

# Skeletal System

## Key Terms

**abduction** (p. 137)

**adduction** (p. 137)

**appendicular skeleton** (p. 117)

**articulation** (p. 115)

**axial skeleton** (p. 117)

**diaphysis** (p. 115)

**epiphysis** (p. 115)

**extension** (p. 137)

**flexion** (p. 137)

**fontanels** (p. 121)

**haversian system** (p. 114)

**osteoblasts** (p. 113)

**osteoclasts** (p. 116)

**periosteum** (p. 115)

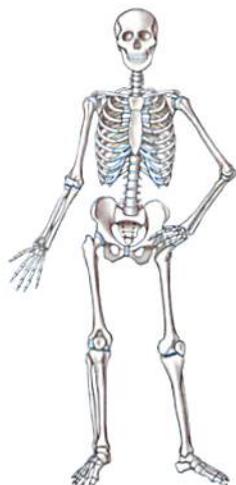
**synovial joint** (p. 133)

## Objectives

1. List the functions of the skeletal system and the classification of bones by size and shape.
2. Differentiate between the composition and location of compact and spongy bone.
3. Describe the structure of a long bone.
4. Describe the roles of osteoblasts and osteoclasts, and how bones grow in length and width.
5. List the bones of the axial skeleton and label important landmarks on selected bones.
6. List the bones of the appendicular skeleton and label important landmarks on selected bones.
7. List the main types and functions of joints and describe the types of joint movement.

The skeletal system consists of the bones, joints, and cartilage and ligaments associated with the joints. Bone tissue is living and metabolically active, but because it contains so much nonliving material, such as calcium and phosphorus, it appears dead or dried up. In fact, the word *skeleton* comes from a Greek word meaning “dried-up body.”

The skeletal system, however, is anything but dead. It contains 206 bones that are very much alive and perform a number of important functions.



## Do You Know...

### About Growing Down with Osteoporosis?

Osteoporosis is a common bone disorder, especially in postmenopausal women. Osteoporosis is characterized by a decline in bone-making activity and the loss of bone tissue. As tissue is lost, the bones weaken and break. Common sites of fracture caused by osteoporosis are the hip, wrist, and vertebrae. Osteoporosis may also affect the vertebral column. As the vertebrae collapse, nerves may be pinched, causing severe pain. The collapsed vertebrae also cause a shortening of the vertebral column (growing down) and a change in its curvature. This change in shape, in turn, often impairs the functioning of organs such as the lungs.

## ARRANGEMENT AND FUNCTIONS OF BONES

The bones of the skeletal system are arranged to provide a framework for our bodies (Figure 8-1). The skeletal system gives us our basic shape. Imagine what you would look like without bones!

### THE SKELETAL SYSTEM: WHAT IT DOES

In addition to shaping us up, the skeletal system performs other functions:

- The bones of the lower extremities support the weight of the body.

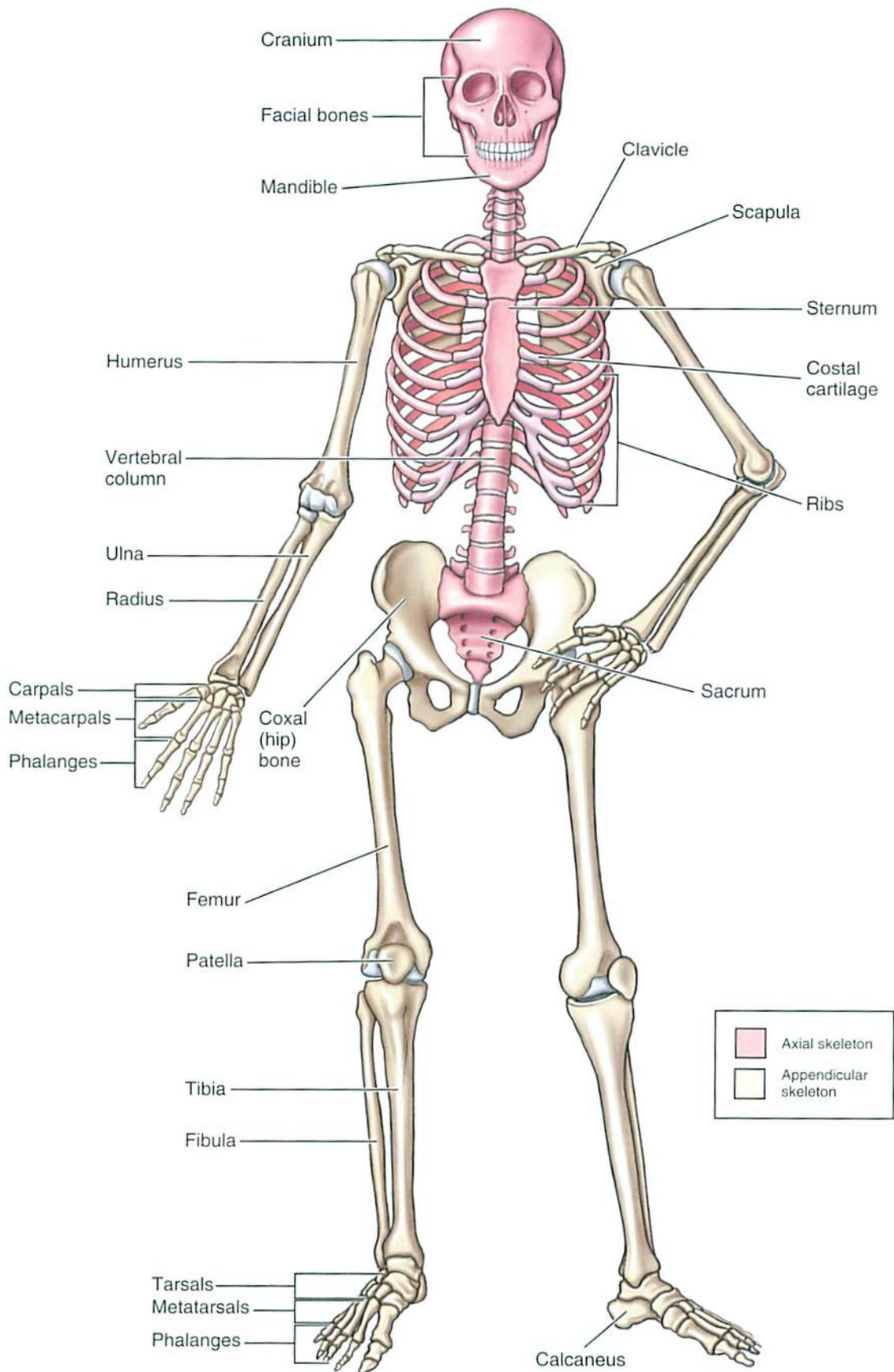


FIGURE 8-1 Skeleton. Axial skeleton (red) and appendicular skeleton (tan).

- The bones support and protect the soft body organs.
- With the assistance of muscles, the skeletal system enables the body to move about.
- Bones store a number of minerals, the most important being calcium and phosphorus. The calcium makes the bones strong and is a readily available source of the mineral for the regulation of calcium in the blood.
- Red bone marrow produces blood cells.

### MANY SIZES AND SHAPES OF BONES

Bones come in many sizes and shapes, from the pea-sized bones in the wrist to the 24-inch femur in the thigh. The size and shape of a bone reflect its function (Figure 8-2). The long strong femur in the thigh, for example, supports a great deal of weight and can withstand considerable force. Some of the skull bones, on the other hand, are thin, flat, and curved. Their function is to encase and protect the brain.

Bones are classified as follows:

- *Long bones.* Long bones are longer than they are wide. They are found in the arms, forearms, palms,

fingers, thighs, legs, and instep. Although it is obvious that the femur (thigh) and the humerus (arm) are long bones, even small bones such as the metacarpals and finger bones are considered long bones.

- *Short bones.* Short bones are shaped like cubes and are found primarily in the wrists and ankles.
- *Flat bones.* Flat bones are thin, flat, and curved. They form the ribs, breastbone, cranium, and bones of the shoulder girdle.
- *Irregular bones.* Irregular bones are differently shaped and are not classified as long, short, or flat. They include the hip bones, vertebrae, and various bones in the skull.

### BONE TISSUE AND BONE FORMATION

Bone is also called *osseous tissue* and the process of bone formation is called *ossification*. Bone cells, called **osteoblasts**, secrete an intercellular matrix, containing calcium, other minerals, and protein fibers. The osteoblasts mature into osteocytes that sit within the hard bone matrix and maintain the bone.

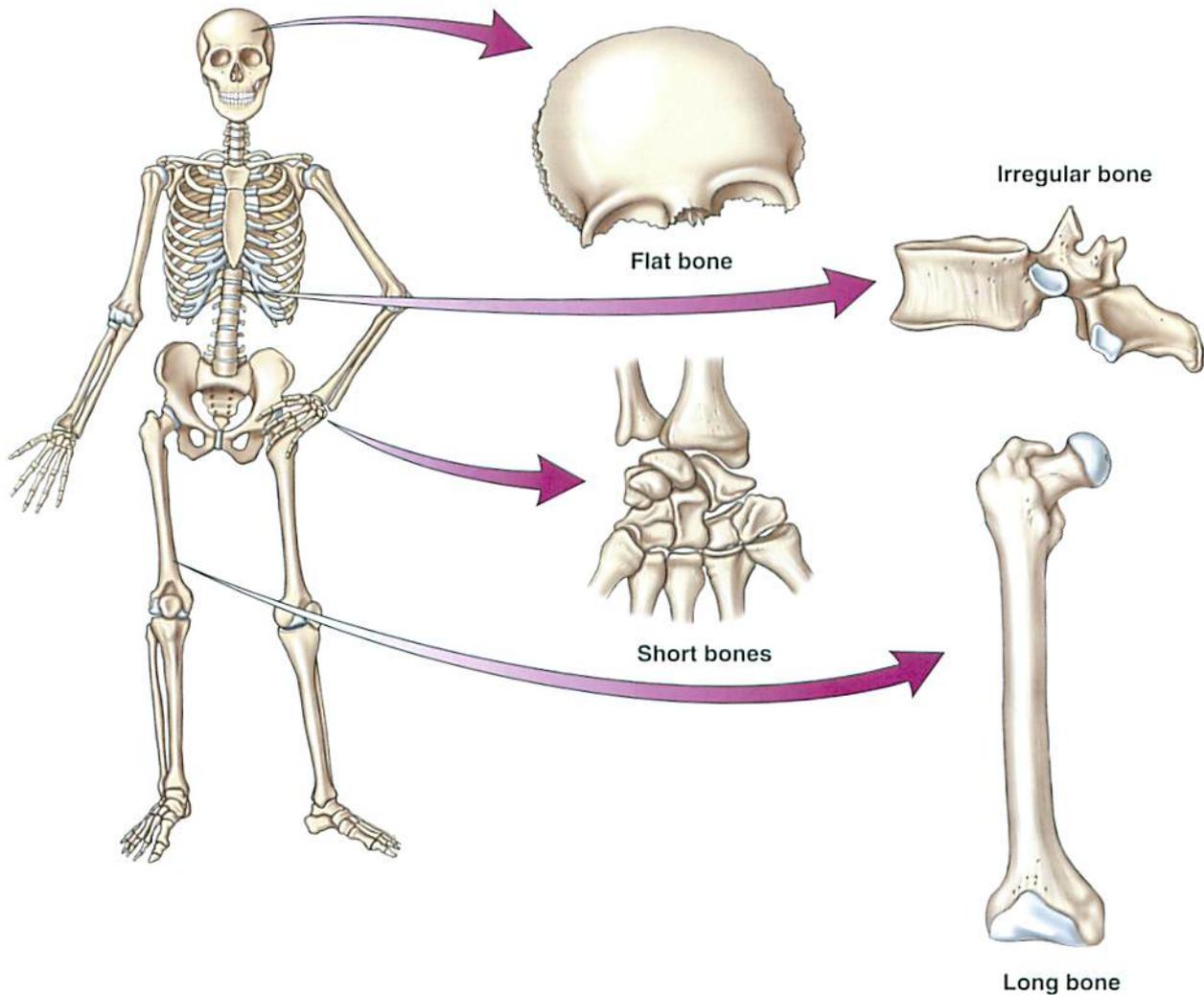


FIGURE 8-2 Types of bones.

## COMPACT AND SPONGY BONE

There are two types of bone: compact and spongy (Figure 8-3). Compact bone refers to dense, hard bone tissue found primarily in the shafts of long bones and on the outer surfaces of other bones. Spongy, or cancellous, bone is less dense. Spongy bone is located primarily at the ends of long bones and in the center of other bones.

Compact and spongy bone look different under the microscope. Compact bone is tightly packed, so that its density can provide a great deal of strength (see Figure 8-3, B). The microscopic unit of compact bone

is the osteon, or **haversian** (hah-VER-shun) **system**. Each haversian system consists of mature osteocytes arranged in concentric circles around large blood vessels. The area surrounding the osteocytes is filled with protein fibers, calcium, and other minerals. The protein fibers provide elasticity, and the minerals make bone tissue hard and strong. Each haversian system looks like a long cylinder.

Compact bone consists of many haversian systems running parallel to each other. Communicating blood vessels run laterally and connect the haversian systems with each other and with the periosteal lining that surrounds the bone. The network of blood vessels ensures

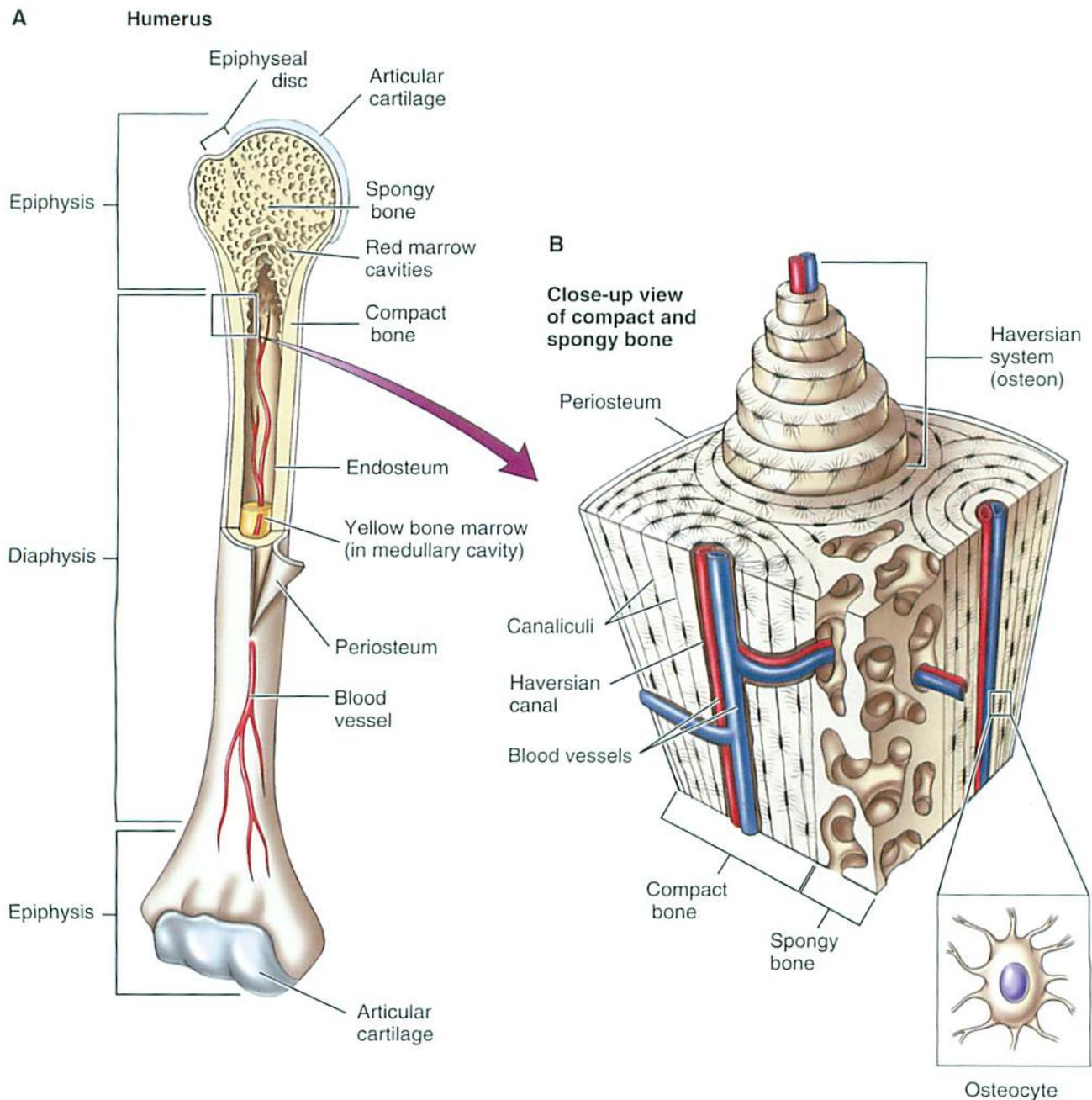


FIGURE 8-3 Bone. A, Anatomy of a long bone. B, Compact and spongy bone.

that the bone tissue receives an adequate supply of blood. Blood supplies tissues with oxygen and nutrients.

Spongy, or cancellous, bone has a much different structure than compact bone (see Figure 8-3, B). Unlike compact bone, spongy bone does not contain haversian systems. In spongy bone, the bone tissue is arranged in plates called *trabeculae* (trah-BEK-yoo-lay). These bony plates are separated by holes that give spongy bone a punched-out Swiss cheese appearance. The holes are important for two reasons: (1) they decrease the weight of the bone, and (2) they contain red bone marrow. The red bone marrow richly supplies the spongy bone with blood and also produces blood cells for use throughout the body. Spongy bone is located in the short, flat, and irregular bones. It is also found in the ends of long bones.

### Re-Think

1. What are two types of bones?
2. What is the structure of an osteon, or haversian system?

## LONG BONES

The arrangement of the compact and spongy tissue in a long bone accounts for its strength. Long bones also contain sites of growth and reshaping and structures associated with joints. Locate the parts of a long bone in Figure 8-3, A:

- **Diaphysis.** The **diaphysis** (dye-AF-i-sis) is the long shaft of the bone. It is composed primarily of compact bone and therefore provides considerable strength.
- **Epiphysis.** The enlarged ends of the long bone are the epiphyses. The **epiphysis** (eh-PIF-i-sis) of a bone articulates, or meets, with a second bone at a joint. Each epiphysis consists of a thin layer of compact bone overlying spongy bone. The epiphyses are covered by cartilage.
- **Epiphyseal disc.** A growing long bone contains a band of hyaline cartilage located near the proximal and distal ends of long bones. This band of cartilage is the epiphyseal disc, or growth plate. It is here that longitudinal bone growth occurs.
- **Medullary cavity.** The medullary cavity is the hollow center of the diaphysis. In infancy, the cavity is filled with red bone marrow for blood cell production. In the adult, the medullary cavity is filled with yellow bone marrow and functions as a storage site for fat. The inside of the medullary cavity is lined with connective tissue called the *endosteum* (en-DOS-tee-um).
- **Periosteum.** The **periosteum** is a tough, fibrous, connective tissue membrane that covers the outside of the diaphysis. It is anchored firmly to the outside of the bone on all surfaces except the articular cartilage. The periosteum protects the bone, serves as a

point of attachment for muscle, and contains the blood vessels that nourish the underlying bone. Because the periosteum carries the blood supply to the underlying bone, injury to this structure has serious consequences to the health of the bone. Like any other organ, the loss of blood supply can cause its death.

- **Articular cartilage.** The articular cartilage is found on the outer surface of the epiphysis. It forms a smooth shiny surface that decreases friction within a joint. Because a joint is also called an **articulation**, this cartilage is called *articular cartilage*.

## OSSIFICATION

The process of bone formation is called *ossification*. Ossification begins in the late embryonic period with the formation of fibrous connective tissue and hyaline cartilage that is shaped like a miniskeleton (Figure 8-4). As the fetus matures, the cartilage and connective tissue change into bone. Ossification occurs in two ways: intramembranous ossification and endochondral ossification.

### OSSIFICATION OF FLAT BONES: INTRAMEMBRANOUS OSSIFICATION

In the fetus, the flat bones (those in the skull) consist of thin connective tissue membranes. Ossification begins when osteoblasts, or bone-forming cells, migrate to the region of the flat bones. The osteoblasts secrete calcium and other minerals into the spaces between the membranes, thereby forming bone. This type of ossification involves the replacement of thin membrane with bone.

### OSSIFICATION OF LONG BONES: ENDOCHONDRAL OSSIFICATION

Most bones are formed by endochondral ossification as bone tissue replaces cartilage. The fetal skeleton is composed largely of cartilage, and the layout of the cartilage in the fetus provides a model for bone formation (see Figure 8-4). As the fetus matures, osteoblasts invade the cartilage and gradually replace the cartilage with bone. This process continues in each long bone until all but the articular cartilage and epiphyseal disc have been replaced by bone. By the time the fetus has fully matured, most cartilage of the body has been replaced by bone. Only isolated pieces of cartilage remain, such as the bridge of the nose and parts of the ribs.

## GROWING BONES

Maturation from infancy to adulthood is characterized by two types of bone growth: (1) bones grow longitudinally and determine the height of an individual, and (2) bones grow thicker and become wider to support the weight of the adult body.

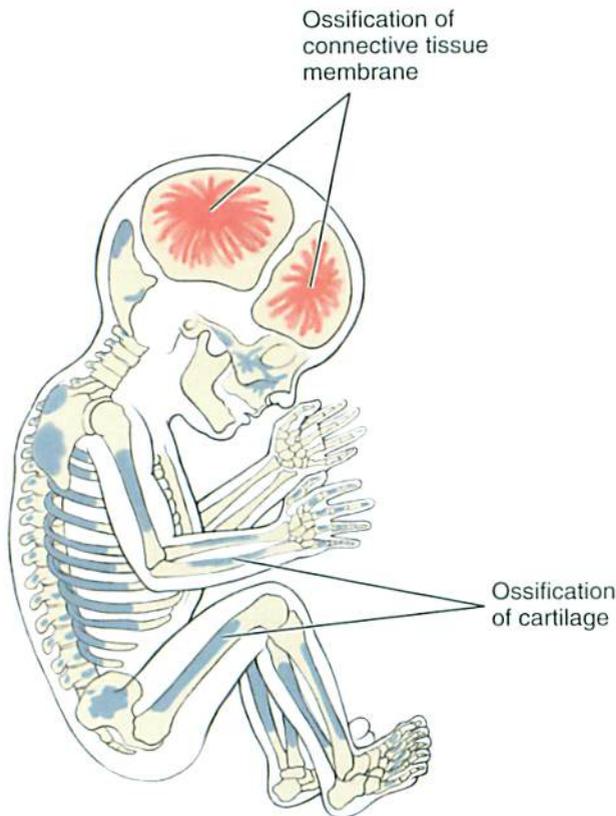


FIGURE 8-4 Ossification.

### GROWING TALLER

Longitudinal bone growth occurs at the epiphyseal disc (also called the growth plate; see Figure 8-3, A). The cartilage adjacent to the epiphysis continues to multiply and grow toward the diaphysis. The cartilage next to the diaphysis, however, is invaded by osteoblasts and becomes ossified. As long as the cartilage continues to form within the epiphyseal disc, the bone continues to lengthen. Longitudinal bone growth ceases when the epiphyseal disc becomes ossified and fused.

The epiphyseal disc is sensitive to the effects of certain hormones, especially growth hormone and the sex hormones. Growth hormone stimulates growth at the epiphyseal disc, making the child taller. The sex hormones estrogen and testosterone, however, cause the epiphyseal disc to fuse, thereby inhibiting further longitudinal growth. Because the epiphyseal disc is especially sensitive to the effects of the female hormone estrogen, girls tend to be shorter than boys. After puberty, which is associated with increasing plasma levels of sex hormones, longitudinal growth eventually ceases.

#### The “What-Ifs” of the Epiphyseal Disc

- What if there is an oversecretion or undersecretion of growth hormone? Giantism occurs with hypersecretion, whereas a type of dwarfism develops with hyposecretion.

- What if the epiphyseal disc is injured? Longitudinal bone growth is impaired in the injured bone. A child who injures the epiphyseal disc in a leg bone, for example, may end up with that leg considerably shorter than the noninjured leg.
- What if a young athlete uses anabolic steroids to enhance performance? Steroids induce premature fusion of the epiphyseal plate, thereby permanently stunting growth.

### GROWING THICKER AND WIDER

During and long after longitudinal bone growth has ceased, bones continue to increase in thickness and width. The bones are continuously being reshaped. Bone remodeling is accomplished by the combined actions of osteoblasts, which are bone-forming cells, and **osteoclasts**, which are bone-destroying cells. Osteoblasts on the undersurface of the periosteum continuously deposit bone on the external bone surface.

Figure 8-5 shows how osteoblastic activity works like a bricklayer. Whereas osteoblasts build new bone, osteoclasts, found on the inner bone surface surrounding the medullary cavity, break down bone tissue, thereby hollowing out the interior of the bone. Osteoclastic activity is like sculpting. The bricklayer and the sculptor gradually create a large, wide hollow bone that is strong but not too heavy.

The process whereby osteoclasts break down bone matrix is called *bone resorption* (not to be confused with *reabsorption*). Bone resorption not only widens bone, but also moves calcium from the bone to the blood. In this way, bone resorption also plays a crucial role in the regulation of blood calcium levels. The influence of parathyroid hormone on bone resorption is described in Chapter 14.

Factors that stimulate bone growth are weight-bearing and exercise; both keep calcium in the bone and increase bone mass. The bones of bedridden or sedentary people tend to lose bone mass and are easily broken when stressed. The weightlessness experienced by astronauts similarly causes a loss of bone mass and easily broken bones. The beneficial effects of exercise on bone strength cannot be overemphasized.

### ? Re-Think

1. Differentiate between the functions of osteoblasts and osteoclasts.
2. Describe how a bone grows in length and in width, using the term *bone resorption*.

### BUMPS AND GROOVES

The surface of bone appears irregular and bumpy as a result of numerous ridges, projections, depressions, and grooves called *bone surface markings*. The projecting bone markings (the markings that stick out) serve as points of attachment for muscles, tendons, and ligaments. The grooves and depressions form the routes



FIGURE 8-5 Bone remodeling.

traveled by blood vessels and nerves as they pass over and through the bones and joints. The projections and depressions also help form joints. The rounded head of the proximal arm bone, for example, fits into a round depression in a shoulder bone, forming the shoulder joint. The specific bone markings are summarized in Table 8-1. Note the various markings on individual bones as they are described.

## BROKEN BONES

Occasionally, a bone breaks, or fractures (Figure 8-6). A simple fracture is a break in which the overlying skin

remains intact; local tissue damage is minimal. A compound fracture is a broken bone that has also pierced the skin. The ends of the broken bone usually cause extensive tissue damage. The risk of infection is a concern with a compound fracture.

A greenstick fracture is an incomplete break in the bone and usually occurs in children. Why is it called a greenstick fracture? If you were to bend a branch of a young tree, the branch would not snap and break apart completely. It would, instead, bend and perhaps break incompletely. The branch responds this way because it is young and pliable, much like a child's bone. Children's bones still contain enough cartilaginous material to make them flexible.

There are many other types of bone fractures. For example, there is a spiral fracture in which the line of the fracture extends in a spiral direction along the diaphysis. It is caused when the bone is subjected to a twisting type of force. There is a comminuted fracture in which there are more than two bone fragments; the small fragments seem to be floating. An impacted fracture is a comminuted fracture in which the two parts of the broken bone have been jammed into each other. The list of fractures goes on.

## 2+2 Sum It Up!

The skeletal system consists of bones, joints, cartilage, and ligaments found in and around the joints. Bones are composed of two types of osseous tissue: compact (dense bone) and spongy (cancellous bone). Bones come in a variety of sizes and shapes and are classified as long, short, flat, or irregular. We begin life in the womb as a skeleton-like frame made of cartilage and thin connective tissue membrane. With maturation, the process of ossification changes most of the cartilage and certain connective tissue membranes into bone. As a person matures, the skeleton enlarges as the bones grow longer, wider, and thicker.

Table 8-1 Bone Markings

BONE MARKINGS	DEFINITION
<b>Projections or Processes</b>	
Condyle	A large rounded knob that usually articulates with another bone
Epicondyle	An enlargement near or above a condyle
Head	An enlarged and rounded end of a bone
Facet	A small flattened surface
Crest	A ridge on a bone
Process	A prominent projection on a bone
Spine	A sharp projection
Tubercle (tuberosity)	A knoblike projection
Trochanter	A large tubercle (tuberosity) found only on the femur
<b>Depressions or Openings</b>	
Foramen	An opening through a bone; usually serves as a passageway for nerves, blood vessels, and ligaments
Fossa	A depression or groove
Meatus	A tunnel or tubelike passageway
Sinus	A cavity or hollow space

## DIVISIONS OF THE SKELETAL SYSTEM

The skeleton is divided into the axial skeleton and appendicular skeletons (see Figure 8-1). The **axial** (AK-see-all) **skeleton** includes the bones of the cranium, face, middle ear bones, hyoid bone, vertebral column, and bony thorax. The **appendicular skeleton** includes the bones of the pelvic girdles, the upper extremities (arms, forearms, wrist, palms, and fingers), and lower extremities (thighs, legs, ankles, instep, and toes). The names of the 206 bones of the skeleton are listed in Table 8-2.

## AXIAL SKELETON

### SKULL

The skull sits on top of the vertebral column and is formed by two groups of bones: the cranium and the facial bones (Figure 8-7).

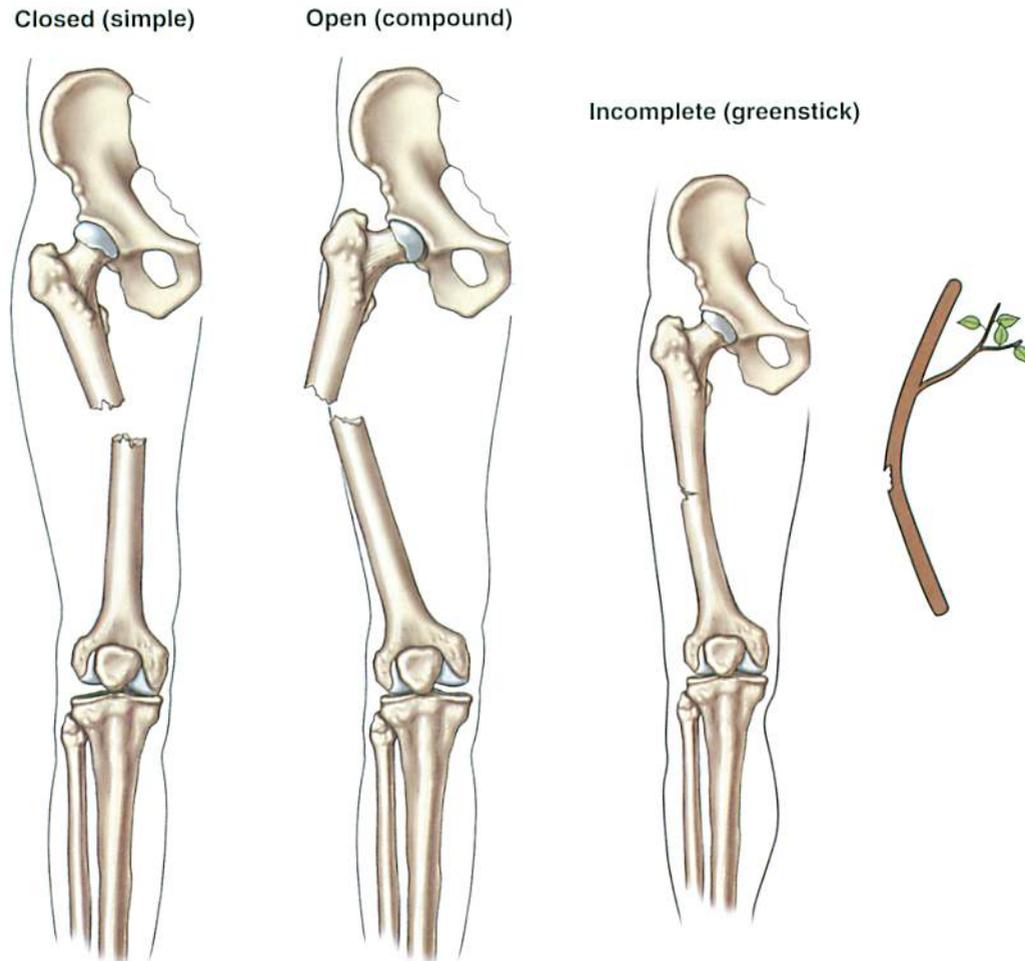


FIGURE 8-6 Common types of fractures.

### Cranium

The cranium is a bony structure that encases and protects the brain. The cranium is composed of eight bones, most of which are curved and flat.

- *Frontal bone.* The frontal bone forms the forehead and the upper part of the bony structure surrounding the eyes.
- *Parietal bones.* The two parietal (pah-RYE-i-tal) bones form the upper sides of the head and the roof of the cranial cavity (top of the head).
- *Temporal bones.* The two temporal bones are on the sides of the head, close to the ears (commonly called the *temples*). Several important bone markings are found on the temporal bones. They include the external auditory meatus (mee-AY-tus), an opening for the ear; the zygomatic (zye-goh-MAT-ik) process, which articulates with the cheekbone (not to be confused with the zygomatic bones); the styloid process, a sharp projection used as a point of attachment for several muscles associated with the tongue and larynx; and the mastoid process, which forms a point of attachment for some of the muscles of the neck.

Here's an interesting note about the temporal bone. *Tempor* is a Latin word meaning "time." As

men age, over time, they usually develop their first grey hairs over the temple area. So, the name of the temporal bone is a reference to aging.

- *Occipital bone* (see Figure 8-7, C). The occipital (ok-SIP-it-al) bone is located at the back and base of the cranium. The large hole in the occipital bone is called the *foramen magnum*. The foramen allows the brain stem to extend downward and become the spinal cord. On either side of the foramen magnum are bony projections, called *occipital condyles* (KON-dylz), that sit on the first vertebra of the vertebral column. Unfortunately, the foramen magnum can act as a deathtrap, because it provides the only escape hatch in the cranium in the event that the brain swells. The increased intracranial pressure created by the swollen brain pushes the brain through the foramen magnum into the spinal region. The downward displacement or herniation of the brain exerts pressure on the brain stem, causing respiratory arrest and death.
- *Sphenoid bone.* The sphenoid (SFEE-noyd) bone is a butterfly-shaped bone that forms part of the floor and sides of the cranium (see Figure 8-7, C). The sphenoid bone also helps form the orbits

**Table 8-2** Bones of the Adult Skeleton

BONES	NUMBER	BONES	NUMBER
<b>Axial Skeleton (80)</b>		<b>Thoracic Cage (25)</b>	
<b>Skull (28)</b>		True ribs	14
<b>Cranium (8)</b>		False ribs	10
Frontal	1	Sternum	1
Parietal	2	<b>Appendicular Skeleton (126)</b>	
Temporal	2	<b>Pectoral Girdle (4)</b>	
Occipital	1	Scapula	2
Sphenoid	1	Clavicle	2
Ethmoid	1	<b>Upper Limbs (60)</b>	
<b>Facial (14)</b>		Humerus	2
Maxilla	2	Radius	2
Zygomatic	2	Ulna	2
Palatine	2	Carpals	16
Mandible	1	Metacarpals	10
Lacrimal	2	Phalanges	28
Nasal	2	<b>Pelvic Girdle (2)</b>	
Inferior concha	2	Coxal	2
Vomer	1	<b>Lower Limbs (60)</b>	
<b>Middle Ear Bones (6)</b>		Femur	2
Malleus	2	Tibia	2
Incus	2	Fibula	2
Stapes	2	Patella	2
<b>Hyoid Bone (1)</b>		Tarsals	14
<b>Vertebral Column (26)</b>		Metatarsals	10
Cervical vertebrae	7	Phalanges	28
Thoracic vertebrae	12	<b>Total Number of Bones</b>	
Lumbar vertebrae	5	<b>206</b>	
Sacrum	1		
Coccyx	1		

surrounding the eyes. In the midline of the sphenoid bone is a depression called the *sella turcica* (Turk's saddle); it forms the seat for the pituitary gland (not shown).

- **Ethmoid bone.** The ethmoid (ETH-moyd) bone is an irregularly shaped bone located between the eye orbits; it is the major supporting bony structure of the nasal cavity. A projection of the ethmoid bone forms a point of attachment for the meninges, or the membranes that surround the brain and contain cerebrospinal fluid. The location and shape of the ethmoid bone has important clinical implications. A sharp blow to the ethmoid bone can drive the pointed bone into the brain, causing severe brain injury and death. Because the shattered bone tears the meninges, cerebrospinal fluid leaks into the nasal passages. This type of injury also creates a direct opening into the brain for pathogens and subsequent infections of brain tissue, so watch that

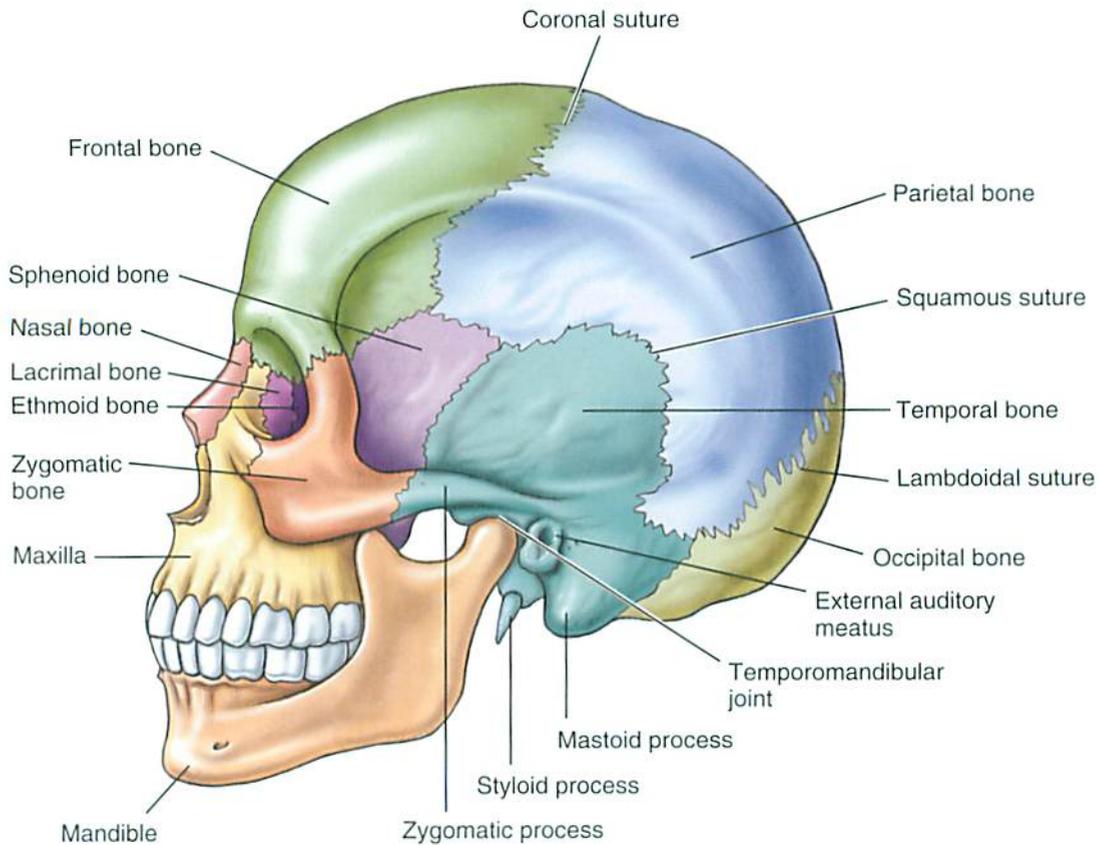
karate chop to the face. The impact of the face with the steering wheel during a car wreck can also drive the shattered ethmoid bone into the brain. Slow down!

### Facial Bones

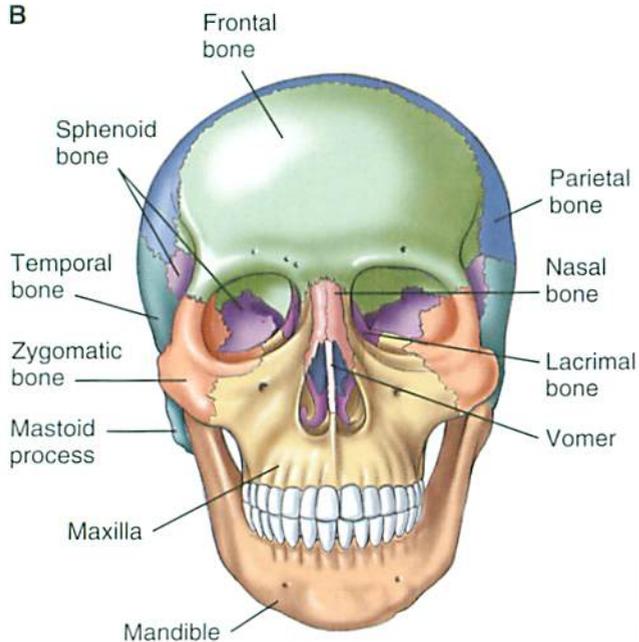
The face has 14 facial bones, most of which are paired (see Figure 8-7, B). Only the mandible and the vomer are single bones.

- **Mandible.** The mandible (MAN-di-bal), the lower jaw bone, carries the lower teeth. The anterior portion of the mandible forms the chin. The mandible forms the only freely movable joint in the skull. Two posterior upright projections on the mandible have bony processes that articulate with the temporal bones at the temporomandibular joint (TMJ). The TMJ can be felt as the depression immediately in front of the ear. Tension or stress often causes pain in the TMJ. This condition is often

A



B



C

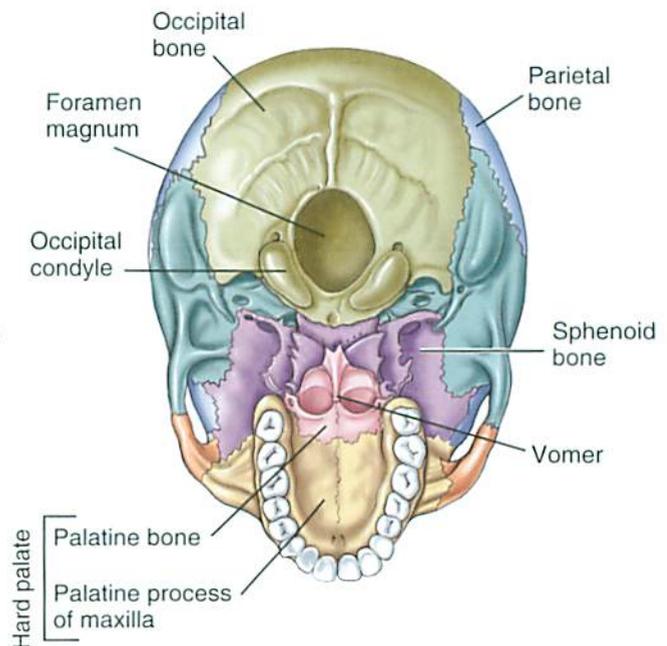


FIGURE 8-7 Bones of the skull. **A**, Side view. **B**, Front view. **C**, Base of the skull.

associated with tooth grinding (bruxism) during sleep. Bony processes on the mandible serve as points of attachment for chewing muscles.

- **Maxilla.** Two maxillary bones fuse to form the upper jaw. The maxilla (mak-SIH-lah) carries the upper

teeth. An extension of the maxilla, the palatine process, forms the anterior portion of the hard palate (roof) of the mouth (see Figure 8-7, C). These bones also form parts of the nasal cavity and the eye orbits.

- **Palatine bones.** Two palatine (PAL-ah-tine) bones form the posterior part of the hard palate and the floor of the nasal cavity. Failure of the palatine and/or maxillary bones to fuse causes a cleft palate, making suckling very difficult for an infant. Fortunately, a cleft palate can be surgically repaired.
- **Zygomatic bones.** The zygomatic bones are the cheekbones. They also form a part of the orbits of the eyes.
- **Other facial bones.** Several other bones complete the facial structure, including the lacrimal bones, nasal bones, vomer, and inferior nasal conchae.



### Do You Know...

#### About Two Drug-Induced Jaw-Breaking Events?

The mandible often takes it on the chin! A rather common mandibular event is the alcohol-fueled Saturday night brawl that often culminates in a broken jaw. Unlike a broken leg bone, which can be immobilized by a cast, the mandible (lower jaw) can be immobilized only by wiring it to the maxilla (upper jaw). Can't talk, can't eat, can't expel vomit. In fact, people with wired jaws must have access to wire cutters in case they vomit. What about nutrition? Puréed food is delivered through a straw.

A second mandibular malady is a drug-induced "Fossy jaw." Alendronate (Fosamax), which belongs to a group of drugs called *bisphosphonates*, is used in the prevention and treatment of osteoporosis in postmenopausal women. It works by inhibiting bone resorption by osteoclasts. A rare but distressing side effect of Fosamax is osteonecrosis of the jaw, characterized by loose teeth and crumbling jaw bone; hence the term *dead jaw*, or *Fossy jaw*. In addition to osteonecrosis, a small group of patients treated with bisphosphonates also experiences a distinctive type of low-energy fracture of the femur. One theory has suggested that by suppressing bone turnover (diminished osteoclastic activity), normal wear-and-tear microscopic bone cracks are not repaired daily, and ultimately progress to bone weakening and fracture.



### Re-Think

1. List the cranial bones that articulate with the parietal bone.
2. What are the functions of the foramen magnum and occipital condyles?
3. With regard to head injury, why is the foramen magnum called a "death trap"?

### Sinuses

Sinuses are air-filled cavities located in several of the bones of the skull. They perform two important functions: (1) they lessen the weight of the skull, and (2) they modulate the sound of the voice.

The four sinuses are called the *paranasal sinuses* because they surround and connect with the nasal structures (Figure 8-8). The names of the four sinuses reflect their location within the various skull bones: frontal sinus, ethmoidal sinuses, sphenoidal sinus, and maxillary sinuses.

Because the sinuses connect with the nasal passages and the throat, infections may spread from the nose and throat into the sinuses. An inflammation of the

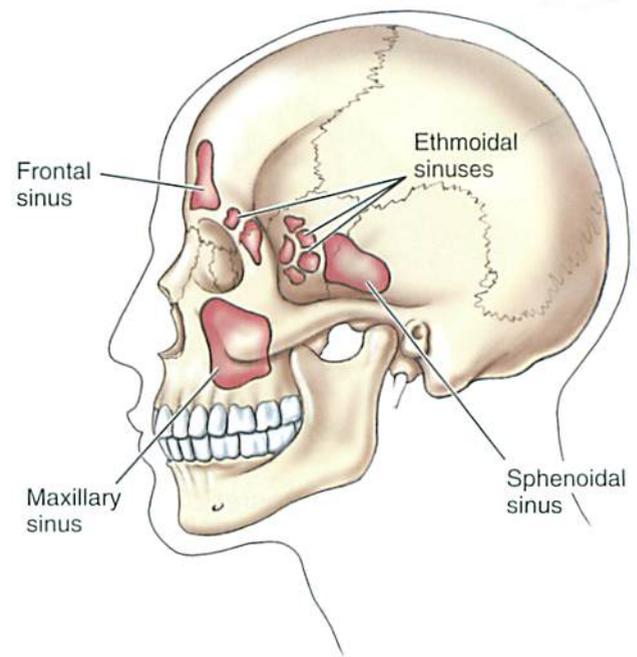


FIGURE 8-8 Sinuses.

sinus is called *sinusitis* and is characterized as stuffiness and pain in the overlying facial regions. Why do allergies sometimes make your face hurt? Allergies often cause the membranes that line the facial sinuses to oversecrete mucus. The mucus forms an excellent medium for bacterial growth. As the mucus accumulates and the membranes swell, pressure and discomfort are often experienced in the facial region, which overlies the sinuses (around the eyes and nose).

### How the Skull Bones Are Held Together

The bones of the adult skull form a unique type of joint called a *suture* (see Figure 8-7, A). The sutures join together the bones of the skull, much like a zipper. The major sutures include the coronal suture, the lambdoidal suture, and the squamosal suture. Unlike other joints in the body, no significant movement occurs between cranial bones.

### The Infant Skull

The two major differences between the infant and adult skulls are the fontanels and unfused sutures in the infant skull.

The infant skull has areas that have not yet been converted to bone. Instead, they are covered by fibrous membrane. Because these areas are soft to touch, they are called a baby's *soft spots*. Also, the rhythm of the baby's pulse can be felt in these soft spots, and so they are called **fontanels** (FON-tah-nels), meaning "little fountains."

The two major fontanels are the larger, diamond-shaped anterior fontanel and the smaller, posterior occipital fontanel. Two smaller fontanels are located more laterally—the anterolateral and posterolateral fontanels (Figure 8-9). By the time a child reaches 2

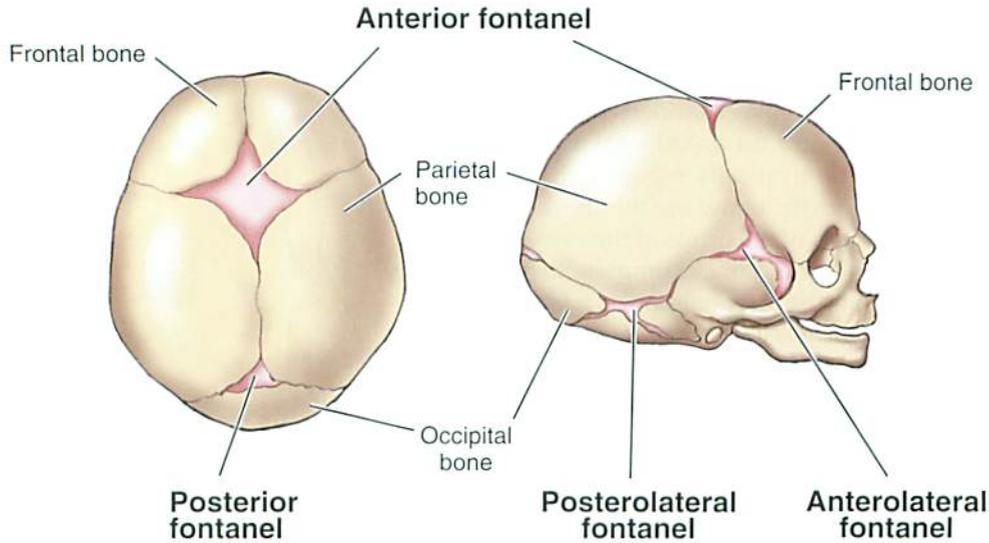


FIGURE 8-9 Fontanels in the infant skull.

years of age, these fontanels have been gradually converted to bone and can no longer be felt.

The fontanels are one reason why infant skull bones are more movable than those of the adult skull. Another reason is that the sutures of the infant skulls are not fused. Unfused sutures allow the skull to be compressed during birth. They also allow for the continued growth of the brain and skull after birth and throughout infancy. It also explains why your adorable newborn may look like a “conehead.” The fetal skull is too large to fit through the birth canal, so the movable bones overlap, thereby decreasing the diameter of the head. Fortunately, the pointy skull reshapes shortly after birth.

Occasionally, the sutures of the infant skull fuse too early, preventing the growth of the brain. This condition is called *microcephalia* and is characterized by a small cranium, restricted brain growth, and impaired intellectual functioning. Sometimes the skull expands too much. For example, if excessive fluid accumulates within the brain of an infant, the bones are forced apart, and the skull enlarges. This condition is called *hydrocephalus* (or “water on the brain”).

Observation of the fontanels can provide valuable information regarding brain swelling. What does a bulging or sunken fontanel indicate? If an infant suffers a head injury or infection, the brain may swell. Because the fontanel is soft tissue, it will bulge outward in response to increasing pressure within the skull. Conversely, the fontanels may become sunken in the presence of dehydration.

### **?** Re-Think

1. What are fontanels?
2. In what sense does the fontanel indicate a state of dehydration? Of increased intracranial pressure?
3. Why is it important that the infant sutures are unfused?

### Hyoid Bone

The hyoid (HYE-oyd) bone is a U-shaped bone located in the upper neck. It anchors the tongue and is associated with swallowing. The hyoid bone is often fractured during strangulation. Watch for this during an autopsy, you forensic sleuths!

### Bones of the Middle Ear

Each ear contains three small bones called *ossicles* (see Chapter 13 for the role of the ossicles in hearing).

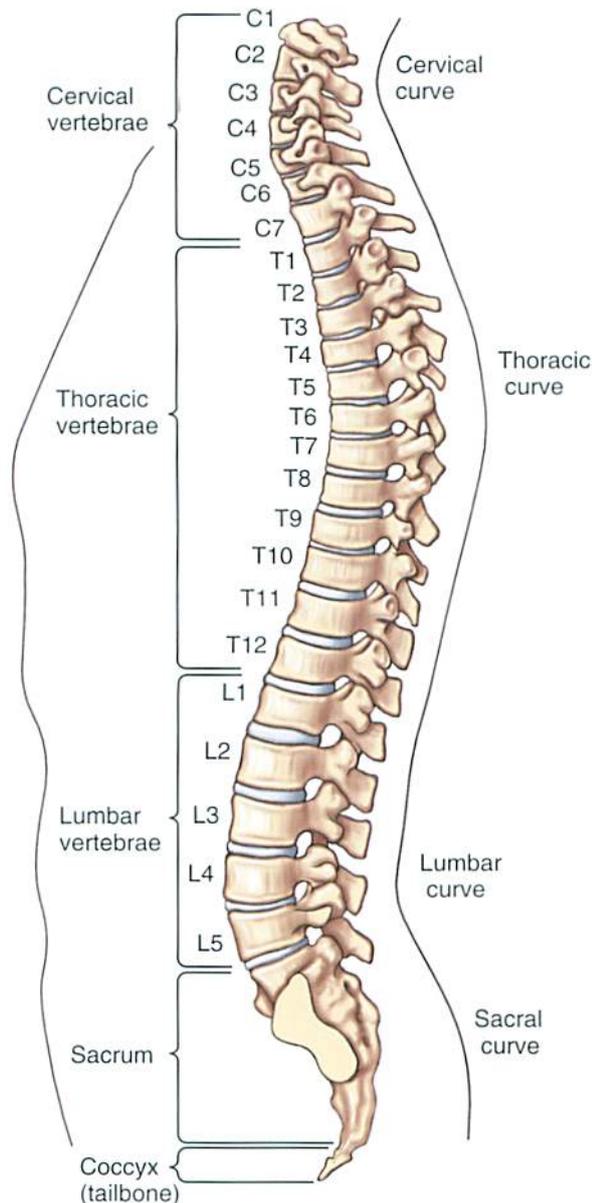
## VERTEBRAL COLUMN

### The Back and Its Stack of Bones

The vertebral column, also called the backbone, extends from the skull to the pelvis (Figure 8-10). The vertebral column consists of 26 bones, called *vertebrae* (VER-teh-bray), stacked in a column. Sitting between each vertebra is a cartilaginous disc. The vertebral column performs four major functions:

- Forms a supporting structure for the head and thorax
- Forms an attachment for the pelvic girdle
- Encases and protects the spinal cord
- Provides flexibility for the body

The vertebrae are named according to their location. Seven cervical vertebrae (C1 to C7) are located in the neck region. If you bend your head forward and run your hand down the cervical vertebrae, you will feel a large bump; this large vertebra is C7, which is called the *vertebra prominens* (VER-teh-bra PRAH-meh-nenz) and is used as a landmark in assessing surface anatomy. Twelve thoracic vertebrae (T1 to T12) are located in the chest region; and the five lumbar vertebrae (L1 to L5) are located in the lower back region. If you place your hands on your hips, you are at the level of L4. In addition, five sacral vertebrae fuse into one sacrum. The sacrum forms the posterior wall of the pelvis. Four small vertebrae fuse into the tailbone. How did the



**FIGURE 8-10** Vertebral column: cervical vertebrae (7), thoracic vertebrae (12), lumbar vertebrae (5), sacrum, and coccyx. Vertebral curves are the cervical, thoracic, lumbar, and sacral curves.

sacrum get its name? The ancients thought that the seat of the soul was located at the base of the spine and therefore called the sacred area the “sacrum.” The tailbone is called the *coccyx* (KOHK-iks) because it resembles the beak of a cuckoo bird.

### Two Special Vertebrae: Atlas (C1) and Axis (C2)

The first and second cervical vertebrae have several special features and names (Figure 8-11). The first cervical vertebra (C1) is called the *atlas*. The atlas has no body but does have depressions into which fit the bony projections of the occipital bone of the skull. The

atlas supports the skull and allows you to nod “yes.” The atlas is named after a figure in Greek mythology, Atlas, who carried the earth on his shoulders.

The second cervical vertebra (C2) is called the *axis*. The axis has a projection, called the *dens* (nicknamed for the toothlike odontoid process), which fits into the atlas and acts as a pivot or swivel for the atlas. The axis allows your head to rotate from side to side as you say “no.” A strong blow to the top of the head can force the dens through the foramen magnum and into the base of the brain, causing sudden death. Not good! In children, the fusion between the dens and the axis is incomplete. Shaking a child can easily dislocate the dens, causing injury to the spinal cord.

### Characteristics of Vertebrae

The vertebra is an irregular bone that contains several distinct structures (see Figure 8-11). The body of the vertebra is padded by a cartilaginous disc and supports the weight of the vertebra sitting on top of it. Some processes provide sites of attachment for ligaments, tendons, and muscles; other processes articulate with bones such as the ribs. The vertebral foramen is the opening for the spinal cord; the vertebral foramen of all vertebrae form the vertebral canal. The vertebrae are aligned so that if you run your hand down your back, you will feel the spinous processes. For this reason, the vertebral column is also called the *spine*. Note that the vertebrae become larger as the vertebral column descends. The larger lower vertebrae support a heavier load.

The bodies of the vertebrae are padded and separated by cartilaginous discs. The intervertebral discs act as shock absorbers. They also act as “spacers” between vertebrae, allowing peripheral nerves to connect to the spinal cord without being squashed. (Ouch!)

### ? Re-Think

1. How does the structure and function of C1 and C2 differ from that of other vertebrae?
2. What is the function of the vertebral foramen?
3. Why is the vertebral column called the spine?

### SOME VERTEBRAL COLUMN CONCERNS

- The vertebra has a barlike lamina. Spina bifida refers to the failure of the lamina to fuse during fetal development. The vertebral defect allows the spinal cord to protrude onto the surface of the back. Depending on the level of the defect, compression of the spinal cord then causes paralysis and loss of bladder and bowel control.
- A surgical procedure called a *laminectomy* may be performed to access the intervertebral disc; the opening allows the surgeon to remove a damaged, or “slipped,” disc. Occasionally, several vertebrae are fused together to stabilize a part of the vertebral column. This procedure is called *spinal fusion*.

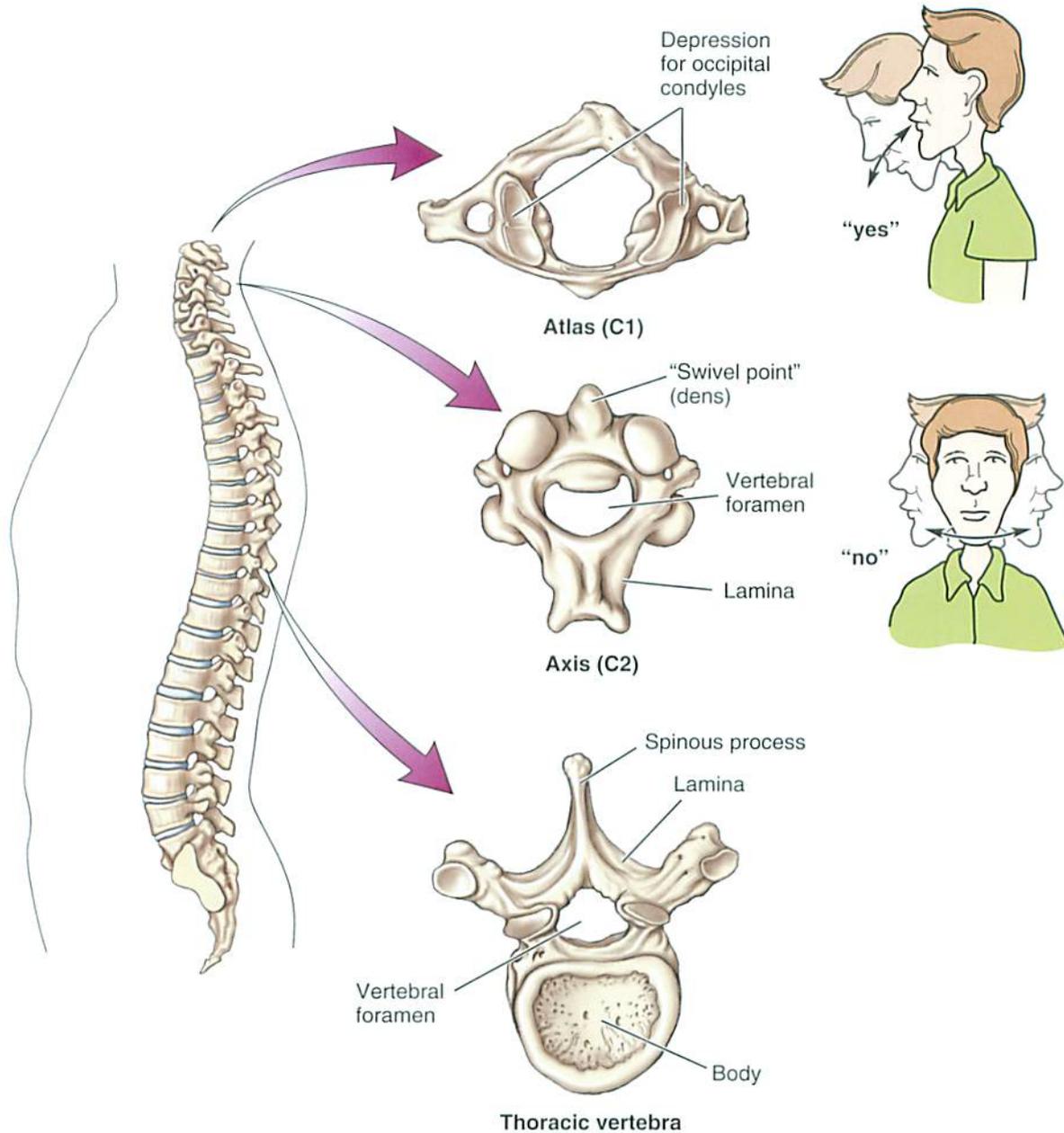


FIGURE 8-11 Anatomy of a vertebra: the atlas (C1) and axis (C2), and a thoracic vertebra.

- Note that the spinal cord descends from the base of the brain through the vertebral foramen of the stack of vertebrae. Injury to the vertebral column at any point can compress or sever the spinal cord, causing paralysis. You must use extreme caution while treating or moving a person with a spinal cord injury. Immobility is a key term in the first-aid treatment of suspected spinal cord injury.

### Curvatures

When viewed from the side, the vertebral column has four normal curvatures (see Figure 8-10): the cervical, thoracic, lumbar, and sacral curves. The directions of the curvatures are important. The cervical and the lumbar curvatures bend toward the front of the body.

The thoracic and sacral curvatures bend away from the front of the body. These curves center the head over the body, thereby providing the balance needed to walk in an upright position.

The curvature of the fetal spine is different. Its single C-shaped curvature bends away from the front of the body. Its shape reflects the curled-up position of the fetus during the 9 months in the cozy, but cramped, uterine living quarters. The cervical curvature develops about 3 to 4 months after birth as infants start to hold up their heads. The lumbar curvature develops at about 1 year of age, when children begin standing and walking.

Figure 8-12 illustrates several abnormal curvatures of the spine. Scoliosis (skoh-lee-OH-sis) refers to a

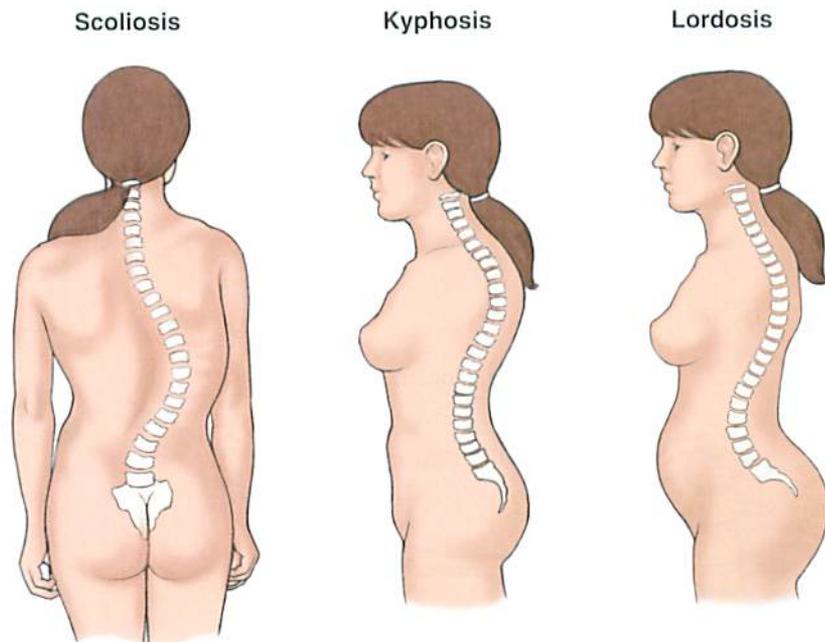


FIGURE 8-12 Abnormal curvatures of the vertebral column.

lateral curvature, usually involving the thoracic vertebrae. If severe, a lateral curvature can compress abdominal organs. It can also diminish expansion of the rib cage and therefore impair breathing. Kyphosis (kye-FOH-sis) is an exaggerated thoracic curvature; it, too, can impair breathing and is sometimes called *hunchback*. Lordosis is an exaggerated lumbar curvature and is sometimes called *swayback*. These abnormalities may be caused by a genetic defect or may develop in response to disease or poor posture.

### THORACIC CAGE

The *thorax* (THOH-raks) is a term that refers to the chest region. The thoracic cage is the skeletal part of the chest; it is a bony, cone-shaped cage that surrounds and protects the lungs, heart, large blood vessels, and some of the abdominal organs, such as the liver, spleen, and kidneys (Figure 8-13). It plays a crucial role in breathing and helps support the bones of the shoulder. The thoracic cage is composed of the sternum, ribs, and thoracic vertebrae.

#### Sternum

The sternum, or breastbone, is a dagger-shaped bone located along the midline of the anterior chest. The three parts are the manubrium (man-OO-bree-ahm), body, and xiphoid (ZYE-foyd) process. The xiphoid process is the tip of the sternum and serves as a point of attachment for some abdominal muscles. It is also a landmark for cardiopulmonary resuscitation (CPR). Note the suprasternal notch (also called the jugular notch), a depression on the upper part of the manubrium between the two clavicles; it is used as a landmark to locate other structures.

#### Ribs

Twelve pairs of ribs attach posteriorly to the thoracic vertebrae. Anteriorly, the top seven pairs of ribs attach directly to the sternum by costal cartilage and are called *true ribs*. The next five pairs attach indirectly to the sternum by cartilage or do not attach at all and are called *false ribs*. The bottom two pairs of false ribs lack sternal attachment and are therefore called *floating ribs*. Because of their location and lack of sternal support, the floating ribs are easily broken. Note that the ribs are numbered, which allows us to describe the location of thoracic structures. The spaces between the ribs (intercostal spaces) are also numbered. For example, the heart is located between the second rib and fifth intercostal space (the space between the fifth and sixth ribs). You will spend a lot of time counting ribs and intercostal spaces as part of your clinical practice.

#### Other Thoracic Cage Structures

Located between the ribs are the intercostal muscles. Contraction of these muscles helps move the thoracic cage during breathing. If you put your hand on your chest and take a deep breath, you will feel your thoracic cage move up and out. The costal margins are the edges of the cartilage that form an angle as they converge near the xiphoid process. The costal angle should be less than 90 degrees. The costal angle can change size; for example, during pregnancy the angle increases. It also increases when the chest diameter expands with certain lung diseases, such as emphysema. Another sternal landmark is the sternomanubrial joint, also called the *angle of Louis*. This landmark is used in counting ribs and is at the level of the second rib.

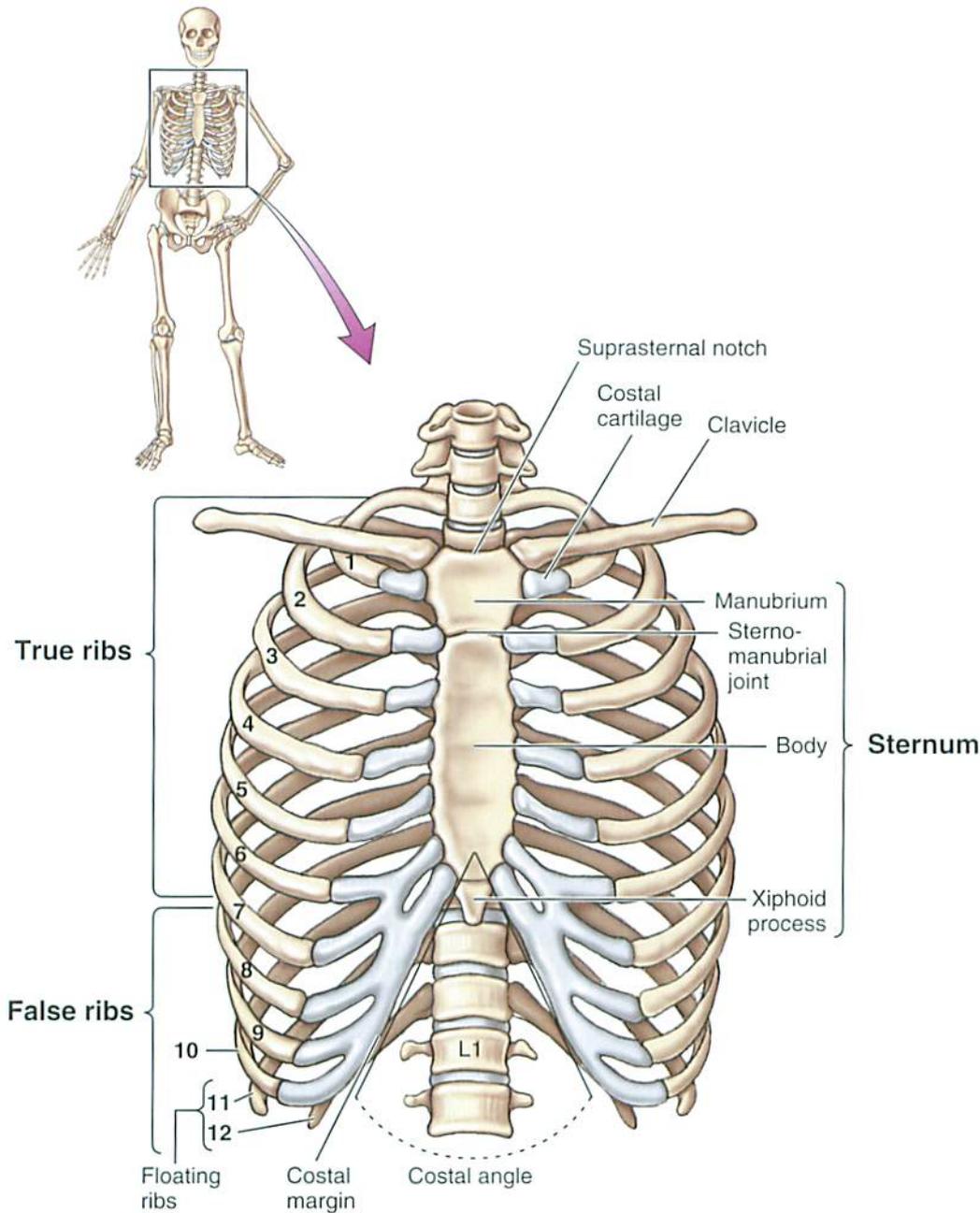


FIGURE 8-13 Thoracic cage: the sternum, ribs, and thoracic vertebrae.

### ? Re-Think

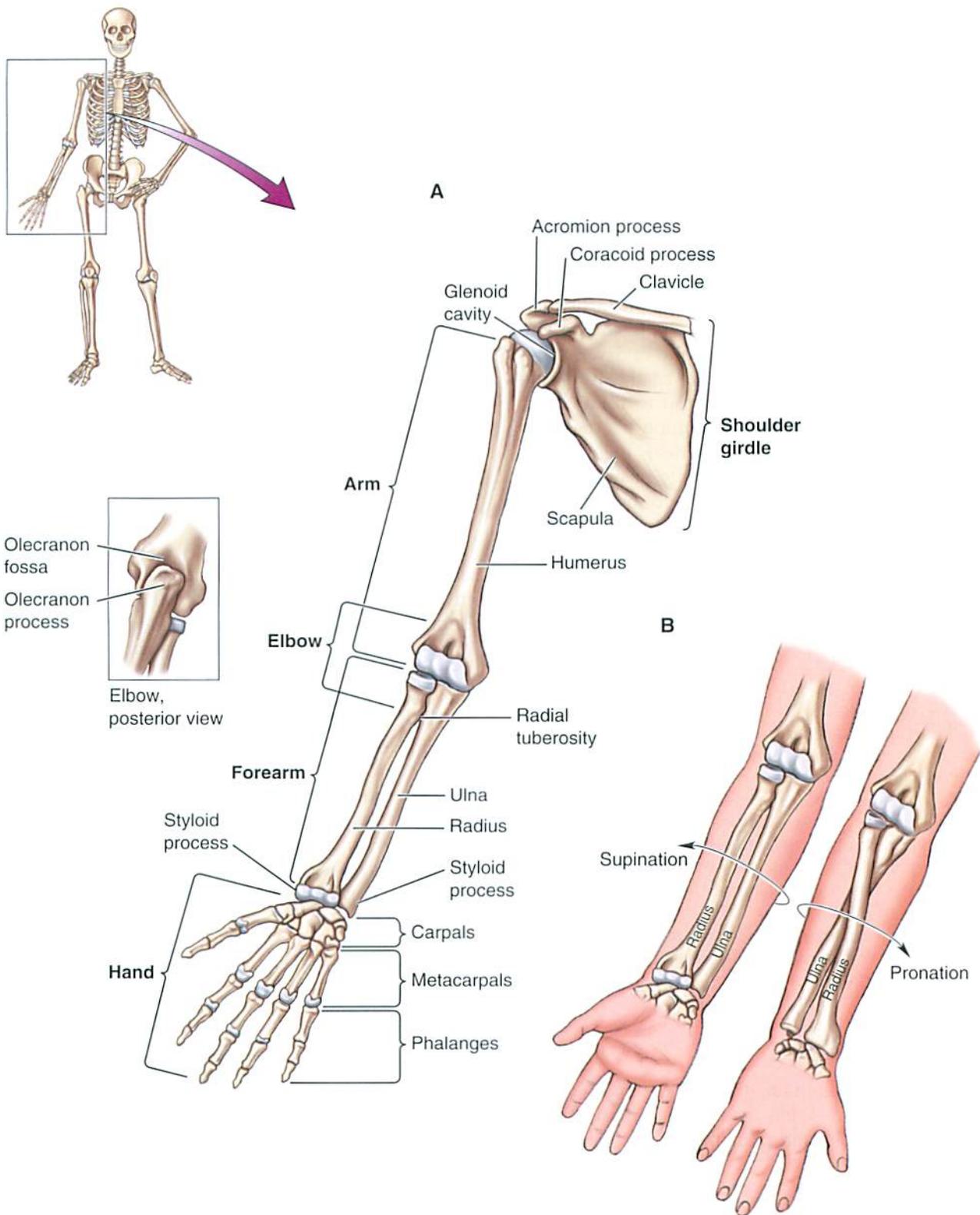
1. What bones form the thoracic cage?
2. With what bony structures do the ribs articulate?
3. Differentiate between the true, false, and floating ribs.

### APPENDICULAR SKELETON

The appendicular skeleton is composed of the bones of the shoulder girdle, upper limbs, pelvic girdle, and lower limbs (see Figure 8-1).

### 2+2 Sum It Up!

The skeleton is divided into the axial and appendicular skeletons. The axial skeleton includes the bones of the skull (facial and cranial), hyoid bone, bones of the middle ear, bones of the vertebral column, and bones of the thoracic cage (ribs and sternum). The skull contains the facial bones, cranial bones, and air-filled cavities called *sinuses*. The skull of a newborn contains fontanels, which are membranous areas that allow brain growth. The vertebral column is formed from 24 vertebrae, one sacrum, and one coccyx. The vertebrae are separated by cartilaginous discs. The vertebral column of the adult has four curvatures: cervical, thoracic, lumbar, and sacral. The thoracic cage is a bony cone-shaped cage formed by the sternum, 12 pairs of ribs, and thoracic vertebrae.



**FIGURE 8-14** Bones of the upper limb. **A**, Shoulder girdle, arm, forearm, and hand. **B**, Position of the radius and ulna during supination and pronation.

## SHOULDER GIRDLE

The shoulder girdle is also called the *pectoral girdle*. Each shoulder girdle contains two bones: one clavicle (KLAV-i-kul) and one scapula (SKAP-yoo-lah) (Figure 8-14). The shoulder girdle supports the upper limbs and

serves as a place of attachment for muscles. The shoulder girdle is designed for great flexibility; move your shoulder and arm around and note how many different movements you can make. Compare this with the limited movement you have at the elbow and the knee.

### Clavicle

The clavicle is also called the *collarbone*. It looks like a long, slender, S-shaped rod and articulates with both the sternum and scapula. The clavicle helps stabilize the shoulder. The attachment, however, is weak and easily dislocated or broken. The clavicle is the most frequently broken bone in the body.

### Scapula

The scapula, also called the *shoulder blade* or *wing bone*, is a large flat bone shaped like a triangle. The two scapulae are located on the posterior thorax. Two large processes on the scapula allow it to articulate with the clavicle and serve as points of attachment for arm and chest muscles. The glenoid cavity on the scapula is the site where the head of the humerus (arm bone) fits, thereby allowing you to rotate your arm at the shoulder. Note the acromion process and coracoid process on the scapula near the glenoid cavity. Both processes serve as points of attachment for ligaments and muscles. The acromion process forms the “pointy” part of the shoulder and articulates with the clavicle.



### Do You Know...

#### About Xtreme Modeling and Toe Cleavage?

The saying, “You can never be too thin” (or off-balance) has taken on a new meaning. In addition to a starvation diet, Xtreme Modeling has taken surgical aim at the skeletal system. It’s called “remodeling the model.” How so? Surgeons have successfully shortened or removed toes, thereby allowing the foot to fit into stylish “pointy” shoes. More importantly, toe removal also creates revealing toe cleavage. The toe is not the only osseous victim of this skeletal redesign. Removal of the lower floating ribs further slims the slim. When accompanied by high colonic irrigations (enemas), our remodeled model easily slips into the elusive size 0. Of obvious concern: the risk of general anesthesia, the loss of ribs that normally protect the kidneys, and the loss of toes that assist in walking, balance, and overall comfort! Go figure!

## UPPER LIMBS

The upper limbs contain the bones of the arm (humerus), forearm (ulna and radius), and hand (carpals, metacarpals, and phalanges).

### Humerus

The humerus is the arm bone. The proximal humerus contains a head, which fits into the glenoid cavity of the scapula, allowing the arm to rotate at the shoulder joint. At the distal end of the humerus are several processes that allow it to articulate with the bones of the forearm. The olecranon (oh-LEK-rah-non) fossa is a depression of the humerus that holds the olecranon process of the ulna when the elbow is extended (not bent).

### Radius

The radius is one of two bones of the forearm. It is located on the lateral or thumb side when the palm of the hand is facing forward. The head of the radius articulates with the humerus and proximal ulna, whereas the distal end articulates with the distal ulna and the carpal or wrist bones. The radial tuberosity at the proximal end of the radius is the site of attachment for one of the muscles responsible for bending the forearm at the elbow.



### Do You Know...

#### Why Hitting My Funny Bone Doesn't Feel Funny?

When you hit your elbow and get that sharp pain that is associated with the “funny bone,” you are actually hitting the ulnar nerve. The unprotected ulnar nerve lies over the distal end of the humerus and is therefore vulnerable to being bumped. Why do we call it funny? Maybe because of its location near the humerus, a “humorous” name for a bone.

### Ulna

The ulna is the second bone of the forearm. The longer of the two bones, the ulna, is located on the medial or little finger side of the forearm. It has processes and depressions that allow it to articulate with the humerus and radius proximally and with the radius distally. The olecranon process of the ulna is what you feel as the bony point of the elbow. Note that the distal ends of both the ulna and radius have a pointed styloid process; the styloid processes can be felt at the wrist.

Also note the relationship of the radius to the ulna when the hand moves from a palm-up (supination) to a palm-down (pronation) position. When the palm is up, the two bones are parallel. When the palm is down, the two bones cross to achieve this movement.

### Hand

The hand is composed of a wrist, palm, and fingers. The wrist contains eight bones called *carpal bones*, which are tightly bound by ligaments. Five metacarpal bones form the palm of the hand; each metacarpal bone is in line with a finger. Feel your metacarpal bones on the back of your hand; note how each aligns with your fingers. The 14 finger bones are called *phalanges* (fah-LAN-jeez), or digits. Note that each digit has three bones except the thumb (called the *pollex*), which has only two bones. The heads of the phalanges are prominent as the knuckles when a fist is made.



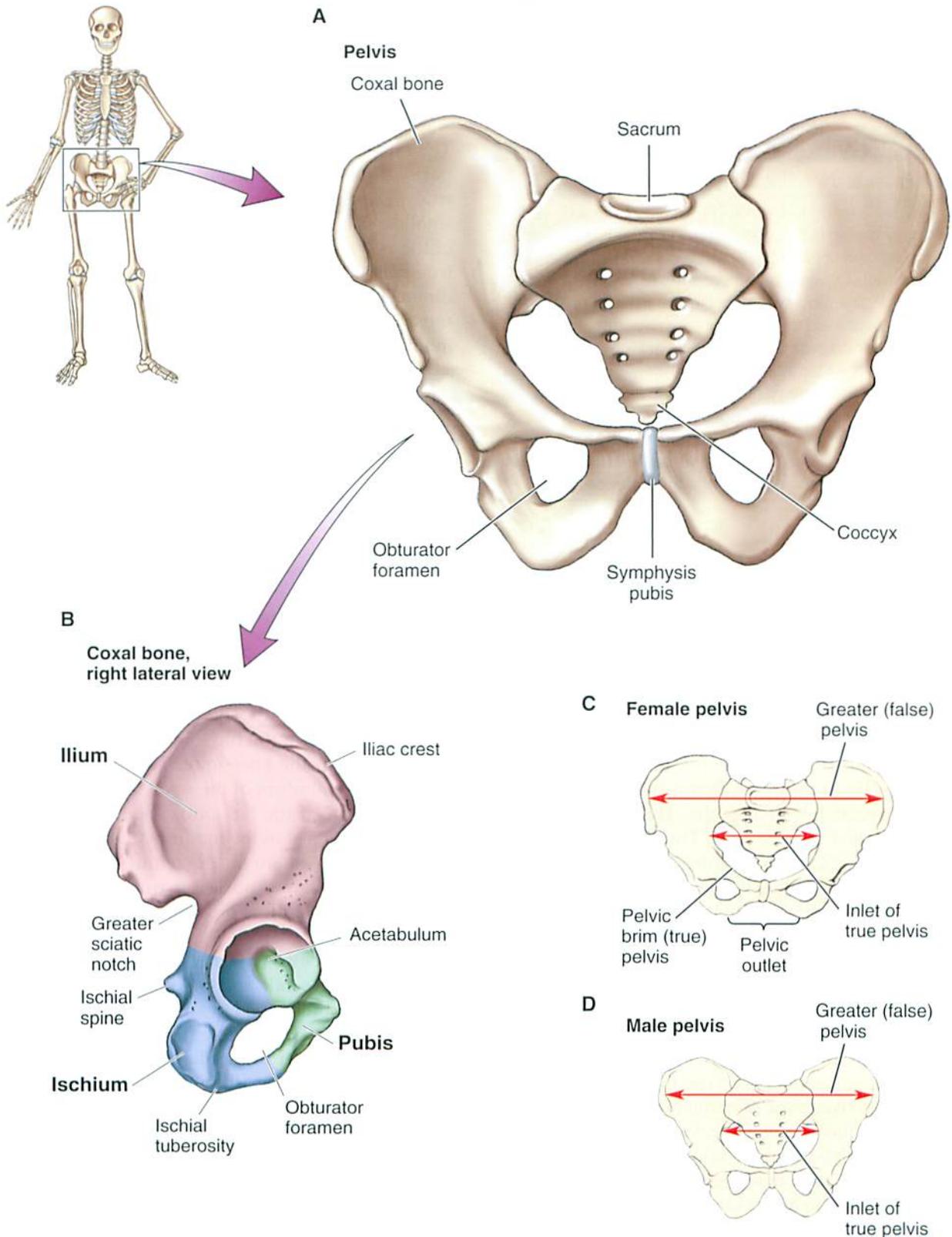
### Re-Think

1. List the bones of the pectoral girdle.
2. What happens at the glenoid cavity?
3. What bones form the elbow? What is the olecranon process?

## Pelvic Girdle

The pelvic girdle is composed of two coxal bones that articulate with each other anteriorly and with the sacrum posteriorly (Figure 8-15, A). The pelvic girdle

performs three functions: (1) it bears the weight of the body; (2) it serves as a place of attachment for the thighs; and (3) it protects the organs located in the pelvic cavity, including the urinary bladder and reproductive organs.



**FIGURE 8-15** Pelvic cavity. **A**, Bones that make up the pelvic cavity. **B**, Coxal bone (ilium, ischium, and pubis). **C**, Female pelvis. **D**, Male pelvis.

## Pelvis

The pelvis is formed by the pelvic girdle, sacrum, and coccyx.

**Male and Female Differences.** The differences between the female and male pelvis are related to the childbearing role of the female. In general, the female pelvis is broader and shallower than the male pelvis. The male pelvis is narrow and funnel-shaped (see Figure 8-15, C and D).



### Do You Know...

#### About Dr. Pollex and Mr. Blackberry's Thumb?

Mr. Blackberry went to his family physician, Dr. Pollex, with a chief complaint of extreme pain in his left thumb. He writhed in pain and sobbed uncontrollably as he punched numbers into his cell and frantically sent text messages to everyone he had ever met. Dr. Pollex, however, was all over it. "Thumb abuse!" he roared. He explained to Mr. Blackberry. "Your thumb (pollex) was not designed to click away 24/7; it's aching for relief. The sheath around your thumb is inflamed and swollen." The digit doc assured Mr. Blackberry that with rest and retraining, he would soon be clicking away again. Other digits could be trained to share the clicking load. Thumb pain resulting from repetitive thumb-clicking marathons is called *Blackberry thumb*, a reference to the popular handheld device.

## Coxal Bone

The coxal bone is the hip bone (see Figure 8-15, B). Each coxal bone is composed of three parts: the ilium, ischium, and pubis. The three bones join together to form a depression called the *acetabulum* (ass-it-TAH-buhl-um). The acetabulum is important because it receives the head of the femur and therefore enables the thigh to rotate at the hip joint.

**Ilium.** The ilium (IL-ee-um) is the largest part of the coxal bone. The ilium is the flared upper part of the bone and can be felt at the hip. The outer edge of the ilium is called the *iliac crest*. The ilium connects in the back with the sacrum, forming the sacroiliac joint. The greater sciatic notch is the site where blood vessels and the sciatic nerve pass from the pelvic cavity into the posterior thigh region. Like the sternum, the ilium produces blood cells and is a site for bone marrow biopsy.

**Ischium.** The ischium (ISH-ee-um) is the most inferior part of the coxal bone. The ischium contains three important structures: the ischial tuberosity, ischial spine, and lesser sciatic notch. The ischial tuberosity is the part of the coxal bone on which you sit. The ischial spine projects into the pelvic cavity and narrows the outlet of the pelvis. If the spines of a woman's two ischial bones are too close together, the pelvic outlet becomes too small to allow for the birth of a baby. The measurement of the distance between the two spines therefore provides valuable information about the adequacy of the pelvis for childbearing.

**Pubis.** The pubis is the most anterior part of the coxal bone. The two pubic bones meet in front as the symphysis (SIM-fi-sis) pubis. A disc of cartilage separates the pubic bones at the symphysis pubis. In women, the disc expands in response to the hormones of pregnancy, thereby enlarging the pelvic cavity to provide a bigger space for the growing fetus.

A large hole called the *obturator foramen* is formed as the pubic bone fuses with a part of the ischium. The obturator is the largest foramen in the body.

What is meant by the true pelvis and false pelvis? The false pelvis is the area surrounded by the flaring parts of the two iliac bones (see Figure 8-15, C). The true pelvis lies below the false pelvis and is much smaller. The true pelvis is a ring formed by the fusion of the pelvic bones; it is also called the *pelvic brim*. The true pelvis has an inlet and outlet area. In women, the dimensions of these areas are important because they must be large enough to allow for the passage of an infant during childbirth.



### Re-Think

1. Name the three bones that form the coxal bone.
2. What is the function of the acetabulum?
3. Locate the symphysis pubis. Explain how it affects the size of the pelvis during pregnancy.

## LOWER LIMBS

The lower limb includes the bones of the thigh, kneecap, leg, and the foot (Figure 8-16).

### Femur

The femur is the thighbone; it is the longest and strongest bone in the body. The femur articulates with the coxal bone to form the hip joint and with the bones of the leg to form the knee joint. The head of the femur sits in the acetabulum of the coxal bone and allows the thigh to rotate at the hip joint. The head of the femur attaches to the rest of the femur by the neck. A number of bony processes are on the femur. The most important are the greater and lesser trochanters (tro-KAN-ters). These trochanters provide sites of attachment for many muscles.

In older persons, the neck of the femur is easily broken during a fall and is known as a broken hip. Forced immobility (bed rest) often results in serious complications. For example, because of the weight of the injured leg, an immobile bedridden person may experience an outward rotation of the hip. If allowed to develop, this outward rotation makes walking very difficult and therefore delays rehabilitation. Other hazards of immobility, such as blood clots and pneumonia, contribute to the seriousness of a fractured hip.

### Patella

The patella is the kneecap. It is a triangular bone located within a tendon that passes over the knee. The

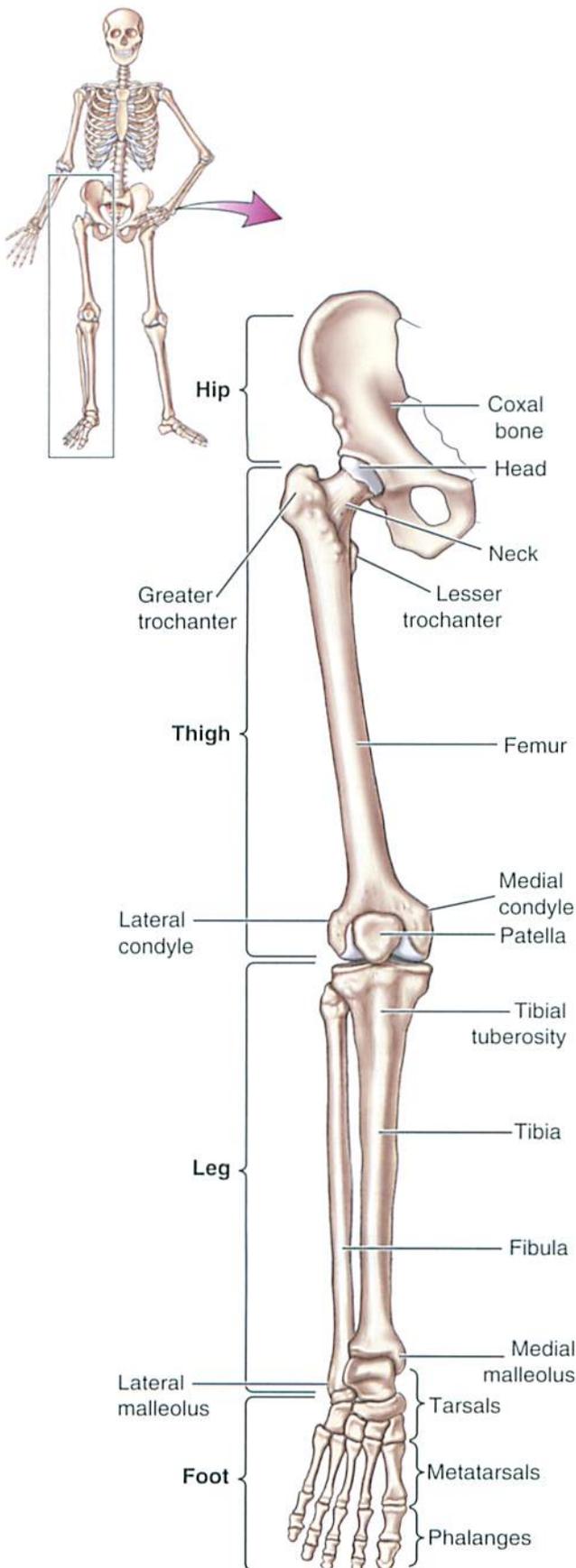


FIGURE 8-16 Bones of the lower limb: thigh, leg, and foot.

patella articulates with both the femur and tibia. An infant is born without kneecaps; somewhere between the ages of 2 and 6 years, in response to weight bearing, a small sesamoid bone (one that looks like a sesame seed) in the patellar region enlarges, thereby forming the kneecap.

### Tibia and Fibula

The tibia and the fibula form the leg. The tibia is the shinbone and articulates with the distal femur at the knee. The tibia is the larger weight-bearing bone of the leg. A protuberance called the *tibial tuberosity* is the site of attachment for the muscles and ligaments from the thigh. At the distal end of the tibia, a protuberance called the *medial malleolus* (mah-LEE-oh-lis) articulates with the inner ankle bones (tarsals).

The fibula (FIB-yoo-lah) is a long, thin bone positioned laterally alongside the tibia in the leg. The proximal end of the fibula articulates with the tibia. It does not articulate with the femur, is not part of the knee, and does not bear any weight. The distal end forms the lateral malleolus, which articulates with the outer ankle bones (tarsals). Skiers often twist their ankles and break the fibula at the lateral malleolus. You don't need snow, however, to hobble. Just roll the ankle and you too can be on crutches!



How do we remember the positions of the leg bones? The **tibia** is the *Thick Inner Bone*; the **fibula** is *L*ateral to the tibia.

### Foot

Each foot (Figure 8-17) has an ankle, instep, and five toes. Seven tarsal bones form the ankle. The most proximal of the tarsal bones, the talus, articulates with the tibia and fibula. Most of the weight of the body is supported by another tarsal bone, the calcaneus (kal-KAY-nee-us), or heel bone. The instep of the foot is formed by five metatarsal bones. The ball of the foot is formed by the distal ends of the metatarsals. The tarsals, metatarsals, and associated tendons and ligaments form the arch of the foot. If the ligaments and tendons weaken, the arches can fall, and the person is said to have flat feet. The toes contain 14 phalanges. The great toe is called the *hallux*.

**Foot Notes:** We all know about the thrill of victory (looking great in heels and flaunting the latest in toe

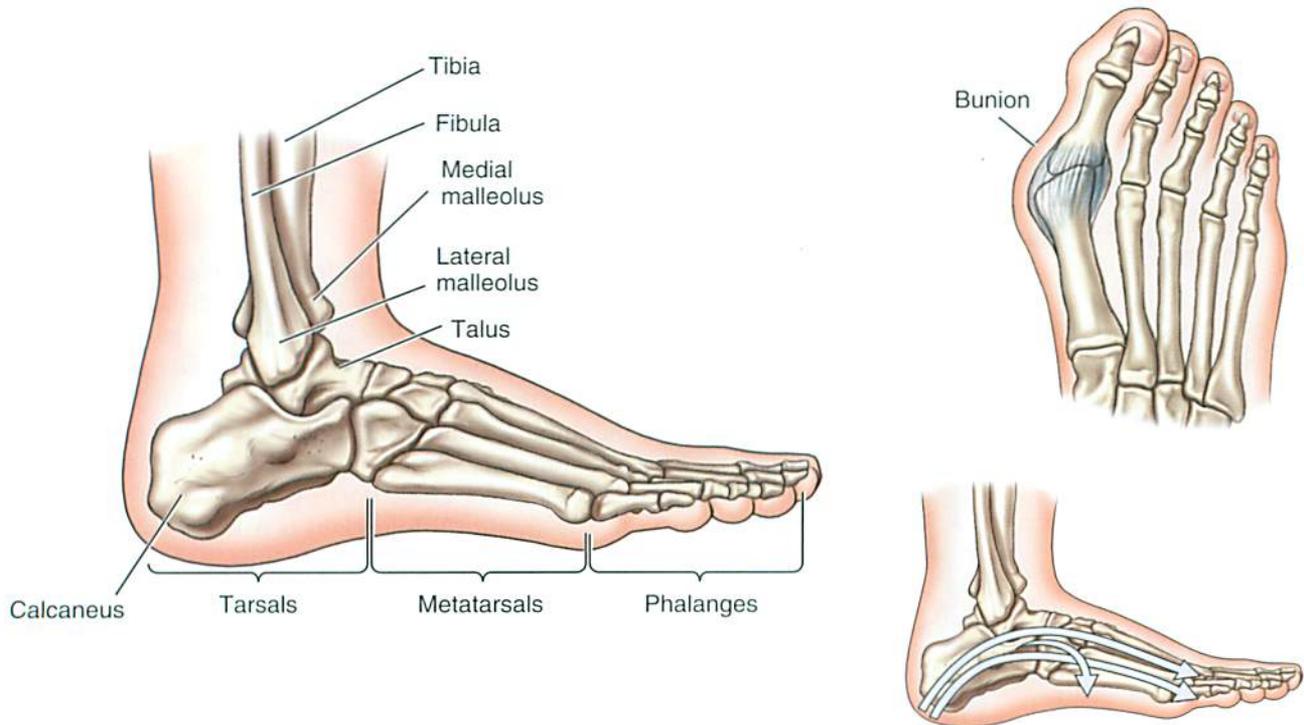


FIGURE 8-17 Bones of the foot: tarsals, metatarsals, and phalanges. Arches support the structure of the foot.

cleavage). What about the “agony of de-feet”? Think about it. Sometimes we jam our square feet into pointy shoes, creating an unnatural, uncomfortable, and crippling tiptoe gait. The entire weight of the body is pushed forward to the balls of the feet. What do we get for this stylish effort?



- **Bunions.** Bunions develop in response to excessive force, whereby the big toe is compressed and forced toward the second toe. The joint becomes distorted, inflamed, and painful.
- **Neuromas.** The shift of body weight to the balls of the feet causes painful and debilitating nerve growths (neuromas) between the toes.
- **Metatarsalgia.** The shift of body weight causes metatarsalgia, or pain in the ball of the foot.
- **Shortening of the Achilles tendon.** The tiptoe position causes contraction of the Achilles tendon; the shortened tendon makes the use of flat shoes uncomfortable.

- **Pump bump.** Excess pressure of the heel of the shoe on bone causes an enlargement (bump) on the heel bone. Pump bump is so common that it has its own medical name: Haglund’s deformity.
- **Knee pain.** The shift in weight adds unnatural stress to the knee joint; knee joint replacement is more common in women and is often related to wearing abusive footwear.
- **Last but not least.** There have been several documented cases of death associated with falling while wearing platform shoes.

What to do? Although it can be performed, the surgical removal of toes is not the answer. Instituting a fashion change is certainly less painful than redesigning the foot. In any event, heels are definitely an anatomical step in the wrong direction!

### ? Re-Think

1. List the bones that articulate with the femur.
2. What bones articulate at the knee?
3. What bones form the foot?

### JOINTS (ARTICULATIONS)

A joint, or articulation, is the site where two bones meet. Joints perform two functions: they hold the bones together, and they provide flexibility to a rigid skeleton. Without joints, we would move around stiffly like robots. Think of how awkward a basketball player would look if the entire skeleton were rigid. There is a branch of science that studies joints, called *arthrology*; the branch of medicine that studies disease of the joints is called *rheumatology*.

**2+2 Sum It Up!**

The appendicular skeleton includes bones of the pectoral girdle (clavicle, scapula), upper extremities (humerus, radius, ulna, carpals, metacarpals, phalanges), pelvic girdle (coxal bone), and lower extremities (femur, patella, tibia, fibula, tarsals, metatarsals, phalanges).

**Do You Know...****What Dripping “Humours” Have to Do with Gout?**

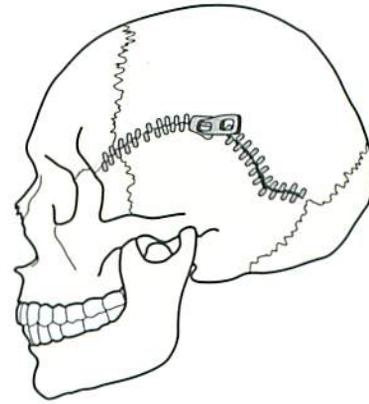
The typical cartoon of a person experiencing gout is that of an older, red-faced, obese, well-off man. His elevated, throbbing big toe fits the picture perfectly. Gout is caused by an increase of uric acid in the blood. The uric acid deposits in joints, where it forms tiny sharp crystals (called *tophi*) that inflame the joint and cause intense pain. Foods high in uric acid can bring on an attack of gout. A diet of meat and alcohol (the rich man’s diet) can cause it; hence, the caricature of a glutton—wealthy, obese, and red-faced—comes to mind. The term *gout* comes from *gutta*, a Latin word meaning “to drop.” It was originally believed that gout was caused by unhealthy humours (fluids) or poisons that dropped or dripped into the joints, particularly the joint of the great toe. This disease was so common that the pubs often had gout stools for their portly porkers. Remember this:

<b>G</b>	great toe
<b>O</b>	one joint, usually the great toe
<b>U</b>	uric acid
<b>T</b>	tophi
<b>Y</b>	Yikes, that hurts!

Joints can be classified into three groups according to the amount of movement: immovable, slightly movable, and freely movable (Table 8-3). Joints can also be classified according to the types of tissues—fibrous, cartilaginous, or synovial—that bind the bones at the joint.

**JOINT CLASSIFICATION****IMMOVABLE JOINTS**

Immovable joints permit no movement. The sutures in the skull are immovable joints. The sutures are formed as the irregular edges of the skull bones interlock and are bound by fibrous connective tissue. When fused, they look like zippers.

**SLIGHTLY MOVABLE JOINTS**

Slightly movable joints permit limited movement. Limited movement is usually achieved by bones connected by a cartilaginous disc. For example, movement of the spinal column occurs at the intervertebral discs. Also, during pregnancy, the symphysis pubis allows the pelvis to widen.

**FREELY MOVABLE JOINTS**

Freely movable joints provide much more flexibility and movement than the other two types of joints. Most of the joints of the skeletal system are freely movable. All freely movable joints are known as **synovial** (si-NO-vee-all) **joints** (Figure 8-18).

A typical synovial joint includes the following structures:

- **Articular cartilage.** The articulating surface of each of the two bones is lined with articular cartilage, forming a smooth surface within the joint.
- **Joint capsule.** The joint capsule is made of fibrous connective tissue. It encloses the joint in a strong sleevelike covering.
- **Synovial membrane.** Lining the joint capsule is the synovial membrane. This membrane secretes synovial fluid into the joint cavity.
- **Synovial fluid.** Synovial fluid lubricates the bones in the joint, thereby decreasing the friction within the joint. Synovial fluid gets its name from an ovum or egg, because the thick consistency of the synovial fluid resembles the consistency of an egg white.

**Table 8-3** Types of Joints

TYPE	DESCRIPTION	EXAMPLES
Immovable	Suture, or “zipper”	Cranial bones
Slightly movable	Disc of cartilage between two bones	Intervertebral discs; symphysis pubis
Freely movable	Ball-and-socket	Shoulder (scapula and humerus); hip (pelvic bone and femur)
	Hinge	Elbow (humerus and ulna); knee (femur and tibia); fingers
	Pivot	Atlas and axis; allows for rotation (side-to-side movement) of the head, indicating “no”
	Saddle	Thumb (carpometacarpal joint); sternoclavicular joint
	Gliding Condylloid	Carpals Temporal bone and mandible (jaw); knuckles

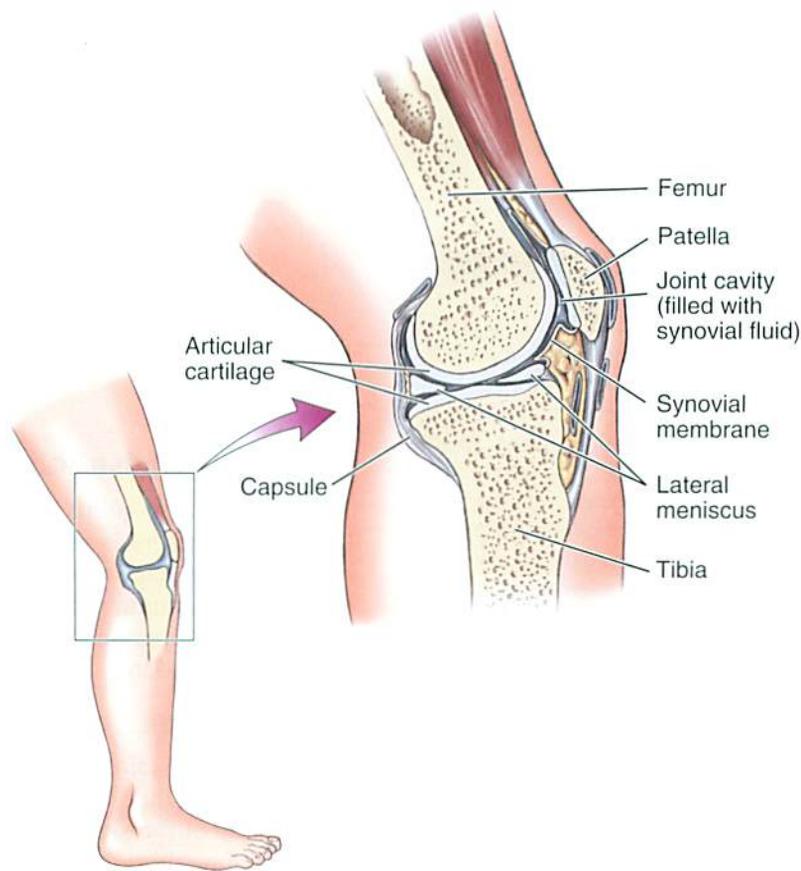


FIGURE 8-18 Synovial joint (knee), structure, and contents.

- *Bursae.* Many synovial joints contain bursae (sing., bursa). Bursae are small sacs of synovial fluid between the joint and the tendons that cross over the joint. Bursae permit the tendons to slide as the bones move. Excessive use of a joint may cause a painful inflammation of the bursae, called *bursitis*. Tennis elbow is bursitis caused by excessive and improper use of the elbow joint.
- *Supporting ligaments.* Surrounding the joint are supporting ligaments. These ligaments join the articulating bones together and stabilize the joint. Sometimes a ligament is stretched or torn, causing pain and loss of mobility.

## NAMING JOINTS

The joints of the body are named so as to provide information about the articulating bones. The joints are named according to the bones they connect. Refer to Figure 8-19 as we identify several joints. The temporomandibular joint connects the temporal bone in the skull with the mandible (lower jaw). The tibiofemoral joint is the articulation between the tibia and the femur—the knee. The knuckles refer to the metacarpophalangeal joints. The name indicates that the metacarpal bone articulates with a phalanx (finger). Some names specify the bony process rather than the bone.

For example, the glenohumeral joint names the glenoid cavity of the scapula and humerus, the arm bone that fits into the glenoid cavity. The acromioclavicular joint is the articulation between the acromion process of the scapula and the clavicle. Finally, locate the sternomanubrial joint (breastbone); it is a landmark used to count ribs.

## MOVING SYNOVIAL JOINTS

The body contains many types of freely movable synovial joints. The type of motion and the degree of flexibility vary with each type of joint. For example, if you move your elbow, your forearm will move like two boards joined by a hinge. This motion is very different from the arm-swinging motion at the shoulder joint. Both the elbow and shoulder joints are freely movable, but the types of movement differ.

Six types of freely movable joints are classified according to the type of movement allowed by the joint (Figure 8-20; see Table 8-3).

### HINGE JOINT

The hinge joint allows movement similar to the movement of two boards joined together by a hinge. The hinge allows movement in one direction, where the angle at the hinge increases or decreases. Hinge joints

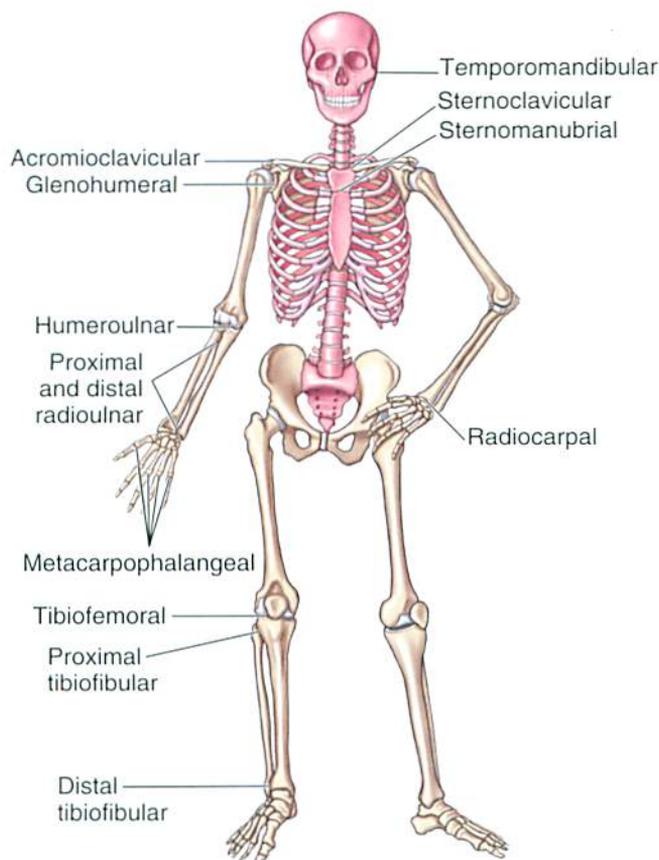


FIGURE 8-19 Naming joints.

include elbows, knees, and fingers. Move each of these joints to clarify the movement described here.

### BALL-AND-SOCKET JOINT

A ball-and-socket joint is formed when the ball-shaped end of one bone fits into the cup-shaped socket of another bone, so that the bones can move in many directions around a central point. The shoulder and hip joints are ball-and-socket joints. The head of the humerus fits into the glenoid cavity of the scapula in the shoulder joint. The head of the femur fits into the acetabulum of the coxal bone in the hip joint.

Move your shoulder all around (as in pitching a softball) and note the freedom of movement. Compare this movement with the limited movement at the elbow or knee joints. Although the ball-and-socket joint allows for a wide range of movement, it also predisposes the joint to easy displacement. When a strong force (as in falling) is applied to the shoulder, for example, a dislocation may occur.

### PIVOT JOINT

A pivot joint allows for rotation around the length of a bone. The pivot joint allows only for rotation. An example is the side-to-side movement of the head indicating “no.” This rotation occurs as the atlas (first cervical vertebra) swivels around, or pivots, on the axis (second cervical vertebra). This joint is called the *atlantoaxial joint*.

### SADDLE JOINT

A saddle joint is formed when the surfaces of both articulating bones are saddle shaped; the saddle shape of one bone is concave whereas the saddle shape of the second bone is convex. The position of the articulating bones is like a rider in a saddle. The clearest example of a saddle joint is the carpometacarpal joint at the base of the thumb, which allows the thumb a wide range of motion. Move your thumb all around to check out its versatility. Now, touch the tip of each finger with your thumb, a movement referred to as opposition. Interestingly, having an opposable thumb is one of the bragging points for being classified as human!

### GLIDING JOINT

A gliding joint is formed by the interaction of the flat surfaces of the articulating bones. A gliding joint allows for a limited but complex gliding movement. Gliding joints are found in the wrist (intercarpal joints), ankle (intertarsal joints), and vertebral column.

### CONDYLOID JOINT

A condyloid (KON-di-loyd) joint is formed when the oval articular surface of one bone fits into the oval depression of the second articulating bone. The radiocarpal joint (wrist) and the metacarpophalangeal joints (knuckles) at the bases of the fingers are examples of condyloid joints.

## CLINICALLY “BIG” SYNOVIAL JOINTS

### KNEE

The knee joint, called the *tibiofemoral joint*, is a hinge joint. In addition to all the structures contained in a synovial joint, the knee joint contains extra cushioning in the form of pads of cartilage. These pads absorb the shock of walking and jumping. Two crescent-shaped pads of cartilage, the medial meniscus (min-ISS-kiss) and lateral meniscus, rest on the tibia. Like other synovial joints, the knee joint is reinforced and aligned by supporting ligaments, the cruciate (KROO-she-ate) ligaments in particular. There is an anterior cruciate ligament (ACL) and a posterior cruciate ligament (PCL). All athletes are very aware of these joint-stabilizing structures.

### PEAS FOR THE KNEES AND MORE DISEASE

- Knees are frequently sprained and strained. As every soccer mom or dad knows, a bag of frozen peas is good first aid for injured knees and is consistent with the first-aid treatment of strains and sprains, or RICE (Rest, Ice, Compression, and Elevation).
- The cruciate ligaments, especially the ACL, are frequent victims of athletic events. The ACL prevents hyperextension of the knee and is torn when the knee is forcibly hyperextended. Torn cartilage is

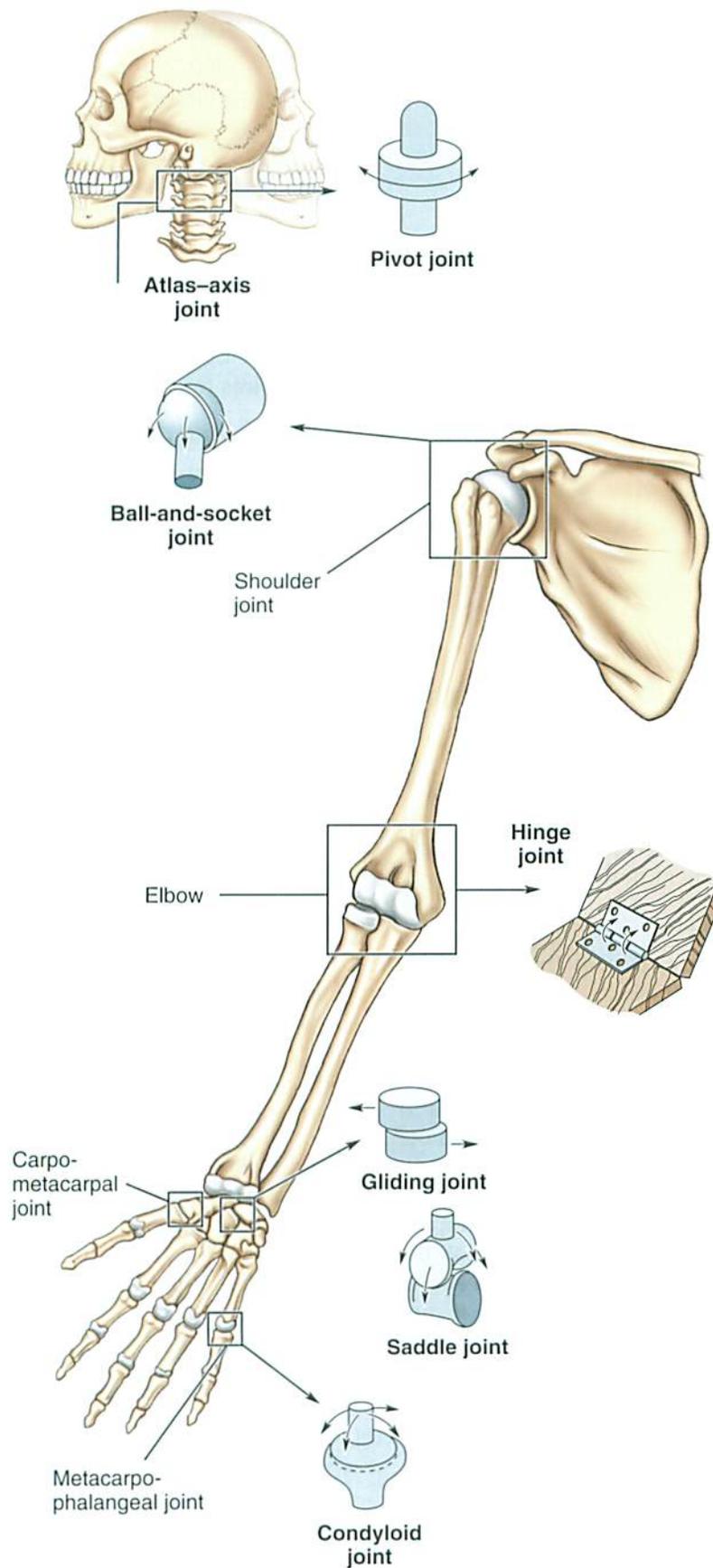


FIGURE 8-20 Freely movable joints.

removed by arthroscopic surgery. An arthroscope is a viewing tube that allows the surgeon to see into the knee joint.

- As any football player knows, being tackled at the sides of the knees can put a fast end to one's career. A clipping penalty attests to the seriousness of knee injuries and is fully deserving of a 15-yard penalty.

## SHOULDER

The shoulder joint is called the *glenohumeral joint*, indicating that the head of the humerus fits into the glenoid cavity of the scapula. The shoulder joint is a ball-and-socket joint that permits the greatest range of motion. The joint is stabilized by surrounding skeletal muscles, tendons, and ligaments. The rotator cuff muscles and tendons, in particular, hold the head of the humerus in the glenoid cavity. The shoulder joint is the most frequently dislocated joint.

## ELBOW

The elbow is called the *humeroulnar joint*. A lesser component of the elbow is the humeroradial joint. The olecranon process of the ulna forms the pointy part of the elbow when it is flexed. The elbow is a hinge joint that is very stable; nonetheless, it can be injured. For example, "nursemaid's elbow" is caused by an impatient parent dragging a toddler by the arm. The upward twisting pull causes a partial dislocation of the child's elbow and possible damage to the growth plate (epiphyseal disc).

## HIP

The hip, called the *coxal joint*, is a ball-and-socket joint formed where the head of the femur articulates with the acetabulum, the depression formed by the three coxal bones. The hip is strengthened by surrounding muscles, tendons, and ligaments. A fractured hip refers to a break in the neck of the femur.

### ? Re-Think

Classify each of the following freely movable joints: tibio-femoral, humeroulnar, glenohumeral, atlas-axis joint, and hip joints.

### Types of Joint Movements

Movements at freely movable joints occur when the muscles that lie across the joints contract and exert pressure on the attached bone. These movements are illustrated in Figure 8-21 and defined as follows:

- **Flexion.** This is the bending of a joint that decreases the angle between the bones (bending the leg at the knee or the fingers).
- **Extension.** This is the straightening of a joint so that the angle between the bones increases (e.g., straightening the leg at the knee or the fingers to open the hand).

- **Plantar flexion.** This is bending the foot down, as in toe dancing.
- **Dorsiflexion.** This is bending the foot up toward the leg.
- **Hyperextension.** This is overextending the joint beyond its normally straightened position, as in moving the hand toward the upper surface of the wrist.
- **Abduction.** This is movement away from the midline of the body (move your leg sideways, away from your body).
- **Adduction.** This is movement toward the midline of the body (return your leg toward your body).
- **Inversion.** This is turning the sole of the foot inward so that it faces the opposite foot.
- **Eversion.** This is turning the sole of the foot outward.
- **Supination.** This is turning the hand so that the palm faces upward.
- **Pronation.** This is turning the hand so that the palm faces downward.
- **Circumduction.** This is a combination of movements, as in the circular arm movement that a softball pitcher makes while pitching the ball.

### ? Re-Think

Refer to Figure 8-19 and describe the type of joint movements of the following parts: left hand at the wrist, right leg at the knee, right forearm at the elbow, left forearm at the elbow, and right hand at the wrist.

### 2+2 Sum It Up!

A joint, or articulation, is the place where two or more bones meet. The three types of joints are immovable joints, slightly movable joints, and freely movable joints. Freely movable joints are synovial joints. Types of freely movable joints include hinge, ball-and-socket, pivot, gliding, saddle, and condyloid joints. Because of the diverse types of joints, the skeleton is capable of a variety of movements.

### As You Age

1. Because of loss of calcium and organic material, bones are less strong and more brittle. Many older women develop osteoporosis. As a result, bones fracture more easily. Moreover, fractured bones heal incompletely and more slowly.
2. As sex hormones in the blood decrease, there is a decrease in new bone growth and in bone mass, thus increasing the susceptibility to osteoporosis.
3. Tendons and ligaments are less flexible. As a result, joints have a decreased range of motion. A thinning of the articular cartilage and bony overgrowths in the joints contributes to joint stiffness.
4. The intervertebral discs shrink. Because of the compressed discs and the loss of bone mass, body height decreases and the thoracic spine curves (causing kyphosis).

*Note: The Medical Terminology and Disorders table appears in Chapter 9.*

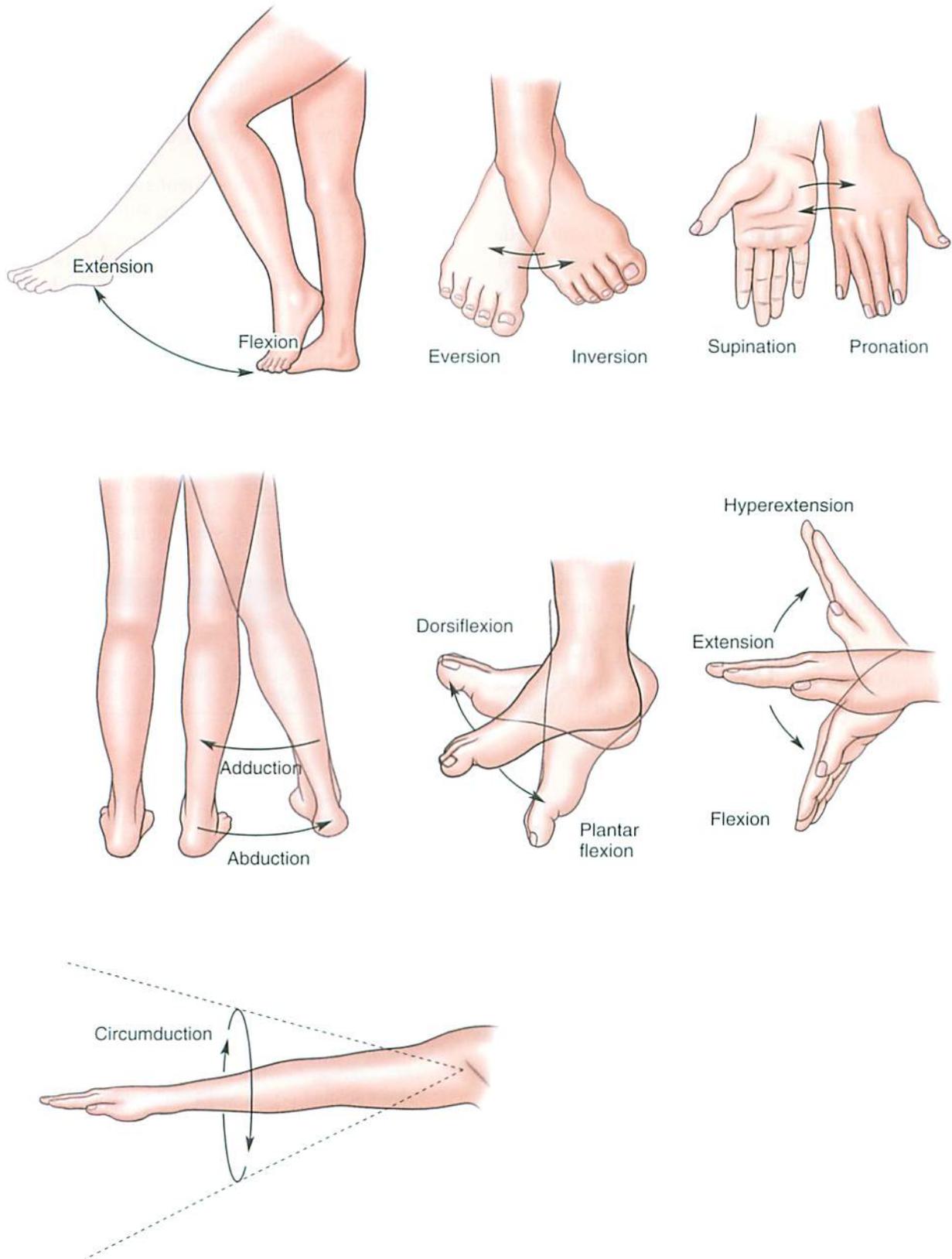


FIGURE 8-21 Types of movements at joints.

## Get Ready for Exams!

### Summary Outline

The skeletal system supports the weight of the body, supports and protects body organs, enables the body to move, acts as a storage site for minerals, and produces blood cells.

#### I. Bones: An Overview

- A. Sizes, shapes, and markings
  1. Bones are classified as long, short, flat, and irregular.
  2. Bone markings: projections and depressions; function as sites of muscle attachments and passages for nerves and blood vessels
  3. Composed of compact (dense) bone and spongy (cancellous) bone
- B. Parts of a long bone
  1. Diaphysis (shaft)
  2. Epiphyses (ends), covered by articular cartilage
  3. Other components: medullary cavity, periosteum, bone marrow, epiphyseal disc, endosteum, and articular cartilage
- C. Ossification
  1. Intramembranous
  2. Endochondral
- D. Bone growth
  1. Bones grow longitudinally at the epiphyseal disc to determine height.
  2. Bones grow thicker and wider to support the weight of the body.

#### II. Divisions of the Skeletal System

The names of the 206 bones of the skeleton are listed in Table 8-2.

- A. Axial skeleton
  1. The axial skeleton includes the bones of the skull (cranium and face), hyoid bone, bones of the middle ear, bones of the vertebral column, and thoracic cage.
  2. The skull of a newborn contains fontanelles, which are membranous areas that allow brain growth.
  3. The skull contains air-filled cavities called *sinuses*.
  4. The vertebral column is formed from 24 vertebrae, one sacrum, and one coccyx. The vertebrae are separated by cartilaginous discs. The vertebral column of the adult has four curvatures: cervical, thoracic, lumbar, and sacral.
  5. The thoracic cage is a bony cone-shaped cage formed by the sternum, 12 pairs of ribs, and thoracic vertebrae.
- B. Appendicular skeleton
  1. The appendicular skeleton includes the bones of the extremities (arms and legs) and the bones of the hip and pectoral (shoulder) girdles.
  2. The pectoral (shoulder) girdle consists of the scapula and the clavicle.
  3. The pelvic girdle is formed by the two coxal bones and is secured to the axial skeleton at the sacrum.

#### III. Joints

A joint or articulation is the site where two bones meet.

- A. Types of joints (based on the degree of movement)
  1. Immovable joints
  2. Slightly movable joints
  3. Freely movable joints or synovial joints.  
Structures within a synovial joint (knee) are the articular cartilage, joint capsule, synovial membrane, synovial fluid, bursae, and supporting ligaments.
  4. The types of freely movable joints include hinge, ball-and-socket, pivot, gliding, saddle, and condyloid joints.
- B. Joint movement
  1. Flexion, extension, and hyperextension
  2. Abduction and adduction
  3. Inversion and eversion
  4. Supination and pronation
  5. Circumduction
  6. Plantar flexion and dorsiflexion

### Review Your Knowledge

#### Matching: Long Bone

Directions: Match the following words with their descriptions below.

- |                     |  |
|---------------------|--|
| a. epiphysis        | 1. ___ Shaft of a long bone                            |
| b. spongy bone      | 2. ___ Site of longitudinal bone growth                |
| c. epiphyseal disc  | 3. ___ Bone-building cell                              |
| d. diaphysis        | 4. ___ Site of blood cell production                   |
| e. medullary cavity | 5. ___ Tough outer covering of the bone                |
| f. haversian system | 6. ___ Enlarged end of a long bone                     |
| g. osteoblast       | 7. ___ Cancellous bone                                 |
| h. osteoclast       | 8. ___ Osteon  |
| i. red bone marrow  | 9. ___ Bone-eroding cell that helps in bone remodeling |
| j. periosteum       | 10. ___ Hollow center of a long bone                   |

#### Matching: Names of Bones

Directions: Match the following words with their descriptions below.

- |               |   |
|---------------|---|
| a. femur      | 1. ___ Manubrium, body, xiphoid process                               |
| b. scapula    | 2. ___ Acetabulum formed by parts of this bone                        |
| c. mandible   | 3. ___ Contains the glenoid cavity that holds the head of the humerus |
| d. ulna       | 4. ___ Contains the "pointy" olecranon process                        |
| e. sternum    | 5. ___ The thick inner bone of the leg                                |
| f. coxal bone | 6. ___ Heel bone  |
| g. tibia      | 7. ___ Fingers and toes   |
| h. calcaneus  | 8. ___ The head of this bone that articulates with the acetabulum     |
| i. frontal    | 9. ___ Lower jaw bone   |
| j. phalanges  | 10. ___ Forms the forehead  |

**Matching: Joints and Joint Movement**

Directions: Match the following words with their descriptions below. Some words may be used more than once.

- |                    |  |
|--------------------|--|
| a. ball-and-socket | 1. ___ Type of joint movement at the elbow (angle decreases)               |
| b. adduction       |  |
| c. flexion         | 2. ___ Turning the forearm so that the palm of the hand "looks" at the sky |
| d. pronation       |  |
| e. dorsiflexion    | 3. ___ Movement away from the midline of the body                          |
| f. circumduction   | 4. ___ Toe dancing   |
| g. extension       | 5. ___ Movement of the ulna toward the humerus                             |
| h. plantar flexion |  |
| i. abduction       | 6. ___ Type of joint at the shoulder and hip                               |
| j. supination      | 7. ___ Shoulder movement, as in pitching a softball                        |
|                    | 8. ___ Movement toward the midline of the body                             |
|                    | 9. ___ Turning the forearm so that the hand "looks" at the floor           |
|                    | 10. ___ Straightening the bended knee                                      |

**Multiple Choice**

- The epiphyseal disc is
  - located in the medullary cavity.
  - composed of cartilage and is involved in the growth of long bones.
  - composed exclusively of osteoclasts.
  - the site of blood cell formation.
- Osteoclastic activity
  - is responsible for longitudinal bone growth.
  - lowers blood calcium levels.
  - stimulates bone breakdown.
  - regulates the production of blood cells.
- Which of the following is not true of the acetabulum?
  - Formed by the ilium, ischium, and pubis
  - Receives the head of the femur
  - Articulates with the greater trochanter
  - Forms a ball-and-socket joint
- The atlas and axis
  - are pelvic bones.
  - are processes located on the posterior scapula.
  - form the glenoid cavity.
  - are vertebrae that allow the head to move.
- To determine the approximate length of the humerus, you would measure from the
  - olecranon process to the styloid process of the radius.
  - acromion to the olecranon process.
  - suprasternal notch to the xiphoid process.
  - greater trochanter to the medial malleolus.
- Depression of the red bone marrow
  - causes a life-threatening decline in blood cells.
  - stunts longitudinal bone growth.
  - causes arthritis.
  - causes loss of bone mineralization and osteoporosis.

- Identify the movement at the elbow that decreases the angle at the humeroulnar joint.
  - Extension
  - Adduction
  - Pronation
  - Flexion
- Which of the following is not true of the skull?
  - The joint between the frontal and parietal bones is called the *coronal suture*.
  - The lambdoidal suture is an immovable joint.
  - Cranial bones include zygomatic, frontal, occipital, and temporal bones.
  - Facial bones include maxilla, mandible, and ethmoid bones.
- Which of the following is true of the foramen magnum? It is
  - a large hole through which the brain exits the cranium.
  - located within the frontal bone.
  - part of C1, the atlas.
  - a suture between the frontal and parietal bones.
- C1 to C7, T1 to T12, and L1 to L5 are
  - responsible for the lumbar curve.
  - vertebrae.
  - cranial sutures.
  - part of the appendicular skeleton.

**Go Figure**

- According to Figures 8-2 and 8-3**
  - The osteon is the structural unit for compact bone.
  - The bone marrow is part of the haversian system.
  - The diaphysis is composed exclusively of cancellous bone.
  - The upper extremity is composed of all long bones.
- According to Figure 8-5**
  - The bricklayer represents osteoclastic activity.
  - Osteoclasts stimulate bone synthesis.
  - Osteoblasts are bone-building cells (as in the bricklayer).
  - Osteoclasts only work on the external surface of the bone.
- According to Figures 8-7, 8-8, and 8-9**
  - The suture is the only type of joint found in the skull.
  - Fontanels are most evident in the side view of the adult skull.
  - The frontal, zygomatic, and sphenoid bones help form the eye socket.
  - The anterior fontanel is located between the occipital and parietal bones.
- According to Figures 8-10, 8-11, and 8-12**
  - The structure of all cervical vertebrae resemble C1.
  - Intervertebral discs are located between all vertebrae.
  - The atlas and axis are cervical vertebrae.
  - Kyphosis refers to a lateral curvature of the vertebral column.