7

Skeletal System

Spaces develop in bones when a person has osteoporosis. The vertebra on the left is normal; the one on the right has been weakened by osteoporosis.

PREVENTING "FRAGILITY FRACTURES." Skeletal health is a matter of balance. Before age 30, cells that form new bone tissue counter cells that degrade it, so that living bone is in a constant state of remodeling. Then the balance shifts so that bone is lost, especially in women past menopause, due to hormonal changes. This imbalance may progress to osteopenia or the more severe osteoporosis.

A "fragility fracture" is a telltale sign of dangerously low bone density. This is a fracture that happens after a fall from less than standing height, which a strong, healthy skeleton could resist. Fragility fractures occur in 1.5 million people in the United States each year, yet despite this warning sign, only one-fourth to one-third of them are followed up with bone scans and treatment to build new bone tissue. Since 1995, five new drugs have become available to treat osteoporosis. One class, the bisphosphonates, actually builds new bone.

Osteopenia and osteoporosis are common. The surgeon general estimates that half of all people over age 50 have one of these conditions, which amounts to 10 million with osteoporosis and another 35 million with osteopenia. Screening is advised for all individuals over age 65, as well as for those with risk factors. The most telling predictor is a previous fragility fracture. Other risk factors include a family history of osteoporosis, recent height loss, and older age.

Osteopenia and osteoporosis are assessed by measuring bone mineral density (BMD). This is most often done in the hip bone and lower spine with a technique called dual-energy X-ray absorptiometry. Osteopenia ("low bone mass") is defined as BMD at least 1 to 2.5 standard deviations below the mean. Osteoporosis is defined as bone mass at least 2.5 standard deviations below the mean for young adults. These measurements produce T values. Another measurement, a Z value, compares BMD to other individuals of a person's age and is used for individuals under age 65.

These two conditions are not just concerns of people approaching retirement age, because they can be prevented. Researchers think that what puts people at risk is failure to attain maximal possible bone density by age 30. To keep bones as strong as possible for as long as possible, it is essential to get at least 30 minutes of exercise daily (some of which should be weight-bearing), consume enough daily calcium (1,000–1,200 mg) and vitamin D (200 IU), and not smoke. There is much you can do to promote skeletal health—at any age.

Learning Outcomes

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

7.1 Introduction

1. List the active tissues in a bone. (p. 131)

7.2 Bone Structure

2. Describe the macroscopic and microscopic structure of a long bone, and list the functions of these parts. (p. 131)

7.3 Bone Development and Growth

3. Distinguish between intramembranous and endochondral bones, and explain how such bones develop and grow. (p. 133)

7.4 Bone Function

4. Discuss the major functions of bones. (p. 135)

7.5 Skeletal Organization

5. Distinguish between the axial and appendicular skeletons, and name the major parts of each. (p. 139)

7.6–7.12 Skull—Lower Limb

6. Locate and identify the bones and the major features of the bones that compose the skull, vertebral column, thoracic cage, pectoral girdle, upper limb, pelvic girdle, and lower limb. (p. 142)

7.13 Joints

7. Classify joints according to the type of tissue binding the bones together, describe their characteristics, and name an example of each. (p. 162)
8. List six types of synovial joints, and describe the actions of each. (p. 163)
9. Explain how skeletal muscles produce movements at joints, and identify several types of joint movements. (p. 165)

Aids to Understanding Words

(Appendix A on page 567 has a complete list of Aids to Understanding Words.)

acetabul- [vinegar cup] *acetabul*um: Depression of the hip bone 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 [bud] 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.

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 that forms blood cells.

7.1 INTRODUCTION

Halloween skeletons and the skull-and-crossbones symbol for poison and pirates may make bones seem like lifeless objects. However, bone consists of a variety of very active, living tissues: bone tissue, cartilage, dense connective tissue, blood, and nervous tissue. 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 form passageways for blood vessels and nerves.

7.2 BONE STRUCTURE

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

Bone Classification

Bones are classified according to their shapes—long, short, flat, irregular, or sesamoid (round).

- **Long bones** have long longitudinal axes and expanded ends. Examples of long bones are the forearm and thigh bones.
- **Short bones** are somewhat cubelike, with their lengths and widths roughly equal. The bones of the wrists and ankles are this type.
- **Flat bones** are platelike structures with broad surfaces, such as the ribs, scapulae, and some bones of the skull.
- **Irregular bones** have a variety of shapes and are usually connected to several other bones. Irregular bones include the vertebrae that comprise the backbone and many facial bones.
- **Sesamoid (round) bones** are usually small and nodular and are embedded within tendons adjacent to joints. The kneecap (patella) is a sesamoid bone.

Parts of a Long Bone

The femur, the 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. One epiphysis, called the proximal epiphysis, is nearest to the center of the body. The other, called the distal epiphysis, is farthest from the center of the body. 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, 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 the connecting ligaments and tendons. 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 where ligaments and tendons 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 extracellular matrix with no spaces. 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

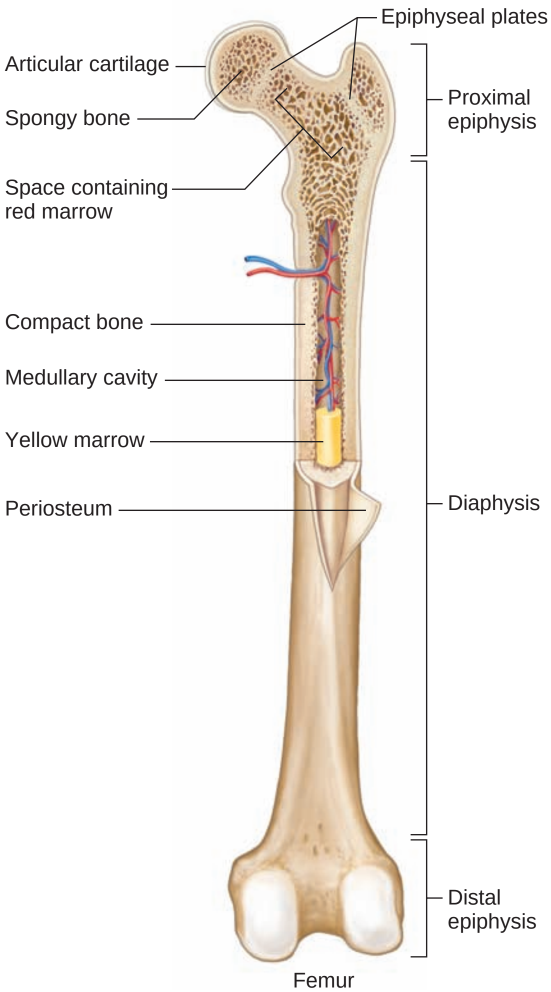


Figure 7.1
Major parts of a long bone. This is a femur, the long bone in the thigh.

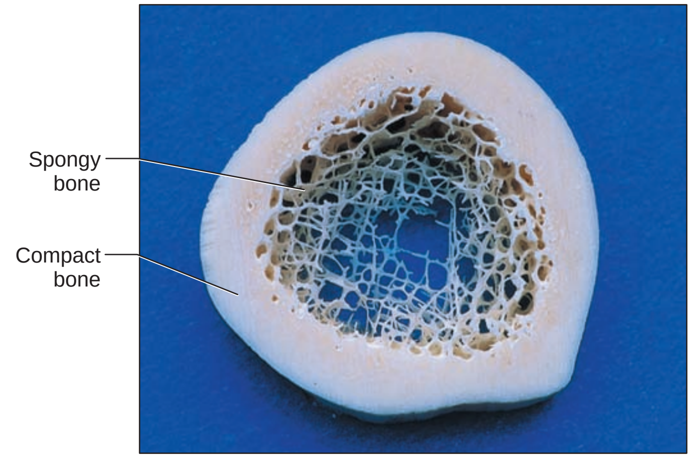


Figure 7.2
This cross section of a long bone reveals a layer of spongy bone beneath a layer of compact bone.

of numerous branching bony plates. Irregular connecting spaces between these plates help reduce the bone's weight (fig. 7.2). 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.

Compact bone in the diaphysis of a long bone forms a semirigid tube, which has 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 the **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. 108) that bone cells called *osteocytes* occupy very small, bony chambers called *lacunae,* which form concentric circles around *central canals* (Haversian canals) (fig. 7.3; see fig. 5.19, p. 108). Osteocytes communicate with nearby cells by means of cellular processes passing through *canaliculi*. The extracellular matrix of bone tissue is largely composed of collagen and inorganic salts (calcium phosphate). 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 extracellular matrix 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. The 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 extracellular matrix, but the bone cells do not aggregate around central canals. Instead, the cells lie within the *trabeculae* and get nutrients from substances diffusing into canaliculi that lead to the surface of these thin, bony plates.

Check Your Recall

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

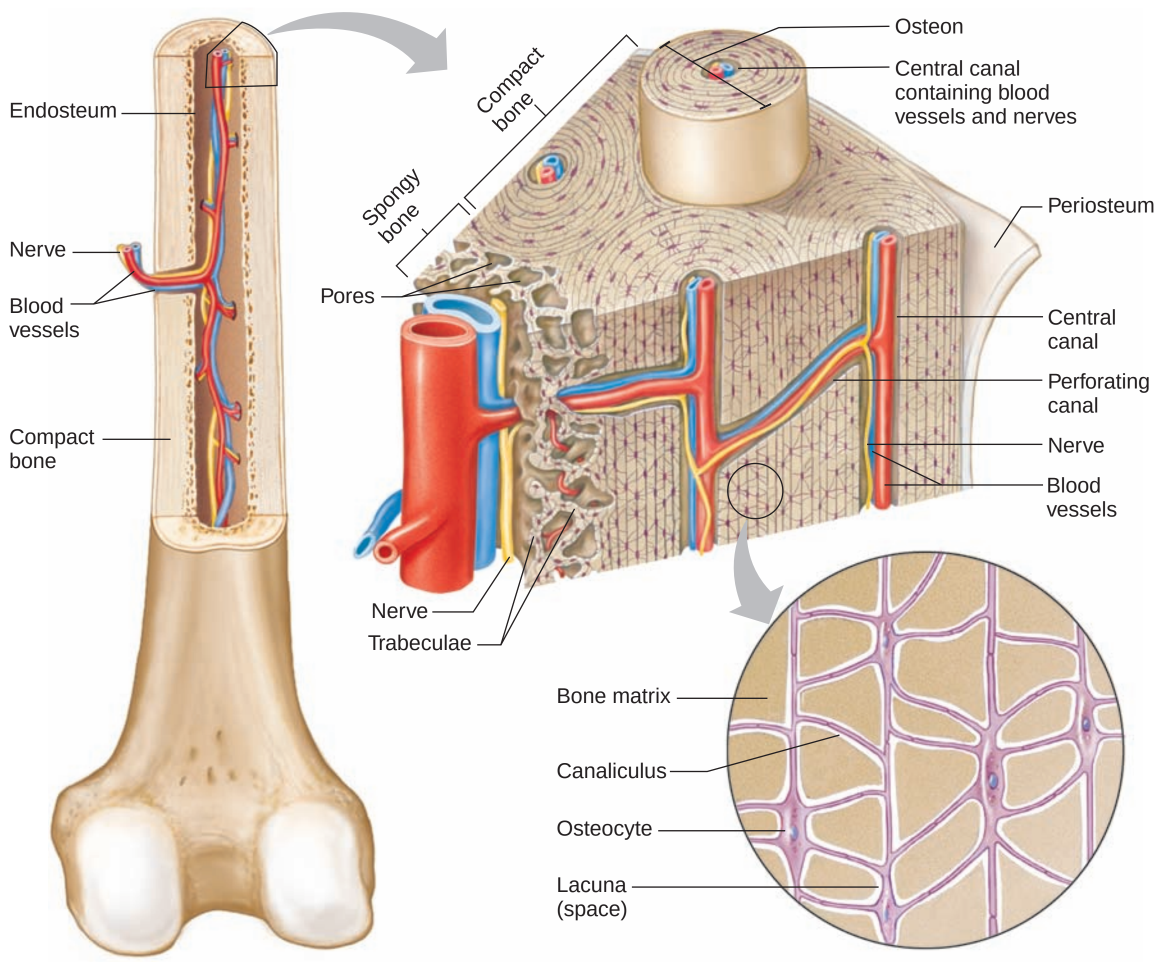


Figure 7.3

Compact bone is composed of osteons cemented by bone matrix. Drawing is not to scale. Extensions from osteocytes communicate through tunnel-like canaliculi.

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 are later replaced by bone tissue.

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 unspecialized, or relatively undifferentiated, connective tissues appear at the sites of the future bones. Then, some of the partially differentiated progenitor cells enlarge and further differentiate into bone-forming

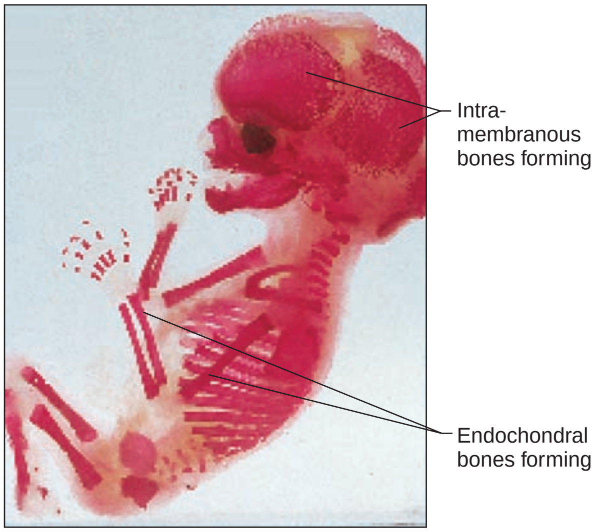


Figure 7.4

Intramembranous bones in the fetus form by replacing unspecialized connective tissue. Endochondral bones form from cartilage "models" that are gradually replaced with the harder tissue of bone. Note the stained, developing bones of this fourteen-week fetus.

cells called **osteoblasts** (os′te-o-blastz). The osteoblasts become active within the layers of connective tissue and deposit bony matrix around themselves. As a result, spongy bone tissue forms in all directions within the layers of connective tissues. When extracellular matrix completely surrounds osteoblasts, they are called **osteocytes.** 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. The formation of bone is called **ossification** (os″ĭ-fi-ka′shun).

Endochondral Bones

Most of the bones of the skeleton are **endochondral bones** (en″do-kon′dral bōnz). They develop in the fetus 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 change extensively.

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

In time, large, multinucleated cells called **osteoclasts** (os′te-o-klastz) break down the calcified extracellular matrix. These large cells originate in bone marrow when certain single-nucleated white blood cells (monocytes) fuse (see chapter 12, p. 323).

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 extracellular 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 (fig. 7.6). However, once the ossification centers of the diaphysis and epiphyses meet and the epiphyseal plates

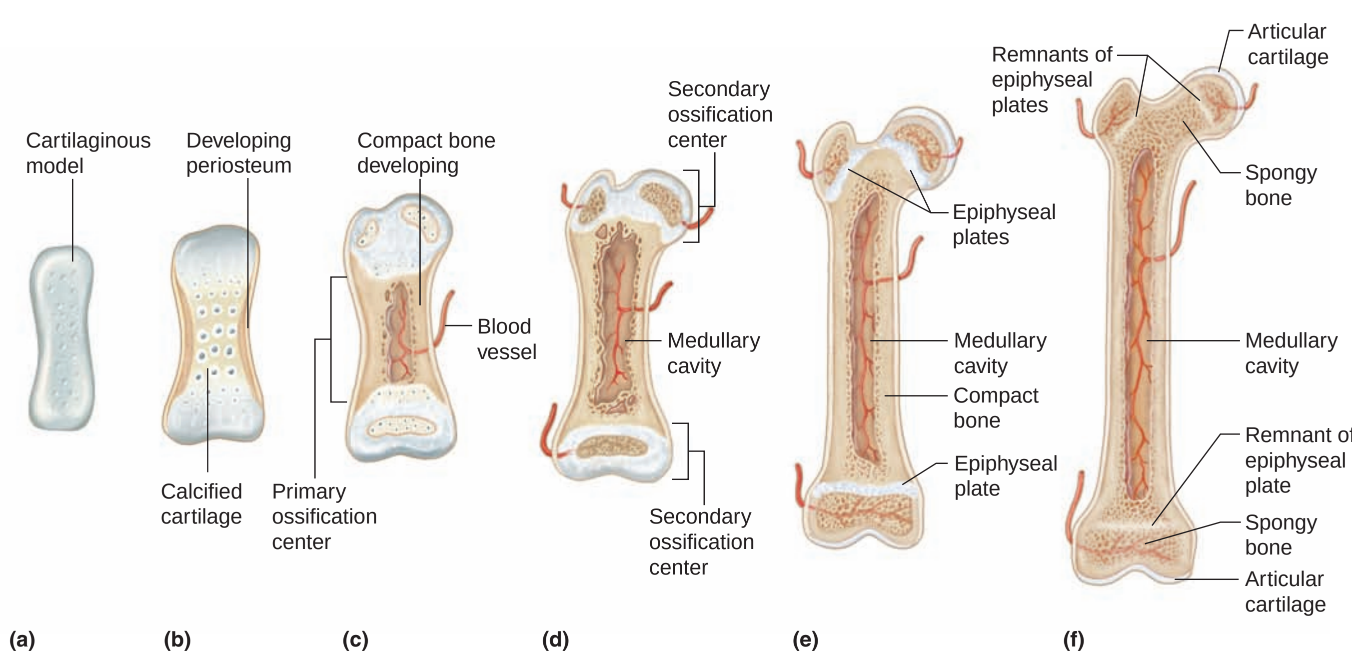


Figure 7.5
Major stages (*a–d* fetal, *e* child, *f* adult) in the development of an endochondral bone. (Relative bone sizes are not to scale.)

Figure 7.6

Radiograph showing epiphyseal plates (arrows) in a child's bones indicates that the bones are still lengthening.

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. An epiphysis is sometimes altered surgically in order 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 that regulate blood calcium help control these opposing processes of *resorption* and *deposition* of matrix (see chapter 11, pp. 300–301). 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.

Factors Affecting Bone Development, Growth, and Repair

A number of factors influence bone development, growth, and repair. These include nutrition, hormonal secretions, and physical exercise. For example, vitamin D is necessary for proper absorption of calcium in the small intestine. In the absence of this vitamin, calcium (provided it is present through dietary consumption) is poorly absorbed, and the inorganic salt portion of bone matrix lacks calcium, softening and thereby deforming bones. Growth hormone secreted by the pituitary gland stimulates division of the cartilage cells in the epiphyseal plates. Sex hormones stimulate ossification of the epiphyseal plates. Physical exercise pulling on muscular attachments to bones stresses the bones, stimulating the bone tissue to thicken and strengthen. The Topic of Interest on pages 136–137 discusses bone repair.

> 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

5. Describe the development of an intramembranous bone.
6. Explain how an endochondral bone develops.
7. Explain how osteoclasts and osteoblasts remodel bone.
8. Explain how nutritional factors, hormones, and physical exercise affect bone development and growth.

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 structures such as the head, face, thorax, and limbs. They 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 the bones of the pelvic girdle protect the lower abdominal and internal reproductive organs.

Topic of Interest

Bone Fractures

A *fracture* is a break in a bone. A fracture is classified by its cause as a traumatic, spontaneous, or pathologic fracture and by the nature of the break as a greenstick, fissured, comminuted, transverse, oblique, or spiral fracture (fig. 7A). A broken bone exposed to the outside by an opening in the skin is termed a compound (open) fracture.

Whenever a bone breaks, blood vessels within it 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 hya-

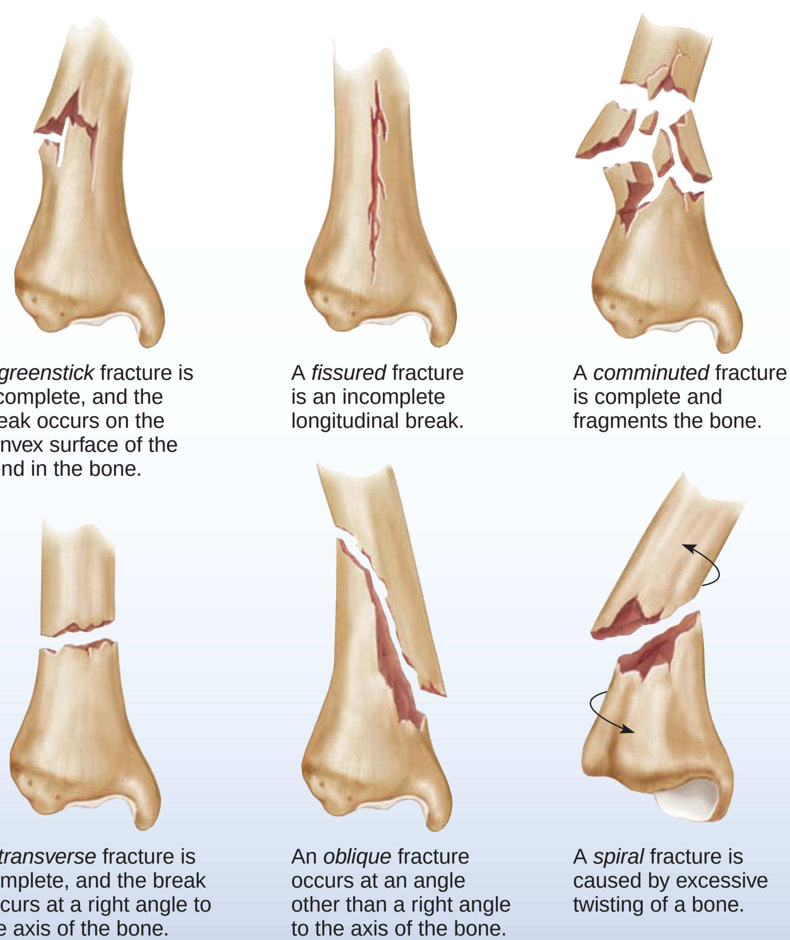
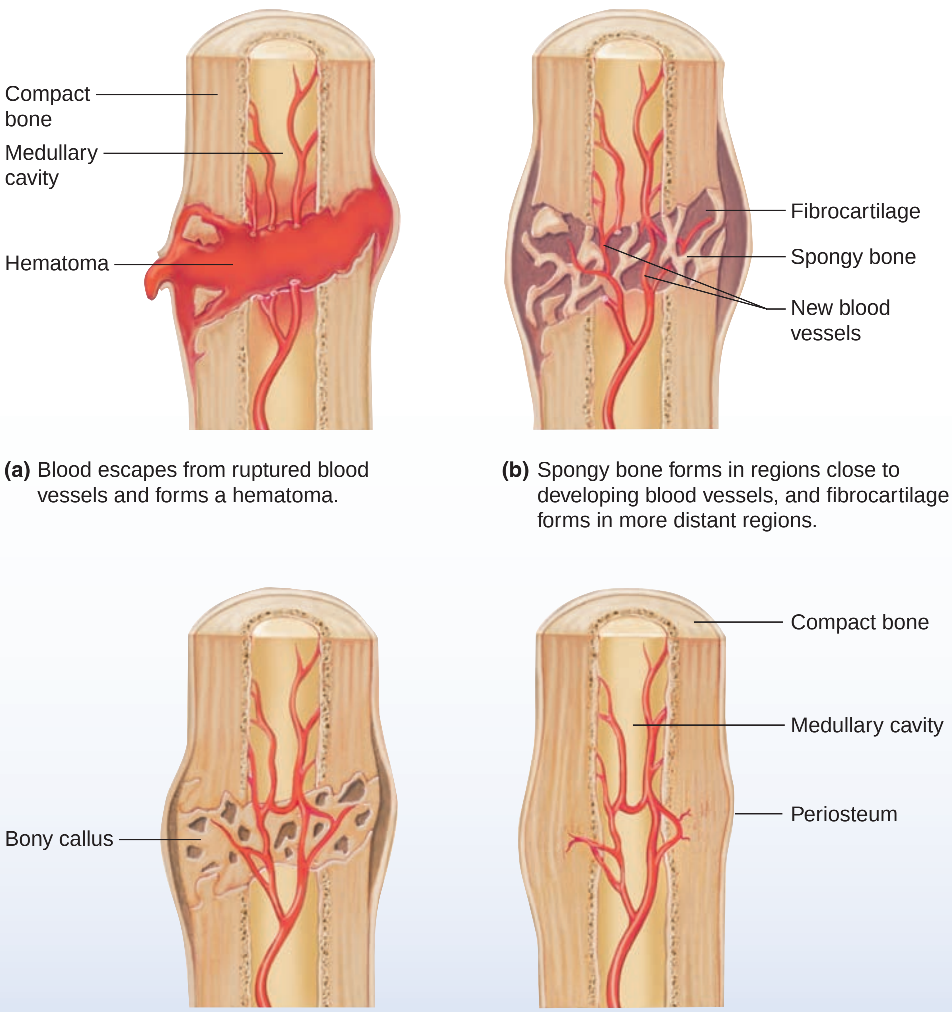


Figure 7A
Various types of fractures.

line 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. 7B).

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 device 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.



(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.

Figure 7B

Major steps (*a–d*) in repair of a fracture.

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 bar or rod, (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 to move the bar.

The actions of bending and straightening the upper limb at the elbow illustrate bones and muscles functioning as levers. When the upper limb bends, the forearm bones represent the rigid bar, the elbow joint is the fulcrum, the hand is moved against the resistance provided by the weight, and the force is supplied by muscles on the anterior side of the arm (fig. 7.7*a*). 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 bar, the elbow joint serves as the fulcrum, and the hand moves against the resistance by pulling on the rope to raise the weight (fig. 7.7*b*). 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 forearm bone (ulna) at the point of the elbow.

Blood Cell Formation

The process of blood cell formation, called **hematopoiesis** (he″mă-to-poi-e′sis), begins in the *yolk sac,* which lies outside the human embryo (see chapter 20, p. 549). 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. Red marrow's color comes from the oxygen-carrying pigment **hemoglobin** in the red blood cells.

In an infant, red marrow occupies the cavities of most bones. With increasing age, however, yellow marrow replaces much of it. *Yellow marrow* stores fat; it is not active in blood cell production. In an adult, red marrow is primarily found in the spongy bone of the skull, ribs, sternum, clavicles, vertebrae, and hip bones. However, if the body requires more blood, yellow marrow can be replaced by extensions of red bone marrow from elsewhere in the bone, which then reverts to yellow marrow when there is enough or a surplus of blood. Chapter 12 (pp. 320, 323, and 325) describes blood cell formation in more detail.

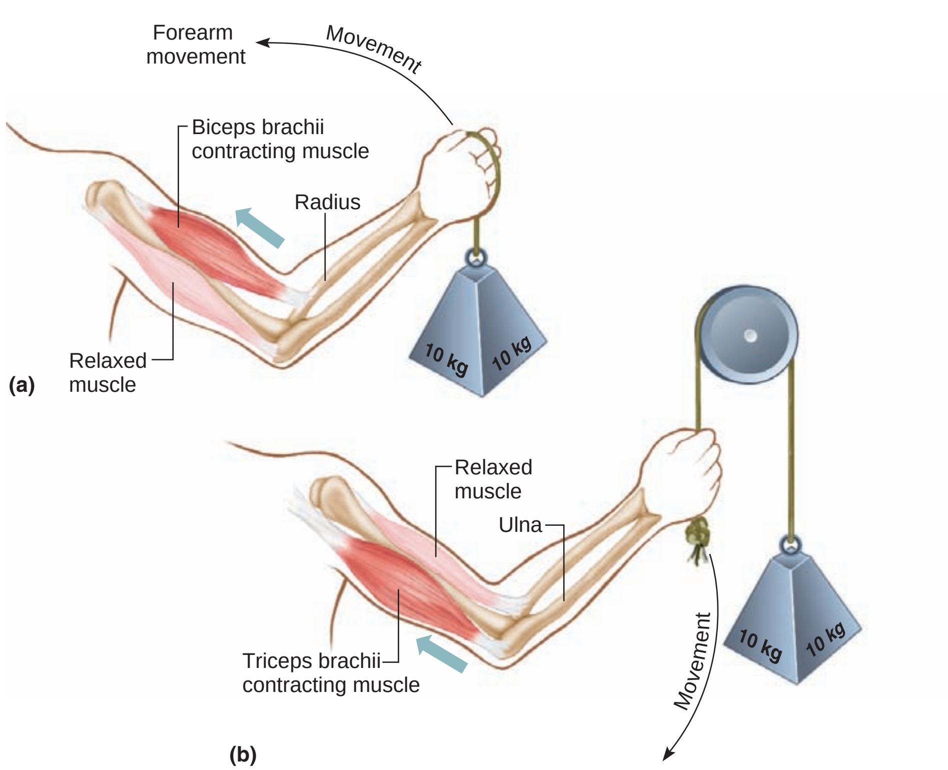


Figure 7.7

Bones and muscles form lever systems when they interact to move body parts. (*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.

In bone marrow transplant (BMT) 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 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, 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 damages bone marrow. BMT is used when other cancer treatments have failed. 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. In one clinical trial, for example, a patient's own bone marrow progenitor cells are taken from the hip bone and injected into failing heart muscle.

Storage of Inorganic Salts

Bones store calcium. The extracellular 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 extracellular 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 extracellular matrix (fig. 7.8). Chapter 11 (p. 300) describes the details of this homeostatic mechanism. Maintaining sufficient blood calcium levels is important in muscle contraction, nerve impulse conduction, blood clotting, and other physiological processes.

Bone tissue includes fewer magnesium, sodium, potassium, and carbonate ions than it does 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.

Check Your Recall

9. Name the major functions of bones.
10. Distinguish between the functions of red marrow and yellow marrow.
11. List the substances normally stored in bone tissue.

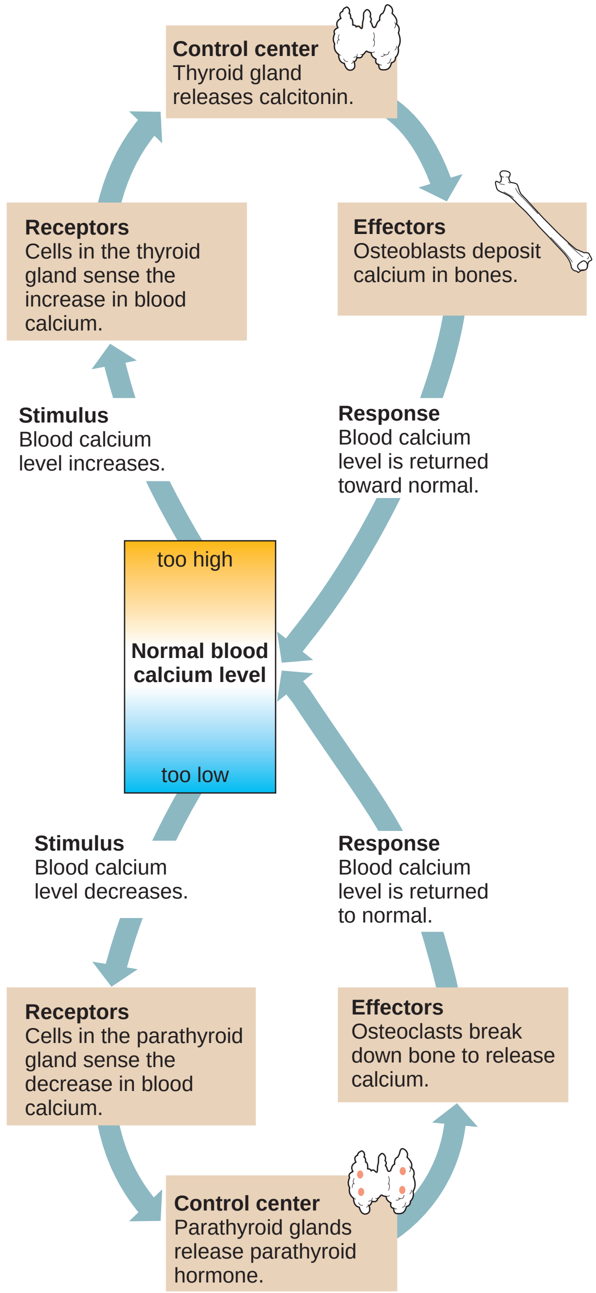


Figure 7.8
Hormones regulate deposition and resorption of bone calcium.

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. 7.9). 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.*

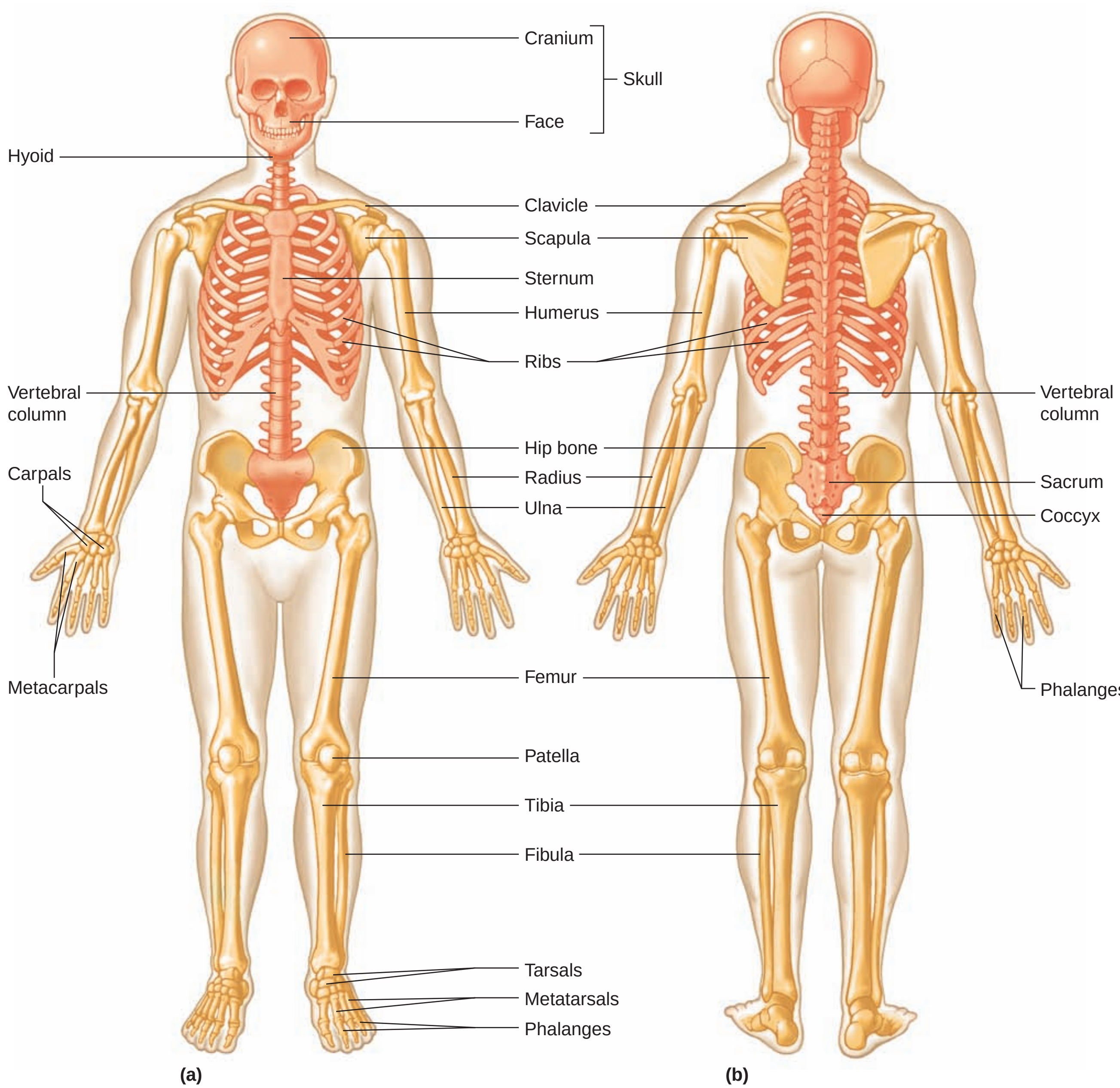


Figure 7.9

Major bones of the skeleton. (*a*) Anterior view. (*b*) Posterior view. The axial portion is shown in orange, and the appendicular portions are shown in yellow.

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 end, several vertebrae fuse to form the **sacrum** (sa′krum), which is part of the pelvis. The **coccyx** (kok′siks), a small, rudimentary tailbone composed of several fused vertebrae, 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), or breastbone, 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** (pek′to-ral) **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 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 hand. 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); singular, *phalanx* (fa′lanks).
3. **Pelvic girdle** Two hip bones 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 thigh bone, two leg bones—a large **tibia** (tib′e-ah) and a slender **fibula** (fib′u-lah)—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 foot. There are seven **tarsals** (tahr′sals), or ankle bones. 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

12. Distinguish between the axial and appendicular skeletons.
13. List the bones of the axial skeleton and of the appendicular skeleton.

Table 7.1 Bones of the Adult Skeleton

1. Axial Skeleton		
a. Skull		
8 cranial bones		
frontal 1	temporal 2	
parietal 2	sphenoid 1	
occipital 1	ethmoid 1	
14 facial bones		
maxilla 2	lacrimal 2	
zygomatic 2	nasal 2	
palatine 2	vomer 1	
inferior nasal concha 2		
mandible 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		
hip 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. 7.13)
Crest (krest)	A narrow, ridgelike projection	Iliac crest of ilium (fig. 7.28)
Epicondyle (ep″ĭ-kon′dīl)	A projection situated above a condyle	Medial epicondyle of humerus (fig. 7.24)
Facet (fas′et)	A small, nearly flat surface	Rib facet of thoracic vertebra (fig. 7.17)
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. 7.16)
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. 7.13)
Fossa (fos′ah)	A relatively deep pit or depression	Olecranon fossa of humerus (fig. 7.24)
Fovea (fo′ve-ah)	A tiny pit or depression	Fovea capitis of femur (fig. 7.30)
Head (hed)	An enlargement on the end of a bone	Head of humerus (fig. 7.24)
Meatus (me-a′tus)	A tubelike passageway within a bone	External acoustic meatus of ear (fig. 7.12)
Process (pros′es)	A prominent projection on a bone	Mastoid process of temporal bone (fig. 7.12)
Sinus (si′nus)	A cavity within a bone	Frontal sinus of frontal bone (fig. 7.15)
Spine (spīn)	A thornlike projection	Spine of scapula (fig. 7.23)
Suture (soo′cher)	An interlocking line of union between bones	Lambdoid suture between occipital and parietal bones (fig. 7.12)
Trochanter (tro-kan′ter)	A relatively large process	Greater trochanter of femur (fig. 7.30)
Tubercle (tu′ber-kl)	A small, knoblike process	Greater tubercle of humerus (fig. 7.24)
Tuberosity (tu″bĕ-ros′ĭ-te)	A knoblike process usually larger than a tubercle	Radial tuberosity of radius (fig. 7.25)

7.6 SKULL

A human skull usually consists of twenty-two bones that, except for the lower jaw, are firmly interlocked along *sutures* (soo′cherz) (fig. 7.10). Eight of these interlocked bones make up the cranium, and fourteen 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 in each middle ear are discussed in chapter 10, p. 269.) Reference plates 8–11 on pages 173–175 show 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 *paranasal sinuses,* which are lined with mucous membranes and connected by passageways to the nasal cavity (fig. 7.11). 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, shown in figures 7.10 and 7.12, are:

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 (see fig. 7.11).
2. **Parietal bones** One parietal (pah-ri′ĕ-tal) bone is located on each side of the skull just behind the frontal bone (fig. 7.12). 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 *lambdoid* (lam′doid) *suture* (figs. 7.12 and 7.13). 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 *occipital condyles,* located on each side of the foramen magnum, articulate with the first vertebra (atlas) of the vertebral column.

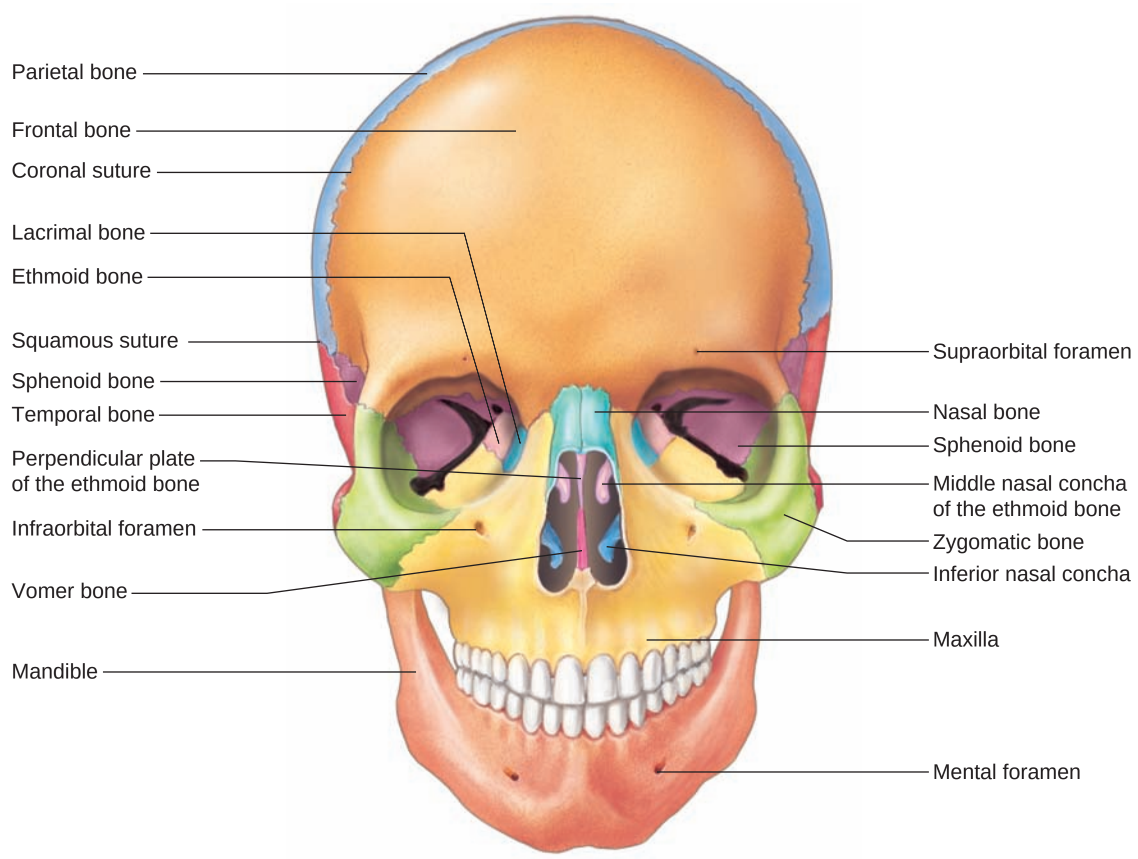


Figure 7.10
Anterior view of the skull.

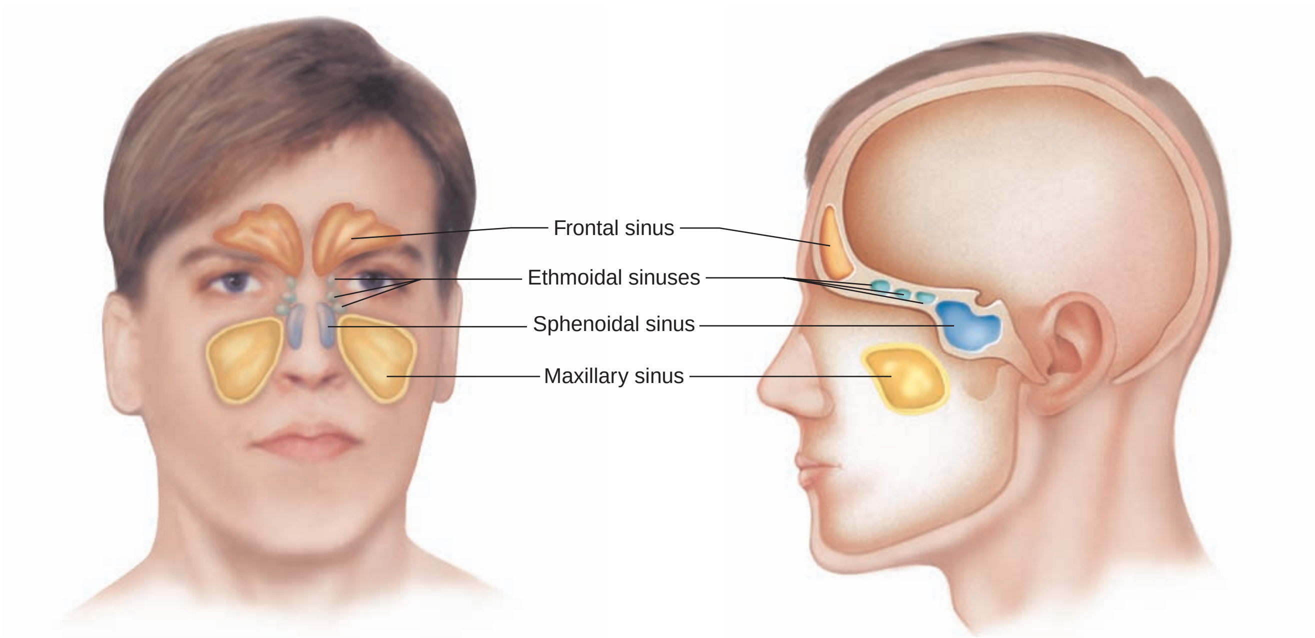


Figure 7.11
Locations of the paranasal sinuses.

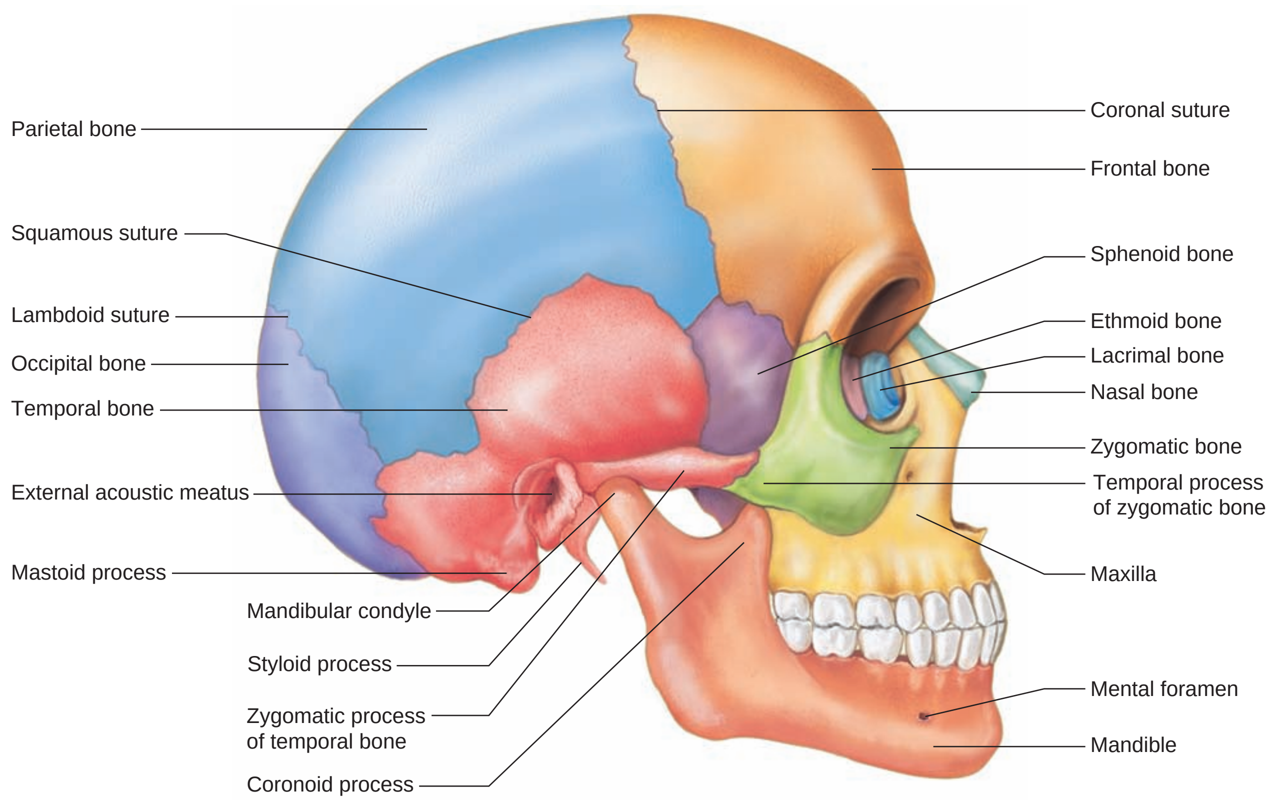


Figure 7.12
Right lateral view of the skull.

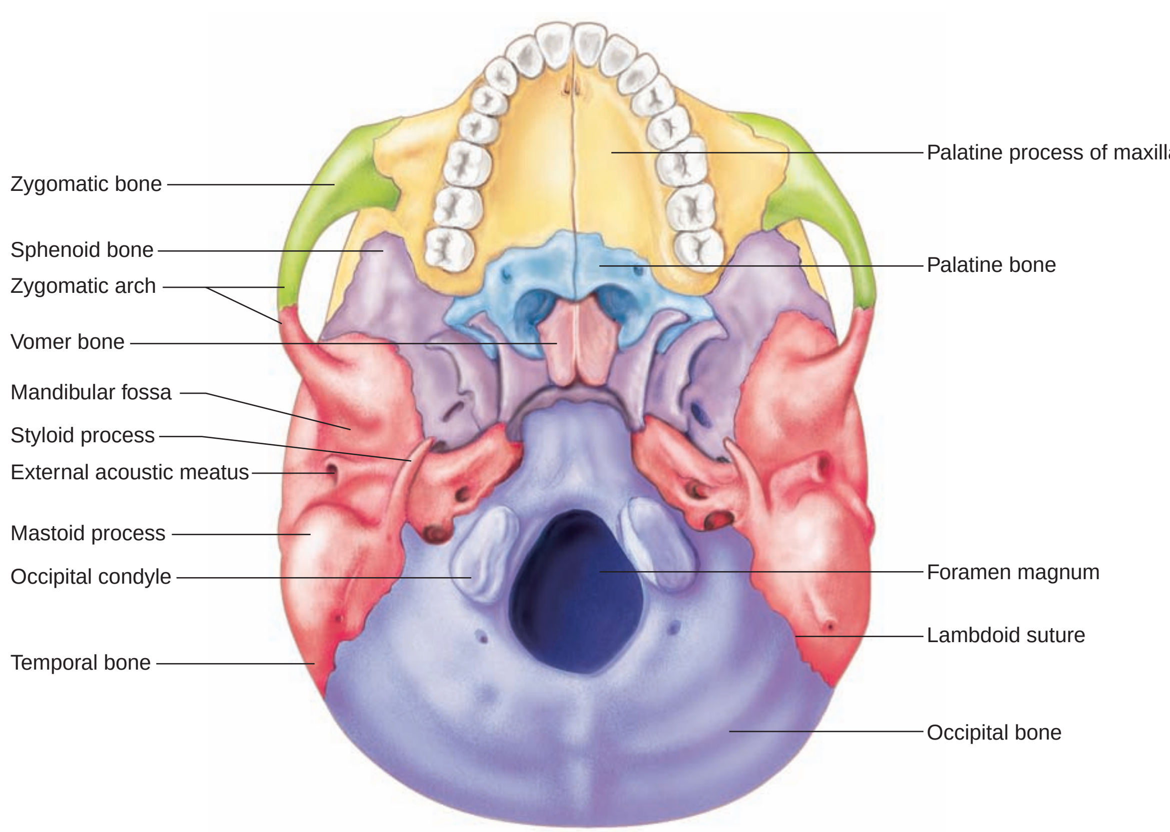


Figure 7.13
Inferior view of the skull.

4. **Temporal bones** A temporal (tem′po-ral) bone on each side of the skull joins the parietal bone along a *squamous suture* (see figs. 7.10 and 7.12). The temporal bones form parts of the sides and the base of the cranium. Located near the inferior margin is an opening, the *external acoustic 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 acoustic 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. 7.12 and 7.13). 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. 7.11).
6. **Ethmoid bone** The ethmoid (eth′moid) bone is located in front of the sphenoid bone (figs. 7.12 and 7.14). 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. 7.14).

    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. 7.14 and 7.15). 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. 7.15).

    Delicate scroll-shaped plates called the *superior nasal conchae* (kong′ke) and the *middle nasal conchae* project inward from the lateral portions of the ethmoid

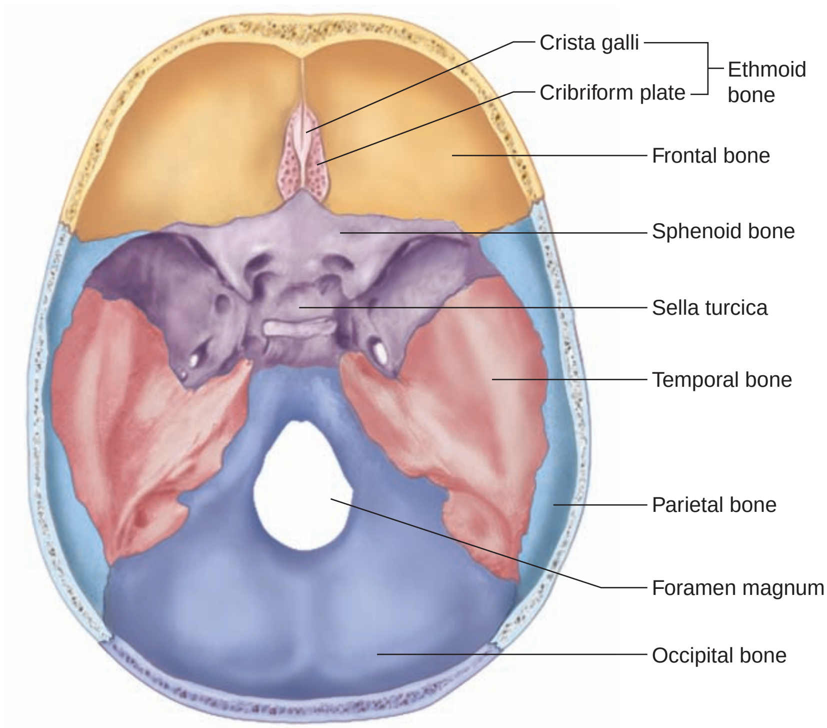


Figure 7.14

Floor of the cranial cavity, viewed from above.

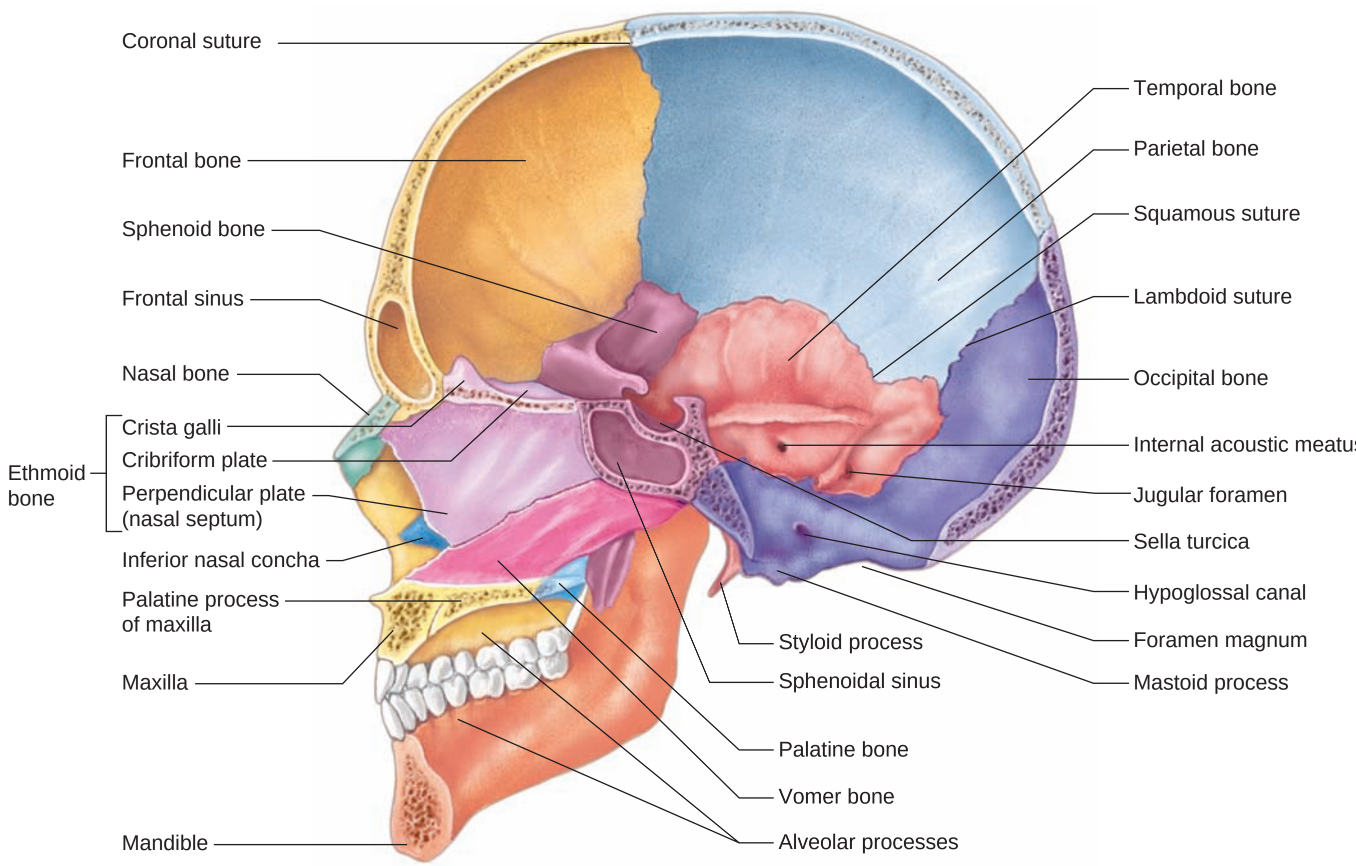


Figure 7.15
Sagittal section through the skull.

bone toward the perpendicular plate (see fig. 7.10). The lateral portions of the ethmoid bone contain many small air spaces, the *ethmoidal sinuses* (see fig. 7.11).

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. 7.12 and 7.13). 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. 7.11).

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* (fig. 7.15). Together, these processes form a horseshoe-shaped *alveolar arch* (dental arch). 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 into 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. 7.13 and 7.15). 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. 7.12 and 7.13). 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. 7.10 and 7.12).
5. **Nasal bones** The nasal (na′zal) bones are long, thin, and nearly rectangular (see figs. 7.10 and 7.12). 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. 7.10 and 7.15). 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 are fragile, scroll-shaped bones attached to the lateral walls of the nasal cavity (see figs. 7.10 and 7.15). Like the superior and middle 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. 7.10 and 7.12). 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. 7.13), whereas the coronoid processes provide attachments for muscles used in chewing. 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.

Infantile Skull

At birth, the skull is incompletely developed, with fibrous membranes connecting the cranial bones. These membranous areas of incomplete intramembranous ossification are called **fontanels** (fon″tah-nelz′) or, more commonly, soft spots (fig. 7.16). 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 skull bones.

Check Your Recall

14. Locate and name each of the bones of the cranium.
15. Locate and name each of the facial bones.
16. 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. 7.17). 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

Although vertebrae in different regions of the vertebral column have special characteristics, they also have features in common. A typical vertebra has a drum-shaped *body,* which forms the thick, anterior portion of the bone (fig. 7.18). 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.

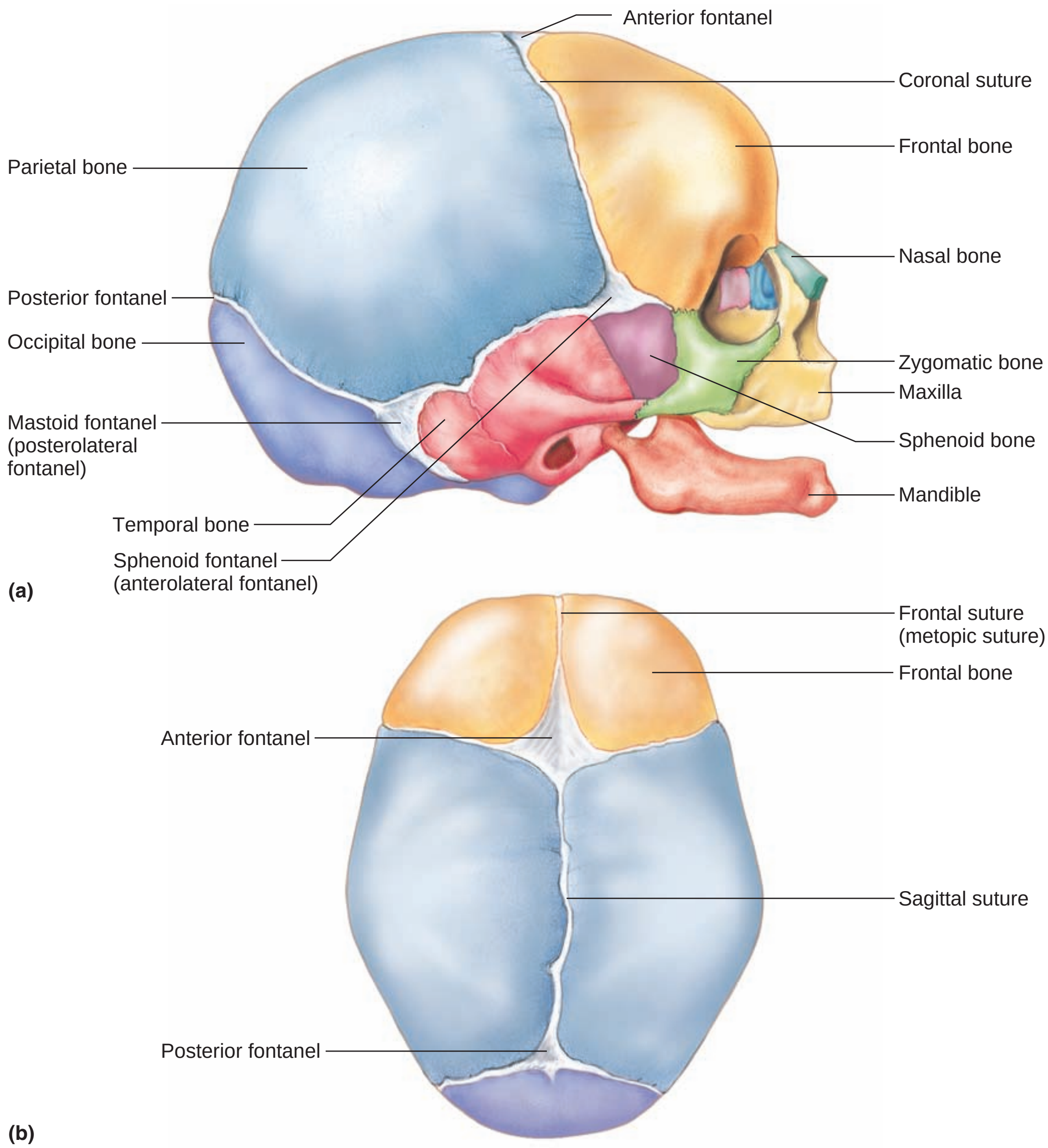


Figure 7.16

Fontanels. (*a*) Right lateral view and (*b*) superior view of the infantile skull.

> If the laminae of the vertebrae fail to unite during development, the vertebral arch remains incomplete, causing a condition called *spina bifida*. The contents of the vertebral canal protrude outward. This problem occurs most frequently in the lumbosacral region. Spina bifida is associated with folic acid deficiency in certain genetically susceptible individuals.

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 articular processes*. These processes bear cartilage-covered facets by which each vertebra is joined to the one above and the one below it.

On the lower surfaces of the vertebral pedicles are notches that align with adjacent vertebrae to form openings called *intervertebral foramina* (in″ter-ver′tě-bral fo-ram′ĭ-nah) (see fig. 7.17). These openings provide passageways for spinal nerves.

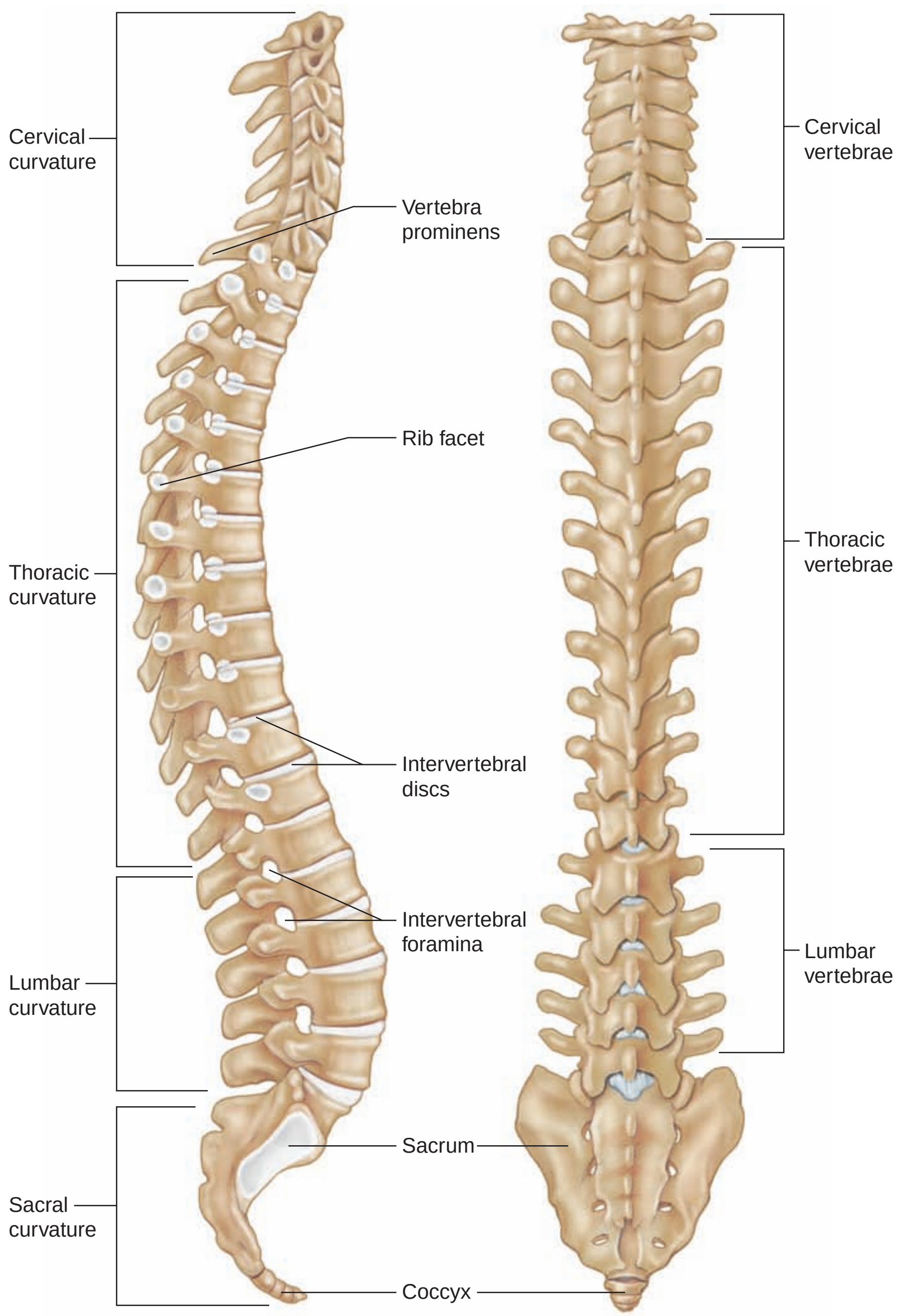


Figure 7.17

The curved vertebral column consists of many vertebrae separated by intervertebral discs. (*a*) Right lateral view. (*b*) Posterior view.

Cervical Vertebrae

Seven **cervical vertebrae** comprise the bony axis of the neck (see fig. 7.17). The transverse processes of these vertebrae are distinctive because they have *transverse foramina,* which are passageways for arteries leading to the brain (see fig. 7.18*a*). Also, the spinous processes of the second through the fifth cervical vertebrae are uniquely forked (bifid). These processes provide attachments for muscles.

Two of the cervical vertebrae are of special interest: the atlas and the axis (fig. 7.19). 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.

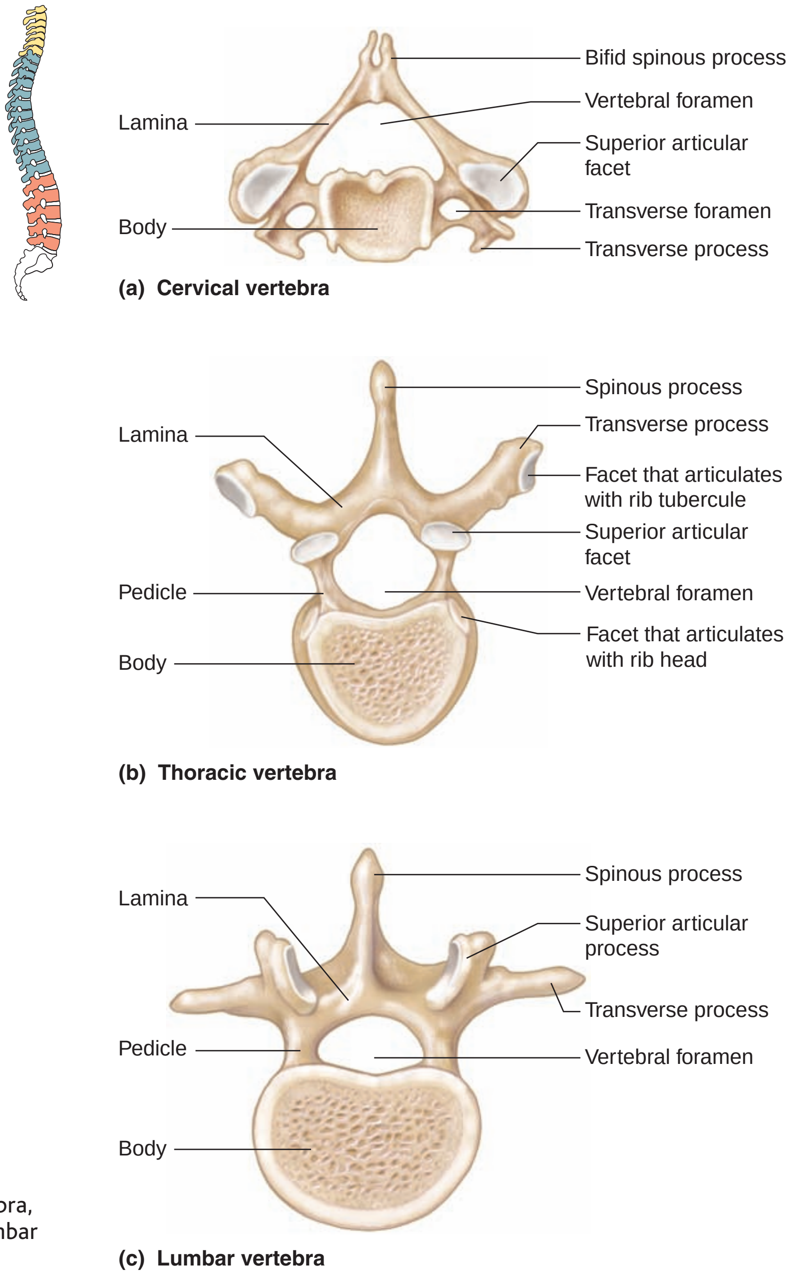


Figure 7.18
Superior view of (*a*) a cervical vertebra, (*b*) a thoracic vertebra, and (*c*) a lumbar vertebra.

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

Thoracic Vertebrae

The twelve **thoracic vertebrae** are larger than the cervical vertebrae (see fig. 7.17). Each vertebra has a long, pointed spinous process, which slopes downward, and facets on the sides of its body, which articulate with a rib (see fig. 7.18*b*).

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. 7.17). These vertebrae are adapted with larger and stronger bodies to support more weight than the vertebrae above them (see fig. 7.18*c*).

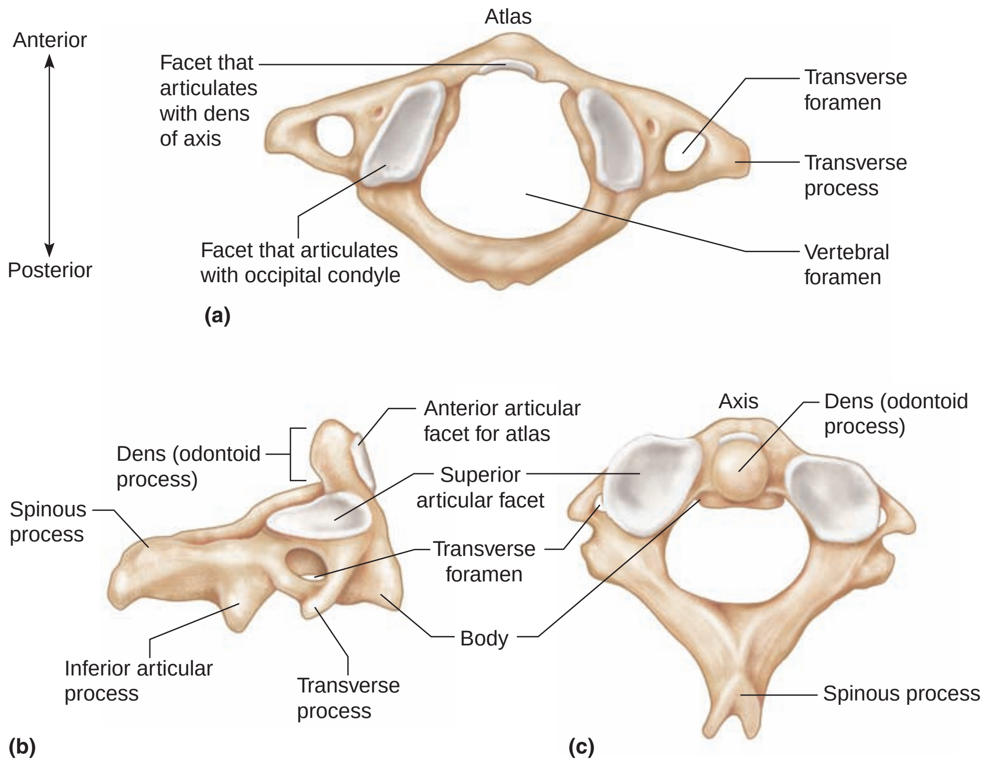


Figure 7.19
Atlas and axis. (*a*) Superior view of the atlas. (*b*) Right lateral view and (*c*) superior view of the axis.

Sacrum

The **sacrum** (sa′krum) is a triangular structure, composed of five fused vertebrae, that forms the base of the vertebral column (fig. 7.20). The spinous processes of these fused bones form a ridge of *tubercles.* To the sides of the tubercles are rows of openings, the *posterior 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 *anterior sacral foramina* provide passageways for nerves and blood vessels.

Coccyx

The **coccyx** (kok′siks), or tailbone, is the lowest part of the vertebral column and is usually composed of four fused vertebrae (fig. 7.20). Ligaments attach it to the margins of the sacral hiatus.

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

17. Describe the structure of the vertebral column.
18. Describe a typical vertebra.
19. Explain how the structures of cervical, thoracic, and lumbar vertebrae differ.

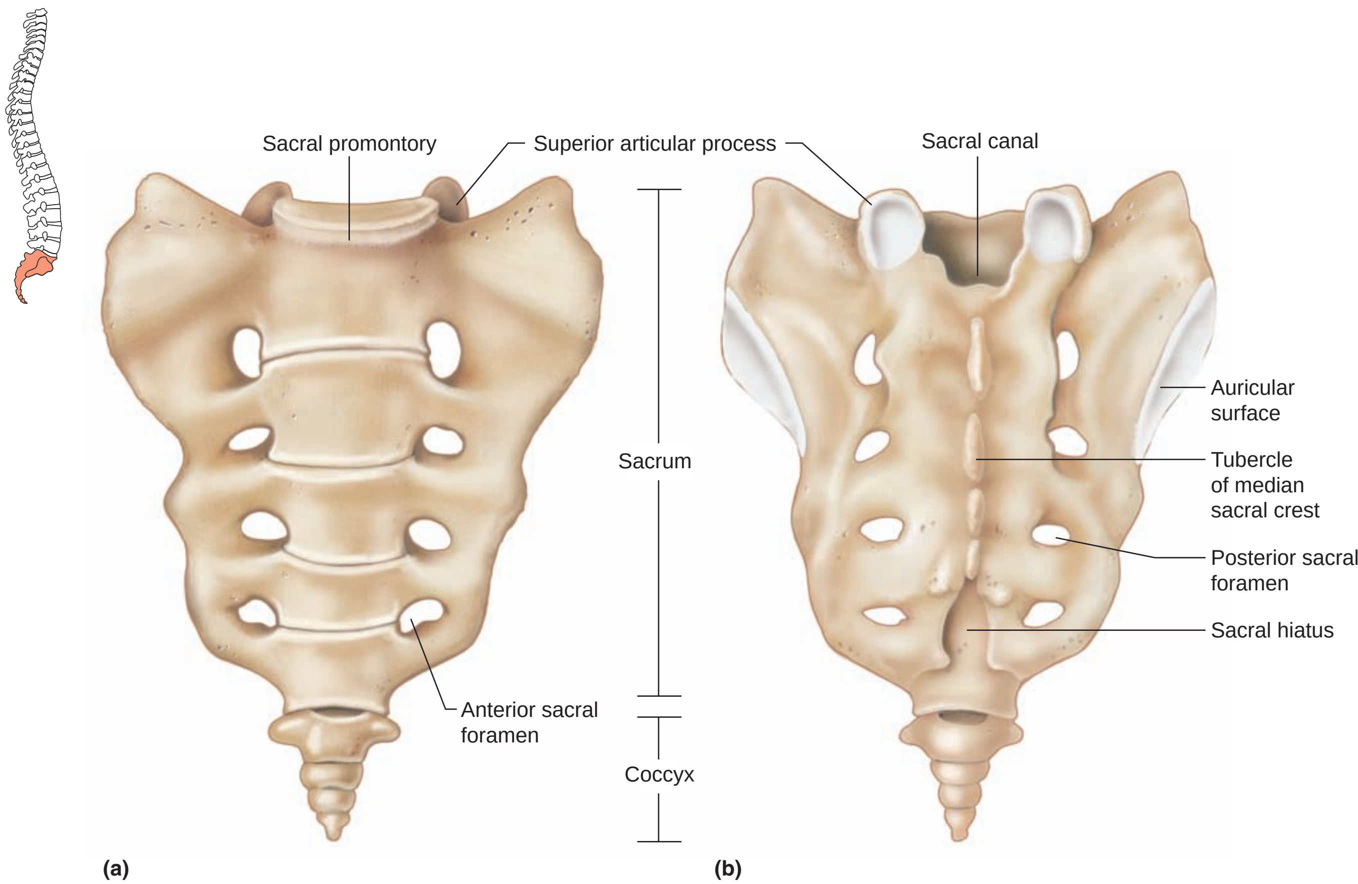


Figure 7.20
Sacrum and coccyx. (*a*) Anterior view and (*b*) posterior view.

7.8 THORACIC CAGE

The **thoracic cage** includes the ribs, the thoracic vertebrae, the sternum, and the costal cartilages that attach the ribs to the sternum (fig. 7.21). These bones support the pectoral 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 twenty-four—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. 7.21). 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.

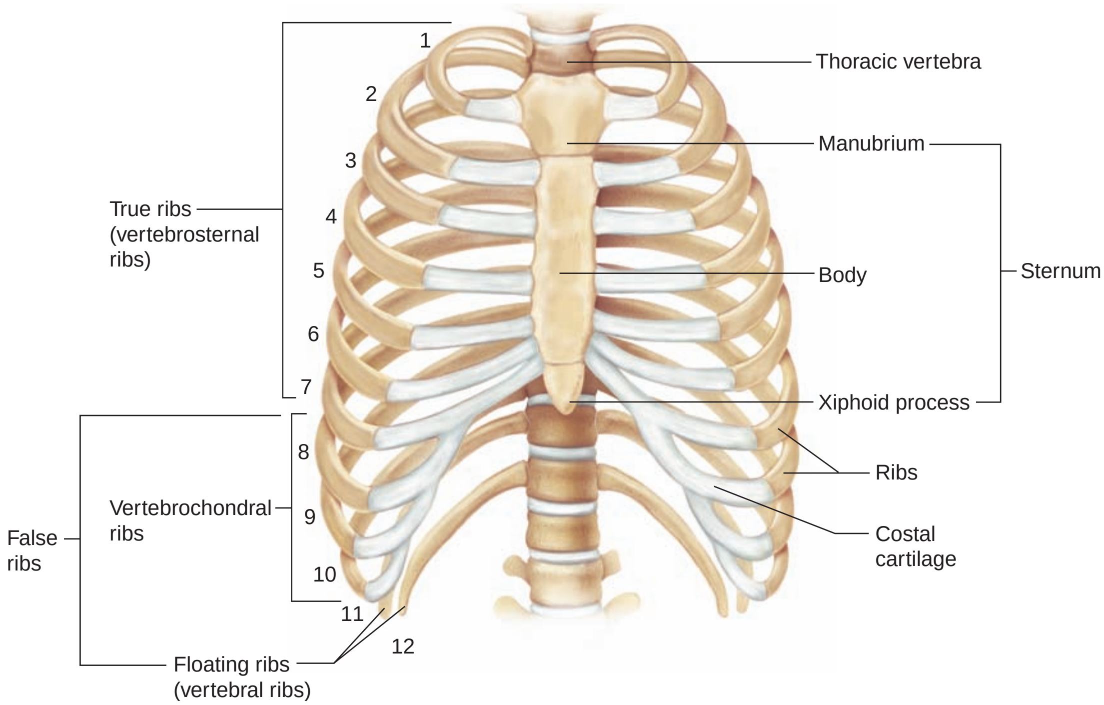


Figure 7.21

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

Check Your Recall

20. Which bones compose the thoracic cage?
21. What are the differences among true, false, and floating ribs?
22. Name the three parts of the sternum.

7.9 PECTORAL GIRDLE

The **pectoral girdle,** or shoulder girdle, is composed of four parts—two clavicles and two scapulae (fig. 7.22). 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.

Clavicles

The **clavicles,** or collarbones, are slender, rodlike bones with elongated S shapes (fig. 7.22). Located at the base of the neck, they run horizontally between the manubrium and the 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. 7.22 and 7.23). 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

23. Which bones form the pectoral girdle?
24. What is the function of the pectoral girdle?

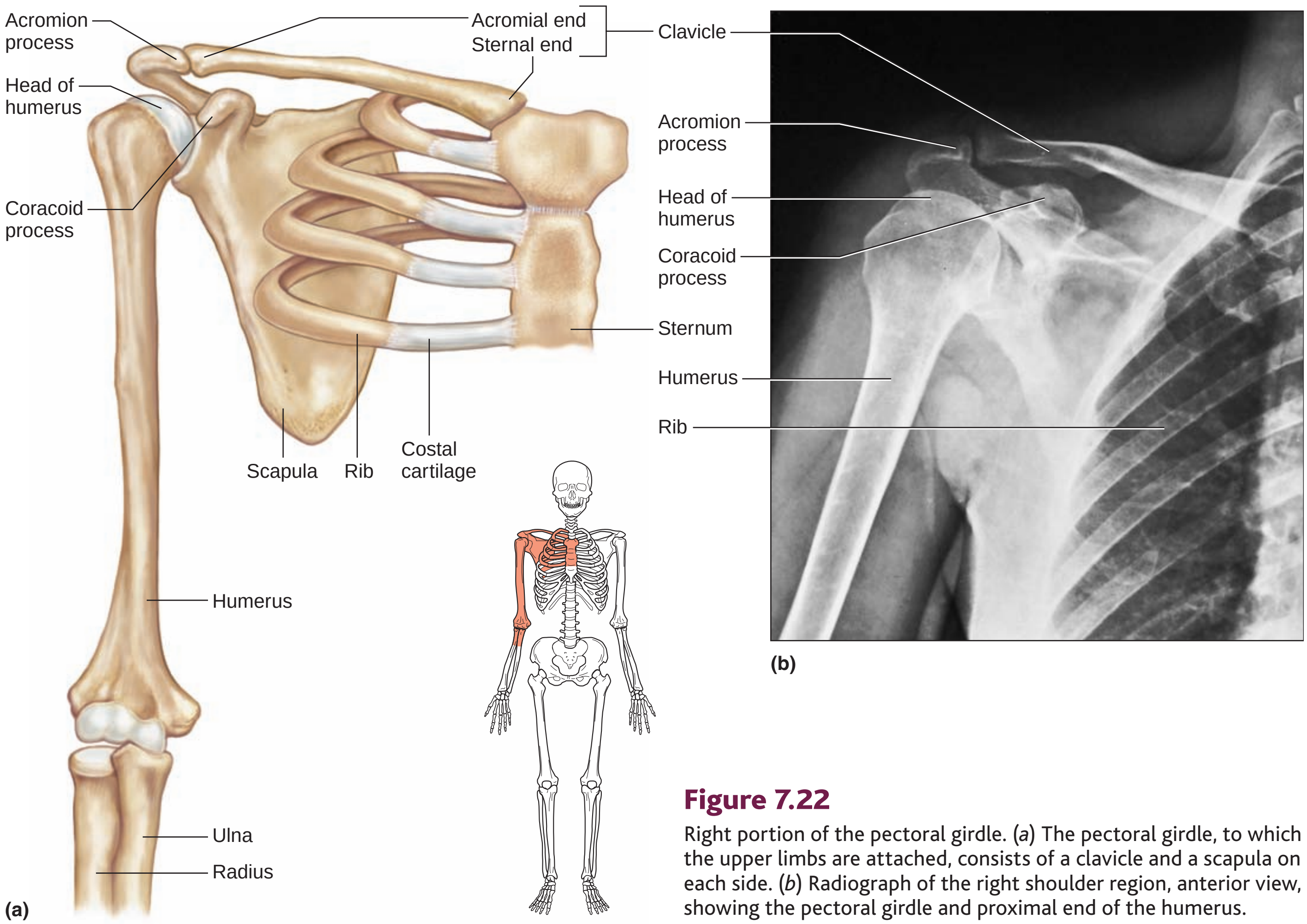


Figure 7.22

Right portion of the pectoral girdle. (*a*) The pectoral girdle, to which the upper limbs are attached, consists of a clavicle and a scapula on each side. (*b*) Radiograph of the right shoulder region, anterior view, showing the pectoral girdle and proximal end of the humerus.

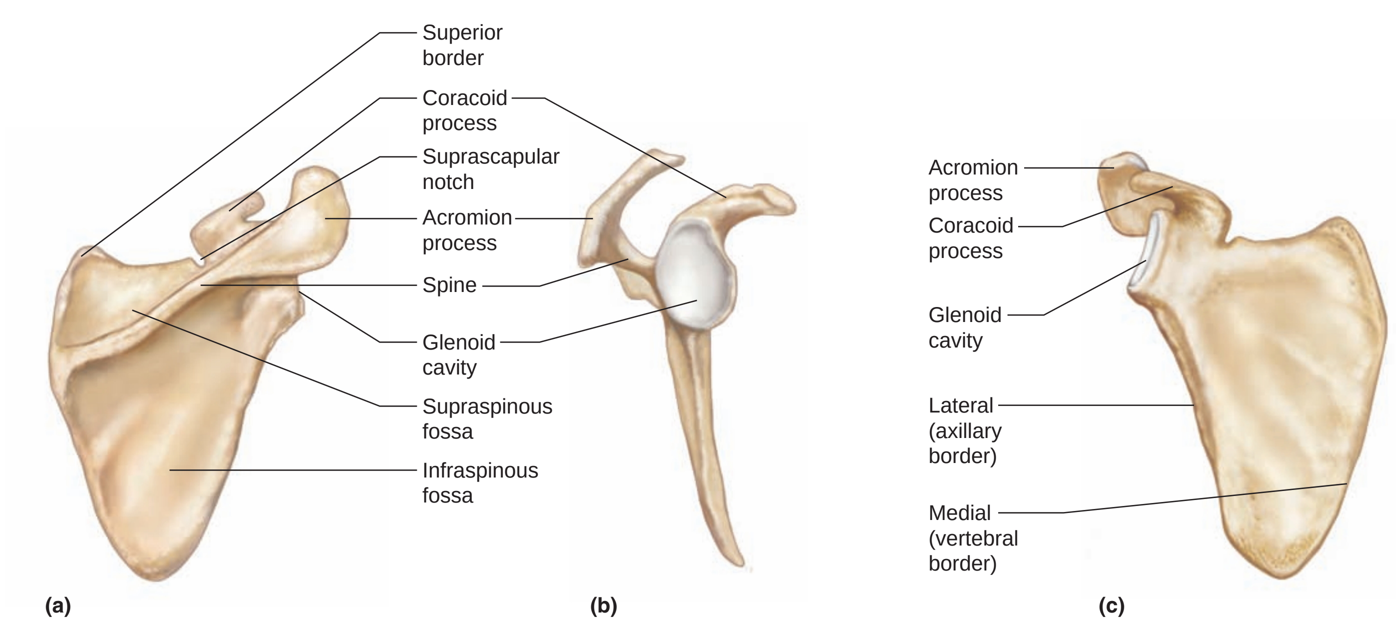


Figure 7.23

Right scapula. (*a*) Posterior surface. (*b*) Lateral view showing the glenoid cavity that articulates with the head of the humerus. (*c*) Anterior surface.

7.10 UPPER LIMB

The bones of the upper limb form the framework of the arm, forearm, 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. 7.9).

Humerus

The **humerus** is a long bone that extends from the scapula to the elbow (fig. 7.24). At its upper end is a smooth, rounded *head* that fits into the glenoid cavity 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 the 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

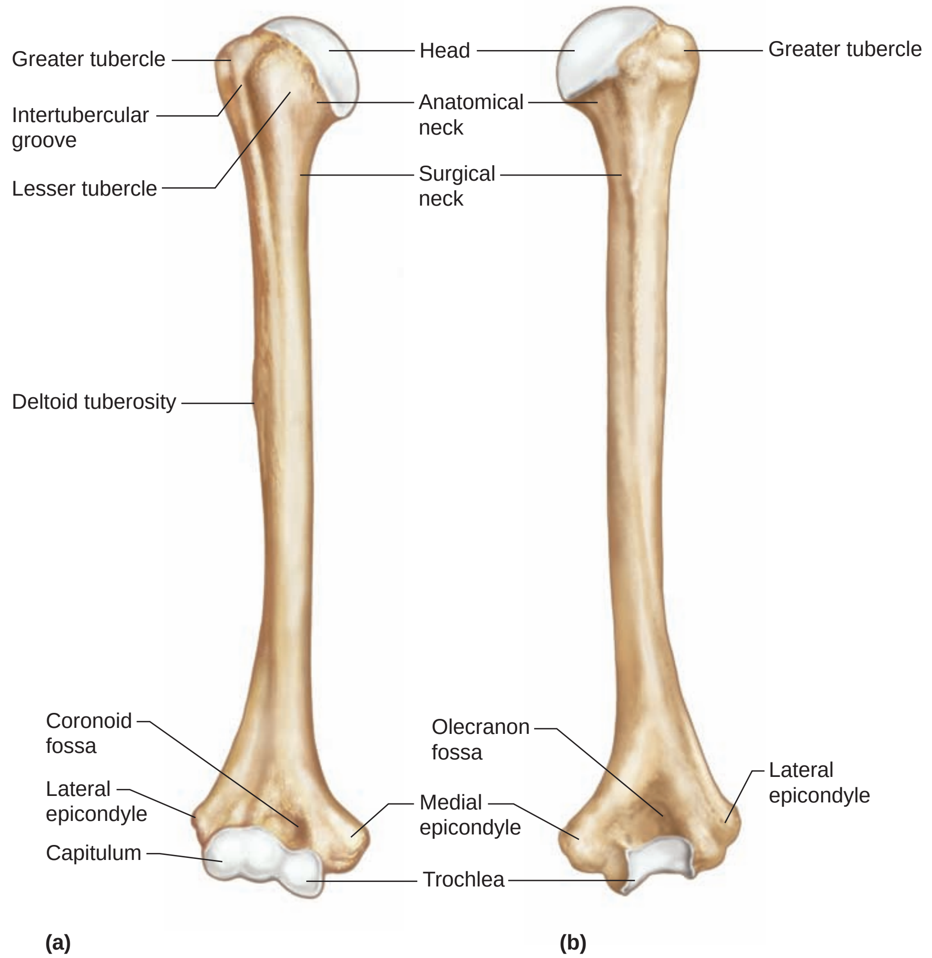


Figure 7.24
Right humerus. (*a*) Anterior surface. (*b*) Posterior surface.

faces backward (fig. 7.25). 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.

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.

Ulna

The **ulna** is longer than the radius and overlaps the end of the humerus posteriorly (fig. 7.25). 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.

Hand

The hand is made up of the wrist, palm, and fingers. 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 7.26 names the individual bones of the carpus.

Five **metacarpal bones,** one in line with each finger, form the framework of the palm or *metacarpus* (met″ah-kar′pus) of the hand. These bones are cylindrical,

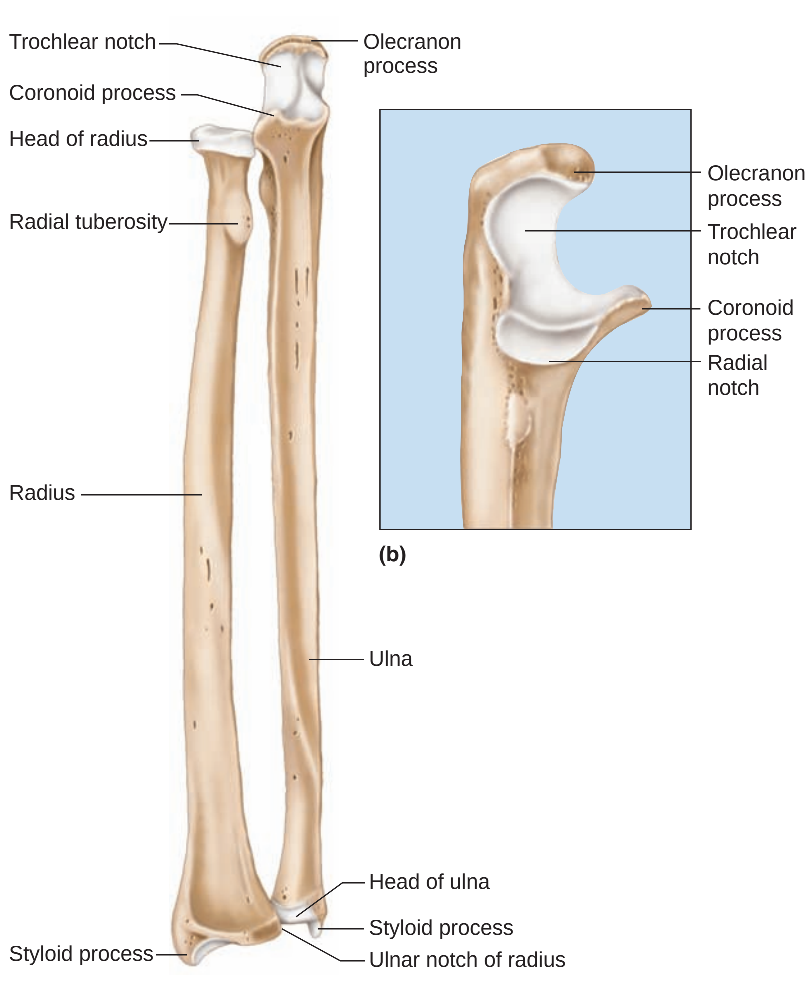


Figure 7.25

Right radius and ulna. (*a*) The head of the 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.

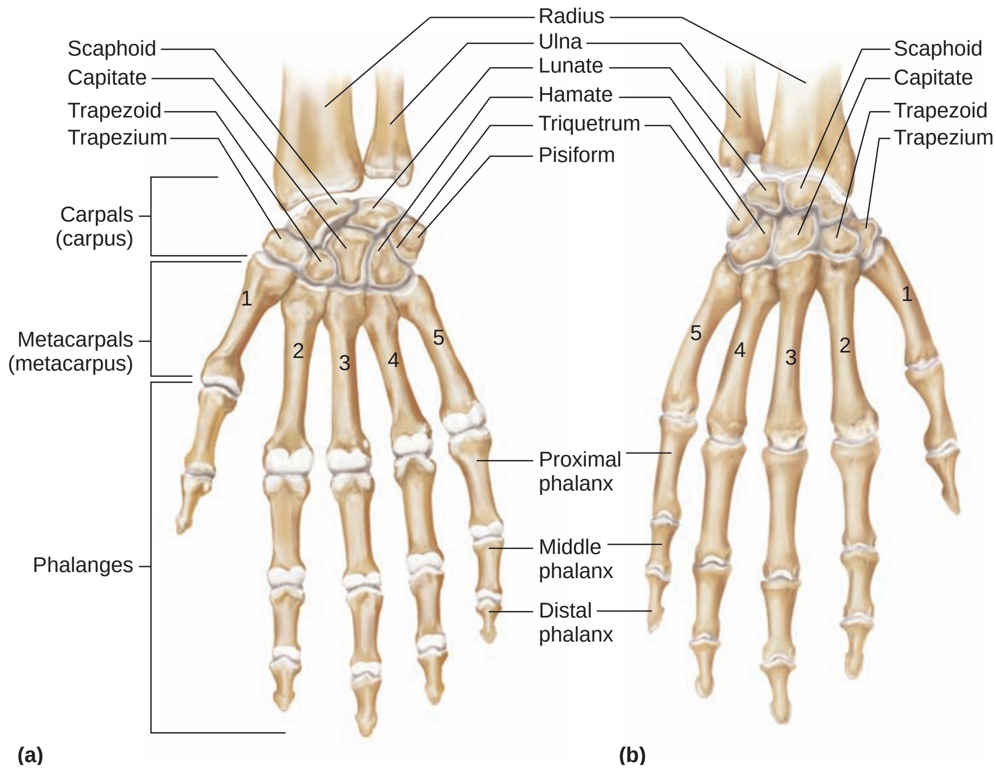


Figure 7.26
Right hand. (*a*) Anterior view. (*b*) Posterior view.

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. 7.26). 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

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

7.11 PELVIC GIRDLE

The **pelvic girdle** consists of two hip bones (coxal bones, pelvic bones, or innominate bones) which articulate with each other anteriorly and with the sacrum posteriorly. The sacrum, coccyx, and pelvic girdle together form the bowl-shaped **pelvis** (fig. 7.27). 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 hip bone develops from three parts—an ilium, an ischium, and a pubis (fig. 7.28). 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 hip bone, receives the rounded head of the femur (thigh bone).

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

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 hip bone, 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 distance between the ischial spines is the shortest diameter of the pelvic outlet.

The **pubis** (pu′bis) constitutes the anterior portion of the hip bone. The two pubic bones join at the midline, forming a joint called the *symphysis pubis* (sim′fi-sis

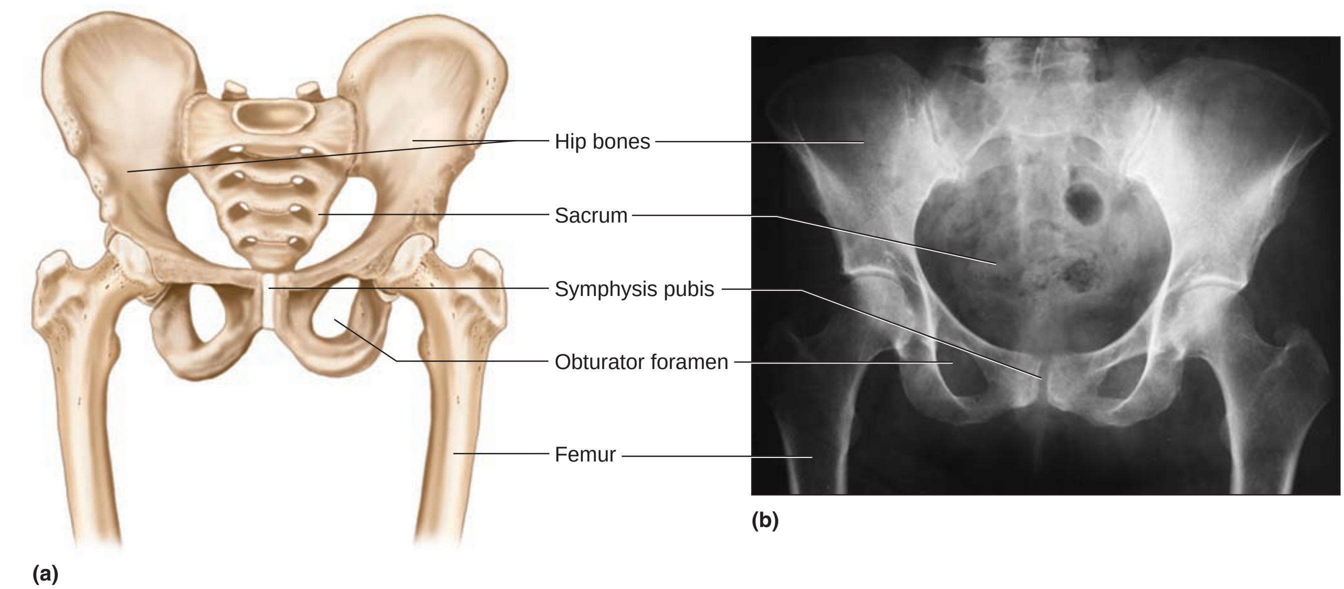


Figure 7.27
Pelvic girdle. (*a*) The pelvic girdle is formed by two hip bones. The pelvis includes the pelvic girdle as well as the sacrum and the coccyx. (*b*) Radiograph of the pelvic girdle showing the sacrum, coccyx, and proximal ends of the femurs.

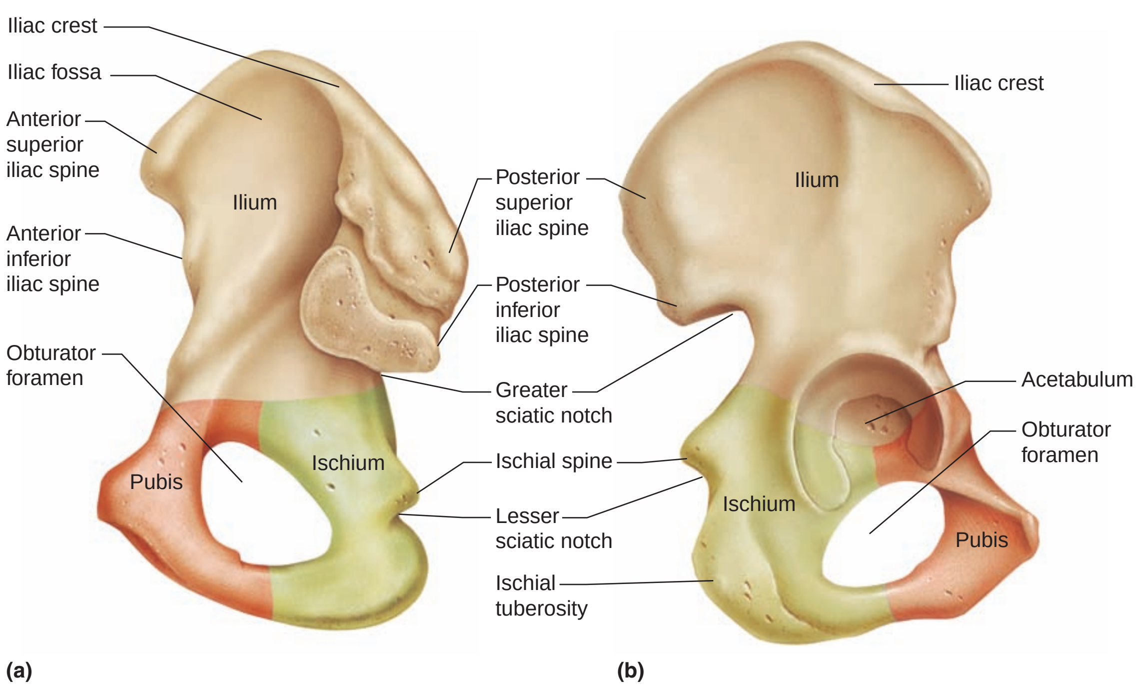


Figure 7.28
Right hip bone. (*a*) Medial surface. (*b*) Lateral view.

pu′bis). The angle these bones form below the symphysis is the *pubic arch* (fig. 7.29).

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. 7.27 and 7.28).

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. 7.29). This margin separates the lower, or lesser (true), pelvis from the upper, or greater (false), pelvis. Table 7.3 summarizes some differences in the female and male pelves and other skeletal structures.

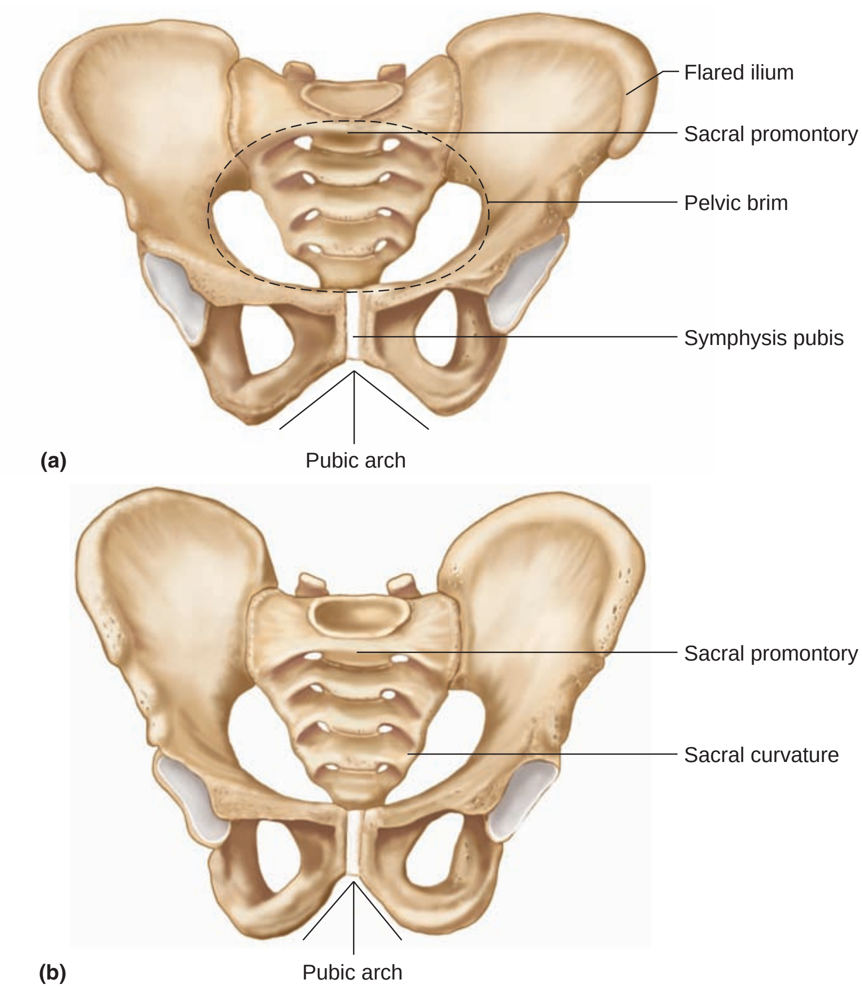


Figure 7.29
The female pelvis is usually wider in all diameters and roomier than that of the male. (*a*) Female pelvis. (*b*) Male pelvis.

Table 7.3 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 hip bones 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 the sacral curvature is bent more sharply posteriorly than in a male.
Coccyx	Female coccyx is more movable than that of a male.

Check Your Recall

27. Locate and name each bone that forms the pelvis.
28. Name the bones that fuse to form a hip bone.

7.12 LOWER LIMB

Bones of the lower limb form the frameworks of the thigh, leg, and foot. They include a femur, a tibia, a fibula, tarsals, metatarsals, and phalanges (see fig. 7.9).

Femur

The **femur,** or thigh bone, is the longest bone in the body and extends from the hip to the knee (fig. 7.30). A large, rounded *head* at its proximal end projects medially into the acetabulum of the hip bone. 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 made of cast steel.

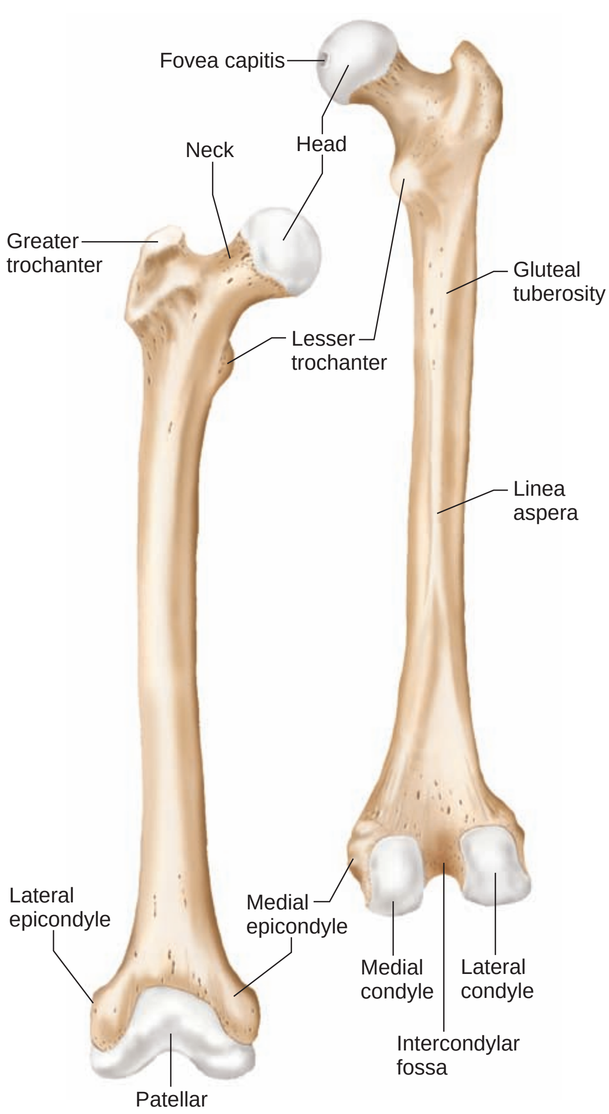


Figure 7.30
Right femur. (*a*) Anterior surface. (*b*) Posterior surface.

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. 7.9). It is located in a tendon that passes anteriorly over the knee.

Hip 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. Often a hip fracture is a cause of a fall, rather than the result of a fall.

Tibia

The **tibia,** or shin bone, is the larger of the two leg bones and is located on the medial side (fig. 7.31). Its proximal end is expanded into *medial* and *lateral condyles,* which have concave surfaces and articulate with the condyles of

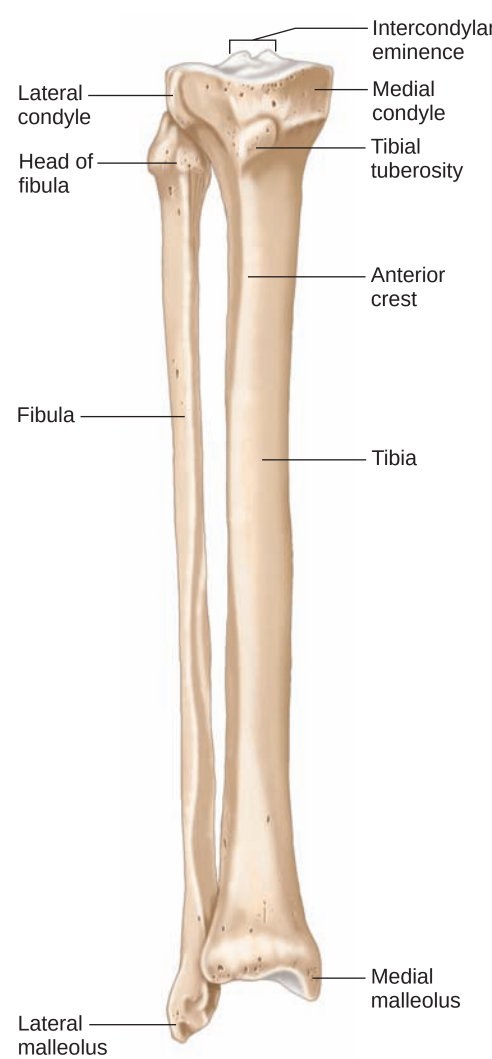


Figure 7.31
Right tibia and fibula, anterior view.

the femur. Below the condyles, on the anterior surface, is a process called the *tibial 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. 7.31). 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.

Foot

The foot is made up of the ankle, the instep, and the toes. The ankle, or *tarsus* (tahr′sus), is composed of seven **tarsal bones** (figs. 7.32 and 7.33). 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 7.33 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 the muscles that move the foot.

The instep, or *metatarsus* (met″ah-tar′sus), consists of five elongated **metatarsal bones** that articulate with the tarsus. They are numbered 1–5, beginning on the medial side (fig. 7.33). 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, which are similar to those of the fingers, 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

29. Locate and name each of the bones of the lower limb.
30. Explain how the bones of the lower limb articulate with one another.
31. 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,

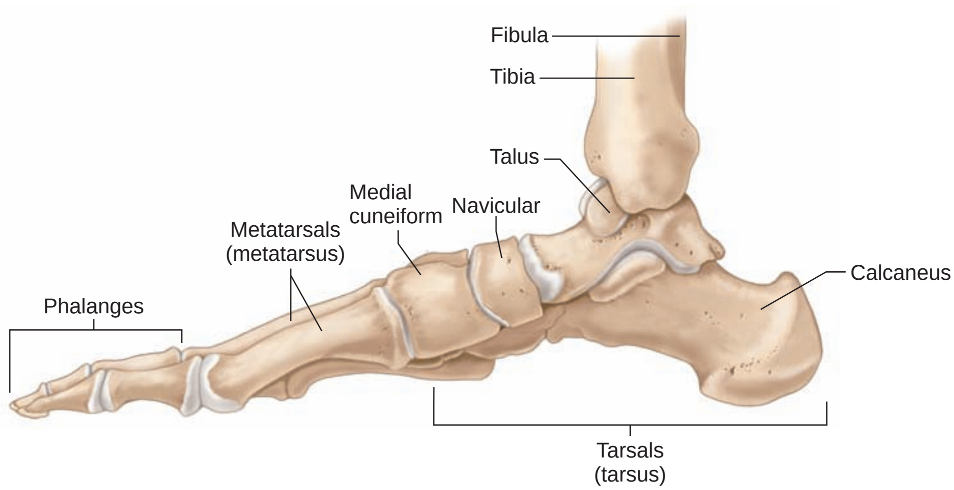


Figure 7.32
Right foot. The talus moves freely where it articulates with the tibia and fibula.

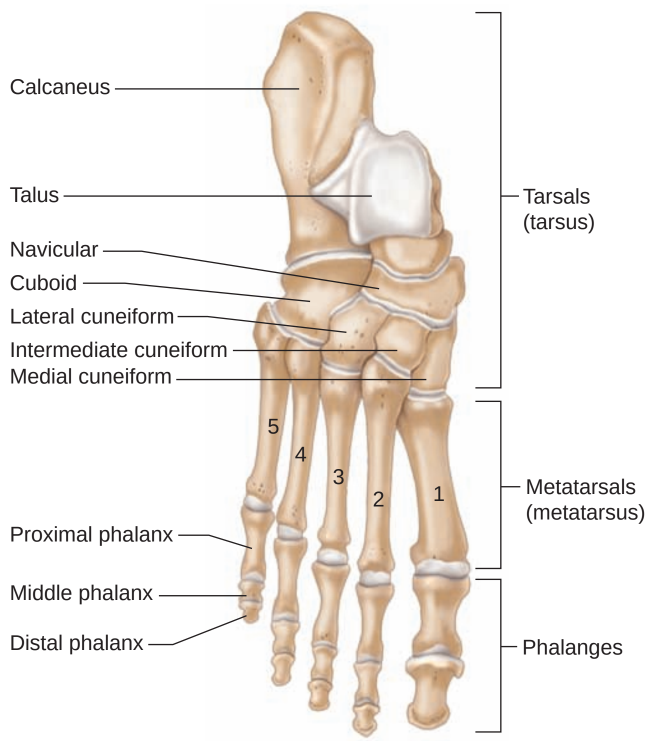


Figure 7.33

Right foot, viewed superiorly.

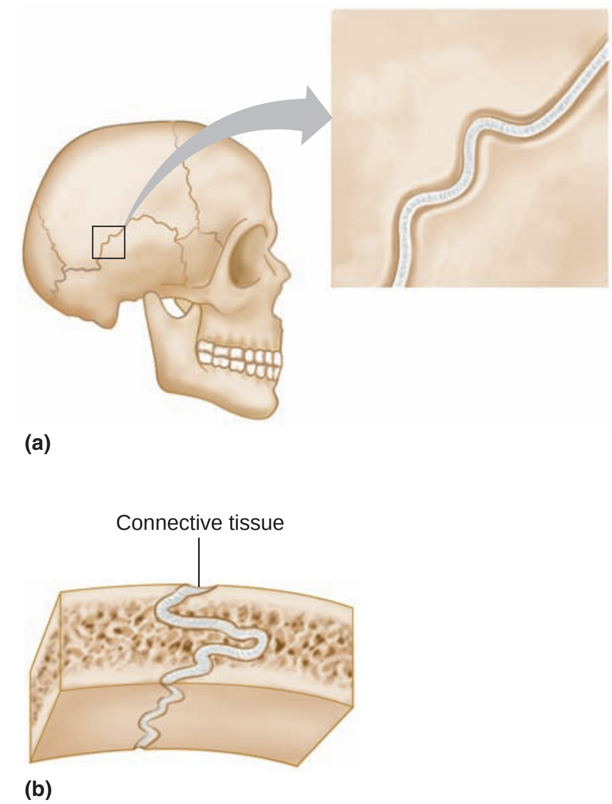


Figure 7.34

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.

joints can be immovable (synarthrotic), slightly movable (amphiarthrotic), or freely movable (diarthrotic). Joints also can be grouped according to the type of tissue (fibrous, cartilaginous, or synovial) that binds the bones together at each junction. Currently, this structural classification by tissue type is more commonly used.

A human body has 230 joints.

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 a *suture* between a pair of flat bones of the skull (fig. 7.34). Generally, no appreciable movement (synarthrotic) 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 (amphiarthrotic).

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. 7.17).

Due to the slight flexibility of the discs, cartilaginous joints allow limited movement (amphiarthrotic), 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,** which allow free movement (diarthrotic). 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. 7.35). This *joint capsule* is composed of an outer layer of ligaments and an inner lining of *synovial membrane,* which secretes synovial

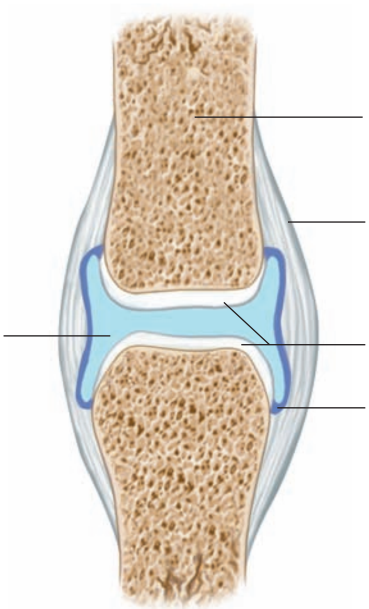


Figure 7.35
The generalized structure of a synovial joint.

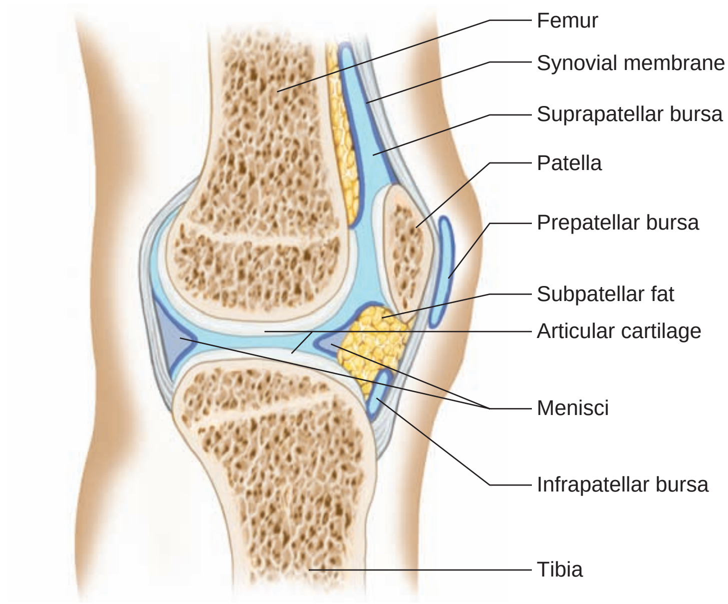


Figure 7.36
Menisci separate the articulating surfaces of the femur and tibia. Several bursae are associated with the knee joint.

fluid. Having a consistency similar to that of 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. 7.36). 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 tendons and underlying bony prominences, as in the patella of the knee or the olecranon process of the elbow. They aid the movement of tendons that glide over these bony parts or over other tendons. Figure 7.36 shows and names some of the bursae associated with the knee.

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 globular or slightly egg-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 have joints of this type (fig. 7.37).
2. In a **condyloid joint,** or **ellipsoidal joint,** an oval-shaped condyle of one bone fits into an elliptical cavity of another bone, such as in the joints between the metacarpals and phalanges (fig. 7.37). 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,** or **plane joints,** are nearly flat or slightly curved. Most of the joints within the wrist (fig. 7.37) 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. 7.37) 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 (fig. 7.37).
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 bones of the thumb (fig. 7.37).

Table 7.4 summarizes the types of joints.

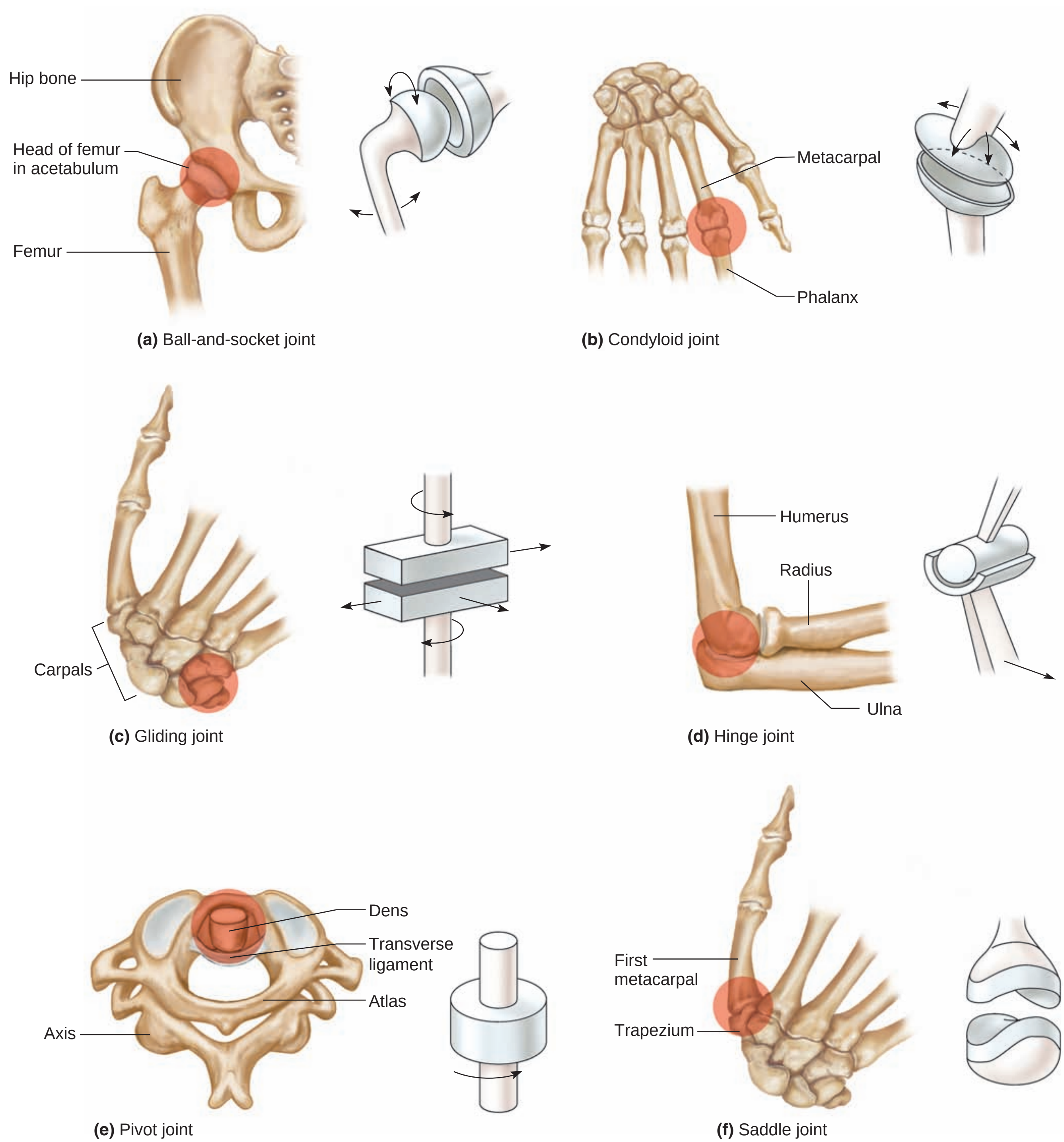


Figure 7.37

Types and examples of synovial (freely movable) joints.

Table 7.4 Types of Joints

Type of Joint	Description	Possible Movements	Examples
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 ends of 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 or Ellipsoidal	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 or Plane	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, mainly in two planes	Joint between the carpal and metacarpal of thumb

Arthritis is a group of disorders that cause inflamed, swollen, and painful joints. More than a hundred different types of arthritis affect millions of people worldwide. 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.

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, the *insertion,* toward its fixed end, the *origin,* and a movement occurs at the joint.

The following terms describe movements at joints (figs. 7.38, 7.39, and 7.40).

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

dorsiflexion (dor″sĭ-flek′shun) Movement at the ankle that brings the foot closer to the shin (walking on heels).

plantar flexion (plan′tar flek′shun) Movement at the ankle that brings the foot farther from the shin (walking or standing on toes).

hyperextension (hi″per-ek-sten′shun) Extension of the parts at a joint beyond the anatomical position (bending the head back beyond the upright position); often used to describe an abnormal extension beyond the normal range of motion resulting in injury.

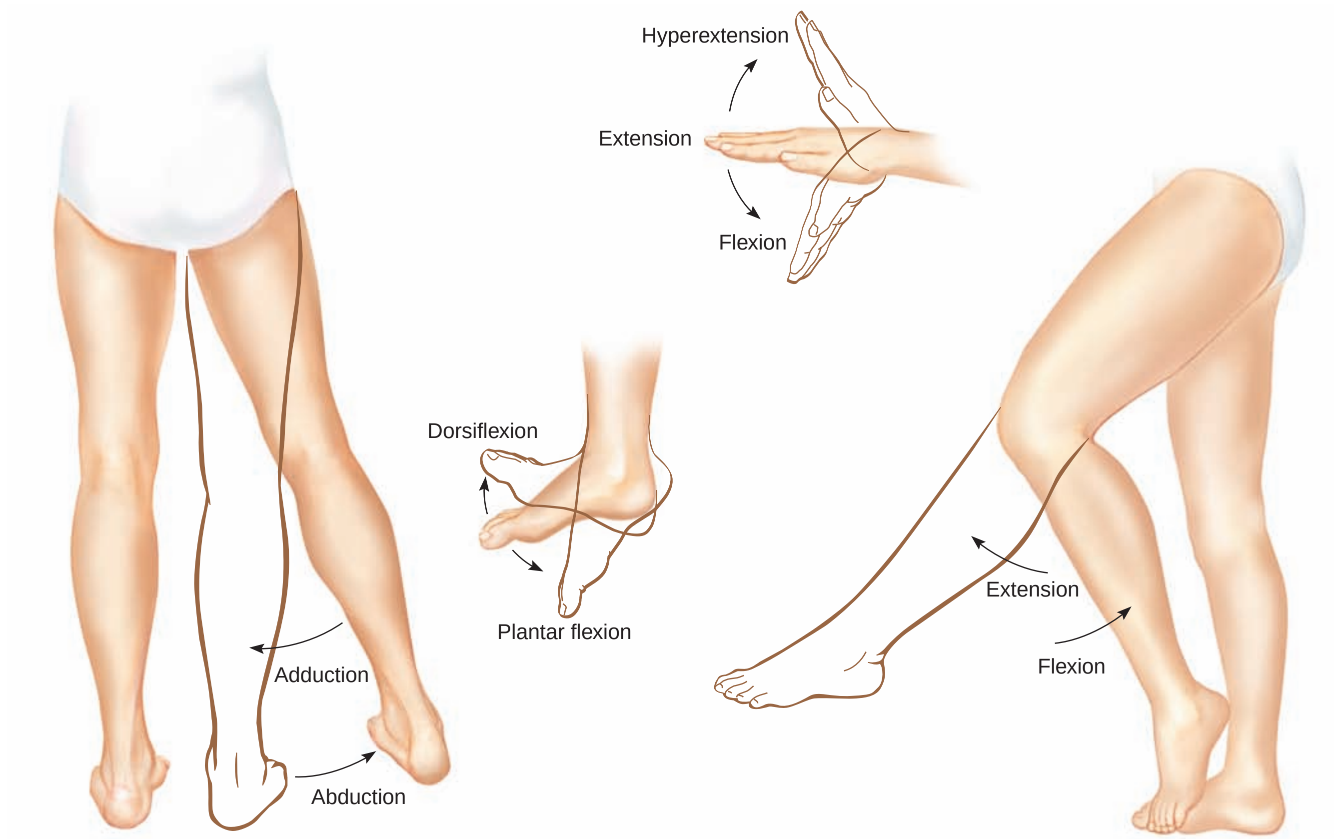


Figure 7.38

Joint movements: adduction, abduction, dorsiflexion, plantar flexion, hyperextension, extension, and flexion.

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 the plantar surface faces laterally.

inversion (in-ver′zhun) Turning the foot so the plantar surface faces medially.

retraction (re-trak′shun) Moving a part backward (pulling the head backward).

protraction (pro-trak′shun) Moving a part forward (thrusting the head forward).

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

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

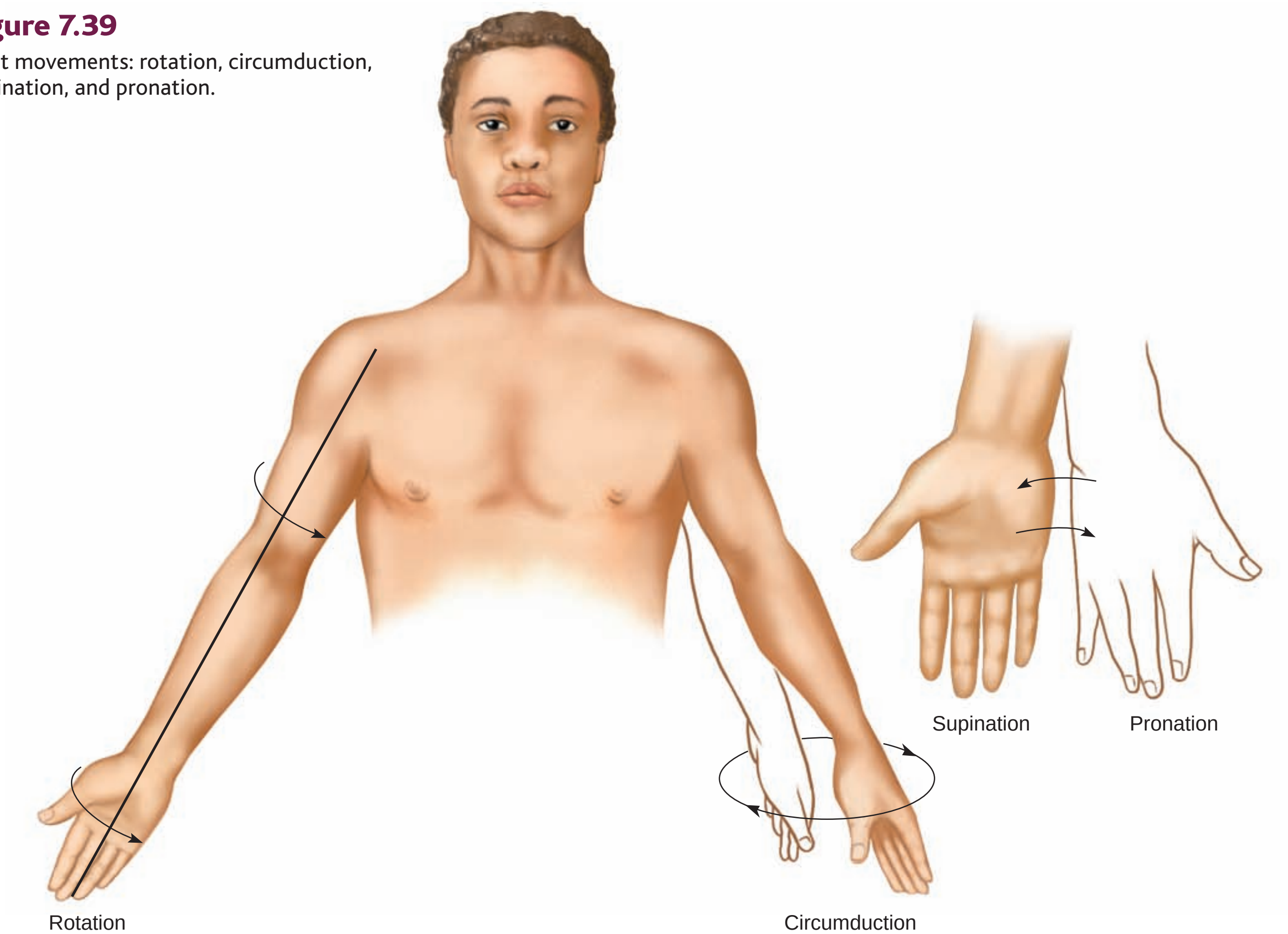
Check Your Recall

32. Describe the characteristics of the three major types of joints.
33. Name six types of synovial joints.
34. 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 the interior of a joint and 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.

Figure 7.39

Joint movements: rotation, circumduction, supination, and pronation.



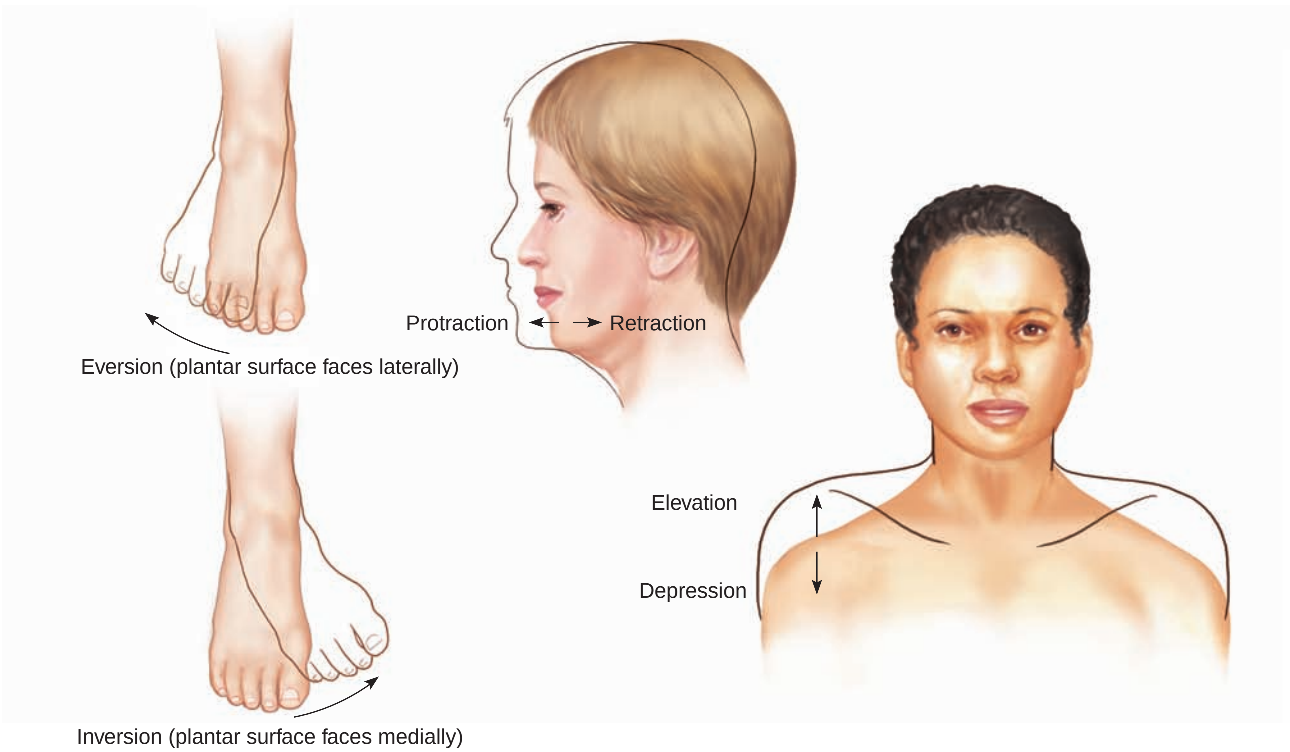
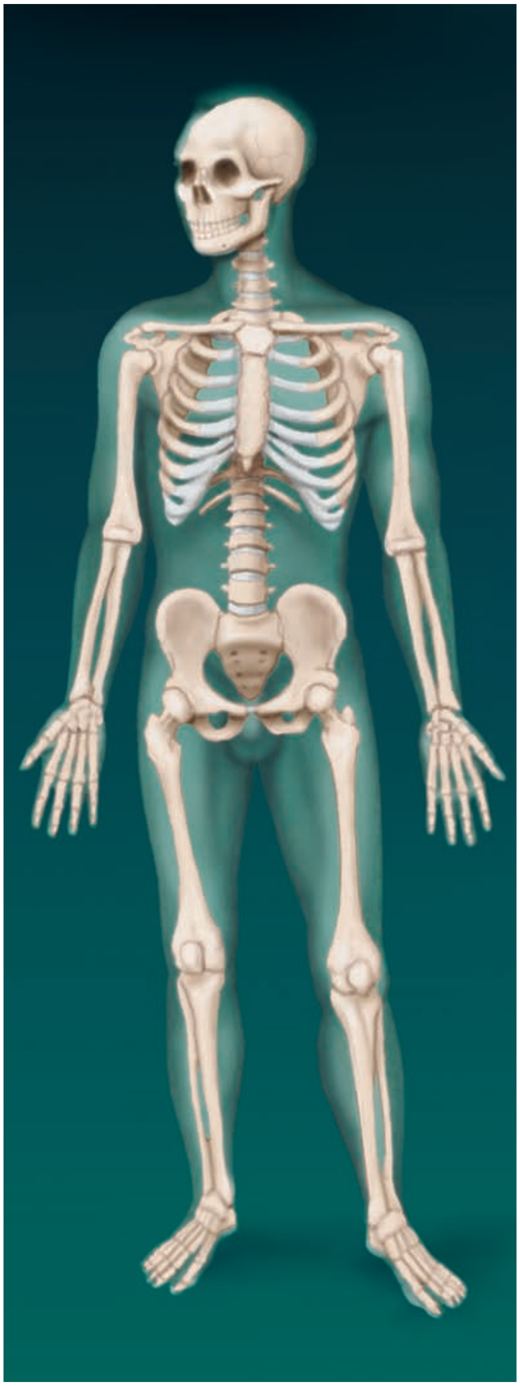


Figure 7.40

Joint movements: eversion, inversion, retraction, protraction, elevation, and depression.

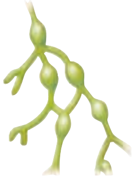
Skeletal System



Integumentary System

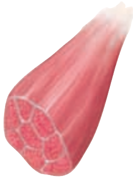
Vitamin D, activated in the skin, plays a role in calcium absorption and availability for bone matrix.

Lymphatic System



Cells of the immune system originate in the bone marrow.

Muscular System

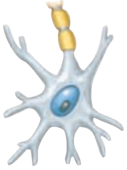


Muscles pull on bones to cause movement.

Digestive System

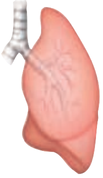
Absorption of dietary calcium provides material for bone matrix.

Nervous System



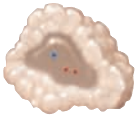
Proprioceptors sense the position of body parts. Pain receptors warn of trauma to bone. Bones protect the brain and spinal cord.

Respiratory System



Ribs and muscles work together in breathing.

Endocrine System

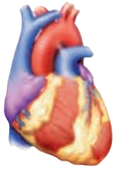


Some hormones act on bone to help regulate blood calcium levels.

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. Bones provide a source of calcium during lactation.

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

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′cher) 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 the 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′tah) 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.
osteomyelitis (os″te-o-mi″ĕ-li′tis) Bone inflammation caused by the body's reaction to a 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 twenty-year-old professional soccer player jammed his left toe at high speed against the ball and howled in pain, he thought it would 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 continue 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 department, where a sample of the pus revealed no bacteria. Instead, X rays 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. In this case, however, the physician in charge suspected that the soccer player's spike was a response to trauma—followed by 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. 131)

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

7.2 Bone Structure (p. 131)

Bone structure reflects its function.

1. Bones are classified according to their shapes including long, short, flat, irregular, and sesamoid (round).
2. 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 extracellular 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.
3. 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. 133)

1. Intramembranous bones
   a. Intramembranous bones develop from layers of unspecialized 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 ossification beneath the periosteum.
3. Homeostasis of bone tissue
    a. Osteoclasts break down bone matrix and osteoblasts deposit bone matrix to continually remodel bone.
    b. The total mass of bone remains nearly constant.
4. Factors affecting bone development, growth, and repair include nutrition, hormonal secretions, and physical exercise.

7.4 Bone Function (p. 135)

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 bar, a pivot (fulcrum), a resistance, and a force that supplies energy.
3. Blood cell formation
    a. At different ages, hematopoiesis 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. Bones store calcium in the extracellular matrix of bone tissue, which 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. 139)

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. 142)

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

1. Cranium
    a. The cranium encloses and protects the brain.
    b. Some cranial bones contain air-filled paranasal 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. 147)

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. 152)

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. 153)

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 the 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. 155)

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. Hand
   a. The wrist is composed of eight carpal bones that form a carpus.
   b. The palm or metacarpus includes five metacarpal bones and fourteen phalanges compose the fingers.

7.11 Pelvic Girdle (p. 157)

The pelvic girdle consists of two hip bones 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 hip bone 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 hip bone.
      (2) It joins the sacrum at the sacroiliac joint.
   b. The ischium
      (1) The ischium is the lowest portion of the hip bone.
      (2) It supports the body weight when sitting.
   c. The pubis
      (1) The pubis is the anterior portion of the hip bone.
      (2) The pubic bones are fused anteriorly at the symphysis pubis.

7.12 Lower Limb (p. 159)

Bones of the lower limb provide frameworks for the thigh, leg, 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 proximally with the femur and distally 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. Foot
   a. The ankle consists of the tarsus formed by the talus and six other tarsal bones.
   b. The instep or metatarsus includes five metatarsals, and fourteen phalanges compose the toes.

7.13 Joints (p. 161)

Joints can be classified according to degree of movement as well as 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 (amphiarthrotic) or no movement (synarthrotic) occurs at a fibrous joint.
2. Cartilaginous joints
   a. A layer of cartilage joins the bones of cartilaginous joints.
   b. Such joints allow limited movement (amphiarthrotic).
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. Pads of fibrocartilage, menisci, act as shock absorbers in some synovial joints.
   d. Bursae are located between tendons and underlying bony prominences.
   e. Synovial joints that allow free movement (diarthrotic) 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 the 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.

CHAPTER ASSESSMENTS

7.1 Introduction

1. Active, living tissues found in bone include ______________. (p. 131)
   a. blood
   b. nervous tissue
   c. dense connective tissue
   d. bone tissue
   e. all of the above

7.2 Bone Structure

2. Sketch a typical long bone, and label its epiphyses, diaphysis, medullary cavity, periosteum, and articular cartilages. On the sketch, designate the locations of compact and spongy bone. (p. 131)

3. Discuss the functions of the parts labeled in the sketch you made for question 2. (p. 131)

4. Differentiate between the microscopic structure of compact bone and spongy bone. (p. 132)

7.3 Bone Development and Growth

5. Explain how the development of intramembranous bone differs from that of endochondral bone. (p. 133)

6. ______________ are mature bone cells, whereas ______________ are bone-forming cells and ______________ are bone-resorbing cells. (p. 134)

7. Explain the function of an epiphyseal plate. (p. 134)

8. Physical exercise pulling on muscular attachments to bones stimulates ______________. (p. 135)

7.4 Bone Function

9. Give several examples of how bones support and protect body parts. (p. 135)

10. List and describe other functions of bones. (p. 138)

7.5 Skeletal Organization

11. Bones of the head, neck, and trunk compose the ______________ skeleton; bones of the limbs and their attachments compose the ______________ skeleton. (p. 139)

7.6–7.12 (Skull–Lower Limb)

12. Name the bones of the cranium and the facial skeleton. (pp. 142–147)
13. Describe a typical vertebra, and distinguish among the cervical, thoracic, and lumbar vertebrae. (pp. 147–150)
14. Name the bones that compose the thoracic cage. (p. 152)
15. The clavicle and scapula form the ____________ girdle, whereas the hip bones and sacrum form the ____________ girdle. (pp. 153 and 157)
16. Name the bones of the upper and lower limbs. (pp. 155–161)
17. Match the parts listed on the left with the bones listed on the right. (pp. 142–161)

(1) Foramen magnum	A. Maxilla
(2) Mastoid process	B. Occipital bone
(3) Palatine process	C. Temporal bone
(4) Sella turcica	D. Femur
(5) Deltoid tuberosity	E. Fibula
(6) Greater trochanter	F. Humerus
(7) Lateral malleolus	G. Radius
(8) Medial malleolus	H. Sternum
(9) Radial tuberosity	I. Tibia
(10) Xiphoid process	J. Sphenoid bone

7.13 Joints

18. Describe and give an example of a fibrous joint, a cartilaginous joint, and a synovial joint. (p. 162)
19. Name an example of each type of synovial joint, and describe the parts of the joint as they relate to the movement(s) allowed by that particular joint. (p. 163)
20. Joint movements occur when a muscle contracts and the muscle fibers pull the muscle's movable end of attachment to the bone, the ____________, toward its fixed end, the ____________. (p. 165)
21. Match the movement on the left with the appropriate description on the right. (pp. 165–166)

(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 axis
(5) Protraction	E. moving part toward midline
(6) Flexion	F. turning foot so plantar surface faces laterally
(7) Pronation	G. increasing angle between parts
(8) Abduction	H. lowering a part
(9) Depression	I. turning palm downward
(10) Adduction	J. moving part away from midline

INTEGRATIVE ASSESSMENTS/ CRITICAL THINKING

OUTCOME 7.2

1. How does the structure of a bone make it strong yet lightweight?

OUTCOME 7.3

2. 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?

OUTCOMES 7.3, 7.4, 7.11

3. 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.

OUTCOME 7.13

4. Based upon knowledge of joint structures, which could be more satisfactorily replaced by a prosthetic device, a hip joint or a knee joint? Why?

WEB CONNECTIONS

Visit the text website at **aris.mhhe.com** for additional quizzes, interactive learning exercises, and more.

APR SKELETAL SYSTEM

Anatomy & Physiology | REVEALED includes cadaver photos that allow you to peel away layers of the human body to reveal structures beneath the surface. This program also includes animations, radiologic imaging, audio pronunciation, and practice quizzing. To learn more visit **www.aprevealed.com**.

Human Skull

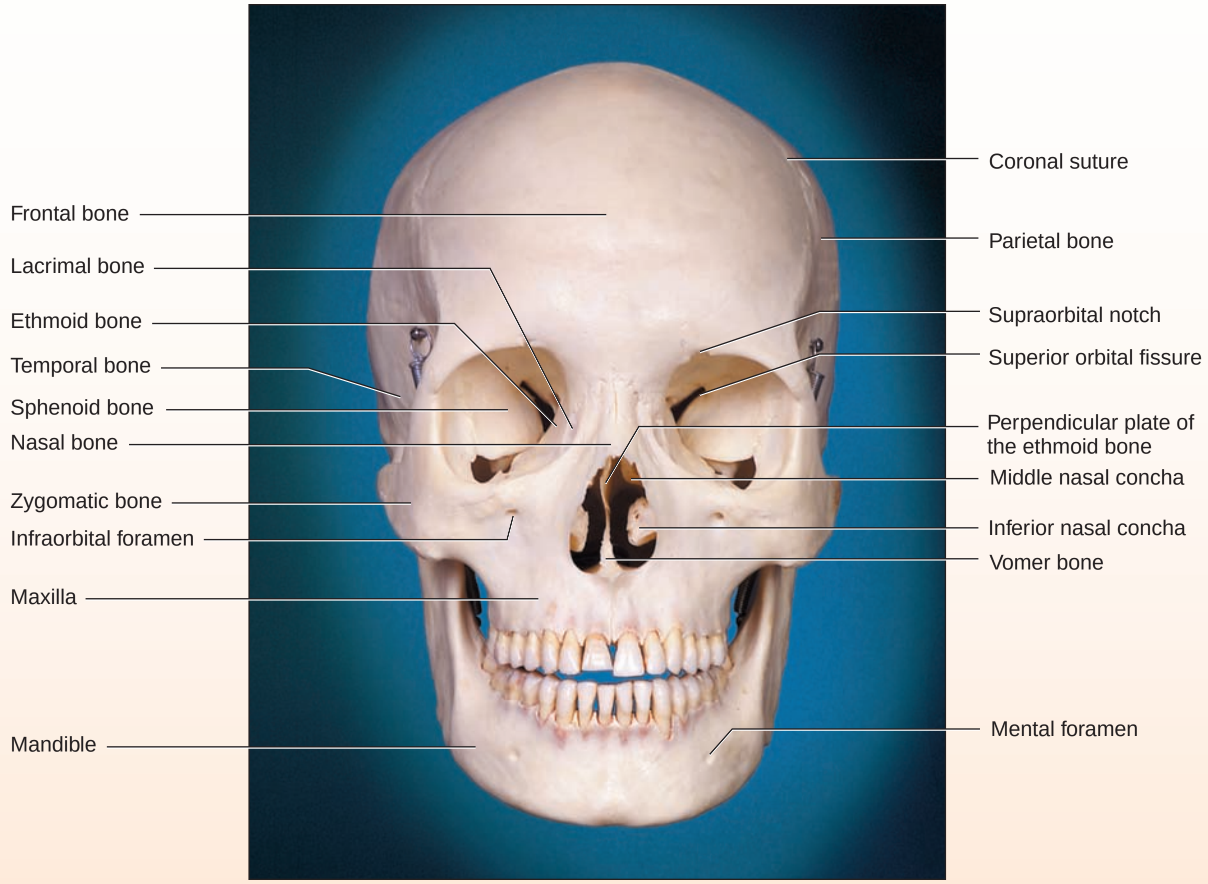


PLATE 8

The skull, anterior view.

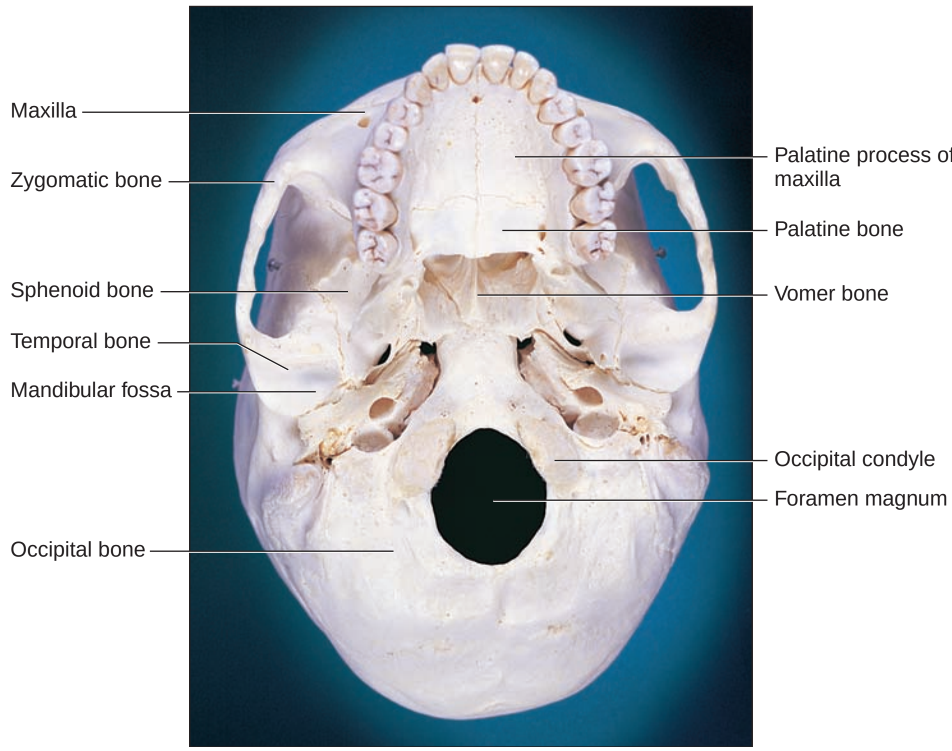


PLATE 9

The skull, inferior view.

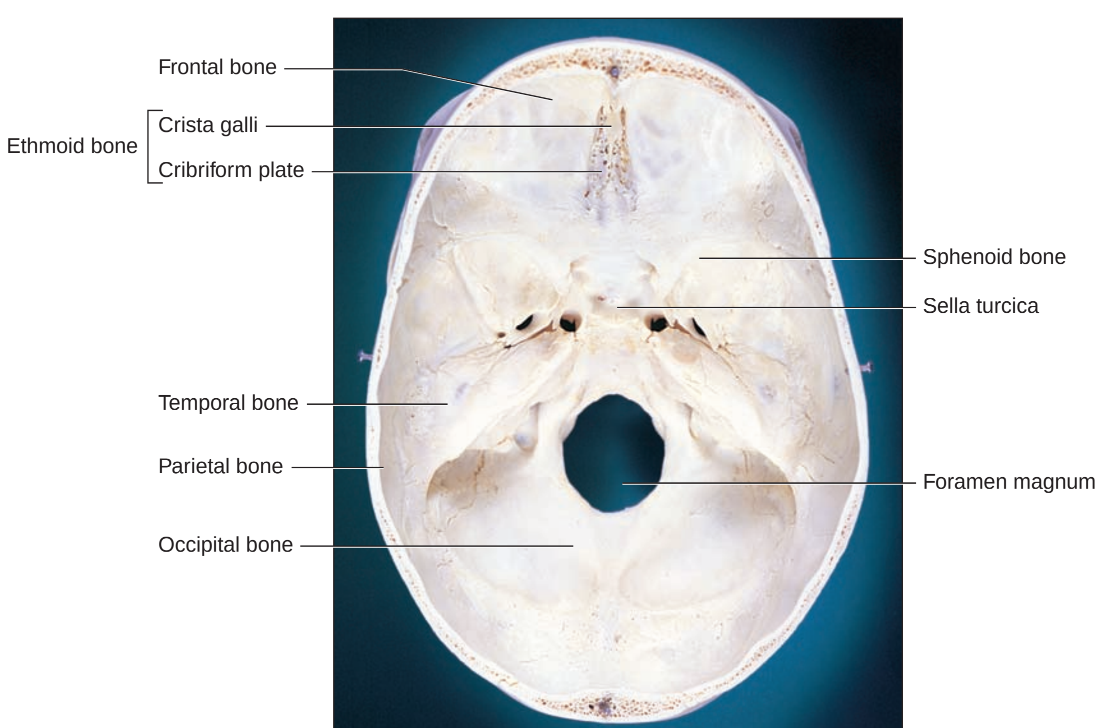


PLATE 10

The skull, floor of the cranial cavity.

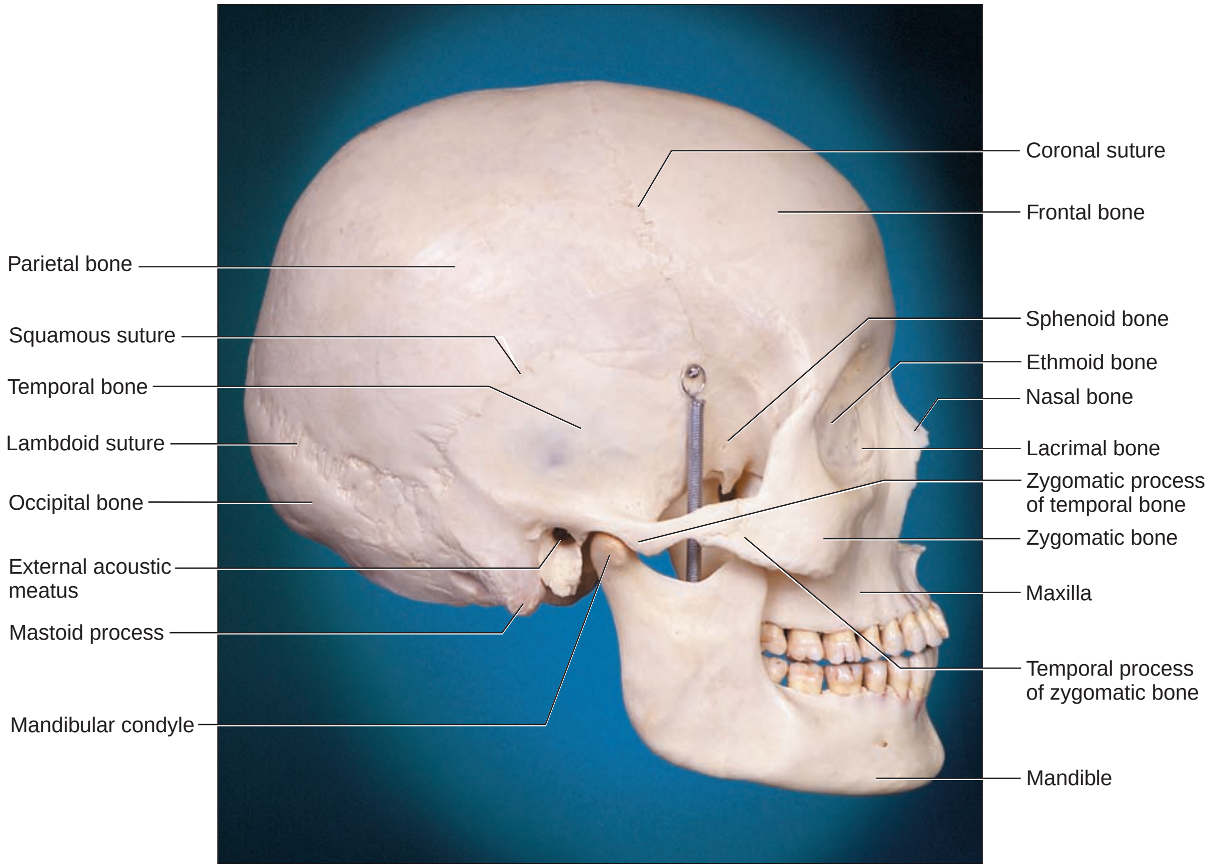


PLATE 11

The skull, lateral view.