosa** involves a minimum of two eating binges per week for at least three months; an associated feeling of lack of control; use of self-induced vomiting, laxatives, diuretics, strict dieting, or exercise to prevent weight gain; and an obsession with body image.

Although the incidence of osteoporosis among female athletes is unknown, the consequences of the female athlete triad are potentially tragic. Amenorrheic, premenopausal female athletes are known to have an elevated rate of stress fractures. More important, the loss of bone that occurs may be irreversible, and osteoporotic wedge fractures of the vertebrae can ruin posture for life.

Female athletes who are extremely thin and are missing menstrual periods, may have disordered eating, or experience stress fractures should be evaluated by a medical professional to check for bone density. Treatment for the female athlete triad often requires a team of medical professionals. The team may include a primary care provider, gynecologist, nutritionist, and psychological counselor.

What Research Tells Us

...about Preventing Osteoporosis

Osteoporosis is not inevitable with advancing age. It is typically the result of a lifetime of habits that are erosive to the skeletal system. Simply stated, it is easier to prevent osteoporosis than it is to treat it.

The single most important strategy for preventing or delaying the onset of osteoporosis is maximizing bone mass during childhood and adolescence. Weight-bearing exercise such as running, jumping, and even walking is particularly important prior to puberty because of the high level of growth hormone present during this period (**Figure 4.37**). Growth hormone makes exercise particularly effective in increasing bone density.

oliveromg/Shutterstock.com

Figure 4.37 *How can this activity help prevent osteoporosis in later life?*

Diet also plays an important role in bone health. Physicians now recognize that a predisposition for osteoporosis can begin in childhood and adolescence when a poor diet interferes with bone mass development. Adequate dietary calcium is particularly important during the teenage years, but unfortunately the typical American girl falls below the recommended daily intake of 1,200 mg per day by 11 years of age. A modified diet or calcium supplementation can be critically important for the development of peak bone mass among adolescent females who have this dietary deficiency.

The role of vitamin D is also important, because vitamin D enables bone to absorb calcium. In North America, more than 50% of women being treated for low bone density also have a vitamin D deficiency.

Other lifestyle factors also affect bone mineralization. Risk factors for developing osteoporosis include a sedentary lifestyle, weight loss or excessive thinness, and smoking tobacco. To help prevent later development of osteoporosis, young women are encouraged to engage in regular physical activity and to avoid the lifestyle factors that negatively affect bone health.

Taking It Further

1. Make a list of activities that you can engage in now that will increase your chances of preventing or delaying the onset of osteoporosis. Share your list with classmates.
2. What foods might you recommend for bone health in young teenage girls?

Bone Cancer

Although cancers from other systems in the body can metastasize and spread to bone, only cancers that begin in bone are called *bone cancer*. Noncancerous bone tumors are much more common than cancerous ones, with true bone cancer constituting less than 1 percent of all cancers. The most common sites are the pelvis and the long bones of the arms and legs.

Symptoms of bone cancer include bone pain that may be accompanied by swelling and tenderness, as well as weakening of the bone that can result in fracture. Symptoms of many other cancers, such as fatigue and unintended weight loss, may also be present. Bone cancers are typically removed surgically, with chemotherapy or radiation therapy also possible.

Check Your Understanding

1. How does osteoporosis differ from osteopenia?
2. What two eating disorders are common in women diagnosed with the female athlete triad?
3. Describe the symptoms of bone cancer.

4.5-3 Common Joint Injuries

The freely movable joints of the human body are subject to significant wear over the course of a lifetime. Both acute and overuse injuries affect the joints. The etiology, strategies for prevention, pathology, diagnosis, and common treatments for these common joint injuries and disorders are summarized in **Figure 4.38**.

Sprains

Sprains are injuries caused by abnormal motion of the articulating bones that results in overstretching or tearing of ligaments, tendons, or other connective tissues crossing a joint. The most common site of sprain is the ankle, and the most common mechanism is injury to the lateral ligaments. Lateral ankle sprains occur frequently because the ankle is a major weight-bearing joint and because there is less ligamentous support on the lateral than on the medial side of the ankle.

Pain and swelling are the symptoms of joint sprains. Immediate self-treatment should include R.I.C.E.:

Rest. (Avoid activities that exacerbate the pain.)

Ice. (Apply an ice pack as soon as possible for 15–20 minutes and repeat every two to three hours while you are awake for the first few days after the injury.)

Compression. (Use an elastic bandage to gently compress the joint until the swelling stops. Be careful not to tighten the bandage to the point of stopping circulation.)

Elevation. (Elevate the injured joint above the level of your heart, especially at night, which allows gravity to help reduce swelling.)

Common Joint Injuries and Disorders

	Etiology	Prevention	Pathology	Diagnosis	Treatment
Sprains	motion causing overstretching of ligaments and tendons	Be careful!	swelling and pain that is exacerbated with use of the joint	physical exam, MRI to check for complete rupture of a ligament or tendon	R.I.C.E. (Rest, intermittent Icing, Compression with an elastic bandage, Elevation), surgical repair if necessary
Dislocations	force that dislodges a bone from its normal position in a joint	Be careful!	visible joint deformity, pain, swelling, some loss of movement capability	physical exam, X-ray or MRI to assess joint damage	may include immobilization with a splint or sling, surgical repair if necessary
Bursitis	overuse of a joint	avoid excessive, repetitive joint motion	joint aching, stiffness, pain with motion, swelling	physical exam	cease the activity that caused the injury, rest the joint
Lyme disease	borrelia bacteria is transmitted in the bite of a deer tick	avoid wooded or grassy areas, insecticide, prompt removal of any ticks	bull's-eye shaped rash, fever, head-ache, fatigue; if untreated can cause joint pain and other problems	physical exam, blood test for presence of antibodies to the bacteria	oral or injected antibiotics
Rheumatoid arthritis	the body's immune system attacks the synovial membranes	no known prevention	inflammation and thickening of synovial membranes leading to destruction of the joint over time	physical exam, blood tests for inflammation, imaging tests to track joint destruction	anti-inflammatory drugs, steroids, disease-modifying anti-rheumatic drugs
Osteoarthritis	wearing away of articular cartilage	no known prevention	pain, tenderness, loss of flexibility, and joint stiffness	physical exam, imaging tests	anti-inflammatory medications, joint injections of cortisone or hyaluronic acid, joint replacement

Figure 4.38

Goodheart-Willcox Publisher

Over-the-counter pain medications can also be taken. Serious sprains should be evaluated by a physician, who may ask for an MRI to determine whether a ligament or tendon has been completely ruptured (**Figure 4.39**). Such cases may require surgical repair.

Dislocations

When one of the articulating bones is displaced from the joint socket, the injury is called a **dislocation** of that joint (**Figure 4.40**). Dislocations usually result from falls or forceful collisions. Common dislocation sites are the shoulders, fingers, knees, elbows, and jaw.

Signs and symptoms include visible joint deformity, pain, swelling, and some loss of movement capability. Treatment involves first reducing the dislocation, which means restoring the displaced bone to its correct anatomical location. A physician may order an X-ray or MRI to assess the damaged joint. Depending on the nature of the damage, a splint or sling may be used to immobilize the joint for a time. Surgical repair may be necessary if tendons or ligaments have ruptured.

Bursitis

Bursitis is the inflammation of one or more bursae, the fluid-filled sacs that provide cushioning of the moving tissues around a joint. Bursitis is an overuse injury that produces irritation and inflammation of the bursae due to friction (**Figure 4.41**). The most common locations are the shoulder, elbow, and hip. Symptoms of bursitis may include aching and stiffness of the joint, pain with joint motion, and sometimes swelling. Treatment consists of simply resting the joint until symptoms disappear.

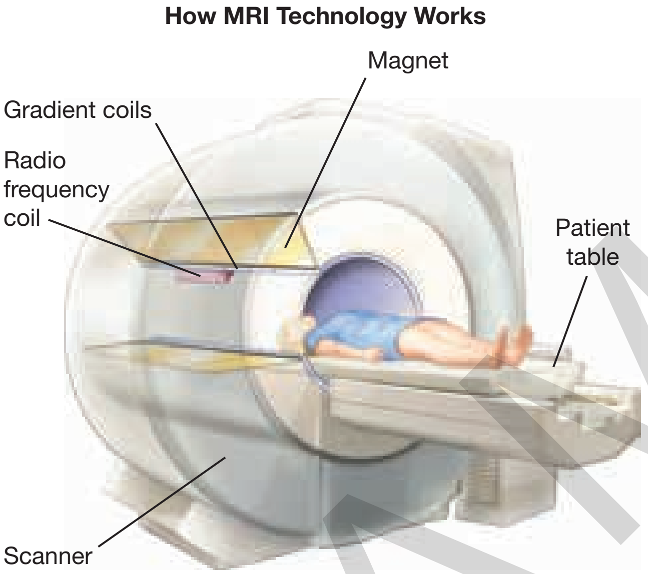


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Figure 4.39 Magnetic resonance imaging (MRI) scanner.

filipp101/Shutterstock.com

Figure 4.40 Dislocation and fracture of the clavicle.

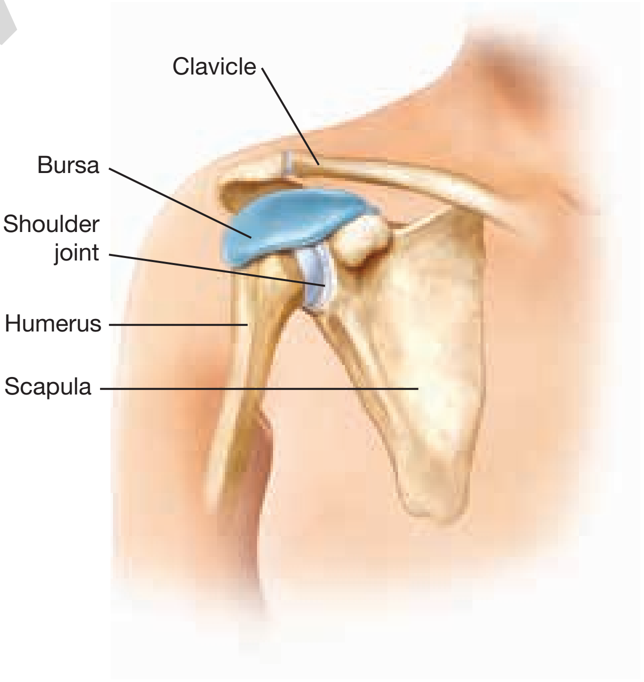

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Figure 4.41 Bursitis is an inflammation of the bursa, a pad-like sac filled with lubricating fluid, which reduces friction between tendons, muscles, and bones.

Check Your Understanding

1. Which structures are affected when a joint is sprained?
2. What types of actions may result in dislocations?
3. What are the causes and symptoms of bursitis?

4.5-4 Arthritis

Arthritis is a common pathology associated with aging. It is characterized by joint inflammation accompanied by pain, stiffness, and sometimes swelling. Arthritis is not a single condition but a large family of pathologies. More than 100 different types of arthritis have been identified.

Rheumatoid Arthritis

Rheumatoid arthritis is a chronic inflammatory disorder in which the body's own immune system attacks the healthy membranes that surround synovial joints (**Figure 4.42**). The disorder can affect multiple joints, with those most commonly affected being the small gliding, condyloid, and saddle joints present in the wrists, hands, and feet. The progression includes inflammation and thickening of the synovial membranes followed by breakdown of the joint structures over time. The result is extremely limited joint motion and, in extreme cases, complete fusing of the articulating bones. Associated symptoms include tenderness, warmth, and swelling of the joints, with stiffness that is usually worse in the mornings and after inactivity.

Chaowalit Seeneha/Shutterstock.com

Figure 4.42 This person's hands have been disfigured by rheumatoid arthritis. Most patients take medication for the intense pain.

Fatigue, fever, and weight loss may also occur. This is the most debilitating and painful form of arthritis. It is more common in adults but occasionally occurs in children (juvenile rheumatoid arthritis).

The cause of rheumatoid arthritis is unknown, although genetics may play a role. Diagnosis is difficult in the early stages because the symptoms are like those of many other diseases. Blood tests can reveal the presence of inflammation in the body and imaging tests can help to detect progression of the disorder. There is no cure for rheumatoid arthritis. Treatment may include anti-inflammatory drugs, steroids, and a class of drugs called *disease-modifying anti-rheumatic drugs (DMARDs)*. These drugs can slow the progression of rheumatoid arthritis and save the joints and other tissues from permanent damage.

Osteoarthritis

Arthritis also takes a noninflammatory form as **osteoarthritis**, a degenerative disorder of articular cartilage. Onset of osteoarthritis is characterized by progressive roughening of the normally smooth joint cartilage, with the cartilage eventually wearing away completely. The most commonly affected joints are in the hands, knees, hips, and spine, although any joint can be affected.

Pain, tenderness, loss of flexibility, and stiffness are all symptoms, with the pain typically relieved by rest and joint stiffness improved by activity. Bone spurs may form around affected joints, causing a grating sound with joint motion. Diagnosis is achieved with physical examination and imaging tests. Treatments include anti-inflammatory medications and injections into the joint of cortisone or hyaluronic acid (a joint lubricant). When the condition becomes too painful, joint replacement is warranted.

Check Your Understanding

1. What are the general symptoms associated with all forms of arthritis?
2. What is believed to be the cause of rheumatoid arthritis?

What Research Tells Us

...about Bone Tissue Engineering

Bones can be damaged through birth defects, infections, cancers, wear, or traumatic injury. These defects can be unsightly, painful, or even dangerous for the patient. Traditional repair and reconstruction techniques include fixation of an artificial plate to the damaged bone with screws and grafting of new bone tissue to the region. However, these approaches often involve complications, including poor fitting of the plate and graft failure.

An exciting frontier of medical research involves bone tissue engineering for repair of bone defects. In essence, this involves growing new bone tissue using the patient's own mesenchymal stem cells. *Mesenchymal stem cells* are cells that can form a variety of different tissue types, including bone, cartilage, muscle, fat, and connective tissue. A surgeon extracts a small amount of mesenchymal stem cells from the patient's iliac crest. These are then carefully spread in a growth medium to grow into larger cell colonies that can differentiate into cells that form bone. More recently, scientists have discovered that stem cells can also be extracted from fat.

Whatever the source, once cultured, the live bone cells are then implanted on a biomaterial scaffold and dosed with growth factors. Many different growth factor delivery techniques and scaffold compositions have been explored, although none have yet emerged as universally recommended. Scientists have discovered that the size of the pores in the scaffolding material is important in influencing the ability of the cells to attach and colonize.

A surgeon then implants this bone cell colony and scaffold material into the site of damage in the bone. The additional challenges at this point are promoting the development of a blood supply to the implant and ensuring the survival of the live cells. Achievement of long-term repair requires infusion of antibiotics and growth factors in appropriate amounts and with optimal timing during the healing and repair processes.

Another novel approach begins with a CT scan of the bone defect and extraction of a small sample of fat from the patient. The CT scan is used to create a precise 3-dimensional model of the site requiring repair. The model is then placed in a growth chamber along with stem cells from the patient's fat sample. Ideally, in a few weeks a perfectly fitting bony replacement part has been grown with the patient's own cells. This promising approach is currently being developed in animals. Tissue engineering using a patient's own stem cells is being cited as "the next generation of medicine."

Taking It Further

1. Why is bone tissue engineering useful?
2. What are the current challenges for this field?

LESSON 4.5 Review and Assessment

Mini Glossary

Make sure that you know the meaning of each key term.

amenorrhea absence of a menstrual period in women of reproductive age

anorexia nervosa condition characterized by body weight 15% or more below the minimal normal weight range, extreme fear of gaining weight, an unrealistic body image, and amenorrhea

apophysis site at which a tendon attaches to bone

arthritis family of more than 100 common pathologies associated with aging, characterized by joint inflammation accompanied by pain, stiffness, and sometimes swelling

avulsion a fracture caused when a tendon or ligament pulls away from its attachment to a bone, taking a small chip of bone with it

bulimia nervosa disordered eating that involves a minimum of two eating binges a week for at least three months; an associated feeling of lack of control; use of self-induced vomiting, laxatives, diuretics, strict dieting, or exercise to prevent weight gain; and an obsession with body image

bursitis inflammation of one or more bursae

dislocation injury that involves displacement of a bone from its joint socket

female athlete triad a combination of disordered eating, amenorrhea, and osteoporosis

fracture any break or disruption of continuity in a bone

osteoarthritis degenerative disease of articular cartilage, characterized by pain, swelling, range-of-motion restriction, and stiffness

osteopenia reduced bone mass without the presence of a fracture

osteoporosis condition in which bone mineralization and strength are so abnormally low that regular, daily activities can result in painful fractures

rheumatoid arthritis autoimmune disorder in which the body's own immune system attacks healthy joint tissues; the most debilitating and painful form of arthritis

sprain injury caused by abnormal motion of the articulating bones that results in overstretching or tearing of ligaments, tendons, or other connective tissues crossing a joint

stress fracture tiny, painful crack in bone that results from overuse

Know and Understand

1. What is an avulsion? (LO 4.5-1)
2. At what point in a person's life is osteochondrosis most likely to occur? (LO 4.5-1)
3. What is the most common symptom of osteoporosis? (LO 4.5-2)
4. Which joint in the skeleton is the most commonly sprained? (LO 4.5-3)
5. What happens to healthy joint tissue in a person with rheumatoid arthritis? (LO 4.5-4)

Analyze and Apply

1. Explain how the remodeling of a bone and a stress fracture are related. (LO 4.1-3, LO 4.5-1)
2. Why are epiphyseal injuries especially worrisome in children? (LO 4.5-1)
3. Why are females who participate in certain sports more vulnerable to the condition known as *female athlete triad*? (LO 4.5-2)
4. A 17-year-old soccer player has sustained several fractures to different parts of her body. When her bone density was tested, she was found to be on the low end of the normal range. What would you suggest that she do to increase her bone strength? (LO 4.5-2)
5. Keeping in mind the description in this chapter of mineral content and structure of the two types of bone tissue, explain why fractures in someone with osteoporosis occur most often in trabecular bone. (LO 4.5-2)

IN THE LAB

1. You are a healthcare worker, and you have a patient with one of the following conditions: osteoporosis, osteopenia, rheumatoid arthritis, bursitis, or osteoarthritis.

   Decide which condition your patient has and then create a treatment plan for the patient. Your plan should include a description of the disorder; age groups typically affected by the disorder; medications to ease pain and inflammation, if any; foods to help minimize the progression of the disorder; foods to omit from the diet; physical activities to add to or increase in the daily routine; and a workout schedule for each day of the week.

   Create your treatment plan in the form of a presentation. Share the presentation with the class, as though the class were your patient. Ask for and answer any questions that your "patient" might have. (LO4.5-2, LO 4.5-4)
2. You are a research scientist studying the effects of lifestyle choices (regarding diet and exercise) on the risks of developing osteoporosis. Your task is to create a lifestyle plan to educate people of all ages on the things they can do to lower or possibly even eliminate their risk for developing osteoporosis later in life. (LO 4.5-2)

CAREER CORNER

Anatomy & Physiology at Work

Orthopedics is a field of medical science that specializes in treating injuries, disorders, and diseases of the bones and joints. Many different health professionals, however, are involved in helping patients overcome skeletal injuries and improve the health of their bones and joints.

Physician

When bone and joint injuries or age-related conditions arise, which healthcare professionals team up to take care of these problems? The person injured should usually seek help first from a family physician, general practitioner, or other primary care provider who offers comprehensive healthcare for people of all ages.

Family physicians have either the MD (Doctor of Medicine) degree or the DO (Doctor of Osteopathic Medicine) degree. The family physician can examine the patient and, as appropriate, administer a series of tests to determine whether referral to an orthopedic surgeon is warranted for more specialized care.

Orthopedic surgeons have specialized training beyond the MD or DO degree in the care of bone and joint injuries and pathologies. The orthopedic surgeon most likely will want to see an X-ray and sometimes an MRI (magnetic resonance image) to determine whether surgery is warranted, and what other follow-up care may be appropriate.

Radiographer

Radiographers use imaging techniques, such as radiographs (X-rays) and MRI scans, to capture pictures of injured or pathological tissues. These professionals, also called *medical radiation technologists*, provide the images to doctors, who evaluate the images to determine the most effective treatment for the patient.

These technologists are trained in positioning patients to get the best kinds of images for evaluation (**Figure 4.43**). Radiographers may specialize in mammography, fluoroscopy, computed tomography, ultrasound, or MRI. The education required to become a radiologic technologist typically is a bachelor's degree that includes training in radiography.

Orthotist/Prosthetist

Sometimes the best way to treat an orthopedic injury is with a customized device. Such devices, called *orthotics*, include custom shoe inserts and leg braces. For more serious injuries, a patient's limb may need to be replaced with a prosthetic one. A *prosthetic* is a fabricated substitute developed to assist a damaged body part or replace one that is missing. A person who treats patients with orthotics or prosthetics is called an orthotist/prosthetist (OR-tha-tist/PRAHS-theh-tist), or O&P professional.

Poznyakov/Shutterstock.com

Figure 4.43 A radiographer needs to know how to operate the many types of imaging equipment used to help diagnose patient injuries.

O&P professionals have a master's degree in orthotics and prosthetics, and they have passed a certification exam administered by the American Board for Certification in Orthotics, Prosthetics and Pedorthics (ABC). O&P professionals may specialize in both orthotics and prosthetics, or only one of these fields. To be certified in both fields, candidates must complete one year of residency in each specialty and pass the required ABC exams.

Orthotists and prosthetists meet with patients to evaluate their needs, measure patients for custom design and fitting of medical devices, and design their patients' devices and repair or update them as needed (**Figure 4.44**). They also instruct patients in the proper use and care of their devices. O&P professionals are employed in small, private offices or in larger medical facilities, and they often work in the shops where orthotics and prosthetics are made.

Planning for a Health-Related Career

Research the career of an orthopedic surgeon, a radiographer, or an orthotist/prosthetist. Alternatively, select a profession from the list of related career options. Using the internet or resources at your local library, find answers to questions such as the following:

1. What are the main tasks and responsibilities of the career you are researching?
2. What is the outlook for this career? Are workers in demand, or are jobs dwindling? For complete information, consult the current edition of the *Occupational Outlook Handbook*, published by the US Department of Labor. This handbook is available online or at your local library.
3. What special skills or talents are required? For example, do you need to be good at biology and chemistry? Do you need to enjoy interacting with other people?
4. What personality traits do you think are needed to be successful in this job? For example, a career as a surgeon requires directing other people. Are you comfortable with giving directions to others?

fotoliza/Shutterstock.com

Figure 4.44 Orthotists may use a digital foot scan to provide the basis for custom shoe insoles.

5. Does this career involve a great deal of routine, or are the day-to-day responsibilities varied?
6. Does the work require long hours, or is it a standard, "9-to-5" job?
7. What is the salary range for this job?
8. What do you think you would like about this career? Is there anything about it that you might dislike?

Related Career Options

- Family practitioner
- Magnetic resonance (MR) technologist
- Orthotist/prosthetist
- Physical therapist
- Physician assistant
- Podiatrist
- Surgical nurse

CHAPTER 4

Review

LESSON 4.1

Bone as a Living Tissue

Key Points

4.1-1 The five functions of the skeletal system are support, protection, movement, storage, and blood cell formation.

4.1-2 The five categories (by shape) of bones are long bones, short bones, flat bones, sesamoid bones, and irregular bones.

4.1-3 Remodeling of bones continues throughout life to keep bones strong.

Key Terms

articular cartilage
bone marrow
cortical bone
diaphysis
endosteum
epiphyseal plate
epiphysis
Haversian canals
Haversian system
hematopoiesis
lacunae
medullary cavity
ossification
osteoblasts
osteoclasts
osteocytes
osteon
perforating (Volkmann's) canals
periosteum
remodeling
trabecular bone

LESSON 4.2

The Axial Skeleton

Key Points

4.2-1 The skull contains eight cranial bones and fourteen facial bones.

4.2-2 The five sections of the vertebral column, or spine, are the cervical region, thoracic region, lumbar region, sacrum, and coccyx.

4.2-3 The thoracic cage, which protects the heart and lungs, is made up of the ribs, sternum, and thoracic vertebrae.

Key Terms

atlas
axial skeleton
axis
cervical region
coccyx
cranium
facial bones
fontanel
intervertebral discs
lumbar region
mandible
maxillary bones
process
sacrum
skull
sternum
sutures
thoracic cage
thoracic region
vertebra
vomer

LESSON 4.3

The Appendicular Skeleton

Key Points

4.3-1 The upper extremity includes the pectoral girdle, arms, wrists, and hands; the pectoral girdle includes the clavicles and scapulae.

4.3-2 The lower extremity, which includes the pelvic girdle, legs, ankles, and feet, is designed for weight-bearing and gait.

Key Terms

appendicular skeleton
carpal bones
clavicle
femur
fibula
humerus
lower extremity
metacarpal bones
metatarsal bones
patella
pectoral girdle
pelvis
phalanges
radius
scapula
tarsal bones
tibia
ulna
upper extremity

LESSON 4.4
Joints

Key Points

4.4-1 The three main categories of joints, with regard to function, are the immovable joints (synarthroses), the slightly movable joints (amphiarthroses), and the freely movable joints (diarthroses).

4.4-2 Articular tissues include articular fibrocartilage, tendons, and ligaments.

Key Terms

amphiarthrosis
articular fibrocartilage
ball-and-socket joint
bursae
condyloid joint
diarthrosis
gliding joint
hinge joint
ligament
pivot joint
saddle joint
symphysis
synarthrosis
synchondrosis
syndesmosis
synovial joint
tendon
tendon sheath

LESSON 4.5
Common Injuries and Disorders of the Skeletal System

Key Points

4.5-1 Common bone injuries include fractures, or breaks, and epiphyseal injuries.

4.5-2 Osteoporosis is a condition in which bone mineralization and strength are critically low, often leading to fractures.

4.5-3 Sprains, dislocations, and bursitis are common joint injuries and disorders.

4.5-4 The signs and symptoms of arthritis include joint inflammation, pain, stiffness, and sometimes swelling.

Key Terms

amenorrhea
anorexia nervosa
apophysis
arthritis
avulsion
bulimia nervosa
bursitis
dislocation
female athlete triad
fracture
osteoarthritis
osteopenia
osteoporosis
rheumatoid arthritis
sprain
stress fracture

Assessment

LESSON 4.1
Bone as a Living Tissue

Learning Key Terms and Concepts

1. The five functions of the skeletal system are blood cell formation, movement, support, storage, and _____. (LO 4.1-1)
2. The term for blood cell formation is _____. (LO 4.1-1)
   A. osteocyte
   B. hematopoiesis
   C. osteogenesis
   D. osteoblast
3. The strong, dense type of bone tissue is called _____. (LO 4.1-2)
   A. trabecular bone
   B. coxal bone
   C. cortical bone
   D. hard bone

4. The shape categories of bones are irregular, short, flat, long, and _____. (LO 4.1-2)
5. The shaft of a long bone is called the _____; the ends of a bone are called the epiphyses. (LO 4.1-2)
6. Specialized bone cells that build new bone are called _____. (LO 4.1-2)
   A. osteocytes
   B. osteoclasts
   C. osteoblasts
   D. osteopaths
7. Specialized bone cells that break down bone are called _____. (LO 4.1-2)
   A. osteocytes
   B. osteoclasts
   C. osteoblasts
   D. osteopaths

Thinking Critically

1. The microscopic structure of long bones can be compared to a city. Using the following terms, describe what each type of long bone could be compared to in your city (a building, streets running through the city, or a water tower, for example): Haversian canal, lacunae, lamellae, canaliculi. Draw a picture to illustrate. (LO 4.1-2)
2. Write a short story about the development of a bone from when it was created and continuing into adulthood. The bone is the main character in the story. Have the bone describe the changes that occur after its development. Include anatomical terms from this chapter in your story. (LO 4.1-2)
3. Remembering the shape categories of bones, discuss their cortical-trabecular bone ratios and relate structure to function. (LO 4.1-2)
4. Compare and contrast hypertrophy and atrophy of bones. Include a person's level of activity in your discussion, and explain what is happening on a cellular level. (LO 4.1-3)

LESSON 4.2

The Axial Skeleton

Learning Key Terms and Concepts

1. The three major parts of the axial skeleton are the vertebral column, the thoracic cage, and the _____. (LO 4.2-1)
2. The immovable joints that connect the bones of the skull and face are known as _____. (LO 4.2-1)
3. Which thoracic region includes the vertebrae of the neck? (LO 4.2-2)
   A. thoracic
   B. lumbar
   C. sacral
   D. cervical
4. Which thoracic region connects to the ribs? (LO 4.2-2)
   A. thoracic
   B. lumbar
   C. sacral
   D. cervical
5. Which condition causes a lateral (sideways) curvature of the spine? (LO 4.2-2)
   A. osteopenia
   B. kyphosis
   C. scoliosis
   D. lordosis
6. Which of the following is part of the thoracic cage? (LO 4.2-3)
   A. the fibula
   B. the zygomatic bones
   C. the sternum
   D. the pelvic girdle
7. Which of the following is true about the false ribs? (LO 4.2-3)
   A. They do not attach directly to the sternum.
   B. They do not attach directly to the vertebrae.
   C. They do not attach directly to anything.
   D. They do not exist.

Thinking Critically

1. The bones of the cranium form a solid case to allow maximum protection for the brain. Would this solid structure be more beneficial to the lungs and offer more protection than the thoracic cage, with its open spaces between each rib? Why or why not? (LO 4.2-1)
2. Given your knowledge of the intervertebral discs, what activities should a person avoid to promote disc health? Name at least two activities and explain why each should be avoided. (LO 4.2-2)
3. Discuss the five spinal curves and tell why each of the spinal curves is the shape it is. (LO 4.2-2)
4. Explain why people who have led sedentary lives tend to "shrink" as they age. (LO 4.2-2)

LESSON 4.3

The Appendicular Skeleton

Learning Key Terms and Concepts

1. Which structures are part of the appendicular skeleton? (LO 4.3-1)
   A. the head
   B. the spinal column
   C. the legs
   D. the trunk
2. The pectoral girdle consists of the right and left scapula and the right and left _____. (LO 4.3-1)
3. The bone in the forearm that attaches on the "little finger" side is the _____. (LO 4.3-1)
4. There are _____ bones in each wrist and hand. (LO 4.3-1)
5. The _____ is the prominent, upper edge of the hip bone. (LO 4.3-2)
6. The longest, strongest bone in the body is the _____. (LO 4.3-2)
7. Which of the following is the heel bone? (LO 4.3-2)
   A. talus
   B. femur
   C. patella
   D. calcaneus

Thinking Critically

1. Using the internet, research the origin of the word *appendicular*. Then explain why the bones of the appendicular skeleton are so named and how they relate to the axial skeleton. (LO 4.3-1, LO 4.3-2)
2. In terms of functionality, why does it make sense that there is only one bone in the upper arm but two in the forearm? (LO 4.3-1)
3. If a forensic scientist finds skeletal remains after a house fire, how will she determine whether the individual was a male or female? (LO 4.3-2)
4. How would the function of the body be different if the foot had no arches? (LO 4.3-2)

LESSON 4.4

Joints

Learning Key Terms and Concepts

1. Another term for freely movable joints is _____. (LO 4.4-1)
2. The two main types of immovable joints are sutures and _____. (LO 4.4-1)
3. The vertebral joints are examples of _____ movable joints. (LO 4.4-1)
4. _____ are small sacs filled with synovial fluid that cushion the structures they separate. (LO 4.4-2)
5. The functions of the _____ tissues are to cushion the joints and reduce friction and wear on them. (LO 4.4-2)
6. Ligaments connect bone to bone, while _____ connect muscle to bone. (LO 4.4-2)

Thinking Critically

1. Give reasons why you either would or would not want all of your joints to be ball-and-socket joints. (LO 4.4-1)
2. What would be the effect on human function if the bursae and tendon sheaths were not present? (LO 4.4-1)
3. In terms of function, explain why tendons and ligaments are made of elastic fibers instead of a more rigid tissue. (LO 4.4-2)

LESSON 4.5

Common Injuries and Disorders of the Skeletal System

Learning Key Terms and Concepts

1. A(n) _____ fracture is one in which the ends of a bone protrude from the skin. (LO 4.5-1)
2. A(n) _____ fracture is more common in children than in adults because children's bones are more flexible than those of adults. (LO 4.5-1)
3. _____ fractures are tiny, painful cracks in a bone that result from overuse. (LO 4.5-1)
4. The site where a tendon attaches to a bone is known as the _____. (LO 4.5-1)
5. Injuries to which of the following can stop the growth of a long bone? (LO 4.5-1)
   A. intervertebral disc
   B. meniscus
   C. epiphyseal plate
   D. sutures
6. A condition that involves reduced bone mass but no fractures is _____. (LO 4.5-2)
7. A combination of amenorrhea, disordered eating, and _____, called the female athlete triad, is a dangerous condition that may occur in females who participate in endurance or appearance-related sports. (LO 4.5-2)

8. In the acronym R.I.C.E. for self-treatment of sprains, the *C* stands for _____. (LO 4.5-3)
9. _____ is an autoimmune disorder in which the body's own immune system attacks healthy joint tissues. (LO 4.5-4)

Thinking Critically

1. A 10-year-old boy and his 42-year-old father were building a tree house when the branch they were standing on broke away from the tree. The father sustained two broken ribs, but the boy had only a few bruises. Explain. (LO 4.5-1)
2. Explain how a stress fracture can happen, in terms of osteoblasts and osteoclasts. Further explain why stress fractures are particularly common in the tibia and metatarsals, given the functions of those bones. (LO 4.5-1)
3. Compare and contrast rheumatoid arthritis and osteoarthritis. In your own words, explain anatomically and physiologically what is occurring in each condition. (LO 4.5-4)

Building Skills and Connecting Concepts

Analyzing and Evaluating Data

Instructions: The astronaut in **Figure 4.45** is exercising on a special treadmill system in the International Space Station. Without this type of resistance training, he could lose 1% to 2% bone mass per month. Consider this information as you answer the following questions.

1. If the astronaut spends three months in space and never exercises, what percentage of his bone mass might he lose? (LO 4.1)
2. You read in this chapter that bones account for about 15% of human body weight. If this astronaut weighs 170 pounds, how much do his bones weigh? (LO 4.1)
3. If he fails to exercise for six months in space, how much weight might this astronaut lose in bone mass? (LO 4.1)
4. If this astronaut spends 12 months in space, but only exercises for 3 months, what percentage of bone mass will he lose? (LO 4.1)

Figure 4.45 *NASA/JSC*

Communicating about Anatomy & Physiology HOSA EVENT PREP

1. **Writing** Write an "osteostory" about a superhero who helps someone in distress. Be creative and find ways to mention the following bones in your story: skull, sternum, femur, humerus, tibia, calcaneus, tarsals, carpals, metatarsals, metacarpals, ribs, clavicle, scapula, mandible, and patella. Try to work into the story reasons for describing the locations of these bones in the body. (LO 4.2, LO 4.3)
2. **Speaking** Divide into groups of four or five students. Each group should choose one of the following topics: anorexia nervosa, bursitis, dislocation, female athlete triad, fracture, osteoporosis, rheumatoid arthritis, sprain, or stress fracture.

   Using your textbook as a starting point, research your topic and prepare a report on causes and treatments. As a group, deliver your presentation to the rest of the class. Take notes while other students give their reports. Ask questions about any details that you would like clarified. (LO 4.5)
3. **Listening** Take notes while other students give their reports for the previous question. Ask questions about any details that you would like clarified. (LO 4.5)

Lab Investigations HOSA EVENT PREP

1. Using medical textbooks and other biological resources, gather information about bone matrix, various types of bone cells, and glycoproteins, such as osteocalcin and alpha-glycoprotein. Identify bone minerals and explain how they can change bone cells during bone development. Prepare a written report, and include your sources. (LO 4.1-1)
2. Construct a skeleton of an animal of your choice using toothpicks and glue. Use labels to identify the bones. At a minimum, include these bones in your skeleton: carpals, cervical vertebrae, coxal bones, femur, fibula, humerus, lumbar vertebrae, mandible, maxilla, metacarpals, metatarsals, patella, phalanges, radius, ribs, scapula, skull, sternum, tarsals, thoracic vertebrae, tibia, ulna. (LO 4.2, LO 4.3)
3. People with bone fractures, especially to the lower limbs, often require assistive devices while they are recovering. Examples of assistive devices include crutches, walkers, and canes. Assistive devices must be used correctly in order to be effective. Choose a specific assistive device and conduct research on its proper use for various types of injuries. Obtain or borrow the device and provide a demonstration for your class on its proper use. Identify incorrect usage, as well as limitations of the device and abnormalities that may prevent a patient from using the device effectively. (LO 4.5-1)
4. Conduct research to find out what range-of-motion exercises are commonly used in physical therapy sessions to help people who are recovering from injuries to regain their full range of motion. Find out the difference between active and passive range-of-motion exercises. Perform a demonstration of active and passive exercises for the class. Include exercises for the shoulders, arms, wrists, knees, and ankles. As you demonstrate, explain the purpose of each exercise. Refer to HOSA's *Physical Therapy* event for additional knowledge and skills related to this topic. (LO 4.5)
5. Conduct research on the internet to find out the basic steps involved in repairing a fracture of a long bone. Be sure to use good internet etiquette and follow safety guidelines for working on the internet. Write a summary report, and list your sources. (LO 4.5-1)
6. Consult HOSA's *Medical Innovation* event and follow the guidelines to create a new assistive device for an injury or condition of your choice. (LO 4.5)
7. Review HOSA's *Sports Medicine* event. Research wrapping techniques, then work with a partner to practice wrapping and taping techniques for an ankle, Achilles tendon, shoulder spica, and wrist/hand. (LO 4.5-3)