Joints

CHAPTER 9

X-ray of hands with severe rheumatoid arthritis

CHAPTER OUTLINE

DEEPER INSIGHTS

BRUSHING UP

To understand this chapter, you may find it helpful to review the following concepts:

- Anatomical planes (p. 12)
- The distinction between hyaline cartilage and fibrocartilage (p. 67)
- Anatomy of the skeletal system (chapter 8)

Anatomy & Physiology REVEALED apreveal ed.com

Skeletal System

Joints, or articulations, link the bones of the skeletal system into a functional whole—a system that supports the body, permits effective movement, and protects the softer organs. Joints such as the shoulder, elbow, and knee are remarkable specimens of biological design—self-lubricating, almost frictionless, and able to bear heavy loads and withstand compression while executing smooth and precise movements. Yet, it is equally important that other joints be less movable or even immobile. Such joints are better able to support the body and protect delicate organs. The vertebral column, for example, is only moderately movable, for it must allow for flexibility of the torso and yet protect the delicate spinal cord and support much of the body's weight. Bones of the cranium must protect the brain and sense organs, but need not allow for movement (except during birth); thus, they are locked together by immobile joints, the sutures studied in chapter 7.

In everyday life, we take the greatest notice of the most freely movable joints of the limbs, and it is here that people feel most severely compromised by disabling diseases such as arthritis. Much of the work of physical therapists focuses on limb mobility. In this chapter, we will survey all types of joints, from the utterly immobile to the most movable, but with an emphasis on the latter. This survey of joint anatomy and movements will provide a foundation for the study of muscle actions in chapters 11 and 12.

9.1 Joints and Their Classification

Expected Learning Outcomes

When you have completed this section, you should be able to

- explain what joints are, how they are named, and what functions they serve;
- name and describe the four major classes of joints;
- name some joints that become solidly fused by bone as they age;
- describe the three types of fibrous joints and give an example of each;
- distinguish between the three types of sutures; and
- describe the two types of cartilaginous joints and give an example of each.

Any point where two bones meet is called a **joint (articulation),** whether or not the bones are movable at that interface. The science of joint structure, function, and dysfunction is called **arthrology.**[1] The study of musculoskeletal movement is **kinesiology**[2] (kih-NEE-see-OL-oh-jee). This is a branch of **biomechanics,** which deals with a broad variety of movements and mechanical processes in the body, including the physics of blood circulation, respiration, and hearing.

The name of a joint is typically derived from the names of the bones involved. For example, the *atlanto–occipital joint* is where the atlas meets the occipital condyles, the *glenohumeral joint* is where the glenoid cavity of the scapula meets the humerus, and the *radioulnar joint* is where the radius meets the ulna.

Joints are classified according to the manner in which the adjacent bones are bound to each other, with corresponding differences in how freely the bones can move. Authorities differ in their classification schemes, but one common view places the joints in four major categories: *bony, fibrous, cartilaginous,* and *synovial joints.* This section will describe the first three of these and the subclasses of each. The remainder of the chapter will then be concerned primarily with synovial joints.

Bony Joints

A **bony joint,** or **synostosis**[3] (SIN-oss-TOE-sis), is an immobile joint formed when the gap between two bones ossifies and they become, in effect, a single bone. Bony joints can form by ossification of either fibrous or cartilaginous joints. An infant is born with right and left frontal and mandibular bones, for example, but these soon fuse seamlessly to form single bones. In old age, some cranial sutures become obliterated by ossification, and the adjacent cranial bones, such as the parietal bones, fuse. The epiphyses and diaphyses of the long bones are joined by cartilaginous joints in childhood and adolescence, and these become synostoses in early adulthood. The attachment of the first rib to the sternum also becomes a synostosis with age.

Fibrous Joints

A **fibrous joint** is also called a **synarthrosis**[4] (SIN-ar-THRO-sis) or **synarthrodial joint.** It is a point at which adjacent bones are bound by collagen fibers that emerge from the matrix of one bone, cross the space between them, and penetrate into the matrix of the other (fig. 9.1). There are three kinds of fibrous joints: *sutures, gomphoses,* and *syndesmoses.* In sutures and gomphoses, the fibers are very short and allow for little or no movement. In syndesmoses, the fibers are longer and the attached bones are more movable.

Sutures

Sutures are immobile or only slightly movable fibrous joints that closely bind the bones of the skull to each other; they occur nowhere else. In chapter 7, we did not take much notice of the differences between one suture and another, but some differences may have caught your attention as you studied the diagrams in that chapter or examined laboratory specimens. Sutures can be classified as *serrate, lap,* and *plane sutures.* Readers with some knowledge of woodworking may recognize that the structures and functional

[1] *arthro* = joint + *logy* = study of
[2] *kinesio* = movement + *logy* = study of
[3] *syn* = together + *ost* = bone + *osis* = condition
[4] *syn* = together + *arthr* = joined + *osis* = condition

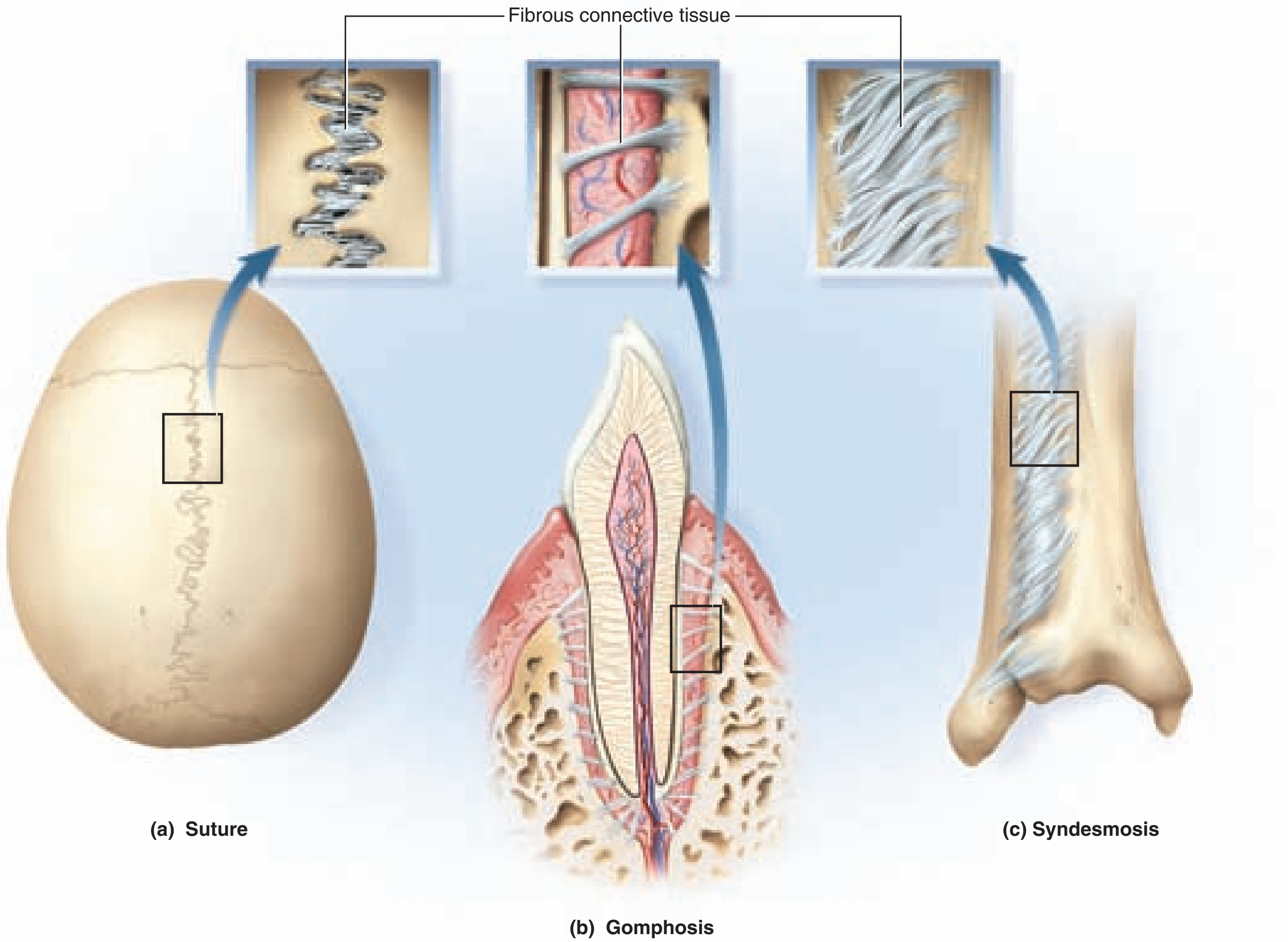


Figure 9.1 Fibrous Joints. (a) A suture between the parietal bones. (b) A gomphosis between a tooth and the jaw. (c) A syndesmosis between the tibia and fibula.
• *Which of these is* not *a joint between two bones? Why?*

properties of these sutures have something in common with basic types of carpentry joints (fig. 9.2).

A **serrate suture** is one in which the adjoining bones firmly interlock by their serrated margins, like pieces of a jigsaw puzzle. It is analogous to a dovetail wood joint. On the surface, it appears as a wavy line between the two bones, as we see in the coronal, sagittal, and lambdoid sutures that border the parietal bones.

A **lap (squamous) suture** is one in which the adjacent bones have overlapping beveled edges, like a miter joint in carpentry. An example is the squamous suture that encircles most of the temporal bone. Its beveled edge can be seen in figure 7.10b (p. 160). On the surface, a lap suture appears as a relatively smooth (nonserrated) line.

A **plane (butt) suture** is one in which the adjacent bones have straight nonoverlapping edges. The two bones merely border each other, like two boards glued together in a butt joint. An example is seen between the palatine processes of the maxillae in the roof of the mouth.

Gomphoses

Even though the teeth are not bones, the attachment of a tooth to its socket is classified as a **gomphosis** (gom-FOE-sis). The term refers to its similarity to a nail hammered into wood.[5] The tooth is held firmly in place by a fibrous **periodontal ligament,** which consists of collagen fibers that extend from the bone matrix of the jaw into the dental tissue (see fig. 9.1b). The periodontal ligament allows the tooth to move or give a little under the stress of chewing. This allows us to sense how hard we are biting and to sense a particle of food stuck between the teeth.

Syndesmoses

A **syndesmosis**[6] (SIN-dez-MO-sis) is a fibrous joint at which two bones are bound by relatively long collagenous fibers. The separa-

[5] *gomph* = nail, bolt + *osis* = condition
[6] *syn* = together + *desm* = band + *osis* = condition

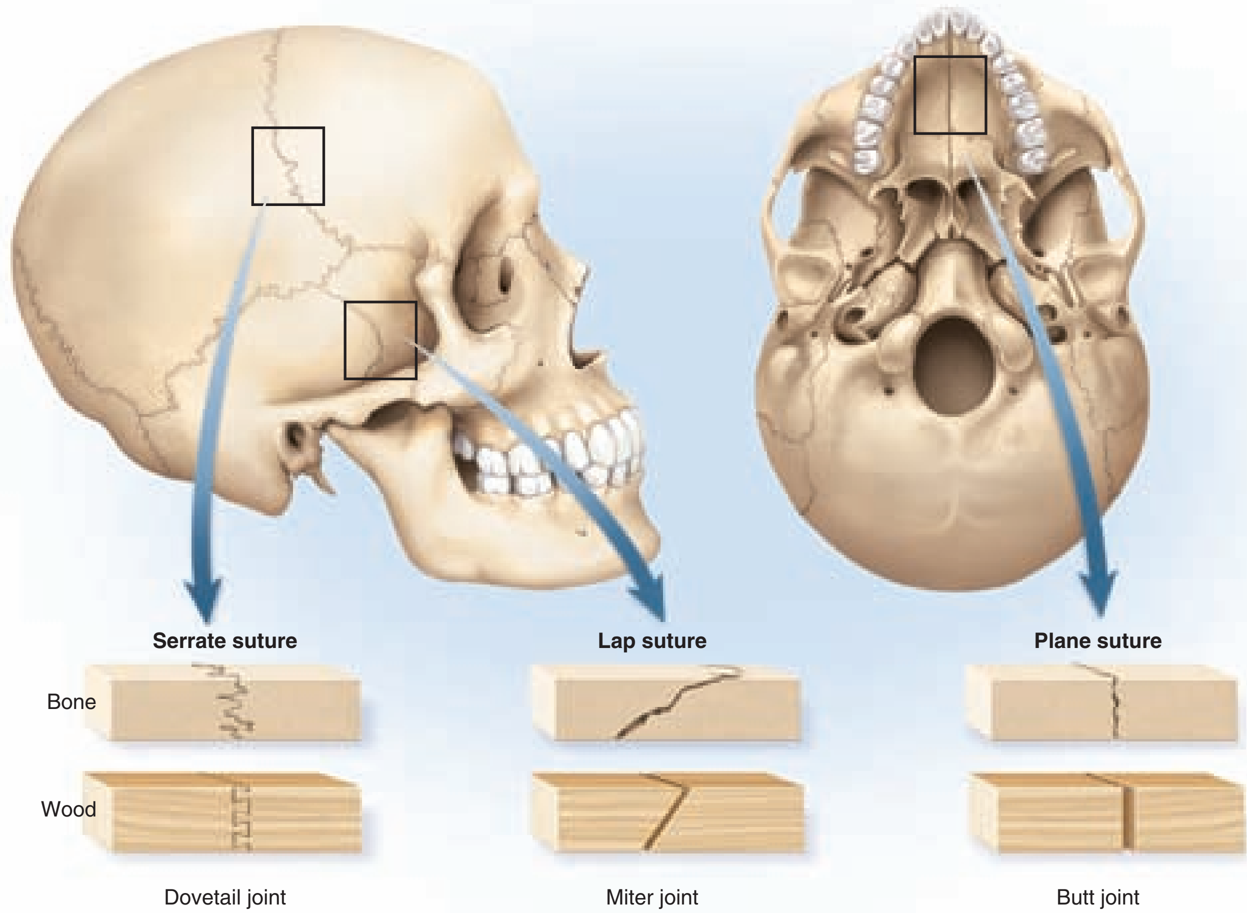


Figure 9.2 Sutures. Serrate, lap, and plane sutures compared to some common wood joints.

tion between the bones and length of the fibers gives these joints more mobility than a suture or gomphosis. An especially movable syndesmosis exists between the shafts of the radius and ulna, which are joined by a broad fibrous *interosseous membrane.* This syndesmosis permits such movements as pronation and supination of the forearm. A less mobile syndesmosis is the one that binds the distal ends of the tibia and fibula together, side by side (fig. 9.1c).

Cartilaginous Joints

A **cartilaginous joint** is also called an **amphiarthrosis**[7] (AM-fee-ar-THRO-sis) or **amphiarthrodial joint.** In these joints, two bones are linked by cartilage (fig. 9.3). The two types of cartilaginous joints are *synchondroses* and *symphyses*.

Synchondroses

A **synchondrosis**[8] (SIN-con-DRO-sis) is a joint in which the bones are bound by hyaline cartilage. An example is the temporary joint between the epiphysis and diaphysis of a long bone in a child, formed by the cartilage of the epiphyseal plate. Another is the attachment of the first rib to the sternum by a hyaline costal cartilage (fig. 9.3a). (The other costal cartilages are joined to the sternum by synovial joints.)

Symphyses

In a **symphysis**[9] (SIM-fih-sis), two bones are joined by fibrocartilage (fig. 9.3b, c). One example is the pubic symphysis, in which the right and left pubic bones are joined by the cartilaginous interpubic disc. Another is the joint between the bodies of two vertebrae,

[7] *amphi* = on all sides + *arthr* = joined + *osis* = condition

[8] *syn* = together + *chondr* = cartilage + *osis* = condition
[9] *sym* = together + *physis* = growth

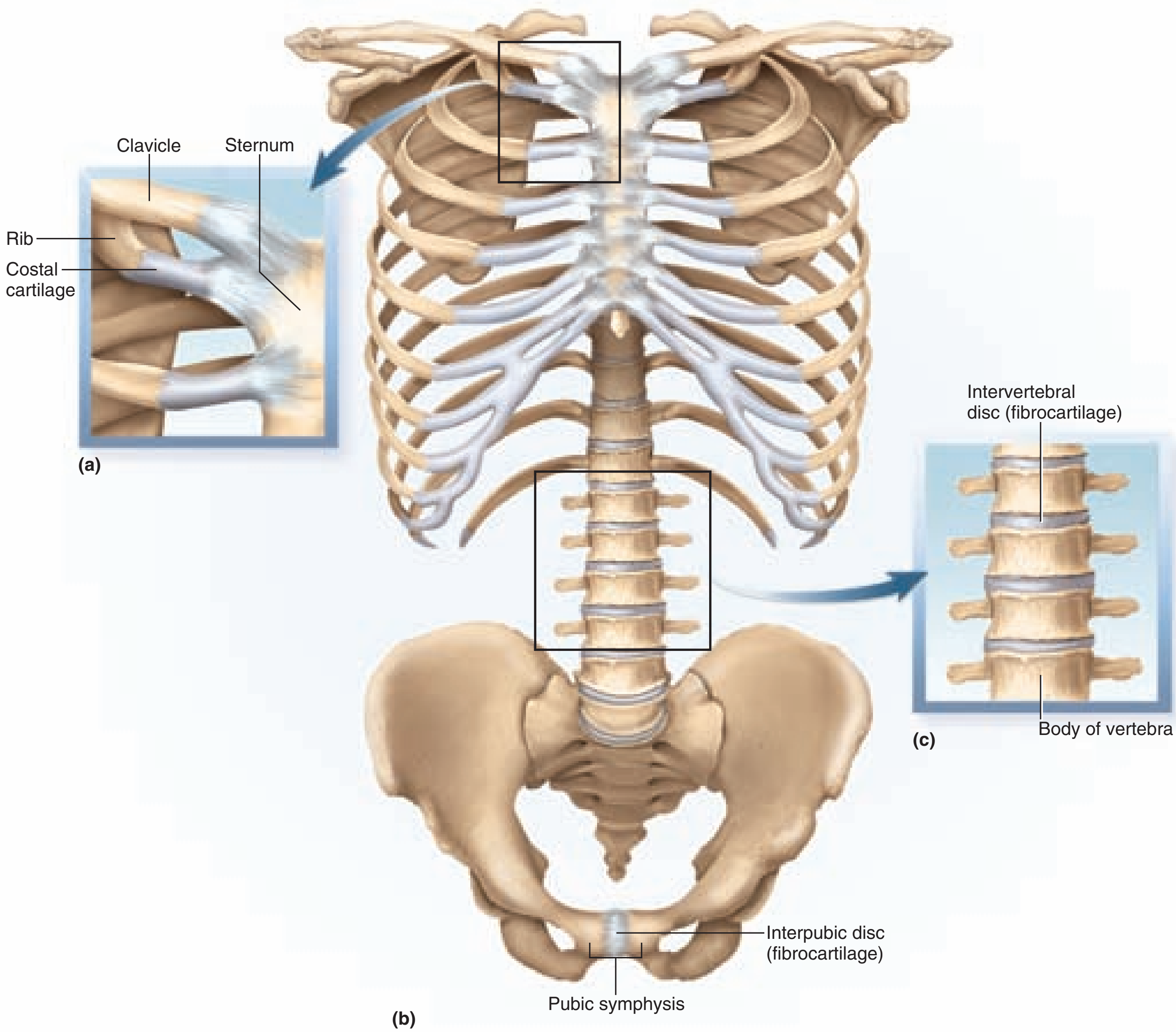


Figure 9.3 Cartilaginous Joints. (a) A synchondrosis, represented by the costal cartilage joining rib 1 to the sternum. (b) The pubic symphysis. (c) Intervertebral discs, which join adjacent vertebrae to each other by symphyses.
• *What is the difference between the pubic symphysis and the interpubic disc?*

united by an intervertebral disc. The surface of each vertebral body is covered with hyaline cartilage. Between the vertebrae, this cartilage becomes infiltrated with collagen bundles to form fibrocartilage. Each intervertebral disc permits only slight movement between adjacent vertebrae, but the collective effect of all 23 discs gives the spine considerable flexibility.

Apply What You Know

The intervertebral joints are symphyses only in the cervical through the lumbar region. How would you classify the intervertebral joints of the sacrum and coccyx in a middle-aged adult?

Before You Go On

Answer the following questions to test your understanding of the preceding section:

1. What is the difference between arthrology and kinesiology?
2. Explain the distinction between a synostosis, amphiarthrosis, and synarthrosis.
3. Give some examples of joints that become synostoses with age.
4. Define *suture, gomphosis,* and *syndesmosis,* and explain what these three joints have in common.
5. Name the three types of sutures and describe how they differ.
6. Name two synchondroses and two symphyses.

9.2 Synovial Joints

Expected Learning Outcomes

When you have completed this section, you should be able to

- describe the anatomy of a synovial joint and its associated structures;
- describe the six types of synovial joints;
- list and demonstrate the types of movements that occur at diarthroses; and
- discuss the factors that affect the range of motion of a joint.

The most familiar type of joint is the **synovial** (sih-NO-vee-ul) **joint,** also called a **diarthrosis**[10] (DY-ar-THRO-sis) or **diarthrodial joint.** Ask most people to point out any joint in the body, and they are likely to point to a synovial joint such as the elbow, knee, or knuckles. Many synovial joints, like these examples, are freely movable. Others, such as the joints between the wrist and ankle bones and between the articular processes of the vertebrae, have more limited mobility. Synovial joints are the most structurally complex type of joint and are the most likely to develop uncomfortable and crippling dysfunctions.

[10]*dia* = separate, apart + *arthr* = joint + *osis* = condition

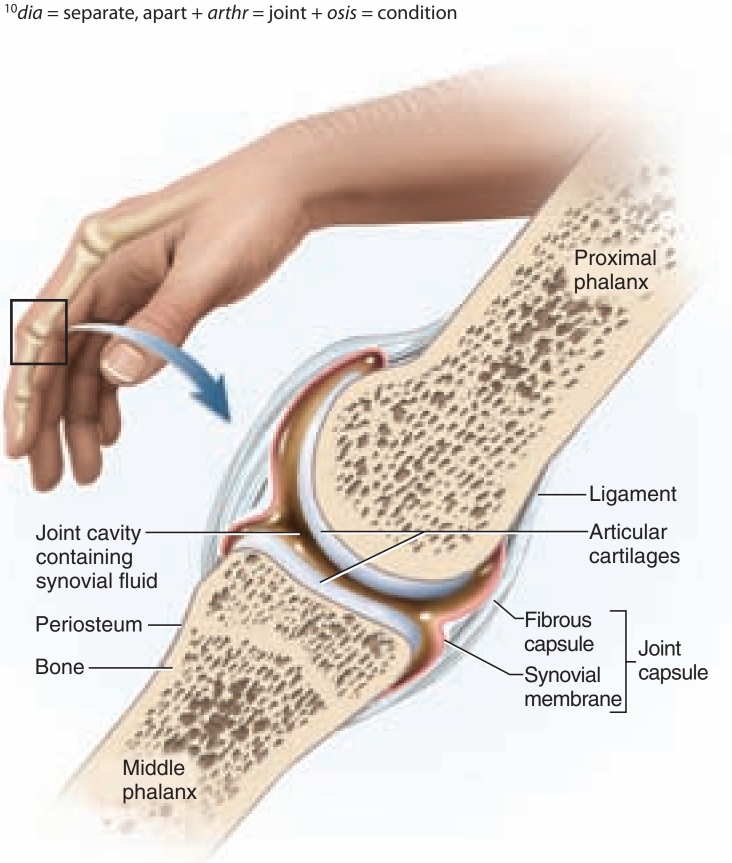


Figure 9.4 Structure of a Simple Synovial Joint. Most synovial joints are more complex than the interphalangeal joints.

• *Why is a meniscus unnecessary in an interphalangeal joint?*

General Anatomy

In synovial joints, the facing surfaces of the two bones are covered with **articular cartilage,** a layer of hyaline cartilage usually about 2 or 3 mm thick. These surfaces are separated by a narrow space, the **joint (articular) cavity,** containing a slippery lubricant called **synovial fluid** (fig. 9.4). This fluid, for which the joint is named, is rich in albumin and hyaluronic acid, which give it a viscous, slippery texture similar to raw egg white.[11] It nourishes the articular cartilages, removes their wastes, and makes movements at synovial joints almost friction-free. A connective tissue **joint (articular) capsule** encloses the cavity and retains the fluid. It has an outer **fibrous capsule** continuous with the periosteum of the adjoining bones, and an inner, cellular **synovial membrane.** The synovial membrane consists mainly of fibroblast-like cells that secrete the fluid, and is populated by macrophages that remove debris from the joint cavity.

In a few synovial joints, fibrocartilage grows inward from the joint capsule and forms a pad between the articulating bones. In the jaw and distal radioulnar joints, and at both ends of the clavicle (sternoclavicular and acromioclavicular joints), the pad crosses the entire joint capsule and is called an **articular disc** (see fig. 9.18c). In the knee, two cartilages extend inward from the left and right but do not entirely cross the joint (see fig. 9.23d). Each is called a **meniscus**[12] because of its crescent shape. These cartilages absorb shock and pressure, guide the bones across each other, improve the fit between the bones, and stabilize the joint, reducing the chance of dislocation.

Accessory structures associated with a synovial joint include tendons, ligaments, and bursae. A **tendon** is a strip or sheet of tough collagenous connective tissue that attaches a muscle to a

DEEPER INSIGHT 9.1

Exercise and Articular Cartilage

When synovial fluid is warmed by exercise, it becomes thinner (less viscous) and more easily absorbed by the articular cartilage. The cartilage then swells and provides a more effective cushion against compression. For this reason, a warm-up period before vigorous exercise helps protect the articular cartilage from undue wear and tear.

Because cartilage is nonvascular, its repetitive compression during exercise is important to its nutrition and waste removal. Each time a cartilage is compressed, fluid and metabolic wastes are squeezed out of it. When weight is taken off the joint, the cartilage absorbs synovial fluid like a sponge, and the fluid carries oxygen and nutrients to the chondrocytes. Lack of exercise causes the articular cartilages to deteriorate more rapidly from lack of nutrition, oxygenation, and waste removal.

Weight-bearing exercise builds bone mass and strengthens the muscles that stabilize many of the joints, thus reducing the risk of joint dislocations. Excessive joint stress, however, can hasten the progression of osteoarthritis (p. 228) by damaging the articular cartilage. Swimming is a good way of exercising the joints with minimal damage.

[11]*ovi* = egg
[12]*men* = moon, crescent + *iscus* = little

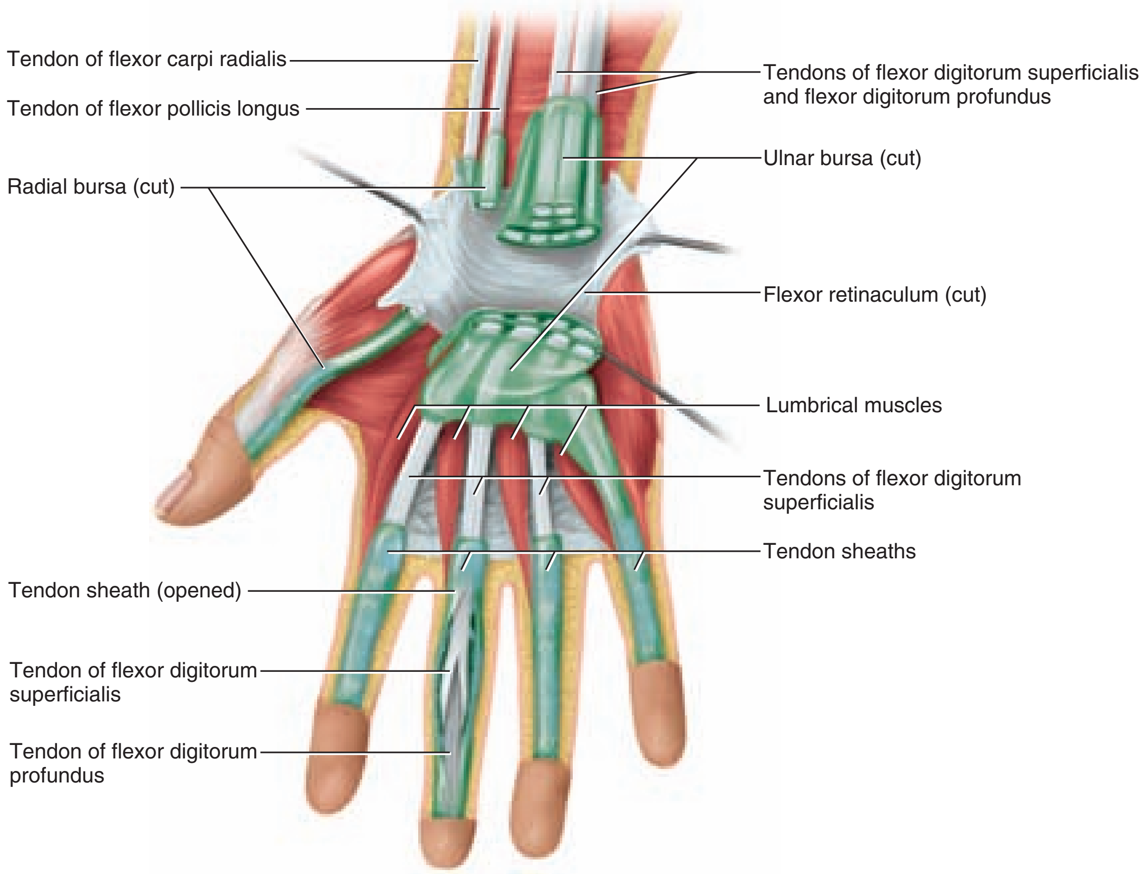


Figure 9.5 **Tendon Sheaths and Other Bursae in the Hand and Wrist.**

bone. Tendons are often the most important structures in stabilizing a joint. A **ligament** is a similar tissue that attaches one bone to another. Several ligaments are named and illustrated in our later discussion of individual joints, and tendons are more fully considered in chapters 10 through 12 along with the gross anatomy of muscles.

A **bursa**[13] is a fibrous sac filled with synovial fluid, located between adjacent muscles, between bone and skin, or where a tendon passes over a bone (see fig. 9.19). Bursae cushion muscles, help tendons slide more easily over the joints, and sometimes enhance the mechanical effect of a muscle by modifying the direction in which its tendon pulls. Bursae called **tendon sheaths** are elongated cylinders wrapped around a tendon. These are especially numerous in the hand and foot (fig. 9.5). **Bursitis** is inflammation of a bursa, usually due to overexertion of a joint. **Tendinitis** is a form of bursitis in which a tendon sheath is inflamed.

Classes of Synovial Joints

There are six fundamental classes of synovial joints, distinguished by patterns of motion determined by the shapes of the articular surfaces of the bones (table 9.1). We will examine them here in descending order of mobility, from multiaxial to monaxial joints. A **multiaxial** joint is one that can move in any of the three fundamental mutually perpendicular planes (*x, y,* and *z*); a **biaxial** joint is able to move in only two planes; and a **monaxial** joint moves in only one plane. Ball-and-socket joints are the only multiaxial type; condylar, saddle, and plane joints are biaxial; and hinge and pivot joints are monaxial. As we see in figure 9.6, all six types of synovial joints have representatives in the upper limb.

1. **Ball-and-socket joints.** These are the shoulder and hip joints. In both cases, one bone (the humerus or femur) has a smooth hemispherical head that fits into a cuplike socket on the other (the glenoid cavity of the scapula or the acetabulum of the hip bone).
2. **Condylar (ellipsoid) joints.** These joints exhibit an oval convex surface on one bone that fits into a similarly shaped depression on the other. The radiocarpal joint of the wrist and metacarpophalangeal (MET-uh-CAR-po-fah-LAN-jee-ul) joints at the bases of the fingers are examples. To demonstrate their biaxial motion, hold your hand with the palm facing you. Make a fist, and these joints flex in the sagittal plane. Fan your fingers apart, and they move in the frontal plane.

[13]*burs* = purse

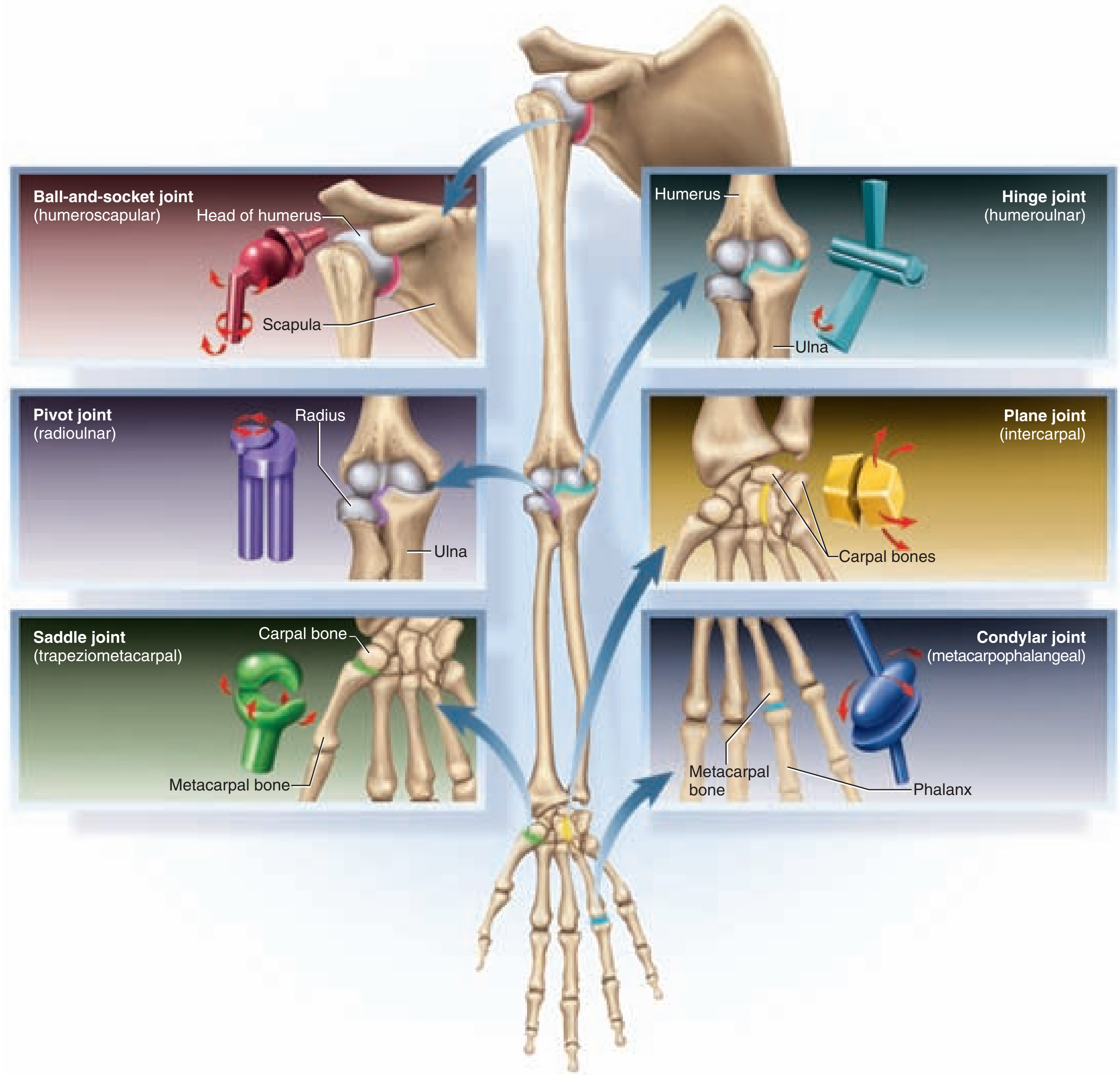


Figure 9.6 **The Six Types of Synovial Joints.** All six have representatives in the forelimb. Mechanical models show the types of motion possible at each joint.

3. **Saddle joints.** Here, both bones have a saddle-shaped surface—concave in one direction (like the front to rear curvature of a horse's saddle) and convex in the other (like the left to right curvature of a saddle). The clearest example of this is the trapeziometacarpal joint between the trapezium of the wrist and metacarpal I at the base of the thumb. Saddle joints are also biaxial. The thumb, for example, moves in a frontal plane when you spread the fingers apart, and in a sagittal plane when you move it as if to grasp a tool such as a hammer. This range of motion gives us and other primates that anatomical hallmark, the opposable thumb. Another saddle joint is the sternoclavicular joint, where the clavicle articulates with the sternum. The clavicle moves vertically in the frontal plane at this joint when you lift a suitcase, and moves horizontally in the transverse plane when you reach forward to push open a door.

4. **Plane (gliding) joints.** Here the bone surfaces are flat or only slightly concave and convex. The adjacent bones slide over each other and have relatively limited movement. Plane joints are found between the carpal bones of the wrist, the tarsal bones of the ankle, and the articular processes of the vertebrae. Their movements, although slight, are complex. They are usually biaxial. For example, when the head is tilted forward and back, the articular facets of the vertebrae slide anteriorly and posteriorly; when the head is tilted from side to side, the facets slide laterally. Although any one joint moves only slightly, the combined action of the many joints in the wrist, ankle, and vertebral column allows for a significant amount of overall movement.
5. **Hinge joints.** These are essentially monaxial joints, moving freely in one plane with very little movement in any other, like a door hinge. Examples include the elbow, knee, and interphalangeal (finger and toe) joints. In these cases, one bone has a convex (but not hemispherical) surface, such as the trochlea of the humerus and the condyles of the femur. This fits into a concave depression on the other bone, such as the trochlear notch of the ulna and the condyles of the tibia.
6. **Pivot joints.** These are monaxial joints in which a bone spins on its longitudinal axis. There are two principal examples: the radioulnar joint at the elbow and the atlantoaxial joint between the first two vertebrae. At the atlantoaxial joint, the dens of the axis projects into the vertebral foramen of the atlas and is held against its anterior arch by the transverse ligament (see fig. 7.24, p. 169). As the head rotates left and right, the skull and atlas pivot around the dens. At the radioulnar joint, the anular ligament of the ulna wraps around the neck of the

TABLE 9.1 Anatomical Classification of the Joints

Joint	Characteristics and Examples
Bony joint (synostosis)	Former fibrous or cartilaginous joint in which adjacent bones have become fused by ossification. Examples: median line of frontal bone; fusion of epiphysis and diaphysis of an adult long bone; and fusion of ilium, ischium, and pubis to form hip bone
Fibrous joint (synarthrosis)	Adjacent bones bound by collagen fibers extending from the matrix of one into the matrix of the other
Suture (figs. 9.1a, 9.2)	Immobile fibrous joint between cranial or facial bones
Serrate suture	Bones joined by a wavy line formed by interlocking teeth along the margins. Examples: coronal, sagittal, and lambdoid sutures
Lap suture	Bones beveled to overlap each other; superficial appearance is a smooth line. Example: squamous suture around temporal bone
Plane suture	Bones butted against each other without overlapping or interlocking. Example: palatine suture
Gomphosis (fig. 9.1b)	Insertion of a tooth into a socket, held in place by collagen fibers of periodontal ligament
Syndesmosis (fig. 9.1c)	Slightly movable joint held together by ligaments or interosseous membranes. Examples: tibiofibular joint and radioulnar joint
Cartilaginous joint (amphiarthrosis)	Adjacent bones bound by cartilage
Synchondrosis (fig. 9.3a)	Bones held together by hyaline cartilage. Examples: articulation of rib 1 with sternum, and epiphyseal plate uniting the epiphysis and diaphysis of a long bone of a child
Symphysis (fig. 9.3b, c)	Slightly movable joint held together by fibrocartilage. Examples: intervertebral discs and pubic symphysis
Synovial joint (diarthrosis) (Figs. 9.4 and 9.6)	Adjacent bones covered with hyaline articular cartilage, separated by lubricating synovial fluid and enclosed in a fibrous joint capsule
Ball-and-socket joint	Multiaxial diarthrosis in which a smooth hemispherical head of one bone fits into a cuplike depression of another. Examples: shoulder and hip joints
Condylar (ellipsoid) joint	Biaxial diarthrosis in which an oval convex surface of one bone articulates with an elliptical depression of another. Examples: radiocarpal and metacarpophalangeal joints
Saddle joint	Joint in which each bone surface is saddle-shaped (concave on one axis and convex on the perpendicular axis). Examples: trapeziometacarpal and sternoclavicular joints
Plane (gliding) joint	Usually biaxial diarthroses with slightly concave or convex bone surfaces that slide across each other. Examples: intercarpal and intertarsal joints; joints between the articular processes of the vertebrae
Hinge joint	Monaxial diarthrosis, able to flex and extend in only one plane. Examples: elbow, knee, and interphalangeal joints
Pivot joint	Joint in which a projection of one bone fits into a ringlike ligament of another, allowing one bone to rotate on its longitudinal axis. Examples: atlantoaxial joint and proximal radioulnar joint

radius. During pronation and supination of the forearm, the disclike radial head pivots like a wheel turning on its axle. The edge of the wheel spins against the radial notch of the ulna like a car tire spinning in snow.

Some joints cannot be easily classified into any one of these six categories. The jaw joint, for example, has some aspects of condylar, hinge, and plane joints. It clearly has an elongated condyle where it meets the temporal bone of the cranium, but it moves in a hingelike fashion when the mandible moves up and down in speaking, biting, and chewing; it glides slightly forward when the jaw juts (protracts) to take a bite; and it glides from side to side to grind food between the molars. The knee is a classic hinge joint, but has an element of the pivot type; when we lock our knees to stand more effortlessly, the femur pivots slightly on the tibia. The humeroradial joint (between humerus and radius) acts as a hinge joint when the elbow flexes and a pivot joint when the forearm pronates.

Movements of Synovial Joints

Kinesiology, physical therapy, and other medical and scientific fields have a specific vocabulary for the movements of synovial joints. The following terms form a basis for describing the muscle actions in chapters 11 and 12 and may also be indispensable to your advanced coursework or intended career. This section introduces the terms for joint movements, many of which are presented in pairs or groups with opposite or contrasting meanings. This section relies on familiarity with the three cardinal anatomical planes and the directional terms in chapter 1 (p. 13). All directional terms used here refer to a person in standard anatomical position. When one is in anatomical position, each joint is said to be in its **zero position.** Joint movements can be described as deviation from the zero position or returning to it.

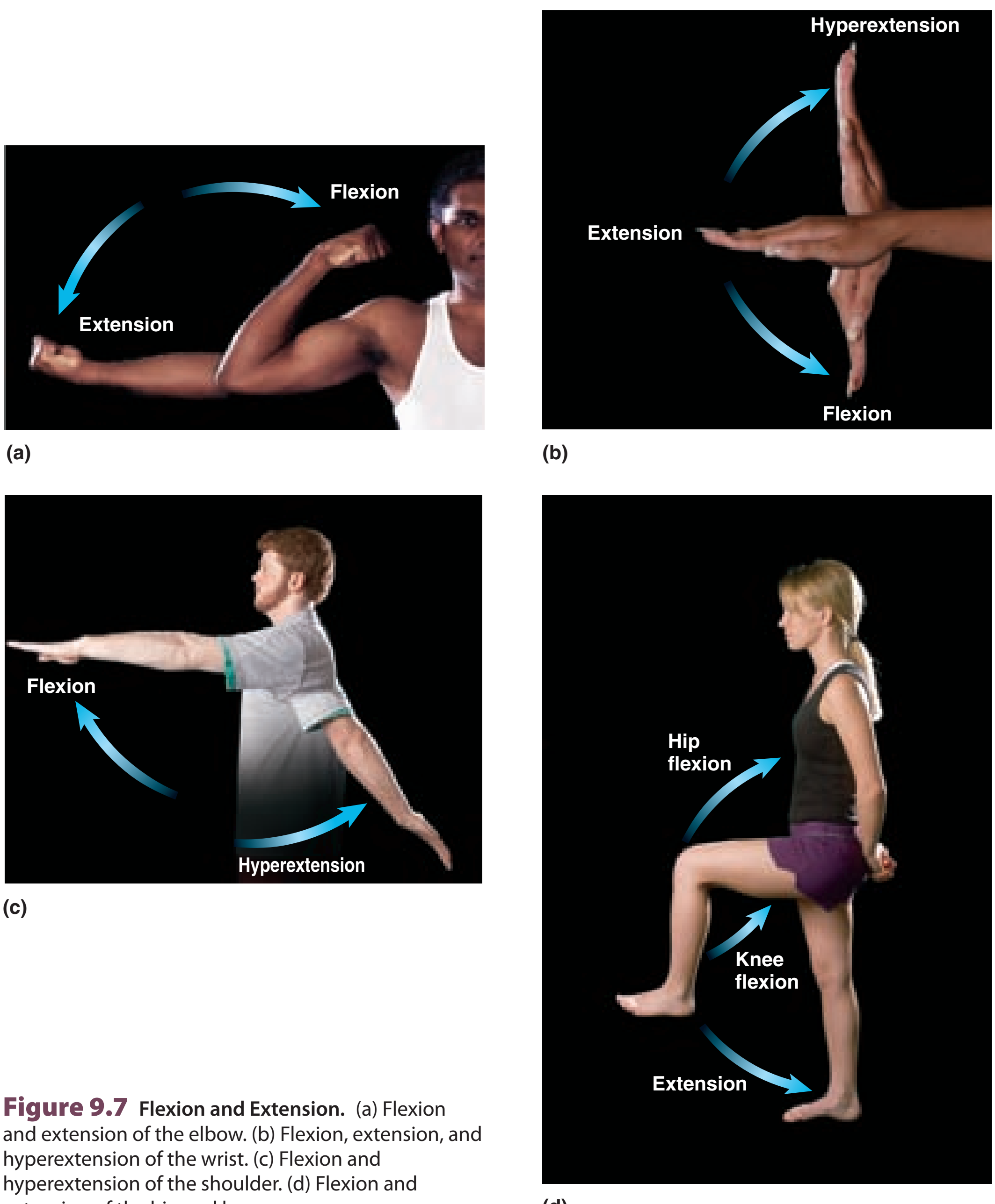


Figure 9.7 Flexion and Extension. (a) Flexion and extension of the elbow. (b) Flexion, extension, and hyperextension of the wrist. (c) Flexion and hyperextension of the shoulder. (d) Flexion and extension of the hip and knee.

Flexion and Extension

Flexion (fig. 9.7) is a movement that decreases a joint angle, usually in the sagittal plane. This is particularly common at hinge joints—for example, bending of the elbow or knee—but it occurs in other types of joints as well. For example, if you hold out your hands with the palms up, flexion of the wrist tips your palms toward you. The meaning of *flexion* is perhaps least obvious in the ball-and-socket joints of the shoulder and hip. At the shoulder, it means to raise your arm as if pointing at something directly in front of you or to continue in that arc and point toward the sky. At the hip, it means to raise the thigh, for example to place your foot on the next higher step when ascending a flight of stairs.

Extension is a movement that straightens a joint and generally returns a body part to the zero position—for example, straightening the elbow, wrist, or knee, or returning the arm or thigh back to zero position. In stair climbing, both the hip and knee extend when lifting the body to the next higher step.

Extreme extension of a joint, beyond the zero position, is called **hyperextension**.[14] For example, if you hold your hand in front of you with the palm down, then raise the back of your hand as if you were admiring a new ring, you hyperextend the wrist. Hyperextension of the upper or lower limb means to move the limb to a position behind the frontal plane of the trunk, as in reaching around with your arm to scratch your back. Each backswing of the lower limb when you walk hyperextends the hip.

Flexion and extension occur at nearly all diarthroses, but hyperextension is limited to only a few. At most diarthroses, ligaments or bone structure prevents hyperextension.

Apply What You Know

Try hyperextending some of your synovial joints and list a few for which this is impossible.

[14]*hyper* = excessive, beyond normal

Abduction and Adduction

Abduction[15] (ab-DUC-shun) (fig. 9.8a) is the movement of a body part in the frontal plane away from the midline of the body—for example, moving the feet apart to stand spread-legged, or raising an arm to one side of the body. **Adduction**[16] (fig. 9.8b) is movement in the frontal plane back toward the midline. Some joints can be **hyperadducted**, as when you stand with your ankles crossed, cross your fingers, or hyperadduct the shoulder to stand with your elbows straight and your hands clasped below your waist. You **hyperabduct** the arm if you raise it high enough to cross slightly over the front or back of your head.

Elevation and Depression

Elevation (fig. 9.9a) is a movement that raises a body part vertically in the frontal plane. **Depression** (fig. 9.9b) lowers a body part in the

[15]*ab* = away + *duc* = to lead or carry
[16]*ad* = toward + *duc* = to lead or carry

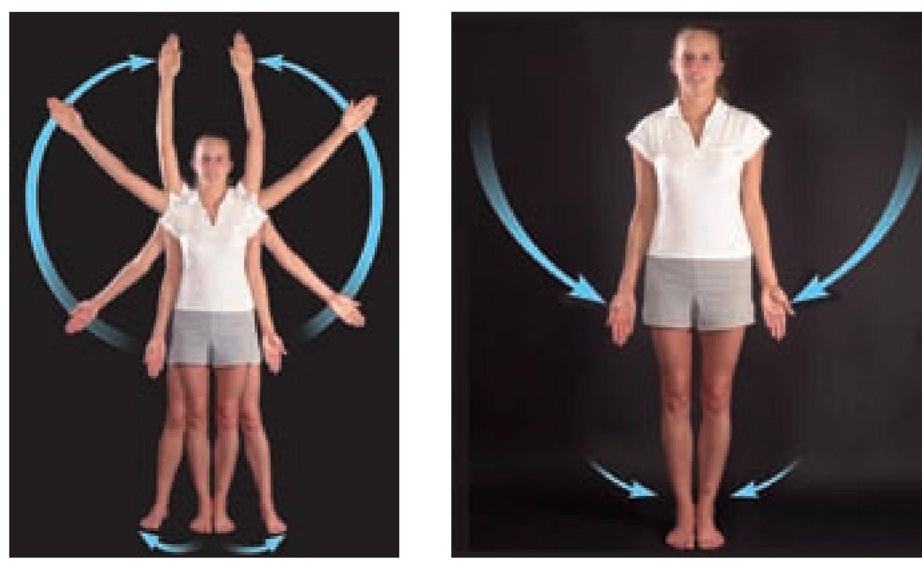


Figure 9.8 **Abduction and Adduction.**

(a) Abduction **(b) Adduction**

Figure 9.9 **Elevation and Depression.**

(a) Elevation **(b) Depression**

(a) Protraction (b) Retraction

Figure 9.10 Protraction and Retraction.

Figure 9.11 Circumduction.

same plane. For example, to lift a heavy suitcase from the floor, you elevate your scapula; in setting it down again, you depress the scapula. These are also important jaw movements in biting.

Protraction and Retraction

Protraction[17] (fig. 9.10a) is the anterior movement of a body part in the transverse (horizontal) plane, and **retraction**[18] (fig. 9.10b) is posterior movement. Your shoulder protracts, for example, when you reach in front of you to push a door open. It retracts when you return it to the resting (zero) position or pull the shoulders back to stand at military attention. Such exercises as rowing a boat, bench presses, and push-ups involve repeated protraction and retraction of the shoulders.

Circumduction

In **circumduction**[19] (fig. 9.11), one end of an appendage remains fairly stationary while the other end makes a circular motion. If an artist standing at an easel reaches forward and draws a circle on a canvas, she circumducts the upper limb; the shoulder remains stationary while the hand moves in a circle. A baseball player winding up for the pitch circumducts the upper limb in a more extreme "windmill" fashion. One can also circumduct an individual finger, the hand, the thigh, the foot, the trunk, and the head.

Apply What You Know

Choose any example of circumduction and explain why this motion is actually a sequence of flexion, abduction, extension, and adduction.

Rotation

In one sense, the term *rotation* applies to any bone turning around a fixed axis, as described earlier. But in the terminology of specific joint movements, **rotation** (fig. 9.12) is a movement in which a bone spins on its longitudinal axis. For example, if you stand with bent elbow and move your forearm to place your palm against your abdomen, your humerus spins in a motion called **medial (internal) rotation.** If you make the opposite action, so the forearm points away from the trunk, your humerus undergoes **lateral (external) rotation.** If you turn your right foot so your toes are pointing away from your left foot, and then turn it so your toes are pointing toward your left foot, your femur undergoes lateral and medial rotation, respectively. Other examples are given in the ensuing discussions of forearm and head movements.

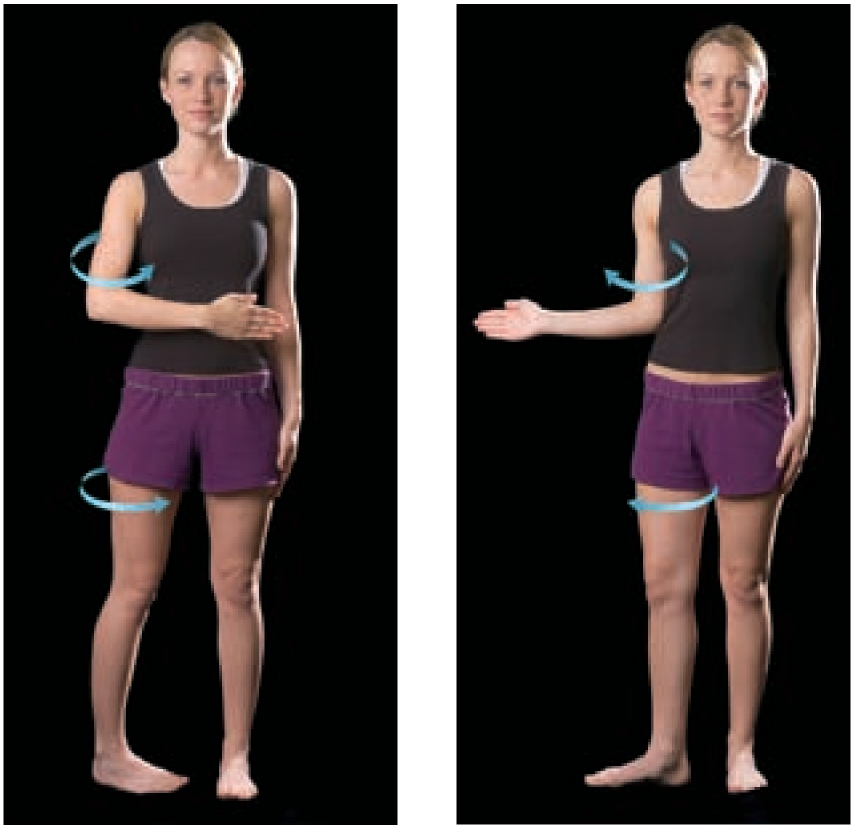
Supination and Pronation

Supination and pronation (fig. 9.13) are known primarily as forearm movements, but see also the later discussion of foot movements. **Supination**[20] (SOO-pih-NAY-shun) of the forearm is a movement that turns the palm to face anteriorly or upward; in anatomical position, the forearm is supinated and the radius is parallel to the ulna. **Pronation**[21] is the opposite movement, causing the palm to face posteriorly or downward and the radius to cross the ulna like an X. During these movements, the concave end of the disc-shaped head of the radius spins on the capitulum of the humerus, and the edge of the disc spins in the radial notch of the ulna. The ulna remains relatively stationary.

As an aid to remembering these terms, think of it this way: You are *prone* to stand in the most comfortable position, which is with the forearm *pronated*. But if you were holding a cup of *soup* in your palm, you would need to *supinate* the forearm to keep from spilling it.

Chapter 12 describes the muscles that perform these actions. Of these, the *supinator* is the most powerful. Supination is the type of movement you would usually make with your right hand to turn a doorknob clockwise or to drive a screw into a piece of wood. The threads of screws and bolts are designed with the relative strength of the supinator in mind, so the greatest power can be applied when driving them with a screwdriver in the right hand.

[17] *pro* = forward + *trac* = to pull or draw
[18] *re* = back + *trac* = to pull or draw
[19] *circum* = around + *duc* = to carry, lead
[20] *supin* = to lay back
[21] *pron* = to bend forward



(a) Medial (internal) rotation **(b) Lateral (external) rotation**

Figure 9.12 Medial (Internal) and Lateral (External) Rotation. Shows rotation of both the humerus and the femur.

We will now consider a few body regions that combine the foregoing motions or have unique movements and terminology.

Special Movements of the Head and Trunk

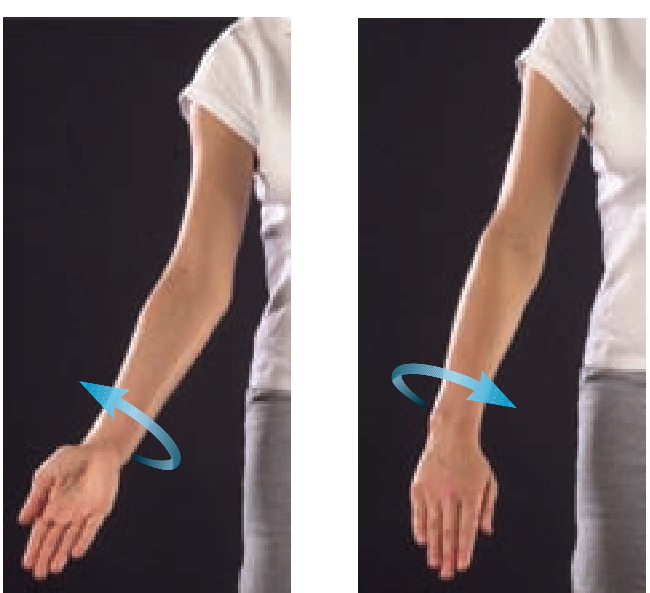
Flexion of the spine produces forward-bending movements, as in tilting the head forward or bending at the waist in a toe-touching exercise (fig. 9.14a). *Extension* of the spine straightens the trunk or neck, as in standing up or returning the head to a forward-looking zero position. *Hyperextension* is employed in looking toward the sky or bending over backward (fig. 9.14b).

Lateral flexion is tilting the head or the trunk to the right or left of the midline (fig. 9.14c). Twisting at the waist or turning the head is called **right rotation** or **left rotation** when the chest or the face turns to the right or left of the forward-facing zero position (fig. 9.14d, e). Powerful right and left rotation at the waist is important in baseball pitching, golf, discus throwing, and other sports.

Special Movements of the Mandible

Movements of the mandible are concerned especially with biting and chewing (fig. 9.15). Imagine taking a bite of raw carrot. Most people have some degree of overbite; at rest, the upper incisors (front teeth) overhang the lower ones. For effective biting, however, the chisel-like edges of the incisors must meet. In preparation to bite, we therefore *protract* the mandible to bring the lower incisors forward. After the bite is taken, we *retract* it. To actually take the bite, we must *depress* the mandible to open the mouth, then *elevate* it so the incisors can cut off the piece of food.

Next, to chew the food, we do not simply raise and lower the mandible as if hammering away at the food between the teeth; rather, we exercise a grinding action that shreds the food between the broad, bumpy surfaces of the premolars and molars. This entails a side-to-side movement of the mandible called **lateral excursion** (movement to the left or right of the zero position) and **medial excursion** (movement back to the median, zero position).



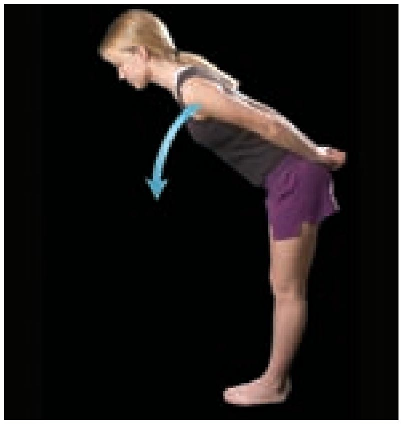
(a) Supination **(b) Pronation**

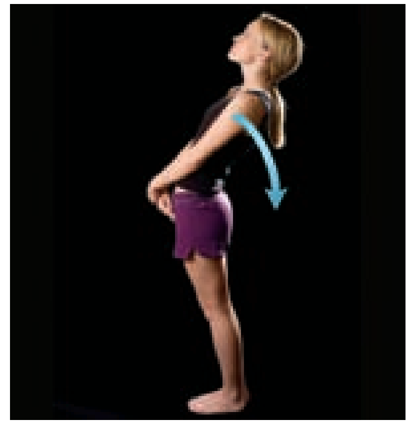
Figure 9.13 Supination and Pronation.

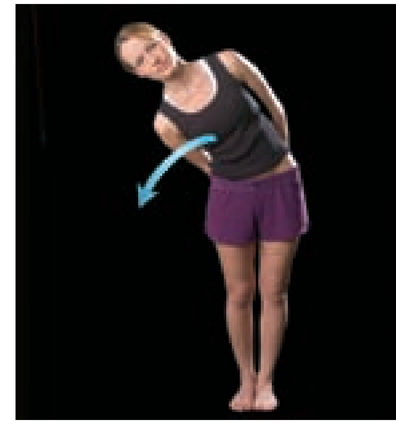
Special Movements of the Hand and Fingers

The hand moves anteriorly and posteriorly by flexion and extension of the wrist. It can also move in the frontal plane. **Radial flexion** tilts the hand toward the thumb, and **ulnar flexion** tilts it toward the little finger (fig. 9.16a, b). We often use such motions when waving hello to someone with a side-to-side wave of the hand, or when washing windows, polishing furniture, or keyboarding.

Movements of the fingers are more varied, especially those of the thumb (fig. 9.16c–e). *Flexion* of the fingers is curling them; *extension* is straightening them. Most people cannot hyperextend their fingers. Spreading the fingers apart is *abduction,* and bringing them together again so they touch along their surfaces is *adduction.*


(a) Flexion


(b) Hyperextension


(c) Lateral flexion


(d) Rotation

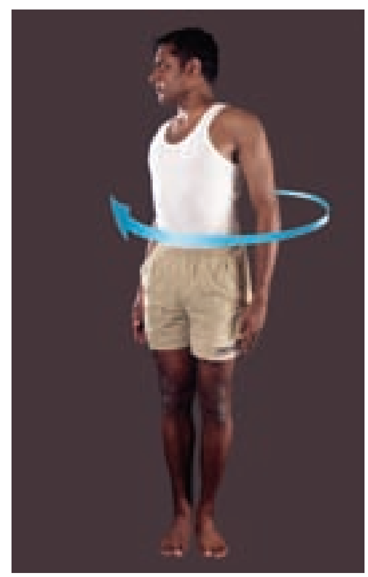
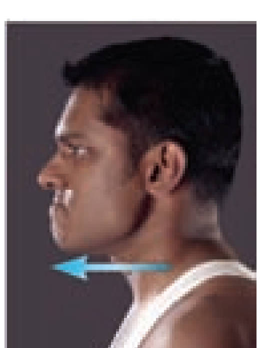
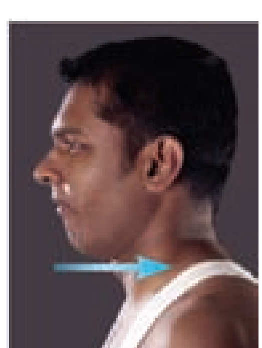
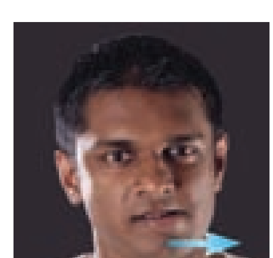

(e) Right rotation

Figure 9.14 **Movements of the Head and Trunk.**
• *In rotation of the head (d), what bone spins on its axis?*


(a) Protraction


(b) Retraction


(c) Lateral excursion

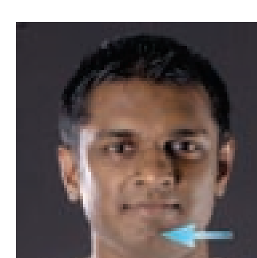

(d) Medial excursion

Figure 9.15 **Movements of the Mandible.**

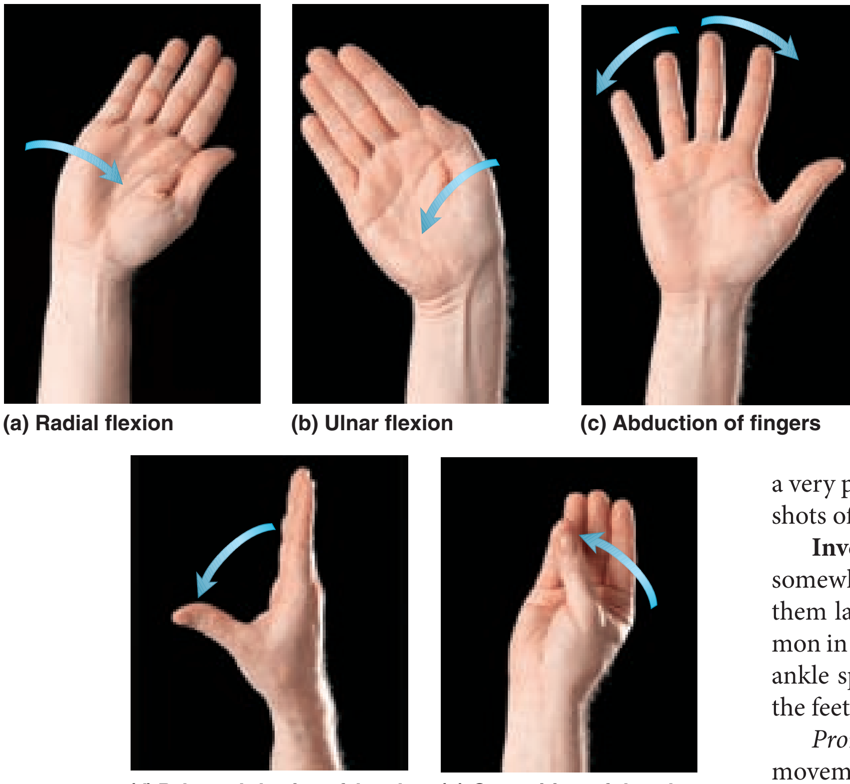


Figure 9.16 Movements of the Hand and Fingers. (a) Radial flexion of the wrist. (b) Ulnar flexion of the wrist. (c) Abduction of the fingers. The thumb position in this figure is called *radial abduction.* Parts (a) and (b) show adduction of the fingers. (d) Palmar abduction of the thumb. (e) Opposition of the thumb (reposition is shown in parts [a] and [b]).

The thumb is different, however, because in embryonic development it rotates nearly 90° from the rest of the hand. If you hold your hand in a completely relaxed position, you will probably see that the plane that contains your thumb and index finger is about 90° to the plane that contains the index through little fingers. Much of the terminology of thumb movement therefore differs from that of the other four fingers. *Flexion* of the thumb is bending the joints so the tip of the thumb is directed toward the palm, and *extension* is straightening it. If you place the palm of your hand on a table top with all five fingers parallel and touching, the thumb is extended. Keeping your hand there, if you move your thumb away from the index finger so they form a 90° angle (but both are on the plane of the table), the thumb movement is called **radial abduction.** Another movement, **palmar abduction,** moves the thumb away from the plane of the hand so it points anteriorly, as you would do if you were about to wrap your hand around a tool handle (fig. 9.16d). From either position—radial or palmar abduction—*adduction* of the thumb means to bring it back to touch the base of the index finger.

Two additional terms are unique to the thumb: **Opposition**[22] means to move the thumb to touch the tip of any of the other four fingers (fig. 9.16e). **Reposition**[23] is the return to zero position.

Special Movements of the Foot

A few additional movement terms are unique to the foot (fig. 9.17). **Dorsiflexion** (DOR-sih-FLEC-shun) is a movement in which the toes are elevated, as one might do in applying toenail polish. In each step you take, the foot dorsiflexes as it comes forward. This prevents you from scraping your toes on the ground and results in the characteristic *heel strike* of human locomotion when the foot touches down in front of you. **Plantar flexion** is movement of the foot so the toes point downward, as in pressing the gas pedal of a car or standing on tiptoes. This motion also produces the *toe-off* in each step you take, as the heel of the foot behind you lifts off the ground. Plantar flexion can be a very powerful motion, epitomized by high jumpers and the jump shots of basketball players.

Inversion[24] is a foot movement that tips the soles medially, somewhat facing each other, and **eversion**[25] is a movement that tips them laterally, away from each other. These movements are common in fast sports such as tennis and football, and sometimes cause ankle sprains. These terms also refer to congenital deformities of the feet, which are often corrected by orthopedic shoes or braces.

Pronation and *supination,* while used mainly for forearm movements, also apply to the feet but refer here to a more complex combination of movements. Pronation of the foot is a combination of dorsiflexion, eversion, and abduction—that is, the toes are elevated and turned away from the other foot and the sole is tilted away. Supination of the foot is a combination of plantar flexion, inversion, and adduction—the toes are lowered and turned toward the other foot and the sole is tilted toward it. These may seem a little difficult to visualize and perform, but they are ordinary motions in walking, running, ballet, and crossing uneven surfaces such as stepping stones.

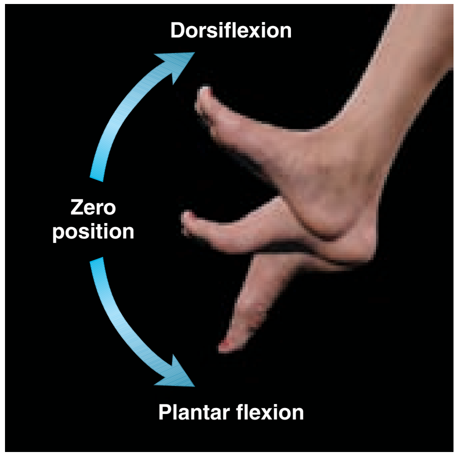
You can perhaps understand why these terms apply to the feet if you place the palms of your hands on a table and pretend they are your soles. Tilt your hands so the inner edge (thumb side) of each is raised from the table. This is like raising the medial edge of your foot from the ground, and as you can see, it involves a slight supination of your forearms. Resting your hands palms down on a table, your forearms are already pronated; but if you raise the outer edges of your hands (the little finger side), like pronating the feet, you will see that it involves a continuation of the pronation movement of the forearm.

Range of Motion

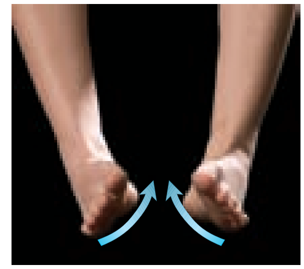
A joint's **range of motion (ROM)** is the number of degrees through which one bone can move relative to another at that joint. For example, the ankle has an ROM of about 74°, the first knuckle about 90°, and the knee about 130° to 140°. Range of motion obviously affects a person's functional independence and quality of life. It is

[22]*op* = against + *posit* = to place
[23]*re* = back + *posit* = to place

[24]*in* = inward + *version* = turning
[25]*e* = outward + *version* = turning



(a) Flexion of ankle



(b) Inversion

(c) Eversion

Figure 9.17 **Movements of the Foot.**
• *Identify some common activities in which inversion and eversion of the foot would be important.*

also an important consideration in training for athletics or dance, in clinical diagnosis, and in monitoring the progress of rehabilitation. Several factors affect the ROM and stability of a joint:

- **Structure of the articular surfaces of the bones.** In many cases, joint movement is limited by the shapes of the bone surfaces. For example, you cannot straighten your elbow beyond 180° or so because, as it straightens, the olecranon of the ulna swings into the olecranon fossa of the humerus and cannot move farther.
- **Strength and tautness of ligaments and joint capsules.** Some bone surfaces impose little if any limitation on joint movement. The articulations of the phalanges are an example; as one can see by examining a dry skeleton, an interphalangeal joint can bend through a broad arc. In life, however, these bones are joined by ligaments that limit their movement. As you flex one of your knuckles, ligaments on the anterior (palmar) side of the joint go slack, but ligaments on the posterior (dorsal) side tighten and prevent the joint from flexing beyond 90° or so. The knee is another case in point. In kicking a football, the knee rapidly extends to about 180°, but it can go no farther. Its motion is limited in part by a *cruciate ligament* and other knee ligaments described later. Gymnasts, dancers, and acrobats increase the ROM of their synovial joints by gradually stretching their ligaments during training. "Double-jointed" people have unusually large ROMs at some joints, not because the joint is actually double or fundamentally different from normal in its anatomy, but because the ligaments are unusually long or slack.
- **Action of the muscles and tendons.** Extension of the knee is also limited by the *hamstring muscles* on the posterior side of the thigh. In many other joints, too, pairs of muscles oppose each other and moderate the speed and range of joint motion. Even a resting muscle maintains a state of tension called *muscle tone,* which serves in many cases to stabilize a joint. One of the major factors preventing dislocation of the shoulder joint, for example, is tension in the *biceps brachii* muscle, whose tendons cross the joint, insert on the scapula, and hold the head of the humerus against the glenoid cavity. The nervous system continually monitors and adjusts joint angles and muscle tone to maintain joint stability and limit unwanted movements.

Before You Go On

Answer the following questions to test your understanding of the preceding section:

7. What are the two components of a joint capsule? What is the function of each?
8. Give at least one example each of a monaxial, biaxial, and multiaxial joint, and explain the reason for its classification.
9. Name the joints that would be involved if you reached directly overhead and screwed a lightbulb into a ceiling fixture. Describe the joint actions that would occur.

9.3 Anatomy of Selected Synovial Joints

Expected Learning Outcomes

When you have completed this section, you should be able to

- identify the major anatomical features of the jaw, shoulder, elbow, hip, knee, and ankle joints; and
- explain how the anatomical differences between these joints are related to differences in function.

We now examine the gross anatomy of certain diarthroses. It is beyond the scope of this book to discuss all of them, but the ones selected here most often require medical attention and many of them have a strong bearing on athletic performance and everyday function.

The Jaw Joint

The **temporomandibular joint (TMJ)** is the articulation of the condyle of the mandible with the mandibular fossa of the temporal bone (fig. 9.18). You can feel its action by pressing your fingertips against the jaw immediately anterior to the ear while opening and closing your mouth. This joint combines elements of condylar, hinge, and plane joints. It functions in a hingelike fashion when the mandible is elevated and depressed, it glides slightly forward when the jaw is protracted to take a bite, and it glides from side to side to grind food between the molars.

The synovial cavity of the TMJ is divided into superior and inferior chambers by an articular disc, which permits lateral and medial excursion of the mandible. Two ligaments support the joint. The **lateral ligament** prevents posterior displacement of the mandible. If the jaw receives a hard blow, this ligament normally prevents the condylar process from being driven upward and fracturing the base of the skull. The **sphenomandibular ligament** on the medial side of the joint extends from the sphenoid bone to the ramus of the mandible. A *stylomandibular ligament* extends from the styloid process to the angle of the mandible but is not part of the TMJ proper.

A deep yawn or other strenuous depression of the mandible can dislocate the TMJ by making the condyle pop out of the fossa and slip forward. The joint can be relocated by pressing down on the molars while pushing the jaw backward.

DEEPER INSIGHT 9.2

TMJ Syndrome

Temporomandibular joint (TMJ) syndrome has received medical recognition only recently, although it may affect as many as 75 million Americans. It can cause moderate intermittent facial pain, clicking sounds in the jaw, limitation of jaw movement, and in some people, more serious symptoms—severe headaches, vertigo (dizziness), tinnitus (ringing in the ears), and pain radiating from the jaw down the neck, shoulders, and back. It seems to be caused by a combination of psychological tension and malocclusion (misalignment of the teeth). Treatment may involve psychological management, physical therapy, analgesic and anti-inflammatory drugs, and sometimes corrective dental appliances to align the teeth properly.

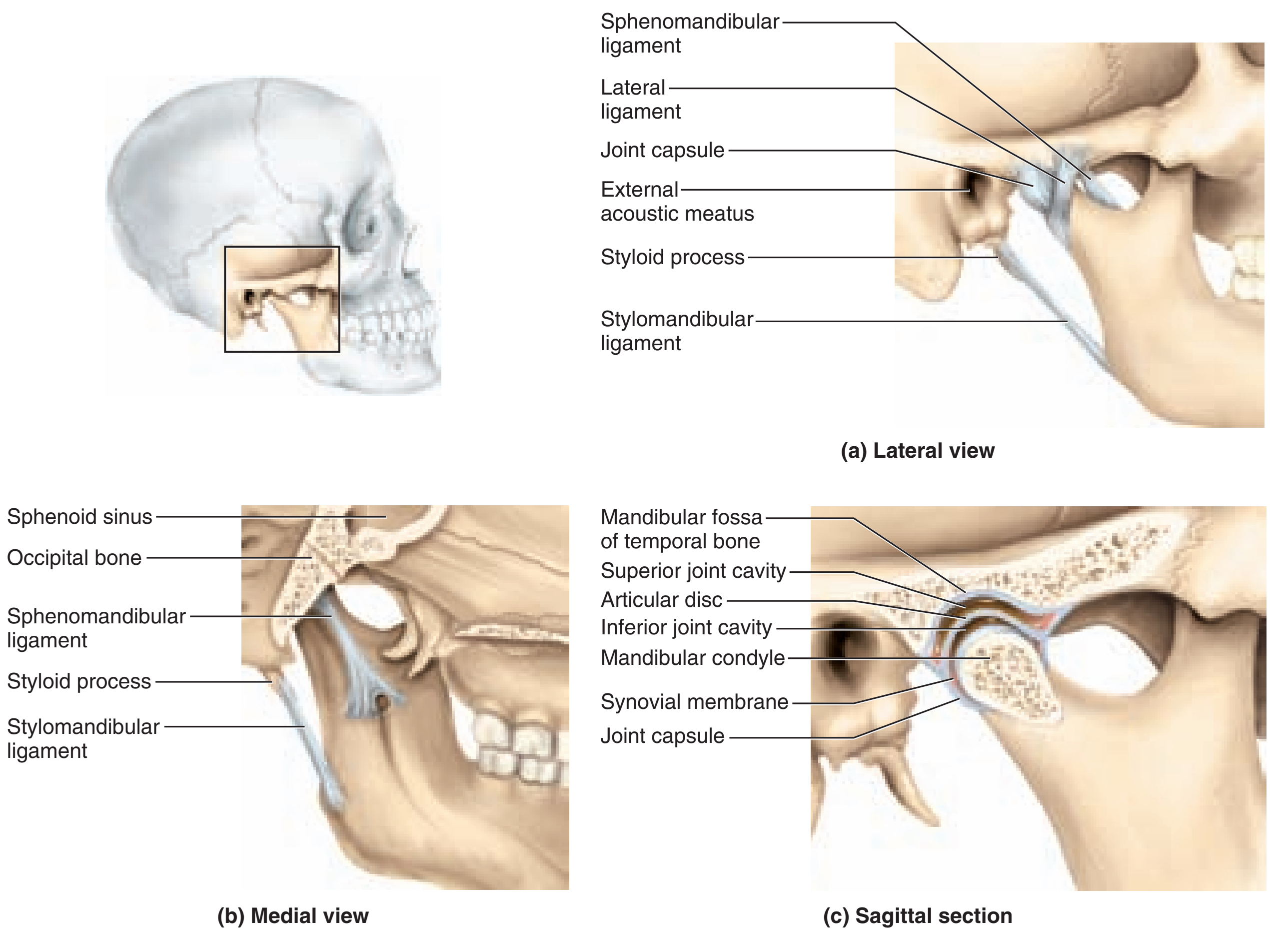


Figure 9.18 **The Jaw (Temporomandibular) Joint.**

The Shoulder Joint

The **glenohumeral (humeroscapular) joint,** or shoulder joint, is where the hemispherical head of the humerus articulates with the glenoid cavity of the scapula (fig. 9.19). Together, the shoulder and elbow joints serve to position the hand for the performance of a task; without a hand, shoulder and elbow movements are far less useful. The relatively loose shoulder joint capsule and shallow glenoid cavity sacrifice joint stability for freedom of movement. The cavity, however, has a ring of fibrocartilage called the **glenoid labrum**[26] around its margin, making it somewhat deeper than it looks on a dried skeleton.

Five principal ligaments support this joint. The **coracohumeral ligament** extends from the coracoid process of the scapula to the greater tubercle of the humerus, and the **transverse humeral ligament** extends from the greater to the lesser tubercle of the humerus,

[26] *labrum* = lip

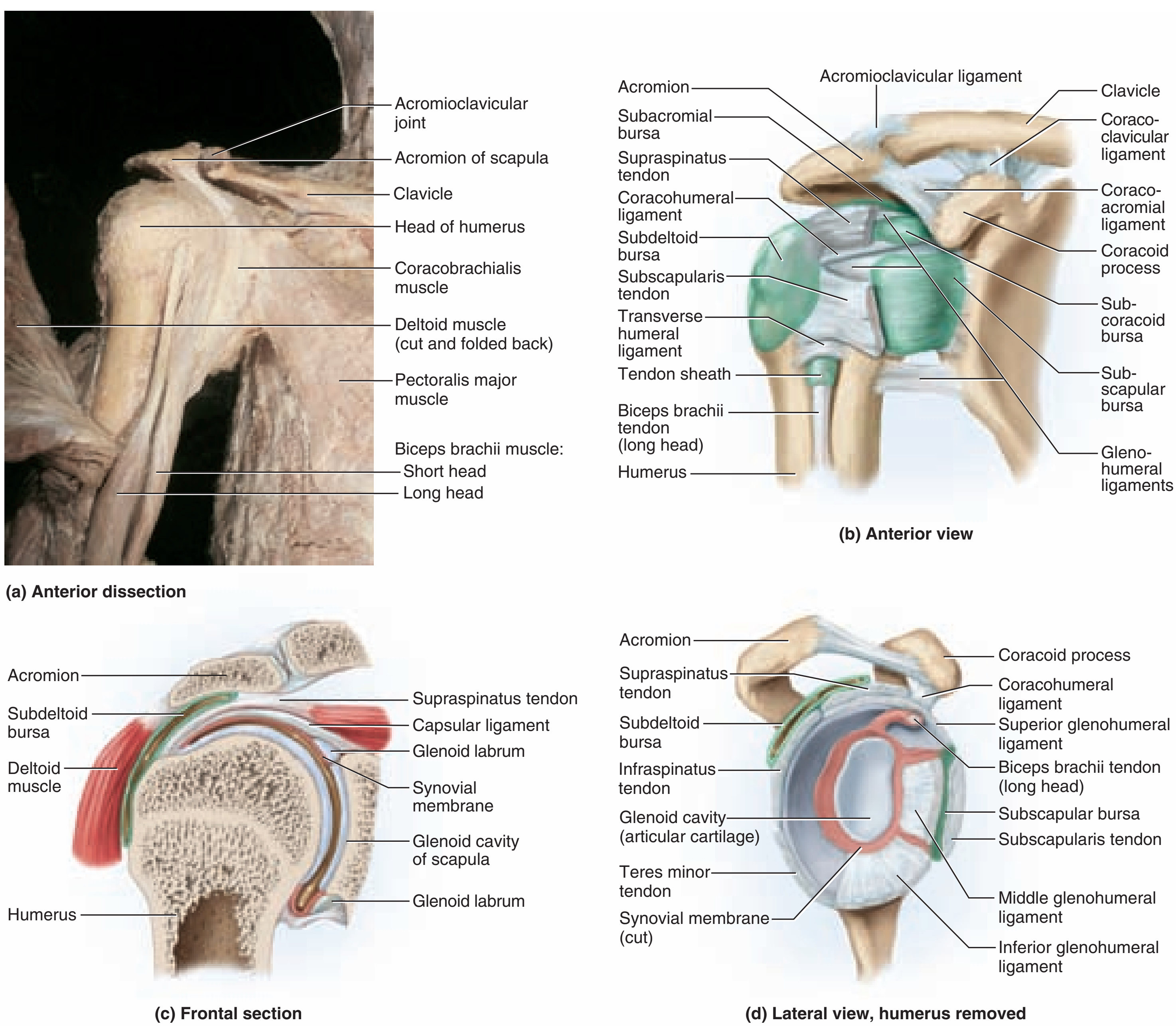


Figure 9.19 **The Shoulder (Glenohumeral) Joint.**
• *The socket of the shoulder joint is a little deeper in life than it appears on a dried skeleton. What structure makes it so?*

creating a tunnel, the intertubercular sulcus, through which a tendon of the biceps brachii passes. The other three ligaments, called **glenohumeral ligaments,** are relatively weak and sometimes absent.

A tendon of the biceps brachii muscle is the most important stabilizer of the shoulder. It originates on the margin of the glenoid cavity, passes through the joint capsule, and emerges into the intertubercular sulcus, where it is held by the transverse humeral ligament. Inferior to the sulcus, it merges into the biceps brachii. Thus, the tendon functions as a taut, adjustable strap that holds the humerus against the glenoid cavity.

In addition to the biceps brachii, four muscles important in stabilizing the glenohumeral joint are the *subscapularis, supraspinatus, infraspinatus,* and *teres minor.* The tendons of these four muscles form the *rotator cuff,* which is fused to the joint capsule on all sides except inferiorly. The rotator cuff is discussed more fully on page 300.

Four bursae are associated with the shoulder joint. Their names describe their locations—the **subdeltoid, subacromial, subcoracoid,** and **subscapular bursae.**

Shoulder dislocations are very painful and sometimes result in permanent damage. The most common dislocation is downward displacement of the humerus, because (1) the rotator cuff protects the joint in all directions except inferiorly, and (2) the joint is protected from above by the coracoid process, acromion, and clavicle. Dislocations most often occur when the arm is abducted and then receives a blow from above—for example, when the outstretched arm is struck by heavy objects falling off a shelf. They also occur in children who are jerked off the ground by one arm or forced to follow by a hard tug on the arm. Children are especially prone to such injury not only because of the inherent stress caused by such abuse, but also because a child's shoulder is

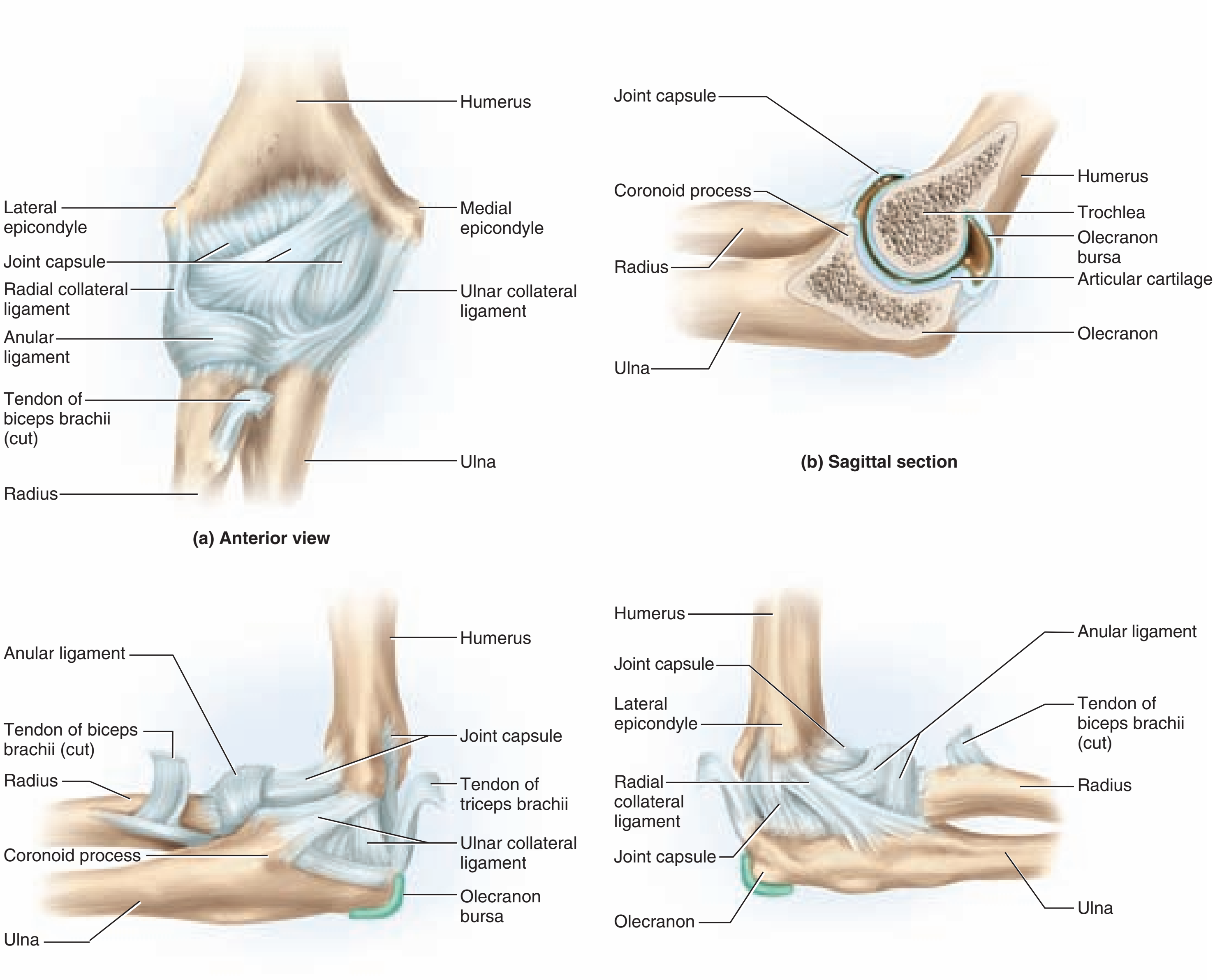


Figure 9.20 The Elbow Joint. This region includes two joints that form the elbow hinge—the humeroulnar and humeroradial—and one joint, the radioulnar, not involved in the hinge but involved in forearm rotation.

not fully ossified and the rotator cuff is not strong enough to withstand such stress. Because this joint is so easily dislocated, you should never attempt to move an immobilized person by pulling on his or her arm.

The Elbow Joint

The elbow is a hinge joint composed of two articulations—the **humeroulnar joint,** where the trochlea of the humerus joins the trochlear notch of the ulna, and the **humeroradial joint,** where the capitulum of the humerus meets the head of the radius (fig. 9.20). Both are enclosed in a single joint capsule. On the posterior side of the elbow, there is a prominent **olecranon bursa** to ease the movement of tendons over the elbow. Side-to-side motions of the elbow joint are restricted by a pair of ligaments, the **radial (lateral) collateral ligament** and **ulnar (medial) collateral ligament.**

Another joint occurs in the elbow region, the **proximal radioulnar joint,** but it is not involved in the hinge. At this joint, the disclike head of the radius fits into the radial notch of the ulna and is held in place by the **anular ligament**, which encircles the head of the radius and attaches at each end to the ulna.

The Hip Joint

The **coxal (hip) joint** is the point where the head of the femur inserts into the acetabulum of the hip bone (fig. 9.22). Because the coxal joints bear much of the body's weight, they have deep sockets and are much more stable than the shoulder joints. The depth of the socket is somewhat greater than you see on dried bones because a horseshoe-shaped ring of fibrocartilage, the **acetabular labrum,** is attached to its rim. A **transverse acetabular ligament** bridges a gap in the inferior margin of the acetabular labrum. Dislocations of the hip are rare, but some infants suffer congenital dislocations because the acetabulum is

DEEPER INSIGHT 9.3

Pulled Elbow

The immature skeletons of children and adolescents are especially vulnerable to injury. Pulled elbow (dislocation of the radius) is a common injury in preschool children (especially girls). It typically results from an adult lifting or jerking a child up by one arm when the arm is pronated, as in lifting a child into a high chair or shopping cart (fig. 9.21). This tears the anular ligament from the head of the radius, and the radius pulls partially or entirely out of the ligament. The proximal part of the torn ligament is then painfully pinched between the radial head and the capitulum of the humerus. Radial dislocation is treated by supinating the forearm with the elbow flexed and then putting the arm in a sling for about 2 weeks—time enough for the anular ligament to heal.

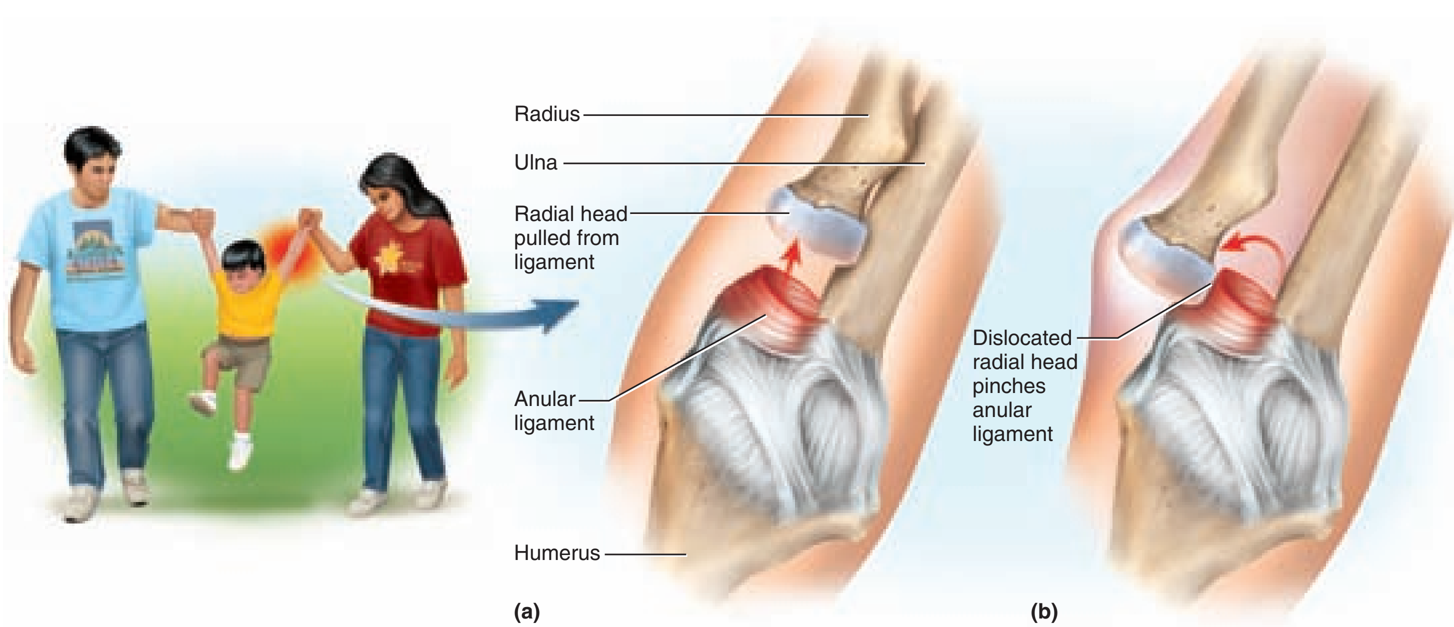


Figure 9.21 Pulled Elbow. Lifting a child by the arm can dislocate the radius. (a) The anular ligament tears, and the radial head is pulled from the ligament. (b) Muscle contraction pulls the radius upward. The head of the radius produces a lump on the lateral side of the elbow and may painfully pinch the anular ligament.

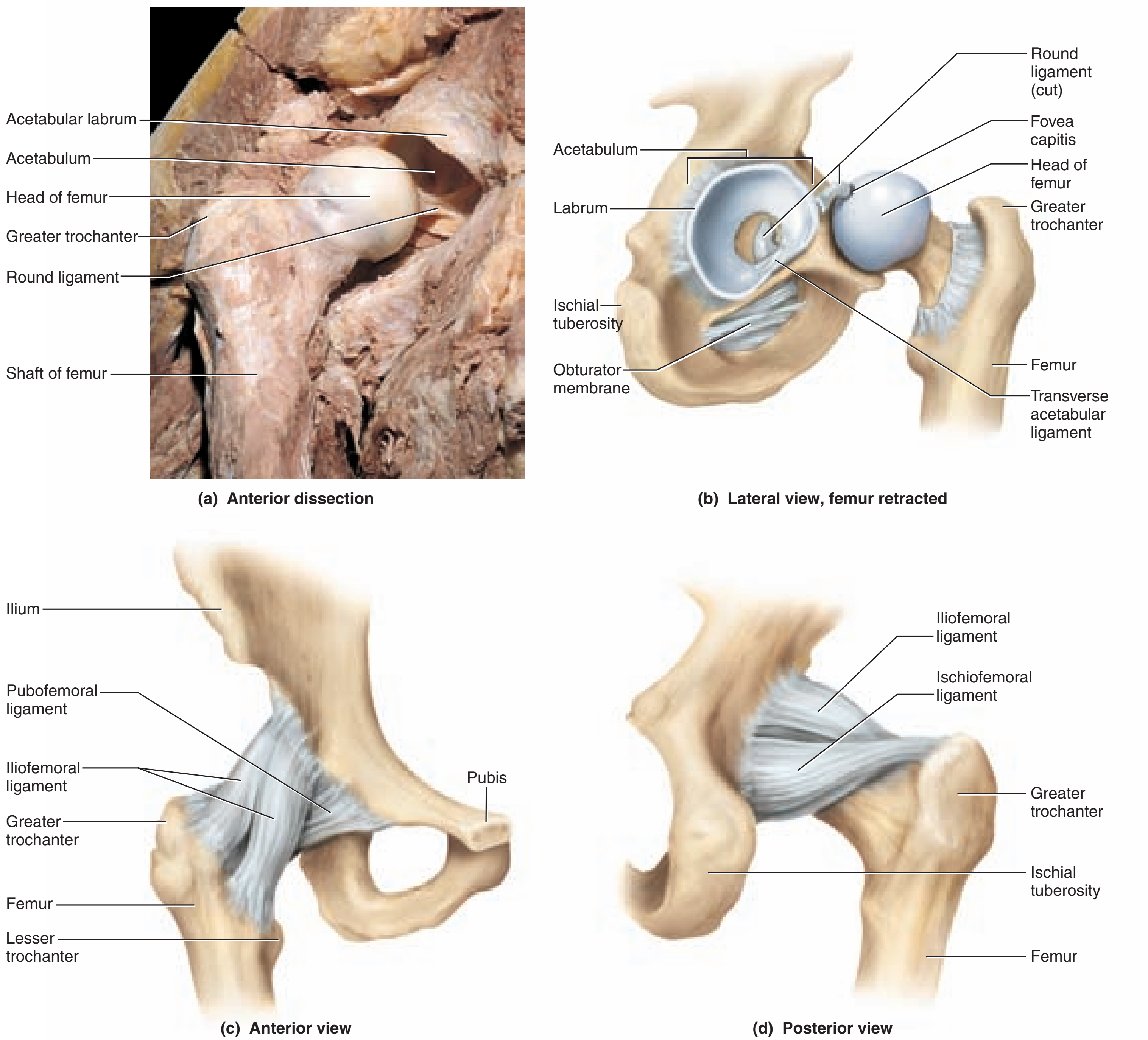


Figure 9.22 **The Hip (Coxal) Joint.**

not deep enough to hold the head of the femur in place. This condition can be treated by placing the infant in traction until the acetabulum develops enough strength to support the body's weight.

Apply What You Know

Where else in the body is there a structure similar to the acetabular labrum? What do those two locations have in common?

Ligaments that support the coxal joint include the **iliofemoral** (ILL-ee-oh-FEM-oh-rul) and **pubofemoral** (PYU-bo-FEM-or-ul) **ligaments** on the anterior side and the **ischiofemoral** (ISS-kee-oh-FEM-or-ul) **ligament** on the posterior side. The name of each ligament refers to the bones to which it attaches—the femur and the ilium, pubis, or ischium. When you stand up, these ligaments become twisted and pull the head of the femur tightly into the acetabulum. The head of the femur has a conspicuous pit called the *fovea capitis.* The **round ligament,** or **ligamentum**

teres[27] (TERR-eez), arises here and attaches to the lower margin of the acetabulum. This is a relatively slack ligament, so it is doubtful that it plays a significant role in holding the femur in its socket. It does, however, contain an artery that supplies blood to the head of the femur.

[27]*teres* = round

The Knee Joint

The **tibiofemoral** (knee) **joint** is the largest and most complex diarthrosis of the body (figs. 9.23 and 9.24). It is primarily a hinge joint, but when the knee is flexed it is also capable of slight rotation and lateral gliding. The patella and its ligament also form a plane **patellofemoral joint** with the femur.

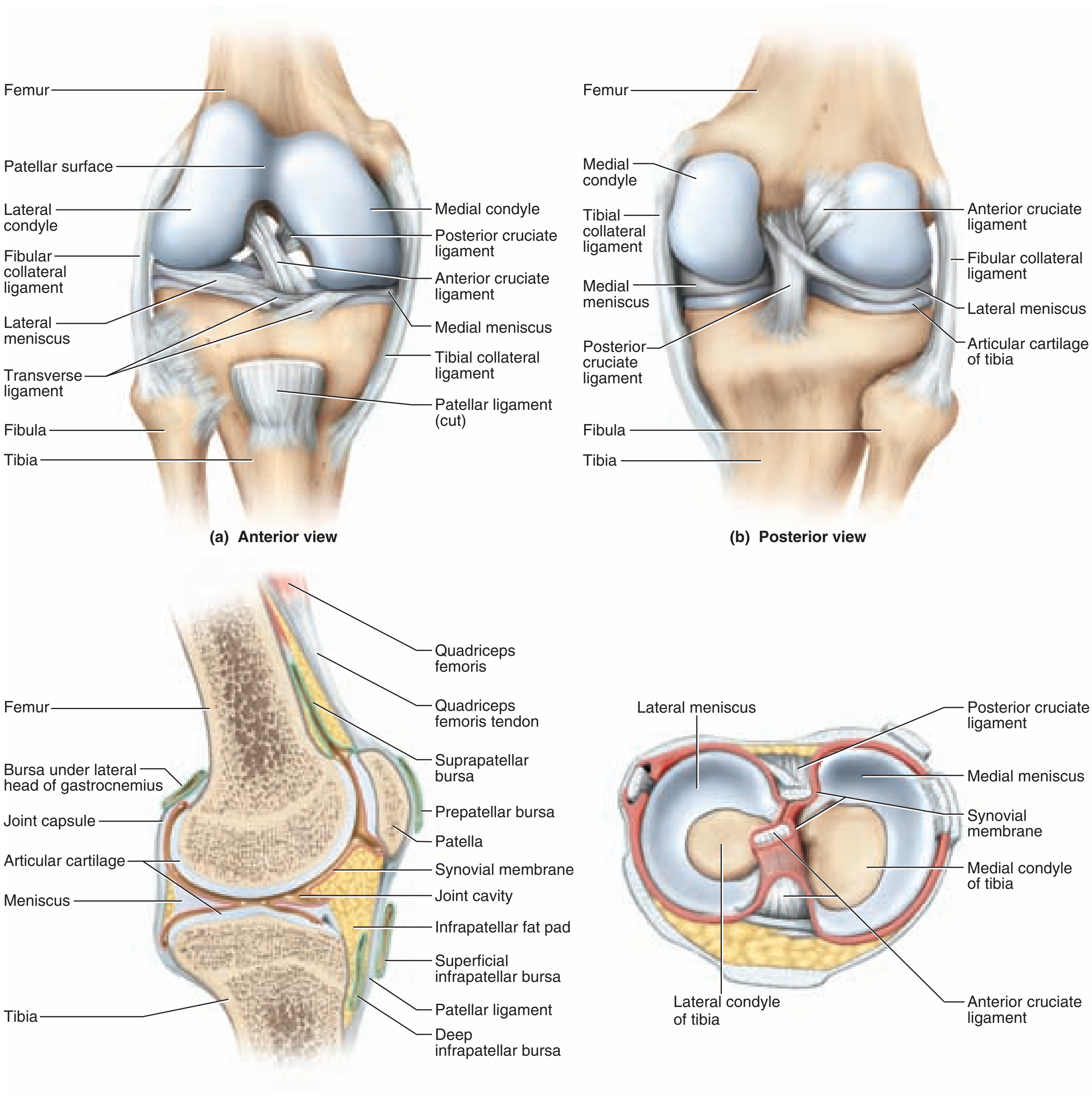


Figure 9.23 The Knee (Tibiofemoral) Joint.

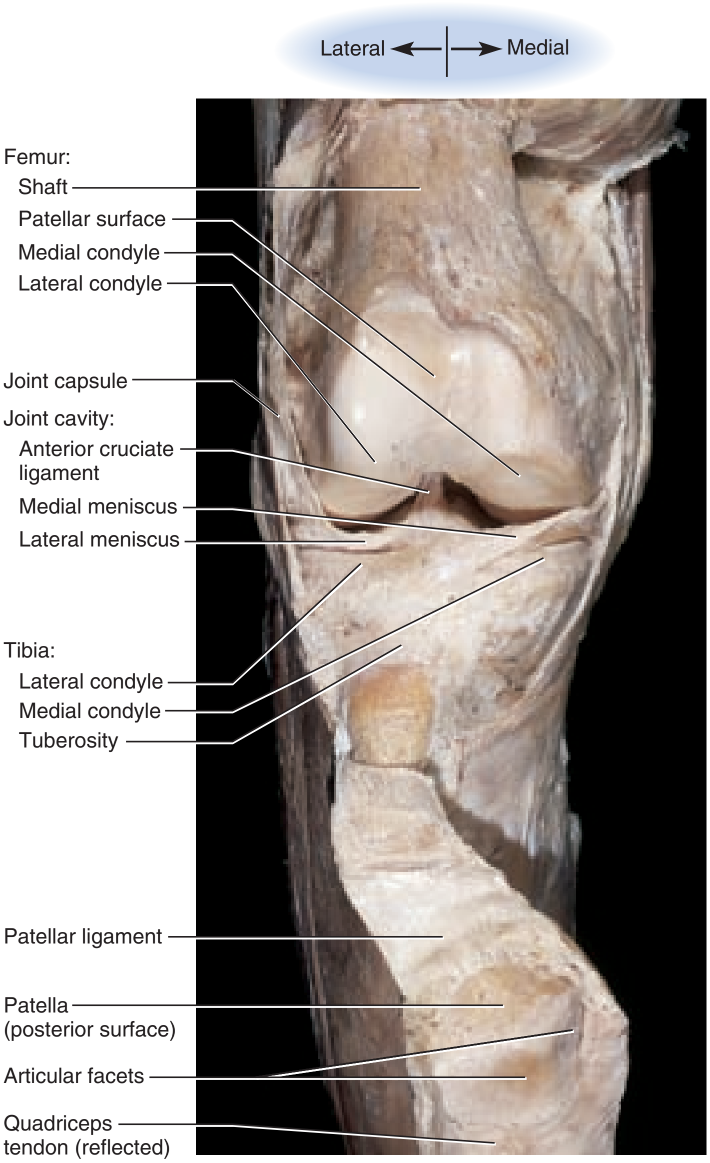


Figure 9.24 The Right Knee, Anterior Dissection. The quadriceps tendon has been cut and folded (reflected) downward to expose the joint cavity and the posterior surface of the patella.

The joint capsule encloses only the lateral and posterior sides the patellar ligament and the *lateral* and *medial patellar retinacula* (not illustrated). These are extensions of the tendon of the *quadriceps femoris* muscle, the large anterior muscle of the thigh. The knee is stabilized mainly by the quadriceps tendon in front and the tendon of the *semimembranosus* muscle on the rear of the thigh. Developing strength in these muscles therefore reduces the risk of knee injury.

The joint cavity contains two C-shaped cartilages called the **lateral** and **medial menisci** (singular, **meniscus**) joined by a **transverse ligament.** They absorb the shock of the body weight jostling up and down on the knee and prevent the femur from rocking from side to side on the tibia. The posterior side of the knee, the **popliteal** (pop-LIT-ee-ul) **region,** is supported by a complex array of **intracapsular ligaments** within the joint capsule and **extracapsular ligaments** external to it. The extracapsular ligaments are the **oblique popliteal ligament** (an extension of the tendon of the *semimembranosus* hamstring muscle), **arcuate** (AR-cue-et) **popliteal ligament, fibular (lateral) collateral ligament,** and **tibial (medial) collateral ligament.** Only the two collateral ligaments are illustrated; they prevent the knee from rotating when the joint is extended.

There are two intracapsular ligaments deep within the joint cavity. The synovial membrane folds around them, however, so that they are excluded from the fluid-filled synovial cavity. These ligaments cross each other in the form of an X; hence, they are called the **anterior cruciate**[28] (CROO-she-ate) **ligament (ACL)** and **posterior cruciate ligament (PCL).** These are named according to whether they attach to the anterior or posterior side of the tibia, not for their attachments to the femur. When the knee is extended, the ACL is pulled tight and prevents hyperextension. The PCL prevents the femur from sliding off the front of the tibia and prevents the tibia from being displaced backward. The ACL is one of the most common sites of knee injury (see Deeper Insight 9.4).

An important aspect of human bipedalism is the ability to lock the knees and stand erect without tiring the extensor muscles of the thigh. When the knee is extended to the fullest degree allowed by the ACL, the femur rotates medially on the tibia. This action locks the knee, and in this state, all the major knee ligaments are twisted and taut. To unlock the knee, the *popliteus* muscle rotates the femur laterally, causing the ligaments to untwist.

The knee joint has at least 13 bursae. Four of these are anterior—the **superficial infrapatellar, suprapatellar, prepatellar,** and **deep infrapatellar.** Located in the popliteal region are the **popliteal bursa** and **semimembranosus bursa** (not illustrated). At least seven more bursae are found on the lateral and medial sides of the knee joint. From figure 9.23a, your knowledge of the relevant word elements *(infra-, supra-, pre-),* and the terms *superficial* and *deep,* you should be able to work out the reasoning behind most of these names and develop a system for remembering the locations of these bursae.

The Ankle Joint

The **talocrural**[29] **(ankle) joint** includes two articulations—a medial joint between the tibia and talus and a lateral joint between the fibula and talus, both enclosed in one joint capsule (fig. 9.26). The malleoli of the tibia and fibula overhang the talus on each side like a cap and prevent most side-to-side motion. The ankle therefore has a more restricted range of motion than the wrist.

The ligaments of the ankle include (1) **anterior** and **posterior tibiofibular ligaments,** which bind the tibia to the fibula; (2) a multipart **medial (deltoid) ligament,** which binds the tibia to the foot on the medial side; and (3) a multipart **lateral collateral ligament,** which binds the fibula to the foot on the lateral side. The **calcaneal (Achilles) tendon** extends from the calf muscles to the

[28]*cruci* = cross + *ate* = characterized by
[29]*talo* = ankle + *crural* = pertaining to the leg

DEEPER INSIGHT 9.4

Knee Injuries and Arthroscopic Surgery

Although the knee can bear a lot of weight, it is highly vulnerable to rotational and horizontal stress, especially when the knee is flexed (as in skiing or running) and receives a blow from behind or from the side (fig. 9.25). The most common injuries are to a meniscus or the anterior cruciate ligament (ACL). Knee injuries heal slowly because ligaments and tendons have a scanty blood supply and cartilage usually has no blood vessels at all.

The diagnosis and surgical treatment of knee injuries have been greatly improved by *arthroscopy,* a procedure in which the interior of a joint is viewed with a pencil-thin instrument, the *arthroscope,* inserted through a small incision. The arthroscope has a light, a lens, and fiber optics that allow a viewer to see into the cavity and take photographs or video recordings. A surgeon can also withdraw samples of synovial fluid by arthroscopy or inject saline into the joint cavity to expand it and provide a clearer view. If surgery is required, additional small incisions can be made for the surgical instruments and the procedures can be observed through the arthroscope or on a monitor. Arthroscopic surgery produces much less tissue damage than conventional surgery and enables patients to recover more quickly.

Orthopedic surgeons often replace a damaged ACL with a graft from the patellar ligament or a hamstring tendon. The surgeon "harvests" a strip from the middle of the patient's ligament or tendon, drills a hole into the femur and tibia within the joint cavity, threads the ligament through the holes, and fastens it with biodegradable screws. The grafted ligament is more taut and "competent" than the damaged ACL. It becomes ingrown with blood vessels and serves as a substrate for the deposition of more collagen, which further strengthens it in time. Following arthroscopic ACL reconstruction, a patient typically must use crutches for 7 to 10 days and undergo supervised physical therapy for 6 to 10 weeks, followed by self-directed exercise therapy. Healing is completed in about 9 months.

Figure 9.25 **Knee Injuries.**

calcaneus. It plantarflexes the foot and limits dorsiflexion. Plantar flexion is limited by extensor tendons on the anterior side of the ankle and by the anterior part of the joint capsule.

Sprains (torn ligaments and tendons) are common at the ankle, especially when the foot is suddenly inverted or everted to excess. They are painful and usually accompanied by immediate swelling. They are best treated by immobilizing the joint and reducing swelling with an ice pack, but in extreme cases may require a cast or surgery.

The synovial joints described in this section are summarized in table 9.2.

Before You Go On

Answer the following questions to test your understanding of the preceding section:

10. What keeps the mandibular condyle from slipping out of its fossa in a posterior direction?
11. List at least three ways that the shoulder joint is stabilized.
12. What keeps the femur from slipping backward off the tibia?
13. What keeps the tibia from slipping sideways off the talus?

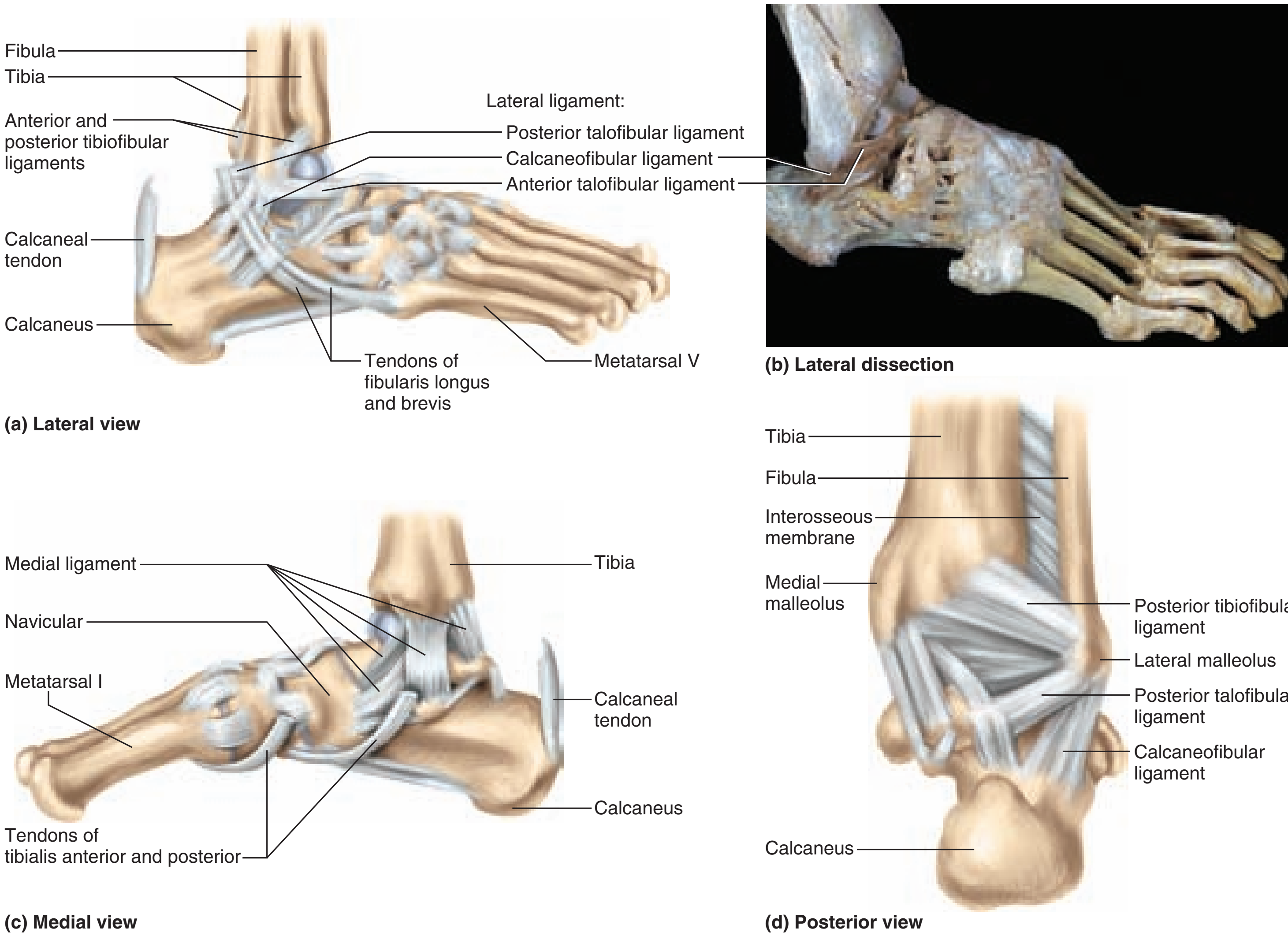


Figure 9.26 The Ankle (Talocrural) Joint and Ligaments of the Right Foot.

9.4 Clinical Perspectives

Expected Learning Outcomes

When you have completed this section, you should be able to

- define *rheumatism* and describe the profession of rheumatology;
- define *arthritis* and describe its forms and causes;
- discuss the design and application of artificial joints; and
- identify several joint diseases other than arthritis.

Our quality of life depends greatly on mobility, and mobility depends on proper functioning of the diarthroses. Not surprisingly, therefore, joint dysfunctions are among the most common medical complaints. **Rheumatism** is a broad term for any pain in the supportive and locomotor organs of the body, including bones, ligaments, tendons, and muscles. Physicians who deal with the study, diagnosis, and treatment of joint disorders are called **rheumatologists.**

Arthritis

The most widespread crippling disorder in the United States is **arthritis,**[30] a broad term that embraces more than a hundred diseases of largely obscure or unknown causes. In general, arthritis means inflammation of a joint. Nearly everyone develops arthritis to some degree after middle age and sometimes earlier.

The most common form of arthritis is **osteoarthritis (OA),** also called "wear-and-tear arthritis" because it is apparently a normal consequence of years of wear on the joints. As joints age, the articular cartilage softens and degenerates. As the cartilage be-

[30]*arthr* = joint + *itis* = inflammation

TABLE 9.2 Review of the Principal Diarthroses

Joint	Major Anatomical Features and Actions
Jaw joint (fig. 9.18)	*Type:* condylar, hinge, and plane *Movements:* elevation, depression, protraction, retraction, lateral and medial excursion *Articulation:* condyle of mandible, mandibular fossa of temporal bone *Ligaments:* lateral, sphenomandibular *Cartilage:* articular disc
Shoulder joint (fig. 9.19)	*Type:* ball-and-socket *Movements:* adduction, abduction, flexion, extension, circumduction, medial and lateral rotation *Articulation:* head of humerus, glenoid fossa of scapula *Ligaments:* coracohumeral, transverse humeral, three glenohumerals *Tendons:* rotator cuff (tendons of subscapularis, supraspinatus, infraspinatus, teres minor), tendon of biceps brachii *Bursae:* subdeltoid, subacromial, subcoracoid, subscapular *Cartilage:* glenoid labrum
Elbow joint (fig. 9.20)	*Type:* hinge and pivot *Movements:* flexion, extension, pronation, supination, rotation *Articulation:* humeroulnar—trochlea of humerus, trochlear notch of ulna; humeroradial—capitulum of humerus, head of radius; radioulnar—head of radius, radial notch of ulna *Ligaments:* radial collateral, ulnar collateral, anular *Bursa:* olecranon
Hip joint (fig. 9.22)	*Type:* ball-and-socket *Movements:* adduction, abduction, flexion, extension, circumduction, medial and lateral rotation *Articulation:* head of femur, acetabulum of hip bone *Ligaments:* iliofemoral, pubofemoral, ischiofemoral, ligamentum teres, transverse acetabular *Cartilage:* acetabular labrum
Knee joint (fig. 9.23)	*Type:* primarily hinge *Movements:* flexion, extension, slight rotation *Articulation:* tibiofemoral, patellofemoral *Ligaments:* anterior—lateral patellar retinaculum, medial patellar retinaculum; popliteal intracapsular—anterior cruciate, posterior cruciate; popliteal extracapsular—oblique popliteal, arcuate popliteal, lateral collateral, medial collateral *Bursae:* anterior—superficial infrapatellar, suprapatellar, prepatellar, deep infrapatellar; popliteal—popliteal, semimembranosus; medial and lateral—seven other bursae not named in this chapter *Cartilages:* lateral meniscus, medial meniscus (connected by transverse ligament)
Ankle joint (fig. 9.26)	*Type:* hinge *Movements:* dorsiflexion, plantar flexion, extension *Articulation:* tibia–talus, fibula–talus, tibia–fibula *Ligaments:* anterior and posterior tibiofibular, deltoid, lateral collateral *Tendon:* calcaneal (Achilles)

comes roughened by wear, joint movement may be accompanied by crunching or crackling sounds called *crepitus.* Osteoarthritis affects especially the fingers, intervertebral joints, hips, and knees. As the articular cartilage wears away, exposed bone tissue often develops spurs that grow into the joint cavity, restrict movement, and cause pain. Though OA rarely occurs before age 40, it affects about 85% of people older than 70. It usually does not cripple, but in severe cases it can immobilize the hip.

Rheumatoid arthritis (RA), which is far more severe, results from an autoimmune attack against the joint tissues. Like other autoimmune diseases, RA is caused by an *autoantibody*—a misguided antibody that attacks the body's own tissues instead of limiting its attack to foreign matter. In RA, an autoantibody called *rheumatoid factor* attacks the synovial membranes. Inflammatory cells accumulate in the synovial fluid and produce enzymes that degrade the articular cartilage. The synovial membrane thickens and adheres to the articular cartilage, fluid accumulates in the joint capsule, and the capsule is invaded by fibrous connective tissue. As articular cartilage degenerates, the joint begins to ossify, and sometimes the bones become solidly fused and immobilized, a condition called **ankylosis**[31] (fig. 9.27). RA tends to develop symmetrically—if the right wrist or hip develops RA, so does the left.

Rheumatoid arthritis tends to flare up and subside (go into remission) periodically.[32] It affects women far more than men and typically begins between the ages of 30 and 40. There is no cure, but

[31] *ankyl* = bent, crooked + *osis* = condition
[32] *rheumat* = tending to change

(a)

(b)

Figure 9.27 Rheumatoid Arthritis (RA). (a) A severe case with ankylosis of the joints. (b) Colorized X-ray of hands with RA.

joint damage can be slowed with hydrocortisone or other steroids. Because long-term use of steroids weakens the bone, however, aspirin is the treatment of first choice to control the inflammation. Physical therapy is also used to preserve the joint's range of motion and the patient's functional ability.

Several common pathologies of the joints are briefly described in table 9.3.

Joint Prostheses

Arthroplasty,[33] a treatment of last resort, is the replacement of a diseased joint with an artificial device called a **joint prosthesis.**[34] Joint prostheses were first developed to treat war injuries in World War II and the Korean War. Total hip replacement (THR), first performed in 1963 by English orthopedic surgeon Sir John Charnley, is now the most common orthopedic procedure for the elderly. The first knee replacements were performed in the 1970s. Joint prostheses are now available for finger, shoulder, elbow, hip, and knee joints. Arthroplasty is performed on over 250,000 patients per year in the United States, primarily to relieve pain and restore function in elderly people with OA or RA.

Arthroplasty presents ongoing challenges for biomedical engineering. An effective prosthesis must be strong, nontoxic, and corrosion-resistant. In addition, it must bond firmly to the patient's bones and enable a normal range of motion with a minimum of friction. The heads of long bones are usually replaced with prostheses made of a metal alloy such as cobalt-chrome, titanium alloy, or stainless steel. Joint sockets are made of polyethylene (fig. 9.28). Prostheses are bonded to the patient's bone with screws or bone cement.

---

[33]*arthro* = joint + *plasty* = surgical repair
[34]*prosthe* = something added

TABLE 9.3	Disorders of the Joints
Dislocation (luxation)	Displacement of a bone from its normal position at a joint, usually accompanied by a sprain of the adjoining connective tissues. Most common at the fingers, thumb, shoulder, and knee.
Gout	A hereditary disease, most common in men, in which uric acid crystals accumulate in the joints and irritate the articular cartilage and synovial membrane. Causes *gouty arthritis,* with swelling, pain, tissue degeneration, and sometimes fusion of the joint. Most commonly affects the great toe.
Strain	Painful overstretching of a tendon or muscle without serious tissue damage. Often results from inadequate warm-up before exercise.
Subluxation	Partial dislocation in which two bones maintain contact between their articular surfaces.
Synovitis	Inflammation of a joint capsule, often as a complication of a sprain.

Disorders Described Elsewhere

Ankle sprains 227	Dislocation of the shoulder 222	Rotator cuff injury 300
Bursitis 210	Knee injuries 227	Tendinitis 210
Congenital hip dislocation 223	Osteoarthritis 228	TMJ syndrome 220
Dislocation of the elbow 223	Rheumatoid arthritis 229	

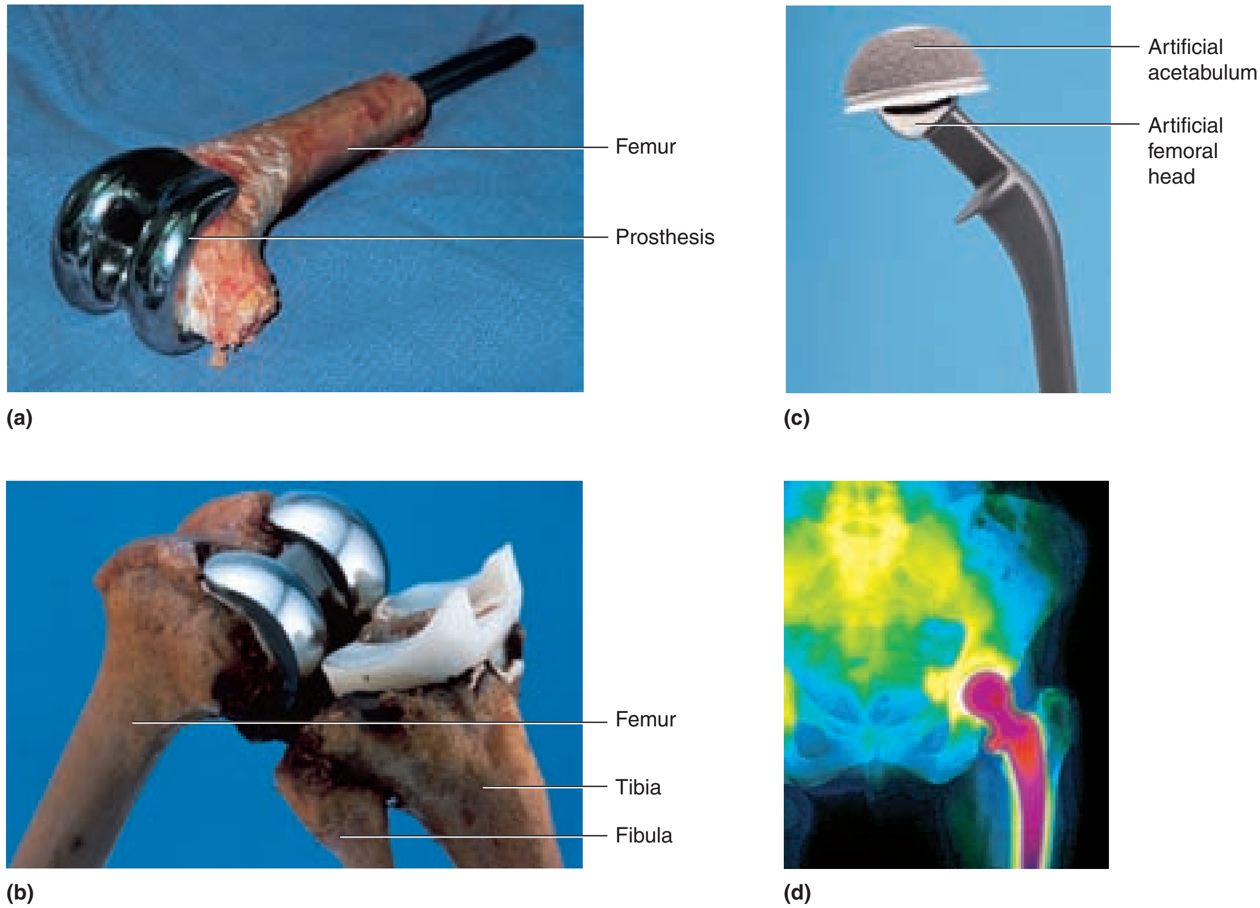


Figure 9.28 Joint Prostheses. (a) Artificial femoral condyles affixed to the distal end of the femur. (b) An artificial knee joint bonded to a natural femur and tibia. (c) A porous-coated hip prosthesis. The caplike portion replaces the acetabulum of the hip bone, and the ball and shaft below it are bonded to the proximal end of the femur. (d) X-ray of a patient with a total hip replacement.

Over 90% of artificial knees last 10 years, 85% for 15 years, and 75% for 20 years. The most common form of failure is detachment of the prosthesis from the bone. This problem has been reduced by using *porous-coated prostheses,* which become infiltrated by the patient's own bone and create a firmer bond. A prosthesis is not as strong as a natural joint, however, and is not an option for many young, active patients.

Before You Go On

Answer the following questions to test your understanding of the preceding section:

14. Define *arthritis.* How do the causes of osteoarthritis and rheumatoid arthritis differ? Which type is more common?
15. What are the major engineering problems in the design of joint prostheses? What is the most common cause of failure of a prosthesis?

Study Guide

Assess Your Learning Outcomes

You should have a good understanding of this chapter if you can accurately address the following issues.

9.1 Joints and Their Classification (p. 205)

1. The definition of *joint (articulation)*
2. Names of the sciences concerned with joint structure and movement
3. The general rule for how joints are commonly named
4. The criteria used to classify joints into anatomical and functional categories
5. The distinguishing characteristics of bony joints, fibrous joints, and cartilaginous joints; synonyms for these terms; and examples of joints in each category
6. The three subclasses of fibrous joints and three types of sutures, and examples of each
7. The two subclasses of cartilaginous joints, and examples of each

9.2 Synovial Joints (p. 209)

1. The definition of *synovial joint*
2. The anatomical features of a generalized synovial joint
3. The functions of articular discs and menisci at certain synovial joints, where they can be found, and their appearance
4. The defining characteristics of tendons, ligaments, and bursae, and the roles they play at the joints; how tendon sheaths differ from other bursae
5. The distinction between monaxial, biaxial, and multiaxial joints
6. The six types of synovial joints and where they can be found
7. The definitions of joint *flexion, extension,* and *hyperextension;* some everyday scenarios in which these movements occur; and the ability to demonstrate them with your own body
8. The same for *abduction, adduction, hyperabduction,* and *hyperadduction*
9. The same for *elevation* and *depression*
10. The same for *protraction* and *retraction*
11. The same for *circumduction*
12. The same for *medial (internal)* and *lateral (external) rotation*
13. The same for *supination* and *pronation* of the forearm
14. The same for *flexion, extension, hyperextension,* and *lateral flexion* of the vertebral column
15. The same for *rotation* of the head or torso
16. The same for *lateral* and *medial excursion* of the mandible
17. The same for wrist *flexion* and *extension* anteriorly and posteriorly, and *ulnar* and *radial flexion* from side to side
18. The same for the thumb movements of *radial abduction, palmar abduction, opposition,* and *reposition*
19. The same for the ankle or foot movements of *dorsiflexion, plantar flexion, inversion,* and *eversion,* and how several of these movements are combined in foot pronation and supination
20. How a joint's range of motion (ROM) is measured and what anatomical features govern the ROM

9.3 Anatomy of Selected Synovial Joints (p. 219)

1. Special functional qualities of the temporomandibular joint (TMJ); its major anatomical features; and two common disorders of the TMJ
2. Special functional qualities of the glenohumeral joint; its major anatomical features; and two of its common injuries
3. The names of the three joints that occur at the elbow; how they enable the varied movements of the forearm; and the major anatomical features of the elbow joints
4. Special functional qualities of the coxal joint; its major anatomical features; and the actions of the ligaments at this joint when a person stands
5. Special functional qualities of the tibiofemoral joint; its major anatomical features (especially its menisci and cruciate ligaments); and the common injuries of this joint
6. Special functional qualities of the talocrural joint; its major anatomical features; and the nature of sprains at this joint

9.4 Clinical Perspectives (p. 228)

1. The range of disorders included in the concept of rheumatism, and the related term for physicians who specialize in joint disorders
2. The general meaning of *arthritis,* and the pathology and distinctions between osteoarthritis and rheumatoid arthritis
3. Joint prostheses and arthroplasty

Testing Your Recall

1. Lateral and medial excursion are movements unique to
   a. the ankle.
   b. the thumb.
   c. the mandible.
   d. the knee.
   e. the clavicle.
2. Which of the following is the least movable?
   a. a diarthrosis
   b. a synostosis
   c. a symphysis
   d. a syndesmosis
   e. a condylar joint
3. Which of the following movements are unique to the foot?
   a. dorsiflexion and inversion
   b. elevation and depression
   c. circumduction and rotation
   d. abduction and adduction
   e. opposition and reposition

4. Which of the following joints cannot be circumducted?
   a. trapeziometacarpal
   b. metacarpophalangeal
   c. glenohumeral
   d. coxal
   e. interphalangeal
5. Which of the following terms denotes a general condition that includes the other four?
   a. gout
   b. arthritis
   c. rheumatism
   d. osteoarthritis
   e. rheumatoid arthritis
6. In the adult, the ischium and pubis are united by
   a. a synchondrosis.
   b. a diarthrosis.
   c. a synostosis.
   d. an amphiarthrosis.
   e. a symphysis.
7. Articular discs are found only in certain
   a. synostoses.
   b. symphyses.
   c. diarthroses.
   d. synchondroses.
   e. amphiarthroses.
8. Which of the following joints has anterior and posterior cruciate ligaments?
   a. the shoulder
   b. the elbow
   c. the hip
   d. the knee
   e. the ankle
9. To bend backward at the waist involves _____ of the vertebral column.
   a. rotation
   b. hyperextension
   c. dorsiflexion
   d. abduction
   e. flexion
10. If you sit on a sofa and then raise your left arm to rest it on the back of the sofa, your left shoulder joint undergoes primarily
    a. lateral excursion.
    b. abduction.
    c. elevation.
    d. adduction.
    e. extension.
11. The lubricant of a diarthrosis is _____.
12. A fluid-filled sac that eases the movement of a tendon over a bone is called a/an _____.
13. A _____ joint allows one bone to swivel on another.
14. _____ is the science of movement.
15. The joint between a tooth and the mandible is called a/an _____.
16. In a/an _____ suture, the articulating bones have interlocking wavy margins, somewhat like a dovetail joint in carpentry.
17. In kicking a football, what type of action does the knee joint exhibit?
18. The angle through which a joint can move is called its _____.
19. A person with a degenerative joint disorder would most likely be treated by a physician called a/an _____.
20. The femur is prevented from slipping sideways off the tibia in part by a pair of cartilages called the lateral and medial _____.

Answers in the Appendix

Building Your Medical Vocabulary

State a medical meaning of each of the following word elements, and give a term in which it is used.

1. arthro-
2. re-
3. sym-
4. amphi-
5. -physis
6. circum-
7. ab-
8. ad-
9. duc-
10. kinesio-

Answers in the Appendix

True or False

Determine which five of the following statements are false, and briefly explain why.

1. More people get rheumatoid arthritis than osteoarthritis.
2. A doctor who treats arthritis is called a kinesiologist.
3. Synovial joints are also known as synarthroses.
4. Most ligaments, but not all, connect one bone to another.
5. Reaching behind you to take something out of your hip pocket involves hyperextension of the elbow.
6. The anterior cruciate ligament normally prevents hyperextension of the knee.
7. There is no meniscus in the elbow joint.
8. The knuckles are diarthroses.
9. Synovial fluid is secreted by the bursae.
10. Most condylar joints can move in more planes than a hinge joint.

Answers in the Appendix

Testing Your Comprehension

1. Why are there menisci in the knee joint but not in the elbow, the corresponding joint of the upper limb? Why is there an articular disc in the temporomandibular joint?
2. What ligaments would most likely be torn if you slipped and your foot was suddenly forced into an excessively inverted position: (a) the posterior talofibular and calcaneofibular ligaments, or (b) the medial ligament? Explain. What would the resulting condition of the ankle be called?
3. In order of occurrence, list the joint actions (flexion, pronation, etc.) and the joints where they would occur as you (a) sit down at a table, (b) reach out and pick up an apple, (c) take a bite, and (d) chew it. Assume that you start in anatomical position.
4. What structure in the elbow joint serves the same purpose as the anterior cruciate ligament (ACL) of the knee?
5. List the six types of synovial joints and for each one, if possible, identify a joint in the upper limb and a joint in the lower limb that fall into each category. Which of these six joints have no examples in the lower limb?

Answers at www.mhhe.com/saladinha3

Improve Your Grade at www.mhhe.com/saladinha3

Practice quizzes, labeling activities, games, and flashcards provide fun ways to master concepts. You can also download image PowerPoint files for each chapter to create a study guide or for taking notes during lecture.