

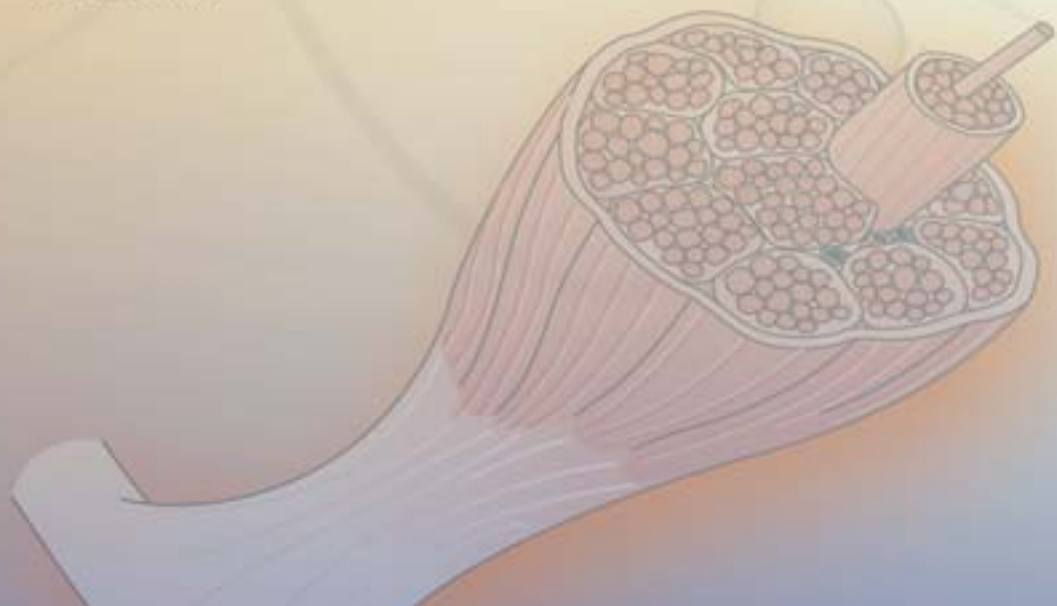


unit

III

Movement and Support

*T*his unit deals with the skeletal and muscular systems, which work together to execute movement and to support and protect vital organs. It covers the additional functions of the skeletal system in housing the blood-forming tissue and storing some minerals. The chapter on muscles describes the characteristics of all types of muscles and then concentrates on the muscles that are attached to the skeleton and how they function. The main skeletal muscles are named and located and their actions are described.



SELECTED KEY TERMS

The following terms and other boldface terms in the chapter are defined in the Glossary



amphiarthrosis
arthritis
bursa
circumduction
diaphysis
diarthrosis
endosteum
epiphysis
fontanel
joint
osteoblast
osteoclast
osteocyte
osteon
osteopenia
osteoporosis
periosteum
resorption
skeleton
synarthrosis
synovial

LEARNING OUTCOMES

After careful study of this chapter, you should be able to:

1. List the functions of bones
2. Describe the structure of a long bone
3. Differentiate between compact bone and spongy bone with respect to structure and location
4. Differentiate between red and yellow marrow with respect to function and location
5. Name the three different types of cells in bone and describe the functions of each
6. Explain how a long bone grows
7. Name and describe various markings found on bones
8. List the bones in the axial skeleton
9. Explain the purpose of the infant fontanel
10. Describe the normal curves of the spine and explain their purpose
11. List the bones in the appendicular skeleton
12. Compare the structure of the female pelvis and the male pelvis
13. Describe five bone disorders
14. Name and describe eight types of fractures
15. Describe how the skeleton changes with age
16. Describe the three types of joints
17. Describe the structure of a synovial joint and give six examples of synovial joints
18. Demonstrate six types of movement that occur at synovial joints
19. Describe four types of arthritis
20. List some causes of backache
21. Show how word parts are used to build words related to the skin (see Word Anatomy at the end of the chapter)

chapter

7

The Skeleton: Bones and Joints



The skeleton is the strong framework on which the body is constructed. Much like the frame of a building, the skeleton must be strong enough to support and protect all the body structures. Bone tissue is the most dense form of the connective tissues described in Chapter 4. Bones work with muscles to produce movement at the joints. The bones and joints, together with supporting connective tissue, form the skeletal system.

► Bones

Bones have a number of functions, several of which are not evident in looking at the skeleton:

- To serve as a firm framework for the entire body
- To protect such delicate structures as the brain and the spinal cord

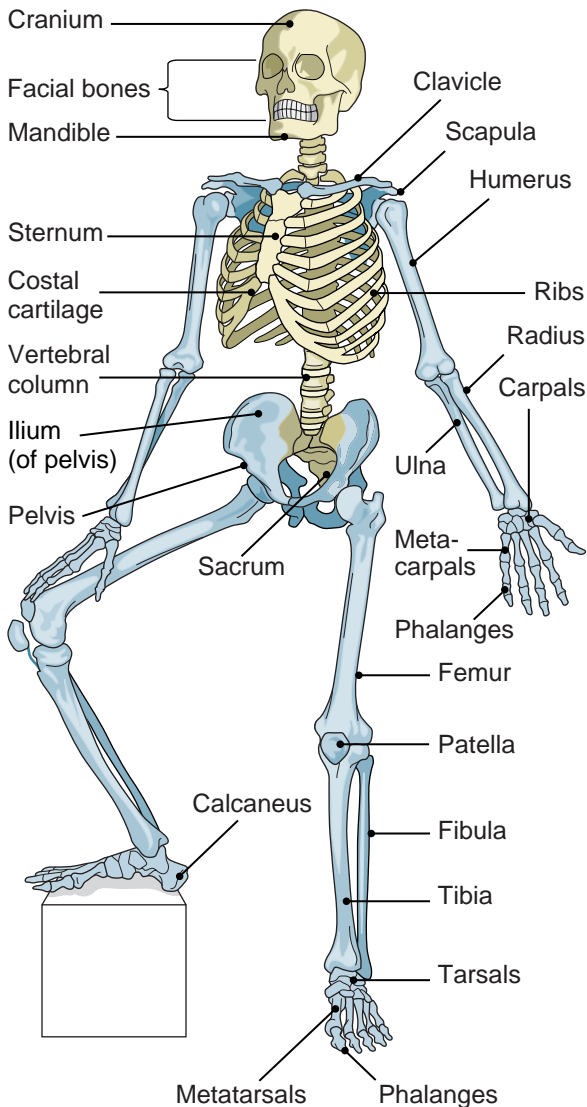


Figure 7-1 The skeleton. The axial skeleton is shown in yellow; the appendicular, in blue.

- To serve as levers, working with attached muscles to produce movement
- To serve as a storehouse for calcium salts, which may be resorbed into the blood if there is not enough calcium in the diet
- To produce blood cells (in the red marrow)

Bone Structure

The complete bony framework of the body, known as the **skeleton** (Fig. 7-1), consists of 206 bones. It is divided into a central portion, the axial skeleton, and the extremities, which make up the appendicular skeleton. The individual bones in these two divisions will be described in detail later in this chapter. The bones of the skeleton can be of several different shapes. They may be flat (ribs, cranium), short (carpals of wrist, tarsals of ankle), or irregular (vertebrae, facial bones). The most familiar shape, however, is the **long bone**, the type of bone that makes up almost all of the skeleton of the arms and legs. The long narrow shaft of this type of bone is called the **diaphysis** (di-AF-ih-sis). At the center of the diaphysis is a **medullary** (MED-u-lar-e) **cavity**, which contains bone marrow. The long bone also has two irregular ends, a proximal and a distal epiphysis (eh-PIF-ih-sis) (Fig. 7-2).

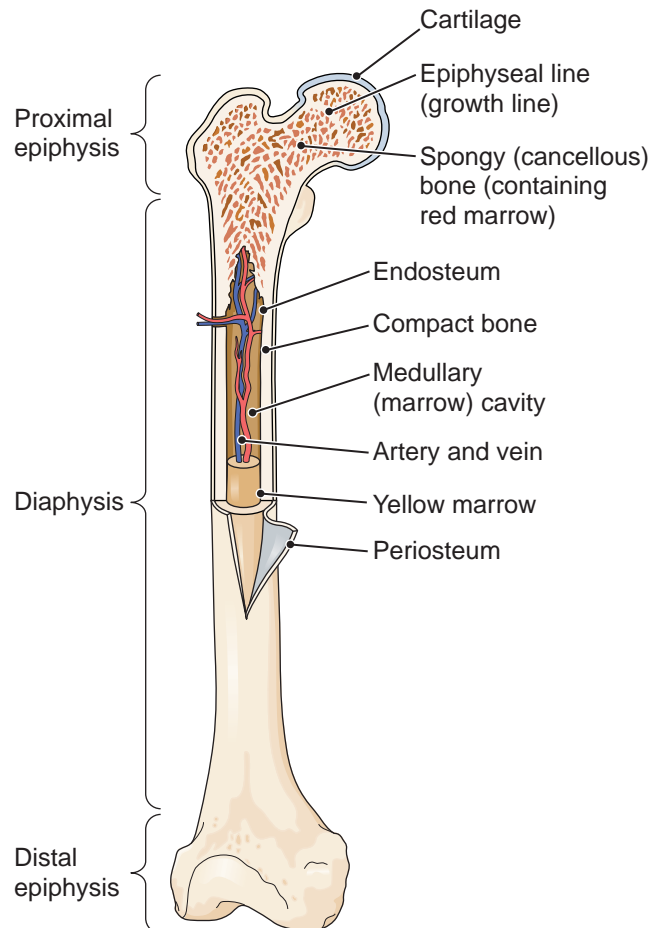


Figure 7-2 The structure of a long bone.

Bone Tissue Bones are not lifeless. Even though the spaces between the cells of bone tissue are permeated with stony deposits of calcium salts, the bone cells themselves are very much alive. Bones are organs, with their own system of blood vessels, lymphatic vessels, and nerves.

There are two types of bone tissue, also known as **osseous** (OS-e-us) **tissue**. One type is **compact bone**, which is hard and dense (Fig. 7-3). This tissue makes up the main shaft of a long bone and the outer layer of other bones. The cells in this type of bone are located in rings of bone tissue around a central **haversian** (ha-VER-shan) **canal** containing nerves and blood vessels. The bone cells live in spaces (lacunae) between the rings and extend out into many small radiating channels so that they can be in contact with nearby cells. Each ringlike unit with its central canal makes up a **haversian system**, also known as an **osteon** (OS-te-on) (see Fig. 7-3 B). Forming a channel

across the bone, from one side of the shaft to the other, are many **perforating** (Volkman) **canals**, which also house blood vessels and nerves.

The second type of bone tissue, called **spongy**, or **cancellous, bone**, has more spaces than compact bone. It is made of a meshwork of small, bony plates filled with red marrow. Spongy bone is found at the epiphyses (ends) of the long bones and at the center of other bones. Figure 7-4 shows a photograph of both compact and spongy tissue in a bone section.

Checkpoint 7-1 A long bone has a long, narrow shaft and two irregular ends. What are the scientific names for the shaft and the ends of a long bone?

Checkpoint 7-2 What are the two types of osseous (bone) tissue and where is each type found?

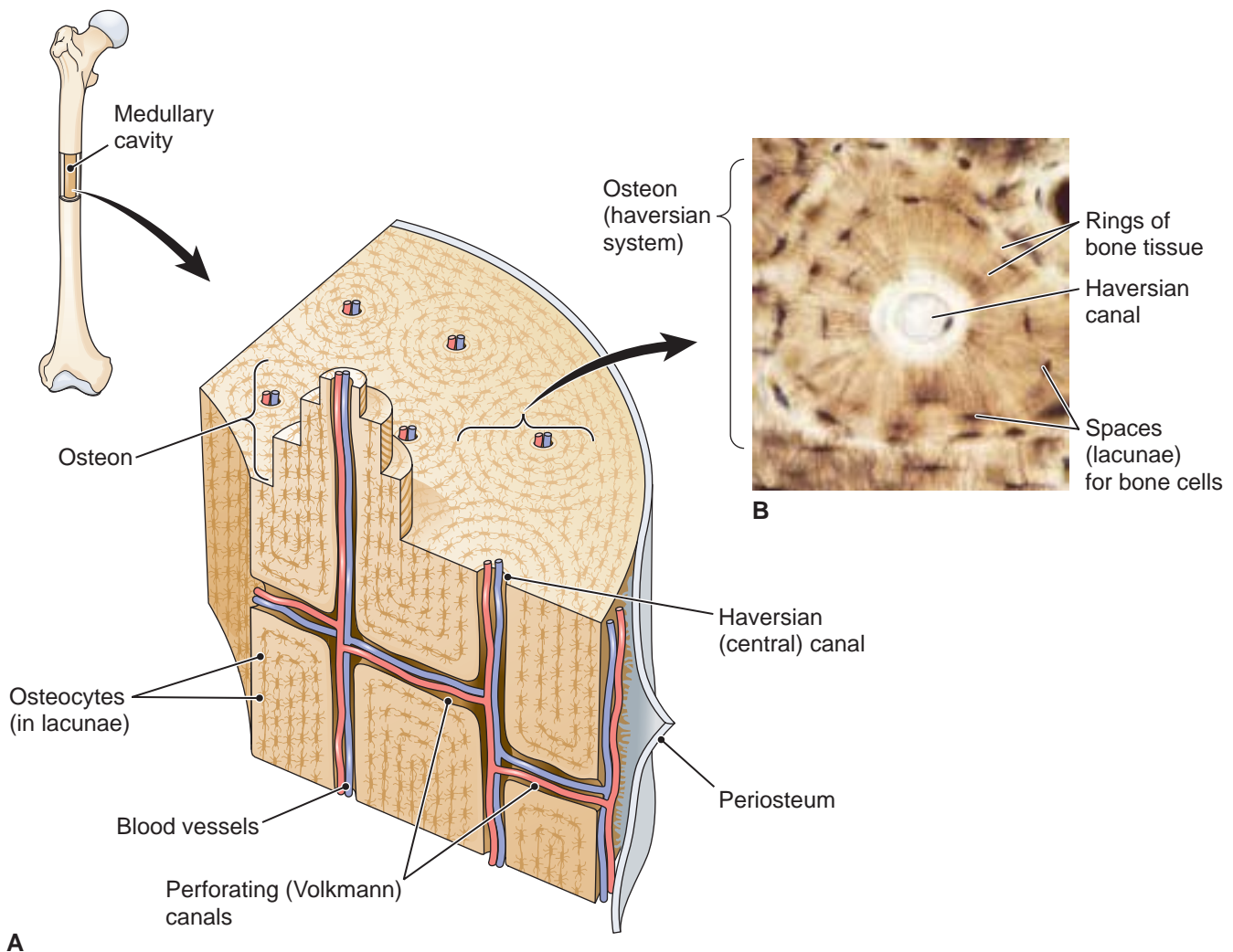


Figure 7-3 Compact bone tissue. (A) This section shows osteocytes (bone cells) within osteons (haversian systems). It also shows the canals that penetrate the tissue. (B) Microscopic view of compact bone in cross section ($\times 300$) showing a complete osteon. In living tissue, osteocytes (bone cells) reside in spaces (lacunae) and extend out into channels that radiate from these spaces. (B, Reprinted with permission from Ross MH, Kaye GI, Pawlina, W. *Histology*. 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2003.)



Figure 7-4 Bone tissue, longitudinal section. Spongy (cancellous) bone makes up most of the epiphysis (end) of this long bone, shown by the arrows. (Reprinted with permission from Ross MH, Kaye GI, Pawlina, W. *Histology*. 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2003.)

Bone Marrow Bones contain two kinds of marrow. **Red marrow** is found at the ends of the long bones and at the center of other bones (see Fig. 7-2). Red bone marrow manufactures blood cells. **Yellow marrow** is found chiefly in the central cavities of the long bones. Yellow marrow is composed largely of fat.

Bone Membranes Bones are covered on the outside (except at the joint region) by a membrane called the **periosteum** (per-e-OS-te-um) (see Fig. 7-2). The inner layer of this membrane contains cells (osteoblasts) that are essential in bone formation, not only during growth but also in the repair of injuries. Blood vessels and lymphatic vessels in the periosteum play an important role in the nourishment of bone tissue. Nerve fibers in the periosteum make their presence known when one suffers a fracture, or when one receives a blow, such as on the shinbone. A thinner membrane, the **endosteum** (en-DOS-te-um), lines the marrow cavity of a bone; it too contains cells that aid in the growth and repair of bone tissue.

Bone Growth and Repair

During early development, the embryonic skeleton is at first composed almost entirely of cartilage. (Portions of the skull develop from fibrous connective tissue.) The conversion of cartilage to bone, a process known as **ossification**, begins during the second and third months of embryonic life. At this time, bone-building cells, called

osteoblasts (OS-te-o-blasts), become active. First, they begin to manufacture the **matrix**, which is the material located between the cells. This intercellular substance contains large quantities of **collagen**, a fibrous protein that gives strength and resilience to the tissue. Then, with the help of enzymes, calcium compounds are deposited within the matrix.

Once this intercellular material has hardened, the cells remain enclosed within the lacunae (small spaces) in the matrix. These cells, now known as **osteocytes** (OS-te-o-sites), are still living and continue to maintain the existing bone matrix, but they do not produce new bone tissue. When bone has to be remodeled or repaired later in life, new osteoblasts develop from stem cells in the endosteum and periosteum.

One other type of cell found in bone develops from a type of white blood cell (monocyte). These large, multinucleated **osteoclasts** (OS-te-o-klasts) are responsible for the process of **resorption**, which is the breakdown of bone tissue. Resorption is necessary for remodeling and repair of bone, as occurs during growth and after injury. Bone tissue is also resorbed when its stored minerals are needed by the body.

The formation and resorption of bone tissue are regulated by several hormones. Vitamin D promotes the absorption of calcium from the intestine. Other hormones involved in these processes are produced by glands in the neck. Calcitonin from the thyroid gland promotes the uptake of calcium by bone tissue. Parathyroid hormone (PTH) from the parathyroid glands at the posterior of the thyroid causes bone resorption and release of calcium into the blood. These hormones are discussed more fully in Chapter 12.

Checkpoint 7-3 What are the three types of cells found in bone and what is the role of each?

Formation of a Long Bone In a long bone, the transformation of cartilage into bone begins at the center of the shaft during fetal development. Around the time of birth, secondary bone-forming centers, or **epiphyseal** (ep-ih-FIZ-e-al) **plates**, develop across the ends of the bones. The long bones continue to grow in length at these centers by calcification of new cartilage through childhood and into the late teens. Finally, by the late teens or early 20s, the bones stop growing in length. Each epiphyseal plate hardens and can be seen in x-ray films as a thin line, the epiphyseal line, across the end of the bone. Physicians can judge the future growth of a bone by the appearance of these lines on x-ray films.

As a bone grows in length, the shaft is remodeled so that it grows wider as the central marrow cavity increases in size. Thus, alterations in the shape of the bone are a result of the addition of bone tissue to some surfaces and its resorption from others.

The processes of bone resorption and bone formation continue throughout life, more actively in some places

than in others, as bones are subjected to “wear and tear” or injuries. The bones of small children are relatively pliable because they contain a larger proportion of cartilage and are undergoing active bone formation. In elderly people, there is a slowing of the processes that continually renew bone tissue. As a result, the bones are weaker and more fragile. Elderly people also have a decreased ability to form the protein framework on which calcium salts are deposited. Fractures in elderly people heal more slowly because of these decreases in bone metabolism.

Checkpoint 7-4 As the embryonic skeleton is converted from cartilage to bone, the intercellular matrix becomes hardened. What compounds are deposited in the matrix to harden it?

Checkpoint 7-5 After birth, long bones continue to grow in length at secondary centers. What are these centers called?

Bone Markings

In addition to their general shape, bones have other distinguishing features, or **bone markings**. These markings include raised areas and depressions that help to form joints or serve as points for muscle attachments and various holes that allow the passage of nerves and blood vessels. Some of these identifying features are described next.

Projections

- ▶ **Head**—a rounded, knoblike end separated from the rest of the bone by a slender region, the neck.
- ▶ **Process**—a large projection of a bone, such as the upper part of the ulna in the forearm that creates the elbow.
- ▶ **Condyle** (KON-dile)—a rounded projection; a small projection above a condyle is an epicondyle.

- ▶ **Crest**—a distinct border or ridge, often rough, such as over the top of the hip bone.
- ▶ **Spine**—a sharp projection from the surface of a bone, such as the spine of the scapula (shoulder blade).

Depressions or Holes

- ▶ **Foramen** (fo-RA-men)—a hole that allows a vessel or a nerve to pass through or between bones. The plural is foramina (fo-RAM-ih-nah).
- ▶ **Sinus** (SI-nus)—an air space found in some skull bones.
- ▶ **Fossa** (FOS-sah)—a depression on a bone surface. The plural is fossae (FOS-se).
- ▶ **Meatus** (me-A-tus)—a short channel or passageway, such as the channel in the temporal bone of the skull that leads to the inner ear.

Examples of these and other markings can be seen on the bones illustrated in this chapter. To find out how these markings can be used in healthcare, see Box 7-1, Landmarking: Seeing With Your Fingers.

Checkpoint 7-6 Bones have a number of projections, depressions, and holes. What are some functions of these markings?

Bones of the Axial Skeleton

The skeleton may be divided into two main groups of bones (see Fig. 7-1):

- ▶ The **axial** (AK-se-al) **skeleton** consists of 80 bones and includes the bony framework of the head and the trunk.
- ▶ The **appendicular** (ap-en-DIK-u-lar) **skeleton** consists of 126 bones and forms the framework for the **extremities** (limbs) and for the shoulders and hips.

Box 7-1 Clinical Perspectives

Landmarking: Seeing With Your Fingers

Most body structures lie beneath the skin, hidden from view except in dissection. A technique called **landmarking** allows healthcare providers to visualize hidden structures without cutting into the patient. Bony prominences, or landmarks, can be palpated (felt) beneath the skin to serve as reference points for locating other structures. Landmarking is used during physical examinations and surgeries, when giving injections, and for many other clinical procedures. The lower tip of the sternum, the xiphoid process, is a reference point in the administration of cardiopulmonary resuscitation (CPR).

Practice landmarking by feeling for some of the other bony prominences. You can feel the joint between the mandible and the temporal bone of the skull (the temporomandibular joint, or TMJ) anterior to the ear canal as you move your lower jaw up and down. Feel for the notch in the sternum (breast bone) between the clavicles (collar bones). Approximately 4 cm

below this notch you will feel a bump called the sternal angle. This prominence is an important landmark because its location marks where the trachea splits to deliver air to both lungs. Move your fingers lateral to the sternal angle to palpate the second ribs, important landmarks for locating the heart and lungs. Feel for the most lateral bony prominence of the shoulder, the acromion process of the scapula (shoulder blade). Two to three fingerbreadths down from this point is the correct injection site into the deltoid muscle of the shoulder. Place your hands on your hips and palpate the iliac crest of the hip bone. Move your hands forward until you reach the anterior end of the crest, the anterior superior iliac spine (ASIS). Feel for the part of the bony pelvis that you sit on. This is the ischial tuberosity. It and the ASIS are important landmarks for locating safe injection sites in the gluteal region.

Table 7-1 Bones of the Skeleton

REGION	BONES	DESCRIPTION
Axial Skeleton		
Skull		
Cranium	Cranial bones (8)	Chamber enclosing the brain; houses the ear and forms part of the eye socket
Facial portion	Facial bones (14)	Form the face and chambers for sensory organs
Hyoid		U-shaped bone under lower jaw; used for muscle attachments
Ossicles	Ear bones (3)	Transmit sound waves in inner ear
Trunk		
Vertebral column	Vertebrae (26)	Encloses the spinal cord
Thorax	Sternum Ribs (12 pair)	Anterior bone of the thorax Enclose the organs of the thorax
Appendicular Skeleton		
Upper division		
Shoulder girdle	Clavicle Scapula	Anterior; between sternum and scapula Posterior, anchors muscles that move arm
Upper extremity	Humerus Ulna Radius Carpals (8) Metacarpals (5) Phalanges (14)	Proximal arm bone Medial bone of forearm Lateral bone of forearm Wrist bones Bones of palm Bones of fingers
Lower division		
Pelvis	Os coxae (2)	Join sacrum and coccyx of vertebral column to form the bony pelvis
Lower extremity	Femur Patella Tibia Fibula Tarsal bones (7) Metatarsals (5) Phalanges (14)	Thigh bone Kneecap Medial bone of leg Lateral bone of leg Ankle bones Bones of instep Bones of toes

We describe the axial skeleton first and then proceed to the appendicular skeleton. **Table 7-1** provides an outline of all the bones included in this discussion.

Framework of the Skull

The bony framework of the head, called the **skull**, is subdivided into two parts: the cranium and the facial portion. Refer to **Figures 7-5 through 7-8**, which show different views of the skull, as you study the following descriptions. Color-coding of the bones will aid in identification as the skull is seen from different positions.

Cranium This rounded chamber that encloses the brain is composed of eight distinct cranial bones.

♦ The **frontal bone** forms the forehead, the anterior of the skull's roof, and the roof of the eye orbit (socket). The

frontal sinuses (air spaces) communicate with the nasal cavities (see **Figs. 7-7 and 7-8**). These sinuses and others near the nose are described as **paranasal sinuses**.

- ♦ The two **parietal** (pah-RI-eh-tal) bones form most of the top and the side walls of the cranium.
- ♦ The two **temporal bones** form part of the sides and some of the base of the skull. Each one contains **mastoid sinuses** as well as the ear canal, the eardrum, and the entire middle and internal portions of the ear. The **mastoid process** of the temporal bone projects downward immediately behind the external part of the ear. It contains the mastoid air cells and serves as a place for muscle attachment.
- ♦ The **ethmoid** (ETH-moyd) **bone** is a light, fragile bone located between the eyes (see **Fig. 7-7**). It forms a part of the medial wall of the eye orbit, a small portion of the cranial floor, and most of the nasal cavity roof. It contains several air spaces, comprising some of the paranasal sinuses. A thin, platelike, downward extension of this bone (the perpendicular plate) forms much of the nasal septum, a midline partition in the nose (see **Fig. 7-5 A**)
- ♦ The **sphenoid** (SFE-noyd) **bone**, when seen from a superior view, resembles a bat with its wings extended. It lies at the base of the skull anterior to the temporal bones and forms part of the eye socket. The sphenoid contains a saddlelike depression, the **sella turcica** (SEL-ah TUR-sih-ka), that holds and protects the pituitary gland (see **Fig. 7-7**).

♦ The **occipital** (ok-SIP-ih-tal) **bone** forms the posterior and a part of the base of the skull. The **foramen magnum**, located at the base of the occipital bone, is a large opening through which the spinal cord communicates with the brain (see **Figs. 7-6 and 7-7**).

Uniting the bones of the skull is a type of flat, immovable joint known as a **suture** (SU-chur) (see **Fig. 7-5**). Some of the most prominent cranial sutures are the:

- ♦ **Coronal** (ko-RO-nal) suture, which joins the frontal bone with the two parietal bones along the coronal plane
- ♦ **Squamous** (SKWA-mus) suture, which joins the temporal bone to the parietal bone on the lateral surface of the cranium (named because it is in a flat portion of the skull)
- ♦ **Lambdoid** (LAM-doyd) suture, which joins the occipital bone with the parietal bones in the posterior cra-

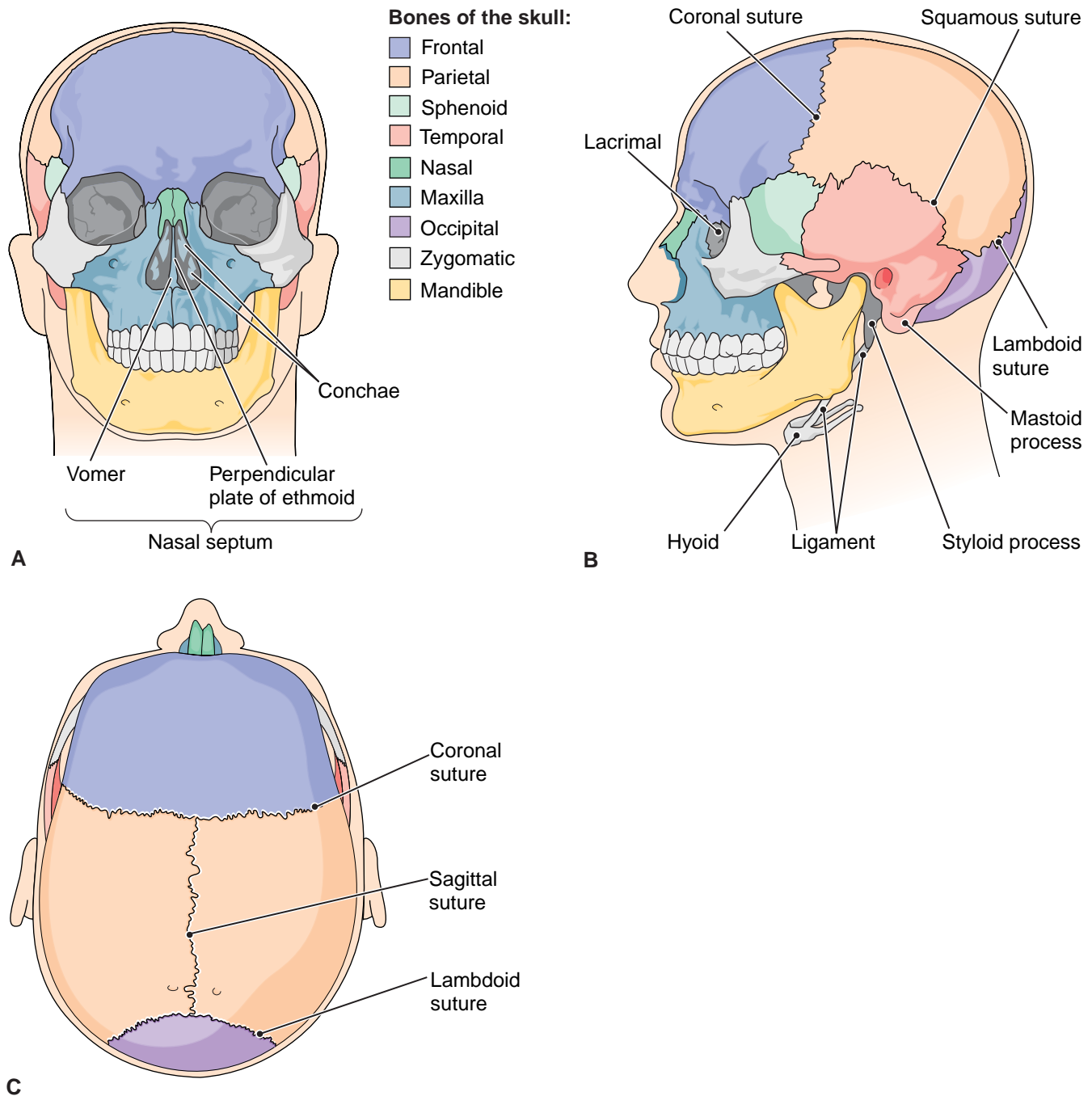


Figure 7-5 The skull. (A) Anterior view. (B) Left lateral view. (C) Superior view. **ZOOMING IN** ♦ What type of joint is between bones of the skull?

nium (named because it resembles the Greek letter lambda)

- ▶ Sagittal (SAJ-ih-tal) suture, which joins the two parietal bones along the superior midline of the cranium, along the sagittal plane

Facial Bones The facial portion of the skull is composed of 14 bones (see Fig. 7-5):

- ▶ The **mandible** (MAN-dih-bl), or lower jaw bone, is the only movable bone of the skull.
- ▶ The two **maxillae** (mak-SIL-e) fuse in the midline to form the upper jaw bone, including the front part of the hard palate (roof of the mouth). Each maxilla contains a large air space, called the **maxillary sinus**, that communicates with the nasal cavity.
- ▶ The two **zygomatic** (zi-go-MAT-ik) bones, one on each side, form the prominences of the cheeks.
- ▶ Two slender **nasal bones** lie side by side, forming the bridge of the nose.
- ▶ The two **lacrimal** (LAK-rih-mal) bones, each about the size of a fingernail, lie near the inside corner of the

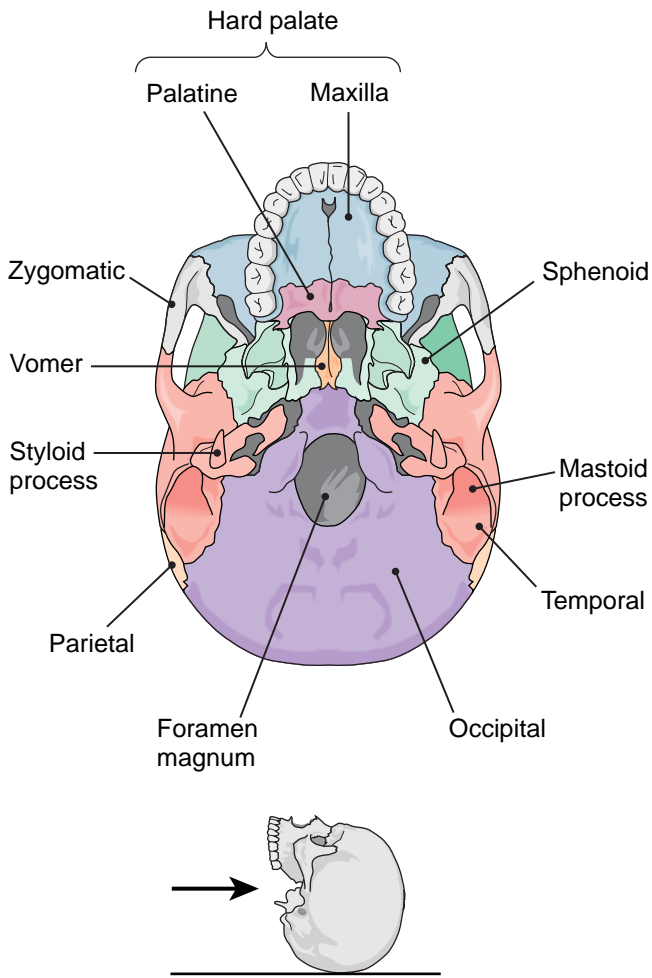


Figure 7-6 The skull, inferior view. The mandible (lower jaw) has been removed. **ZOOMING IN ♦** What two bones make up each side of the hard palate?

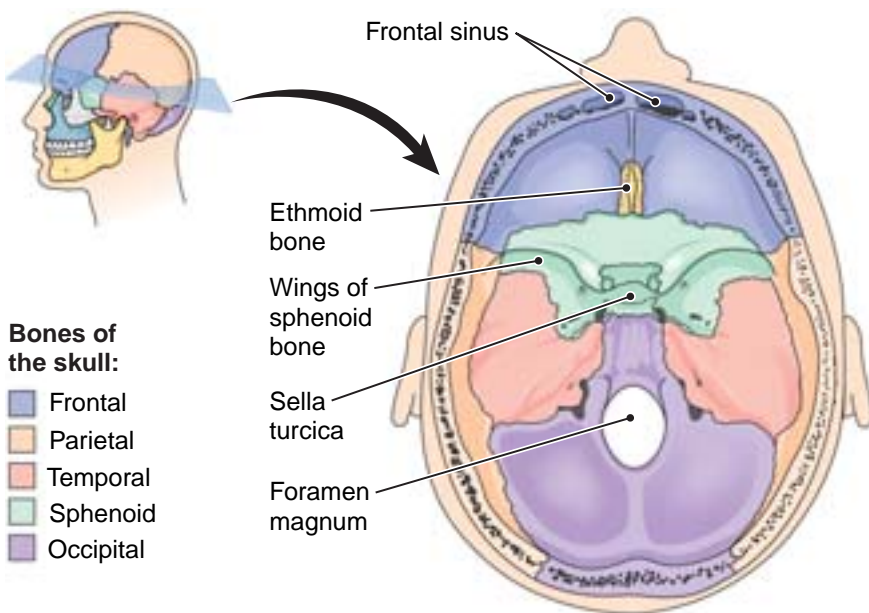


Figure 7-7 Floor of cranium, superior view. The internal surfaces of some of the cranial bones are visible. **ZOOMING IN ♦** What is a foramen?

eye in the front part of the medial wall of the orbital cavity.

- ▶ The vomer (VO-mer), shaped like the blade of a plow, forms the lower part of the nasal septum (see Fig. 7-5 A).
- ▶ The paired palatine (PAL-ah-tine) bones form the back part of the hard palate (see Figs. 7-6 and 7-8).
- ▶ The two inferior nasal conchae (KON-ke) extend horizontally along the lateral wall (sides) of the nasal cavities. The paired superior and middle conchae are part of the ethmoid bone (see Figs. 7-5 A and 7-8).

In addition to the bones of the cranium and the facial bones, there are three tiny bones, or ossicles (OS-sik-ls), in each middle ear (see Chapter 11) and a single horseshoe, or U-shaped, bone just below the skull proper, called the hyoid (HI-oyd) bone, to which the tongue and other muscles are attached (see Fig. 7-5 B).

Openings in the base of the skull provide spaces for the entrance and exit of many blood vessels, nerves, and other structures. Projections and slightly elevated portions of the bones provide for the attachment of muscles. Some portions protect delicate structures, such as the eye orbit and the part of the temporal bone that encloses the inner portions of the ear. The sinuses provide lightness and serve as resonating chambers for the voice (which is why your voice sounds better to you as you are speaking than it sounds when you hear it played back as a recording).

Infant Skull The skull of the infant has areas in which the bone formation is incomplete, leaving so-called soft spots, properly called fontanel (fon-tah-NELS) (Fig. 7-9). These flexible regions allow the skull to compress and change shape during the birth process. They also allow for rapid growth of the brain during infancy. Although there are a number of fontanel, the largest and most recognizable is near the front of the skull at the junction of the two parietal bones and the frontal bone. This anterior fontanel usually does not close until the child is about 18 months old.

Framework of the Trunk

The bones of the trunk include the spine, or vertebral (VER-teh-bral), column, and the bones of the chest, or thorax (THO-raks).

Vertebral Column This bony sheath for the spinal cord is made of a series of irregularly shaped bones. These number 33 or 34 in the child, but because of fusions that occur later in the lower part of the spine, there usually are just 26 separate bones in the adult spinal column. Figures 7-10

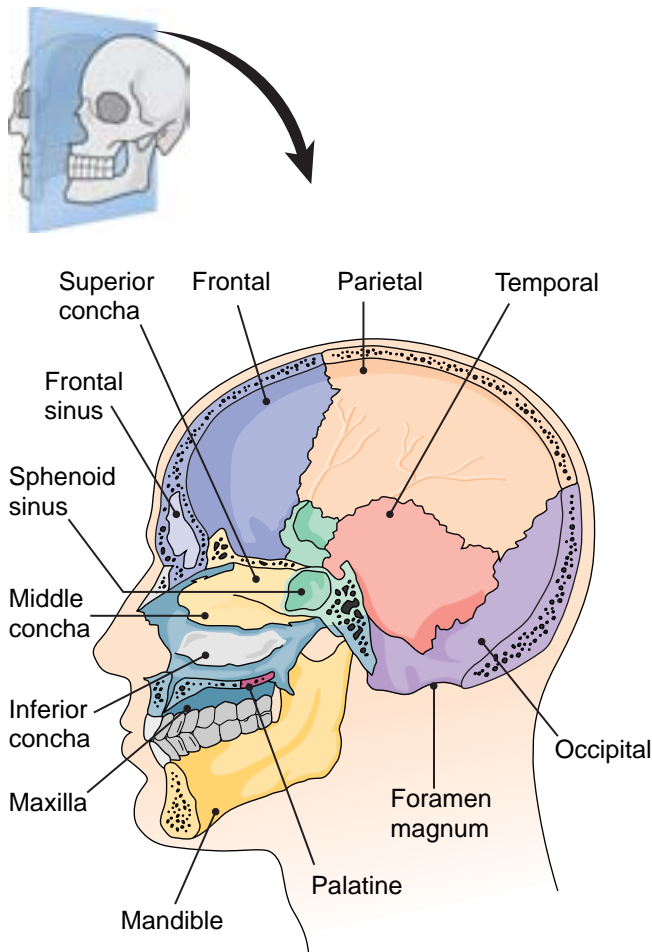


Figure 7-8 The skull, sagittal section.

and 7-11 show the vertebral column from lateral and anterior views.

The **vertebrae** (VER-teh-bre) have a drum-shaped **body** (centrum) located anteriorly (toward the front) that serves as the weight-bearing part; disks of cartilage between the vertebral bodies act as shock absorbers and provide flexibility (see Fig. 7-11). In the center of each vertebra is a large hole, or **foramen**. When all the vertebrae are linked in series by strong connective tissue bands (ligaments), these spaces form the **spinal canal**, a bony cylinder that protects the spinal cord. Projecting dorsally (toward the back) from the bony arch that encircles the spinal cord is the **spinous process**, which usually can be felt just under the skin of the back. Projecting laterally is a **transverse process** on each side. These processes are attachment points for muscles. When viewed from a lateral aspect, the vertebral column can be seen to have a series of **intervertebral foramina**, formed between the vertebrae as they join together, through which spinal nerves emerge as they leave the spinal cord (see Fig. 7-10).

The bones of the vertebral column are named and numbered from above downward, on the basis of location. There are five regions:

- The **cervical** (SER-vih-kal) **vertebrae**, seven in number (C1 to C7), are located in the neck (see Fig. 7-11). The first vertebra, called the **atlas**, supports the head (Fig. 7-12). (This vertebra is named for the mythologic character who was able to support the world in his hands.) When one nods the head, the skull rocks on the atlas at the occipital bone. The second cervical vertebra, the **axis** (see Fig. 7-12), serves as a pivot when the head is turned from side to side. It has an upright toothlike part, the **dens**, that projects into the atlas and serves as a pivot point. The absence of a body in these vertebrae allows for the extra movement. Only the cervical vertebrae have a hole in the transverse process on each side (see Fig. 7-11). These **transverse foramina** accommodate blood vessels and nerves that supply the neck and head.
- The **thoracic vertebrae**, 12 in number (T1 to T12), are located in the chest. They are larger and stronger than the cervical vertebrae and each has a longer spinous process that points downward (see Fig. 7-11). The posterior ends of the 12 pairs of ribs are attached to these vertebrae.
- The **lumbar vertebrae**, five in number (L1 to L5), are located in the small of the back. They are larger and heavier than the vertebrae superior to them and can support more weight (see Fig. 7-11). All of their processes are shorter and thicker.

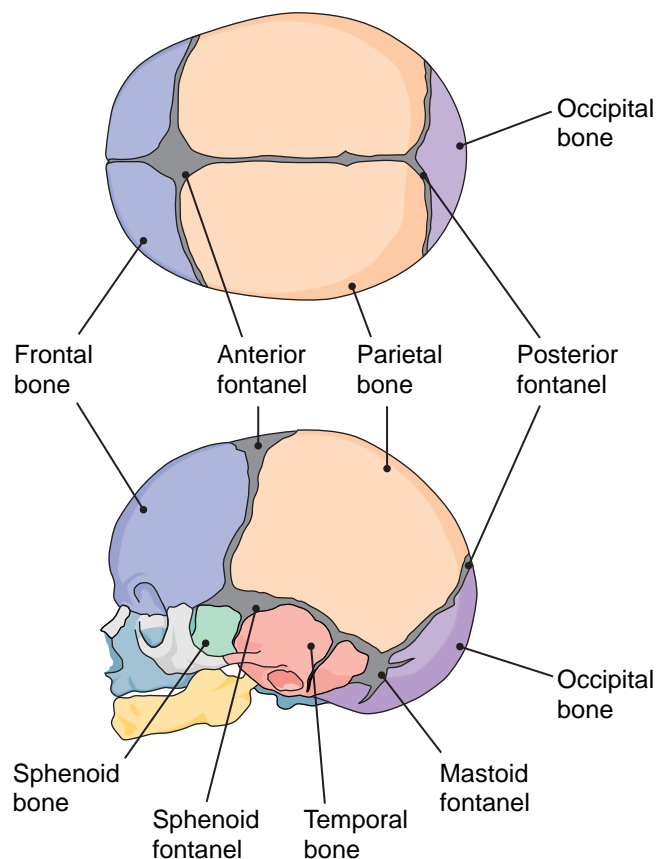


Figure 7-9 Infant skull, showing fontanelles. **ZOOMING IN** ♦ Which is the largest fontanel?

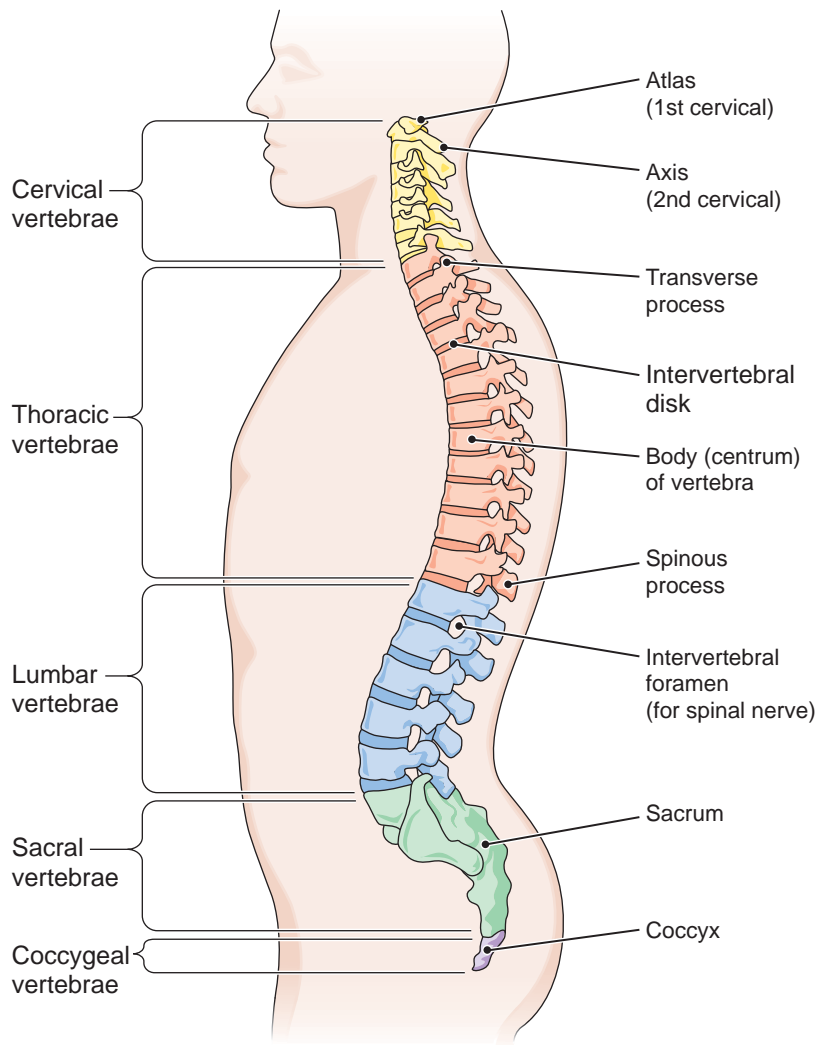


Figure 7-10 Vertebral column, left lateral view. **ZOOMING IN** ♦ From an anterior view, which group(s) of vertebrae form a convex curve? Which group(s) form a concave curve?

- ▶ The **sacral** (SA-kral) vertebrae are five separate bones in the child. They eventually fuse to form a single bone, called the **sacrum** (SA-krum), in the adult. Wedged between the two hip bones, the sacrum completes the posterior part of the bony pelvis.
- ▶ The **coccygeal** (kok-SIJ-e-al) vertebrae consist of four or five tiny bones in the child. These later fuse to form a single bone, the **coccyx** (KOK-siks), or tail bone, in the adult.

Curves of the Spine When viewed from the side, the vertebral column can be seen to have four curves, corresponding to the four groups of vertebrae (see Fig. 7-10). In the fetus, the entire column is concave forward (curves away from a viewer facing the fetus), as seen in Figure 7-13. This is the primary curve.

When an infant begins to assume an erect posture, secondary curves develop. These curves are convex (curve toward the viewer). The cervical curve appears when the head is held up at about 3 months of age; the

lumbar curve appears when the child begins to walk. The thoracic and sacral curves remain the two primary curves. These curves of the vertebral column provide some of the resilience and spring so essential in balance and movement.

Thorax The bones of the thorax form a cone-shaped cage (Fig. 7-14). Twelve pairs of ribs form the bars of this cage, completed by the **sternum** (STER-num), or breastbone, anteriorly. These bones enclose and protect the heart, lungs, and other organs contained in the thorax.

The superior portion of the sternum is the broadly T-shaped **manubrium** (mah-NU-bre-um) that joins laterally on the right and left with the clavicle (collarbone) (see Fig. 7-1). The point on the manubrium where the clavicle joins can be seen on Figure 7-14 as the clavicular notch. Laterally, the manubrium joins with the anterior ends of the first pair of ribs. The **body** of the sternum is long and bladelike. It joins along each side with ribs two through seven. Where the manubrium joins the body of the sternum, there is a slight elevation, the **sternal angle**, which easily can be felt as a surface landmark.

The lower end of the sternum consists of a small tip that is made of cartilage in youth but becomes bone in the adult. This is the **xiphoid** (ZIF-oyd) **process**. It is used as a landmark for CPR (cardiopulmonary resuscitation) to locate the region for chest compression.

locate the region for chest compression.

All 12 of the ribs on each side are attached to the vertebral column posteriorly. However, variations in the anterior attachment of these slender, curved bones have led to the following classification:

- ▶ **True ribs**, the first seven pairs, are those that attach directly to the sternum by means of individual extensions called **costal** (KOS-tal) **cartilages**.
- ▶ **False ribs** are the remaining five pairs. Of these, the 8th, 9th, and 10th pairs attach to the cartilage of the rib above. The last two pairs have no anterior attachment at all and are known as **floating ribs**.

The spaces between the ribs, called **intercostal spaces**, contain muscles, blood vessels, and nerves.

Checkpoint 7-7 The axial skeleton consists of the bones of the skull and the trunk. What bones make up the skeleton of the trunk?

Checkpoint 7-8 What are the five regions of the vertebral column?

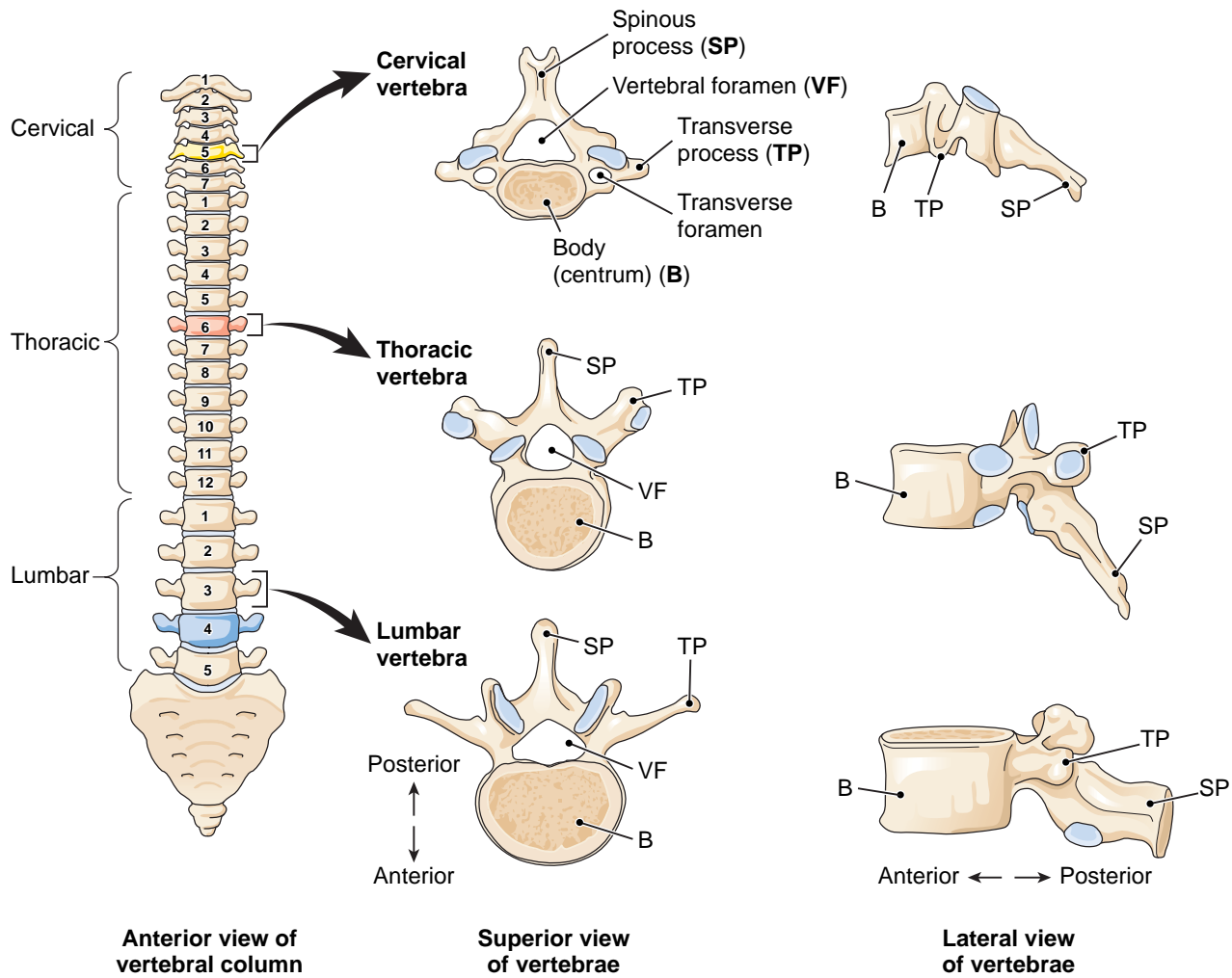


Figure 7-11 The vertebral column and vertebrae.

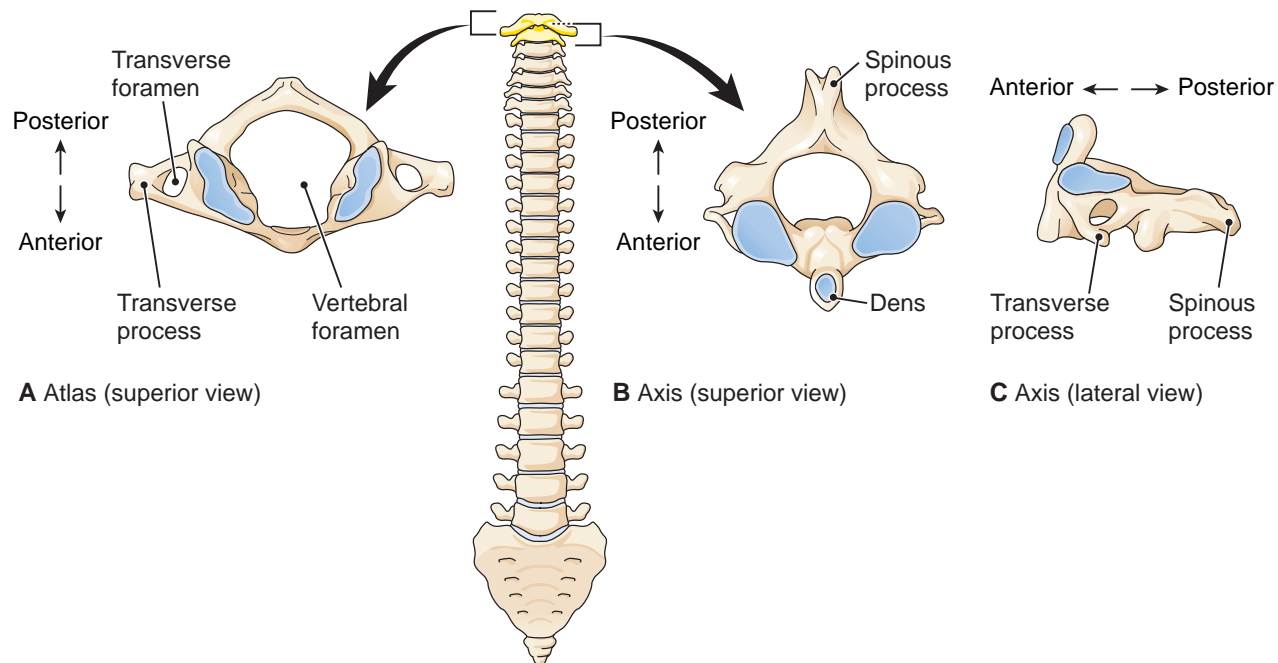


Figure 7-12 The first two cervical vertebrae. (A) The atlas (1st cervical vertebra), superior view. (B) The axis (2nd cervical vertebra), superior view. (C) The axis, lateral view.

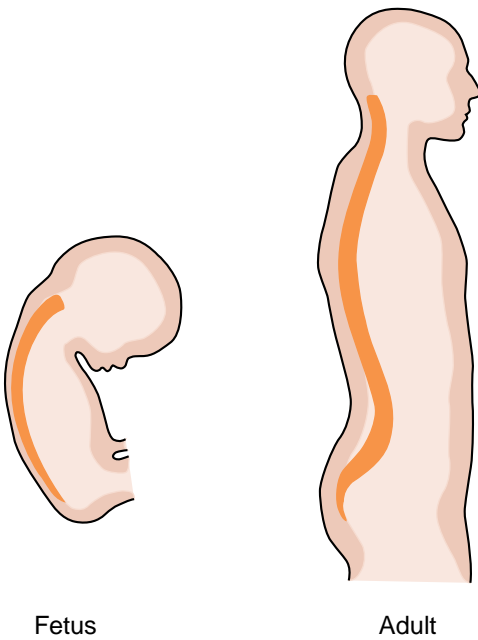


Figure 7-13 Curves of the spine. Compare the fetus (left) with the adult (right).

► Bones of the Appendicular Skeleton

The appendicular skeleton may be considered in two divisions: upper and lower. The upper division on each side includes the shoulder, the arm (between the shoulder and the elbow), the forearm (between the elbow and the wrist), the hand, and the fingers. The lower division includes the hip (part of the pelvic girdle), the thigh (between the hip and the knee), the leg (between the knee and the ankle), the ankle, the foot, and the toes.

The Upper Division of the Appendicular Skeleton

The bones of the upper division may be divided into two groups, the shoulder girdle and the upper extremity.

The Shoulder Girdle The shoulder girdle consists of two bones (Fig. 7-15):

- The clavicle (KLAV-ih-kl), or collarbone, is a slender bone with two shallow curves. It joins the sternum anteriorly and the scapula laterally and helps to support the shoulder. Because it often receives the full force of

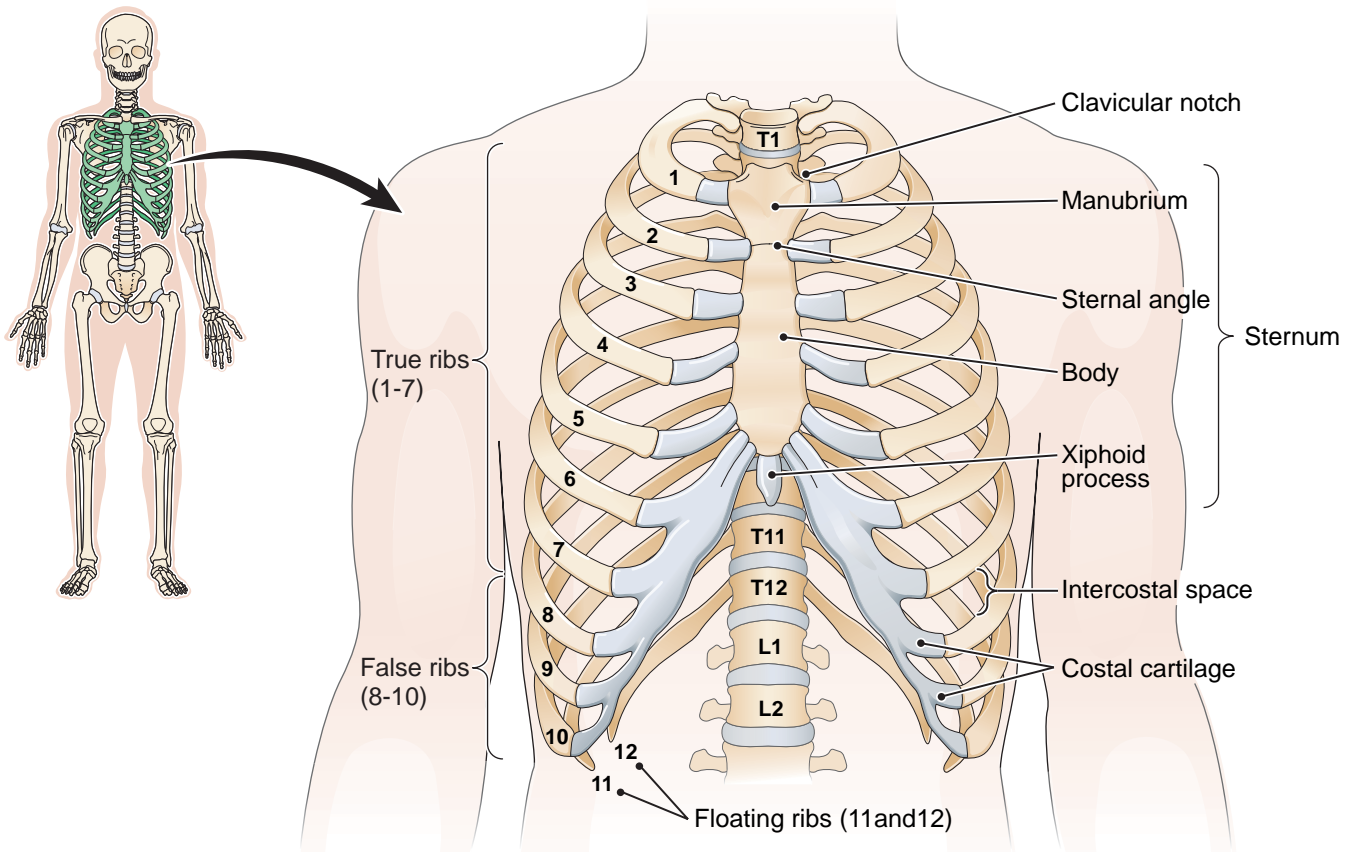


Figure 7-14 Bones of the thorax, anterior view. The first seven pairs of ribs are the true ribs; pairs 8 through 12 are the false ribs, of which the last two pairs are also called floating ribs. **ZOOMING IN** ♦ *To what bones do the costal cartilages attach?*

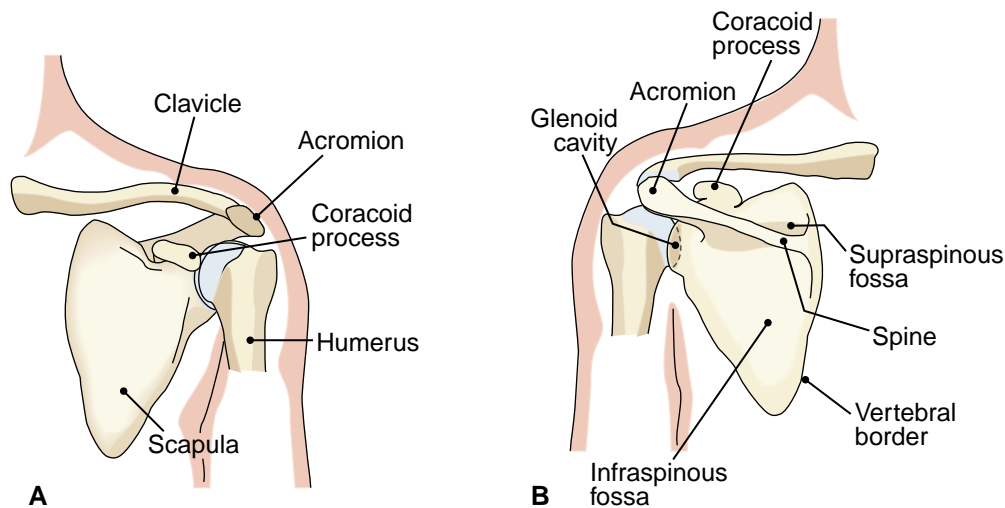


Figure 7-15 The shoulder girdle and scapula. (A) Bones of the shoulder girdle, left anterior view. (B) Left scapula, posterior view. **ZOOMING IN** ♦ What does the prefix *supra* mean? What does the prefix *infra* mean?

falls on outstretched arms or of blows to the shoulder, it is the most frequently broken bone.

- ▶ The **scapula** (SKAP-u-lah), or shoulder blade, is shown from anterior and posterior views in Figure 7-15. The **spine** of the scapula is the posterior raised ridge that can be felt behind the shoulder in the upper portion of the back. Muscles that move the arm attach to fossae (depressions), known as the **supraspinous fossa** and the **infraspinous fossa**, superior and inferior to the scapular spine. The **acromion** (ah-KRO-me-on) is the process that joins the clavicle. This can be felt as the highest point of the shoulder. Below the acromion there is a shallow socket, the **glenoid cavity**, that forms a ball-and-socket joint with the arm bone (humerus). Medial to the glenoid cavity is the **coracoid** (KOR-ah-koyd) process, to which muscles attach.

The Upper Extremity The upper extremity is also referred to as the upper limb, or simply the arm, although technically, the arm is only the region between the shoulder and the elbow. The region between the elbow and wrist is the forearm. The upper extremity consists of the following bones:

- ▶ The proximal bone is the **humerus** (HU-mer-us), or arm bone (Fig. 7-16). The head of the humerus forms a joint with the glenoid cavity of the scapula. The distal end has a projection on each side, the medial and lateral epicondyles (ep-ih-KON-diles), to which tendons at-

tach, and a pulley-shaped midportion, the **trochlea** (TROK-le-ah), that forms a joint with the ulna of the forearm.

- ▶ The forearm bones are the **ulna** (UL-nah) and the **radius** (RA-de-us). In the anatomic position, the ulna lies on the medial side of the forearm in line with the little finger, and the radius lies laterally, above the thumb (Fig. 7-17). When the forearm is supine, with the palm up or forward, the two bones are parallel; when the forearm is prone, with the palm down or back, the dis-

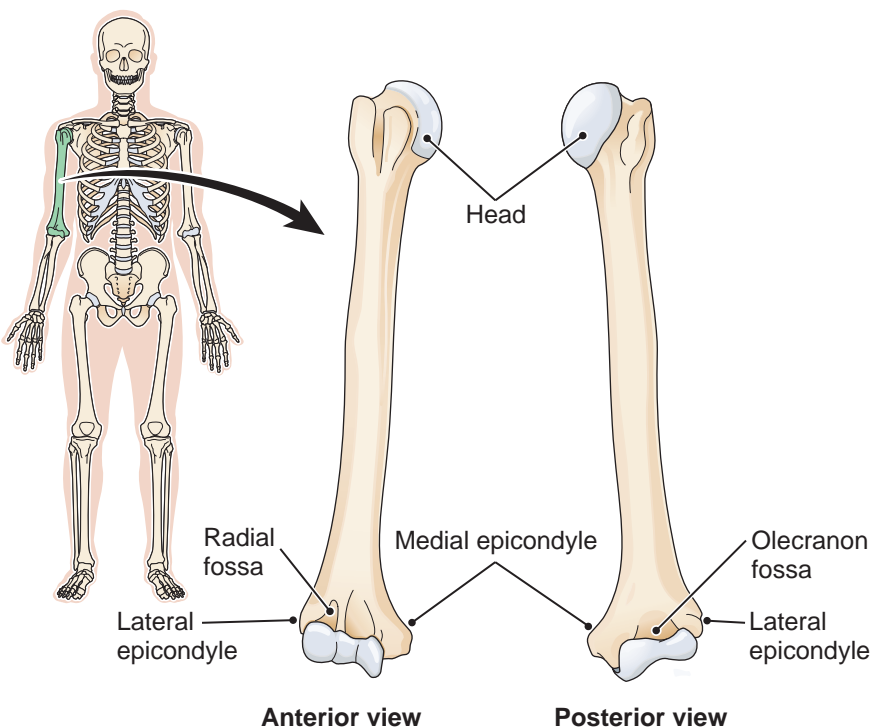


Figure 7-16 The right humerus.

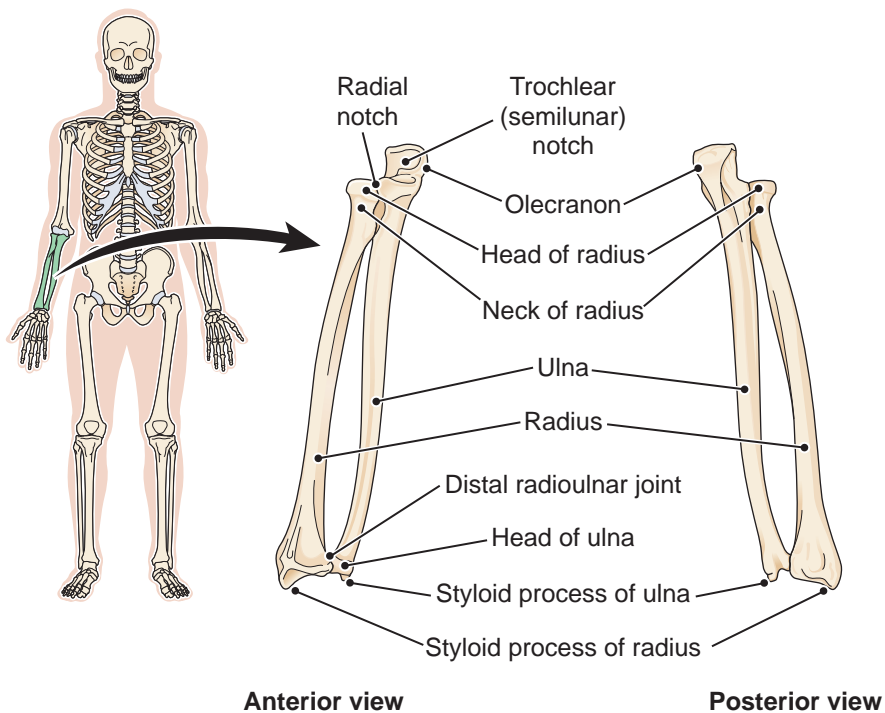


Figure 7-17 Radius and ulna of the right forearm. **ZOOMING IN** ♦ What is the lateral bone of the forearm?

tal end of the radius rotates around the ulna so that the shafts of the two bones are crossed (Fig. 7-18). In this position, a distal projection (styloid process) of the ulna pops up at the outside of the wrist.

► The proximal end of the ulna has the large **olecranon** (o-LEK-rah-non) that forms the point of the elbow (see Fig. 7-17). The trochlea of the distal humerus fits into the deep **trochlear notch** of the ulna, allowing a hinge action at the elbow joint. This ulnar depression, because of its deep half-moon shape, is also known as the **semilunar notch** (Fig. 7-19).

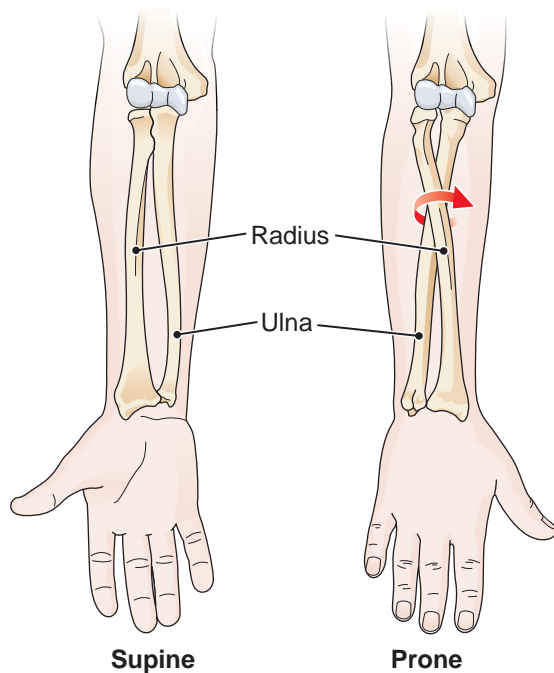


Figure 7-18 Movements of the forearm. When the palm is supine (facing up or forward), the radius and ulna are parallel. When the palm is prone (facing down or to the rear), the radius crosses over the ulna.

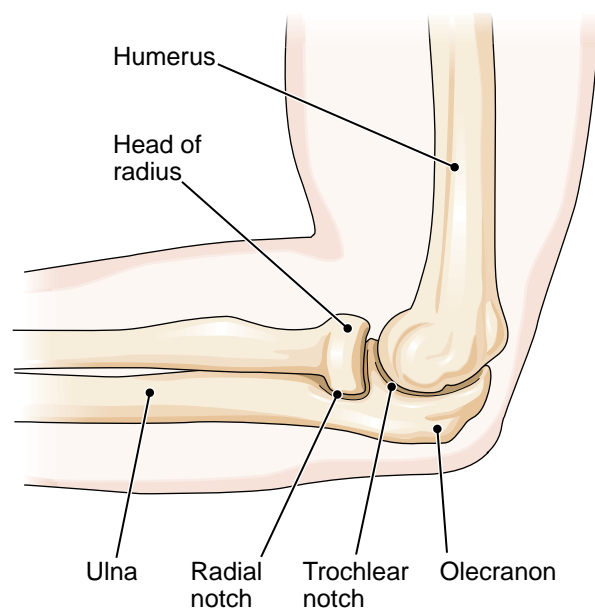


Figure 7-19 Left elbow, lateral view. **ZOOMING IN** ♦ What part of what bone forms the bony prominence of the elbow?

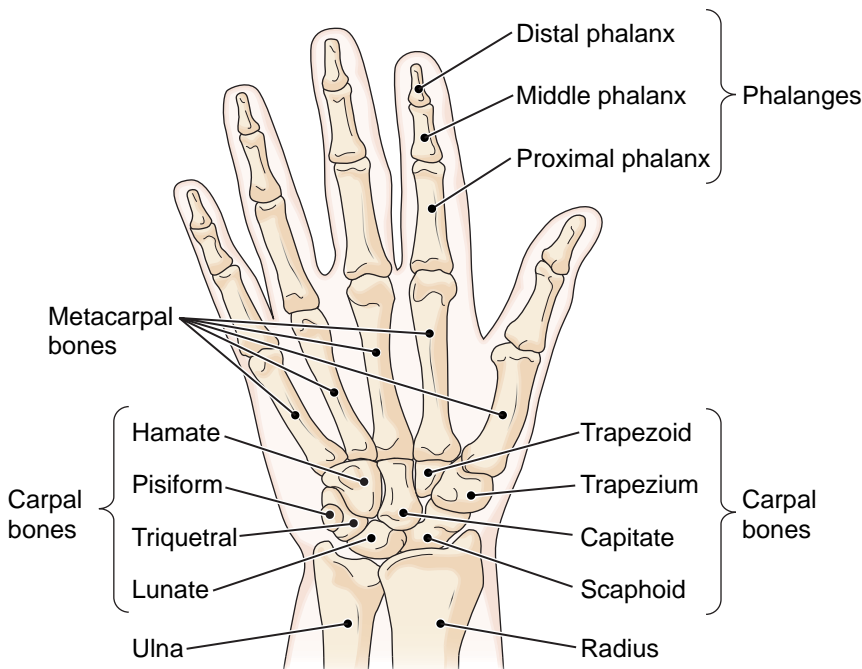


Figure 7-20 Bones of the right hand, anterior view.

- The wrist contains eight small **carpal** (KAR-pal) bones arranged in two rows of four each. The names of these eight different bones are given in [Figure 7-20](#).
- Five **metacarpal** bones are the framework for the palm of each hand. Their rounded distal ends form the knuckles.
- There are 14 **phalanges** (fah-LAN-jeze), or finger bones, in each hand, two for the thumb and three for each finger. Each of these bones is called a **phalanx** (FA-lanx). They are identified as the first, or proximal, which is attached to a metacarpal; the second, or middle; and the third, or distal. Note that the thumb has only two phalanges, a proximal and a distal ([see Fig. 7-20](#)).

The Lower Division of the Appendicular Skeleton

The bones of the lower division also fall into two groups, the pelvis and the lower extremity.

The Pelvic Bones The hip bone, or *os coxae*, begins its development as three separate bones that later fuse ([Fig. 7-21](#)). These individual bones are:

- The **ilium** (IL-e-um), which forms the upper, flared portion. The **iliac** (IL-e-ak) **crest** is the curved rim along the superior border of the ilium. It can be felt just below the waist. At either end of the crest are two bony projections. The most prominent of these is the **anterior superior iliac spine**, which is often used as a surface landmark in diagnosis and treatment.
- The **ischium** (IS-ke-um), which is the lowest and strongest part. The **ischial** (IS-ke-al) **spine** at the poste-

rior of the pelvic outlet is used as a point of reference during childbirth to indicate the progress of the presenting part (usually the baby's head) down the birth canal. Just inferior to this spine is the large **ischial tuberosity**, which helps support the weight of the trunk when one sits down. One is sometimes aware of this projection of the ischium when sitting on a hard surface for a while.

- The **pubis** (PU-bis), which forms the anterior part. The joint formed by the union of the two hip bones anteriorly is called the **pubic symphysis** (SIM-fih-sis). This joint becomes more flexible late in pregnancy to allow for passage of the baby's head during childbirth.

Portions of all three pelvic bones contribute to the formation of the **acetabulum** (as-eh-TAB-u-lum), the deep socket that holds the head of the femur (thigh bone) to form the hip joint.

The largest foramina in the entire body are found near the front of each hip bone, one on each side of the pubic symphysis. Each opening is partially covered by a membrane and is called an **obturator** (OB-tu-ra-tor) **foramen** ([see Fig. 7-21](#)).

The two *os coxae* join in forming the pelvis, a strong bony girdle completed by the sacrum and coccyx of the spine posteriorly. The pelvis supports the trunk and the organs in the lower abdomen, or pelvic cavity, including the urinary bladder, the internal reproductive organs, and parts of the intestine.

The female pelvis is adapted for pregnancy and childbirth ([Fig. 7-22](#)). Some of the ways in which the female pelvis differs from that of the male are:

- It is lighter in weight
- The ilia are wider and more flared
- The pubic arch, the anterior angle between the pubic bones, is wider
- The pelvic opening is wider and more rounded
- The lower diameter, the pelvic outlet, is larger
- The sacrum and coccyx are shorter and less curved

The Lower Extremity The lower extremity is also referred to as the lower limb, or simply the leg, although technically the leg is only the region between the knee and the ankle. The portion of the extremity between the hip and the knee is the thigh. The lower extremity consists of the following bones:

- The **femur** (FE-mer), the bone of the thigh, is the longest and strongest bone in the body. Proximally, it has a large ball-shaped head that joins the *os coxae* ([Fig. 7-23](#)). The large lateral projection near the head of

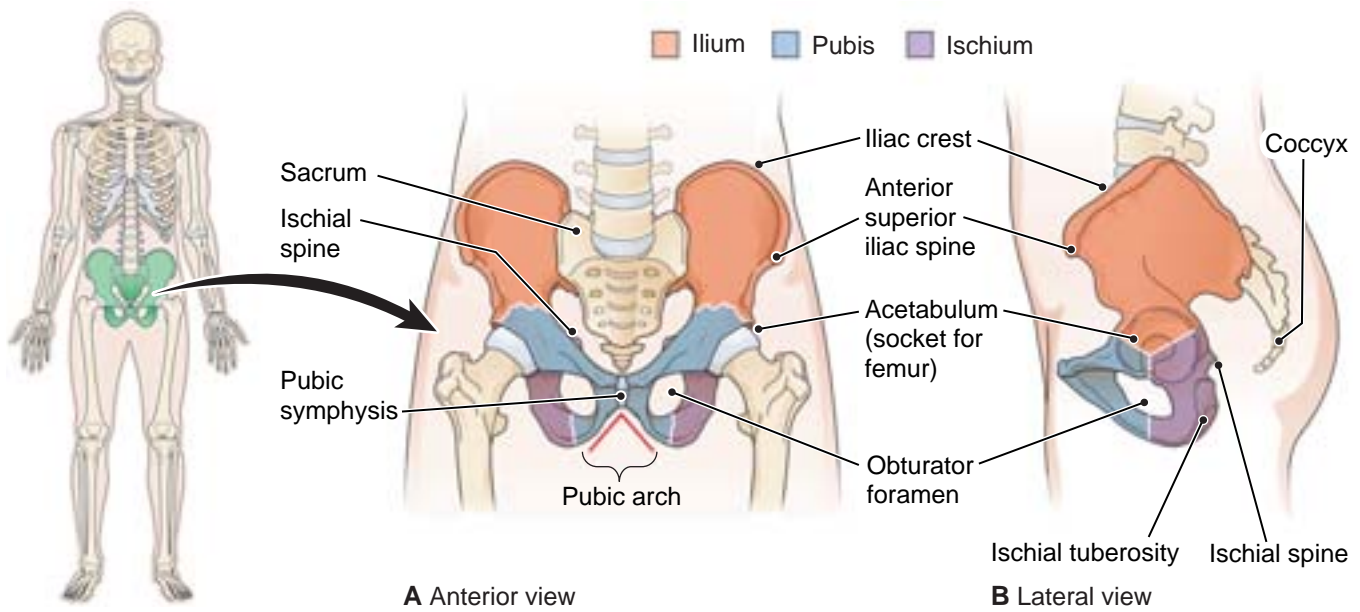


Figure 7-21 The pelvic bones. (A) Anterior view. (B) Lateral view; shows joining of the three pelvic bones to form the acetabulum. **ZOOMING IN** ♦ What bone is nicknamed the “sit bone”?

the femur is the **greater trochanter** (tro-KAN-ter), used as a surface landmark. The **lesser trochanter**, a smaller elevation, is located on the medial side. On the posterior surface there is a long central ridge, the **linea aspera**, which is a point for attachment of hip muscles.

- ♦ The **patella** (pah-TEL-lah), or kneecap (see Fig. 7-1), is embedded in the tendon of the large anterior thigh muscle, the quadriceps femoris, where it crosses the knee joint. It is an example of a **sesamoid** (SES-ah-moyd) **bone**, a type of bone that develops within a tendon or a joint capsule.
- ♦ There are two bones in the leg (Fig. 7-24). Medially (on the great toe side), the **tibia**, or shin bone, is the longer, weight-bearing bone. It has a sharp anterior crest that can be felt at the surface of the leg. Later-

ally, the slender **fibula** (FIB-u-lah) does not reach the knee joint; thus, it is not a weight-bearing bone. The **medial malleolus** (mal-LE-o-lus) is a downward projection at the distal end of the tibia; it forms the prominence on the inner aspect of the ankle. The **lateral malleolus**, at the distal end of the fibula, forms the prominence on the outer aspect of the ankle. Most people think of these projections as their “ankle bones,” whereas, in truth, they are features of the tibia and fibula.

- ♦ The structure of the foot is similar to that of the hand. However, the foot supports the weight of the body, so it is stronger and less mobile than the hand. There are seven **tarsal bones** associated with the ankle and foot. These are named and illustrated in Figure 7-25. The

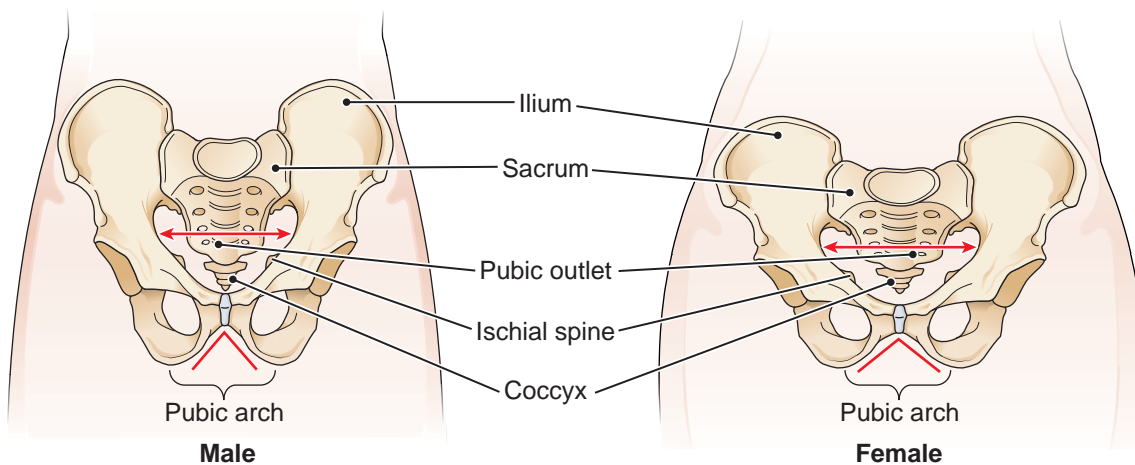


Figure 7-22 Comparison of male and female pelvis, anterior view. Note the broader angle of the pubic arch and the wider pelvic outlet in the female. Also, the ilia are wider and more flared; the sacrum and coccyx are shorter and less curved.

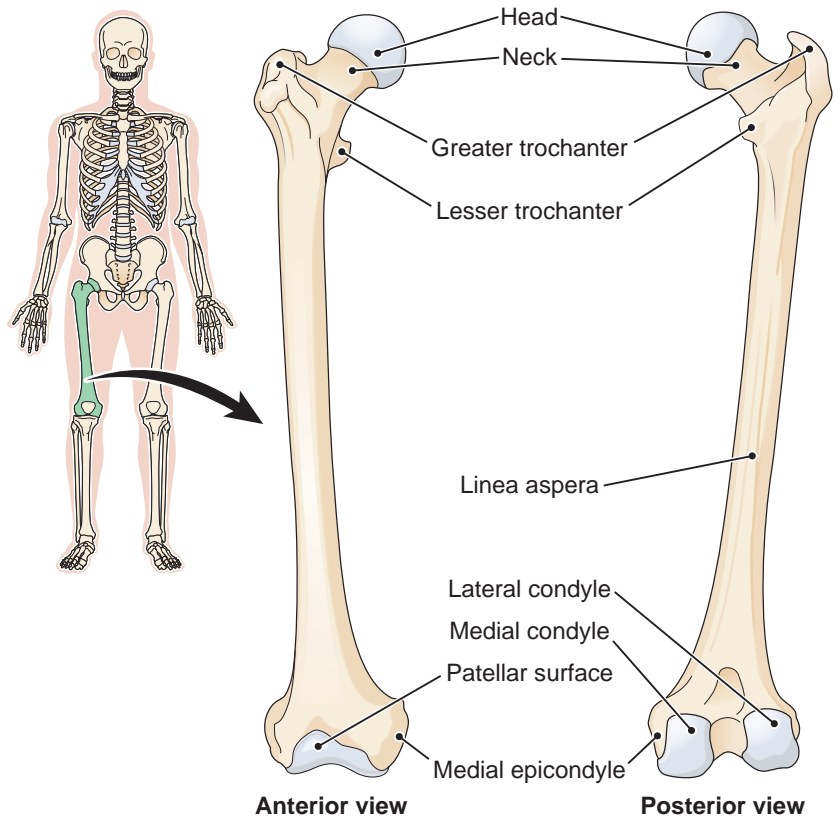


Figure 7-23 The right femur (thigh bone).

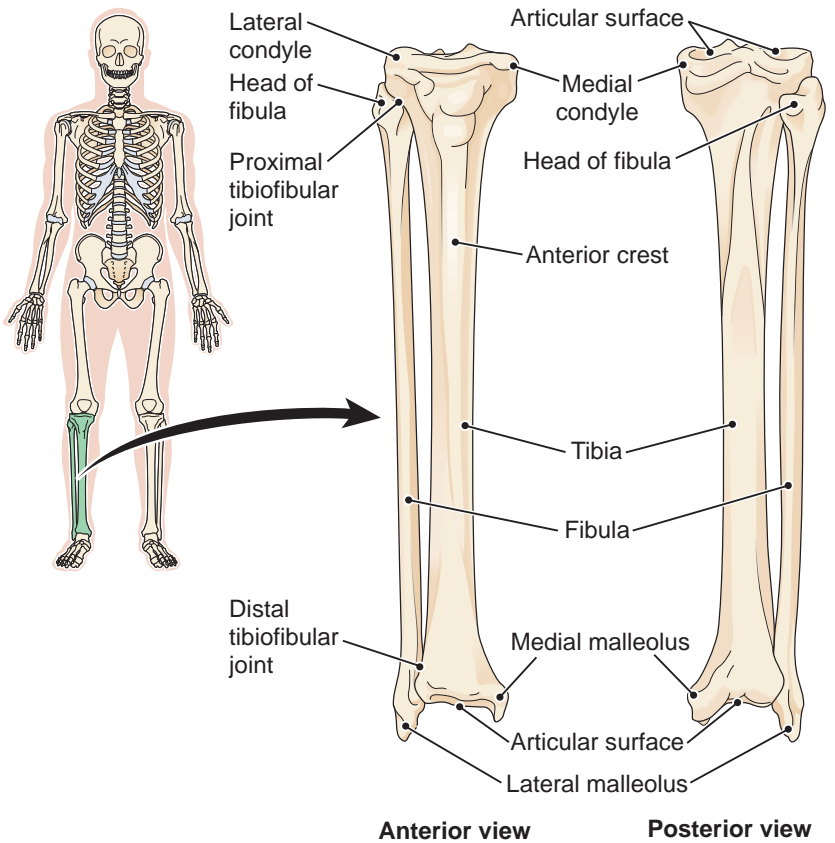


Figure 7-24 Tibia and fibula of the right leg. **ZOOMING IN** ♦ What is the medial bone of the leg?

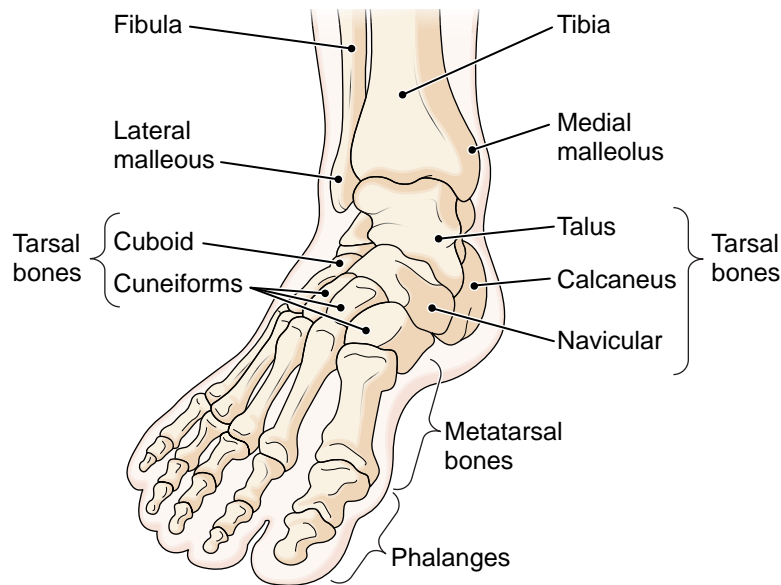


Figure 7-25 Bones of the right foot. **ZOOMING IN** ♦ Which tarsal bone is the heel bone?

largest of these is the **calcaneus** (kal-KA-ne-us), or heel bone.

- ▶ Five **metatarsal bones** form the framework of the instep, and the heads of these bones form the ball of the foot (see Fig. 7-25).
- ▶ The **phalanges** of the toes are counterparts of those in the fingers. There are three of these in each toe except for the great toe, which has only two.

Checkpoint 7-9 What division of the skeleton consists of the bones of the shoulder girdle, hip, and extremities?

Disorders of Bone

Bone disorders include metabolic diseases, in which there is a lack of normal bone formation or excess loss of bone tissue; tumors; infections; and structural problems, such as malformation or fractures.

Metabolic Disorders

Osteoporosis (os-te-o-po-RO-sis) is a disorder of bone formation in which there is a lack of normal calcium salt deposits and a decrease in bone protein. There is an increased breakdown of bone tissue without increase in the deposit of new bone by osteoblasts (Fig. 7-26). The bones thus become fragile and break easily, most often involving the spine, pelvis, and long bones.

Although everyone loses bone tissue with age, this loss is most apparent in postmenopausal women, presumably because of reduction in estrogen. The early stages of bone loss involve a reduction in bone density to below average levels, a condition known as **osteopenia** (os-te-o-PE-nah). Several treatments for osteopenia are available, but medical experts are not in agreement about when treat-

ment should be given and what that treatment should be. Hormone replacement therapy (HRT) is currently being reevaluated because recent studies have cast doubt on the safety and effectiveness of the most common form of the drugs currently in use. Nonhormonal medications are available to reduce bone resorption and even promote the development of new bone tissue. With regard to non-drug measures, an increase in calcium intake throughout life delays the onset and decreases the severity of this disorder. Weight-bearing exercises, such as weight lifting and brisk walking, are also important to stimulate growth of bone tissue. (See Box 7-2, Three Steps Toward a Strong and Healthy Skeleton.)

Changes in bone can be followed with radiographic bone mineral density (BMD) tests to determine possible loss of bone mass. However, there is no clear correlation between bone density alone and the risk of fractures among postmenopausal women.

Other conditions that can lead to osteoporosis include nutritional deficiencies; disuse, as in paralysis or immobilization in a cast; and excess steroids from the adrenal gland.

Abnormal calcium metabolism may cause various bone disorders. In one of these, called Paget disease, or

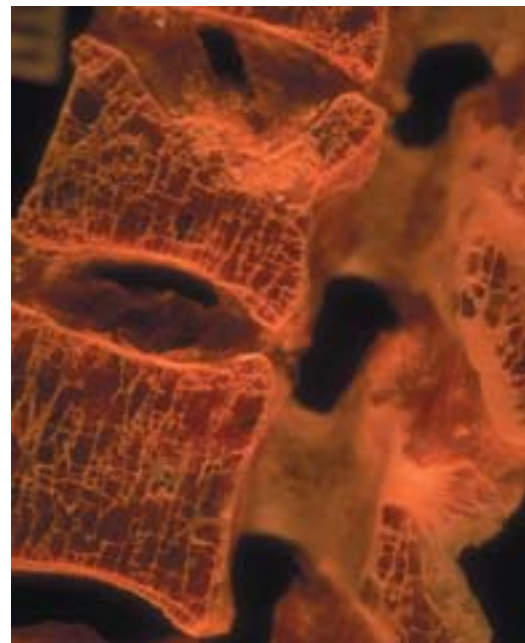


Figure 7-26 Osteoporosis. A section of the vertebral column showing loss of bone tissue and a compression fracture of a vertebral body (top). (Reprinted with permission from Rubin E, Farber JL. Pathology. 3rd ed. Philadelphia: Lippincott Williams & Wilkins, 1999.)

Box 7-2 • Health Maintenance

Three Steps Toward a Strong and Healthy Skeleton

The skeleton is the body's framework. It supports and protects internal organs, helps to produce movement, and manufactures blood cells. Bone also stores nearly all of the body's calcium, releasing it into the blood when needed for processes such as nerve transmission, muscle contraction, and blood clotting. Proper nutrition, exercise, and a healthy lifestyle can help the skeleton perform all these essential roles.

A well-balanced diet supplies the nutrients and energy needed for strong, healthy bones. Calcium and phosphorus confer strength and rigidity. Protein supplies the amino acids needed to make collagen, which gives bone tissue flexibility, and vitamin C helps stimulate collagen synthesis. Foods rich in both calcium and phosphorus include dairy products, fish, beans, and leafy green vegetables. Meat is an excellent source of protein, whereas citrus fruits are rich in vitamin C. Vitamin D helps the digestive system absorb calcium into the

bloodstream, making it available for bone. Foods rich in vitamin D include fish, liver, and eggs.

When body fluids become too acidic, bone releases calcium and phosphate and is weakened. Both magnesium and potassium help regulate the pH of body fluids, with magnesium also helping bone absorb calcium. Foods rich in magnesium and potassium include beans, potatoes, and leafy green vegetables. Bananas and dairy products are high in potassium.

Like muscle, bone becomes weakened with disuse. Consistent exercise promotes a stronger, denser skeleton by stimulating bone to absorb more calcium and phosphate from the blood, reducing the risk of osteoporosis. A healthy lifestyle also includes avoiding smoking and excessive alcohol consumption, both of which decrease bone calcium and inhibit bone growth. High levels of caffeine in the diet may also rob the skeleton of calcium.

osteitis deformans (os-te-I-tis de-FOR-mans), the bones undergo periods of calcium loss followed by periods of excessive deposition of calcium salts. As a result, the bones become deformed. Cause and cure are not known at the present time. The bones also can become decalcified owing to the effect of a tumor of the parathyroid gland (see Chap. 12).

In **osteomalacia** (os-te-o-mah-LA-she-ah) there is a softening of bone tissue due to lack of formation of calcium salts. Possible causes include vitamin D deficiency, renal disorders, liver disease, and certain intestinal disorders. When osteomalacia occurs in children, the disease is known as **rickets**. The disorder is usually caused by a deficiency of vitamin D and was common among children in past centuries who had poor diets and inadequate exposure to sunlight. Rickets affects the bones and their growth plates, causing the skeleton to remain soft and become distorted.

Tumors

Tumors, or neoplasms, that develop in bone tissue may be benign, as is the case with certain cysts, or they may be malignant, as are **osteosarcomas** and **chondrosarcomas**. Osteosarcoma most commonly occurs in a young person in the growing region of a bone, especially around the knee. Chondrosarcoma arises in cartilage and usually appears in midlife. In older people, tumors at other sites often metastasize (spread) to bones, most commonly to the spine.

Infection

Osteomyelitis (os-te-o-mi-eh-LI-tis) is an inflammation of bone caused by **pyogenic** (pi-o-JEN-ik) (pus-producing) bacteria. It may remain localized, or it may spread through

the bone to involve the marrow and the periosteum. The bacteria may reach the bone through the bloodstream or by way of an injury in which the skin has been broken.

Before the advent of antibiotics, bone infections were resistant to treatment, and the prognosis for people with such infections was poor. Now, there are fewer cases because many bloodstream infections are prevented or treated early and do not progress to affect the bones. If those bone infections that do appear are treated promptly, the chance of a cure is usually excellent.

Tuberculosis may spread to bones, especially the long bones of the extremities and the bones of the wrist and ankle. Tuberculosis of the spine is **Pott disease**. Infected vertebrae are weakened and may collapse, causing pain, deformity, and pressure on the spinal cord. Antibiotics can control the disease if the strains involved are not resistant to the drugs and the host is not weakened by other diseases.

Structural Disorders

Abnormalities of the spinal curves, known as **curvatures of the spine** (Fig. 7-27) include an exaggeration of the thoracic curve, or **kyphosis** (ki-FO-sis) (hunchback), an excessive lumbar curve, called **lordosis** (lor-DO-sis) (swayback), and a lateral curvature of the vertebral column, or **scoliosis** (sko-le-O-sis). Scoliosis is the most common of these disorders. In extreme cases, there may be compression of some of the internal organs. Scoliosis occurs in the rapid growth period of the teens, more often in girls than in boys. Early discovery and treatment produce good results.

Cleft palate is a congenital deformity in which there is an opening in the roof of the mouth owing to faulty union of the maxillary bones. An infant born with this defect has difficulty nursing because the mouth communi-

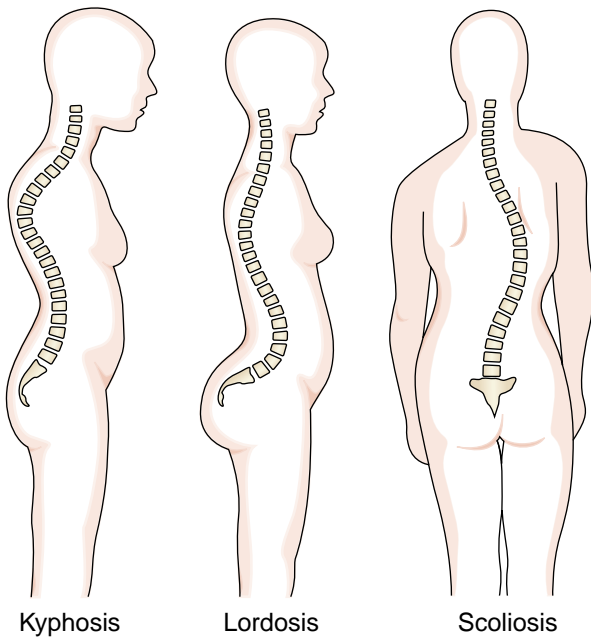


Figure 7-27 Abnormalities of the spinal curves.

cates with the nasal cavity above, and the baby therefore sucks in air rather than milk. Surgery is usually performed to correct the condition.

Flatfoot is a common disorder in which the tendons and ligaments that support the long arch of the foot are weakened and the curve of the arch flattens (see Fig. 7-25). This arch normally helps to absorb shock and distribute body weight and aids in walking. Flatfoot may be brought on by excess weight or poor posture and may also be due to a hereditary failure of the arch to form. It may cause difficulty or pain in walking. An arch support may be helpful in treating flatfoot.

Fractures

A **fracture** is a break in a bone, usually caused by trauma (Fig. 7-28). Almost any bone can be fractured with sufficient force. Such injuries may be classified as follows:

- ▶ **Closed fracture**, which is a simple fracture of the bone with no open wound
- ▶ **Open fracture**, in which a broken bone protrudes through the skin or an external wound leads to a broken bone
- ▶ **Greenstick fracture**, in which one side of the bone is broken and the other is bent. These are most common in children.
- ▶ **Impacted fracture**, in which the broken ends of the bone are jammed into each other
- ▶ **Comminuted (KOM-ih-nu-ted) fracture**, in which there is more than one fracture line and the bone is splintered or crushed
- ▶ **Spiral fracture**, in which the bone has been twisted apart. These are relatively common in skiing accidents.
- ▶ **Transverse fracture**, in which the fracture goes straight across the bone
- ▶ **Oblique fracture**, in which the break occurs at an angle across the bone

The most important step in first aid care of fractures is to prevent movement of the affected parts. Protection by simple splinting after careful evaluation of the situation, leaving as much as possible “as is,” and a call for expert help are usually the safest measures. People who have back injuries may be spared serious spinal cord damage if they are carefully and correctly moved on a firm board or door. If trained paramedics or rescue personnel can reach the scene, a “hands off” rule for the untrained is strongly recommended. If there is no external bleeding, covering the victim with blankets may help combat shock. First aid should always be immediately directed toward the control of hemorrhage.

Skeletal Changes in the Aging

The aging process includes significant changes in all connective tissues, including bone. There is a loss of calcium salts and a decrease in the amount of protein formed in bone tissue. The reduction of collagen in bone and in tendons, ligaments, and skin contributes to the stiffness so

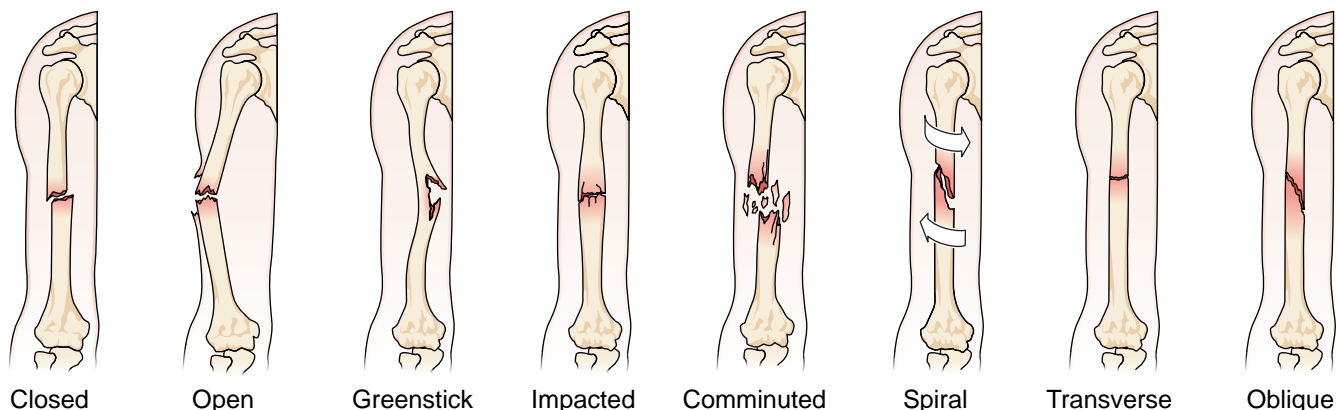


Figure 7-28 Types of fractures.

often found in older people. Muscle tissue is also lost throughout adult life. Thus, there is a tendency to decrease the exercise that is so important to the maintenance of bone tissue.

Changes in the vertebral column with age lead to a loss in height. Approximately 1.2 cm (about 0.5 inches) are lost each 20 years beginning at 40 years of age, owing primarily to a thinning of the intervertebral disks (between the bodies of the vertebrae). Even the vertebral bodies themselves may lose height in later years. The costal (rib) cartilages become calcified and less flexible, and the chest may decrease in diameter by 2 to 3 cm (about 1 inch), mostly in the lower part.

► The Joints

An **articulation**, or **joint**, is an area of junction or union between two or more bones. Joints are classified into three main types on the basis of the material between the adjoining bones. They may also be classified according to the degree of movement permitted (Table 7-2):

- **Fibrous joint.** The bones in this type of joint are held together by fibrous connective tissue. An example is a **suture** (SU-chur) between bones of the skull. This type of joint is immovable and is termed a **synarthrosis** (sin-ar-THRO-sis).

- **Cartilaginous joint.** The bones in this type of joint are connected by cartilage. Examples are the joint between the pubic bones of the pelvis—the pubic symphysis—and the joints between the bodies of the vertebrae. This type of joint is slightly movable and is termed an **amphiarthrosis** (am-fe-ar-THRO-sis).

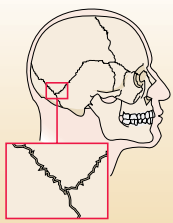
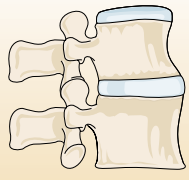
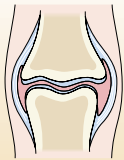
- **Synovial (sin-O-ve-al) joint.** The bones in this type of joint have a potential space between them called the **joint cavity**, which contains a small amount of thick, colorless fluid. This lubricant, **synovial fluid**, resembles uncooked egg white (ov is the root, meaning “egg”) and is secreted by the membrane that lines the joint cavity. The synovial joint is freely movable and is termed a **diarthrosis** (di-ar-THRO-sis). Most joints are synovial joints; they are described in more detail next.

Checkpoint 7-10 What are the three types of joints classified according to the type of material between the adjoining bones?

More About Synovial Joints

The bones in freely movable joints are held together by **ligaments**, bands of fibrous connective tissue. Additional ligaments reinforce and help stabilize the joints at various points (Fig. 7-29 A). Also, for strength and protection, there is a **joint capsule** of connective tissue that encloses each joint and is continuous with the periosteum of the

Table 7•2 Joints

TYPE	MOVEMENT	MATERIAL BETWEEN THE BONES	EXAMPLES
Fibrous 	Immovable (synarthrosis)	No joint cavity; fibrous connective tissue between bones	Sutures between bones of skull
Cartilaginous 	Slightly movable (amphiarthrosis)	No joint cavity; cartilage between bones	Pubic symphysis; joints between bodies of vertebrae
Synovial 	Freely movable (diarthrosis)	Joint cavity containing synovial fluid	Gliding, hinge, pivot, condyloid, saddle, ball-and-socket joints

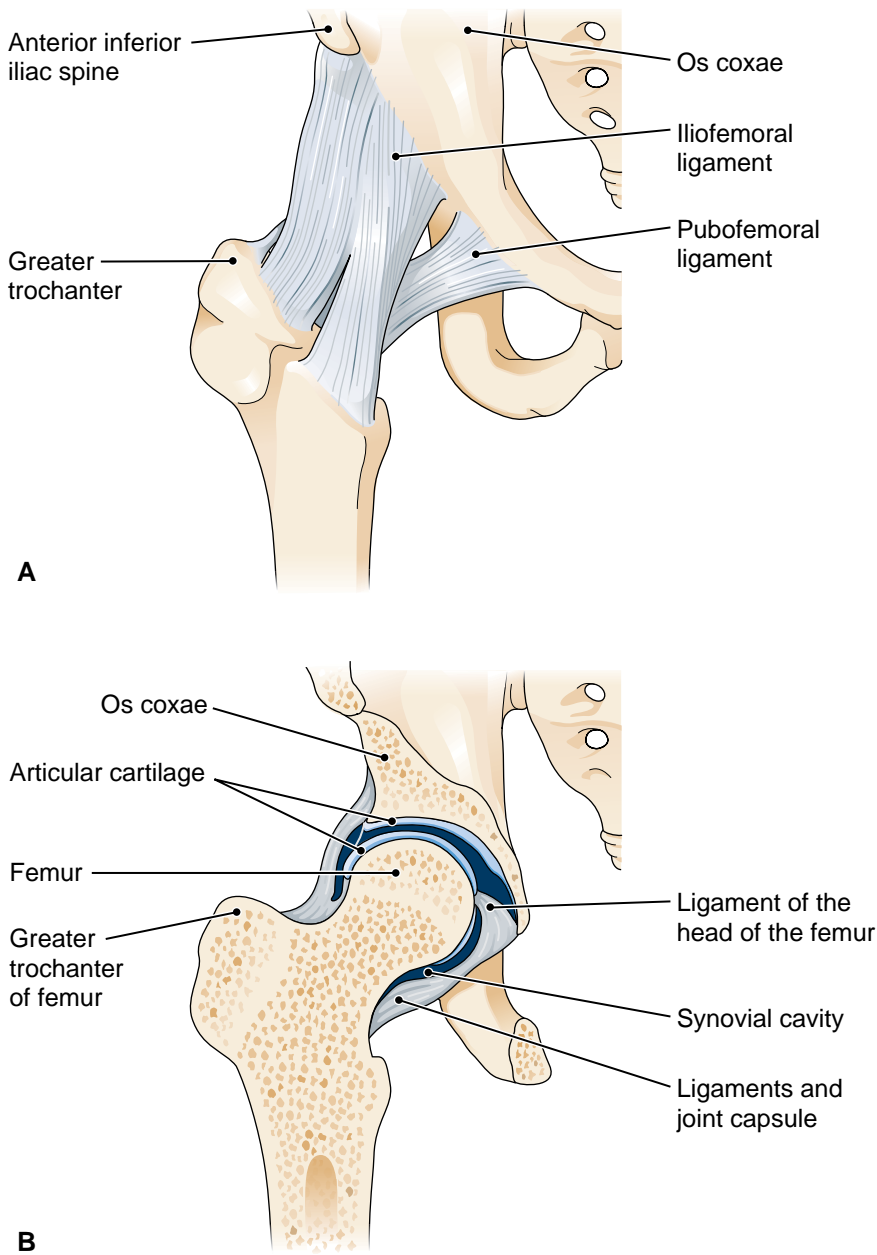


Figure 7-29 Structure of a synovial joint. (A) Anterior view of the hip joint showing ligaments that reinforce and stabilize the joint. (B) Frontal section through right hip joint showing protective structures.

bones. The bone surfaces in freely movable joints are protected by a smooth layer of hyaline cartilage called the **articular** (ar-TIK-u-lar) **cartilage** (see Fig. 7-29 B). Some complex joints may have cartilage between the bones that acts as a cushion, such as the crescent-shaped medial meniscus (meh-NIS-kus) and lateral meniscus in the knee joint (Fig. 7-30). Fat may also appear as padding around a joint.

Near some joints are small sacs called **bursae** (BER-se), which are filled with synovial fluid (see Fig. 7-30). These lie in areas subject to stress and help ease move-

ment over and around the joints. Inflammation of a bursa, as a result of injury or irritation, is called **bursitis**.

Types of Synovial Joints Synovial joints are classified according to the types of movement they allow, as described and illustrated in Table 7-3. Listed in order of increasing range of motion, they are:

- ▶ Gliding joint
- ▶ Hinge joint
- ▶ Pivot joint
- ▶ Condylloid joint
- ▶ Saddle joint
- ▶ Ball-and-socket joint

Movement at Synovial Joints

The chief function of the freely movable joints is to allow for changes of position and so provide for motion. These movements are named to describe changes in the positions of body parts (Fig. 7-31). For example, there are four kinds of angular movement, or movement that changes the angle between bones, as listed below:

- ▶ **Flexion** (FLEK-shun) is a bending motion that decreases the angle between bones, as in bending the fingers to close the hand.
- ▶ **Extension** is a straightening motion that increases the angle between bones, as in straightening the fingers to open the hand.
- ▶ **Abduction** (ab-DUK-shun) is movement away from the midline of the body, as in moving the arms straight out to the sides.
- ▶ **Adduction** is movement toward the midline of the body, as in bringing the arms back to their original position beside the body.

A combination of these angular movements enables one to execute a movement referred to as **circumduction** (ser-kum-DUK-shun). To perform this movement, stand with your arm outstretched and draw a large imaginary circle in the air. Note the smooth combination of flexion, abduction, extension, and adduction that makes circumduction possible.

Rotation refers to a twisting or turning of a bone on its own axis, as in turning the head from side to side to say “no,” or rotating the forearm to turn the palm up and down.

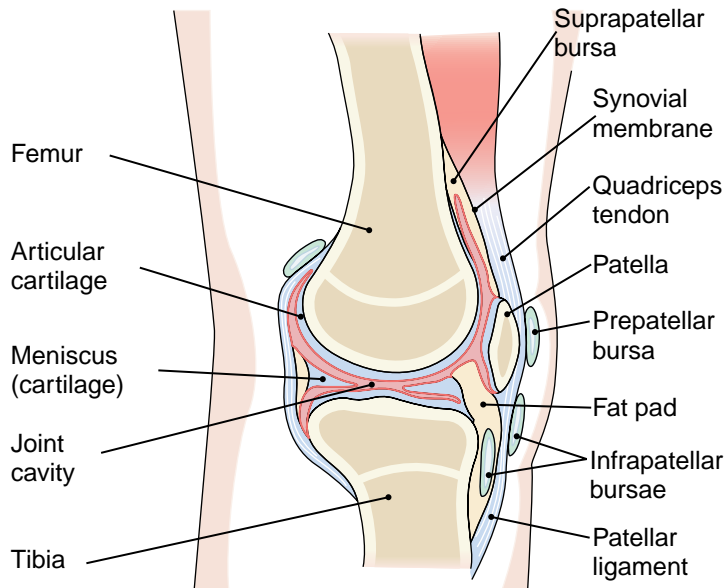


Figure 7-30 The knee joint, sagittal section. Protective structures are also shown.

There are special movements that are characteristic of the forearm and the ankle:

- **Supination** (su-pin-A-shun) is the act of turning the palm up or forward; **pronation** (pro-NA-shun) turns the palm down or backward.
- **Inversion** (in-VER-zhun) is the act of turning the sole inward, so that it faces the opposite foot; **eversion** (e-VER-zhun) turns the sole outward, away from the body.
- In **dorsiflexion** (dor-sih-FLEK-shun), the foot is bent upward at the ankle, narrowing the angle between the leg and the top of the foot; in **plantar flexion**, the toes point

downward, as in toe dancing, flexing the arch of the foot.

Checkpoint 7-11 What is the most freely movable type of joint?

Disorders of Joints

Joints are subject to certain mechanical disorders. A **dislocation** is a derangement of the parts of the joint. Ball-and-socket joints, which have the widest range of motion, also have the greatest tendency to dislocate. The shoulder joint is the most frequently dislocated joint in the body. A **sprain** is the wrenching of a joint with rupture or tearing of the ligaments. There may also be injuries to the cartilage within the joint, most commonly in the knee joint.

Injured joints can be examined from outside and even repaired surgically with a lighted instrument known as an **arthroscope**, a type of endoscope (Fig.

7-32). With arthroscopic surgery, ligaments can be repaired or replaced and cartilage can be removed or reshaped with a minimum of invasion. If abnormal amounts of fluid accumulate in the joint cavity as a result of injury, it can be drained by a tapping procedure called **arthrocentesis** (arthro-sen-TE-sis). Box 7-3, Arthroplasty: Bionic Parts for a Better Life, has information on joint replacement.

Herniated Disk The disks between the vertebrae of the spine consist of an outer ring of fibrocartilage and a central mass known as the nucleus pulposus. In the case of a **herniated disk**, this central mass protrudes through a weak-

Box 7-3 Hot Topics

Arthroplasty: Bionic Parts for a Better Life

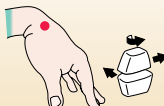

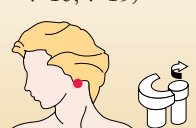
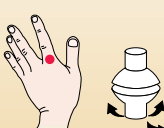


Since the first total hip replacement in the early 1960s, millions of joint replacements, called **arthroplasties**, have been performed successfully. Most are done to decrease joint pain in older people with arthritis and other chronic degenerative bone diseases after other treatments such as weight loss, physical therapy, and medication have been tried. Hips and knees are most commonly restored, with 300,000 hip arthroplasties and an equal number of knee replacements performed each year in the United States. Orthopedic surgeons can also replace shoulder, elbow, wrist, hand, ankle, and foot joints.

Artificial, or **prosthetic**, joints are engineered to be strong, nontoxic, corrosion-resistant, and firmly bondable to the patient. Computer-controlled machines now produce individualized joints in less time and at less cost than before. Ball-and-socket joint prostheses, like those used in total hip replacement, consist of a cup, ball, and stem. The cup replaces

the hip socket (acetabulum) and is bonded to the pelvis using screws or glue. The cup is usually plastic but may also be made of longer-lasting ceramic or metal. The ball, made of metal or ceramic, replaces the femoral head and is attached to the stem, which is implanted into the femoral shaft. Stems are made of various metal alloys such as cobalt and titanium and are often glued into place. Stems designed to promote bone growth into them are usually used in younger, more active patients because it is believed that they will remain firmly attached longer.

Until recently, arthroplasty was rarely performed on young people because prosthetics had a short lifespan of about 10 years. Today's materials and surgical techniques could increase the lifespan to 20 years or more, and young people who undergo arthroplasty will require fewer future replacements. This is especially important because sports-related joint injuries in young adults are increasing.

Table 7-3 Synovial Joints

TYPE OF JOINT	TYPE OF MOVEMENT	EXAMPLES
Gliding joint	Bone surfaces slide over one another	Joints in the wrist and ankles (Figs. 7-20 and 7-25) 
Hinge joint	Allows movement in one direction, changing the angle of the bones at the joint	Elbow joint; joints between phalanges of fingers and toes (Figs. 7-19, 7-20, 7-25) 
Pivot joint	Allows rotation around the length of the bone	Joint between the first and second cervical vertebrae; joint at proximal ends of the radius and ulna (Figs. 7-10, 7-19) 
Condyloid joint	Allows movement in two directions	Joint between the metacarpal and the first phalanx of the finger (knuckle) (Fig. 7-20); joint between the occipital bone of the skull and the first cervical vertebra (atlas) (Fig. 7-10) 
Saddle joint	Like a condyloid joint, but with deeper articulating surfaces	Joint between the wrist and the metacarpal bone of the thumb (Fig. 7-20) 
Ball-and-socket joint	Allows movement in many directions around a central point. Gives the greatest freedom of movement	Shoulder joint and hip joint (Figs. 7-15, 7-29) 

ened outer ring of cartilage into the spinal canal (Fig. 7-33). The herniated or “slipped” disk puts pressure on the spinal cord or spinal nerves, often causing back spasms or pain along the sciatic nerve that travels through the leg, a pain known as sciatica. It is sometimes necessary to remove the disk and fuse the vertebrae involved. Newer surgical techniques make it possible to remove only a specific portion of the disk.

Arthritis The most common type of joint disorder is termed **arthritis**, which means “inflammation of the joints.” There are different kinds of arthritis, including the following:

- **Osteoarthritis** (os-te-o-arth-RI-tis), also known as degenerative joint disease (DJD), usually occurs in elderly people as a result of normal wear and tear. Although it appears to be a natural result of aging, such factors as obesity and repeated trauma can contribute. Osteoarthritis occurs mostly in joints used in weight bearing, such as the hips, knees, and spinal column. It involves degeneration of the joint cartilage, with growth of new bone at the edges of the joints (Fig. 7-34). Degenerative changes include the formation of spurs at the edges of the articular surfaces, thickening of the synovial membrane, atrophy of the cartilage, and calcification of the ligaments.
- **Rheumatoid arthritis** is a crippling condition characterized by swelling of the joints of the hands, the feet, and other parts of the body as a result of inflammation and overgrowth of the synovial membranes and other joint tissues. The articular cartilage is gradually destroyed, and the joint cavity develops adhesions—that is, the surfaces tend to stick together—so that the joints stiffen and ultimately become useless. The exact cause of rheumatoid arthritis is uncertain. However, the disease shares many characteristics of autoimmune disorders, in which antibodies are produced that attack the body’s own tissues. The role of inherited susceptibility is clear. Treat-

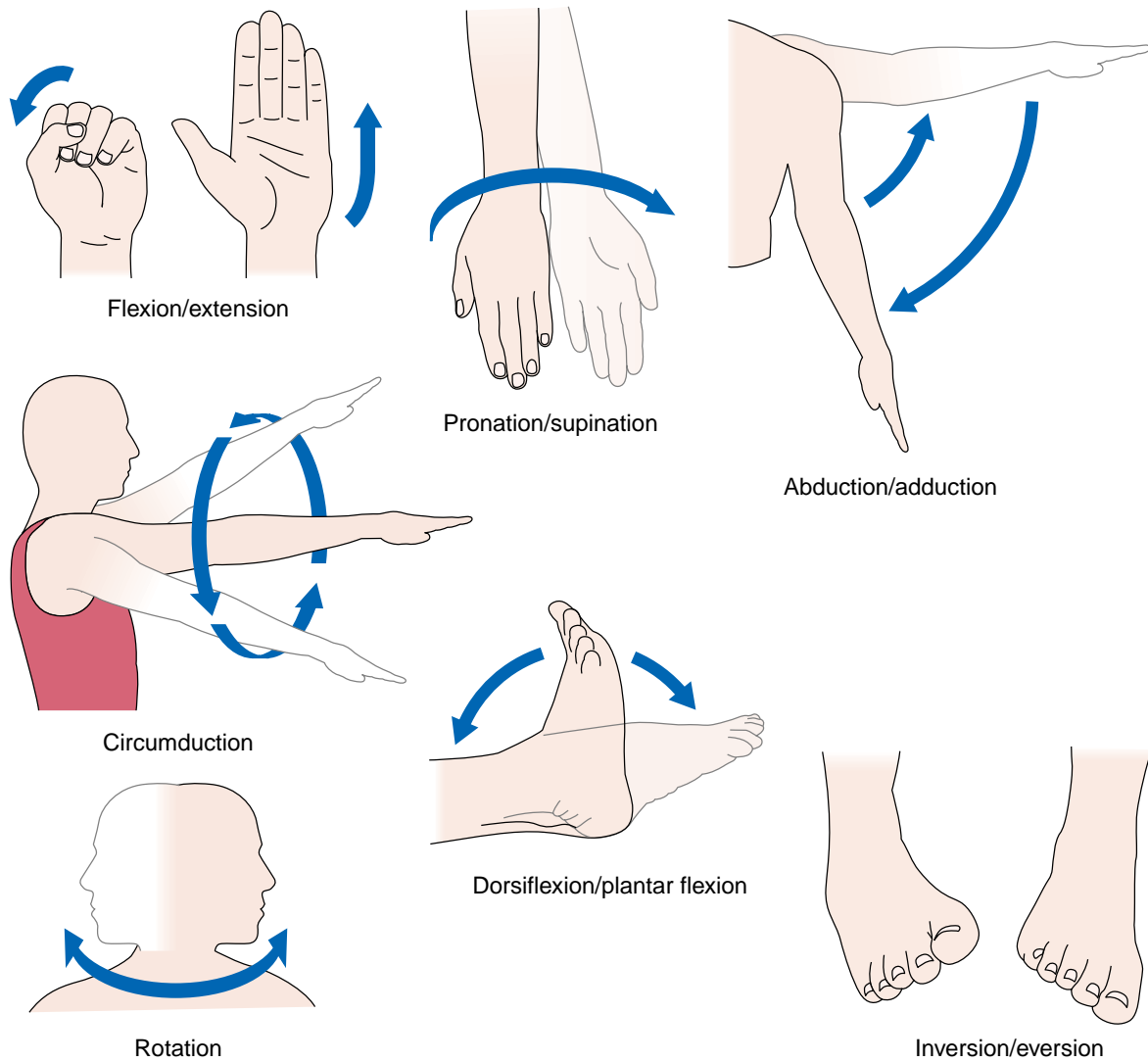


Figure 7-31 Movements at synovial joints.

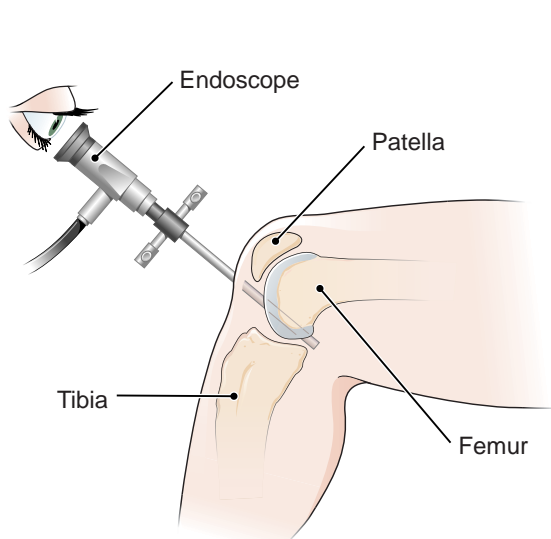


Figure 7-32 Arthroscopic examination of the knee. Endoscope is inserted between projections at the end of the femur to view the posterior of the knee. (Reprinted with permission from Cohen BJ. *Medical Terminology*. 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2004.)

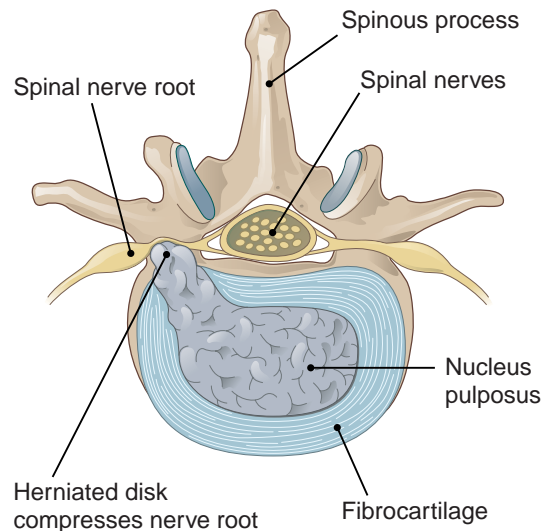


Figure 7-33 Herniated disk. The central portion (nucleus pulposus) of an intervertebral disk protrudes through the outer rim of cartilage to put pressure on a spinal nerve. (Reprinted with permission from Cohen BJ. *Medical Terminology*. 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2004.)

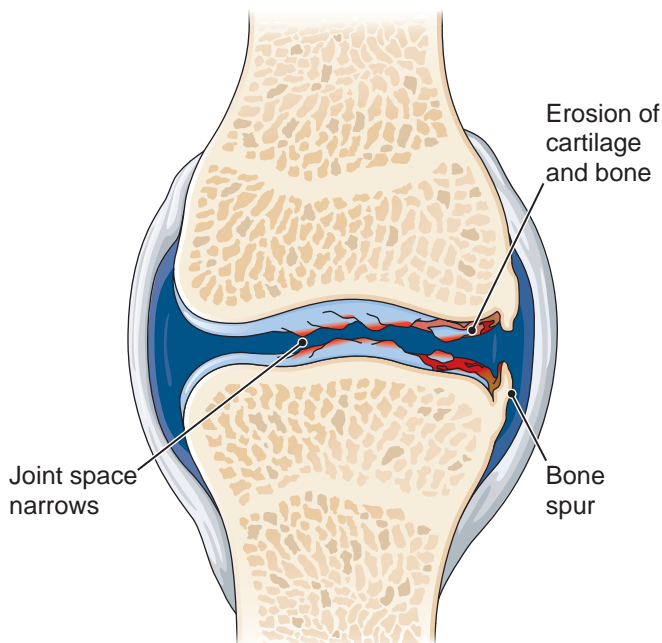


Figure 7-34 Joint changes in osteoarthritis (DJD). The left side shows early changes with breakdown of cartilage and narrowing of the joint space. The right side shows progression of the disease with loss of cartilage and formation of bone spurs.

ment includes rest, appropriate exercise, and medications to reduce pain and swelling. Removal of specific antibodies from the blood and administration of drugs to suppress abnormal antibody production have been successful.

- ▶ **Septic (infectious) arthritis** arises when bacteria spread to involve joint tissue, usually by way of the bloodstream. Bacteria introduced during invasive medical procedures, injections of illegal drugs, or by other means can settle in joints. A variety of organisms are commonly involved, including *Streptococcus*, *Staphylococcus*, and *Neisseria* species. The joints and the bones themselves are subject to attack by the tuberculosis or-

ganism, and the result may be gradual destruction of bone near the joint.

- ▶ **Gout** is a kind of arthritis caused by a disturbance of metabolism. One of the products of metabolism is uric acid, which normally is excreted in the urine. If there happens to be an overproduction of uric acid, or for some reason not enough is excreted, the accumulated uric acid forms crystals that are deposited as masses around the joints and other parts of the body. As a result, the joints become inflamed and extremely painful. Any joint can be involved, but the one most commonly affected is the big toe. Most victims of gout are men past middle life.

Backache Backache is another common complaint. Some of its causes are listed below:

- ▶ Diseases of the vertebrae, such as infections or tumors, and in older people, osteoarthritis or atrophy (wasting away) of bone following long illnesses and lack of exercise.
- ▶ Disorders of the intervertebral disks, especially those in the lower lumbar region. Pain may be very severe, with muscle spasms and the extension of symptoms along the course of the sciatic nerve in the leg.
- ▶ Abnormalities of the lower vertebrae or of the ligaments and other supporting structures.
- ▶ Disorders involving abdominopelvic organs or those in the space behind the peritoneum (such as the kidney). Variations in the position of the uterus are seldom a cause.
- ▶ Strains on the lumbosacral joint (where the lumbar region joins the sacrum) or strains on the sacroiliac joint (where the sacrum joins the ilium of the pelvis).

Backache can be prevented by attention to proper movement and good posture. It is most important that the back itself not be used for lifting. A weight to be lifted should be brought close to the body and then the legs should do the actual lifting. An adequate exercise program and control of body weight are also important.

Checkpoint 7-12 What is the most common type of joint disorder?

Word Anatomy

Medical terms are built from standardized word parts (prefixes, roots, and suffixes). Learning the meanings of these parts can help you remember words and interpret unfamiliar terms.

WORD PART	MEANING	EXAMPLE
Bones		
dia-	through, between	The <i>diaphysis</i> , or shaft, of a long bone is between the two ends, or epiphyses.
oss, osse/o	bone, bone tissue	<i>Osseous</i> tissue is another name for bone tissue.
oste/o	bone, bone tissue	The <i>periosteum</i> is the fibrous membrane around a bone.
-clast	break	An <i>osteoclast</i> breaks down bone in the process of resorption.
Divisions of the Skeleton		
para-	near	The <i>paranasal</i> sinuses are near the nose.
pariet/o	wall	The <i>parietal</i> bones form the side walls of the skull.
cost/o	rib	<i>Intercostal</i> spaces are located between the ribs.
supra-	above, superior	The <i>supraspinous</i> fossa is a depression superior to the spine of the scapula.
infra-	below, inferior	The <i>infraspinous</i> fossa is a depression inferior to the spine of the scapula.
meta-	near, beyond	The <i>metacarpal</i> bones of the palm are near and distal to the carpal bones of the wrist.

WORD PART	MEANING	EXAMPLE
Disorders of Bone		
-penia	lack of	In <i>osteopenia</i> , there is a lack of bone density.
-malacia	softening	<i>Osteomalacia</i> is a softening of bone tissue.
The Joints		
arthr/o	joint, articulation	A <i>synarthrosis</i> is an immovable joint, such as a suture.
amphi-	on both sides, around, double	An <i>amphiarthrosis</i> is a slightly movable joint.
ab-	away from	<i>Abduction</i> is movement away from the midline of the body.
ad-	toward, added to	<i>Adduction</i> is movement toward the midline of the body.
circum-	around	<i>Circumduction</i> is movement around a joint in a circle.

Summary

I. Bones

- Main functions of bones—serve as body framework; protect organs; serve as levers for movement; store calcium salts; form blood cells

A. Bone structure

- Long bone
 - Diaphysis—shaft
 - Epiphysis—end
- Bone tissue
 - Compact—in shaft of long bones; outside of other bones
 - Spongy (cancellous)—in end of long bones; center of other bones
- Bone marrow
 - Red—in spongy bone
 - Yellow—in central cavity of long bones
- Bone membranes—contain bone-forming cells
 - Periosteum—covers bone
 - Endosteum—lines marrow cavity

B. Bone growth and repair

- Bone cells
 - Osteoblasts—bone-forming cells
 - Osteocytes—mature bone cells that maintain bone
 - Osteoclasts—cells that break down (resorb) bone; derived from monocytes, types of white blood cells
- Formation of a long bone—begins in center of shaft and continues at epiphyseal plate

D. Bone markings

- Projections—head, process, condyle, crest, spine
- Depressions and holes—foramen, sinus, fossa, meatus

II. Bones of the axial skeleton

A. Framework of the skull

- Cranium—frontal, parietal, temporal, ethmoid, sphenoid, occipital
- Facial—mandible, maxilla, zygomatic, nasal, lacrimal, vomer, palatine, inferior nasal conchae
- Other—ossicles (of ear), hyoid
- Infant skull—fontanel (soft spots)

B. Framework of the trunk

- Vertebral column—divisions: cervical, thoracic, lumbar, sacral, coccygeal
 - Curves
 - Thoracic and sacral—concave, primary
 - Cervical and lumbar—convex, secondary

2. Thorax

- Sternum—manubrium, body, xiphoid process
- Ribs
 - True—first seven pairs
 - False—remaining five pairs, including two floating ribs

III. Bones of the appendicular skeleton

A. Upper division

- Shoulder girdle—clavicle, scapula
- Upper extremity—humerus, ulna, radius, carpals, metacarpals, phalanges

B. Lower division

- Pelvic bones—os coxae (hip bone): ilium, ischium, pubis
 - Female pelvis lighter, wider, more rounded than male
- Lower extremity—femur, patella, tibia, fibula, tarsals, metatarsals, phalanges

IV. Disorders of bone

- Metabolic—osteoporosis, osteopenia, osteitis deformans, osteomalacia, rickets
- Tumors
- Infection—osteomyelitis, tuberculosis (in spine is called Pott disease)
- Structural disorders—curvature of the spine, cleft palate, flat foot
- Fractures—closed, open, greenstick, impacted, comminuted, spiral, transverse, oblique
- Changes in aging—loss of calcium salts, decreased production of collagen, thinning of intervertebral disks, loss of flexibility

V. Joints (articulations)

1. Kinds of joints

- Fibrous—immovable (synarthrosis)
- Cartilaginous—slightly movable (amphiarthrosis)
- Synovial—freely movable (diarthrosis)

A. More about synovial joints

- Structure of synovial joints
 - Joint cavity—contains synovial fluid
 - Ligaments—hold joint together
 - Joint capsule—strengthens and protects joint
 - Articular cartilage—covers ends of bones
 - Bursae—fluid-filled sacs near joints; cushion and protect joints and surrounding tissue

2. Types of synovial joints—gliding, hinge, pivot, condyloid, saddle, ball-and-socket
 3. Movement at synovial joints
 - a. Angular—flexion, extension, abduction, adduction
 - b. Circular—circumduction, rotation
 - c. Special at forearm—supination, pronation,
 - d. Special at ankle—inversion, eversion, dorsiflexion, plantar flexion
- B. Disorders of Joints
 1. Dislocations and sprains
 2. Herniated disk—central portion of intervertebral disk projects through outer cartilage
 3. Arthritis—osteoarthritis, rheumatoid arthritis, infectious arthritis, gout
 4. Backache

Questions for Study and Review

Building Understanding

Fill in the blanks

1. The shaft of a long bone is called the _____.
2. The structural unit of compact bone is the _____.
3. Red bone marrow manufactures _____.
4. Bones are covered by a connective tissue membrane called _____.
5. Bone matrix is produced by _____.

Matching

Match each numbered item with the most closely related lettered item.

- | | |
|-----------------------------------|------------|
| ___ 6. A rounded bony projection | a. condyle |
| ___ 7. A sharp bony prominence | b. foramen |
| ___ 8. A hole through bone | c. fossa |
| ___ 9. A bony depression | d. sinus |
| ___ 10. An air-filled bony cavity | e. spine |

Multiple choice

- ___ 11. On which of the following bones would the mastoid process be found?
 - a. occipital bone
 - b. femur
 - c. temporal bone
 - d. humerus
- ___ 12. An abnormal exaggeration of the thoracic curve is called
 - a. kyphosis
 - b. lordosis
 - c. osteitis deformans
 - d. Pott disease
- ___ 13. A splintered or crushed bone with multiple fractures is classified as having a(n) _____ fracture
 - a. open
 - b. impacted
 - c. comminuted
 - d. greenstick
- ___ 14. A joint that is freely moveable is called a(n) _____ joint.
 - a. arthrotic
 - b. amphiarthrotic
 - c. diarthrotic
 - d. synarthrotic
- ___ 15. Which of the following synovial joints describes the hip?
 - a. gliding
 - b. hinge
 - c. pivot
 - d. ball-and-socket

Understanding Concepts

16. List five functions of bone and describe how a long bone's structure enables it to carry out each of these functions.
17. Explain the differences between the terms in each of the following pairs:
 - a. osteoblast and osteocyte
 - b. periosteum and endosteum
 - c. compact bone and spongy bone
 - d. epiphysis and diaphysis
 - e. axial skeleton and appendicular skeleton
18. Discuss the process of long bone formation during fetal development and childhood. What role does resorption play in bone formation?
19. Name the bones of the:
 - a. cranium and face
 - b. thoracic cavity, vertebral column, and pelvis
 - c. upper and lower limbs

20. Compare and contrast osteoporosis, osteomalacia, and osteomyelitis
21. Name three effects of aging on the skeletal system.
22. What are the similarities and differences between osteoarthritis, rheumatoid arthritis, and gout?
23. Differentiate between the terms in each of the following pairs:
 - a. flexion and extension
 - b. abduction and adduction
 - c. supination and pronation
 - d. inversion and eversion

- e. circumduction and rotation
- f. dorsiflexion and plantar flexion

Conceptual Thinking

24. The vertebral bodies are much larger in the lower back than the neck. What is the functional significance of this structural difference?

25. Nine-year-old Alek is admitted into Emergency with a closed fracture of the right femur. Radiography reveals that the fracture crosses the distal epiphyseal plate. What concerns should Alek's healthcare team have about the location of his injury?