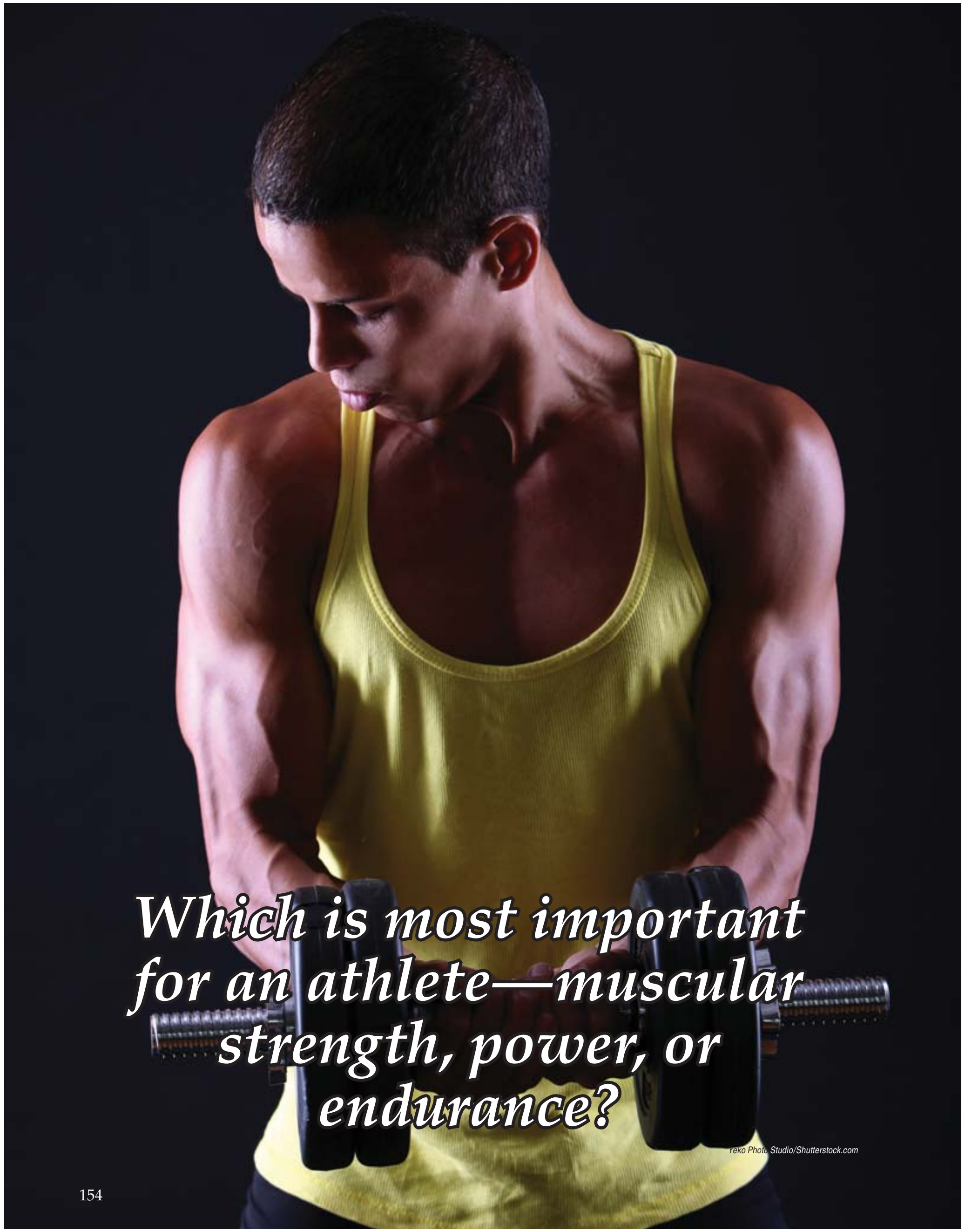

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Chapter 5

The Muscular System

Muscle is the only human tissue capable of shortening, or contracting. This unique ability is what makes body movements possible.

Without muscle the powerful movements required in athletic performances would be impossible, as would the finely tuned, graceful movements needed to send a text message or play a musical instrument. Muscles also control the movements of our eyes, the movement of food through our digestive systems, and the beating of our hearts.

What enables muscle to be so versatile? In this chapter we will look at the different types, properties, and structures of muscle, and examine the effects of different kinds of physical training on skeletal muscle. We will also discuss some of the common injuries and disorders of muscles, how these problems tend to occur, and how their likelihood, in some cases, can be reduced.

Chapter 5 Lessons

While studying, look for the online icon to:

- **Practice** with e-flash cards and vocabulary games
- **Review** with interactive art labeling
- **Assess** with online exercises
- **Expand** with interactive activities and animated videos
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Lesson 5.1 Muscle Tissue Categories and Functions

Before You Read

Try to answer the following questions before you read this lesson.

Why are some muscles controlled involuntarily?

When a skeletal muscle is stimulated to contract, what three types of actions can occur?

Are muscles irritable?

Lesson Objectives

1. Discuss the structural and functional characteristics of each of the three categories of muscle.
2. Describe the four behavioral characteristics of all muscle tissue.
3. Explain the roles of agonist and antagonist muscles.

Key Terms

E-Flash Cards

agonist	extensibility
antagonist	fascicle
aponeurosis	irritability
concentric	isometric
contractility	muscle fiber
eccentric	perimysium
endomysium	peristalsis
epimysium	sarcolemma

Muscle Categories

The three major categories of muscle fibers are *skeletal*, *smooth*, and *cardiac*. In this section we will examine the important structural and functional differences among these three types of muscle fibers.

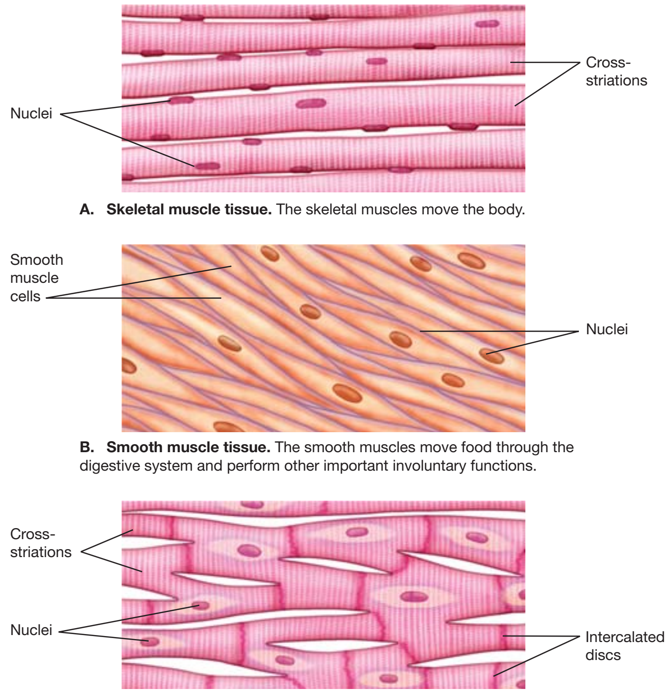
Skeletal Muscle

The skeletal muscles attach to bones and are largely responsible for body movements. Skeletal muscle is also known as *striated muscle* due to the prominent cross-stripes, or striations, which can be seen when examining this tissue under a microscope (**Figure 5.1A**). A third name, *voluntary muscle*, is an appropriate name because this type of muscle is stimulated by consciously directed nerve activity.

An individual skeletal muscle cell is referred to as a **muscle fiber** because of its thread-like shape. Muscle fibers include many nuclei and vary considerably in length and diameter. Some fibers run the entire length of a muscle; others are much shorter.

The number of muscle fibers in a given person is genetically determined, and does not change as we age, except for occasional loss of fibers resulting from injury. Although fiber number doesn't change, the skeletal muscle fibers grow in length and diameter from birth to adulthood. Adults can increase their fiber diameter, and strength, by resistance training with just a few repetitions of heavy loads on a regular basis over a period of time.

As **Figure 5.2** shows, skeletal muscle is highly organized. The cell membrane of the muscle fiber is called the **sarcolemma** (SAR-koh-LEHM-a). Over the sarcolemma of each muscle fiber is a fine, protective sheath of connective



A. Skeletal muscle tissue. The skeletal muscles move the body.

B. Smooth muscle tissue. The smooth muscles move food through the digestive system and perform other important involuntary functions.

C. Cardiac muscle tissue. Cardiac muscle is found only in the heart.

Figure 5.1 The three primary types of muscle tissue. *What are two additional names for skeletal muscle?*

tissue called an **endomysium** (EHN-doh-MIZ-ee-um). Groups of muscle fibers are bundled together by a strong fibrous membrane called a **perimysium** (PER-i-MIZ-ee-um) into a unit known as a **fascicle** (FAS-i-kuhl).

All of the fascicles in a muscle are enclosed by a thick, tough connective tissue called an **epimysium** (EHP-i-MIZ-ee-um). The epimysium connects at both ends of the muscle with either a cordlike tendon composed of extremely strong connective tissue or with a flat, sheetlike **aponeurosis** (AP-oh-noo-ROH-sis).

Tendons and aponeuroses directly connect each muscle to a bone, cartilage, or other connective tissue. Recall from chapter 4 that tendons differ from ligaments in that ligaments connect bone to bone.

Smooth Muscle

In contrast to skeletal muscle fibers, smooth muscle cells are small, spindle-shaped, and nonstriated. They are involuntary (not under conscious control), and they have a single nucleus (**Figure 5.1B**). Also known as *visceral muscle*, this type of muscle is found in the walls of many internal organs such as the stomach, intestines, urinary bladder, and respiratory passages.

Smooth muscle cells are arranged in layers, with one layer running lengthwise and the other

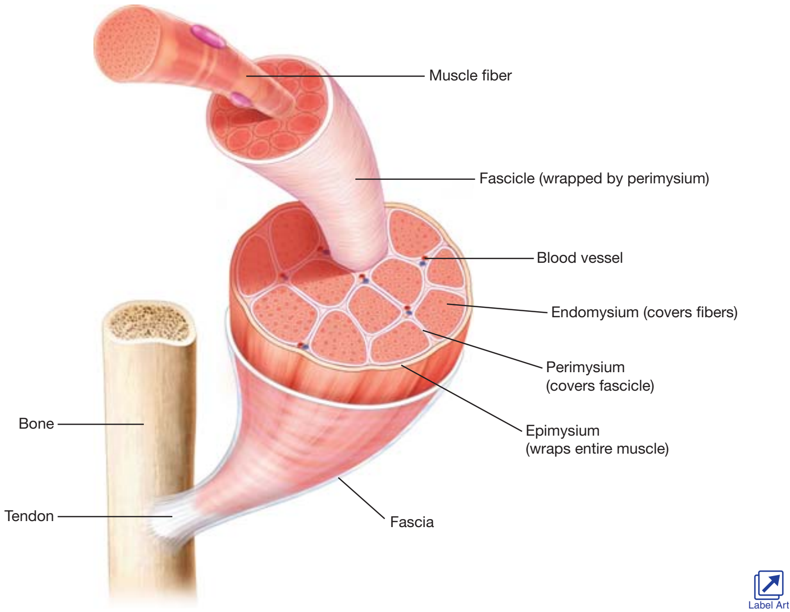


Figure 5.2 The organization of skeletal muscle. The sarcolemma (membrane of muscle fiber) is not shown in this view. *What is the benefit of increasing the diameter of skeletal muscles through repeated lifting?*

surrounding the organ in which the muscles are contained. The coordinated, alternate contracting and relaxing of these layers changes the size and shape of the organ and can aid in moving the contents of the organ. Moving food through the digestive system, emptying the bladder, and changing the diameter of the blood vessels are examples of the important functions of these muscles. During digestion, food is propelled along by a wave of symmetrical squeezing of the walls of the digestive tract. This process is called **peristalsis**, which you will learn more about in chapter 13.

The autonomic (automatic) nervous system controls smooth muscle activity. Unlike the skeletal muscles, smooth muscles can sustain contraction for long periods of time without the muscles becoming fatigued.

Cardiac Muscle

As the name suggests, cardiac muscle is located solely in the walls of the heart. Cardiac muscle cells are branched, cross-striated, and involuntary—under the control of the autonomic nervous system (**Figure 5.1C**). Cardiac cells are arranged in an interconnected network of figure-eight or spiral-shaped bundles that join together at structures called *intercalated* (in-TER-kah-lay-tehd) *discs*. This arrangement enables simultaneous contraction of neighboring cells to produce the heartbeat.

The table in **Figure 5.3** summarizes the major features of the three categories of muscle tissue. Although all three types are important and, in fact, essential for human life, we will focus primarily on the skeletal muscles in this chapter.

Figure 5.3 Muscle Categories

Characteristic	Skeletal	Smooth	Cardiac
Cell structure	varying lengths, thread-shaped, striated	short, spindle-shaped, no striations	branching interconnected chains, striated
Nucleus	multinucleate	one nucleus	one nucleus
Control	voluntary	involuntary	involuntary
Location	most attach to bones; some facial muscles attach to skin	walls of internal organs other than the heart	walls of the heart

Check Your Understanding

1. What is the difference between voluntary and involuntary muscles?
2. Categorize each muscle type as voluntary or involuntary.
3. What are the three layers of tissue that run the length of a skeletal muscle?

Muscle Functions

Despite the different properties of the three types of muscle, certain behavioral characteristics are common to all muscle tissue. In the case of skeletal muscles, there are also certain functional roles that muscles can play in contributing to different movements of the body.

Behavioral Properties

All muscle tissues have four behavioral characteristics in common: irritability, extensibility, elasticity, and contractility. Two of these—**extensibility**, the ability to be stretched, and elasticity, the ability to return to normal length after a stretch—are common not just to muscle, but to many types of biological tissues. For example, when a muscle group such as the hamstrings (on the posterior side of the thigh) is stretched over a period of time, the muscles lengthen, and the range of motion at the hip increases, making it easier to touch the toes. The stretched muscles do not return to resting length immediately, but shorten over a period of time.

Another behavioral characteristic common to all muscle is **irritability**, or the ability to respond to a stimulus. Muscles are routinely stimulated by signals from the nerves that supply them. Muscles can also be irritated by a mechanical stimulus, such as an external blow to a muscle. The response to all forms of stimuli is muscle contraction.

As mentioned in the chapter introduction, **contractility**, the ability to contract or shorten, is the one behavioral characteristic unique to muscle tissue. Most muscles have a tendon attaching to a bone at one end and a tendon attaching to another bone at the other end. When a muscle contracts, it pulls on the bones at the attachment sites. This pulling force is called a *tensile force*, or tension. The amount of tension developed is constant throughout the muscle, tendons, and attachment sites.

Tension and Types of Skeletal Muscle Contraction

Although we commonly use the term *contraction* (which implies *shortening*) to mean that tension has developed in a muscle, muscles do not always shorten when they develop tension. When a skeletal muscle develops tension, one of three actions can happen: the muscle can shorten, remain the same length, or actually lengthen. Let's look at the familiar large muscle groups, the biceps and triceps, on the anterior and posterior sides of your upper arm, to see examples of these three different types of tension.

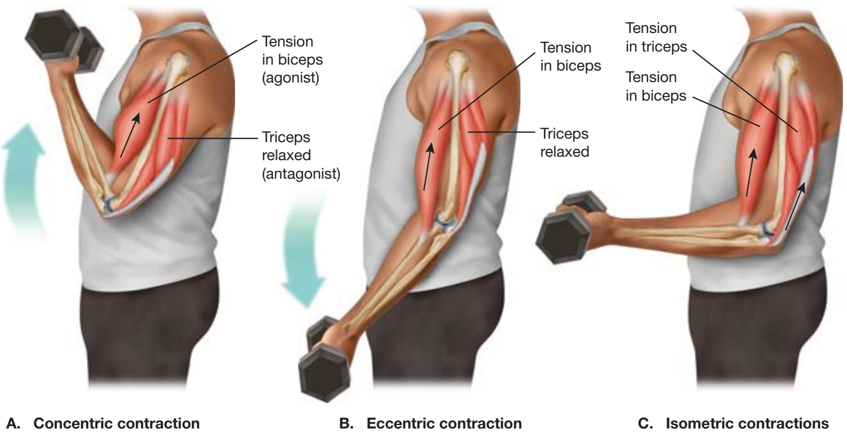


Figure 5.4 A—In this depiction of concentric contraction, the agonist biceps contracts and the antagonist triceps relaxes. B—The biceps is eccentrically contracting (lengthening) while serving as a brake to control the downward motion of the weight. C—Isometric contractions involve both the biceps and triceps developing tension, but neither muscle shortens, and there is no motion. *If you push against an immovable object, such as a wall, as hard as you can, do your muscles contract? If so, what kind of contraction occurs?*

When the biceps muscle develops tension and shortens, your hand moves up toward your shoulder (**Figure 5.4A**).This is called a **concentric** (kun-SEHN-trik), or shortening, contraction of the biceps.

In the example just described, the biceps is performing the role of **agonist** (AG-un-ist), or prime mover, and the opposing muscle group, the triceps, is playing the role of **antagonist** (an-TAG-un-ist). The antagonist muscles may be completely relaxed or may develop a slight amount of tension, depending on the requirements of the movement.

You might wonder if a muscle can lengthen while developing tension, and if so, how it can lengthen. Suppose someone were to place in your hands a very heavy weight that was too heavy for you to hold in position. At first, your biceps would develop tension in an effort to hold the weight in place. But if the weight were too heavy to manage, causing you to lower the weight, your biceps would lengthen. This type of action is known as an **eccentric** (ehk-SEHN-trik), or lengthening, contraction (**Figure 5.4B**). In this case the force of gravity (not the triceps) acting on the weight causes the weight to lower.

In a third scenario (**Figure 5.4C**) you "flex" the muscles in your arm, developing tension in both the biceps and triceps, but there is no movement. This is called an **isometric** (IGH-soh-MEHT-rik) contraction of both the biceps and triceps. With an isometric contraction no change in muscle length occurs.

It is the versatility of the arrangements of human muscles in agonist and antagonist pairs around joints that enables the different movements of the human body. These versatile arrangements also help to stabilize joints and maintain body posture.

The Production of Heat

We all know that vigorous exercise is typically accompanied by an increase in body temperature and sweating. Do you know why this happens? It happens because the working muscles generate heat.

But even when we are not exercising, the muscles, typically comprising at least 40% of body mass, generate heat, and this heat helps maintain normal body temperature.

How does this happen? Muscles require energy in the form of adenosine triphosphate (ATP) to function. You may recall from your study of chapter 2 that ATP is generated within muscle cells. The ATP is then released to provide energy when the muscle is stimulated, generating heat in the process.

Check Your Understanding

1. Explain contractility and how it creates movement.
2. When you are in the process of moving from a standing to a sitting position, what type of contraction are your quadricep (page 180) muscles experiencing?
3. What chemical substance in the body provides energy for muscles?

Lesson 5.1 Review and Assessment

Mini Glossary

Make sure that you know the meaning of each key term.

Build vocabulary with e-flash cards and games

agonist role played by a skeletal muscle to cause a movement

antagonist role played by a skeletal muscle acting to slow or stop a movement

aponeurosis a flat, sheetlike fibrous tissue that connects muscle or bone to other tissues

concentric a type of contraction that results in shortening of a muscle

contractility the ability to contract or shorten

eccentric contraction accompanied by lengthening of a muscle

endomysium a fine, protective sheath of connective tissue around a skeletal muscle fiber

epimysium the outermost sheath of connective tissue that surrounds a skeletal muscle

extensibility the ability to be stretched

fascicle a bundle of muscle fibers

irritability the ability to respond to a stimulus

isometric a type of contraction that involves no change in muscle length

muscle fiber an individual skeletal muscle cell

perimysium a connective tissue sheath that envelops each primary bundle of muscle fibers

peristalsis a wave of symmetrical squeezing of the digestive tract walls that occurs during digestion

sarcolemma the delicate membrane surrounding each striated muscle fiber

Know and Understand

Assess

1. Starting with a muscle fiber and working from the inside out, name each part of the skeletal muscle structure.
2. Describe the role of each type of muscle tissue (cardiac, smooth, and skeletal).
3. Explain the difference between irritability and contractility.
4. What is the difference between extensibility and elasticity?

Analyze and Apply

5. Give three examples of how you use isometric contractions during a typical day.
6. Compare and contrast the three types of muscles.
7. What do you think would happen if your antagonist muscles no longer functioned?

In the Lab

8. Using spaghetti and plastic wrap, create a muscle that includes muscle fibers, fascicles, endomysium, perimysium, and the epimysium. Work in groups and verbally describe which part of the muscle you are constructing as you assemble it.
9. Do a full push-up (up then down). Determine when the triceps experienced concentric contractions and when they experienced eccentric contractions.
10. Dissect a chicken leg and identify the muscle, tendon, aponeurosis, and epimysium.

Lesson 5.2 Skeletal Muscle Actions

Before You Read

Try to answer the following questions before you read this lesson.

Do sprinters and distance runners have different types of skeletal muscle fibers?

What factors influence how rapidly a muscle fatigues?

Lesson Objectives

1. Describe a motor unit and explain the functional differences between motor units that contain large and small numbers of muscle fibers.
2. Explain how a nerve impulse generates an action potential in a muscle fiber.
3. Explain how muscle contraction occurs at the level of the sarcomere.
4. Describe the differences between slow-twitch and fast-twitch skeletal muscle fibers.
5. Discuss the concepts of muscular strength, power, and endurance.

Key Terms

E-Flash Cards

acetylcholine	motor unit
action potential	neuromuscular junction
all-or-none law	parallel
axon	pennate
axon terminals	sarcomeres
cross bridges	slow-twitch
fast-twitch	synaptic cleft
motor neuron	tetanus

The development of tension in a skeletal muscle is influenced by a number of variables. Among these variables are signals from the nervous system, the properties of the muscle fibers, and the arrangement of fibers within the muscle. This lesson describes the effects of these influences. You will also learn in this lesson how muscle actions contribute to muscular strength, power, and endurance.

The Motor Unit

Muscle tissue is not able to develop tension unless stimulated by one or more nerves. Because of the dependent relationship of the muscular system on the nervous system, the two are often referred to collectively as the *neuromuscular system*.

A nerve that stimulates skeletal muscle, which is under voluntary control, is known as a **motor neuron**. A single motor neuron and all of the muscle cells that it stimulates is known as a **motor unit** (**Figure 5.5**). The motor unit is considered to be the functional unit of the neuromuscular system.

One motor neuron supplying impulses to a muscle may connect to anywhere between 100 to nearly 2,000 skeletal muscle fibers, depending on the size and function of the muscle. The small muscles responsible for finely tuned movements, such as those in the eyes and fingers, have small motor units with few fibers per motor unit. Large, powerful muscles, such as those surrounding the hips, have large motor units with many fibers. Motor units are typically contained within a portion of a muscle, but may also be interspersed with the muscle cells of other motor units.

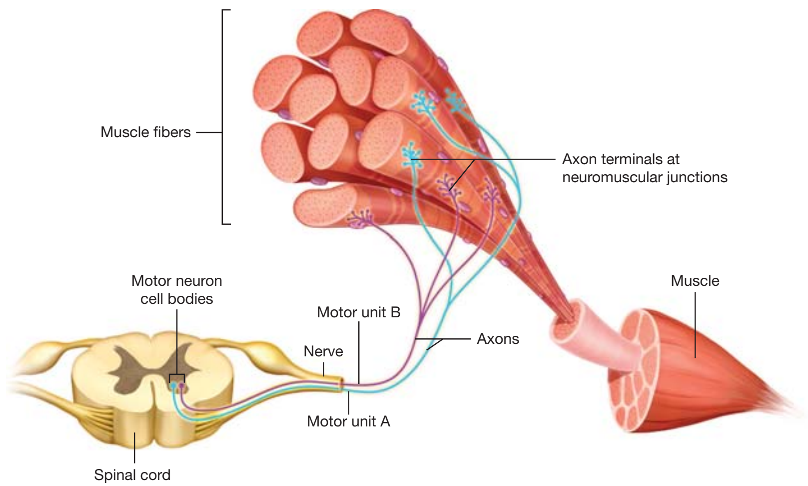


Figure 5.5 Each motor unit includes a motor neuron and all the muscle fibers it activates. *How does a motor neuron activate muscle fibers?*

Generating Action Potentials

How does the motor neuron communicate with the muscle cells in the motor unit to stimulate them? As **Figure 5.5** shows, a long, thin fiber called an **axon** connects the motor neuron cell body with the muscle fibers included in the motor unit. Close to the fibers, the axon branches into **axon terminals** which in turn branch out to individual muscle fibers. The link between each axon terminal and muscle fiber is called the **neuromuscular junction**. The axon terminal and fiber are separated by a tiny gap known as the **synaptic cleft**, which is filled with interstitial fluid (**Figure 5.6** on the next page).

When a nerve impulse reaches the end of an axon terminal, a chemical called a *neurotransmitter* discharges and diffuses across the synaptic cleft to attach to receptors on the muscle fiber sarcolemma. The neurotransmitter that stimulates muscle is called **acetylcholine** (a-SEE-til-KOH-leen).

The effect of acetylcholine is to make the sarcolemma temporarily permeable. Channels open that allow positive sodium ions (Na+) to rapidly invade the fiber at the same time that positive potassium ions (K+) rush out of the fiber. Because more Na+ enters than K+ exits, the net effect is the creation of a positive charge inside the muscle fiber.

This reversal of electrical charge is known as *depolarization*. Depolarization triggers the opening of additional channels in the fiber membrane that allow only entry of additional Na+. This flood of positive ions into the fiber generates an electrical charge called an **action potential**.

Contractions of the Sarcomeres

Glucose stored in the form of glycogen within the muscle cell provides the energy for creating the action potential. Phosphocreatine within the cell enables the transfer of energy to the protein filaments actin and myosin. Actin and myosin are contractile proteins that reside in functional units called **sarcomeres** (SAR-koh-mairz) inside the muscle fiber. The release of calcium ions (Ca++) triggers the sliding of

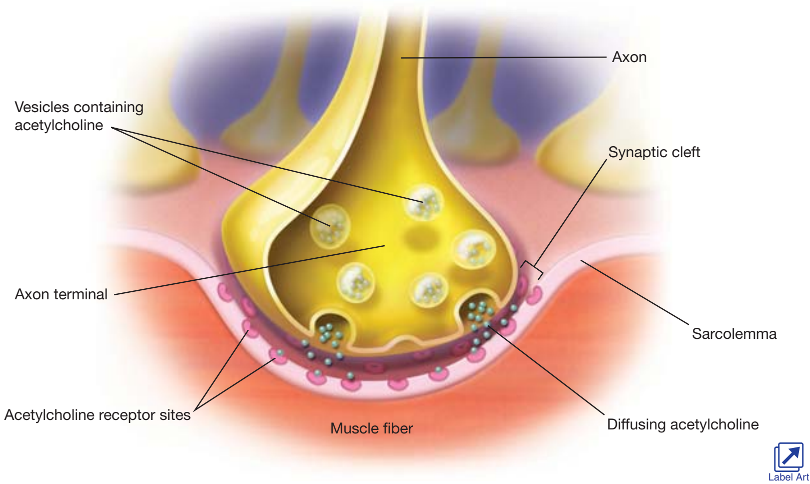


Figure 5.6 The neuromuscular junction, the site at which nerve impulses are transmitted to muscle. *Which chemical labeled in this drawing is a neurotransmitter?*

the actin filaments over the myosin filaments, resulting in a contraction of the sarcomere (**Figure 5.7**).

What causes the actin filaments to slide over the myosin filaments? Notice in **Figure 5.7** that the myosin filaments are encircled by small protrusions called *heads*. When the sarcomere is activated by an action potential, these heads attach to receptor sites on the actin filaments, forming **cross bridges**. The cross bridges contract, pulling the actin filaments toward the center of the sarcomere. During the process of sarcomere contraction, these cross bridges attach, pull, and release multiple times. The Ca++ ions released with the arrival of the action potential enable the attachments of the myosin heads to the actin filaments.

The neuromuscular system has the ability to produce slow, gentle movements as well as fast, forceful movements. This ability to produce different kinds of movements and force variance is accomplished by regulating the number and frequency of action potentials. Only a small number of action potentials are needed for slow, gentle movements, while fast or forceful movements require a large number of action potentials, released rapidly.

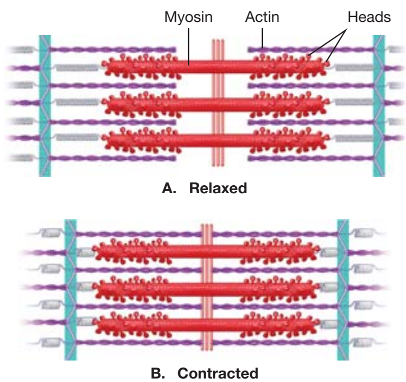


Figure 5.7 The sarcomere is the contractile unit of muscle. When the muscle is stimulated, the actin filaments slide together, producing contraction of the sarcomere.

Maximum Tension and Return to Relaxation

When receiving an action potential, a given motor unit always develops maximum tension, a physiological principle known as the **all-or-none law**. But because each whole muscle includes multiple motor units, simultaneous activation of many motor units is required for the muscle to develop maximum tension. The diagram in **Figure 5.8** displays the relationship between number and frequency of action potentials and the development of tension in the muscle. With high-frequency stimulation, the muscle develops a sustained, maximal level of tension called **tetanus**.

Almost all skeletal motor units develop tension in a twitch-like fashion, generating maximum tension very briefly and then immediately relaxing. After the action potential has traveled the length of the muscle fiber, chemical processes return the fiber to its resting state. Sodium ions diffuse back out of the cell into the interstitial fluid, and calcium ions return to storage sites within the cell. The actin filaments slide back to their original positions as the cross bridges release them, and the muscle fiber returns to a state of relaxation.

Check Your Understanding

1. What structures make up a motor unit?
2. Describe the neuromuscular junction.
3. What is an action potential?
4. Why do you want a small motor unit for fine motor skills?
5. Explain the all-or-none law.
6. How do muscles relax?

Skeletal Fiber Types

Why are some athletes especially good at events or tasks that require endurance, whereas others excel at activities that require explosive strength or speed? The answer may have something to do with the ways in which these individuals train, but that is only a small part of the explanation. In fact, a big part of why certain people are better at particular activities and sports may relate to the characteristics of their skeletal muscle fibers.

Skeletal muscle fibers may be divided into two umbrella categories—**slow-twitch** (Type I) and **fast-twitch** (Type II). As the names suggest,

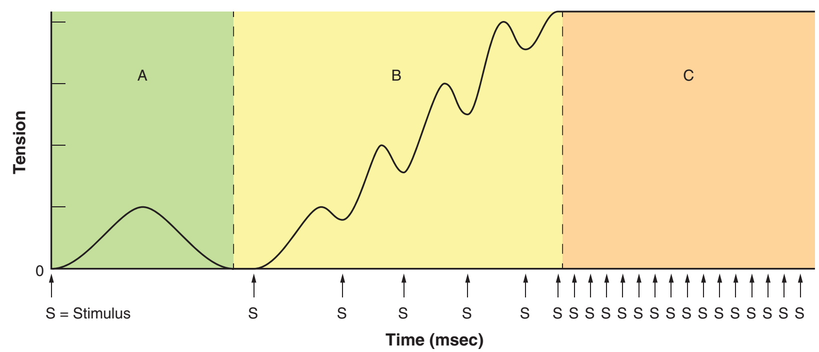


Figure 5.8 Tension developed in a muscle in response to a single stimulus (A), in response to repetitive stimulation (B), and in response to high-frequency stimulation, or tetanus (C). *Do you think this graph represents the activation of one or many motor units? Explain.*

WHAT RESEARCH TELLS US

...about Fast- and Slow-Twitch Muscles

Researchers have taken muscle biopsies (small, needle-sized plugs of muscle tissue) from elite athletes in a variety of sports. They have found that individuals specializing in events that require explosive strength or speed have unusually high proportions of fast-twitch (FT) fibers, and that elite endurance athletes tend to have very high proportions of slow-twitch (ST) fibers.

It may be the case that many of those who are able to achieve athletic success at the highest levels are simply born with high percentages of either FT or ST fibers. Once these individuals have experienced success in a particular sport or event, it is likely that they gravitate toward that sport or event (**Figure 5.9**).

Of course, certain individuals within the general population of untrained people also have high percentages of FT or ST muscles. The distribution of FT/ST ratios among the general population is represented in the normal, bell-shaped curve (**Figure 5.10**).

We also know from research that FT-fiber types can change over time. FT fibers can be converted to ST fibers with years of endurance training. No evidence exists, however, that any form of training can convert ST fibers to FT fibers. We do know that a progressive loss of FT motor units and fibers occurs as we age, although this loss can be minimized by regular, high-intensity exercise throughout life.

Rena Schild/Shutterstock.com

Figure 5.9 Elite sprint cyclists tend to have high percentages of fast-twitch muscle fibers. *Aside from sprint cycling, what are some sports in which athletes with high percentages of fast-twitch muscle fibers would be particularly successful?*

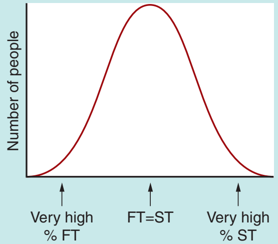


Figure 5.10 The percentages of fast-twitch (FT) and slow-twitch (ST) fibers in the general population are normally distributed.

Taking It Further

1. Why do FT muscle fibers affect strength and speed? Why do ST muscle fibers provide increased endurance?
2. Why might regular exercise minimize the natural loss of FT muscle fibers with age?

the fast-twitch fibers contract much faster than slow-twitch fibers.

Because sufficient variation exists among the fast-twitch fibers, they too have been divided into two categories—Type IIa and Type IIb. The Type IIa fibers are intermediate in contraction speed between the slow-twitch fibers and the classic fast-twitch fibers, which are Type IIb. The Type IIb fibers contract very rapidly, in about one-seventh the time required for slow-twitch fibers to contract. As a result, the Type IIb fibers also fatigue rapidly. Although all of the muscle fibers in a motor unit are of the same type, most skeletal muscles include motor units of both fast-twitch and slow-twitch fibers. The fast-twitch/slow-twitch ratio varies from muscle to muscle and from person to person.

Fiber Architecture

Another factor that affects the ways in which skeletal muscles function is fiber architecture. Fiber architecture refers to the ways in which fibers are arranged within the muscle. The two major categories of muscle fiber arrangement are **parallel** and **pennate**.

Parallel Fiber Architecture

With parallel fiber architecture, the fibers run largely parallel to each other along the length of the muscle. As **Figure 5.11** shows, these parallel fiber arrangements may result in muscle shapes that are fusiform (wide in the middle and tapering on both ends), bundled, or triangular. Examples of muscles with this type of architecture are the biceps brachii (fusiform), rectus abdominis (bundled), and pectoralis major (triangular).

The individual fibers in the parallel architecture typically do not run the entire length of the muscle. Instead, the individual parallel fibers have interconnections with neighboring fibers. These interconnections promote contraction when the muscle is stimulated. This fiber arrangement enables shortening of the muscle and the ability to move body segments through large ranges of motion.

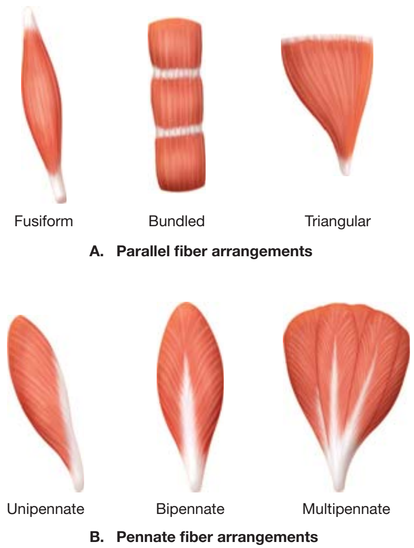


Figure 5.11 Fibers within a muscle may be arranged so that they are largely parallel or pennate (feathered). *Can you identify a muscle with parallel fiber arrangement? With pennate fiber arrangement?*

Pennate Fiber Architecture

In a pennate fiber arrangement, each fiber attaches obliquely to a central tendon, and sometimes attaches to more than one tendon. As **Figure 5.11** shows,

- fibers that are aligned in one direction to a central tendon are *unipennate*;
- fibers that attach to a central tendon are *bipennate*; and
- fibers that attach to a central tendon in more than two directions are referred to as *multipennate*.

Certain muscles of the hand are unipennate, the rectus femoris (a member of the quadriceps group in the thigh) is bipennate, and the deltoid is multipennate.

With a pennate fiber arrangement, the muscle does not shorten as much upon contraction as a muscle with a parallel fiber arrangement. However, the pennate arrangement makes it possible to pack more fibers into the muscle. This means that the muscle can generate more force.

Check Your Understanding

1. What is the difference between fast-twitch and slow-twitch fibers?
2. Which fiber type helps a sprinter get out of the blocks fast?
3. Why can pennate-arranged fibers generate more force than parallel-arranged fibers?

Muscular Strength, Power, and Endurance

In everyday conversation we sometimes use *strength* and *power* interchangeably. However, as we will discuss in this section of the lesson, muscular strength and power are quite different concepts. We will examine what it means to have muscle fatigue, along with the related concept of muscular endurance, which is a little more complicated.

Muscular Strength

It may be tempting to think that muscular strength is the amount of force a given muscle can produce. It is impossible, however, to measure muscle force directly without penetrating the body. So to avoid invasive procedures, we use external measures (such as the amount of resistance a person can move) to establish an indirect measure of muscle strength.

Remember that most joints in the human body are crossed by more than just one muscle. Additionally, many exercises involve more than one joint. This means that an index-of-strength measure such as maximum bench press actually assesses the collective work of several muscles that cross the shoulder and elbow (**Figure 5.12**). The main muscles that work during execution of a bench press include the pectoralis major, pectoralis minor, anterior deltoid, and triceps brachii.

Figure 5.12 The amount of weight being lifted is an indirect measure of this person's muscular strength. *What would be a more precise, direct method of measuring his strength?*

A more precise assessment of the strength of a muscle group at a given joint is the amount of torque (TORK), or rotary force, that the muscles can generate. Torque is the product of the size of a force and the perpendicular distance of that force from an axis of rotation. For the joint shown in **Figure 5.13**, the torque produced by a muscle is the product of muscle force and the perpendicular distance from the muscle attachment to the center of rotation at the joint.

The more torque a muscle generates at a joint, the greater the tendency for movement of the bones at the joint. Machines called *dynamometers* measure joint torques. Measures of joint torque, which we use as a measure of strength, are based solely on the resistance moved or matched. The speed with which a resistance is moved is not relevant to the strength measurement.

Muscular Power

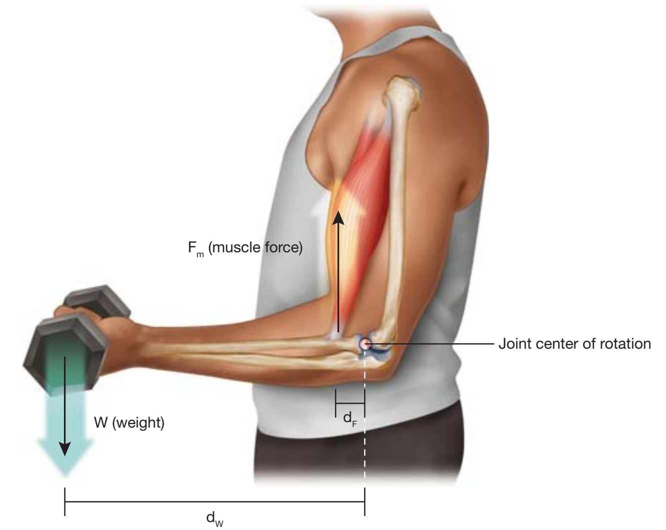
The variable that does involve speed is muscular power. Mechanical power is defined as force multiplied by velocity (force × velocity). Muscular power, then, has been defined specifically as muscle force multiplied by muscle-shortening velocity during contraction. Notice, however, that neither muscle force nor shortening velocity can be measured from outside the body. Research dynamometers have the ability to generate estimates of muscular power based on the resistance moved and movement speed.

Like muscular strength, muscular power is typically generated by several different muscles working collectively. Sprinting, along with the jumping and throwing events in track and field, are good examples of activities that require muscular power. Because force production and movement speed contribute equally to muscular power, the sprinter with the greatest leg strength may not necessarily be the fastest.

Muscular Endurance

Muscular endurance is the ability of a muscle to produce tension over a period of time. The tension may be constant (for example, when a gymnast holds a motionless handstand), or it may vary cyclically (for example, during running, cycling, or rowing). Generally, the longer the physical activity is maintained, the greater the required muscular endurance. Because the force and speed requirements of different movements can vary significantly, the

Figure 5.13 Calculating Muscle Force



Do you know how much force your muscle must generate to hold a five-pound weight in the position shown in the illustration? Let's see if we can calculate the amount of force needed.

To hold the weight in this position, the torque at the elbow joint *generated by the muscle* (muscle torque) must balance the torque *produced by the weight* (weight torque) at the elbow.

As you know from reading this lesson, muscle torque is the product of muscle force and the perpendicular distance of that force from the center of rotation at the joint. We can state this in a formula as

$$T_m = F_m \times d_F$$

where T_m = muscle torque, F_m = muscle force, and d_F = the perpendicular distance.

Weight torque is the product of the weight and the perpendicular distance of that weight from the center of rotation at the joint. This formula can be stated as

$$T_W = W \times d_W$$

where T_W = weight torque, W = weight, and d_W = the perpendicular distance.

Let's suppose that the weight in the illustration is 5 pounds, and that it is being held at a distance (d_W) of 12 inches from the center of the joint. The distance of the muscle attachment from the joint center (d_F) is 1 inch. How much force must the muscle produce to support the weight?

$$T_m = T_W$$
$$F_m \times d_F = W \times d_W$$
$$F_m \times 1'' = 5 \text{ lb} \times 12''$$
$$F_m = 60 \text{ lb}$$

Are you surprised? To support just 5 pounds in the hand, the muscle must generate 60 pounds of force. What can we learn from this? Because muscles attach so closely to joints, the human musculoskeletal system is designed more for movement speed than for strength.

Now you try: Suppose that the weight (W) in this picture is 10 pounds, the d_W is 15 inches, and the d_F is 1 inch. What is the F_m?

definition of muscular endurance is specific to each physical activity.

In general, muscle fatigue can be thought of as the opposite of muscular endurance. The faster a muscle fatigues, the less endurance it has. A variety of factors affect the rate at which a muscle fatigues, including the nature of the work or exercise being done, how often the muscle is used, the muscle fiber composition of the muscle, and the temperature and humidity of the environment.

Check Your Understanding

1. What is measured to determine muscular strength?
2. What is measured to determine muscular power?
3. Is the strongest athlete the fastest? Why or why not?
4. What is muscular endurance?
5. What influences muscular endurance?

Lesson 5.2 Review and Assessment

Mini Glossary

Make sure that you know the meaning of each key term.

Build vocabulary with e-flash cards and games

acetylcholine a neurotransmitter chemical that stimulates muscle

action potential the electric charge produced in nerve or muscle fiber by stimulation

all-or-none law the rule stating that the fibers in a given motor unit always develop maximum tension when stimulated

axon a long, thin fiber connected to the motor neuron cell body

axon terminals offshoots of the axon that branch out to connect with individual muscle fibers

cross bridges connections between the heads of myosin filaments and receptor sites on the actin filaments

fast-twitch type of muscle that contracts quickly

motor neuron a nerve that stimulates skeletal muscle tissue

motor unit a single motor neuron and all of the muscle fibers that it stimulates

neuromuscular junction the link between an axon terminal and a muscle fiber

parallel a type of muscle fiber arrangement in which fibers run largely parallel to each other along the length of the muscle

pennate a type of muscle fiber arrangement in which each fiber attaches obliquely to a central tendon

sarcomeres units composed of actin and myosin that contract inside the muscle fiber

slow-twitch type of muscle that contracts slowly and is fatigue resistant

synaptic cleft the tiny gap that separates the axon terminal and muscle fiber

tetanus a sustained, maximal level of muscle tension that occurs with high-frequency stimulation

Know and Understand

Assess

1. Explain the role of acetylcholine in muscle contractions.
2. Describe the parts of a motor unit.
3. Discuss the differences between a large and small motor unit and their functions.
4. Describe parallel and pennate fiber patterns.

Analyze and Apply

5. Which fiber types do you think contribute to each of the following: muscular strength, power, and endurance? Explain your reasoning.
6. What would happen if you had no Na+ in your body? no Ca++?
7. Why do temperature and humidity increase the rate of muscle fatigue?
8. Do you think a soccer player has more fast-twitch or slow-twitch muscle fibers? Why?

In the Lab

9. Try an experiment. Get into and then hold a squatting position for as long as you can while a partner times you. Allow five minutes to rest; then continually move into and out of a squatting position for as long as possible, again with your partner timing you. Did you fatigue more quickly holding a squatting position or while moving up and down in a squatting motion? Why? Now reverse roles with your partner.

Lesson 5.3 The Major Skeletal Muscles

Before You Read

Try to answer the following questions before you read this lesson.

What muscles are responsible for breathing?

What important functions do the neck and trunk muscles contribute beyond movement capabilities?

What are the primary functions of the lower limb?

Lesson Objectives

1. Describe and give examples of the types of body motions that occur in the sagittal, frontal, and transverse planes.
2. Identify the locations and functions of the muscles of the head and neck.
3. Identify the locations and functions of the trunk muscles.
4. Identify the locations and functions of the muscles of the upper limb.
5. Identify the locations and functions of the muscles of the lower limb.

Key Terms

E-Flash Cards

abduction	lateral rotation
adduction	medial rotation
circumduction	opposition
dorsiflexion	origin
eversion	plantar flexion
extension	pronation
flexion	radial deviation
hyperextension	supination
insertion	ulnar deviation
inversion	

There are more than 650 skeletal muscles in the human body. In this lesson we will present only the most important muscles from the standpoint of functional movement. Almost all of these muscles are arranged in agonist-antagonist pairs, causing opposing actions at one or more joints.

Directional Motions

To understand the functional movement of muscles, you need to learn a new concept about muscle attachments. It will also be helpful to review some directional terms that you learned in chapter 1.

Skeletal muscles attach at either end of the muscle; the most common attachments are tendon connections to bone. The end of a muscle that attaches to a relatively fixed structure is called the **origin**. The end of a muscle that attaches to a bone that typically moves when the muscle contracts is called the **insertion**.

For an example of origin and insertion, let's look at the brachialis muscle, which crosses the anterior side of the elbow. Its origin is on the humerus, and its insertion is on the ulna in the forearm. When the brachialis contracts, the forearm (ulna) is pulled toward the upper arm, while the upper arm (humerus) remains stationary.

Remember—when stimulated to develop tension, muscles can only pull. They are incapable of pushing.

In addition, remember from chapter 1 that to describe the human body and its movements, we refer to three major planes that pass through the center of the body:

- The *sagittal* plane is in line with forward and backward motions;
- The *frontal* plane is in line with sideways movement; and

- Rotational movements occur in the *transverse* plane.

As we learned in chapter 1, the frame of reference for all movement is the anatomical position. In this position the human body is erect with the hands at the sides and the palms facing forward.

Check Your Understanding

1. Which end of the muscle typically moves?
2. Define anatomical position.
3. What are the three major anatomical planes?

Sagittal Plane Movements

The primary sagittal plane (forward/backward) movements are **flexion** (FLEHK-shun), **extension**, and **hyperextension** (**Figure 5.14**). Flexion describes forward- bending motion of the head, trunk, upper arm, forearm, hand, and hip; and backward motion of the lower leg at the knee. In flexion movements, body surfaces are coming together. Extension returns body segments from a position of flexion to anatomical position. Hyperextension continues the extension motion past anatomical position.

Two movements of the foot also occur primarily in the sagittal (SAJ-i-tal) plane. Bringing the top of the foot toward the lower leg is called **dorsiflexion** (DOR-si-FLEHK-shun), and moving the foot in the opposite direction away from the lower leg is called **plantar flexion** (**Figure 5.14**).

Memory Tip
Planting the ball of the foot is the motion involved in *plantar* flexion.

Frontal Plane Movements

Common movements in the frontal plane include **abduction** and **adduction** (**Figure 5.14**). Movements at the shoulder and hip that take the arm and leg away from the midline of the body are called *abduction*. Oppositely directed movements that bring the arm and leg closer to the midline of the body are called *adduction*.

Memory Tip
Just as *abduct* means "to take away," abduction takes a body segment away from the body. Just as *add* means "to bring back," adduction returns a body segment closer to the body.

Movements of the foot that occur mainly in the frontal plane are **inversion** and **eversion**. Rolling the sole of the foot inward is inversion, while rolling the sole of the foot outward is eversion (**Figure 5.14**).

Frontal plane movements of the hand at the wrist are called **radial deviation** and **ulnar deviation**. Recall from chapter 4 that the forearm has two bones—the radius and the ulna. The radius is on the thumb side of the hand, and the ulna is on the "little finger" side of the arm. From anatomical position, with the palms facing forward, abduction of the hand toward the thumb is called *radial deviation*, and adduction of the hand toward the little finger is called *ulnar deviation* (**Figure 5.14**).

Trunk and neck motions away from anatomical position in the frontal plane are called *lateral flexion* and *side bending*. Return from a position of lateral flexion to anatomical position is called *lateral extension*.

Transverse Plane Movements

Transverse plane movements mostly involve rotation around the long axis of a body segment. When the head or trunk rotate from side to side, the movement is simply called *left* or *right rotation*. Rotation of an arm or a leg in the transverse plane is called **medial rotation** if the rotation is directed medially, or inward, and **lateral rotation** if the movement is directed laterally, or outward (**Figure 5.14**). The special terms used for rotation of the forearm are **pronation** for medial (palm down) rotation and **supination** (SOO-pi-NAY-shun) for lateral (palm up) rotation (**Figure 5.14**).

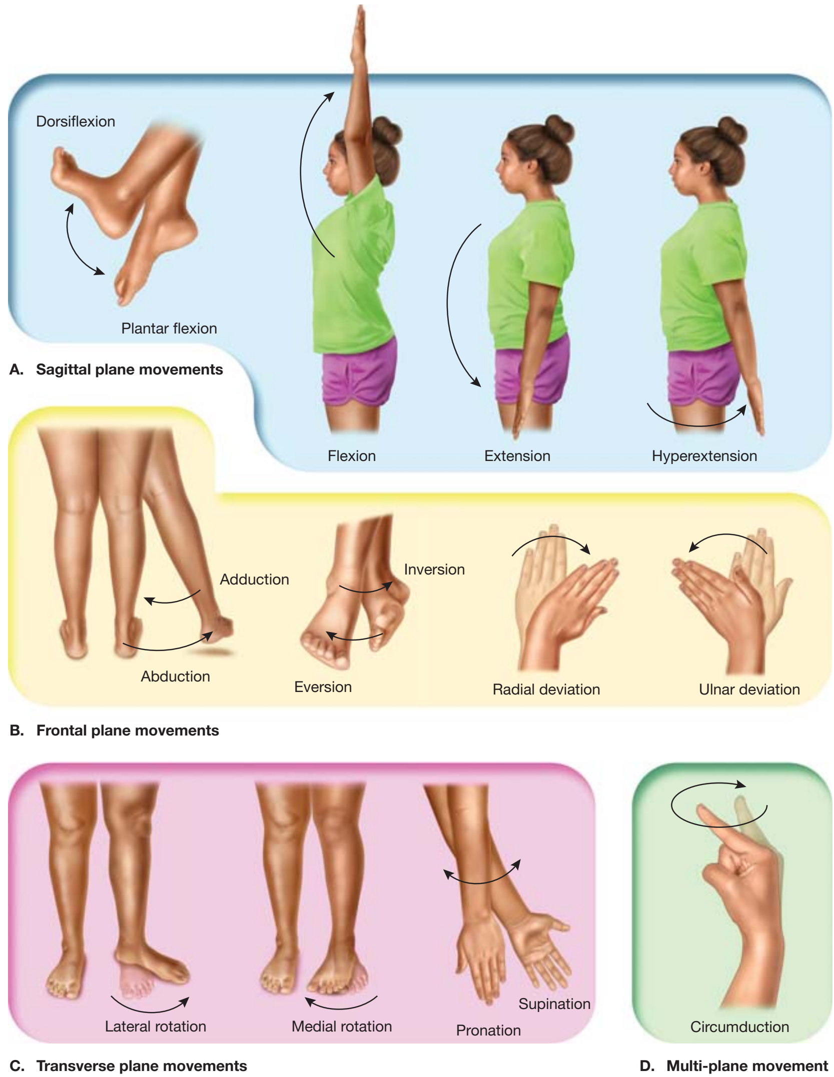


Figure 5.14 Directional movement terminology.

Multiplanar Movements

A few movements of body segments do not fall within a single plane. If you have ever purchased running shoes, you may have heard the terms *pronation* and *supination* used to describe motions of the foot occurring specifically at the subtalar joint (where the heel and ankle bones meet). Pronation at the subtalar joint is a combination of eversion, abduction, and dorsiflexion. Supination at this joint includes inversion, adduction, and plantar flexion. Moving a finger, arm, or leg in a rotational manner such that the end of the segment traces a circle is called **circumduction** (SER-kum-DUK-shun), which you can see in **Figure 5.14**. And, finally, touching any of your four fingers to the thumb is known as **opposition**. Having an opposable thumb gives us the all-important ability to grasp objects.

Check Your Understanding

1. In what direction are movements guided on the sagittal plane?
2. What special movements occur on the frontal plane at the hand? the foot?
3. What is the difference between pronation and supination of the hand and the foot?
4. Describe circumduction.
5. Define medial and lateral rotation.

Head and Neck Muscles

The muscles of the head and neck can be divided into three groups: facial muscles, chewing muscles, and neck muscles. The difference between facial muscles and most other muscles is that facial muscle insertions connect them to other muscles or skin. When these muscles contract, pulling on the skin, they produce an array of facial expressions.

With the exception of the orbicularis oris, which encircles the mouth, and the sheetlike platysma on the front and sides of the neck, all of the other head and neck muscles are paired—one on the right and one on the left. The head and neck muscles are displayed in **Figure 5.15**, and their locations and functions are summarized in **Figure 5.16**.

Trunk Muscles

The trunk muscles provide stability for the vertebral column. They are also responsible for maintaining upright posture. American football players train to strengthen the neck and trunk muscles in an effort to maximize spinal stability and minimize risk of injury to the delicate spinal cord and internal organs (**Figure 5.17**). Conversely, female gymnasts train to enhance the flexibility of the spine and are capable of extraordinary spinal hyperextension, especially during balance-beam and floor-exercise routines.

Collectively, the trunk muscles enable flexion, extension, hyperextension, lateral flexion, and rotation of the head and trunk. From a functional perspective, the anterior abdominal muscles also assist with urination, defecation, forced expiration during breathing, and childbirth. The all-important diaphragm muscle regulates breathing. The trunk muscles also

Figure 5.17 Football players conditioning. *Why is it critically important for football players to strengthen their neck and trunk muscles?*

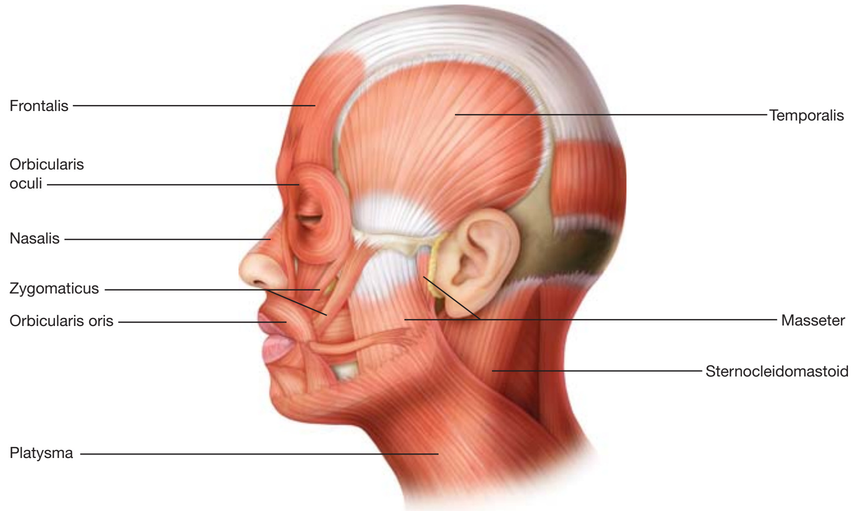


Figure 5.15 Major muscles of the head and neck. *Which muscle is referred to as the "smiling" muscle?*

Figure 5.16 Muscles of the Head and Neck

Muscle	Location	Primary Functions
Facial Muscles		
Frontalis	forehead; connects cranium to skin above eyebrows	raises eyebrows, wrinkles forehead
Orbicularis oculi	encircles the eyes	closes eyes, enables squinting
Nasalis	nose	modifies size of nostrils
Orbicularis oris	encircles mouth	closes lips, produces kissing motion
Zygomaticus	connects cheekbones to corners of mouth	the "smiling" muscle
Platysma	front and sides of neck	pulls corners of mouth down, opens mouth wide
Chewing Muscles		
Masseter	connects zygomatic bone to mandible	closes the jaw
Temporalis	fan-shaped muscle over temporal bone	assists masseter with closing jaw
Neck Muscles		
Sternocleidomastoid	sides of neck	flexion of head, rotation of head toward opposite side of contraction

serve as a protective sheath for the organs of the thoracic and abdominal cavities. The locations and primary functions of the major muscles of the anterior and posterior trunk are summarized in the table in **Figure 5.18**. These muscles are showin in **Figure 5.19**.

Upper Limb Muscles

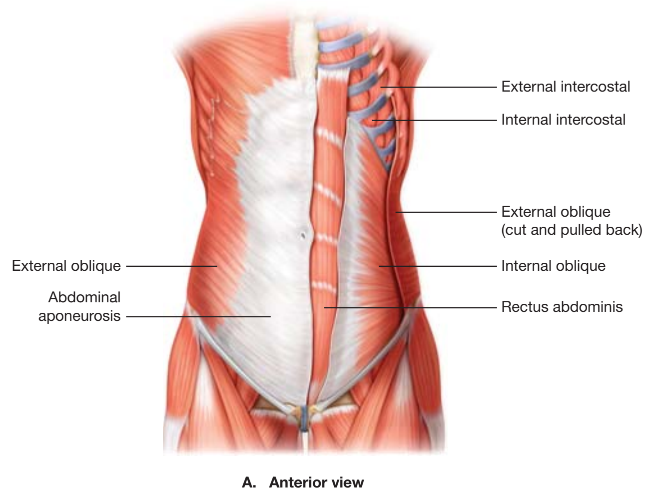
Because the shoulder is a ball-and-socket joint and the most freely movable joint in the human body, the movement capabilities of the upper limb are impressive. This large range of motion is achieved because the bone structure of the glenohumeral (GLEH-noh-HYOO-mer-al) joint provides little to no stability, rendering it susceptible to dislocation. Therefore, it is up to the large, powerful muscles surrounding the shoulder to maintain the stability and integrity of the joint.

The arm muscles enable strong, controlled movements in sports such as gymnastics, rowing, and archery, as well as fast, powerful movements in weightlifting, boxing, and throwing. The dexterity of the finger muscles enables precise movements, such as typing, texting, knitting, and playing musical instruments.

The joints of the upper limb include those of the shoulder, elbow, wrist, and fingers. In this lesson we include information about the major muscles that cross the shoulder and elbow joints. Because there are nine muscles that cross the wrist and ten muscles within the hand (some

Figure 5.18 Muscles of the Trunk

Muscle	Location	Primary Functions
Anterior Muscles		
Pectoralis major	upper chest; connects sternum, shoulder girdle, and upper ribs to proximal humerus	adduction and flexion of arm
Rectus abdominis	center front of abdomen; connects ribs to pubic crest	flexion and lateral flexion of trunk
External oblique	front of abdomen; connects lower eight ribs to anterior iliac crest	flexion, lateral flexion, and rotation to opposite side of trunk
Internal oblique	front of abdomen beneath the external obliques;connects lower four ribs with the iliac crest	flexion, lateral flexion, and rotation to same side of trunk
Posterior Muscles		
Trapezius	upper back and neck; connects skull and thoracic vertebrae to clavicle and scapula	extension and hyperextension of head
Erector spinae	length of vertebral column; connects adjacent vertebrae	extension, lateral flexion, and rotation to opposite side of vertebral column
Muscles for Breathing		
Diaphragm	dome-shaped muscle separating thoracic and abdominal cavities	enlarges thoracic cavity for inhalation
Internal intercostals	connect the ribs; located between them	decrease thoracic cavity during forced expiration
External intercostals	connect the ribs; located between them	help enlarge thoracic cavity for inhalation



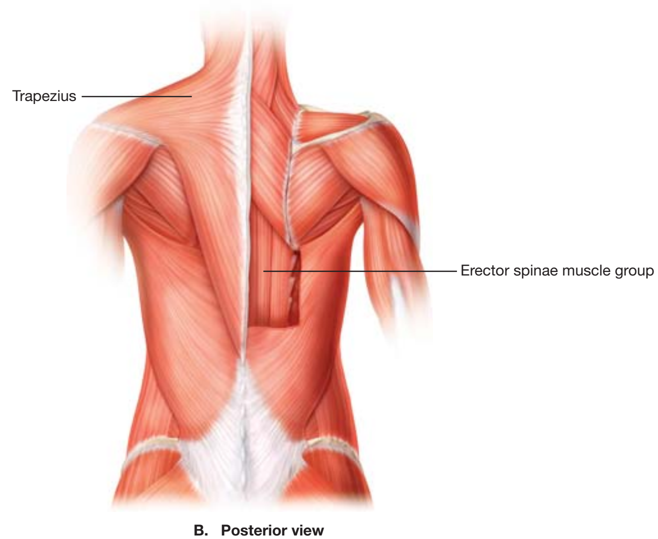
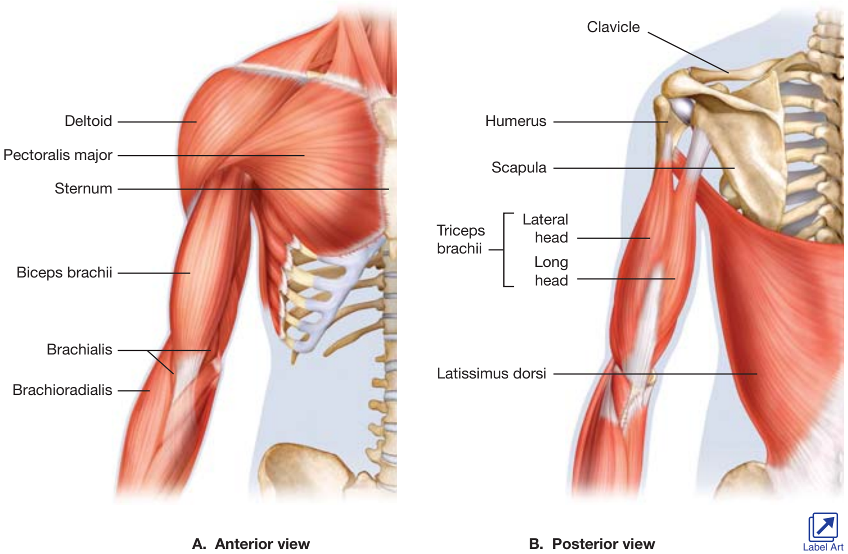


Figure 5.19 Major muscles of the trunk. *What are some basic functions that the muscles of the trunk assist with, in addition to movement of the trunk and the head and protection of the organs?*



A. Anterior view B. Posterior view

Figure 5.20 Muscles of the upper limb.

Figure 5.21 Muscles of the Upper Limb

Muscle	Location	Primary Functions
Shoulder Muscles		
Pectoralis major	upper chest; connects sternum, shoulder girdle, and upper ribs to proximal humerus	adduction and flexion of arm
Deltoid	covers external shoulder; connects scapula and clavicle to humerus	abduction, flexion, extension, and rotation of arm
Latissimus dorsi	midback and lower back; connects lower vertebral column and lower ribs to the humerus	extension, adduction, and medial rotation of arm
Elbow Muscles		
Biceps brachii	anterior arm; connects scapula to radius	flexion, and assists with supination of forearm
Brachialis	connects upper arm to forearm (humerus to ulna)	flexion of forearm
Brachioradialis	connects upper arm to forearm (humerus to radius)	flexion of forearm
Triceps brachii	posterior arm; connects scapula and humerus to ulna	extension of forearm

of which branch out to several of the fingers) these are not discussed. **Figure 5.20** lists the major muscles of the upper limb, and **Figure 5.21** summarizes their locations and functions.

Lower Limb Muscles

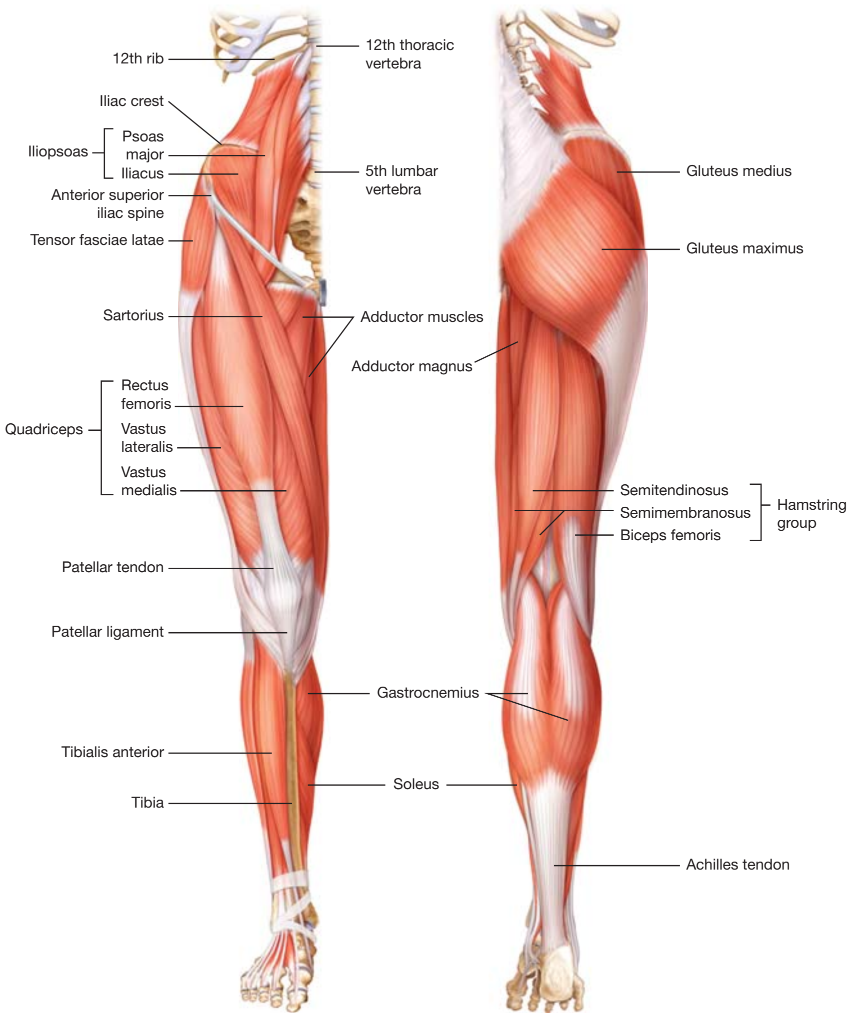
While the structure of the upper limb lends itself well to activities that involve large ranges of motion, the lower limb is well designed for its primary jobs of standing and walking. Running, jumping, kicking, climbing, skipping, hopping, and dancing are just a few of the additional capabilities of the lower limb.

The lower limb includes the joints of the hip, knee, and ankle, along with numerous joints in the foot. In this lesson we include the major muscles of the hip, knee, and ankle, but we omit a number of small muscles that play assistive roles. The table in **Figure 5.22** outlines the locations and primary functions of the major muscles of the lower limb. **Figure 5.23** on the next page shows these muscles.

Notice in **Figures 5.22** and **5.23** the two muscle groups on the anterior side and posterior side of the thigh. The anterior group, the quadriceps, includes the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius, which lies under the rectus femoris. These four muscles are often referred to as a group because they all attach to the patellar tendon.

Figure 5.22 Muscles of the Lower Limb

Muscle	Location	Primary Functions
Hip Muscles		
Gluteus maximus	external buttocks; connects pelvis to femur	extension and lateral rotation of leg
Gluteus medius	directly under maximus; connects ilium of pelvis to femur	abduction and medial rotation of leg
Iliopsoas	anterior groin; connects ilium and lower vertebrae to femur	flexion of leg at hip
Adductor muscles	anterior-medial thigh	adduction and medial rotation of leg
Knee Muscles		
Quadriceps	anterior thigh; connects ilium and proximal femur to tibia	extension of leg at knee
Hamstrings	posterior thigh; connect ischium to tibia and fibula	flexion of leg at knee
Sartorius	long, straplike muscle that crosses anterior thigh obliquely; connects ilium to proximal tibia	assists with flexion, abduction, and lateral rotation of thigh
Ankle/Foot Muscles		
Gastrocnemius	prominent muscle on posterior calf; connects femur to calcaneus (heel bone) via Achilles tendon	plantar flexion of foot, flexion of leg at knee
Soleus	underlies gastrocnemius on posterior calf; connects fibula and tibia to calcaneus	plantar flexion of foot
Tibialis anterior	anterior lower leg; connects tibia to tarsal and metatarsal bones of foot	dorsiflexion and inversion of foot



Label Art

Figure 5.23 Major muscles of the lower limb. *Are your hamstring muscles part of an anterior or posterior muscle group?*

The posterior group, the hamstrings, includes the biceps femoris, semimembranosus (SEHM-ee-MEHM-bray-NOH-suhs), and semitendinosus (SEHM-ee-TEHN-di-NOH-suhs). What these muscles have in common, besides their general location, is strong, stringlike tendons that can be felt on either side of the back of the knee. The name *hamstrings* comes from the fact that hams consist of thigh and hip muscles, and butchers use the tendons of these muscles to hang the hams for smoking.

Check Your Understanding

1. How do the attachments for facial muscles differ from the attachments for other muscles?
2. Which muscles help with posture?
3. What is sacrificed at the shoulder to allow greater range of motion?
4. For which two primary functions is the lower limb designed?

Lesson 5.3 Review and Assessment

Mini Glossary

Make sure that you know the meaning of each key term.

Build vocabulary with e-flash cards and games

abduction movement of a body segment away from the body in the frontal plane

adduction movement of a body segment closer to the body in the frontal plane

circumduction rotational movement of a body segment such that the end of the segment traces a circle

dorsiflexion movement of the top of the foot toward the lower leg

eversion movement in which the sole of the foot is rolled outward

extension movement that returns a body segment to anatomical position in the sagittal plane

flexion forward movement of a body segment away from anatomical position in the sagittal plane

hyperextension backward movement of a body segment past anatomical position in the sagittal plane

insertion muscle attachment to a bone that tends to move when the muscle contracts

inversion movement in which the sole of the foot is rolled inward

lateral rotation outward (lateral) movement of a body segment in the transverse plane

medial rotation inward (medial) movement of a body segment in the transverse plane

opposition touching any of your four fingers to your thumb; this movement enables grasping of objects

origin muscle attachment to a relatively fixed structure

plantar flexion downward motion of the foot away from the lower leg

pronation medial rotation of the forearm (palm down)

radial deviation rotation of the hand toward the thumb

supination lateral rotation of the forearm (palm up)

ulnar deviation rotation of the hand toward the little finger

Know and Understand

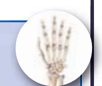
Assess

1. What are the directions of movement for the sagittal, frontal, and transverse planes?
2. Describe hyperextension.
3. Describe the difference between abduction and adduction.
4. Using the drawings and tables in this lesson, identify the agonist/antagonist pairs for abduction/adduction of the hip and plantar flexion/dorsiflexion of the ankle.

Analyze and Apply

5. What type of motor units do you think the forearm and hands have? Why?
6. Compare and contrast inversion and eversion of the foot and supination and pronation of the hand.
7. Which joints in the upper and lower limbs can perform flexion and extension?

In the Lab



8. Try writing the answers to one of the questions at the left without using your thumb. Why is opposition important?
9. What position are you in if all of your joints that can perform flexion do so at the same time?
10. In a push-up, what movements are happening at the shoulder and elbow when you are moving up? Which muscles are performing these movements? What movements occur when you move down? Which muscles cause these movements?

Lesson 5.4 Common Injuries and Disorders of Muscles

Before You Read

Try to answer the following questions before you read this lesson.

What causes muscle cramps?

Which individuals are at greatest risk for developing low back pain?

Lesson Objectives

1. Explain the differences between a muscle sprain, a contusion, and a cramp.
2. Discuss the differences between tendinitis and tendinosis.
3. Explain the causes of common muscular injuries that occur during participation in different sports.
4. Describe the causes and symptoms of whiplash injuries and hernias.
5. Describe the risk factors for low back pain and explain what strategies can be used to avoid it.

Key Terms

E-Flash Cards

contusion
delayed-onset muscle soreness (DOMS)
hernia
muscle cramps
muscle strain
muscular dystrophy (MD)
myositis ossificans
shin splints
tendinitis
tendinosis

Although common, most muscle injuries are relatively minor. Fortunately, the healthy human body has considerable ability to self-repair a variety of injuries, such as those to muscles. In this lesson you will learn about some of the common muscle injuries and disorders.

Strains

A **muscle strain** happens when a muscle is stretched beyond its usual limits. Someone who has a large degree of flexibility at a particular joint is at much lower risk of straining those muscles than someone with extremely "tight" muscles crossing that same joint.

Another factor in muscle strains is the speed with which the muscles are stretched. Many strains to the hamstrings, for example, result from participating in activities in which the individual is running, accelerating, and changing direction all at the same time. When the muscle group is overstretched, a strain results.

Strains are classified as *Grade I*, *II*, or *III*:

- With a grade I (mild) strain, you would feel a tightness in the muscle the day after the injury, but nothing more.
- Grade II (moderate) strains produce pain caused by a partial tear in the muscle. Associated weakness and temporary loss of function may also occur.
- With a grade III (severe) strain, the damage and symptoms are significantly greater than those accompanying grades I and II strains. Grade III strains involve a tearing of the muscle, loss of function, internal bleeding, and swelling.

Strains of the hamstrings are a frequent problem for athletes because these injuries are slow to heal and tend to recur. One-third of all hamstring strains will recur within the first year of returning to a sport or an activity.

Memory Tip

The terms *strain* (to muscles or tendons) and *sprain* (to a ligament at a joint) are very similar. Remember that Tight muscles and Tendons get sTrains.

Contusions

A **contusion** is a bruise or bleeding within a muscle, resulting from an impact. When an already injured muscle is repeatedly struck, a more serious condition, called **myositis ossificans** (migh-oh-SIGH-tis ah-SIF-i-kanz), can develop.

Myositis ossificans involves the formation of a calcium mass within the muscle over a period of three to four weeks. After six or seven weeks the mass usually begins to dissolve and is resorbed by the body. In some cases a bony lesion can remain in the muscle.

Cramps

Muscle cramps involve moderate to severe muscle spasms that cause pain. The cause of cramps is unknown; in fact, there may be numerous causes. Some of the possible causes include an electrolyte imbalance; deficiency in calcium, magnesium, or potassium; and dehydration.

Delayed-Onset Muscle Soreness

Muscle soreness is common and typically arises shortly after unaccustomed activity. **Delayed-onset muscle soreness (DOMS)** follows participation in a particularly long or strenuous activity, with the soreness beginning 24 to 72 hours after the activity. DOMS involves multiple, microscopic tears in the muscle tissue and causes inflammation, pain, swelling, and stiffness.

Check Your Understanding

1. Describe the differences among the three classifications of muscle strains.
2. Why are athletes more likely than others to have problems with strains?
3. What is the difference between cramps and DOMS?
4. What causes contusions? Give an example.
5. What are possible causes of cramps?

Tendinitis and Tendinosis

Tendons are the bands of tough, fibrous connective tissue that connect muscles to bones. **Tendinitis** is inflammation of a tendon, usually accompanied by pain and swelling.

Both acute and overuse injuries can cause tendinitis. The condition can also occur with aging, as the tendon wears and elasticity decreases. Diseases such as diabetes and rheumatoid arthritis can also promote the development of tendinitis. Tendinitis can occur in any part of the body, but common sites involving injury include the shoulder, elbow, wrist, and the Achilles tendon of the heel.

Treatment of tendinitis includes rest and application of heat or cold. Pain relievers such as aspirin and ibuprofen can reduce pain and inflammation. In severe cases, steroid injections into the tendon can help control pain. Once the pain is reduced, physical therapy to stretch and strengthen both muscle and tendon promotes healing and can help prevent reinjury.

If untreated, chronic tendinitis can progress to **tendinosis**. Tendinosis, or degeneration of a tendon, is believed to be caused by microtears in the tendon connective tissue that decrease the tendon's strength. This weakened condition increases the likelihood that the tendon will rupture.

Although the condition is painful, no inflammation is present, unlike with tendinitis. Once tendinosis has developed, recovery takes months to years of minimal use. In many cases physical therapy can help.

Rotational Injuries of the Shoulder

Repetition of forceful overhead motions at the shoulder (as in throwing and spiking in volleyball and serving in tennis) can lead to inflammation or tears of the muscles and muscle tendons surrounding the shoulder (**Figure 5.24**). A similar condition among competitive swimmers is known as *swimmer's shoulder*.

Improper motion mechanics increases the likelihood of these types of shoulder injuries. The symptoms are pain and stiffness with overhead or rapid movements. If not treated, the pain can become constant. Treatment includes application of ice, rest, and, when necessary, surgical repair.

Overuse Injuries of the Elbow

Epicondylitis (EHP-ih-kahn-di-LIGH-tis) involves inflammation and sometimes microtearing of the muscle tendons that cross the lateral and medial sides of the elbow. If unchecked, the condition can worsen, leading to swelling and then scarring of the tendons near the elbow. Lateral epicondylitis, which is reported in 30%–40% of tennis players, is known as *tennis elbow*, although it also occurs in activities such as swimming, fencing, and repetitious hammering. Medial epicondylitis, known as *Little Leaguer's elbow*, can result from repeated throwing, especially with improper pitching mechanics. Both lateral and medial epicondylitis commonly occur among amateur golfers.

Val Thoermer/Shutterstock.com

Figure 5.24 Sports such as volleyball can sometimes lead to overuse injuries of the shoulder muscles. *What other activities can cause injuries to the shoulder muscles?*

Memory Tip

The suffix *-itis* means "inflammation." You will learn about numerous conditions that involve inflammation of a part of the body. The names for all of those conditions contain the *-itis* suffix.

Shin Splints

The term **shin splint** is often used to describe pain localized to the medial lower leg. The condition is an overuse injury that typically arises from running or dancing—particularly running on a hard surface or uphill. The cause of the pain is believed to be microdamage to the muscle tendons that attach to the tibia or inflammation of the periosteum of the tibia. The muscles potentially involved include the soleus, tibialis anterior, and extensor digitorum.

Whiplash Injuries

Whiplash injuries to the neck are fairly common, often resulting from automobile accidents in which the victim's car was rear-ended. Such injuries result from abnormal motion of the cervical vertebrae, accompanied by rapid, forceful contractions of the neck muscles as the neuromuscular system attempts to stabilize and protect the spine. Symptoms can include neck muscle pain; pain or numbness extending down to the shoulders, arms, and even the hands; as well as headache.

WHAT RESEARCH TELLS US

...about Low Back Pain (LBP)

Low back pain (LBP) is a major health problem. Approximately 80%–85% of people experience it at some time during their lives.

In addition, back injuries are the most common and most expensive of all worker's compensation claims. Second only to the common cold in causing absences from work, the incidence of LBP has steadily increased in the US for the past 15 years. This is likely due, in part, to the increasing proportion of overweight and obese individuals. LBP is significantly associated with excess weight in both men and women of all ages.

Nearly 30% of children in the US also experience LBP. The likelihood that children will experience LBP increases with age. By age 16, the percentage of children with LBP is similar to that of adults. Children who are more physically active tend to incur LBP more often than sedentary children.

Athletes of all ages have a much higher incidence of LBP than nonathletes. In fact, more than 9% of college athletes receive treatment for LBP. Gymnasts (particularly those who are female) have much higher incidences of LBP. Studies show that as many as 85% of competitive gymnasts experience this health problem (**Figure 5.25**).

What causes LBP? Although injuries and certain disorders may cause LBP, 60% of LBP is of unknown origin. Low back muscle strains, resulting in soreness and stiffness, can be one source of LBP. In almost all cases of LBP, the low back muscles are sore and painful.

Sergej Khakimullin/Shutterstock.com

Figure 5.25 Repeated, extreme lumbar hyperextension increases the likelihood that female gymnasts will develop low back pain.

In some cases this pain is caused by muscle injury. In many cases, however, this pain may be due to what is called a *sympathetic contraction* of the low back muscles. This means that the muscles involuntarily contract as the body attempts to stabilize an underlying injury of the spinal column.

Fortunately, most LBP is self-limiting—75% of patients are back to normal within three weeks. Approximately 90% have recovered within two months, with or without medical treatment.

What can you do to avoid developing LBP? Known risk factors for LBP include the following:

- sitting for prolonged periods;
- standing for long periods in an unchanging position;
- working in an unnatural posture;
- working with one hand;
- encountering sudden or unexpected motions; and
- performing heavy manual labor.

Taller and heavier individuals are at increased risk for developing LBP. Cigarette smoking is also associated with increased risk of LBP, most likely because habitual smoking can contribute to degeneration of the intervertebral discs.

Taking It Further

1. Why do you think LBP is so common? Based on what you have read about LBP, do you think a higher or lower percentage of people will have LBP in the future? Explain your reasoning.
2. What do you think *self-limiting* means? Do some research, write a definition, and then give some examples of self-limiting behavior.
3. Conduct a survey among people you know to find out who has and who has not experienced LBP. Include males and females, athletes and nonathletes, and people of various ages in your survey. What conclusions can you draw from your survey about the occurrence of LBP?

Muscular Dystrophy

Muscular dystrophy (MD) is a group of similar, inherited disorders characterized by progressively worsening muscle weakness and loss of muscle tissue. Depending on the specific type, the onset of MD may occur during either childhood or adulthood, and the symptoms vary.

Some forms of MD affect only certain muscle groups, whereas other forms affect all of the muscles. The more severe types of MD begin in childhood; symptoms may include intellectual disability, delayed development of motor skills, frequent falling, drooling, and drooping of the eyelids. Some forms of MD also affect the heart muscle, resulting in an irregular heartbeat.

There are no known cures for the various muscular dystrophies; the goal of treatment is to control symptoms. Some types of muscular dystrophy lead to a shortened life; others cause little disability, allowing for a normal lifespan.

Check Your Understanding

1. What is the role of the neuromuscular system in whiplash injuries?
2. What causes swimmer's shoulder?
3. What is the difference between tennis elbow and Little Leaguer's elbow?
4. What are the characteristics of MD?
5. What are the different forms that MD may take?

Hernia

A **hernia** is a balloon-like section of the abdominal cavity lining that protrudes through a hole or weakened section of the muscles in the abdomen. A hernia can be caused by heavy lifting or by any activity or medical problem that increases pressure inside the abdominal cavity. In most cases, however, no specific cause is evident. Some hernias are present at birth, and some occur in infants and children. A hernia that is present at birth may not become noticeable until later in life.

Most hernias produce no symptoms, although some are accompanied by discomfort or pain that intensifies with heavy lifting or other activities that produce abdominal strain. A large hernia may "strangulate," or cut off the blood supply to the tissue inside the hernia. A strangulated hernia requires immediate surgery.

Small hernias that cause no symptoms do not necessarily require treatment. Larger hernias and those that cause discomfort can be permanently remedied with surgery.

Figure 5.26 Two young girls, both with rare forms of muscular dystrophy, have fun playing together at an event to benefit the Muscular Dystrophy Association (MDA). We currently have no cures for the various forms of muscular dystrophy but hopefully research conducted in genetics labs such as the one shown here will lead to methods and treatments that reduce the effects of or eliminate the disease. *Have you donated to a campaign to raise money for muscular dystrophy research?*

Lesson 5.4 Review and Assessment

Mini Glossary

Make sure that you know the meaning of each key term.

Build vocabulary with e-flash cards and games

contusion the bruises or bleeding within a muscle that result from an impact

delayed-onset muscle soreness (DOMS) muscle pain that follows participation in a particularly long or strenuous activity, begins 24–73 hours later, and involves multiple, microscopic tears in the muscle tissue that cause inflammation, pain, swelling, and stiffness

hernia a balloon-like section of the lining of the abdominal cavity that protrudes through a hole or weakened section of the muscles in the abdomen

muscle cramps moderate to severe muscle spasms that cause pain

muscle strain an injury that occurs when a muscle is stretched beyond the limits to which it is accustomed

muscular dystrophy (MD) a group of similar, inherited disorders characterized by progressively worsening muscle weakness and loss of muscle tissue

myositis ossificans a condition in which a calcium mass forms within a muscle three to four weeks after a muscle injury

shin splint the name for pain localized to the anterior lower leg

tendinitis inflammation of a tendon, usually accompanied by pain and swelling

tendinosis degeneration of a tendon believed to be caused by microtears in the tendon connective tissue

Know and Understand

Assess

1. What causes a muscle strain?
2. What can you do to increase your chances of avoiding muscle strains?
3. What is myositis ossificans? What problems can it cause?
4. What do shoulder, elbow, and shin injuries have in common?
5. What is the main cause of DOMS?
6. Why is it important to treat chronic tendinitis?
7. What is believed to be the main cause of shin splints?
8. Name an activity often associated with hernias.

Analyze and Apply

9. If obesity is a major cause of LBP, why would gymnasts experience this health problem?
10. How do poor mechanics contribute to overuse injuries such as swimmer's shoulder and tennis elbow? Describe and analyze the effect of torque in these injuries.
11. What types of muscle can be affected by muscular dystrophy?

In the Lab

12. Interview a physical therapist or an athletic trainer. Ask the person to describe a typical day at work. Here are some questions you might ask:
    - What is the work environment like?
    - What are the job duties?
    - What kinds of injuries are dealt with?
    - What other types of professionals does he or she work with?

    Report your findings to the class, giving reasons why you would or would not want to pursue a career similar to that of the person you interviewed. You may want to incorporate additional research from the Career Corner activity on the next two pages into your report.
13. Research shin-splint taping. Determine its purpose and how it helps the athlete.

Career Corner
Anatomy and Physiology at Work

Many challenging and rewarding careers involve treating and rehabilitating the muscles of the body. We will discuss two career options below.

Physical Therapist

Physicians often prescribe physical therapy for patients with muscle injuries. Frequently employed in physical therapy clinics, physical therapists and related professionals treat each patient's condition with appropriate exercise, stretching, and other therapeutic protocols (**Figure 5.27**). Treatment at a physical therapy clinic can last from a few visits to a series of visits over a period of months, depending on the severity of the condition being treated.

Prescribed exercise and stretching regimens are typically progressive in nature, beginning with a relatively easy routine that grows increasingly challenging. All patient activity in the clinic is closely supervised by a physical therapist to ensure that all movements are carried out in the correct directions and through appropriate ranges of motion.

The academic degree that physical therapists must earn is the DPT, or Doctor of Physical Therapy. Nationwide, entry into DPT programs is highly competitive. To qualify, students must possess a bachelor's degree and must also have completed prerequisite courses in biology, chemistry, physics, calculus, and human anatomy and physiology, to name just a few. When applying to a DPT program, candidates must provide documentation showing that they have a substantial amount of experience (paid or unpaid) assisting patients in a physical therapy clinic. This documentation ensures that applicants are appropriately familiar with the field of physical therapy. Most DPT programs take approximately three years to complete and require supervised clinical rotations as well as academic coursework. Physical therapists are employed by schools and universities, as well as in hospitals and other clinical environments.

Tyler Olson/Shutterstock.com

Figure 5.27 A physical therapist works with a patient to rehabilitate her knee after surgery. *Why do all physical-therapy patient activities need to be closely monitored by the physical therapist?*

Athletic Trainer

If an injury is related to a sport played at the high school or collegiate level, the first professional to examine the patient will likely be an expert in athletic training (**Figure 5.28**). Athletic trainers are knowledgeable first responders who are trained to apply advanced first aid, as well as to know when immediate referral to emergency care, a physician, or a specialist is necessary.

Athletic trainers are also well qualified to administer rehabilitative treatments when appropriate, typically after the injured athlete has been seen by a physician. Athletic trainers work with active individuals of all ages and physical abilities in industrial settings, gyms, fitness centers, youth athletic leagues, the Special Olympics, and anywhere that people are active.

To become an ATC, or Certified Athletic Trainer, students must complete a bachelor's degree in athletic training and then pass a national certification examination. Programs of study in athletic training include a number of basic science courses, human anatomy and physiology, and in-depth lecture/laboratory courses that cover prevention and treatment of athletic injuries to all parts of the body. Athletic trainers are employed in high schools, colleges and universities, hospitals, and clinics.

Planning for a Health-Related Career

Do some research on career opportunities for physical therapists or athletic trainers. Keep in mind the different levels of education and certifications that are required.

You may want to select a profession from the list of **Related Career Options**. Using the Internet or resources at your local library, find answers to the following questions:

1. What are the main tasks and responsibilities of an athletic trainer or a physical therapist?
2. What is the outlook for these careers? Are workers in demand, or are jobs dwindling? For complete information, consult the current edition of the *Occupational Outlook Handbook*, published by the US Department of Labor. This handbook is available online or at your local library.
3. What special skills or talents are required? For example, do you need to be capable of lifting? Are you comfortable looking at injuries that may be severe?
4. What personality traits do you think are needed to be successful in these jobs? For instance, both athletic trainers and physical therapist must work closely with their patients. Do you enjoy working with others?
5. Do these careers involve a great deal of routine, or are the day-to-day responsibilities varied?
6. Does the work require long hours, or are these standard, "9-to-5" jobs?
7. What is the salary range for these jobs?
8. What do you think you would like about each career? Is there anything about them that you might dislike?

Related Career Options

- Athletic Trainer
- Massage Therapist
- Occupational Therapist
- Physical Therapist Assistant
- Recreational Therapist
- Rehabilitation Counselor

Aspen Photo/Shutterstock.com

Figure 5.28 Athletic trainers work with student athletes to prevent, treat, and rehabilitate injuries.

Chapter 5 Review and Assessment

Chapter Summaries

Lesson 5.1 Muscle Tissue Categories and Functions

Build vocabulary with e-flash cards and games

Key Points

- The three major categories of muscle fibers are *smooth*, *cardiac*, and *skeletal* (striated), each with a different function.
- Muscles are either voluntary or involuntary.
- Muscles have four common behavioral characteristics: extensibility, elasticity, irritability, and contractility.
- Skeletal muscles work in an agonist/antagonist relationship and can experience concentric, eccentric, or isometric contractions.

Key Terms

agonist
antagonist
aponeurosis
concentric
contractility
eccentric
endomysium
epimysium
extensibility
fascicle
irritability
isometric
muscle fiber
perimysium
peristalsis
sarcolemma

Lesson 5.2 Skeletal Muscle Actions

Key Points

- The muscular and nervous systems work together and are known as the *neuromuscular system*.
- The motor unit is the functional unit of the neuromuscular system and is made up of the neuron and the muscle fibers that the neuron stimulates. The location at which the neurons and the fibers come together is known as the *neuromuscular junction*.
- Skeletal muscle fibers are divided into fast-twitch fibers, which are powerful and fatigue quickly, or slow-twitch fibers, which are fatigue resistant.
- Muscular strength is determined by measuring torque, muscular power is defined as force × velocity, and muscular endurance is how long a muscle fiber can continuously contract before it fatigues.

Key Terms

acetylcholine
action potential
all-or-none law
axon
axon terminals
cross bridges
fast-twitch
motor neuron
motor unit
neuromuscular junction
parallel
pennate
sarcomeres
slow-twitch
synaptic cleft
tetanus

Lesson 5.3 The Major Skeletal Muscles

Key Points

- Muscles are attached to bone via the origin and insertion.
- The sagittal plane movements are forward and backward actions.
- The frontal plane movements take the body part toward or away from the midline of the body.
- Transverse plane movements are actions that move side to side or rotate around a longitudinal axis.
- The upper limb sacrifices stability for increased range of motion when compared with the lower limb.

Key Terms

abduction
adduction
circumduction
dorsiflexion
eversion
extension
flexion
hyperextension
insertion
inversion
lateral rotation
medial rotation
opposition
origin
plantar flexion
pronation
radial deviation
supination
ulnar deviation

Lesson 5.4 Common Injuries and Disorders of Muscles

Key Points

- Strains are injuries that occur when muscles are stretched beyond their limits.
- Contusions are caused by impact; severe contusions can result in myositis ossificans.
- Possible causes of cramps are dehydration, mineral deficiency, and electrolyte imbalance.
- Delayed-onset muscle soreness is brought on by long, strenuous activity resulting in inflammation, pain, swelling, and stiffness.
- Many muscle injuries, such as DOMS, strains, rotational injuries, and shin splints, result from muscle overuse.
- Low back pain (LBP) can be caused by obesity, muscle strain, muscle overuse, or an issue with the spinal column.
- Muscular dystrophy (MD) is a neuromuscular disease that results in progressively worsening muscle weakness and atrophy.

Key Terms

contusion
delayed-onset muscle soreness (DOMS)
hernia
muscle cramps
muscle strain
muscular dystrophy (MD)
myositis ossificans
shin splint
tendinitis
tendinosis

Chapter Assessments

Assess

Lesson 5.1

Muscle Tissue Categories and Functions

Learning Key Terms and Concepts

1. The individual skeletal muscle cell is referred to as a(n) _____.
2. The three layers of muscle tissue, from the inside out, are _____, _____, and _____.
3. Skeletal muscle is connected to bone by either _____ or aponeuroses.
4. _____ muscle is found in organs and blood vessels.
5. The heart is made up of _____ muscle cells.
6. The ability of a muscle and other tissue to be stretched is the behavioral characteristic known as _____.
   A. extensibility
   B. elasticity
   C. irritability
   D. contractility
7. The ability of a muscle to respond to stimuli is the behavioral characteristic known as _____.
   A. extensibility
   B. elasticity
   C. irritability
   D. contractility

Thinking Critically

8. Discuss in depth the differences between concentric, isometric, and eccentric contractions and provide examples of how each one is used in daily life.
9. What do you think would be the pros and cons of body organs being made up exclusively of voluntary muscle (no involuntary muscle)? Provide specific examples and some pros and some cons for each.
10. Describe the structure of skeletal muscle. What different parts make up what we typically think of as a muscle?

Lesson 5.2

Skeletal Muscle Actions

Learning Key Terms and Concepts

11. A nerve that stimulates skeletal muscle is called a(n) _____.
12. The functional unit of the neuromuscular system is the _____.

13. A(n) _____ is an electrical charge that creates tension within a muscle fiber.
14. _____ twitch muscle fibers contract powerfully but fatigue quickly.

Thinking Critically

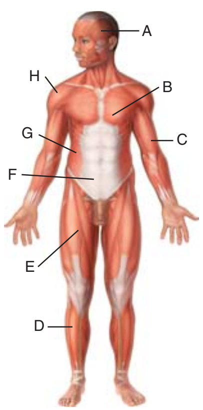
15. Discuss muscle fiber arrangements that contribute to the force a muscle can generate.
16. How do you think slow-twitch muscle fibers are usually arranged? Give reasons for your answer.
17. Who generates more power: an olympic weight lifter who must lift 400 pounds from the ground to a position over his head very rapidly, or a power lifter who must squat down and stand up with 800 pounds on his back? Defend your answer.
18. Discuss how torque is used to measure the strength of a muscle group at a specific joint.

Lesson 5.3

The Major Skeletal Muscles

Learning Key Terms and Concepts

Instructions: Write the **letter** of the name of the **muscle** on your answer sheet next to the corresponding number.



_____ 19. Deltoid
_____ 20. Abdominal aponeurosis
_____ 21. Biceps brachii
_____ 22. Rectus femoris
_____ 23. Temporalis
_____ 24. Pectoralis major
_____ 25. Tibialis anterior
_____ 26. External oblique

Thinking Critically

27. Compare and contrast the sagittal and frontal planes. Be sure to discuss the movements that occur in each plane.
28. In circumduction, which planes does the limb move through and what actions do you think are being utilized to make the conical/circular motion?
29. Do agonists and antagonists have to perform their actions in the same plane? Why?

Lesson 5.4

Common Injuries and Disorders of Muscles

Learning Key Terms and Concepts

30. A muscle strain is classified as _____, _____, or _____.
31. A(n) _____ is a bruise or bleeding within a muscle.
32. A complication that can arise from a contusion is _____.
    A. sarcolemma
    B. myositis ossificans
    C. neuroma
    D. spondylosis
33. Which of the following may be a cause of cramps?
    A. electrolyte imbalance
    B. dehydration
    C. deficiency in minerals such as calcium or potassium
    D. all of the above
34. The role of the neuromuscular system in a whiplash injury is _____.
    A. an inhibitory response that causes the muscles to relax and the head to move freely
    B. a strong, fast series of contractions that attempt to stabilize the head
    C. not present because the movement is so intense that muscles don't have time to contract
    D. dependent upon whether the movement is mediolateral or anteroposterior
35. Lateral epicondylitis is also known as _____.
    A. Little Leaguer's elbow
    B. Swimmer's shoulder
    C. Jumper's knee
    D. Tennis elbow

Thinking Critically

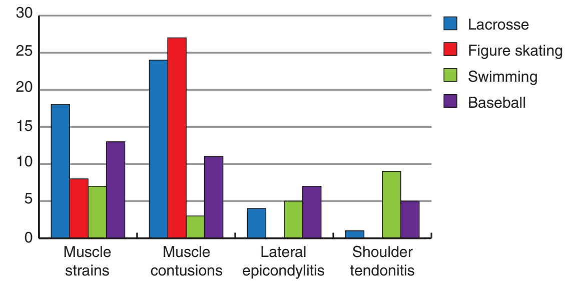
36. If being active is considered healthy, why do you think active people and athletes have a significantly higher incidence of LBP than inactive, sedentary people?
37. Compare and contrast the responsibilities of physical therapists and athletic trainers. How are they similar? How are they different? Which job seems more appealing to you and why?

Building Skills and Connecting Concepts

Analyzing and Evaluating Data

Use the bar graph to answer the following questions.

38. Which sport involves the most muscle strains?
39. Which sport involves the most muscle contusions?
40. What percentage of swimming injuries is attributed to muscle strains?
41. What is the approximate ratio of muscle contusions in figure skating to muscle contusions in baseball?
42. Compare the total number of swimming injuries with the total number of figure skating injuries.



Communicating about Anatomy and Physiology

43. **Listening** In small groups discuss with your classmates—in basic, everyday language—your knowledge and awareness of your muscles as you go about your daily routine. Conduct this discussion as though you had never read this chapter. Take notes on the observations expressed. Then review the points discussed, factoring in your new knowledge of muscles. Develop a summary of what you have learned about muscles and present it to the class, using the terms that you have learned about the muscular system in this chapter.
44. **Speaking** Pick a figure in this chapter, such as Figure 5.1, 5.4, or 5.6. Working with a partner, tell and then retell the important information being conveyed by that figure. Through your collaboration, develop what you and your partner believe is the most interesting verbal description of the importance of the chosen figure. Present your narration to the class.

Lab Investigations

45. Do a push-up starting in the "up" position. Go down. Which muscles are experiencing concentric contractions? Which muscles are experiencing eccentric contractions? Which muscles are experiencing isometric contractions? Which plane(s) is the shoulder moving through? What actions are occurring at the shoulder, elbow, and wrist? Record your observations and then compare them with those of your classmates in a class discussion.
46. Make a working model of a joint that includes both the agonist and the antagonist muscles. Write a brief explanation of how they work together to produce movement.
47. Try to switch the common (what we think of as normal) origin and insertion points of as many muscles as you can. Focus on the most frequent, everyday movements. Make a list and describe what you did to switch them. Hint: Compare origin and insertion points when doing straight-leg sit-ups and straight-leg leg lifts.

Expand your learning with additional online resources
- Supplemental Lab Activities
- Interactive Exercises
- Animations

Expand
Companion Website
www.g-wlearning.com/healthsciences