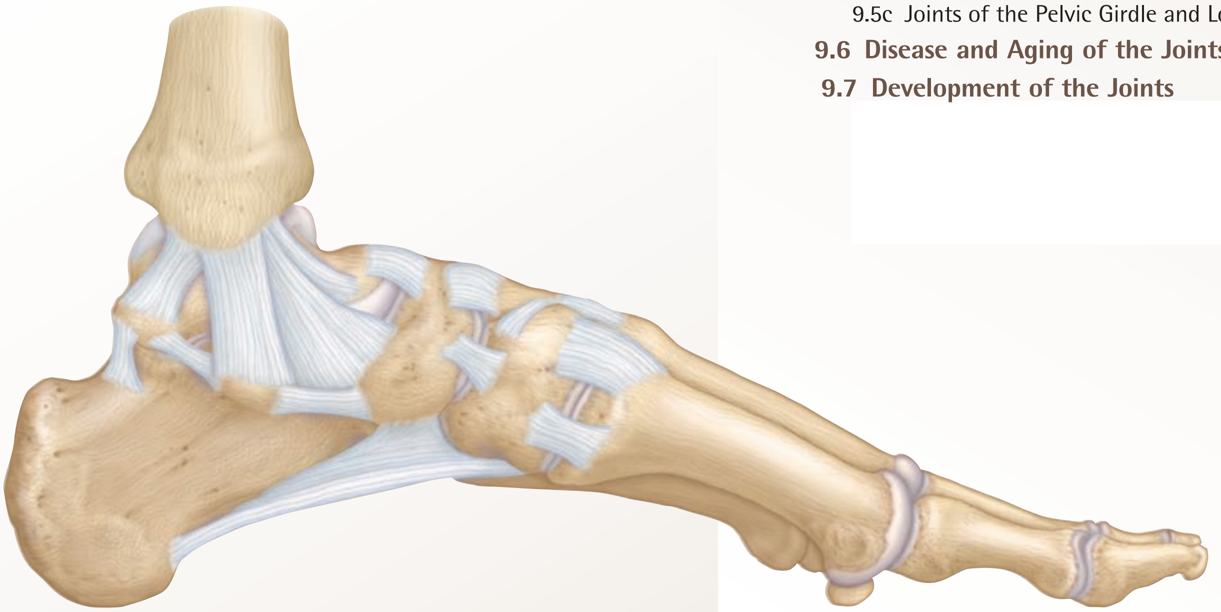
2

Articulations

OUTLINE



Our skeleton protects vital organs and supports soft tissues. Its marrow cavity is the source of new blood cells. When it interacts with the muscular system, the skeleton helps the body move. Although bones are slightly flexible, they are too rigid to bend so they meet at joints, which anatomists call articulations. In this chapter, we examine how bones articulate and may allow some freedom of movement, depending on the shapes and supporting structures of the various joints.

9.1 Articulations (Joints)

Learning Objectives:

1. Describe the general structure of articulations.
2. Discuss the connection between degree of movement and joint structure.
3. Identify both the structural and functional classifications of joints.

A **joint,** or **articulation** (ar-tik-ū-lā′shŭn), is the place of contact between bones, between bone and cartilage, or between bones and teeth. Bones are said to **articulate** with each other at a joint. The scientific study of joints is called **arthrology** (ar-throl′ō-jē; *arthron* = joint, *logos* = study).

> **Study Tip!**
>
> You can figure out the names of most joints by piecing together the names of the bones that form them. For example, the *glenohumeral* joint is where the glenoid cavity of the scapula meets the head of the humerus, and the *sternoclavicular* joint is where the manubrium of the sternum articulates with the sternal end of the clavicle.

The motion permitted at a joint ranges from no movement (e.g., where some skull bones interlock at a suture) to extensive movement (e.g., at the shoulder, where the arm connects to the scapula). The structure of each joint determines its mobility and its stability. There is an inverse relationship between mobility and stability in articulations. The more mobile a joint is, the less stable it is; and the more stable a joint is, the less mobile it is. **Figure 9.1** illustrates the "tradeoff" between mobility and stability for various joints.

9.1a Classification of Joints

Joints are categorized structurally on the basis of the type of connective tissue that binds the articulating surfaces of the bones, and whether a space occurs between the articulating bones:

- A **fibrous** (fī′brŭs) **joint** occurs where bones are held together by dense regular (fibrous) connective tissue.
- A **cartilaginous** (kar-ti-laj′i-nŭs; *cartilago* = gristle) **joint** occurs where bones are joined by cartilage.
- A **synovial** (si-nō′vē-ăl) **joint** has a fluid-filled joint cavity that separates the cartilage-covered articulating surfaces of the bones. The articulating surfaces are enclosed within a capsule, and the bones are also joined by various ligaments.

Joints may also be classified functionally based on the extent of movement they permit:

- A **synarthrosis** (sin′ar-thrō′sis; pl., sin′ar-thrō′sēz; *syn* = joined together) is an immobile joint.
- An **amphiarthrosis** (am′fi-ar-thrō′sis; pl., -sēz; *amphi* = around) is a slightly mobile joint.
- A **diarthrosis** (dī-ar-thrō′sis; pl., -sēz; *di* = two) is a freely mobile joint.

The following discussion of articulations is based on their structural classification, with functional categories included as appropriate. As you read about the various types of joints, it may help you to refer to the summary of joint classifications in **table 9.1**.

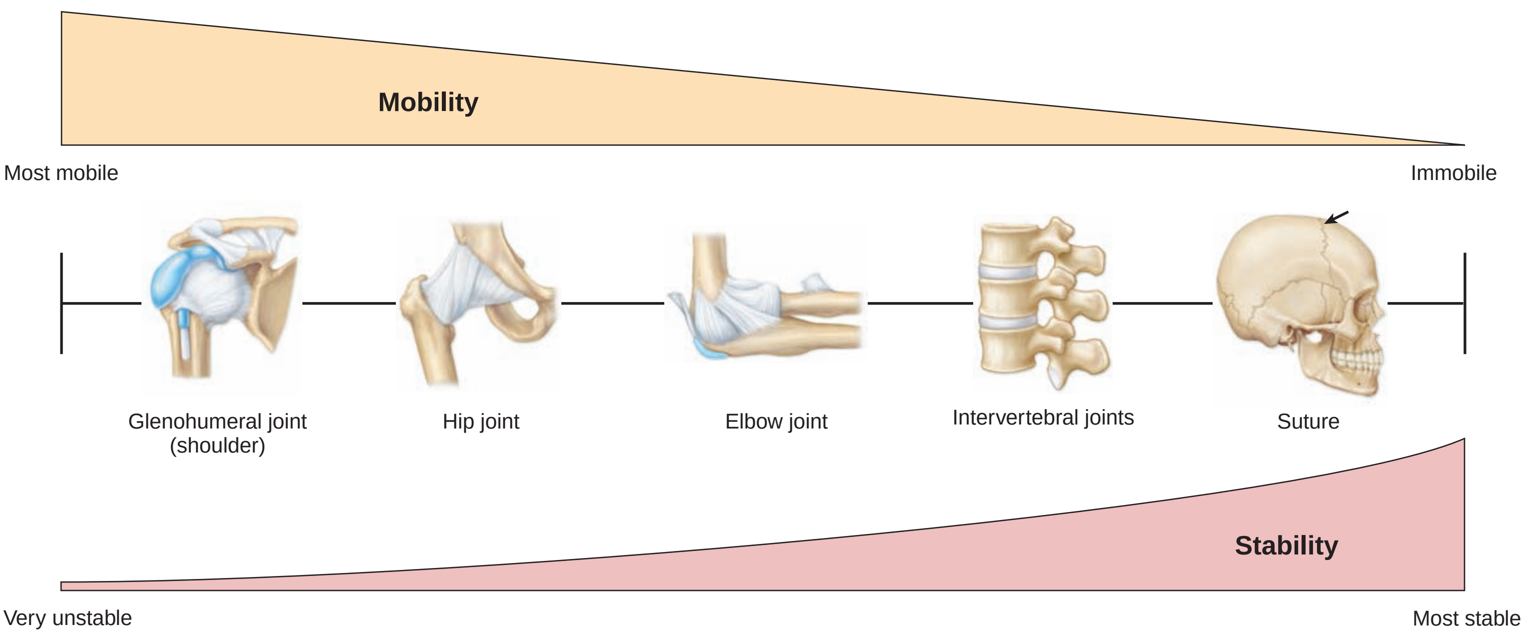


Figure 9.1

Relationship Between Mobility and Stability in Joints. In every joint, there is a "tradeoff" between the relative amounts of mobility and stability. The more mobile the joint, the less stable it is. Conversely, the more stable the joint, the less mobile it is. Note how the glenohumeral (shoulder) joint is very mobile but not very stable, while a suture is immobile and yet very stable.

Table 9.1 Joint Classifications

Structural Classification	Structural Characteristics	Structural Category	Example	Functional Classification
Fibrous	Dense regular connective tissue holds together the ends of bones and bone parts; no joint cavity	Gomphosis: Periodontal membranes hold tooth to bony jaw	Tooth to jaw	Synarthrosis (immobile)
		Suture: Dense regular connective tissue connects skull bones	Lambdoid suture (connects occipital and parietal bones)	Synarthrosis (immobile)
		Syndesmosis: Dense regular connective tissue fibers (interosseous membrane) between bones	Articulation between radius and ulna, and between tibia and fibula	Amphiarthrosis (slightly mobile)
Cartilaginous	Pad of cartilage is wedged between the ends of bones; no joint cavity	Synchondrosis: Hyaline cartilage plate between bones	Epiphyseal plates in growing bones; costochondral joints	Synarthrosis (immobile)
		Symphysis: Fibrocartilage pad between bones	Pubic symphysis; intervertebral disc articulations	Amphiarthrosis (slightly mobile)
Synovial	Ends of bones covered with articular cartilage; joint cavity separates the articulating bones; enclosed by a joint capsule, lined by a synovial membrane; contains synovial fluid	Plane joint: Flattened or slightly curved faces slide across one another	Plane joint: Intercarpal joints, intertarsal joints	Diarthrosis (freely mobile)
		Hinge joint: Permits angular movements in a single plane	Hinge joint: Elbow joint	
		Pivot joint: Permits rotation only	Pivot joint: Atlantoaxial joint	
		Biaxial Condylar joint: Oval articular surface on one bone closely interfaces with a depressed oval surface on another bone	Condylar joint: MP (metacarpophalangeal) joints	Diarthrosis (freely mobile)
		Saddle joint: Saddle-shaped articular surface on one bone closely interfaces with depressed surface on another bone	Saddle joint: Articulation between carpal and first metacarpal bone	
		Multiaxial (triaxial) Ball-and-socket joint: Round head of one bone rests within cup-shaped depression in another bone	Ball-and-socket joint: Glenohumeral joint, hip joint	Diarthrosis (freely mobile)

WHAT DID YOU LEARN?

1. What type of articulation uses dense regular connective tissue to bind the bones?
2. What term is used to describe immobile joints?

9.2 Fibrous Joints

Learning Objectives:

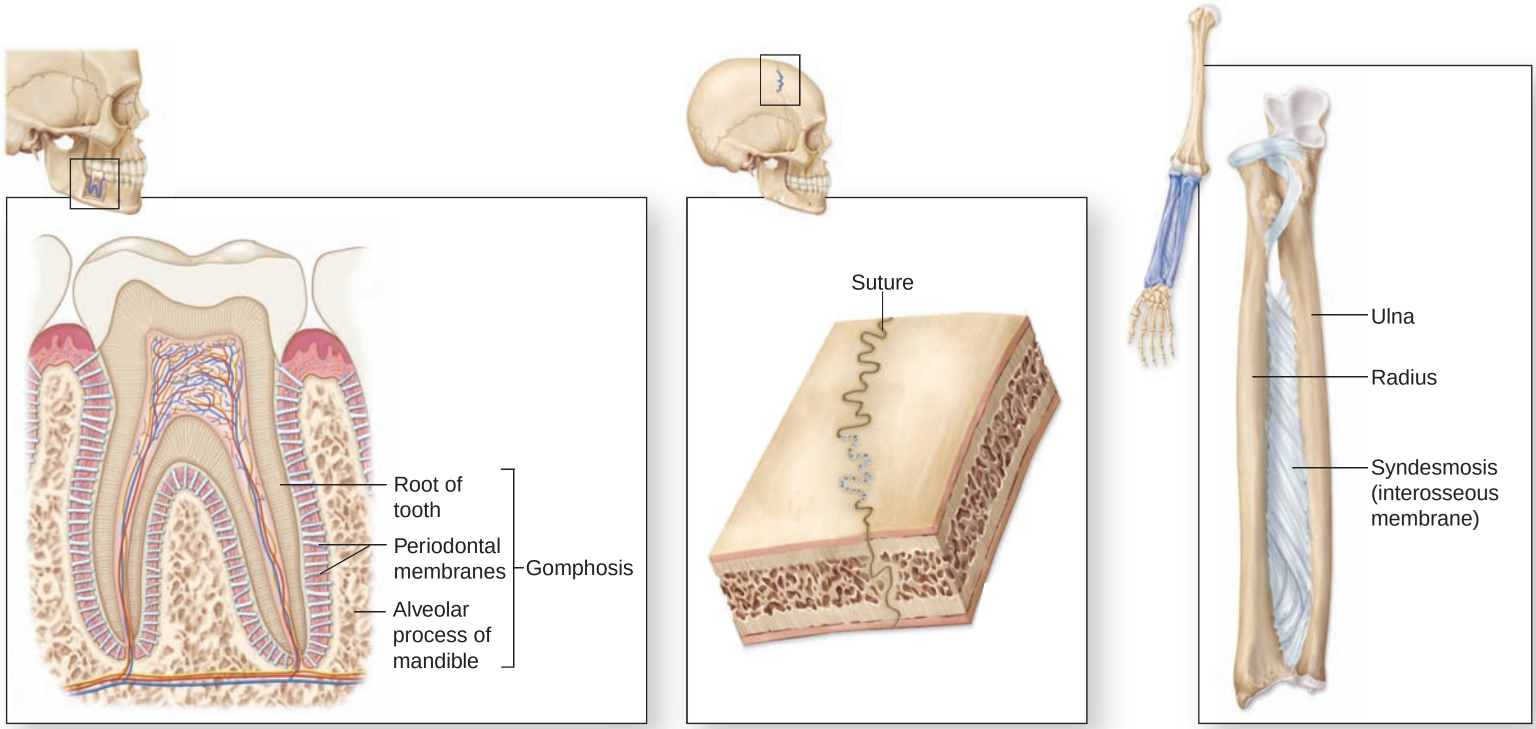
1. Describe the characteristics of the three types of fibrous joints.
2. Identify locations of gomphoses, sutures, and syndesmoses in the body.

Articulating bones are joined by dense regular connective tissue in fibrous joints. Most fibrous joints are immobile or only slightly mobile. Fibrous joints have no joint cavity (space between the articulating bones). The three types of fibrous joints are gomphoses, sutures, and syndesmoses **(figure 9.2)**.

9.2a Gomphoses

A **gomphosis** (gom-fō′sis; pl., -sēz; *gomphos* = bolt, *osis* = condition) resembles a "peg in a socket." The only gomphoses in the human body are the articulations of the roots of individual teeth with the sockets of the mandible and the maxillae. A tooth is held firmly in place by a fibrous **periodontal** (per′ē-ō-don′tăl; *peri* = around, *odous* = tooth) **membrane.** This joint is functionally classified as a synarthrosis.

The reasons orthodontic braces can be painful and take a long time to correctly position the teeth are related to the gomphosis architecture. The orthodontist's job is to reposition these normally immobile joints through the use of bands, rings, and braces. In response to these mechanical stressors, osteoblasts and osteoclasts work together to modify the alveolus, resulting in the remodeling of the joint and the slow repositioning of the teeth.



(a) Gomphosis **(b) Suture** **(c) Syndesmosis**

Figure 9.2

Fibrous Joints. Dense regular connective tissue binds the articulating bones in fibrous joints to prevent or severely restrict movement. (*a*) A gomphosis is the immobile joint between a tooth and the jaw. (*b*) A suture is an immobile joint between bones of the skull. (*c*) A syndesmosis permits slight mobility between the radius and the ulna.

9.2b Sutures

Sutures (soo′choor; *sutura* = a seam) are immobile fibrous joints (synarthoses) that are found only between certain bones of the skull. Sutures have distinct, interlocking, usually irregular edges that both increase their strength and decrease the number of fractures at these articulations. In addition to joining bones, sutures permit the skull to grow as the brain increases in size during childhood. In an older adult, the dense regular connective tissue in the suture becomes ossified, fusing the skull bones together. When the bones have completely fused across the suture line, these obliterated sutures become **synostoses** (sin-os-tō′sēz; sing., -sis).

9.2c Syndesmoses

Syndesmoses (sin′dez-mō′sēz; sing., -sis; *syndesmos* = a fastening) are fibrous joints in which articulating bones are joined by long strands of dense regular connective tissue only. Because syndesmoses allow for slight mobility, they are classified as amphiarthroses. Syndesmoses are found between the radius and ulna, and between the tibia and fibula. The shafts of the two articulating bones are bound side by side by a broad ligamentous sheet called an **interosseous membrane** (or *interosseous ligament*). The interosseous membrane provides a pivot point where the radius and ulna (or the tibia and fibula) can move against one another.

WHAT DID YOU LEARN?

3. Describe the three types of fibrous joints, and name a place in the body where each type is found.

9.3 Cartilaginous Joints

Learning Objectives:

1. Discuss the characteristics of the two types of cartilaginous joints.
2. Name locations of synchondroses and symphyses in the body.

The articulating bones in cartilaginous joints are attached to each other by cartilage. These joints lack a joint cavity. The two types of cartilaginous joints are synchondroses and symphyses **(figure 9.3)**.

9.3a Synchondroses

An articulation in which bones are joined by hyaline cartilage is called a **synchondrosis** (sin′kon-drō′sis; pl., -sēz; *chondros* = cartilage). Functionally, all synchondroses are immobile and thus are classified as synarthroses. The hyaline cartilage of epiphyseal plates in children forms synchondroses that bind the epiphyses and the diaphysis of long bones. When the hyaline cartilage stops growing, bone replaces the cartilage, and a synchondrosis no longer exists.

The spheno-occipital synchondrosis is found between the body of the sphenoid and the basilar part of the occipital bone. This synchondrosis fuses between 18 and 25 years of age, making it a useful tool for assessing the age of a skull.

Another synchondrosis is the attachment of the first rib to the sternum by costal cartilage (called the first sternocostal joint). Here, the first rib and its costal cartilage (formed from hyaline

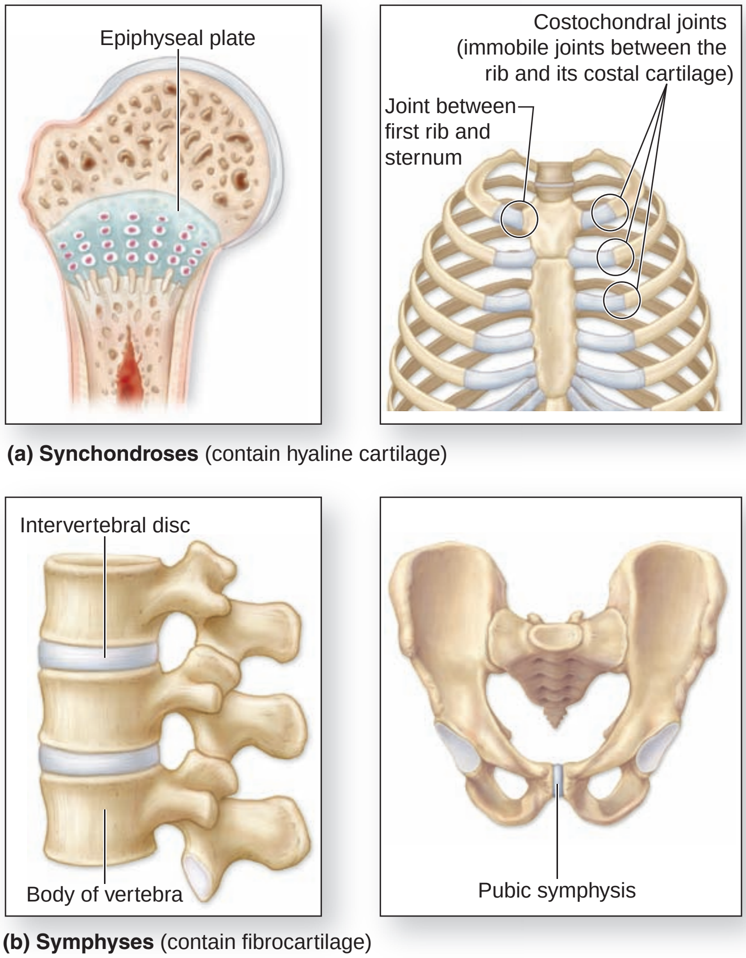


Figure 9.3

Cartilaginous Joints. Articulating bones are joined by cartilage. (*a*) Synchondroses are immobile joints that occur in an epiphyseal plate in a long bone and in the joint between a rib and the sternum. (*b*) Symphyses are amphiarthroses and occur in the intervertebral discs and the pubic symphysis.

cartilage) are united firmly to the manubrium of the sternum to provide stability to the rib cage. A final example of synchondroses are the **costochondral** (kos-tō-kon′drăl; *costa* = rib) **joints,** the joints between each bony rib and its respective costal cartilage. (Note that the costochondral joints are different from the articulation between the sternum and the costal cartilage of ribs 2–7, which is a synovial joint, not a synchondrosis.)

WHAT DO YOU THINK?

1 Why is a synchondrosis a synarthrosis? Why would you want a synchondrosis to be immobile?

9.3b Symphyses

A **symphysis** (sim′fi-sis; pl., -sēz; growing together) has a pad of fibrocartilage between the articulating bones. The fibrocartilage resists compression and tension stresses and acts as a resilient shock absorber. All symphyses are amphiarthroses, meaning that they allow slight mobility.

One example of a symphysis is the pubic symphysis, which is located between the right and left pubic bones. In pregnant females, the pubic symphysis becomes more mobile to allow the pelvis to change shape slightly as the fetus passes through the birth canal.

Other examples of symphyses are the intervertebral joints, where the bodies of adjacent vertebrae are both separated and united by intervertebral discs. These intervertebral discs allow only slight movements between the adjacent vertebrae; however, the collective movements of all the intervertebral discs afford the spine considerable flexibility.

CLINICAL VIEW

Costochondritis

Costochondritis (kos-tō-kon-drī′tis; *itis* = inflammation) refers to inflammation and irritation of the costochondral joints, resulting in localized chest pain. Any costochondral joint may be affected, although the joints for ribs 2–6 are those most commonly injured. The cause of costochondritis is usually unknown, but some documented causes include repeated minor trauma to the chest wall (e.g., from forceful repeated coughing during a respiratory infection or overexertion during exercise) and bacterial or viral infection of the joints themselves. Some backpackers who do not use a chest brace have experienced bouts of costochondritis.

The most common symptom of costochondritis is localized chest pain, typically following exertion or a respiratory infection. The pain may be mistaken for that caused by a myocardial infarction (heart attack), and thus may cause needless anxiety for the patient. Sitting, lying on the affected side, and increased mental stress can exacerbate symptoms. Costochondritis is not a medical emergency and may be treated with NSAIDs (nonsteroidal anti-inflammatory drugs, such as aspirin). With proper rest and treatment, symptoms typically disappear after several weeks.

WHAT DID YOU LEARN?

4 Describe a symphysis. In what functional category is this type of joint placed, and why?

9.4 Synovial Joints

Learning Objectives:

1. Describe the general anatomy of synovial joints and their accessory structures.
2. Name the classes of synovial joints based on the joint surface shapes, and identify the types of movement permitted.
3. Discuss the variety of dynamic movements which occur at synovial joints.

Synovial joints are freely mobile articulations. Unlike the joints previously discussed, the bones in a synovial joint are separated by a space called a joint cavity. Most of the commonly known joints in the body are synovial joints, including the glenohumeral (shoulder) joint, the temporomandibular joint, the elbow joint, and the knee joint. Functionally, all synovial joints are classified as diarthroses, since all are freely mobile. Often, the terms *diarthrosis* and *synovial joint* are equated.

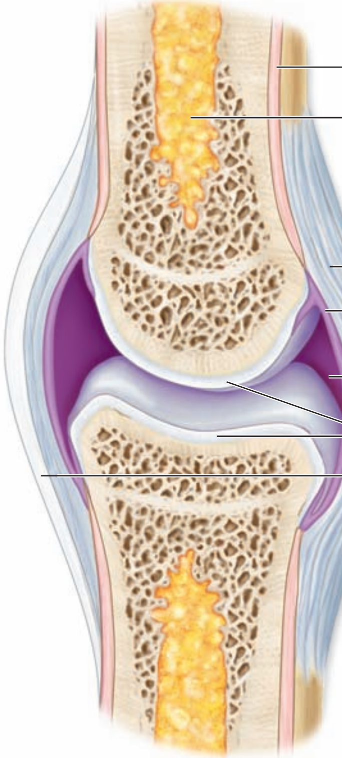


Figure 9.4

Synovial Joints. All synovial joints are diarthroses, and they permit a wide range of motion.

9.4a General Anatomy of Synovial Joints

All types of synovial joints have several basic features: an articular capsule, a joint cavity, synovial fluid, articular cartilage, ligaments, and nerves and blood vessels **(figure 9.4)**.

Each synovial joint is composed of a double-layered capsule called the **articular** (ar-tik′ū-lăr) **capsule** (or *joint capsule*). The outer layer is called the **fibrous layer,** while the inner layer is a **synovial membrane** (or *synovium*). The fibrous layer is formed from dense connective tissue, and it strengthens the joint to prevent the bones from being pulled apart. The synovial membrane is composed primarily of areolar connective tissue, covers all the internal joint surfaces not covered by cartilage, and lines the articular capsule.

Only synovial joints house a **joint cavity** (or *articular cavity*), a space that contains a small amount of synovial fluid. The cavity permits separation of the articulating bones. The articular cartilage and synovial fluid within the joint cavity reduce friction as bones move at a synovial joint.

Lining the joint cavity is the synovial membrane, which secretes a viscous, oily **synovial fluid.** Synovial fluid is composed of secretions from synovial membrane cells and a filtrate from blood plasma. Synovial fluid has three functions:

1. Synovial fluid lubricates the articular cartilage on the articulating bones (in the same way that oil in a car engine lubricates the moving engine parts).
2. Synovial fluid nourishes the articular cartilage's chondrocytes. The relatively small volume of synovial fluid must be circulated continually to provide nutrients and remove wastes to these cells. Whenever movement occurs at a synovial joint, the combined compression and re-expansion of the articular cartilage circulate the synovial fluid into and out of the cartilage matrix.
3. Synovial fluid acts as a shock absorber, distributing stresses and force evenly across the articular surfaces when the pressure in the joint suddenly increases.

All articulating bone surfaces in a synovial joint are covered by a thin layer of hyaline cartilage called **articular cartilage.** This cartilage reduces friction in the joint during movement, acts as a spongy cushion to absorb compression placed on the joint, and prevents damage to the articulating ends of the bones. This special hyaline cartilage lacks a perichondrium. Mature cartilage is avascular, so it does not have blood vessels to bring nutrients to and remove waste products from the tissue. The repetitious compression/relaxation that occurs during exercise is vital to the articular cartilage's well-being because the accompanying pumping action enhances its nutrition and waste removal.

Ligaments (lig′ă-ment; *ligamentum* = a band) are composed of dense regular connective tissue. Ligaments connect one bone to another bone and strengthen and reinforce most synovial joints. **Extrinsic ligaments** are outside of and physically separate from the articular capsule, whereas **intrinsic ligaments** represent thickenings of the articular capsule itself. Intrinsic ligaments include *extracapsular ligaments* outside the articular capsule and *intracapsular ligaments* within the articular capsule.

Tendons (ten′dŏn; *tendo* = extend) are not part of the synovial joint itself. Like a ligament, a tendon is composed of dense regular connective tissue. However, whereas a ligament binds bone to bone, a tendon attaches a muscle to a bone. When a muscle contracts, the tendon from that muscle moves the bone to which it is attached, thus creating movement at the joint. Tendons help stabilize joints because they pass across or around a joint providing mechanical support, and can limit the range or amount of movement permitted at a joint.

All synovial joints have numerous sensory **nerves** and **blood vessels** that innervate and supply the articular capsule and associated ligaments. The sensory nerves detect painful stimuli in the joint and report on the amount of movement and stretch in the joint. By monitoring stretching at a joint, the nervous system can detect changes in our posture and adjust body movements.

In addition to the main structures just described, synovial joints usually have the following accessory structures: bursae, fat pads, and tendons.

A **bursa** (ber′să; pl., *bursae,* ber′sē; a purse) is a fibrous, saclike structure that contains synovial fluid and is lined by a synovial membrane **(figure 9.5*a*)**. Bursae are found around most synovial joints and also where bones, ligaments, muscles, skin, or tendons overlie each other and rub together. Bursae may be either connected to the joint cavity or completely separate from it. They are designed to alleviate the friction resulting from the various body movements, such as a tendon or ligament rubbing against bone. An elongated bursa called a **tendon sheath** wraps around tendons where there may be excessive friction. Tendon sheaths are especially common in the confined spaces of the wrist and ankle (figure 9.5*b*).

Fat pads are often distributed along the periphery of a synovial joint. They act as packing material and provide some protection for the joint. Often fat pads fill the spaces that form when bones move and the joint cavity changes shape.

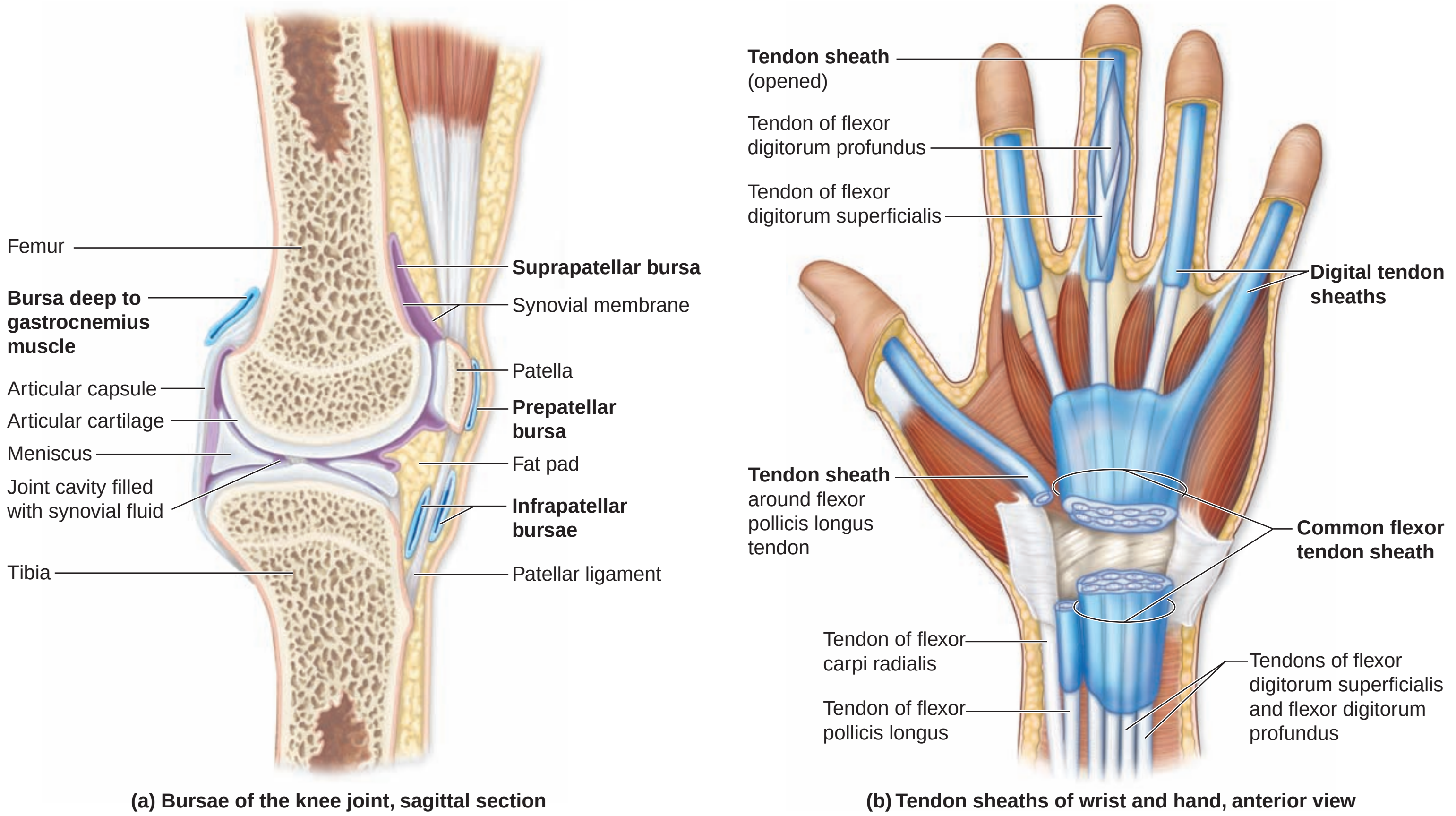


Figure 9.5

Bursae and Tendon Sheaths. Synovial-fluid-filled structures called bursae and tendon sheaths reduce friction where ligaments, muscles, tendons, and bones rub together. (*a*) The knee joint contains a number of bursae. (*b*) The wrist and hand contain numerous tendon sheaths (blue).

CLINICAL VIEW

"Cracking Knuckles"

Cracking or popping sounds often result when people pull forcefully on their fingers. Stretching or pulling on a synovial joint causes the joint volume to immediately expand and the pressure on the fluid within the joint to decrease, so that a partial vacuum exists within the joint. As a result, the gases dissolved in the fluid become less soluble, and they form bubbles, a process called **cavitation.** When the joint is stretched to a certain point, the pressure in the joint drops even lower, so the bubbles in the fluid burst, producing a popping or cracking sound. (Similarly, displaced water in a sealed vacuum tube makes this sound as it hits against the glass wall.) It typically takes about 25 to 30 minutes for the gases to dissolve back into the synovial fluid. You cannot crack your knuckles again until these gases dissolve. Contrary to popular belief, cracking your knuckles does *not* cause arthritis.

9.4b Types of Synovial Joints

Synovial joints are classified by the shapes of their articulating surfaces and the types of movement they allow. Movement of a bone at a synovial joint is best described with respect to three intersecting perpendicular planes or axes:

- A joint is said to be **uniaxial** (yū-nē-ak′sē-ăl; *unus* = one) if the bone moves in just one plane or axis.
- A joint is **biaxial** (bī-ak′sē-ăl; *bi* = double) if the bone moves in two planes or axes.
- A joint is **multiaxial** (or **triaxial** [trī-ak′sē-ăl; *tri* = three]) if the bone moves in multiple planes or axes.

Note that all synovial joints are diarthroses, although some are more mobile than others. From least mobile to most freely mobile, the six specific types of synovial joints are plane joints, hinge joints, pivot joints, condylar joints, saddle joints, and ball-and-socket joints **(figure 9.6)**.

A **plane** (*planus* = flat) **joint,** also called a *planar* or *gliding joint,* is the simplest synovial articulation and the least mobile type of diarthrosis. This type of synovial joint is also known as a uniaxial joint because only side-to-side movements are possible. The articular surfaces of the bones are flat, or planar. Examples of plane joints include the intercarpal and intertarsal joints (the joints between the cube-shaped carpal and tarsal bones).

A **hinge joint** is a uniaxial joint in which the convex surface of one articulating bone fits into a concave depression on the other bone. Movement is confined to a single axis, like the hinge of a door. An example is the elbow joint. The trochlear notch of the ulna fits directly into the trochlea of the humerus, so the forearm can be moved only anteriorly toward the arm or posteriorly away from the arm. Other hinge joints occur in the knee and the finger (interphalangeal [IP]) joints.

A **pivot** (piv′ŏt) **joint** is a uniaxial joint in which one articulating bone with a rounded surface fits into a ring formed by a ligament and another bone. The first bone rotates on its longitudinal axis relative to the second bone. An example is the proximal radioulnar

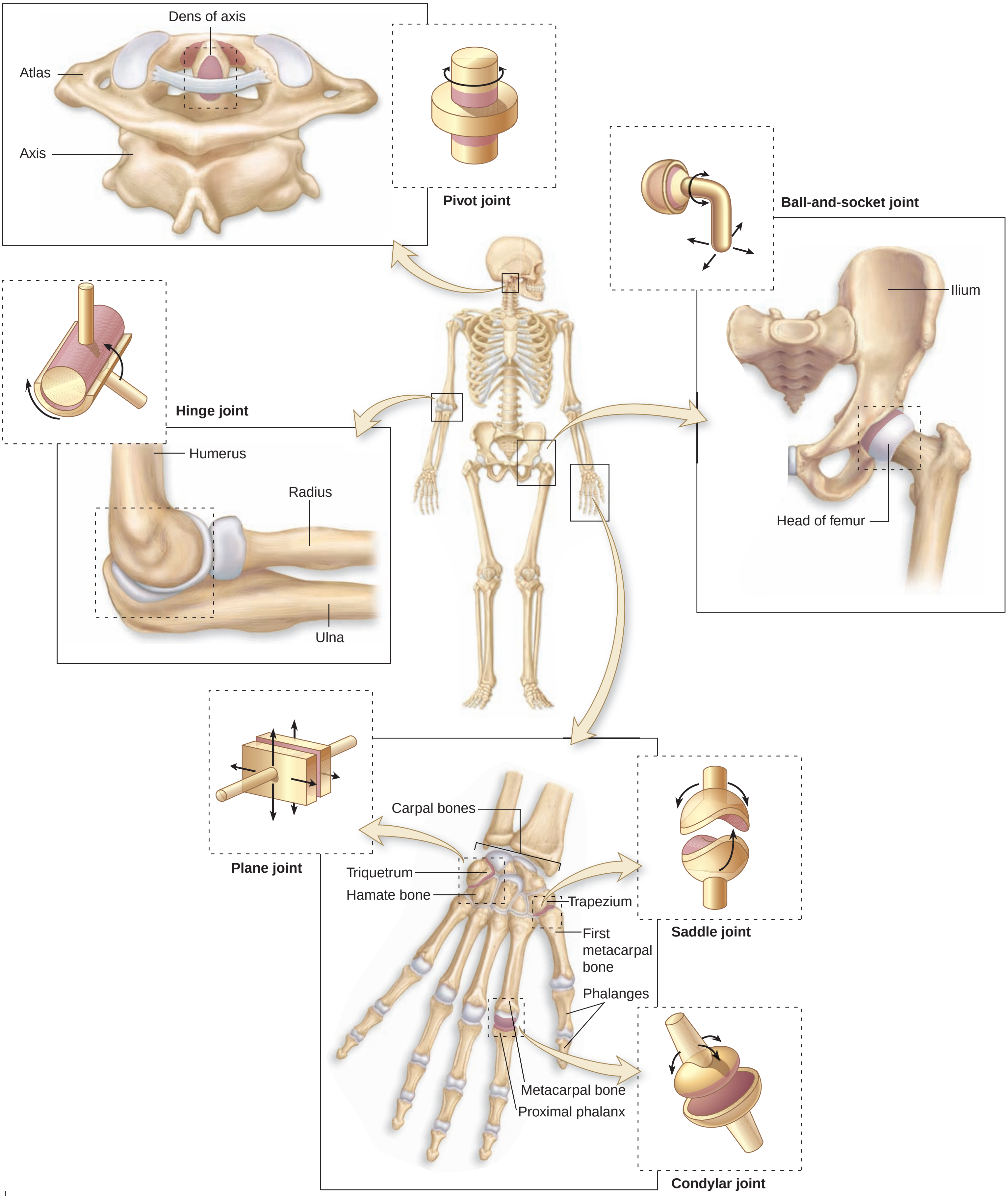


Figure 9.6

Types of Synovial Joints. These six types of synovial joints permit specific types of movement.

joint, where the rounded head of the radius pivots along the ulna and permits the radius to rotate. Another example is the atlantoaxial joint between the first two cervical vertebrae. The rounded dens of the axis fits snugly against an articular facet on the anterior arch of the atlas. This joint pivots when you shake your head "no."

Condylar (kon′di-lar) **joints,** also called *condyloid* or *ellipsoid joints,* are biaxial joints with an oval, convex surface on one bone that articulates with a concave articular surface on the second bone. Biaxial joints can move in two axes, such as back-and-forth and side-to-side. Examples of condylar joints are the metacarpophalangeal (MP) (met′ă-kar′pō-fă-lan′jē-ăl) joints of fingers 2 through 5. The MP joints are commonly referred to as "knuckles." Examine your hand and look at the movements along the MP joints; you can flex and extend the fingers at this joint (that is one axis of movement). You also can move your fingers apart from one another and move them closer together, which is the second axis of movement.

A **saddle joint** is so named because the articular surfaces of the bones have convex and concave regions that resemble the shape of a saddle. It allows a greater range of movement than either a condylar or hinge joint. The carpometacarpal joint of the thumb (between the trapezium and the first metacarpal) is an example of a saddle joint. This joint permits the thumb to move toward the other fingers so that we can grasp objects.

Ball-and-socket joints are multiaxial joints in which the spherical articulating head of one bone fits into the rounded, cup-like socket of a second bone. Examples of these joints are the hip joint and the glenohumeral joint. The multiaxial nature of these joints permits movement in three axes. Move your arm at your shoulder, and observe the wide range of movements that can be produced. This is why the ball-and-socket joint is considered the most freely mobile type of synovial joint.

WHAT DO YOU THINK?

2. If a ball-and-socket joint is more mobile than a plane joint, which of these two joints is more stable?

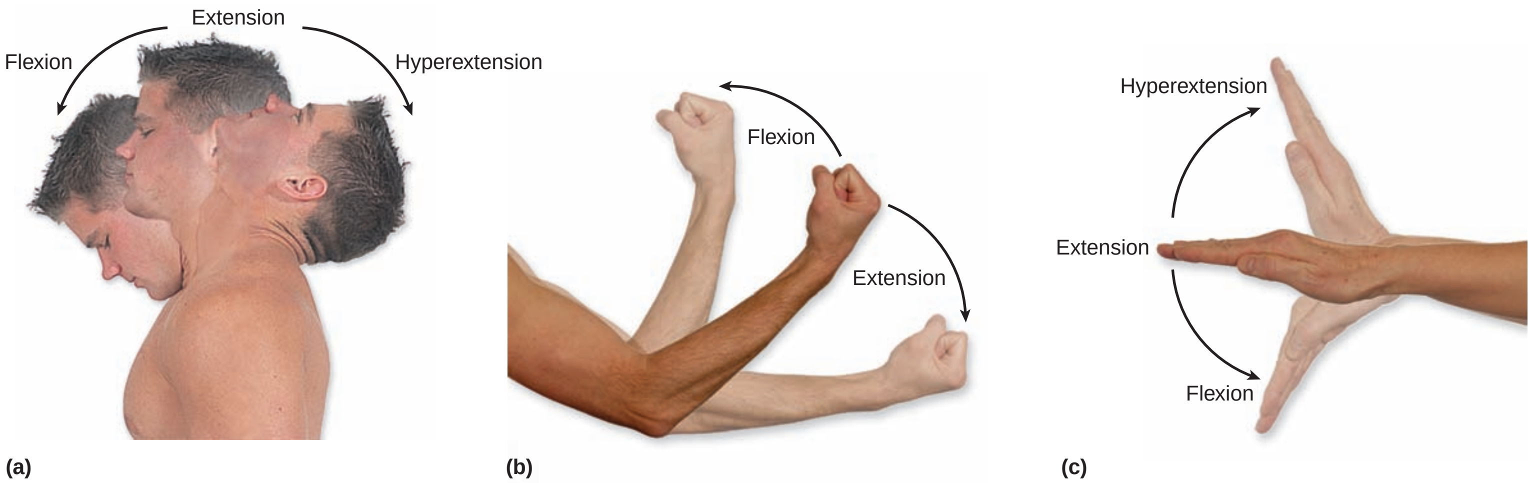
9.4c Movements at Synovial Joints

Four types of motion occur at synovial joints: gliding, angular, rotational, and special movements (motions that occur only at specific joints) **(table 9.2)**.

Table 9.2 Movements at Synovial Joints

Movement	Description	Opposing Movement[1]
Gliding Motion	Two opposing articular surfaces slide past each other in almost any direction; the amount of movement is slight	None
Angular Motion	The angle between articulating bones increases or decreases	
Flexion	The angle between articulating bones decreases; usually occurs in the sagittal plane	Extension
Extension	The angle between articulating bones increases; usually occurs in the sagittal plane	Flexion
Hyperextension	Extension movement continues past the anatomic position	Flexion
Lateral flexion	The vertebral column moves in either lateral direction along a coronal plane	None
Abduction	Movement of a bone away from the midline; usually in the coronal plane	Adduction
Adduction	Movement of a bone toward the midline; usually in the coronal plane	Abduction
Circumduction	A continuous movement that combines flexion, abduction, extension, and adduction in succession; the distal end of the limb or digit moves in a circle	None
Rotational Motion	A bone pivots around its own longitudinal axis	None
Pronation	Rotation of the forearm whereby the palm is turned posteriorly	Supination
Supination	Rotation of the forearm whereby the palm is turned anteriorly	Pronation
Special Movements	Types of movement that don't fit in the previous categories	
Depression	Movement of a body part inferiorly	Elevation
Elevation	Movement of a body part superiorly	Depression
Dorsiflexion	Ankle joint movement whereby the dorsum of the foot is brought closer to the anterior surface of the leg	Plantar flexion
Plantar flexion	Ankle joint movement whereby the sole of the foot is brought closer to the posterior surface of the leg	Dorsiflexion
Inversion	Twisting motion of the foot that turns the sole medially or inward	Eversion
Eversion	Twisting motion of the foot that turns the sole laterally or outward	Inversion
Protraction	Anterior movement of a body part from anatomic position	Retraction
Retraction	Posterior movement of a body part from anatomic position	Protraction
Opposition	Special movement of the thumb across the palm toward the fingers to permit grasping and holding of an object	Reposition

1. Some movements (e.g., circumduction) do not have an opposing movement.



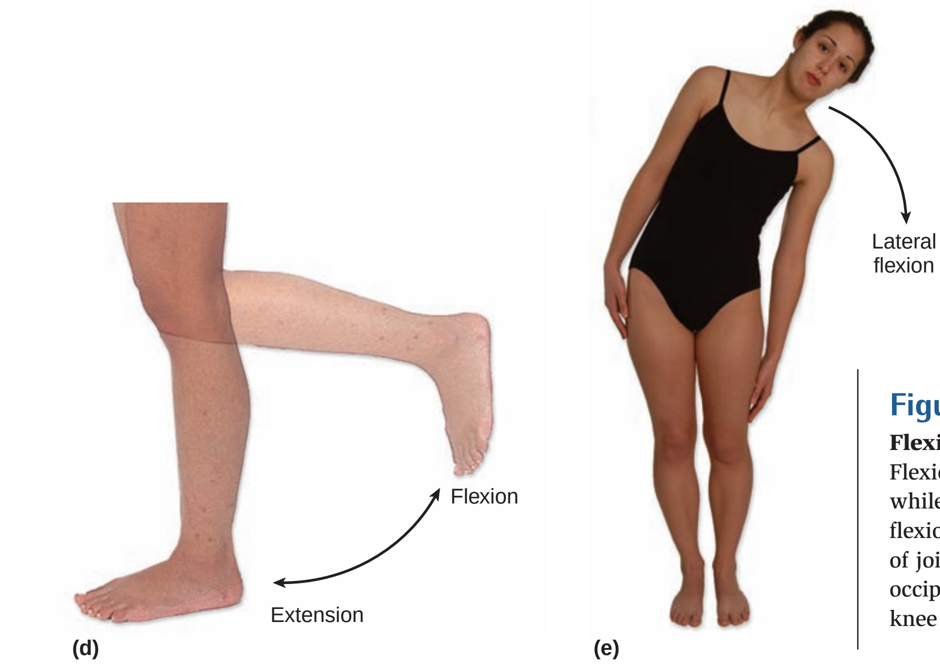


Figure 9.7

Flexion, Extension, Hyperextension, and Lateral Flexion. Flexion decreases the joint angle in an anterior-posterior (AP) plane, while extension increases the joint angle in the AP plane. Lateral flexion decreases a joint angle, but in a coronal plane. Examples of joints that allow some of these movements are (*a*) the atlanto-occipital joint, (*b*) the elbow joint, (*c*) the radiocarpal joint, (*d*) the knee joint, and (*e*) the intervertebral joints.

Gliding Motion

Gliding is a simple movement in which two opposing surfaces slide slightly back-and-forth or side-to-side with respect to one another. In a gliding motion, the angle between the bones does not change, and only limited movement is possible in any direction. Gliding motion typically occurs along plane joints.

Angular Motion

Angular motion either increases or decreases the angle between two bones. These movements may occur at many of the synovial joints; they include the following specific types: flexion and extension, hyperextension, lateral flexion, abduction and adduction, and circumduction.

Flexion (flek′shŭn; *flecto* = to bend) is movement in an anterior-posterior (AP) plane of the body that *decreases* the angle between the articulating bones. Bones are brought closer together as the angle between them decreases. Examples include bending your fingers toward your palm to make a fist, bending your forearm toward your arm at the elbow, flexion at the shoulder when you raise an arm anteriorly, and flexion of the neck when you bend your head anteriorly to look down at your feet. The opposite of flexion is **extension** (eks-ten′shŭn; *extensio* = a stretching out), which is movement in an anterior-posterior plane that *increases* the angle between the articulating bones. Extension is a straightening action that usually occurs in the sagittal plane of the body. Straightening your arm and forearm until the upper limb projects directly away from the anterior side of your body or straightening your fingers after making a clenched fist are examples of extension. Flexion and extension of various body parts are illustrated in **figure 9.7*a–d***.

Hyperextension (hī′per-eks-ten′shŭn; *hyper* = above normal) is the extension of a joint beyond 180 degrees. For example, if you extend your arm and hand with the palm facing inferiorly, and then raise the back of your hand as if admiring a new ring on your finger, the wrist is hyperextended. If you glance up at the ceiling while standing, your neck is hyperextended.

Lateral flexion occurs when the trunk of the body moves in a coronal plane laterally away from the body. This type of movement occurs primarily between the vertebrae in the cervical and lumbar regions of the vertebral column (figure 9.7*e*).

Abduction (ab-dŭk′shŭn), which means to "move away," is a lateral movement of a body part *away from* the body midline. Abduction occurs when either the arm or the thigh is moved laterally away from the body midline. Abduction of either the fingers or the toes means that you spread them apart, away from the longest digit, which is acting as the midline. Abducting the wrist (also

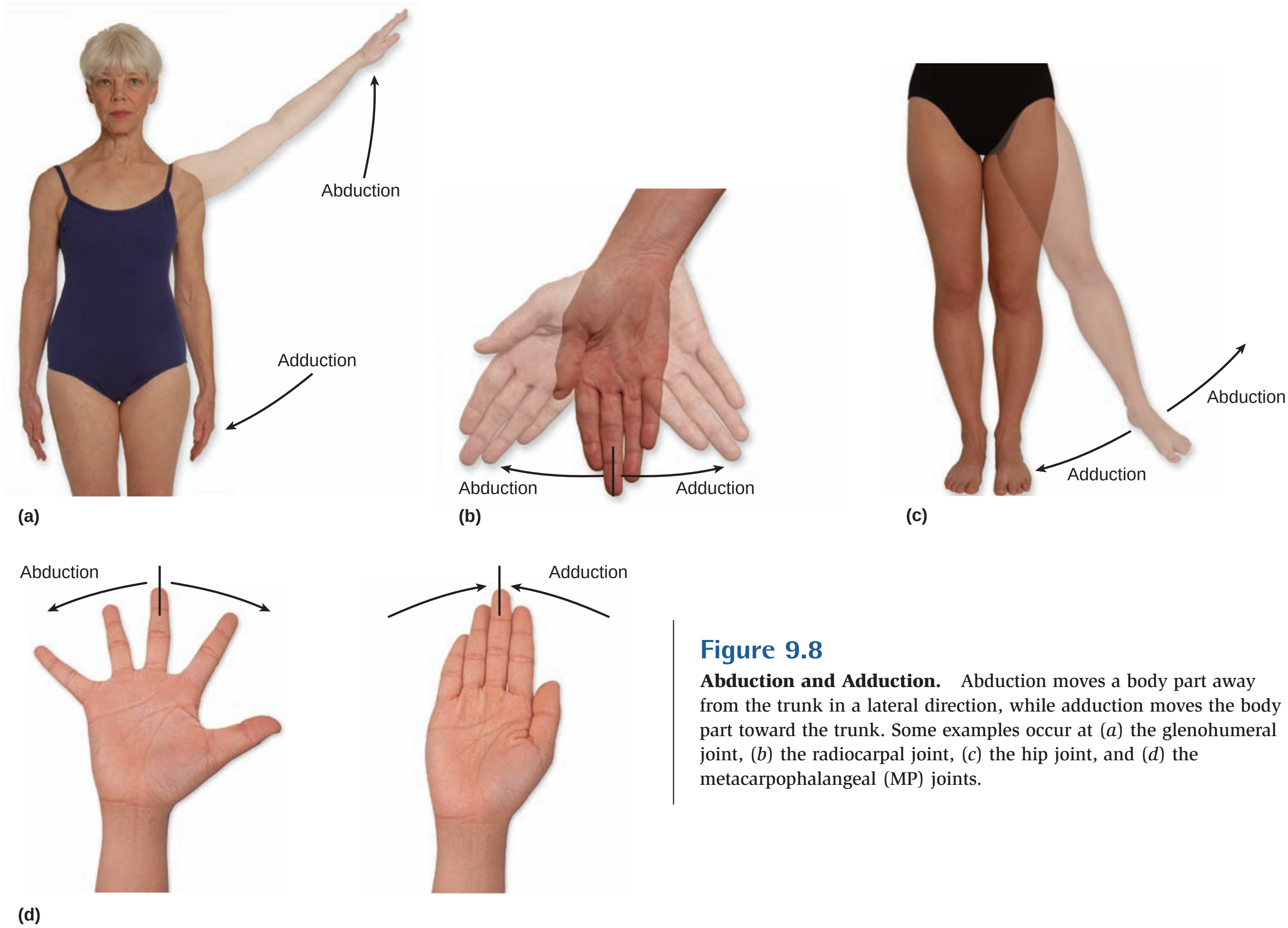


Figure 9.8

Abduction and Adduction. Abduction moves a body part away from the trunk in a lateral direction, while adduction moves the body part toward the trunk. Some examples occur at (*a*) the glenohumeral joint, (*b*) the radiocarpal joint, (*c*) the hip joint, and (*d*) the metacarpophalangeal (MP) joints.

known as *radial deviation*) involves pointing the hand and fingers laterally, away from the body. The opposite of abduction is **adduction** (ad-dŭk′shŭn), which means to "move toward," and is the medial movement of a body part *toward* the body midline. Adduction occurs when you bring your raised arm or thigh back toward the body midline, or in the case of the digits, toward the midline of the hand. Adducting the wrist (also known as *ulnar deviation*) involves pointing the hand and fingers medially, toward the body. Abduction and adduction of various body parts are shown in **figure 9.8**.

Circumduction (ser-kŭm-dŭk′shŭn; *circum* = around, *duco* = to draw) is a sequence of movements in which the proximal end of an appendage remains relatively stationary while the distal end makes a circular motion **(figure 9.9)**. The resulting movement makes an imaginary cone shape. For example, when you draw a circle on the blackboard, your shoulder remains stationary while your hand moves. The tip of the imaginary cone is the stationary shoulder, while the rounded "base" of the cone is the circle the hand makes. Circumduction is a complex movement that occurs as a result of a continuous sequence of flexion, abduction, extension, and adduction.

WHAT DO YOU THINK?

3. When sitting upright in a chair, are your hip and knee joints flexed or extended?

Rotational Motion

Rotation is a pivoting motion in which a bone turns on its own longitudinal axis **(figure 9.10)**. Rotational movement occurs at the atlantoaxial joint, which pivots when you rotate your head to gesture "no." Some limb rotations are described as either away from the median plane or toward it. For example, **lateral rotation** (or *external rotation*) turns the anterior surface of the femur or humerus laterally, while **medial rotation** (or *internal rotation*) turns the anterior surface of the femur or humerus medially.

Pronation (prō-nā′shŭn) is the medial rotation of the forearm so that the palm of the hand is directed posteriorly or inferiorly. The radius and ulna are crossed to form an X. **Supination** (soo′pi-nā′shŭn; *supinus* = supine) occurs when the forearm rotates laterally so that the palm faces anteriorly or superiorly, and the radius is parallel with the ulna. In the anatomic position, the forearm is supinated. Figure 9.10*d* illustrates pronation and supination.

Special Movements

Some motions occur only at specific joints and do not readily fit into any of the functional categories previously discussed. These **special movements** include depression and elevation, dorsiflexion and plantar flexion, inversion and eversion, protraction and retraction, and opposition.

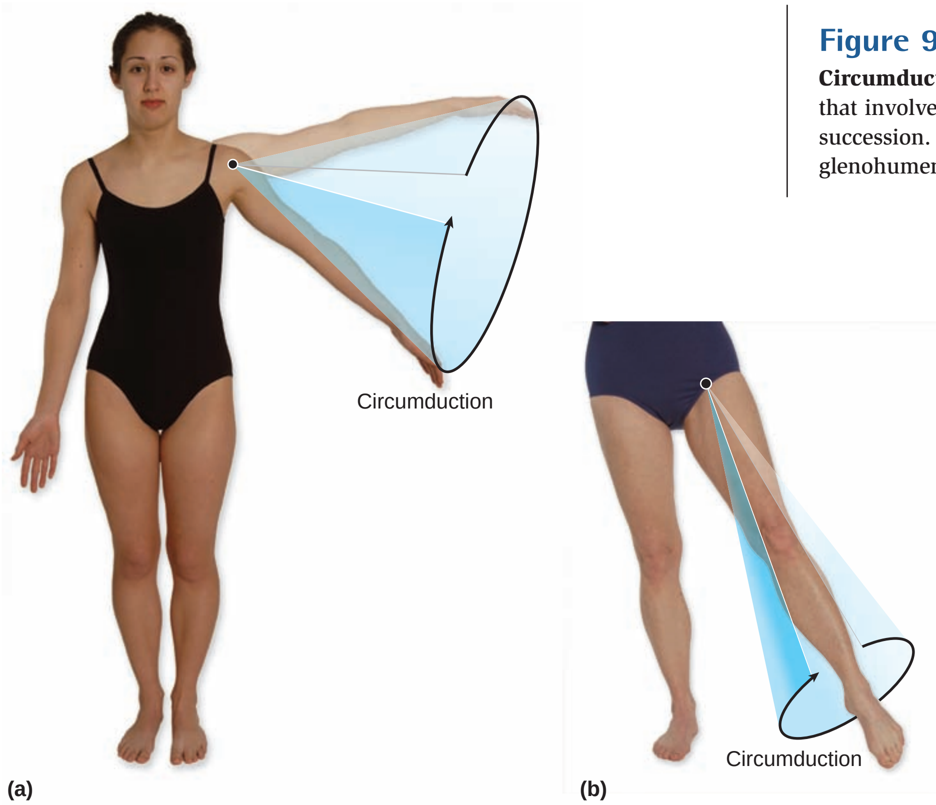


Figure 9.9

Circumduction. Circumduction is a complex movement that involves flexion, abduction, extension, and adduction in succession. Examples of joints that allow this movement are (*a*) the glenohumeral joint and (*b*) the hip joint.

Figure 9.10

Rotational Movements. Rotation allows a bone to pivot on its longitudinal axis. Examples of joints that allow this movement are (*a*) the atlantoaxial joint, (*b*) the glenohumeral joint, and (*c*) the hip joint. (*d*) Pronation and supination occur at the forearm.

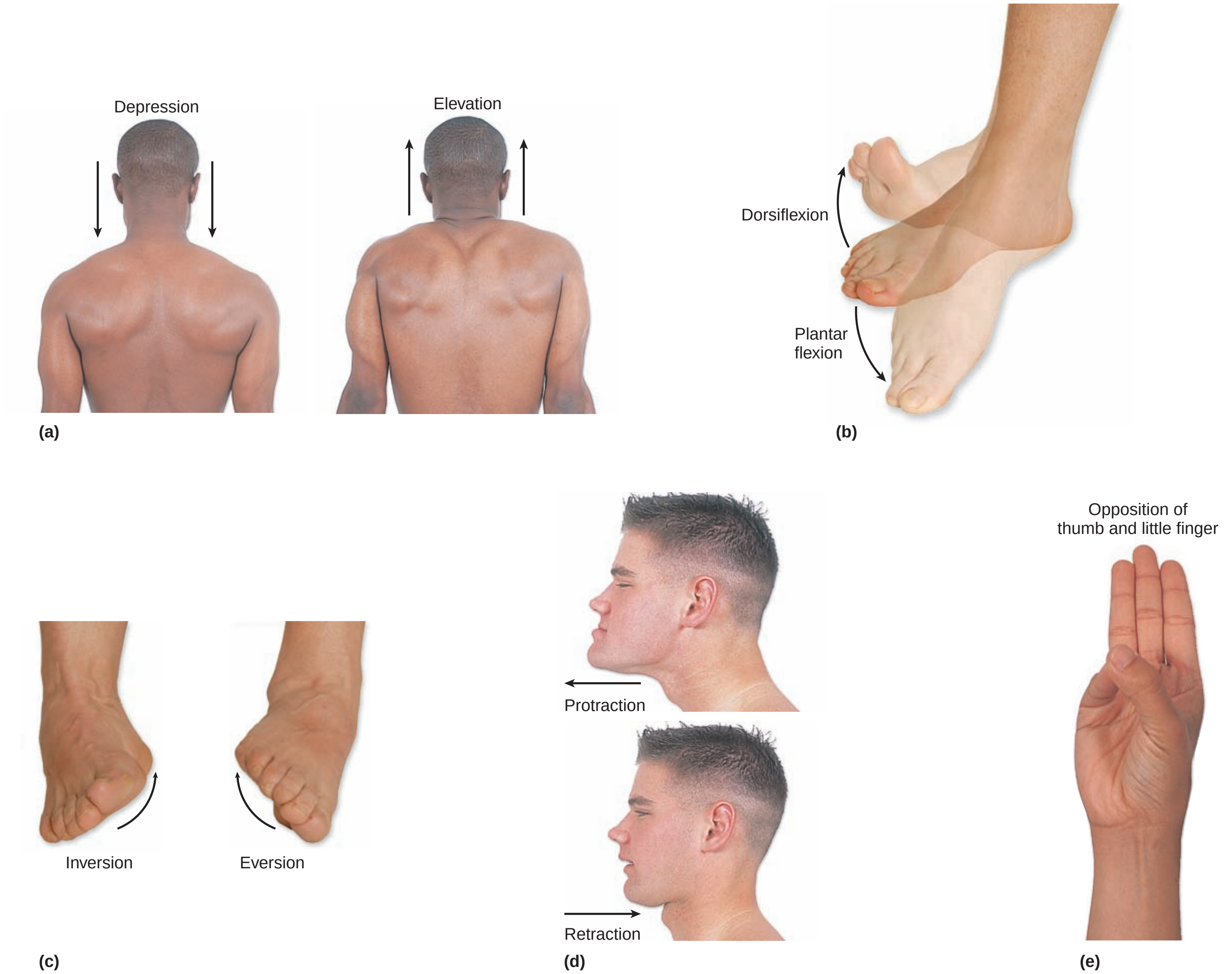


Figure 9.11

Special Movements Allowed at Synovial Joints. (*a*) Depression and elevation at the glenohumeral joint. (*b*) Dorsiflexion and plantar flexion at the talocrural joint. (*c*) Inversion and eversion at the intertarsal joints. (*d*) Protraction and retraction at the temporomandibular joint. (*e*) Opposition at the carpometacarpal joints.

Depression (*de* = away or down, *presso* = to press) is the inferior movement of a part of the body. Examples of depression include the movement of the mandible while opening your mouth to chew food and the movement of your shoulders in an inferior direction. **Elevation** is the superior movement of a body part. Examples of elevation include the superior movement of the mandible while closing your mouth at the temporomandibular joint and the movement of the shoulders in a superior direction (shrugging your shoulders). **Figure 9.11*a*** illustrates depression and elevation at the glenohumeral joint.

Dorsiflexion and plantar flexion are limited to the ankle joint (figure 9.11*b*). **Dorsiflexion** (dōr-si-flek′shŭn) occurs when the talocrural (ankle) joint is bent such that the superior surface of the foot and toes moves toward the leg. This movement occurs when you dig in your heels, and it prevents your toes from scraping the ground when you take a step. In **plantar** (plan′tăr; *planta* = sole of foot) **flexion,** movement at the talocrural joint permits extension of the foot so that the toes point inferiorly. When a ballerina is standing on her tiptoes, her ankle joint is in full plantar flexion.

Inversion and eversion are movements that occur at the intertarsal joints of the foot only (figure 9.11*c*). In **inversion** (in-ver′zhŭn; turning inward), the sole of the foot turns medially. In **eversion** (ē-ver′zhŭn; turning outward), the sole turns to face laterally. (Note: Some orthopedists and runners use the terms pronation and supination when describing foot movements as well, instead of using inversion and eversion. Inversion is foot supination, whereas eversion is foot pronation.)

Protraction (prō-trak′shŭn; to draw forth) is the anterior movement of a body part from anatomic position, as when moving your jaw anteriorly at the temporomandibular joint or hunching your shoulders anteriorly by crossing your arms. In the latter case, the clavicles move anteriorly due to movement at both the acromioclavicular and sternoclavicular joints. **Retraction** (rū-trak′shŭn; to draw back) is the posteriorly directed movement of a body part from anatomic position. Figure 9.11*d* illustrates protraction and retraction at the temporomandibular joint.

At the carpometacarpal joint, the thumb moves toward the palmar tips of the fingers as it crosses the palm of the hand. This movement is called **opposition** (op′pō-si′shŭn) (figure 9.11*e*). It enables the hand to grasp objects and is the most distinctive digital movement in humans. The opposite movement is called reposition.

Study Tip!

When your mother tells you to "pull your shoulders back and stand up straight," you are *retracting* your shoulders. Conversely, when you are slumped forward in a chair, your shoulders are protracted.

WHAT DID YOU LEARN?

5 What are the basic characteristics of all types of synovial joints?

6 Compare the structure and motion permitted in saddle and condylar joints.

7 Describe the following types of movements, and give an example of each: (a) flexion, (b) circumduction, and (c) opposition.

9.5 Selected Articulations in Depth

Learning Objective:

1. **Describe the characteristics of the major articulations of the axial and appendicular skeletons.**

In this section, we examine the structure and function of the more commonly known articulations of the axial and appendicular skeletons. For the axial skeleton, we present in-depth descriptions of the temporomandibular joint and the intervertebral articulations. **Table 9.3** summarizes the main features of these two areas and also provides comparable information about the other major joints of the axial skeleton.

9.5a Joints of the Axial Skeleton

Temporomandibular Joint

The **temporomandibular** (tem′pŏ-rō-man-dib′ū-lăr) **joint (TMJ)** is the articulation formed at the point where the head of the mandible articulates with the articular tubercle of the temporal bone anteriorly and the mandibular fossa posteriorly. This small, complex articulation is the only mobile joint between skull bones. The temporomandibular joint has several unique anatomic features **(figure 9.12)**. A loose **articular capsule** surrounds the joint and promotes an extensive range of motion. The TMJ is poorly stabilized, and thus a forceful anterior or lateral movement of the mandible can result in partial or complete dislocation of the mandible. The joint contains an **articular disc,** which is a thick pad of fibrocartilage separating the articulating bones and extending horizontally to divide the joint cavity into two separate chambers. As a result, the temporomandibular joint is really two synovial joints—one between the temporal bone and the articular disc, and a second between the articular disc and the mandible.

Several ligaments support this joint. The **sphenomandibular ligament** (an extracapsular ligament) is a thin band that extends anteriorly and inferiorly from the sphenoid to the medial surface of the mandibular ramus. The **stylomandibular ligament** (an extracapsular ligament) is a thick band that extends from the styloid process of the temporal bone to the mandibular angle. The **temporomandibular ligament** (or *lateral ligament*) is composed of two short bands on the lateral portion of the articular capsule. These

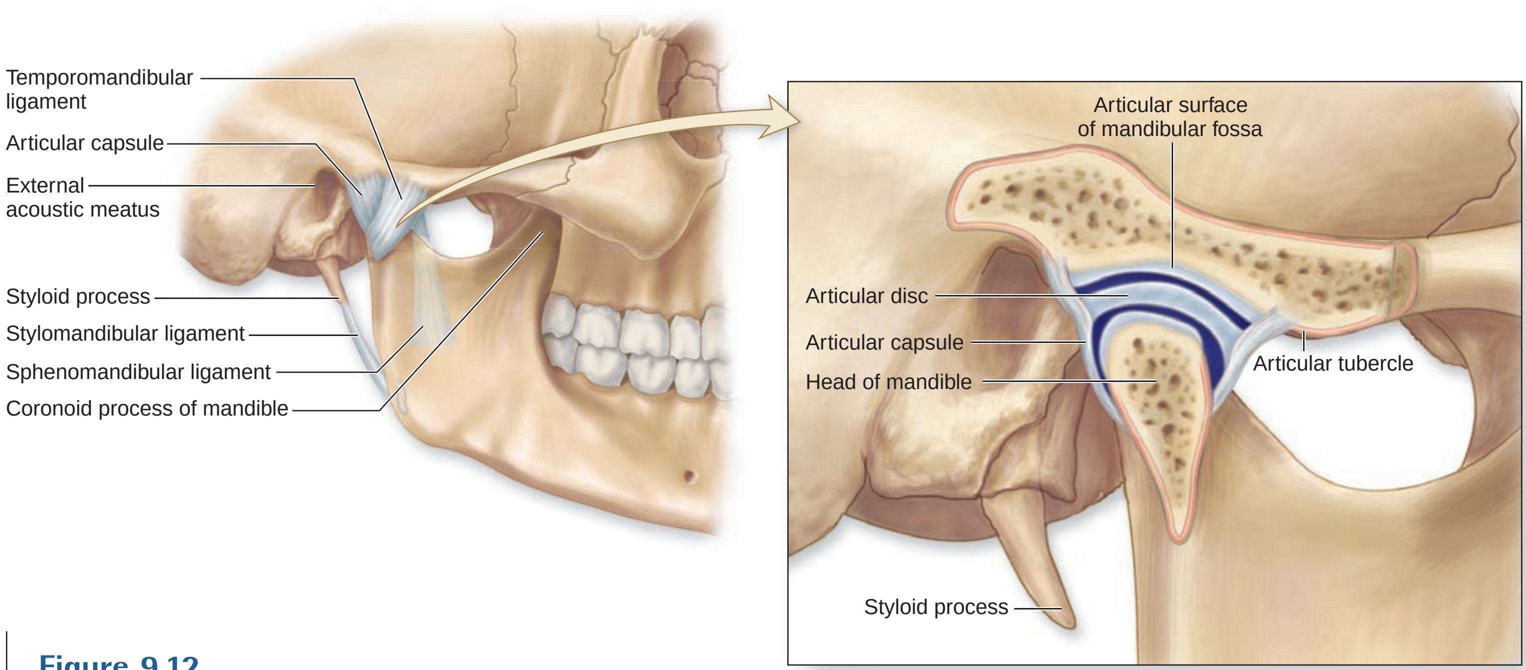
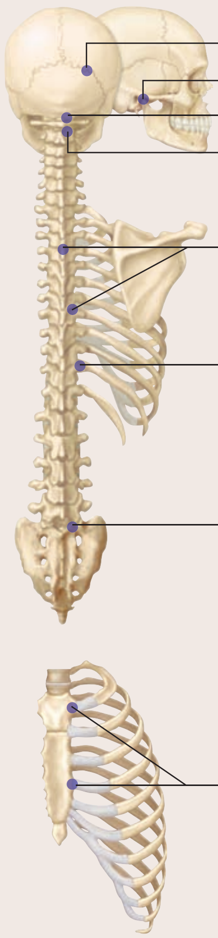


Figure 9.12

Temporomandibular Joint. The articulation between the head of the mandible and the mandibular fossa of the temporal bone exhibits a wide range of movements.

Table 9.3 Axial Skeleton Joints



Joint	Articulation Components	Structural Classification
Suture	Adjacent skull bones	Fibrous joint
Temporomandibular	Head of mandible and mandibular fossa of temporal bone Head of mandible and articular tubercle of temporal bone	Synovial (hinge, plane) joints
Atlanto-occipital	Superior articular facets of atlas and occipital condyles of occipital bone	Synovial (condylar) joint
Atlantoaxial	Anterior arch of atlas and dens of axis	Synovial (pivot) joint
Intervertebral	Vertebral bodies of adjacent vertebrae Superior and inferior articular processes of adjacent vertebrae	Cartilaginous joint (symphysis) between vertebral bodies; synovial (plane) joint between articular processes
Vertebrocostal	Facets of heads of ribs and bodies of adjacent thoracic vertebrae and intervertebral discs between adjacent vertebrae Articular part of tubercles of ribs and facets of transverse processes of thoracic vertebrae	Synovial (plane) joint
Lumbosacral	Body of the fifth lumbar vertebra and base of the sacrum Inferior articular facets of fifth lumbar vertebra and superior articular facets of first sacral vertebra	Cartilaginous joint (symphysis) between lumbar body and base of sacrum; synovial (plane) joint between articular facets
Sternocostal	Sternum and first seven pairs of ribs	Cartilaginous joint (synchondrosis) between sternum and first ribs; synovial (plane) joint between sternum and ribs 2–7

bands extend inferiorly and posteriorly from the articular tubercle to the mandible.

The temporomandibular joint exhibits hinge, gliding, and some pivot joint movements. It functions like a hinge during jaw depression and elevation while chewing. It glides slightly forward during protraction of the jaw for biting, and glides slightly from side-to-side to grind food between the teeth during chewing.

Intervertebral Articulations

Intervertebral articulations occur between the bodies of the vertebrae, as well as between the superior and inferior articular processes of adjacent vertebrae. All of the vertebral bodies, between the axis (C_2) and the sacrum, are separated and cushioned by pads of fibrocartilage called **intervertebral discs** **(figure 9.13).** Each intervertebral disc consists of two components: (1) an anulus fibrosus and (2) a nucleus pulposus. The **anulus fibrosus** is the tough outer layer of fibrocartilage that covers each intervertebral disc. The anulus fibrosus contains collagen fibers that attach the disc to the bodies of adjacent vertebrae. The anulus fibrosus also shares connections with many of the ligaments that run along the bodies of the vertebrae. The **nucleus pulposus** is the inner gelatinous core of the disc and is primarily composed of water, with some scattered reticular and elastic fibers.

Two factors compress the substance of the nucleus pulposus and displace it in every direction—movement of the vertebral column and the weight of the body. However, as humans age, water is gradually lost from the nucleus pulposus within each disc. Thus, over time the discs become less effective as a cushion, and the chances for vertebral injury increase. Loss of water by the discs also contributes to the shortening of the vertebral column, which accounts for the characteristic decrease in height that occurs with advanced age.

Several ligaments stabilize the vertebral column by supporting vertebrae through attachments to either their bodies or their

Functional Classification	Description of Movement
Synarthrosis	None allowed
Diarthrosis	Depression, elevation, lateral displacement, protraction, retraction, slight rotation
Diarthrosis	Extension and flexion of the head; slight lateral flexion of head to sides
Diarthrosis	Head rotation
Amphiarthrosis between vertebral bodies; diarthrosis between articular processes	Extension, flexion, lateral flexion of vertebral column
Diarthrosis	Some slight gliding
Amphiarthrosis between body and base; diarthrosis between articular facets	Extension, flexion, lateral flexion of vertebral column
Synarthrosis between sternum and first ribs; diarthrosis between sternum and ribs 2–7	No movement between sternum and first ribs; some gliding movement permitted between sternum and ribs 2–7

processes. The **anterior longitudinal ligament** is a thick, sturdy ligament that attaches vertebral bodies and intervertebral discs at their anterior surfaces. The **posterior longitudinal ligament** attaches the posterior aspects of the vertebral bodies and discs. It is much thinner than the anterior longitudinal ligament, and it runs within the vertebral canal. Multiple **interspinous ligaments** interconnect the spinous processes of adjacent vertebrae. Their angled fibers merge with the supraspinous ligament. The **supraspinous ligament** interconnects the tips of the spinous processes from C_7 to the sacrum. The **ligamentum** (lig′ă-men′tŭm) **nuchae** (noo′kē; back of neck) is the part of the supraspinous ligament that extends between C_7 and the base of the skull. The ligamentum nuchae is very thick and sturdy, and helps stabilize the skull on the cervical vertebrae. The **ligamentum flavum** (flā′vŭm) connects the laminae of adjacent vertebrae.

A second type of intervertebral articulation occurs at the synovial joints between adjacent superior and inferior articular

CLINICAL VIEW

TMJ Disorders

The temporomandibular joint (TMJ) is subject to various disorders. The most common TMJ disorder occurs as a result of alternations in the ligaments that secure the joint, causing progressive internal displacement of the articular disc. As the articular disc is forced out of its normal position, a clicking or popping noise may be heard as the person opens or closes the mouth. Other symptoms may include headaches and sinus pressure as well as pain in such areas as the paranasal sinuses, tympanic membrane, oral cavity, eyes, and teeth. The widespread distribution of pain is due to the fact that all of these structures, including the muscle and jaw, are innervated by numerous sensory fibers of the trigeminal nerve.

TMJ disorders are often seen in people who habitually chew gum or grind or clench their teeth. Patients are advised to avoid activities that cause jaw fatigue and to follow a soft diet. The physician may also prescribe a bite appliance for the patient to wear at night to prevent grinding and clenching of the teeth. Surgery can correct structural TMJ disorders, but is usually used only as a last resort.

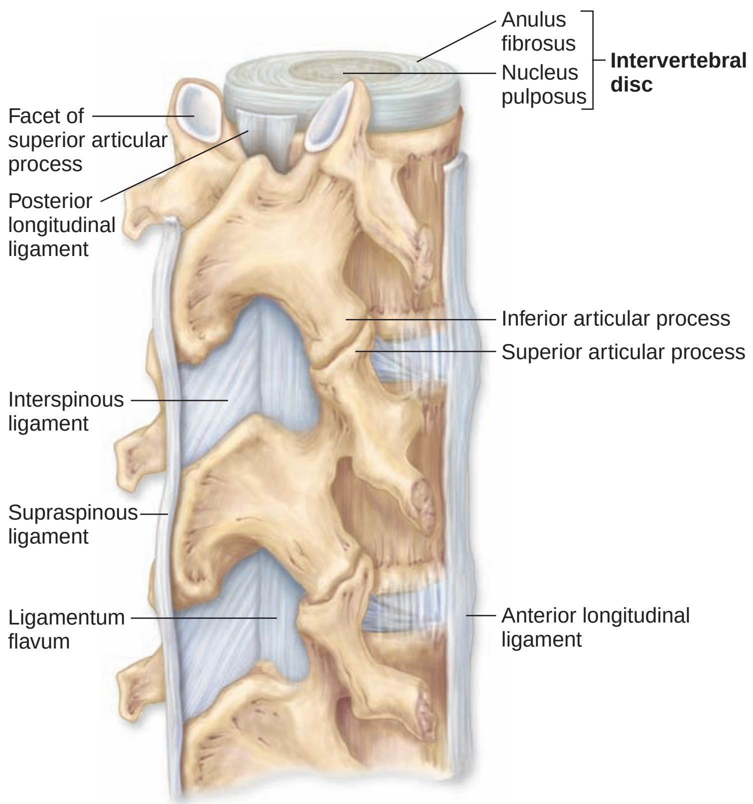
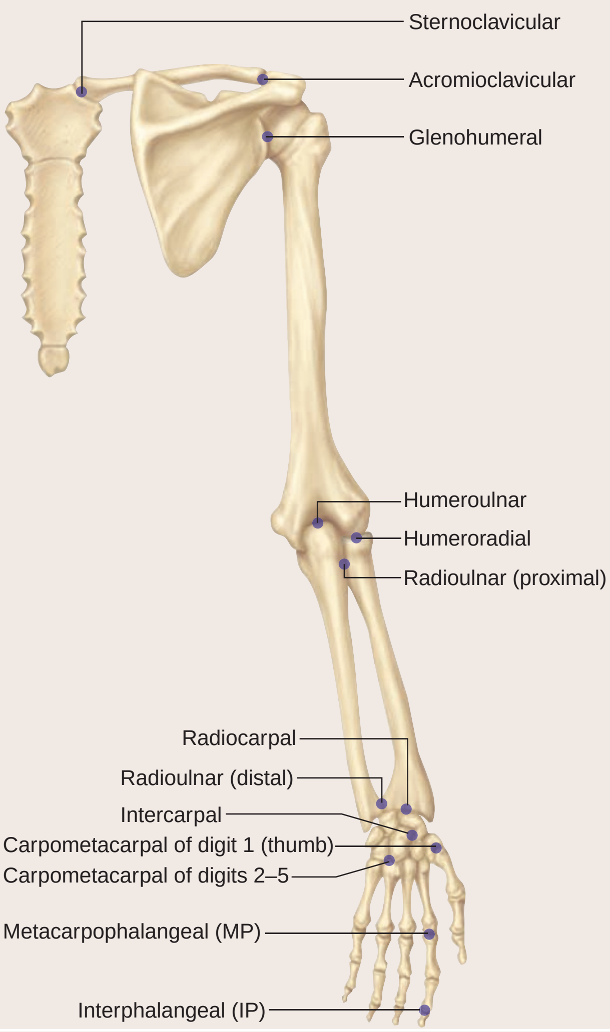


Figure 9.13

Intervertebral Articulations. Vertebrae articulate with adjacent vertebrae at both their superior and inferior articular processes. Intervertebral discs separate the bodies of adjacent vertebrae.

Table 9.4 Pectoral Girdle and Upper Limb Joints



Joint	Articulation Components
Sternoclavicular	Sternal end of clavicle, manubrium of sternum, and first costal cartilage
Acromioclavicular	Acromial end of clavicle and acromion of scapula
Glenohumeral	Glenoid cavity of scapula and head of humerus
Humeroulnar	Trochlea of humerus and trochlear notch of ulna
Humeroradial	Capitulum of humerus and head of radius
Radioulnar	**Proximal joint:** Head of radius and radial notch of ulna **Distal joint:** Distal end of ulna and ulnar notch of radius
Radiocarpal	Distal end of radius; lunate, scaphoid, and triquetrum
Intercarpal	Adjacent bones in proximal row of carpal bones Adjacent bones in distal row of carpal bones Adjacent bones between proximal and distal rows (midcarpal joints)
Carpometacarpal	Thumb: Trapezium (carpal bone) and first metacarpal Other digits: Carpals and metacarpals II–V
Metacarpophalangeal (MP joints, "knuckles")	Head of metacarpals and bases of proximal phalanges
Interphalangeal (IP joints)	Heads of proximal and middle phalanges with bases of middle and distal phalanges, respectively

processes. The articular facets of the superior and inferior articular processes form plane joints that permit restricted gliding movements. An articular capsule surrounds these articular processes.

The movement possible between a single set of vertebrae is limited. However, when you add the movements of all the intervertebral joints of all the vertebrae together, an entire range of movements becomes possible, including flexion, extension, lateral flexion, and some rotation.

WHAT DO YOU THINK?

4 In which position does the anterior longitudinal ligament become taut: flexion or extension?

9.5b Joints of the Pectoral Girdle and Upper Limbs

Table 9.4 lists the features of the major joints of the pectoral girdle and upper limbs. Here, we provide an in-depth examination of several of these joints.

Sternoclavicular Joint

The **sternoclavicular** (ster′nō-kla-vik′ū-lăr) **joint** is a saddle joint formed by the articulation between the manubrium of the sternum and the sternal end of the clavicle **(figure 9.14)**. An **articular disc** partitions the sternoclavicular joint into two parts and creates two separate joint cavities. As a result, a wide range of movements is possible, including elevation, depression, and circumduction.

Support and stability are provided to this articulation by the fibers of the articular capsule. The **anterior sternoclavicular ligament** and the **posterior sternoclavicular ligament** reinforce the capsule. In addition, two extracapsular ligaments also help strengthen the joint: (1) The clavicle is attached to the first rib by the strong, wide **costoclavicular ligament.** This ligament stabilizes the joint and prevents dislocation of the shoulder when the shoulder is elevated. (2) The **interclavicular ligament** runs along the sternal notch and attaches to each clavicle. It reinforces the superior regions of the adjacent capsules. This design makes

Structural Classification	Functional Classification	Description of Movement
Synovial (saddle)	Diarthrosis	Elevation, depression, circumduction
Synovial (plane)	Diarthrosis	Gliding of scapula on clavicle
Synovial (ball-and-socket)	Diarthrosis	Abduction, adduction, circumduction, extension, flexion, hyperextension, lateral rotation, and medial rotation of arm
Synovial (hinge)	Diarthrosis	Extension and flexion of forearm
Synovial (hinge)	Diarthrosis	Extension and flexion of forearm
Synovial (pivot)	Diarthrosis	Rotation of radius with respect to the ulna
Synovial (condylar)	Diarthrosis	Abduction, adduction, circumduction, extension, and flexion of wrist
Synovial (plane)	Diarthrosis	Gliding
Synovial (saddle) at thumb; synovial (plane) at other digits	Diarthrosis	Abduction, adduction, circumduction, extension, flexion, and opposition at thumb; gliding at other digits
Synovial (condylar)	Diarthrosis	Abduction, adduction, circumduction, extension, and flexion of phalanges
Synovial (hinge)	Diarthrosis	Extension and flexion of phalanges

the sternoclavicular joint very stable. If a person falls on an outstretched hand so that force is applied to the joint, the clavicle will fracture before this joint ever dislocates.

Acromioclavicular Joint

The **acromioclavicular** (ă-krō′mē-ō-kla-vik′ū-lăr) **joint** is a plane joint between the acromion and the acromial end of the clavicle **(figure 9.15)**. A fibrocartilaginous **articular disc** lies within the joint cavity between these two bones. This joint works with both the sternoclavicular joint and the glenohumeral joint to give the upper limb a full range of movement.

Several ligaments provide great stability to this joint. The articular capsule is strengthened superiorly by an **acromioclavicular ligament**. In addition, a very strong **coracoclavicular** (kōr′ă-kō-kla-vik′ū-lăr) **ligament** binds the clavicle to the coracoid process of the scapula. The coracoclavicular ligament is responsible for most of the stability of the joint, because it indirectly prevents the clavicle from losing contact with the acromion. If this ligament is

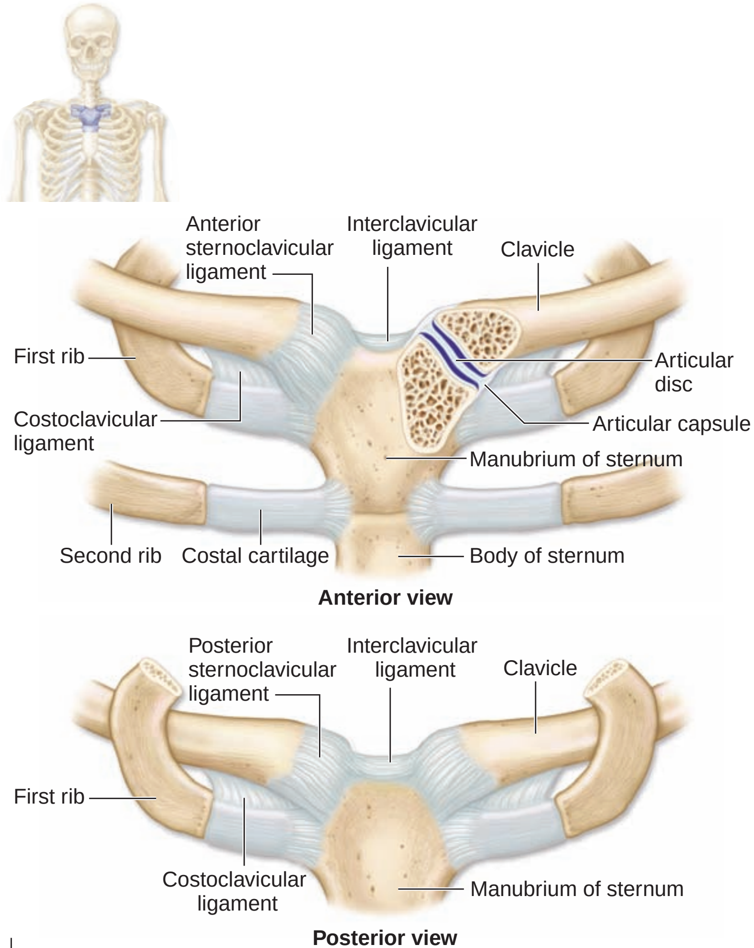


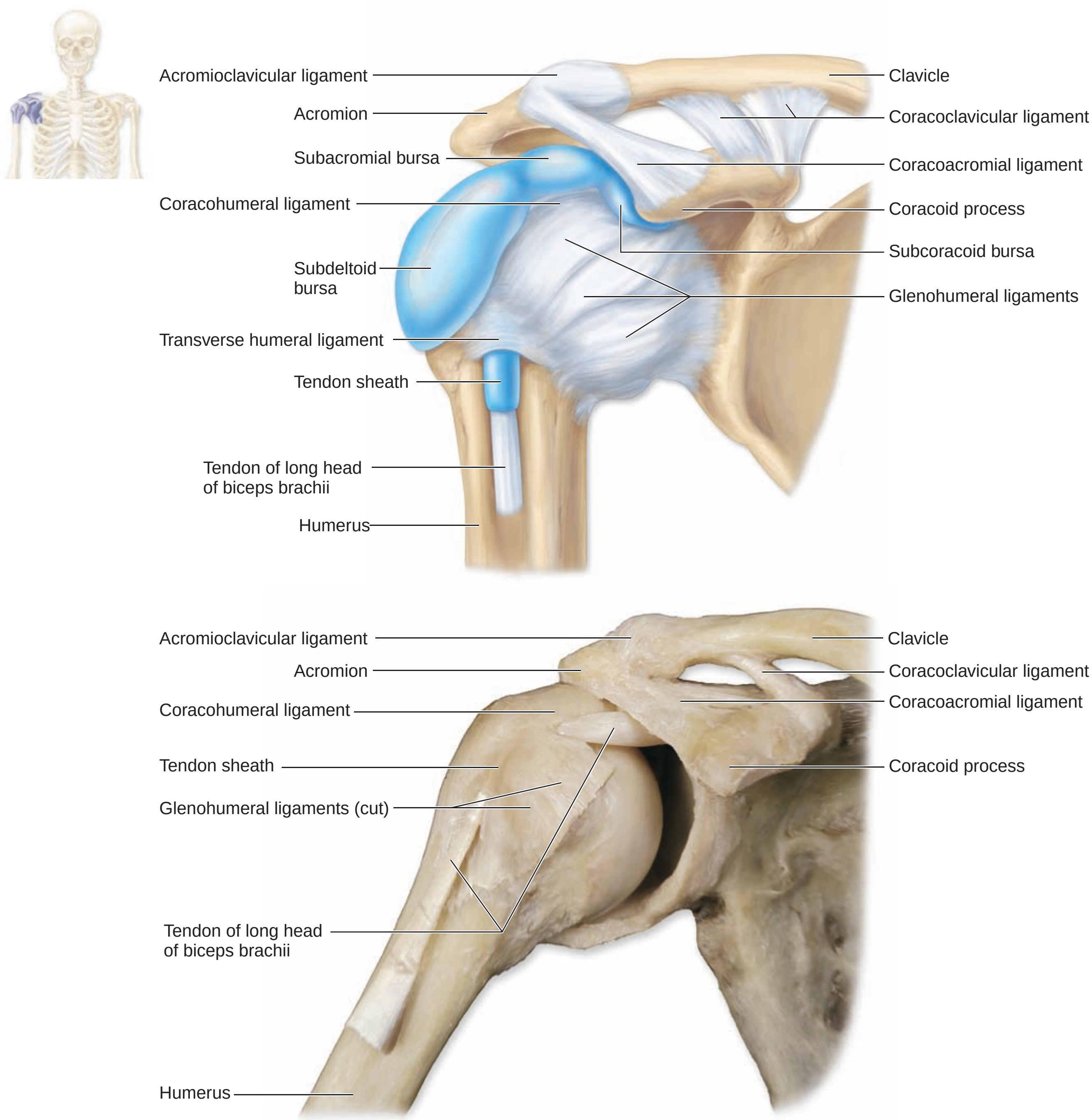
Figure 9.14
Sternoclavicular Joint. The sternoclavicular joint helps stabilize movements of the entire shoulder.

torn (as occurs in severe shoulder separations; see Clinical View), the acromion and clavicle no longer align properly.

Glenohumeral (Shoulder) Joint

The **glenohumeral** (glē′nō-hū′mer-ăl) **joint** is commonly referred to as the shoulder joint. It is a ball-and-socket joint formed by the articulation of the head of the humerus and the glenoid cavity of the scapula (figure 9.15). It permits the greatest range of motion of any joint in the body, and so it is also the most unstable joint in the body and the one most frequently dislocated.

The fibrocartilaginous **glenoid labrum** encircles and covers the surface of the glenoid cavity. A relatively loose articular capsule attaches to the surgical neck of the humerus. The glenohumeral joint has several major ligaments. The **coracoacromial** (kōr′ă-kō-ă-krō′mē-ăl) **ligament** extends across the space between the coracoid process and the acromion. The large **coracohumeral** (kōr′ă-kō-hū′mer-ăl) **ligament** is a thickening of the superior part of the joint capsule. It runs from the coracoid process to the humeral head. The **glenohumeral ligaments** are three thickenings of the anterior portion of the articular capsule. These ligaments are often indistinct or absent and provide only minimal support. The **transverse humeral ligament** is a narrow sheet that extends between the greater and lesser tubercles of the humerus. In addition, the **tendon of the long head of biceps brachii** travels within the articular capsule and helps stabilize the humeral head in the joint.



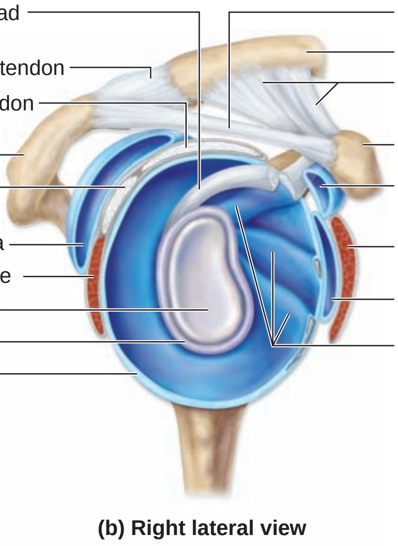
(a) Right shoulder region, anterior view

Figure 9.15

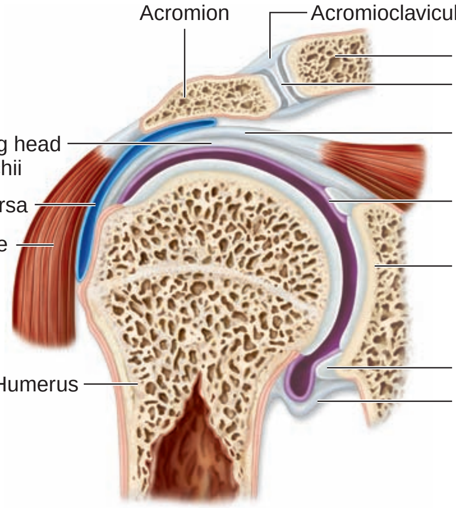
Acromioclavicular and Glenohumeral Joints. (*a*) Anterior diagrammatic view and cadaver photo of both joints on the right side of the body. (*b*) Right lateral view and (*c*) right coronal section show the articulating bones and supporting structures at the shoulder.

Ligaments of the glenohumeral joint strengthen the joint only minimally. Most of the joint's strength is due to the **rotator cuff** muscles surrounding it. The rotator cuff muscles (supraspinatus, infraspinatus, teres minor, and subscapularis) work as a group to hold the head of the humerus in the glenoid cavity. The tendons of these muscles encircle the joint (except for the inferior portion) and fuse with the articular capsule. Because the inferior portion of the joint lacks rotator cuff muscles, this area is weak and is the most likely site of injury.

Bursae help decrease friction at the specific places on the shoulder where both tendons and large muscles extend across the articular capsule. The shoulder has a relatively large number of bursae. The **subacromial** (sŭb-ă-krō′mē-ăl) **bursa** prevents rubbing between the acromion and the articular capsule. The



(b) Right lateral view



(c) Right coronal section

CLINICAL VIEW

Shoulder Separation

The term **shoulder separation** refers to a dislocation of the acromioclavicular joint. **Dislocation** (dis-lō-kā′shŭn; *dis* = apart, *locatio* = placing) is a joint injury in which the articulating bones have separated. This injury often results from a hard blow to the joint, as when a hockey player is "slammed into the boards." Shoulder separation is also common in wrestlers. The symptoms of a shoulder separation include:

- Tenderness and edema (swelling) in the area of the joint
- Surface deformity at the acromioclavicular joint; since the bones are displaced, the acromion is very prominent and appears more pointed.
- Pain when the arm is abducted more than 90 degrees, the position at which significant movement occurs between the separated clavicular and acromial surfaces

Acromioclavicular dislocations are graded according to severity. In the most severe injury, the joint is completely dislocated, and the coracoclavicular ligament is torn. Since the coracoclavicular ligament provides most of the stability to this joint, damage to it means the bones will not stay in alignment. The coracoclavicular ligament must be surgically repaired in order for the bones of the joint to remain fixed in place.

subcoracoid bursa prevents contact between the coracoid process and the articular capsule. The **subdeltoid bursa** and the **subscapular bursa** allow for easier movements of the deltoid and supraspinatus muscles, respectively.

Elbow Joint

The **elbow joint** is a hinge joint composed primarily of two articulations: (1) the humeroulnar joint, where the trochlear notch of the ulna articulates with the trochlea of the humerus; and (2) the humeroradial joint, where the capitulum of the humerus articulates with the head of the radius. These joints are enclosed within a single articular capsule **(figure 9.16)**.

The elbow is an extremely stable joint for several reasons. First, the articular capsule is fairly thick, and thus effectively protects the articulations. Second, the bony surfaces of the humerus and ulna interlock very well, and thus provide a solid bony support. Finally, multiple strong supporting ligaments help reinforce the articular capsule. Remember that there is a tradeoff between stability and mobility in a joint. Thus, while the elbow joint is very stable, it is not as mobile as some other joints, such as the glenohumeral joint.

The elbow joint has two main supporting ligaments. The **radial collateral ligament** (or *lateral collateral ligament*) is responsible for stabilizing the joint at its lateral surface; it extends around the head of the radius between the anular ligament and the lateral epicondyle of the humerus. The **ulnar collateral ligament** (or *medial collateral ligament*) stabilizes the medial side of the joint and extends from the medial epicondyle of the humerus to the coronoid process of the ulna, and posteriorly to the olecranon. In addition, an **anular** (an′ū-lăr; *anulus* = ring) **ligament** surrounds the neck of the radius and binds the proximal head of the radius to the ulna. The anular ligament helps hold the head of the radius in place, allowing for rotation of the radial head against the ulna for pronation and supination of the forearm.

Despite the support from the capsule and ligaments, the elbow joint is subject to damage from a severe impact or unusual

CLINICAL VIEW

Dislocation of the Glenohumeral Joint

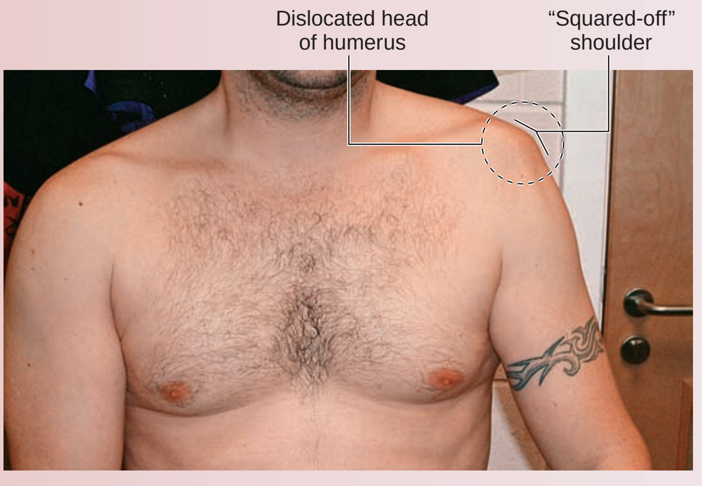
Because the glenohumeral joint is very mobile and yet unstable, dislocations are very common. Glenohumeral dislocations usually occur when a fully abducted humerus is struck hard—for example, when a quarterback is hit as he is about to release a football, or when a person falls on an outstretched hand.

The following sequence of events occurs in a glenohumeral dislocation:

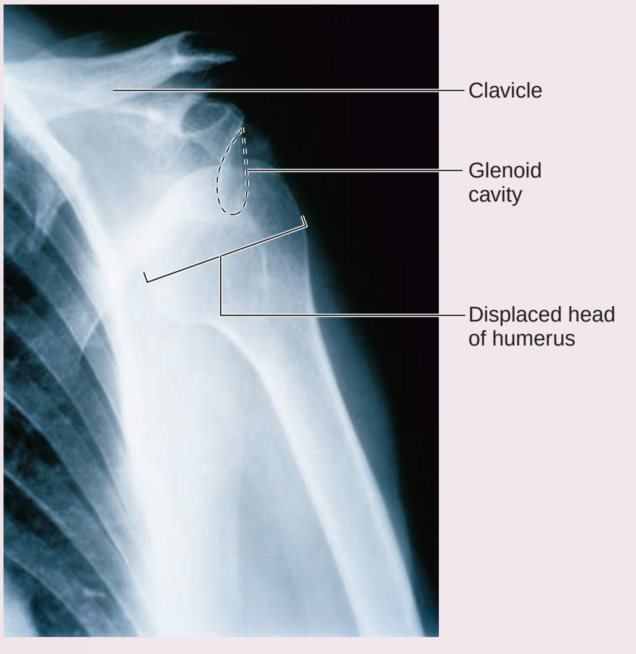
1. Immediately after the initial blow, the head of the humerus pushes into the inferior part of the articular capsule. (Recall the inferior part of the capsule is relatively weak and not protected by muscle tendons as the other surfaces of the capsule are.)
2. The head of the humerus tears the inferior part of the capsule and dislocates the humerus, so that the humerus lies inferior to the glenoid cavity.
3. Once the humeral head has become dislocated from the glenoid cavity, the anterior thorax (chest) muscles pull on the head superiorly and medially, causing the humeral head to lie just inferior to the coracoid process.

The result is that the shoulder appears flattened and "squared-off," because the humeral head is dislocated anteriorly and inferiorly to the glenohumeral joint capsule.

Some glenohumeral dislocations can be repaired by "popping" the humerus back into the glenoid cavity. More severe dislocations may need surgical repair.



(a) Dislocated glenohumeral joint



(b) Radiograph of a glenohumeral dislocation

stress. For example, if you fall on an outstretched hand with your elbow joint partially flexed, the posterior stress on the ulna combined with contractions of muscles that extend the elbow may break the ulna at the center of the trochlear notch. Sometimes dislocations result from stresses to the elbow. This is particularly true when growth is still occurring at the epiphyseal plate, so children and teenagers may be prone to humeral epicondyle dislocations or fractures.

Radiocarpal (Wrist) Joint

The **radiocarpal** (rā′dē-ō-kar′păl) **joint,** also known as the wrist joint, is an articulation among the three proximal carpal bones (scaphoid, lunate, and triquetrum), the distal articular surface of the radius, and a fibrocartilaginous **articular disc** **(figure 9.17)**. This articular disc separates the ulna from the radiocarpal joint (which is why the ulna is not considered part of this joint). The entire wrist complex is ensheathed by an articular capsule that has reinforcing broad ligaments to support and stabilize the carpal bone positions. The radiocarpal joint is a condylar articulation that permits flexion, extension, adduction, abduction, and circumduction, but no rotation. Rotational movements (in the form of supination and pronation) occur at the distal and proximal radioulnar joints.

Additional movements in the carpus region are made possible by **intercarpal articulations,** which are plane joints that permit gliding movements between the individual carpal bones.

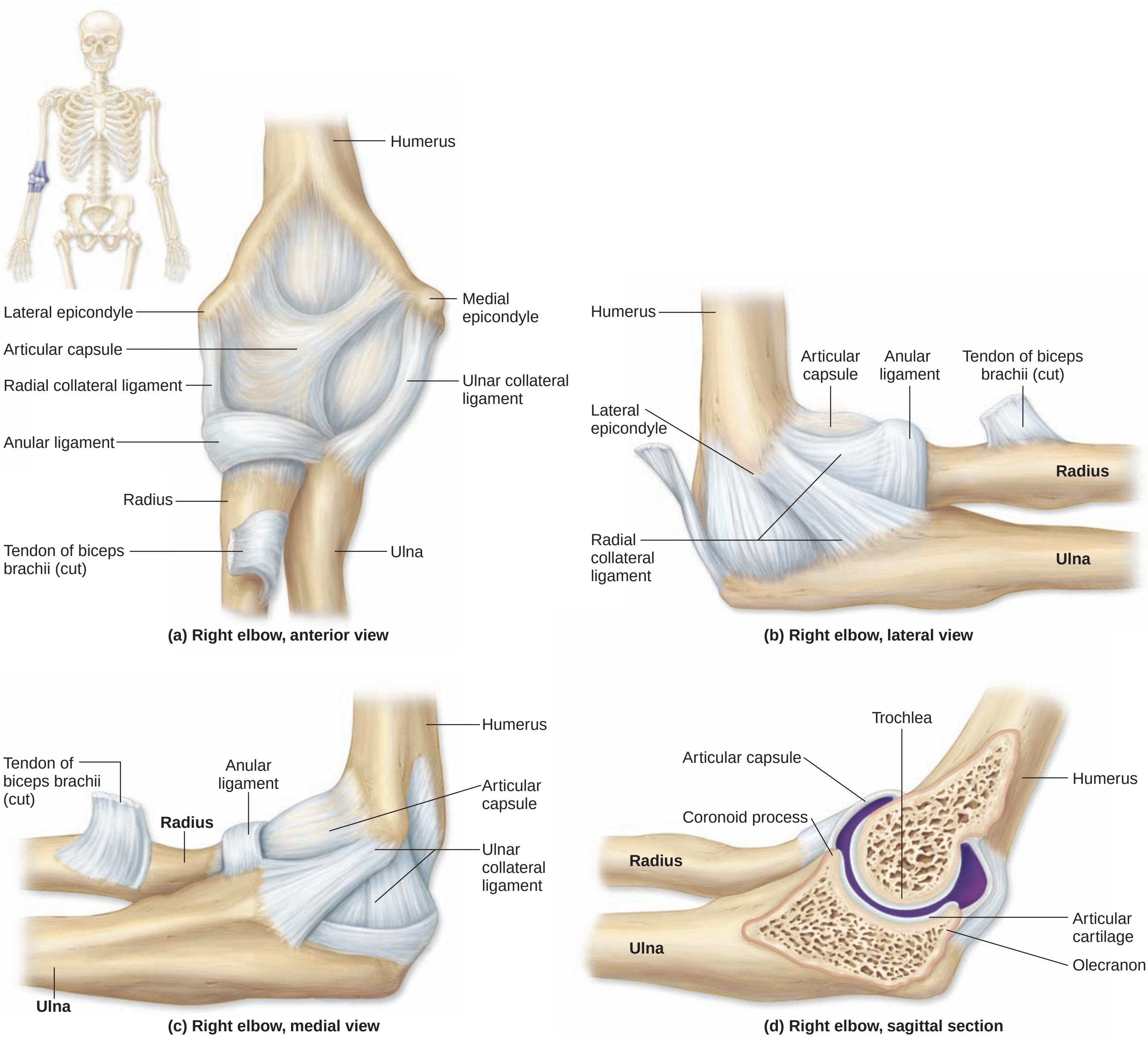


Figure 9.16

Elbow Joint. The elbow joint is a hinge joint. The right elbow is shown here in (*a*) anterior view, (*b*) lateral view, (*c*) medial view, and (*d*) sagittal section.

WHAT DID YOU LEARN?

8. Describe the structural arrangement and function of the anulus fibrosus and the nucleus pulposus in an intervertebral disc.
9. Which ligaments limit the relative mobility of the clavicle at the sternal end? At the acromial end?
10. Which structures are the primary stabilizers of the glenohumeral joint?
11. What is the function of the anular ligament in the elbow joint?

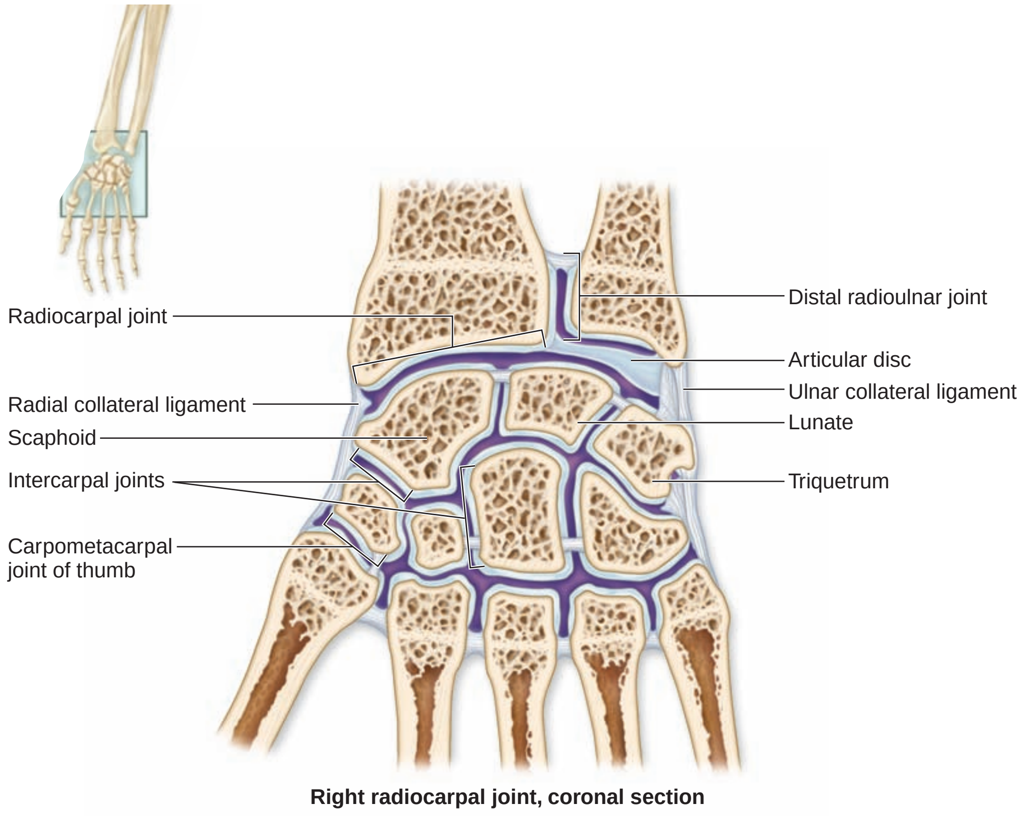


Figure 9.17

Radiocarpal Joint. A right coronal section depicts the condylar articulation between the radius and three proximal carpal bones.

CLINICAL VIEW

Subluxation of the Radial Head

The term **subluxation** refers to an incomplete dislocation, in which the contact between the bony joint surfaces is altered, but they are still in partial contact. In subluxation of the head of the radius, the head is pulled out of the anular ligament. Laymen's terms for this injury include "pulled elbow," "nursemaid's elbow," or "slipped elbow." This injury occurs commonly and almost exclusively in children (typically those younger than age 5), because a child's anular ligament is thin and the head of the radius is not fully formed. Thus, it is much easier for the head of the radius to be pulled out of the anular ligament. After age 5, both the ligament and the radial head are more fully formed, and the risk of this type of injury lessens dramatically.

A classic example of subluxation of the radial head occurs when a parent or caregiver suddenly pulls on a child's pronated forearm, and the child, resisting, puts his or her upper limb in a flexed and partially pronated position. As the child resists moving and the adult pulls on the upper limb, the head of the radius pulls out of the anular ligament. The child later complains of pain on the lateral side of the elbow, where a prominent "bump" (caused by the subluxated radial head) also appears. Luckily, treatment is simple: The pediatrician applies posteriorly placed pressure to the head of the radius while slowly supinating and extending the child's forearm. This movement literally "screws" the radial head back into the anular ligament. In most cases, this manual treatment brings immediate relief. A child who has had this injury may be more likely to reinjure this articulation prior to age 5.

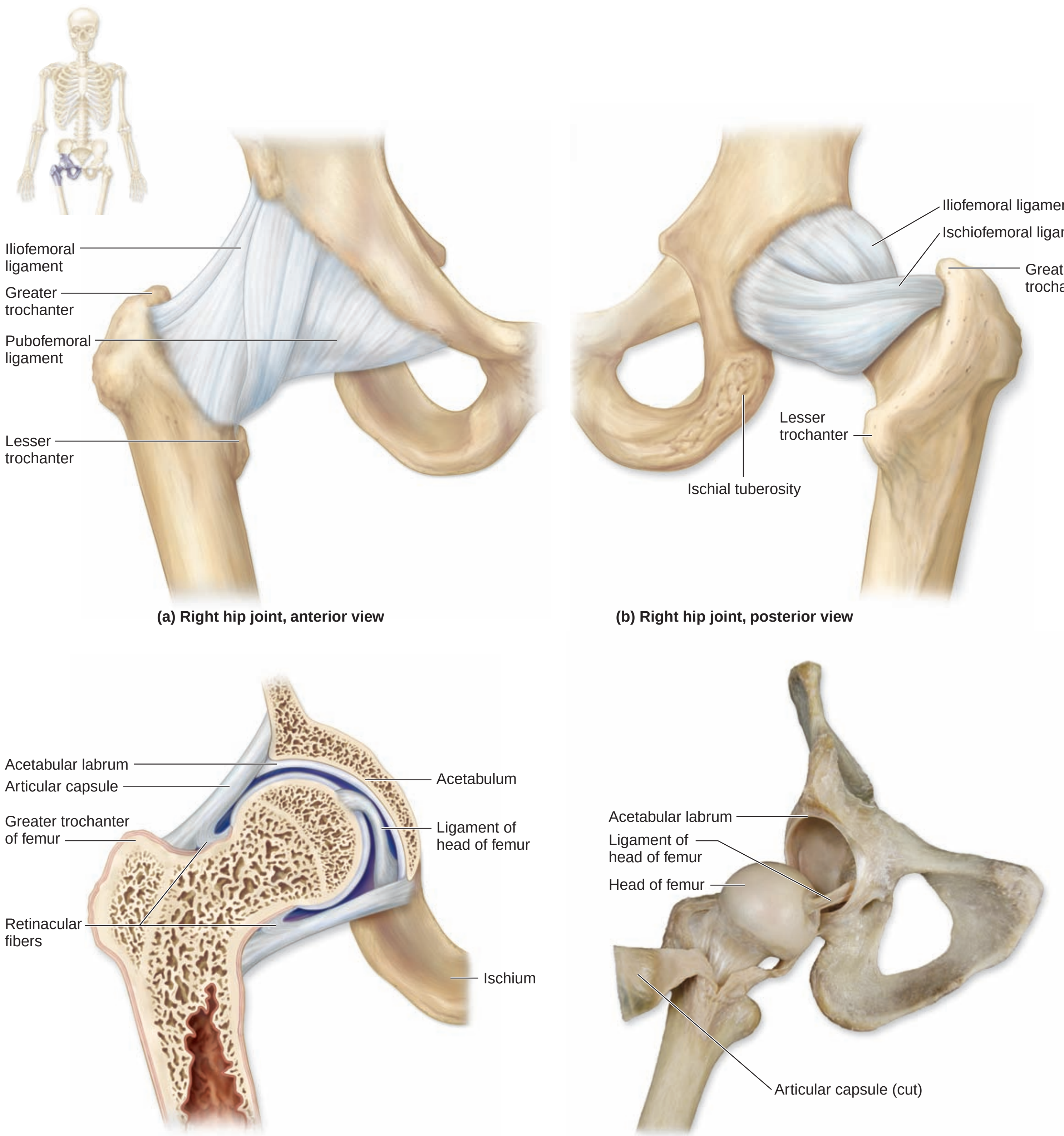
9.5c Joints of the Pelvic Girdle and Lower Limbs

Table 9.5 lists the features of the major joints of the pelvic girdle and lower limbs. Here, we provide an in-depth examination of several of these joints.

Hip (Coxal) Joint

The **hip joint,** also called the *coxal joint,* is the articulation between the head of the femur and the relatively deep, concave acetabulum of the os coxae **(figure 9.18)**. A fibrocartilaginous **acetabular labrum** further deepens this socket. The hip joint's more extensive bony architecture is therefore much stronger and more stable than that of the glenohumeral joint. Conversely, the hip joint's increased stability means that it is less mobile than the glenohumeral joint. The hip joint must be more stable (and thus less mobile) because it supports the body weight.

The hip joint is secured by a strong articular capsule, several ligaments, and a number of powerful muscles. The articular capsule extends from the acetabulum to the trochanters of the femur, enclosing both the femoral head and neck. This arrangement prevents the head from moving away from the acetabulum. The ligamentous fibers of the articular capsule reflect around the neck of the femur. These reflected fibers, called **retinacular** (ret-i-nak′ū-lăr; retinacula =



(a) Right hip joint, anterior view

(b) Right hip joint, posterior view

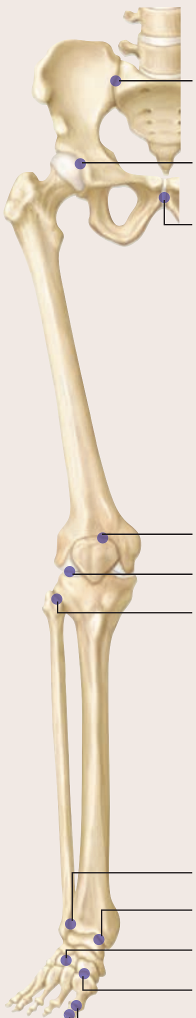
(c) Right hip joint, coronal section

(d) Right hip joint, anterior view, internal aspect of joint

Figure 9.18

Hip Joint. The hip joint is formed by the head of the femur and the acetabulum of the os coxae. The right hip joint is shown in (*a*) anterior view, (*b*) posterior view, and (*c*) coronal section. (*d*) Cadaver photo of the hip joint, with the articular capsule cut to show internal structures.

Table 9.5 Pelvic Girdle and Lower Limb Joints



Joint	Articulation Components	Structural Classification
Sacroiliac	Auricular surfaces of sacrum and ilia	Synovial (plane)
Hip (coxal)	Head of femur and acetabulum of os coxae	Synovial (ball-and-socket)
Pubic symphysis	Two pubic bones	Cartilaginous (symphysis)
Knee	**Patellofemoral joint:** Patella and patellar surface of femur **Tibiofemoral joint:** Condyles of femur and condyles of tibia	Both synovial (acts as hinge) and synovial (plane) at patellofemoral joint; synovial (acts as hinge) at tibiofemoral joint[1]
Tibiofibular	**Superior joint:** Head of fibula and lateral condyle of tibia **Inferior joint:** Distal end of fibula and fibular notch of tibia	**Superior joint:** Synovial (plane) **Inferior joint:** Fibrous (syndesmosis)
Talocrural	Distal end of tibia and medial malleolus with talus Lateral malleolus of fibula and talus	Synovial (hinge)
Intertarsal	Between the tarsal bones	Synovial (plane)
Tarsometatarsal	Three cuneiforms (tarsal bones), cuboid, and bases of five metatarsal bones	Synovial (plane)
Metatarsophalangeal (MP joints)	Heads of metatarsals and bases of proximal phalanges	Synovial (condylar)
Interphalangeal (IP joints)	Heads of proximal and middle phalanges with bases of middle and distal phalanges, respectively	Synovial (hinge)

1. Although anatomists classify the tibiofemoral joint as a hinge joint, some kinesiologists and exercise scientists prefer to classify the tibiofemoral joint as a modified condylar joint.

a band) **fibers,** provide additional stability to the capsule. Traveling through the retinacular fibers are retinacular arteries (branches of the deep femoral artery), which supply almost all of the blood to the head and neck of the femur.

The articular capsule is reinforced by three spiraling intracapsular ligaments. The **iliofemoral** (il′ē-ō-fem′ŏ-răl) **ligament** is a Y-shaped ligament that provides strong reinforcement for the anterior region of the articular capsule. The **ischiofemoral** (is-kē-ō-fem′ŏ-răl) **ligament** is a spiral-shaped, posteriorly located ligament. The **pubofemoral** (pū′bō-fem′ŏ-răl) **ligament** is a triangular thickening of the capsule's inferior region. All of these spiraling ligaments become taut when the hip joint is extended, so the hip joint is most stable in the extended position. Try this experiment: Flex your hip joint, and try to move the femur; you may notice a great deal of mobility. Now extend your hip joint (stand up), and try to move the femur. Because those ligaments are taut, you don't have as much mobility in the joint as you did when the hip joint was flexed.

Another tiny ligament, the **ligament of head of femur,** also called the *ligamentum teres,* originates along the acetabulum. Its attachment point is the center of the head of the femur. This ligament does not provide much strength to the joint; rather, it typically contains a small artery that supplies the head of the femur.

The combination of a deep bony socket, a strong articular capsule, supporting ligaments, and muscular padding gives the hip joint its stability. Movements possible at the hip joint include flexion, extension, abduction, adduction, rotation, and circumduction.

Knee Joint

The **knee joint** is the largest and most complex diarthrosis of the body **(figure 9.19)**. It primarily functions as a hinge joint, but

Functional Classification	Description of Movement
Diarthrosis	Slight gliding; more movement during pregnancy and childbirth
Diarthrosis	Abduction, adduction, circumduction, extension, flexion, medial and lateral rotation of thigh
Amphiarthrosis	Very slight movements; more movement during childbirth
Diarthrosis	Extension, flexion, lateral rotation of leg in flexed position, slight medial rotation
Amphiarthrosis	Slight rotation of fibula during dorsiflexion of foot
Diarthrosis	Dorsiflexion and plantar flexion
Diarthrosis	Eversion and inversion of foot
Diarthrosis	Slight gliding
Diarthrosis	Abduction, adduction, circumduction, extension, and flexion of proximal phalanges
Diarthrosis	Extension and flexion of phalanges

CLINICAL VIEW

Fracture of the Femoral Neck

Fracture of the femoral neck is a common and complex injury. Although this injury is often referred to as a "fractured hip," the os coxae isn't broken, just the femoral neck. When the femoral neck breaks, the pull of the lower limb muscles causes the leg to rotate laterally and shorten by several inches. Fractures of the femoral neck are of two types: intertrochanteric and subcapital.

Intertrochanteric fractures of the femoral neck occur distally to or outside the hip articular capsule—in other words, these fractures are *extracapsular*. The fracture line runs between the greater and lesser trochanters. This type of injury typically occurs in younger and middle-aged individuals, and usually in response to trauma.

Subcapital fractures (*or intracapsular fractures*) of the femoral neck occur within the hip articular capsule, very close to the head of the femur itself. This type of fracture usually occurs in elderly people whose bones have been weakened by osteoporosis.

Subcapital fractures result in tearing of the retinacular fibers and the retinacular arteries that supply the head and neck of the femur. The ligament to the head of the femur may be torn as well. As a result, the head and neck of the femur lose their blood supply. If a bone doesn't have an adequate blood supply, it develops **avascular necrosis,** which is death of the bone tissue due to lack of blood. Avascular necrosis of the femoral head and neck is a common complication in subcapital fractures. Frequently, hip replacement surgery is needed, whereby a metal femoral head and neck replace the dying bone. This surgery is not without risk, and many elderly patients do not survive.

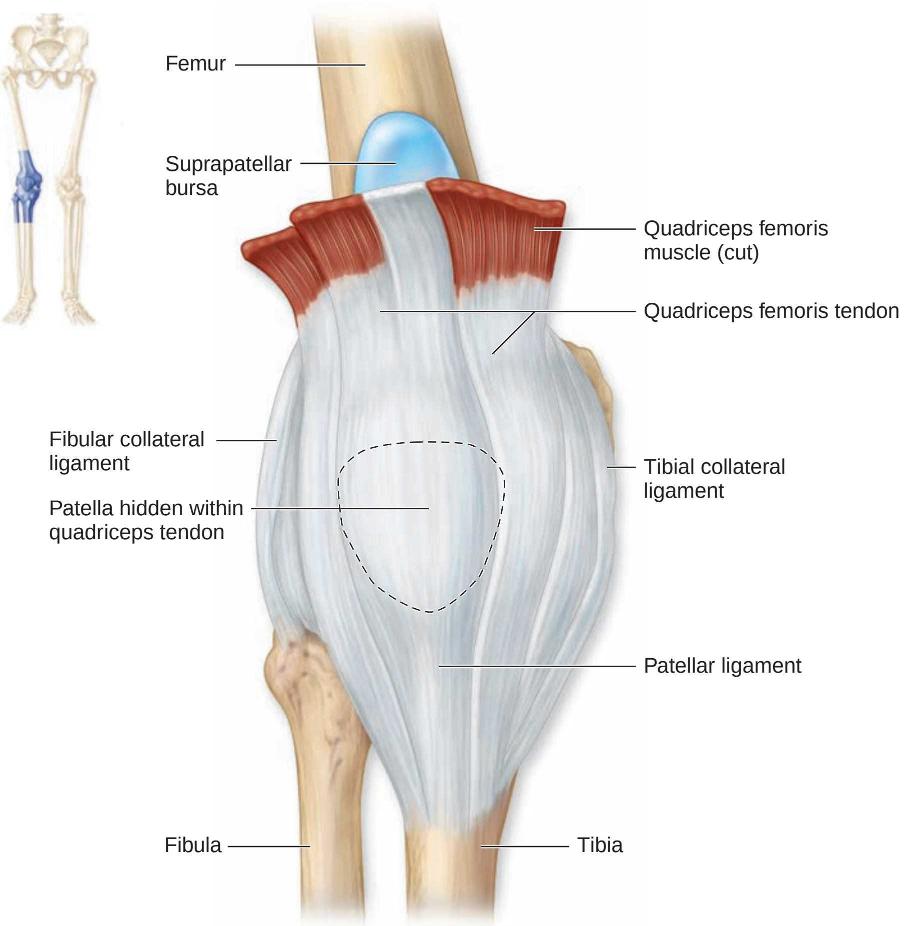
when the knee is flexed, it is also capable of slight rotation and lateral gliding. Structurally, the knee is composed of two separate articulations: (1) the **tibiofemoral** (tib-ē-ō-fem′ō-răl) **joint** is between the condyles of the femur and the condyles of the tibia, and (2) the **patellofemoral joint** is between the patella and the patellar surface of the femur.

The knee joint has an articular capsule that encloses only the medial, lateral, and posterior regions of the knee joint. The articular capsule does not cover the anterior surface of the knee joint; rather, the quadriceps femoris muscle tendon passes over the anterior surface. The patella is embedded within this tendon, and the **patellar ligament** extends beyond the patella and continues to its attachment on the tibial tuberosity of the tibia. Thus, there is no single unified capsule in the knee, nor is there a common joint cavity.

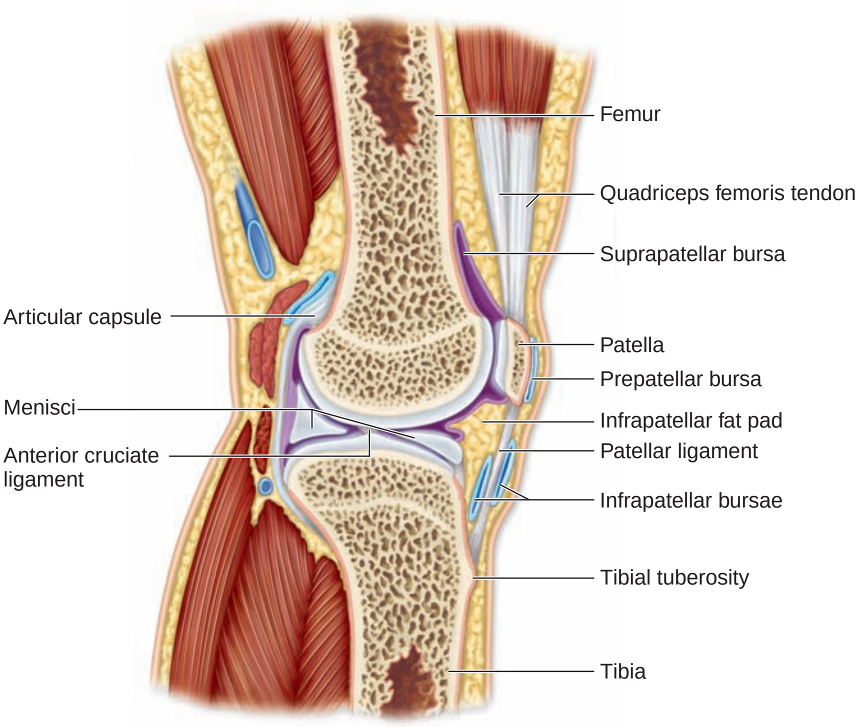
On either side of the joint are two collateral ligaments that become taut on extension and provide additional stability to the joint. The **fibular collateral ligament** (*lateral collateral ligament*) reinforces the lateral surface of the joint. This ligament runs from the femur to the fibula and prevents hyperadduction of the leg at the knee. (In other words, it prevents the leg from moving too far medially relative to the thigh.) The **tibial collateral ligament** (*medial collateral ligament*) reinforces the medial surface of the knee joint. This ligament runs from the femur to the tibia and prevents hyperabduction of the leg at the knee. (In other words, it prevents the leg from moving too far laterally relative to the thigh.) This ligament is attached to the medial meniscus of the knee joint as well, so an injury to the tibial collateral ligament usually affects the medial meniscus.

Deep to the articular capsule and within the knee joint itself are a pair of C-shaped fibrocartilage pads located on the condyles of the tibia. These pads, called the **medial meniscus** and the **lateral meniscus,** partially stabilize the joint medially and laterally, act as cushions between articular surfaces, and continuously change shape to conform to the articulating surfaces as the femur moves.

Also deep to the articular capsule of the knee joint are two **cruciate** (kroo′shē-āt) **ligaments,** which limit the anterior and posterior movement of the femur on the tibia. These ligaments cross each other in the form of an X, hence the name "cruciate" (which means "cross"). The **anterior cruciate ligament (ACL)** runs from the posterior femur to the anterior side of the tibia.



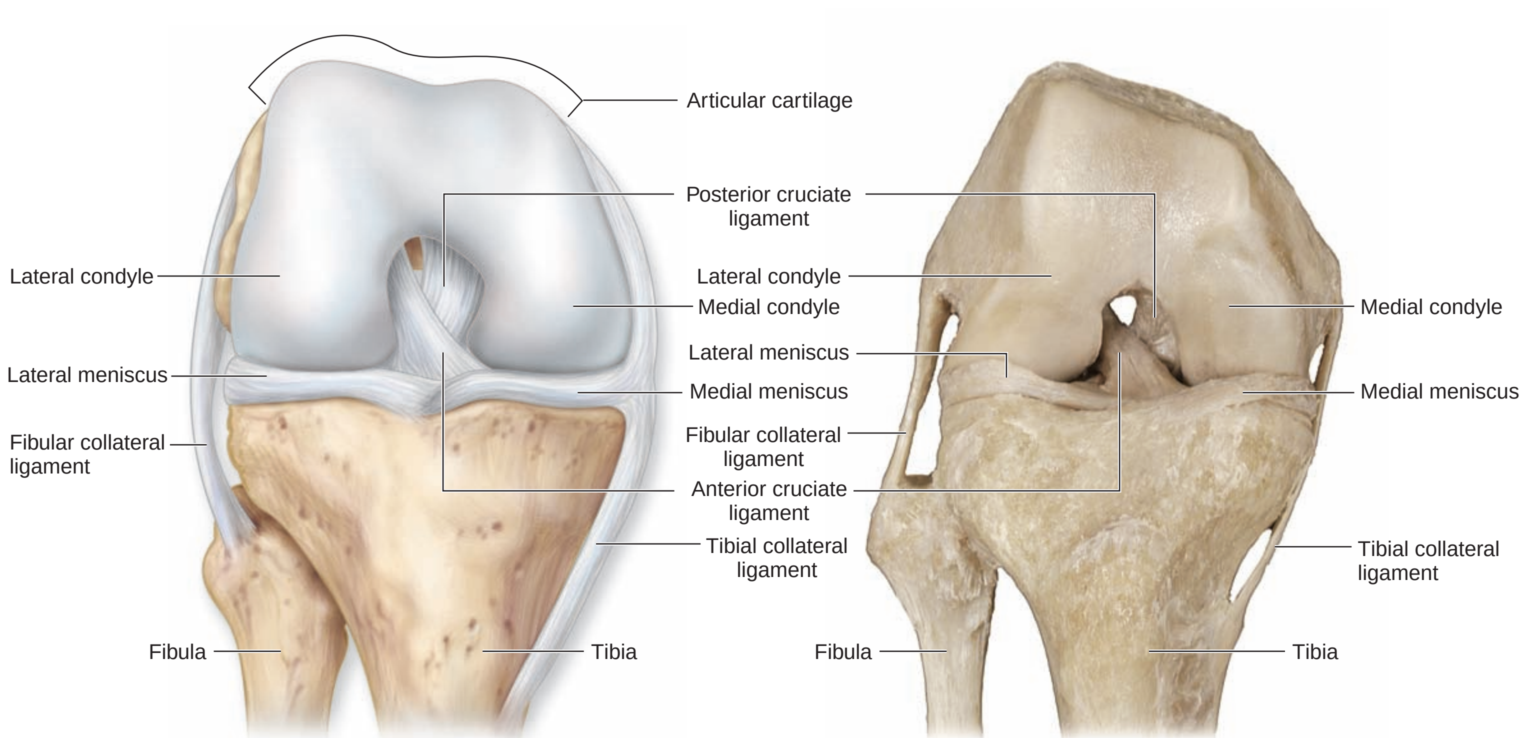
(a) Right knee, anterior superficial view



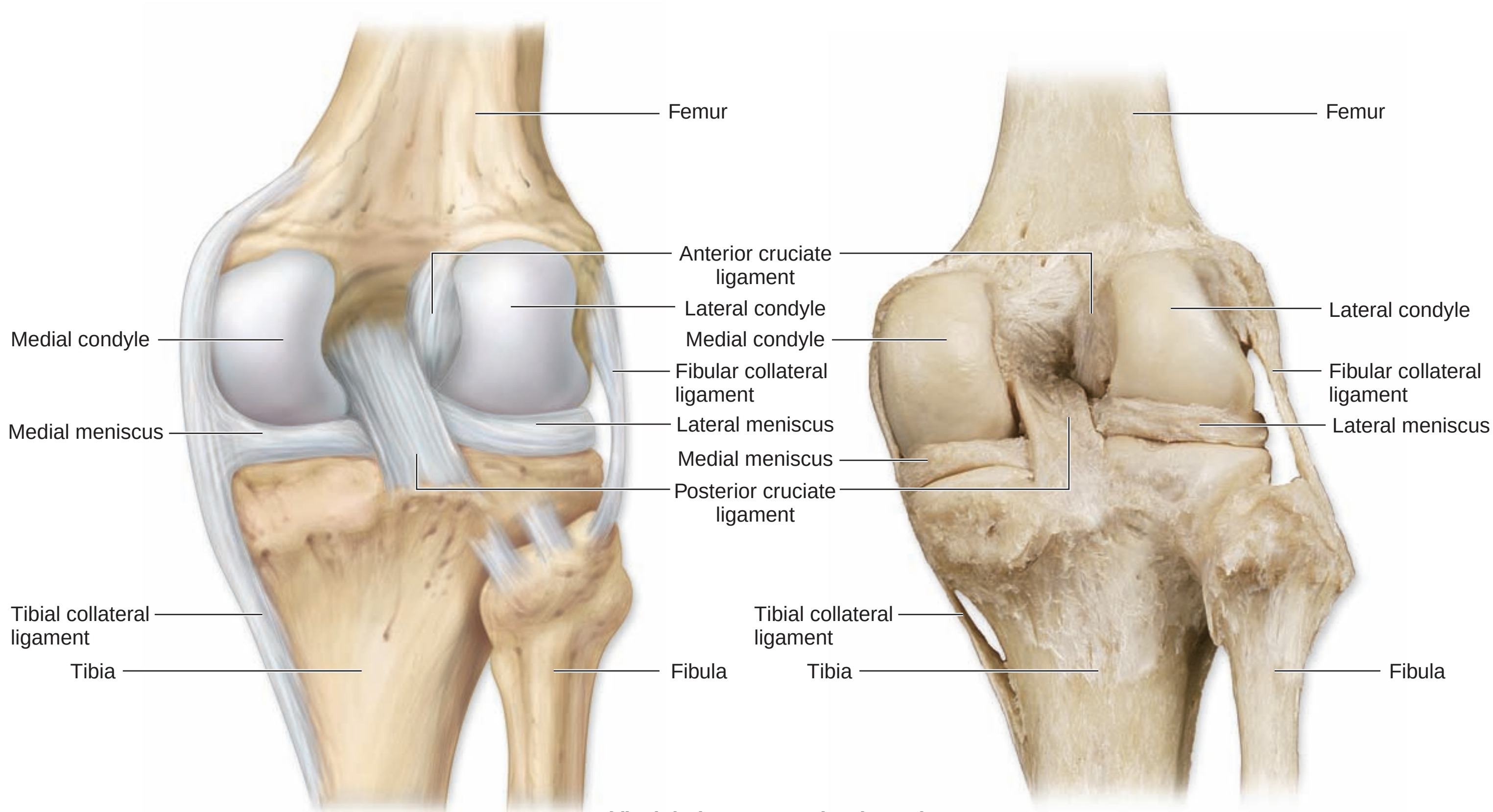
(b) Right knee, sagittal section

Figure 9.19

Knee Joint. This joint is the largest and most complex diarthrosis of the body. (*a*) Anterior superficial, (*b*) sagittal section, (*c*) anterior deep, and (*d*) posterior deep views reveal the complex interrelationships among the parts of the right knee.



(c) Right knee, anterior deep view



(d) Right knee, posterior deep view

When the knee is extended, the ACL is pulled tight and prevents hyperextension. The ACL prevents the tibia from moving too far anteriorly on the femur. The **posterior cruciate ligament (PCL)** runs from the anteroinferior femur to the posterior side of the tibia. The PCL becomes taut on flexion, and so it prevents hyperflexion of the knee joint. The PCL also prevents posterior displacement of the tibia on the femur.

"Locking" the Knee Humans are bipedal animals, meaning that they walk on two feet. An important aspect of bipedal locomotion is the ability to "lock" the knees in the extended position and stand erect for long periods without tiring the leg muscles. At full extension, the tibia rotates laterally so as to tighten the anterior cruciate ligament and squeeze the meniscus between the tibia and femur. Muscular contraction by the popliteus muscle unlocks the knee joint. Contraction of this muscle causes a slight rotational movement between the tibia and the femur.

Talocrural (Ankle) Joint The **talocrural joint,** or ankle joint, is a highly modified hinge joint that permits dorsiflexion and plantar flexion, and includes two articulations within one articular capsule. One of these articulations is between the distal end of the tibia and the talus, and the other is between the distal end of the fibula and the lateral aspect of the talus **(figure 9.20)**. The

CLINICAL VIEW: In Depth

Knee Ligament Injuries

Although the knee is capable of bearing much weight and has numerous strong supporting ligaments, it is highly vulnerable to injury, especially among athletes. The knee is susceptible to both horizontal and rotational stress, most commonly when struck either from the lateral or posterior aspect while slightly flexed. Because the knee is reinforced by tendons and ligaments only, ligamentous injuries to the knee are very common.

The tibial collateral ligament is frequently injured when the leg is forcibly abducted at the knee. For example, if a person's knee is hit on the lateral side, the leg is hyperabducted, and the tibial collateral ligament is strained and frequently torn. Because the tibial collateral ligament is attached to the medial meniscus, the medial meniscus may be injured as well.

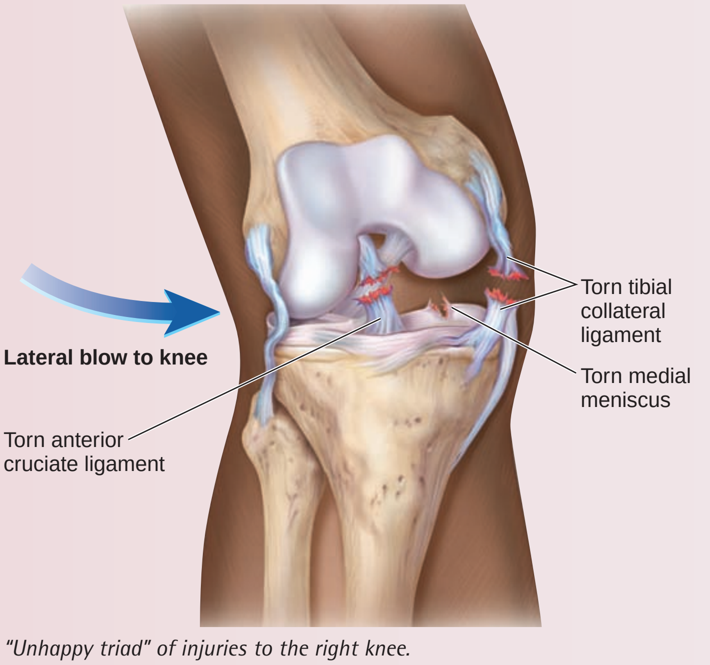
Injury to the fibular collateral ligament can occur if the medial side of the knee is struck, resulting in hyperadduction of the leg at the knee. This type of injury is fairly rare, in part because the fibular collateral ligament is very strong and also because medial blows to the knee are not common.

The anterior cruciate ligament (ACL) can be injured when the leg is hyperextended—for example, if a runner's foot hits a hole. Because the ACL is rather weak compared to the other knee ligaments, it is especially prone to injury. ACL injury often occurs in association with another ligament injury. To test for ACL injury, a physician gently tugs anteriorly on the tibia when the knee is flexed and not bearing weight. In this so-called "anterior drawer test," too much forward movement indicates an ACL tear.

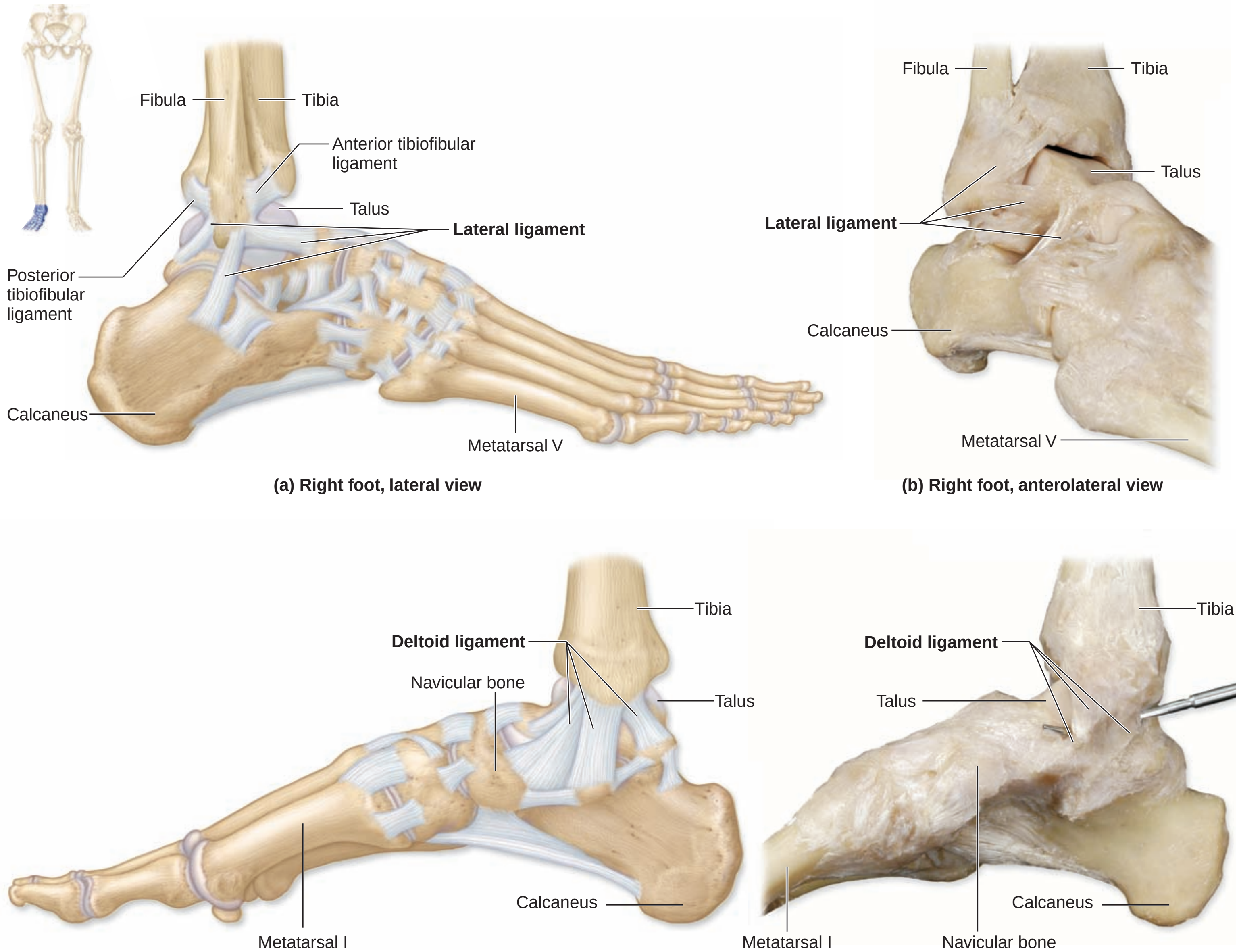
Posterior cruciate ligament (PCL) injury may occur if the leg is hyperflexed or if the tibia is driven posteriorly on the femur. PCL injury occurs rarely, because this ligament is rather strong. To test for PCL injury, a physician gently pushes on the tibia while the knee is flexed and not bearing weight. In this "posterior drawer test," too much posterior movement indicates a PCL tear.

The **unhappy triad** of injuries refers to a triple ligamentous injury of the tibial collateral ligament, medial meniscus, and anterior cruciate ligament, and is the most common type of football injury. It occurs when a player is illegally "clipped" by a lateral blow to the knee, and the leg is forcibly abducted and laterally rotated. If the blow is severe enough, the tibial collateral ligament tears, followed by tearing of the medial meniscus, because these two structures are connected. The force that tears the tibial collateral ligament and the medial meniscus is thus transferred to the ACL. Because the ACL is relatively weak, it tears as well.

The treatment of ligamentous knee injuries depends upon the severity and type of injury. Conservative treatment involves immobilizing the knee for a period of time to rest the joint. Surgical treatment can include repairing the torn ligaments or replacing the ligaments with a graft from another tendon or ligament (such as the quadriceps tendon). Rehabilitation of the knee also requires strengthening the muscles and tendons that surround the knee, so they can provide additional support to the joint.



"Unhappy triad" of injuries to the right knee.



(a) Right foot, lateral view

(b) Right foot, anterolateral view

(c) Right foot, medial view

Figure 9.20

Talocrural Joint. (*a*) Lateral, (*b*) anterolateral, and (*c*) medial views of the right foot show that the talocrural joint contains articulations among the tibia, fibula, and talus. This joint permits dorsiflexion and plantar flexion only.

medial and lateral malleoli of the tibia and fibula, respectively, form extensive medial and lateral margins and prevent the talus from sliding side-to-side.

The talocrural joint includes several distinctive anatomic features. An articular capsule covers the distal surfaces of the tibia, the medial malleolus, the lateral malleolus, and the talus. A multipart **deltoid ligament** (or *medial ligament*) binds the tibia to the foot on the medial side. This ligament prevents overeversion of the foot. The deltoid ligament is incredibly strong and rarely tears; in fact, it will pull the medial malleolus off the tibia before it ever ruptures! A much thinner, multipart **lateral ligament** binds the fibula to the foot on the lateral side. This ligament prevents overinversion of the foot. It is not as strong as the deltoid ligament, and is prone to sprains and tears. Two **tibiofibular** (tib-ē-ō -fib′ū -lăr) **ligaments** (**anterior** and **posterior**) bind the tibia to the fibula.

Joints of the Foot

Four types of synovial joints are found in the foot: intertarsal joints, tarsometatarsal joints, metatarsophalangeal joints, and interphalangeal joints **(figure 9.21)**. **Intertarsal joints** are the articulations between the tarsal bones. Some of these joints go by specific names (e.g., talonavicular joint, calcaneocuboid joint). It is at the intertarsal joints that inversion and eversion of the foot occur.

The articulations between the tarsal and metatarsal bones form the **tarsometatarsal** (tar-sō-met′ă-tar′săl) **joints.** These are plane articulations that permit some twisting and limited side-to-side movements. The medial, intermediate, and lateral cuneiform

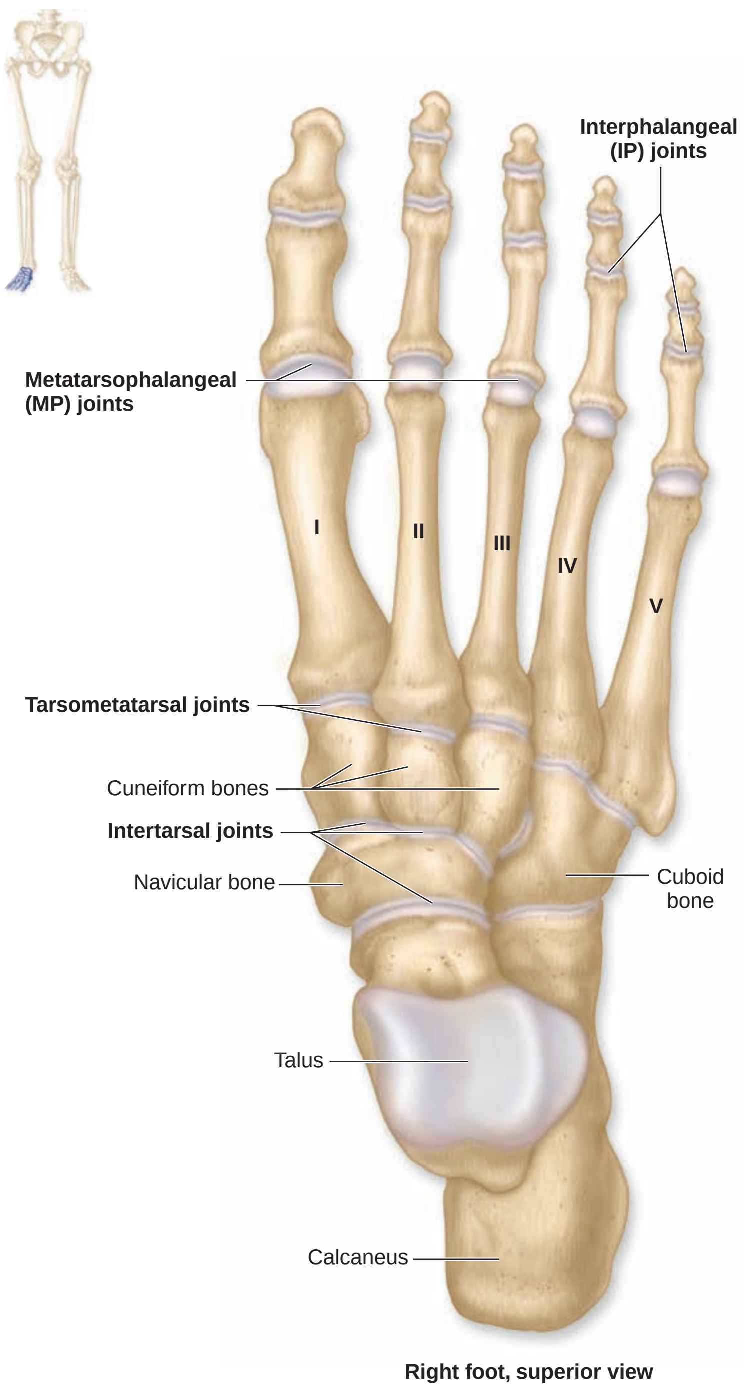


Figure 9.21

Joints of the Foot. The intertarsal, tarsometatarsal, metatarsophalangeal (MP), and interphalangeal (IP) joints help move the toes and foot.

bones articulate with the first three metatarsals. The fourth and fifth metatarsals articulate with the cuboid.

The **m etatarsophalangeal** (met′ -tar′s -f -lan′jē- l) **joints,** also called the **MP joints,** are between the metatarsals and the phalanges of the toes. These are condylar joints, and they permit limited abduction and adduction of the toes, as well as flexion and extension.

Finally, th e **in terphalangeal (IP) joints** occur between indi-vidual phalanges. Each interphalangeal joint is a hinge joint that permits flexion and extension only.

CLINICAL VIEW

Ankle Sprains and Pott Fracture

A **sprain** is a stretching or tearing of ligaments, without fracture or dislocation of the joint. An ankle sprain results when the foot is twisted, almost always due to **overinversion.** Fibers of the lateral ligaments are either stretched (in mild sprains) or torn (in more severe sprains), producing localized swelling and tenderness anteroinferior to the lateral malleolus. **Overeversion** sprains rarely occur due to the strength of the deltoid ligament. Remember from chapter 4 that ligaments are composed of dense regular connective tissue, which is poorly vascularized. Tissue that is poorly vascularized takes a long time to heal, and that is the case with ankle sprains. They are also prone to reinjury.

If overeversion *does* occur, the injury that usually results is called a **Pott fracture** (see chapter 6). If the foot is overeverted, it pulls on the deltoid ligament, which is very strong and doesn't tear. Instead, the pull on the deltoid ligament can avulse (pull off) the medial malleolus of the tibia. The force from the injury then continues to move the talus laterally, because the medial malleolus can no longer restrict side-to-side movements of the ankle. As the talus moves laterally and puts force on the fibula, the fibula fractures as well (usually at its distal end or by the lateral malleolus). Thus, both the tibia and the fibula fracture in this injury, and yet the deltoid ligament remains intact.

WHAT DID YOU LEARN?

12. Which ligaments support the hip joint?
13. List the intracapsular ligaments of the knee joint, and discuss their function.
14. Compare the deltoid and lateral ligaments of the ankle joint. Which of these ligaments is stronger? What types of injuries are associated with these ligaments?

9.6 Disease and Aging of the Joints

Learning Objective:

1. Identify the effects of aging on the joints.

During a person's lifetime, the joints are subjected to extensive wear and tear. A joint's size, flexibility, and shape are affected and modified by use. Active joints develop larger and thicker capsules, and the supporting ligaments and bones increase in size.

Prior to the closure of the epiphyseal plates in early adulthood, some injuries to a young person may result in subluxation or fracture of an epiphysis, with potential adverse effects on the future development and health of the joint. After the epiphyseal plates close, injuries at the epiphyses typically result in sprains.

Arthritis is a disease that involves damage to articular cartilage (see Clinical View: In Depth). A highly prevalent problem that develops in an aging joint is osteoarthritis, also known as degenerative arthritis. The cause of the damage may vary, but it can be related to cumulative wear and tear at the joint surface.

CLINICAL VIEW: In Depth

Arthritis

Arthritis (ar-thrī′tis) is a group of inflammatory or degenerative diseases of joints that occur in various forms. Each form presents the same symptoms: swelling of the joint, pain, and stiffness. It is the most prevalent crippling disease in the United States. Some common forms of arthritis are gouty arthritis, osteoarthritis, and rheumatoid arthritis.

Gouty arthritis is typically seen in middle-aged and older individuals, and is more common in males. Often called "gout," this disease occurs as a result of an increased level of uric acid (a normal cellular waste product) in the blood. This abnormal level causes urate crystals to accumulate in the blood, synovial fluid, and synovial membranes. The body's inflammatory response to the urate crystals results in joint pain. Gout usually begins with an attack on a single joint (often in the great toe), and later progresses to other joints. Eventually, gouty arthritis may immobilize joints by causing fusion between the articular surfaces of the bones. Often, nonsteroidal anti-inflammatory drugs (NSAIDs) are used to alleviate symptoms and reduce the inflammation.

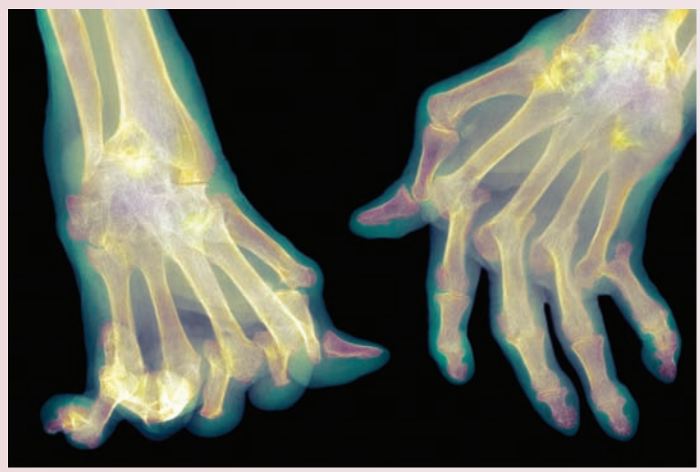
Osteoarthritis is the most common type of arthritis. This chronic degenerative joint condition is termed "wear-and-tear arthritis" because of its prevalence in weight-bearing joints and its association with older adults. The entire joint is affected but the articular cartilage appears to break down first. Eventually, bone rubs against bone, causing abrasions on the bony surfaces, or eburnation. Without the protective articular cartilage, movements at the joints become stiff and painful. Weight-bearing joints most affected by osteoarthritis are those of the hips, knees, feet, and cervical and lumbar regions of the spine. Other joints commonly affected include the shoulders and interphalangeal joints. Osteoarthritis is typically seen in older individuals, although more and more athletes are experiencing arthritis at an earlier age due to the repetitive stresses placed on their joints. NSAIDs are used to alleviate the symptoms of osteoarthritis.

Rheumatoid (roo′mă-toyd) **arthritis** is typically seen in younger and middle-aged adults, and is much more prevalent in women. It presents with pain and swelling of the joints, muscle weakness, osteoporosis, and assorted problems with both the heart and the blood vessels.

Rheumatoid arthritis is an *autoimmune disorder* in which the body's immune system targets its own tissues for attack. Although the cause of this reaction is unknown, it often follows infection by certain bacteria and viruses that have surface molecules similar to molecules normally present in the joints. When the body's immune system is stimulated to attack the foreign molecules, it also destroys its own joint tissue, thus initiating the autoimmune disorder.

Rheumatoid arthritis starts with synovial membrane inflammation. Fluid and white blood cells leak from small blood vessels into the joint cavity, causing an increase in synovial fluid volume. As a consequence, the joint swells, and the inflamed synovial membrane thickens; eventually, the articular cartilage and, often, the underlying bone become eroded. Scar tissue later forms and ossifies, and bone ends fuse together, immobilizing the joint. Medications that help suppress the immune system (e.g., prednisone) are frequently used to alleviate the symptoms of rheumatoid arthritis.

(a) Hands with rheumatoid arthritis



(b) Radiograph of hands with rheumatoid arthritis

Just as the strength of a bone is maintained by continual application of stress, the health of joints is directly related to moderate exercise. Exercise compresses the articular cartilages, causing synovial fluid to be squeezed out of the cartilage and then pulled back inside the cartilage matrix. This flow of fluid gives the chondrocytes within the cartilage the nourishment required to maintain their health. Joints become stronger, and the rate of degeneration of the articular cartilage is reduced. Exercise also strengthens the muscles that support and stabilize the joint. However, extreme exercise should be avoided, because it aggravates potential joint problems and may worsen osteoarthritis. Athletes such as baseball player Nolan Ryan and Olympic figure skater Dorothy Hamill have experienced osteoarthritis at an early age due to extreme exercise in their youth.

CLINICAL VIEW

Joint Replacement

Surgical joint replacement (arthroplasty) may be performed after failure of other nonsurgical approaches. Before surgery is considered, treatment regimens include activity modification, use of braces, exercise, medications such as nonsteroidal **anti-inflammatory** drugs, and/or cortisone injections or viscosupplementation (e.g., hyaluronic acid injections) into the joint. Surgery involves removing the damaged cartilage and joint surface, modifying the bone architecture to align the joint properly, and then a metal or plastic prosthetic is implanted to replace the joint surface. The options available, materials used, and recovery time are dependent upon the joint being replaced. For instance, hip replacement usually includes complete replacement of the head and the neck of the femur; and shoulder replacement includes the articular surfaces. The recovery time for total knee replacement surgery is the shortest, between 6 and 8 weeks, with full recovery expected within 6 months. Total shoulder replacement incurs the longest recovery time because the joint is immobilized between 6 and 8 weeks before extensive physical therapy can begin. As materials and methods advance, the longevity of the replaced joint has lengthened so that between 75% and 95% are still functional after 15 years.

WHAT DID YOU LEARN?

15 Define osteoarthritis, and discuss what contributes to it.

9.7 Development of the Joints

Learning Objective:

1. Describe how joints develop in the embryo.

Joints start to form by the sixth week of development and become better differentiated during the fetal period. Some of the mesenchyme around the developing bones develops into the connective tissues of the articulations. For example, in the area of future fibrous joints, the mesenchyme around the developing bones differentiates into dense regular connective tissue, and later joins the developing bones together. In cartilaginous joints, the mesenchyme differentiates into either fibrocartilage or hyaline cartilage.

The development of the synovial joints is more complex than that of fibrous and cartilaginous joints **(figure 9.22)**. The mesenchyme around the articulating bones differentiates into the components of a synovial joint. The most *laterally* placed mesenchyme forms the articular capsule and supporting ligaments of the joint. Just medial to this region, the mesenchyme forms the synovial membrane, which then starts secreting synovial fluid into the joint

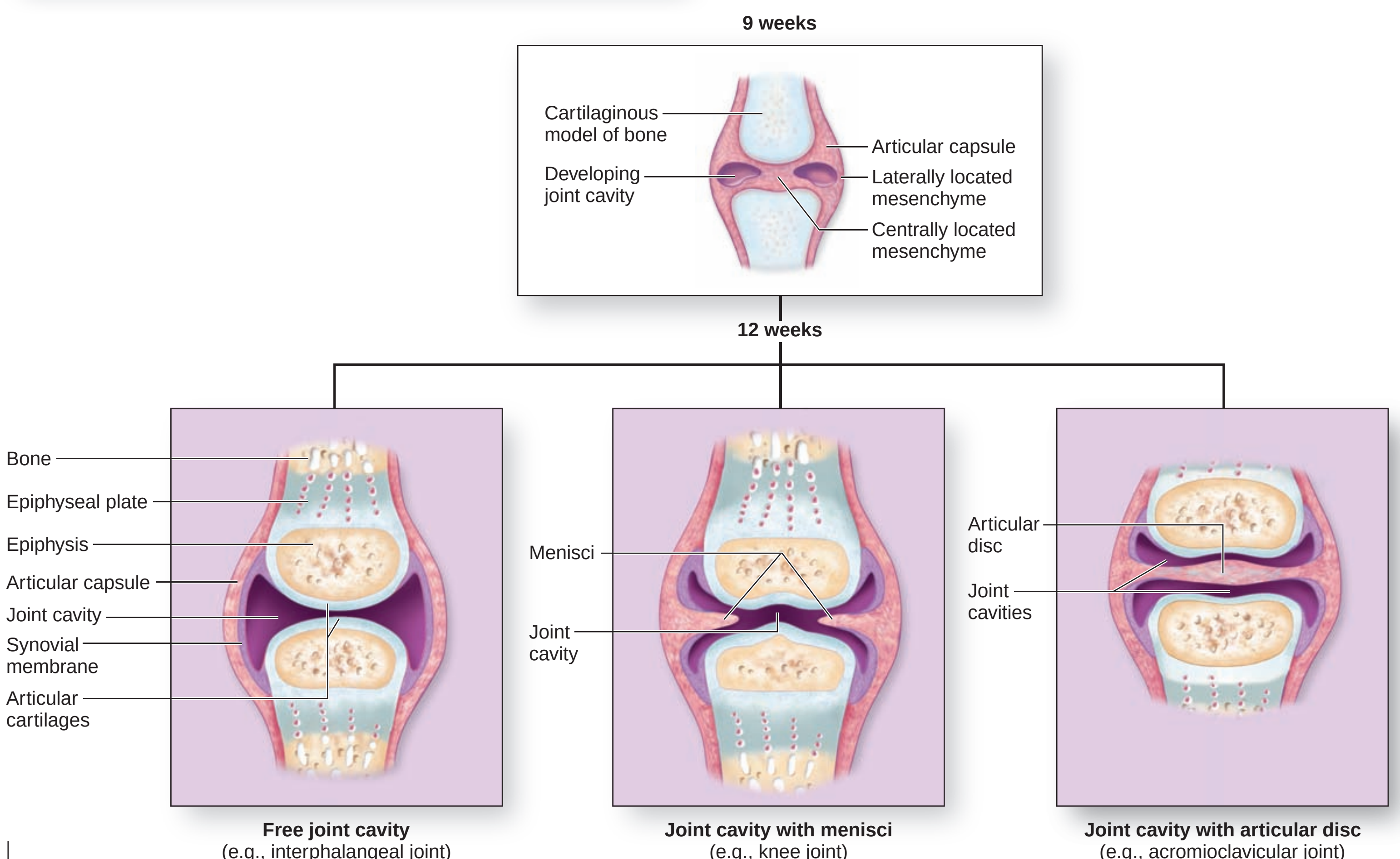


Figure 9.22

Development of the Synovial Joints. By 9 weeks of development, as the future bones are developing, a primitive model of the synovial joint cavities forms. Over the next several weeks, the synovial joints continue to differentiate. By 12 weeks, some have formed free joint cavities (e.g., the interphalangeal joints) while others have formed menisci (e.g., the knee joint). Still other joints have an articular disc (e.g., the acromioclavicular joint) that separates the articulating bones.

cavity. The *centrally* located mesenchyme differentiates in one of three ways, depending upon the type of synovial joint:

1. The centrally located mesenchyme is resorbed, and a **free joint cavity** forms. Examples of free joint cavities are the interphalangeal joints of the fingers and toes.
2. The centrally located mesenchyme forms incomplete cartilaginous rings or blocks called **menisci,** which serve as shock absorbers in joints. The knee joint is a synovial joint that contains menisci.
3. The centrally located mesenchyme condenses and forms a cartilaginous **articular disc** within the joint cavity.

The articular disc assists the movement of the articulating bones. Examples of synovial joints with articular discs are the sternoclavicular joint, the acromioclavicular joint, and the radiocarpal joint.

Differentiation of the centrally located mesenchyme occurs by about the twelfth week of development, and the entire joint continues to differentiate throughout the fetal period.

WHAT DID YOU LEARN?

16 Joints start to form during which week of development?

Clinical Terms

ankylosis (ang′ki-lō′sis) Stiffening of a joint due to the union of fibers or bones across the joint as the result of a disease.

arthralgia (ar-thral′jē-ă) Joint-associated pain that is not usually inflammatory.

arthroplasty (ar′thrō-plas-tē) Construction of an artificial joint to provide relief from or to correct advanced degenerative arthritis.

bursitis Inflammation of a bursa.

chondromalacia (kon′drō-mă-lā′shē-ă) **patellae** Softening of the articular cartilage of the patella; sometimes considered a subtype of patellofemoral syndrome.

rheumatism (roo′mă-tizm) Any one of various conditions exhibiting joint pain or other symptoms of articular origin; often associated with muscular or skeletal system problems.

synovitis (sin-ō-vī′tis) Inflammation of the synovial membrane of a joint.

Chapter Summary

9.1 Articulations (Joints)	■ Articulations occur where bones interact. Joints differ in structure, function, and the amount of movement they allow, which may be extensive, slight, or none at all. **9.1a ClassificationofJoints** ■ There are three structural categories of joints: fibrous, cartilaginous, and synovial. ■ The three functional categories of joints are synarthroses, which are immobile; amphiarthroses, which are slightly mobile; and diarthroses, which are freely mobile.
9.2 Fibrous Joints	■ In fibrous joints, articulating bones are interconnected by dense regular connective tissue. **9.2a Gomphoses** ■ A gomphosis is a synarthrosis between the tooth and either the mandible or the maxillae. **9.2b Sutures** ■ A suture is a synarthrosis that tightly binds bones of the skull. Closed sutures are called synostoses. **9.2c Syndesmoses** ■ A syndesmosis is an amphiarthrosis, and the bones are connected by interosseous membranes.
9.3 Cartilaginous Joints	■ In cartilaginous joints, articulating bones are attached to each other by cartilage. **9.3a Synchondroses** ■ A synchondrosis is a synarthrosis where hyaline cartilage is wedged between articulating bones. **9.3b Symphyses** ■ A symphysis is an amphiarthrosis, and has a disc of fibrocartilage wedged between the articulating bones.
9.4 Synovial Joints	■ Synovial joints are diarthroses. **9.4a General Anatomy of Synovial Joints** ■ Synovial joints contain an articular capsule, a joint cavity, synovial fluid, articular cartilage, ligaments, and nerves and blood vessels. **9.4b Types of Synovial Joints** ■ The six types of synovial joints are plane, hinge, pivot, condylar, saddle, and ball-and-socket. **9.4c Movements at Synovial Joints** ■ Motions that occur at synovial joints include gliding, angular, rotational, and special.

(*continued on next page*)

Chapter Summary *(continued)*

9.5 Selected Articulations in Depth	■ In each articulation, unique features of the articulating bones support only the intended movement. **9.5a Joints of the Axial Skeleton** ■ The temporomandibular joint is an articulation between the head of the mandible and the mandibular fossa of the temporal bone. ■ Vertebrae articulate between their bodies as well as between the inferior and superior articular processes. **9.5b Joints of the Pectoral Girdle and Upper Limbs** ■ The sternoclavicular joint is a saddle joint between the manubrium of the sternum and the sternal end of the clavicle. ■ The acromioclavicular joint is a plane synovial joint between the acromion and the acromial end of the clavicle. ■ The glenohumeral joint is a ball-and-socket joint between the glenoid cavity of the scapula and the head of the humerus. ■ The elbow is a hinge joint. ■ The radiocarpal joint involves the distal radius and three proximal carpal bones. **9.5c Joints of the Pelvic Girdle and Lower Limbs** ■ The hip joint is a ball-and-socket joint between the head of the femur and the acetabulum of the os coxae. ■ The knee joint is primarily a hinge joint, but is capable of slight rotation and gliding. ■ The talocrural joint is a hinge joint that permits dorsiflexion and plantar flexion. ■ Intertarsal joints occur between the tarsal bones. ■ Tarsometatarsal joints are the articulations between the tarsal and metatarsal bones. ■ Metatarsophalangeal joints are the articulations between the metatarsals and the proximal phalanges. ■ Interphalangeal joints occur between individual phalanges.
9.6 Disease and Aging of the Joints	■ Osteoarthritis is a common joint problem that occurs with aging.
9.7 Development of the Joints	■ Joints begin to form during week 6 of development.

Challenge Yourself

Matching

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

______ 1. joint between sternum and clavicle

______ 2. joint between tooth and jaw

______ 3. joint angle is increased in an AP plane

______ 4. bursa

______ 5. palm faces posteriorly

______ 6. standing on tiptoe

______ 7. intervertebral disc

______ 8. articulation among tibia, fibula, and talus

______ 9. menisci

______10. ligament of head of femur

a. talocrural joint
b. plantar flexion
c. gomphosis
d. hip joint
e. located in knee joint
f. has anulus fibrosus and nucleus pulposus
g. pronation
h. extension
i. sternoclavicular joint
j. sac filled with synovial fluid

Multiple Choice

Select the best answer from the four choices provided.

______ 1. The greatest range of mobility of any joint in the body is found in the
a. knee joint.
b. hip joint.
c. glenohumeral joint.
d. elbow joint.

______ 2. The movement of the foot that turns the sole laterally is called
a. dorsiflexion.
b. inversion.
c. eversion.
d. plantar flexion.

______ 3. A ________ is formed when two bones previously connected in a suture fuse.
a. gomphosis
b. synostosis
c. symphysis
d. syndesmosis

______ 4. The ligament that helps to maintain the alignment of the condyles between the femur and tibia and to limit the anterior movement of the tibia on the femur is the
a. tibial collateral ligament.
b. posterior cruciate ligament.
c. anterior cruciate ligament.
d. fibular collateral ligament.

______ 5. The glenohumeral joint is primarily stabilized by the
a. coracohumeral ligament.
b. glenohumeral ligaments.
c. rotator cuff muscles that move the humerus.
d. scapula.

______ 6. In a biaxial articulation,
a. movement can occur in all three planes.
b. only circumduction occurs.
c. movement can occur in two planes.
d. movement can occur in only one plane.

______ 7. A metacarpophalangeal (MP) joint, which has oval articulating surfaces and permits movement in two planes, is what type of synovial joint?
a. condylar
b. plane
c. hinge
d. saddle

______ 8. The ligament that is not associated with the intervertebral joints is the
a. anterior longitudinal ligament.
b. pubofemoral ligament.
c. ligamentum flavum.
d. supraspinous ligament.

______ 9. Which of the following is a function of synovial fluid?
a. lubricates the joint
b. provides nutrients for articular cartilage
c. absorbs shock within the joint
d. All of these are correct.

______10. All of the following movements are possible at the radiocarpal joint except
a. circumduction.
b. abduction.
c. flexion.
d. rotation.

Content Review

1. Discuss the factors that influence both the stability and the mobility of a joint. What is the relationship between a joint's mobility and its stability?
2. Describe the structural differences between fibrous joints and cartilaginous joints.
3. Describe all joints that are functionally classified as synarthroses.
4. Discuss the origin and function of synovial fluid within a synovial joint.
5. Compare a hinge joint and a pivot joint with respect to structure, function, and location within the body.
6. Describe and compare the movements of abduction, adduction, pronation, and supination.
7. Describe the basic anatomy of the glenohumeral joint.
8. What are the main supporting ligaments of the elbow joint?
9. How do the tibia and talus maintain their correct positioning in the talocrural joint?
10. What is the primary age-related change that can occur in a joint?

Developing Critical Reasoning

1. During soccer practice, Erin tripped over the outstretched leg of a teammate and fell directly onto her shoulder. She was taken to the hospital in excruciating pain. Examination revealed that the head of the humerus had moved inferiorly and anteriorly into the axilla. What happened to Erin in this injury?
2. While Lucas and Omar were watching a football game, a player was penalized for "clipping," meaning that he had hit an opposing player on the lateral knee, causing hyperabduction at the knee joint. Lucas asked Omar what the big deal was about "clipping." What joint is most at risk, and what kind of injuries can occur if a player gets "clipped"?

Answers to "What Do You Think?"

1. A synchondrosis is designed to be a synarthrosis because as the bone ends are growing, they must not be allowed to move in relation to one another. For example, if the epiphysis and diaphysis move along the epiphyseal plate, bone growth is compromised and the bone becomes misshapen.
2. The plane joint, the least mobile of the two joints, must be more stable than the ball-and-socket joint.
3. When sitting upright in a chair, both the hip and knee joints are flexed.
4. The anterior longitudinal ligament becomes taut during extension, so it is taut when we are standing and more relaxed when we are sitting.