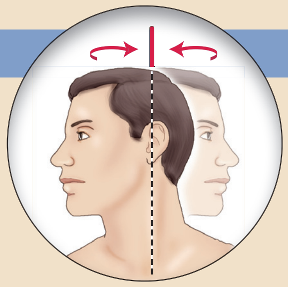


PART I

Fundamentals of Structure and Motion of the Human Body

CHAPTER 1

Parts of the Human Body

CHAPTER OUTLINE

CHAPTER OBJECTIVES

After completing this chapter, the student should be able to perform the following:

1. Define the key terms of this chapter and state the meanings of the word origins of this chapter.
2. List the major divisions of the body.
3. List and locate the 11 major parts of the body.
4. Describe the concept of and give an example of movement of a body part.
5. List the aspects of and give an example of fully naming a movement of the body.
6. Describe the concept of and give an example of movement of smaller body parts located within larger (major) body parts.
7. Explain the difference between and give an example of true movement of a body part compared with "going along for the ride."
8. List and locate the major regions of the body.

OVERVIEW

The human body is composed of 11 major parts that are located within the axial and appendicular portions of the body. Some of these major body parts have smaller body parts within them. Separating two adjacent body parts from each other is a joint. True movement of a body part involves movement of that body part relative to another body part at the joint that is located between them.

KEY TERMS

Abdominal (ab-DOM-i-nal)
Antebrachial (AN-tee-BRAKE-ee-al)
Antecubital (an-tee-KYU-bi-tal)
Anterior view (an-TEER-ee-or)
Appendicular (ap-en-DIK-u-lar)
Arm
Axial (AK-see-al)
Axillary (AK-sil-err-ee)
Body part
Brachial (BRAKE-ee-al)
Carpal (KAR-pal)
Cervical (SER-vi-kal)
Cranial (KRAY-nee-al)
Crural (KROO-ral)
Cubital (KYU-bi-tal)
Digital (DIJ-i-tal)
Facial
Femoral (FEM-o-ral)

2-3

SECTION 2.8 PLANES

2

All too often, planes are presented in textbooks with an illustration and a one-line definition for each one. Consequently, students often memorize them with a weak understanding of what they really are and their importance. Because a clear and thorough understanding of planes greatly facilitates learning and understanding the motions caused by muscular contractions, the following is presented.

- We have already mapped the human body to describe the location of structures and/or points of the body.
- However, when we want to describe motion of the human body, we need to describe or map the space through which motion occurs.
- As we all know, space is three-dimensional (3-D); therefore to map space we need to describe its three dimensions.
- We describe each one of these dimensions with a **plane**. Because three dimensions exist, three types of planes exist.
- The word *plane* actually means *a flat surface.* Each of the planes is a flat surface that cuts through space, describing a dimension of space.
- The three major types of planes are called *sagittal, frontal,* and *transverse* (Figure 2-7).[4]
- The human body or a part of the body can move in each of these three dimensions or planes:
  - A body part can move in an anterior to posterior (or posterior to anterior) direction. This direction describes the **sagittal plane**.[4]
  - A body part can move in a left to right (or right to left) direction; this could also be described as a medial to lateral (or lateral to medial) direction of movement. This direction describes the **frontal plane**.[4]
  - A body part can stay in place and spin (i.e., rotate). This direction describes the **transverse plane**.[4]

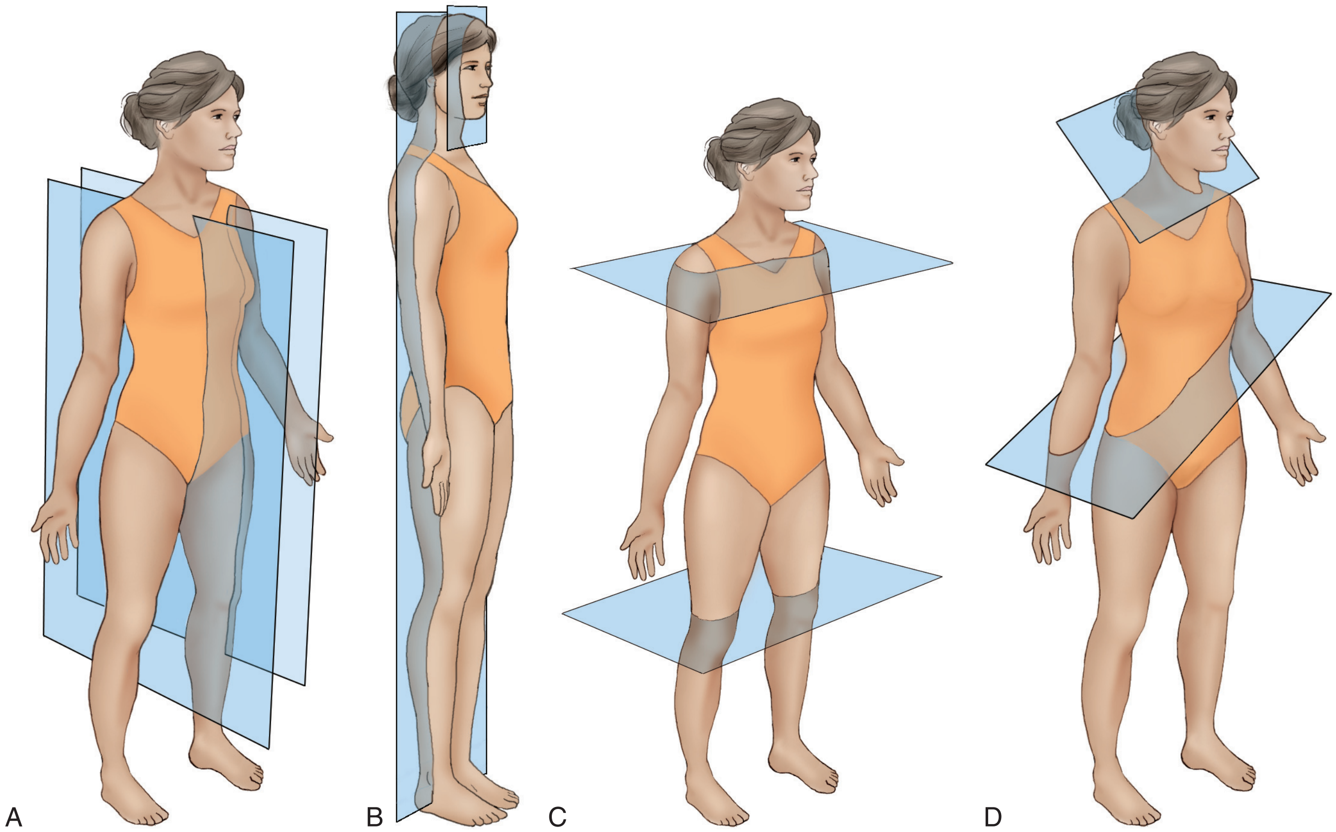


FIGURE 2-7 Anterolateral views of the body, illustrating the four types of planes: sagittal, frontal, transverse, and oblique. **A,** Two examples of sagittal planes; a sagittal plane divides the body into left and right portions. **B,** Two examples of frontal planes; a frontal plane divides the body into anterior and posterior portions. **C,** Two examples of transverse planes; a transverse plane divides the body into upper (superior and/or proximal) and lower (inferior and/or distal) portions. **D,** Two examples of oblique planes; an oblique plane is a plane that is not exactly sagittal, frontal, or transverse (i.e., it has components of two or three cardinal planes). The upper oblique plane has frontal and transverse components; the lower oblique plane has sagittal and transverse components.

2-6

SECTION 2.11 PLANES AND THEIR CORRESPONDING AXES

- When motion of a body part occurs, it can be described as occurring within a plane.
  - If the motion is axial, it can be further described as moving around an axis.
  - Therefore for each one of the three cardinal planes of the body, a corresponding **cardinal axis** exists; hence three cardinal axes exist (Figure 2-10, *A* to *C*).[6]
  - For every motion that occurs within an oblique plane, a corresponding **oblique axis** exists (Figure 2-10, *D*). Therefore an infinite number of oblique axes exist, one for each possible oblique plane.
- Naming an axis is straightforward; simply describe its orientation.
  - The three cardinal axes are the mediolateral, anteroposterior, and superoinferior (vertical) axes (see Figure 2-10, *A* to *C*).
- Please note that an axis around which motion occurs is always perpendicular to the plane in which the motion is occurring.
- An axial movement of a body part is one in which the body part moves within a plane and around an axis.

MEDIOLATERAL AXIS

- A **mediolateral axis** is a line that runs from medial to lateral (or lateral to medial [i.e., left to right or right to left]) in direction (see Figure 2-10, *A*).
- Movements that occur in the sagittal plane move around a mediolateral axis.
- The mediolateral axis is also known as the **frontal-horizontal axis** because it runs horizontally and is located within the frontal plane.[6]

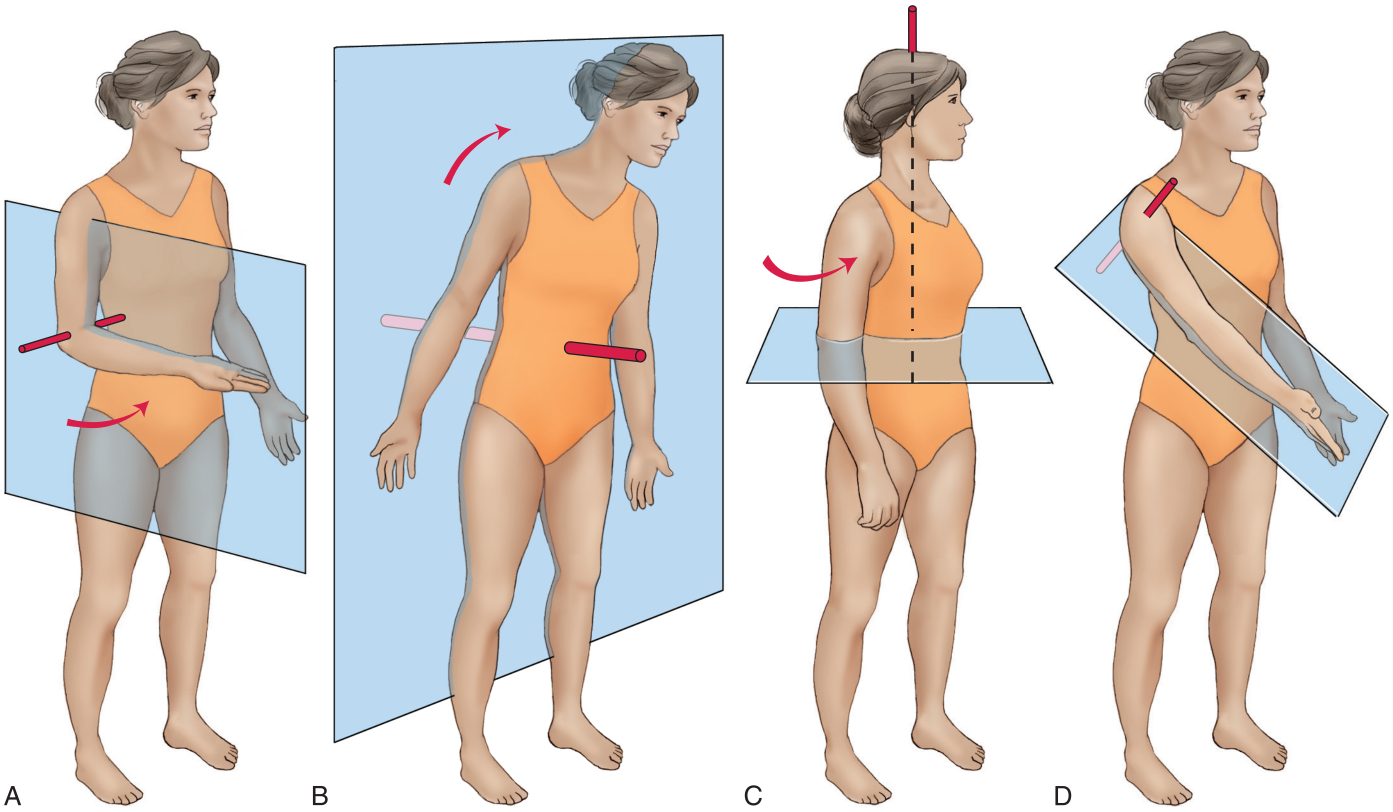


FIGURE 2-10 Anterolateral views that illustrate the corresponding axes for the three cardinal planes and an oblique plane; the axes are shown as red tubes. Note that an axis always runs perpendicular to the plane in which the motion is occurring. **A,** Motion occurring in the sagittal plane; because this motion is occurring around an axis that is running horizontally in a medial to lateral orientation, it is called the mediolateral axis. **B,** Motion occurring in the frontal plane; because this motion is occurring around an axis that is running horizontally in an anterior to posterior orientation, it is called the anteroposterior axis. **C,** Motion occurring in the transverse plane; because this motion is occurring around an axis that is running vertically in a superior to inferior orientation, it is called the superoinferior axis, or, more simply, the vertical axis. **D,** Motion occurring in an oblique plane; this motion is occurring around an axis that is running perpendicular to that plane (i.e., it is the oblique axis for this oblique plane).

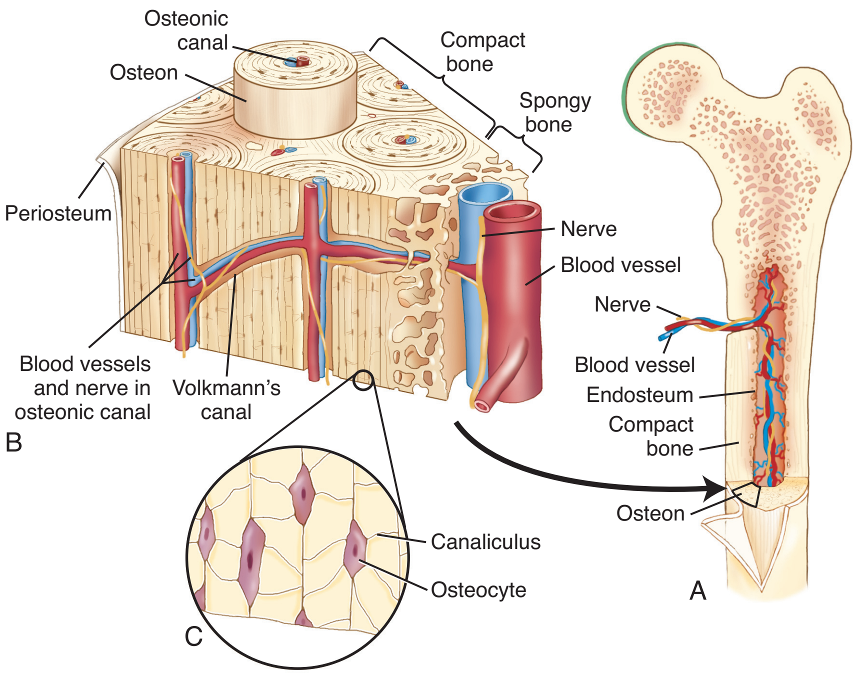


FIGURE 3-7 **A,** Section of a long bone illustrating the interior of the bone. **B,** Enlargement of a pie-shaped wedge of the shaft of the long bone displaying the osteons of the compact bone, as well as the spongy bone located in the interior of the shaft. **C,** Further enlargement of the compact bony tissue showing the osteocytes (located within the lacunae) that communicate with one another via the canaliculi that connect the lacunae to one another.

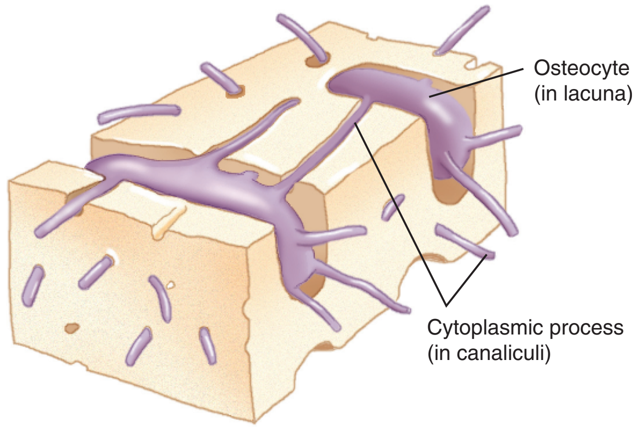


FIGURE 3-8 Illustration of the concept of osteocytes being located within lacunae and the cytoplasmic processes of the osteocytes communicating with other osteocytes via the canaliculi.

lacunae around the blood vessel in the osteonic canal. Therefore no need exists for the ordered arrangement of osteons.

- Spongy bone consists of a latticework of bars and plates of bony tissue called **trabeculae**[4] (singular: trabecula). Between these plates are the spaces of spongy bone (see Figure 3-6, *D*).
- When we say that these spaces are irregular, it may give the impression that spongy bone is very haphazard in its arrangement, which is not true. There is a pattern to spongy bone. The trabeculae of spongy bone are arranged in a fashion that allows them to best deal with the compressive forces of weight bearing (Box 3-7).

BOX 3-7

The pattern of trabeculae of spongy bone is usually apparent on a radiograph (i.e., x-ray).

SECTION 3.6 BONE DEVELOPMENT AND GROWTH

- When the skeleton begins to form in utero, it is not calcified. Rather, it is composed of cartilage and fibrous structures shaped like the bones of the skeleton. These cartilage and fibrous structures gradually calcify as the child grows (both in utero and after birth) and act as models for development of the mature skeleton.
- The skeleton forms by two major methods[1]: (1) **endochondral ossification** and (2) **intramembranous ossification**.

ENDOCHONDRAL OSSIFICATION:

- Endochondral ossification, as its name implies, is ossification that occurs within a cartilage model (*chondral* means cartilage).[1]

sheets and bags also separate structures from each other, directing specific flow of fluids and transfer of forces. By forming tightly woven sacs, our fascia is able to support the two-thirds of us that is water up off the surface of the earth. Nearly every organ—the brain, the heart, the liver, the kidney, and each and every muscle—is contained in fascial sacs that at once contain each organ within its confines as well as allowing (or not, if it is adhesed) a lubricated movement between each organ and adjacent structures.[8]

TYPES OF FASCIA:

- The term *fascia* derives from the Latin meaning *bandage* or *bundle,* in that it wraps around and bundles (i.e., connects) structures (Box 4-1). The word reminds us of the Aesop's fable of the farmer who came across his three sons fighting over their inheritance. The farmer picked up three sticks and broke each easily over his knee. He took another three sticks and bundled them together to demonstrate that they could not be broken as long as they remained united. The Romans adapted this story into a symbol of their power, the *fasces*, which was a bundle of rods bound around an ax, an outward representation of the strength through unity—later appropriated in a negative way into the concept of Fascism. (Tired of being called "fascists," those of us advocating for the new understanding of *fascia* explored in these pages, prefer the term *afascianado*.[9])

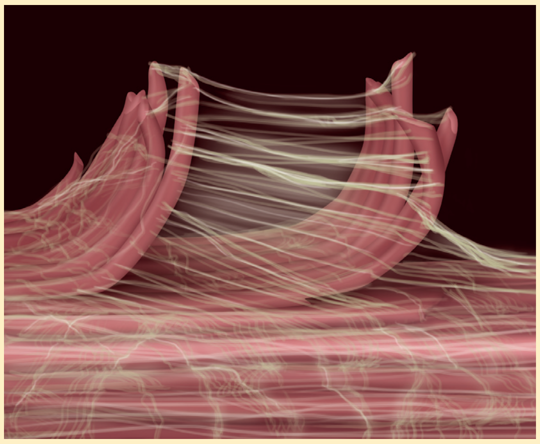
BOX 4-1

The terms fascia and fascism share the same Latin word root origin, fascia, which means bandage. Fascial tissue is so named because like a bandage, it wraps around and connects structures. Fascism derives from the Latin word fasces, which was a bundle of rods tied (bandaged) around an axe, and was an ancient Roman symbol of authority. The symbolism of the fasces represented strength through unity because whereas a single rod is easily broken, a bundle is difficult to break.

- In a similar way, no one element of our fascial system is strong, but bundled together from microscopic elements into macroscopic structures, they can be stronger than steel of comparable weight, yet pliable, elastic, efficient, and adjustable—a nearly miraculous example of what Walter Cannon called "the wisdom of the body."[10]
- While the system is everywhere continuous from one structure to another and strict boundaries are difficult to define, it is still a useful exercise to distinguish the components of fascia and the generalized types of structures they create. For example, fasciae are often named, and therefore subdivided, based on the region of the body where they are located. By this naming system, fasciae are usually divided into myofascial, arthrofascial, visceral, and subcutaneous fascial tissues.
    - Myofascial tissue concerns itself with the fascia of the musculature.
    - Arthrofascial tissue is the intrinsic fascial tissue of joints. It includes the fibrous joint capsule and ligaments.
    - Visceral fascial tissue is involved with the internal visceral organs of the body cavities.
    - Subcutaneous fascial tissue is the fascia located immediately deep to the skin.
- Fasciae are often further divided into two main structural types, **fibrous fascia** and **loose fascia**.
    - Fibrous fascia is often called **deep fascia**, which includes many types of **dense fascia**.
    - Loose fascia is often called **areolar fascia**, including the **subcutaneous fascia** just beneath your skin.
- Fibrous fascia is composed primarily of tough collagen fibers. It inhabits the bone and cartilage already discussed, as well as the ligaments, periostea, tendons, aponeuroses, and membranous coverings of muscle tissue that bind muscles to bones and other structures, as well as connect and ensheath muscle fibers. These examples of fibrous fascia are often called *muscular fascia* (Box 4-2) or *myofascia*. Note: For more on myofascia, see Section 12.4.

BOX 4-2

Fascial collagen fibers of the peri- and endomysium of muscles fibers have a spider-webby appearance. Gil Hedley, educator and author, has coined the term *fuzz* to describe fibrous fascia.



Reproduced with kind permission from Joseph E. Muscolino. Modeled from a photo by Ronald Thompson.

- Loose fascia is primarily composed of ground substance (see *Components of Fascia,* immediately following) that mixes fluid, gel, and various types of collagen and elastin fibers, more loosely woven. This amorphous fascia is found in every area of the body, including the layer directly under the skin that simultaneously acts to bind the dermis layer of the skin while allowing it to move easily in any direction. Loose fascia also allows movement in the underlying visceral organs and between skeletal muscles.
- It is worth noting that the tolerance of this tissue for movement is not limitless: areolar tissue becomes a very effective force transmitter when it reaches its elastic limit. To see this for yourself, put a finger on the opposite forearm and move the skin 1 cm in any direction; it will move easily. Now move the skin away from

lie in wait to resist infection by pathogenic microorganisms if the skin barrier is broken.

- Now let's turn our attention to the *body-wide* functions of the fascial web. The two major body-wide functions are creating a "skeletal" framework and transmitting tension forces throughout the body.

Skeletal Framework:

- The fascial web is a necessary complement to the skeletal framework; together, the web and framework truly connect and support all parts of the body. Not only does this network form the *immediate environment* of each of the cells, most cells are firmly "Velcro®-ed" to the net with up to thousands of tiny adhesive bonds. (The "free swimming" red blood cells (erythrocytes) are the exceptions, but even they can be "caught up" in these connections, for repair, recycling, or in pathological or toxic conditions.) Contrary to our common conception, cells do not simply float within the body but are instead held in place by several hundred types of these adhesive molecules.[16] Thus all cells are connected biomechanically to one another, and the messages of mechanics—tension and compression and their relatives, shear, bending, and torsion—that run through the fascial net are also transmitted to the cells (Figure 4-6).
- At this intimate level, the fascial web continues even more deeply to create an **extracellular-to-intracellular web**, connecting the fascia outside of the cells to the internal cytoskeleton framework within the cells (Figure 4-7). These connections are made via internal cytoskeletal contractile actin filaments and compression-resistant microtubules attached to the cell's membrane via larger internal **focal adhesion molecules**. These focal adhesion molecules then attach to **integrin molecules** (or other molecules in this adhesive clan) that traverse the cell membrane to then connect to **fibronectin molecules** (or other mucus-like ground substance molecules) just outside the cell. These fibronectin molecules are attached in turn to collagen fibers in the fascial web. Thus the fascial web is truly an intimate connecting network that communicates externally and internally with every cell of the body from the DNA to the coordination of organismic movement!

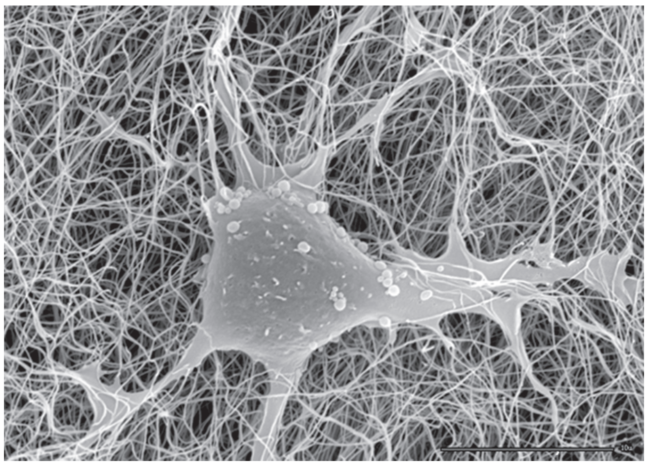


FIGURE 4-6 The fascial web extends down to the cellular level, creating a fine meshwork of intercellular fibers that attach to and connect every cell. *(From Jiang H, Grinnell F: Cell-matrix entanglement and mechanical anchorage of fibroblasts in three dimensional collagen matrices,* Molecular Biology of the Cell *16:5070-5076, 2005.)*

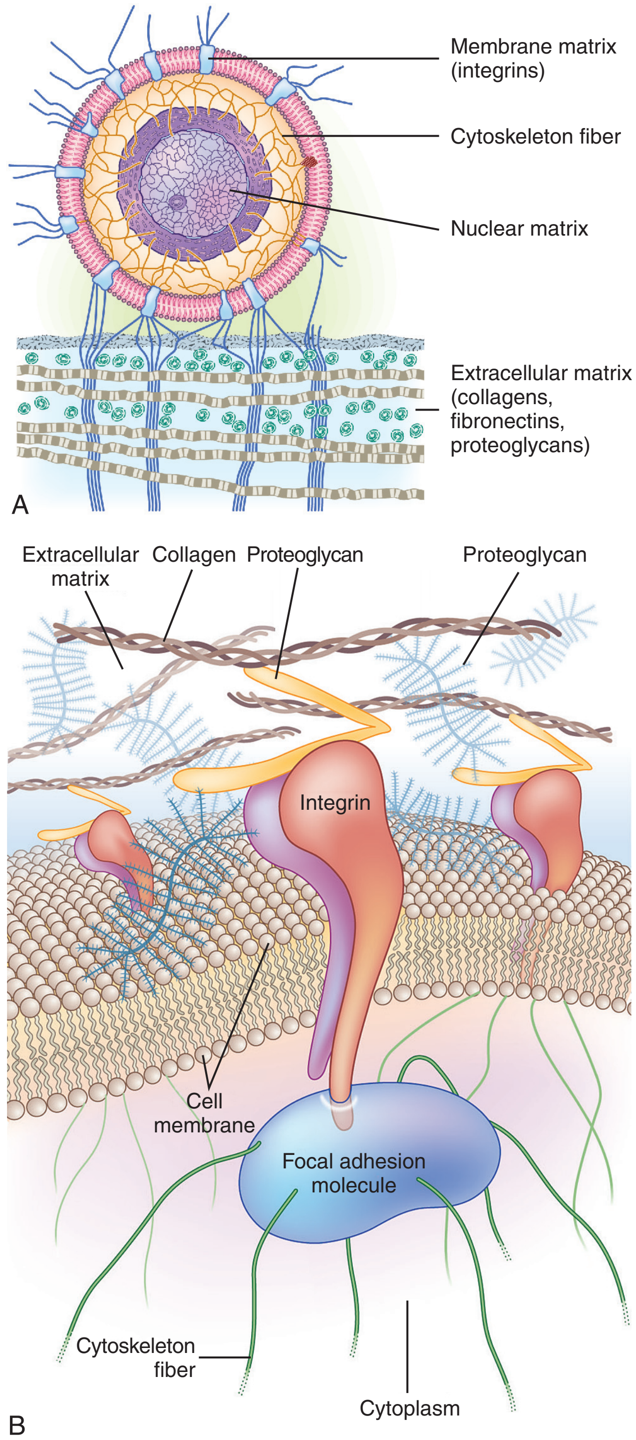


FIGURE 4-7 The fascial web of the extracellular matrix extends even more intimately to connect to the interior of cells via fibronectin molecules, integrins, focal adhesion molecules, and internal cytoskeletal (actin) fibers. **A,** Broad view. **B,** Detailed view. *(A, Reprinted from Pianta KJ, Coffey DS: Medical Hypotheses, "Cellular harmonic information transfer through a tissue tensegrity-matrix system," Jan 1991. With permission from Elsevier. B, From Tomasek J et al: Nature reviews, Molecular Cell Biology, 2002. In Myers T:* Anatomy trains, *ed 2, Edinburgh, 2009, Churchill Livingstone/ Elsevier.)*

4

SECTION 5.1 BONES OF THE HEAD

SKULL—ANTERIOR VIEW (COLORED)

Superior

Right

Left

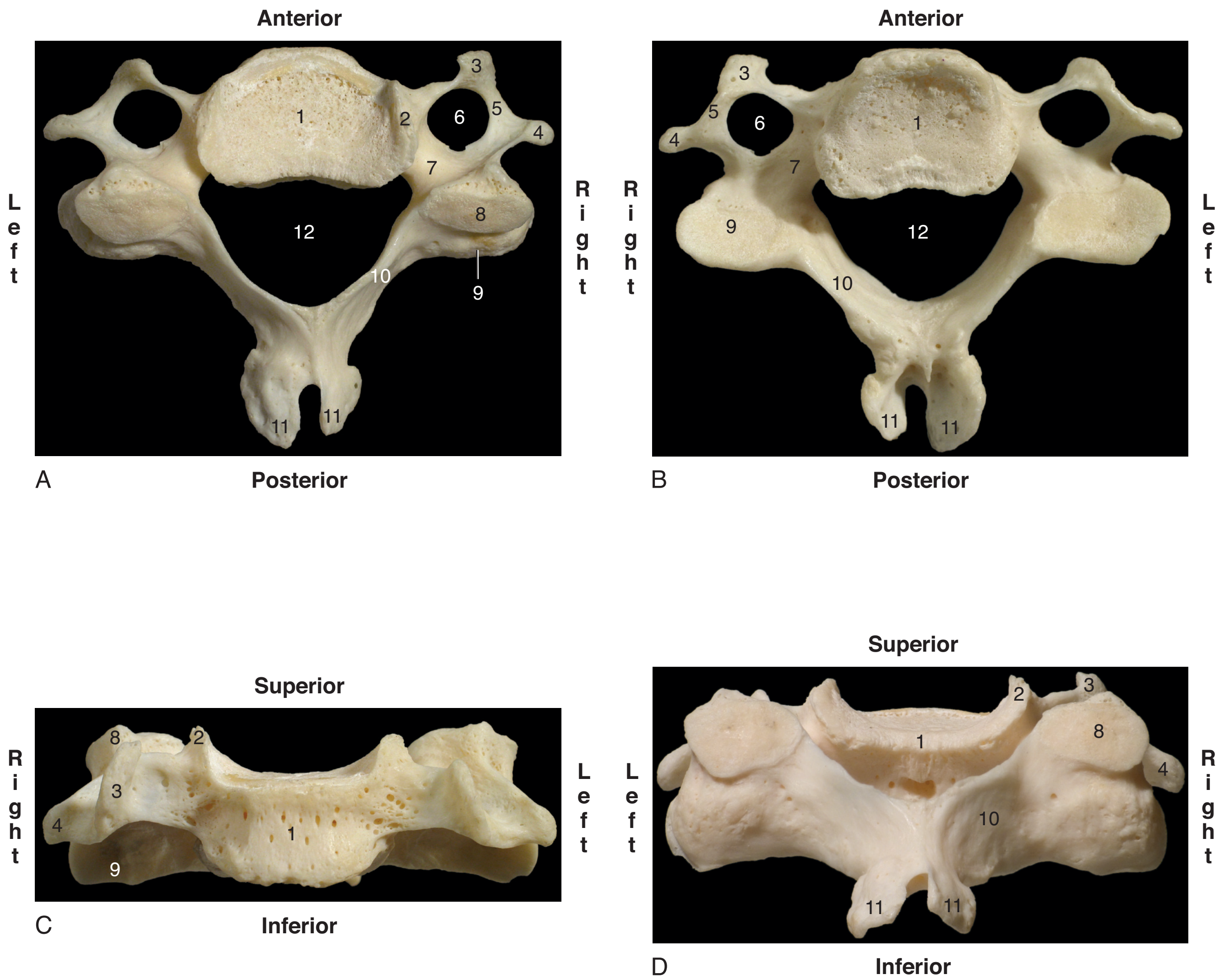
Inferior

FIGURE 5-3
Frontal bone
Parietal bone
Occipital bone (not seen)
Temporal bone
Sphenoid bone
Zygomatic bone
Maxilla
Mandible
Nasal bone
Lacrimal bone
Ethmoid bone
Vomer
Palatine bone
Inferior nasal concha

NOTES

1. Embryologically, two maxillary bones (left and right) exist. However, these two bones fuse to form one maxilla[3] (an incomplete fusion results in a cleft palate). For this reason, we may speak of one maxilla (singular) or of two maxillary bones (plural).
2. The frontal, sphenoid, zygomatic, maxillary, lacrimal, and ethmoid bones all have a presence in the orbital cavity.[4]
3. The ethmoid, vomer, and inferior nasal concha are all visible in this anterior view of the nasal cavity.

C5 (TYPICAL CERVICAL VERTEBRA)



5

FIGURE 5-23 **A,** Superior view. **B,** Inferior view. **C,** Anterior view. **D,** Posterior view.

- **1** Body
- **2** Uncus of body
- **3** Anterior tubercle of transverse process (TP)
- **4** Posterior tubercle of TP
- **5** Groove for spinal nerve (on TP)
- **6** Transverse foramen
- **7** Pedicle
- **8** Superior articular process/facet
- **9** Inferior articular process/facet
- **10** Lamina
- **11** Spinous process (SP) (bifid)
- **12** Vertebral foramen

NOTES

1. The articular process is the entire structural landmark that projects outward from the bone; the articular facets (#8, 9) are the smooth articular surfaces located on the articular process.[2]
2. The plural of foramen is foramina.
3. The cervical vertebrae possess a number of structures that the other vertebrae do not: an uncus (#2) is located on the left and right sides of the body[2]; they have bifid (i.e., two points on their) spinous processes (SPs)[3]; their transverse processes (TPs) have an anterior and posterior tubercle[3]; and they have a foramen located within the TP[3] (hence the name transverse foramen, #6).
4. The bifid SP of a cervical vertebra is often asymmetric. This may lead one to conclude on palpatory examination that the vertebra is rotated when it is not.
5. The cervical transverse foramen allows passage up to the skull of the vertebral artery.[7]

COSTOSPINAL JOINTS

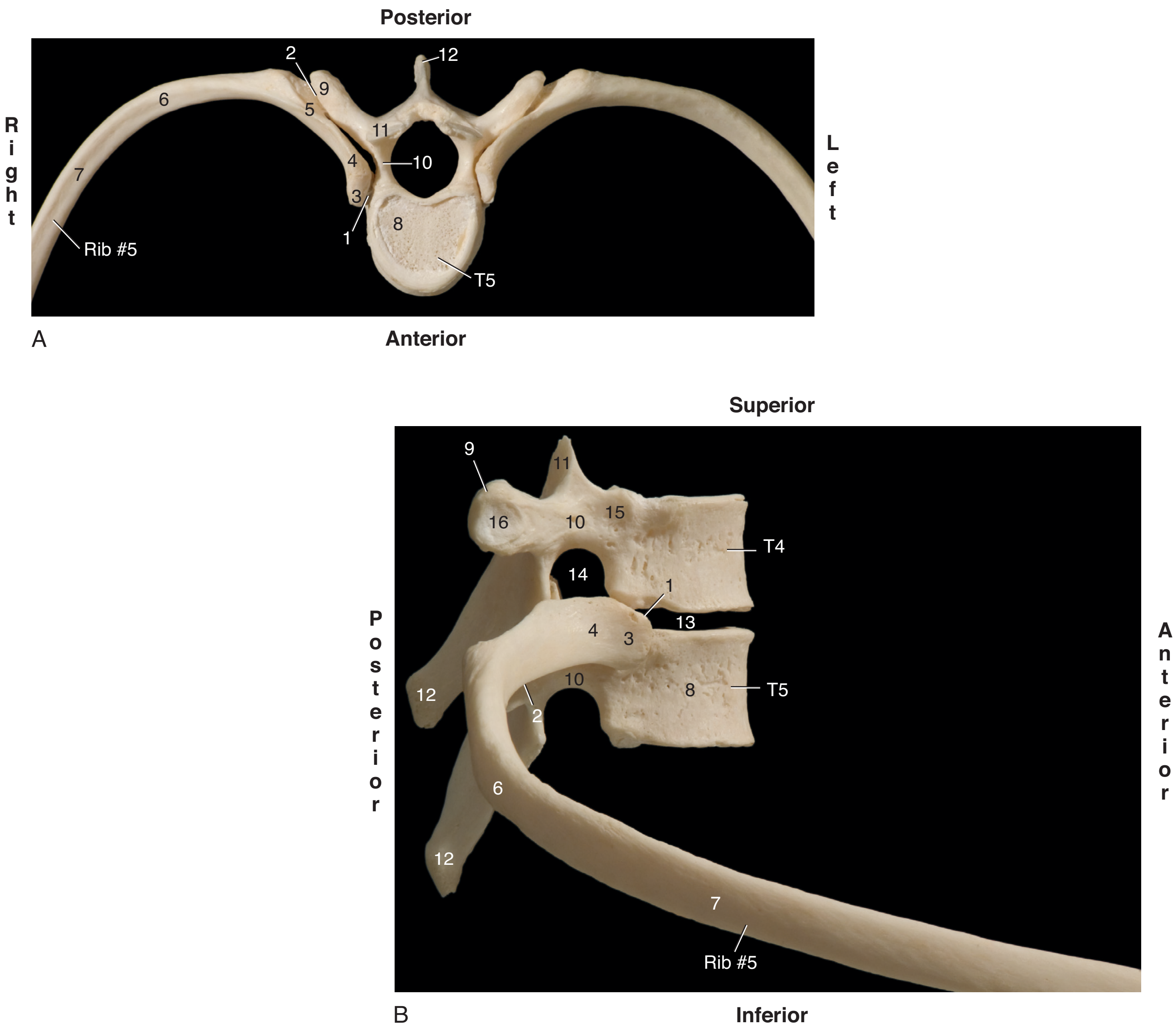


FIGURE 5-36 **A,** Superior view. **B,** Right lateral view.

1 Costovertebral joint
2 Costotransverse joint
3 Head of rib
4 Neck of rib
5 Tubercle of rib
6 Angle of rib
7 Body of rib
8 Vertebral body
9 Transverse process (TP)
10 Pedicle
11 Superior articular process/facet
12 Spinous process (SP)
13 Disc space (T4-T5)
14 Intervertebral foramen (T4-T5)
15 Costal hemifacet for rib #4
16 Transverse costal facet for rib #4

NOTES[10]

1. A rib articulates with the spinal column in two places, forming two costospinal joints, the costovertebral joint (#1) and the costotransverse joint (#2).
2. The costovertebral joint is typically formed by the head of the rib articulating with the (vertebral costal hemifacets of the) bodies of two contiguous vertebrae, as well as the disc that is located between them. Usually ribs #1, #11, and #12 articulate with only one (full vertebral costal facet of a) vertebral body.
3. The costotransverse joint is formed by the tubercle of a rib articulating with the (transverse costal facet of the) transverse process of a vertebra.

SECTION 5.6 BONES OF THE THIGH AND KNEE JOINT

RIGHT FEMUR—ANTERIOR AND POSTERIOR VIEWS

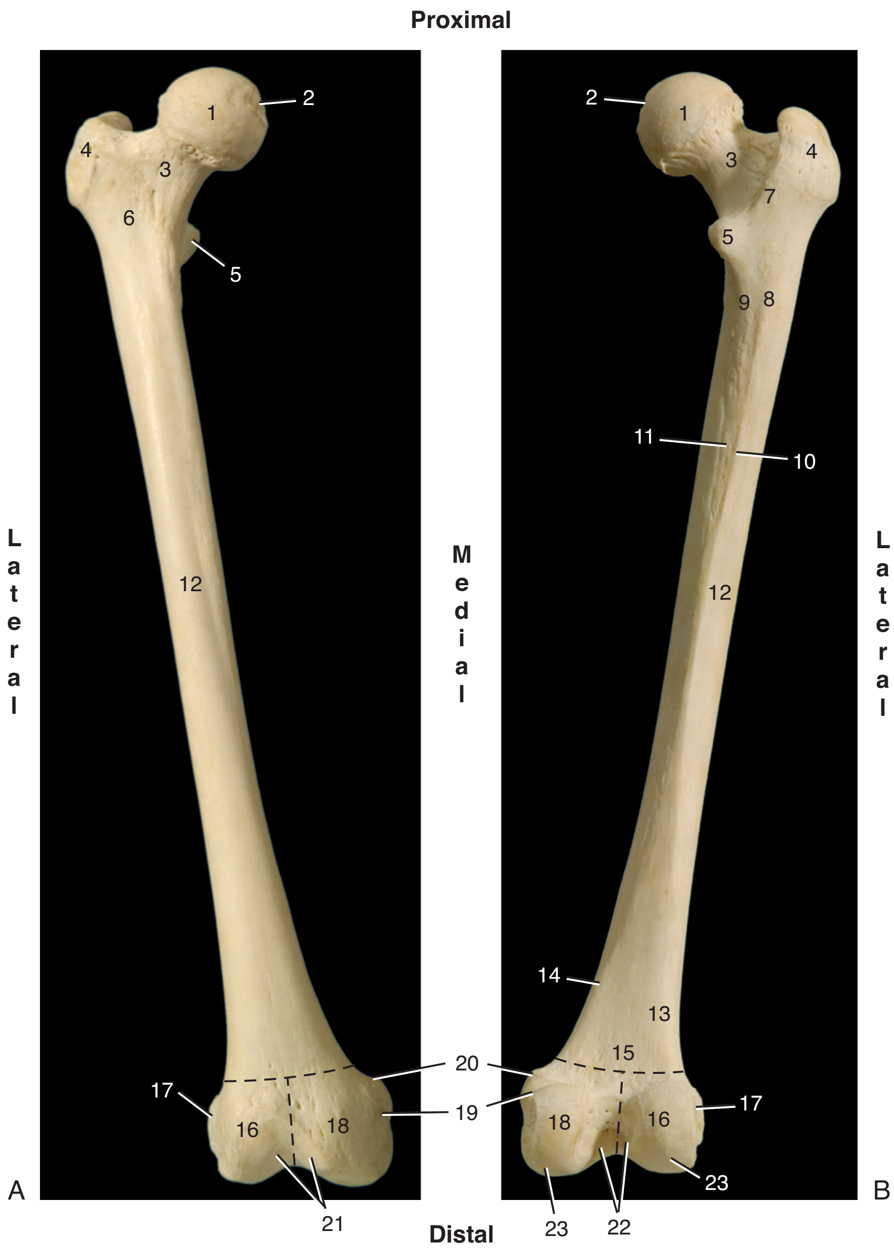


FIGURE 5-44

1 Head
2 Fovea of the head
3 Neck
4 Greater trochanter
5 Lesser trochanter
6 Intertrochanteric line
7 Intertrochanteric crest
8 Gluteal tuberosity
9 Pectineal line
10 Lateral lip of linea aspera
11 Medial lip of linea aspera
12 Body (shaft)
13 Lateral supracondylar line
14 Medial supracondylar line
15 Popliteal surface
16 Lateral condyle
17 Lateral epicondyle
18 Medial condyle
19 Medial epicondyle
20 Adductor tubercle
21 Articular surface for patellofemoral joint
22 Intercondylar fossa
23 Articular surface for knee (tibiofemoral) joint

NOTES

1. The fovea of the head of the femur (#2) is the attachment site for the ligamentum teres of the hip joint.[3]
2. The intertrochanteric line (#6) runs between the greater and lesser trochanters anteriorly; the intertrochanteric crest (#7) runs between the greater and lesser trochanters posteriorly.
3. The linea aspera (#10, 11) is an attachment site for seven muscles.[2] The linea aspera can be looked at as branching proximally to give rise to the gluteal tuberosity (#8) and pectineal line (#9), and branching distally to give rise to the lateral and medial supracondylar lines (#13, 14).
4. The gluteal tuberosity (#8) is a distal attachment of the gluteus maximus.[12]
5. The pectineal line (#9) is the distal attachment of the pectineus.[3]
6. The adductor tubercle (#20) is a distal attachment site for the adductor magnus.[3]
7. The borders of the lateral and medial condyles (#16, 18) are shown by dashed lines.

RIGHT CARPAL BONES (SEPARATED)—ANTERIOR VIEW

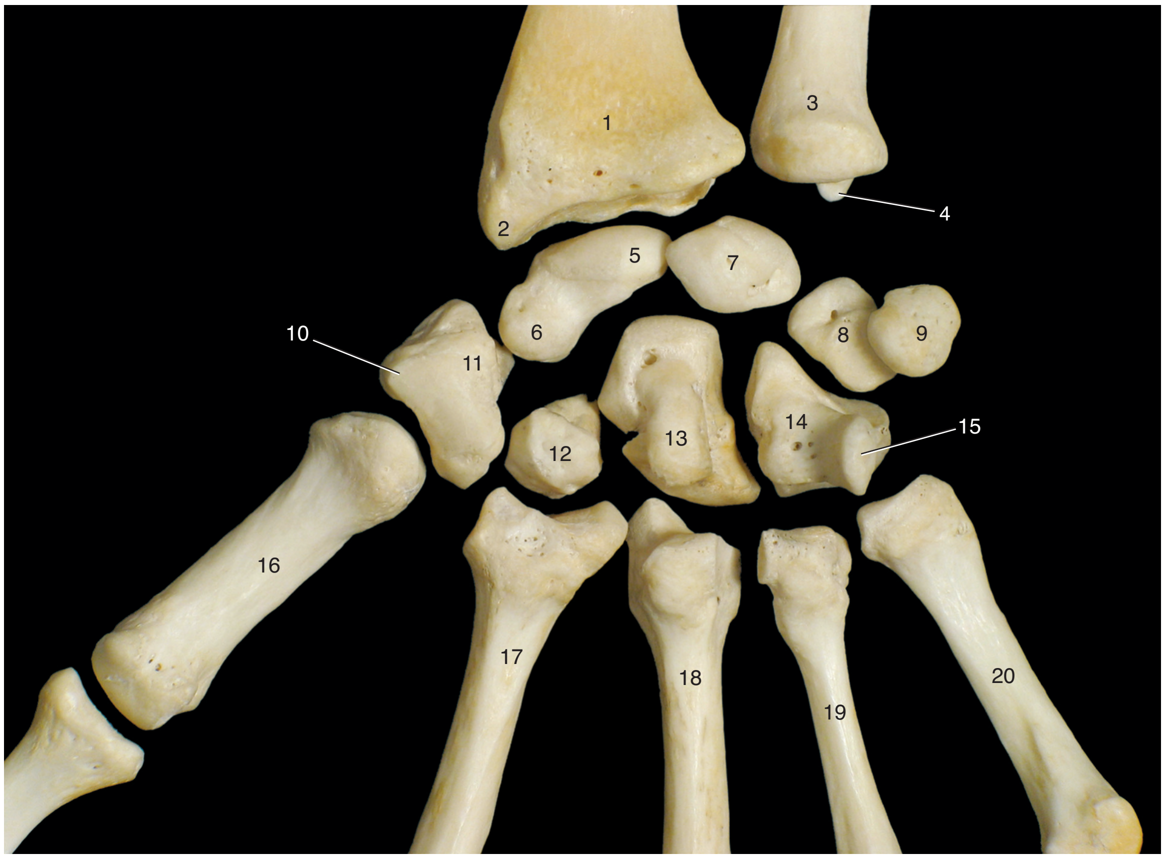


FIGURE 5-74

1 Radius
2 Styloid process of radius
3 Ulna
4 Styloid process of ulna
5 Scaphoid
6 Tubercle of scaphoid
7 Lunate
8 Triquetrum
9 Pisiform
10 Trapezium
11 Tubercle of trapezium
12 Trapezoid
13 Capitate
14 Hamate
15 Hook of hamate
16 First metacarpal (of thumb)
17 Second metacarpal (of index finger)
18 Third metacarpal (of middle finger)
19 Fourth metacarpal (of ring finger)
20 Fifth metacarpal (of little finger)

NOTES

1. Eight carpal bones are arranged in two rows: proximal and distal. The proximal row (radial to ulnar) is composed of the scaphoid, lunate, triquetrum, and pisiform (#5, 7, 8, 9); the distal row (radial to ulnar) is composed of the trapezium, trapezoid, capitate, and hamate (#10, 12, 13, 14).[2]
2. A mnemonic can be used to learn the names of the carpal bones. From proximal row to distal row (always radial to ulnar), it is: Some Lovers Try Positions That They Can't Handle.
3. The flexor retinaculum, which forms the ceiling of the carpal tunnel, attaches to the tubercles of the scaphoid and trapezium (#6, 11) on the radial side and the hook of the hamate (#15) and pisiform (#9) on the ulnar side.[13]
4. The pisiform (#9) is a sesamoid bone (explaining why humans have eight carpal bones and seven tarsal bones).[3]
5. The metacarpal bones are numbered 1 to 5 (numbering begins on the radial [i.e., thumb] side).[3]

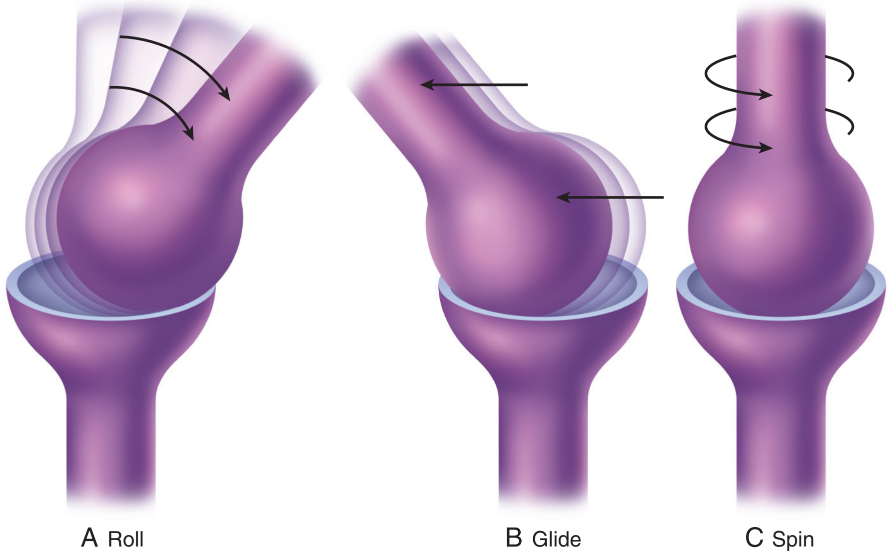


FIGURE 6-8 **A,** Rolling of one bone on another; roll is an axial movement. **B,** Gliding of one bone on another; glide is a nonaxial movement. **C,** Spinning of one bone on another; spin is an axial movement. This figure shows the fundamental motions of roll, glide, and spin by showing the convex-shaped bone moving on the concave-shaped bone.

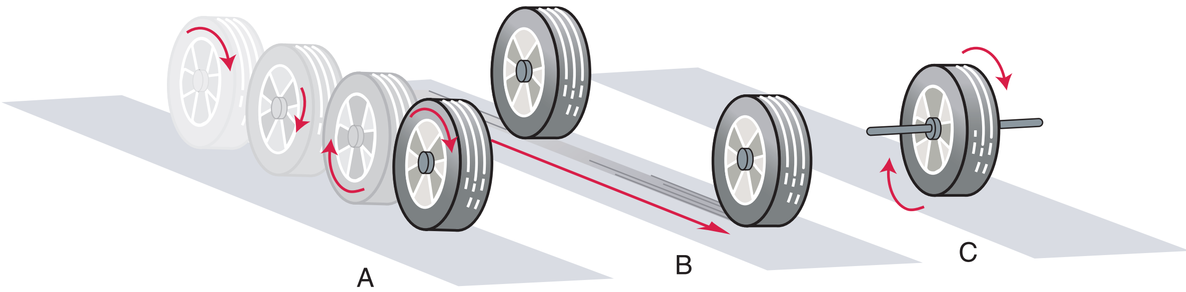


FIGURE 6-9 To better visualize the fundamental joint motions of roll, glide, and spin, an analogy can be made to a car tire. **A,** Tire that is rolling along the ground. **B,** Tire that is gliding/sliding (skidding) along the ground. **C,** Tire that is spinning without changing location.

6-1

SECTION 6.9 NAMING JOINT ACTIONS—COMPLETELY

- When we want to name a specific cardinal plane movement of the body, we will refer to it as an **action**.
- Because movement of a body part occurs at a joint, the term **joint action** is synonymous with action.
- It is worth noting that most of the commonly thought-of actions of the human body are axial (i.e., circular) movements (i.e., the body part that moves at a joint moves in a circular path around the axis of movement).
- Generally the axis of movement is a line that runs through the joint.[3]
- When we describe these movements that occur, we will use terms that indicate the direction that the body part has moved. These terms come in pairs, and the terms of each pair are the opposites of each other.
- Joint action terminology pairs are similar to the pairs of terms that are used to describe a location on the body (see Chapter 2 for more details). The difference is that the terms described in Chapter 2 were used to describe a static location on the body, whereas these movement terms are used to describe the direction that a body part is moving during an action that is occurring at a joint.
- Once we know these terms, we will then use three steps to describe an action that occurs:
  1. We will use the directional term describing the direction of the action.
  2. We will then state which body part moved during this action.
  3. We will then state at which joint the action occurred.
- For example, the action that is occurring in Figure 6-10 would be described the following way: Flexion of the right forearm at the elbow joint. This tells us three things:
  1. The direction of the action: flexion
  2. The body part that is moving: the right forearm
  3. At which joint the action is occurring: the right elbow joint

CLAVICLE (FIGURE 6-21, *B* AND *C*):

- Upward rotation may also be used to describe the rotation of the clavicle in which the inferior surface comes to face anteriorly.
- Being the opposite action, downward rotation returns the inferior surface (now facing anteriorly) back to face inferiorly again.
- If one were to look at the right clavicle from the (right) lateral side, upward rotation would be a counterclockwise motion of the clavicle; downward rotation would be a clockwise motion of the clavicle.
- Viewing the left clavicle from the left side, upward rotation would be a clockwise motion and downward rotation would be a counterclockwise motion.
- Upward rotation and downward rotation of the clavicle are axial movements that occur in a sagittal plane around an axis that is approximately mediolateral in orientation.
- Because of the curve in the distal clavicle, when the clavicle upwardly rotates, the distal end elevates. Therefore one important aspect of upward rotation of the clavicle is to help elevate the shoulder girdle as a whole to facilitate further flexion and/or abduction of the arm relative to the trunk. (For more detailed information on the role of the clavicle [and scapula] in motion of the upper extremity, see Section 10.6.)

SECTION 6.22 ANTERIOR TILT/POSTERIOR TILT

- **Anterior tilt** and **posterior tilt** are terms that may be used to describe movement of the pelvis.
- Unfortunately, many terminology systems exist for naming movements of the pelvis. Because *anterior tilt* and *posterior tilt* are the most common and easiest terms to use when describing sagittal plane movements of the pelvis, this book will use these terms.
- Anterior tilt is defined as the movement of the pelvis wherein the superior aspect of the pelvis tilts anteriorly[3] (Figure 6-22, *A*).
- Posterior tilt is defined as the movement of the pelvis wherein the superior aspect of the pelvis tilts posteriorly (Figure 6-22, *B*).
- Anterior tilt and posterior tilt are movements that occur in the sagittal plane.
- Anterior tilt and posterior tilt are axial movements that occur around a mediolateral axis.
- *Anterior tilt* and *posterior tilt* are terms that are used for the pelvis moving at the lumbosacral and/or the hip joints. The majority of pelvic motion occurs at the hip joints.
- The postural position of anterior/posterior tilt of the pelvis is extremely important because the spine sits on the pelvis; if the amount of anterior/posterior tilt of the pelvis changes, the curves of the spine must change (i.e., increase or decrease) to compensate. (For more information on the effect of the pelvis on the posture of the spine, see Section 9.8.)
- The word *pelvis* is derived from the Latin word for basin. If one thinks of the pelvis as a basin filled with water, then the word *tilt* refers to where the water would spill out when the pelvis tilts (Figure 6-23).
  - Note: The terms *right lateral tilt* and *left lateral tilt* are sometimes used to describe movements of the pelvis in the frontal plane. This book will use the term *depression of the pelvis* (see Sections 9.3 through 9.5) in place of *lateral tilt of the pelvis.*

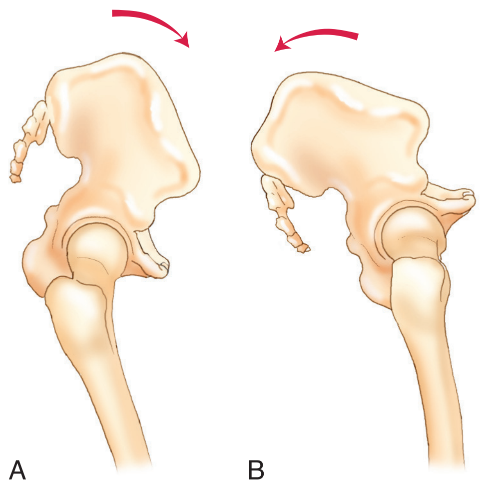


FIGURE 6-22 **A,** Anterior tilt of the pelvis. **B,** Posterior tilt of the pelvis. Motions are shown as occurring at the hip joint.

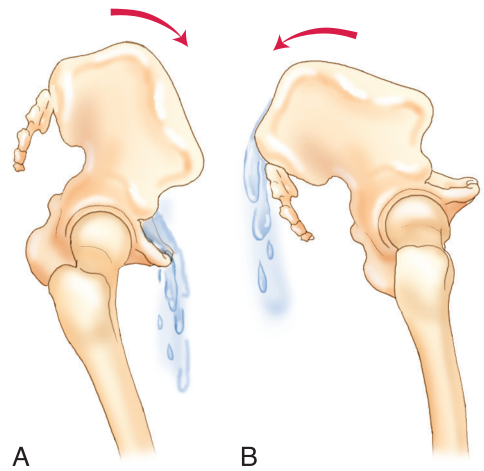


FIGURE 6-23 Water spilling out of the pelvis based on the tilt of the pelvis. To learn the tilt actions of the pelvis, it can be helpful to think of the pelvis as a basin that holds water. Whichever way that the pelvis tilts, water will spill out in that direction.

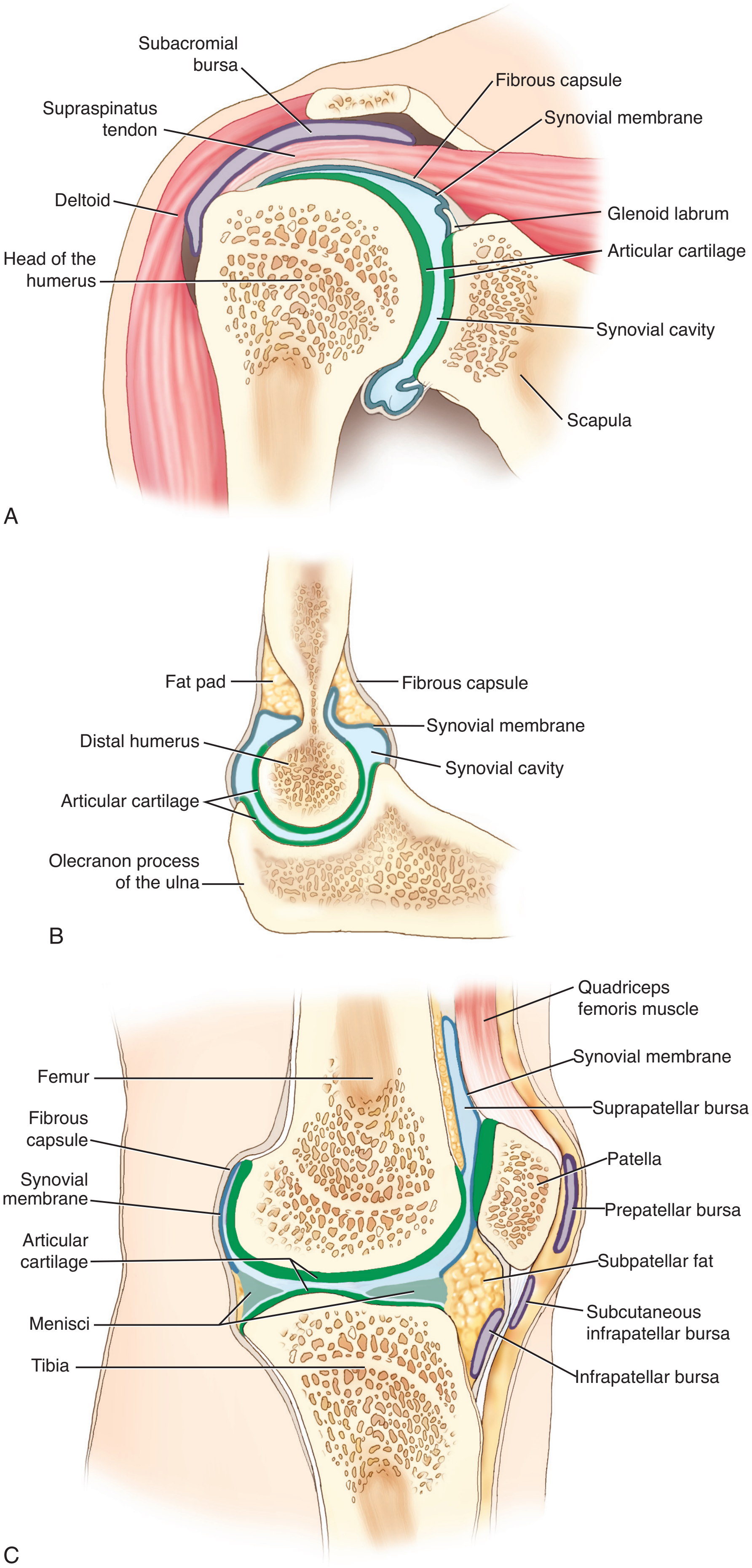
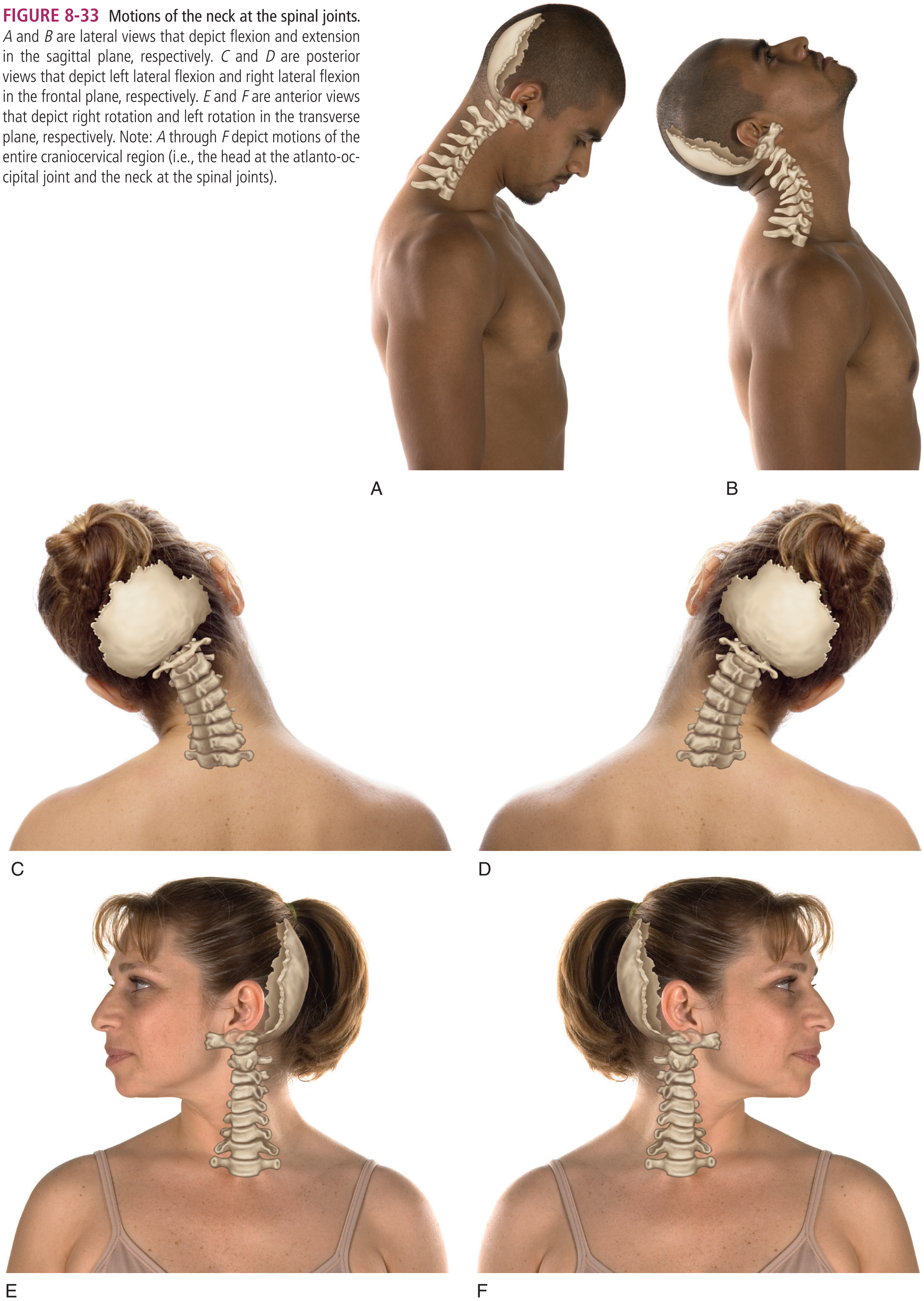


FIGURE 7-11 Examples of synovial joints. **A,** Anterior view cross-section of the shoulder joint. **B,** Lateral view cross-section of the elbow (humeroulnar) joint. **C,** Lateral view cross-section of the knee joint.

7

FIGURE 8-33 Motions of the neck at the spinal joints. *A* and *B* are lateral views that depict flexion and extension in the sagittal plane, respectively. *C* and *D* are posterior views that depict left lateral flexion and right lateral flexion in the frontal plane, respectively. *E* and *F* are anterior views that depict right rotation and left rotation in the transverse plane, respectively. Note: *A* through *F* depict motions of the entire craniocervical region (i.e., the head at the atlanto-occipital joint and the neck at the spinal joints).

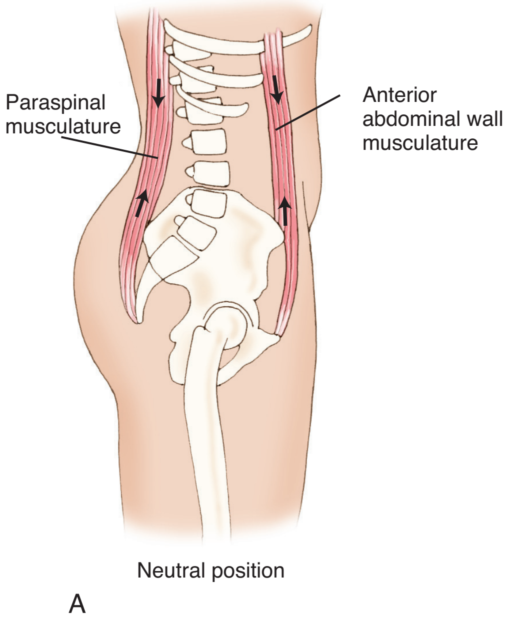


SECTION 9.6 RELATIONSHIP OF PELVIC/SPINAL MOVEMENTS AT THE LUMBOSACRAL JOINT

- Now that the motion of the pelvis is clearly understood, it is valuable to examine the relationship that pelvic movements have to spinal movements. If we picture the muscles that cross from the trunk to the pelvis (i.e., crossing the lumbosacral joint), then these pelvic movements would be considered the reverse actions of these muscles. The following sections describe the relationship between the pelvis and the spine for the six major movements within the three cardinal planes:

SAGITTAL PLANE MOVEMENTS:

- Posterior tilt of the pelvis at the lumbosacral joint is analogous to flexion of the trunk at the lumbosacral joint. Therefore muscles that perform flexion of the trunk also perform posterior tilt of the pelvis at the lumbosacral joint[4] (Figure 9-9).
  - Examples: The muscles of the anterior abdominal wall, such as the rectus abdominis, external abdominal oblique, and the internal abdominal oblique



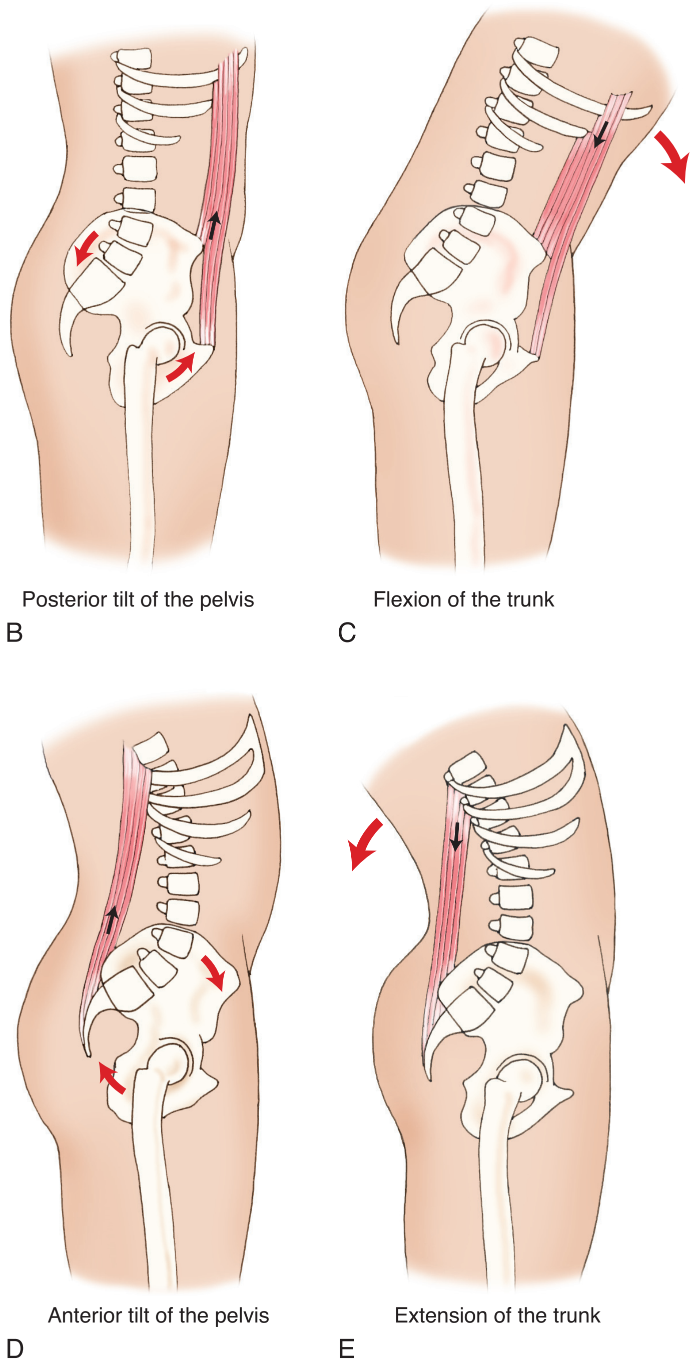


FIGURE 9-9 Lateral views of two groups of muscles that cross the lumbosacral (LS) joint and create sagittal plane actions of the pelvis and trunk. The anterior group contains the anterior abdominal wall muscles; the posterior group contains the paraspinal musculature (i.e., erector spinae and transversospinalis groups). **A,** Both groups are illustrated; *arrows* within the muscle groups represent the lines of pull of these muscles. **B** and **C,** Actions of the anterior group on the pelvis and the trunk, respectively; these actions are posterior tilt of the pelvis at the LS joint and flexion of the trunk at the LS joint (and the other spinal joints). **D** and **E,** Actions of the posterior group on the pelvis and the trunk; these actions are anterior tilt of the pelvis at the LS joint and extension of the trunk at the LS joint (and other spinal joints).

SECTION 9.17 OVERVIEW OF THE ANKLE/FOOT REGION

ORGANIZATION OF THE ANKLE/ FOOT REGION:

Generally, the organization of the ankle/foot region is as follows (Figure 9-32):

- The two bones of the leg articulate with the foot at the **talocrural joint** (usually simply referred to as the *ankle joint*).
- The foot is defined as everything distal to the tibia and fibula.
    - The bones of the foot can be divided into tarsals, metatarsals, and phalanges.
    - Just as the carpal bones are the wrist bones, the tarsal bones are known as the *ankle bones*.
- The foot can be divided into three regions[6]: (1) hindfoot, (2) midfoot, and (3) forefoot.
    - The **hindfoot** consists of the talus and calcaneus, which are tarsal bones.
    - The **midfoot** consists of the navicular, the cuboid, and the three cuneiforms, which are tarsal bones.
    - The **forefoot** consists of the metatarsals and phalanges.
- The term **ray** refers (in the foot) to a metatarsal and its associated phalanges; the foot has five rays. (The first ray is composed of the first metatarsal and the two phalanges of the big toe; the second ray is composed of the second metatarsal and the three phalanges of the second toe; and so forth.)

FUNCTIONS OF THE FOOT:

- The foot is truly a marvelous structure because it must be both stable and flexible.
    - The foot must be sufficiently stable to support the tremendous weight-bearing force from the body above it, absorb the shock from landing on the ground below, and propel the body through space by pushing off the ground. Stability such as this requires the foot to be a rigid structure.[10]
    - However, the foot must also be sufficiently flexible and pliable (i.e., mobile) that it can adapt to the uneven ground surfaces that it encounters.
    - Stability and flexibility are two antagonist concepts that the foot must balance to be able to meet these divergent demands.
    - Generally, weight/shock absorption and propulsion by the foot are factors of dorsiflexion/plantarflexion of the foot at the ankle (i.e., talocrural) joint.[6]
    - Generally, adapting to uneven ground surfaces is a factor of pronation/supination (primarily composed of eversion/inversion) of the foot at the subtalar joint.[6]
    - However, it must be emphasized that the ankle joint region is a complex of joints that must function together to accomplish these tasks.[10] (Note: For more on the functions of the foot during weight bearing and the gait cycle, see Sections 20.7 and 20.8.)
    - Movements at the talocrural, subtalar, and transverse tarsal joints must occur together smoothly and seamlessly for proper functioning of the foot!

JOINTS OF THE ANKLE/FOOT REGION:

Ankle Joint:

- The ankle joint is located between the distal tibia/fibula and the talus (see Figure 9-34, *A* in Section 9.18).
    - This joint is usually referred to as the *talocrural joint*.[3]
    - Note: Because the ankle joint involves the distal tibia and fibula meeting the talus, the joints between the tibia and fibula (distal, middle, and proximal tibiofibular joints) are functionally related to the functioning of the ankle joint. (For more on this, see Section 9.18.)

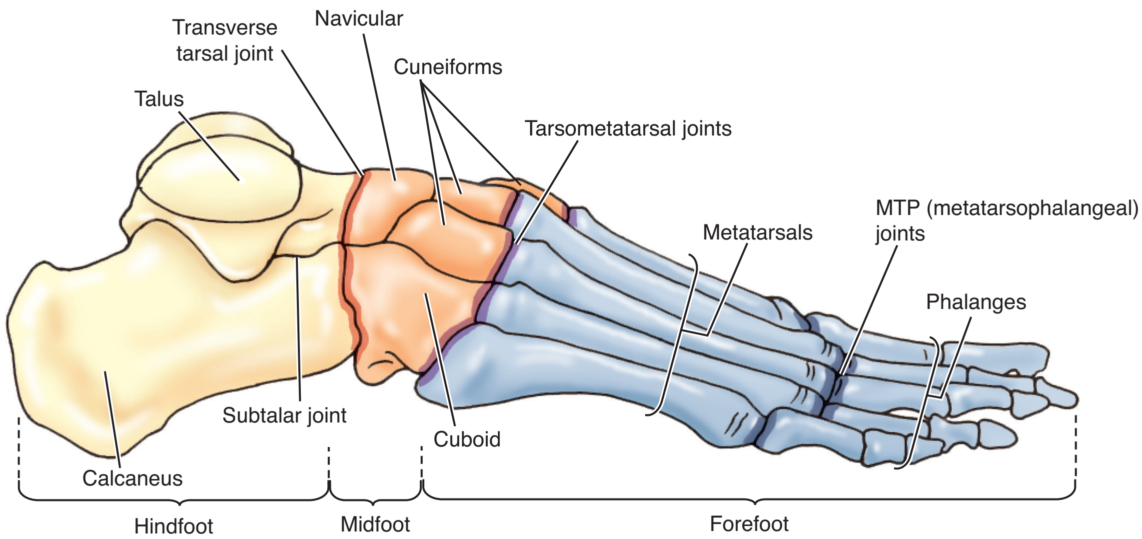


FIGURE 9-32 The three regions of the foot. The hindfoot is composed of the calcaneus and talus. The midfoot is composed of the navicular, cuboid, and the three cuneiforms. The forefoot is composed of the metatarsals and phalanges. (Note: The major joints of the foot are also labeled.)

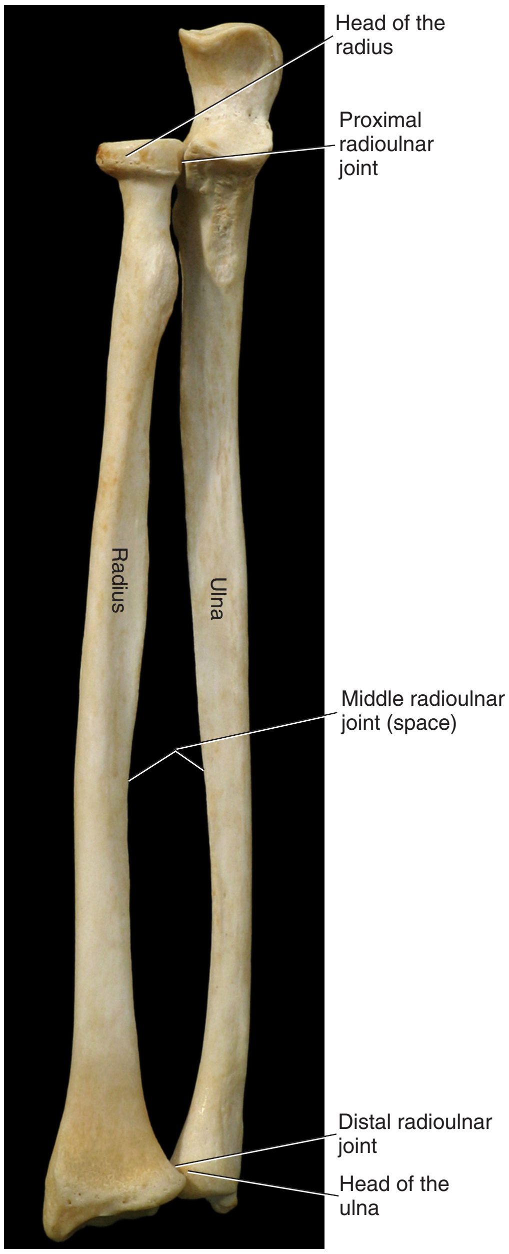


FIGURE 10-25 Anterior view that illustrates the three radioulnar (RU) joints of the right forearm.

MAJOR ACTIONS OF THE RADIOULNAR JOINTS:

- The combined movements at the RU joints allow for pronation and supination of the forearm (Figure 10-26; Table 10-7; and see Figures 5-68 and 5-72.)
- During pronation and supination of the forearm, it is usually the radius that accomplishes the majority of the motion around a relatively fixed ulna.[6] However, when the hand is fixed (i.e., closed-chain activity), the radius becomes fixed during pronation and supination motions, and it is the ulna that performs the majority of the motion (see Section 13.9, Figure 13-15).

BOX 10-13 Spotlight on Motion at the Distal Radioulnar Joint

The terms pronation and supination are used to describe motions of the radius, because the radius does not move in a typical manner for a long bone. During pronation of the radius, the head of the radius clearly medially rotates relative to the proximal ulna. This medial rotation involves the proximal radius spinning medially and remaining "in place." However, the distal radioulnar (RU) joint does not allow the distal radius to perform pure medial rotation and stay in its same location in space (medial rotation and lateral rotation of a long bone usually occur around an axis that runs through the shaft of the bone; consequently the bone spins in place). When the proximal radius medially rotates, the distal radius is forced to rotate and "swing around" the distal ulna.

This *rotating-and-swinging* motion can be described in terms of roll, spin, and glide (see Sections 6.7 and 6.8). In this case the distal radius rolls and glides in the same direction, as is usual for a concave bone moving relative to a convex bone. However, what is unusual about the roll/glide dynamics here is that the roll and glide occur in a line that is perpendicular to the long axis of the radius; roll and glide usually occur in the same line as the long axis of the bone.

Describing distal RU motion in the terminology system of flexion/extension, abduction/adduction, and medial rotation/lateral rotation is even more awkward because it does not fit well into any one of these categories. If one were to try to place this motion into one of these categories of motion, the closest fit would be to say that the distal radius medially rotates, but that this rotation occurs around an axis that lies outside of the shaft of the radius. Because this axis runs through the distal ulna (see Section 6.18, Figure 6-18), pronation and supination of the radius at the distal RU joint involve the distal end of the radius actually rotating and "swinging" around the distal ulna.

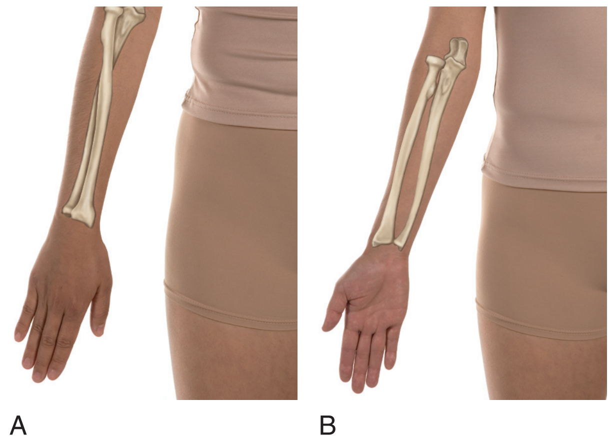


FIGURE 10-26 Pronation and supination of the right forearm at the radioulnar (RU) joints. **A,** Pronation. **B,** Supination, which is anatomic position for the forearm. (Note: Both figures are anterior views of the forearm.)

- This action of the radius occurs around an axis that runs from the head of the radius to the head of the ulna; this axis is not purely vertical (see Section 6.18, Figure 6-18).
  - Movement at the proximal RU joint: The head of the radius medially rotates during pronation of the forearm; the

SECTION 11.8 MUSCLES OF THE SPINAL JOINTS

Full Spine:
ERECTOR SPINAE GROUP:

Attachments:

- **Pelvis**

to the

- **Spine, Rib Cage, and Head**

Functions:

Major Standard Mover Actions	Major Reverse Mover Action
1. Extends the trunk, neck, and head at the spinal joints[1–5,7]	1. Anteriorly tilts the pelvis at the LS joint and extends the lower spine relative to the upper spine[2–5,7]
2. Laterally flexes the trunk, neck, and head at the spinal joints[1–5,7]	

LS joint = lumbosacral joint

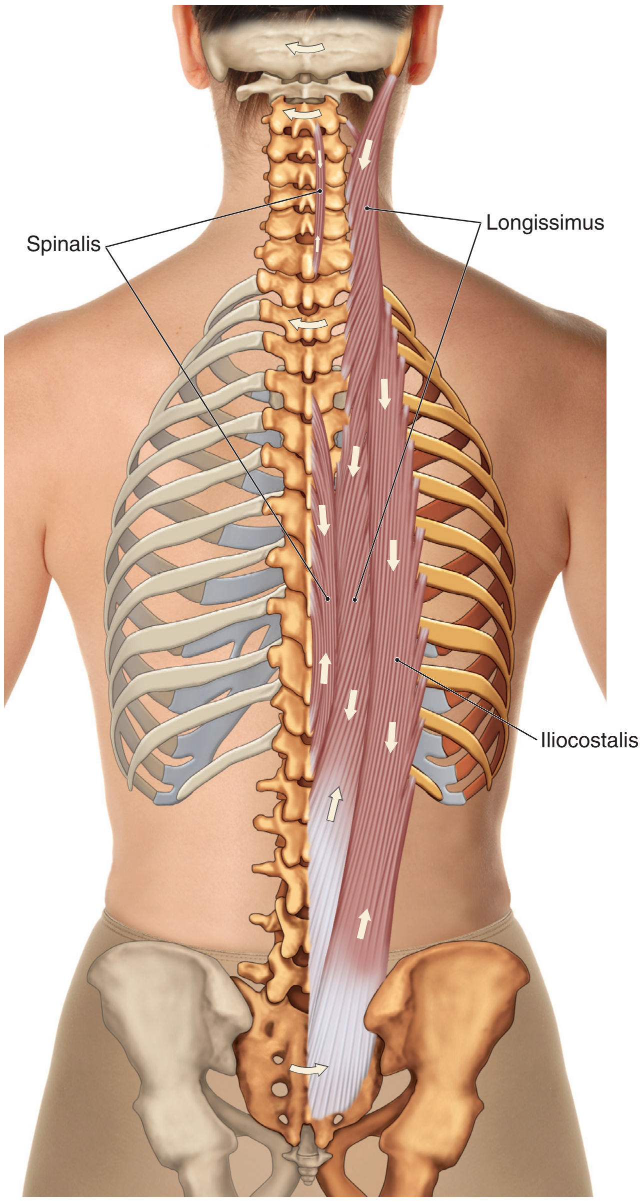


FIGURE 11-52 Posterior view of the right erector spinae group.

GLUTEUS MINIMUS (OF GLUTEAL GROUP):

Attachments:

- **External Ilium**
  - ❍ between the anterior and inferior gluteal lines

to the

- **Greater Trochanter of the Femur**
  - ❍ the anterior surface

Functions:

Major Standard Mover Actions	Major Reverse Mover Actions
1. Abducts the thigh at the hip joint (entire muscle)[1–4,6,7,10]	1. Depresses the same-side pelvis at the hip joint[2–4,6,7,10]
2. Flexes the thigh at the hip joint (anterior fibers)[2,6,7,18]	2. Anteriorly tilts the pelvis at the hip joint[2,6,7,18]
3. Extends the thigh at the hip joint (posterior fibers)[12,13,19]	3. Posteriorly tilts the pelvis at the hip joint[1,2,13,19]
4. Medially rotates the thigh at the hip joint (anterior fibers)[1–4,6,7,10]	
5. Laterally rotates the thigh at the hip joint (posterior fibers)[2,4,7,10]	4. Contralaterally rotates the pelvis at the hip joint[2,4,7,10]

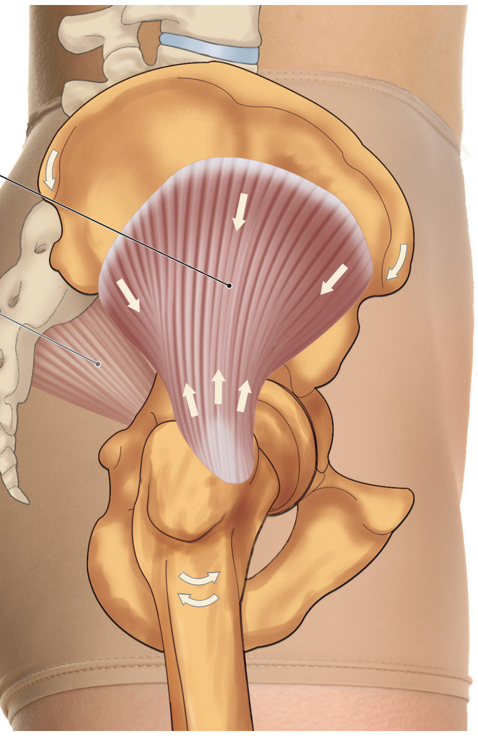


FIGURE 11-134 Lateral view of the right gluteus minimus. The piriformis has been ghosted in.

PIRIFORMIS (OF DEEP LATERAL ROTATOR GROUP):

Attachments:

- **Anterior Sacrum**
  - ❍ and the anterior surface of the sacrotuberous ligament

to the

- **Greater Trochanter of the Femur**
  - ❍ the superomedial surface

Functions:

Major Standard Mover Actions	Major Reverse Mover Action
1. Laterally rotates the thigh at the hip joint[1–4,6,7,10]	1. Contralaterally rotates the pelvis at the hip joint[2–4,7]
2. Horizontally extends the thigh at the hip joint[1,10]	
3. Medially rotates the thigh at the hip joint[2,4,7,10]	

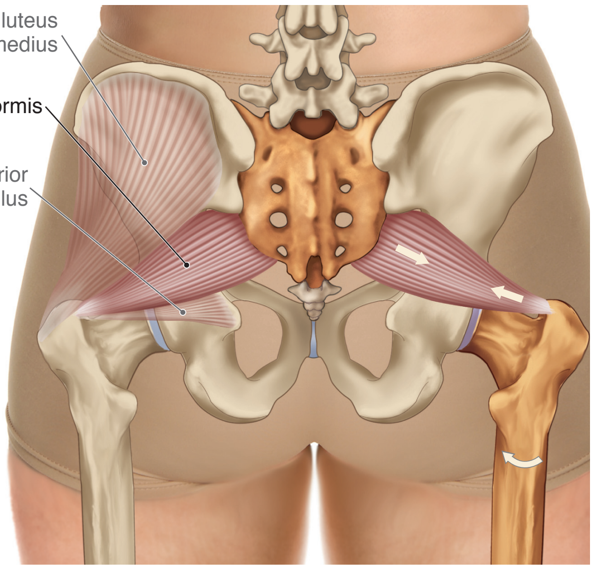


FIGURE 11-135 Posterior view of the piriformis bilaterally. The gluteus medius and superior gemellus have been ghosted in on the left.

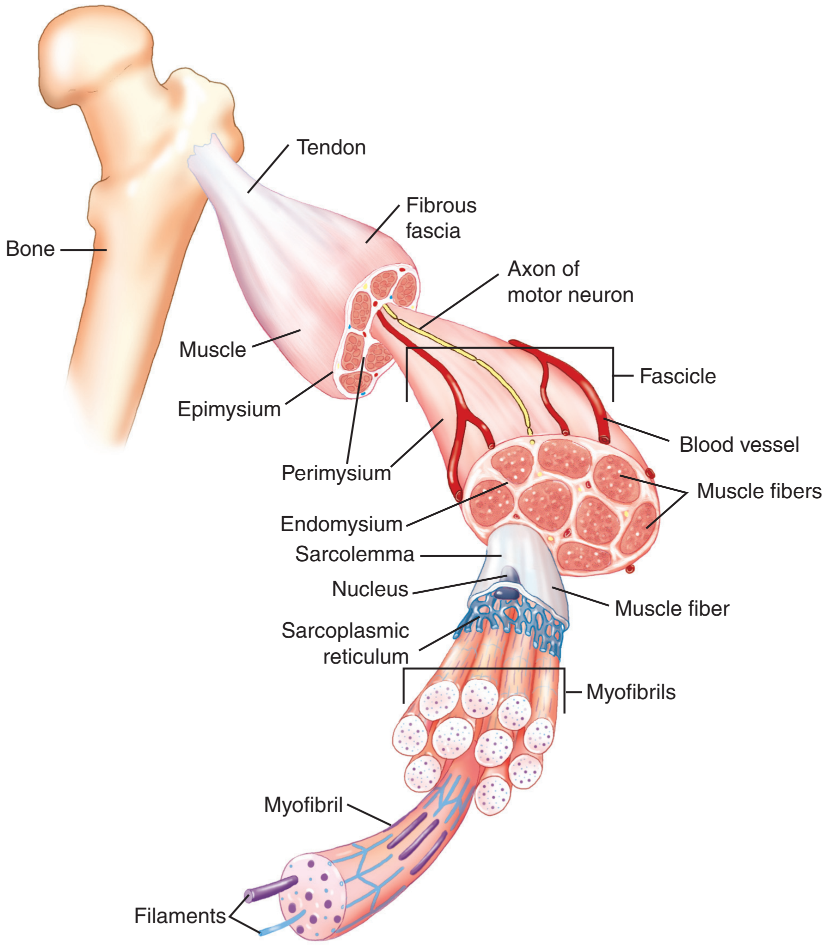


FIGURE 12-7 Interior of a muscle fiber (i.e., muscle cell). Note how the nerves and blood vessels travel along fascial planes.

SECTION 12.5 MICROANATOMY OF MUSCLE FIBER/SARCOMERE STRUCTURE

- Like any other type of cell in the human body, skeletal muscle fibers are enveloped by a cell membrane and contain many **cytoplasmic organelles**.
- However, the names given to many of these cellular structures are slightly different from those given to most of the other types of cells of the body in that the root word *sarco* is often incorporated into the name.
- *Sarco* is the Greek word root denoting flesh (i.e., muscle tissue).
- For example, the cytoplasm of a skeletal muscle fiber is called the **sarcoplasm**; the endoplasmic reticulum is called the **sarcoplasmic reticulum**; and the cell membrane is called the **sarcolemma**.[10]
- Skeletal muscle fibers are unusual in many ways.
- They are multinucleate (they contain many nuclei). This is because each muscle fiber (cell) developed from multiple stem cells grouping together.[2]
- They are rich in mitochondria. Mitochondria create adenosine triphosphate (ATP) molecules aerobically. Because muscle tissue contraction requires a great amount of energy expenditure, multiple mitochondria furnish this energy in the form of ATP molecules.[2]
- And they contain an oxygen-binding molecule called **myoglobin**. Myoglobin is similar to hemoglobin of red blood cells, except that it has an even greater ability to bind oxygen.[4]
- However, the most stunning structural characteristic of skeletal muscle fibers is their tremendous number of cytoplasmic organelles called *myofibrils.* Each **myofibril** is longitudinally oriented within the cytoplasm, running the entire length of the muscle fiber[4] (see Figure 12-7).
- Approximately 1000 myofibrils exist in a muscle fiber.[4]
- Myofibrils are composed of units called **sarcomeres** that are laid end to end from one end of the myofibril to the other end (they also lie side by side).[10]
- Sarcomeres are very short. On average, approximately 10,000 sarcomeres are found per linear inch (approximately 4000 per cm) of myofibril.
- The boundaries of each sarcomere are known as **Z-lines**.[4]

SECTION 13.5 LINES OF PULL OF A MUSCLE

- Because the line of pull of a muscle relative to the joint it crosses determines the actions that it has, it is extremely important to fully understand the line or lines of pull of a muscle[6] (Box 13-2).

BOX 13-2

For each scenario that is presented in this section with regard to a line of pull of a muscle and the resultant action that the muscle has, we are not considering the reverse action of a muscle. Given that a reverse action is always theoretically possible for every named standard action of a muscle, the complementary reverse action always exists.

- It is helpful to examine four scenarios regarding a muscle and its line or lines of pull:
  - Scenario 1: A muscle with one line of pull in a cardinal plane
  - Scenario 2: A muscle with one line of pull in an oblique plane
  - Scenario 3: A muscle that has more than one line of pull
  - Scenario 4: A muscle that crosses more than one joint

SCENARIO 1—A MUSCLE WITH ONE LINE OF PULL IN A CARDINAL PLANE:

- If a muscle has one line of pull and that line of pull lies perfectly in a cardinal plane, then that muscle will have one action (plus the reverse action of that action).
- A perfect example is the brachialis muscle. The brachialis crosses the elbow joint anteriorly with a vertical direction to its fibers. All of its fibers are essentially running parallel to one another and are oriented in the sagittal plane. Therefore the brachialis has one action, namely flexion of the forearm at the elbow joint[5] (as well as its reverse action of flexion of the arm at the elbow joint). The brachialis's line of pull is in the sagittal plane; therefore the action that it creates must be in the sagittal plane, and that action is flexion (Figure 13-6).

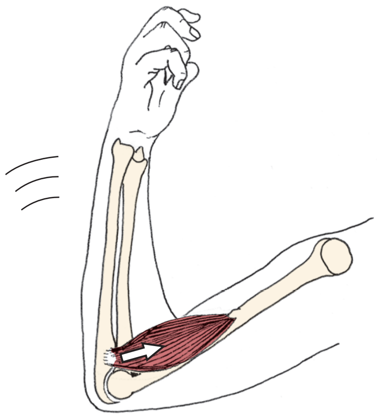


FIGURE 13-6 The brachialis muscle has one line of pull to its fibers, and that line of pull is located within the sagittal plane; therefore the brachialis can flex the elbow joint. (Note: Flexion of the forearm at the elbow joint is its standard action; flexion of the arm at the elbow joint would be the complementary reverse action.) *(From Muscolino JE:* The muscular system manual: the skeletal muscles of the human body, *ed 4, St Louis, 2017, Mosby.)*

SCENARIO 2—A MUSCLE WITH ONE LINE OF PULL IN AN OBLIQUE PLANE:

- If a muscle has one line of pull, but that line of pull is in an oblique plane, then the muscle will create movement in that oblique plane. However, when this movement is named, no name for oblique plane movement exists. Instead this movement has to be broken up into names for its component cardinal plane actions. (The concept of naming oblique plane motions is covered in Section 6.28.)
  - An excellent example is the coracobrachialis. The coracobrachialis has a line of pull that is in an oblique plane. That oblique plane is a combination of sagittal and frontal cardinal planes. When the coracobrachialis pulls, it pulls the arm diagonally in a direction that is both anterior and medial at the same time. However, no one name for this oblique plane motion exists. To name this one motion that would occur, we must break it up into its component cardinal plane actions of flexion in the sagittal plane and adduction in the frontal plane. Therefore even though the muscle actually creates only one movement in an oblique plane, we describe it as having two cardinal plane actions[1] (Figure 13-7). (To understand how an oblique plane muscle can create only one of its cardinal plane actions, see Section 15.4.)
  - For this reason, a muscle that has one line of pull can be said to have more than one cardinal plane action if that muscle's line of pull is oriented within an oblique plane. Of course, for each of its actions, a reverse action is theoretically possible.

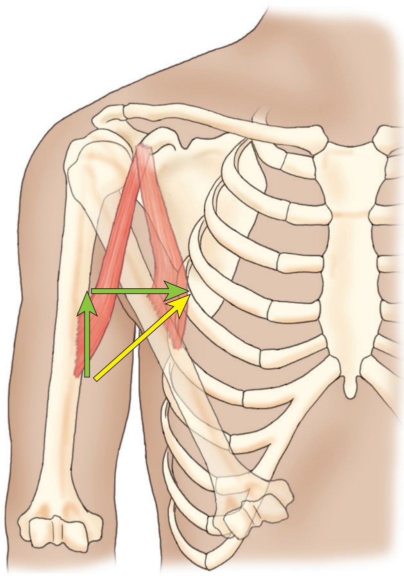


FIGURE 13-7 Illustration of the motion that is caused when the coracobrachialis contracts (with the scapula fixed and the humerus mobile). This one oblique plane motion (*yellow arrow*) must be broken down into its two cardinal plane actions (*green arrows*) when the joint actions of the coracobrachialis are discussed. Hence the coracobrachialis can flex the arm in the sagittal plane and adduct the arm in the frontal plane (all at the glenohumeral joint).

13

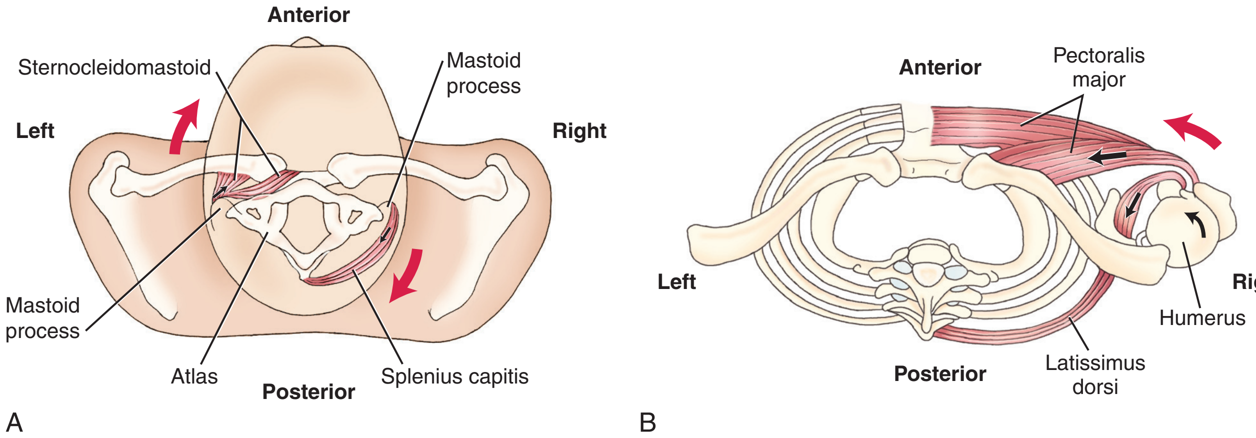


FIGURE 13-13 **A,** Superior view of the right splenius capitis and left sternocleidomastoid muscles. Even though one of these muscles is posterior and on the right side and the other is primarily anterior and on the left side, they both have the same action of right rotation of the neck and head at the spinal joints. This is because they both wrap around the neck/head in the same direction. **B,** Superior view of the right pectoralis major and right latissimus dorsi. Because they both wrap around the humerus in the same direction, they are both able to medially rotate the arm at the glenohumeral joint. As can be seen in these two examples, unlike other functional groups of movers, muscles of the same mover functional rotation group are often not located together in the same structural group location.

SECTION 13.8 OFF-AXIS ATTACHMENT METHOD FOR DETERMINING ROTATION ACTIONS

13

- Seeing how the direction of a muscle's fibers *wrap* around the bone to which it attaches is a convenient visual method for determining the transverse plane rotation action of a muscle.[9]
- However, another method can be used to determine rotation actions that might be a little more challenging to visualize at first; but once the rotation is visualized and understood, this method is a more accurate and elegant method to use. This method is called the **off-axis attachment method**.
- Figure 13-14, *A* illustrates a side view of a muscle that crosses from one bone (labeled *fixed*) to another bone (labeled *mobile*).

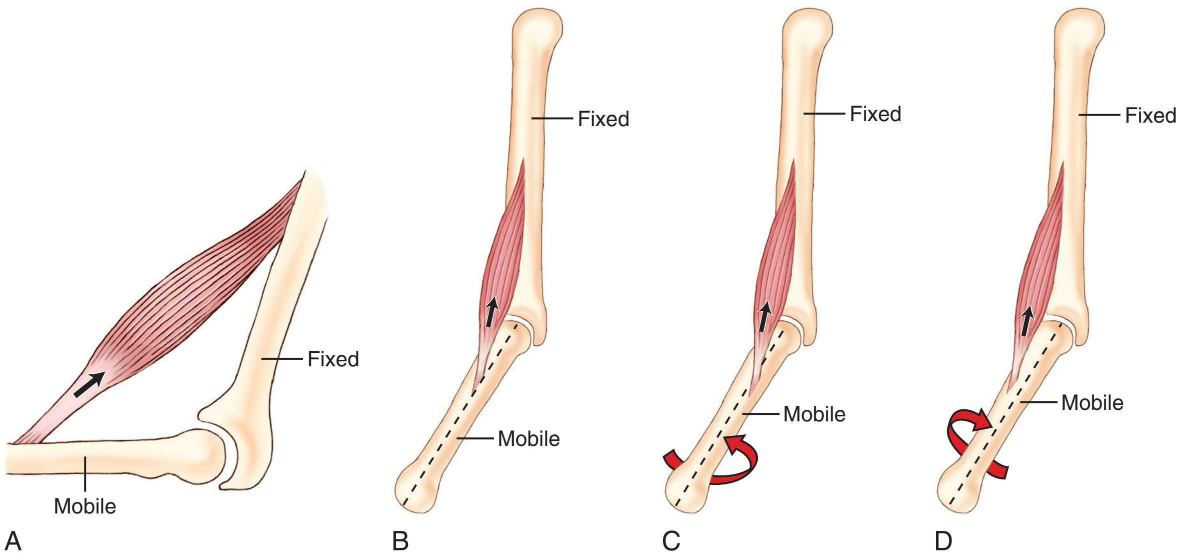


FIGURE 13-14 **A,** Side view of a muscle that attaches from one bone to another. When this muscle contracts and shortens, the mobile bone will be moved toward the fixed bone. **B** to **D,** Oblique views of muscles that cross from the same fixed bone to the same mobile bone. (Note: In all cases a dashed line indicates the long axis of the mobile bone.) The muscle in **B** attaches on-axis; therefore it produces no rotation action of the mobile bone. The muscles in **C** and **D** attach off-axis; therefore they can produce a rotation action of the mobile bone. The red arrows indicate these rotation actions. (Note: The muscles, bones, and joint illustrated in **A** to **D** are hypothetical; they are not meant to represent any specific structures of the body.)

- Scenario 1: If we are driving a car uphill (i.e., against gravity), we step on the gas to make the motor of the car power the car up the hill (Figure 14-7, *A*).
- Scenario 2: If we are driving a car on a level surface (i.e., gravity neutral), we step on the gas to make the motor power the car to go forward (Figure 14-7, *B*).
- Scenario 3: If we are driving a car downhill (i.e., with gravity), and we want to drive *faster* than gravity would bring us down the hill, we step on the gas to make the motor power the car down the hill faster than coasting by gravity would create (Figure 14-7, *C*).

CONCLUSION:

- Concentric contractions occur to move a body part in three scenarios:
  - Scenario 1: Vertically upward (i.e., against gravity)
  - Scenario 2: Horizontally (i.e., gravity neutral)
  - Scenario 3: Vertically downward (i.e., to move faster than gravity would move us)

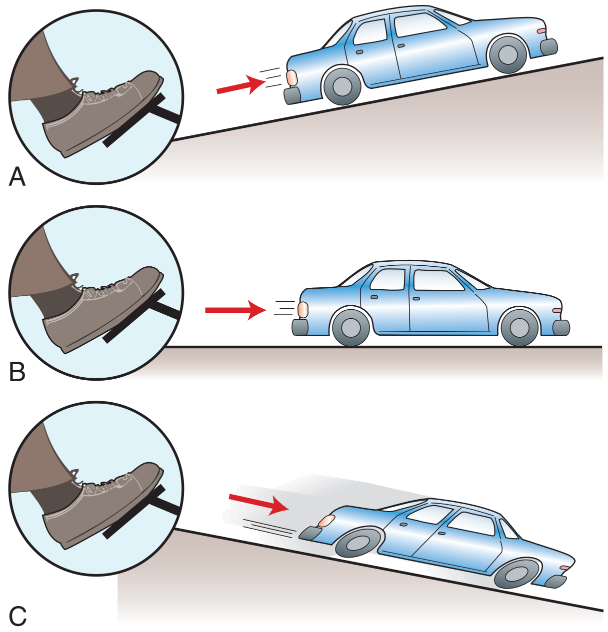


FIGURE 14-7 Illustration of the idea of the motor of a car being necessary to power the car in three scenarios. **A,** Car moving uphill. **B,** Car moving on level ground. **C,** Car moving downhill (faster than coasting with gravity). The concept of the motor powering the car to move in these three scenarios can be compared with a muscle concentrically contracting to move a body part and creating a joint action in three scenarios of movement: (1) vertically upward against gravity; (2) on level ground (i.e., gravity neutral); and (3) vertically downward, but faster than gravity would create.

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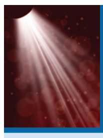
SECTION 14.5 ECCENTRIC CONTRACTIONS IN MORE DETAIL

ECCENTRIC CONTRACTIONS—LENGTHENING CONTRACTIONS:

- An eccentric contraction is defined as a lengthening contraction[9] (i.e., a muscle contracts and lengthens).
- Note: Just because a muscle is lengthening, it does not mean that it is eccentrically contracting! A muscle can lengthen when it is relaxed (e.g., when a person stretches). A muscle can also lengthen while it is contracting (i.e., when myosin filament heads are grabbing actin filaments). Lengthening while contracting is defined as an eccentric contraction. It is important to distinguish between these two instances of a muscle lengthening!
- If a muscle is lengthening, then its attachments are moving away from each other.[10]
- This means that instead of the myosin heads succeeding in pulling the actin filaments toward the center of the sarcomere, the resistance force to contraction is greater than the contraction force and the myosin heads are actually stretched in the opposite direction. Consequently, the actin filaments are pulled away from the center of the sarcomere and the sarcomeres lengthen (Figure 14-8).
- Movement of a muscle's attachments away from each other is usually not caused by muscle contractions within our body; rather, it is usually caused by an external resistance force. An external force is a force that is generated external to—in other words, outside of—our body (Box 14-4). The movement



BOX 14-4 Spotlight on Internal and External Forces

An **internal force** is a force that originates inside our body; internal forces are created primarily by our muscles. An **external force** is any force that originates outside our body.[6] Gravity is the most common external force that acts on our body, but it is not the only one. By virtue of being an external force, it is not a force that we directly can control. When we move our body with muscular contractions (i.e., internal forces), we can speed up or slow down the movement by altering the command from the nervous system to the muscles. External forces, however, do not respond to our commands. For that reason, the movements that they create usually need to be modified or controlled by our muscular internal forces. These muscular internal forces modify/control the external forces acting on our body by opposing them—similar to how a brake controls the movement of a car. The muscles that do this braking eccentrically contract, allowing the motion by the external force to occur, but slowing it down as is necessary. Other examples of external forces that may act on the body are springs, rubber tubing (see Figure 14-3, *B*), and bands that pull on the body during strengthening and rehabilitative exercising. Other examples include a strong wind, an ocean wave, wrestling with another person, or even the jostling of a subway train.

SECTION 15.2 ANTAGONIST MUSCLES

- An **antagonist** is a muscle (or other force) that can perform the opposite action of the action in question.[1]
- By definition, antagonists lengthen when the action in question occurs.
- An antagonist can lengthen in two ways:
  1. It can eccentrically contract and lengthen, generating a braking force on the action in question.[7] (For more information on eccentric contractions, see Sections 14.1, 14.2, and 14.5.)
  2. It can be relaxed and lengthen, allowing the action in question to occur.
- When an antagonist lengthens, it lengthens because the joint action that is occurring (the action in question) is causing the two attachments of the antagonist muscle to move away from each other (either one or both attachments of the antagonist could be moving). If the attachments of the antagonist are moving away from each other, then the joint action that is occurring must be the opposite action from the joint action that the antagonist muscle would perform if it were to shorten. Thus an antagonist can perform the opposite action of the action in question (Box 15-2).
  - For example, if the action that is occurring is protraction of the scapula at the scapulocostal (ScC) joint, then the scapula is moving anteriorly. An antagonist to this action is the rhomboids, and as the scapula protracts, the attachments of the rhomboids are moving farther from each other (i.e., the scapula is moving away from the spine). If the rhomboids were to concentrically contract, they would cause the opposite action of this action in question (i.e., they would cause retraction of the scapula at the ScC joint).
- Because an antagonist is usually located on the opposite side of the joint from the mover muscle(s) that can create the action in question, an antagonist is sometimes called a **contralateral muscle** (the term *contralateral* literally means *opposite side*).
- Usually for any joint action there will be a group of antagonists that can perform the opposite action of the action in question. Among the muscles of the antagonist group, the antagonist that is most powerful at opposing the action in question is called the **prime antagonist**.
- Although we usually think of antagonists as being muscles, any force can oppose the action in question. For this reason, the definition of an antagonist is *a muscle (or other force) that can perform the opposite action of the action in question.* The most common *other force* that can be an antagonist is gravity.
  - Any joint action that moves upward is opposed by gravity. Therefore in any upward movement, gravity is an antagonist.
- When a mover contracts and shortens, creating a joint motion, the antagonist must lengthen. If this lengthening is sufficient, the antagonist will stretch. Like a rubber band that is stretched, a passive elastic recoil tension force will build up in the stretched antagonist. If the mover is relaxed and the antagonist is now contracted, the passive tension force that is built up within the antagonist will augment the force of the antagonist's active contraction, creating a stronger force by the muscle. Given the benefit of this passive tension force, this phenomenon has been termed **productive antagonism**.[3]
  - The term *productive antagonism* was coined by Don Neumann, PT, PhD. For more on this concept, please see his textbook *Kinesiology of the Musculoskeletal System*, second edition (2010, Elsevier).

BOX 15-2 Spotlight on What an Antagonist Is Antagonistic To

The name *antagonist* literally means antiagonist (i.e., antimover); therefore many people assume that the definition of an antagonist is that it performs the opposite action of the mover (i.e., it opposes the mover). Although the antagonist can oppose the action in question that is performed by the mover, the mover may have other actions that the antagonist cannot oppose. For this reason, it is always best to remember that an antagonist is defined as being able to do the opposite action *of the action in question*. For example, if the action in question is elevation of the scapula at the scapulocostal (ScC) joint and we choose to consider the upper trapezius as our mover (because it can perform elevation of the scapula), then the lower trapezius would be an antagonist because it can perform depression of the scapula at the ScC joint (i.e., the action that is opposite the action in question). Is the lower trapezius an antagonist to the upper trapezius? It is, only relative to the action of elevation of the scapula. The upper trapezius can also retract the scapula, as can the lower trapezius. With regard to the mover's action of retraction of the scapula, it should be noted that not only does the lower trapezius not perform the opposite action (protraction), but it can actually help the upper trapezius perform retraction. Therefore when we look at the action in question as being retraction of the scapula, the upper trapezius and lower trapezius are synergistic to each other (i.e., they perform the same action). For this reason, it is best to avoid saying that a muscle is or is not an antagonist to another muscle; rather it is or is not an antagonist to a specific joint action (i.e., the action in question).

DETERMINING HOW AN ANTAGONIST LENGTHENS:

- It is critically important to realize that whenever a joint action occurs, the antagonist muscles must lengthen.
- However, as previously stated, an antagonist can lengthen in two manners:
  1. It can eccentrically contract and lengthen, allowing the action in question to occur, but also creating a braking force upon it (i.e., slowing the action in question).
  2. It can be relaxed and lengthen, allowing the action in question to occur.
- To determine how an antagonist lengthens (i.e., whether it is relaxed or eccentrically contracting), we need to look at whether the action in question needs to be slowed down in some manner.

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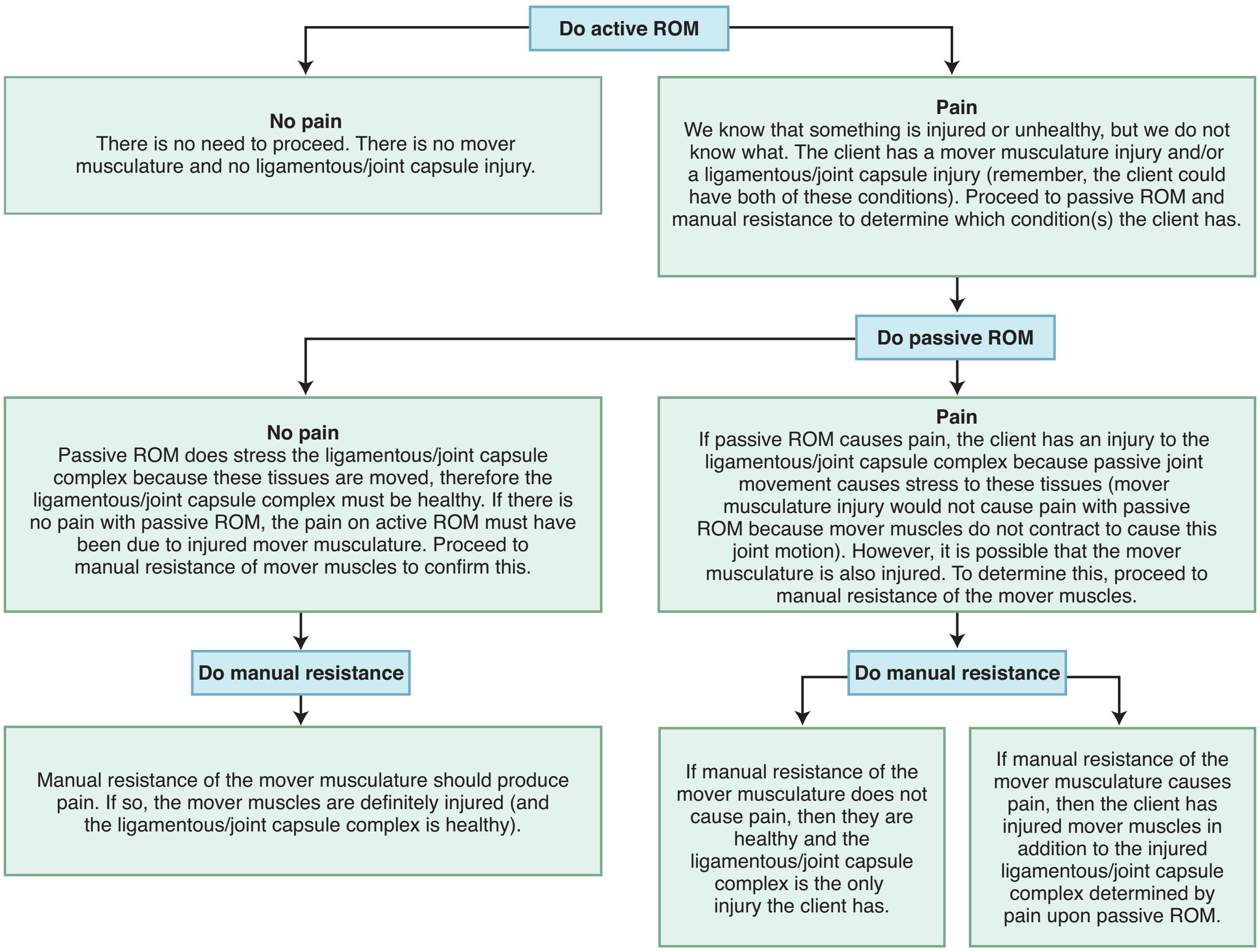

FIGURE 16-5 Flow chart demonstrates the proper sequence to follow for the orthopedic test procedures of active range of motion, passive range of motion, and manual resistance to assess a musculoskeletal soft tissue injury. *ROM*, Range of motion.

SECTION 16.4 MUSCLE PALPATION

- Regarding musculoskeletal assessment, perhaps no skill is more important or more valuable than assessment of resting muscle tone by muscle palpation. For this reason, it is extremely important for manual therapists to have a solid foundation in how to palpate the skeletal muscles of the body.
- Most textbooks on muscles offer a method to palpate each skeletal muscle of the human body. Although providing these palpation directions can be helpful, memorization of them on the part of the student should not be necessary. If a student knows the attachments and actions of the muscles, palpation can be figured out. The best way to become a better palpator is to spend more time palpating. Beyond that, if the student has extra time, that time should be spent reinforcing the knowledge of the attachments and actions of a muscle, not spent trying to memorize palpation directions.
- The student does not need to memorize the actions of a muscle—only the attachments need to be memorized. With use of the five-step approach to learning muscles presented in Section 13.3, once the attachments are known, the line of pull of the muscle relative to the joint is known. Knowledge of this allows the actions to be figured out. Less memorization and more understanding eases the stress of being a student and allows for better critical thought and clinical application!

FIVE-STEP MUSCLE PALPATION GUIDELINE:

- Following are the five basic guidelines to follow when looking to palpate the **target muscle** (i.e., the muscle that you desire to palpate) (Figure 16-6):
  1. Know the attachments of the target muscle so that you know where to place your palpating fingers.
  2. Know the actions of the target muscle so that you can ask the client to contract it. A contracted muscle is palpably firmer and easier to feel and discern from the adjacent soft

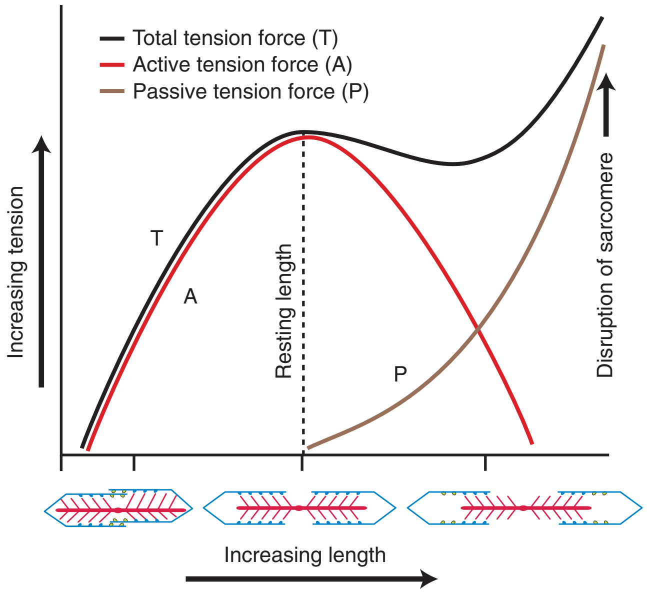

FIGURE 17-5 Three sarcomere length-tension relationship curves. These curves depict the relationship between the length of a sarcomere and the tension that it generates (i.e., its pulling force) at that length. The *red line* represents the active tension force that a sarcomere can generate when it contracts via the sliding filament mechanism. The *brown line* represents the passive tension force that the sarcomere generates when it is stretched. The *black line* represents the sum total of the active tension curve and the passive tension curve; therefore it represents the total pulling force of the sarcomere.

an entire muscle. (Note: The active length-tension relationship curve depicted in Figure 17-5 was created by measuring the contractile force of an isometric contraction for the continuum of lengths displayed. Some researchers caution that the values derived may not be 100% accurately correlated to concentric and eccentric contractions.)

Extrapolating these values for an entire muscle, we see the following:

- The red line in Figure 17-5 considers only the active tension as the length of a muscle changes. The shape of this curve is a bell curve wherein the greatest tension is clearly when the muscle is at resting length. When the length of the muscle changes in either direction (i.e., gets longer or shorter), the active tension that the muscle can generate decreases.
  - Lessened active tension when a muscle is shortened is called *shortened active insufficiency.*
  - Lessened active tension when a muscle is lengthened is called *lengthened active insufficiency.*
- The brown line in Figure 17-5 considers only the passive tension as the length of the muscle changes. We see that passive tension is nonexistent when the muscle is shortened. However, as the muscle lengthens beyond resting length, the passive tension of the muscle increases.
  - This increased passive tension of a muscle as it lengthens is called *passive tension* and results from the natural elasticity of the tissue.
- The black line in Figure 17-5 considers both the active tension and the passive tension of a muscle as its length changes.
  - We see that the overall tension (i.e., pulling force of the muscle) increases from a shortened length to resting length. The tension force in this range of the muscle's length is caused by increasing active tension.
  - The pulling force then stays fairly high beyond resting length for quite some time. Most of the tension in this range of the muscle's length results from increasing passive tension.
  - It is important to note that (as the graph shows) even though the total tension/pulling force of a muscle is greatest when it is longest, working a muscle at a much lengthened state is very dangerous, because at the end of this curve is tearing/disruption of the muscle tissue!
  - The length-tension relationship curve expresses the tension force of a muscle relative to its length. At each length of the muscle, the tension that it can generate can be located on the curve. However, this relationship is technically for an isometrically contracting muscle. That is, each point along the curve displays the isometric strength of the muscle at that static length. There is another curve that is used to express the tension force of a muscle but better expresses the muscle's tension force when the muscle is moving.[6]
  - This curve is called the **force-velocity relationship curve** (Figure 17-6). Regarding concentric contractions (shown on the right side of the curve), the force-velocity relationship curve essentially states that the tension force of a muscle is greatest when the muscle is contracting slowly. As the velocity of the muscle contraction increases, its tension force decreases. In other words, the faster a muscle contracts, the weaker its contraction force becomes; the slower a muscle contracts, the stronger its contraction force becomes.[6]

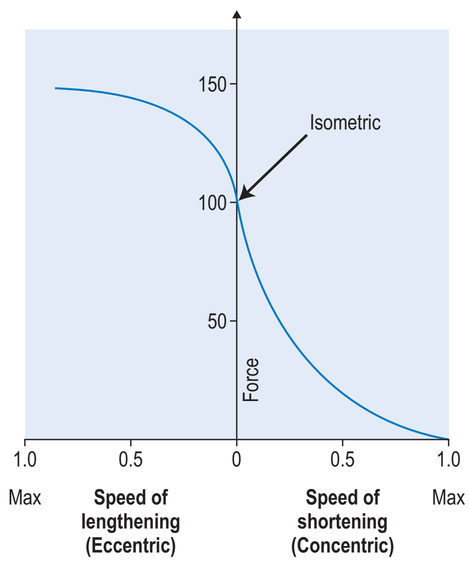

FIGURE 17-6 Illustration of the force-velocity relationship curve. This curve correlates the tension force that a muscle can develop relative to its velocity (i.e., speed) of contraction. Concentric contraction is shown on the right; eccentric contraction on the left. Regarding concentric contraction, the slower a muscle contracts, the stronger its contraction force; the faster a muscle contracts, the weaker its contraction force. *(Modified from Watkins, J:* Pocket podiatry: functional anatomy, *ed 1, Edinburgh, 2010, Churchill Livingstone.*

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FIGURE 18-4 The overhead squat assessment.

FIGURE 18-5 Being able to biomechanically analyze an individual's posture and movement is essential for the manual and movement professional. (From Muscolino JE: *Body mechanics: The price of smart phones*, Massage Therapy Journal, Springer, 2015. Art by Giovanni Rimasti.)

SECTION 18.2 A BRIEF INTRODUCTION TO FORCES

WHAT ARE FORCES?

- Forces will be defined with great detail later in this chapter. To get started, think of forces as simply a *push or a pull* of one body on another (please note, the word "body" in this case just means a physical object, not necessarily a human body).[2,3,7,9]
    - In most cases a force will be a push or a pull of two bodies *in contact*. However, there are exceptions to this; the most important example of a force with no contact is that of bodyweight. **Weight** is the force due to **gravity** acting upon an object's mass, always pulling the object *down* (toward the center of the earth). Being that gravity is causing the force and there is no direct contact between two objects, it is an exception to the rule above.
- Forces can affect a body in two ways:
1. Forces can move the body through space and/or
2. Deform the body (i.e., create changes in its shape—see below)[11]

BOX 19-3 Spotlight on Learned Behavior and Neural Facilitation

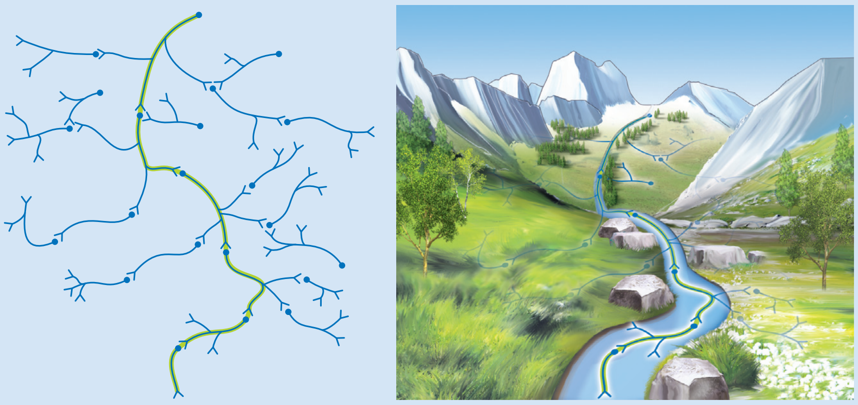
Sometimes the term **learned reflex** is used. Technically, this term is incorrect because reflexes are not learned; all reflexes are innate. The correct term that should be used is **learned behavior** or **patterned behavior**. A learned/patterned behavior describes an activity that is learned and so well patterned that it is carried out in what appears to be a "reflexive" manner. However, this learned/patterned behavior does not involve a reflex arc. The patterning of a learned behavior initially involves association within the brain between a certain stimulus and a certain response. After many repetitions, the association becomes so well patterned that our response becomes automatic without the necessity of conscious thought. A classic example of learned behavior is Pavlov's dog salivating after hearing a bell because the dog learned to associate the sound of the bell with being fed. Many if not most of our daily activities are learned behavior patterns. We rarely think of the muscles that we need to contract to walk across the room, tie our shoes, speak, or drive a car along a route that we have taken many times before. In fact, it is likely that we may be driving our car while drinking a café latte and having a conversation at the same time, and we may realize halfway home that we have not even thought about which turns we have taken. If asked, we may not even know which road we are on; the body has been carrying out a series of learned behaviors as if it were operating on autopilot, with little or no conscious awareness!

The explanation that is given for how all associations are made, as well as why learned behaviors become so rooted in our nervous system, is the process of **neural facilitation**. Functionally, neural facilitation patterning that is made between a certain stimulus and a certain response becomes easier and easier to make as the association becomes reinforced through intensity or repetition.[20] Structurally, neural facilitation results from actual physical changes in the pathways of neurons that lower their threshold to form a certain pattern of connections (see figure). The result is a pattern of thinking and a pattern of behaving that becomes learned. The more this pattern is reinforced, the more entrenched this pattern becomes.

Some crucially important applications of the concept of learned behavior (i.e., neural facilitation) are found in the health field. Application can be made to the fields of manual and movement therapy and fitness training. Just as certain tasks and movement patterns are learned and patterned, the **resting tone** of our musculature can be learned and patterned. Normally, the resting tone of all our musculature should be relaxed. However, for many reasons the resting tone of a client's muscle may increase when certain stressful circumstances occur. If the relationship of this muscle tightening is not addressed, the pattern of this muscle tightening because of certain stimuli such as being stressed psychologically can become entrenched. As a result, each time in the future when the client becomes psychologically stressed, it will be a triggering stimulus that will more easily cause the muscle to tighten up. In time, the stimulus/tight muscle response can become a learned behavior that occurs without us having any realization of the link between the two. As therapists working on the musculoskeletal system, changing this pattern of muscle tightness involves more than just working on the muscle itself; it involves working with the nervous system to retrain its responses. In effect, we have to help the client's nervous system unlearn a certain pattern of response and relearn a new and healthier pattern of response.

An equally important application of neural facilitation to exercise exists. The pattern of co-ordering muscles (i.e., coordination) is also a learned/patterned behavior. When working with a client who exhibits poor technique when doing an exercise, this poor technique pattern is most likely entrenched via neural facilitation. To correct this faulty technique pattern, the client must create a new pattern that is healthy and proper to replace the old unhealthy pattern. In this regard, repetition is essential toward creating a new healthy neural facilitation pattern.

The concept of learned behavior/neural facilitation can also be applied to movement patterns and movement therapies. Often our movements are learned patterns that have become ingrained without conscious realization. As a result, poor movement patterns may be adopted that are inefficient, unhealthy, and functionally limiting. It is important to realize that these patterns exist within the nervous system, not within the musculoskeletal system. Therefore correction of these faulty patterns may be most efficiently accomplished by addressing the nervous system directly. **Feldenkrais technique** is a movement therapy that seeks to create client awareness of their movements including their faulty patterns of movement. Once aware, if the client desires to change his or her movement patterns, new patterns that are healthier and functionally freer may be learned.



A pattern of neuronal synaptic connections being made via neural facilitation is analogous to water etching a deeper and deeper pathway into the side of a mountain over a period of time. *(Courtesy of Giovanni Rimasti)*

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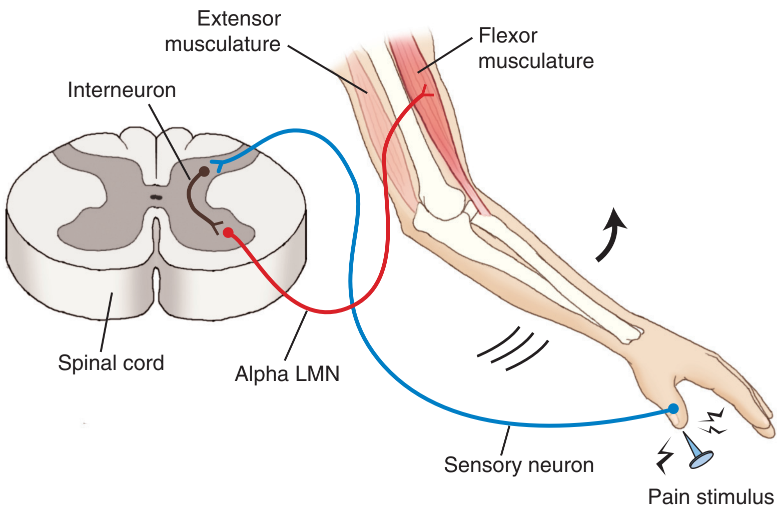

FIGURE 19-13 Illustration of the flexor withdrawal reflex, which is reflex mediated by the spinal cord. When a painful stimulus has occurred, it travels via a sensory neuron into the spinal cord, where it synapses with an interneuron, which then synapses with an alpha lower motor neuron (LMN). The alpha LMN then directs the flexor musculature in that region of the body to contract so that the body part is flexed and withdrawn from the cause of the painful stimulus.

CROSSED EXTENSOR REFLEX:

- The **crossed extensor reflex** is a reflex that works in conjunction with the flexor withdrawal reflex.[3] As the body part that experiences pain flexes and withdraws, the extensor muscles of the contralateral (i.e., opposite side) extremity contract to move that extremity into extension. Figure 19-14 illustrates the crossed extensor reflex.
  - The crossed extensor reflex is so named because this reflex crosses to the other side of the spinal cord to create a contraction in the contralateral extensor muscles.
  - The purpose of the crossed extensor reflex is to create a balanced posture of the body when one side flexes and withdraws. For example, if one lower extremity flexes and withdraws, the contralateral lower extremity must go into extension to support the body from falling; if one upper extremity flexes and withdraws, then extension of the contralateral upper extremity helps to create a more balanced posture.
- Note that reciprocal inhibition is a part of the crossed extensor reflex. As the extensor muscles are ordered to contract, the flexor muscles on that side of the body are inhibited from contracting (i.e., ordered to relax); otherwise, extension of the contralateral extremity would not be efficiently possible. (Note: The reciprocal inhibition component of the crossed extensor reflex is not shown in Figure 19-14.)

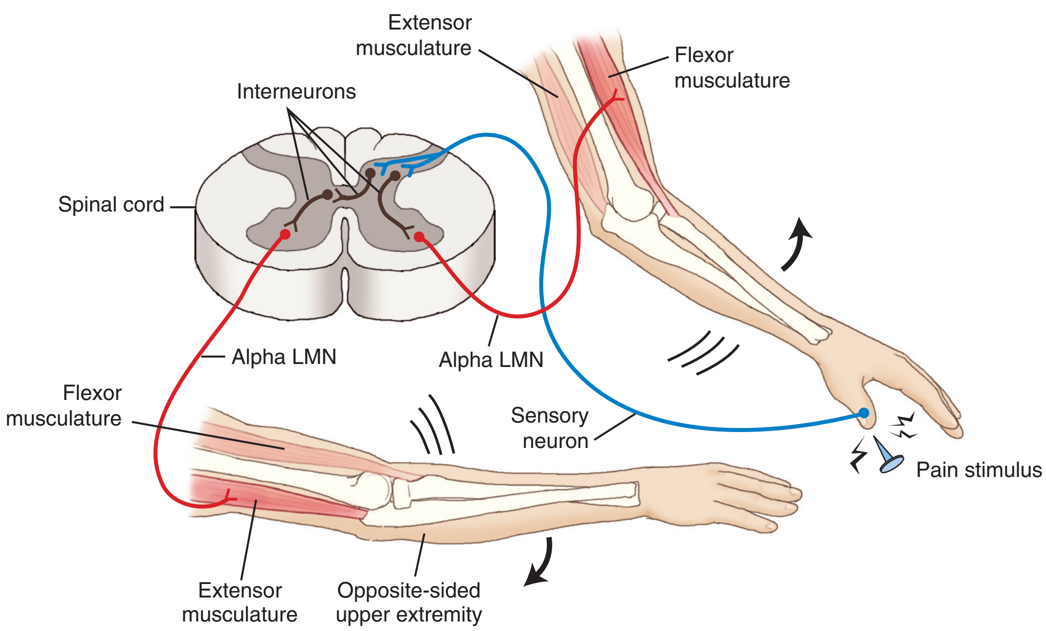

FIGURE 19-14 Illustration of the crossed extensor reflex and the flexor withdrawal reflex. When the flexor withdrawal reflex causes flexion and withdrawal of the extremity on the same side as the painful stimulus, the information that enters the spinal cord also crosses over to the other side of the cord and synapses with alpha lower motor neurons (LMNs), which direct the extensor musculature of the opposite-sided extremity to contract. This additional reflex component that crosses to the other side of the cord and directs extensor contraction is called the crossed extensor reflex.

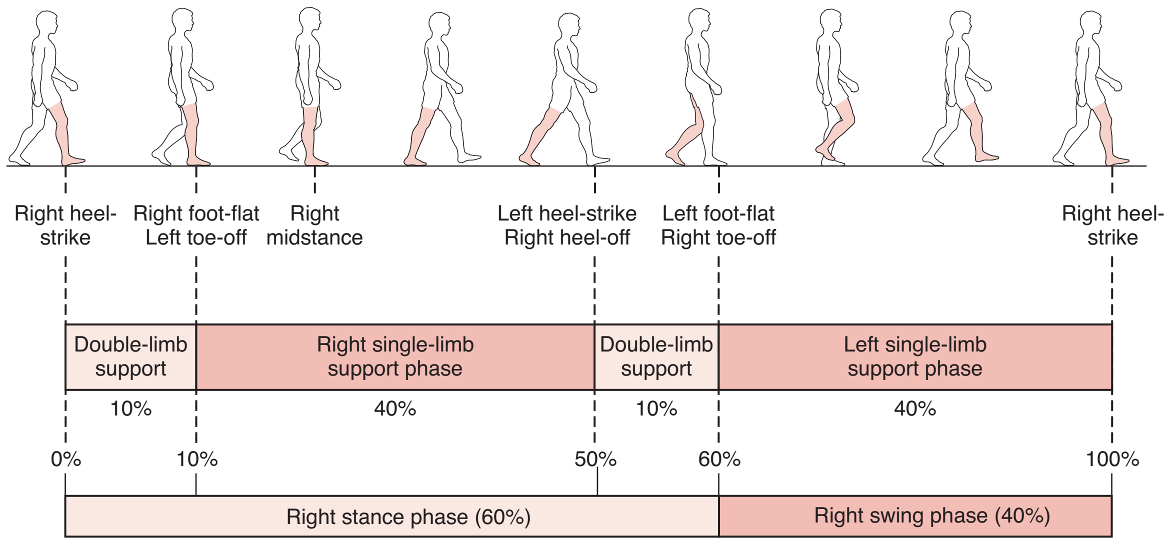

FIGURE 20-7 Gait cycle. The gait cycle begins with one heel-strike and ends with the same-side heel-strike. One gait cycle is composed of one stride, which in turn is composed of two steps. Phases and landmarks of the gait cycle. The gait cycle can be divided into two main phases: (1) the stance phase and (2) the swing phase. The stance phase is defined as when the foot is on the ground and accounts for 60% of the gait cycle for each foot; the swing phase is defined as when the foot is swinging in the air and accounts for 40% of the gait cycle for each foot. The period of double-limb support in which both feet are on the ground should be noted; walking is defined by the presence of double-limb support. The major landmarks of stance phase are heel-strike, foot-flat, midstance, heel-off, and toe-off. The swing phase is often divided into an early swing, midswing, and late swing. *(Modified from Cameron M, Monroe L:* Physical rehabilitation: evidence-based examination, evaluation, and intervention*, ed. 1, St. Louis, 2007, Saunders.)*

Stance Phase:

- Stance phase contains the following five landmarks of the gait cycle (Box 20-7).[1]
  1. **Heel-strike** is defined as the moment that a person's heel strikes (i.e., makes contact with) the ground.

Heel-strike is the landmark that begins stance phase (and ends swing phase).

  2. **Foot-flat** is defined as the moment that the entire plantar surface of the foot comes into contact with the ground (i.e., the foot is flat).
  3. **Midstance** is the midpoint of stance phase and occurs when the weight of the body is directly over the lower extremity. Midstance occurs when the greater trochanter is directly above the middle of the foot.
  4. **Heel-off** is defined as the moment that the heel leaves the ground.
  5. **Toe-off** is defined as the moment that a person's toes push off and leave the ground. Toe-off is the landmark that ends stance phase (and begins swing phase).

BOX 20-7 Spotlight on the Function of the Foot during the Gait Cycle

When walking, the foot must be supple and flexible during the early stages of the stance cycle to adapt to the uneven surfaces of the ground. This requires the foot to be in its open-packed position, which is pronation (primarily composed of eversion). Pronation allows the arch structure to collapse, thus allowing the foot to adapt to the contour of the ground. However, during the later stages of the stance cycle when toeing-off (i.e., pushing off) the ground, the foot must be stiff and stable to propel the body forward. This requires the foot to be in its closed-packed position, which is supination (primarily composed of inversion). Supination holds the arches high and creates a more rigid, stable foot for propulsion. The ability of the foot to change from being supple (able to pronate) to rigid (held in supination) is largely created by the laxity/tautness of the plantar fascia of the foot. When the plantar fascia is taut, the arch structure is supported and the foot becomes somewhat rigid; when the plantar fascia is lax, the arch structure is more mobile and the foot becomes supple. The ability of the plantar fascia to change from being lax to being taut is created by the windlass mechanism (see Section 9.17). During the early stages of the stance cycle when the foot is in anatomic position, the plantar fascia is lax, resulting in a supple foot. However, during the later stages of the stance cycle when extension occurs at the metatarsophalangeal (MTP) joints, because of the windlass mechanism, the plantar fascia is pulled taut around these joints. The resulting tension in the plantar fascia is then transferred to the arch structure of the foot, causing it to rise, creating a rigid foot for propulsion. Thus the foot shifts between being supple and flexible during the early stance cycle to adapt to the ground, and being stable and rigid during the late stance cycle for propulsion.[7]

SECTION 21.2 ROUNDED LOW BACK/PELVIS

DEFINITION

- A **rounded low back/pelvis** is marked by a **posteriorly tilted pelvis** with a **kyphotic lumbar spine**[2] (Figure 21-2). This postural dysfunction is extremely important because it is occurring more and more frequently in recent years. Note: Rounded low back/pelvis is sometimes described as "swayback." However, the use of this term can be misleading because swayback is also sometimes used to describe the posture of an excessively anteriorly tilted pelvis with a hyperlordotic lumbar spine (in other words, the posture involved in lower crossed syndrome).

Figure 21-2 Rounded low back/pelvis is a sagittal plane distortion pattern of the thoracolumbar spine that involves kyphosis of the lumbar spine and hyperkyphosis of the thoracic spine. *(From Muscolino JE:* The Price of Smart Phones, Massage Ther J Winter 2015:17–24. *Illustration by Giovanni Rimasti.)*

ETIOLOGY

- The most common cause of a kyphotic lumbar spine is a collapsing of the low back and pelvis into flexion to round forward when working down in front of oneself. This condition is becoming extremely common in recent years due to the increased use of digital devices such as laptop computers, tablets, and smart phones (see Figure 21-2). A rounded low back/pelvis can also be caused by excessively tight hamstrings.[6] Hamstrings are posterior tilt musculature of the pelvis. If they are tight, they can pull the pelvis into posterior tilt, which then results in lumbar kyphosis, hence rounded low back.

EFFECTS

- Rounded low back/pelvis shifts the weight bearing of the lumbar spine anteriorly, which increases compression upon the intervertebral discs.[2] This drives the nucleus pulposus posteriorly into the posterior annular fibers as they are being pulled taut and subjected to increased tension due to the position of flexion. These factors increase the likelihood of pathologic disc changes, resulting in disc bulging and/or herniation. Of course, if weight is shifted anteriorly, it is shifted off of the facet joints, resulting in an unloading of the facet joints. This could be considered to be a positive effect. But this posture places the facet joints into a position of flexion, which is an open-packed unstable position for the joints.[2] Decreased stability may predispose toward increased aberrant motions of these joints with resultant degenerative osteoarthritic changes. Another effect is that lumbar spine flexion results in increased size of the lumbar intervertebral foramina, which could help to decrease pressure upon a nerve in the intervertebral foramina.

TREATMENT APPROACH

- The manual and movement therapy treatment approach for rounded low back/pelvis should be two-pronged. First, the client must be counseled to change their postural patterns so that they do not collapse into the dysfunctional posture.[8] Using lumbar support pillows and avoiding use of digital devices down in front of them is key. Second, strengthening the low back extensor musculature is important to prevent the collapse of the lumbar spine into flexion and pelvis into posterior tilt; and, if needed, stretching/loosening the hamstring musculature is important.[2]

SECTION 21.6 SCOLIOSIS

DEFINITION

- A **scoliosis** is a frontal plane postural distortion of the spine in which the spine has curves when viewed from posterior to anterior (or anterior to posterior).[8] Because of the coupling of lateral flexion with rotation, a scoliosis also has a transverse plane component.[10] Generally, a lumbar scoliosis couples lateral flexion with contralateral rotation; for example, left lateral flexion couples with right rotation; this results in the spinous processes turning into the concavity of the curve, making the degree of scoliotic curve visually appear to be less than what it is. A cervical scoliosis couples lateral flexion with ipsilateral rotation; for example, left lateral flexion couples with left rotation. The lower thoracic spine usually follows the pattern of the lumbar region and the upper thoracic spine usually follows the pattern of the cervical spine. A scoliosis can be described as being either a "**C curve**," an "**S curve**," or a "**double S curve**"[5]; and each scoliotic curve is named for its side of convexity (Figure 21-6).[2] The degree of a scoliotic curve can be measured by the angle formed from the intersecting lines drawn along the superior bodies of the highest and lowest vertebrae of the curve[2] (see Figure 21-6, *C*). Like most postural distortions of the body, a scoliosis can be a primary problem or a secondary problem.

ETIOLOGY

- One type of scoliosis is known as **idiopathic scoliosis** because its cause is not known (idiopathic means of unknown cause). This is a primary form of scoliosis that can be quite severe and usually affects adolescent/teenage girls.[12] However, a scoliosis can be mild or moderate in severity and be secondary to a simple mechanical asymmetry of musculature of posture. For example, if a muscle such as the quadratus lumborum is excessively tight on one side, it can pull the lumbar spine into lateral flexion on that side (and/or pull the pelvis up into elevation on that side, which would also result in lateral flexion of the lumbar spine to that side). Posturally, any condition that creates a short lower extremity, often referred to as a ***short leg***, on one side (such as asymmetrical muscular pull upon the pelvis in the frontal plane or overpronation/dropped arch) would result in an unlevel iliac crest height,[15] which would then create a scoliosis as a compensation to bring the eyes and inner ears back to level for proprioception.[2] A scoliosis could even develop secondary to an asymmetrical postural habit in which the client leans into lateral flexion on one side; perhaps due to a habit of sitting in a desk chair and leaning to one side.

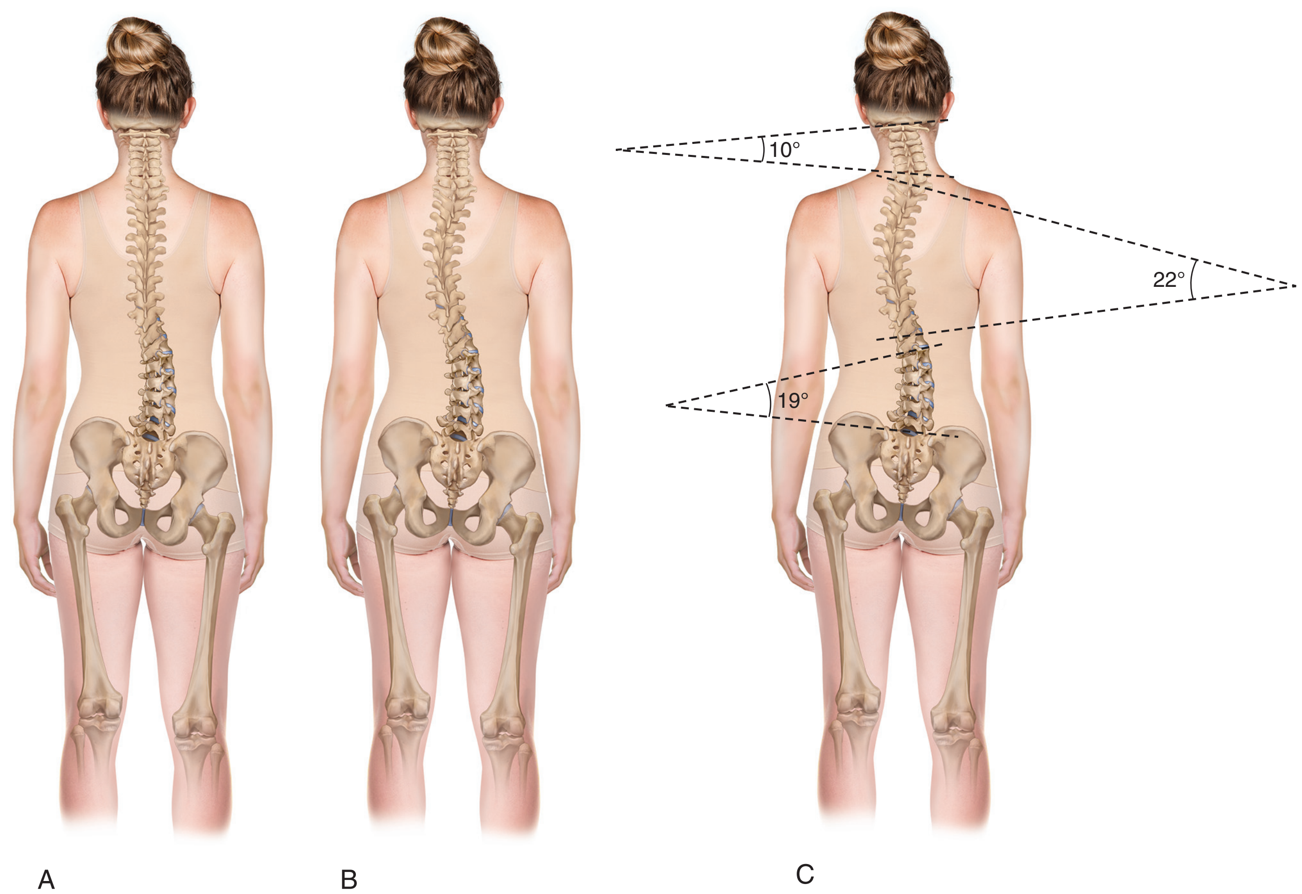

Figure 21-6 Scoliosis. **A,** A right lumbar "C scoliosis." Note the rotation that couples with the lateral flexion. **B,** A right lumbar left thoracic "S scoliosis." **C,** A right lumbar, left lower thoracic, right cervicothoracic "double S scoliosis." Each scoliotic curve has been measured in **C**.

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SECTION 22.3 ADVANCED STRETCHING TECHNIQUES: PIN AND STRETCH TECHNIQUE

- Beyond the choice of performing a stretch statically or dynamically, there are other, more advanced stretching options. One of these advanced options is pin and stretch technique. **Pin and stretch** technique is a stretching technique in which the therapist/trainer pins (stabilizes) one part of the client's body and then stretches the tissues up to that pinned spot.
- The purpose of the pin and stretch is to direct a stretch to a more specific region of the client's body. As stated previously, when a body part is moved to create a stretch, a line of tension is created. Everything along the line of tension will be stretched. However, if we want only a certain region of the soft tissues along that line of tension to be stretched, then we can specifically direct the stretch to that region by using the pin and stretch technique.[11]
- For example, if a side-lying stretch is done on a client as demonstrated in Figure 22-6, *A*, the entire lateral side of the client's body from the therapist/trainer's right hand on the client's distal thigh to the therapist/trainer's left hand on the client's upper trunk will be stretched. The problem with allowing the line of tension of a stretch to spread over such a large region of the client's body is that the intensity of the stretch is diluted over this large expanse, and if one region of soft tissue of the client's body within that line of tension is very tight, it might stop the stretch

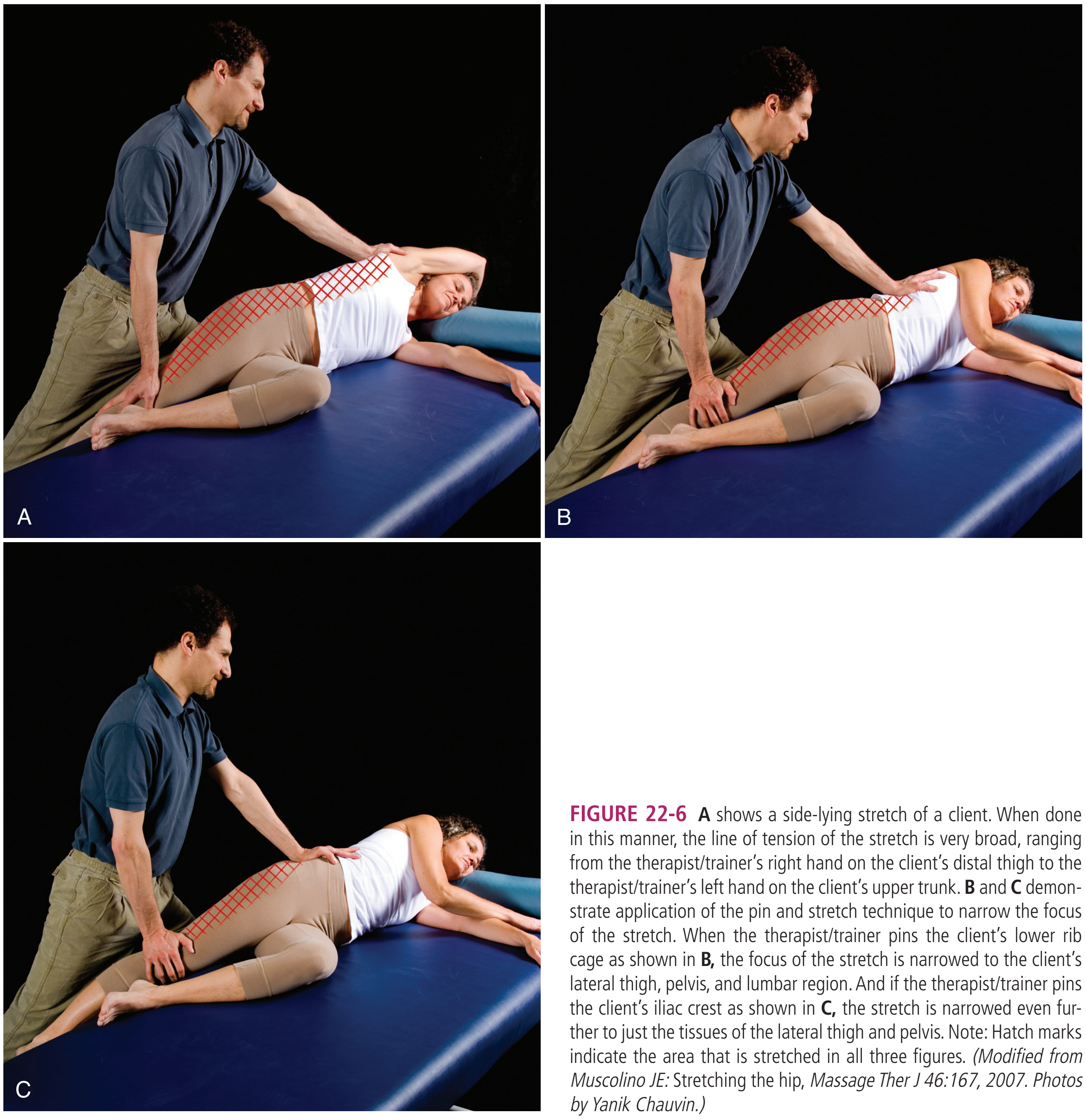

FIGURE 22-6 **A** shows a side-lying stretch of a client. When done in this manner, the line of tension of the stretch is very broad, ranging from the therapist/trainer's right hand on the client's distal thigh to the therapist/trainer's left hand on the client's upper trunk. **B** and **C** demonstrate application of the pin and stretch technique to narrow the focus of the stretch. When the therapist/trainer pins the client's lower rib cage as shown in **B,** the focus of the stretch is narrowed to the client's lateral thigh, pelvis, and lumbar region. And if the therapist/trainer pins the client's iliac crest as shown in **C,** the stretch is narrowed even further to just the tissues of the lateral thigh and pelvis. Note: Hatch marks indicate the area that is stretched in all three figures. *(Modified from Muscolino JE:* Stretching the hip, *Massage Ther J 46:167, 2007. Photos by Yanik Chauvin.)*

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movement, the client must overpower the force of gravity applied to the body in order to move from a squatted position to a standing position. The muscles in action are not only overcoming gravitational force but are also stabilizing the trunk in order to direct the movement in the proper direction. The overall weight of the body determines the amount of resistance that the muscles involved need to overcome (Box 23-4).

BOX 23-4

Something fun you can try is to perform a push-up on a typical bathroom weight scale to see how much resistance is being applied through your arms. Then, by elevating your legs onto a chair, you can see how the resistance increases depending on the angle of the body. Of course, a handstand push-up would be equivalent to the whole weight of your body, as well as requiring the greatest amount of stabilization when compared with a regular push-up.

- ❍ It is important to note that the body is always under a state of resistance: the resistance of gravity. By simply lifting an upper extremity into the air, its weight (approximately 5% of total body weight) is providing resistance that the mover muscles must overcome. This is why astronauts must use special training methods when in space, because without the resistance of gravity, their muscles would quickly atrophy and weaken! (See Figure 23-4.)

❍ Bodyweight exercises are common among athletes and those wishing to improve their day-to-day functional strength. When certain exercises such as the squat are mastered and can no longer provide enough desired resistance, the movement can be manipulated in many different ways. Various methods of bodyweight resistance exercises include plyometrics, speed, endurance, agility, balance, and unilateral training.

Plyometrics:

❍ A **plyometric exercise** is typically defined as a movement in which a muscle or muscle group is quickly stretched and then immediately thereafter contracts with a maximal concentric force, usually resulting in the feet (or hands) leaving the ground. By rapidly stretching the muscles involved and then contracting them, a ballistic movement is created that allows for a very high level of force output[12] (see Section 19.6 for the relationship of plyometric exercise to the muscle spindle reflex). This technique of training eccentric-concentric sequence movements is also known as the **stretch-shorten cycle**.

- ❍ An example of a plyometric exercise is the squat jump (Figure 23-5). In this exercise, the client quickly drops down into a squatting position and then applies maximal force during the concentric contraction to jump into the air. As the amount of force applied to the muscles overcomes the force of gravity, the client becomes momentarily airborne. The client is then instructed to land softly using the legs to absorb the impact as the body returns to the ground.
- ❍ External resistance, such as from elastic bands or weights, can be added for additional challenge to a plyometric exercise. These movements tend to be closed kinetic chain exercises, but there are some that are open chain as well. For example, medicine balls are commonly used to challenge the upper extremities (Figure 23-6). Available in several different sizes, weights, and compositions, medicine balls can help the client develop power, coordination, and aerobic capacity. Many athletes incorporate this type of training into their program because of these benefits.

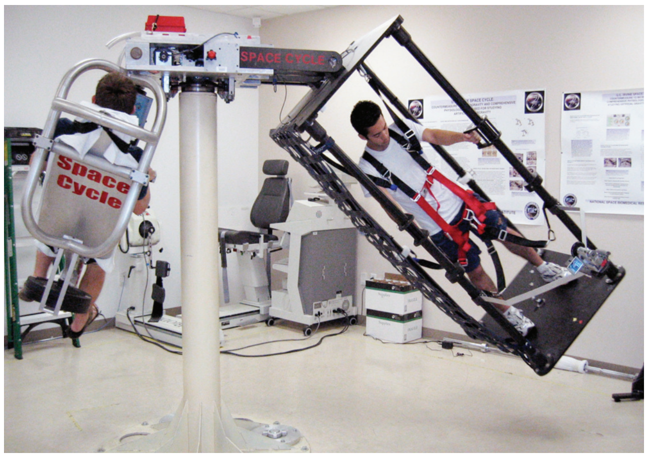

FIGURE 23-4 In order to create artificial gravity, the Space Cycle, a machine designed for astronauts, uses the principles of centrifugal force by rotating in circles around the central vertical axis (like a merry-go-round) at a speed that increases as the cyclist pedals with the feet (there is also a hand pedal attachment for an upper body workout). The faster the apparatus rotates, the more artificial gravity is created, with as much as seven times the Earth's gravity having been recorded. While the machine is in motion, the user inside the cage can perform various exercises against the resistance of the gravity that the client creates with the centrifugal force. *(Photo courtesy VJ Caiozzo, University of California, Irvine.)*

FIGURE 23-5 The squat jump is one of the most common plyometric exercises. Many sports involve some form of jumping, and this exercise is designed to help train the body to achieve an optimal movement pattern for this action, as well as strengthen the muscles and connective tissues during the impact phase of the landing.

SECTION 23.5 EXERCISE TECHNIQUE

- Exercise variety is a wonderful tool that can keep workouts fun and interesting, as well as teaching the body new movement patterns and motor skills to stimulate growth and prevent injury. Although there are many resources available that list specific exercises with very specific guidelines as to how to perform them, it is important to realize that there is an infinite number of possibilities when it comes to training the body. Any movement imaginable can be placed under external resistance and by definition will become an exercise (Box 23-12).
- In this section, the following aspects of exercise technique are discussed: joint angle and gravity, range of motion, proper form, and training for specificity.

BOX 23-12

It should be noted that just because something can be done, it does not mean that it should be done. There are many movements that put a great amount of stress on our joints and soft tissues, and by adding resistance to these movements we put ourselves at risk for injury. Trainers should try to be aware of their client's preexisting injuries, imbalances, and/or dangerous tendencies. It is critically important to use your knowledge and problem-solving skills when working with a client to overcome these obstacles.

FIGURE 23-28 A biceps curl performed in two different setups. In **A,** we see that the shoulder joint is in a position of slight extension, which will alter the length-tension relationship of the two heads of the biceps brachii, putting them into a stretched state. In **B,** a preacher biceps curl is being performed and we can see that now the shoulder joint is in a position of flexion, putting the two heads of the biceps brachii into a shortened position.

JOINT ANGLE AND GRAVITY:

- Are all exercises created equally? When looking at the execution of an exercise, it is important to note the body position relative to the joint or joints in motion and determine if it will have any effect on the outcome of the movement. For example, a biceps curl while seated on an inclined bench will have a different effect than a preacher biceps curl in which the client is standing with his (upper) arm resting on the inclined bench (Figure 23-28).
  - The biceps curl is considered to be a single-joint, isolated exercise. Elbow joint flexors are called on to curl the weight up to shoulder level, and shoulder joint extensors and wrist joint flexors are called on to stabilize the shoulder joint and wrist joint from moving, respectively. In Figure 23-28, *A*, the inclined biceps curl, the shoulder joint is in a position of slight extension, which causes a lengthening of the muscles that cross the shoulder joint anteriorly, including the two heads of the biceps brachii. Because free weight is being used, the moment arm of the resistance changes during the range of motion because of the gravitational pull as the weight is being lifted. This stimulates the muscle in a unique way. By contrast, in Figure 23-28, *B*, the preacher curl uses a pad placed in front of the client that puts the shoulder joint in a position of flexion, which once again changes the moment arm. This technique of manipulating the length of a muscle before an exercise works only for a muscle that crosses more than one joint. This type of muscle is described as a **multijoint muscle**. An example would be the two heads of the biceps brachii, which attach proximally to the scapula and distally to the radius, thereby crossing the shoulder, elbow, and radioulnar joints. By contrast, a muscle that crosses only one joint is described as a **single-joint muscle**. An example would be the brachialis, which serves a function similar to that of the biceps brachii but crosses only the elbow joint.