

7

The Muscular System

MOVEMENT FOR THE JOURNEY



As we continue our journey of exploration, we obviously need a transportation method so that we may reach our destination. We can go by plane, train, or car. However, no matter what transportation system we use, we must utilize the body's muscular system to get to the vehicle. Although the skeletal system provides the framework for the human body, the body also needs a system that allows movement, or locomotion, which is the job of the muscular system. The movement we are most familiar with is the use of our external muscles to walk, run, or lift objects. This external movement allows us to explore all the wonderful sites throughout our journey and, yes, even to turn the pages as we journey through this book. However, movement is also required within the body. This internal movement occurs when food, air, waste products, and body fluids such as blood must all be transported within our bodies. For example, if you drink some bad water on your journey, the smooth muscles in your digestive tract will rapidly pass it through your system to be expelled in the form of urgent diarrhea. Different types of specialized muscles within the muscular system allow for both external and internal movement. This chapter defines and contrasts the different muscle types needed for both external and internal body movement.

LEARNING OUTCOMES

At the completion of your journey through this chapter, you will be able to:

- Differentiate the three major muscle types.
- Explain the difference between voluntary and involuntary muscles.
- Explain the types of skeletal muscle movement and the relationship between muscles.
- Review movement terminology.
- Identify and explain the components of a muscle cell.
- Describe the cellular activities required for muscle movement.
- Discuss how muscles receive the fuel they need to function.
- Identify specific skeletal muscles in different body regions.
- Define function and location of visceral or smooth muscle.
- Describe the function and actions of cardiac muscle.
- Name common disorders of the musculoskeletal system.

Pronunciation Guide *Pro·nun·ci·a·tion*

Correct pronunciation is important in any journey so that you and others are completely understood. Here is a “see and say” Pronunciation Guide for the more difficult terms to pronounce in this chapter. Please note that even though there are standard pronunciations, regional variations of the pronunciations can occur.

acetylcholine (ah SEET ul KOH leen)

actin (ak TIN)

adenosine triphosphate

(ah DEN oh sin try FOSS fate)

aponeurosis (APP oh new ROH sis)

ataxia (ah TAK see uh)

atrophy (AT roh fee)

biceps brachii (BRA key eye)

diaphragm (DYE ah fram)

electromyography (ee LEK troh my OG rah fee)

fibromyalgia (FIE broh my AL jee uh)

flaccid (FLAS sid)

flexion (FLEK shun)

glycogen (GLIE koh jen)

Guillain-Barré syndrome (GEY yan bar RAY)

hypertrophy (high PER troh fee)

intercalated discs (in TER kuh LATE ed)

muscular dystrophy (MUS kyoo lahr DIS troh fee)

myalgia (my AL jee uh)

myasthenia gravis (my as THEE nee uh GRAV iss)

myofibril (my oh FIE bril)

myosin (MY oh sin)

rigor mortis (RIG or MORE tiss)

sarcomeres (SAR koh meerz)

sphincter (SFING ter)

tetanus (TET ah nus)

tonus (TONE us)

OVERVIEW OF THE MUSCULAR SYSTEM

Because of the numerous functions they must perform, muscles come in many shapes and sizes. The structure of the muscle matches its function, as you will see shortly.

Types of Muscles

Muscle is a general term for all contractile tissue. The term *muscle* comes from the Latin word *mus*, which means “mouse,” because the movement of muscles looks like mice running around under our skin. The contractile property of muscle tissue allows it to become short and thick in response to a nerve impulse. Muscles then relax back to their original length once that impulse is removed. When contracting, the muscles do not simply shorten, but exert a force as they become shorter. This alternate contraction and relaxation is what causes movement. Muscle cells are elongated and resemble strands of metal such as those found in cables. Muscle tissue is constructed of bundles of these strands that are referred to as *muscle fibers*. These fibers are approximately the diameter of human hair. Under the direction of the nervous system, all the muscles provide for motion of some type for your body.

The body has three major types of muscles: skeletal, smooth, and cardiac. We begin with a general description and comparison of these three muscle types and then get more specific about each type.

Skeletal muscles are *voluntary muscles*, which means they are under conscious control and derive their name because they are attached to the skeleton. The fibers in skeletal muscles appear to be striped and are therefore called *striated* (striped) muscle. These muscles allow us to perform external movements—running, lifting, or scratching, for example. These are the muscles we try to develop through exercise and sports and also so we look good at the beach.

Amazing Facts

Muscles

- Muscles make up almost half the weight of the body.
- There are 650 different muscles in the human body.
- The size of your muscles is influenced by how much you use them. This is why speed skaters have large leg muscles.
- Individual elongated muscle cells can be up to 12 inches, or 30 centimeters, in length.
- At about the age of 40, the number and diameter of muscle fibers begin to decrease, and by age 80, up to 50 percent of the muscle mass may be lost. Exercise and good nutrition help to minimize this loss.

Unlike skeletal muscle, smooth muscle is *involuntary* and not under our conscious control. It is also called **smooth muscle** because it does not have the striped appearance of skeletal muscles. This involuntary muscle is found within certain organs, blood vessels, and airways. Because it is the muscle of organs, it is sometimes called *visceral muscle*. Smooth muscle allows for the internal movement of food (*peristalsis*) in the case of the stomach and other digestive organs. In addition, smooth muscle facilitates the movement of blood by changing the diameter of the blood vessels (vasoconstriction and vasodilation) and also the movement of air by changing the diameter of the airways found in our lungs.

The third type of muscle is the specialized **cardiac muscle**, which is striated like skeletal muscle. This muscle type is found solely in the heart. It makes up the walls of the heart and causes it to contract. These contractions cause the

internal movement (circulation) of blood within the body. Fortunately, cardiac muscle, like smooth muscle, is an involuntary muscle. Imagine if we had to think each time for our heart to beat.

All muscles share certain characteristics such as the ability to stretch, called *extensibility*. For example, if you would swallow a large bolus of food, the smooth muscle in your esophagus must be able to stretch and allow it to pass or it would become painfully stuck. In addition they all share *contractility*, which is the ability to contract or shorten muscle fibers forcefully. All muscles exhibit *excitability*, which is muscle response to stimulation by either nerves or hormones. Finally, all muscles show some level of *elasticity*, which is the ability to return to original resting length after being stretched. **FIGURE 7-1** ■ contrasts the three types of muscles found within the body. We will now explore each of these types in further depth.

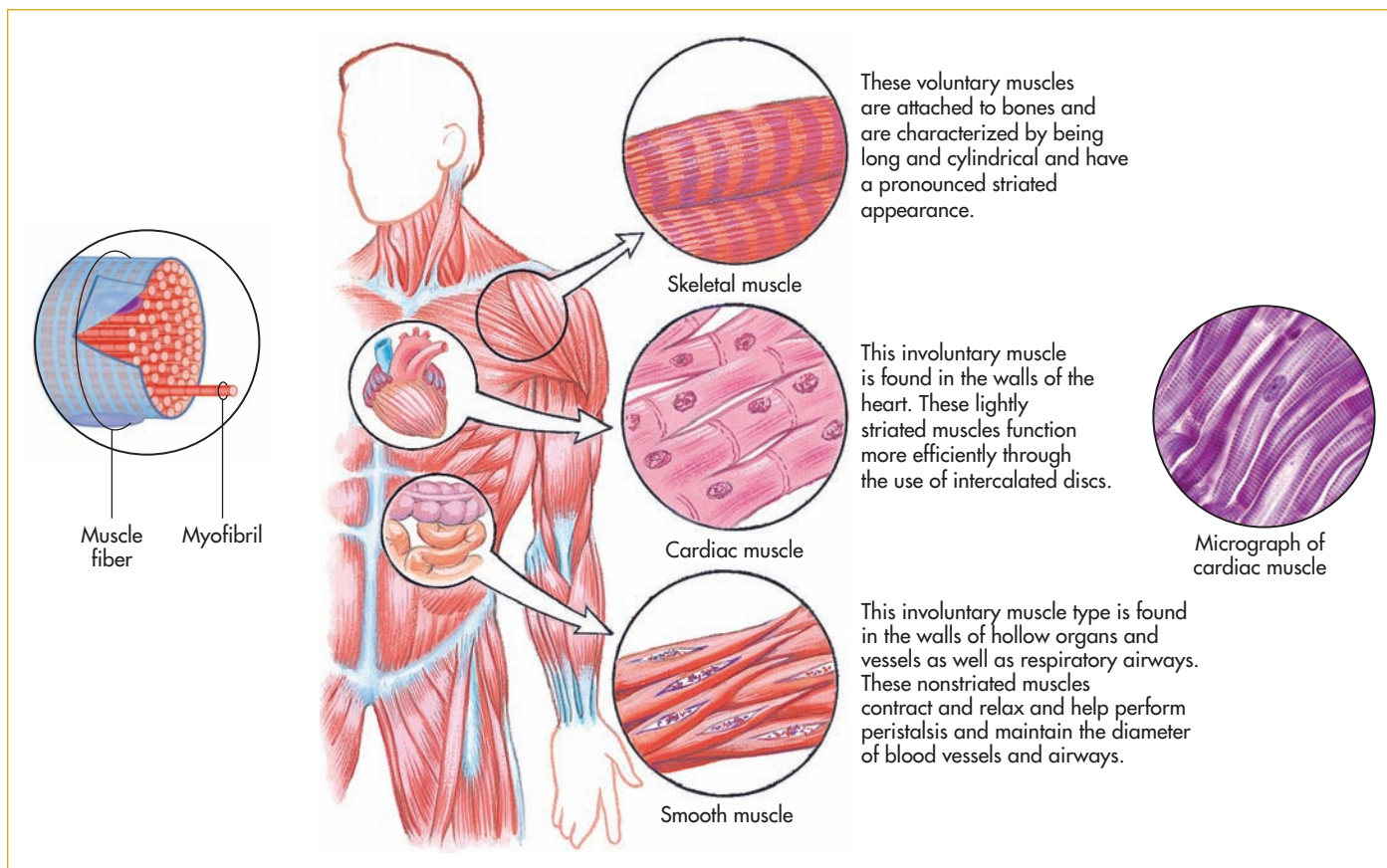


FIGURE 7-1 ■

The three types of muscle: Skeletal, cardiac, and smooth.

Clinical Application

MUSCLE TONE

Have you ever had a cast on for an extended period of time? When it is removed, the arm or leg is much smaller and weaker than the limb without the cast. Why does this occur? Normally, all muscles exhibit muscle tone (tonus). **Tonus** is the partial contraction of a muscle with a resistance to stretching. Athletes who exercise regularly have increased muscle tone, making their muscles more pronounced. The muscle fibers in an athlete increase in diameter (*hypertrophy*) and become stronger. **Hypertrophy** refers to increased growth or development. When muscles are

not used, they begin to lose their tone and become flaccid (soft and flabby). For example, if a patient is required to remain in bed (bedfast) for an extended period of time, his or her muscles waste away (**atrophy**) from the lack of use. One of the reasons patients are encouraged to get out of bed as soon as possible is to prevent atrophy from occurring. If skeletal muscle is damaged, it can regenerate itself, though not as well as bone or epithelium. However, if the damage is extensive, then a scar forms.

SKELETAL MUSCLES

Skeletal muscles are attached to bones and provide movement for your body. Remember from Chapter 6, “The Skeletal System,” that **tendons** are fibrous tissues that usually attach skeletal muscle to bones and that **ligaments** attach bone to bone? Note that some muscles can attach to a bone or soft tissue without a tendon. Such muscles use broad sheets of connective tissue called **aponeuroses**. This type

of connection is found, for example, in some facial and abdominal muscles.

As mentioned earlier, skeletal muscle is known as voluntary muscle; this is because its movement can be controlled by conscious thought. The numerous skeletal muscles found throughout the body are responsible for movement, maintaining our body posture, and heat generation. **FIGURE 7-2** ■ shows some of the major skeletal muscles found in the human body.

TEST YOUR KNOWLEDGE 7-1

Choose the best answer:

- Muscle contraction is the ability of a muscle to
 - relax when there is no nerve impulse.
 - get smaller.
 - shorten with force.
 - recoil.
- Smooth muscle is found in all the following *except* the
 - airways.
 - digestive system.
 - blood vessels.
 - heart.
- Which types of muscles are striated?
 - smooth and cardiac
 - cardiac and skeletal
 - skeletal and smooth
 - smooth only
- Striations are
 - collagen strands that strengthen the muscle matrix.
 - tendons.
 - muscle cells.
 - stripes on muscles.
- Which characteristics are shared by all muscle types?
 - contractility
 - excitability
 - extensibility
 - all the above

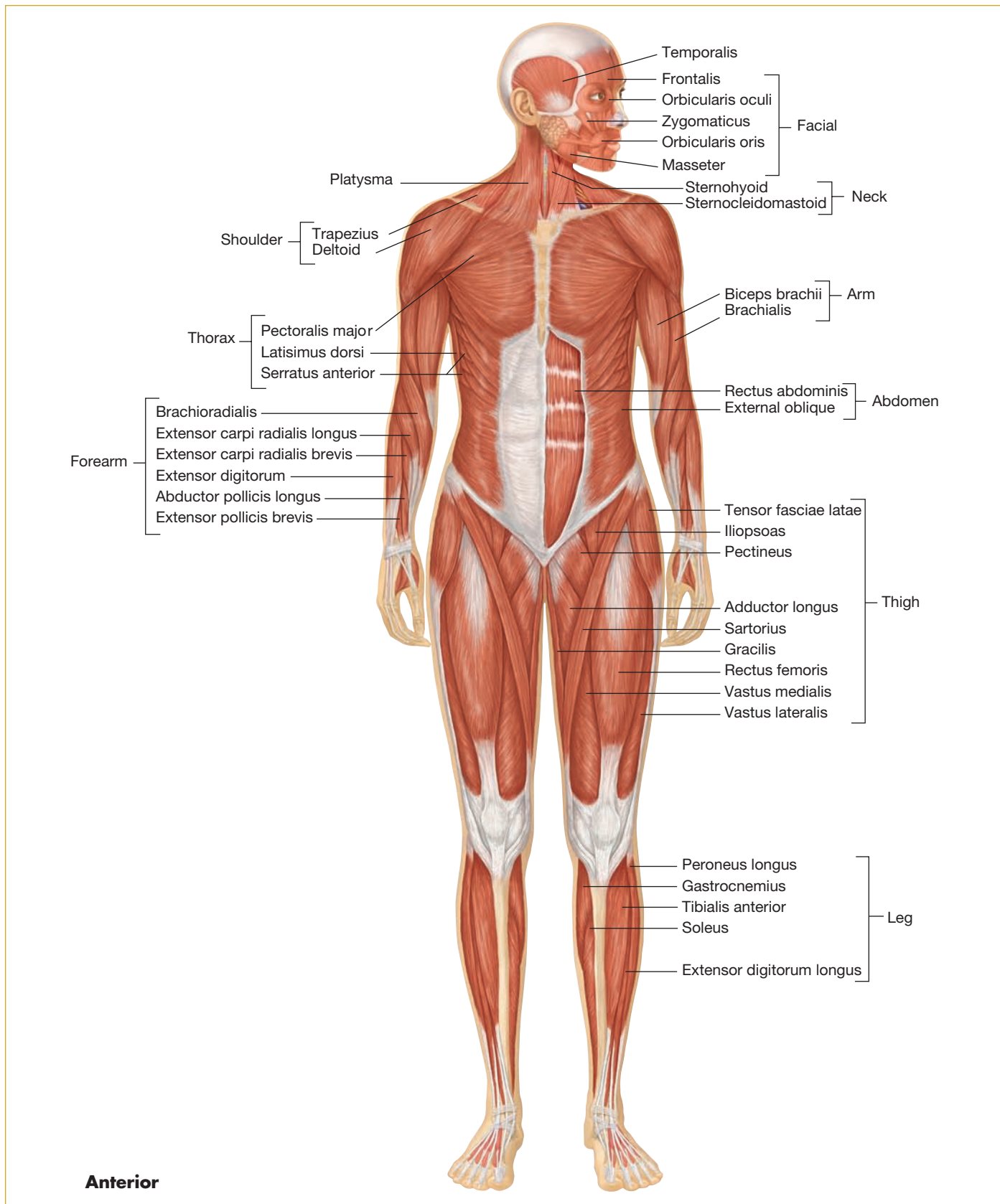


FIGURE 7-2 ■ Anterior and posterior view of major muscles.

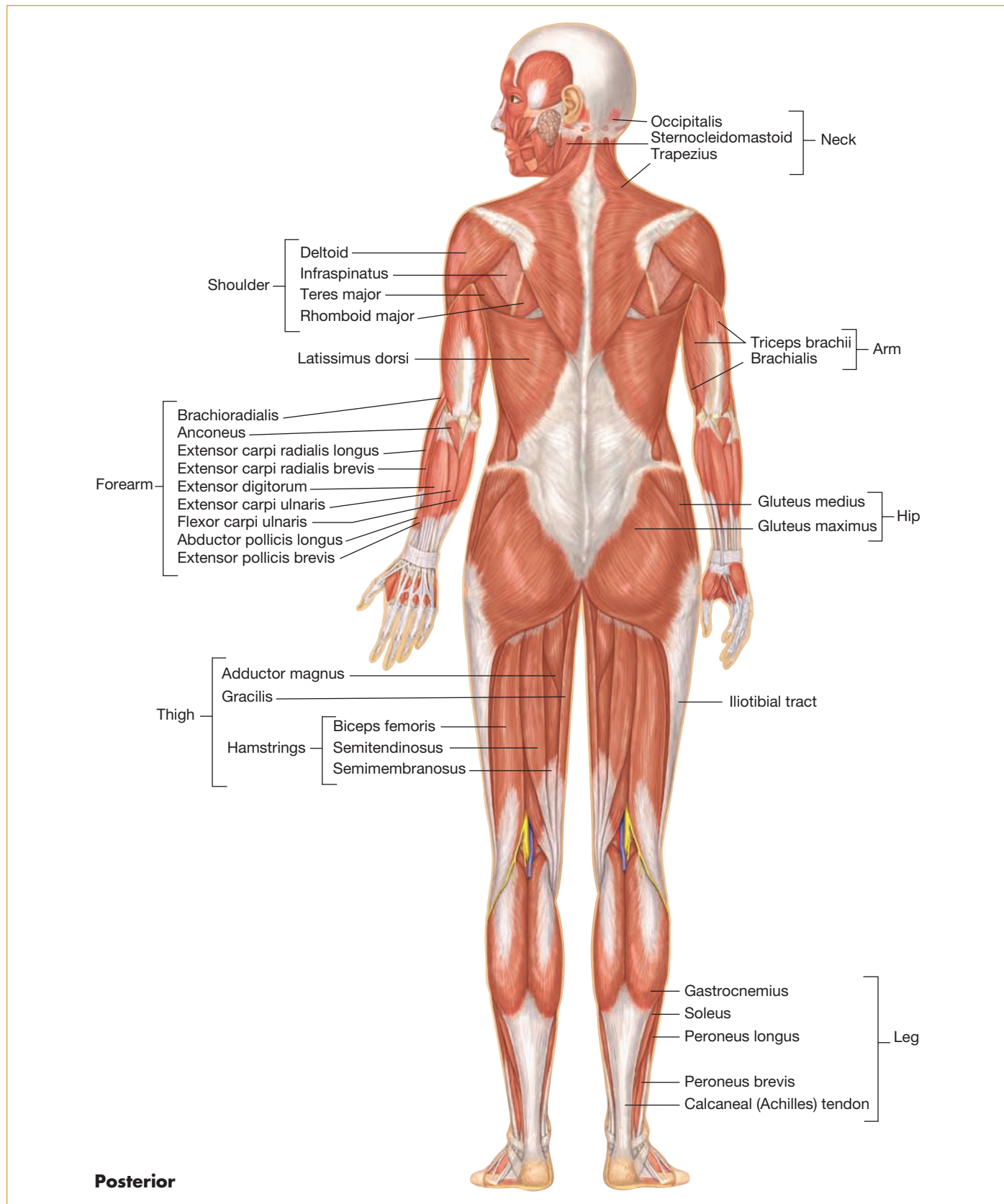


FIGURE 7-2 ■ (continued)

Skeletal Muscle Movement

The body requires several different types of movement to perform various tasks. This movement is accomplished through the coordination of the contraction and relaxation of different muscles.

Contraction and Relaxation

Body movement is a result of the contraction (shortening of the muscle fibers) of certain muscles, and the relaxation of others. Consider the act of bending your arm so your fingers touch your shoulder. To really learn the concept, actually bend your arm and touch your fingers to your shoulder while resting your other hand on your biceps muscle. To do this, your forearm is drawn to your shoulder as a result of the contraction of your biceps brachii. Did you feel the shortening and bulging of the biceps brachii? Muscles, either by themselves or in muscle groups that cause movement, are known as **agonists**, or **primary movers**.

The chief muscle causing the movement is the primary mover—in this example, the biceps muscle. Typically, as

your muscle contracts, one of the bones will move (lower forearm) while the other (humerus) will remain stationary. The end of the muscle that is attached to the stationary bone is the **point of origin**, and in this example, it is at the shoulder area. The muscle end that is attached to the moving bone is the **point of insertion**. It is near the elbow (see **FIGURE 7-3** ■). The action of the primary mover is to move the point of insertion toward the point of origin as the muscle contracts.

Other muscles can assist this movement, such as some of the muscles in the hands and wrist. These are called **synergistic** muscles because they assist the primary mover. (The brachioradialis muscle is a synergist to the biceps brachii because it also flexes the elbow.) To straighten that same arm requires you to relax your biceps muscle and to contract your triceps muscles. Because these muscles cause movement in the opposite direction when they contract, they are called **antagonists**. This brings us to an important concept. All movement is a result of contraction of primary movers and relaxation of *opposing* muscles. In our example, you cannot forcefully contract the biceps muscles and straighten your arm. Try it.

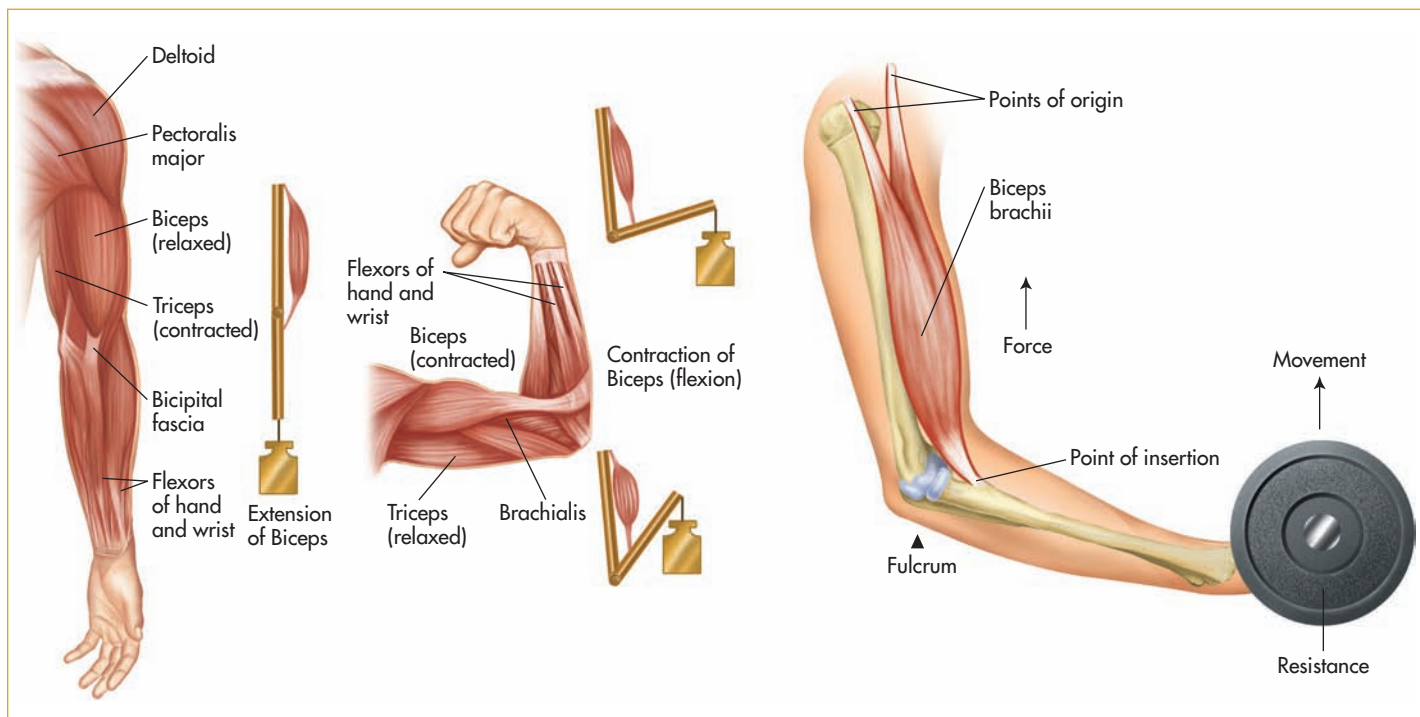


FIGURE 7-3 ■

Coordination of antagonist muscles to perform movement.

One very important skeletal muscle that controls our breathing is the **diaphragm**. This dome-shaped muscle separates the abdominal and thoracic cavities and is responsible for performing the major work of bringing air into our lungs. Exactly how this process occurs is discussed in detail in Chapter 14, “The Respiratory System.” The diaphragm is unique in that it is under both voluntary and involuntary control. You don’t have to think each time you breathe, but you can voluntarily change the way you breathe. **FIGURE 7-4** ■ shows the major muscle of breathing.

Movement Terminology

Certain terms are utilized to describe the direction of body movement. In Chapter 6, we discussed movement as it relates to joints in the skeletal system. In this chapter, we briefly discuss movement as it relates to muscles. (Because muscles move joints, the movement terminology is the same, but it’s worth reviewing it again.) **Rotation** describes circular movement that occurs around an axis. Rotation occurs, for example, when you turn your head from left to right or right to left. **Circumduction** is the movement of a limb in a circle. Making arm circles is an example of circumduction. **Abduction** means to move *away* from the midline of the body.

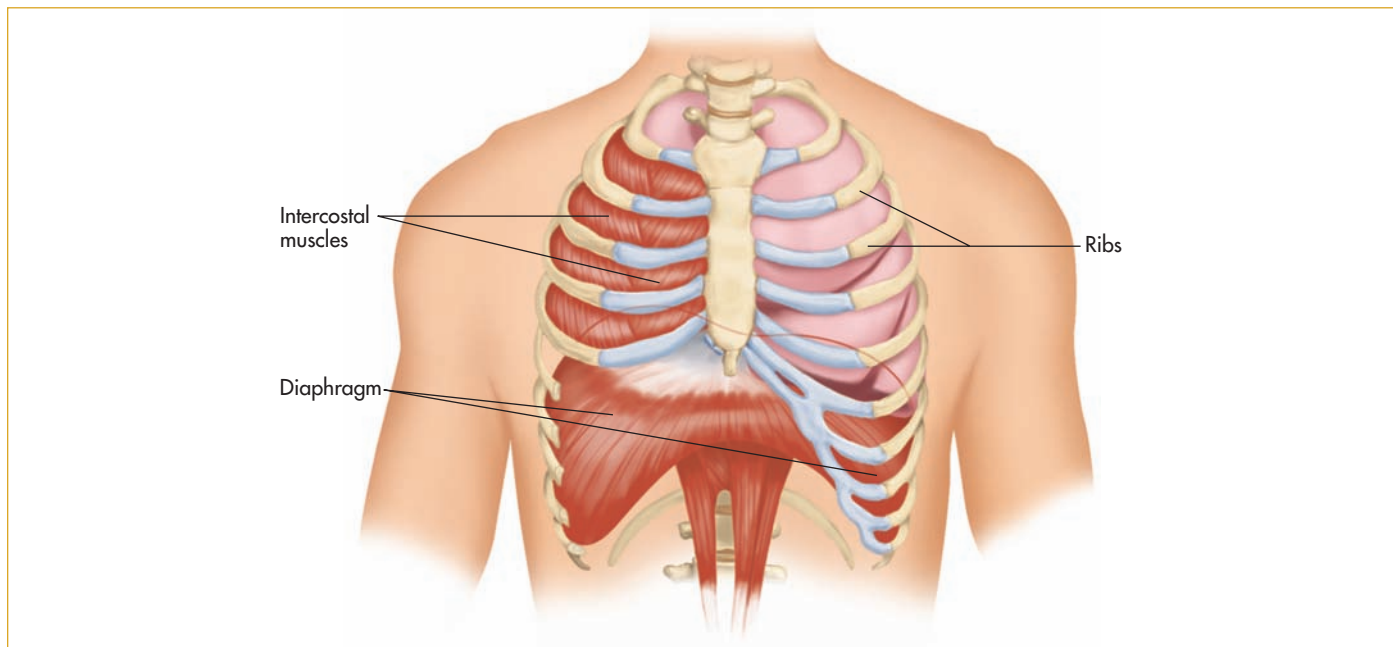


FIGURE 7-4 ■
The diaphragm: The major muscle of breathing.

Clinical Application

LAUGHING UNTIL IT HURTS

Why is it you can get a pain in your side from hard laughing or running too long? This is because when you are breathing in deeply, your lungs push down on your diaphragm while your abdominal muscles are

contracting and pushing up on the diaphragm at the same time. The repeated compression on your diaphragm is what causes a muscle spasm known in lay terms as a “runner’s stitch.”

FOCUS ON PROFESSIONS



Kinesiology is the study of muscles and movement. A kinesiologist is one who studies movement and can perform therapeutic treatment (kinesiotherapy) utilizing specific movements or exercises. Learn more about these specialties within the field of kinesiology by visiting the websites of national associations such as the American Kinesiology Association (AKA) and the National Association of Kinesiology and Physical Education in Higher Education (NAKPEHE).

When you raise your arm to point when giving directions, you are performing abduction. **Adduction** occurs when you produce a movement that moves *toward* the midline of the body. When you bring your arm back down to your side from pointing, you are performing adduction.

Extension is a term used for *increasing* the angle between two bones connected at a joint. Extension is needed when you kick a football. In this situation, extension occurs when your leg straightens during the kick. The muscle that

straightens the joint is called the **extensor muscle**. **Flexion** is the opposite of extension. In this situation, you *decrease* the angle between two bones. Flexion occurs when you bend your legs to sit down. Flexion and rotation occur when you get your arm into position to arm wrestle. The muscle that bends the joint is called the **flexor muscle**. In this case, a picture is worth a thousand words or at least the 124 words used to explain these concepts. **FIGURE 7-5** ■ illustrates these movements.

TEST YOUR KNOWLEDGE 7-2

Give the correct body movement term for the following activities:

1. Looking right and left at a stop sign _____
2. The first movement in curling a weight _____
3. Returning the weight from the curled position to your side _____

Complete the following:

4. The muscle that causes a movement is the _____.
5. The muscle attachment that does not move during muscle action is the _____.
6. The science of muscles and their movement is termed _____.

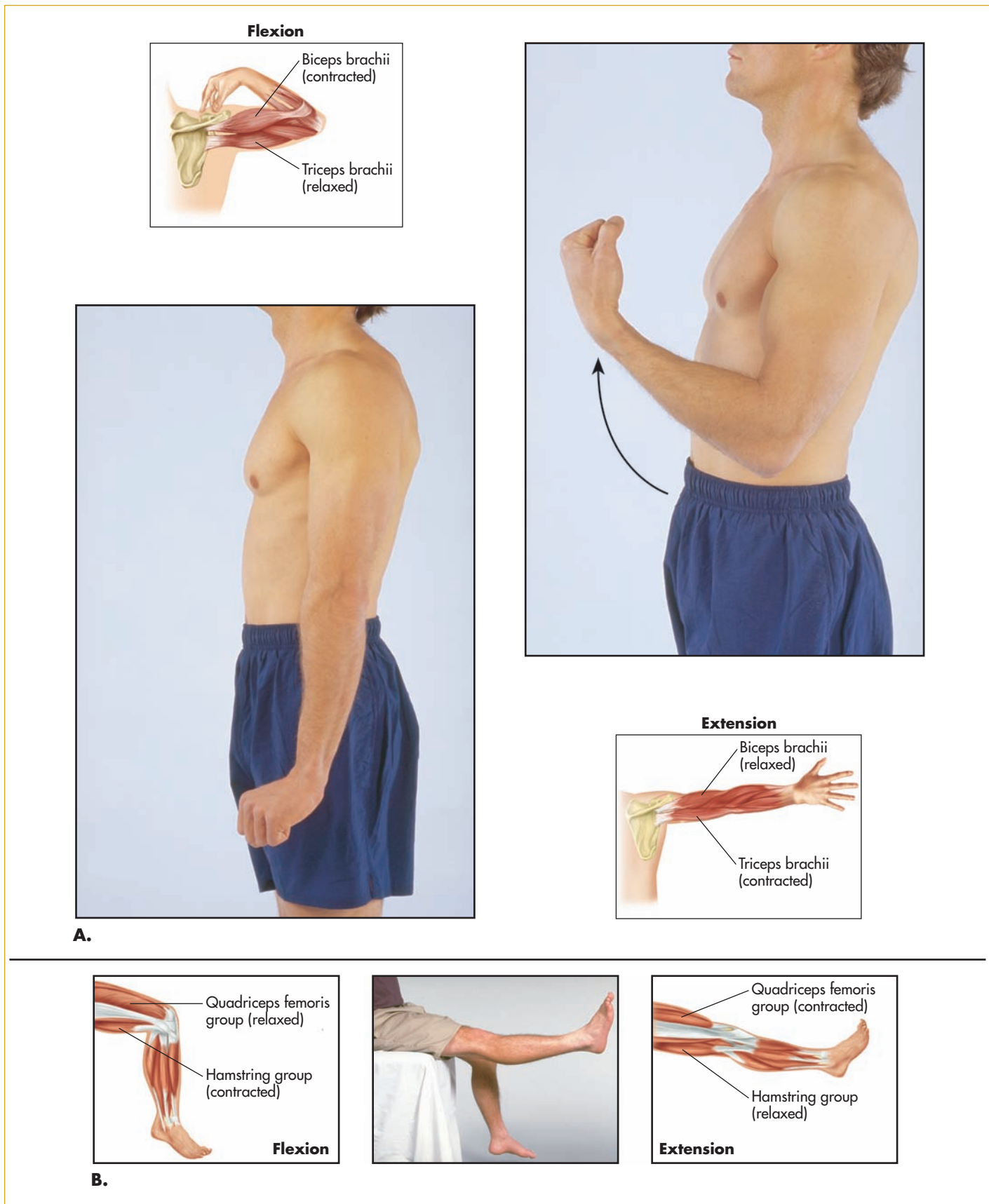


FIGURE 7-5 ■ The types of skeletal movement. (A) Flexion and extension of left forearm. (B) Flexion and extension of the leg.

MUSCULAR MOVEMENT AT THE CELLULAR LEVEL

Exactly how are muscular contraction and relaxation accomplished? How does the muscle tissue cause a coordinated and smooth contraction? Let's look in more detail at how muscles work.

The Functional Unit of the Muscle

Skeletal muscles look very simple if you examine only their macroanatomy. However, if you look deep into a skeletal muscle, it is divided into several layers of cylinders packed inside each other.

The typical muscle, like the biceps brachii, is surrounded by connective tissue, continuous with the tendon, called **epimysium**. Inside the muscle are bundles of muscle fibers (cells) surrounded by **perimysium**. The bundles are called **fascicles**.

The muscle fibers themselves are elongated cells up to 12 inches, or 30 centimeters, in length. Each muscle fiber is encased in a connective tissue sheath called **endomysium** and is filled with cylinders called **myofibrils**. The myofibrils are like a strand of metal, and these strands of metal can be put together to form a cable, which would be a muscle segment (see **FIGURE 7-6A** ■).

For contraction to take place, each fiber must possess many functional contractile units called **sarcomeres**, which are

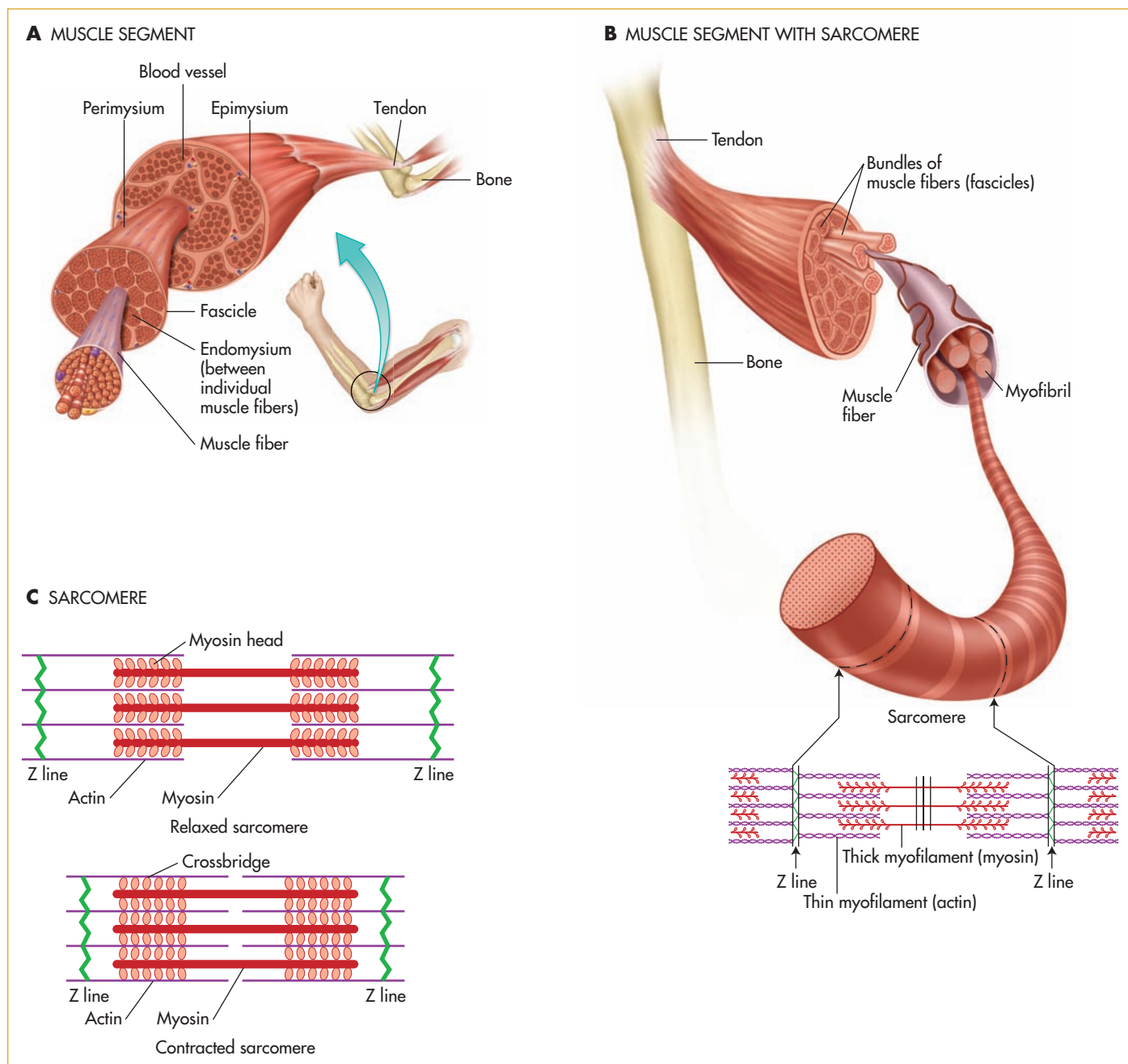


FIGURE 7-6 ■ (A) The muscle segment. (B) The muscle segment with sarcomere. (C) Relaxed and contracted sarcomeres.

subunits of the myofibrils. Each fiber has the ability to contract because of the makeup of the sarcomere. Each sarcomere unit has two types of threadlike structures called thick and thin *myofilaments*. The thick myofilaments are made up of the protein **myosin**, and the thin ones are primarily made up of the protein **actin**. The sarcomere has the actin and myosin filaments arranged in repeating units separated from each other by bands called **Z lines**, which give the striated appearance to skeletal muscle. The arrangement of the myofilaments cause the striations on skeletal muscle (see Figure 7–6B and C).

In addition, muscle fibers have several other modifications for contraction, including the **sarcolemma**, a specialized cell membrane; the **sarcoplasmic reticulum (SR)**, which is a modified endoplasmic reticulum that stores calcium; and **T-tubules**, which help spread excitation into the inside of the cell (see **FIGURE 7-7** ■).

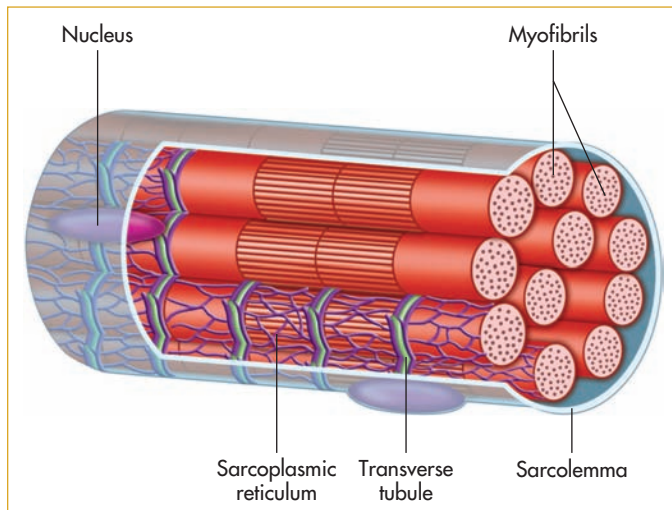


FIGURE 7-7 ■

The distribution of the sarcoplasmic reticulum and tubules around myofibrils of skeletal muscle.

The Mechanism of Muscle Contraction

Note in Figure 7–6C that the contraction of a muscle causes the two types of myofilaments to slide toward each other, shortening each sarcomere and therefore the entire muscle. Picture a tube sliding within a tube, such as on a trombone. This sliding filament action and corresponding contraction requires that temporary connections, or cross-bridges, be formed between the thick filament (myosin) heads and the thin filaments (actin) to pull the sarcomere together. When a muscle is relaxed, these cross-bridges do not form. In order for muscle to contract, the muscle must be stimulated. Just how does that happen?

A chemical signal called a **neurotransmitter**—in this case, **acetylcholine**—is released from the nervous system. (This will be discussed in more detail in Chapter 9, “The Nervous System (Part I)”.) The acetylcholine binds to specialized areas

on the sarcolemma and opens channels that let sodium ions enter the muscle cell. This excites the muscle. When the muscle is excited, calcium is released from the sarcoplasmic reticulum (SR) and flows into the cytoplasm of the muscle fiber.

Remember that the relaxed muscle has no cross-bridges? The calcium released allows these cross-bridges to form so the muscle can contract. When the cross-bridges form, the myosin heads rotate and pull the actin toward the center of the sarcomere. But the myosin doesn’t make cross-bridges only once; it does it repeatedly, binding and unbinding until the actin filaments overlap (see Figure 7–6C). The whole sarcomere is shorter.

When the sarcomere relaxes, the filaments return to their resting or relaxed position. Visualize a raised drawbridge, where cars cannot pass. To be functional, the cross-connection—or lowering of the drawbridge—must occur, similar to the cross-bridges needed for a muscle contraction. This model of skeletal muscle contraction is aptly called the *sliding filament–cross-bridge* model. Consider however, that a toll must be paid for the bridge to lower and connect. The body’s toll is **adenosine triphosphate (ATP)**, which provides the energy to help the myosin heads form and break the cross-bridges with actin.

How does the muscle stop contracting? Acetylcholine is broken down by an enzyme **acetylcholinesterase** (*ase* = to break down), the muscle fiber is no longer excited, so the calcium is pumped back into the SR, the cross-bridges are broken, and the muscle relaxes.

Have you ever heard of a dead body rising from a table or showing signs of movement? This may sound like the opening for a movie about zombies or the “undead.” Actually, it is a normal physiologic process called **rigor mortis** that can be explained by science and not by science fiction.

When a body dies, all the stored calcium cannot be pumped back into the sarcoplasmic reticulum. Therefore, excess calcium remains in the muscles throughout the body and causes the muscle fibers to shorten (contract) and stiffen the whole body. In addition, ATP is not present in a dead body to break the cross-bridges. This stiffening process of the entire body is termed *rigor mortis*.

APPLIED SCIENCE

Interrelatedness of Neuromuscular System

Contraction of a skeletal muscle requires the coordination of both the muscular and nervous systems. The initiation of a skeletal muscular contraction requires an impulse from a motor neuron of the nervous system to trigger a release of the neurotransmitter acetylcholine (ACh), which opens the sodium channels and sets the process of muscle contraction into motion. This all occurs at the neuromuscular junction. The nervous system’s role in this action and the neuromuscular connection are fully explored in Chapters 9 and 10.

LEARNING HINT

Muscle Contraction Step by Step

1. Acetylcholine, a neurotransmitter, is released from a neuron.
2. Acetylcholine binds to muscle and causes sodium channels to open. Sodium flows into the muscle fiber, and the fiber becomes excited.
3. The excitement of the muscle fiber causes calcium to be released into the cytoplasm from the sarcoplasmic reticulum.
4. The calcium allows the forming of cross-bridges between myosin heads and actin myofilaments.
5. Adenosine triphosphate (ATP) is used up, allowing cross-bridges to break and reform, pulling the actin myofilaments closer together as they slide along the myosin myofilaments. The sarcomere shortens.
6. Many shortened sarcomeres result in shortening of many muscle fibers. This is muscle contraction.
7. Acetylcholinesterase degrades acetylcholine so the muscle can relax.

TEST YOUR KNOWLEDGE 7-3

Fill in the blank.

1. The thin myofilament needed for muscle contraction is composed of _____.
2. The two ingredients needed for cross-bridges to form and break are _____ and _____.
3. The fundamental unit of muscle contraction is the _____.
4. Sodium flowing into muscle fibers is triggered by the binding of _____ released from neurons.
5. During contraction _____ heads bind to _____ myofilaments.
6. The neurotransmitter substance responsible for skeletal muscle contraction is _____.

FOCUS ON PROFESSIONS



Not only do the skeletal muscles facilitate movement but, integrated with the nervous system, they provide support for posture while standing or sitting. Promoting balance and posture, along with proper muscle function, is one of the responsibilities of **physical therapists**. These professionals, referred to as PTs, perform many therapies, such as range of motion (ROM) exercises, to ensure full muscle movement. **Occupational therapists** (OTs) assist clients in using and adapting their muscle function to perform activities of daily living and improving their quality of life. Learn more about these professions by visiting the websites of national associations such as the American Physical Therapy Association (APTA) and the American Occupational Therapy Association (AOTA).

MUSCULAR FUEL

Muscle, like all tissue, needs fuel in the form of nutrients and oxygen to survive and function. The body stores a carbohydrate called **glycogen** in the muscle. Glycogen is always on reserve waiting to be converted to a usable energy source. When needed, the muscle can convert glycogen to **glucose**, which releases energy for the muscle to function. Remember cellular respiration from Chapters 3 and 4? Your cells must have glucose to make adenosine triphosphate (ATP) efficiently. Muscles with very high demands (such as leg muscles) also store fat and use it as energy. The release of energy also produces heat, and this is why strenuous or prolonged exercises can overheat our bodies.

The higher-demand muscles not only use fat as an energy source, but they also have a much richer blood supply than do less demanding muscles. These muscles are needed for endurance, such as required by long-distance running. The richer blood supply carries extra oxygen to hardworking muscles, giving those muscles a darker color.

Some muscles, such as those in the hand, have fewer heavy demands placed on them and need only a small supply of blood. They therefore have a lighter color. These muscles are faster but do not have the endurance capabilities that heavily used muscles have. Next time you take a long walk, keep pumping your hand. Although the muscles in the hand can move faster than the leg muscles, they will tire more quickly.

Another example can be found in birds. Chickens, because the breast and wing muscles are not heavily used, have white meat breasts and wings. The legs, however, endure constant use, and the meat is therefore dark. By contrast, a woodcock,

a migratory bird that must fly long distances (endurance), has dark breast meat. Now you know why a chicken's breast meat is white. When is the last time you saw a chicken flying overhead?

APPLIED SCIENCE

Maintaining a Core Body Temperature

Not only do muscles produce movement, but they also help maintain posture, stabilize joints, and produce heat. Producing heat is important in maintaining the body core temperature. As the energy-rich ATP is used for muscle contraction, three-fourths of its energy escapes as heat. This process helps maintain body temperature by producing heat when muscles are utilized. This is why your temperature rises when exercising and also why you shiver when you are very cold. Shivering is your body's way of saying it is too cold, and it needs to generate a lot of heat via many muscle contractions (shivering). In turn, this increases the body temperature.

SKELETAL MUSCLES OF SPECIFIC BODY REGIONS

Many times on a journey, we need a road map for reference. These road maps are often big maps of an entire state. However, there are also inserts of specific cities that give much greater detail. Think of Figure 7–2 as our “state map” of the anterior and posterior major muscles. The following series of “city maps” will provide you with greater detail. See **TABLE 7-1** for specific information about selected muscles.

LEARNING HINT

Muscle Names

There are several ways to name muscles. If you remember these examples, you will have an easier time remembering the muscles. Muscles can be named based on any of the following criteria:

1. Muscle location (Example: Biceps brachii is in the arm. Brachii = arm.)
2. Number of origins (Example: Biceps brachii has two origins. Biceps = two heads.)
3. Action (Example: Adductor longus adducts the thigh.)
4. Size (Example: Gluteus maximus. Maximus = biggest.)
5. Location of attachments (Example: Brachioradialis. Radialis refers to the radius.)
6. Shape (Example: Deltoid is triangular. Delta = triangle.)
7. Direction of fibers (Example: External oblique. Oblique = angled.)
8. Combination (Example: Pectoralis major. Pectoral = chest, major = big.)

TABLE 7-1 MAJOR MUSCLES: ORIGINS, INSERTIONS, AND ACTIONS

MUSCLE NAME	MUSCLE LOCATION	MUSCLE ORIGIN	MUSCLE INSERTION	MUSCLE ACTION
Biceps brachii	anterior upper arm	scapula	radius	flexes arm at the elbow
Triceps brachii	posterior upper arm	proximal humerus & scapula	posterior ulna (proximal)	extends arm at the elbow
Orbicularis oculi	encircles eye	frontal, maxilla, and orbit	eyelid	closes eyelid
Masseter	jaw or mandible	zygomatic arch	mandible	closes jaw
Sternocleidomastoid	anterolateral neck	sternum & clavicle	mastoid process	flexes and rotates head
Pectoralis major	chest	clavicle, ribs, sternum	proximal humerus	flexes, rotates, and adducts arm
Deltoid	shoulder	clavicle & scapula	proximal humerus	abducts arm
Intercostals:	between ribs			assist in ventilation
external		inferior rib	superior rib	elevate rib cage
internal		superior rib	inferior rib	depress rib cage
Diaphragm	floor of thoracic cavity	inferior rib cage & sternum	central tendon	prime mover of inspiration
Gluteus maximus	buttocks	ilium, sacrum, & coccyx	proximal femur	extends thigh
Hamstring group	posterior portion of thigh	ischium	tibia	flexes leg at knee
Quadriceps group	anterior portion of thigh	pelvis	patella & tibia	extends leg at knee
Tibialis anterior	anterior of lower leg	proximal tibia	metatarsals	dorsiflexes foot
Gastrocnemius	main muscle of calf (posterior lower leg)	distal femur	calcaneus via calcaneal (Achilles) tendon	plantar flexes foot
Vastus lateralis	anterior thigh	femur	tibia	extends the leg; also used as site for injections

TEST YOUR KNOWLEDGE 7-4

Fill in the blank.

- The _____ are the primary knee flexors.
- The _____, knee extensors, originate on the _____ and insert on the _____ and _____.

(continued)

TEST YOUR KNOWLEDGE 7-4 (continued)

3. The _____ originates on the sternum and clavicle and inserts on the mastoid process.
4. This muscle inserts via the Achilles tendon _____.
5. The _____, an elbow flexor, is the antagonist of the _____, an elbow extensor.
6. Ben is in the middle of the Olympic trials for the 400-meter hurdles when he falls to the ground, clutching his leg. Upon examination he has pain in the posterior thigh and cannot flex his knee. Which muscles are injured?

7. The muscle in the leg used for an injection site is _____.

Facial Skeletal Muscles

Please see **FIGURE 7-8** ■, which shows the facial skeletal muscles.

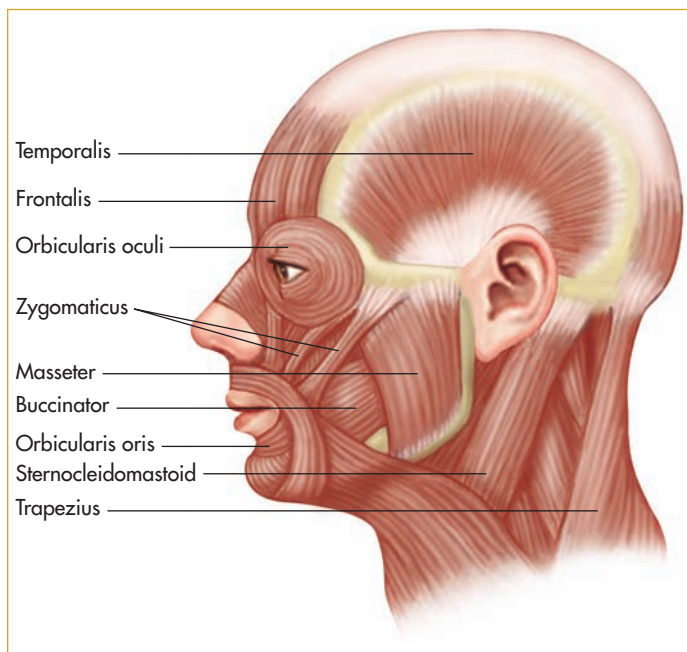


FIGURE 7-8 ■
Skeletal facial muscles.

Anterior and Posterior Trunk Skeletal Muscles

Now, take an in-depth look at the muscles of the anterior and posterior trunk of the body in **FIGURE 7-9** ■.

Skeletal Muscles of the Arm and Shoulder

Moving out to the peripheral area of the body, we now zoom in on the skeletal muscles of the hand, arm, and shoulder in **FIGURE 7-10** ■.

Skeletal Muscles of the Legs

We finish our tour with the skeletal muscles of the hip and leg in **FIGURE 7-11** ■.

FOCUS ON PROFESSIONS

With physical activity and the daily stress of life, muscles often become sore and fatigued. **Massage therapists** work directly on the muscles to aid in their relaxation and optimal functioning. Massaging techniques help stimulate blood flow and relax tense muscles. Learn more about this profession by visiting the website of national organizations, such as the National Association of Massage Therapists (NAMT), the American Massage Therapy Associations (AMTA), and the National Association of Nurse Massage Therapists (NANMT).

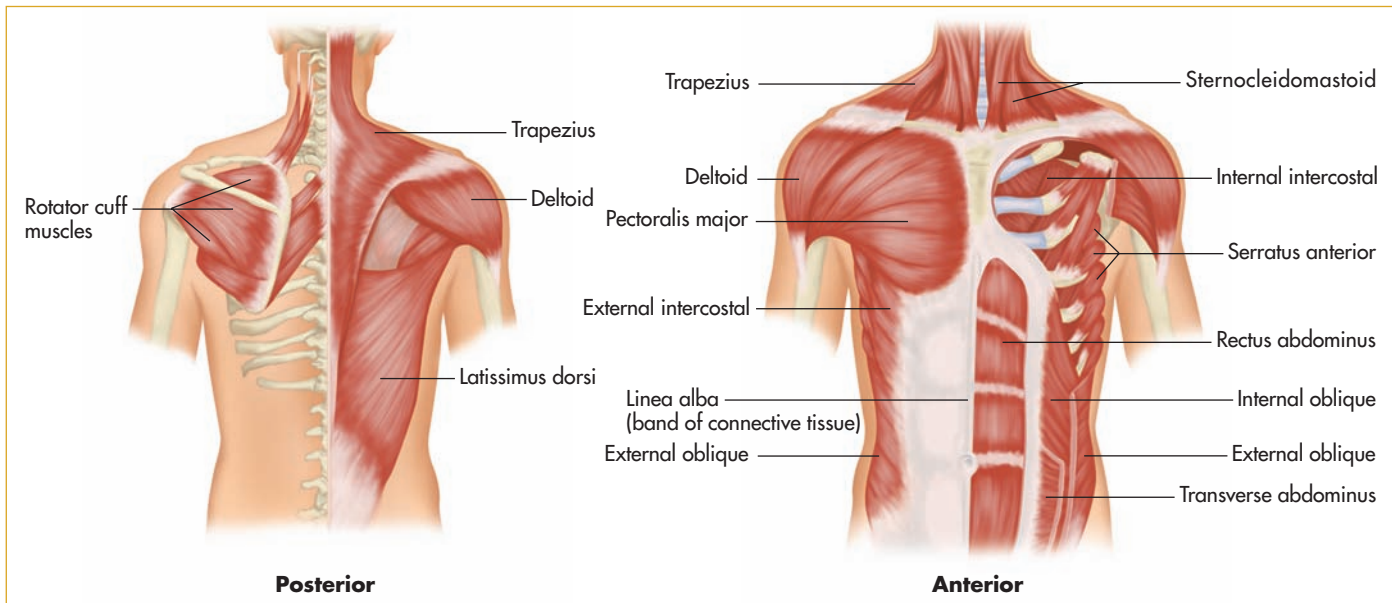


FIGURE 7-9 ■
Skeletal muscles of the posterior and anterior trunk.

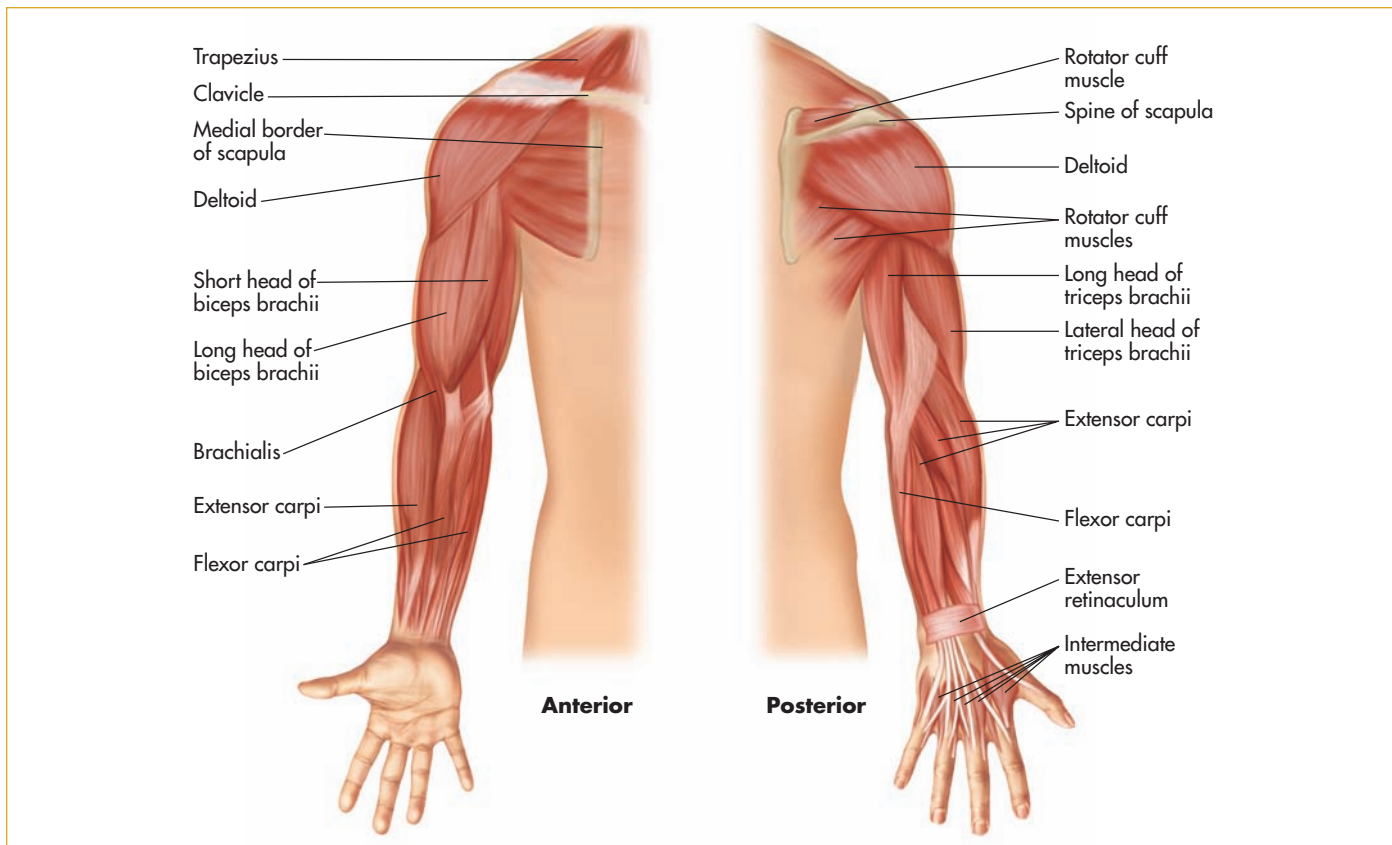


FIGURE 7-10 ■
Skeletal muscles of the shoulder, arm, and hand.

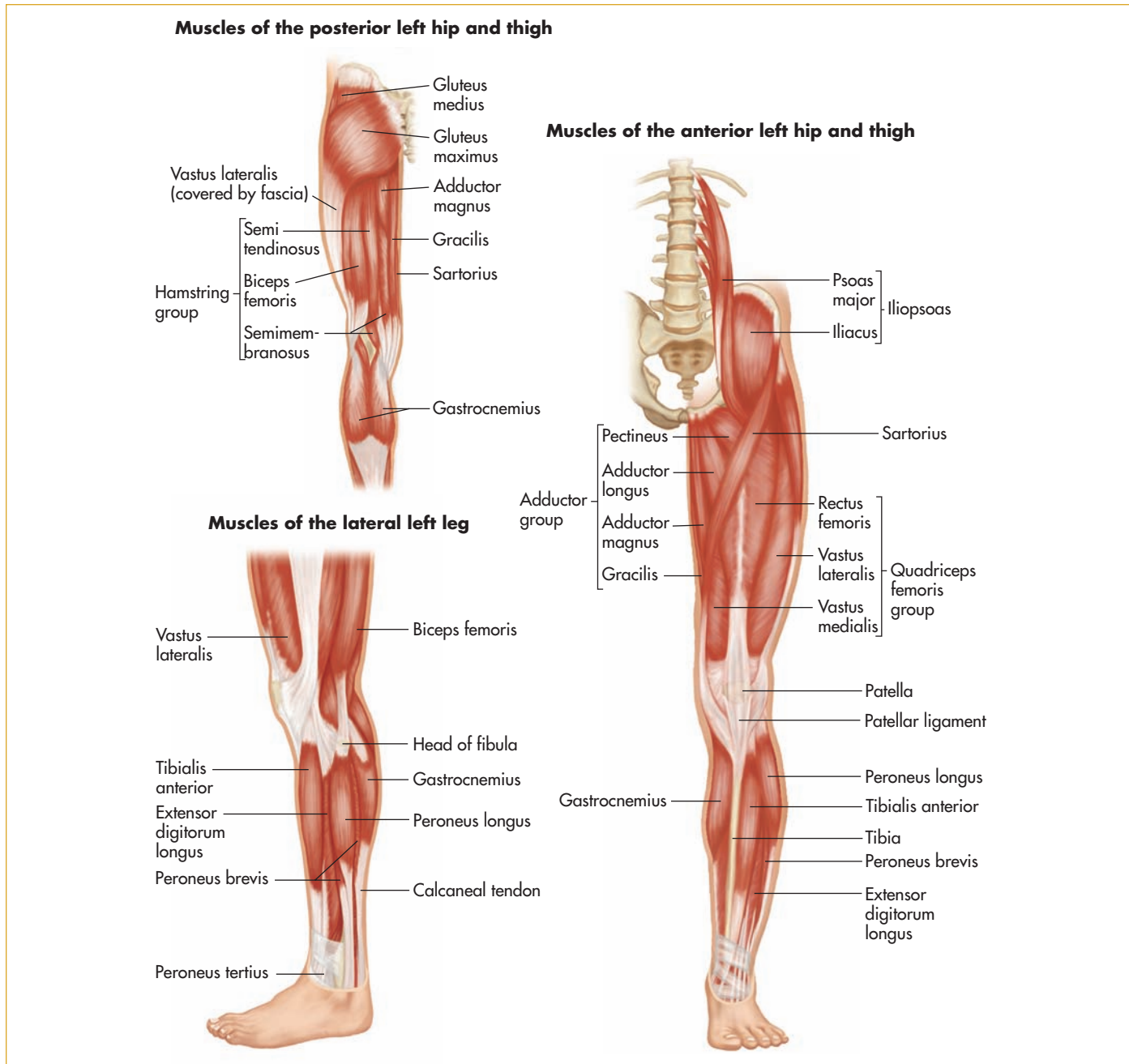


FIGURE 7-11 ■ Skeletal muscles of the hip and leg.

VISCERAL OR SMOOTH MUSCLE

We introduced the concept of smooth muscle earlier in this chapter; now let's take a closer look. **Visceral muscle**, or **smooth muscle**, is found in all the organs (except the heart) of the body, such as the stomach and other digestive organs, the uterus, and the blood vessels and bronchial airways. Smooth muscle's ability to contract and return to a relaxed state plays a vital role in many of the body's internal workings. For example, the vital sign blood pressure

can be affected by whether the blood vessels get larger in diameter (**vasodilation**) or get smaller in diameter (**vasoconstriction**). Vasodilation can lead to decreases in blood pressure due to smooth muscle relaxation in the vessel that allows it to enlarge. The enlarged vessel has less resistance to flow, and the blood pressure therefore goes down. Conversely, vasoconstriction can cause increased blood pressure due to the smooth muscle contraction that restricts the blood vessel.

As another example, during an asthma attack, smooth muscles in the airways of the lungs constrict, making it difficult to get air into and out of the lungs. This is what causes the wheezing sound heard during an attack.

Special structures composed of smooth muscle, called **sphincters**, are found throughout your digestive system. These donut-shaped muscles act as doorways to let materials in and out by alternately contracting and relaxing. For example, two sphincters in the stomach act like doors. One opens to allow food in from the esophagus, and another opens to allow food into the small intestine. Have you ever swallowed a large amount of bread or stuffing and had it get stuck on the way down to your stomach? This is a painful reminder that there is a sphincter that must relax and open to allow food to enter your stomach. The muscles of the digestive system are discussed in greater depth in Chapter 16, “The Gastrointestinal System.”

LEARNING HINT

Smooth Muscle Regulation of Blood Pressure

In considering blood pressure, visualize a large highway. If one lane is taken away (vasoconstriction), the same number of cars must now fit through one less lane, leading to traffic congestion (increase in pressure). If you open up another lane (vasodilate), you relieve some of this pressure.

Smooth, or visceral, muscles are involuntary muscles and do not contract as rapidly as skeletal muscles. Skeletal muscles, once stimulated, can contract 50 times faster than smooth muscle. Because of their slower activity and lower metabolic rate, smooth muscles receive only moderate

amounts of blood. Once injured, smooth muscle rarely repairs itself and, instead, forms a scar.

CARDIAC MUSCLE

Cardiac muscle forms the walls of the heart. The rhythmic contraction of cardiac muscle squeezes blood out of the chambers of the heart, causing the blood to circulate through your body. Cardiac muscle is an involuntary muscle. Remember, this means that we don't have to consciously think about making our heart contract every time we need a heartbeat. Cardiac muscle fibers are somewhat shorter than the other muscle types, but they are striated like skeletal muscle. Because the heart must work constantly until you die, the cardiac muscles must receive a generous blood supply via the coronary arteries to get enough oxygen and nutrition, as well as to get rid of waste. In fact, cardiac muscle has a richer supply of blood than any other muscle in the body. The cardiac muscle fibers are connected to each other by **intercalated discs**. Because of this connection, as one fiber contracts, the adjacent one contracts, and so on. This is similar to the domino effect or the human wave at a football stadium if done correctly. A wave of contraction occurs, allowing blood to be squeezed out of the heart and into the body. This directed wave is important for a full and effective emptying of the blood within the heart. Imagine if everyone squeezed the tube of toothpaste in the middle: Think of all the wasted toothpaste that would be left in the tube and how happy the toothpaste manufacturers would be. See **FIGURE 7-12** ■.

Cardiac muscle does not regenerate after severe damage; this leads to tissue death known as **necrosis**, such as what occurs in a severe heart attack. If the blood supply going

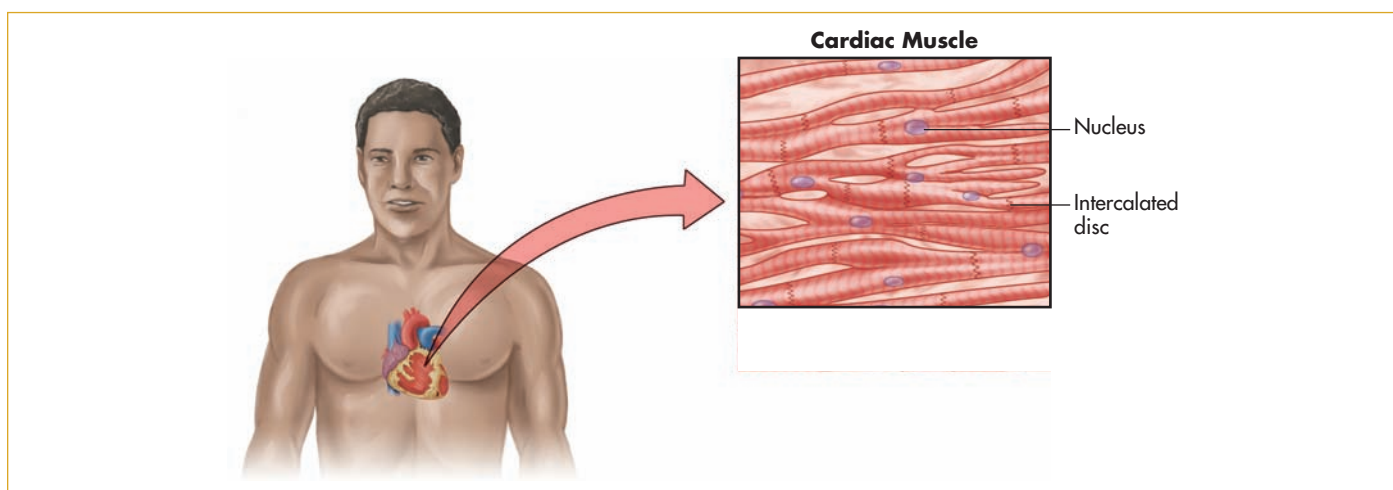


FIGURE 7-12 ■
Heart and intercalated discs.

to the heart from the coronary arteries is blocked, cardiac muscle damage can occur, causing scarring of the heart. Scar tissue does not help the healthy muscles of the heart to contract. If the scarred area is extensive, the remaining cardiac muscle may not be sufficient to pump blood efficiently. An individual with scarred cardiac muscle may have a severely diminished cardiac output, which could lead to severe disability or even death.

COMMON DISORDERS OF THE MUSCULAR SYSTEM

Because there are so many muscles covering the entire body and they are constantly being used, many disorders can occur within this system. Here are just a few examples. **Myalgia** means pain or tenderness in a muscle. **Fibromyalgia** may be one of the most common musculoskeletal disorders affecting women under age 40, but it is still not fully understood. Symptoms include aches, pains, and muscle stiffness with specific tender points on anatomical regions of the body. The exact cause is unknown, but evidence suggests that hypersensitivity to pain by the nervous system may be involved.

Ataxia is a condition in which the muscles are irregular in their actions or there is a lack of coordination. **Paralysis** is the partial or total loss of the ability of voluntary muscles to move. Sometimes it might be temporary; other times it might be permanent. A muscle that contracts involuntarily suddenly and violently for a prolonged period of time is said to have a **spasm**, or **cramp**. A spasm can occur in a single muscle or in a muscle group. **Sprains** are tears or, in severe cases, breaks in ligaments, whereas **strains** are tears or injury in muscles and tendons. A common running-related inflammatory condition of the connective muscles surrounding the tibia is called *medial tibial stress syndrome*, or, in lay terms, **shin splints**.

A **hernia** occurs when an organ or structure protrudes through the wall that normally contains it. For example, in an abdominal hernia a portion of an intestine may protrude through the muscle of the abdominal wall and become strangulated. **Tendonitis** is an inflammatory condition in which tendons may become damaged. **Muscular dystrophy** is an inherited muscular disease in which muscle fibers degenerate and there is progressive muscular weakness. Muscular disorders can be quantified by **electromyography (EMG)**, a test

in which a muscle or group of muscles are stimulated with an electrical impulse. This impulse causes a muscle contraction. The strength of that muscle contraction is then recorded. Certain diseases can alter the strength of muscles.

Due to the close integration of the two systems, several diseases involve both the *nervous* system and the *muscular* system—hence, the term **neuromuscular** disease. **Myasthenia gravis** is a neuromuscular disease in which the patient exhibits gradually increasing profound muscle weakness. The first symptom of this disease is often the drooping of one or both of the upper eyelids. There is also progressive paralysis. Interestingly, tendon reflexes almost always remain. **Guillain-Barré syndrome** is a disorder of the *peripheral* nervous system that causes *flaccid* paralysis (limp muscles) and the loss of reflexes. Interestingly, the paralysis is usually *ascending*, meaning that it starts in the feet or lower extremities and progresses toward the head. Paralysis usually peaks within 10 to 14 days. Eventually, most patients return to normal, although it may take several weeks or months.

Tetanus, on the other hand, creates rigid paralysis. With this disease, any type of minor stimulus can cause muscles to go into major spasm. The stimulus can be something as simple as a loud noise or turning on a light in a room. Tetanus is a result of toxins produced by the bacteria *Clostridium tetani* found in the ground and can be spread by any type of skin puncture, not just the “rusty nail” many were warned about when they were kids. Smooth and cardiac muscle conditions are discussed in upcoming chapters.

APPLIED SCIENCE

A Useful Application of a Deadly Toxin

Botulism is a potentially deadly disease caused by food poisoning with the *Clostridium botulinum* bacteria. The toxin decreases the release of acetylcholine, thereby decreasing stimulation of skeletal muscles. Science has found a way to utilize the poison generated by this bacteria for medical and cosmetic treatment. Small amounts of botulinum toxin are used to treat wrinkles without the use of surgery. The treatment is known as Botox. In addition to cosmetic applications, botulinum toxin injections are also used to treat several other disorders, including overactive bladder, migraines, chronic muscle spasms, cerebral palsy, excessive sweating (hyperhidrosis), and strabismus (eye misalignment).



SUMMARY: Points of Interest

- The three main types of muscles are skeletal, smooth, and cardiac. Skeletal muscle is a striated, or striped, voluntary muscle that allows movement, stabilizes joints, and helps maintain body temperature. Smooth muscle is a nonstriated involuntary muscle found in the organs of the body and linings of vessels; it facilitates internal movement within the body. Cardiac muscle is an involuntary, striated muscle found only in the heart.
- All movement is a result of contraction of primary movers and relaxation of opposing muscles.
- Large muscles consist of many single muscle fibers comprised of myofibrils. The smallest functional contractile unit is called a sarcomere. Each sarcomere unit contains the two threadlike contractile proteins myosin and actin.
- Muscles contract as the actin and myosin protein filaments, in the presence of ATP and calcium, form cross-bridges that cause the filaments to slide past each other, thereby causing the muscle to contract or shorten. There is a relationship between the nervous and muscular systems in which the motor neuron of the nervous system initiates the activity of muscle contraction through the release of a neurotransmitter.
- There are many common diseases and conditions of the muscles, and because the nervous system is so closely related, there are also many common neuromuscular diseases.

CASE STUDY

A 30-year-old patient complains of ascending flaccid paralysis that began with tingling in the toes and muscle weakness. He had just recovered from a viral flu. This individual presented to the emergency department after the leg weakness became so profound that he could barely walk, and now he notices his arms weakening. Loss of reflexes was also noted.

a. What disease do you think this is?

b. Knowing that this patient is losing the ability to use skeletal muscles, what life-threatening condition could occur?

c. What vital signs must you monitor?

d. Why is muscle atrophy a problem?

e. What areas of patient care must be addressed?

f. What is the likely prognosis?

REVIEW QUESTIONS

Multiple Choice

- Another name for voluntary muscle is
 - skeletal.
 - smooth.
 - cardiac.
 - nonstriated.
- Which structure does *not* contain smooth muscle?
 - blood vessels
 - heart
 - digestive tract
 - bronchi
- Most skeletal muscles attach to bones via
 - ligaments.
 - joints.
 - flexors.
 - tendons.
- The state of partial skeletal muscle contraction is known as
 - homeostasis.
 - muscle tone.
 - partialus contractus.
 - flexerus.
- Cardiac muscle
 - is a voluntary muscle.
 - has intercalated discs to assist contraction.
 - regenerates after injury.
 - lines the blood vessels.
 - I only
 - I and II
 - II only
 - I, II, III, IV
- Jill falls and twists her ankle. Later she cannot point her toes. Her doctor tells her she has torn a tendon and must have surgery. Which tendon?
 - patellar
 - calcaneal
 - rotator cuff
 - anterior cruciate

- Sam wakes up one morning unable to move his toes. Within a few hours he can't move his legs and calls 911. Within a week he is completely paralyzed. What disease most likely caused this?
 - tetanus
 - Guillain Barré
 - muscular dystrophy
 - muscular atrophy

Fill in the Blank

- A sudden or violent muscle contraction is a(n) _____.
- Partial or total loss of voluntary muscle use is _____.
- A tear in the muscle wall through which an organ can protrude is a(n) _____.
- The body stores a carbohydrate called _____ in the muscle; it can be converted to a usable energy source.
- _____ means pain or tenderness in the muscle.
- Elbow flexion is the action of the _____ muscle.

Short Answer

- List the three major muscle types and give an example of each.

- Explain the relationship between origin, insertion, and action of skeletal muscles.

3. List criteria for naming skeletal muscles and give examples.

4. Explain the steps needed in a skeletal muscle contraction.

5. Considering the knee, list the major muscles involved in control of the joint, their attachments, and their actions.

Visit our new **MyHealthProfessions Lab** to accompany *Anatomy & Physiology for Health Professions*. Here you'll find a rich collection of quizzes, case studies, and animations for deeper understanding and application.