

## Key Terms

**acetylcholine (ACh)** (p. 147)

**actin** (p. 145)

**antagonists** (p. 152)

**aponeurosis** (p. 145)

**belly** (p. 143)

**cardiac muscle** (p. 143)

**fascia** (p. 144)

**insertion** (p. 152)

**motor unit** (p. 147)

**myosin** (p. 147)

**neuromuscular junction (NMJ)** (p. 147)

**origin** (p. 152)

**prime mover** (p. 152)

**recruitment** (p. 147)

**sarcomere** (p. 145)

**sarcoplasmic reticulum (SR)** (p. 145)

**skeletal muscle** (p. 142)

**smooth muscle** (p. 142)

**synergists** (p. 152)

**tetanus** (p. 151)

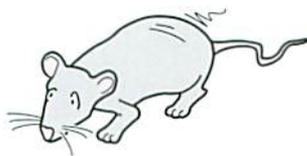
**tonus** (p. 151)

**twitch** (p. 150)

## Objectives

1. Identify three types of muscle tissue.
2. Compare the structure of the whole muscle and the structure of a single muscle fiber.
3. Describe the sliding filament mechanism of muscle contraction.
4. Explain the role of calcium and adenosine triphosphate (ATP) in muscle contraction.
5. Describe the relationship between skeletal muscles and nerves, including the motor unit and its relationship to recruitment and the events that occur at the neuromuscular junction.
6. Discuss the force of muscle contraction, including:
  - Define *twitch* and *tetanus*.
  - Identify the sources of energy for muscle contraction.
  - Trace the sequence of events from nerve stimulation to muscle contraction.
7. Define muscle terms and state the basis for naming muscles.
8. Identify and list the actions of the major muscles.

The word *muscle* comes from the Latin word *mus*, meaning “little mouse.” As muscles contract, the muscle movements under the skin resemble the movement of mice scurrying around—thus the name *mus*, or *muscle*. Muscle tissue makes up 40% to 50% of body weight.



## TYPES AND FUNCTIONS OF MUSCLES

The three types of muscles are skeletal, smooth, and cardiac (Figure 9-1). Smooth muscle is discussed throughout the book and cardiac muscle in Chapters 16 and 17. In this chapter, the focus is on skeletal muscle.

### SKELETAL MUSCLE

**Skeletal muscle** is generally attached to bone. Because skeletal muscle can be controlled by choice (I choose

to move my arm), it is also called *voluntary muscle*. The skeletal muscle cells are long, shaped like cylinders or tubes, and composed of proteins arranged to make the muscle appear striped, or striated (STRYE-ay-ted). Skeletal muscles produce movement, maintain body posture, and stabilize joints. They also produce considerable heat and therefore help maintain body temperature. If damaged, skeletal muscle has a limited capacity for regeneration.

### SMOOTH MUSCLE

**Smooth muscle** is generally found in the walls of the viscera, such as the stomach, and is called *visceral muscle*. It is also found in tubes and passageways such as the bronchioles (breathing passages) and blood vessels. Because smooth muscle functions automatically, it is called *involuntary muscle*. Unlike skeletal muscles, smooth muscle does not appear striped, or striated, and is therefore called *nonstriated muscle*.

Smooth muscle contraction has two unique characteristics in comparison with skeletal muscle contraction. First, smooth muscle contraction is slower and continues for a longer period. This characteristic allows

**5. According to Figures 8-13 and 8-14**

- a. The clavicle articulates with the scapula at the coracoid process.
- b. The pectoral girdle refers to the humerus, clavicle, and scapula.
- c. The costal angle is formed by the true ribs.
- d. The second rib is at the level of the sternomanubrial joint.

**6. According to Figure 8-15**

- a. The symphysis pubis is cartilage that lines the acetabulum.
- b. The symphysis pubis stretches across both obturator foramen.
- c. The sacrum does not articulate with the coxal bone.
- d. The acetabulum is formed by all three parts of the coxal bone.

**7. According to Figures 8-16 and 8-17**

- a. The patella articulates with the distal femur, proximal tibia, and lateral malleolus.
- b. The lateral malleolus is located on the distal tibia.
- c. The calcaneus articulates with the proximal fibula.
- d. The talus articulates with the distal tibia and fibula.

**8. According to Figures 8-19 and 8-20**

- a. The humeroulnar joint is a hinge joint that is known as the elbow.
- b. The glenohumeral joint is formed by the scapula and the clavicle.
- c. Both the proximal and distal tibiofibular joints are ball-and-socket joints.
- d. All of the above are true.

**9. According to Figures 8-19 and 8-21**

- a. Movement at the tibiofemoral joint is called *abduction* and *adduction*.
- b. Movement at the hip joint allows for adduction and abduction of the thigh; it also allows for flexion, extension, and hyperextension of the thigh.
- c. Plantar flexion and dorsiflexion occurs at the glenohumeral joint.
- d. All of the above are true.

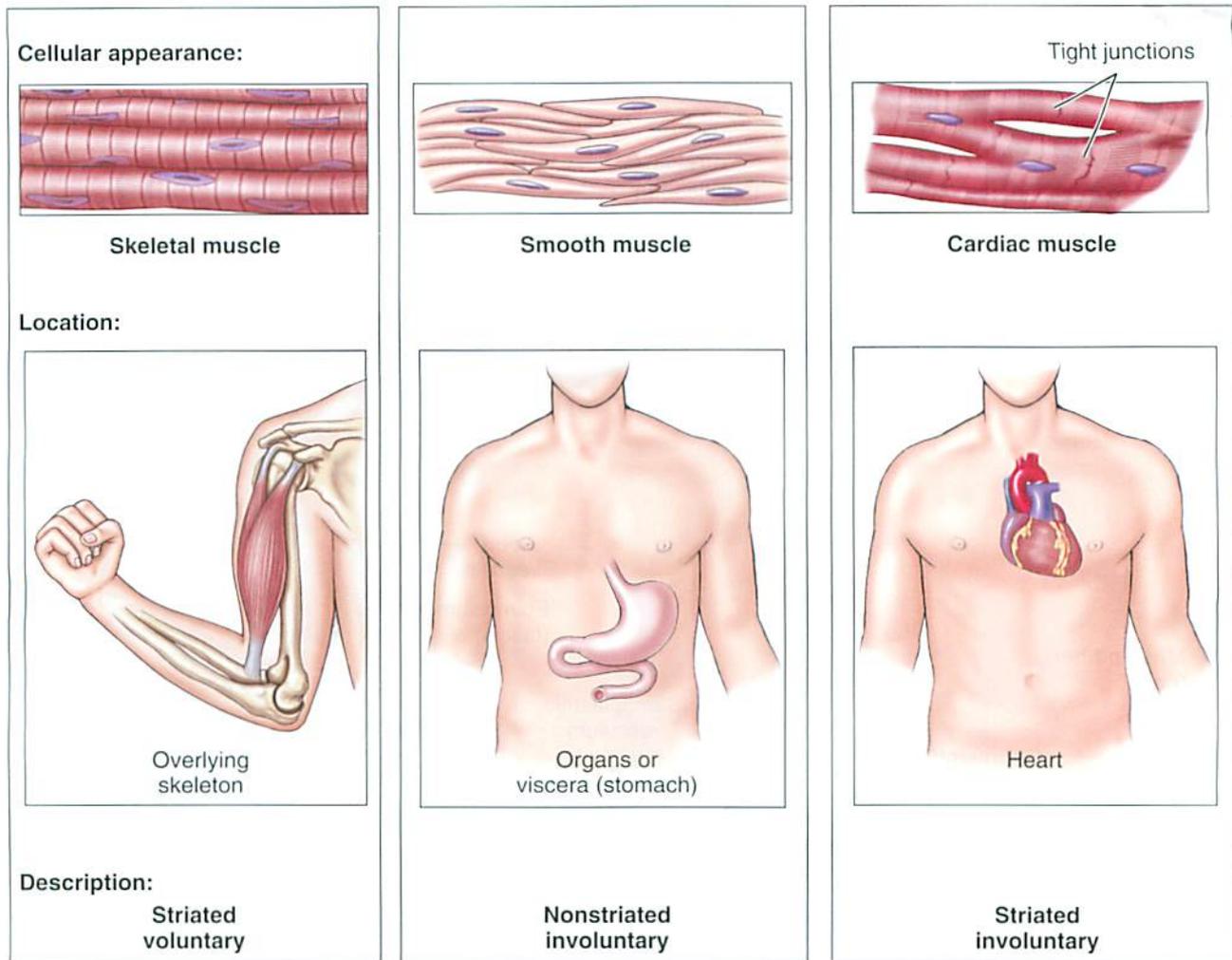


FIGURE 9-1 Three types of muscle: skeletal, smooth, and cardiac.

for a continuous partial contraction of the smooth muscle, called *smooth muscle tone*. Smooth muscle tone plays an important role physiologically. For example, the muscle tone of the smooth muscle in blood vessels helps maintain blood pressure. If the muscle tone were to decrease, the person might experience a life-threatening decline in blood pressure. In addition to its contractile ability, smooth muscle has a greater degree of stretchiness as compared with skeletal muscle. This allows the walls of organs such as the uterus, urinary bladder, and stomach to expand to store their contents temporarily. Contraction of the smooth muscle of the organ then expels its content. For example, the urinary bladder expands to store urine. When the bladder fills, the smooth muscle of the urinary bladder contracts, thereby expelling the urine. Similarly, contraction of the smooth muscles of the stomach mixes solid food into a paste and then pushes it forward into the intestine. If injured, smooth muscle has a better capacity for regeneration than does skeletal muscle.

## CARDIAC MUSCLE

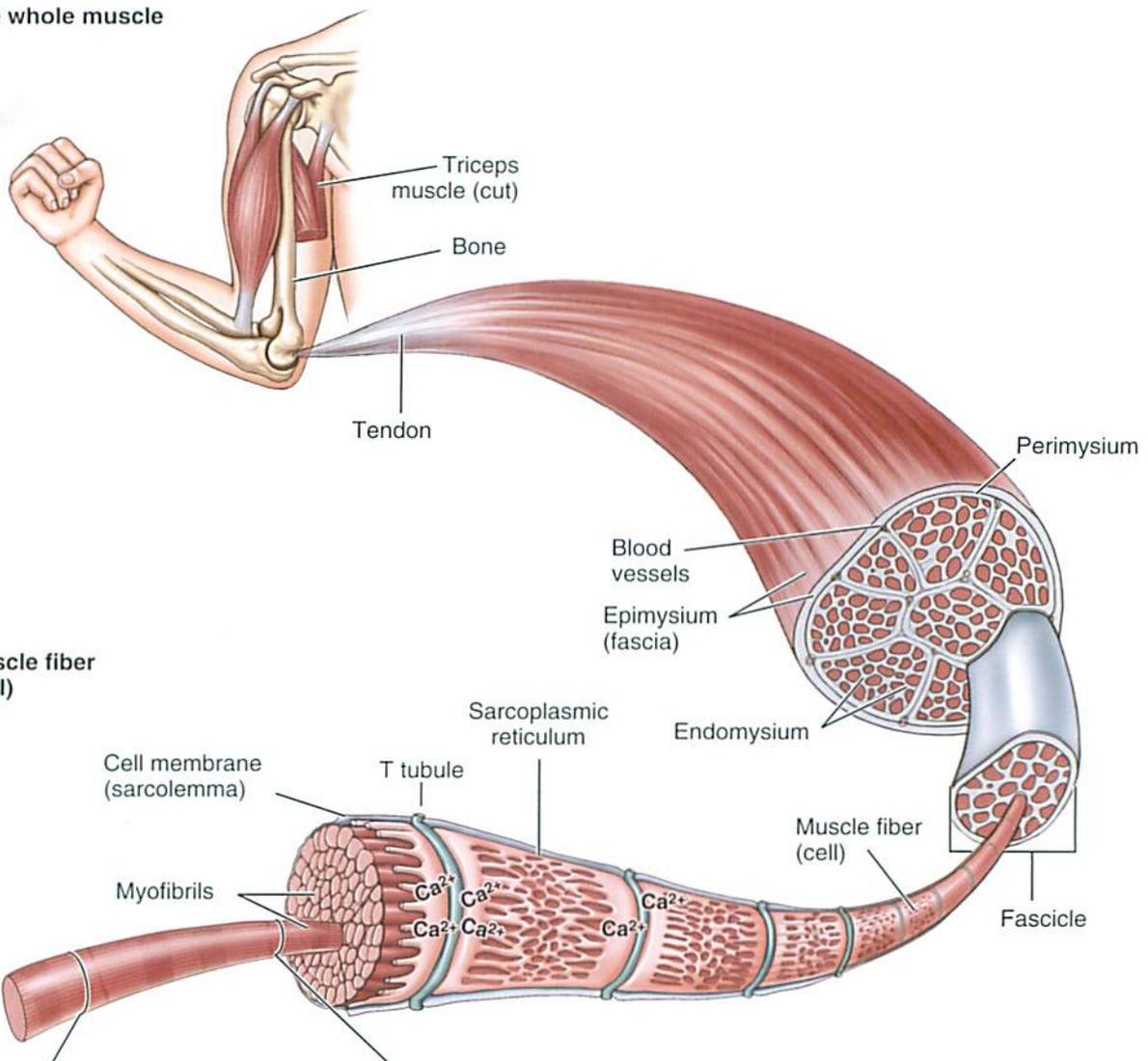
**Cardiac muscle** is found only in the heart, where it functions to pump blood throughout the body. Cardiac muscle cells are long branching cells that fit together tightly at junctions called *intercalated discs*. These tight-fitting junctions promote rapid conduction of electrical signals throughout the heart. Cardiac muscle is classified as striated and involuntary muscle. If damaged, as in a heart attack, cardiac muscle has no capacity for regeneration.

## STRUCTURE OF THE WHOLE MUSCLE

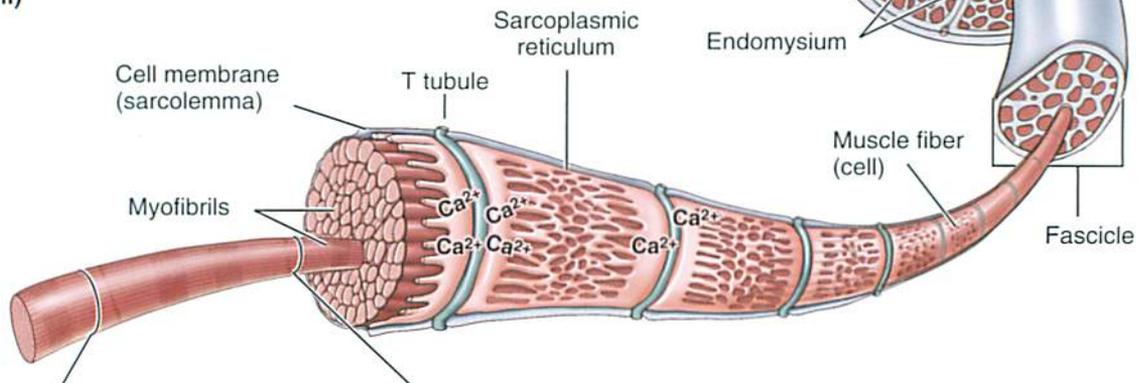
### MUSCLE

If you touch your anterior thigh, you will feel a large muscle. What you are actually feeling are thousands of elongated muscle fibers (cells) packaged together by various layers of connective tissue. The **belly** refers to the enlarged fleshy body of the muscle between the slender points of attachment.

## A The whole muscle



## B Muscle fiber (cell)



## C Sarcomere

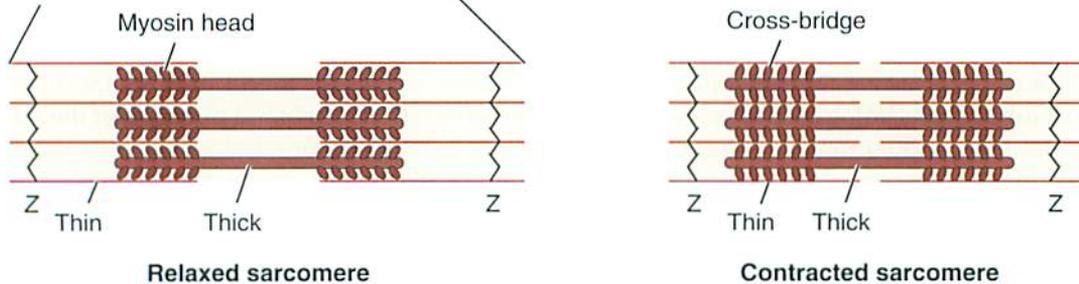


FIGURE 9-2 Muscle structure. **A**, Structure of a whole muscle attached to the bone by a tendon. **B**, Structure of a muscle fiber (muscle cell). **C**, Sarcomeres, relaxed and contracted.

### LAYERS OF CONNECTIVE TISSUE

A large skeletal muscle is surrounded by layers of tough connective tissue called **fascia** (FASH-uh) (Figure 9-2, *A*). This outer layer of fascia is called the *epimysium*. Another layer of connective tissue, called the *perimysium*, surrounds smaller bundles of muscle fibers. The bundles of muscle fibers are called *fascicles* (FAS-i-kuls). Individual muscle fibers are found within

the fascicles and are surrounded by a third layer of connective tissue called the *endomysium*. The epimysium, perimysium, and endomysium extend toward and attach to the bone as a tendon, a long cordlike structure.

In the limbs, the extensive amount of fascia separates the muscles into isolated compartments. Each muscle compartment also receives blood vessels and nerves necessary for muscle function. With a severe

crush injury, the muscle is damaged; it becomes inflamed and leaks fluid into the compartment. Pressure within the compartment increases and compresses the nerves and blood vessels. Deprived of its oxygen and nourishment, the muscle and nerves begin to die—condition called *compartment* or *crush syndrome*. Immediate treatment involves reduction of the compartment pressure by surgically slicing the fascia lengthwise. Failure to restore blood flow to the muscle results in permanent muscle and nerve damage.

## MUSCLE ATTACHMENTS

Muscles form attachments to other structures in three ways: (1) the tendon attaches the muscle to the bone, (2) muscles attach directly (without a tendon) to a bone or to soft tissue, and (3) a flat sheetlike fascia called **aponeurosis** (ap-oh-nyoo-ROH-sis) connects muscle to muscle or muscle to bone.

### ? Re-Think

1. List the three types of muscles.
2. With regard to muscle types, what is meant by striated/nonstriated and voluntary/involuntary?
3. How does the connective tissue of muscle relate to the development of compartment syndrome?

## STRUCTURE AND FUNCTION OF A SINGLE MUSCLE FIBER

The muscle cell is an elongated muscle fiber (see Figure 9-2, B). The muscle fiber has more than one nucleus and is surrounded by a cell membrane called a *sarcolemma*. At several points, the cell membrane penetrates deep into the interior of the muscle fiber, forming transverse tubules (T tubules). Within the muscle fiber is a specialized endoplasmic reticulum called the **sarcoplasmic reticulum (SR)**.

Each muscle fiber is composed of long cylindrical structures called *myofibrils* (my-oh-FYE-brils). Each myofibril is made up of a series of contractile units called **sarcomeres** (SAR-koh-meers) (see Figure 9-2, C). Each sarcomere extends from Z line to Z line and is formed by a unique arrangement of contractile proteins, referred to as thin and thick filaments. The thin filaments extend toward the center of the sarcomere from the Z lines. The thin filament is composed of two proteins called **actin** and the *troponin-tropomyosin* (troh-POH-nin-troh-poh-MY-oh-sin) *complex*. The actin contains binding sites for the **myosin**. The thicker myosin filaments sit between the thin filaments. Extending from the thick myosin filaments are structures called *myosin heads*. The arrangement of the thin and thick filaments in each sarcomere gives skeletal and cardiac muscle their striated appearances.

### Do You Know...

#### Why Beef Is Red and Chicken Meat is White?

Certain muscle fibers contain a reddish-brown protein called *myoglobin*. The myoglobin stores oxygen in the muscle and gradually releases it when the muscle starts to work. Fibers that contain myoglobin are red because of the iron pigment. This is the red meat of a steak. Fibers that do not contain myoglobin are white, as in the meat of chicken.

## HOW MUSCLES CONTRACT

### SLIDING FILAMENT MECHANISM

Muscles can only pull, not push! To pull, muscles contract. When muscles contract, they shorten. Muscles shorten because the sarcomeres shorten, and the sarcomeres shorten because the thin and thick filaments slide past each other. Note how much shorter the contracted sarcomere appears compared with the relaxed sarcomere (see Figure 9-2, C). The following statements explain how the sarcomere shortens.

- When the contractile apparatus is stimulated, the myosin heads make contact with special sites on the actin, forming temporary connections called *cross-bridges*.
- Once the cross-bridges are formed, the myosin heads rotate, pulling the actin toward the center of the sarcomere. The rotation of the myosin heads causes the thin filaments to slide past the thick filaments. (The sarcomere shortens.)
- Muscle relaxation occurs when the cross-bridges are broken and the thin and thick filaments return to their original positions. (The sarcomere lengthens.)

Because of this sliding activity of the thin and thick filaments, muscle contraction is called the sliding filament mechanism of muscle contraction. *Repeat:* The sarcomeres shorten not because the thin and thick filaments shrink or shrivel up, but because they slide past one another. The sliding is like a trombone. The trombone shortens because the parts slide past one another, not because the metal shrinks. The thin and thick filaments do the same thing—they slide.



## THE ROLE OF CALCIUM AND ADENOSINE TRIPHOSPHATE

Adenosine triphosphate (ATP) and calcium play important roles in the contraction and relaxation of muscle. The ATP helps the myosin heads form and

## Ramp It Up!

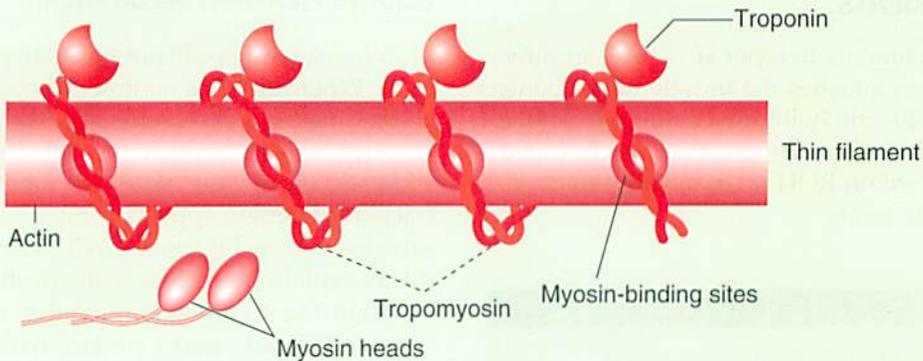
### The Troponin-Tropomyosin Complex and Calcium

Muscle contraction occurs when the myosin heads bind to actin, thereby causing the thin and thick filaments to slide past one another. The sliding occurs only in the presence of calcium. What role does calcium play in muscle contraction and relaxation?

Panel A illustrates the components of the thin filament in the relaxed state. The thin filament is composed of two

proteins: actin and the troponin-tropomyosin complex. (The cup-shaped troponin sits on the tropomyosin.) The actin protein contains sites to which myosin heads bind. In the relaxed state the myosin-binding sites on actin are blocked by the troponin-tropomyosin complex. Thus, cross-bridge formation and muscle contraction cannot occur.

Panel A: Thin Filament

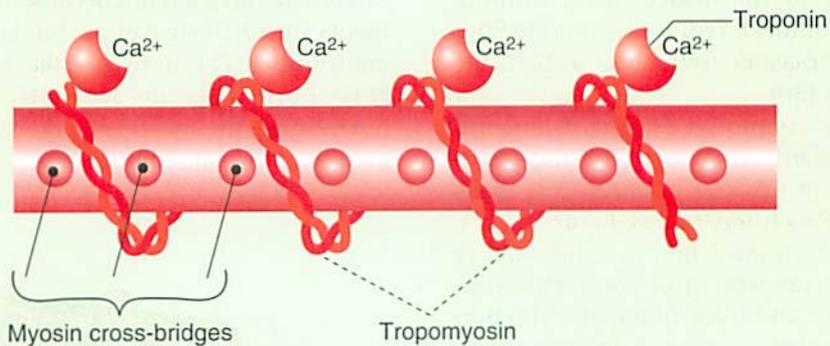


Panel B illustrates the effects of calcium. When the calcium is released from the sarcoplasmic reticulum, it floods the troponin sites. The activation of the troponin with calcium causes the tropomyosin to move, thereby exposing the myosin-binding sites on actin. The myosin heads can now bind to the actin, forming cross-bridges. The swiveling of the cross-bridges causes the sliding movements of the thin and thick filaments and muscle contraction. What causes the muscle to relax? Calcium is pumped back into the SR away from the troponin.

The troponin-tropomyosin complex then moves back to its original position (panel A) where it blocks the myosin-binding sites on actin. Thus, the removal of calcium causes muscle relaxation.

An interesting clinical point! When muscle tissue (skeletal and cardiac) is injured, the contents of the muscle cell leak into the blood. Thus, following a heart attack, enzymes such as creatine phosphokinase and troponin elevate in the blood and act as biological markers in the diagnosis of a heart attack.

Panel B: Effect of Calcium



break cross-bridges with the actin. The ATP, however, can perform its role only if calcium is present. When the muscle is relaxed, the calcium is stored in the sarcoplasmic reticulum (SR), away from the thin and thick filaments. When the muscle is stimulated, calcium is released from the SR and causes the actin, myosin, and ATP to interact and slide. Muscle contraction then occurs. When calcium is pumped back into the SR, away from the actin, myosin, and ATP, the cross-bridges are broken and the muscle relaxes. (See “Ramp It Up: The Troponin-Tropomyosin Complex and Calcium” for further details of calcium and the thin filament.)

### Re-Think

Why is calcium necessary for muscle contraction? (Use the words *actin*, *myosin*, *cross-bridges*, and *sliding filaments*.)

### Sum It Up!

The three types of muscle are skeletal, smooth, and cardiac. A whole muscle is composed of many muscle fibers (muscle cells) arranged in bundles. Each muscle fiber contains actin-containing thin filaments and myosin-containing thick filaments, arranged into a series of sarcomeres. In accordance with the sliding filament mechanism, the sliding interaction of the actin and the myosin heads causes muscle contraction.

## SKELETAL MUSCLES AND NERVES

### SOMATIC MOTOR NEURON

Skeletal muscle contraction can take place only when the muscle is first stimulated by a nerve. The type of nerve that supplies the skeletal muscle is a somatic motor nerve (Figure 9-3, A). A motor nerve, composed of many nerve cells called *motor neurons*, emerges from the spinal cord and travels to the skeletal muscle. The interaction of the motor neuron and the muscle is described in terms of the motor unit and neuromuscular junction.

### Do You Know...

#### What the “Stiffness of Death” Is?

Both the formation of cross-bridges (muscle contraction) and the detachment of cross-bridges (muscle relaxation) depend on ATP. When a person dies, calcium leaks out of the SR, causing the muscles to contract. In addition, the production of ATP ceases. The deficiency of ATP prevents the detachment of the cross-bridges, so muscles remain contracted and become stiff. This change is called *rigor mortis*, or “stiffness of death.” An assessment of rigor mortis often helps determine the exact time of death. For example, rigor begins 2 hours after death, peaks in 12 hours, and subsides in 36 hours. By assessing the degree of rigor, one can therefore determine the time of death. This fact has been used successfully in murder mysteries. By altering the environmental temperature, the murderer can alter the time course of rigor mortis and therefore make it difficult to determine the time of death.

## THE MOTOR UNIT

As a motor neuron approaches the skeletal muscle, it forms many branches. Each branch innervates a single muscle fiber. The **motor unit** (see Figure 9-3, A) consists of a single motor neuron and the muscle fibers that are supplied by the motor neuron. Each muscle is innervated by many motor neurons, thereby forming many motor units. The strength of muscle contraction can vary, depending on the number of motor units that are stimulated. A stronger force of muscle contraction develops if many motor units are stimulated at the same time; a weaker force of muscle contraction develops when fewer motor units are stimulated. The consequences of activation of additional motor units is called **recruitment** and is discussed later.

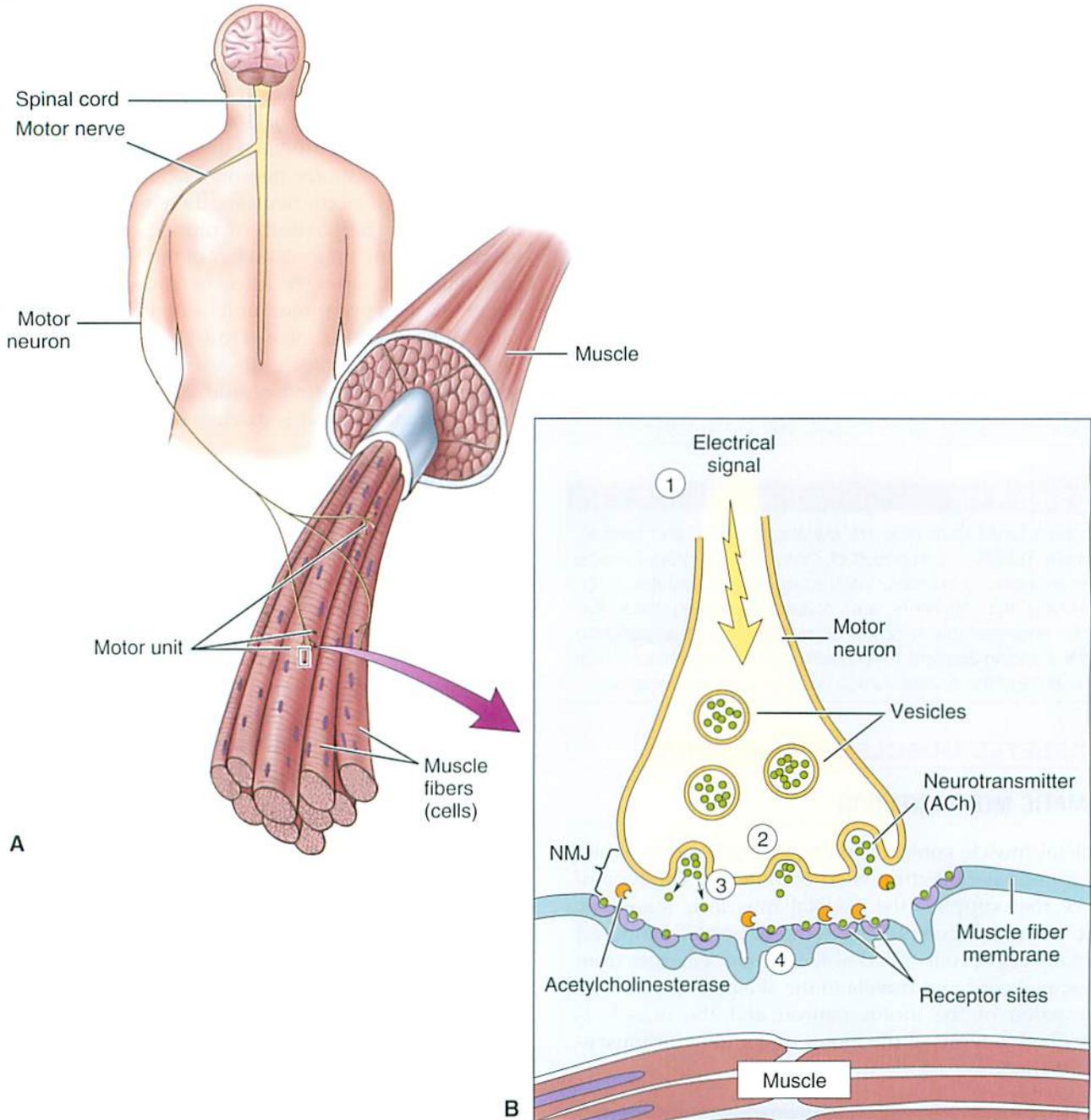
## THE NEUROMUSCULAR JUNCTION

The area where the motor neuron meets the muscle is called the **neuromuscular junction (NMJ)**. The NMJ includes the membrane at the end of the neuron, the space between the neuron and the muscle, and the receptors on the muscle membrane. What happens at the NMJ? The stimulated neuron causes the release of a chemical substance that diffuses across the NMJ and stimulates the muscle membrane. Four steps are involved in the transfer of the information from neuron to muscle at the NMJ (see Figure 9-3, B).

- Step 1. Stimulation of the neuron causes an electrical signal, or nerve impulse, to move along the neuron toward the ending of the neuron. Stored within its ending are vesicles, or membranous pouches, filled with a chemical substance called a *neurotransmitter*. The neurotransmitter at the NMJ is **acetylcholine** (ass-ee-til-KOH-leen) (**ACh**).
- Step 2. The nerve impulse causes the vesicles to move toward and fuse with the membrane at the end of the neuron. ACh is released from the vesicles into the space between the neuron and the muscle membrane.
- Step 3. ACh diffuses across the space and binds to the receptor sites on the muscle membrane.
- Step 4. The ACh stimulates the receptors and causes an electrical signal to develop along the muscle membrane. The ACh then unbinds the receptor site and is immediately destroyed by an enzyme that is found within the NMJ, near the muscle membrane. The name of the enzyme is *acetylcholinesterase* (ass-ee-til-koh-lin-ES-ter-ase) or *cholinesterase*. The free binding sites are then ready for additional ACh when the neuron is stimulated again.

## THE STIMULATED MUSCLE MEMBRANE

What happens to the electrical signal that forms in the muscle membrane? It travels along the muscle membrane and triggers a series of events that result



**FIGURE 9-3** Innervation of a skeletal muscle. **A**, Motor unit. **B**, The four steps in the transmission of the signal at the neuromuscular junction (NMJ).

in muscle contraction (see Figure 9-2, *B* and *C*). Specifically, the electrical signal travels along the muscle cell membrane and penetrates into its interior through the T tubules. The electrical signal stimulates the SR to release calcium. The calcium floods the sarcomeres, thereby causing the thin and thick filaments to slide past one another, producing muscle contraction. Eventually, the calcium is pumped back into the SR, causing muscle relaxation.

### DISORDERS OF THE NEUROMUSCULAR JUNCTION

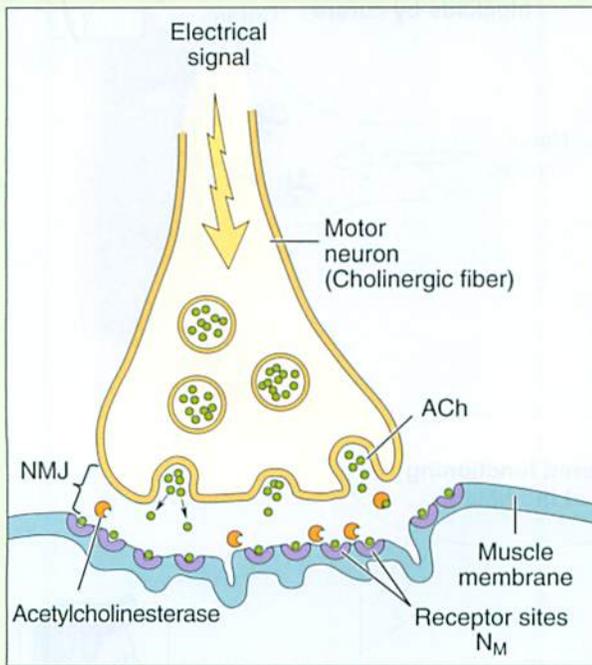
Certain conditions affect events at the NMJ (Figure 9-4).

#### Myasthenia Gravis

Myasthenia gravis is a disease that affects the NMJ. The symptoms of the disease are caused by damaged receptor sites ( $N_M$  receptors) on the muscle membrane. The receptor sites are altered so that they cannot effectively bind ACh. Consequently, muscle contraction is impaired, and the person experiences extreme muscle weakness. (The word *myasthenia* means muscle weakness.) The muscle weakness first becomes noticeable as low tolerance to exercise. As the disease progresses, the person experiences difficulty in breathing because the breathing muscles are skeletal muscles.

## Ramp It Up!

### The Muscle Receptors ( $N_M$ ) at the Neuromuscular Junction



Follow the sequence of events within the neuromuscular junction (NMJ) as they are described. A nerve impulse travels along a somatic motor neuron causing the release of acetylcholine (ACh). The ACh diffuses across the NMJ and binds to the muscle membrane receptors. The receptor on the muscle membrane is a cholinergic receptor; it is called a *nicotinic receptor*. Because it is located on the muscle membrane, it is called a *nicotinic muscle ( $N_M$ ) receptor*. Activation of the  $N_M$  receptor causes a series of events that result in muscle contraction. A great deal of pharmacology involves the  $N_M$  receptor. For example, curare is a skeletal muscle blocker because it blocks the  $N_M$  receptors. Receptor blockade, in turn, prevents skeletal muscle contraction. What about a drug that activates the  $N_M$  receptor? It stimulates muscle contraction. For example, neostigmine (Prostigmin) is a drug that inactivates acetylcholinesterase (the enzyme that destroys ACh), thereby increasing the amount of ACh that can bind to the  $N_M$  receptors. (Because this drug inactivates acetylcholinesterase, it is called an *anticholinesterase agent*.) You can now understand why anticholinesterase agents improve the symptoms of myasthenia gravis and reverse postoperative sluggish intestinal activity. (Other nicotinic receptors are described in Chapter 12.)

### Neuromuscular Blockade Caused by Curare

Curare is a drug classified as a skeletal muscle blocker. Skeletal muscle blockers are often used during surgery to promote muscle relaxation and paralysis. Curare works by blocking the receptor sites on the muscle membrane. Because the receptors are occupied by the drug, the ACh cannot bind with the receptor sites, and muscle contraction is prevented.

Because the respiratory muscles are also affected by curare, the patient must be mechanically ventilated until the effects of the drug disappear. Otherwise, the patient stops breathing and dies. Historically, curare was used as a paralyzing drug when hunting animals. The tip of an arrowhead was dipped in curare. When the arrow pierced the skin of the animal, the curare was absorbed and eventually caused skeletal muscle blockade and paralysis. Succinylcholine (Anectine) also blocks  $N_M$  receptors and is used to induce muscle paralysis for short-term critical care situations such as intubation.

### Effects of Neurotoxins on Muscle Function

Neurotoxins are chemical substances that in some way disrupt normal function of the nervous system. Neurotoxins are produced by certain bacteria. For example, *Clostridium tetani* (a bacterium) secretes a neurotoxin that causes excessive firing of the motor nerves. This, in turn, causes excessive release of ACh, overstimulation of the muscle membrane, and severe muscle spasm and tetanic contractions—hence the

name *tetanus*. Because the muscles of the jaw are the first muscles affected, the disease is often called *lockjaw*.

A second neurotoxin is secreted by the bacterium *Clostridium botulinum*. This bacterium appears most often when food has been improperly processed and canned. Infection with this organism causes botulism, a very serious form of food poisoning. The neurotoxin works by preventing the release of ACh from the ends of the neurons within the NMJ. Without ACh, the muscle fibers cannot contract, and the muscles, including the breathing muscles, become paralyzed. On a more positive note, the injection of small amounts of this “poison” (Botox) has been used successfully to treat severe muscle spasm (torticollis, cerebral palsy) and migraine headaches, as well as, for cosmetic reasons, to erase muscle-induced wrinkles.

Note that muscle paralysis can occur if there is an excess or a deficiency of ACh activity. An excess of ACh causes spastic paralysis, a state of continuous muscle contraction. A deficiency of ACh activity causes flaccid paralysis, a state in which the muscles are limp and unable to contract.

### ? Re-Think

1. Explain how the signal is passed from the nerve to the muscle at the NMJ.
2. Explain the effects of curare at the NMJ.

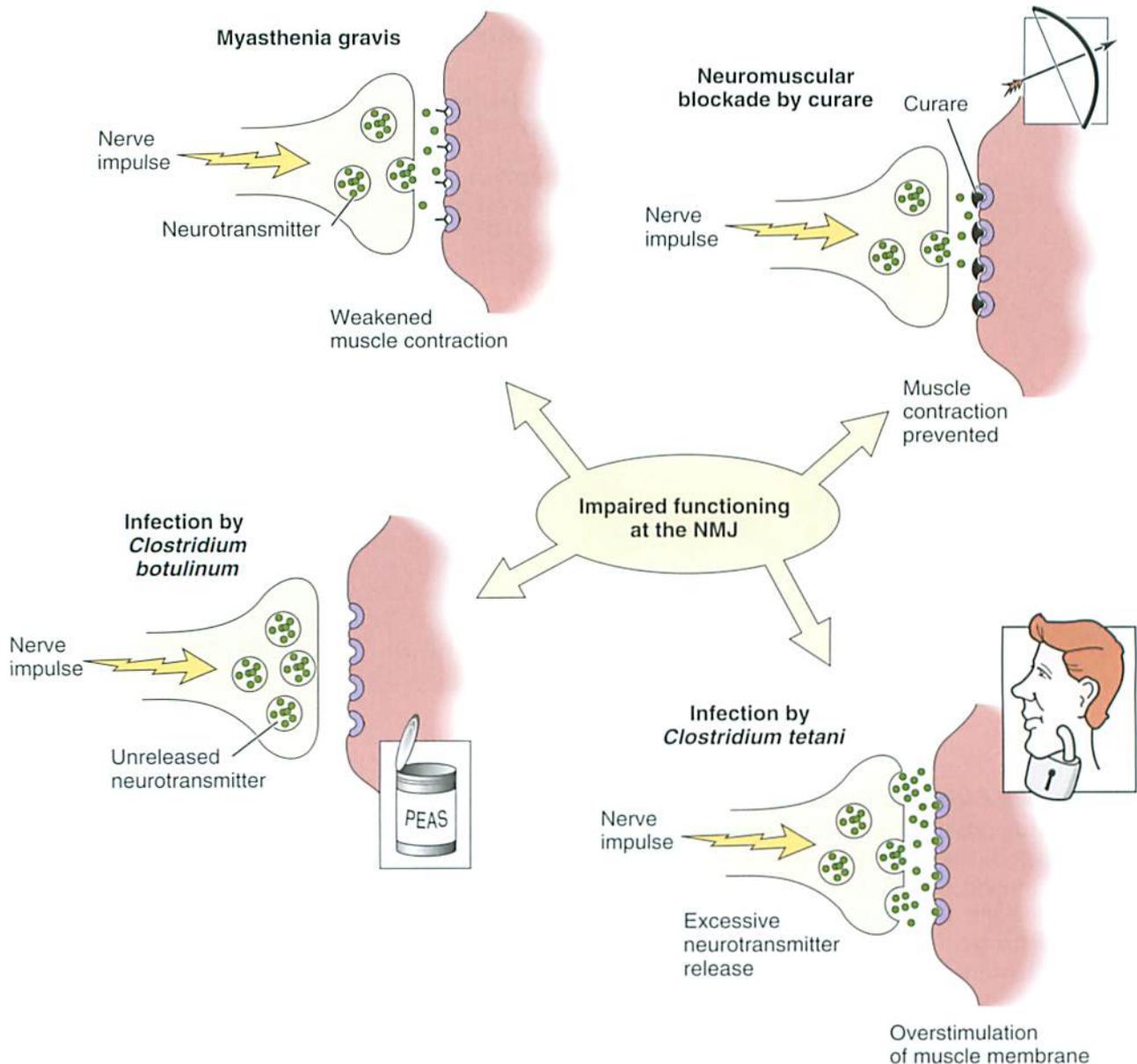


FIGURE 9-4 Impaired functioning at the neuromuscular junction (NMJ).

### Do You Know...

#### What the Difference Is between Isometric Contraction and Isotonic Contraction?

An isotonic muscle contraction is a muscle contraction that causes movement, as in lifting a 20-lb object. An isometric muscle contraction is a muscle contraction that does not cause movement. For example, if you try to lift a 1000-lb object, your muscles contract but do not move the object (it is too heavy).

As you sit reading this text, you can do isometric exercises. Tighten the muscle in your thigh. Hold the tension for 30 seconds and then relax the muscle. Repetition of this type of exercise can provide you with a mini-workout without leaving your desk.

### FORCE OF MUSCLE CONTRACTION

The sliding filament mechanism explains the contraction and relaxation of a single muscle fiber. A whole skeletal muscle, such as a large thigh muscle, is composed of thousands of muscle fibers. The contractile response of a whole muscle is much greater than that of a single muscle fiber. How does that happen?

### CONTRACTILE FORCE OF A SINGLE MUSCLE FIBER

If a single electrical stimulus is delivered to a muscle fiber, the fiber contracts and then fully relaxes. This single muscle response is called a **twitch**. Twitches are not useful physiologically. However, if the muscle fiber

is stimulated repeatedly, the muscle responds in two ways. First, repetitive stimulation increases the contractile force of the muscle fiber. Repetitive stimulation prolongs the presence of calcium within the sarcomere. Second, the muscle fiber has no time to relax and therefore remains contracted. Sustained muscle contraction is called **tetanus**. Thus, contractile force in the single muscle fiber develops in response to increasing the frequency of electrical stimulation.

### MORE ABOUT TETANUS

In addition to increasing contractile force of a muscle, tetanus performs another important role; tetanic muscle contraction maintains posture. If the muscles that maintain our upright posture merely twitched, we would be unable to stand and would instead twitch and flop around on the ground (not a pretty sight). Because the muscle is able to tetanize, we are able to maintain an upright posture. (Do not confuse the “tetanus” described in this section with the disease called tetanus, or lockjaw.)

### CONTRACTILE FORCE OF A WHOLE MUSCLE

A whole muscle increases its contractile force primarily by recruitment (see Figure 9-3). Recruitment of additional motor units increases contractile force because more muscle fibers are contracting. For example, the muscles in the arm contract when they lift a pencil; they contract more forcefully when lifting a 100-lb weight. Contraction and relaxation of the whole muscle is summarized in Figure 9-5.

### MUSCLE TONE

Muscle tone, or **tonus**, refers to a normal continuous state of partial muscle contraction. Tone is caused by the contraction of different groups of muscle fibers within a whole muscle. To maintain muscle tone, one group of muscle fibers contracts first. As these fibers begin to relax, a second group contracts. This pattern of contraction and relaxation continues to maintain muscle tone. Muscle tone plays a number of important roles. For example, the tone of the skeletal muscles in the back of the neck prevents the head from falling forward.

### Re-Think

Why can a whole muscle develop a greater force of contraction than a single muscle fiber?

### ENERGY SOURCE FOR MUSCLE CONTRACTION

Muscle contraction requires a rich supply of energy (ATP). As ATP is consumed by the contracting muscle, it is replaced in three ways:

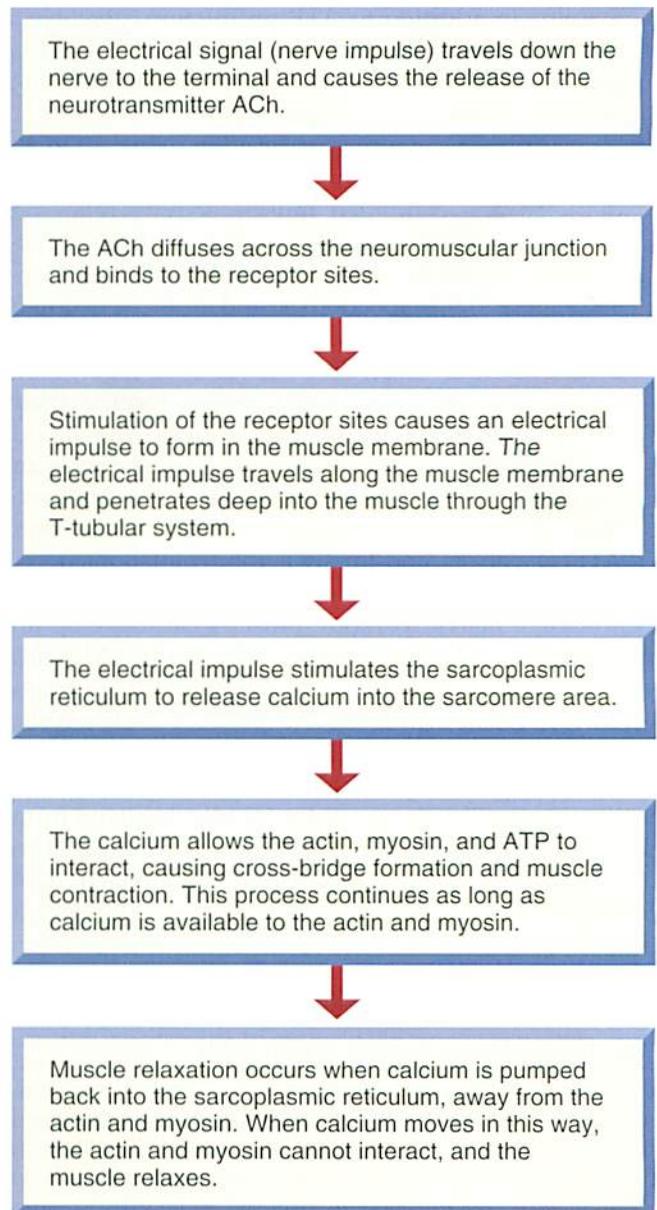


FIGURE 9-5 Steps in the contraction and relaxation of skeletal muscle.

1. *Metabolism of creatine phosphate.* The resting muscle produces excess ATP and uses some of it to make creatine (KREE-ah-tin) phosphate. Creatine phosphate is a storage form of energy that can be used to replenish ATP quickly during muscle contraction. For example, a brief 15-second burst of intense muscle activity is sustained by ATP and creatine phosphate. When creatine phosphate supplies are depleted (15 seconds), the muscle switches to glycolysis for its supply of ATP.
2. *Glycolysis.* Glycolysis is a series of chemical reactions that break down glucose anaerobically (without oxygen), generating small amounts of ATP. The glucose is obtained from two sources: blood glucose and the glycogen that is stored in skeletal muscle. Glycolysis provides enough energy (ATP) for an additional 30 to 40 seconds of intense muscle

activity. In addition to ATP production, glycolysis also produces lactic acid. Some of the lactic acid is picked up by the blood and transported to the liver, where it is used to make glucose.

3. *Aerobic (oxygen-requiring) metabolism.* After 30 to 40 seconds, the supply of ATP from glycolysis is depleted and continued muscle activity relies on ATP production by aerobic respiration. In the presence of oxygen, pyruvic acid (formed from glycolysis) enters the mitochondria and is broken down completely to  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , and ATP. Aerobic metabolism generates large amounts of ATP compared with glycolysis. The mitochondria receive their supply of oxygen from two sources: the blood (oxyhemoglobin) and myoglobin. Myoglobin is an oxygen-carrying protein found in the muscle fibers. Note the time sequence—creatine phosphate and ATP, glycolysis, and finally aerobic metabolism.

Why are your muscles sore after a heavy workout?

Following a heavy workout, muscles can develop an immediate and latent soreness. Why is this? Muscles generate ATP aerobically and anaerobically through glycolysis. Lactic acid is the end-product of glycolysis, and its brief accumulation in the muscle tissue is thought to be the cause of the immediate soreness (30 to 60 minutes). The lactic acid is rapidly removed from the muscle and metabolized. The latent soreness (1 to 3 days after the workout) is attributed not to lactic acid but to tears of the connective tissue in the muscles and muscle cell membranes.

### Do You Know...

#### What the Good News Is about Oxygen Debt?

Credit card debt? Bad! Oxygen debt? Good! What's so great about oxygen debt? The payment of an oxygen debt means that you continue to expend energy and burn fat long after you have come off the treadmill and have taken to your couch. In other words, you continue to exercise metabolically while recovering from your workout. When a person exercises strenuously, he or she burns fuel (fat). To do this, the body uses up available oxygen and borrows on the additional stores of oxygen found in the hemoglobin in blood and the myoglobin in muscles. When the person stops exercising, the body requires an increased intake of oxygen to do some additional, exercise-induced metabolic work (to convert lactic acid to glucose), so 30 minutes of exercise is actually more than 30 minutes of exercise.

### MUSCLE FATIGUE

Muscle fatigue occurs if the muscle is not allowed to rest and is defined as the inability of a muscle to contract forcefully following prolonged activity. Muscle fatigue is the result of a number of factors, such as a decrease in the release of calcium from the SR, a depletion of nutrients, oxygen, glycogen, and energy stores, such as creatine phosphate, and a buildup of waste, such as lactic acid.

### ? Re-Think

What are the three ways that muscle obtains its energy for muscle contraction?

### MUSCLE TERMS

#### ORIGIN AND INSERTION

The terms *origin* and *insertion* refer to the sites of muscle attachment. Most muscles cross or span at least one joint. When muscle contracts, one bone remains relatively stationary or immovable. The **origin** of the muscle attaches to the stationary bone, whereas the **insertion** attaches to the more movable bone (Figure 9-6). For example, the origin of the biceps brachii is the scapula and the insertion is on the radius. On contraction of the biceps brachii, the radius (insertion) is pulled toward the scapula (origin). Be sure that you understand origin and insertion because these terms will be used to describe muscle actions.

#### PRIME MOVER, SYNERGIST, AND ANTAGONIST

Although most movement is accomplished through the cooperation of groups of muscles, a single muscle is generally responsible for most of the movement. The “chief muscle” is called the **prime mover**. Assisting the prime mover are “helper muscles” called **synergists** (SIN-er-jists). Synergists are said to work with other muscles. In contrast, **antagonists** are muscles that oppose the action of another muscle. For example, contraction of the biceps brachii pulls the forearm toward the shoulder. The triceps brachii (posterior arm) is the antagonist. It opposes the action of the biceps brachii (see Figure 9-6).

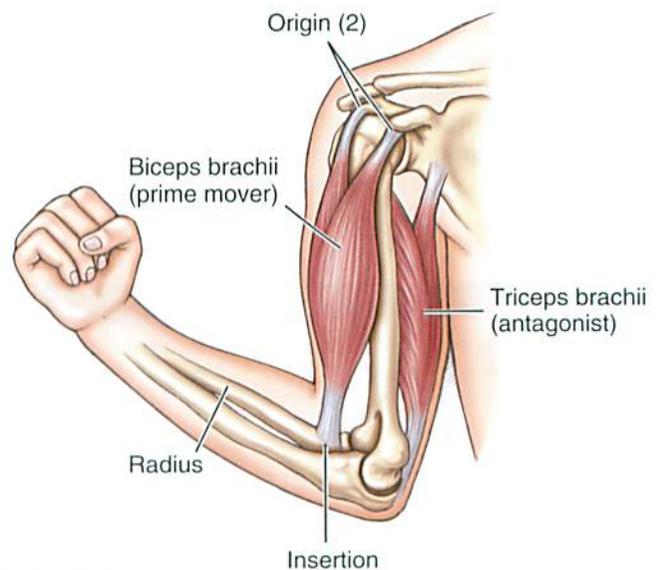


FIGURE 9-6 Origin and insertion: prime mover and antagonist.

## MUSCLE OVERUSE AND UNDERUSE TERMS

### HYPERTROPHY

Overused muscles increase in size. This response to overuse is called *hypertrophy*. Athletes intentionally cause their muscles to hypertrophy. Weight lifters, for example, develop larger muscles than couch potatoes.

Like skeletal muscle, cardiac muscle can also hypertrophy. Cardiac hypertrophy is undesirable and usually indicates an underlying disease, causing the heart to overwork. Hypertension, for example, causes the heart to push blood into blood vessels that are very resistant to the flow of blood. This extra work causes the heart muscle to enlarge.

### ATROPHY

If muscles are not used, they will waste away, or decrease in size. A person with a broken leg in a cast, for example, is unable to exercise that leg for several months. This lack of exercise causes the muscles of the leg to atrophy, which is called *disuse atrophy*. When weight bearing and exercise are resumed, muscle size and strength can be restored. Muscle atrophy can also develop when the nerves to the muscle are severed, which is called *denervation atrophy*. Finally, muscle atrophy is part of the normal aging process; this is called *senile atrophy*. Senile atrophy can be delayed when the aging person carries out a regular exercise routine. Muscle motto: use it or lose it.

### CONTRACTURE

If a muscle is immobilized for a prolonged period, it may develop a contracture, an abnormal formation of fibrous tissue within the muscle. It generally “freezes” the muscle in a flexed position and severely restricts joint mobility.

## HOW SKELETAL MUSCLES ARE NAMED

The names of the various skeletal muscles are generally based on one or more of the following characteristics: size, shape, orientation of the fibers, location, number of origins, identification of origin and insertion, and muscle action.

### SIZE

These terms indicate size: *vastus* (huge), *maximus* (large), *longus* (long), *minimus* (small), and *brevis* (short). Examples of skeletal muscles include the *vastus lateralis* and *gluteus maximus*.

### SHAPE

Various shapes are included in muscle names, such as *deltoid* (triangular), *latissimus* (wide), *trapezius* (trapezoid), *rhomboideus* (rhomboid), and *teres* (round).

Examples include the *trapezius* muscle, *latissimus dorsi*, and *teres major*.

### ORIENTATION OF FIBERS

Fibers are oriented, or lined up, in several directions: *rectus* (straight), *oblique* (diagonal), *transverse* (across), and *circularis* (circular). Examples include the *rectus abdominis* and the *superior oblique*.

### LOCATION

The names of muscles often reflect their location in the body, such as *pectoralis* (chest), *gluteus* (buttock), *brachii* (arm), *supra* (above), *infra* (below), *sub* (underneath), and *lateralis* (lateral). Examples include the *biceps brachii*, *pectoralis major*, and *vastus lateralis*.

### NUMBER OF ORIGINS

A muscle may be named according to the number of sites to which it is anchored: *biceps* (2), *triceps* (3), and *quadriceps* (4). Examples include the *biceps brachii*, *triceps brachii*, and *quadriceps femoris*.

### ORIGIN AND INSERTION

Some muscles are named for sites of attachment both at their origin and insertion. The *sternocleidomastoid*, for example, has its origin on the sternum and clavicle and its insertion on the mastoid process of the temporal bone. This information allows you to determine the function of the muscle. The *sternocleidomastoid* flexes the neck and rotates the head. As noted here, many muscles have multiple points of origin and insertion.

### MUSCLE ACTION

The action of the muscle may be included in the name. For example, an *abductor* muscle moves the limb away from the midline of the body, whereas an *adductor* moves the limb toward the midline. In the same way, a *flexor* muscle causes flexion, whereas an *extensor* muscle straightens the limb. A *levator* muscle elevates a structure, and a *masseter* muscle enables you to chew. Examples include the *adductor magnus*, *flexor digitorum*, and *levator palpebrae superioris*.

### ? Re-Think

What is the basis for the naming of the following muscles: *quadriceps femoris*, *rectus abdominis*, *sternocleidomastoid*, and *vastus lateralis*?

## 2+2 Sum It Up!

A skeletal muscle requires innervation by a somatic motor neuron. The electrical signal of the neuron causes the release of ACh into the NMJ, activation of the  $N_M$  receptors on the muscle membrane, and muscle contraction. A whole muscle contracts more forcefully than a single muscle fiber primarily because of recruitment of additional motor units. There are three energy sources for skeletal muscle contraction: aerobic metabolism, anaerobic metabolism, and metabolism involving creatine phosphate. Muscles are named according to their size, shape, orientation of fibers, location, number of origins, muscle action, and origin and insertion sites.

## MUSCLES FROM HEAD TO TOE

Figure 9-7 shows the major skeletal muscles of the body. Details of muscle location and function are summarized in Table 9-1.

### MUSCLES OF THE HEAD

The muscles of the head are grouped into two categories: the facial muscles and the chewing muscles (Figure 9-8).

#### FACIAL MUSCLES

Many of the facial muscles are inserted directly into the soft tissue of the skin and other muscles of the face. When the facial muscles contract, they pull on the soft tissue. This kind of muscular activity is responsible for our facial expressions like smiling and frowning.

- *Frontalis*. The frontalis (fron-TAL-is) is a flat muscle that covers the frontal bone. It extends from the cranial aponeurosis (origin) and inserts in the skin above the eyebrows. Contraction of the muscle raises the eyebrows, giving you a surprised look. It also wrinkles your forehead.
- *Orbicularis oculi*. The orbicularis (or-bik-yoo-LAR-is) oculi is a sphincter muscle that encircles the eyes. A sphincter (SFINGK-ter) is a ring-shaped muscle that controls the size of an opening. Contraction of the muscle closes the eye and assists in winking, blinking, and squinting.
- *Levator palpebrae superioris*. The levator palpebrae (leh-VAH-tor PAL-peh-bray) superioris muscle has its origin in the bony orbit of the eye and inserts on the upper eyelid. As its name implies, the muscle elevates the eyelid (opens the eye).
- *Orbicularis oris*. The orbicularis oris is a sphincter muscle that encircles the mouth. Contraction of this muscle assists in closing the mouth, forming words, and pursing the lips. It is sometimes called the kissing muscle.
- *Buccinator*. The buccinator (BUK-si-NAY-tor) is a muscle that has its origin on the maxilla and mandible and inserts into the orbicularis oris. The buccinator is used in actions requiring compression of

the cheeks, as in sucking, whistling, and playing the trumpet. The buccinator may also be considered a chewing muscle because, on contraction, it helps position the food between the teeth for chewing. The buccinator is particularly important for an infant because its contraction enables the infant to suck; it therefore plays an important role in the nourishment and comfort of a hungry infant.

- *Zygomaticus*. The zygomaticus (zye-goh-MAT-ik-us) is a smiling muscle; it extends from the corners of the mouth to the cheekbone (zygomatic bone).
- *Platysma*. Want to pout? The platysma (plah-TIZ-mah) is your muscle. It originates in the fascia of the shoulder and anterior chest and inserts on the mandible and tissue of the mouth and lower face. In addition to pouting, it allows you to open your mouth wide, per order of your dentist. Here's another platysmal downer—with aging, there is a loss of muscle tone of the platysma, creating loose skin in the throat area and the dreaded “turkey neck” look.

#### CHEWING MUSCLES

The chewing muscles are also called the muscles of mastication (chewing). All of them are inserted on the mandible, or lower jaw bone, and are considered some of the strongest muscles of the body (see Table 9-1).

- *Masseter*. The masseter (MAS-eh-ter) is a muscle that has its origin on the maxilla and zygomatic process of the temporal bone and its insertion on the mandible. Contraction of this muscle closes the jaw. It acts synergistically with the temporalis muscle to close the jaw.
- *Temporalis*. The temporalis (tem-poh-RAL-is) is a fan-shaped muscle that extends from the flat portion of the temporal bone (origin) to the mandible (insertion).

### ? Re-Think

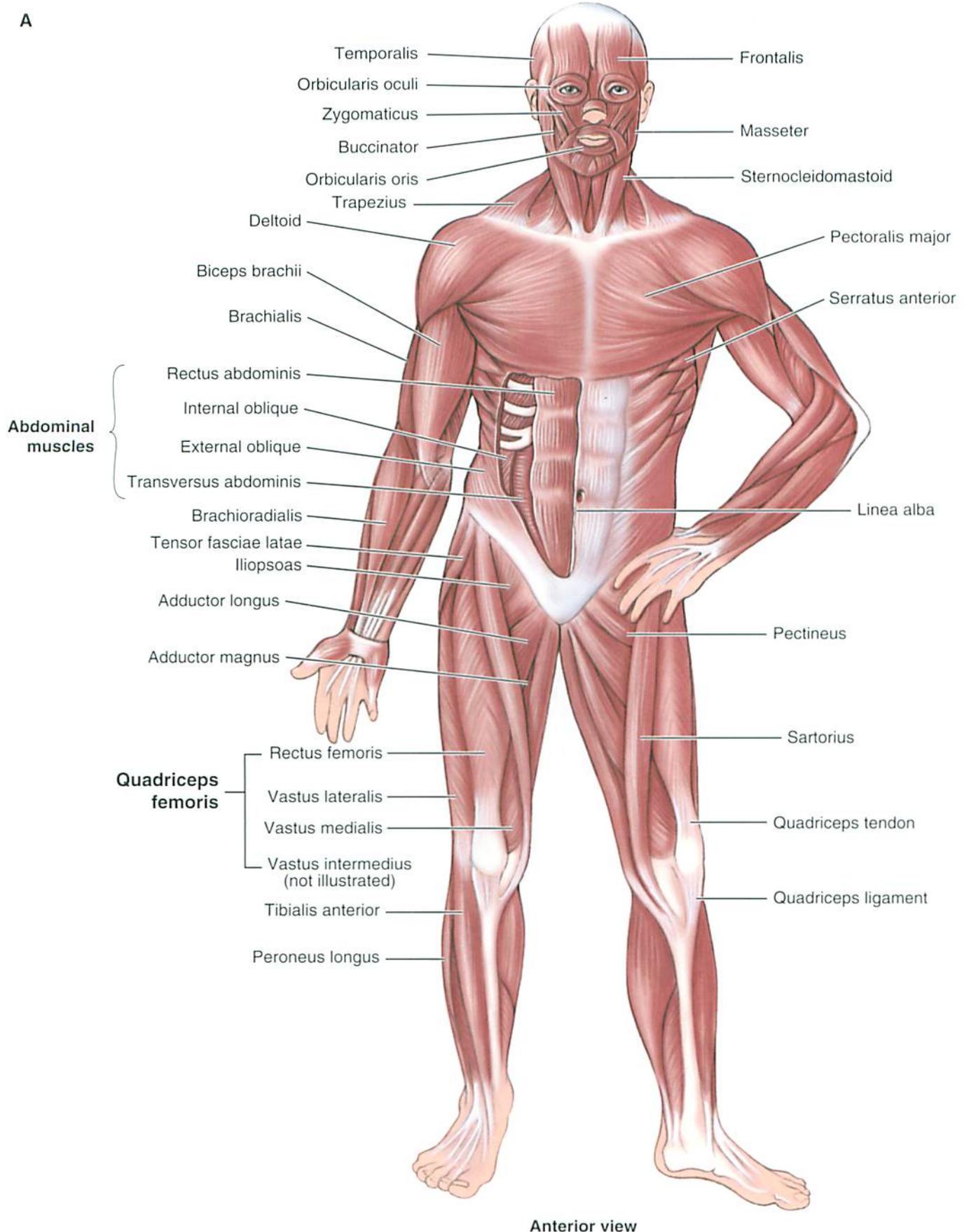
1. Explain why the frontalis muscle can effect facial expression.
2. To which facial bone must the chewing muscles insert?

### Do You Know...

#### About the “Droops and Drools” of Botox?

In the arsenal of anti-aging drugs, Botox is a star. It is the wrinkle-remover par excellence. Beware of Botox blunders, however. Misplaced Botox around the eyelids can cause droopy lids. Similarly, poor aim around the mouth region can cause drooling. Mercifully, the effects of Botox gradually wear off, although there may be many weeks during which you sport the droop-and-drool look. Botched batches of Botox have also caused severe, long-term paralysis.

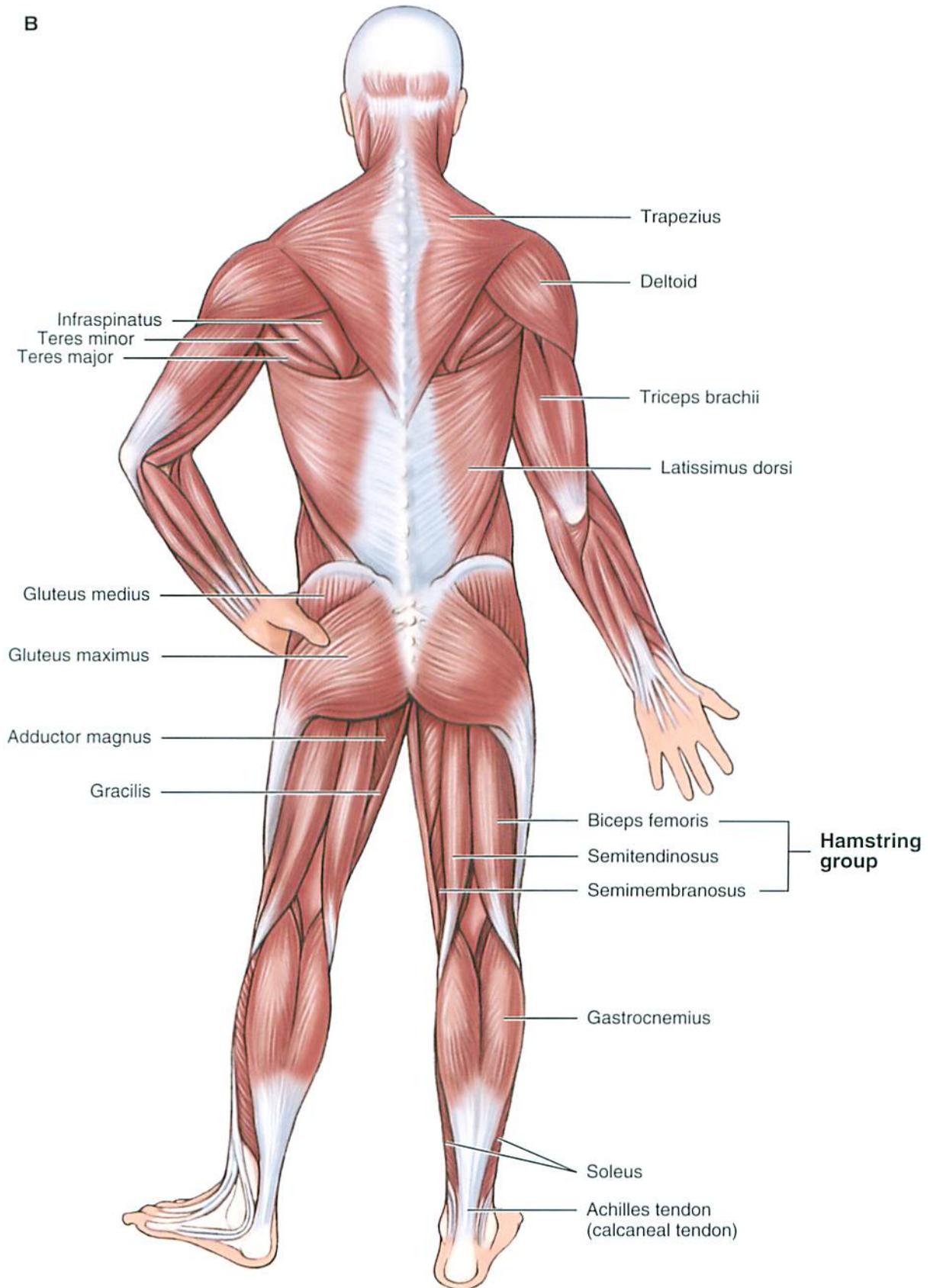
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**FIGURE 9-7** Major muscles of the body. **A**, Anterior view. **B**, Posterior view.

*Continued*

B



Posterior view

FIGURE 9-7, cont'd

**Table 9-1** Muscles of the Body

MUSCLE	LOCATION, DESCRIPTION	FUNCTION
<b>Head</b>		
<b>Muscles of Facial Expression</b>		
Frontalis	Flat muscle covering forehead; origin on cranial aponeurosis; inserts on skin above eyebrows	Raises eyebrows; surprised look; wrinkles forehead
Orbicularis oculi	Circular muscle around eye	Closes eyes; winking, blinking, and squinting
Levator palpebrae superioris	Origin on bony orbit of eye; inserts on upper eyelid	Elevates eyelid (opens eye)
Orbicularis oris	Encircles mouth	Closes, purses lips; kissing muscle
Buccinator	Horizontal cheek muscle; origin on maxilla and mandible; inserts on orbicularis oris	Flattens cheek; trumpeter's muscle; whistling muscle; helps with chewing by positioning food between teeth
Zygomaticus	Origin on cheekbone (zygomatic bone); inserts on corner of mouth	Elevates corner of mouth; smiling muscle
Platysma	Origin in fascia of shoulder and anterior chest; inserts on mandible, angle of lower mouth, soft tissue of lower face	Pouting muscle; "open your mouth wide" muscle
<b>Chewing Muscles</b>		
Temporalis	Flat fan-shaped muscle over temporal bone (origin); inserts on mandible	Closes jaw; retracts jaw
Masseter	Covers lateral part of lower jaw; origin on maxilla, zygomatic process of the temporal bone; inserts on mandible	Closes jaw; retracts jaw
<b>Neck</b>		
Sternocleidomastoid	Extends along each side of neck; strong narrow muscles that extend obliquely from sternum and clavicle (origin) upward to mastoid process of temporal bone (insertion)	Contraction of both muscles flexes the head at the neck; contraction of one rotates head toward opposite side
Trapezius	Large, flat, trapezoid-shaped muscle on back of neck and upper back; origin on occipital bone, C7, and all thoracic vertebrae; inserts on clavicle and scapula	Hyperextends head so as to look at sky; lateral flexion of head (see actions on shoulder)
Scalenes (3)	Origin on cervical vertebrae (C1–C7); insert on ribs 1 and 2	Act synergistically with sternocleidomastoid to flex neck
<b>Muscles of the Trunk</b>		
<b>Muscles Involved in Breathing</b>		
External intercostals	Located between ribs (intercostal space); both origin and insertion on ribs	Breathing (enlarges thoracic cavity during inhalation)
Internal intercostals	Located between ribs (intercostal space); both origin and insertion on ribs	Breathing (decreases thoracic cavity in forced exhalation)
Diaphragm	Dome-shaped muscle that separates thoracic and abdominal cavities	Breathing—chief muscle of inhalation (enlarges thoracic cavity)
<b>Muscles of Abdominal Wall</b>		
External oblique Internal oblique Transverse abdominis Rectus abdominis	As a group, muscles are arranged vertically, horizontally, and obliquely to strengthen abdominal wall	As a group, abdominal wall muscles compress the abdomen, thereby aiding in urination, defecation, childbirth, and forced expiration (breathing); also flex and rotate vertebral column

Continued

**Table 9-1** Muscles of the Body—cont'd

MUSCLE	LOCATION, DESCRIPTION	FUNCTION
<b>Muscles of Vertebral Column</b>		
Trapezius	See trapezius above (Neck)	Helps to maintain spine in extension
Erector spinae	Extends length of vertebral column from cranium to sacrum	Extends and laterally flexes vertebral column; rotates head; assists in maintenance of erect posture
Sternocleidomastoid	See above (Neck)	Flexes and rotates cervical vertebral column
Abdominal muscles	See above (Muscles of Abdominal Wall)	Flexes and rotates vertebral column
Iliopsoas	Origin on ilium and lumbar vertebrae; inserts on femur	Flexes vertebral column
<b>Muscles of Pelvic Floor</b>		
	Flat muscle sheets	Support pelvic viscera; aid in urination and defecation
<b>Muscles of Shoulder (Pectoral) Girdle and Arm</b>		
Trapezius	See description above (Neck)	Causes shrugging and medial rotation of shoulders (by pulling shoulder blades and scapulae together)
Serratus anterior	Forms upper sides of chest wall; origin on upper ribs; inserts on scapula	Lowers shoulder and moves the arm forward as in pushing a cart
Pectoralis major	Large muscle that covers upper anterior chest; origin on clavicle, sternum, and cartilages of upper ribs; inserts on anterior humerus	Adducts and medially rotates arm across chest; flexes and extends arm at shoulder
Latissimus dorsi	Large, broad, flat muscle on mid and lower back; origin on lower vertebral column and lower ribs; inserts on posterior humerus	Adducts and rotates arm medially, behind the back; "swimmer's muscle"
Deltoid	Thick muscle that covers shoulder joint; origin on clavicle and scapula; inserts on humerus	Abducts arm as in "scarecrow" position; flexes, extends, and rotates arm at shoulder
Rotator cuff muscles Supraspinatus Subscapularis Infraspinatus Teres minor	Group of four muscles that attaches humerus (insertion) to scapula (origin); tendons form cuff over proximal humerus	Adduct, extend, and rotate arm at shoulder; the "cuff" stabilizes shoulder joint
Teres major	Origin on scapula; inserts on humerus	Extends and adducts arm at shoulder; medially rotates arm at shoulder
<b>Muscles That Move Forearm</b>		
Biceps brachii	Major muscle on anterior surface of arm; origin on scapula; inserts on radius	Flexes and supinates forearm at elbow and flexes arm at shoulder; muscle used to "make a muscle"; acts synergistically with brachialis and brachioradialis
Triceps brachii	Origin on posterior surface of arm (scapula and humerus); inserts on ulna	Extends forearm at elbow, extends arm at shoulder; "boxer's muscle"
Brachialis	Origin on humerus; inserts on ulna	Flexes forearm at elbow
Brachioradialis	Origin on humerus; inserts on radius	Flexes forearm at elbow
Supinator	Origin on humerus and ulna; inserts on radius	Supinates forearm (palm turns upward or faces forward, as in anatomical position)
Pronator teres	Origin on humerus and ulna; inserts on radius	Pronates forearm so that palm faces downward or backward

**Table 9-1** Muscles of the Body—cont'd

MUSCLE	LOCATION, DESCRIPTION	FUNCTION
<b>Muscles That Move Wrist, Hand, and Fingers</b>		
Flexor and extensor carpi group	Origin on humerus and ulna; inserts on tendon in wrist	Flex and extend hand at wrist; adduct and abduct hand at wrist
Flexor and extensor digitorum group	Origin on humerus, ulna, and radius; inserts on phalanges (fingers)	Flex and extend fingers; flex hand at wrist
<b>Muscles That Move Thigh and Leg</b>		
Gluteus maximus	Largest and most superficial of gluteal muscles; located on posterior surface of buttocks; origin on ilium of coxal bone, sacrum, coccyx, and local aponeurosis; inserts on femur	Forms buttocks; extends and rotates thigh laterally at hip; muscle for sitting and climbing stairs; produces backswing of leg while walking
Gluteus medius	Thick muscle partly behind and superior to gluteus maximus; origin on ilium; inserts on femur	Abducts and rotates thigh medially at hip; common site of intramuscular injections
Gluteus minimus	Smallest and deepest of gluteal muscles; origin on ilium; inserts on femur	Abducts and rotates thigh medially at hip
Iliopsoas	Located on anterior surface of groin; origin on ilium and lumbar vertebrae; inserts on femur	Flexes and rotates thigh laterally; antagonist to gluteus maximus
Tensor fasciae latae	Located on lateral thigh; origin on ilium; inserts on tibia	Flexes and abducts thigh at hip
Adductor group Adductor longus Adductor brevis Adductor magnus	As a group, located on anteromedial surface of thigh	Adducts and medially rotates thigh; muscles used by horseback riders to stay on horse
Gracilis	Located along medial thigh; origin on symphysis pubis; inserts on proximal tibia	Adducts and medially rotates thigh at hip; flexes leg at knee
Pectineus	Located on medial thigh; origin on pubis; inserts on femur	Adducts and flexes thigh at hip
Quadriceps femoris Rectus femoris Vastus lateralis Vastus medialis Vastus intermedius	Located on anterior thigh; all insert on tibia; rectus femoris originates on ilium (coxal bone); other "quads" originate on femur	Group used to extend leg at the knee (e.g., kicking a football); rectus femoris can flex thigh at hip; vastus lateralis is common site for intramuscular injections in children
Sartorius	Long muscle that crosses obliquely over anterior thigh; origin on ilium; inserts on tibia	Allows you to sit in crossed leg position; flexes, abducts, laterally rotates thigh at hip; flexes leg at knee
Hamstrings Biceps femoris Semitendinosus Semimembranosus	Located on posterior surface of thigh; as a group, attaches to ischium (origin) to their points of insertion on tibia. Biceps femoris also originates on femur and inserts on both tibia and fibula.	As a group, they flex leg at knee, extend thigh at hip; antagonistic to quadriceps femoris
<b>Muscles That Move Ankle and Foot</b>		
Tibialis anterior	Located on anterior leg; origin on tibia; inserts on tarsal and metatarsal bones	Dorsiflexes and inverts foot
Peroneus longus	Lateral surface of leg; origin on fibula and tibia; inserts on metatarsal and tarsal bones	Plantar flexion and eversion of foot; supports arch
Gastrocnemius	Posterior surface of leg; large two-headed muscle that forms calf; origin on femur; inserts on calcaneus (heel bone) by way of Achilles tendon	Plantar flexion of foot; toe dancer muscle; flexes leg at knee
Soleus	Posterior surface of leg; origin on fibula and tibia; inserts on calcaneus	Plantar flexion of foot

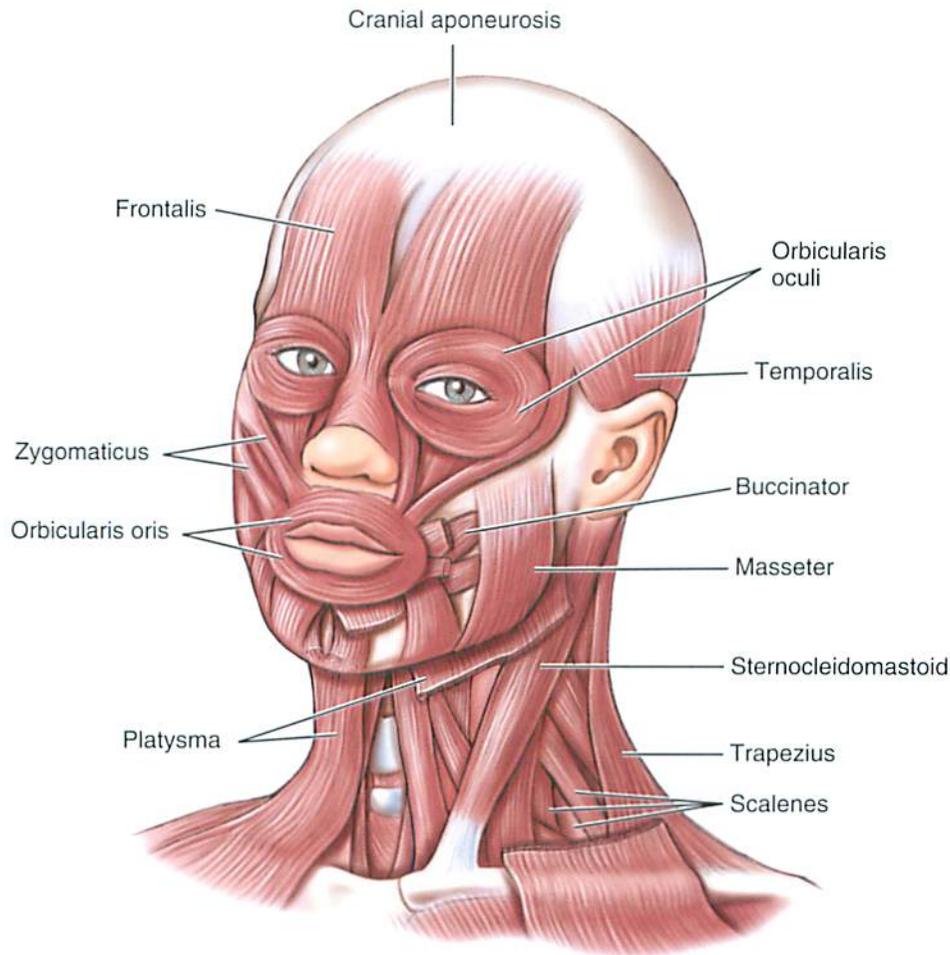


FIGURE 9-8 Muscles of the head and neck.

## MUSCLES OF THE NECK

Many muscles are involved in the movement of the head and shoulders and participate in throat movements.

### STERNOCLEIDOMASTOID

As the name implies, the sternocleidomastoid (STERN-oh-KLYE-doh-MAS-toyd) muscle extends from the sternum and clavicle to the mastoid process of the temporal bone in the skull. Contraction of both muscles on either side of the neck causes flexion of the head. Because the head bows as if in prayer, the muscle is called the *praying muscle*. Contraction of only one of the sternocleidomastoid muscles causes the head to flex and to rotate toward the opposite direction. A spasm of this muscle can cause torticollis, or wryneck. This condition is characterized by twisting of the neck and rotation of the head to one side. Botox has been used successfully in the treatment of torticollis. Although the sternocleidomastoid muscle is the prime mover of neck flexion, three scalene (SKAY-leen) muscles act synergistically to flex the neck. The scalenes have their origin on the cervical vertebrae (C1–C7) and insert on ribs 1 and 2.

### TRAPEZIUS

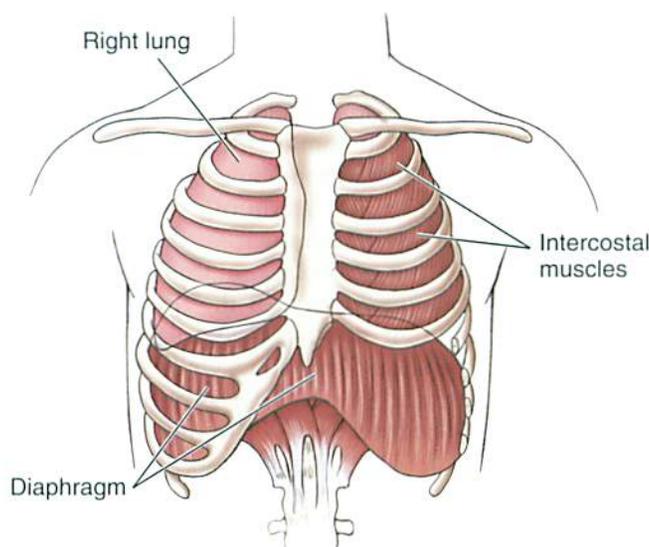
The trapezius (trah-PEE-zee-us) has its origins at the base of the occipital bone of the cranium and on the spines of C7 to T4 of the upper vertebral column (see Figure 9-7). The trapezius inserts on both the scapula and clavicle. Contraction of the trapezius allows the head to tilt back (hyperextension) so that the face looks at the sky. The trapezius works antagonistically with the sternocleidomastoid muscle, which flexes and bows the head. The trapezius also causes lateral flexion of the head and shrugs the shoulder.

## MUSCLES OF THE TRUNK

The muscles of the trunk are involved in breathing, form the abdominal wall, move the vertebral column, and form the pelvic region.

### MUSCLES INVOLVED IN BREATHING

The muscles of the chest include the intercostal muscles and the diaphragm. These muscles are primarily responsible for breathing (Figure 9-9). The intercostal muscles are located between the ribs. They have their origin and insertion on the ribs and are responsible for raising and lowering the rib cage during breathing.



**FIGURE 9-9** Breathing muscles: the intercostal muscles and the diaphragm.

The ribs that you barbecue are the intercostals (bone *appétit!*).

The diaphragm is a dome-shaped muscle that separates the thoracic cavity from the abdominal cavity. The diaphragm is the chief muscle of inhalation, or the breathing-in phase of respiration. Without the contraction and relaxation of the intercostal muscles and diaphragm, breathing cannot occur. The breathing muscles are more fully described in Chapter 22.

### MUSCLES THAT FORM THE ABDOMINAL WALL

The abdominal wall consists of four muscles (see Figure 9-7, *A*) in an arrangement that provides considerable strength. The muscles are layered so that the fibers of each of the four muscles run in four different directions. This arrangement enables the muscles to contain, support, and protect the abdominal organs. Contraction of the abdominal muscles performs other functions. It causes flexion and rotation of the vertebral column and compression of the abdominal organs during urination, defecation, and childbirth.

The four abdominal muscles include the following:

- *Rectus abdominis*. As the name implies, the fibers of the rectus abdominis run in an up and down, or longitudinal, direction. They extend from the sternum to the pubic bone. Contraction of this muscle flexes the vertebral column.
- *External oblique*. Abdominal muscles called the external obliques make up the lateral walls of the abdomen. The fibers run obliquely (slanted).
- *Internal oblique*. The internal oblique muscles are part of the lateral walls of the abdomen. They add to the strength provided by the external oblique muscles; the fibers of the internal and external oblique muscles form a crisscross pattern.
- *Transversus abdominis*. The transversus abdominis muscles form the innermost layer of the abdominal

muscles. The fibers run horizontally across the abdomen.

To remember the abdominal muscles, think of that spare **TIRE**:

<b>T</b>	transversus abdominis
<b>I</b>	internal oblique
<b>R</b>	rectus abdominis
<b>E</b>	external oblique

The abdominal muscles are attached to fascia that forms a large aponeurosis along the midline of the abdominal wall. The aponeuroses of the abdominal muscles on opposite sides of the midline of the abdomen form a white line called the *linea alba*. The linea alba extends from the sternum to the pubic bone.

### ? Re-Think

1. Describe the movement of the head in response to contraction of the right sternocleidomastoid muscle.
2. Explain why the arrangement of the abdominal muscles conveys added strength to the abdominal wall.

### MUSCLES THAT MOVE THE VERTEBRAL COLUMN

A number of muscles attach to the vertebrae and assist in the movement of the vertebral column; the movements include flexion, extension, hyperextension, lateral flexion, and rotation of the vertebral column. Muscles that move the vertebral column include the erector spinae, sternocleidomastoid, trapezius, abdominal muscles, and iliopsoas. Deep to the trapezius and the latissimus dorsi is the erector spinae (eh-REK-tor SPIN-ay); it extends the length of the vertebral column, from the sacrum to the cranium. As the erector spinae muscle ascends, it forms three columns of muscles. The erector spinae muscle causes extension and lateral flexion of the vertebral column and rotation of the head. This muscle assists in the maintenance of an erect posture. With aging, this muscle loses contractile strength and accounts in part for the stooped posture of an older person. Hungry? The erector spinae are best known by laypersons as pork chops and T-bone steaks.

Contraction of both sternocleidomastoid muscles causes flexion of the head at the neck, whereas contraction of one muscle rotates the head in the opposite direction (causes rotation of the cervical vertebral column). The trapezius maintains the vertebral column in extension. The abdominal muscles cause flexion and rotation of the vertebral column, and the iliopsoas (see later) flexes the vertebral column at the hip.

### MUSCLES THAT FORM THE PELVIC FLOOR

The pelvic floor consists primarily of two flat muscle sheets and the attached fascia. These structures support the pelvic viscera and play a role in expelling the contents of the urinary bladder and rectum.

## Do You Know...

### What Is Wrong with Bulking Up?

Nothing is wrong with bulking up if it is done through weight lifting, exercise, and a healthy diet. Bulking up with the use of steroids, however, is dangerous. Steroids are thought to cause liver cancer, atrophy of the testicles in males, stunting of growth, and severe psychotic mood swings, among other health-related effects.



Then there is “roid rage”—uncontrollable aggressive behavior. ‘Roid rage has been implicated in many instances of serious sports-related injuries and has sent many a steroid abuser to prison for fighting, scrapping, brawling, and mauling—not a pretty picture.

## MUSCLES OF THE SHOULDER (PECTORAL) GIRDLE AND ARM

Many muscles move the shoulder and the arm. The most important are the trapezius, serratus anterior, pectoralis major, latissimus dorsi, and deltoid and a group of muscles called the *rotator cuff muscles* (see Figure 9-7, A and B).

- *Trapezius*. The trapezius has its origin at the base of the occipital bone and the spines of all thoracic vertebrae; it inserts on the clavicle and scapula (shoulder blade). When contracted, the trapezius moves the clavicle and scapula and allows for a shrugging and rotating movement of the pectoral girdles. The trapezius causes medial rotation by pulling the shoulder blades (scapulae) together. The muscle gets its name because the right and left trapezius form the shape of a trapezoid.
- *Serratus anterior*. The serratus (sehr-AH-tis) anterior is located on the sides of the chest and extends from the upper ribs (origin) to the scapula (insertion). The serratus muscle has a jagged shape, much like the jagged edge of a serrated knife blade. When the serratus anterior contracts, the shoulders are lowered and the arm moves forward as if pushing a cart. The trapezius and serratus anterior attach the scapula to the axial skeleton.
- *Pectoralis major*. The pectoralis (pek-toh-RAL-is) major is a large broad muscle that helps form the anterior chest wall. It connects the humerus (arm) with the clavicle (collarbone) and structures of the axial skeleton (ribs and sternum). Contraction of this muscle moves the arm across the front of the chest, as if pointing to an object in front of the body. (A more precise description of the function of the pectoralis major: It adducts and rotates the arm medially at the shoulder joint as well as flexes and extends the arm at the shoulder joint.) Many gym exercises are designed to hypertrophy the “pecs.”
- *Latissimus dorsi*. The latissimus (LAT-iss-im-ahs) dorsi is a large broad muscle located in the middle and lower back region. Its origin is on the lower thoracic vertebrae, lumbar vertebrae, sacrum, and lower ribs; it inserts on the posterior humerus. Contraction of this muscle lowers the shoulders and brings the arm back, as if pointing to an object behind you. This same backward movement occurs in swimming and rowing. (A more precise description: The latissimus dorsi extends, adducts, and rotates the arm medially at the shoulder.) The pectoralis major and latissimus dorsi attach the humerus to the axial skeleton.
- *Deltoid*. The deltoid forms the rounded portion of the shoulder and forms the shoulder pad. The deltoid extends from its origins on the clavicle and scapula to its insertion on the humerus. Contraction of the deltoid muscle abducts the arm, raising it to a horizontal position (the scarecrow position). It also flexes, extends, and rotates the arm at the shoulder joint. Because of its size, location, and good blood supply, the deltoid is a common site of an intramuscular injection.
- *Teres major*. The teres (TER-eez) major is a long, round muscle that has its origin on the scapula and inserts on the humerus. It extends the arm at the shoulder joint and assists with the medial rotation and adduction of the arm at the shoulder joint.
- *Rotator cuff muscles*. The rotator cuff muscles are a group of four muscles that attach the humerus (insertion) to the scapula (origin). They include the subscapularis, supraspinatus, infraspinatus, and teres minor. The tendons of these muscles form a cap, or a cuff, over the proximal humerus, thus stabilizing the joint capsule. The muscles help rotate the arm at the shoulder joint. What about tennis buffs and their rotator cuffs? One of the most common causes of shoulder pain in athletes is known as *impingement syndrome*, or rotator cuff injury. It is caused by repetitive overhead motions and is commonly experienced by tennis players, swimmers, and baseball pitchers. The tendons are pinched and become inflamed, resulting in pain. If this continues, the inflamed tendon can degenerate

and separate from the bone. The condition can be a career-ending sports injury.

Note how many different movements are possible at the shoulder joint. The ball-and-socket joint and the many muscles that attach to the arm and pectoral girdle permit this freedom of movement.

### **? Re-Think**

Identify the origins and insertions of the following muscles: trapezius, pectoralis major, deltoid, and latissimus dorsi. Citing the origins and insertions of each, describe the movements caused by the contraction of the muscles.

## **MUSCLES THAT MOVE THE FOREARM**

Most of the muscles that move the forearm (ulna and radius) are located along the humerus and are classified as flexors, extensors, supinators, or pronators. The flexors, those that cause flexion at the elbow joint, include the biceps brachii, brachialis, and brachioradialis. Extension is due to contraction of the triceps brachii.

The triceps brachii (TRY-seps BRAYK-ee-eye) lies along the posterior surface of the humerus; it has its origins on the scapula and humerus and its insertion on the ulna. Contraction causes extension of the forearm at the elbow joint; it also extends the arm at the shoulder joint. The triceps brachii is the muscle that supports the weight of the body when a person does push-ups or walks with crutches. It is also the muscle that packs the greatest punch for a boxer, hence the nickname “the boxer’s muscle” (see Figure 9-7, B).

The biceps brachii is located along the anterior surface of the humerus; its two heads attach to the scapula (origin) and the distal end inserts on the radius of the forearm. The biceps brachii acts synergistically with the brachialis and brachioradialis to flex the forearm. The biceps brachii and brachialis are the prime movers for flexion of the forearm. When someone is asked to “make a muscle,” the biceps brachii becomes most visible.

Pronation (palm down) is achieved by two pronator muscles located along the anterior forearm (origin on the humerus and ulna, insertion on the radius). The actions of the biceps brachii and a supinator muscle (origin on the humerus and ulna, insertion on the radius) located along the posterior forearm cause supination (palm up).

## **MUSCLES THAT MOVE THE WRIST, HAND, AND FINGERS**

More than 20 muscles move the wrist, hand, and fingers. The muscles are numerous and small, making the wrist, hand, and fingers capable of delicate movements. The muscles are generally located along the forearm and consist of flexors and extensors. The flexors are located on the anterior surface of the forearm

and the extensors are located on the posterior surface. The tendons of these muscles pass through the wrist into the hand and fingers. The flexor carpi radialis and the flexor carpi ulnaris flex the hand at the wrist joint; they also adduct and abduct the hand at the wrist. Contraction of the flexor digitorum muscle (in the forearm) pulls on the tendons of the phalanges, thereby moving the fingers (like puppet strings). Imagine how fat your fingers would be if they were filled with muscle rather than tendons—your ring size would double or triple!

The puppet string setup, with the muscles in the forearm and tendons in the wrists and fingers, is responsible for another clinical mishap. If the tendons in the wrist are accidentally severed, the muscles in the forearm pull the tendons up into the forearm. The tendons “disappear” from the injured site. If the surgeon merely patches up the wrist injury and fails to retrieve and reattach the tendons, finger movement is lost.

The extensors of the wrist, hand, and fingers lie along the posterior forearm. The extensor carpi radialis longus extends and abducts the hand at the wrist. The extensor carpi ulnaris extends and adducts the hand at the wrist. The extensor digitorum extends the hand at the wrist and extends the fingers.

The flexors of the fingers are stronger than the extensors so that in a relaxed hand, the fingers are slightly flexed. If a person is unconscious for an extended period, the fingers remain in a flexed position. In response to inactivity, the tendons of the fingers shorten, thereby preventing extension of the fingers, which gives a clawlike appearance to the hand. This problem can be prevented by an exercise program that includes passive exercises of the hands and fingers.

## **THE CARPAL TUNNEL**

Most of the tendons of the muscles that supply the hand pass through a narrow tunnel created by transversely oriented carpal ligaments and the carpal (wrist) bones (Figure 9-10). The flexor tendons in the carpal tunnel are encased in tendon sheaths and normally slide back and forth very easily. However, repetitive motion of the hand and fingers can cause the tissues within the carpal tunnel to become inflamed and swollen. The swelling puts pressure on the median nerve, which is also located in the carpal tunnel. The irritated nerve causes tingling, weakness, and pain in the hand and arm. The condition, carpal tunnel syndrome, is a major cause of disability in persons who must perform repetitive wrist motion (e.g., pianists, machinists, butchers, and keyboard operators).

### **? Re-Think**

Identify the origins and insertions of the following muscles: biceps brachii, brachialis, triceps brachii, and supinators. Citing the origins and insertions of each, describe the movements caused by the contraction of the muscles.

### Carpal Tunnel Syndrome

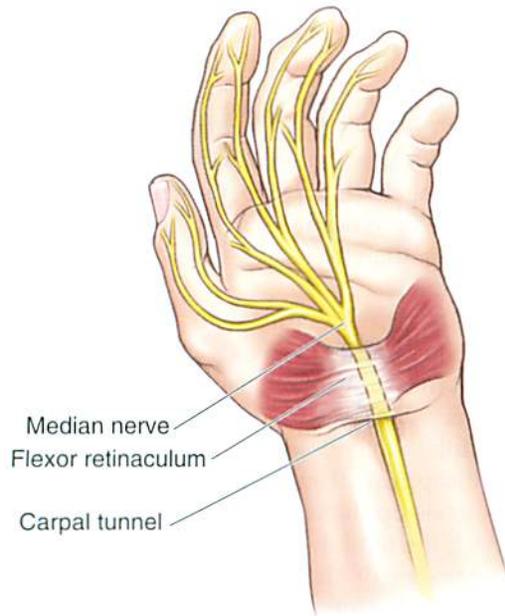


FIGURE 9-10 Carpal tunnel syndrome.

## MUSCLES THAT MOVE THE THIGH, LEG, AND FOOT

The muscles that move the thigh, leg, and foot are some of the largest and strongest muscles in the body. These muscles not only move the lower extremities, but also provide stability for the joints and help maintain posture.

### MUSCLES THAT MOVE THE FEMUR (THIGH BONE)

The muscles that move the thigh at the hip all attach to some part of the pelvic girdle (coxal bones) and the femur (thigh bone). These include the gluteal muscles, the iliopsoas, the tensor fasciae latae, and a group of adductor muscles. Contraction of these muscles causes movement at the hip joint (see Figure 9-7).

The gluteal muscles are located on the posterior surface and include the gluteus maximus, gluteus medius, and gluteus minimus. The gluteus maximus is the largest muscle in the body; it forms the area of the buttocks and is the muscle on which you sit.

The gluteus maximus has its origins on the ilium (coxal bone) and sacrum and inserts on the femur. It rotates the thigh laterally and extends the thigh at the hip, as in climbing stairs or walking. It produces the backswing of the leg while walking. The gluteus medius and gluteus minimus have their origins on the ilium (coxal bone) and insert on the femur. They abduct and rotate the thigh medially at the hip joint. Both the gluteus maximus and gluteus medius are commonly used sites for intramuscular injections.

The iliopsoas (il-ee-OHP-so-us) is located near the groin; it has its origins on the lower vertebrae and ilium (coxal bone) and its insertion on the femur. Contraction of this muscle flexes and rotates the thigh laterally.

The tensor fasciae latae (TEN-sor FASH-ee-ah LAT-ah) is on the lateral thigh; it has its origin on the ilium (coxal bone) and inserts on the tibia. Contraction of this muscle flexes and abducts the thigh at the hip joint.

The adductor muscles are located on the medial surface of the thigh; they have their origin on the lower coxal bones and insert on the medial and posterior surfaces of the femurs. This group of muscles adduct the thighs, pressing them together. These are the muscles that a horse rider uses to stay on the horse. The adductor muscles include the adductor longus, adductor brevis, adductor magnus, gracilis (GRAH-sil-is), and pectineus (pek-TIN-ee-us). In addition to adduction, most of the adductor muscles rotate the thigh. (See Table 9-1.)

The quadriceps femoris, sartorius, and hamstring muscles (described later) also move the thigh. The quadriceps femoris flexes the thigh at the hip, whereas the hamstrings extend the thigh at the hip. The sartorius allows you to sit cross-legged on the floor.

Note the many types of movement that occur at the hip, a ball-and-socket joint.

### MUSCLES THAT MOVE THE LEG

The muscles that move the leg are located in the thigh. The extensor muscles lie along the anterior and lateral surfaces of the leg, whereas the flexors lie along the posterior and medial surfaces. Muscles that move the legs include the quadriceps femoris, sartorius, hamstring group, and the gastrocnemius.

The quadriceps femoris is located on the anterior thigh, is the most powerful muscle in the body, and has four heads as its origin. All four parts of the muscle insert on the tibia by the quadriceps ligament. (The quadriceps tendon extends distally to the tibial tuberosity as the quadriceps ligament.) The “quads” straighten, or extend, the leg at the knee, as in kicking a football. The four heads of the muscle give rise to four parts of the quadriceps femoris muscle, each of which has its own name: the vastus lateralis, vastus intermedius, vastus medialis, and rectus femoris. The vastus lateralis is frequently used as an injection site for children because it is more developed than the gluteal muscles.

The sartorius allows you to sit cross-legged on the floor. It assists in knee and hip flexion, abduction, and lateral rotation of the thigh. At one time tailors used to sit cross-legged as they worked. The Latin word for tailor is *sartor*, so this muscle was named the sartorius.

The hamstrings are a group of muscles located on the posterior surface of the thigh. All the muscles

extend from the ischium (coxal bone) to the tibia. They flex the leg at the knee and are therefore antagonistic to the quadriceps femoris. Because these muscles also span the hip joint, they extend the thigh. The strong tendons of these muscles can be felt behind the knee. The tendons form the pit behind the knee called the *popliteal fossa*. These same tendons are found in hogs. In times past butchers used these tendons to hang the hams for smoking and curing—hence the name *hamstrings*. The hamstring muscles include the biceps femoris, semimembranosus, and semitendinosus. An athlete often pulls a hamstring or experiences a groin injury.

Because the gastrocnemius has its origin on the distal femur, it also flexes the leg at the knee. This large calf muscle is described later.



### Do You Know...

#### What a Wolf Knows about the Hamstrings?

Hungry wolves spot their prey—and the chase is on. The wolf will often attack the knee joint of its prey, severing the tendons of the hamstrings. Once the tendons are severed, the victim's legs are useless. Dinner is served!

### MUSCLES THAT MOVE THE FOOT

The muscles that move the foot are located on the anterior, lateral, and posterior surfaces of the leg. See Figure 8-21 for movements of the foot. The tibialis anterior is located on the anterior surface. It has its origin on the tibia (shin bone) and inserts on the tarsal and metatarsal bones. It causes dorsiflexion and inversion of the foot. There are a number of muscles that cause plantar flexion. The peroneus (per-oh-NEE-us) longus muscle is on the lateral surface. It everts (turns outward) the foot, supports the arch of the foot, and assists in plantar flexion. The gastrocnemius (GAS-trok-NEE-mee-us) and soleus are the major muscles on the posterior surface of the leg and form the calf of the leg. They attach to the calcaneus (heel bone) by the calcaneal tendon, or Achilles tendon. Contraction of these muscles causes plantar flexion. The tibialis posterior also assists in plantar flexion and inverts the foot.

Plantar flexion aids in walking and allows a person to stand on tiptoes. For this reason the gastrocnemius is sometimes called the *toe dancer's muscle*. Runners, especially sprinters, occasionally tear or rupture the Achilles tendon. Because the heel then cannot be lifted, this injury severely impedes the ability of the runner to perform.

Finally, there are the toes. Like the fingers, some of the toes are tugged on by tendons whose muscles (flexors and extensors) lie in the leg. Other muscles have their origin in the tarsal and metatarsal bones.

Some muscles have acquired rather interesting names. Figure 9-11 shows the many interesting movements we are able to make.



### Re-Think

Identify the origins and insertions of the following *muscles*: gluteus maximus, quadriceps femoris, biceps femoris, tibialis anterior, soleus, and gastrocnemius. Citing the origins and insertions of each, describe the movements caused by the contraction of these muscles.



### Sum It Up!

The skeleton is stabilized and covered with muscle. The ability of the muscles to contract and relax allows the skeleton to move about and engage in all the activities that make life so enjoyable. The location and function of the major muscles of the body are summarized in Table 9-1.



### As You Age

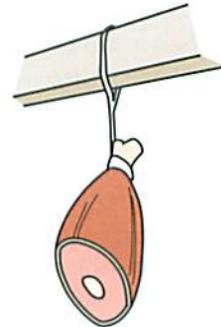
1. At about the age of 40, the number and diameter of muscle fibers decrease. Muscles become smaller, dehydrated, and weaker. Muscle fibers are gradually replaced by connective tissue, especially adipose or fat cells. By the age of 80, about 50% of the muscle mass has been lost.
2. Mitochondrial function in muscles decreases, especially in muscles that are not exercised regularly.
3. Motor neurons are gradually lost, resulting in muscle atrophy.
4. These changes lead to decreased muscle strength and slowing of muscle reflexes.



Kissing muscle  
(orbicularis oris)



Trumpeter's muscle  
(buccinator)



Hamstrings



Smiling muscle  
(zygomaticus)



Toe dancer's muscles  
(gastrocnemius  
and soleus)

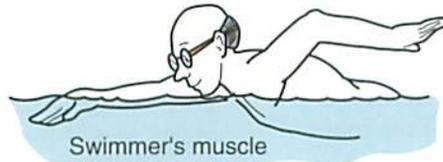


Praying muscle  
(sternocleidomastoid)

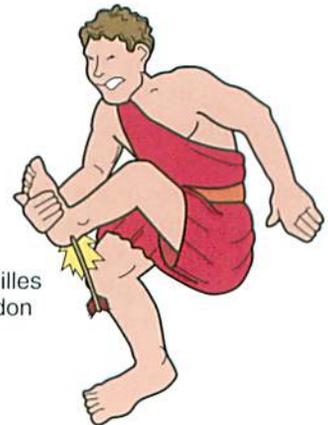
Lotus  
position



Tailor's muscle  
(sartorius)



Swimmer's muscle  
(latissimus dorsi)



Achilles  
tendon



Surprised! muscle  
(frontalis)

FIGURE 9-11 A medley of special muscles.



## MEDICAL TERMINOLOGY AND DISORDERS

## Disorders of the Musculoskeletal System

Medical Term	Word Parts	Word Part Meaning or Derivation	Description
<b>Words</b>			
adduction/ abduction	ad-	to, toward, or near	Adduction of the thigh indicates that the thigh is moving toward the midline of the body, whereas abduction means it is moving away from the midline of the body.
	ab-	away from	
	-duction	From the Latin word <i>ducere</i> , meaning “to lead”	
myalgia	my/o- -algia	muscle pain	<b>Myalgia</b> means <i>muscle pain</i> , a characteristic of many musculoskeletal disorders.
myopathy	my/o- -path/o- -y	muscle disease process or condition	A <b>myopathy</b> is a <i>muscle disease where the primary defect is within the muscle itself and not in the neuromuscular junction or brain</i> .
osteocyte	oste/o- -cyte	bone cell	<b>Osteocytes</b> are <i>bone cells</i> . Osteoblasts (-blast = immature) mature into osteocytes ( <i>bone cells</i> ), while osteoclasts (-clast = breakdown) break down osseous (bone) tissue.
periosteum	peri- -osteon	around bone	The <b>periosteum</b> is <i>the membrane around a bone</i> .
synergist	syn-	together	Refers to <i>muscles that work together to generate a movement</i> . Several muscles may work synergistically to flex the forearm.
	-erg-	From a Greek word meaning “to work”	
	-ist	one that specializes in	
<b>Disorders</b>			
arthralgia	arthr/o- -algia	joint pain	<b>Arthralgia</b> , also called noninflammatory joint pain, has multiple causes: injury, infection, many diseases, or a reaction to medications.
arthritis	arthr/o -itis	joint inflammation	<b>Arthritis</b> is <i>inflammation of a joint</i> . There are over 25 types of arthritis; two common types are <b>osteoarthritis</b> and <b>rheumatoid arthritis</b> . <b>Osteoarthritis</b> is called <i>degenerative or “wear-and-tear” arthritis</i> , most frequently seen in older persons. It affects primarily the weight-bearing joints, but may also affect the hands. Bony nodules may develop in the interphalangeal joints. <b>Rheumatoid arthritis (RA)</b> — <i>the most debilitating type of arthritis—is an autoimmune disease characterized by inflammation of the joints and systemic symptoms such as fever, fatigue, and anemia</i> . Joint disease progresses from <b>thickening of joint tissue</b> , called <b>pannus formation</b> , to cartilage destruction and finally to deformity and fusion of the joints.
bursitis	burs- -itis	bursa inflammation	<b>Bursitis</b> is <i>the inflammation of one or more bursae, causing pain, swelling, and restriction of movement</i> . Common forms include subacromial bursitis (painful shoulder), olecranon bursitis (student’s elbow, water on the elbow), and prepatellar bursitis (housemaid’s knee, carpet layer’s knee).
luxation	lux- -ation	From a Latin word meaning “to dislocate” condition or state	<b>Luxation</b> refers to <i>the displacement of a bone from its joint, with tearing of ligaments, tendons, and articular capsule</i> . The shoulder joint is a commonly dislocated joint. A <i>partial dislocation</i> is called a <b>subluxation</b> .
fibromyalgia	fibr/o- -my/o- -algia	fiber muscle pain	<b>Fibromyalgia</b> is a <i>syndrome characterized by pain in the muscles, tendons, and soft tissues</i> . Although the joints are not affected, the pain is experienced as originating in the joints. The musculoskeletal symptoms are accompanied by generalized feelings of fatigue, depression, headache, and anxiety.

Continued

**MEDICAL TERMINOLOGY AND DISORDERS** Disorders of the Musculoskeletal System—cont'd

Medical Term	Word Parts	Word Part Meaning or Derivation	Description
fracture		From a Latin word meaning "to break"	<b>Fracture</b> refers to a <i>broken bone</i> . Most fractures are due to traumatic injuries; a small number are a result of another disease and are called <b>pathological fractures</b> . There are numerous ways to classify fractures: open/closed; stable/unstable; spiral, comminuted; transverse; stress.
multiple myeloma	myel/o- -oma	bone marrow tumor	Also called plasma cell myeloma, <b>multiple myeloma</b> refers to <i>malignant tumors of the bone marrow in which there are collections of abnormal plasma cells</i> . <b>CRAB</b> is a mnemonic that indicates the characteristic tetrad (four parts) of multiple myeloma: calcium (hypercalcemia), renal failure, anemia, and bone lesions.
muscular dystrophy	dys-  -troph/o-  -y	painful, difficulty, or faulty  nourishment or development  condition or process of	<b>Muscular dystrophy (MD)</b> is a <i>group of inherited muscle disorders that cause progressive muscle weakness and degeneration of muscle tissue</i> . Numerous disorders are included in this category, with Duchenne MD being the most common.
neoplasms (bone)	neo- plas/o-	new formation	Osteogenic sarcoma or osteosarcoma is a highly malignant and rapidly metastasizing neoplasm. Osteoclastoma (tumor originating from osteoclasts) or giant cell tumor is most often nonmalignant, but highly destructive; it occurs in the long bones of the lower extremities. Ewing's sarcoma is a common malignancy of bone and soft tissue. Its rapid growth occurs within the pelvis and the medullary cavities of long bones of the extremities. Pathological fractures develop in response to the cancer-inducing osteonecrosis.
osteomalacia	oste/o- -malacia	bone softening	<b>Osteomalacia</b> refers to <i>softening of the bones</i> . The loss of calcium and phosphorus is caused by vitamin D deficiency. The bone softening results in skeletal deformities and fractures. Osteomalacia in the growing bones of children is called <i>rickets</i> .
osteomyelitis	oste/o- -myel/o- -itis	bone bone marrow inflammation	<b>Osteomyelitis</b> is a <i>serious infection of the bone, bone marrow, and surrounding tissue</i> . It can be caused by many pathogens, the most common being <i>Staphylococcus aureus</i> . Infection can occur by direct (open wound) or indirect (hematogenous) entry.
osteoporosis	oste/o- -por/os-  -osis	bone From a Greek word meaning "pore" or "passage" condition of	A loss of bone mass that makes the bones so porous that they crumble under the ordinary stress of moving about. Osteoporosis is related to the loss of estrogen in older women, a dietary deficiency of calcium and vitamin D, and low levels of exercise. Osteopenia (-penia = abnormal reduction) is indicative of early osteoporosis.
plantar fasciitis	fasci/o- -itis	fascia inflammation of	<b>Plantar fasciitis</b> is <i>inflammation of the plantar fascia on the bottom of the foot</i> . It is usually exercise-induced and painful.
rhabdomyolysis	rhabd/o-  -my/o- -lysis	rod-shaped or striated (skeletal) muscle breakdown	<b>Rhabdomyolysis</b> is the <i>breakdown of muscle with the release of myoglobin into the blood</i> . It is a consequence of conditions in which muscle activity is excessive (seizures, drugs) or injurious (crush injuries).
strains and sprains			The two most common musculoskeletal injuries, usually as a result of twisting forces associated with physical activity. A <b>sprain</b> is an <i>injury or tearing of the ligaments of a joint</i> . A <b>strain</b> is <i>excess stretching of a muscle and its surrounding fascia</i> .
tendonitis	tend/o- -itis	tendon inflammation	<i>Inflammation of a tendon causing pain and tenderness just outside the joint</i> . The joints most often affected are the elbows (tennis elbow, golfer's elbow), shoulders (pitcher's shoulder, swimmer's shoulder), wrists, and heels (Achilles tendonitis).

## Get Ready for Exams!

### Summary Outline

The purpose of muscle is to contract and to cause movement.

#### I. Muscle Function: Overview

- A. Types and functions of muscles
  1. Skeletal muscle is striated and voluntary; its primary function is to produce movement.
  2. Smooth (visceral) muscle is nonstriated and involuntary; it helps the organs perform their functions.
  3. Cardiac muscle is striated and involuntary; it is found only in the heart and allows the heart to function as a pump.
- B. Structure of the whole muscle
  1. A large muscle consists of thousands of single muscle fibers (muscle cells).
  2. Connective tissue binds the muscle fibers (cells) together, forming compartments in the limbs, and attaches muscle to bone and other tissue by tendons and aponeuroses.
- C. Structure and function of a single muscle fiber
  1. The muscle fiber (cell) is surrounded by a cell membrane (sarcolemma). The cell membrane penetrates to the interior of the muscle as the transverse tubule (T tubule).
  2. An extensive sarcoplasmic reticulum (SR) stores calcium.
  3. Each muscle fiber consists of a series of sarcomeres. Each sarcomere contains thin filaments (actin and troponin-tropomyosin complex) and thick filaments (myosin).
- D. How muscles contract
  1. Electrical signals run along the muscle membrane.
  2. Electrical signal enters the T tubule system and stimulates the SR to release calcium.
  3. Muscles shorten or contract as the actin and myosin (in the presence of calcium and ATP) interact through cross-bridge formation, according to the sliding filament mechanism.
  4. Calcium is pumped back into the SR and the muscles relax.
- E. Skeletal muscles and nerves: for a skeletal muscle to contract, it must be stimulated by a motor nerve.
  1. Motor unit: formed by a motor neuron and the muscle fibers that it innervates (forms the basis of recruitment)
  2. Neuromuscular junction (NMJ): the nerve terminal (ending) containing neurotransmitter (ACh), the space between the nerve terminal and muscle membrane, and the muscle membrane with its receptors
- F. Force of muscle contraction
  1. A single muscle fiber increases force of contraction through repetitive nerve stimulation.
  2. A whole muscle increases its force of contraction in two ways: by repetitive nerve stimulation or recruitment of additional motor units.

- G. Energy for muscle contraction can be obtained from three sources: burning fuel aerobically, burning fuel anaerobically, and metabolizing creatine phosphate.
- H. Terms that describe muscle movement
  1. Origin and insertion: the attachments of the muscles
  2. Prime mover: the muscle most responsible for the movement achieved by the muscle group
  3. Synergist or antagonist: works with or has an opposing action

#### II. Muscles from Head to Toe

- A. Skeletal muscles are named according to size, shape, orientation of fibers, location, number of origins, place of origin and insertion, and muscle action.
- B. See Table 9-1 for a list of the body's muscles.

### Review Your Knowledge

#### Matching: Muscle Terms

Directions: Match the following words with their descriptions below. Some words may be used more than once, and others not at all.

- a. origin
  - b. sarcoplasmic reticulum
  - c. smooth muscle
  - d. aponeurosis
  - e. actin
  - f. sarcomere
  - g. insertion
  - h. atrophy
  - i. synergist
  - j. skeletal muscle
  - k. myosin
  - l. tendon
1. \_\_\_ Cordlike structure that attaches muscle to bone
  2. \_\_\_ Type of muscle classified as striated and voluntary
  3. \_\_\_ Type of muscle that must be stimulated by a somatic motor nerve
  4. \_\_\_ Flat, sheetlike fascia that attaches muscle to muscle or muscle to bone
  5. \_\_\_ The head of this contractile protein binds to actin; forms a cross-bridge
  6. \_\_\_ Calcium is stored within this muscle structure
  7. \_\_\_ Series of contractile units that make up each myofibril: extends from Z line to Z line
  8. \_\_\_ The muscle attachment to the movable bone
  9. \_\_\_ Use it or lose it
  10. \_\_\_ A helper muscle

**Matching: Names of Muscles**

Directions: Match the following words with their descriptions below. Some words may be used more than once, and others not at all.

- a. quadriceps femoris
- b. gastrocnemius
- c. masseter
- d. hamstrings
- e. triceps brachii
- f. deltoid
- g. pectoralis major
- h. latissimus dorsi
- i. gluteus maximus
- j. biceps brachii
- k. diaphragm

1. \_\_\_ A muscle of mastication
2. \_\_\_ The major breathing muscle
3. \_\_\_ Major muscle of the anterior chest; attaches to the humerus
4. \_\_\_ The shoulder pad; pulls the arm into the scarecrow position
5. \_\_\_ A muscle that flexes the arm at the elbow
6. \_\_\_ A muscle that lies along the anterior thigh; flexes the thigh at the hip and extends the leg
7. \_\_\_ The muscle group that lies along the posterior thigh; flexes the leg at the knee
8. \_\_\_ The large muscle on which you sit
9. \_\_\_ Contraction of this muscle causes plantar flexion
10. \_\_\_ This muscle attaches to the calcaneus by the Achilles tendon

**Multiple Choice**

1. When the electrical signal travels along the T tubule and stimulates the sarcoplasmic reticulum (SR),
  - a. calcium is released, causing cross-bridge formation between actin and myosin.
  - b. acetylcholine (ACh) is released into the neuromuscular junction (NMJ).
  - c. calcium is pumped into the SR from the sarcomere.
  - d. ACh binds to the receptor on the muscle membrane.
2. Which of the following does not occur within the neuromuscular junction (NMJ)?
  - a. ACh is released from the motor nerve terminal.
  - b. ACh diffuses across the junction.
  - c. Actin and myosin "slide."
  - d. ACh is inactivated by an enzyme.
3. When skeletal muscle is stimulated quickly and repetitively,
  - a. ACh within the NMJ is depleted.
  - b. the muscle tetanizes and the force of contraction increases.
  - c. the sarcoplasmic reticulum is depleted of calcium and the muscle becomes flaccid.
  - d. the muscle merely twitches.
4. Which of the following slides?
  - a. ACh and cholinesterase
  - b. Calcium and ATP
  - c. Troponin and tropomyosin
  - d. Actin and myosin

5. Which of the following happens when calcium is pumped back into the sarcoplasmic reticulum?
  - a. The muscle relaxes.
  - b. ACh binds to the muscle membrane receptors in the NMJ.
  - c. ACh is destroyed by cholinesterase.
  - d. Actin and myosin slide.
6. Which of the following must occur to achieve flexion of the forearm?
  - a. The triceps brachii contracts.
  - b. The biceps brachii and brachialis contract.
  - c. The brachioradialis relaxes.
  - d. The deltoid and brachioradialis relax.
7. Which of the following does not characterize the quadriceps femoris?
  - a. Has four heads, or points of attachment
  - b. Is the prime mover for extension of the leg
  - c. Inserts on the proximal tibia at the tibial tuberosity
  - d. Causes plantar flexion as in toe dancing
8. Which of the following is true of the hamstrings?
  - a. Located along the anterior thigh
  - b. Is the prime mover for flexion of the leg
  - c. Acts synergistically with the gastrocnemius to cause dorsiflexion
  - d. Attaches to the Achilles tendon and inserts on the calcaneus
9. Which of the following is least descriptive of the masseter and temporalis muscles?
  - a. Insert on the mandible
  - b. Muscles of mastication
  - c. Nonstriated and involuntary
  - d. Innervated by somatic motor neurons
10. This muscle is best viewed on an anterior view of the body.
  - a. Biceps femoris
  - b. Pectoralis major
  - c. Latissimus dorsi
  - d. Gastrocnemius

**Go Figure**

1. According to Figure 9-1
  - a. Visceral muscle is nonstriated and voluntary.
  - b. The heart is primarily comprised of visceral or smooth muscle.
  - c. Skeletal muscle is striated and voluntary.
  - d. Cardiac muscle is smooth and involuntary.
2. According to Figure 9-2
  - a. Panel C compares sarcomere length in the contracted and relaxed muscle.
  - b. Panel C illustrates the location of the sarcoplasmic reticulum and T tubular system.
  - c. Panel A indicates that we are using the biceps brachii to illustrate skeletal muscle function at the sarcomere level.
  - d. Panel B illustrates the relationship of the thin and thick filaments within the sarcomere.