learning objectives

1 State the characteristics and functions of muscle tissue.
2 Describe the structure of a skeletal muscle.
3 List and describe the sequence of events involved in the contraction of a skeletal muscle fiber.
4 Explain how energy is provided for a muscle contraction.
5 Describe oxygen debt.
6 Describe and illustrate the movements accomplished by the contraction of skeletal muscle.
7 Identify and describe the major muscles making up the axial skeleton.
8 Identify and describe the major muscles making up the appendicular skeleton.
9 Describe ways in which the aging of an individual affects the muscular system.
10 Identify pathology related to the muscular system.

Key Terms
antagonist (an-TAG-oh-nist)
insertion (in-SIR-shun)
motor unit (MOH-toar YOO-nit)
neuromuscular junction (noo-roe-MUSK-yoo-lar JUNK-shun)
neurotransmitter (noo-roh-TRANS-mit-ter)
origin (OR-ih-jin)
prime mover (PRYM MOO-ver)
synergist (SIN-er-gist)
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Introduction to the Muscular System

As described in Chapter 5, there are three types of muscle tissue: skeletal, visceral, and cardiac. These are reviewed in Table 8-1. This chapter takes a closer look at skeletal muscle, which makes up about 40% of an individual's body weight. It forms more than 600 muscles that are attached to the bones of the skeleton. Skeletal muscles are under conscious control, and when they contract they move the bones. Skeletal muscles also allow us to smile, frown, pout, show surprise, and exhibit other forms of facial expression.

Characteristics and Functions of the Muscular System

Skeletal muscle has four primary characteristics that relate to its functions:

Excitability: Excitability (eks-eye-tah-BILL-ih-tee) is the ability to receive and respond to a stimulus. To function properly, muscles have to respond to a stimulus from the nervous system.
Contractility: Contractility (kon-track-TILL-ih-tee) is the ability to shorten or contract. When a muscle responds to a stimulus, it shortens to produce movement.
Extensibility: Extensibility (eks-ten-sih-BILL-ih-tee) means that a muscle can be stretched or extended. Skeletal muscles are often arranged in opposing pairs. When one muscle contracts, the other muscle is relaxed and stretched.
Table 8-1 Summary of Muscle Tissue

Feature	Skeletal	Visceral	Cardiac
Location	Attached to bones	Walls of internal organs and blood vessels	Heart
Function	Produce body movement	Contraction of viscera and blood vessels	Pump blood through heart and blood vessels
Cell shape	Cylindric	Spindle-shaped; tapered ends	Cylindric, branching
Number of nuclei	Many	One	One
Striations	Present	Absent	Present
Type of control	Voluntary	Involuntary	Involuntary

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Elasticity: Elasticity (ee-lass-TISS-ih-tee) is the capacity to recoil or return to the original shape and length after contraction or extension

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Muscle contraction fulfills four important functions in the body:

•Movement
•Posture
•Joint stability
•Heat production

Nearly all *movement* in the body is the result of muscle contraction. Some exceptions to this are the action of cilia, the motility of the flagella on sperm cells, and the ameboid movement of some white blood cells. The integrated action of joints, bones, and skeletal muscles produces obvious movements such as walking and running. Skeletal muscles also produce more subtle movements that result in various facial expressions, eye movements, and respiration. *Posture*, such as sitting and standing, is maintained as a result of muscle contraction. The skeletal muscles are continually making fine adjustments that hold the body in stationary positions. Skeletal muscles contribute to *joint stability*. The tendons of many muscles extend over joints and in this way contribute to joint stability. This is particularly evident in the knee and shoulder joints, where muscle tendons are a major factor in stabilizing the joint. *Heat production*, to maintain body temperature, is an important by-product of muscle metabolism. Nearly 85% of the heat produced in the body is the result of muscle contraction.

Structure of Skeletal Muscle

A whole skeletal muscle is considered an organ of the muscular system. For example, the biceps muscle is an organ of the muscular system. Each organ or muscle consists of skeletal muscle tissue, connective tissue, nerve tissue, and blood or vascular tissue.

Whole Skeletal Muscle

An individual skeletal muscle such as the biceps muscle may consist of hundreds, or even thousands, of muscle fibers bundled together and wrapped in a connective tissue covering. Each muscle is surrounded by a connective tissue sheath called the *epimysium* (ep-ih-MYE-see-um). Fascia consists of connective tissue located outside the epimysium. Fascia surrounds and separates the muscles. Skeletal muscle cells (fibers), like other body cells, are soft and fragile. The connective tissue coverings furnish support and protection for the delicate cells and allow them to withstand the forces of contraction. The coverings also provide pathways for the passage of blood vessels and nerves.

Highlight on the Muscular System

Rigor mortis: The term *rigor mortis* means the "stiffness of death." Within a short time of death, the adenosine triphosphate in muscles breaks down. This causes the myofilaments to remain locked in a contracted position and the body becomes rigid. A day or so later, muscle proteins begin to deteriorate and the rigor mortis disappears.
Tetanus: The word *tetanus* is often confusing because it means different things to different people. In reference to muscle contraction, the term denotes a steady contraction of a muscle fiber, without a relaxation phase. The word also refers to a disease, commonly called "lockjaw," that is caused by the bacterium *Clostridium tetani*. The toxin from the bacteria causes nerves to be highly excitable, which, in turn, causes uncontrollable muscle contractions, or spasms. A third use of the word is to denote a condition caused by a deficiency of calcium ions in the extracellular fluid. The lack of calcium increases nerve excitability with resulting muscle spasms, particularly of the extremities. The word *tetany* is also sometimes used to mean tetanus.
Cramps: Cramps are painful, spastic contractions of muscles. They are usually caused by an irritation within the muscles that results in reflex contractions. Local inflammation from the accumulation of lactic acid is one source of irritation.
Wryneck: Injury to one of the sternocleidomastoid muscles may result in torticollis, or wryneck. This is characterized by a twisting of the neck and an unnatural position of the head.
Diaphragm: Voluntary forceful contractions of the diaphragm increase intraabdominal pressure to assist in urination, defecation, and childbirth.
Electrical shock: The muscles that flex the fingers and hand are stronger than the extensor muscles. In a normal relaxed position the fingers are slightly flexed because the normal muscle tone is greater in the flexors. Persons who receive a high-voltage electrical shock through the arms flex their hands tightly and "can't let go." All of the flexors and extensors receive the electrical stimulus, but because the flexor muscles are stronger, they contract more forcefully.
Intramuscular injections: The gluteus medius is a common site for intramuscular injections. Generally, the injection is given in the center of the upper outer quadrant of the buttock, or gluteal, area. The gluteus medius, rather than the gluteus maximus, is used to avoid damaging the sciatic nerve.
Horseback riding: The adductor muscles in the medial compartment are the horse rider's muscles. These muscles adduct, or press, the thighs together to keep a person on a horse.
Quads: The quadriceps femoris group is a powerful knee extensor that is used in climbing, running, and rising from a chair. ▪

Skeletal Muscle Fibers

Each individual skeletal muscle fiber consists of a single cylindric muscle cell. The cell membrane is called the *sarcolemma* (sar-koh-LEM-mah), and the cytoplasm is the *sarcoplasm* (SAR-koh-plazm). Multiple nuclei are next to the sarcolemma at the periphery of the cell. Because the muscle 124125cell needs energy for contraction, there are numerous mitochondria.

Nerve and Blood Supply

Skeletal muscles have an abundant supply of blood vessels and nerves. This is directly related to the primary function of skeletal muscle contraction. Before a skeletal muscle fiber can contract, it must receive an impulse from a nerve cell. Muscle contraction requires adenosine triphosphate (ATP), and blood vessels deliver the necessary nutrients and oxygen to produce it. Blood vessels also remove the waste products that are produced as a result of muscle contraction.

In general, an artery and at least one vein accompany each nerve that penetrates the epimysium of a skeletal muscle. Branches of the nerve and blood vessels follow the connective tissue components of the muscle so that each muscle fiber is in contact with a branch of a nerve cell and with one or more minute blood vessels called *capillaries*.

Skeletal Muscle Attachments

In some instances, fibers of the epimysium fuse directly with the periosteum of a bone to form a *direct* attachment. The fleshy part of the muscle is known as the *belly* or *gaster*. More commonly, the connective tissue coverings extend beyond the belly of the muscle to form a thick,

ropelike *tendon* or a broad, flat, sheetlike *aponeurosis* (ah-pah-noo-ROE-sis). The tendons or aponeuroses form *indirect* attachments from

muscles to the periosteum of bones or to the connective tissue of other muscles. Typically, a muscle spans a joint and is attached to bones by tendons at both ends. One of the bones remains relatively fixed or stable while the other end moves as a result of muscle contraction. The fixed or stable end is called the **origin** of the muscle, and the more movable attachment is called the **insertion.**

Contraction of Skeletal Muscle

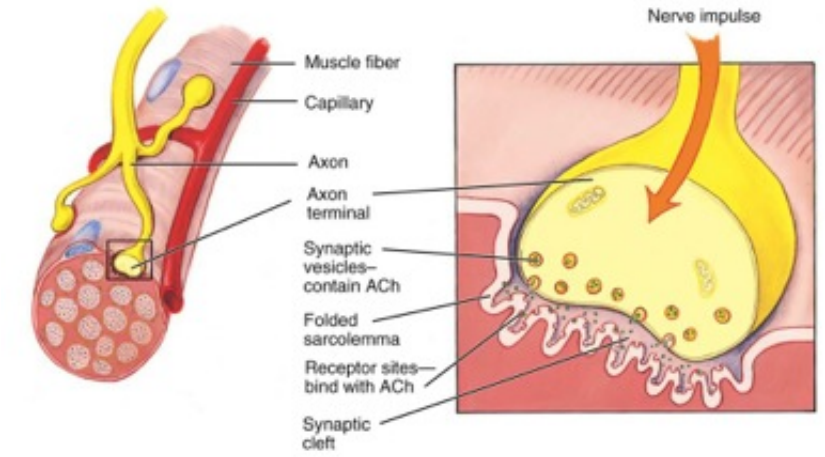
Skeletal muscle contraction is the result of a complex series of events based on chemical reactions at the cellular (muscle fiber) level. This chain of reactions begins with stimulation by a nerve cell and ends when the muscle fiber is again relaxed. Contraction of a whole muscle is the result of the simultaneous contraction of many muscle fibers.

Stimulus for Contraction

Skeletal muscles are stimulated to contract by special nerve cells called *motor neurons*. As the axon of the motor neuron penetrates the muscle, the axon branches, so there is an axon terminal for each muscle fiber. A single motor neuron and all the muscle fibers it stimulates make up a **motor unit.** Some motor units include several hundred individual fibers; others contain fewer than 10. Because all the muscle fibers in a motor unit receive a nerve impulse at the same time, all the fibers contract at the same time.

The region in which an axon terminal meets a muscle fiber is called a **neuromuscular junction** or myoneural 125126

Figure 8-1 Neuromuscular junction. The axon terminal fits into a depression on the sarcolemma. A nerve impulse travels down the axon to the axon terminal. The impulse causes the synaptic vesicles to release acetylcholine, which diffuses across the synaptic cleft and binds with receptors on the sarcolemma.



junction, which is illustrated in Figure 8-1. The axon terminal does not actually touch the sarcolemma of the muscle cell but fits into a shallow depression in the cell membrane. The fluid-filled space between the axon terminal and sarcolemma is called a *synaptic cleft* (gap). *Acetylcholine (ACh)* (ah-see-till-KOH-leen), a **neurotransmitter,** is contained within synaptic vesicles in the axon terminal. Receptor sites for the ACh are located on the sarcolemma.

When a nerve impulse reaches the axon terminal, ACh is released. The ACh diffuses across the synaptic cleft and binds with the receptor sites on the sarcolemma. This reaction is the stimulus for contraction.

The ACh is rapidly inactivated by the enzyme *acetylcholinesterase* (ah-see-till-koh-lin-ES-ter-ase). This ensures that one nerve impulse will result in only one contraction of the muscle fiber. Anything that interferes with the production, release, or inactivation of ACh, or its ability to bind with the receptor sites on the sarcolemma, will have an effect on muscle contraction. Muscle relaxant drugs work in this manner.

Highlight on Conditions and Procedures Related to the Muscular System Conditions
Conditions

Cramp (KRAMP) Painful involuntary muscle spasm; often caused by myositis but can be a symptom of any irritation or ion imbalance
Muscular dystrophy (MUSS-kyoo-lar DIS-troh-fee) An inherited, chronic, progressive wasting and weakening of muscles without involvement of the nervous system
Myasthenia gravis (mye-as-THEE-nee-ah GRAY-vis) An autoimmune disease, more common in females, that is characterized by weakness of skeletal muscles caused by an abnormality at the neuromuscular junction
Myoparesis (mye-oh-pah-REE-sis) Weakness or slight paralysis of a muscle
Myopathy (mye-AHP-ah-thee) Muscle disease
Myorrhexis (mye-oh-REK-sis) Rupture of a muscle
Myositis (mye-oh-SYE-tis) Inflammation of muscle tissue
Repetitive stress disorder (ree-PET-ah-tiv STRESS dis-OAR-der) Condition with symptoms caused by repetitive motions that involve muscles, tendons, nerves, and joints; most commonly occur as work-related or sports injuries
Shin splint (SHIN SPLINT) Strain of the long flexor muscle of the toes resulting in pain along the tibia (shinbone); usually caused by repeated stress to the lower leg
Tic (TIK) A spasmodic involuntary twitching of a muscle that is normally under voluntary control

Procedures

Electromyography (ee-lek-troh-mye-AHG-rah-fee) The process of recording the strength of muscle contraction as a result of electrical stimulation
Muscle biopsy (MUSS-uhl BYE-ahp-see) Removal of muscle tissue for microscopic examination
Tenomyoplasty (ten-oh-MY-oh-plas-tee) Surgical repair of a tendon and muscle; applied especially to an operation for inguinal hernia
Tenoplasty (TEN-oh-plas-tee) Surgical repair of a tendon

Tenorrhaphy (ten-OAR-ah-fee) Suture of a tendon ▪

Energy Sources and Oxygen Debt

The immediate or initial source of energy for muscle contraction is ATP. Surprisingly, muscles have limited storage facilities for ATP. In working muscles the stored ATP is depleted in about 6 seconds, and new ATP must be regenerated if muscle contraction is to continue.

Creatine phosphate (KREE-ah-tin FOS-fate) is a unique high-energy compound that is stored in muscles This compound provides almost instantaneous regeneration of ATP.

This reaction is so effective that there is little change in ATP levels during the initial stages of muscle contraction. Muscles store enough creatine phosphate to regenerate sufficient ATP to sustain contraction for about 10 seconds.

When muscles are actively contracting for extended periods of time, *fatty acids* and *glucose* become the primary energy sources. As ATP and creatine phosphate stores are being used, more ATP is produced from the metabolism of glucose and fatty acids.

If adequate oxygen is available, fatty acids and glucose are broken down in the mitochondria by a process called *aerobic respiration*. The products are carbon dioxide, water, and large amounts of ATP.

When muscles are contracting vigorously for long periods of time, the circulatory system is unable to deliver oxygen fast enough to maintain the aerobic pathways. Processes that do not require oxygen are necessary. Under these conditions, glucose is the primary energy source. If adequate oxygen is not available, glucose is broken down by a process called *anaerobic respiration*. The products of the anaerobic pathway are lactic acid and a small amount of ATP.

Some of the lactic acid accumulates in the muscle and causes a burning sensation. Most of it diffuses out of the muscle and into the bloodstream, which takes it to the liver. Later, when sufficient oxygen is available, the liver converts the lactic acid back to glycogen, the storage form of glucose.

The aerobic pathway produces about 20 times more ATP than the anaerobic pathway. However, the anaerobic pathway provides ATP about two and one-half times faster than the aerobic pathway. Most of the energy for vigorous activity over a moderate period of time comes from anaerobic respiration. Prolonged activities requiring endurance depend on aerobic mechanisms.

Periods of strenuous exercise that require anaerobic mechanisms to regenerate ATP create an *oxygen debt* that must be repaid before equilibrium can be restored. There is an accumulation of lactic acid in the muscle that may cause 126127temporary muscular pain and cramping. The ATP and creatine phosphate in the muscle are depleted and need to be replenished. This additional oxygen is necessary to convert the lactic acid into glycogen, a process that occurs in the liver. Oxygen is also necessary to replenish the ATP and the creatine phosphate in the muscle. Oxygen debt is defined as the additional oxygen that is required after physical activity to restore resting conditions. The debt is paid back by labored breathing that continues after the activity has stopped.

Movements

Most intact skeletal muscles are attached to bones by tendons that span joints. When the muscle contracts, one bone (the insertion) moves relative to the other bone (the origin). Frequently muscles work in groups to perform a particular movement. If one muscle has a primary role in providing a movement, it is called a **prime mover.** Muscles that work with, or assist, the prime mover to cause a movement are called **synergists** (SIN-er-jists). Often muscles span more than one joint, and a synergist will stabilize one joint while the prime mover acts on the other joint. For example, the fingers can be flexed to make a fist without bending the wrist because certain muscles fix the wrist in a stabilized position. **Antagonists** are muscles that oppose, or reverse, a particular movement. The biceps brachii muscle on the anterior arm flexes the forearm at the elbow. The triceps brachii muscle on the posterior arm extends the forearm at the elbow. The two muscles are on opposite sides of the humerus and have opposite functions. They are antagonists.

Bones and muscles work together to perform different types of movement at the various joints. Describing muscular action or movement at joints requires a frame of reference and descriptive terminology with definite meaning. Some commonly used terms that are used to describe particular movements are defined and illustrated in Figure 8-2.

Skeletal Muscle Groups

The body is composed of more than 600 skeletal muscles. A discussion of each muscle is certainly beyond the scope of this book. Only the more significant and obvious muscles are identified and described here. These are arranged in groups according to location and/or function. If you identify and learn the muscles as group associations, it will make them easier to remember. If you can locate a muscle on your own body, you will be able to contract the muscle and describe its action. Learning anatomy in this manner makes it more meaningful.

Naming Muscles

Most skeletal muscles have names that describe some feature of the muscle. Often several criteria are combined into one name. Associating the muscles' characteristics with their names will help you learn and remember them. The following are some terms relating to muscle features that are used in naming muscles:

•*Size:* vastus (huge); maximus (large); longus (long); minimus (small); brevis (short)
•*Shape:* deltoid (triangular); rhomboid (like a rhombus with equal and parallel sides); latissimus (wide); teres (round); trapezius (like a trapezoid, a four-sided figure with two sides parallel) 127128 128129
Figure 8-2 Types of body movements.

Flexion (FLEK-shun)
Means to bend. Flexion usually brings two bones closer together and decreases the angle between them. Example: bending the elbow or the knee.

Dorsiflexion (dor-sih-FLEK-shun)
Flexion of the ankle in which the dorsum or top of the foot is lifted upward, decreasing the angle between the foot and leg. Example: standing on your heels.

Extension (ek-STEN-shun)
Means to straighten. Extension is the opposite of flexion. It increases the angle between two bones. Example: straightening the elbow or the knee after it has been flexed.

Plantar flexion (PLAN-tar FLEK-shun)
Plantar flexion is movement at the ankle that increases the angle between the foot and leg. Example: standing on your toes.

Hyperextension (hye-perk-ek-STEN-shun)
Hyperextension occurs when a part of the body is extended beyond the anatomical position. The joint angle becomes greater than 180°. Example: moving the head backward.

Abduction (ab-DUCK-shun)
Means to take away. Abduction moves a bone or limb away from the midline or axis of the body. Examples: the outward movement of the legs in "jumping jacks," moving the arms away from the body, or spreading the fingers apart.

Adduction (ad-DUCK-shun)
Means to bring together. Adduction is the opposite of abduction. It moves a bone or limb toward the midline of the body. Examples: bringing the arms back to the sides of the body after they have been abducted or moving the legs back to anatomical position after abduction.

Circumduction (sir-kum-DUCK-shun)
Circumduction is the conelike, circular movement of a body segment. The proximal end of the segment remains relatively stationary while the distal end outlines a large circle. Example: the movement of the arm at the shoulder joint, with the elbow extended, so that the tips of the fingers move in a large circle.

Rotation (roh-TAY-shun)
Rotation is the movement of a bone around its own axis in a pivot joint. Example: shaking your head "no".

Inversion (in-VER-zhun)
Inversion is the movement of the sole of the foot inward or medially.

Supination (soo-pih-NAY-shun)
Supination is a specialized rotation of the forearm that turns the palm of the hand forward or anteriorly. If the elbow is flexed, supination turns the palm of the hand upward or superiorly.

Eversion (ee-VER-zhun)
Eversion is the opposite of inversion. It is the movement of the sole of the foot outward or laterally.

Pronation (proh-NAY-shun)
Pronation is the opposite of supination. It is a specialized rotation of the forearm that turns the palm of the hand backward or posteriorly. If the elbow is flexed, pronation turns the palm of the hand downward or inferiorly.

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•*Direction of fibers:* rectus (straight); transverse (across); oblique (diagonal); orbicularis (circular)
•*Location:* pectoralis (chest); gluteus (buttock or rump); brachii (arm); supra- (above); infra- (below); sub- (under or beneath); lateralis (lateral)
•*Number of origins:* biceps (two heads); triceps (three heads); quadriceps (four heads)
•*Origin and insertion:* sternocleidomastoid (origin on the sternum and clavicle, insertion on the mastoid process); brachioradialis (origin on the brachium or arm, insertion on the radius)
•*Action:* abductor (to abduct a structure); adductor (to adduct a structure); flexor (to flex a structure); extensor (to extend a structure); levator (to lift or elevate a structure); masseter (to chew)

Muscles of the Head and Neck

Muscles of Facial Expression

Humans have well-developed muscles in the face that permit a large variety of facial expressions. Because these muscles are used to show surprise, disgust, anger, fear, and other emotions, they are an important means of nonverbal communication. The following are some of the muscles used to produce facial expressions.

The *frontalis* (frun-TAL-is) is over the frontal bone of the forehead. It is attached to the soft tissue of the eyebrow; when it contracts, it raises the eyebrows and wrinkles the forehead. The *orbicularis oris* (oar-BIK-yoo-lair-is OAR-is) is a sphincter that encircles the mouth. This muscle is used to close the mouth, to form words, and to pucker the lips as in kissing. The *orbicularis oculi* (oar-BIK-yoo-lair-is OK-yoo-lye) is another sphincter but is around the eye (oculus). The actions of winking, blinking, and squinting use this muscle. The *buccinator* (BUCK-sin-ay-ter) is the principal muscle in the cheek area and is used to compress the cheek when whistling, sucking, or blowing air out. It is sometimes called the *trumpeter's muscle*. The *zygomaticus* (zye-goh-MAT-ih-kus) extends from the zygomatic arch to the corners of the mouth. It contracts to raise the corner of the mouth when we smile.

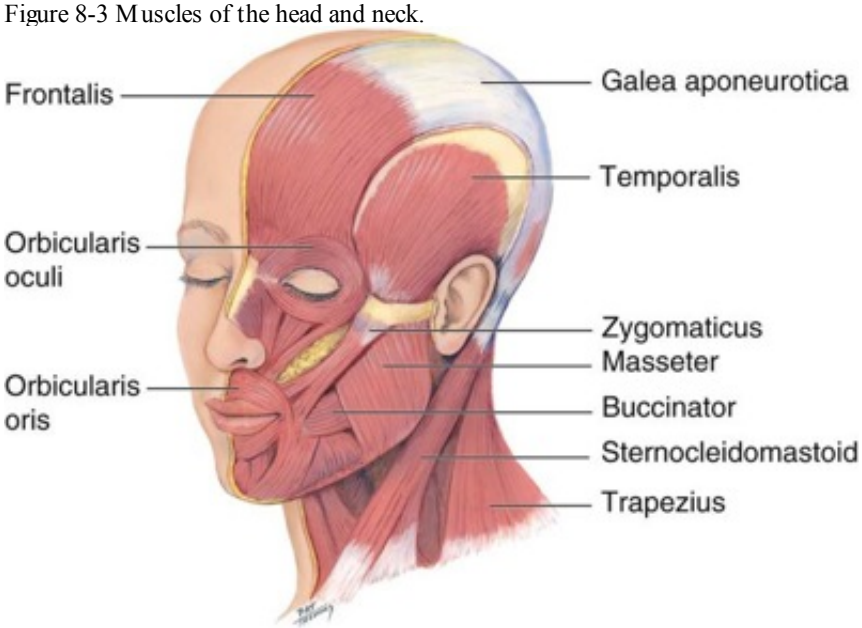
Muscles of Mastication

Four pairs of muscles are responsible for chewing movements or mastication. All of these muscles insert on the mandible, and they are some of the strongest muscles in the body. Two of the muscles, the *temporalis* (tem-poar-AL-is) and *masseter* (MASS-eh-ter), are superficial and are identified in Figure 8-3. The others, the lateral and medial pterygoids, are deep to the mandible and are not shown in the figure. The *temporalis* is the largest of the mastication muscles. As the name implies, it has its origin on the temporal bone. The *masseter* is located along the ramus of the mandible and is a synergist of the temporalis.

Neck Muscles

Only two of the more obvious and superficial neck muscles are considered here. Numerous muscles are associated with

Figure 8-3 Muscles of the head and neck.



the throat, hyoid bone, and vertebral column, a discussion of which is beyond the scope of this text.

The *sternocleidomastoid* (stir-no-klye-doh-MAS-toyd) muscles ascend obliquely across the anterior neck from the sternum and clavicle to the mastoid process. When both of these muscles contract together, the neck is flexed and the head is bent toward the chest. When one of the muscles contracts, the head turns toward the direction opposite the side that is contracting. When the left muscle contracts, the head turns to the right. A portion of the *trapezius* (trah-PEEZ-ee-us) muscle is in the neck region and moves the head. Each trapezius muscle extends from the occipital bone at the base of the skull to the end of the thoracic vertebrae and also inserts on the scapula laterally. A portion of this muscle extends the head and is antagonistic to the sternocleidomastoid.

Muscles of the Trunk

The muscles of the trunk include those that move the vertebral column, the muscles that form the thoracic and abdominal walls, and those that cover the pelvic outlet.

Vertebral Column Muscles

The *erector spinae* (ee-REK-ter SPY-nee) group of muscles on each side of the vertebral column is a large muscle mass that extends from the sacrum to the skull. These muscles are primarily responsible for extending the vertebral column to maintain erect posture. Muscle contraction on only one side bends the vertebral column to that side.

Thoracic Wall Muscles

The muscles of the thoracic wall are involved primarily in the process of breathing. The intercostal muscles are located in spaces between the ribs. The *external intercostal muscles* contract to elevate the ribs during the inspiration phase of breathing. The *internal intercostals* contract during forced expiration.

The *diaphragm* is a dome-shaped muscle that forms a partition between the thorax and the abdomen. It has three openings in it for structures that have to pass from the 130131thorax to the abdomen. The diaphragm is responsible for the major movement in the thoracic cavity during quiet, relaxed breathing. When the diaphragm contracts, the dome is flattened. This increases the volume of the thoracic cavity and results in

inspiration. When the muscle relaxes, it again resumes its dome shape and decreases the volume of the thoracic cavity, which forces air out during expiration.

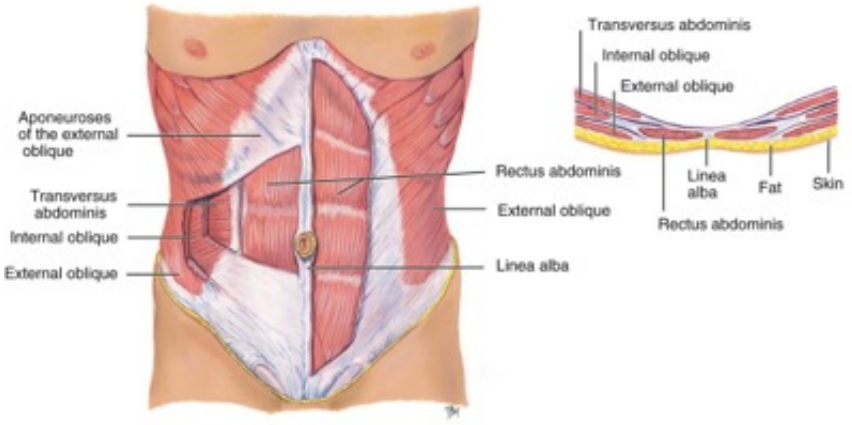
Abdominal Wall Muscles

The abdomen, unlike the thorax and pelvis, has no bony reinforcements or protection. The wall consists entirely of four muscle pairs, arranged in layers, and the fascia that envelops them (Figure 8-4). The aponeuroses of the muscles on opposite sides meet in the anterior midline to form the *linea alba* ("white line"), a band of connective tissue that extends from the sternum to the pubic symphysis. The outer muscle layer is the *external oblique*. The *internal oblique* lies just underneath it, and the deepest layer of muscle is the *transversus abdominis*. The arrangement of the muscle layers with the fibers in each layer going in different directions is similar to the type of construction found in plywood and adds strength to the anterolateral abdominal wall. The fascia of these muscles extends anteriorly to form a broad aponeurosis along much of the anterior aspect of the abdomen. The fascia also envelops the *rectus abdominis* muscle, which runs vertically from the pubic bones to the ribs and the sternum on each side of the midline. All of these muscles compress the abdominal wall and increase intraabdominal pressure. The rectus abdominis also flexes the vertebral column.

Pelvic Floor Muscles

The *pelvic diaphragm* forms the floor of the pelvic cavity. Most of the pelvic diaphragm is formed by the two *levator*

Figure 8-4 Abdominal wall muscles.



ani muscles, which support the pelvic viscera. They resist increased pressure in the abdominopelvic cavity and thus play a role in the control of the urinary bladder and rectum.

Muscles of the Upper Extremity

The muscles of the upper extremity include those that attach the scapula to the thorax and generally move the scapula, those that attach the humerus to the scapula and generally move the arm, and those that are located in the arm or forearm and move the forearm, wrist, and hand. Figure 8-5 illustrates the anterior view of body musculature and Figure 8-6 illustrates the posterior view.

Muscles That Move the Shoulder and Arm

The *trapezius* attaches the scapula to the axial skeleton. It is a large superficial triangular muscle of the back. When the trapezius contracts, it adducts and elevates the scapula, as in shrugging the shoulders.

Both the *pectoralis major* (pek-tor-AL-iss MAY-jer) and the *latissimus dorsi* (lah-TISS-ih-mus DOR-sye) muscles attach the humerus to the axial skeleton. The pectoralis major is a superficial muscle on the anterior chest. It has a broad origin on the sternum, costal cartilages, and clavicle, but then the fibers converge to insert on the humerus by way of a short tendon. The primary function of the pectoralis major is to adduct and rotate the arm medially across the chest. The latissimus dorsi is a large, superficial muscle located in the lower back region. It has an extensive origin from the spines of the thoracic vertebrae, ilium, and ribs and then extends upward to insert on the humerus. The latissimus dorsi adducts and rotates the arm medially and lowers the shoulder. It is an important muscle in swimming and rowing motions.

The *deltoid* is a large, fleshy muscle that covers the shoulder and attaches the humerus to the scapula. This muscle 131132 132133

Figure 8-5 General overview of body musculature. Anterior view.

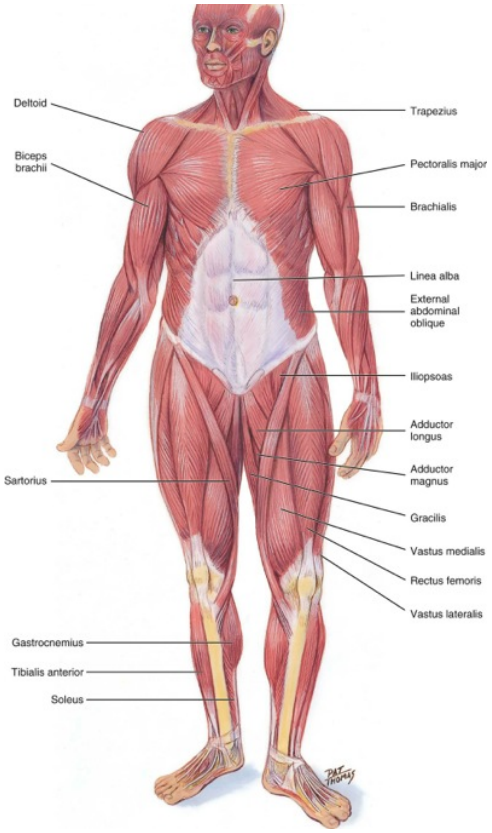


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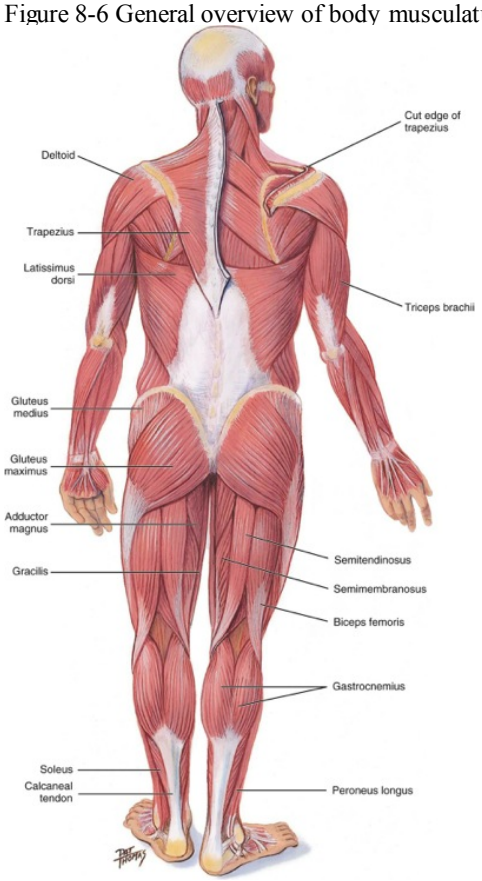
Figure 8-6 General overview of body musculature. Posterior view.



abducts the arm to a horizontal position. It is a common site for administering intramuscular injections. Another group of muscles, called the *rotator cuff muscles*, attaches the humerus to the scapula and moves the humerus in some way. These muscles form a cuff or cap over the proximal humerus. A rotator cuff injury involves damage to one or more of these muscles or their tendons.

Muscles That Move the Forearm and Hand

The muscles that move the forearm are located along the humerus. The arm is divided into anterior and posterior muscle compartments. The

triceps brachii, the primary extensor of the forearm, is the only muscle in the posterior compartment. As the name implies, it has three heads of

origin. The anterior muscle compartment contains the *biceps brachii*, a primary flexor of the forearm.

The 20 or more muscles that cause most wrist, hand, and finger movements are located along the forearm. These muscles are divided into anterior and posterior compartments. Most of the anterior compartment muscles flex the wrist and fingers, whereas the posterior muscles cause extension.

Muscles of the Lower Extremity

The muscles of the lower extremity include those that are located in the hip region and generally move the thigh, those that are located in the thigh and move the leg, and those that are located in the leg and move the ankle and foot. See Figure 8-5 and Figure 8-6 to visualize these muscles.

Muscles That Move the Thigh

The muscles that move the thigh have their origins on some part of the pelvic girdle and their insertions on the femur. The largest muscle mass belongs to the posterior group, the gluteal muscles. The *gluteus maximus* forms the area of the buttocks. The *gluteus medius*, a common site for intramuscular injections, is superior and deep to the gluteus maximus. The *gluteus minimus* is the smallest and deepest of the gluteal muscles and is not illustrated. These muscles abduct the thigh—that is, they raise the thigh sideways to a horizontal position. The gluteus maximus also extends or straightens the thigh at the hip for walking or climbing stairs.

The anterior muscle that moves the thigh is the *iliopsoas* (ill-ee-oh-SOH-as). This muscle is formed from the iliacus, which originates on the iliac fossa, and the psoas, which originates on the lumbar vertebrae. The fibers converge into the iliopsoas and insert on the femur. The iliopsoas flexes the thigh, making it antagonistic to the gluteus maximus.

The medial muscles adduct the thigh—that is, they press the thighs together. This group includes the *adductor longus, adductor brevis, adductor magnus*, and *gracilis* (grah-SILL-is) muscles. These muscles are often called the *horse rider's muscles* because their action keeps the rider on the horse.

Muscles That Move the Leg

Muscles that move the leg are located in the thigh region. The *quadriceps femoris* (KWAHD-rih-seps FEM-oar-is) includes four muscles that are on the anterior and lateral sides of the thigh, namely the *vastus lateralis, vastus intermedius, vastus medialis*, and *rectus femoris*. As a group, these muscles are the primary extensors of the leg, straightening the leg at the knee. The other muscle on the anterior surface of the thigh is the long, strap like *sartorius* (sar-TOAR-ee-us), which passes obliquely over the quadriceps group. The sartorius, the longest muscle in the body, flexes and medially rotates the leg when one sits cross-legged.

The posterior thigh muscles are called the *hamstrings*, and they are used to flex the leg at the knee. All have origins on the ischium and insert on the tibia. Because these muscles extend over the hip joint, as well as over the knee joint, they also extend the thigh. The strong tendons of these muscles can be felt behind the knee. These same tendons are present in hogs, and butchers used them to hang the hams for smoking and curing, so they were called "ham strings." The hamstring muscles are the *biceps femoris, semimembranosus* (sem-ee-MEM-brah-noh-sus), and *semitendinosus* (sem-ee-TEN-dih-noh-sus). A "pulled hamstring" is a tear in one or more of these muscles or their tendons.

Muscles That Move the Ankle and Foot

The muscles located in the leg that move the ankle and foot are divided into anterior, posterior, and lateral compartments. The *tibialis anterior* is the primary muscle in the anterior group, and its contraction causes dorsiflexion of the foot. The *peroneus* (pear-oh-NEE-us) muscles occupy the lateral compartment of the leg. Contraction of these muscles everts the foot and also helps in plantar flexion. The *gastrocnemius* (gas-trok-NEE-mee-us) and *soleus* (SOH-lee-us) are the major muscles in the posterior compartment. These two muscles form the fleshy mass in the calf of the leg. They have a common tendon called the *calcaneal tendon* or *Achilles tendon*. These muscles are strong plantar flexors of the foot. They are sometimes called the *toe dancer's muscles* because they allow one to stand on tiptoe. Numerous other deep muscles in the leg cause flexion and extension of the toes.

Aging of the Muscular System

One of the most "obvious" age-related changes in skeletal muscles is the loss of muscle mass. This involves a decrease in both the number of muscle fibers and the diameter of the remaining fibers. Because muscle fibers are amitotic, once they are lost they cannot be replaced by new ones. Instead, they are replaced by connective tissue, primarily adipose. The number of muscle cells lost depends on several factors, including the amount of physical activity, the nutritional state of the individual, heredity, and the condition of the motor neurons that supply the muscle tissue. There is an age-related loss of motor neurons to skeletal muscle cells, and this is considered an important cause of muscle atrophy. 134135It is probable that exercise enhances the ability of nerves to stimulate muscle fibers and to reduce atrophy.

As muscle mass decreases, there is a corresponding reduction in muscle strength. The amount of strength loss differs, depending to a large extent on the amount of physical activity. There is evidence that the mitochondria function less effectively in nonexercised muscle cells than in exercised cells. When mitochondria are inefficient, lactic acid accumulates, which contributes to muscle weakness.

There is a tendency for the skeletal muscles of older people to be less responsive, or to respond more slowly, than those of younger people. This is because the latent, contraction, and relaxation phases of muscle action all increase in duration. The increase in response time is less in muscles that are used regularly. Continued physical activity and good nutrition are probably the best deterrents to loss of muscle mass and muscle strength and to increased muscle response time.

Terminology Review

Medical Term	Word Parts	Definition
Antagonist	*anti-:* against	A muscle that has an action opposite to that of the prime mover.

Insertion		The end of a muscle that is attached to a relatively movable part; the end opposite the origin.
Motor unit		A single neuron and all the muscle fibers it stimulates.
Neuromuscular junction	*neur/o:* nerve	The area of communication between the axon terminal of a motor neuron and the sarcolemma of a muscle fiber; also called a *myoneural junction*.
Neurotransmitter	*neur/o:* nerve *trans-:* across	A chemical substance that is released at the axon terminals to stimulate a muscle fiber contraction or an impulse in another neuron.
Origin		The end of a muscle that is attached to a relatively immovable part; the end opposite the insertion.
Prime mover		The muscle that is mainly responsible for a particular body movement; also called *agonist*.
Synergist	*syn-:* together *erg/o:* work	A muscle that assists a prime mover but is not capable of producing the movement by itself; two or more muscles work together to produce a movement.


On the Web

For information on muscles and joints:

Gateway Community College: Muscles Tutorial: www.gwc.maricopa.edu/class/bio201/muscle/mustut.htm
Loyola University Medical Education Network: Master Muscle List: www.meddean.luc.edu/lumen/meded/grossanatomy/dissector/mml/index.htm
Merck Manual—Musculoskeletal Disorders: www.merck.com/mmpe/sec04.html *(Click on "Musculoskeletal Disorders")*
San Diego State University College of Sciences: Actin Myosin Crossbridges: www.sci.sdsu.edu/movies/actin_myosin_gif.html
Science Animations: science.nhmccd.edu/biol/animatio.htm
Skeletal Muscles of the Human Body: ptcentral.com/muscles
Skeleton: The Joints: www.zoology.ubc.ca/%7Ebiomania/tutorial/bonejt/outline.htm
University of Washington: Lower Extremity Muscle Atlas: www.rad.washington.edu/atlas2
University of Washington: Upper Extremity Muscle Atlas: www.rad.washington.edu/atlas
University of Wisconsin Medical School: Anatomy Dissections: www.anatomy.wisc.edu/courses/gross/index.html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Types of Skeletal Muscle Contractions