chapter 7

Skeletal System

CLUES FROM SKELETONS PAST. As the hardest and therefore most enduring of human tissues, bone has persisted over time to provide clues to early humans and their forebears. Some glimpses into the past, courtesy of skeletal remains or fossils, include:

7300–6220 B.C. Skulls with circular holes are the earliest evidence of trepanation, a technique used to relieve pressure following a skull fracture or as a spiritual treatment for headache, tumors, or mental illness. A few of the people treated with trepanation were lucky—they survived, as evidenced by new bony growth over the holes made in their skulls. However, most trepanated skulls have gaping, drilled holes, indicating that the "treatment" was lethal.

2.8–2.6 million years ago "Mr. Ples" is the name anthropologists have given to the face and left side of a skull from Sterkfontein, South Africa, which once belonged to a member of *Australopithecus africanus* (see photo), a type of primate that preceded *Homo sapiens*. Using computer modeling to fashion a "virtual endocast" of the entire skull contents, researchers have estimated the cranial capacity of *A. africanus* at 515 cubic centimeters (cc). By comparison, a chimp's cranial capacity averages 370 cc, and a modern human's, 1,350. Expanded cranial capacity correlates to increase in intelligence.

3.5 million years ago Not all evidence of a skeletal system is in the form of preserved bone. On the Serengeti Plain are clues to our ancestors who first began to walk upright, a stance that freed their hands, perhaps making possible the development of tools. This evidence consists of shallow footprints where an animal called *Australopithecus afarensis* once lived. The prints reveal that it had long big toes and arched feet.

Photo:
Australopithecus africanus lived from 2.8 to 2.6 million years ago. Our knowledge of this primate comes from skeletal evidence.

6.5 Regulation of Body Temperature (p. 120)

Regulation of body temperature is vital because heat affects the rates of metabolic reactions. The normal temperature of deeper body parts is close to a set point of 37°C (98.6°F).

1. When body temperature rises above the normal set point, dermal blood vessels dilate, and sweat glands secrete sweat.
2. If body temperature drops below the normal set point, dermal blood vessels constrict, and sweat glands become inactive.
3. Excessive heat loss stimulates skeletal muscles to contract involuntarily.
4. Fever results from an elevated temperature set point.

6.6 Healing of Wounds (p. 120)

Skin injuries trigger inflammation. The affected area becomes red, warm, swollen, and tender.

1. Dividing epithelial cells fill in shallow cuts in the epidermis.
2. Clots close deeper cuts, sometimes leaving a scar where connective tissue replaces skin.
3. Granulations form in large, open wounds as part of the healing process.

REVIEW EXERCISES

1. Explain why a membrane is an organ. (p. 113)
2. Define *integumentary system.* (p. 113)
3. Distinguish between serous and mucous membranes. (p. 113)
4. Explain the functions of synovial membranes. (p. 113)
5. List six functions of skin. (p. 113)
6. Distinguish between the epidermis and the dermis. (p. 113)
7. Explain what happens to epidermal cells as they undergo keratinization. (p. 113)
8. Describe the function of melanocytes. (p. 114)
9. List the factors that affect skin color. (p. 116)
10. Review the functions of dermal nervous tissue. (p. 116)
11. Describe the subcutaneous layer and its functions. (p. 116)
12. Explain how blood is supplied to various skin layers. (p. 116)
13. Distinguish between a hair and a hair follicle. (p. 117)
14. Explain the function of sebaceous glands. (p. 118)
15. Describe how nails are formed. (p. 118)
16. Distinguish between eccrine and apocrine sweat glands. (p. 119)
17. Explain how body heat is produced. (p. 120)
18. Explain how sweat glands help regulate body temperature. (p. 120)
19. Describe the body's responses to decreasing body temperature. (p. 120)
20. Distinguish between the healing of shallow and deeper breaks in the skin. (p. 120)

CRITICAL THINKING

1. Everyone's skin contains about the same number of melanocytes even though people are of many different colors. How is this possible?
2. Why would collagen and elastin added to skin creams be unlikely to penetrate the skin—as some advertisements imply they do?
3. A severe form of the inherited illness epidermolysis bullosa causes extreme blistering of the skin. The person lacks a protein called laminin, which normally attaches the dermis to the epidermis. Explain how lack of this protein disrupts the skin's structure.
4. How is skin peeling after a severe sunburn protective? How might a fever be protective?
5. What special problems would result from the loss of 50% of a person's functional skin surface? How might this person's environment be modified to compensate partially for such a loss?
6. A premature infant typically lacks subcutaneous adipose tissue. Also, the surface area of an infant's small body is relatively large compared to its volume. How do you think these factors affect the ability of an infant to regulate its body temperature?
7. Which of the following would result in the more rapid absorption of a drug: a subcutaneous injection or an intradermal injection? Why?
8. How would you explain to an athlete the importance of keeping the body hydrated when exercising in warm weather?

WEB CONNECTIONS

Visit the website for additional study questions and more information about this chapter at:

http://www.mhhe.com/shieress8

Chapter Objectives

After studying this chapter, you should be able to do the following:

7.1 Introduction

1. List the active tissues in a bone. (p. 128)

7.2 Bone Structure

2. Describe the general structure of a bone, and list the functions of its parts. (p. 128)

7.3 Bone Development and Growth

3. Distinguish between intramembranous and endochondral bones, and explain how such bones develop and grow. (p. 130)

7.4 Bone Function

4. Discuss the major functions of bones. (p. 131)

7.5 Skeletal Organization

5. Distinguish between the axial and appendicular skeletons, and name the major parts of each. (p. 135)

7.6–7.12 Skull—Lower Limb

6. Locate and identify the bones and the major features of the bones that comprise the skull, vertebral column, thoracic cage, pectoral girdle, upper limb, pelvic girdle, and lower limb. (p. 136)

7.13 Joints

7. List three classes of joints, describe their characteristics, and name an example of each. (p. 156)
8. List six types of synovial joints, and describe the actions of each. (p. 157)
9. Explain how skeletal muscles produce movements at joints, and identify several types of joint movements. (p. 159)

Aids to Understanding Words

acetabul- [vinegar cup] *acetabul*um: Depression of the coxa that articulates with the head of the femur.

ax- [axis] *ax*ial skeleton: Upright portion of the skeleton that supports the head, neck, and trunk.

-blast [budding] osteo*blast:* Cell that will form bone tissue.

carp- [wrist] *carp*als: Wrist bones.

-clast [break] osteo*clast:* Cell that breaks down bone tissue.

condyl- [knob] *condyl*e: Rounded, bony process.

corac- [a crow's beak] *corac*oid process: Beaklike process of the scapula.

cribr- [sieve] *cribr*iform plate: Portion of the ethmoid bone with many small openings.

crist- [crest] *crist*a galli: Bony ridge that projects upward into the cranial cavity.

fov- [pit] *fov*ea capitis: Pit in the head of a femur.

glen- [joint socket] *glen*oid cavity: Depression in the scapula that articulates with the head of the humerus.

hema- [blood] *hema*toma: Blood clot.

inter- [among, between] *inter*vertebral disc: Structure located between adjacent vertebrae.

intra- [inside] *intra*membranous bone: Bone that forms within sheetlike masses of connective tissue.

meat- [passage] auditory *meat*us: Canal of the temporal bone that leads inward to parts of the ear.

odont- [tooth] *odont*oid process: Toothlike process of the second cervical vertebra.

poie- [make, produce] hemato*poie*sis: Process by which blood cells are formed.

Key Terms

articular cartilage (ar-tik´u-lar kar´tĭ-lij)
bursa (ber´sah)
cartilaginous joint (kar´´tĭ-lah´jin-us joint)
compact bone (kom´pakt bōn)
diaphysis (di-af´ĭ-sis)
endochondral bone (en´´do-kon´dral bōn)
epiphyseal plate (ep´´ĭ-fiz´e-al plāt)
epiphysis (e-pif´ĭ-sis)
fibrous joint (fi´brus joint)
hemopoiesis (he´´mo-poi-e´sis)
intramembranous bone (in´´trah-mem´brah-nus bōn)
lever (lev´er)
marrow (mar´o)
medullary cavity (med´u-lār´´e kav´ĭ-te)
meniscus (mĕ-nis´kus)
osteoblast (os´te-o-blast)
osteoclast (os´te-o-klast)
osteocyte (os´te-o-sīt)
periosteum (per´´e-os´te-um)
spongy bone (spun´je bōn)
synovial joint (sĭ-no´ve-al joint)

7.1 Introduction

Halloween skeletons and the skull-and-crossbones symbol of poison and pirates may make bones seem like lifeless objects, but in actuality, bones are not only very much alive but also multifunctional. Bones, the organs of the skeletal system, provide points of attachment for muscles, protect and support softer tissues, house blood-producing cells, store inorganic salts, and contain passageways for blood vessels and nerves. Bone contains a variety of very active tissues: bone tissue, cartilage, dense connective tissue, blood, and nervous tissue.

7.2 Bone Structure

The bones of the skeletal system differ greatly in size and shape, yet they are similar in structure, development, and functions.

Parts of a Long Bone

The femur, a long bone in the thigh, illustrates the structure of bone (fig. 7.1). At each end of such a bone is an expanded portion called an **epiphysis** (e-pif´ĭ-sis) (plural, *epiphyses*), which articulates (forms a joint) with another bone. On its outer surface, the articulating portion of the epiphysis is coated with a layer of hyaline cartilage called **articular cartilage** (ar-tik´u-lar kar´tĭ-lij). The shaft of the bone, which is located between the epiphyses, is called the **diaphysis** (di-af´ĭ-sis).

A tough, vascular covering of fibrous tissue called the **periosteum** (per´´e-os´te-um) completely encloses the bone, except for the articular cartilage on the bone's ends. The periosteum is firmly attached to the bone, and periosteal fibers are continuous with ligaments and tendons that connect to the membrane. The periosteum also helps form and repair bone tissue.

A bone's shape makes possible its functions. For example, bony projections called *processes* provide sites for ligaments and tendons to attach; grooves and openings form passageways for blood vessels and nerves; and a depression of one bone may articulate with a process of another.

The wall of the diaphysis is mainly composed of tightly packed tissue called **compact bone** (kom´pakt bōn), or cortical bone. This type of bone has a continuous matrix with no gaps. The epiphyses, in contrast, are composed largely of **spongy bone** (spun´je bōn), or cancellous bone, with thin layers of compact bone on their surfaces. Spongy bone consists of numerous branching bony plates. Irregular connecting spaces between these plates help reduce the bone's weight. The bony plates are most highly developed in the regions of the epiphyses that are subjected to compressive forces. Both compact and spongy bone are strong and resist bending (fig. 7.2).

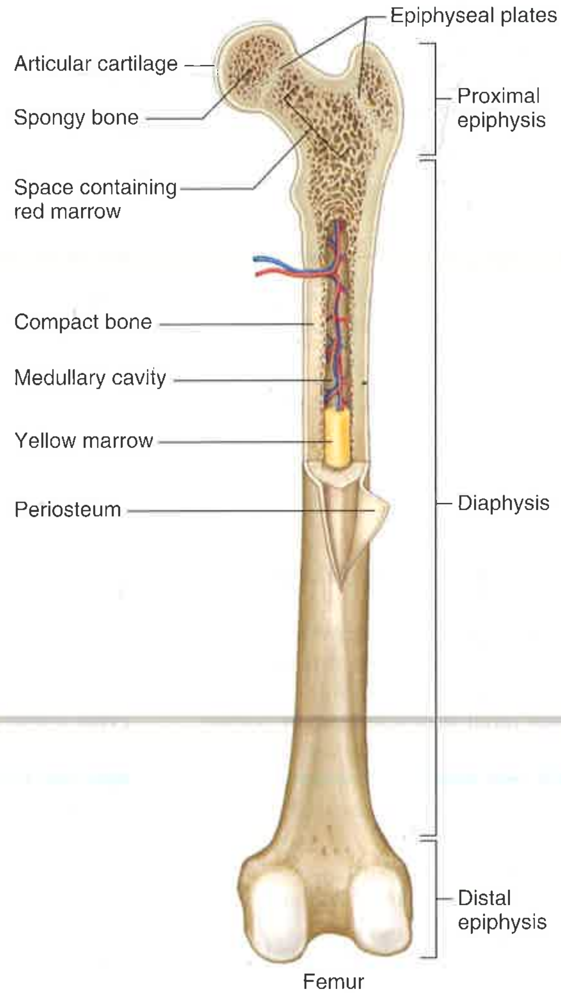


Figure 7.1
Major parts of a long bone.

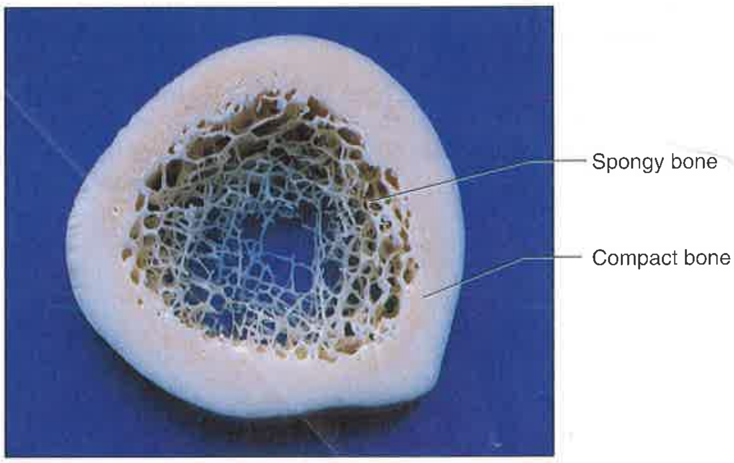


Figure 7.2
This cross section of a long bone contains a layer of spongy bone beneath a layer of compact bone.

Compact bone in the diaphysis of a long bone forms a semirigid tube with a hollow chamber called the **medullary cavity** (med´u-lār´´e kav´ĭ-te) that is continuous with the spaces of the spongy bone. A thin layer of cells called **endosteum** (en-dos´te-um) lines these areas, and a specialized type of soft connective tissue called **marrow** (mar´o) fills them.

Microscopic Structure

Recall from chapter 5 (p. 103) that bone cells called **osteocytes** (os´te-o-sītz) are located in very small, bony chambers called *lacunae,* which form concentric circles around *central canals* (Haversian canals) (fig. 7.3; see fig. 5.19). Osteocytes communicate with nearby cells by means of cellular processes passing through canaliculi. The intercellular material of bone tissue is largely collagen and inorganic salts. Collagen gives bone its strength and resilience, and inorganic salts make it hard and resistant to crushing.

In compact bone, the osteocytes and layers of intercellular material concentrically clustered around a central canal form a cylinder-shaped unit called an *osteon* (Haversian system). Many of these units cemented together form the substance of compact bone.

Each central canal contains blood vessels (usually capillaries) and nerve fibers surrounded by loose connective tissue. Blood in these vessels nourishes bone cells associated with the central canal.

Central canals extend longitudinally through bone tissue, and transverse *perforating canals* (Volkmann's canals) connect them. Perforating canals contain larger blood vessels and nerves by which the smaller blood vessels and nerve fibers in central canals communicate with the surface of the bone and the medullary cavity (fig. 7.3).

Spongy bone is also composed of osteocytes and intercellular material, but the bone cells do not aggregate around central canals. Instead, substances diffusing into canaliculi that lead to the surface of these thin, bony plates nourish the cells.

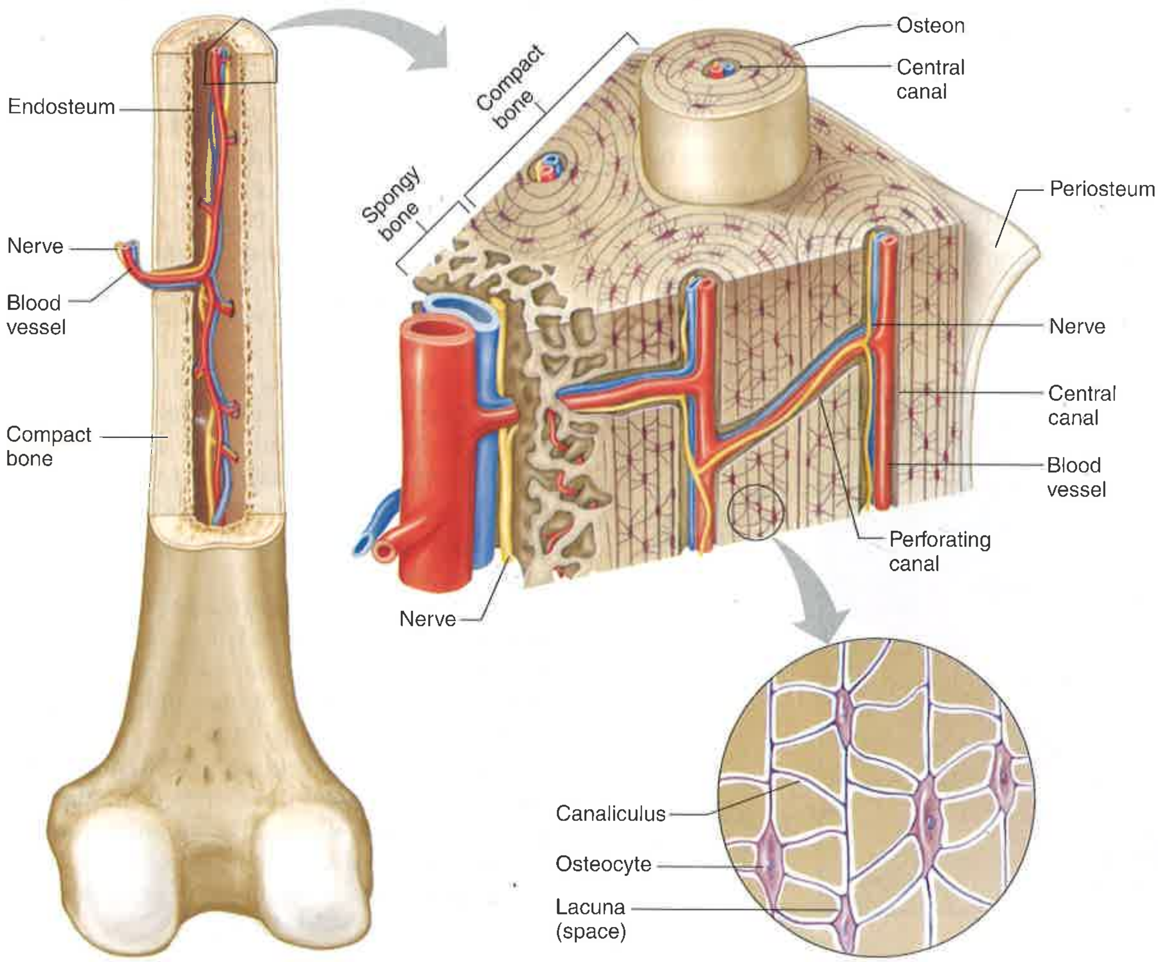


Figure 7.3
Compact bone is composed of osteons cemented together by bone matrix.

CHECK YOUR RECALL

1. List five major parts of a long bone.
2. How do compact and spongy bone differ in structure?
3. Describe the microscopic structure of compact bone.

7.3 Bone Development and Growth

Parts of the skeletal system begin to form during the first few weeks of prenatal development, and bony structures continue to develop and grow into adulthood. Bones form by replacing existing connective tissues in either of two ways: (1) Intramembranous bones originate between sheetlike layers of connective tissues. (2) Endochondral bones begin as masses of cartilage that bone tissue later replaces.

Intramembranous Bones

The broad, flat bones of the skull are **intramembranous bones** (in′′trah-mem′brah-nus bōnz) (fig. 7.4). During their development, membranelike layers of connective tissues appear at the sites of the future bones. Then, some of the primitive connective tissue cells enlarge and differentiate into bone-forming cells called **osteoblasts** (os′te-o-blastz). The osteoblasts become active within the membranes and deposit bony matrix around themselves. As a result, spongy bone tissue forms in all directions within the layers of primitive connective tissues. Eventually, cells of the membranous tissues that persist outside the developing bone give rise to the periosteum. Osteoblasts on the inside of the periosteum form a layer of compact bone over the surface of the newly formed spongy bone. When matrix completely surrounds osteoblasts, they are called osteocytes.

Figure 7.4
Note the stained, developing bones of this fourteen-week fetus.

Endochondral Bones

Most of the bones of the skeleton are **endochondral bones** (en′′do-kon′dral bōnz). They develop from masses of hyaline cartilage shaped like future bony structures (fig. 7.4). These cartilaginous models grow rapidly for a time and then begin to extensively change. In a long bone, for example, the changes begin in the center of the diaphysis, where the cartilage slowly breaks down and disappears (fig. 7.5). At about the same time, a periosteum forms from connective tissue that encircles the developing diaphysis. Blood vessels and osteoblasts from the periosteum invade the disintegrating cartilage, and spongy bone forms in its place. This region of bone formation is called the *primary ossification center,* and bone tissue develops from it toward the ends of the cartilaginous structure.

Meanwhile, osteoblasts from the periosteum deposit a thin layer of compact bone around the primary ossification center. The epiphyses of the developing bone remain cartilaginous and continue to grow. Later, *secondary ossification centers* appear in the epiphyses, and spongy bone forms in all directions from them. As spongy bone is deposited in the diaphysis and in the epiphysis, a band of cartilage called the **epiphyseal plate** (ep′′ĭ-fiz′e-al plāt), or metaphysis, remains between these two ossification centers.

The cartilaginous cells of the epiphyseal plate include layers of young cells that are undergoing mitosis and producing new cells. As these cells enlarge and matrix forms around them, the cartilaginous plate thickens, lengthening the bone. At the same time, calcium salts accumulate in the matrix adjacent to the oldest cartilaginous cells, and as the matrix calcifies, the cells begin to die.

In time, large, multinucleated cells called **osteoclasts** (os′te-o-klastz) break down the calcified matrix. These large cells originate in bone marrow when certain single-nucleated white blood cells (monocytes) fuse (see chapter 12, p. 312).

Osteoclasts secrete an acid that dissolves the inorganic component of the calcified matrix, and their lysosomal enzymes digest the organic components. After osteoclasts remove the matrix, bone-building osteoblasts invade the region and deposit new bone tissue in place of the calcified cartilage.

A long bone continues to lengthen while the cartilaginous cells of the epiphyseal plates are active. However, once the ossification centers of the diaphysis

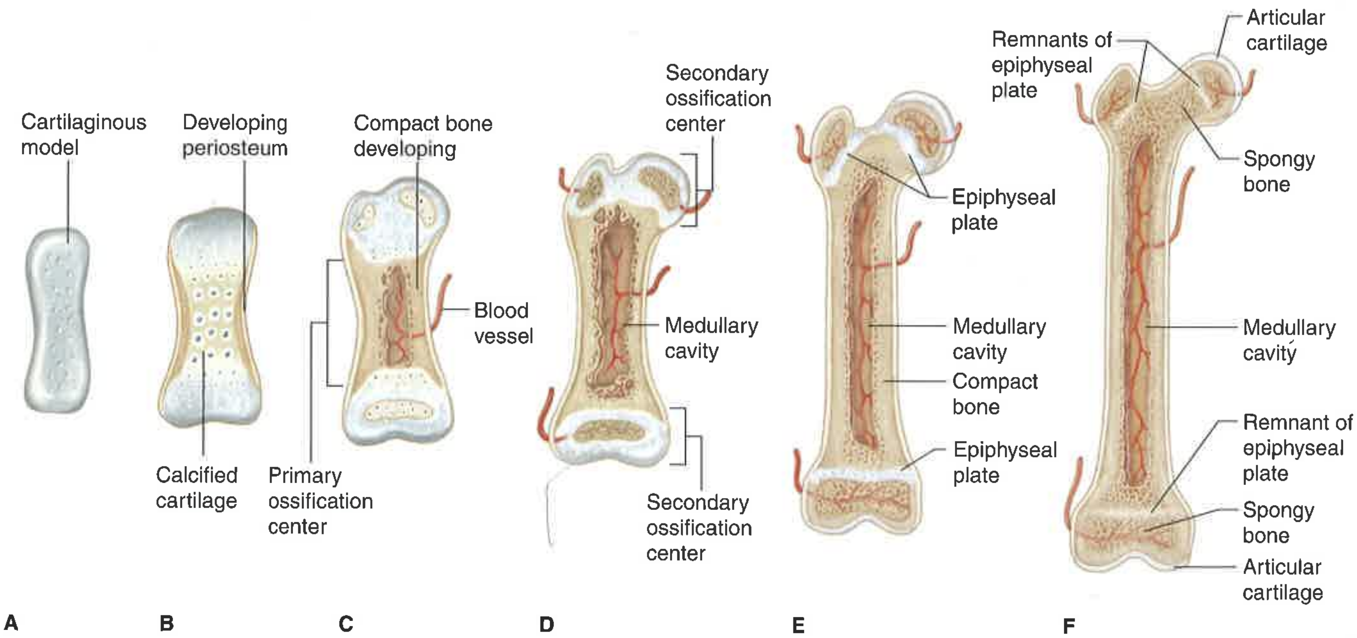


Figure 7.5
Major stages (*A–F*) in the development of an endochondral bone. (Relative bone sizes are not to scale.)

and epiphyses meet and the epiphyseal plates ossify, lengthening is no longer possible in that end of the bone.

A developing long bone thickens as compact bone is deposited on the outside, just beneath the periosteum. As this compact bone forms on the surface, osteoclasts erode other bone tissue on the inside. The resulting space becomes the medullary cavity of the diaphysis, which later fills with marrow. The bone in the central regions of the epiphyses and diaphysis remains spongy, and hyaline cartilage on the ends of the epiphyses persists throughout life as articular cartilage.

If an epiphyseal plate is damaged before it ossifies, elongation of the long bone may cease prematurely, or growth may be uneven. For this reason, injuries to the epiphyses of a young person's bones are of special concern. Surgeons can alter an epiphysis to equalize the growth rate of bones developing at very different rates.

Homeostasis of Bone Tissue

After the intramembranous and endochondral bones form, the actions of osteoclasts and osteoblasts continually remodel them. Throughout life, osteoclasts resorb bone matrix, and osteoblasts replace it. Hormones regulate these opposing processes of *resorption* and *deposition* of calcium (see chapter 11, p. 291). As a result, the total mass of bone tissue of an adult skeleton normally remains nearly constant, even though 3–5% of bone calcium is exchanged each year.

In bone cancers, abnormally active osteoclasts destroy bone tissue. Interestingly, cancer of the prostate gland can have the opposite effect if the cancer cells reach the bone marrow (as they do in most cases of advanced prostatic cancer). These cells stimulate osteoblast activity, which promotes formation of new bone on the surfaces of the bony plates.

CHECK YOUR RECALL

1. Describe the development of an intramembranous bone.
2. Explain how an endochondral bone develops.
3. Explain how osteoclasts and osteoblasts remodel bone.

7.4 Bone Function

Bones shape, support, and protect body structures. They also aid body movements, house tissues that produce blood cells, and store various inorganic salts.

Support and Protection

Bones give shape to such structures as the head, face, thorax, and limbs and also provide support and protection. For example, the bones of the lower limbs, pelvis, and backbone support the body's weight. The bones of the skull protect the eyes, ears, and brain. Those of the rib cage and shoulder girdle protect the heart and lungs, whereas bones of the pelvic girdle protect the lower abdominal and internal reproductive organs.

A *fracture* is a break in a bone. Whenever a bone breaks, blood vessels within it and its periosteum rupture, and the periosteum is likely to tear. Blood escaping from the broken vessels spreads through the damaged area and soon forms a blood clot, or *hematoma*. Vessels in surrounding tissues dilate, swelling and inflaming the tissues.

Within days or weeks, developing blood vessels and large numbers of osteoblasts from the periosteum invade the hematoma. The osteoblasts rapidly divide in the regions close to the new blood vessels, building spongy bone nearby. Granulation tissue develops, and in regions farther from a blood supply, fibroblasts produce masses of fibrocartilage. Meanwhile, phagocytic cells begin to remove the blood clot, as well as any dead or damaged cells in the affected area. Osteoclasts also appear and resorb bone fragments, aiding in "cleaning up" debris.

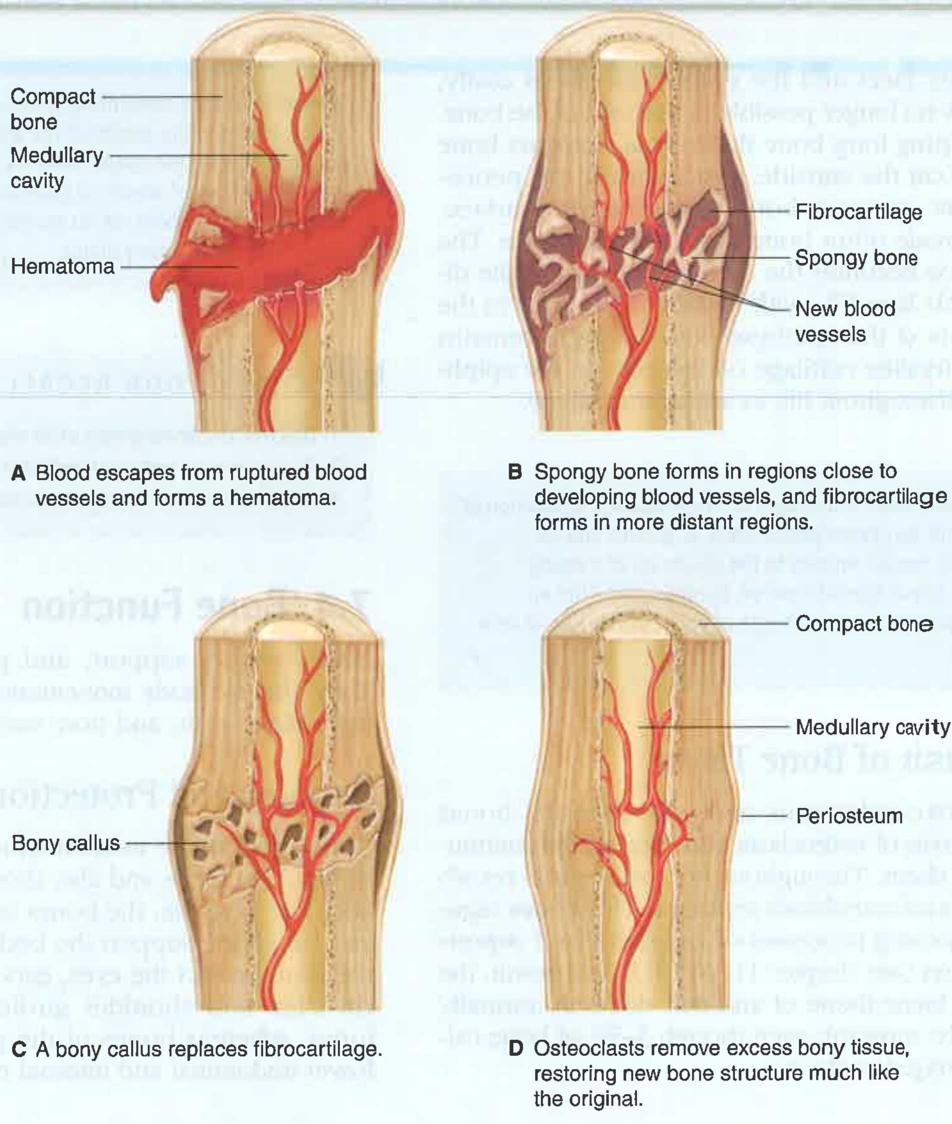
In time, fibrocartilage fills the gap between the ends of the broken bone. This mass, termed a *cartilaginous callus,* is later replaced by bone tissue in much the same way that the hyaline cartilage of a developing endochondral bone is replaced. That is, the cartilaginous callus breaks down, blood vessels and osteoblasts invade the area, and a *bony callus* fills the space.

Typically, more bone is produced at the site of a healing fracture than is required to replace the damaged tissues. Osteoclasts remove the excess, and the final result is a bone shaped very much like the original (fig. 7A).

Physicians can help the bone-healing process. The first casts to immobilize fractured bones were introduced in Philadelphia in 1876, and soon after, doctors began using screws and plates internally to align healing bone parts. Today, orthopedic surgeons also use rods, wires, and nails. These devices have become lighter and smaller; many are built of titanium. A new approach, called a hybrid fixator, treats a broken leg using metal pins internally to align bone pieces. The pins are anchored to a metal ring device worn outside the leg.

Figure 7A

Major steps (A–D) in repair of a fracture.



A Blood escapes from ruptured blood vessels and forms a hematoma.

B Spongy bone forms in regions close to developing blood vessels, and fibrocartilage forms in more distant regions.

C A bony callus replaces fibrocartilage.

D Osteoclasts remove excess bony tissue, restoring new bone structure much like the original.

Body Movement

Whenever limbs or other body parts move, bones and muscles interact as simple mechanical devices called **levers** (lev´erz). A lever has four basic components: (1) a rigid rod or bar, (2) a fulcrum or pivot on which the bar turns, (3) an object that is moved against resistance, and (4) a force that supplies energy for the movement of the bar.

The actions of bending and straightening the upper limb at the elbow illustrate bones and muscles functioning as levers (fig. 7.6). When the upper limb bends, the forearm bones represent the rigid rod, the elbow joint is the fulcrum, the hand is moved against the resistance provided by its weight, and the force is supplied by muscles on the anterior side of the arm. One of these muscles, the *biceps brachii,* is attached by a tendon to a projection on a bone (radius) in the forearm, a short distance below the elbow.

When the upper limb straightens at the elbow, the forearm bones again serve as the rigid rod, and the elbow joint serves as the fulcrum. However, this time, the *triceps brachii,* a muscle located on the posterior side of the arm, supplies the force. A tendon of this muscle attaches to a projection on a bone (ulna) at the point of the elbow.

Blood Cell Formation

Very early in life, the process of blood cell formation, called **hemopoiesis** (he´´mo-poi-e´sis), begins in the *yolk sac,* which lies outside the human embryo (see chapter 20). Later in development, blood cells are manufactured in the liver and spleen, and still later, they form in bone marrow.

Marrow is a soft, netlike mass of connective tissue within the medullary cavities of long bones, in the irregular spaces of spongy bone, and in the larger central canals of compact bone tissue. The two kinds of marrow are red marrow and yellow marrow. *Red marrow* functions in the formation of red blood cells (erythrocytes), white blood cells (leukocytes), and blood platelets. It is red because of the red, oxygen-carrying pigment **hemoglobin** in the red blood cells.

Red marrow occupies the cavities of most bones in an infant. With increasing age, however, yellow marrow replaces much of it. *Yellow marrow* stores fat and is inactive in blood cell production. In an adult, red marrow is primarily found in the spongy bone of the skull, ribs, sternum, clavicles, vertebrae, and pelvis. Chapter 12 (pp. 308 and 311) describes blood cell formation in more detail.

Storage of Inorganic Salts

The intercellular matrix of bone tissue is rich in calcium salts, mostly in the form of calcium phosphate. Vital metabolic processes require calcium. When the blood is low in calcium, parathyroid hormone stimulates osteoclasts to break down bone tissue, which releases calcium salts from the intercellular matrix into the blood. A high blood calcium level inhibits osteoclast activity, and calcitonin from the thyroid gland stimulates osteoblasts to form bone tissue, storing excess calcium in the

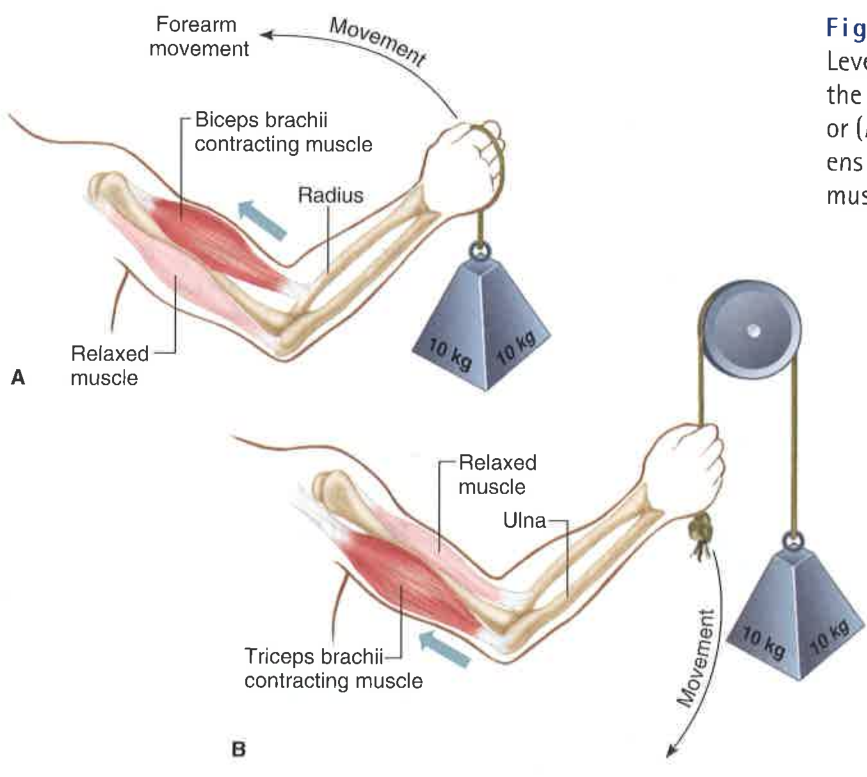


Figure 7.6
Levers and movement. (*A*) When the forearm bends at the elbow or (*B*) when the forearm straightens at the elbow, the bones and muscles function as a lever.

matrix. Chapter 11 (p. 290) describes the details of this homeostatic mechanism (fig. 7.7). Maintaining sufficient blood calcium levels is important in muscle contraction, nervous impulse conduction, blood clotting, and other physiological processes. The Topic of Interest on page 135 discusses bone mass loss due to less calcium in the bones.

Bone tissue contains lesser amounts of magnesium, sodium, potassium, and carbonate ions than the other constituents. Bones also accumulate certain harmful metallic elements, such as lead, radium, or strontium. These are not normally present in the body, but are sometimes ingested accidentally.

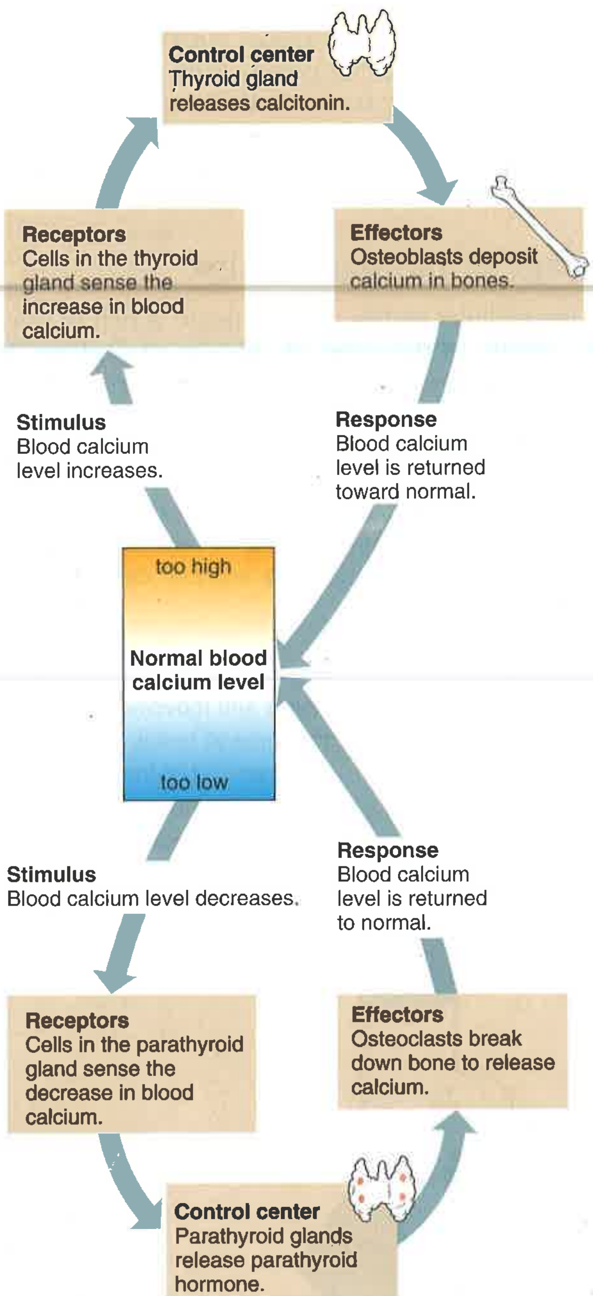


Figure 7.7
Hormonal regulation of bone calcium resorption and deposition.

CHECK YOUR RECALL

1. Name three major functions of bones.
2. Distinguish between the functions of red marrow and yellow marrow.
3. List the substances normally stored in bone tissue.

A bone marrow transplant (BMT) is a life-saving, but risky, procedure. A hollow needle and syringe are used to remove normal red marrow cells from the spongy bone of a donor, or stem cells (which can give rise to specialized blood cells) are separated out from the donor's bloodstream. Stem cells from the umbilical cord of a newborn can also be used in place of bone marrow.

The donor is selected because the pattern of molecules on his or her cell surfaces closely matches that of the recipient. In 30% of BMTs, the donor is a blood relative. The cells are injected into the bloodstream of the recipient, whose own marrow has been intentionally destroyed with radiation or chemotherapy. If all goes well, the donor cells travel to the spaces within bones that red marrow normally occupies and replenish the blood supply—with healthy cells. About 15% of the time, the patient dies from infection because the immune system rejects the transplant, or because the transplanted tissue attacks the recipient, which is a condition called graft-versus-host disease.

BMT is used to treat more than sixty types of illnesses, mostly blood disorders such as sickle cell disease and leukemias. In cancer treatment, BMTs enable a patient to withstand high doses of radiation or chemotherapy, which usually destroys bone marrow along with cancer cells. BMT is used when other cancer treatments have failed. In the future, bone marrow may become a major part of "regenerative medicine," because it contains a variety of stem cells that can replenish many types of tissues.

7.5 Skeletal Organization

For purposes of study, it is convenient to divide the skeleton into two major portions—an axial skeleton and an appendicular skeleton (fig. 7.8). The **axial skeleton** consists of the bony and cartilaginous parts that support and protect the organs of the head, neck, and trunk. These parts include:

1. **Skull** The skull is composed of the **cranium** (kra´ne-um), or brain case, and the *facial bones*.
2. **Hyoid bone** The hyoid (hi´oid) bone is located in the neck between the lower jaw and the larynx. It supports the tongue and is an attachment for certain muscles that help move the tongue during swallowing.
3. **Vertebral column** The vertebral column (backbone) consists of many vertebrae separated by cartilaginous *intervertebral discs*. Near its distal

Topic of Interest OSTEOPOROSIS

In *osteoporosis,* the skeletal system loses bone volume and mineral content. The affected bones develop spaces and canals that enlarge and fill with fibrous and fatty tissues. Such bones easily fracture and may spontaneously break because they are no longer able to support body weight. For example, a person with osteoporosis may suffer a spontaneous fracture of the thighbone (femur) at the hip or a collapse of sections of the backbone (vertebrae).

Osteoporosis is associated with aging and causes many fractures in persons over age forty-five. It is most common in light-complexioned females after menopause.

Factors that increase the risk of osteoporosis include low intake of dietary calcium, lack of physical exercise (particularly during the early growing years), and in females, decrease in blood estrogen concentration. (Estrogen is a hormone the ovaries produce until menopause.) Drinking alcohol, smoking cigarettes, and inheriting certain genes may also increase a person's risk of developing osteoporosis.

Bone mass usually peaks at about age thirty-five. Thereafter, bone loss may exceed bone formation in both males and females. To reduce such loss, people in their mid-twenties and older should take in 1,000–1,500 milligrams of calcium daily. In addition, people should regularly engage in exercise, such as walking or jogging, that requires the bones to support the body weight. Postmenopausal women may also require estrogen replacement therapy to prevent osteoporosis, or drugs to slow the disease process.

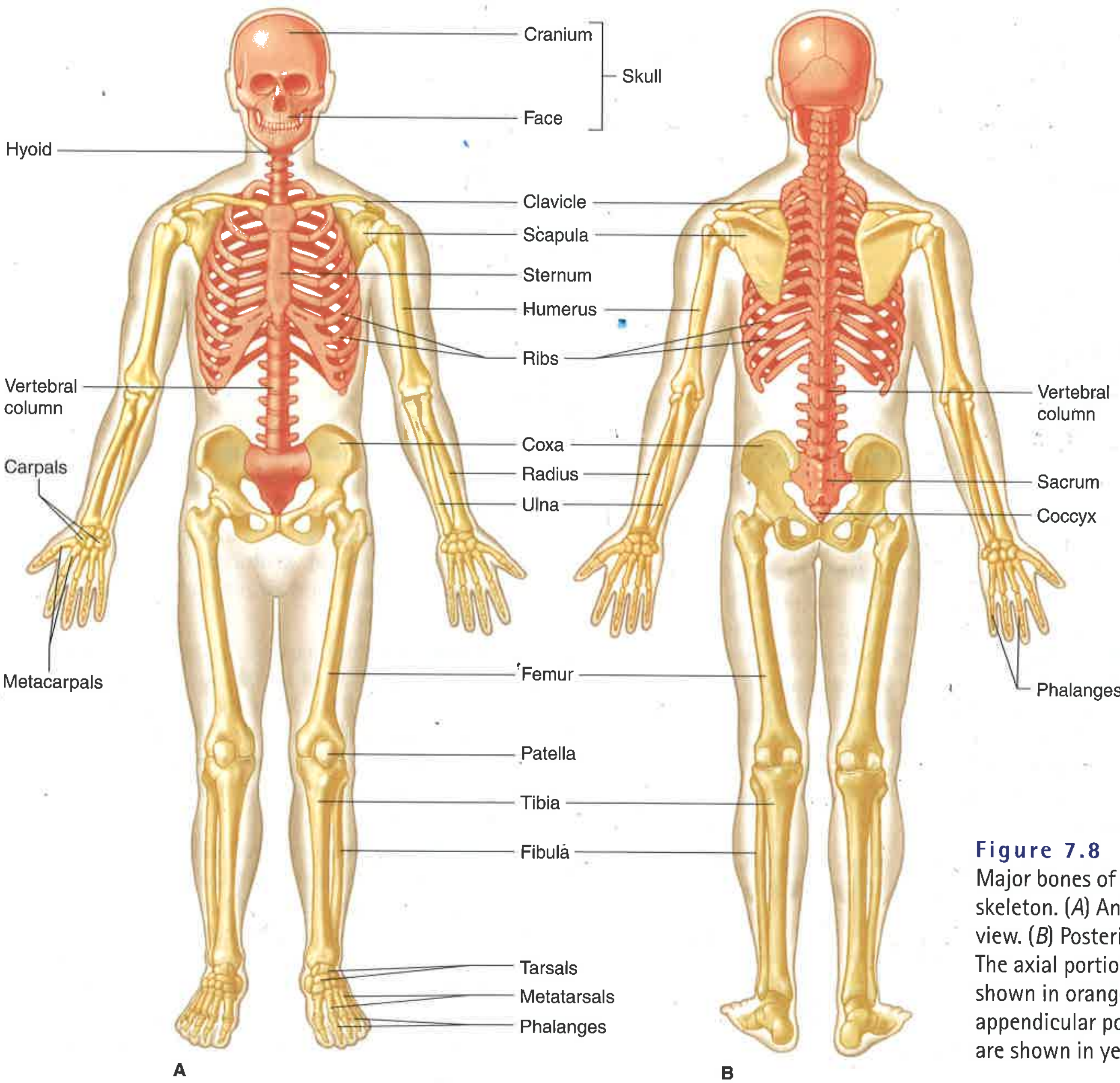


Figure 7.8
Major bones of the skeleton. (*A*) Anterior view. (*B*) Posterior view. The axial portions are shown in orange, and the appendicular portions are shown in yellow.

end, several vertebrae fuse to form the **sacrum** (sa´krum), which is part of the pelvis. A small, rudimentary tailbone called the **coccyx** (kok´siks) is attached to the end of the sacrum.

4. **Thoracic cage** The thoracic cage protects the organs of the thoracic cavity and the upper abdominal cavity. It is composed of twelve pairs of **ribs,** which articulate posteriorly with thoracic vertebrae. The thoracic cage also includes the **sternum** (ster´num), to which most of the ribs attach anteriorly.

The **appendicular skeleton** consists of the bones of the upper and lower limbs and the bones that anchor the limbs to the axial skeleton. It includes:

1. **Pectoral girdle** A **scapula** (scap´u-lah) and a **clavicle** (klav´ĭ-k'l) bone form the pectoral girdle on both sides of the body. The pectoral girdle connects the bones of the upper limbs to the axial skeleton and aids in upper limb movements.
2. **Upper limbs** Each upper limb consists of a **humerus** (hu´mer-us), or arm bone, two forearm bones—a **radius** (ra´de-us) and an **ulna** (ul´nah)—and a wrist and hand. The humerus, radius, and ulna articulate with each other at the elbow joint. At the distal end of the radius and ulna is the wrist. There are eight **carpals** (kar´pals), or wrist bones. The five bones of the palm are called **metacarpals** (met´´ah-kar´pals), and the fourteen finger bones are called **phalanges** (fah-lan´jēz).
3. **Pelvic girdle** Two coxae (kok´se), or hipbones, form the pelvic girdle and are attached to each other anteriorly and to the sacrum posteriorly. They connect the bones of the lower limbs to the axial skeleton and, with the sacrum and coccyx, form the **pelvis.**
4. **Lower limbs** Each lower limb consists of a **femur** (fe´mur), or thighbone, two leg bones—a large **tibia** (tib´e-ah) and a slender **fibula** (fib´u-lah)—an ankle and a foot. The femur and tibia articulate with each other at the knee joint, where the **patella** (pah-tel´ah) covers the anterior surface. At the distal ends of the tibia and fibula is the ankle. There are seven **tarsals** (tahr´sals), or anklebones. The five bones of the instep are called **metatarsals** (met´´ah-tahr´sals), and the fourteen bones of the toes (like the fingers) are called **phalanges.**

Table 7.1 lists the bones of the adult skeleton, and table 7.2 lists terms that describe skeletal structures.

The skeleton of an average 160-pound body weighs about 29 pounds.

CHECK YOUR RECALL

1. Distinguish between the axial and appendicular skeletons.
2. List the bones of the axial skeleton and the appendicular skeleton.

7.6 Skull

A human skull usually consists of twenty-two bones that, except for the lower jaw, are firmly interlocked along lines called *sutures* (soo´cherz) (fig. 7.9). Eight of these interlocked bones make up the cranium, and thirteen form the facial skeleton. The **mandible** (man´dĭ-b'l), or lower jawbone, is a movable bone held to the cranium by ligaments. (Three other bones found in each middle ear are discussed in chapter 10, p. 261.) Reference plates 8–11 on pages 167–169 are a set of photographs of the human skull and its parts.

Cranium

The **cranium** encloses and protects the brain, and its surface provides attachments for muscles that make chewing and head movements possible. Some of the cranial bones contain air-filled cavities called *sinuses,* which are lined with mucous membranes and connected by passageways to the nasal cavity (fig. 7.10). Sinuses reduce the skull's weight and increase the intensity of the voice by serving as resonant sound chambers.

The eight bones of the cranium are (figs. 7.9 and 7.11):

1. **Frontal bone** The frontal (frun´tal) bone forms the anterior portion of the skull above the eyes. On the upper margin of each orbit (the bony socket of the eye), the frontal bone is marked by a *supraorbital foramen* (or *supraorbital notch* in some skulls), through which blood vessels and nerves pass to the tissues of the forehead. Within the frontal bone are two *frontal sinuses,* one above each eye near the midline (fig. 7.10).
2. **Parietal bones** One parietal (pah-ri´ĕ-tal) bone is located on each side of the skull just behind the frontal bone (fig. 7.11). Together, the parietal bones form the bulging sides and roof of the cranium. They are fused at the midline along the *sagittal suture,* and they meet the frontal bone along the *coronal suture.*
3. **Occipital bone** The occipital (ok-sip´ĭ-tal) bone joins the parietal bones along the *lambdoidal* (lam´doid-al) *suture* (figs. 7.11 and 7.12). It forms the back of the skull and the base of the cranium. Through a large opening on its lower surface called the *foramen magnum* pass nerve fibers from the brain, which enter the vertebral canal to become part of the spinal cord. Rounded processes called

TABLE 7.1 BONES OF THE ADULT SKELETON

1. Axial Skeleton
   a. Skull
      8 cranial bones
      - frontal 1
      - parietal 2
      - occipital 1
      - temporal 2
      - sphenoid 1
      - ethmoid 1

      14 facial bones
      - maxilla 2
      - zygomatic 2
      - palatine 2
      - inferior nasal concha 2
      - mandible 1
      - lacrimal 2
      - nasal 2
      - vomer 1

      22 bones

   b. Middle ear bones
      - malleus 2
      - incus 2
      - stapes 2

      6 bones

   c. Hyoid
      - hyoid bone 1

      1 bone

   d. Vertebral column
      - cervical vertebrae 7
      - thoracic vertebrae 12
      - lumbar vertebrae 5
      - sacrum 1
      - coccyx 1

      26 bones

   e. Thoracic cage
      - rib 24
      - sternum 1

      25 bones

2. Appendicular Skeleton
   a. Pectoral girdle
      - scapula 2
      - clavicle 2

      4 bones

   b. Upper limbs
      - humerus 2
      - radius 2
      - ulna 2
      - carpal 16
      - metacarpal 10
      - phalanx 28

      60 bones

   c. Pelvic girdle
      - coxal bone 2

      2 bones

   d. Lower limbs
      - femur 2
      - tibia 2
      - fibula 2
      - patella 2
      - tarsal 14
      - metatarsal 10
      - phalanx 28

      60 bones

Total 206 bones

TABLE 7.2 TERMS USED TO DESCRIBE SKELETAL STRUCTURES

TERM	DEFINITION	EXAMPLES
Condyle (kon'dīl)	A rounded process that usually articulates with another bone	Occipital condyle of occipital bone (fig. 7.12)
Crest (krest)	A narrow, ridgelike projection	Iliac crest of ilium (fig. 7.27)
Epicondyle (ep''ĭ-kon'dīl)	A projection situated above a condyle	Medial epicondyle of humerus (fig. 7.23)
Facet (fas'et)	A small, nearly flat surface	Rib facet of thoracic vertebra (fig. 7.16)
Fontanel (fon''tah-nel')	A soft spot in the skull where membranes cover the space between bones	Anterior fontanel between frontal and parietal bones (fig. 7.15)
Foramen (fo-ra'men)	An opening through a bone that usually is a passageway for blood vessels, nerves, or ligaments	Foramen magnum of occipital bone (fig. 7.12)
Fossa (fos'ah)	A relatively deep pit or depression	Olecranon fossa of humerus (fig. 7.23)
Fovea (fo've-ah)	A tiny pit or depression	Fovea capitis of femur (fig. 7.29)
Head (hed)	An enlargement on the end of a bone	Head of humerus (fig. 7.23)
Meatus (me-a'tus)	A tubelike passageway within a bone	External auditory meatus of ear (fig. 7.11)
Process (pros'es)	A prominent projection on a bone	Mastoid process of temporal bone (fig. 7.11)
Sinus (si'nus)	A cavity within a bone	Frontal sinus of frontal bone (fig. 7.14)
Spine (spīn)	A thornlike projection	Spine of scapula (fig. 7.22)
Suture (soo'cher)	An interlocking line of union between bones	Lambdoidal suture between occipital and parietal bones (fig. 7.11)
Trochanter (tro-kan'ter)	A relatively large process	Greater trochanter of femur (fig. 7.29)
Tubercle (tu'ber-kl)	A small, knoblike process	Greater tubercle of humerus (fig. 7.23)
Tuberosity (tu''bĕ-ros'ĭ-te)	A knoblike process usually larger than a tubercle	Radial tuberosity of radius (fig. 7.24)

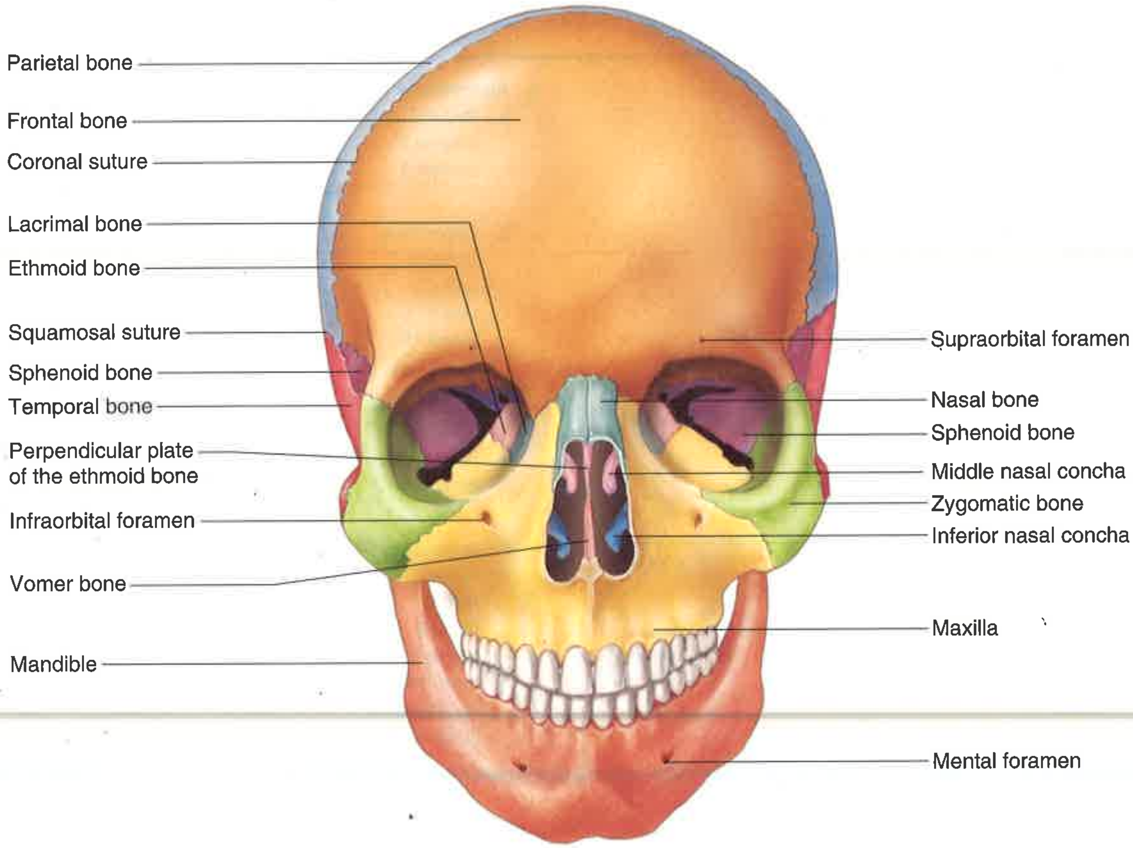


Figure 7.9
Anterior view of the skull.

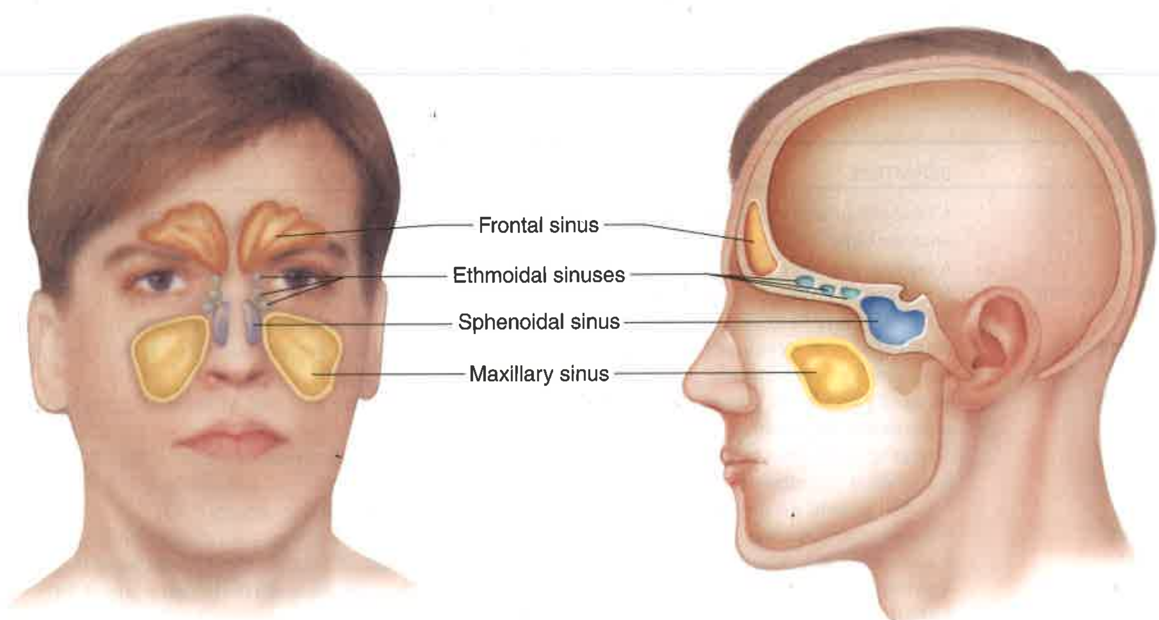


Figure 7.10
Locations of the sinuses.

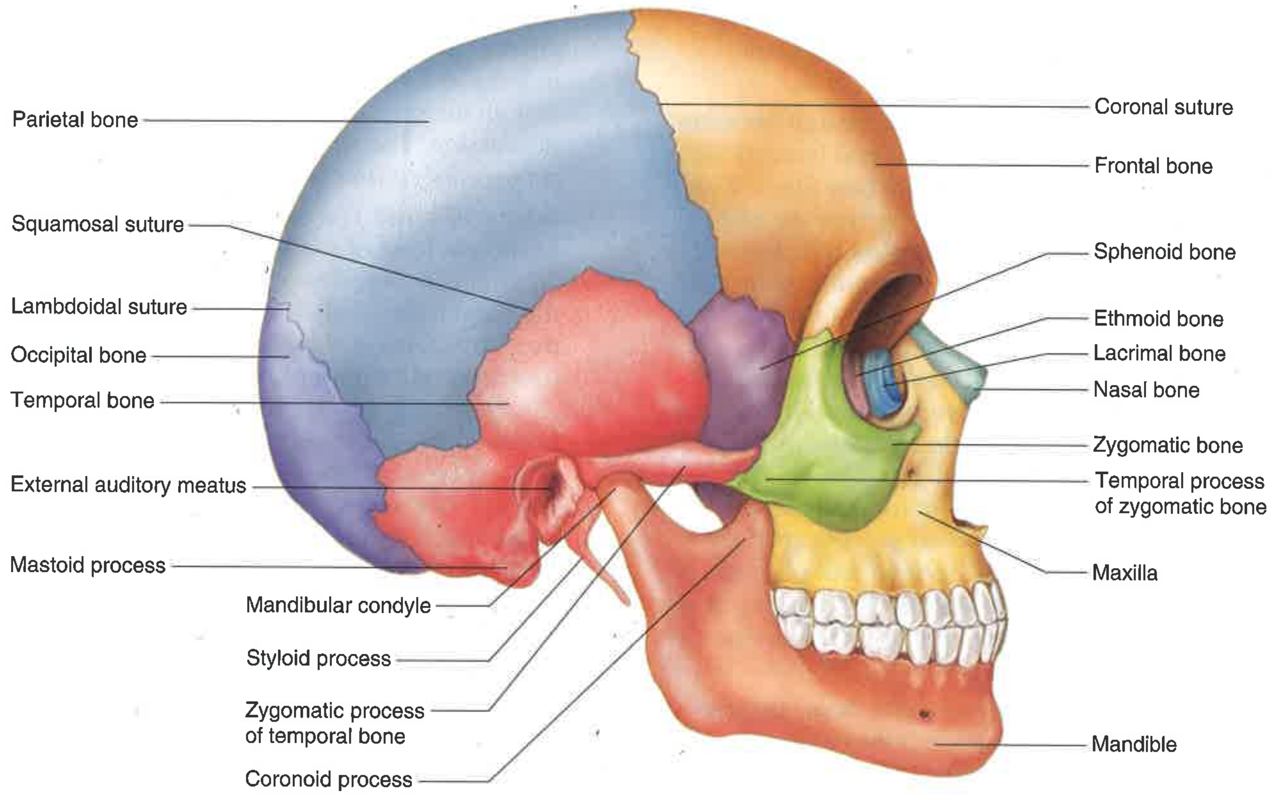


Figure 7.11
Lateral view of the skull.

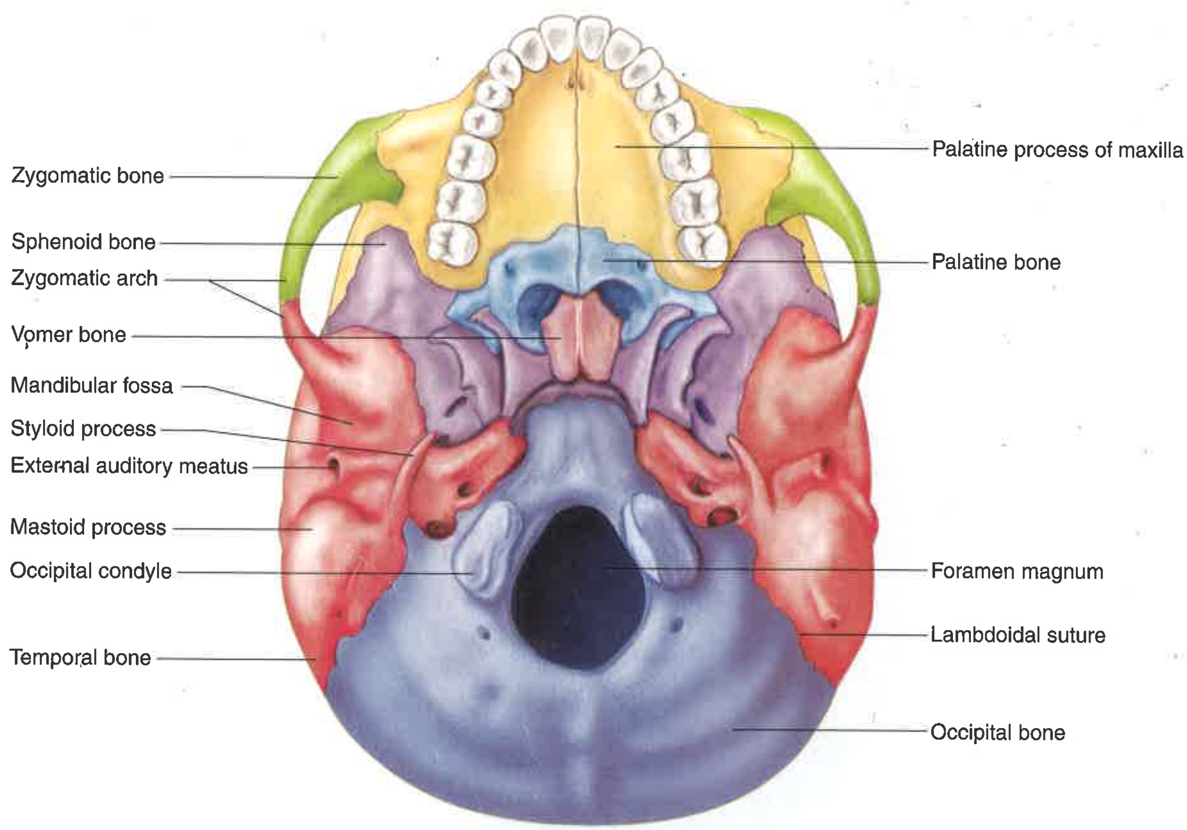


Figure 7.12
Inferior view of the skull.

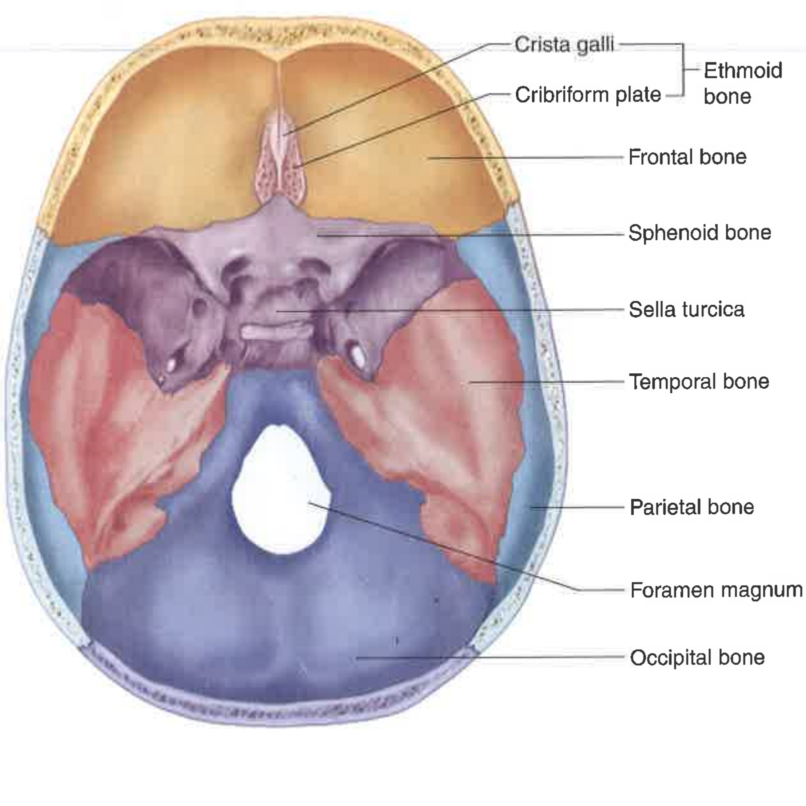
occipital condyles, located on each side of the foramen magnum, articulate with the first vertebra (atlas) of the vertebral column.

4. **Temporal bones** A temporal (tem´po-ral) bone on each side of the skull joins the parietal bone along a *squamosal* (skwa-mo´sal) *suture* (see figs. 7.9 and 7.11). The temporal bones form parts of the sides and the base of the cranium. Located near the inferior margin is an opening, the *external auditory meatus,* which leads inward to parts of the ear. The temporal bones have depressions called the *mandibular fossae* that articulate with condyles of the mandible. Below each external auditory meatus are two projections—a rounded *mastoid process* and a long, pointed *styloid process.* The mastoid process provides an attachment for certain muscles of the neck, whereas the styloid process anchors muscles associated with the tongue and pharynx. A *zygomatic process* projects anteriorly from the temporal bone, joins the *zygomatic bone,* and helps form the prominence of the cheek.
5. **Sphenoid bone** The sphenoid (sfe´noid) bone is wedged between several other bones in the anterior portion of the cranium (figs. 7.11 and 7.12). It consists of a central part and two winglike structures that extend laterally toward each side of the skull. This bone helps form the base of the cranium, the sides of the skull, and the floors and sides of the orbits. Along the midline within the cranial cavity, a portion of the sphenoid bone indents to form the saddle-shaped *sella turcica* (sel´ah tur´si-ka). The pituitary gland occupies this depression. The sphenoid bone also contains two *sphenoidal sinuses* (see fig. 7.10).
6. **Ethmoid bone** The ethmoid (eth´moid) bone is located in front of the sphenoid bone (figs. 7.11 and 7.13). It consists of two masses, one on each side of the nasal cavity, which are joined horizontally by thin *cribriform* (krib´rĭ-form) *plates.* These plates form part of the roof of the nasal cavity (fig. 7.13).

   Projecting upward into the cranial cavity between the cribriform plates is a triangular process of the ethmoid bone called the *crista galli* (kris´tă gal´li) (cock's comb). Membranes that enclose the brain attach to this process (figs. 7.13 and 7.14). Portions of the ethmoid bone also form sections of the cranial floor, the orbital walls, and the nasal cavity walls. A *perpendicular plate* projects downward in the midline from the cribriform plates and forms most of the nasal septum (fig. 7.14).

   Delicate scroll-shaped plates called the *superior nasal concha* (kong´kah) and the *middle nasal concha* project inward from the lateral portions of the ethmoid bone toward the perpendicular plate (see fig. 7.9). The lateral portions of the ethmoid bone contain many small air spaces, the *ethmoidal sinuses* (see fig. 7.10).

Figure 7.13
Floor of the cranial cavity, viewed from above.



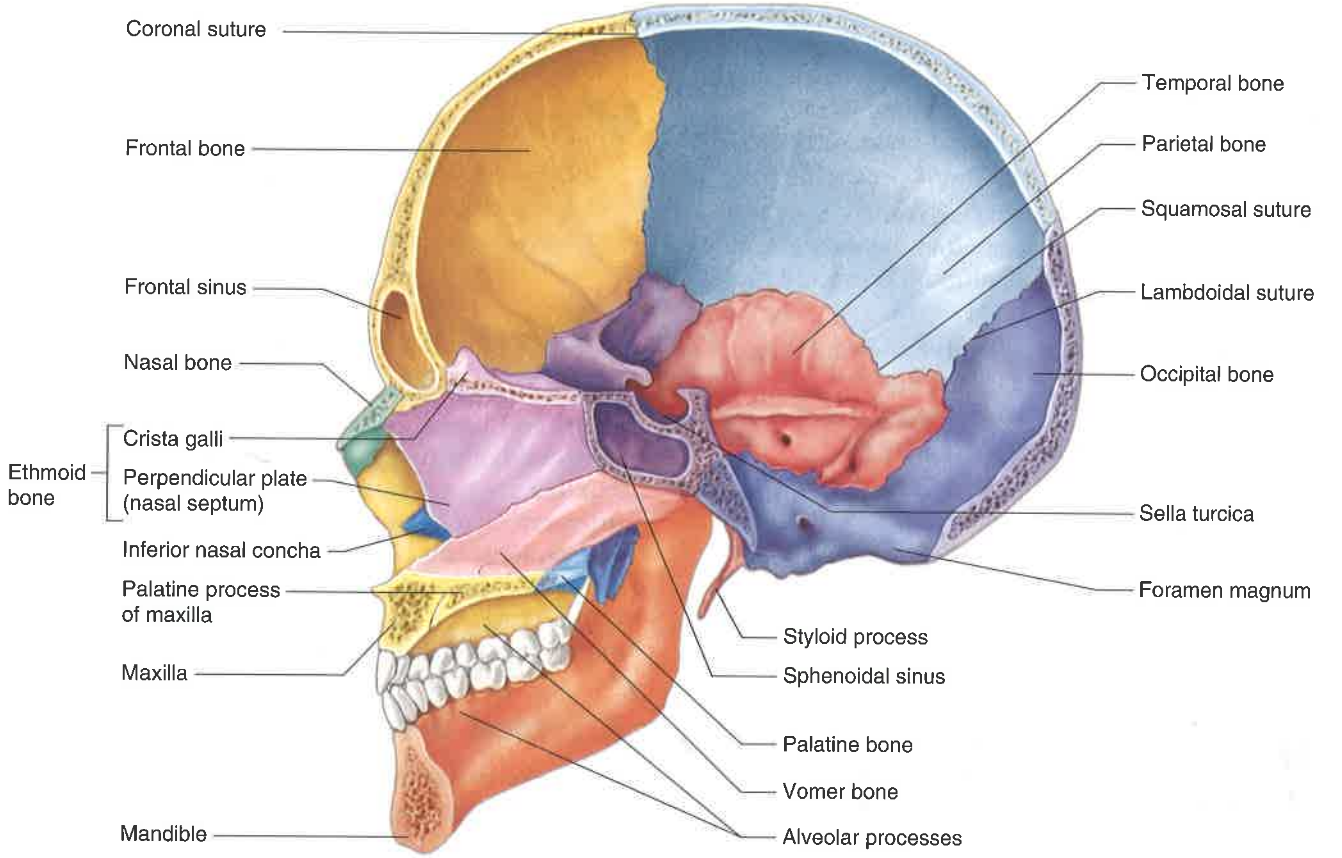


Figure 7.14
Sagittal section of the skull.

Facial Skeleton

The **facial skeleton** consists of thirteen immovable bones and a movable lower jawbone. These bones form the basic shape of the face and provide attachments for muscles that move the jaw and control facial expressions.

The bones of the facial skeleton are:

1. **Maxillae** The maxillae (mak-sil´e; singular, *maxilla,* mak-sil´ah) form the upper jaw (see figs. 7.11 and 7.12). Portions of these bones comprise the anterior roof of the mouth (*hard palate*), the floors of the orbits, and the sides and floor of the nasal cavity. They also contain the sockets of the upper teeth. Inside the maxillae, lateral to the nasal cavity, are *maxillary sinuses,* the largest of the sinuses (see fig. 7.10).

   During development, portions of the maxillae called *palatine processes* grow together and fuse along the midline to form the anterior section of the hard palate. The inferior border of each maxillary bone projects downward, forming an *alveolar* (al-ve´o-lar) *process.* Together, these processes form a horseshoe-shaped *alveolar arch* (dental arch) (fig. 7.14). Teeth occupy cavities in this arch (dental alveoli). Dense connective tissue binds teeth to the bony sockets.

Sometimes, fusion of the palatine processes of the maxillae is incomplete at birth; the result is a *cleft palate.* Infants with a cleft palate may have trouble suckling because of the opening between the oral and nasal cavities. A temporary prosthetic device (artificial palate) may be inserted within the mouth, or a special type of nipple can be placed on bottles until surgery can be performed to correct the condition.

2. **Palatine bones** The L-shaped palatine (pal´ah-tīn) bones are located behind the maxillae (see figs. 7.12 and 7.14). The horizontal portions form the posterior section of the hard palate and the floor of the nasal cavity. The perpendicular portions help form the lateral walls of the nasal cavity.
3. **Zygomatic bones** The zygomatic (zi´´go-mat´ik) bones form the prominences of the cheeks below

and to the sides of the eyes (see figs. 7.11 and 7.12). These bones also help form the lateral walls and the floors of the orbits. Each bone has a *temporal process,* which extends posteriorly to join the zygomatic process of a temporal bone. Together, these processes form a *zygomatic arch*.

4. **Lacrimal bones** A lacrimal (lak´rĭ-mal) bone is a thin, scalelike structure located in the medial wall of each orbit between the ethmoid bone and the maxilla (see figs. 7.9 and 7.11).
5. **Nasal bones** The nasal (na´zal) bones are long, thin, and nearly rectangular (see figs. 7.9 and 7.11). They lie side by side and are fused at the midline, where they form the bridge of the nose.
6. **Vomer bone** The thin, flat vomer (vo´mer) bone is located along the midline within the nasal cavity (see figs. 7.9 and 7.14). Posteriorly, it joins the perpendicular plate of the ethmoid bone, and together they form the nasal septum.
7. **Inferior nasal conchae** The inferior nasal conchae (kong´ke) are fragile, scroll-shaped bones attached to the lateral walls of the nasal cavity (see figs. 7.9 and 7.14). Like the ethmoidal conchae, the inferior conchae support mucous membranes within the nasal cavity.
8. **Mandible** The mandible is a horizontal, horseshoe-shaped body with a flat portion projecting upward at each end (see figs. 7.9 and 7.11). This projection is divided into two processes—a posterior *mandibular condyle* and an anterior *coronoid process*. The mandibular condyles articulate with the mandibular fossae of the temporal bones (see fig. 7.12), whereas the coronoid processes provide attachments for muscles used in chewing. Other large chewing muscles insert on the lateral surface of the mandible. A curved bar of bone on the superior border of the mandible, the *alveolar arch,* contains the hollow sockets (dental alveoli) that bear the lower teeth (fig. 7.14).

Infantile Skull

At birth, the skull is incompletely developed, with fibrous membranes connecting the cranial bones. These membranous areas are called **fontanels** (fon´´tah-nels) or, more commonly, soft spots (fig. 7.15). They permit some movement between the bones, so that the developing skull is partially compressible and can slightly change shape. This enables an infant's skull to more easily pass through the birth canal. Eventually, the fontanels close as the cranial bones grow together.

Other characteristics of an infantile skull include a relatively small face with a prominent forehead and large orbits. The jaw and nasal cavity are small, the sinuses are incompletely formed, and the frontal bone is in two parts. The skull bones are thin, but they are also somewhat flexible and thus are less easily fractured than adult bones.

CHECK YOUR RECALL

1. Locate and name each of the bones of the cranium.
2. Locate and name each of the facial bones.
3. Explain how an adult skull differs from that of an infant.

7.7 Vertebral Column

The **vertebral column** extends from the skull to the pelvis and forms the vertical axis of the skeleton. It is composed of many bony parts called **vertebrae** (ver´tĕ-brā) that are separated by masses of fibrocartilage called *intervertebral discs* and are connected to one another by ligaments (fig. 7.16). The vertebral column supports the head and trunk of the body. It also protects the spinal cord, which passes through a *vertebral canal* formed by openings in the vertebrae.

A Typical Vertebra

Vertebrae in different regions of the vertebral column have special characteristics, but they also have features in common. A typical vertebra has a drum-shaped *body,* which forms the thick, anterior portion of the bone (fig. 7.17). A longitudinal row of these vertebral bodies supports the weight of the head and trunk. The intervertebral discs, which separate adjacent vertebral bodies, cushion and soften the forces from movements such as walking and jumping.

Projecting posteriorly from each vertebral body are two short stalks called *pedicles* (ped´ĭ-k'lz). Two plates called *laminae* (lam'i-ne) arise from the pedicles and fuse in the back to become a *spinous process*. The pedicles, laminae, and spinous process together complete a bony *vertebral arch* around the *vertebral foramen,* through which the spinal cord passes.

If the laminae of the vertebrae fail to unite during development, the vertebral arch remains incomplete, resulting in a condition called *spina bifida*. The contents of the vertebral canal protrude outward. This problem occurs most frequently in the lumbosacral region.

Between the pedicles and laminae of a typical vertebra is a *transverse process,* which projects laterally and posteriorly. Ligaments and muscles are attached to the dorsal spinous process and the transverse processes. Projecting upward and downward from each vertebral arch are *superior* and *inferior articulating processes*. These processes bear cartilage-covered facets that join each vertebra to the ones above and below it.

On the lower surfaces of the vertebral pedicles are notches that align to form openings called *interverte-*

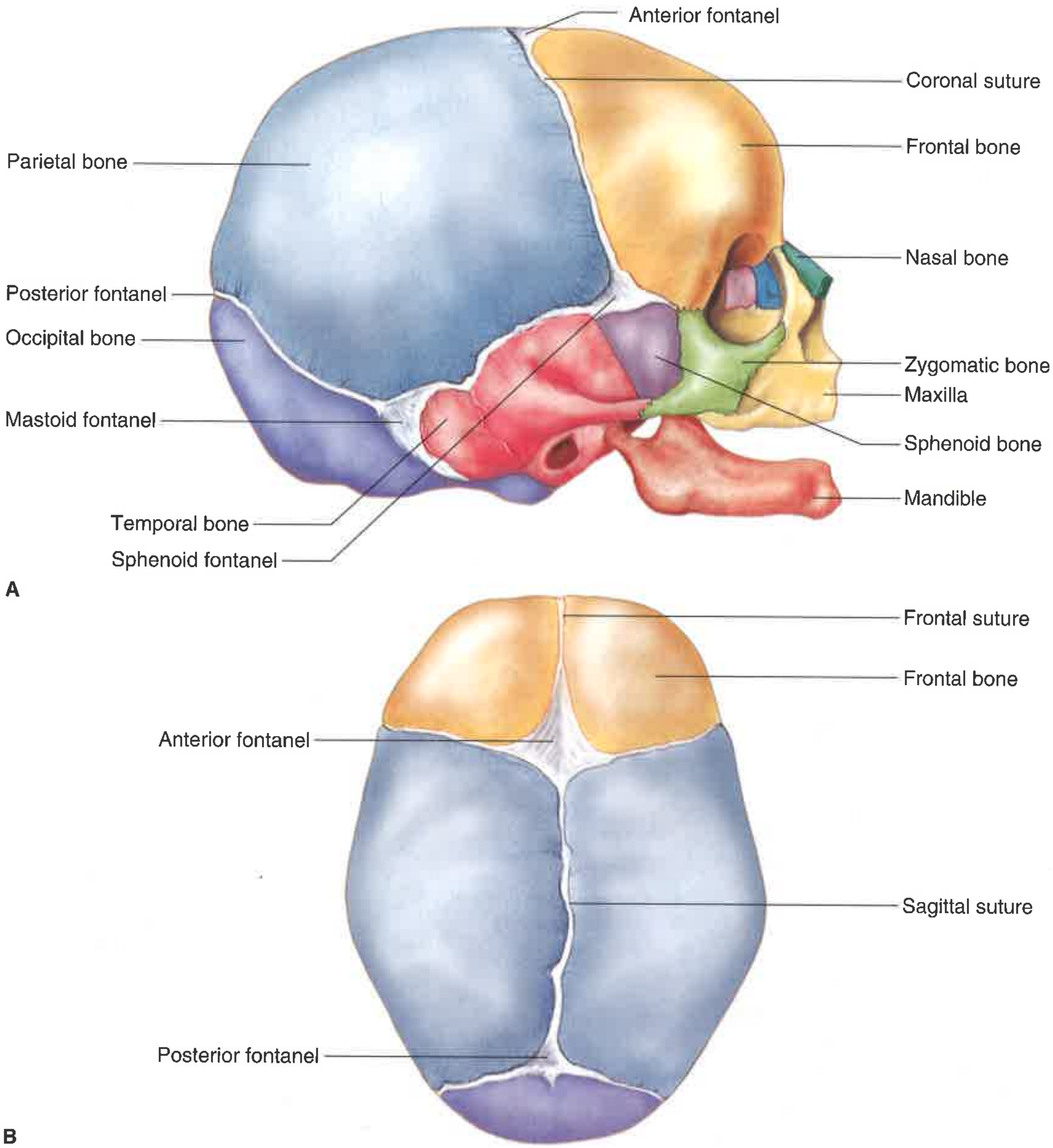


Figure 7.15
Fontanels. (*A*) Lateral view and (*B*) superior view of the infantile skull.

bral foramina (in´´ter-ver´tĕ-bral fo-ram´ĭ-nah). These openings provide passageways for spinal nerves that proceed between vertebrae and connect to the spinal cord (see fig. 7.16).

Cervical Vertebrae

Seven **cervical vertebrae** comprise the bony axis of the neck (see fig. 7.16). The transverse processes of these vertebrae are distinctive because they have *transverse foramina,* which are passageways for arteries leading to the brain (see fig. 7.17). Also, the spinous processes of the second through the fifth cervical vertebrae are uniquely forked (bifid). These processes provide attachments for muscles.

Two cervical vertebrae are of special interest (fig. 7.18). The first vertebra, or **atlas** (at´las), supports the head. On its superior surface are two kidney-shaped *facets* that articulate with the occipital condyles.

The second cervical vertebra, or **axis** (ak´sis), bears a toothlike *dens* (odontoid process) on its body. This process projects upward and lies in the ring of the atlas. As the head is turned from side to side, the atlas pivots around the dens.

Giraffes and humans have the same number of vertebrae in their necks . . . 7.

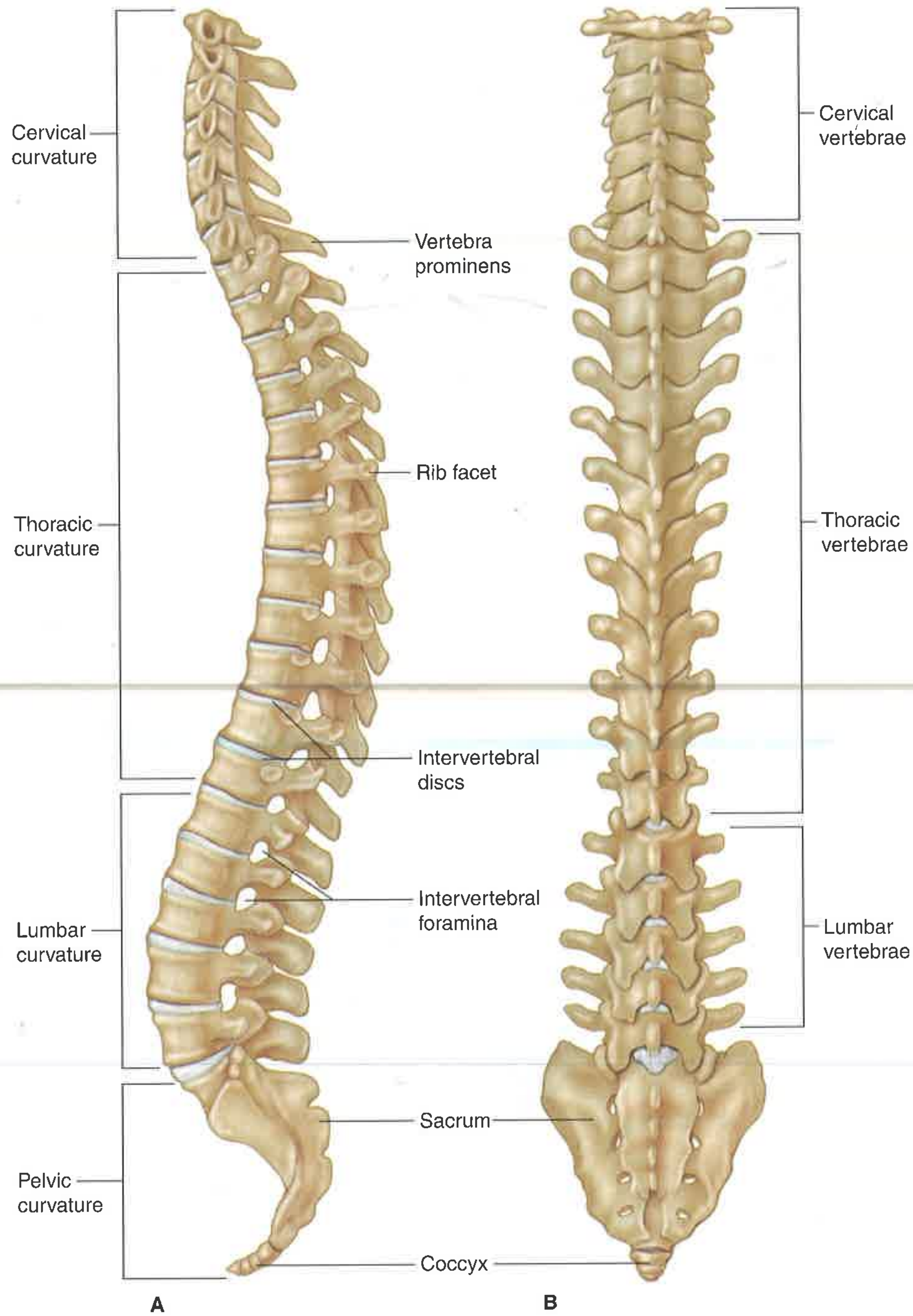


Figure 7.16
The curved vertebral column consists of many vertebrae separated by intervertebral discs. (*A*) Left lateral view. (*B*) Posterior view.

Thoracic Vertebrae

The twelve **thoracic vertebrae** are larger than the cervical vertebrae (see fig. 7.16). Each vertebra has a long, pointed spinous process, which slopes downward, and facets on the sides of its body, which articulate with a rib.

Beginning with the third thoracic vertebra and moving inferiorly, the bodies of these bones increase in size. Thus, they are adapted to bear increasing loads of body weight.

Lumbar Vertebrae

Five **lumbar vertebrae** are in the small of the back (loin) (see fig. 7.16). These vertebrae are adapted with larger and stronger bodies to support more weight than the vertebrae above them.

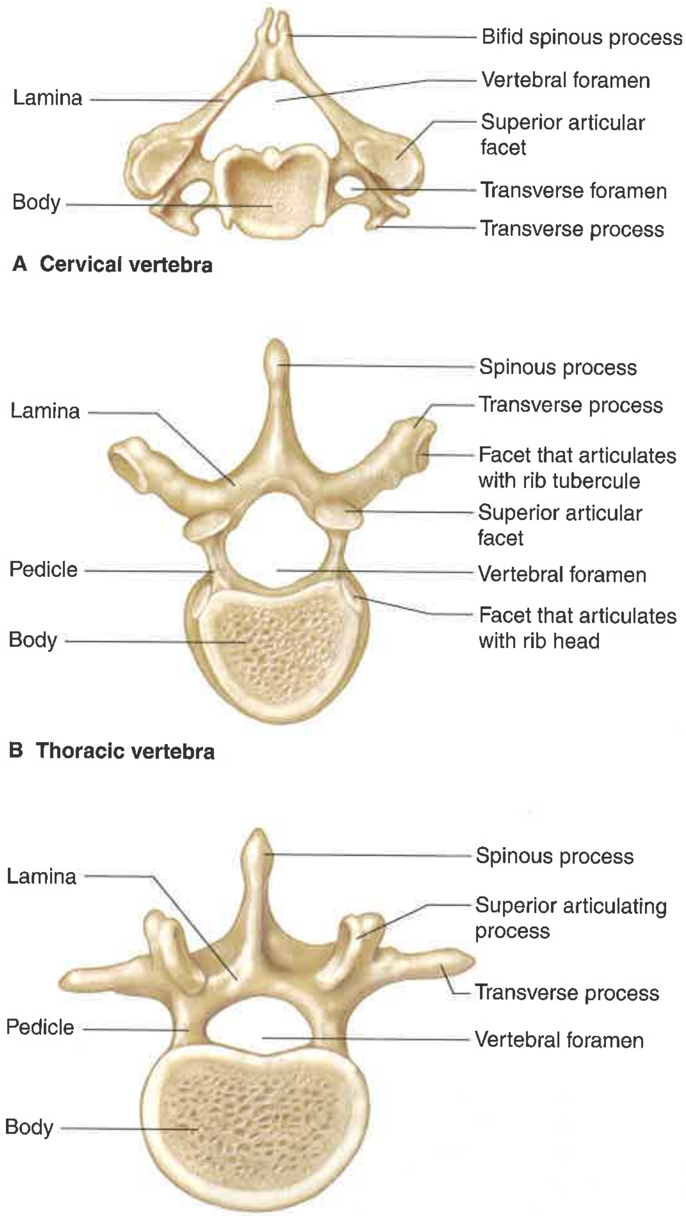


Figure 7.17
Superior view of (*A*) a cervical vertebra, (*B*) a thoracic vertebra, and (*C*) a lumbar vertebra.

Sacrum

The **sacrum** (sa´krum) is a triangular structure, composed of five fused vertebrae, that forms the base of the vertebral column (fig. 7.19). The spinous processes of these fused bones form a ridge of *tubercles.* To the sides of the tubercles are rows of openings, the *dorsal sacral foramina,* through which nerves and blood vessels pass.

The vertebral foramina of the sacral vertebrae form the *sacral canal,* which continues through the sacrum to an opening of variable size at the tip, called the *sacral hiatus* (sa´kral hi-a´tus). On the ventral surface of the sacrum, four pairs of *pelvic sacral foramina* provide passageways for nerves and blood vessels.

Coccyx

The **coccyx** (kok´siks), the lowest part of the vertebral column, is usually composed of four fused vertebrae (fig. 7.19). Ligaments attach it to the margins of the sacral hiatus. Table 7.3 summarizes the various features of the different vertebrae.

Changes in the intervertebral discs can cause back problems. Each disc is composed of a tough outer layer of fibrocartilage and an elastic central mass. With age, these discs degenerate—the central masses lose firmness, and the outer layers thin and weaken, developing cracks. Extra pressure, as when a person falls or lifts a heavy object, can break the outer layer of a disc, squeezing out the central mass. Such a rupture may press on the spinal cord or on a spinal nerve that branches from it. This condition—a ruptured or herniated disc—may cause back pain and numbness or the loss of muscular function in the parts innervated by the affected spinal nerve.

CHECK YOUR RECALL

1. Describe the structure of the vertebral column.
2. Describe a typical vertebra.
3. How do the structures of cervical, thoracic, and lumbar vertebrae differ?

TABLE 7.3 FEATURES OF VERTEBRAE

	FEATURES THAT ARE PRESENT						
TYPE OF VERTEBRAE	BODY	DENS	SPINOUS PROCESS	TRANSVERSE PROCESS	TRANSVERSE FORAMEN	FACETS FOR RIBS	PEDICLES AND LAMINAE
Cervical (7)			Some are bifid				
a. C-1					✓		
b. C-2	✓	✓	✓	✓	✓		✓
c. C-3 through C-7	✓		✓	✓	✓		✓
Thoracic (12)	✓		✓	✓		✓	✓
Lumbar (5)	✓		✓	✓			✓
Sacrum (5 fused)	✓			✓ Fused			
Coccyx (4 fused)							

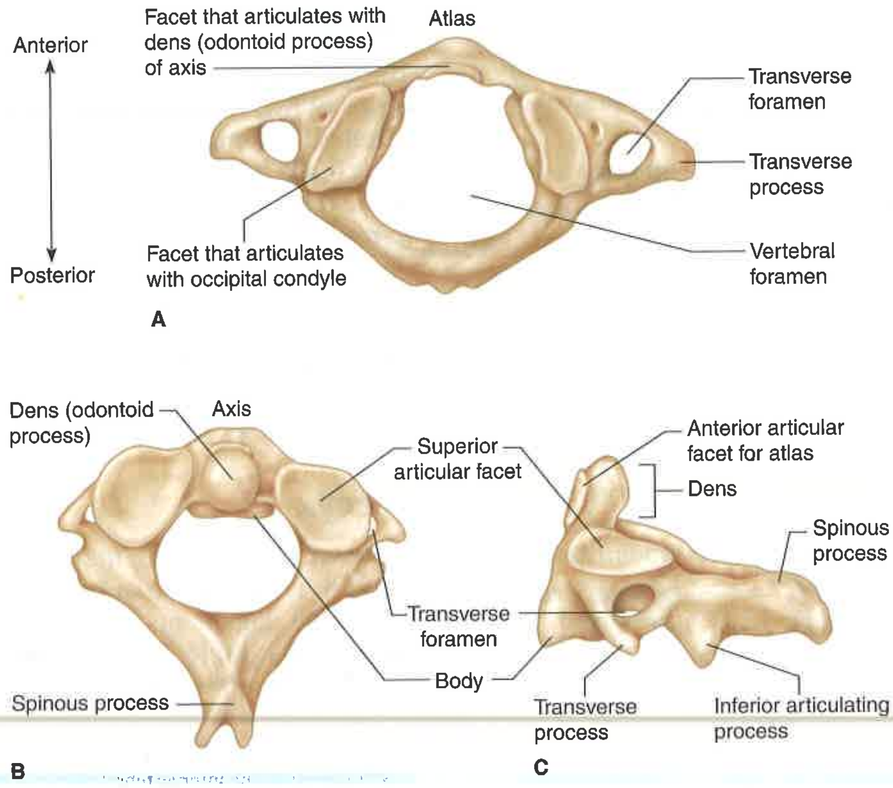


Figure 7.18
Superior view of the (*A*) atlas and (*B*) axis. (*C*) Lateral view of the axis.

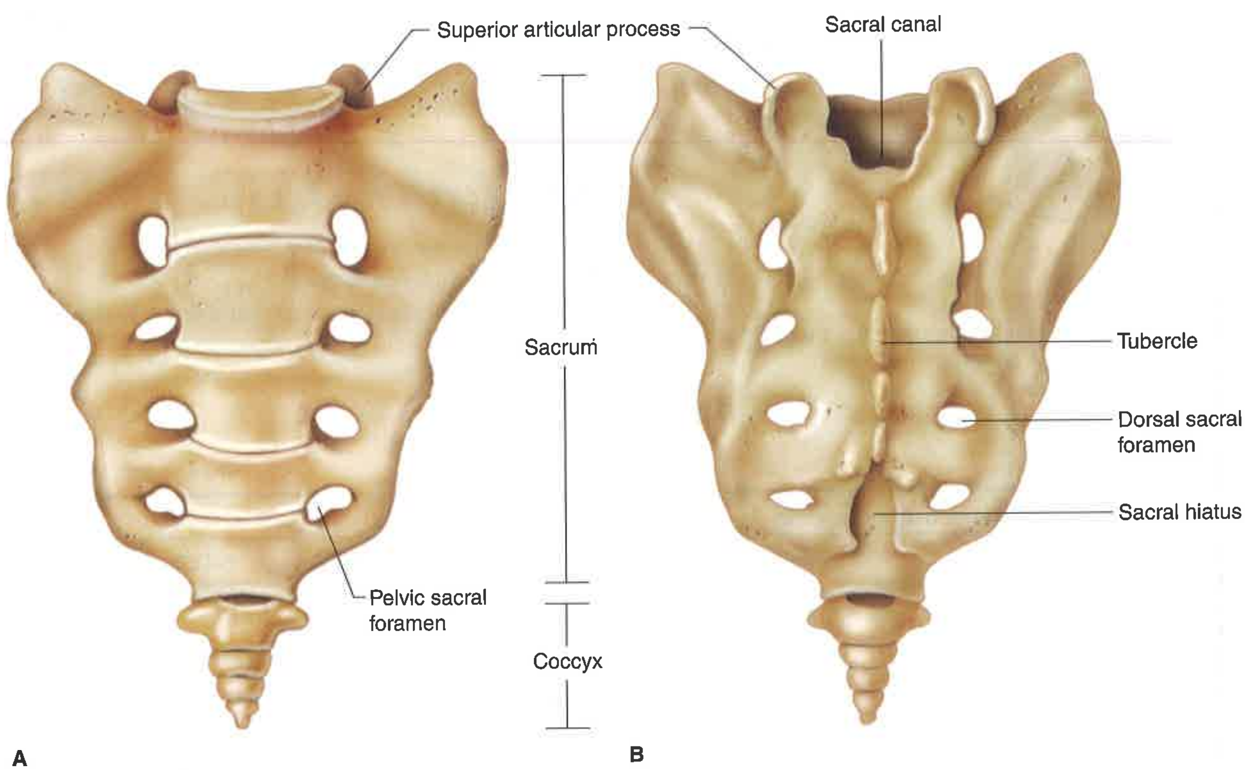


Figure 7.19
Sacrum and coccyx. (*A*) Anterior view and (*B*) posterior view.

7.8 Thoracic Cage

The **thoracic cage** includes the ribs, thoracic vertebrae, sternum, and costal cartilages that attach the ribs to the sternum (fig. 7.20). These bones support the shoulder girdle and upper limbs, protect the viscera in the thoracic and upper abdominal cavities, and play a role in breathing.

Ribs

The usual number of **ribs** is twelve—one pair attached to each of the twelve thoracic vertebrae. The first seven rib pairs, *true ribs* (vertebrosternal ribs), join the sternum directly by their costal cartilages. The remaining five pairs are called *false ribs,* because their cartilages do not reach the sternum directly. Instead, the cartilages of the upper three false ribs (vertebrochondral ribs) join the cartilages of the seventh rib. The last two (or sometimes three) rib pairs are called *floating ribs* (vertebral ribs) because they have no cartilaginous attachments to the sternum.

A typical rib has a long, slender shaft, which curves around the chest and slopes downward. On the posterior end is an enlarged *head* by which the rib articulates with a *facet* on the body of its own vertebra and with the body of the next higher vertebra. A *tubercle,* close to the head of the rib, articulates with the transverse process of the vertebra.

Sternum

The **sternum,** or breastbone, is located along the midline in the anterior portion of the thoracic cage (fig. 7.20). This flat, elongated bone develops in three parts—an upper *manubrium* (mah-nu´bre-um), a middle *body,* and a lower *xiphoid* (zīf´oid) *process* that projects downward. The manubrium articulates with the clavicles by facets on its superior border.

CHECK YOUR RECALL

1. List the components of the thoracic cage.
2. Distinguish between true ribs and false ribs.
3. State the three parts of the sternum.

7.9 Pectoral Girdle

The **pectoral** (pek´to-ral) **girdle,** or shoulder girdle, is composed of four parts—two clavicles and two scapulae (fig. 7.21). Although the word *girdle* suggests a ring-shaped structure, the pectoral girdle is an incomplete ring. It is open in the back between the scapulae, and the sternum separates its bones in front. The pectoral girdle supports the upper limbs and is an attachment for several muscles that move them.

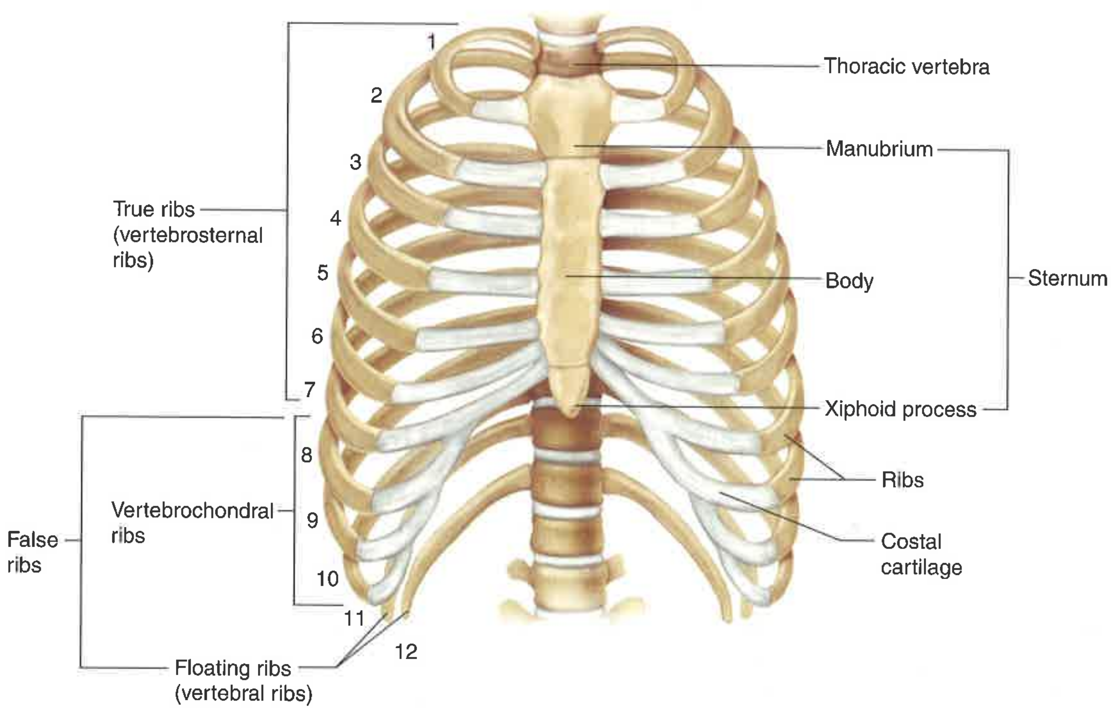


Figure 7.20
The thoracic cage includes the thoracic vertebrae, the sternum, the ribs, and the costal cartilages that attach the ribs to the sternum.

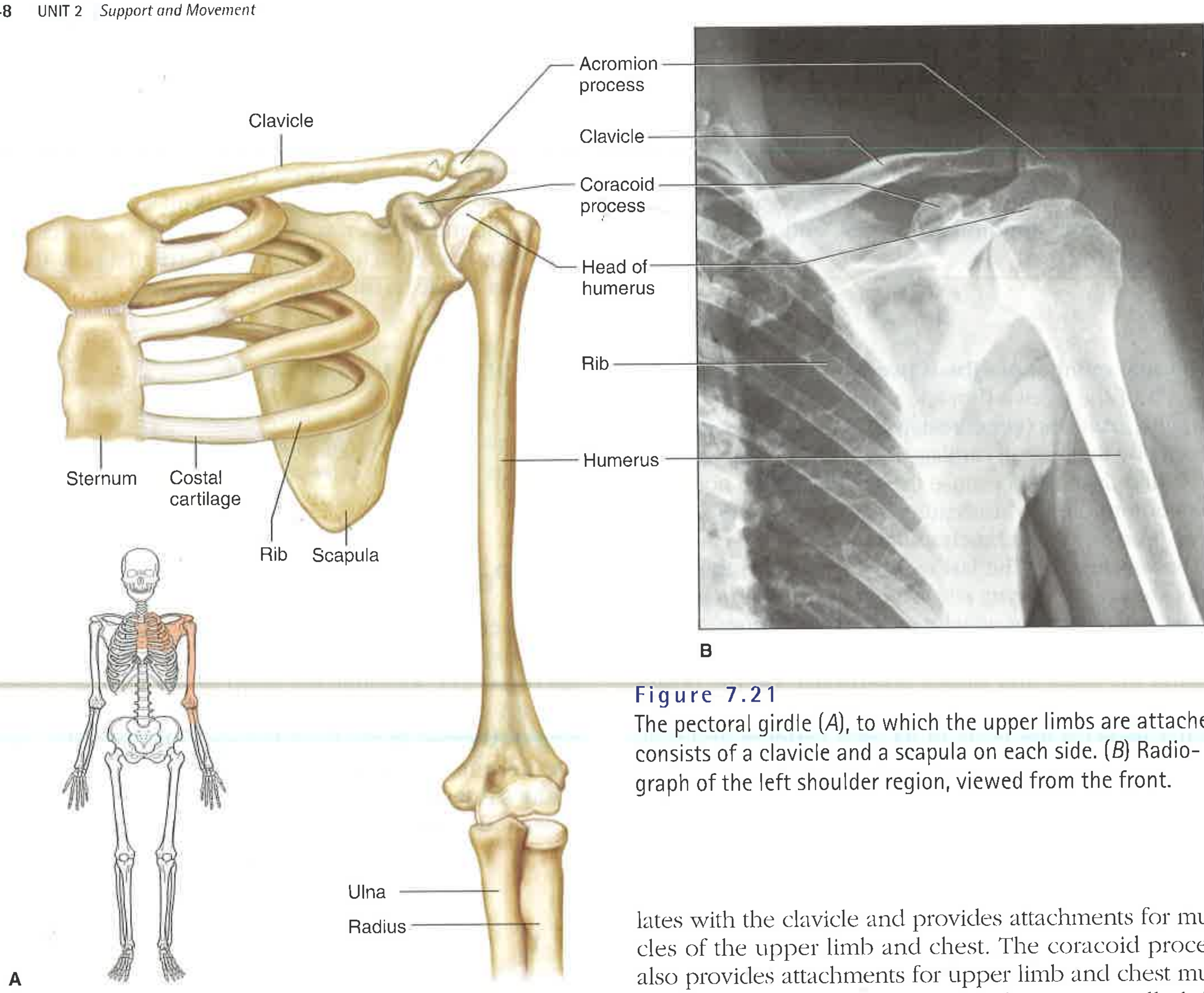


Figure 7.21
The pectoral girdle (*A*), to which the upper limbs are attached, consists of a clavicle and a scapula on each side. (*B*) Radiograph of the left shoulder region, viewed from the front.

Clavicles

The **clavicles,** or collarbones, are slender, rodlike bones with elongated S shapes (fig. 7.21). Located at the base of the neck, they run horizontally between the manubrium and scapulae.

The clavicles brace the freely movable scapulae, helping to hold the shoulders in place. They also provide attachments for muscles of the upper limbs, chest, and back.

Scapulae

The **scapulae** (skap´u-le), or shoulder blades, are broad, somewhat triangular bones located on either side of the upper back (figs. 7.21 and 7.22). A *spine* divides the posterior surface of each scapula into unequal portions. This spine leads to two processes—an *acromion* (ah-kro´me-on) *process* that forms the tip of the shoulder and a *coracoid* (kor´ah-koid) *process* that curves anteriorly and inferiorly to the clavicle. The acromion process articulates with the clavicle and provides attachments for muscles of the upper limb and chest. The coracoid process also provides attachments for upper limb and chest muscles. Between the processes is a depression called the *glenoid cavity* (glenoid fossa of the scapula) that articulates with the head of the arm bone (humerus).

CHECK YOUR RECALL

1. Which bones form the pectoral girdle?
2. What is the function of the pectoral girdle?

7.10 Upper Limb

The bones of the upper limb form the framework of the arm, forearm, wrist, and hand. They also provide attachments for muscles, and they function in levers that move limb parts. These bones include a humerus, a radius, an ulna, carpals, metacarpals, and phalanges (see fig. 7.8).

Humerus

The **humerus** is a heavy bone that extends from the scapula to the elbow (fig. 7.23). At its upper end is a smooth, rounded *head* that fits into the glenoid cavity

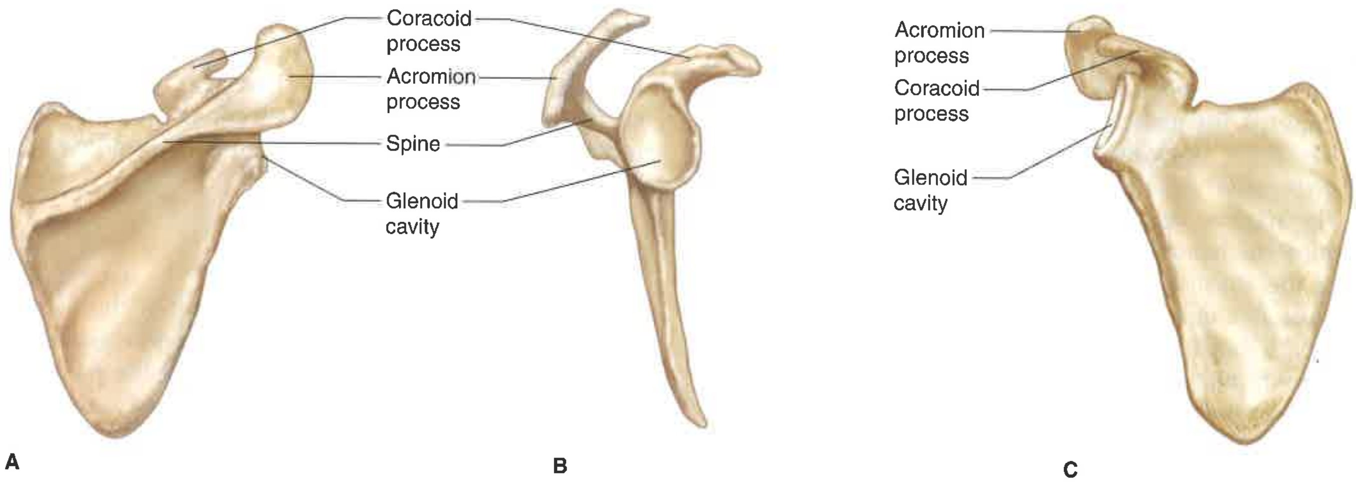


Figure 7.22
Scapula. (*A*) Posterior surface of the right scapula. (*B*) Lateral view showing the glenoid cavity that articulates with the head of the humerus. (*C*) Anterior surface.

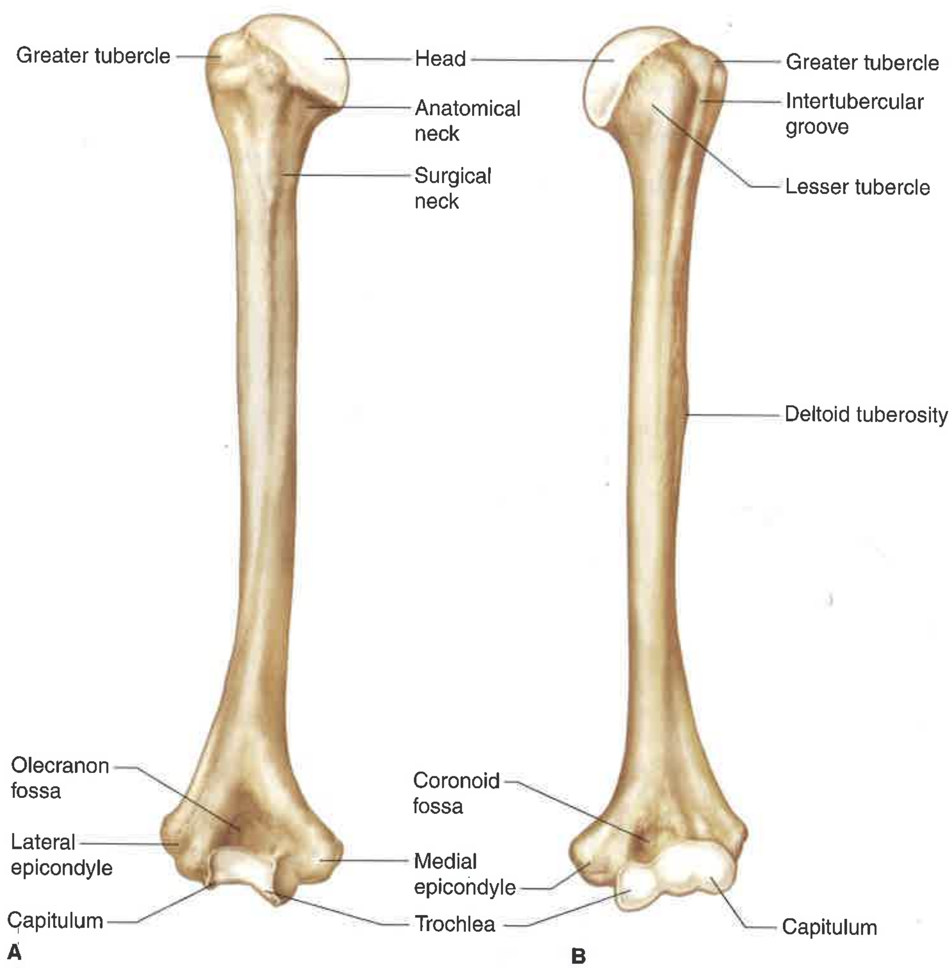


Figure 7.23
Humerus. (*A*) Posterior surface and (*B*) anterior surface of the left humerus.

of the scapula. Just below the head are two processes—a *greater tubercle* on the lateral side and a *lesser tubercle* on the anterior side. These tubercles provide attachments for muscles that move the upper limb at the shoulder. Between them is a narrow furrow, the *intertubercular groove.*

The narrow depression along the lower margin of the humerus head separates it from the tubercles and is called the *anatomical neck.* Just below the head and tubercles is a tapering region called the *surgical neck,* so named because fractures commonly occur there. Near the middle of the bony shaft on the lateral side is a rough V-shaped area called the *deltoid tuberosity.* It provides an attachment for the muscle (deltoid) that raises the upper limb horizontally to the side.

At the lower end of the humerus are two smooth *condyles* (a lateral *capitulum* and a medial *trochlea*) that articulate with the radius on the lateral side and the ulna on the medial side. Above the condyles on either side are *epicondyles,* which provide attachments for muscles and ligaments of the elbow. Between the epicondyles anteriorly is a depression, the *coronoid* (kor´o-noid) *fossa,* that receives a process of the ulna (coronoid process) when the elbow bends. Another depression on the posterior surface, the *olecranon* (o´´lek´ra-non) *fossa,* receives an ulnar process (olecranon process) when the upper limb straightens at the elbow.

Radius

The **radius,** located on the thumb side of the forearm, extends from the elbow to the wrist and crosses over the ulna when the hand is turned so that the palm faces backward (fig. 7.24). A thick, disclike *head* at the upper end of the radius articulates with the humerus and a notch of the ulna (radial notch). This arrangement allows the radius to rotate freely.

On the radial shaft just below the head is a process called the *radial tuberosity.* It is an attachment for a muscle (biceps brachii) that bends the upper limb at the elbow. At the distal end of the radius, a lateral *styloid* (sti´loid) *process* provides attachments for ligaments of the wrist.

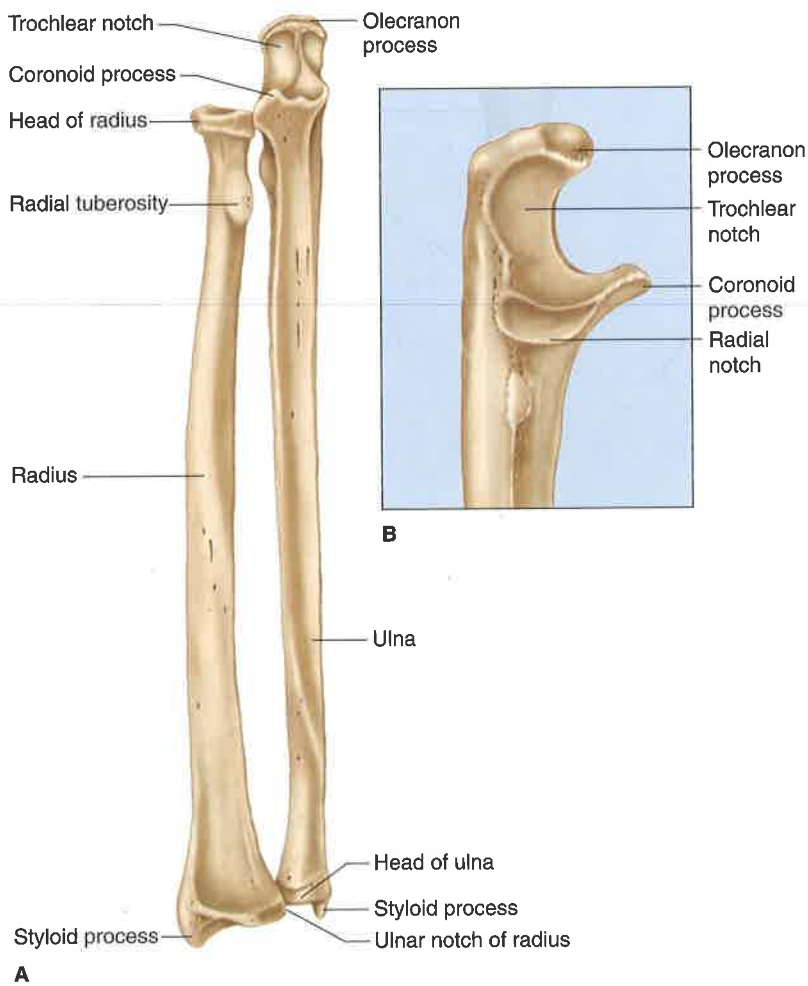


Figure 7.24
Radius and ulna. (*A*) The head of the right radius articulates with the radial notch of the ulna, and the head of the ulna articulates with the ulnar notch of the radius. (*B*) Lateral view of the proximal end of the ulna.

Ulna

The **ulna** is longer than the radius and overlaps the end of the humerus posteriorly (fig. 7.24). At its proximal end, the ulna has a wrenchlike opening, the *trochlear* (trok´le-ar) *notch,* that articulates with the humerus. Two processes on either side of this notch, the *olecranon process* and the *coronoid process,* provide attachments for muscles.

At the distal end of the ulna, its knoblike *head* articulates laterally with a notch of the radius (ulnar notch) and with a disc of fibrocartilage inferiorly. This disc, in turn, joins a wrist bone (triquetrum). A medial *styloid process* at the distal end of the ulna provides attachments for wrist ligaments.

Wrist and Hand

The skeleton of the wrist consists of eight small **carpal bones** that are firmly bound in two rows of four bones each. The resulting compact mass is called a *carpus* (kar´pus). The carpus articulates with the radius and with the fibrocartilaginous disc on the ulnar side. Its distal surface articulates with the metacarpal bones. Figure 7.25 names the individual bones of the carpus.

Five **metacarpal bones,** one in line with each finger, form the framework of the palm of the hand. These bones are cylindrical, with rounded distal ends that form the knuckles of a clenched fist. They are numbered 1–5, beginning with the metacarpal of the thumb (fig. 7.25). The metacarpals articulate proximally with the carpals and distally with the phalanges.

The **phalanges** are the finger bones. Each finger has three phalanges—a proximal, a middle, and a distal phalanx—except the thumb, which has two (it lacks a middle phalanx).

CHECK YOUR RECALL

1. Locate and name each of the bones of the upper limb.
2. Explain how the bones of the upper limb articulate with one another.

7.11 Pelvic Girdle

The **pelvic girdle** consists of two **coxae** (hipbones or innominate bones) which articulate with each other anteriorly and with the sacrum posteriorly. The sacrum,

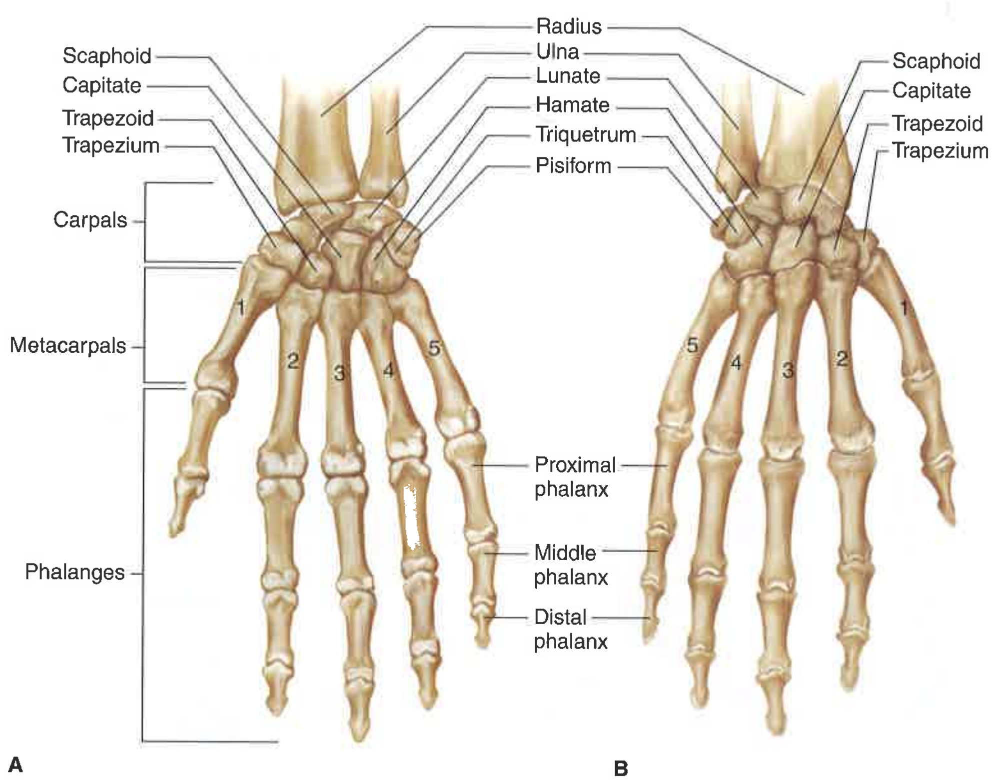


Figure 7.25
Wrist and hand. (*A*) Anterior view and (*B*) posterior view of the right wrist and hand.

coccyx, and pelvic girdle together form the bowl-shaped **pelvis** (fig. 7.26). The pelvic girdle supports the trunk of the body, provides attachments for the lower limbs, and protects the urinary bladder, the distal end of the large intestine, and the internal reproductive organs.

Each coxa develops from three parts—an ilium, an ischium, and a pubis (fig. 7.27). These parts fuse in the region of a cup-shaped cavity called the *acetabulum* (as´´ĕ-tab´u-lum). This depression, on the lateral surface of the hipbone, receives the rounded head of the femur (thighbone).

The **ilium** (il´e-um), which is the largest and uppermost portion of the coxa, flares outward, forming the prominence of the hip. The margin of this prominence is called the *iliac crest*.

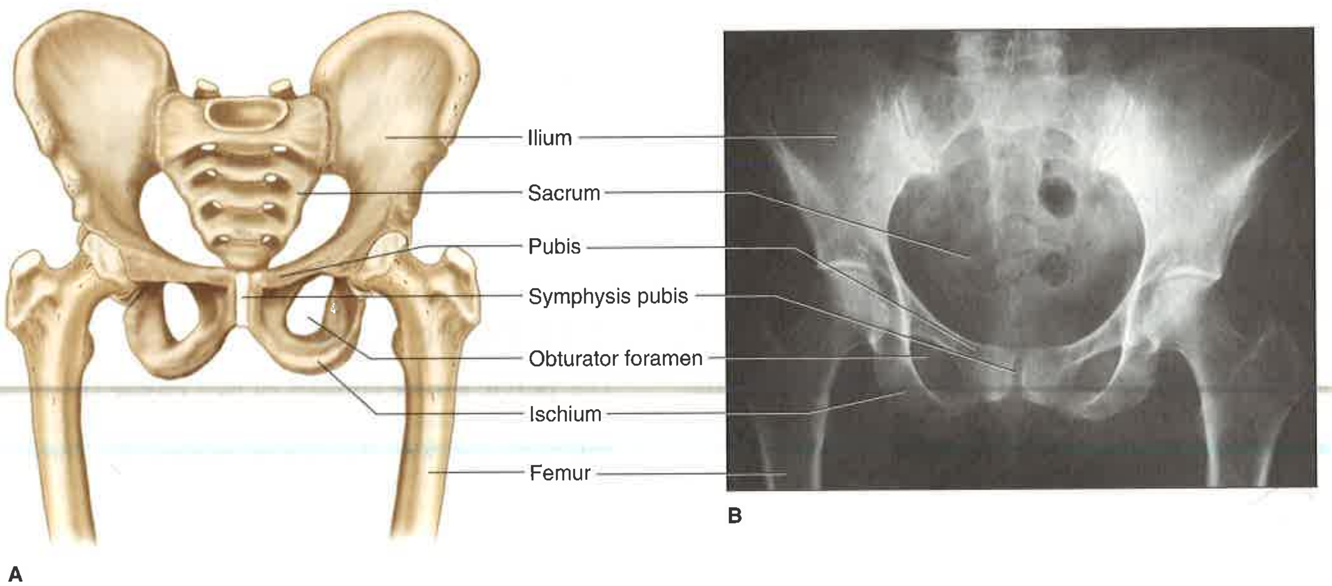


Figure 7.26
Pelvic girdle. (*A*) Formed by two coxae, the sacrum, and coccyx. (*B*) Radiograph of the pelvic girdle.

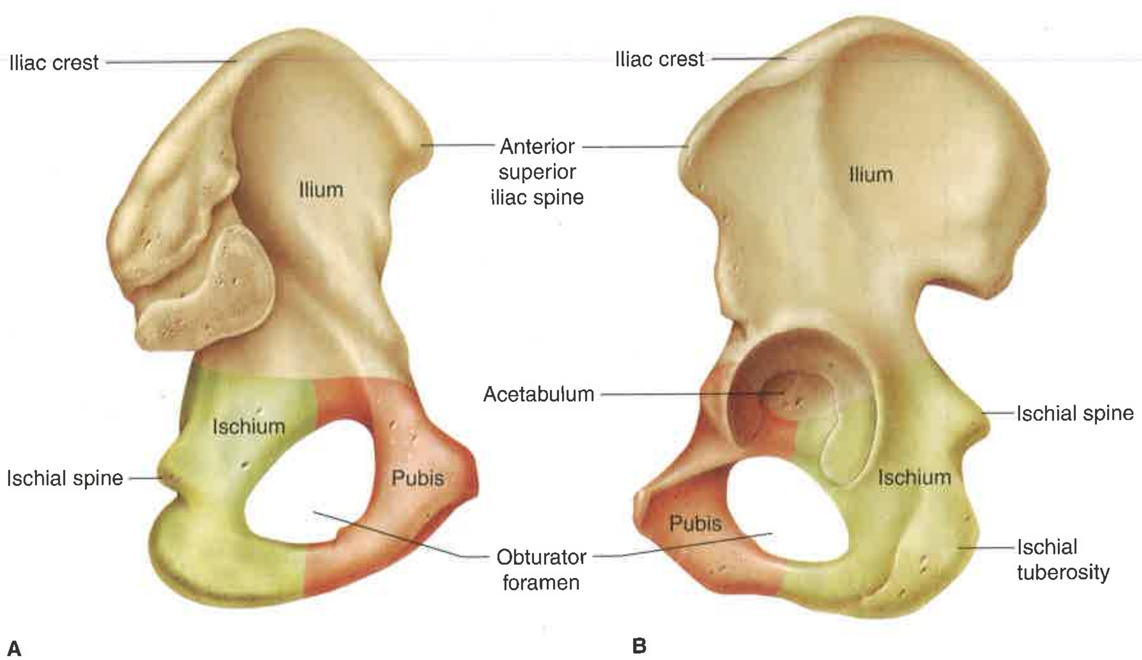


Figure 7.27
Coxa. (*A*) Medial surface of the left coxa. (*B*) Lateral view.

Posteriorly, the ilium joins the sacrum at the *sacroiliac* (sa´´kro-il´e-ak) *joint.* A projection of the ilium, the *anterior superior iliac spine,* can be felt lateral to the groin and provides attachments for ligaments and muscles.

The **ischium** (is´ke-um), which forms the lowest portion of the coxa, is L-shaped, with its angle, the *ischial tuberosity,* pointing posteriorly and downward. This tuberosity has a rough surface that provides attachments for ligaments and lower limb muscles. It also supports the weight of the body during sitting. Above the ischial tuberosity, near the junction of the ilium and ischium, is a sharp projection called the *ischial spine.*

The **pubis** (pu´bis) constitutes the anterior portion of the coxa. The two pubic bones join at the midline, forming a joint called the *symphysis pubis* (sim´fi-sis pu´bis). The angle these bones form below the symphysis is the *pubic arch* (fig. 7.28).

A portion of each pubis passes posteriorly and downward to join an ischium. Between the bodies of these bones on either side is a large opening, the *obturator foramen,* which is the largest foramen in the skeleton (see figs. 7.26 and 7.27).

If a line were drawn along each side of the pelvis from the sacral promontory downward and anteriorly to the upper margin of the symphysis pubis, it would mark the *pelvic brim* (linea terminalis) (fig. 7.28). This margin separates the lower, or lesser (true), pelvis from the upper, or greater (false), pelvis. Table 7.4 summarizes some differences in the female and male pelves and other skeletal structures.

CHECK YOUR RECALL

1. Locate and name each bone that forms the pelvis.
2. Name the bones that fuse to form a coxa.

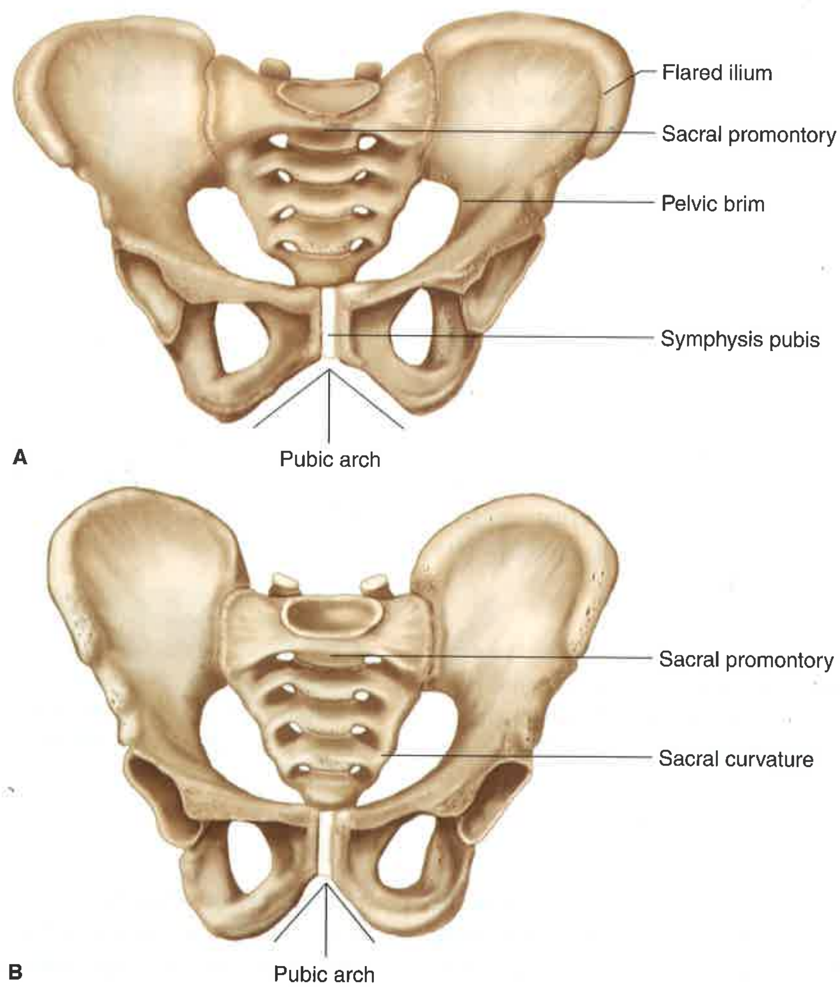


Figure 7.28
The female pelvis is usually wider in all diameters and roomier than that of the male. (*A*) Female pelvis. (*B*) Male pelvis.

TABLE 7.4 DIFFERENCES BETWEEN THE FEMALE AND MALE SKELETONS

PART	DIFFERENCES
Skull	Female skull is smaller and lighter, with less conspicuous muscular attachments. Female facial area is rounder, jaw is smaller, and mastoid process is less prominent than those of a male.
Pelvic girdle	Female coxae are lighter, thinner, and have less obvious muscular attachments. The obturator foramina and acetabula are smaller and farther apart than those of a male.
Pelvic cavity	Female pelvic cavity is wider in all diameters and is shorter, roomier, and less funnel-shaped. The distances between the ischial spines and ischial tuberosities are greater than in a male.
Sacrum	Female sacrum is wider, the first sacral vertebra projects forward to a lesser degree, and sacral curvature is bent more sharply posteriorly than in a male.
Coccyx	Female coccyx is more movable than that of a male.

7.12 Lower Limb

Bones of the lower limb form the frameworks of the thigh, leg, ankle, and foot. They include a femur, a tibia, a fibula, tarsals, metatarsals, and phalanges (see fig. 7.8).

Femur

The **femur,** or thigh bone, is the longest bone in the body and extends from the hip to the knee (fig. 7.29). A large, rounded *head* at its proximal end projects medially into the acetabulum of the coxa. On the head, a pit called the *fovea capitis* marks the attachment of a ligament (ligamentum capitis). Just below the head are a constriction, or *neck,* and two large processes—a superior, lateral *greater trochanter* and an inferior, medial *lesser trochanter.* These processes provide attachments for muscles of the lower limbs and buttocks.

The strongest bone in the body, the femur, is hollow. Ounce for ounce, it has greater pressure tolerance and bearing strength than a rod of equivalent size in cast steel.

At the distal end of the femur, two rounded processes, the *lateral* and *medial condyles,* articulate with the tibia of the leg. A **patella,** or kneecap, also articulates with the femur on its distal anterior surface (see fig. 7.8). It is located in a tendon that passes anteriorly over the knee.

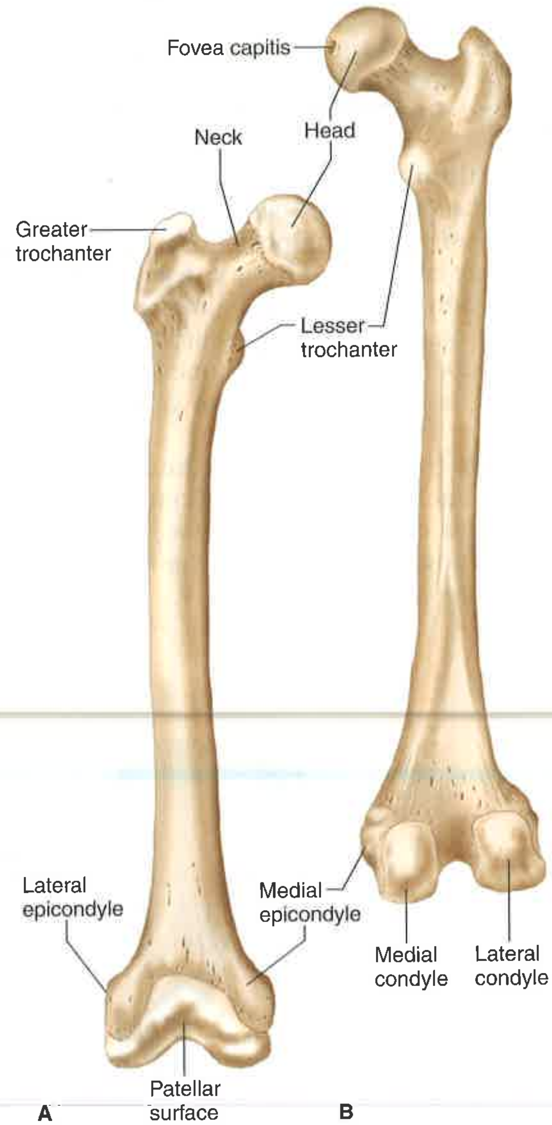


Figure 7.29
Femur. (*A*) Anterior surface and (*B*) posterior surface of the right femur.

H*ip fracture* is one of the more serious causes of hospitalization among elderly persons. The site of hip fracture is most commonly the neck of a femur or the region between the trochanters of a femur. Falls often cause hip fracture, especially in people who have osteoporosis.

Tibia

The **tibia,** or shin bone, is the larger of the two leg bones and is located on the medial side (fig. 7.30). Its proximal end is expanded into *medial* and *lateral condyles,* which have concave surfaces and articulate with the condyles of the femur. Below the condyles, on the anterior surface, is a process called the *tibial*

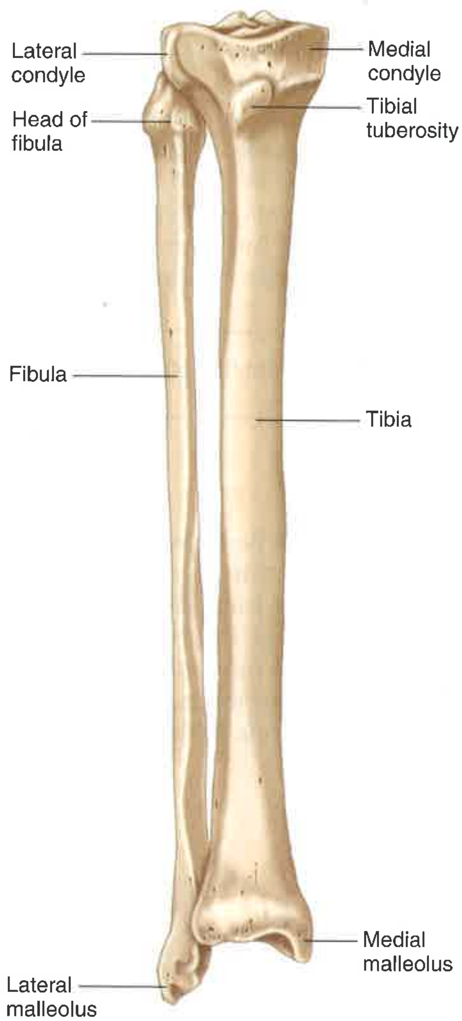


Figure 7.30
Bones of the right leg, viewed from the front.

tuberosity, which provides an attachment for the *patellar ligament*—a continuation of the patella-bearing tendon.

At its distal end, the tibia expands to form a prominence on the inner ankle called the *medial malleolus* (mah-le´o-lus), which is an attachment for ligaments. On its lateral side is a depression that articulates with the fibula. The inferior surface of the tibia's distal end articulates with a large bone (the talus) in the ankle.

Fibula

The **fibula** is a long, slender bone located on the lateral side of the tibia (fig. 7.30). Its ends are slightly enlarged into a proximal *head* and a distal *lateral malleolus.* The head articulates with the tibia just below the lateral condyle; however, it does not enter into the knee joint and does not bear any body weight. The lateral malleolus articulates with the ankle and protrudes on the lateral side.

Ankle and Foot

The ankle and foot consist of a *tarsus* (tahr´sus), a *metatarsus* (met´´ah-tar´sus), and five toes. The tarsus is composed of seven **tarsal bones** (figs. 7.31 and 7.32). These bones are arranged so that one of them, the **talus** (ta´lus), can move freely where it joins the tibia and fibula. The remaining tarsal bones are bound firmly together, forming a mass supporting the talus. Figure 7.32 names the individual bones of the tarsus.

The largest of the tarsals, the **calcaneus** (kal-ka´ne-us), or heel bone, is located below the talus, where it projects backward to form the base of the heel. The calcaneus helps support body weight and provides an attachment for muscles that move the foot.

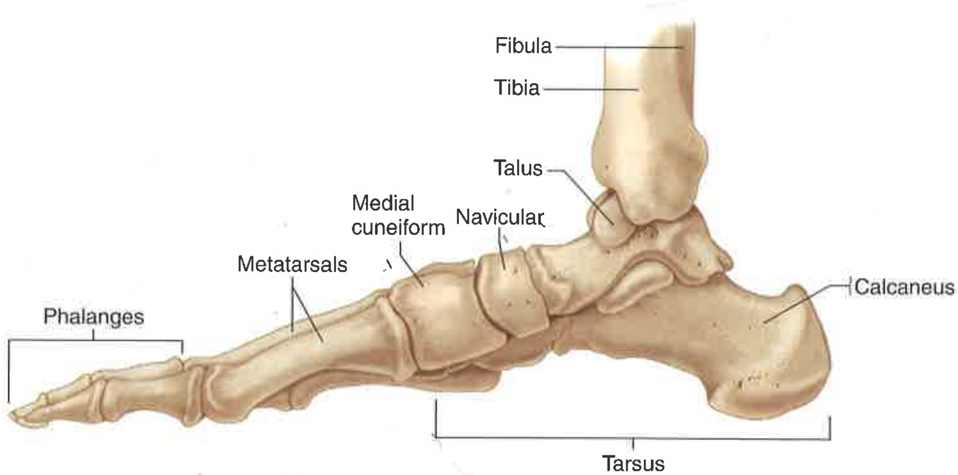


Figure 7.31
The talus moves freely where it articulates with the tibia and fibula.

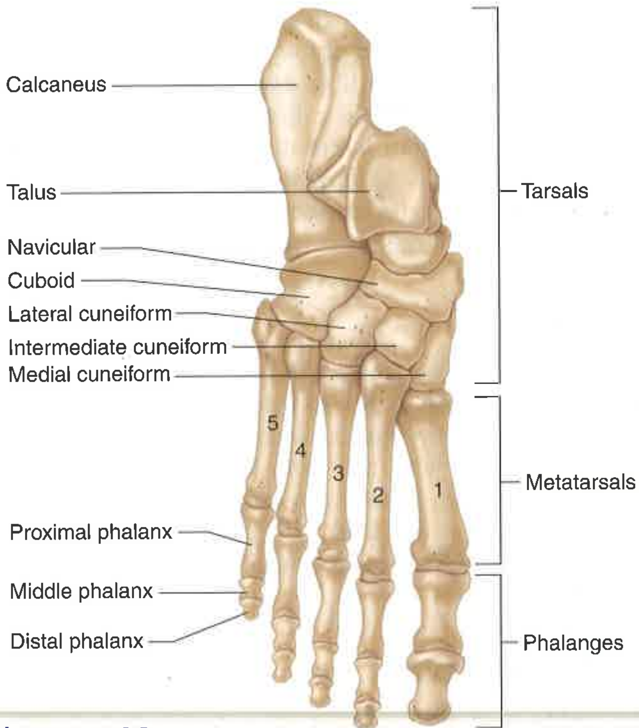


Figure 7.32
The right foot viewed superiorly.

The metatarsus consists of five elongated **metatarsal bones,** that articulate with the tarsus. They are numbered 1–5, beginning on the medial side (fig. 7.32). The heads at the distal ends of these bones form the ball of the foot. The tarsals and metatarsals are arranged and bound by ligaments to form the arches of the foot. A longitudinal arch extends from the heel to the toe, and a transverse arch stretches across the foot. These arches provide a stable, springy base for the body. Sometimes, however, the tissues that bind the metatarsals weaken, producing fallen arches, or flat feet.

The **phalanges** of the toes are similar to those of the fingers and align and articulate with the metatarsals. Each toe has three phalanges—a proximal, a middle, and a distal phalanx—except the great toe, which lacks a middle phalanx.

CHECK YOUR RECALL

1. Locate and name each of the bones of the lower limb.
2. Explain how the bones of the lower limb articulate with one another.
3. Describe how the foot is adapted to support the body.

7.13 Joints

Joints (articulations) are functional junctions between bones. They bind parts of the skeletal system, make possible bone growth, permit parts of the skeleton to change shape during childbirth, and enable the body to move in response to skeletal muscle contractions. Joints vary considerably in structure and function. If classified according to the degree of movement they make possible, joints can be immovable, slightly movable, or freely movable. Joints also can be grouped by the type of tissue (fibrous, cartilaginous, or synovial) that binds the bones together at each junction. Currently, structural classification by tissue type is more commonly used.

There are 230 joints in the body.

Fibrous Joints

Fibrous (fi´brus) **joints** lie between bones that closely contact one another. A thin layer of dense connective tissue joins the bones at such joints, as in the case of a *suture* between a pair of flat bones of the skull (fig. 7.33). No appreciable movement takes place at a fibrous joint. Some fibrous joints, such as the joint in the leg between the distal ends of the tibia and fibula, have limited movement.

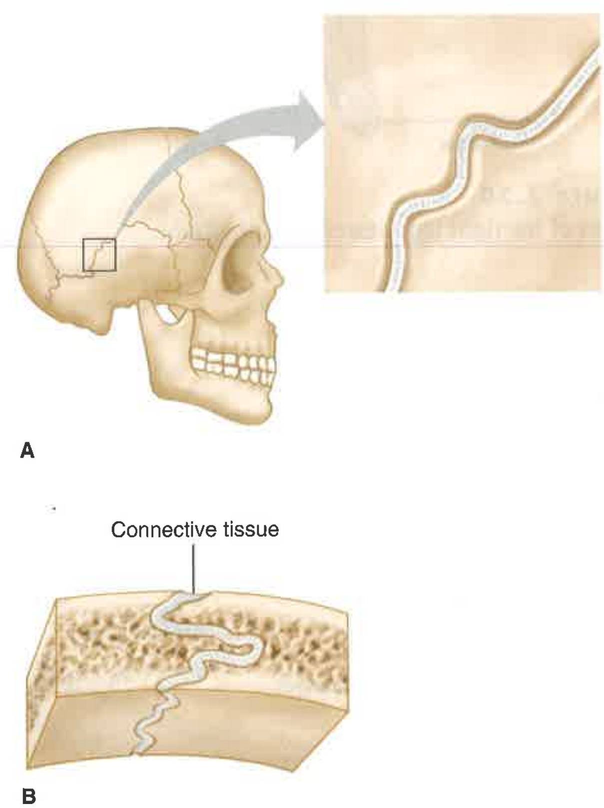


Figure 7.33
Fibrous joints. (*A*) The fibrous joints between the bones of the skull are immovable and are called sutures. (*B*) A thin layer of connective tissue connects the bones at the suture.

Cartilaginous Joints

Hyaline cartilage, or fibrocartilage, connects the bones of **cartilaginous** (kar″tĭ-lah′jin-us) **joints.** For example, joints of this type separate the vertebrae of the vertebral column. Each intervertebral disc is composed of a band of fibrocartilage (annulus fibrosus) surrounding a pulpy or gelatinous core (nucleus pulposus). The disc absorbs shocks and helps equalize pressure between adjacent vertebrae when the body moves (see fig. 7.16).

Due to the slight flexibility of the discs, cartilaginous joints allow limited movement, as when the back is bent forward or to the side or is twisted. Other examples of cartilaginous joints include the symphysis pubis and the first rib with the sternum.

Synovial Joints

Most joints within the skeletal system are **synovial** (sĭ-no′ve-al) **joints** and allow free movement. They are more complex structurally than fibrous or cartilaginous joints.

The articular ends of the bones in a synovial joint are covered with hyaline cartilage (articular cartilage), and a surrounding, tubular capsule of dense connective tissue holds them together (fig. 7.34). This *joint capsule* is composed of an outer layer of ligaments and an inner lining of *synovial membrane,* which secretes synovial fluid. With a consistency similar to uncooked egg white, synovial fluid lubricates joints.

Some synovial joints have flattened, shock-absorbing pads of fibrocartilage called **menisci** (mĕ-nis′ke) (singular, *meniscus*) between the articulating surfaces of the bones (fig. 7.35). Such joints may also have fluid-filled sacs called **bursae** (ber′se) associated with them. Each bursa is lined with synovial membrane, which may be continuous with the synovial membrane of a nearby joint cavity.

Bursae are commonly located between the skin and underlying bony prominences, as in the case of the patella of the knee or the olecranon process of the elbow. They aid movement of tendons that glide over these bony parts or over other tendons. Figures 7.35 and 7.36 show and name some of the bursae associated with the knee and shoulder.

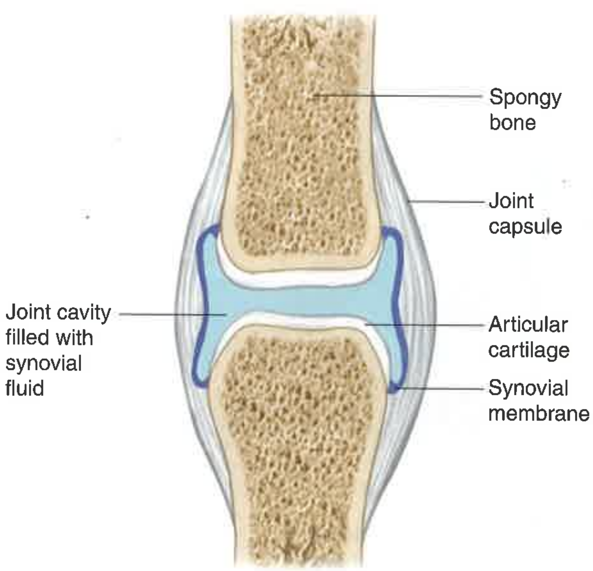


Figure 7.34
The generalized structure of a synovial joint.

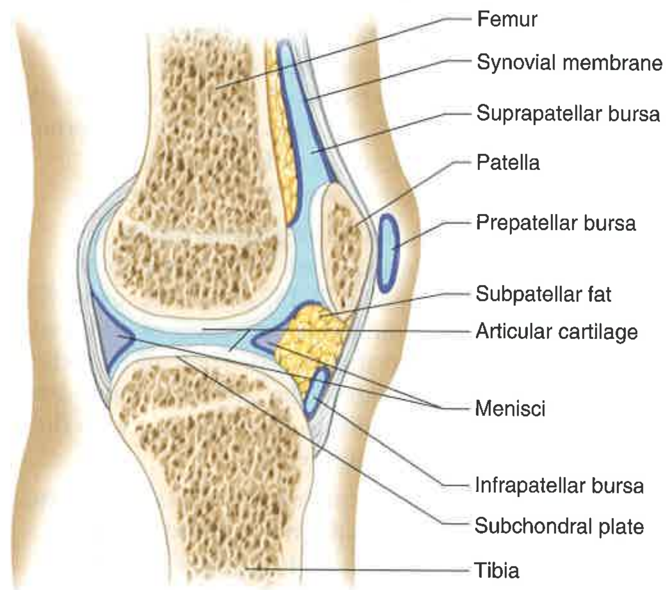


Figure 7.35
Menisci separate the articulating surfaces of the femur and tibia. Several bursae are associated with the knee joint.

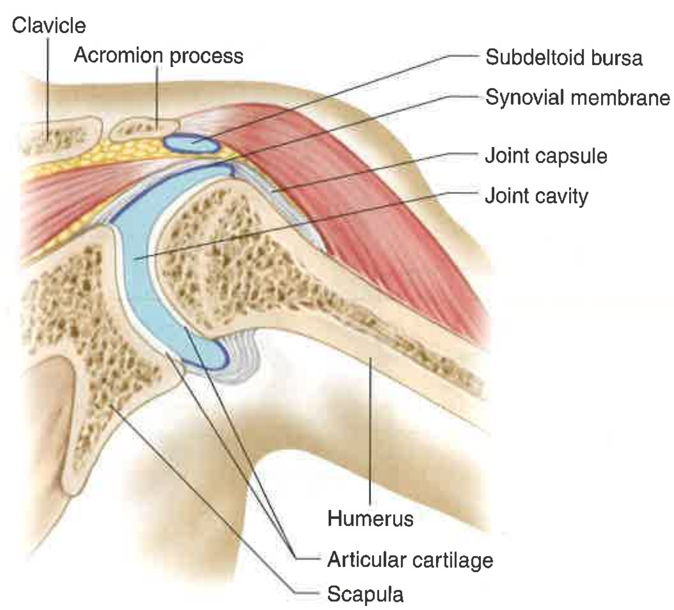


Figure 7.36
The shoulder joint allows movements in all directions. Several bursae are associated with the shoulder joint (not all are shown).

Based on the shapes of their parts and the movements they permit, synovial joints are classified as follows:

1. A **ball-and-socket joint** consists of a bone with a ball-shaped head that articulates with the cup-shaped cavity of another bone. Such a joint allows a wider range of motion than does any other kind, permitting movements in all planes, as well as rotational movement around a central axis. The shoulder and hip contain joints of this type (figs. 7.36 and 7.37).
2. In a **condyloid joint,** an oval-shaped condyle of one bone fits into an elliptical cavity of another bone, as in the joints between the metacarpals and phalanges (see fig. 7.25). This type of joint permits a variety of movements in different planes; rotational movement, however, is not possible.
3. The articulating surfaces of **gliding joints** are nearly flat or slightly curved. Most of the joints within the wrist (see fig. 7.25) and ankle, as well as those between the articular processes of adjacent vertebrae, belong to this group. They allow sliding and twisting movements. The sacroiliac joints and the joints formed by ribs 2–7 connecting with the sternum are also gliding joints.
4. In a **hinge joint,** the convex surface of one bone fits into the concave surface of another, as in the elbow (fig. 7.38) and the joints of the phalanges. Such a joint resembles the hinge of a door in that it permits movement in one plane only.
5. In a **pivot joint,** the cylindrical surface of one bone rotates within a ring formed of bone and ligament. Movement is limited to the rotation around a central axis. The joint between the proximal ends of the radius and the ulna is of this type (see fig. 7.24).
6. A **saddle joint** forms between bones whose articulating surfaces have both concave and convex regions. The surface of one bone fits the complementary surface of the other. This physical relationship permits a variety of movements, as in the joint between the carpal (trapezium) and metacarpal of the thumb (see fig. 7.25).

Table 7.5 summarizes the types of joints.

Arthritis is a disease that causes inflamed, swollen, and painful joints. More than a hundred different types of arthritis affect 50 million people in the United States. The most common forms are *rheumatoid arthritis* and *osteoarthritis.*

In rheumatoid arthritis, which is the most painful and debilitating of the arthritic diseases, the synovial membrane of a freely movable joint becomes inflamed and thickened. Then the articular cartilage is damaged, and fibrous tissue infiltrates, interfering with joint movement. In time, the joint may ossify, fusing the articulating bones. Rheumatoid arthritis is an autoimmune disorder in which the immune system attacks the body's healthy tissues.

Osteoarthritis is a degenerative disorder that occurs as a result of aging, but an inherited form may appear as early as one's thirties. In osteoarthritis, articular cartilage softens and disintegrates gradually, roughening the articular surfaces. Joints become painful, and movement is restricted. Osteoarthritis most often affects joints that are used the most over a lifetime, such as those of the fingers, hips, knees, and lower parts of the vertebral column.

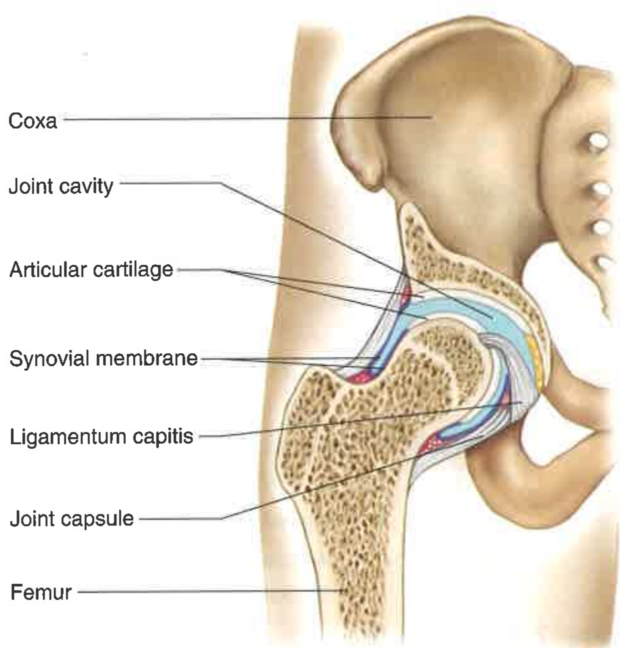


Figure 7.37
The hip is a ball-and-socket joint.

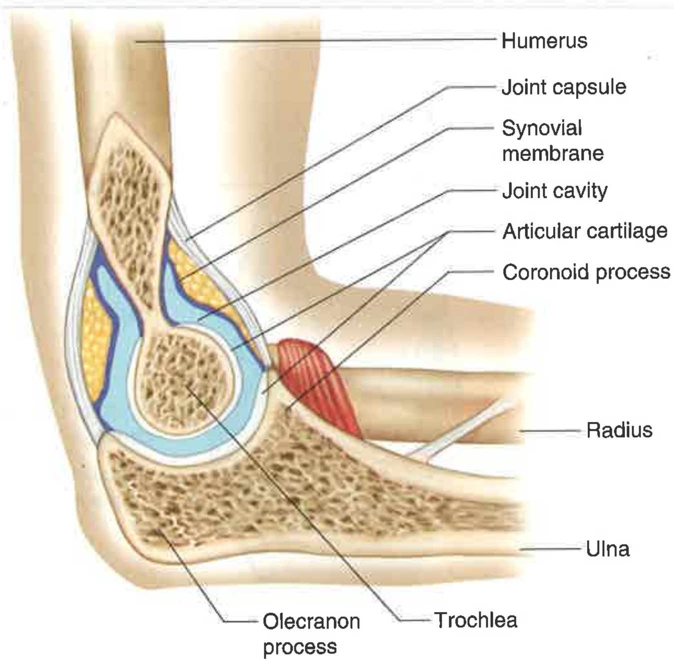


Figure 7.38
The elbow is a hinge joint.

TABLE 7.5 TYPES OF JOINTS

TYPE OF JOINT	DESCRIPTION	POSSIBLE MOVEMENTS	EXAMPLE
Fibrous	Articulating bones are fastened together by a thin layer of dense connective tissue.	None	Suture between bones of skull, joint between the distal ends of tibia and fibula
Cartilaginous	Articulating bones are connected by hyaline cartilage or fibrocartilage.	Limited movement, as when back is bent or twisted	Joints between the bodies of vertebrae, symphysis pubis
Synovial	Articulating bones are surrounded by a joint capsule of ligaments and synovial membranes; ends of articulating bones are covered by hyaline cartilage and separated by synovial fluid.	Allow free movement (see the following list)	
1. Ball-and-socket	Ball-shaped head of one bone articulates with cup-shaped cavity of another.	Movements in all planes and rotation	Shoulder, hip
2. Condyloid	Oval-shaped condyle of one bone articulates with elliptical cavity of another.	Variety of movements in different planes, but no rotation	Joints between the metacarpals and phalanges
3. Gliding	Articulating surfaces are nearly flat or slightly curved.	Sliding or twisting	Joints between various bones of wrist and ankle, sacroiliac joints, joints between ribs 2–7 and sternum
4. Hinge	Convex surface of one bone articulates with concave surface of another.	Flexion and extension	Elbow, joints of phalanges
5. Pivot	Cylindrical surface of one bone articulates with ring of bone and ligament.	Rotation around a central axis	Joint between the proximal ends of radius and ulna
6. Saddle	Articulating surfaces have both concave and convex regions; the surface of one bone fits the complementary surface of another.	Variety of movements	Joint between the carpal and metacarpal of thumb

Types of Joint Movements

Skeletal muscle action produces movements at synovial joints. Typically, one end of a muscle is attached to a relatively immovable or fixed part on one side of a joint, and the other end of the muscle is fastened to a movable part on the other side. When the muscle contracts, its fibers pull its movable end **(insertion)** toward its fixed end **(origin),** and a movement occurs at the joint.

The following terms describe movements at joints (figs. 7.39, 7.40, and 7.41):

flexion (flek´shun) Bending parts at a joint so that the angle between them decreases and the parts come closer together (bending the lower limb at the knee).

extension (ek-sten´shun) Straightening parts at a joint so that the angle between them increases and the parts move farther apart (straightening the lower limb at the knee).

dorsiflexion (dor´´sĭ-flek´shun) Bending the foot at the ankle toward the shin (bending the foot upward).

plantar flexion (plan´tar flek´shun) Bending the foot at the ankle toward the sole (bending the foot downward).

hyperextension (hi´´per-ek-sten´shun) Excess extension of the parts at a joint, beyond the anatomical position (bending the head back beyond the upright position).

abduction (ab-duk´shun) Moving a part away from the midline (lifting the upper limb horizontally to form a right angle with the side of the body).

adduction (ah-duk´shun) Moving a part toward the midline (returning the upper limb from the horizontal position to the side of the body).

rotation (ro-ta´shun) Moving a part around an axis (twisting the head from side to side).

circumduction (ser´´kum-duk´shun) Moving a part so that its end follows a circular path (moving the finger in a circular motion without moving the hand).

pronation (pro-na´shun) Turning the hand so that the palm is downward or facing posteriorly (in anatomical position).

supination (soo´´pĭ-na´shun) Turning the hand so that the palm is upward or facing anteriorly (in anatomical position).

eversion (e-ver´zhun) Turning the foot so that the sole faces laterally.

inversion (in-ver´zhun) Turning the foot so that the sole faces medially.

retraction (re-trak´shun) Moving a part backward (pulling the chin backward).

protraction (pro-trak´shun) Moving a part forward (thrusting the chin forward).

elevation (el´´ĕ-va´shun) Raising a part (shrugging the shoulders).

depression (de-presh´un) Lowering a part (drooping the shoulders).

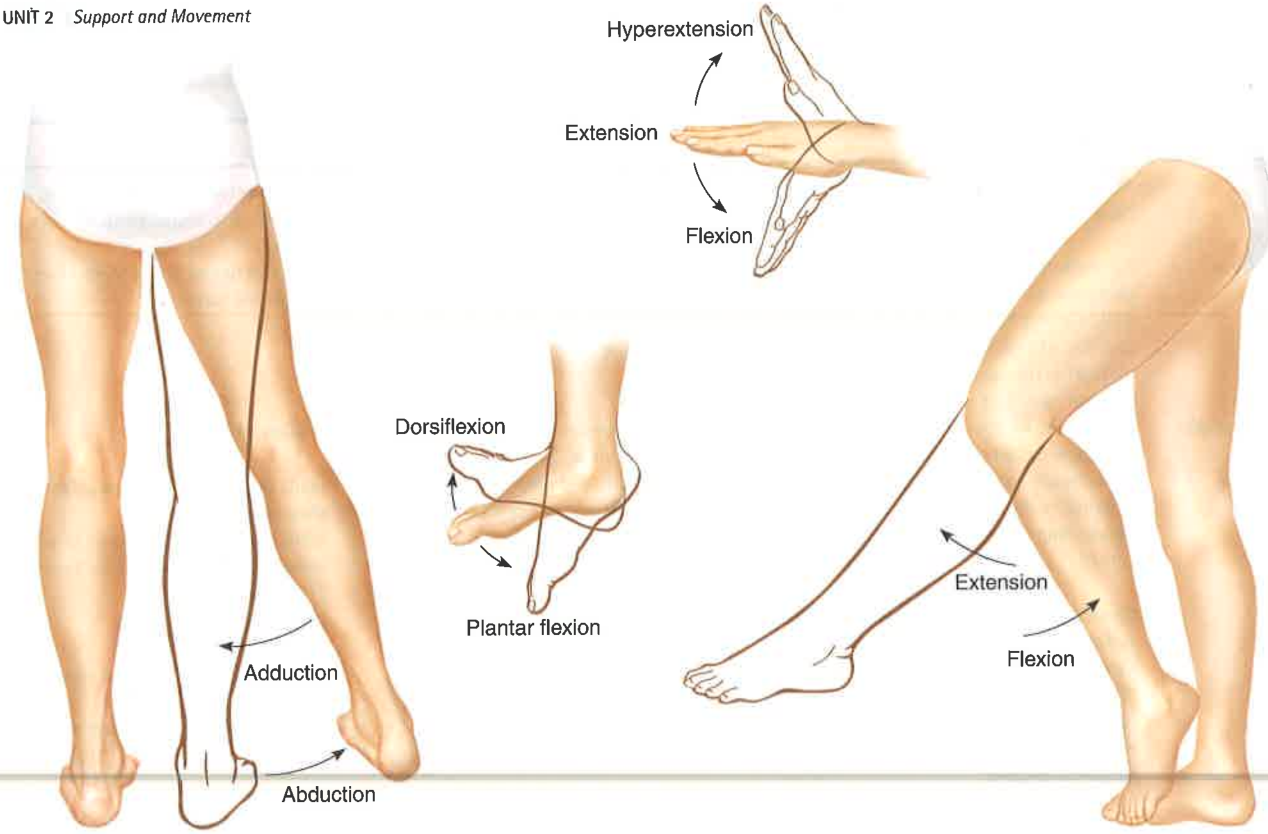
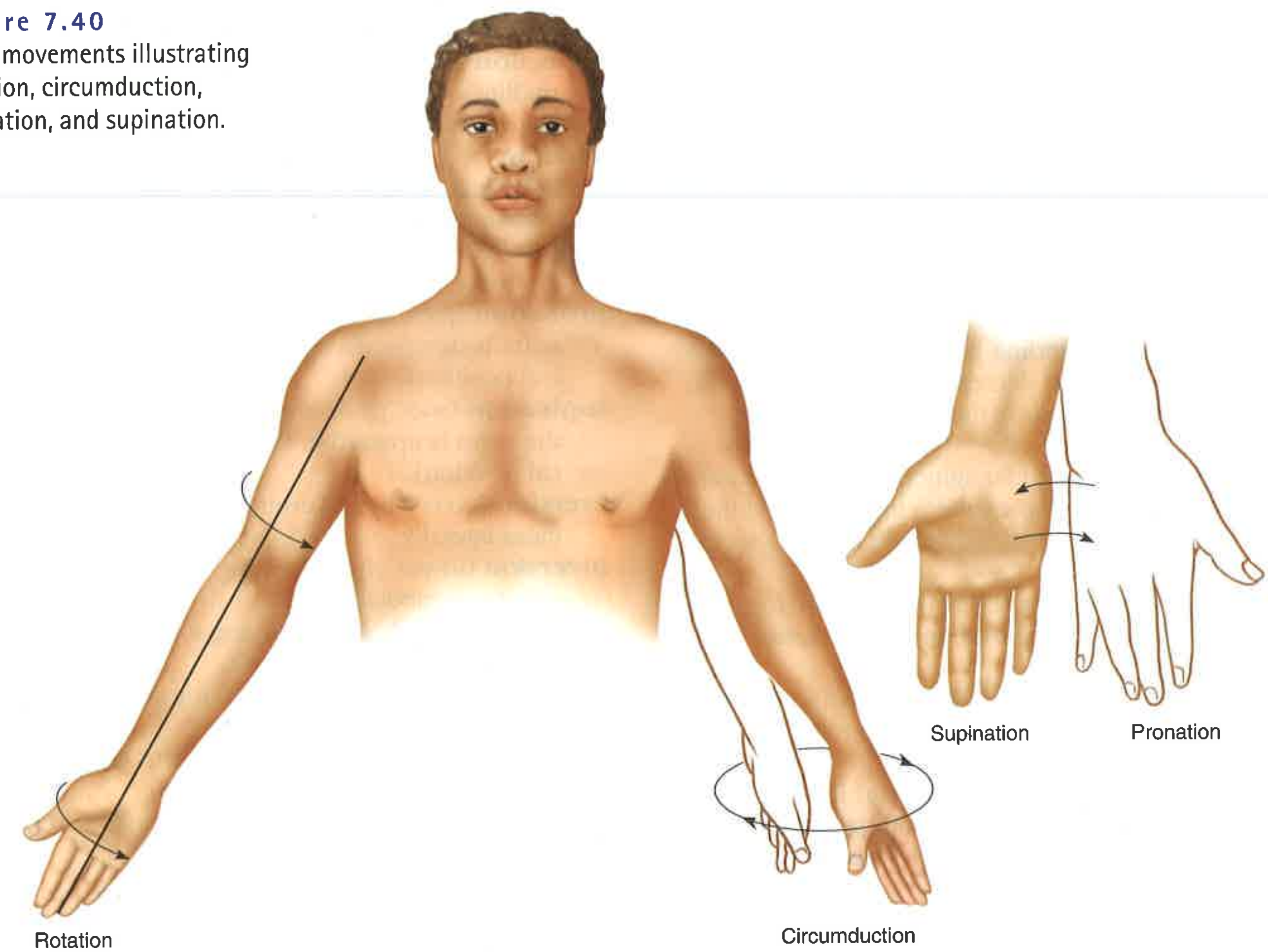


Figure 7.39
Joint movements illustrating adduction, abduction, dorsiflexion, plantar flexion, hyperextension, extension, and flexion.

Figure 7.40
Joint movements illustrating rotation, circumduction, pronation, and supination.



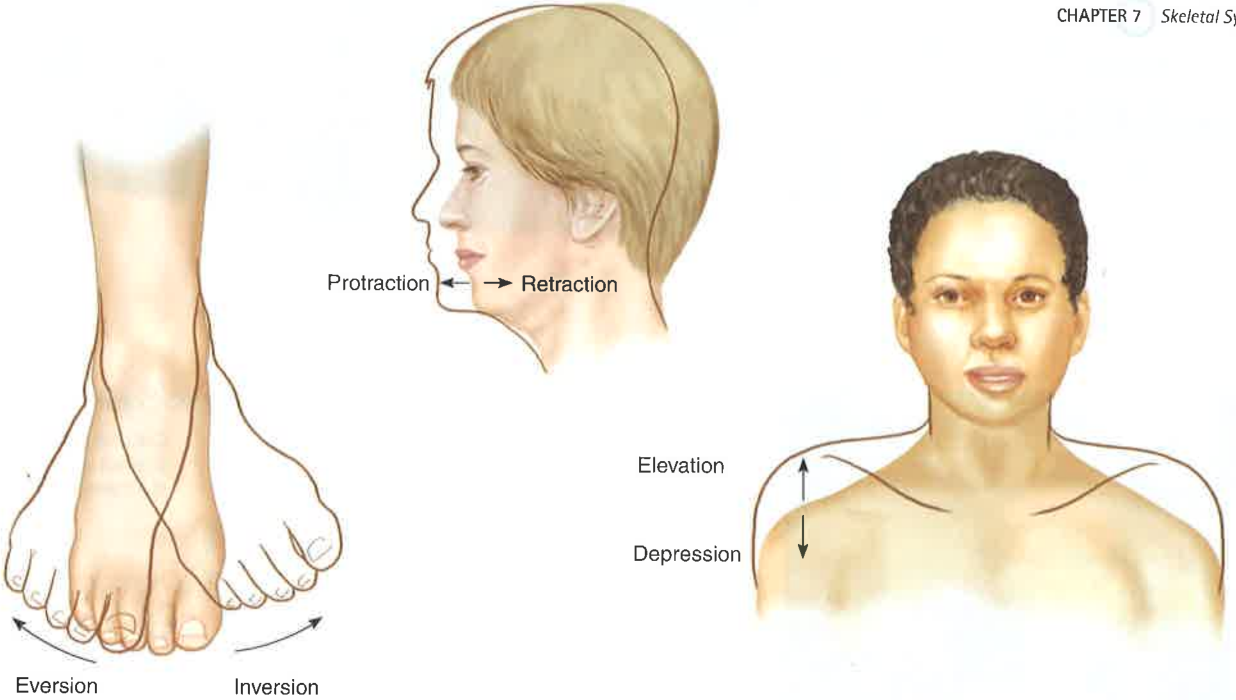


Figure 7.41
Joint movements illustrating eversion, inversion, retraction, protraction, elevation, and depression.

CHECK YOUR RECALL

1. Describe the characteristics of the three major types of joints.
2. Name six types of synovial joints.
3. What terms describe movements possible at synovial joints?

Injuries to the elbow, shoulder, and knee are commonly diagnosed and treated using a procedure called *arthroscopy.* Arthroscopy enables a surgeon to visualize a joint's interior and even perform diagnostic or therapeutic procedures, guided by the image on a video screen. An arthroscope is a thin, tubular instrument about 25 centimeters long containing optical fibers that transmit an image. The surgeon inserts the device through a small incision in the joint capsule. Arthroscopy is far less invasive than conventional surgery. Many runners have undergone uncomplicated arthroscopy and raced just weeks later.

Clinical Terms Related to the Skeletal System

acromegaly (ak´´ro-meg´ah-le) Abnormal enlargement of facial features, hands, and feet in adults as a result of overproduction of growth hormone.

ankylosis (ang´´kĭ-lo´sis) Abnormal stiffness of a joint or fusion of bones at a joint, often due to damage to the joint membranes from chronic rheumatoid arthritis.

arthralgia (ar-thral´je-ah) Pain in a joint.

arthrocentesis (ar´´thro-sen-te´sis) Puncture of and removal of fluid from a joint cavity.

arthrodesis (ar´´thro-de´sis) Surgery to fuse the bones at a joint.

arthroplasty (ar´thro-plas´´te) Surgery to make a joint more movable.

Colles fracture (kol´ēz frak´ture) Fracture at the distal end of the radius that displaces the smaller fragment posteriorly.

epiphysiolysis (ep´´ĭ-fiz´´e-ol´ĭ-sis) Separation or loosening of the epiphysis from the diaphysis of a bone.

hemarthrosis (hem´´ar-thro´sis) Blood in a joint cavity.

laminectomy (lam´´ĭ-nek´to-me) Surgical removal of the posterior arch of a vertebra, usually to relieve symptoms of a ruptured intervertebral disc.

lumbago (lum-ba´go) Dull ache in the lumbar region of the back.

orthopedics (or´´tho-pe´diks) Medical specialty that prevents, diagnoses, and treats diseases and abnormalities of the skeletal and muscular systems.

ostealgia (os´´te-al´je-ah) Pain in a bone.

ostectomy (os-tek´to-me) Surgical removal of a bone.

osteitis (os´´te-i´tis) Inflammation of bone tissue.

osteochondritis (os´´te-o-kon-dri´tis) Inflammation of bone and cartilage tissues.

osteogenesis (os´´te-o-jen´ĕ-sis) Bone development.

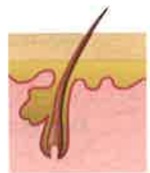
osteogenesis imperfecta (os´´te-o-jen´ĕ-sis im-per-fek´ta) Inherited condition of deformed and abnormally brittle bones.

osteoma (os´´te-o´mah) Tumor composed of bone tissue.

osteomalacia (os´´te-o-mah-la´she-ah) Softening of adult bone due to a disorder in calcium and phosphorus metabolism, usually caused by vitamin D deficiency.

Organization

Integumentary System



Vitamin D, activated in the skin, plays a role in calcium availability for bone matrix.

Lymphatic System

Cells of the immune system originate in the bone marrow.

Muscular System

Muscles pull on bones to cause movement.

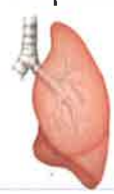
Digestive System

Absorption of dietary calcium provides material for bone matrix.

Nervous System

Proprioceptors sense the position of body parts. Pain receptors warn of trauma to bone. Bones protect the brain and spinal cord.

Respiratory System



Ribs and muscles work together in breathing.

Endocrine System

Some hormones act on bone to help regulate blood calcium levels.

Urinary System

The kidneys and bones work together to help regulate blood calcium levels.

Cardiovascular System

Blood transports nutrients to bone cells. Bone helps regulate plasma calcium levels, important to heart function.

Reproductive System

The pelvis helps support the uterus during pregnancy. Bone may provide a source of calcium during lactation.

Skeletal System

Bones provide support, protection, and movement and also play a role in calcium balance.

osteomyelitis (os´´te-o-mi´´ĕ-li´tis) Bone inflammation caused by the body's reaction to bacterial or fungal infection.

osteonecrosis (os´´te-o-ne-kro´sis) Death of bone tissue. This condition occurs most commonly in the femur head in elderly persons and may be due to obstructed arteries supplying the bone.

osteopathology (os´´te-o-pah-thol´o-je) Study of bone diseases.

osteotomy (os´´te-ot´o-me) Cutting a bone.

synovectomy (sin´´o-vek´to-me) Surgical removal of the synovial membrane of a joint.

Clinical Connection

When the 20-year-old professional soccer player jammed his left toe at high speed against the ball and howled in pain, he thought it would just get better in a few days, as such injuries usually do. This time, the injured toe started to turn bluish red immediately, as a hematoma formed beneath the nail. The pain continued, for weeks. Pus swelled from beneath the darkened nail. Finally, barely able to walk let alone continuing playing his sport, the athlete consulted a physician, who, assuming the wound was infected, prescribed antibiotics and an anti-inflammatory cream. But the unrelenting pain was not due to infection. The young man finally went to an emergency room, where a sample of the pus revealed no bacteria. X-rays instead clearly indicated an osteochondroma, a spike of bone emerging 4 millimeters from the dorsal terminal phalanx of the left great toe, capped with cartilage. Usually an osteochondroma is a benign bone tumor that arises during fetal development. The physician in charge, however, suspected that the soccer player's spike was a response to trauma—and then failure to rest afterwards. Surgery removed the spike, and a month later, the athlete was back on the field.

SUMMARY OUTLINE

7.1 Introduction (p. 128)

Individual bones are the organs of the skeletal system. A bone contains very active tissues.

7.2 Bone Structure (p. 128)

Bone structure reflects its function.

1. Parts of a long bone
   a. Epiphyses at each end are covered with articular cartilage and articulate with other bones.
   b. The shaft of a bone is called the diaphysis.
   c. Except for the articular cartilage, a bone is covered by a periosteum.
   d. Compact bone has a continuous matrix with no gaps.
   e. Spongy bone has irregular interconnecting spaces between bony plates that reduce the weight of bone.
   f. Both compact and spongy bone are strong and resist bending.
   g. The diaphysis contains a medullary cavity filled with marrow.
2. Microscopic structure
   a. Compact bone contains osteons cemented together.
   b. Central canals contain blood vessels that nourish the cells of osteons.
   c. Diffusion from the surface of the thin, bony plates nourishes the cells of spongy bone.

7.3 Bone Development and Growth (p. 130)

1. Intramembranous bones
   a. Intramembranous bones develop from layers of connective tissues.
   b. Osteoblasts within the membranous layers form bone tissue.
   c. Mature bone cells are called osteocytes.
2. Endochondral bones
   a. Endochondral bones develop as hyaline cartilage that is later replaced by bone tissue.
   b. The primary ossification center appears in the diaphysis, whereas secondary ossification centers appear in the epiphyses.
   c. An epiphyseal plate remains between the primary and secondary ossification centers.
   d. The epiphyseal plates are responsible for lengthening.
   e. Long bones continue to lengthen until the epiphyseal plates are ossified.
   f. Growth in thickness is due to intramembranous ossification beneath the periosteum.
3. Homeostasis of bone tissue
   a. Osteoclasts and osteoblasts continually remodel bone.
   b. The total mass of bone remains nearly constant.

7.4 Bone Function (p. 131)

1. Support and protection
   a. Bones shape and form body structures.
   b. Bones support and protect softer, underlying tissues.
2. Body movement
   a. Bones and muscles function together as levers.
   b. A lever consists of a rod, a pivot (fulcrum), a resistance, and a force that supplies energy.
3. Blood cell formation
   a. At different ages, hemopoiesis occurs in the yolk sac, liver and spleen, and red bone marrow.
   b. Red marrow houses developing red blood cells, white blood cells, and blood platelets. Yellow marrow stores fat.
4. Storage of inorganic salts
   a. The intercellular material of bone tissue contains large quantities of calcium phosphate.
   b. When blood calcium is low, osteoclasts break down bone, releasing calcium salts. When blood calcium is high, osteoblasts form bone tissue and store calcium salts.
   c. Bone stores small amounts of magnesium, sodium, potassium, and carbonate ions.

7.5 Skeletal Organization (p. 135)

1. The skeleton can be divided into axial and appendicular portions.
2. The axial skeleton consists of the skull, hyoid bone, vertebral column, and thoracic cage.

3. The appendicular skeleton consists of the pectoral girdle, upper limbs, pelvic girdle, and lower limbs.

7.6 Skull (p. 136)

The skull consists of twenty-two bones: eight cranial bones, fourteen facial bones.

1. Cranium
   a. The cranium encloses and protects the brain.
   b. Some cranial bones contain air-filled sinuses.
   c. Cranial bones include the frontal bone, parietal bones, occipital bone, temporal bones, sphenoid bone, and ethmoid bone.
2. Facial skeleton
   a. Facial bones form the basic shape of the face and provide attachments for muscles.
   b. Facial bones include the maxillae, palatine bones, zygomatic bones, lacrimal bones, nasal bones, vomer bone, inferior nasal conchae, and mandible.
3. Infantile skull
   a. Fontanels connect incompletely developed bones.
   b. The proportions of the infantile skull are different from those of an adult skull.

7.7 Vertebral Column (p. 142)

The vertebral column extends from the skull to the pelvis and protects the spinal cord. It is composed of vertebrae, separated by intervertebral discs.

1. A typical vertebra
   a. A typical vertebra consists of a body and a bony vertebral arch, which surrounds the spinal cord.
   b. Notches on the upper and lower surfaces provide intervertebral foramina through which spinal nerves pass.
2. Cervical vertebrae
   a. Transverse processes bear transverse foramina.
   b. The atlas (first vertebra) supports and balances the head.
   c. The dens of the axis (second vertebra) provides a pivot for the atlas when the head is turned from side to side.
3. Thoracic vertebrae
   a. Thoracic vertebrae are larger than cervical vertebrae.
   b. Facets on the sides articulate with the ribs.
4. Lumbar vertebrae
   a. The vertebral bodies are large and strong.
   b. They support more body weight than other vertebrae.
5. Sacrum
   a. The sacrum is a triangular structure formed of five fused vertebrae.
   b. Vertebral foramina form the sacral canal.
6. Coccyx
   a. The coccyx, composed of four fused vertebrae, forms the lowest part of the vertebral column.
   b. It acts as a shock absorber when a person sits.

7.8 Thoracic Cage (p. 147)

The thoracic cage includes the ribs, thoracic vertebrae, sternum, and costal cartilages. It supports the pectoral girdle and upper limbs, protects viscera, and functions in breathing.

1. Ribs
   a. Twelve pairs of ribs attach to the twelve thoracic vertebrae.
   b. Costal cartilages of the true ribs join the sternum directly. Those of the false ribs join it indirectly or not at all.
   c. A typical rib has a shaft, a head, and tubercles that articulate with the vertebrae.
2. Sternum
   a. The sternum consists of a manubrium, body, and xiphoid process.
   b. It articulates with the clavicles.

7.9 Pectoral Girdle (p. 147)

The pectoral girdle is composed of two clavicles and two scapulae. It forms an incomplete ring that supports the upper limbs and provides attachments for muscles.

1. Clavicles
   a. Clavicles are rodlike bones located between the manubrium and scapulae.
   b. They hold the shoulders in place and provide attachments for muscles.
2. Scapulae
   a. The scapulae are broad, triangular bones.
   b. They articulate with the humerus of each upper limb and provide attachments for muscles.

7.10 Upper Limb (p. 148)

Bones of the upper limb provide the frameworks and attachments of muscles, and function in levers that move the limb and its parts.

1. Humerus
   a. The humerus extends from the scapula to the elbow.
   b. It articulates with the radius and ulna at the elbow.
2. Radius
   a. The radius is located on the thumb side of the forearm between the elbow and the wrist.
   b. It articulates with the humerus, ulna, and wrist.
3. Ulna
   a. The ulna is longer than the radius and overlaps the humerus posteriorly.
   b. It articulates with the radius laterally and with a disc of fibrocartilage inferiorly.
4. Wrist and hand
   a. The wrist is composed of eight carpal bones that form a carpus.
   b. The hand includes five metacarpal bones and fourteen phalanges.

7.11 Pelvic Girdle (p. 152)

The pelvic girdle consists of two coxae that articulate with each other anteriorly and with the sacrum posteriorly.

1. The sacrum, coccyx, and pelvic girdle form the bowl-shaped pelvis.
2. Each coxa consists of an ilium, ischium, and pubis, which are fused in the region of the acetabulum.
   a. The ilium
      (1) The ilium is the largest portion of the coxa.
      (2) It joins the sacrum at the sacroiliac joint.
   b. The ischium
      (1) The ischium is the lowest portion of the coxa.
      (2) It supports body weight when sitting.
   c. The pubis
      (1) The pubis is the anterior portion of the coxa.
      (2) The pubic bones are fused anteriorly at the symphysis pubis.

7.12 Lower Limb (p. 154)

Bones of the lower limb provide frameworks for the thigh, leg, ankle, and foot.

1. Femur
   a. The femur extends from the hip to the knee.
   b. The patella articulates with the femur's anterior surface.
2. Tibia
   a. The tibia is located on the medial side of the leg.
   b. It articulates with the talus of the ankle.
3. Fibula
   a. The fibula is located on the lateral side of the tibia.
   b. It articulates with the ankle but does not bear body weight.

4. Ankle and foot
   a. The ankle and foot consist of the tarsus, metatarsus, and five toes.
   b. Included are the talus that helps form the ankle, six other tarsals, five metatarsals, and fourteen phalanges.

7.13 Joints (p. 156)

Joints can be classified according to the type of tissue that binds the bones together.

1. Fibrous joints
   a. Bones at fibrous joints are tightly joined by a layer of dense connective tissue.
   b. Little or no movement occurs at a fibrous joint.
2. Cartilaginous joints
   a. A layer of cartilage joins bones of cartilaginous joints.
   b. Such joints allow limited movement.
3. Synovial joints
   a. The bones of a synovial joint are covered with hyaline cartilage and held together by a fibrous joint capsule.
   b. The joint capsule consists of an outer layer of ligaments and an inner lining of synovial membrane.
   c. Bursae are located between the skin and underlying bony prominences.
   d. Types of synovial joints include: ball-and-socket, condyloid, gliding, hinge, pivot, and saddle.
4. Types of joint movements
   a. Muscles fastened on either side of a joint produce movements of synovial joints.
   b. Joint movements include flexion, extension, dorsiflexion, plantar flexion, hyperextension, abduction, adduction, rotation, circumduction, pronation, supination, eversion, inversion, retraction, protraction, elevation, and depression.

REVIEW EXERCISES

Part A

1. Sketch a typical long bone, and label its epiphyses, diaphysis, medullary cavity, periosteum, and articular cartilages. (p. 128)
2. Distinguish between spongy and compact bone. (p. 128)
3. Explain how central canals and perforating canals are related. (p. 129)
4. Explain how the development of intramembranous bone differs from that of endochondral bone. (p. 130)
5. Distinguish between osteoblasts and osteocytes. (p. 130)
6. Explain the function of an epiphyseal plate. (p. 130)
7. Explain how a bone thickens. (p. 131)
8. Provide several examples to illustrate how bones support and protect body parts. (p. 131)
9. Describe a lever. (p. 133)
10. Explain how upper limb movements function as levers. (p. 133)
11. Describe the functions of red and yellow bone marrow. (p. 133)
12. Explain the mechanism that regulates the concentration of blood calcium ions. (p. 134)
13. Distinguish between the axial and appendicular skeletons. (p. 135)
14. Name the bones of the cranium and the facial skeleton. (p. 136)
15. Explain the importance of fontanels. (p. 142)
16. Describe a typical vertebra. (p. 142)
17. Explain the differences among the cervical, thoracic, and lumbar vertebrae. (p. 143)
18. Name the bones that comprise the thoracic cage. (p. 147)
19. List the bones that form the pectoral and pelvic girdles. (p. 147)
20. Name the bones of the upper limb. (p. 148)
21. Name the bones that comprise a coxa. (p. 152)
22. List the bones of the lower limb. (p. 154)
23. Define *joint.* (p. 156)
24. Describe a fibrous joint, a cartilaginous joint, and a synovial joint. (p. 156)
25. Define *bursa.* (p. 157)
26. List six types of synovial joints, and name an example of each type. (p. 158)

Part B

Match the parts listed in column I with the bones listed in column II.

I	II
1. Coronoid process	a. Ethmoid bone
2. Cribriform plate	b. Frontal bone
3. Foramen magnum	c. Mandible
4. Mastoid process	d. Maxilla
5. Palatine process	e. Occipital bone
6. Sella turcica	f. Temporal bone
7. Supraorbital foramen	g. Sphenoid bone
8. Temporal process	h. Zygomatic bone
9. Acromion process	i. Femur
10. Deltoid tuberosity	j. Fibula
11. Greater trochanter	k. Humerus
12. Lateral malleolus	l. Radius
13. Medial malleolus	m. Scapula
14. Olecranon process	n. Sternum
15. Radial tuberosity	o. Tibia
16. Xiphoid process	p. Ulna

Part C

Match the movements in column I with the descriptions in column II.

I	II
1. Rotation	a. Turning palm upward
2. Supination	b. Decreasing angle between parts
3. Extension	c. Moving part forward
4. Eversion	d. Moving part around an axis
5. Protraction	e. Turning sole of foot to face laterally
6. Flexion	f. Increasing angle between parts
7. Pronation	g. Lowering a part
8. Abduction	h. Turning palm downward
9. Depression	i. Moving part away from midline

CRITICAL THINKING

1. How does the structure of a bone make it strong yet lightweight?
2. Archaeologists discover skeletal remains of humanlike animals in Ethiopia. Examination of the bones suggests that the remains represent four types of individuals. Two of the skeletons have bone densities that are 30% less than those of the other two skeletons. The skeletons with the lower bone mass also have broader front

pelvic bones. Within the two groups defined by bone mass, smaller skeletons have bones with evidence of epiphyseal plates, but larger bones have only a thin line where the epiphyseal plates should be. Give the age group and gender of the individuals in this find.

3. When a child's bone is fractured, growth may be stimulated at the epiphyseal plate of that bone. What problems might this extra growth cause in an upper or lower limb before the growth of the other limb compensates for the difference in length?

4. Compared to the shoulder and hip joints, in what way is the knee joint poorly protected and thus especially vulnerable to injuries?

WEB CONNECTIONS

Visit the website for additional study questions and more information about this chapter at:

http://www.mhhe.com/shieress8