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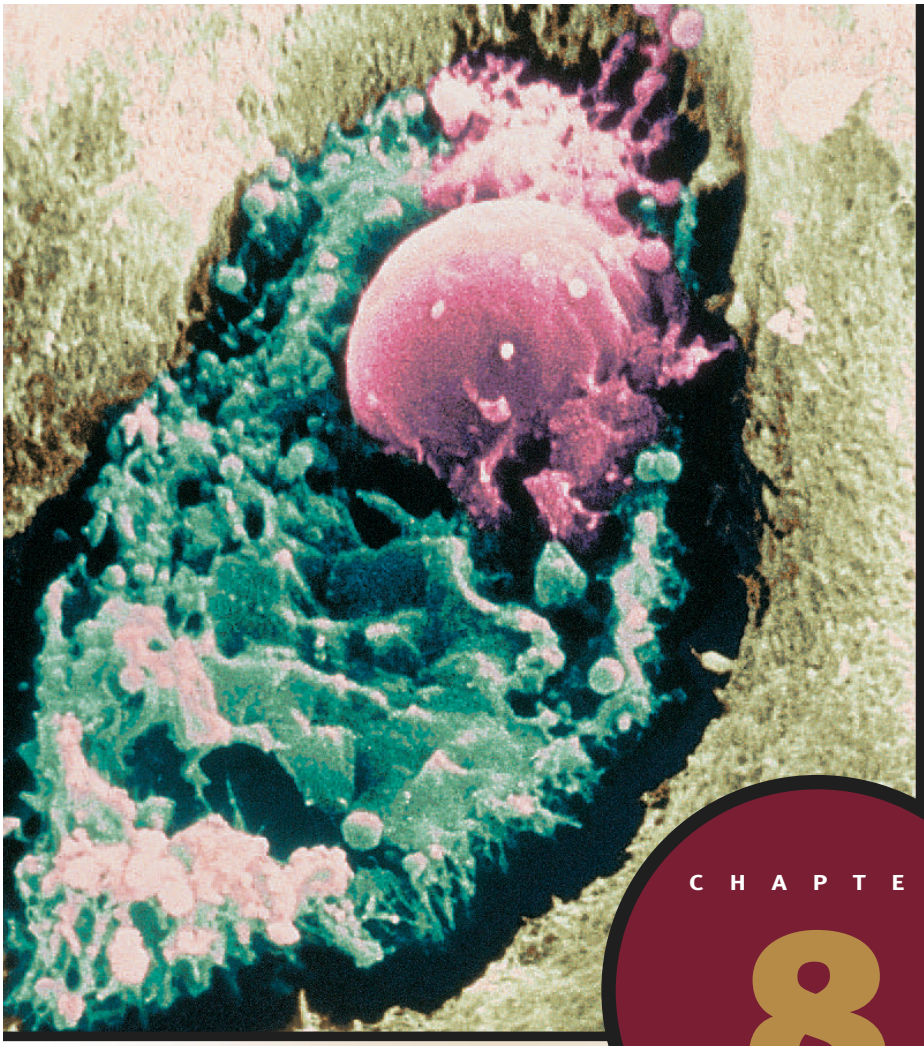


Colorized SEM of a chondrocyte within a lacuna surrounded by cartilage matrix.

CHAPTER

8

Articulations and Movement

Muscles pull on bones to make them move, but movement would not be possible without joints between the bones. Humans would resemble statues were it not for the joints between bones that allow bones to move once the muscles have provided the pull. Machine parts most likely to wear out are those that rub together and they require the most maintenance. Movable joints are places in the body where the bones rub together, yet we tend to pay little attention to them. Fortunately our joints are self-maintaining, but damage to or disease of a joint can make movement very difficult. We realize then how important the movable joints are for normal function.

An **articulation,** or **joint,** is a place where two bones come together. We usually think of joints as being movable, but that's not always the case. Many joints allow only limited movement, and others allow no apparent movement. The structure of a given joint is directly correlated with its degree of movement. Fibrous joints have much less movement than joints containing fluid and having smooth articulating surfaces.

Joints develop between adjacent bones or areas of ossification, and movement is important in determining the type of joint that develops. If movement is restricted—even in a highly movable joint—at any time during an individual's life, the joint may be transformed into a nonmovable joint.

This chapter presents a scheme for *naming joints* (242) and an explanation of *classes of joints* (242), and *types of movement* (248). It then presents a *description of selected joints* (253) and summarizes the *effects of aging on the joints* (263).

Naming Joints

Objective

- *Describe how joints are named.*

Joints are commonly named according to the bones or portions of bones that are united at the joint, such as the temporomandibular joint between the temporal bone and the mandible.

PREDICT 1

What is the name of the joint between the metacarpals and the phalanges?

Some joints are given the name of only one of the articulating bones, such as the humeral (shoulder) joint between the humerus and scapula. Still other joints are simply given the Greek or Latin equivalent of the common name, such as **cubital** (kū′bi-tăl) **joint** for the elbow joint.

1. *What criteria are used to name joints?*

Classes of Joints

Objectives

- *Define and describe fibrous and cartilagenous joints.*
- *Describe the general features of a synovial joint, and explain their function.*
- *List and give examples of six types of synovial joints.*

The three major kinds of joints are classified structurally as fibrous, cartilaginous, and synovial. In this classification scheme, joints are categorized according to the major connective tissue type that binds the bones together, and whether or not a fluid-filled joint capsule is present. Joints may also be classified according to their function. This classification is based on the degree of motion at each joint and includes the terms *synarthrosis* (nonmovable joint), *amphiarthrosis* (slightly movable joint), and *diarthrosis* (freely movable joint). This functional classification is somewhat limited and is not used in this text. The structural classification scheme with its various subclasses allows for a more precise classification and is the scheme we use.

Fibrous Joints

Fibrous joints consist of two bones that are united by fibrous connective tissue, have no joint cavity, and exhibit little or no movement. Joints in this group are classified further as sutures, syndesmoses, or gomphoses (table 8.1) based on their structure.

Sutures

Sutures (soo′choorz) are seams between the bones of the skull (figure 8.1). Some sutures may become completely immovable in older adults. Sutures are seldom smooth, and the opposing bones often interdigitate (have interlocking fingerlike processes). This interdigitation adds considerable stability to sutures. The tissue between the two bones is dense, regular collagenous connective tissue, and the periosteum on the inner and outer surfaces of the adjacent bones continues over the joint. The two layers of periosteum plus the dense fibrous connective tissue in between form a **sutural ligament.**

In a newborn, membranous areas called **fontanels** (fon′tă-nelz′) are present within some of the sutures. The fontanels make the skull flexible during the birth process and allow for growth of the head after birth (figure 8.2).

Table 8.1 Fibrous and Cartilaginous Joints

Class and Example of Joint	Bones or Structures Joined	Movement
Fibrous Joints		
Sutures		
Coronal	Frontal and parietal	None
Lambdoid	Occipital and parietal	None
Sagittal	The two parietal bones	None
Squamous	Parietal and temporal	Slight
Syndesmoses		
Radioulnar (interosseous membrane)	Ulna and radius	Slight
Stylohyoid	Styloid process and hyoid bone	Slight
Stylomandibular	Styloid process and mandible	Slight
Tibiofibular (interosseous membrane)	Tibia and fibula	Slight
Gomphoses		
Dentoalveolar	Tooth and alveolar process	Slight
Cartilaginous Joints		
Synchrondroses		
Epiphyseal plate	The diaphysis and epiphysis of a long bone	None
Sternocostal	Anterior cartilaginous part of first rib; between rib and sternum	Slight
Sphenooccipital	Sphenoid and occipital	None
Symphyses		
Intervertebral	Bodies of adjacent vertebrae	Slight
Manubriosternal	Manubrium and body of sternum	None
Symphysis pubis	The two coxae	None except during childbirth
Xiphisternal	Xiphoid process and body of sternum	None

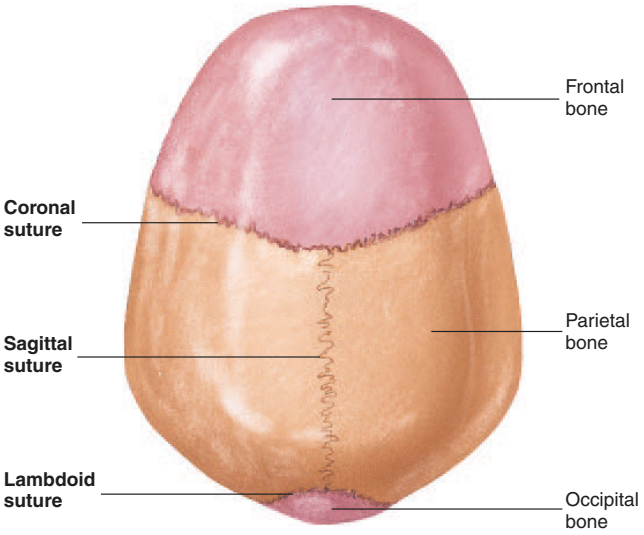


Figure 8.1 Sutures

The margins of bones within sutures are sites of continuous intramembranous bone growth, and many sutures eventually become ossified. For example, ossification of the suture between the two frontal bones occurs shortly after birth so that they usually form a single frontal bone in the adult skull. In most normal adults, the coronal, sagittal, and lambdoid sutures are not fused. In some very old adults, however, even these sutures may become ossified. A **synostosis** (sin-os-tō′sis) results when two bones grow together across a joint to form a single bone.

P R E D I C T 2

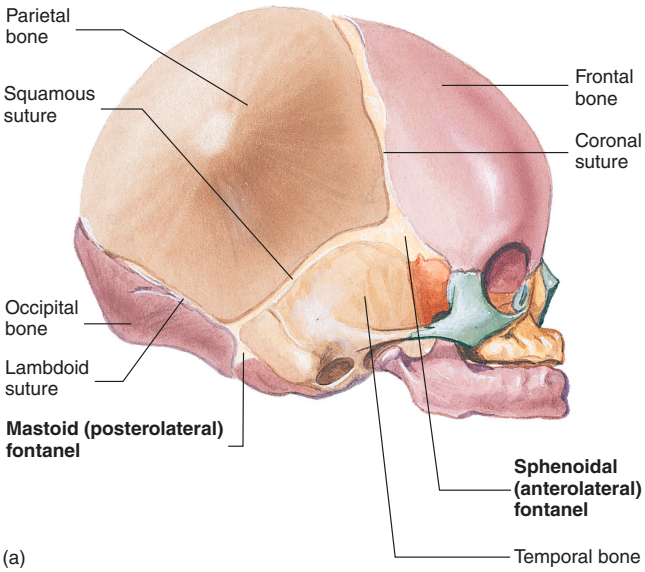
Predict the result of a sutural synostosis that occurs prematurely in a child's skull before the brain has reached its full size.

Syndesmoses

A **syndesmosis** (sin′dez-mō′sis; to fasten or bind) is a fibrous joint in which the bones are farther apart than in a suture and are joined by ligaments. Some movement may occur at syndesmoses because of flexibility of the ligaments, such as in the radioulnar syndesmosis, which binds the radius and ulna together (figure 8.3).

Gomphoses

Gomphoses (gom-fō′sēz) are specialized joints consisting of pegs that fit into sockets and that are held in place by fine bundles of regular collagenous connective tissue. The joints between the teeth and the sockets (alveoli) of the mandible and maxillae are gomphoses (figure 8.4). The connective tissue bundles between the teeth and their sockets are called **periodontal** (per′ē-ō-don′tăl) **ligaments** and allow a slight amount of "give" to the teeth during mastication.



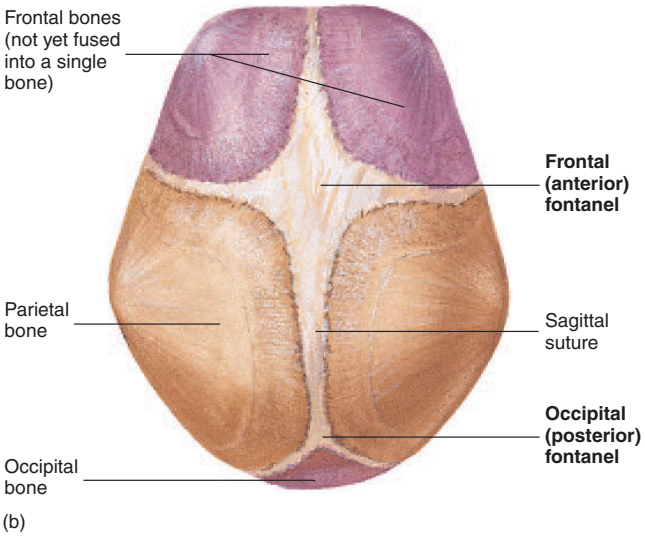


Figure 8.2 Fetal Skull Showing Fontanels and Sutures

(*a*) Lateral view. (*b*) Superior view.

Gingivitis

The gingiva, or gums, are the soft tissues covering the alveolar process. Neglect of the teeth can result in **gingivitis,** an inflammation of the gingiva, often resulting from bacterial infection. Left untreated, gingivitis may spread to the tooth socket, resulting in periodontal disease, the leading cause of tooth loss in the United States. Periodontal disease involves an accumulation of plaque and bacteria, and the resulting inflammation, which gradually destroys the periodontal ligaments and the bone. As a result, teeth may become so loose that they come out of their sockets. Proper brushing, flossing, and professional cleaning to remove plaque can usually prevent gingivitis and periodontal disease.

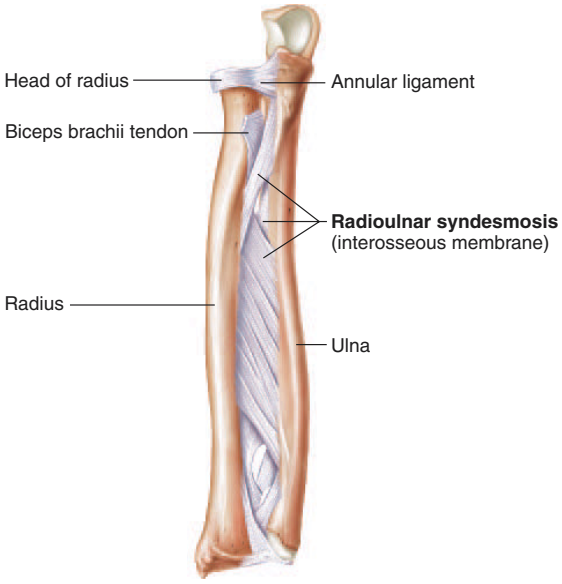


Figure 8.3 Right Radioulnar Syndesmosis
The interosseous membrane between the ulna and radius.

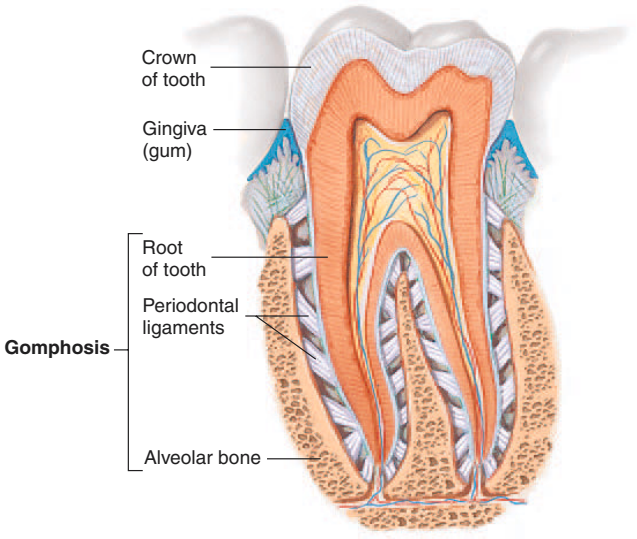


Figure 8.4 Gomphosis Between a Tooth and Alveolar Bone of the Mandible

2. Define the term fibrous joint, describe three different types, and give an example of each. What is a synostosis? Where are periodontal ligaments found?

Cartilaginous Joints

Cartilaginous joints unite two bones by means of either hyaline cartilage or fibrocartilage (table 8.1). Joints containing hyaline cartilage are called synchondroses; joints containing fibrocartilage are called symphyses.

Synchondroses

A **synchondrosis** (sin′kon-drō′sis; union through cartilage) consists of two bones joined by hyaline cartilage where little or no movement occurs (figure 8.5*a*). The epiphyseal plates of growing bones are synchondroses (figure 8.5*b*). Most synchondroses are temporary, with bone eventually replacing them to form synostoses. On the other hand, some synchondroses persist throughout life. An example is the sternocostal synchondrosis between the first rib and the sternum by way of the first costal cartilage (figure 8.5*c*). All the costal cartilages begin as synchondroses, but because of the movement that occurs between them and the sternum, all but the first usually develop synovial joints at those junctions. As a result, even though the **costochondral joints** (between the ribs and the costal cartilages) are retained, most costal cartilages no longer qualify as synchondroses because one end of the cartilage attaches to bone (the sternum) by a synovial joint.

Symphyses

A **symphysis** (sim′fi-sis; a growing together) consists of fibrocartilage uniting two bones. Symphyses include the junction between the manubrium and body of the sternum (figure 8.5*c*), the symphysis pubis (figure 8.6), and the intervertebral disks (see figures 7.15 and 7.17). Some of these joints are slightly movable because of the somewhat flexible nature of fibrocartilage.

Joint Changes During Pregnancy

During pregnancy certain hormones, such as estrogen, progesterone, and relaxin, act on the connective tissue of joints, such as the symphysis pubis, causing them to become more stretchable and allowing the joints to loosen. This change allows the pelvic opening to enlarge at the time of delivery. After delivery, the connective tissue of the symphysis pubis returns to its original condition. The enlarged pelvic opening, however, may not return completely to its original size and the woman may have slightly wider hips after the birth of the child.

These same hormones may act on the connective tissue of other joints in the body, such as the arches of the feet, causing them to relax, which may result in fallen arches (see section on "Arch Problems," p. 262). They may also act on some of the baby's joints, such as the hip, causing the joints to become more mobile than normal. Increased mobility of the hip can result in congenital (appearing at birth) subluxation, or congenital dislocation, of the hip. Congenital hip dislocation occurs approximately once in every 670 births.

3. Define cartilaginous joints, describe two different types, and give an example of each. Why are costochondral joints unique?

Synovial Joints

Synovial (si-nō′vē-ăl; joint fluid; *syn*, coming together, *ovia*, resembling egg albumin) **joints** contain synovial fluid and allow considerable movement between articulating bones (figure 8.7). These joints are anatomically more complex than fibrous and cartilaginous joints. Most joints that unite the bones of the appendicular skeleton are synovial joints, reflecting the far greater

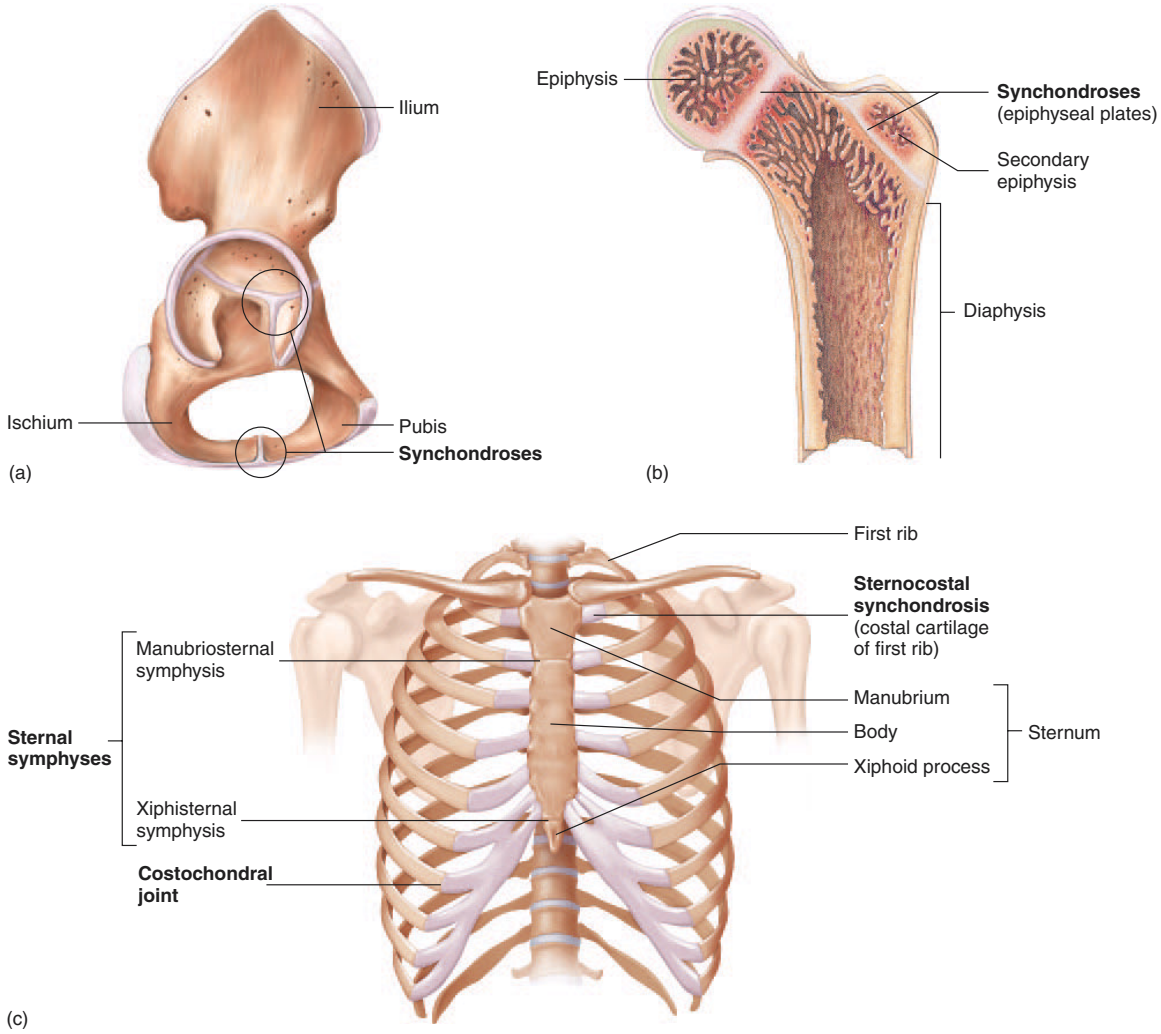


Figure 8.5 Synchondroses

(*a*) Synchondroses (epiphyseal plates) between the developing bones of the coxa. (*b*) Epiphyseal plates. (*c*) Sternocostal synchondroses.

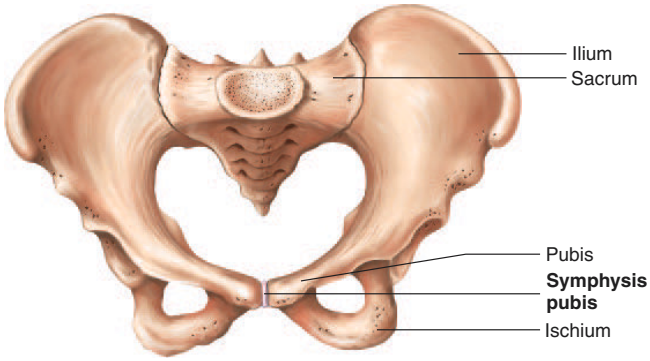


Figure 8.6 Symphysis Pubis

mobility of the appendicular skeleton compared to that of the axial skeleton.

The articular surfaces of bones within synovial joints are covered with a thin layer of hyaline cartilage called **articular cartilage,** which provides a smooth surface where the bones meet. Additional fibrocartilage **articular disks** are associated with several synovial joints, such as the knee and the temporomandibular joint. Articular disks provide extra strength and support to the joint and increase the depth of the joint cavity.

The articular surfaces of the bones that meet at a synovial joint are enclosed within a synovial **joint cavity,** which is surrounded by a **joint capsule.** This capsule helps to hold the bones together while allowing for movement. The joint capsule consists of two layers: an outer **fibrous capsule** and an inner **synovial**

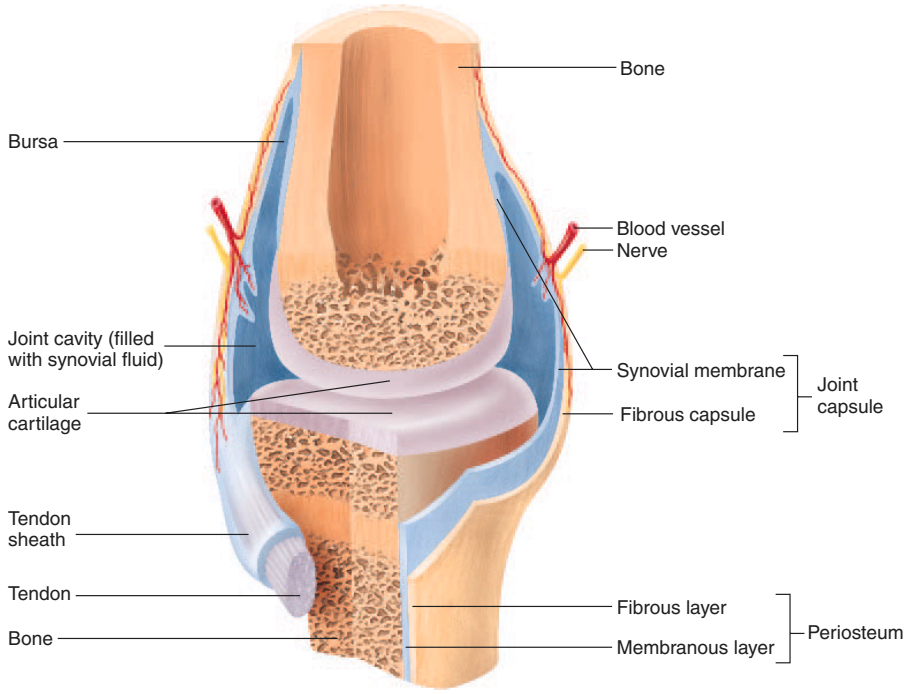


Figure 8.7 Structure of a Synovial Joint

membrane (see figure 8.7). The fibrous capsule consists of dense irregular connective tissue and is continuous with the fibrous layer of the periosteum that covers the bones united at the joint. Portions of the fibrous capsule may thicken to form ligaments. In addition, ligaments and tendons may be present outside the fibrous capsule, thereby contributing to the strength and stability of the joint while limiting movement in some directions.

The synovial membrane lines the joint cavity, except over the articular cartilage. It is a thin, delicate membrane consisting of a collection of modified connective tissue cells either intermixed with part of the fibrous capsule or separated from it by a layer of areolar tissue or adipose tissue. The membrane produces synovial fluid, which consists of a serum (blood fluid) filtrate and secretions from the synovial cells. Synovial fluid is a complex mixture of polysaccharides, proteins, fat, and cells. The major polysaccharide is hyaluronic acid, which provides much of the slippery consistency and lubricating qualities of synovial fluid. Synovial fluid forms an important thin lubricating film that covers the surfaces of a joint.

P R E D I C T 3

What would happen if a synovial membrane covered the articular cartilage?

In certain synovial joints, the synovial membrane may extend as a pocket, or sac, called a **bursa** (ber′să; pocket) for a distance away from the rest of the joint cavity (see figure 8.7). Bursae contain synovial fluid and provide a fluid-filled cushion between structures that otherwise would rub against each other, such as tendons rubbing on bones or other tendons. Some bursae are not associated with joints, such as those located between the skin and underlying bony prominences, where friction could damage the tissues. Other bursae extend along tendons for some distance, forming **tendon sheaths. Bursitis** (ber-sī′tis) is an inflammation of a bursa and may cause considerable pain around the joint and restrict movement.

At the peripheral margin of the articular cartilage, blood vessels form a vascular circle that supplies the cartilage with nourishment, but no blood vessels penetrate the cartilage or enter the joint cavity. Additional nourishment to the articular cartilage comes from the underlying cancellous bone and from the synovial fluid covering the articular cartilage. Sensory nerves enter the fibrous capsule and, to a lesser extent, the synovial membrane. They not only supply information to the brain about pain in the joint but also furnish constant information to the brain about the position of the joint and its degree of movement (see chapter 14). Nerves do not enter the cartilage or joint cavity.

Types of Synovial Joints

Synovial joints are classified according to the shape of the adjoining articular surfaces. The six types of synovial joints are the plane, saddle, hinge, pivot, ball-and-socket, and ellipsoid. These joints are illustrated in figures 8.8 to 8.13 and are listed in table 8.2. Movements at synovial joints are described as **monoaxial** (occurring around one axis), **biaxial** (occurring around two axes situated at right angles to each other), or **multiaxial** (occurring around several axes).

Table 8.2 Types of Joints

Class and Example of Joint		Structures Joined	Movement
Plane	Acromioclavicular	Acromion process of scapula and clavicle	Slight
	Carpometacarpal	Carpals and metacarpals 2–5	Multiple axes as a group
	Costovertebral	Ribs and vertebrae	Slight
	Intercarpal	Between carpals	Slight
	Intertarsal	Between tarsals	Slight
	Intervertebral	Between articular processes of adjacent vertebrae	Slight
	Sacroiliac	Between sacrum and coxa (complex joint with several planes and synchondroses)	Slight
	Tarsometatarsal	Tarsals and metatarsals	Slight
Saddle	Carpometacarpal pollicis	Carpal and metacarpal of thumb	Two axes
	Intercarpal	Between carpals	Slight
	Sternoclavicular	Manubrium of sternum and clavicle	Slight
Hinge	Cubital (elbow)	Humerus, ulna, and radius	One axis
	Genu (knee)	Femur and tibia	One axis
	Interphalangeal	Between phalanges	One axis
	Talocrural (ankle)	Talus, tibia and fibula	Multiple axes, one predominates
Pivot	Atlantoaxial	Atlas and axis	Rotation
	Proximal radioulnar	Radius and ulna	Rotation
	Distal radioulnar	Radius and ulna	Rotation
Ball-and-Socket	Coxal (hip)	Coxa and femur	Multiple axes
	Glenohumeral (shoulder)	Scapula and humerus	Multiple axes
Ellipsoid	Atlantooccipital	Atlas and occipital bone	Two axes
	Metacarpophalangeal (knuckles)	Metatarsals and phalanges	Mostly one axis
	Metatarsophalangeal	Metatarsals and phalanges	Mostly one axis
	Radiocarpal (wrist)	Radius and carpals	Multiple axes
	Temporomandibular	Mandible and temporal bone	Multiple axes, one predominates

Plane, or **gliding, joints** consist of two opposed flat surfaces of about equal size in which a slight amount of gliding motion can occur between the bones (figure 8.8). These joints are considered monoaxial because some rotation is also possible but is limited by ligaments and adjacent bone. Examples are the articular processes between vertebrae.

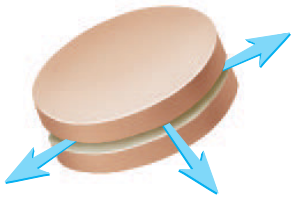


Figure 8.8 Plane Joint

Saddle joints consist of two saddle-shaped articulating surfaces oriented at right angles to each other so that complementary surfaces articulate with each other (figure 8.9). Saddle joints are biaxial joints. The carpometacarpal joint of the thumb is an example.

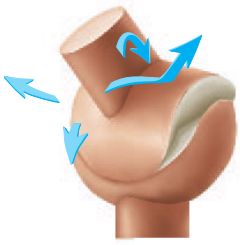


Figure 8.9 Saddle Joint

Hinge joints are monoaxial joints (figure 8.10). They consist of a convex cylinder in one bone applied to a corresponding concavity in the other bone. Examples include the elbow and knee joints.

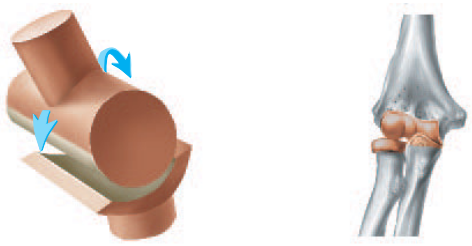


Figure 8.10 Hinge Joint

Pivot joints are monoaxial joints that restrict movement to rotation around a single axis (figure 8.11). A pivot joint consists of a relatively cylindrical bony process that rotates within a ring composed partly of bone and partly of ligament. The articulation between the head of the radius and the proximal end of the ulna is an example. The articulation between the dens, a process on the axis (see chapter 7), and the atlas is another example.

Figure 8.11 Pivot Joint

Ball-and-socket joints consist of a ball (head) at the end of one bone and a socket in an adjacent bone into which a portion of the ball fits (figure 8.12). This type of joint is multiaxial, allowing a wide range of movement in almost any direction. Examples are the shoulder and hip joints.

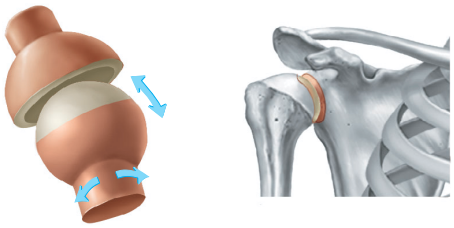


Figure 8.12 Ball-and-Socket Joint

Ellipsoid joints (or condyloid joints) are modified ball-and-socket joints (figure 8.13). The articular surfaces are ellipsoid in shape rather than spherical as in regular ball-and-socket joints. Ellipsoid joints are biaxial, because the shape of the joint limits its range of movement almost to a hinge motion in two axes and restricts rotation. The atlantooccipital joint is an example.

Figure 8.13 Ellipsoid Joint

4. *Describe the structure of a synovial joint. How do the different parts of the joint function to permit joint movement? What are articular disks and where are they found?*
5. *Define the terms bursa and tendon sheath. What is their function?*
6. *On what basis are synovial joints classified? Describe the different types of synovial joints, and give examples of each. What movements does each type of joint allow?*

Types of Movement

Objectives

- *Define and give examples of various types of movements in the body.*
- *Describe the factors that influence range of motion.*

A joint's structure relates to the movements that occur at that joint. Some joints are limited to only one type of movement; others can move in several directions. With few exceptions, movement is best described in relation to the anatomic position: (1) movement away from the anatomic position and (2) movement returning a structure toward the anatomic position. Most movements are accompanied by movements in the opposite direction and therefore are listed in pairs.

Gliding Movements

Gliding movements are the simplest of all the types of movement. These movements occur in plane joints between two flat or nearly flat surfaces where the surfaces slide or glide over each other. These joints often give only slight movement, such as between carpal bones.

Angular Movements

Angular movements are those in which one part of a linear structure, such as the body as a whole or a limb, is bent relative to another part of the structure, thereby changing the angle between the two parts. Angular movements also involve the movement of a solid rod, such as a limb, that's attached at one end to the body, so that the angle at which it meets the body is changed. The most common angular movements are flexion and extension and abduction and adduction.

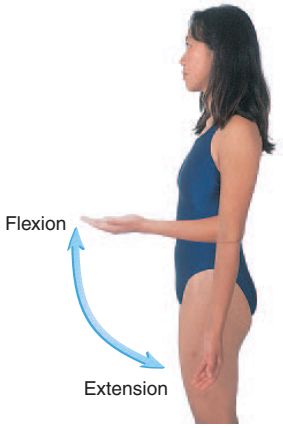


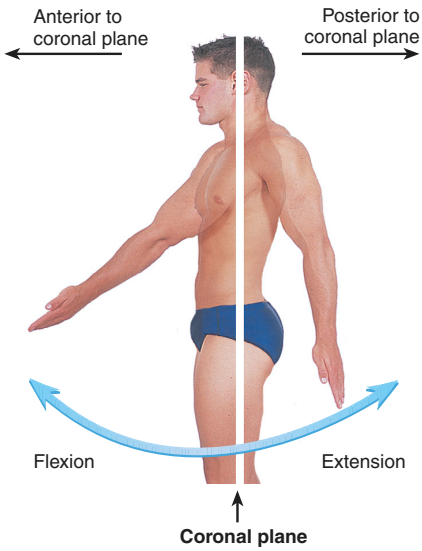
Figure 8.14 Flexion and Extension of the Elbow

Flexion and Extension

Flexion and extension can be defined in a number of ways, but in each case exceptions to the definition exist. The literal definition is to bend and straighten, respectively. This bending and straightening can easily be seen in the elbow (figure 8.14). We have chosen to use a definition with more utility and fewer exceptions. **Flexion** moves a part of the body in the anterior or ventral direction. **Extension** moves a part in a posterior or dorsal direction (figure 8.15). The exception to defining flexion and extension according to the coronal plane is the knee, in which flexion moves the leg in a posterior direction and extension moves it in an anterior direction (figure 8.16).

Figure 8.15 Flexion and Extension Defined According to the Coronal Plane

Flexion and extension of (*a*) the shoulder, (*b*) the neck, (*c*) the trunk.



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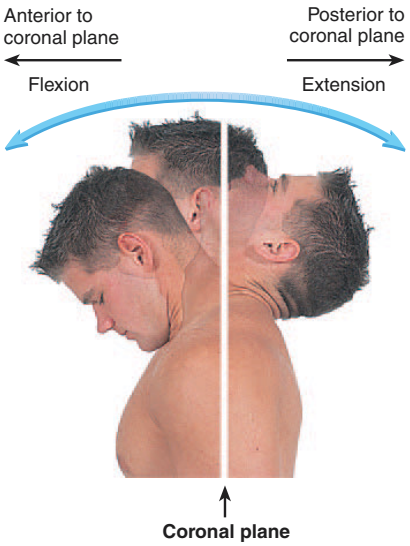

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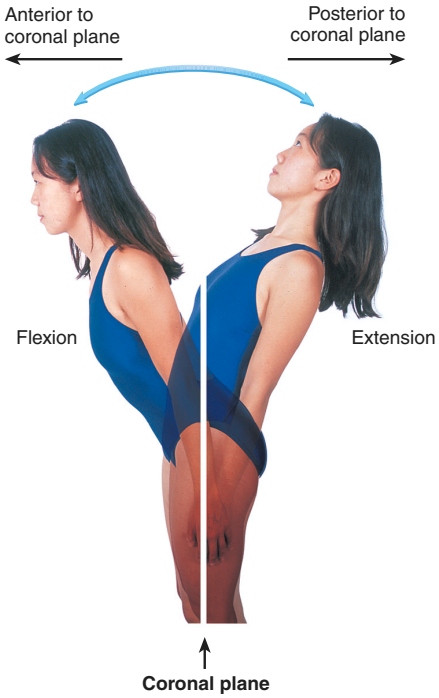

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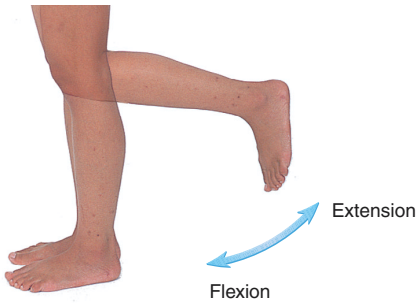
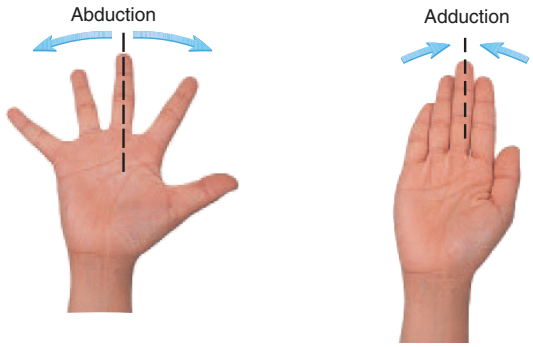


Figure 8.16 Flexion and Extension of the Knee

Figure 8.17 Dorsiflexion and Plantar Flexion of the Foot

(a)



(b)

Figure 8.18 Abduction and Adduction

Abduction and adduction of (*a*) the upper limb and (*b*) the fingers.

Movement of the foot toward the plantar surface, such as when standing on the toes, is commonly called **plantar flexion;** and movement of the foot toward the shin, such as when walking on the heels, is called **dorsiflexion** (figure 8.17).

Hyperextension

Hyperextension is usually defined as an abnormal, forced extension of a joint beyond its normal range of motion. For example, if a person falls and attempts to break the fall by putting out a hand, the force of the fall directed into the hand and wrist may cause hyperextension of the wrist, which may result in sprained joints or broken bones. Some health professionals, however, define hyperextension as the normal movement of structures, except the leg, into the space posterior to the anatomic position.

Abduction and Adduction

Abduction (meaning to take away) is movement away from the midline; **adduction** (meaning to bring together) is movement toward the midline (figure 8.18*a*). Moving the upper limbs away from the body such as in the outward and then upward portion of doing "jumping jacks" is abduction, and bringing the upper limbs back toward the body is adduction. Abduction of the fingers involves spreading the fingers apart, away from the midline of the hand, and adduction is bringing them back together (figure 8.18*b*). Abduction of the wrist, which is sometimes called radial deviation, is movement of the hand away from the midline of the body, and adduction of the wrist, which is sometimes called ulnar deviation, results in movement of the hand toward the midline of the body. Abduction of the head is tilting the head to one side or the other and is sometimes called lateral flexion of the neck. Bending at the waist to one side or the other is usually called **lateral flexion** of the vertebral column, rather than abduction.

Circular Movements

Circular movements involve the rotation of a structure around an axis or movement of the structure in an arc.

Rotation

Rotation is the turning of a structure around its long axis, such as rotation of the head, the humerus, or the entire body (figure 8.19). Medial rotation of the humerus with the forearm flexed brings the hand toward the body. Rotation of the humerus so that the hand moves away from the body is lateral rotation.

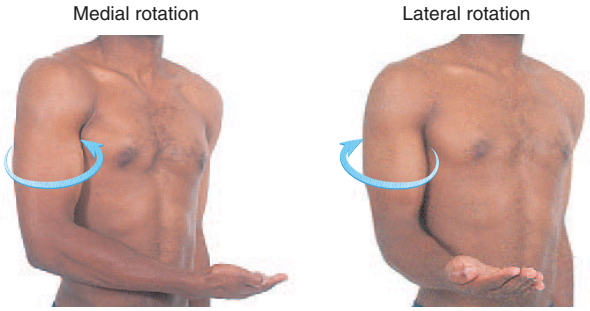


Figure 8.19 Medial and Lateral Rotation of the Arm

Pronation and Supination

Pronation (prō-nā′shŭn) and **supination** (soo′pi-nā′shŭn) refer to the unique rotation of the forearm (figure 8.20). The word *prone* means lying facedown; the word *supine* means lying faceup. Pronation is rotation of the forearm so that the palm faces posteriorly in relation to the anatomic position. The palm of the hand faces inferiorly if the elbow is flexed to 90°. Supination is rotation of the forearm so that the palm faces anteriorly in relation to the anatomic position. The palm of the hand faces superiorly if the elbow is flexed to 90°. In pronation the radius and ulna cross; in supination they are in a parallel position. The head of the radius rotates against the radial notch of the ulna during supination and pronation.

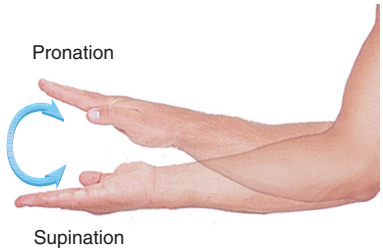


Figure 8.20 Pronation and Supination of the Hand

Circumduction

Circumduction is a combination of flexion, extension, abduction, and adduction (figure 8.21). It occurs at freely movable joints such as the shoulder. In circumduction, the arm moves so that it describes a cone with the shoulder joint at the apex.

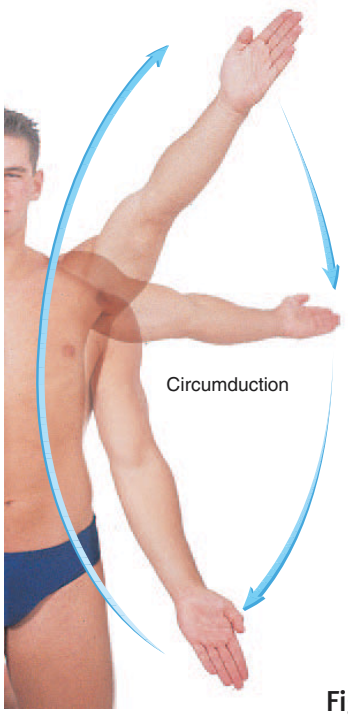


Figure 8.21 Circumduction

Special Movements

Special movements are those movements unique to only one or two joints; they don't fit neatly into one of the other categories.

Elevation and Depression

Elevation moves a structure superiorly; **depression** moves it inferiorly (figure 8.22). The scapulae and mandible are primary examples. Shrugging the shoulders is an example of scapular elevation. Depression of the mandible opens the mouth, and elevation closes it.

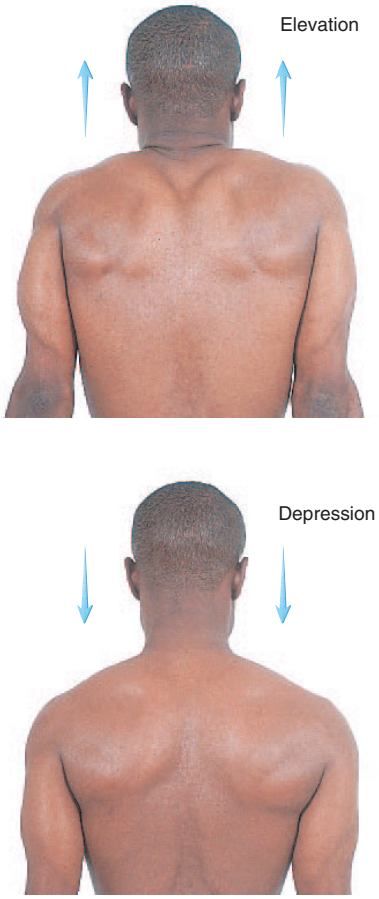


Figure 8.22 Elevation and Depression of the Scapula

Protraction and Retraction

Protraction consists of moving a structure in a gliding motion in an anterior direction (figure 8.23). **Retraction** moves the structure back to the anatomic position or even more posteriorly. As with elevation and depression, the mandible and scapulae are primary examples. Pulling the scapulae back toward the vertebral column is retraction.

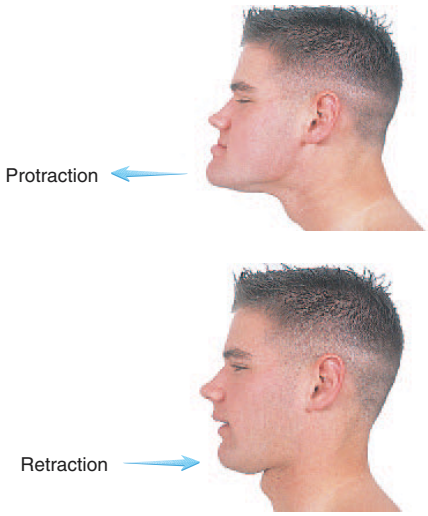


Figure 8.23 Protraction and Retraction of the Mandible

Excursion

Lateral excursion refers to moving the mandible to either the right or left of the midline (figure 8.24), such as in grinding the teeth or chewing. **Medial excursion** returns the mandible to the neutral position.

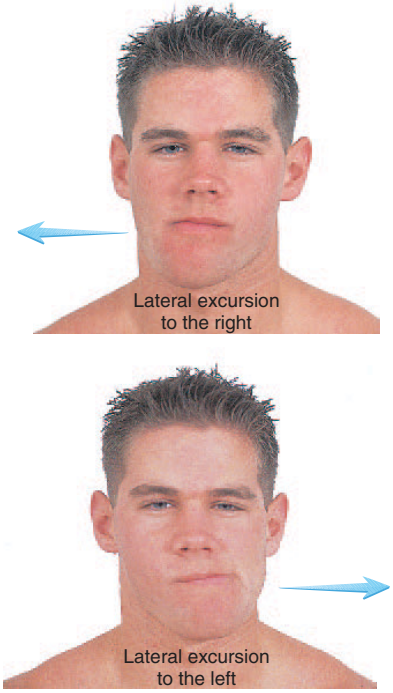


Figure 8.24 Excursion of the Mandible

Opposition and Reposition

Opposition is a unique movement of the thumb and little finger (figure 8.25). It occurs when these two digits are brought toward each other across the palm of the hand. The thumb can also oppose the other digits. **Reposition** is the movement returning the thumb and little finger to the neutral, anatomic position.

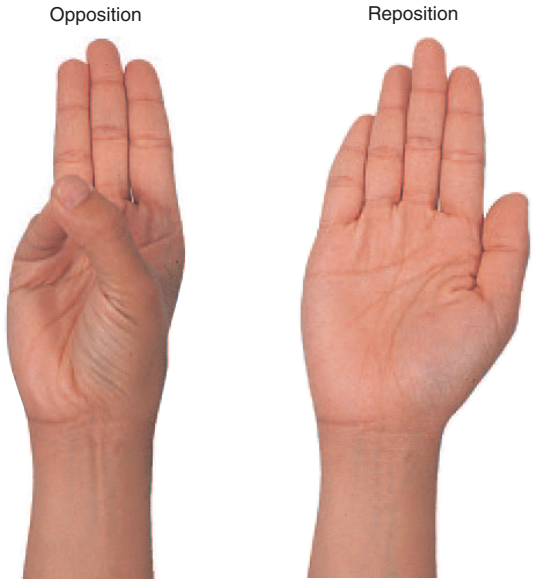


Figure 8.25 Opposition and Reposition of the Thumb and Little Finger

Inversion and Eversion

Inversion consists of turning the ankle so that the plantar surface of the foot faces medially, toward the opposite foot. **Eversion** is turning the ankle so that the plantar surface faces laterally (figure 8.26). Inversion of the foot is sometimes called supination, and eversion is called pronation.

Figure 8.26 Inversion and Eversion of the Foot

Combination Movements

Most movements that occur in the course of normal activities are combinations of the movements named previously and are described by naming the individual movements involved in the combined movement. For example, if a person raises a hand from the anatomic position out to the side and then brings it in front so that it is at shoulder height, that movement could be considered a combination of abduction and flexion.

7. *Define the terms flexion and extension. How are they different for the upper and lower limbs? What is hyperextension?*
8. *Contrast abduction and adduction. Describe these movements for the head, upper limbs, wrist, fingers, lower limbs, and toes. For what part of the body is the term lateral flexion used?*
9. *Distinguish among rotation, circumduction, pronation, and supination. Give an example of each.*
10. *Define the following jaw movements: protraction, retraction, lateral excursion, medial excursion, elevation and depression.*
11. *Define the terms opposition and reposition.*
12. *What terms are used for flexion and extension of the foot? For turning the side of the foot medially or laterally?*

PREDICT 4

What combination of movements is required at the shoulder and elbow joints for a person to move the right upper limb from the anatomic position to touch the right side of the head with the fingertips?

Range of Motion

Range of motion is an expression of the amount of mobility that can be demonstrated in a given joint. The **active range of motion** is the amount of movement that can be accomplished by contraction of the muscles that normally act across a joint. The **passive range of motion** is the amount of movement that can be accomplished at a joint when the structures that meet at the joint are moved by some outside force, such as when a therapist holds onto the forearm of a patient and moves it toward the patient's arm, flexing the joint. The active and passive range of motion for normal joints is usually about equal.

The range of motion for a given joint is influenced by a number of factors, including the shape of the articular surfaces of the bones forming the joint, the amount and shape of cartilage covering those articular surfaces, the strength and location of ligaments and tendons surrounding the joint, the strength and location of the muscles associated with the joint, the amount of fluid in and around the joint, the amount of pain in and around the joint, and the amount of use or disuse the joint has received over time. Abnormalities in the range of motion can occur when any of those components changes. For example, damage to a ligament associated with a given joint may increase the range of motion of that joint. A torn piece of cartilage within a joint can limit its range of motion. If the nerve supply to a muscle is damaged so that the muscle is weakened, the active range of motion for the joint acted upon by that muscle may decrease, but the passive range of motion for the joint should remain unchanged. Fluid buildup and/or pain in or around a joint can severely limit both the active and passive range of motion for that joint. With disuse, both the active and passive range of motion for a given joint decrease.

13. *Define range of motion. Contrast active range of motion with passive range of motion. What factors influence range of motion?*

Description of Selected Joints

Objectives

- *Describe the temporomandibular, shoulder, elbow, hip, knee, and ankle joints. Include the type of movements and special features of each.*
- *Discuss the most common injuries of the shoulder, elbow, hip, knee, ankle, and foot arches.*

It's impossible in a limited space to describe all the joints of the body; therefore, we describe only selected joints in this chapter, and they have been chosen because of their representative structure, important function, or clinical significance.

Temporomandibular Joint

The mandible articulates with the temporal bone to form the **temporomandibular joint (TMJ).** The mandibular condyle fits into the mandibular fossa of the temporal bone. A fibrocartilage articular disk is located between the mandible and the temporal bone, dividing the joint into superior and inferior cavities

(figure 8.27). The joint is surrounded by a fibrous capsule to which the articular disk is attached at its margin, and is strengthened by lateral and accessory ligaments.

The temporomandibular joint is a combination plane and ellipsoid joint, with the ellipsoid portion predominating. Depression of the mandible to open the mouth involves an anterior gliding motion of the mandibular condyle and articular disk relative to the temporal bone, which is about the same motion that occurs in protraction of the mandible; it is followed by a hinge motion that occurs between the articular disk and the mandibular head. The mandibular condyle is also capable of slight mediolateral movement, allowing excursion of the mandible.

TMJ Disorders

TMJ disorders are a group of conditions that cause most chronic orofacial pain. The conditions include joint noise; pain in the muscle, joint, or face; headache; and reduction in the range of joint movement. TMJ pain is often felt as referred pain in the ear. Patients may go to a physician complaining of an earache and are then referred to a dentist. As many as 65%–75% of people between ages 20 and 40 experience some of these symptoms. Symptoms appear to affect men and women about equally, but only about 10% of the symptoms are severe enough to cause people to seek medical attention. Women experience severe pain eight times more often than do men.

TMJ disorders are classified as those involving the joint, with or without pain; those involving only muscle pain; or those involving both the joint disorder and muscle pain. TMJ disorders are also classified as acute or chronic. Acute cases are usually self-limiting and have an identifiable cause. Chronic cases are not self-limiting, may be permanent, and often have no apparent cause. Chronic TMJ disorders are not easily treated, and chronic TMJ pain has much in common with other types of chronic pain. Whereas some people learn to live with the pain, others may experience psychologic problems, such as a sense of helplessness and hopelessness, high tension, and loss of sleep and appetite. Drug dependency may occur if strong drugs are used to control the pain; and relationships, lifestyle, vocation, and social interactions may be disrupted. Many of these problems may make the pain worse through positive feedback. Treatment includes teaching the patient to reduce jaw movements that aggravate the problem and to reduce stress and anxiety. Physical therapy may help to relax the muscles and restore function. Analgesic and antiinflammatory drugs may be used, and oral splints may be helpful, especially at night.

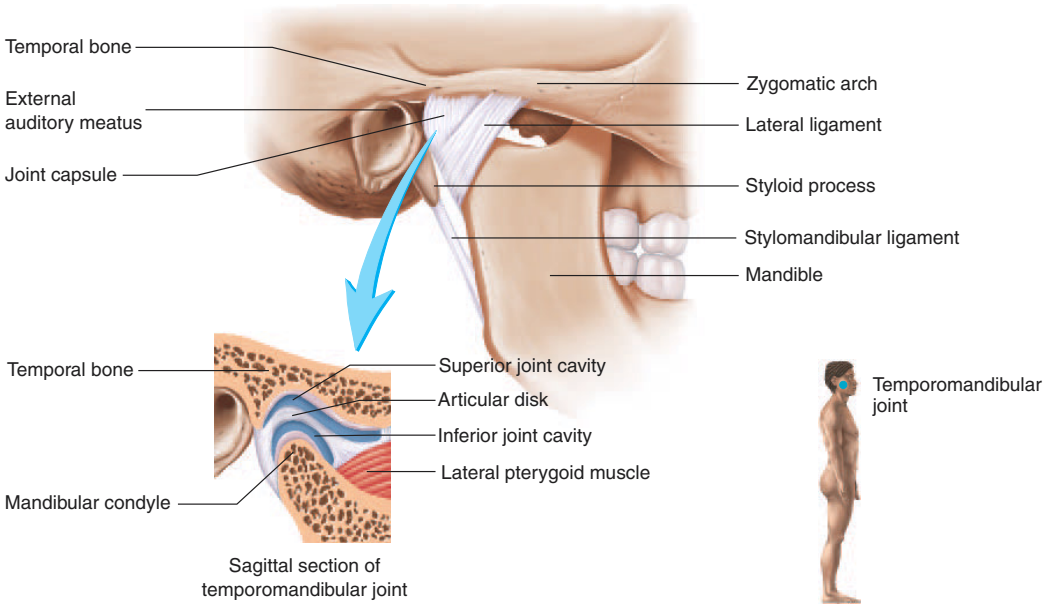
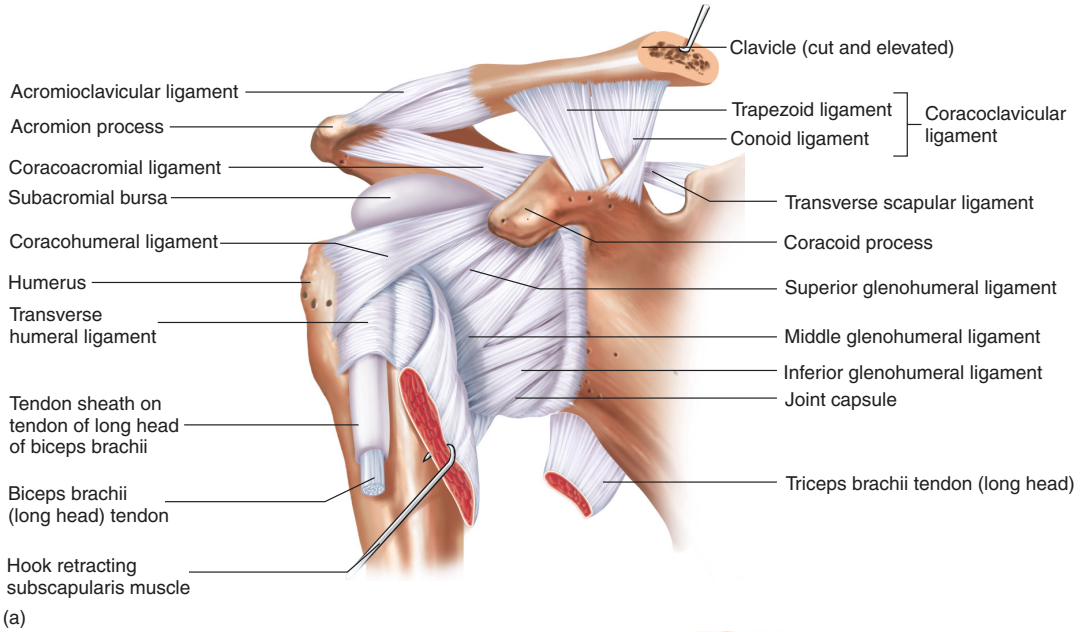


Figure 8.27 Right Temporomandibular Joint, Lateral View

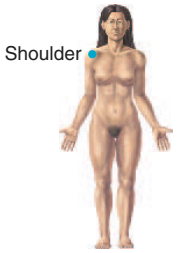
Shoulder Joint

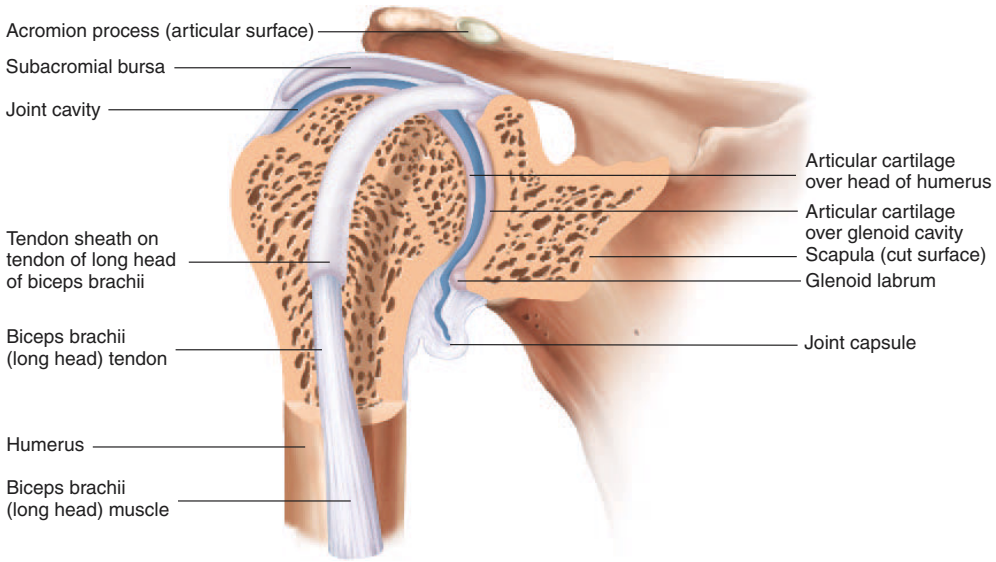
The **shoulder,** or **glenohumeral, joint** is a ball-and-socket joint (figure 8.28) in which stability is reduced and mobility is increased compared to the other ball-and-socket joint, the hip. Flexion, extension, abduction, adduction, rotation, and circumduction can all occur at the shoulder joint. The rounded head of the humerus articulates with the shallow glenoid cavity of the scapula. The rim of the glenoid cavity is built up slightly by a fibrocartilage ring, the **glenoid labrum,** to which the joint capsule is attached. A **subscapular bursa** (not shown in the figure) and a **subacromial bursa** open into the joint cavity.

The stability of the joint is maintained primarily by three sets of ligaments and four muscles. The ligaments of the shoulder are listed in table 8.3. The four muscles, referred to collectively as the



(a)





(b)

Figure 8.28 Right Shoulder Joint

(*a*) Anterior view. (*b*) Frontal section.

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Table 8.3 Ligaments of the Shoulder Joint (see figure 8.28)

Ligament	Description
Glenohumeral (superior, middle, and inferior)	Three slightly thickened longitudinal sets of fibers on the anterior side of the capsule; extend from the humerus to the margin of the glenoid cavity
Transverse humeral	Lateral, transverse fibrous thickening of the joint capsule; crosses between the greater and lesser tubercles and holds down the tendon from the long head of the biceps muscle
Coracohumeral	Crosses from the root of the coracoid process to the humeral neck
Coracoacromial	Crosses above the joint between the coracoid process and the acromion process; an accessory ligament

rotator cuff, pull the humeral head superiorly and medially toward the glenoid cavity. These muscles are discussed in more detail in chapter 10. The head of the humerus is also supported against the glenoid cavity by the tendon from the biceps brachii muscle in the anterior part of the arm. This tendon is unusual in that it passes through the articular capsule of the shoulder joint before crossing the head of the humerus and attaching to the scapula at the supraglenoid tubercle (see figure 7.29*a*).

Shoulder Disorders

The most common traumatic shoulder disorders are **dislocation** and muscle or tendon **tears.** The shoulder is the most commonly dislocated joint in the body. The major ligaments cross the superior part of the shoulder joint, and no major ligaments or muscles are associated with the inferior side. As a result, dislocation of the humerus is most likely to occur inferiorly into the axilla. Because the axilla contains very important nerves and arteries, severe and permanent damage may result from attempts to relocate a dislocated shoulder using inappropriate techniques (see chapter 12). Chronic shoulder disorders include tendonitis (inflammation of tendons), bursitis (inflammation of bursae), and arthritis (inflammation of joints). Bursitis of the subacromial bursa can become very painful when the large shoulder muscle, called the deltoid muscle, compresses the bursa during shoulder movement.

P R E D I C T 5

Separation of the shoulder consists of stretching or tearing the ligaments of the acromioclavicular joint (acromioclavicular, or AC, separation). Using figure 8.28*a* and your knowledge of the articulated skeleton for assistance, explain the nature of a shoulder separation, and predict the problems that may follow a separation.

Elbow Joint

The **elbow joint** (figure 8.29) is a compound hinge joint consisting of the **humeroulnar joint,** between the humerus and ulna, and the **humeroradial joint,** between the humerus and radius. The **proximal radioulnar joint** is also closely related. The shape of the trochlear notch and its association with the trochlea of the humerus (figure 8.29*a*) limit movement at the elbow joint to flexion and extension. The rounded radial head, however, rotates in the radial notch of the ulna and against the capitulum of the humerus (figure 8.29*b*), allowing pronation and supination of the hand.

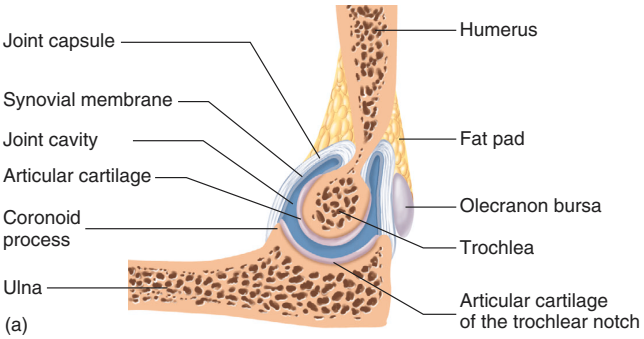
The elbow joint is surrounded by a joint capsule. The humeroulnar joint is reinforced by the **ulnar collateral ligament** (figure 8.29*c*). The humeroradial and proximal radioulnar joints are reinforced by the **radial collateral ligament** and **radial annular ligament** (figure 8.29*d*). A subcutaneous **olecranon bursa** covers the proximal and posterior surfaces of the olecranon process.

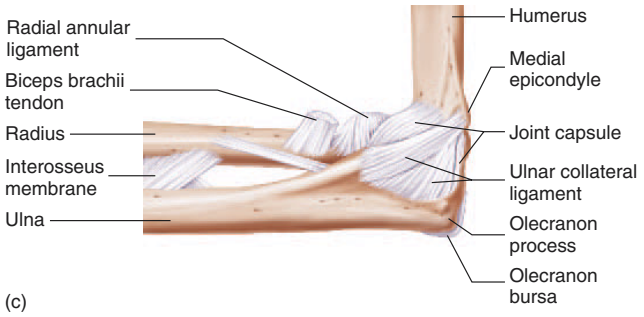
Elbow Problems

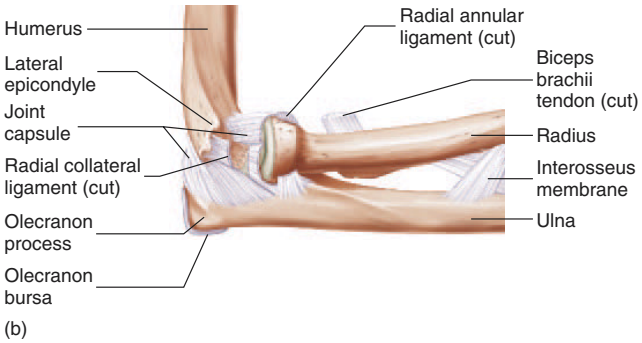
Olecranon bursitis is an inflammation of the olecranon bursa. This inflammation can be caused by excessive rubbing of the elbow against a hard surface and is sometimes referred to as **student's elbow.** The radial head can become subluxated (partial joint separation) from the annular ligament of the radius. This condition is called **nursemaid's elbow.** If a child is lifted by one hand, the action may subluxate the radial head.

Hip Joint

The femoral head articulates with the relatively deep, concave acetabulum of the coxa to form the **coxal,** or **hip joint** (figure 8.30). The head of the femur is more nearly a complete ball than the articulating surface of any other bone of the body. The acetabulum is deepened and strengthened by a lip of fibrocartilage called the **acetabular labrum,** which is incomplete inferiorly, and by a **transverse acetabular ligament,** which crosses the acetabular notch on the inferior edge of the acetabulum. The hip is capable of a wide range of movement, including flexion, extension, abduction, adduction, rotation, and circumduction.







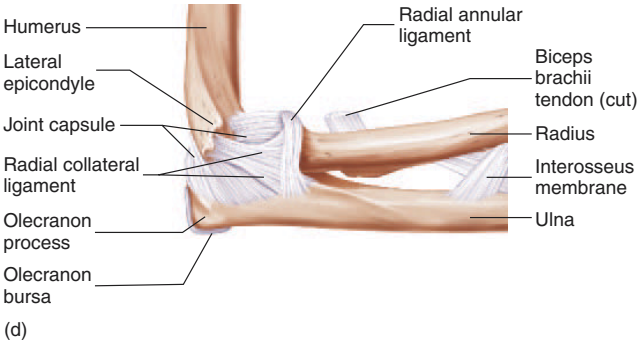


Figure 8.29 Right Elbow Joint

(*a*) Sagittal section showing the relation between the ulna and humerus. (*b*) Lateral side with ligaments cut to show the relation between the radial head, ulna, and humerus. (*c*) Medial side. (*d*) Lateral side.

Hip Dislocation

Dislocation of the hip may occur when the hip is flexed and the femur is driven posteriorly, such as when a person sitting in an automobile is involved in an accident. The head of the femur usually dislocates posterior to the acetabulum, tearing the acetabular labrum, the fibrous capsule, and the ligaments. Fracture of the femur and the coxa often accompany hip dislocation.

An extremely strong joint capsule, reinforced by several ligaments, extends from the rim of the acetabulum to the neck of the femur (table 8.4). The **iliofemoral ligament** is especially strong. When standing, most people tend to thrust the hips anteriorly. This position is relaxing because the iliofemoral ligament supports much of the body's weight. The **ligamentum teres,** which is the ligament of the head of the femur, is located inside the hip joint between the femoral head and the acetabulum. This ligament does not contribute much

Table 8.4 Ligaments of the Hip Joint (see figure 8.30)

Ligament	Description
Transverse acetabular	Bridges gap in the inferior margin of the fibrocartilage acetabular labrum
Iliofemoral	Strong, thick band between the anterior inferior iliac spine and the intertrochanteric line of the femur
Pubofemoral	Extends from the pubic portion of the acetabular rim to the inferior portion of the femoral neck
Ischiofemoral	Bridges the ischial acetabular rim and the superior portion of the femoral neck; less well defined
Ligamentum teres	Weak, flat band from the margin of the acetabular notch and the transverse ligament to a fovea in the center of the femoral head

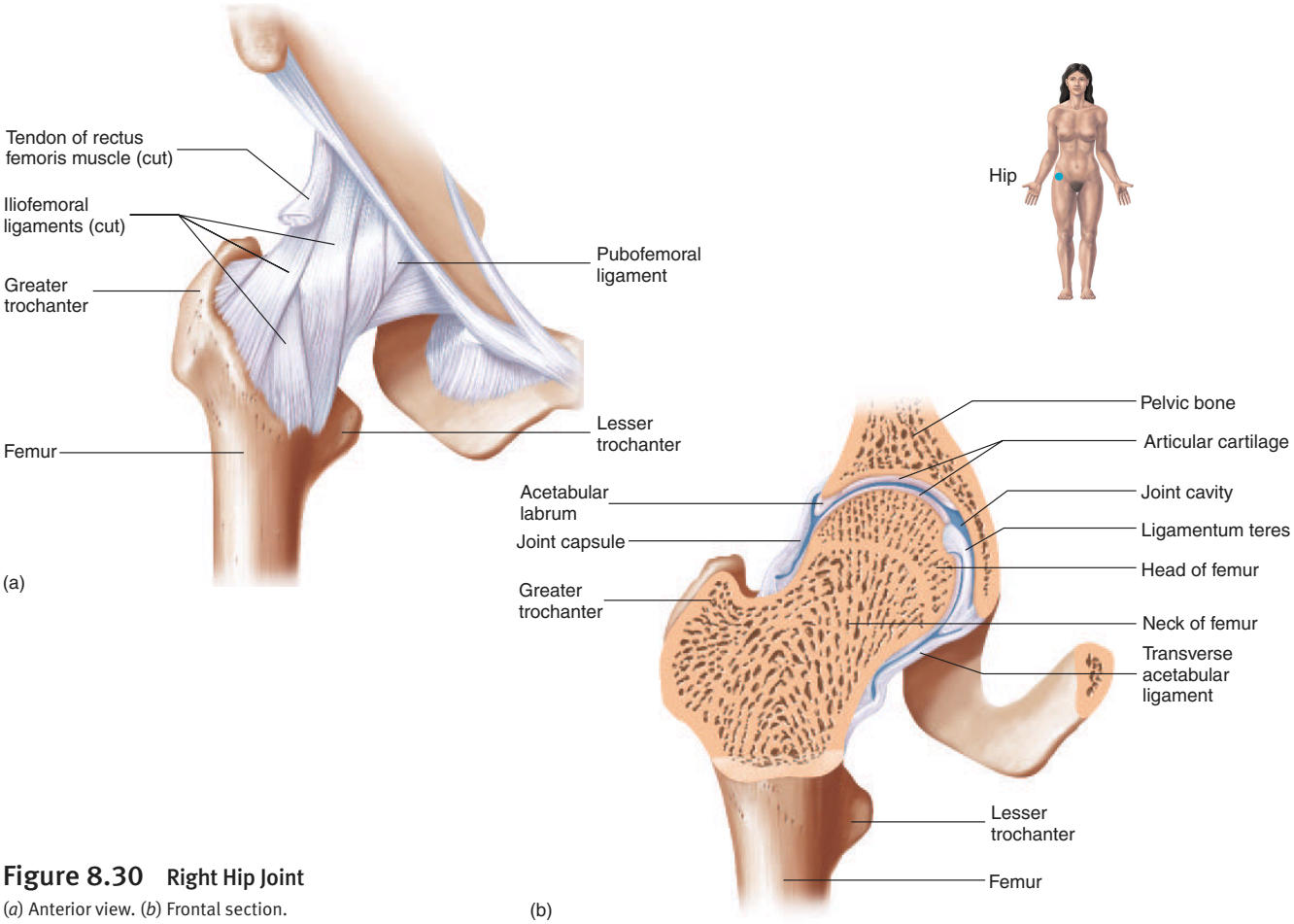


Figure 8.30 Right Hip Joint
(*a*) Anterior view. (*b*) Frontal section.

toward strengthening the hip joint; however, it does carry a small nutrient artery to the head of the femur in about 80% of the population. The acetabular labrum, ligaments of the hip, and the surrounding muscles make the hip joint much more stable but less mobile than the shoulder joint.

Knee Joint

The **knee joint** traditionally is classified as a modified hinge joint located between the femur and the tibia (figure 8.31). Actually, it's a complex ellipsoid joint that allows flexion, extension, and a small amount of rotation of the leg. The distal end of the femur has two large ellipsoid surfaces and a deep fossa between them. The femur articulates with the proximal end of the tibia, which is flattened and smooth laterally, with a crest called the intercondylar eminence in the center (see figure 7.40). The margins of the tibia are built up by thick fibrocartilage articular disks, called **menisci** (mĕ-nis′sī; crescent-shaped; figure 8.31*b* and *d*), that deepen the articular surface. The fibula does not articulate with the femur but articulates only with the lateral side of the tibia.

Two **cruciate** (kroo′shē-āt; crossed) **ligaments** extend between the intercondylar eminence of the tibia and the fossa of the femur (see figure 8.31*b, d,* and *e*). The anterior cruciate ligament prevents anterior displacement of the tibia relative to the femur, and the posterior cruciate ligament prevents posterior displacement of the tibia. The joint is also strengthened by **collateral** and **popliteal ligaments** and by the tendons of the thigh muscles, which extend around the knee (table 8.5).

A number of bursae surround the knee (see figure 8.31*f*). The largest is the **suprapatellar bursa,** which is a superior extension of the joint capsule and allows for movement of the anterior thigh muscles over the distal end of the femur. Other knee bursae include the subcutaneous prepatellar bursa and the deep infrapatellar bursa, as well as the popliteal bursa, the gastrocnemius bursa, and the subcutaneous infrapatellar bursa (not illustrated).

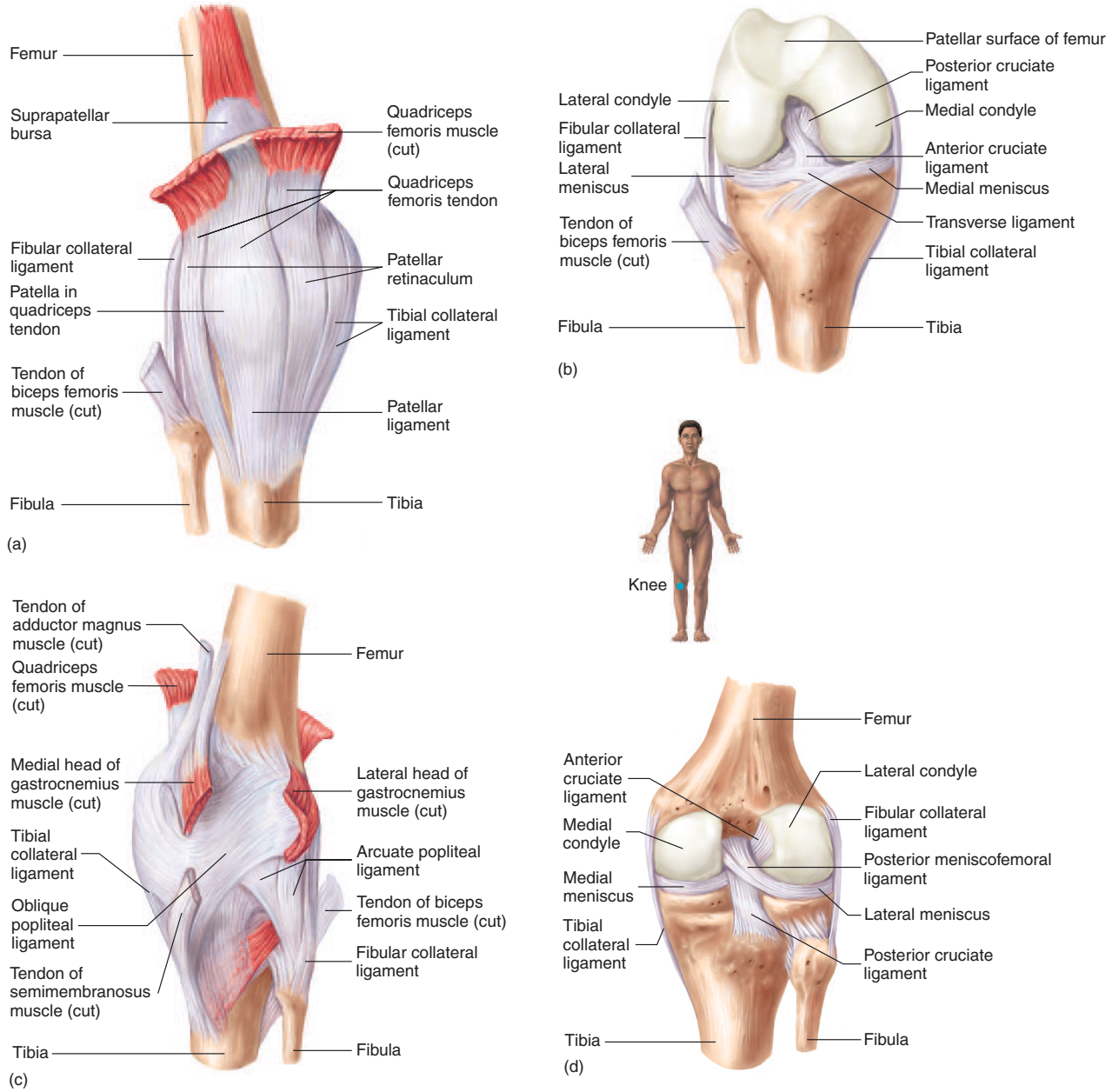
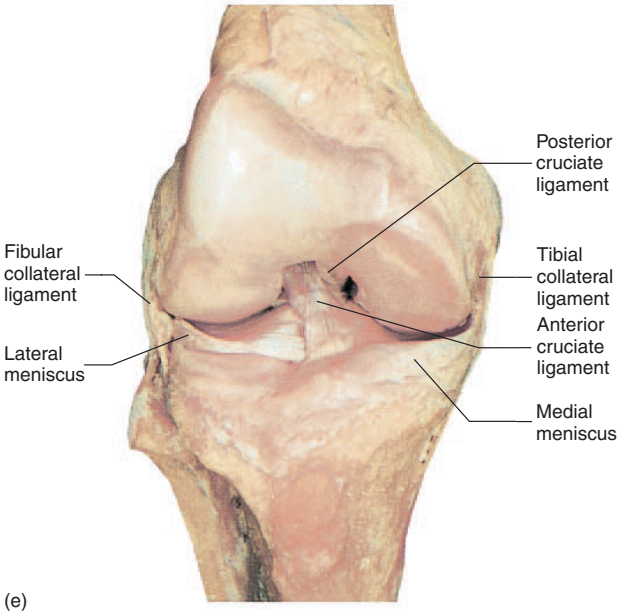
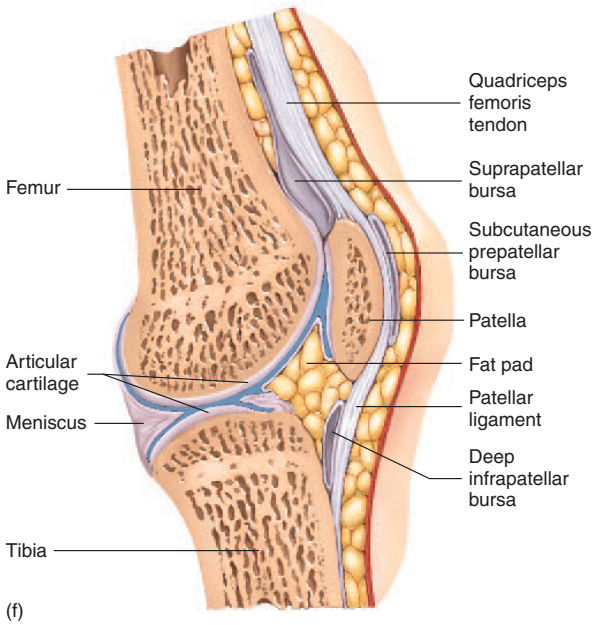


Figure 8.31 Right Knee Joint

(*a*) Anterior superficial view. (*b*) Anterior deep view (knee flexed). (*c*) Posterior superficial view. (*d*) Posterior deep view.



(e)



(f)

Figure 8.31 *(continued)*

(*e*) Photograph of anterior deep view. (*f*) Sagittal section.

Table 8.5 Ligaments of the Knee Joint (see figure 8.31)

Ligament	Description	Ligament	Description
Patellar	Thick, heavy, fibrous band between the patella and the tibial tuberosity; actually part of the quadriceps femoris tendon	Anterior cruciate	Extends obliquely, superiorly, and posteriorly from the anterior intercondylar eminence of the tibia to the medial side of the lateral femoral condyle
Patellar retinaculum	Thin band from the margins of the patella to the sides of the tibial condyles	Posterior cruciate	Extends superiorly and anteriorly from the posterior intercondylar eminence to the lateral side of the medial condyle
Oblique popliteal	Thickening of the posterior capsule; extension of the semimembranous tendon	Coronary (medial and lateral)	Attaches the menisci to the tibial condyles (not illustrated)
Arcuate popliteal	Extends from the posterior fibular head to the posterior fibrous capsule	Transverse	Connects the anterior portions of the medial and lateral menisci
Tibial collateral	Thickening of the lateral capsule from the medial epicondyle of the femur to the medial surface of the tibia; also called the tibial collateral ligament	Meniscofemoral (anterior and posterior)	Joins the posterior part of the lateral menisci to the medial condyle of the femur, passing anterior and posterior to the posterior cruciate ligament (not illustrated)
Fibular collateral	Round ligament extending from the lateral femoral epicondyle to the head of the fibula; also called the fibular collateral ligament		

Clinical Focus Knee Injuries and Disorders

Injuries to the medial side of the knee are much more common than injuries to the lateral side. The fibular (lateral) collateral ligament strengthens the joint laterally and is stronger than the tibial (medial) collateral ligament. Damage to the collateral ligaments occurs as a result of blows to the opposite side of the knee. Severe blows to the medial side of the knee, which would damage the fibular collateral ligament, are far less common than blows to the lateral side of the knee. In addition, the medial meniscus is fairly tightly attached to the tibial collateral ligament and is damaged 20 times more often in a knee injury than the lateral meniscus, which is thinner and more loosely attached. A torn meniscus may result in a "clicking" sound during extension of the leg; or, if the damage is more severe, the torn piece of cartilage may move between the articulating surfaces of the tibia and femur, causing the knee to "lock" in a partially flexed position. If the knee is driven anteriorly or if it is hyperextended, the anterior cruciate ligament may be torn, which causes the knee joint to be very unstable. If the knee is driven posteriorly, the posterior cruciate ligament may be torn. Surgical replacement of a cruciate ligament with a transplanted or artificial ligament is a technique used to repair the damage.

A common type of football injury results from a block or tackle to the lateral side of the knee, which can cause the knee to bend inward, opening the medial side of the joint and tearing the medial collateral ligament. The medial meniscus often is torn as well. Because this ligament is strongly attached to the medial meniscus, in severe injuries, the anterior cruciate ligament, which is attached to the medial meniscus, is also damaged (figure A).

Bursitis in the subcutaneous prepatellar bursa (see figure 8.31*f*), commonly called "housemaid's knee," may result from prolonged work performed while on the hands and knees. Another bursitis, "clergyman's knee," results from excessive kneeling and affects the subcutaneous infrapatellar bursa (not illustrated). This type of bursitis is common in carpet layers and roofers.

Other common knee problems include chondromalacia, or softening of the cartilage, which results from abnormal movement of the patella within the patellar groove, and the "fat pad syndrome," which consists of an accumulation of fluid in the fat pad posterior to the patella. An acutely swollen knee appearing immediately after an injury is usually a sign of blood accumulation within the joint cavity and is called a hemarthrosis. A slower accumulation of fluid, "water on the knee," may be caused by bursitis.

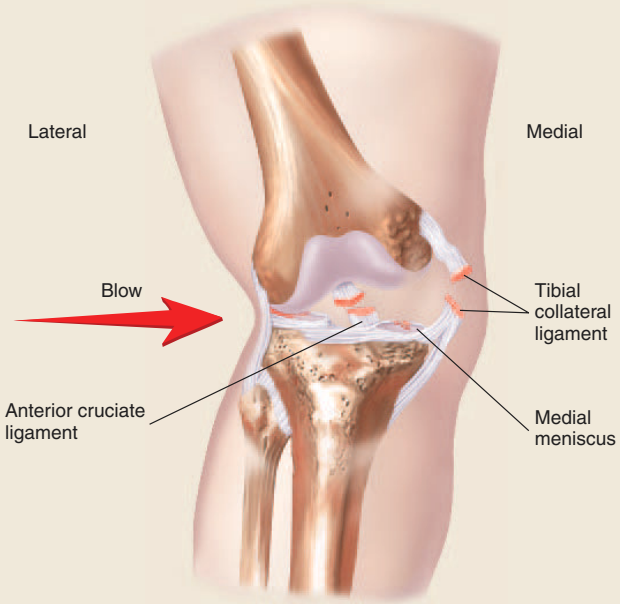


Figure A Injury to the Right Knee

Ankle Joint and Arches of the Foot

The distal tibia and fibula form a highly modified hinge joint with the talus called the **ankle,** or **talocrural** (tā′lō-kroo′răl), **joint** (figure 8.32). The medial and lateral malleoli of the tibia and fibula, which form the medial and lateral margins of the ankle, are rather extensive, whereas the anterior and posterior margins are almost nonexistent. As a result, a hinge joint is created from a modified ball-and-socket arrangement. A fibrous capsule surrounds the joint, with the medial and lateral parts thickened to form ligaments. Other ligaments also help stabilize the joint (table 8.6). Dorsiflexion, plantar flexion, and limited inversion and eversion can occur at this joint.

Ankle Injury

The ankle is the most frequently injured major joint in the body. The most common ankle injuries result from forceful inversion of the foot. A **sprained ankle** results when the ligaments of the ankle are torn partially or completely. The calcaneofibular ligament tears most often, followed in frequency by the anterior talofibular ligament. A fibular fracture can occur with severe inversion because the talus can slide against the lateral malleolus and break it.

The ligaments of the arch serve two major functions: to hold the bones in their proper relationship as segments of the arch and to provide ties across the arch somewhat like a bowstring. As weight is transferred through the arch system, some of the ligaments are stretched, giving the foot more flexibility and allowing it to adjust to uneven surfaces. When weight is removed from the foot, the ligaments recoil and restore the arches to their unstressed shape.

Arch Problems

The arches of the foot normally form early in fetal life. Failure to form results in congenital flat feet, or fallen arches, a condition in which the arches, primarily the medial longitudinal arch, are depressed or collapsed (see figure 7.44). This condition is not always painful. **Flat feet** may also occur when the muscles and ligaments supporting the arch fatigue and allow the arch, usually the medial longitudinal arch, to collapse. During prolonged standing, the plantar calcaneonavicular ligament may stretch, flattening the medial longitudinal arch. The transverse arch may also become flattened. The strained ligaments can become painful.

The plantar fascia is the deep connective tissue superficial to the ligaments in the central plantar surface of the foot and the thinner fascia on the medial and lateral sides of the plantar surface (see figure 8.32). **Plantar fasciitis**, which is an inflammation of the plantar fascia, can be a problem for distance runners as a result of continuous stretching.

14. *For each of the following joints, name the bones of the joint, the specific part of the bones that form the joint, the type of joint, and the possible movement(s) at the joint: temporomandibular, shoulder, elbow, hip, knee, and ankle.*
15. *Describe dislocations of the shoulder and hip. What conditions are most likely to cause each type?*

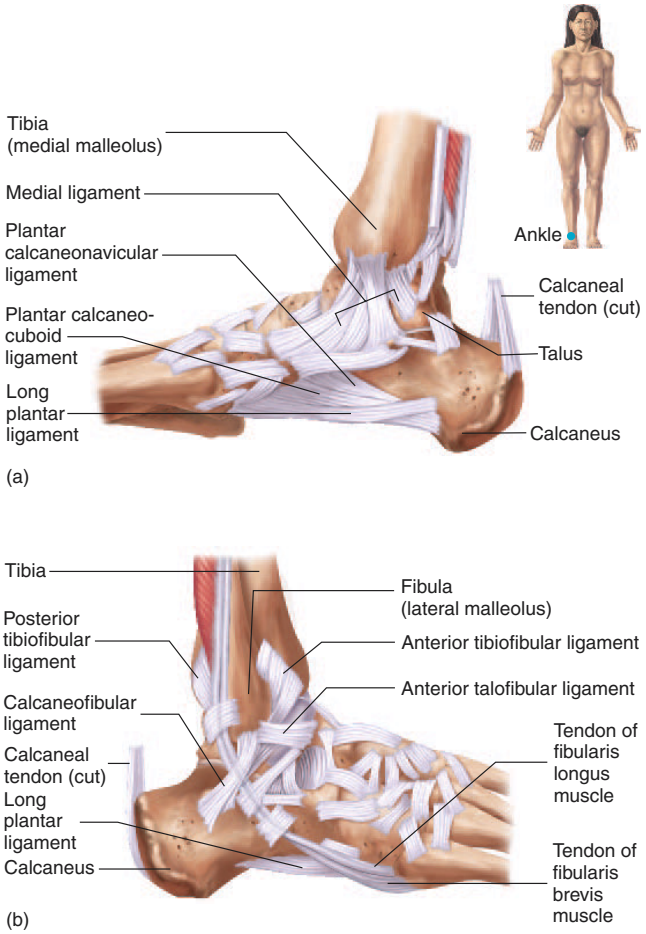


Figure 8.32 Ligaments of the Right Ankle Joint

(*a*) Medial view. (*b*) Lateral view.

Table 8.6 Ligaments of the Ankle and Arch (see figure 8.32)

Ligament	Description
Medial	Thickening of the medial fibrous capsule that attaches the medial malleolus to the calcaneus, navicular, and talus; also called the deltoid ligament
Calcaneofibular	Extends from the lateral malleolus to the lateral surface of the calcaneus; separate from the capsule
Anterior talofibular	Extends from the lateral malleolus to the neck of the talus; fused with the joint capsule
Long plantar	Extends from the calcaneus to the cuboid and bases of metatarsals 2–5
Plantar calcaneocuboid	Extends from the calcaneus to the cuboid
Plantar calcaneonavicular (short plantar)	Extends from the calcaneus to the navicular

16. ***List the most common knee injuries, and tell which part of the knee is most often damaged in each type.***
17. ***Define the term sprain, and describe which portions of the ankle joint are most commonly damaged when it is sprained.***

Effects of Aging on the Joints

Objective

- ***List the factors that contribute to the aging of synovial joints.***

A number of changes occur within many joints as a person ages. Those that occur in synovial joints have the greatest impact and often present major problems for elderly people. In general, as a person ages, the tissues of the body become less flexible and less elastic as protein cross-linking, especially in fibrous connective tissue, increases. The most important proteins related to tissue flexibility are elastin and collagen. Tissue repair slows as cell proliferation rates decline and the rate of new blood vessel development decreases. These general changes can significantly affect synovial joints. With use, the cartilage covering articular surfaces can wear down. When a person is young, production of new, resilient matrix compensates for the wear. As a person ages, the rate of replacement declines and the matrix becomes more rigid, thus adding to its rate of wear. The production rate of lubricating synovial fluid also declines with age, further contributing to the wear of the articular cartilage. In addition, the ligaments and tendons surrounding a joint shorten and become less flexible with age, resulting in a decrease in the range of motion of the joint. With age, muscles, which strengthen the joints, tend to weaken. Older people often experience a general decrease in activity, which causes the joints to become less flexible and their range of motion to decrease.

18. ***List the age-related factors that contribute to cartilage wear in synovial joints. List the age-related factors that cause a loss of flexibility and loss of range of motion in synovial joints.***

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Clinical Focus Joint Disorders

Arthritis

Arthritis, an inflammation of any joint, is the most common and best known of the joint disorders, affecting 10% of the world's population. More than 100 different types of arthritis exist. Classification is often based on the cause and progress of the arthritis. Causes include infectious agents, metabolic disorders, trauma, and immune disorders. Mild exercise retards joint degeneration and enhances mobility. Swimming and walking are recommended for people with arthritis; but running, tennis, and aerobics are not recommended. Therapy depends on the type of arthritis but usually includes the use of antiinflammatory drugs. Current research is focusing on the possible development of antibodies against the cells that initiate the inflammatory response in the joints or against cell surface markers on those cells.

Osteoarthritis (OA) is the most common type of arthritis, affecting 10% of people in the United States (85% of those over age 70). OA may begin as a molecular abnormality in articular cartilage, with heredity and normal wear-and-tear of the joint important contributing factors. Slowed metabolic rates with increased age also seem to contribute to OA. Inflammation is usually secondary in this disorder. It tends to occur in the weight-bearing joints such as the knees and is more common in overweight individuals.

The first line of treatment for osteoarthritis is to change the lifestyle to reduce stress on affected joints. Synovial joints require movement to remain healthy. Long periods of inactivity may cause joints to stiffen. Moderate exercise helps reduce pain and increase flexibility. Exercising also helps people reduce excess weight, which can place stress on joints of the lower limbs. Older people should avoid high-impact sports, such as jogging, tennis, and racquetball, which place stress on the joints. Cycling or walking are recommended, but swimming is the best for people with osteoarthritis, as it exercises the muscles and joints without stressing the joints. Wearing shock-absorbing shoes can help. Splints or braces worn over an affected joint may sometimes be necessary to properly align the joint and distribute weight around it.

Applying heat, such as with hot soaks, warm paraffin application, heating pads, low-power infrared light, or diathermy (mild electric currents that produce heat), directly over the joint may be helpful. Moving to a warmer climate, however, doesn't seem to make much difference.

The American Geriatrics Society has released guidelines for managing chronic pain in elderly patients with osteoarthritis. They recommend acetaminophen (Tylenol) or other nonsteroidal antiinflammatory drugs (NSAIDs), such as aspirin and ibuprofen (Advil), for mild to moderate pain. Capsaicin, a component of hot red peppers, may help relieve pain when applied as a skin cream (Zostrix). Capsaicin seems to reduce levels of a chemical known as substance P that contributes both to inflammation of the joint and to the conduction of pain sensations to the brain. If pain becomes a major problem and over-the-counter pain relievers appear ineffective, physicians may inject corticosteroids directly into the affected joint.

Synvisc and Hyalgan are two drugs derived from hyaluronic acid, a natural substance that lubricates joints. They may be administered by injection into the joint when standard medication and exercise programs fail to relieve pain. Glucosamine and chondroitin sulfate are also natural substances associated with joints. If taken orally or by injection they may help affected joints. However, glucosamine may also raise blood sugar levels, so people with diabetes shouldn't use it without consulting their physician. Injections of genetically treated cells from synovial fluid, which are able to block the immune factors thought to cause the breakdown of joint cartilage, are currently under investigation. An immune system protein called transforming growth factor beta (TGF-β), introduced by gene therapy, is showing some promise in repairing cartilage damaged by osteoarthritis.

If other treatments fail, surgical procedures may be employed to relieve pain and increase function in osteoarthritis patients. Using arthroscopy , a surgeon can examine the joint and clean out bone and cartilage fragments that stimulate pain and inflammation. In osteotomy, the bones of joint are reshaped to better align the joint. In a procedure called chondroplasty, a small amount of healthy cartilage is removed and grown in the laboratory. The newly grown cartilage is then implanted into the joint, where it may stimulate the regeneration of damaged tissue.

Joint replacement is discussed at the end of this Clinical Focus. If the affected joint cannot be replaced, surgeons may perform a procedure called arthrodesis, in which the bones meeting at the joint are fused together. This procedure is intended to eliminate the pain, but the joint is eliminated and movement at that point becomes impossible.

Rheumatoid arthritis (RA) is the second most common type of arthritis. It affects about 3% of all women and about 1% of all men in the United States. It is a general connective tissue disorder that affects the skin, vessels, lungs, and other organs, but it is most pronounced in the joints. It is severely disabling and most commonly destroys small joints, such as those in the hands and feet (figure B). The initial cause is unknown but may involve a transient infection or an autoimmune disease (an immune reaction to one's own tissues; see chapter 22) that develops against collagen. A genetic predisposition may also exist. Whatever the cause, the ultimate course appears to be immunologic. People with classic RA have a protein, **rheumatoid factor,** in their blood. In RA the synovial fluid and associated connective tissue cells proliferate, forming a pannus (clothlike layer), which causes the joint capsule to become thickened and which destroys the articular cartilage. In advanced stages, opposing joint surfaces can become fused. Juvenile rheumatoid arthritis is similar to the adult type in many ways, but no rheumatoid factor is found in the serum.

Hemophilic arthritis may result from bleeding into the joint cavity caused by hemophilia, a hereditary disease characterized by a deficient clotting mechanism in the blood. Some evidence exists that the iron in the blood is toxic to the chondrocytes, resulting in degeneration of the articular cartilage.

Joint Infections

Lyme disease is the result of a bacterial infection (*Borrelia burgdorferi*) transmitted to humans by a tick vector (usually *Ixodes sp.*) that affects the brain, nerves, eyes, heart, and joints. The chronic arthritis and central nervous system dysfunction that are symptoms of the disease are severely disabling but rarely fatal. The disease is named for an epidemic of childhood arthritis occurring in Lyme, Connecticut, in 1975. It has probably existed in Europe for many years and in North America before the first European colonization but was unrecognized. Humans and domestic animals are only incidental hosts to the ticks, which normally infect wild mammals and birds. Deer are of particular concern. The northeastern United States was greatly deforested during the eighteenth and nineteenth centuries, and deer and other wildlife populations declined dramatically. The more recent abandonment and reforestation of farms in New England has lead to an increase in the deer and tick populations, with a resurgence of the associated joint and nervous system disease. Over 100,000 cases of Lyme disease have been reported in the United States since 1982. Although the disease is most common in the northeastern United States, cases have been reported in the north central states, along the West Coast, and scattered throughout the eastern and central states. Early manifestations of the disease include flulike symptoms, with localized skin rash. If untreated, the bacterium can spread to the nervous system, heart, and joints within a few weeks to months. A human vaccine against Lyme disease is currently being used for high-risk individuals.

Suppurative (pus-forming) **arthritis** may result from a number of infectious agents. These joint infections may be transferred from some other infected site in the body or may be systemic (i.e., throughout the body). Usually only one joint, normally one of the larger joints, is affected, and the course of suppurative arthritis, if treated early, is transitory. With prolonged infection, however, the articular surfaces may degenerate. **Tuberculous arthritis** can occur as a secondary infection from pulmonary tuberculosis and is more damaging than typical suppurative arthritis. It usually affects the spine or large joints and causes ulceration of the articular cartilages and even erosion of the underlying bone. Transient arthritis of multiple joints is a common symptom of rheumatic fever, but permanent damage seldom occurs in joints with this disorder.

Gout

Gout is a group of metabolic disorders involving joints. These disorders are largely idiopathic (of unknown cause), although some cases of gout seem to be familial (occur in families and therefore are probably genetic). Gout is more common in males than in females. The ultimate problem in gout patients is an increase in uric acid in the blood because of too much synthesis or decreased removal through the kidneys. The limited solubility of uric acid salts in the body results in precipitation of monosodium urate crystals in various tissues, including the kidneys and joint capsules.

The earliest symptom of gout is transient arthritis resulting from urate crystal accumulation in a joint causing irritation of the synovial membrane. This irritation can ultimately lead to an inflammatory response in the joints, and both the crystal deposition and inflammation can become chronic. Normally only one or two joints are affected. The most commonly affected joints (85% of the cases) are the base of the great toe and other

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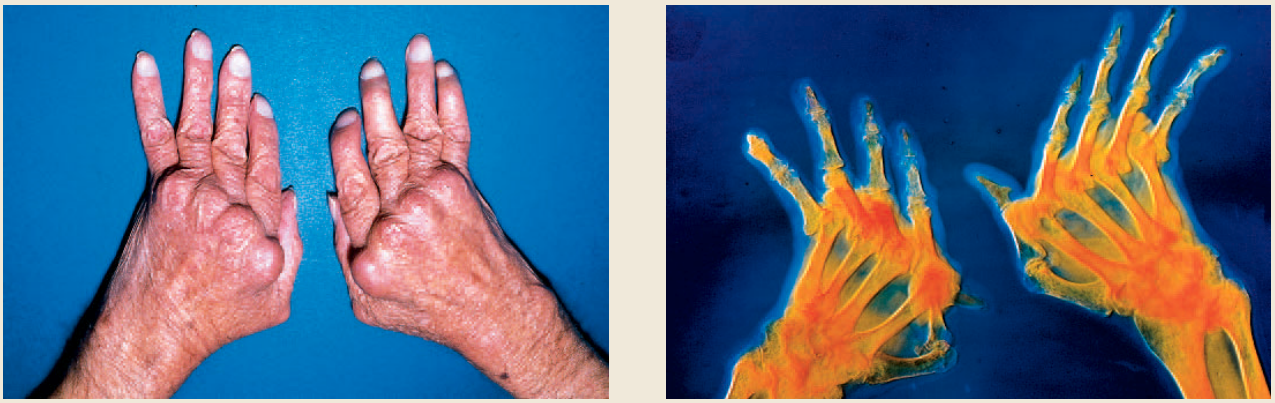


(a) (b)

Figure B Rheumatoid Arthritis

(*a*) Photograph of hands with rheumatoid arthritis. (*b*) Radiographs of the same hands shown in (*a*).

Continued

foot and leg joints to a lesser extent. Any joint may ultimately be involved, and damage to the kidneys from crystal formation occurs in almost all advanced cases. Kidney failure may occur in untreated cases. With modern medications, these complications seldom occur. Weight control and reduced alcohol consumption can help prevent gout.

Pseudogout is a disorder that causes pain and swelling similar to that seen in gout, but it is characterized by calcium hypophosphate crystal deposits in joints.

Hallux Valgus and Bunion

In people who wear pointed shoes, the great toe can be deformed and displaced laterally, a condition called **hallux valgus.** Bunions are often associated with hallux valgus. A **bunion** is a bursitis that develops over the first metatarsophalangeal joint because of pressure and rubbing by shoes.

Joint Replacement

As a result of recent advancements in biomedical technology, many joints of the body can now be replaced by artificial joints. Joint replacement, called **arthroplasty,** was first developed in the late 1950s. One of the major reasons for its use is to eliminate unbearable pain in patients near ages 55 to 60 with joint disorders. Osteoarthritis is the leading disease requiring joint replacement and accounts for two-thirds of the patients. Rheumatoid arthritis accounts for more than half of the remaining cases.

The major objectives in the design of joint prostheses (artificial replacements) include the development of stable articulations, low friction, solid fixation to the bone, and normal range of motion. New synthetic replacement materials are being designed by biomedical engineers to accomplish these objectives. Prosthetic joints usually are composed of metal, such as stainless steel, titanium alloys, or cobalt–chrome alloys, in combination with modern plastics, such as high-density polyethylene, silastic, or elastomer. The bone of the articular area is removed on one side (a procedure called hemireplacement) or both sides (total replacement) of the joint, and the artificial articular areas are glued to the bone with a synthetic adhesive, such as methylmethacrylate. The smooth metal surface rubbing against the smooth plastic surface provides a low-friction contact with a range of movement that depends on the design.

The success of joint replacement depends on the joint being replaced, the age and condition of the patient, and the state of the technology. Most reports are based on examination of patients 2–10 years after joint replacement. The technology is improving constantly, so current reports do not adequately reflect the effect of the most recent improvements. Still, reports indicate a success rate of 80%–90% in hip replacements and 60% or more in ankle and elbow replacements. The major reason for failure of prosthetic joints is loosening of the artificial joint from the bone to which it is attached. New prostheses with porous surfaces help to overcome this problem.

S U M M A R Y

An articulation, or joint, is a place where two bones come together.

Naming Joints (p. 242)

Joints are named according to the bones or parts of bones involved.

Classes of Joints (p. 242)

Joints can be classified according to function or according to the type of connective tissue that binds them together and whether fluid is present between the bones.

Fibrous Joints

1. Fibrous joints are those in which bones are connected by fibrous tissue with no joint cavity. They are capable of little or no movement.
2. Sutures involve interdigitating bones held together by dense fibrous connective tissue. They occur between most skull bones.
3. Syndesmoses are joints consisting of fibrous ligaments.
4. Gomphoses are joints in which pegs fit into sockets and are held in place by periodontal ligaments (teeth in the jaws).
5. Some sutures and other joints can become ossified (synostosis).

Cartilaginous Joints

1. Synchondroses are immovable joints in which bones are joined by hyaline cartilage. Epiphyseal plates are examples.
2. Symphyses are slightly movable joints made of fibrocartilage.

Synovial Joints

1. Synovial joints are capable of considerable movement. They consist of the following:
   - Articular cartilage on the ends of bones, which provides a smooth surface for articulation. Articular disks can provide additional support.
   - A joint cavity surrounded by a joint capsule of fibrous connective tissue, which holds the bones together while permitting flexibility, and a synovial membrane, which produces synovial fluid that lubricates the joint.
2. Bursae are extensions of synovial joints that protect skin, tendons, or bone from structures that could rub against them.
3. Synovial joints are classified according to the shape of the adjoining articular surfaces: plane (two flat surfaces), saddle (two saddle-shaped surfaces), hinge (concave and convex surfaces), pivot (cylindrical projection inside a ring), ball-and-socket (rounded surface into a socket), and ellipsoid (ellipsoid concave and convex surfaces).

Types of Movement (p. 248)

1. Gliding movements occur when two flat surfaces glide over one another.
2. Angular movements include flexion and extension, plantar and dorsiflexion, abduction and adduction.
3. Circular movements include rotation, pronation and supination, and circumduction.
4. Special movements include elevation and depression, protraction and retraction, excursion, opposition and reposition, and inversion and eversion.
5. Combination movements involve two or more of the above-mentioned movements.
6. Range of motion is the amount of movement, active or passive, that can occur at a joint.

Description of Selected Joints (p. 253)

1. The temporomandibular joint is a complex hinge and gliding joint between the temporal and mandibular bones. It is capable of elevation and depression, protraction and retraction, and lateral and medial excursion movements.
2. The shoulder joint is a ball-and-socket joint between the head of the humerus and the glenoid cavity of the scapula that permits a wide range of movements. It is strengthened by ligaments and the muscles of the rotator cuff. The tendon of the biceps brachii passes through the joint capsule. The shoulder joint is capable of flexion and extension, abduction and adduction, rotation, and circumduction.
3. The elbow joint is a compound hinge joint between the humerus, ulna, and radius. Movement at this joint is limited to flexion and extension.
4. The hip joint is a ball-and-socket joint between the head of the femur and the acetabulum of the coxa. It is greatly strengthened by ligaments and that is capable of a wide range of movements, including flexion, extension, abduction, adduction, rotation, and circumduction.
5. The knee joint is a complex ellipsoid joint between the femur and the tibia that is supported by many ligaments. The joint allows flexion and extension and slight rotation of the leg.
6. The ankle joint is a special hinge joint of the tibia, fibula, and talus that allows dorsiflexion and plantar flexion and inversion and eversion.
7. Ligaments of the foot arches hold the bones in an arch and transfer weight in the foot.

Effects of Aging on the Joints (p. 263)

With age, connective tissue of the joints becomes less flexible and less elastic. The resulting joint rigidity increases the rate of ware in the articulating surfaces. The change in connective tissue also reduces the range of motion.

REVIEW AND COMPREHENSION

1. Which of these is commonly used for classifying joints in the body?
   a. the connective tissue that binds the bones together
   b. the degree of motion at each joint
   c. the number of bones that articulate with each other
   d. the embryonic tissue that formed the joint
   e. both a and b
2. Given these types of joints:
   1. gomphosis
   2. suture
   3. symphysis
   4. synchondrosis
   5. syndesmosis

   Choose the types that are held together by fibrous connective tissue.
   a. 1,2,3
   b. 1,2,5
   c. 2,3,5
   d. 3,4,5
   e. 1,2,3,4,5
3. Given these types of joints:
   1. gomphosis
   2. suture
   3. symphysis
   4. synchondrosis
   5. syndesmosis

   Choose the types that are held together by cartilage.
   a. 1,2
   b. 1,4
   c. 2,3
   d. 3,4
   e. 3,5
4. Which of these joints is *not* matched with the correct joint type?
   a. parietal bone to occipital bone—suture
   b. between the coxae—symphysis
   c. humerus and scapula—synovial
   d. shafts of the radius and ulna—synchondrosis
   e. teeth in alveolar process—gomphosis
5. The epiphyseal plate can be described as a type of joint. Choose the term that describes the joint before growth in the length of the bone has ended.
   a. synchondrosis
   b. synostosis
   c. syndesmosis
   d. symphysis
   e. synovial
6. Which of these types of joints are often temporary, with bone replacing them?
   a. syndesmoses
   b. synovial
   c. symphyses
   d. gomphoses
   e. synchondroses
7. Which of these joints are the most movable?
   a. sutures
   b. syndesmoses
   c. symphyses
   d. synovial
   e. gomphoses

8. In which of these joints are periodontal ligaments found?
   a. sutures
   b. syndesmoses
   c. symphyses
   d. synovial
   e. gomphoses
9. The intervertebral disks are an example of
   a. sutures.
   b. syndesmoses.
   c. symphyses.
   d. synovial joints.
   e. gomphoses.
10. Joints containing hyaline cartilage are called _____, and joints containing fibrocartilage are called _____.
    a. sutures; synchondroses
    b. syndesmoses; symphyses
    c. symphyses; syndesmoses
    d. synchondroses; symphyses
    e. gomphoses; synchondroses
11. The inability to produce the fluid that keeps most joints moist would likely be caused by a disorder of the
    a. cruciate ligaments.
    b. synovial membrane.
    c. articular cartilage.
    d. bursae.
    e. tendon sheath.
12. Which of these is *not* associated with synovial joints?
    a. perichondrium on surface of articular cartilage
    b. fibrous capsule
    c. synovial membrane
    d. synovial fluid
    e. bursae
13. All of the costochondral joints, except for the first, usually develop into
    a. bursae.
    b. synovial joints.
    c. syndesmoses.
    d. synostoses.
    e. symphyses.
14. Assume that a sharp object penetrated a synovial joint. From this list of structures:
    1. tendon or muscle
    2. ligament
    3. articular cartilage
    4. fibrous capsule (of joint capsule)
    5. skin
    6. synovial membrane (of joint capsule)

    Choose the order in which they would most likely be penetrated.
    a. 5,1,2,6,4,3
    b. 5,2,1,4,3,6
    c. 5,1,2,6,3,4
    d. 5,1,2,4,3,6
    e. 5,1,2,4,6,3
15. Which of these do hinge joints and saddle joints have in common?
    a. Both are synovial joints.
    b. Both have concave surfaces that articulate with a convex surface.
    c. Both are monoaxial joints.
    d. Both a and b.
    e. All of the above.
16. Which of these joints is correctly matched with the type of joint?
    a. atlas to occipital condyle—pivot
    b. tarsals to metatarsals—saddle
    c. femur to coxa—ellipsoid
    d. tibia to talus—hinge
    e. scapula to humerus—plane
17. Once a doorknob is grasped, what movement of the forearm is necessary to unlatch the door, that is, turn the knob in a clockwise direction? (Assume using the right hand.)
    a. pronation
    b. rotation
    c. supination
    d. flexion
    e. extension
18. After the door is unlatched, what movement of the elbow is necessary to open it? (Assume the door opens in, and you are on the inside.)
    a. pronation
    b. rotation
    c. supination
    d. flexion
    e. extension
19. After the door is unlatched, what movement of the shoulder is necessary to open it? (Assume the door opens in, and you are on the inside.)
    a. pronation
    b. rotation
    c. supination
    d. flexion
    e. extension
20. When grasping a doorknob, the thumb and little finger undergo
    a. opposition.
    b. reposition.
    c. lateral excursion.
    d. medial excursion.
    e. dorsiflexion.
21. Tilting the head to the side is
    a. rotation.
    b. depression.
    c. abduction (lateral flexion).
    d. lateral excursion.
    e. flexion.
22. A runner notices that the lateral side of her right shoe is wearing much more than the lateral side of her left shoe. This could mean that her right foot undergoes more _____ than her left foot.
    a. eversion
    b. inversion
    c. plantar flexion
    d. dorsiflexion
    e. lateral excursion
23. For a ballet dancer to stand on her toes, her feet must
    a. evert.
    b. invert.
    c. plantar flex.
    d. dorsiflex.
    e. abduct.

24. An articular disk is found in the
    a. shoulder joint.
    b. elbow joint.
    c. hip joint.
    d. knee joint.
    e. ankle joint.
25. A lip (labrum) of fibrocartilage deepens the joint cavity of the
    a. temporomandibular joint.
    b. shoulder joint.
    c. elbow joint.
    d. knee joint.
    e. ankle joint.
26. Which of these joints has a tendon inside the joint cavity?
    a. temporomandibular joint
    b. shoulder joint
    c. elbow joint
    d. knee joint
    e. ankle joint
27. Which of these structures help to stabilize the shoulder joint?
    a. rotator cuff muscles
    b. cruciate ligaments
    c. medial and collateral ligaments
    d. articular disk
    e. all of the above
28. Bursitis of the subacromial bursa could result from
    a. flexing the wrist.
    b. kneeling.
    c. overuse of the shoulder joint.
    d. running a long distance.
    e. extending the elbow.
29. Which of these does *not* occur with the aging of joints?
    a. decrease in production of new cartilage matrix
    b. decline in synovial fluid production
    c. ligaments and tendons stretch and increase range of motion
    d. weakening of muscles
    e. increase in protein cross-linking in tissues

Answers in Appendix F

CRITICAL THINKING

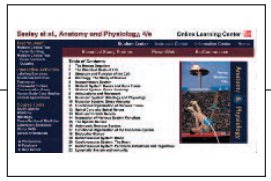
1. What would be the result if the sternal synchondroses and the sternocostal synchondrosis of the first rib were to become synostoses?
2. Using an articulated skeleton, examine the following list of joints. Describe the type of joint and the movement(s) possible.
    a. the joint between the zygomatic bone and the maxilla
    b. the ligamentous connection between the coccyx and the sacrum
    c. the elbow joint
3. For each of the following muscles, describe the motion(s) produced when the muscle contracts. It may be helpful to use an articulated skeleton.
    a. The biceps brachii muscle attaches to the coracoid process of the scapula (one head) and the radial tuberosity of the radius. Name two movements that the muscle accomplishes in the forearm.
    b. The rectus femoris muscle attaches to the anterior superior iliac spine and the tibial tuberosity. How does contraction move the thigh? The leg?
    c. The supraspinatus muscle is located in and attached to the supraspinatus fossa of the scapula. Its tendon runs over the head of the humerus to the greater tubercle. When it contracts, what movement occurs at the glenohumeral (shoulder) joint?
    d. The gastrocnemius muscle attaches to the medial and lateral condyles of the femur and to the calcaneus. What movement of the leg results when this muscle contracts? Of the foot?
4. Crash McBang hurt his knee in an auto accident by ramming it into the dashboard. The doctor tested the knee for ligament damage by having Crash sit on the edge of a table with his leg flexed at a 90-degree angle. The doctor attempted to pull the tibia in an anterior direction (the anterior drawer test) and then tried to push the tibia in a posterior direction (the posterior drawer test). No unusual movement of the tibia occurred in the anterior drawer test but did occur during the posterior drawer test. Explain the purpose of each test, and tell Crash which ligament he has damaged.

Answers in Appendix G

ANSWERS TO PREDICT QUESTIONS

1. The joint between the metacarpals and the phalanges is the metacarpophalangeal joint.
2. Premature sutural synostosis can result in abnormal skull shape, interfere with normal brain growth, and result in brain damage if not corrected. Such an abnormality is usually corrected surgically by removing some of the bone around the suture and creating an artificial fontanel, which then undergoes normal synostosis.
3. The synovial membrane is very thin and delicate. A considerable amount of pressure is exerted on the articular cartilages within a joint, and the articular cartilage is very tough, yet flexible, to withstand the pressure. If the synovial membrane covered the articular cartilage, it would be easily damaged during movement.

4. The movements required are abduction of the arm and flexion of the forearm, or flexion of the arm and forearm and slight pronation of the hand.

5. A shoulder separation involves stretching or tearing of the acromioclavicular ligament and may involve tearing of the coracoclavicular ligament as well. Because the only bony attachment of the upper limb to the body is from the scapula through the clavicle to the sternum, separation of the acromioclavicular joint greatly reduces the stability of the shoulder. The scapula and humerus tend to be displaced inferiorly, and the proximal pivot point for the upper limb is destabilized.

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