Exhibit 8.11 Muscles That Move the Femur (Thigh Bone) *(Figure 8.23)*

OBJECTIVE • Describe the origin, insertion, and action of the muscles that move the femur.

Overview: Muscles of the lower limbs are larger and more powerful than those of the upper limbs to provide stability, locomotion, and maintenance of posture. In addition, muscles of the lower limbs often cross two joints and act equally on both. The majority of muscles that act on the femur originate on the pelvic (hip) girdle and insert on the femur. The anterior muscles are the psoas major and iliacus, together referred to as the ***iliopsoas*** (il′-ē-ō-SŌ-as). The remaining muscles (except for the pectineus, adductors, and tensor fasciae latae) are posterior muscles. Technically, the pectineus and adductors are components of the medial compartment of the thigh, but they are included in this exhibit because they act on the thigh. The tensor fasciae latae is laterally placed. The ***fascia lata*** is a deep fascia of the thigh that encircles the entire thigh. It is well developed laterally, where together with the tendons of the gluteus maximus and tensor fasciae latae it forms a structure called the ***iliotibial tract***. The tract inserts into the lateral condyle of the tibia.

The major muscles of the inner thigh function to move the legs medially. This muscle group is important in activities such as sprinting, hurdling, and horseback riding. A rupture or tear of one or more of these muscles can cause a **groin pull**. Groin pulls most often occur during sprinting or twisting, or from kicking a solid, perhaps stationary object. Symptoms of a groin pull may be sudden, or may not surface until the day after the injury, and include sharp pain in the inguinal region, swelling, bruising, or inability to contract the muscles. As with most strain injuries, treatment involves RICE therapy, which stands for *R*est, *I*ce, *C*ompression, and *E*levation. Ice should be applied immediately, and the injured part should be elevated and rested. An elastic bandage should be applied, if possible, to compress the injured tissue.

Relating muscles to movements: Arrange the muscles in this exhibit according to the following actions on the thigh at the hip joint: (1) flexion, (2) extension, (3) abduction, (4) adduction, (5) medial rotation, and (6) lateral rotation. The same muscle may be mentioned more than once.

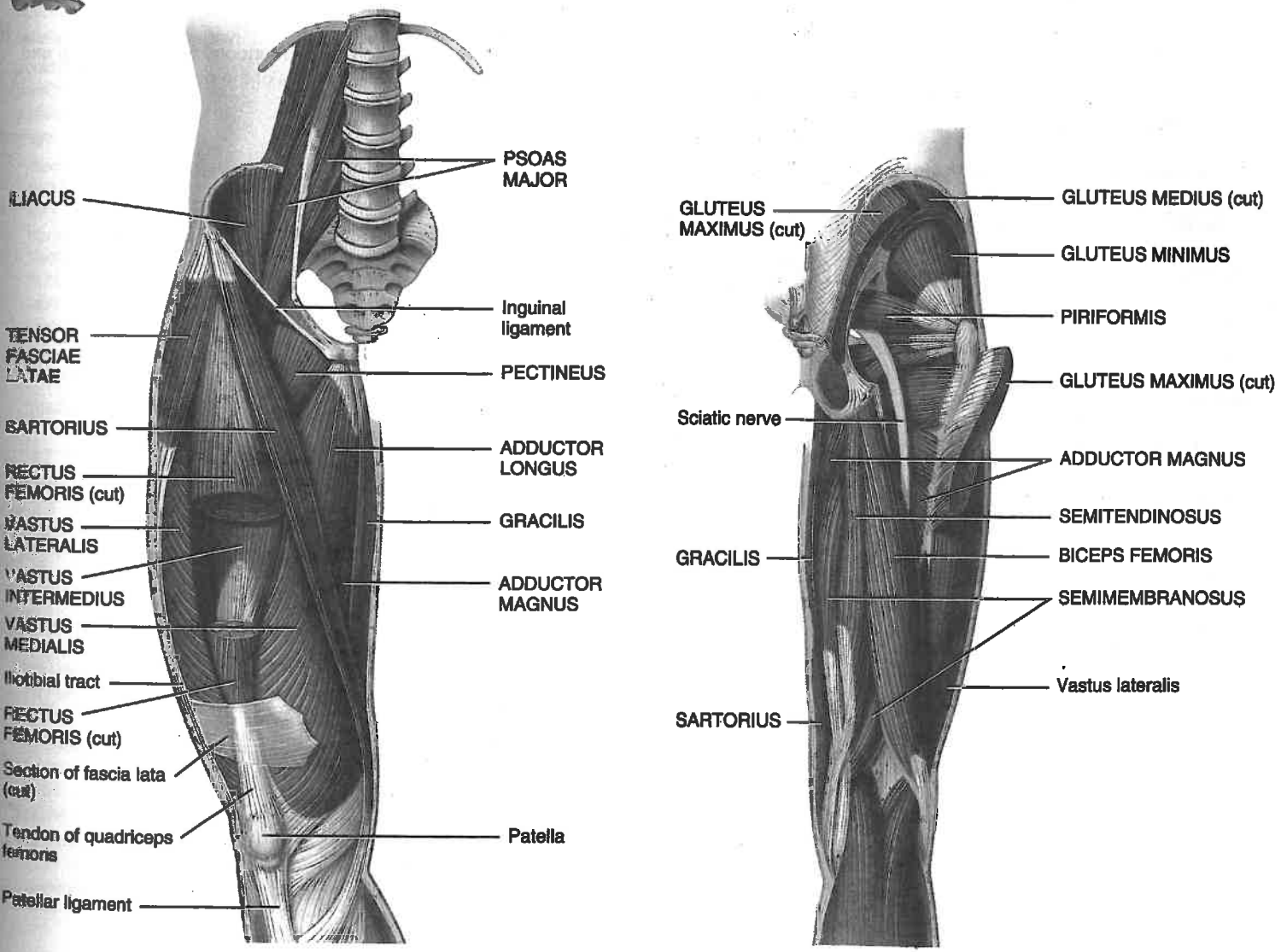
■ **CHECKPOINT**

What forms the iliotibial tract?

Muscle	Origin	Insertion	Action
Psoas major (SŌ-as; *psoa* = a muscle of loin)	Lumbar vertebrae.	Femur.	Flexes and rotates thigh laterally at the hip joint; flexes vertebral column.
Iliacus (il′-ē-AK-us; *iliac* = ilium)	Ilium.	With psoas major into femur.	Flexes and rotates thigh laterally at the hip joint; flexes vertebral column.
Gluteus maximus (GLOO-tē-us MAK-si-mus; *glute-* = buttock; *maximus* = largest) (See also Figure 8.13b.)	Ilium, sacrum, coccyx, and aponeurosis of sacrospinalis.	Iliotibial tract of fascia lata and femur.	Extends and rotates thigh laterally at the hip joint.
Gluteus medius (MĒ-dē-us; *medi-* = middle) (See also Figure 8.13b.)	Ilium.	Femur.	Abducts and rotates thigh medially at the hip joint.
Tensor fasciae latae (TEN-sor FA-shē-ē LĀ-tē; *tensor* = makes tense; *fasciae-* = of the band; *lat-* = wide)	Ilium.	Tibia by means of the iliotibial tract.	Flexes and abducts thigh at the hip joint.
Adductor longus (LONG-us; *adductor* = moves part closer to midline; *longus* = long)	Pubis and pubic symphysis.	Femur.	Adducts, medially rotates, and flexes thigh at the hip joint.
Adductor magnus (MAG-nus; *magnus* = large)	Pubis and ischium.	Femur.	Adducts, flexes, medially rotates and extends thigh (anterior part flexes, posterior part extends) at the hip joint.
Piriformis (pir-i-FOR-mis; *piri-* = pear; *form-* = shape)	Sacrum.	Femur.	Rotates thigh laterally and abducts it at the hip joint.
Pectineus (pek-TIN-ē-us; *pectin-* = comb-shaped)	Pubis.	Femur.	Flexes and adducts thigh at the hip joint.

Figure 8.23 Muscles that move the femur (thigh bone).

Most muscles that move the femur originate on the pelvic (hip) girdle and insert on the femur.



(a) Anterior superficial view

(b) Posterior superficial view

Which muscles are part of the quadriceps femoris? The hamstrings?

Exhibit 8.12 Muscles That Move the Femur (Thigh Bone) and Tibia and Fibula (Leg Bones) *(See Figure 8.23)*

OBJECTIVE • Describe the origin, insertion, and action of the muscles that move the femur, tibia, and fibula.

Overview: The muscles that move the femur, tibia, and fibula originate in the hip and thigh and are separated into compartments by deep fascia. The ***medial (adductor) compartment*** is so named because its muscles adduct the thigh. The adductor magnus, adductor longus, and pectineus muscles, components of the medial compartment, are included in Exhibit 8.11 because they act on the femur. The gracilis, the other muscle in the medial compartment, not only adducts the thigh but also flexes the leg. For this reason, it is included in this exhibit.

The ***anterior (extensor) compartment*** is so designated because its muscles act to extend the leg at the knee joint, and some also flex the thigh at the hip joint. It is composed of the quadriceps femoris and sartorius muscles. The quadriceps femoris muscle is the largest muscle in the body but has four distinct parts, usually described as four separate muscles (rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius). The common tendon for the four muscles is the ***quadriceps tendon***, which attaches to the patella. The tendon continues below the patella as the ***patellar ligament*** and attaches to the tibial tuberosity. The sartorius muscle is the longest muscle in the body, extending from the ilium of the hip bone to the medial side of the tibia. It moves both the thigh and the leg.

The ***posterior (flexor) compartment*** is so named because its muscles flex the leg (but also extend the thigh). Included are the hamstrings (biceps femoris, semitendinosus, and semimembranosus), so named because their tendons are long and string-like in the popliteal area.

> A strain or partial tear of the proximal hamstring muscles is referred to as **"pulled hamstrings"** or **hamstring strains**. They are common sports injuries in individuals who run very hard and/or are required to perform quick starts and stops. Sometimes the violent muscular exertion required to perform a feat tears off part of the tendinous origins of the hamstrings, especially the biceps femoris, from the ischial tuberosity. This injury is usually accompanied by a *contusion* (bruising) and tearing of some of the muscle fibers and rupture of blood vessels, producing a *hematoma* (collection of blood) and pain. Adequate training with good balance between the quadriceps femoris and hamstrings and stretching exercises before running or competing are important in preventing this injury.

Relating muscles to movements: Arrange the muscles in this exhibit according to the following actions on the thigh at the hip joint: (1) abduction, (2) adduction, (3) lateral rotation, (4) flexion, and (5) extension; and according to the following action on the leg: (1) flexion and (2) extension. The same muscle may be mentioned more than once.

■ CHECKPOINT

Which muscle tendons form the medial and lateral borders of the popliteal fossa?

Muscle	Origin	Insertion	Action
Medial (Adductor) Compartment			
Adductor magnus (MAG-nus) **Adductor longus** (LONG-us) **Pectineus** (pek-TIN-ē-us)	See Exhibit 8.11.		
Gracilis (GRAS-i-lis; *gracilis* = slender)	Pubic symphysis.	Tibia.	Adducts and medially rotates thigh at hip joint; flexes leg at knee joint.
Medial (Extensor) Compartment			
Quadriceps femoris (KWOD-ri-seps FEM-or-is; *quadriceps* = four heads of origin, *femoris* = femur)			
Rectus femoris (REK-tus FEM-or-is; *rectus* = straight; here, fibers run parallel to midline)	Ilium.	Patella by means of quadriceps tendon and then tibial tuberosity by means of patellar ligament.	All four heads extend leg at knee joint; rectus femoris muscle alone also flexes thigh at hip joint.
Vastus lateralis (VAS-tus lat′-er-Ā-lis; *vast-* = large; *lateralis* = lateral)	Femur.		
Vastus medialis (mē′-dē-Ā-lis; *medialis* = medial)	Femur.		
Vastus intermedius (in′-ter-MĒ-dē-us; *intermedius* = middle)	Femur.		
Sartorius (sar-TOR-ē-us; *sartor-* = tailor; refers to cross-legged position of tailors) Longest muscle in the body.	Ilium.	Tibia.	Flexes leg at knee joint; flexes, abducts, and laterally rotates thigh at hip joint, thus crossing leg.
Posterior (Flexor) Compartment			
Hamstrings			
Biceps femoris (BĪ-ceps FEM-or-is; *biceps* = two heads of origin)	Ischium and femur.	Fibula and tibia.	Flexes leg at knee joint; extends thigh at hip joint.
Semitendinosus (sem′-ē-TEN-di-nō′-sus; *semi-* = half; *tendo-* = tendon)	Ischium.	Tibia.	Flexes leg at knee joint; extends thigh at hip joint.
Semimembranosus (sem′-ē-MEM-bra-nō′-sus; *membran-* = membrane)	Ischium.	Tibia.	Flexes leg at knee joint; extends thigh at hip joint.

Exhibit 8.13 Muscles That Move the Foot and Toes *(Figure 8.24)*

OBJECTIVE • Describe the origin, insertion, and action of the muscles that move the foot and toes.

Overview: Muscles that move the foot and toes are located in the leg. The muscles of the leg, like those of the thigh, are divided into three compartments by deep fascia. The ***anterior compartment*** consists of muscles that dorsiflex the foot. In a situation like that at the wrist, the tendons of the muscles of the anterior compartment are held firmly to the ankle bones by thickenings of deep fascia called the ***superior extensor retinaculum*** and ***inferior extensor retinaculum***. The ***lateral compartment*** contains muscles that plantar flex and evert the foot. The ***posterior compartment*** consists of superficial and deep muscles. The superficial muscles (gastrocnemius and soleus) share a common tendon of insertion, the calcaneal (Achilles) tendon, the strongest tendon of the body.

Shinsplint syndrome, or simply **shinsplints**, refers to pain or soreness along the medial, distal two-thirds of the tibia. It may be caused by tendinitis of the tibialis anterior or toe flexors, inflammation of the periosteum around the tibia, or stress fractures of the tibia. The tendinitis usually occurs when poorly conditioned runners run on hard or banked surfaces with poorly supportive running shoes or walking or running up and down hills. The condition may also occur as a result of vigorous activity of the legs following a period of relative inactivity. The muscles in the anterior compartment (mainly the tibialis anterior) can be strengthened to balance the stronger posterior compartment muscles.

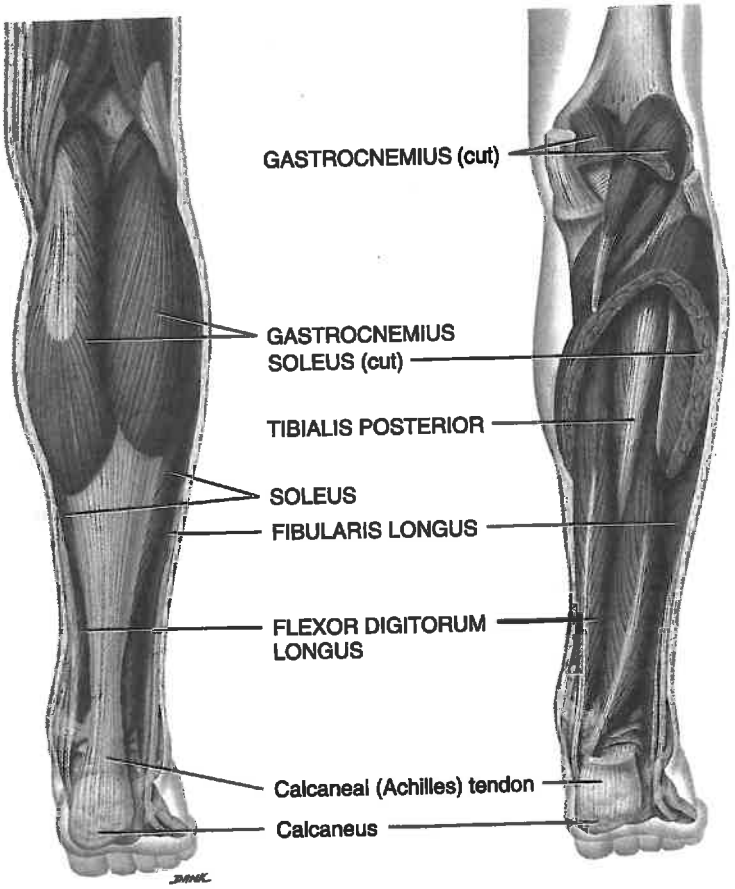
Relating muscles to movements: Arrange the muscles in this exhibit according to the following actions on the foot: (1) dorsiflexion, (2) plantar flexion, (3) inversion, and (4) eversion; and according to the following actions on the toes: (1) flexion and (2) extension. The same muscle may be mentioned more than once.

■ **CHECKPOINT**

What is the function of the superior and inferior extensor retinaculum?

Figure 8.24 Muscles that move the foot and toes.

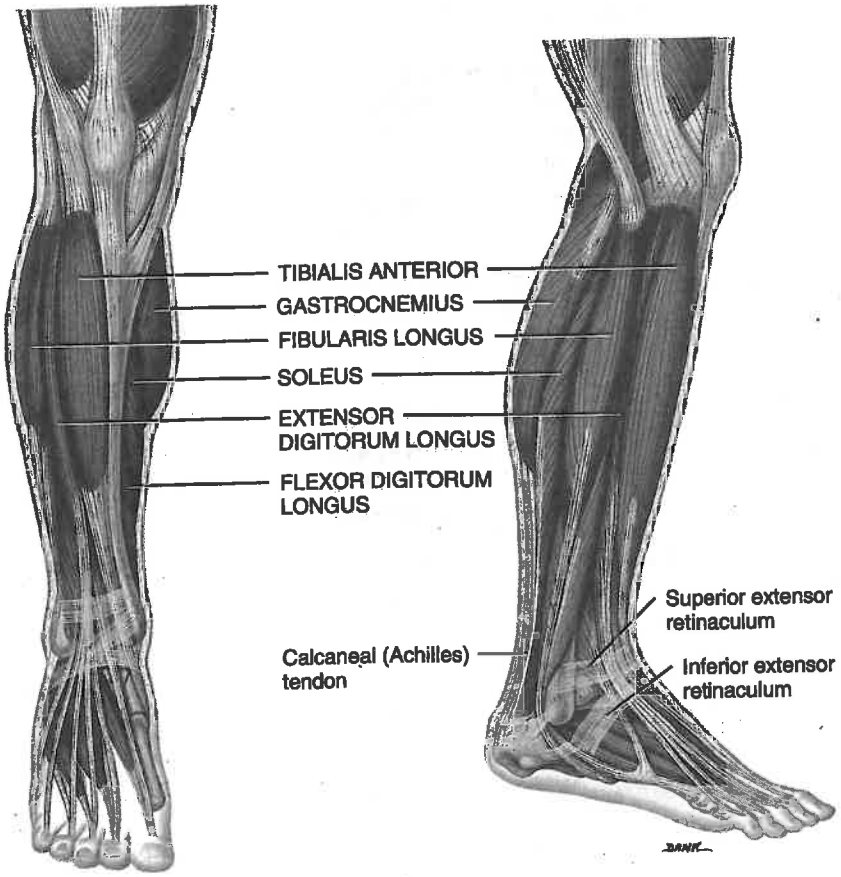
The superficial muscles of the posterior compartment share a common tendon of insertion, the calcaneal (Achilles) tendon, that inserts into the calcaneal bone of the ankle.



(a) Posterior superficial view

(b) Posterior deep view

Muscle	Origin	Insertion	Action
Anterior Compartment			
Tibialis anterior (tib′-ē-Ā-lis; *tibialis* = tibia; *anterior* = front)	Tibia.	First metatarsal and first cuneiform.	Dorsiflexes and inverts foot.
Extensor digitorum longus (eks-TEN-sor di′-ji-TOR-um LON-gus; *extensor* = increases angle at joint; *digitorum* = finger or toe; *longus* = long)	Tibia and fibula.	Middle and distal phalanges of four outer toes.	Dorsiflexes and everts foot; extends toes.
Lateral Compartment			
Fibularis (Peroneus) longus (fib-ū-LAR-is LON-gus)	Fibula and tibia.	First metatarsal and first cuneiform.	Plantar flexes and everts foot.
Posterior Compartment			
Gastrocnemius (gas′-trok-NĒ-mē-us; *gastro-* = belly; *-cnem* = leg)	Femur.	Calcaneus by means of calcaneal (Achilles) tendon.	Plantar flexes foot; flexes leg at knee joint.
Soleus (SŌ-lē-us; *soleus* = a type of flatfish)	Fibula and tibia.	Calcaneus by means of calcaneal (Achilles) tendon.	Plantar flexes foot.
Tibialis posterior (*posterior* = back)	Tibia and fibula.	Second, third, and fourth metatarsals; navicular; all three cuneiforms, and cuboid.	Plantar flexes and inverts foot.
Flexor digitorum longus (FLEK-sor; *flexor* = decreases angle at joint)	Tibia.	Distal phalanges of four outer toes.	Plantar flexes foot; flexes toes.



(c) Anterior superficial view

(d) Right lateral superficial view

Which muscle is primarily affected in shinsplint syndrome?

FOCUS ON HOMEOSTASIS

THE MUSCULAR SYSTEM

BODY SYSTEM	CONTRIBUTION OF THE MUSCULAR SYSTEM
For all body systems	The muscular system and muscular tissues produce body movements, stabilize body positions, move substances within the body, and produce heat that helps maintain normal body temperature.
Integumentary system	Pull of skeletal muscles on attachments to skin of face causes facial expressions; muscular exercise increases skin blood flow.
Skeletal system	Skeletal muscle causes movement of body parts by pulling on attachments to bones; skeletal muscle provides stability for bones and joints.
Nervous system	Smooth, cardiac, and skeletal muscles carry out commands for the nervous system; shivering—involuntary contraction of skeletal muscles that is regulated by the brain—generates heat to raise body temperature.
Endocrine system	Regular activity of skeletal muscles (exercise) improves the action of some hormones, such as insulin; muscles protect some endocrine glands.
Cardiovascular system	Cardiac muscle powers the pumping action of the heart; contraction and relaxation of smooth muscle in blood vessel walls help adjust the amount of blood flowing through various body tissues; contraction of skeletal muscles in the legs assists return of blood to the heart; regular exercise causes cardiac hypertrophy (enlargement) and increases the heart's pumping efficiency; lactic acid produced by active skeletal muscles may be used for ATP production by the heart.
Lymphatic system and immunity	Skeletal muscles protect some lymph nodes and lymphatic vessels and promote the flow of lymph inside lymphatic vessels; exercise may increase or decrease some immune responses.
Respiratory system	Skeletal muscles involved with breathing cause air to flow into and out of the lungs; smooth muscle fibers adjust the size of airways; vibrations in skeletal muscles of the larynx control air flowing past vocal cords, regulating voice production; coughing and sneezing, due to skeletal muscle contractions, help clear airways; regular exercise improves the efficiency of breathing.
Digestive system	Skeletal muscles protect and support organs in the abdominal cavity; alternating contraction and relaxation of skeletal muscles power chewing and initiate swallowing; smooth muscle sphincters control the volume of organs of the gastrointestinal (GI) tract; smooth muscles in the walls of the GI tract mix and move its contents through the tract.
Urinary system	Skeletal muscle and smooth muscle sphincters and smooth muscle in the wall of the urinary bladder control whether urine is stored in the urinary bladder or voided (urination).
Reproductive systems	Skeletal and smooth muscle contractions eject semen; smooth muscle contractions propel oocytes through uterine tubes, help regulate flow of menstrual blood from the uterus, and force baby from the uterus during childbirth; during intercourse, skeletal muscle contractions are associated with orgasm and pleasurable sensations in both sexes.

COMMON DISORDERS

Skeletal muscle function may be abnormal due to disease or damage of any of the components of a motor unit: somatic motor neurons, neuromuscular junctions, or muscle fibers. The term ***neuromuscular disease*** encompasses problems at all three sites; the term ***myopathy*** (mī-OP-a-thē; *-pathy* = disease) signifies a disease or disorder of the skeletal muscle tissue itself.

Myasthenia Gravis

Myasthenia gravis (mī-as-THĒ-nē-a GRAV-is) is an autoimmune disease that causes chronic, progressive damage of the neuromuscular junction. In people with myasthenia gravis, the immune system inappropriately produces antibodies that bind to and block some ACh receptors, thereby decreasing the number of functional ACh receptors at the motor end plates of skeletal muscles (see Figure 8.5). Because 75% of patients with myasthenia gravis have hyperplasia or tumors of the thymus, it is possible that thymic abnormalities cause the disorder. As the disease progresses, more ACh receptors are lost. Thus, muscles become increasingly weaker, fatigue more easily, and may eventually cease to function.

Myasthenia gravis occurs in about 1 in 10,000 people and is more common in women, who typically are ages 20 to 40 at onset, than in men, who usually are ages 50 to 60 at onset. The muscles of the face and neck are most often affected. Initial symptoms include weakness of the eye muscles, which may produce double vision, and difficulty in swallowing. Later, the person has difficulty chewing and talking. Eventually the muscles of the limbs may become involved. Death may result from paralysis of the respiratory muscles, but often the disorder does not progress to this stage.

Muscular Dystrophy

The term ***muscular dystrophy*** refers to a group of inherited muscle-destroying diseases that cause progressive degeneration of skeletal muscle fibers. The most common form of muscular dystrophy is *DMD—Duchenne muscular dystrophy* (doo-SHĀN). Because the mutated gene is on the X chromosome, which males have only one of, DMD strikes boys almost exclusively. (Sex-linked inheritance is described in Chapter 24.) Worldwide, about 1 in every 3500 male babies—21,000 in all—are born with DMD each year. The disorder usually becomes apparent between the ages of 2 and 5, when parents notice the child falls often and has difficulty running, jumping, and hopping. By age 12 most boys with DMD are unable to walk. Respiratory or cardiac failure usually causes death between the ages of 20 and 30.

In DMD, the gene that codes for the protein dystrophin is mutated and little or no dystrophin is present (dystrophin provides structural reinforcement for the skeletal muscle fiber sarcolemma). Without the reinforcing effect of dystrophin, the sarcolemma easily tears during muscle contraction. Because their plasma membranes are damaged, muscle fibers slowly rupture and die.

Fibromyalgia

Fibromyalgia (*algia* = painful condition) is a painful, nonarticular rheumatic disorder that usually appears between the ages of 25 and 50. An estimated 3 million people in the United States suffer from fibromyalgia, which is 15 times more common in women than in men. The disorder affects the fibrous connective tissue components of muscles, tendons, and ligaments. A striking sign is pain that results from gentle pressure at specific "tender points." Even without pressure, there is pain, tenderness, and stiffness of muscles, tendons, and surrounding soft tissues. Besides muscle pain, those with fibromyalgia report severe fatigue, poor sleep, headaches, depression, and inability to carry out their daily activities. Often, a gentle aerobic fitness program is beneficial.

Abnormal Contractions of Skeletal Muscle

One kind of abnormal muscular contraction is a ***spasm***, a sudden involuntary contraction of a single muscle in a large group of muscles. A painful spasmodic contraction is known as a ***cramp***. A ***tic*** is a spasmodic twitching made involuntarily by muscles that are ordinarily under voluntary control. Twitching of the eyelid and facial muscles are examples of tics. A ***tremor*** is a rhythmic, involuntary, purposeless contraction that produces a quivering or shaking movement. A ***fasciculation*** is an involuntary, brief twitch of an entire motor unit that is visible under the skin; it occurs irregularly and is not associated with movement of the affected muscle. Fasciculations may be seen in multiple sclerosis (see page 237) or in amyotrophic lateral sclerosis (Lou Gehrig's disease). A ***fibrillation*** is a spontaneous contraction of a single muscle fiber that is not visible under the skin but can be recorded by electromyography. Fibrillations may signal destruction of motor neurons.

Running Injuries

Nearly 70% of those who jog or run sustain some type of running-related injury. Most such injuries are minor, but some are quite serious. In addition, untreated or inappropriately treated minor injuries may become chronic. Among runners, common sites of injury include the ankle, knee, calcaneal (Achilles) tendon, hip, groin, foot, and back. Of these, the knee often is the most severely injured area.

Running injuries are frequently related to faulty training techniques. This may involve improper (or lack of) warm-up routines, running too much, or running too soon after an injury. Or it might involve extended running on hard and/or uneven surfaces. Poorly constructed or worn-out running shoes can also contribute to injury, as can any biomechanical problem (such as a fallen arch) aggravated by running.

Most sports injuries should be treated initially with RICE therapy, which stands for Rest, Ice, Compression, and Elevation. Immediately apply ice, and rest and elevate the injured part. Then apply an elastic bandage, if possible, to compress the injured tissue. Continue using RICE for 2 to 3 days, and resist the temptation to apply heat, which may worsen the swelling. Follow-up treatment may include alternating moist heat and ice massage to enhance blood flow in the injured area. Sometimes it is helpful to take nonsteroidal anti-inflammatory drugs (NSAIDs) or to have local injections of corticosteroids.

During the recovery period, it is important to keep active using an alternative fitness program that does not worsen the original injury. This activity should be determined in consultation with a physician. Finally, careful exercise is needed to rehabilitate the injured area itself.

Effects of Anabolic Streroids

The use of ***anabolic steroids*** by athletes has received widespread attention. These steroid hormones, similar to testosterone, are taken to increase muscle size and strength. The large doses needed to produce an effect, however, have damaging, sometimes even devastating side effects, including liver cancer, kidney damage, increased risk of heart disease, stunted growth, wide mood swings, and increased irritability and aggression. Additionally, females who take anabolic steroids may experience atrophy of the breasts and uterus, menstrual irregularities, sterility, facial hair growth, and deepening of the voice. Males may experience diminished testosterone secretion, atrophy of the testes, and baldness.

MEDICAL TERMINOLOGY AND CONDITIONS

Electromyography or ***EMG*** (e-lek′-trō-mī-OG-ra-fē; *electro-* = electricity; *myo-* = muscle; *-graphy* = to write) The recording and study of electrical changes that occur in muscular tissue.

Hypertonia (*hyper-* = above) Increased muscle tone, characterized by increased muscle stiffness and sometimes associated with a change in normal reflexes.

Hypotonia (*hypo-* = below) Decreased or lost muscle tone.

Muscle strain Tearing of a muscle because of forceful impact, accompanied by bleeding and severe pain. Also known as a *charley horse* or pulled muscle. It often occurs in contact sports and typically affects the quadriceps femoris muscle on the anterior surface of the thigh.

Myalgia (mī-AL-jē-a; *-algia* = painful condition) Pain in or associated with muscles.

Myoma (mī-Ō-ma; *-oma* = tumor) A tumor consisting of muscular tissue.

Myomalacia (mī′-ō-ma-LĀ-shē-a; *-malacia* = soft) Pathological softening of muscle tissue.

Myositis (mī′-ō-SĪ-tis; *-itis* = inflammation of) Inflammation of muscle fibers (cells).

Myotonia (mī′-ō-TŌ-nē-a; *-tonia* = tension) Increased muscular excitability and contractility, with decreased power of relaxation; tonic spasm of the muscle.

STUDY OUTLINE

Overview of Muscular Tissue (p. 173)

1. The three types of muscular tissue are skeletal muscle, cardiac muscle, and smooth muscle (summarized in Table 8.1 on page 188).
2. Skeletal muscle tissue is mostly attached to bones. It is striated and voluntary.
3. Cardiac muscle tissue forms most of the wall of the heart. It is striated and involuntary.
4. Smooth muscle tissue is located in viscera. It is nonstriated and involuntary.
5. Through contraction and relaxation, muscular tissue has five key functions: producing body movements, stabilizing body positions, regulating organ volume, moving substances within the body, and producing heat.

Skeletal Muscle Tissue (p. 173)

1. Connective tissue coverings associated with skeletal muscle include the epimysium, covering an entire muscle; perimysium, covering fascicles; and endomysium, covering individual muscle fibers.
2. Tendons are extensions of connective tissue beyond muscle fibers that attach the muscle to bone.
3. Skeletal muscles are well supplied with nerves and blood vessels, which provide nutrients and oxygen for contraction.
4. Skeletal muscle consists of muscle fibers (cells) covered by a sarcolemma that features tunnel-like extensions, the transverse tubules. The fibers contain sarcoplasm, multiple nuclei, many mitochondria, myoglobin, and sarcoplasmic reticulum.
5. Each fiber also contains myofibrils that contain thin and thick filaments. The filaments are arranged in functional units called sarcomeres.
6. Thin filaments are composed of actin, tropomyosin, and troponin; thick filaments consist of myosin.

Contraction and Relaxation of Skeletal Muscle (p. 177)

1. Muscle contraction occurs when myosin heads attach to and "walk" along the thin filaments at both ends of a sarcomere, progressively pulling the thin filaments toward the center of a sarcomere. As the thin filaments slide inward, the Z discs come closer together, and the sarcomere shortens.
2. The neuromuscular junction (NMJ) is the synapse between a motor neuron and a skeletal muscle fiber. The NMJ includes the axon terminals and synaptic end bulbs of a motor neuron plus the adjacent motor end plate of the muscle fiber sarcolemma.

3. A motor neuron and all of the muscle fibers it stimulates form a motor unit. A single motor unit may include as few as 10 or as many as 2000 muscle fibers.
4. When a nerve impulse reaches the synaptic end bulbs of a somatic motor neuron, it triggers the release of acetylcholine (ACh) from synaptic vesicles. ACh diffuses across the synaptic cleft and binds to ACh receptors, initiating a muscle action potential. Acetylcholinesterase then quickly destroys ACh.
5. An increase in the level of Ca^{2+} in the sarcoplasm, caused by the muscle action potential, starts the contraction cycle; as a decrease in the level of Ca^{2+} turns off the contraction cycle.
6. The contraction cycle is the repeating sequence of events that causes sliding of the filaments: (1) myosin ATPase splits ATP and becomes energized, (2) the myosin head attaches to actin forming a crossbridge, (3) the crossbridge generates force as it swivels or rotates toward the center of the sarcomere (power stroke), and (4) binding of ATP to myosin detaches myosin from actin. The myosin head again splits ATP, returns to its original position, and binds to a new site on actin as the cycle continues.
7. Ca^{2+} active transport pumps continually remove Ca^{2+} from the sarcoplasm into the sarcoplasmic reticulum (SR). When the level of Ca^{2+} in the sarcoplasm decreases, the troponin–tropomyosin complexes slide back over and cover the myosin-binding sites, and the muscle fiber relaxes.
8. Continual involuntary activation of a small number of motor units produces muscle tone, which is essential for maintaining posture.

Metabolism of Skeletal Muscle Tissue (p. 180)

1. Muscle fibers have three sources for ATP production: creatine phosphate, anaerobic cellular respiration, and aerobic cellular respiration.
2. The transfer of a high-energy phosphate group from creatine phosphate to ADP forms new ATP molecules. Together, creatine phosphate and ATP provide enough energy for muscles to contract maximally for about 15 seconds.
3. Glucose is converted to pyruvic acid in the reactions of glycolysis, which yield two ATPs without using oxygen. These anaerobic reactions can provide enough ATP for about 30 to 40 seconds of maximal muscle activity.
4. Muscular activity that lasts longer than half a minute depends on aerobic cellular respiration, mitochondrial reactions that require oxygen to produce ATP. Aerobic cellular respiration yields about 36 molecules of ATP from each glucose molecule.
5. The inability of a muscle to contract forcefully after prolonged activity is muscle fatigue.
6. Elevated oxygen use after exercise is called recovery oxygen uptake.

Control of Muscle Tension (p. 183)

1. A twitch contraction is a brief contraction of all the muscle fibers in a motor unit in response to a single action potential.
2. A record of a contraction is called a myogram. It consists of a latent period, a contraction period, and a relaxation period.
3. Wave summation is the increased strength of a contraction that occurs when a second stimulus arrives before the muscle has completely relaxed after a previous stimulus.
4. Repeated stimuli can produce unfused tetanus, a sustained muscle contraction with partial relaxation between stimuli; more rapidly repeating stimuli will produce fused tetanus, a sustained contraction without partial relaxation between stimuli.
5. Motor unit recruitment is the process of increasing the number of active motor units.
6. On the basis of their structure and function, skeletal muscle fibers are classified as slow oxidative (SO), fast oxidative–glycolytic (FOG), and fast glycolytic (FG) fibers.
7. Most skeletal muscles contain a mixture of all three fiber types; their proportions vary with the typical action of the muscle.
8. The motor units of a muscle are recruited in the following order: first SO fibers, then FOG fibers, and finally FG fibers.
9. In an isometric contraction, there is no change in the length of a muscle, but the muscle develops considerable tension. In an isotonic contraction, there is a change in the length of a muscle, but no change in its tension.

Exercise and Skeletal Muscle Tissue (p. 186)

1. Various types of exercises can induce changes in the fibers in a skeletal muscle. Endurance-type (aerobic) exercises cause a gradual transformation of some fast glycolytic (FG) fibers into fast oxidative–glycolytic (FOG) fibers.
2. Exercises that require great strength for short periods produce an increase in the size and strength of fast glycolytic (FG) fibers. The increase in size is due to increased synthesis of thick and thin filaments.

Cardiac Muscle Tissue (p. 186)

1. Cardiac muscle tissue, which is striated and involuntary, is found only in the heart.
2. Each cardiac muscle fiber usually contains a single centrally located nucleus and exhibits branching.
3. Cardiac muscle fibers are connected by means of intercalated discs, which hold the muscle fibers together and allow muscle action potentials to quickly spread from one cardiac muscle fiber to another.
4. Cardiac muscle tissue contracts when stimulated by its own autorhythmic fibers. Due to its continuous, rhythmic activity, cardiac muscle depends greatly on aerobic cellular respiration to generate ATP.

Smooth Muscle Tissue (p. 186)

1. Smooth muscle tissue is nonstriated and involuntary.
2. In addition to thin and thick filaments, smooth muscle fibers contain intermediate filaments and dense bodies.
3. Visceral (single-unit) smooth muscle is found in the walls of hollow viscera and of small blood vessels. Many visceral fibers form a network that contracts in unison.
4. Multiunit smooth muscle is found in large blood vessels, large airways to the lungs, arrector pili muscles, and the eye. The fibers contract independently rather than in unison.
5. The duration of contraction and relaxation is longer in smooth muscle than in skeletal muscle.

6. Smooth muscle fibers can be stretched considerably and still retain the ability to contract.
7. Smooth muscle fibers contract in response to nerve impulses, stretching, hormones, and local factors.

Aging and Muscular Tissue (p. 187)

1. Beginning at about 30 years of age, there is a slow, progressive loss of skeletal muscle, which is replaced by fibrous connective tissue and fat.
2. Aging also results in a decrease in muscle strength, slower muscle reflexes, and loss of flexibility.

How Skeletal Muscles Produce Movement (p. 188)

1. Skeletal muscles produce movement by pulling on tendons attached to bones.
2. The attachment to the stationary bone is the origin. The attachment to the movable bone is the insertion.
3. The prime mover (agonist) produces the desired action. The antagonist produces an opposite action. The synergist assists the prime mover by reducing unnecessary movement. The fixator stabilizes the origin of the prime mover so that it can act more efficiently.

Principal Skeletal Muscles (p. 189)

1. The principal skeletal muscles of the body are grouped according to region, as shown in Exhibits 8.1 through 8.13.
2. In studying muscle groups, refer to Figure 8.13 on pages 192–193 to see how each group is related to all others.
3. The names of most skeletal muscles indicate specific characteristics.
4. The major descriptive categories are direction of fibers, location, size, number of origins (or heads), shape, origin and insertion, and action (see Table 8.2 on page 191).

SELF-QUIZ

1. The characteristic of muscular tissue that allows it to return to its original shape after contraction is
   a. extensibility **b.** excitability **c.** fused tetanus **d.** contractility **e.** elasticity
2. Match the connective tissue coverings with their locations:
   ___ **a.** wraps an entire muscle
   ___ **b.** lies immediately under the skin
   ___ **c.** separates muscle into functional groups
   ___ **d.** surrounds each individual muscle fiber
   ___ **e.** divides muscle fibers into fascicles

   A. endomysium **B.** deep fascia **C.** perimysium **D.** epimysium **E.** superficial fascia
3. Which of the following statements about skeletal muscle tissue is NOT true?
   a. Skeletal muscle requires a large blood supply.
   b. Skeletal muscle fibers have many mitochondria.
   c. The arrangement of thick and thin filaments produces the striations in skeletal muscle tissue.
   d. Skeletal muscle fibers contain gap junctions that help conduct action potentials from one fiber to another.
   e. A skeletal muscle fiber has many nuclei.
4. Match the following:
   ___ **a.** network of tubules that stores calcium
   ___ **b.** pigment that stores oxygen
   ___ **c.** composed of myosin
   ___ **d.** composed of actin, tropomyosin, and troponin
   ___ **e.** tunnel-like extensions of sarcolemma

   A. thick filaments **B.** transverse tubules **C.** sarcoplasmic reticulum **D.** myoglobin **E.** thin filaments
5. The sarcolemma is the equivalent of the
   a. cytoplasm **b.** nucleus **c.** plasma membrane **d.** endoplasmic reticulum **e.** mitochondria
6. You begin an intensive weightlifting plan because you want to enter a weightlifting contest. During the activity of weightlifting, your skeletal muscles will obtain energy (ATP) primarily through
   a. anaerobic cellular respiration **b.** the complete breakdown of pyruvic acid in the mitochondria **c.** hyperplasia **d.** hypertrophy **e.** aerobic cellular respiration
7. Which of the following events of skeletal muscle contraction does NOT occur during the latent period?
   a. Sarcomeres shorten.
   b. Action potentials conduct into the T tubules.
   c. The concentration of calcium ions increases in the sarcoplasm.
   d. Myosin-binding sites on the thin filaments are exposed.
   e. Calcium release channels in the sarcoplasmic reticulum open.
8. For each of the following descriptions, indicate if it refers to skeletal muscle, cardiac muscle, or smooth muscle. Use the abbreviations SK for skeletal, CA for cardiac, and SM for smooth. The same response may be used more than once.
   ___ **a.** involuntary
   ___ **b.** multinucleated
   ___ **c.** striated
   ___ **d.** contain intercalated discs
   ___ **e.** elongated, cylindrical cells
   ___ **f.** voluntary
   ___ **g.** cells that taper at both ends
   ___ **h.** nonstriated
   ___ **i.** muscle fibers contractindividually
   ___ **j.** autorhythmic

9. When ATP in the sarcoplasm is exhausted, the muscle must rely on _____ to quickly produce more ATP from ADP for contraction.
   a. acetylcholine b. creatine phosphate c. lactic acid
   d. pyruvic acid e. acetylcholinesterase

10. A motor unit consists of
   a. a transverse tubule and its associated sarcomeres
   b. a motor neuron and all of the muscle fibers it stimulates
   c. a muscle and all of its motor neurons
   d. all of the filaments encased within a sarcomere
   e. the motor end plate and the transverse tubules

11. Thick filaments
   a. include actin, troponin, and tropomyosin
   b. compose the I band
   c. stretch the entire length of a sarcomere
   d. have binding sites for Ca^{2+}
   e. have myosin heads (crossbridges) used for the power stroke

12. The chemical that prevents the continuous stimulation of a muscle fiber is
   a. Ca^{2+} b. acetylcholinesterase c. ATP
   d. acetylcholine e. troponin–tropomyosin

13. Which of the following is NOT associated with muscle fatigue?
   a. depletion of creatine phosphate b. lack of oxygen
   c. decrease in Ca^{2+} levels in the sarcoplasm
   d. decrease in lactic acid levels e. lack of glycogen

14. All of the following may result in an increase in muscle size EXCEPT
   a. denervation atrophy b. weight training
   c. human growth hormone d. testosterone
   e. isotonic contraction

15. Skeletal muscles are named using several characteristics. Which characteristic is NOT used to name skeletal muscles?
   a. direction of fibers b. size c. speed of contraction
   d. location e. shape

16. Arrange the following in the correct order for skeletal muscle fiber contraction.
   1. Sarcoplasmic reticulum releases Ca^{2+}.
   2. Ca^{2+} combines with troponin.
   3. Acetylcholine is released from the axon terminal.
   4. Action potential travels into transverse tubules.
   5. Energized myosin heads (crossbridges) attach to actin.
   6. Thin filaments slide toward the center of the sarcomere.

   a. 3, 4, 1, 2, 5, 6
   b. 4, 3, 2, 1, 5, 6
   c. 1, 2, 3, 4, 5, 6
   d. 4, 1, 3, 5, 2, 6
   e. 3, 1, 4, 5, 2, 6

17. Your instructor asks you to pick up a box of books and carry them to the library in another building. You try to pick up the box, but the box is too heavy to move. Which of the following types of muscle contractions would you be utilizing?
   a. hypertonic b. isotonic only c. spastic
   d. isometric only e. isometric and isotonic

18. Match the following:
   ____ a. extends and laterally rotates thigh at the hip joint
   ____ b. adducts and medially rotates thigh at the hip joint
   ____ c. compresses abdomen and flexes vertebral column
   ____ d. flexes the neck
   ____ e. flexes and abducts wrist joint
   ____ f. extends phalanges
   ____ g. adducts and rotates arm medially at shoulder joint
   ____ h. extends leg at the knee and flexes thigh at hip joint
   ____ i. plantar flexes foot at ankle joint and flexes leg at knee joint
   ____ j. dorsiflexes and inverts foot
   ____ k. abducts, flexes, extends, and rotates arm at shoulder joint
   ____ l. elevates clavicle; depresses or elevates scapula
   ____ m. elevates mandible; closes mouth
   ____ n. wrinkles skin of forehead horizontally as in a look of surprise
   ____ o. extends, adducts, and rotates arm medially at shoulder joint

   A. trapezius
   B. flexor carpi radialis
   C. tibialis anterior
   D. adductor longus
   E. gluteus maximus
   F. quadriceps group
   G. rectus abdominis
   H. sternocleidomastoid
   I. frontal belly of occipitofrontalis
   J. gastrocnemius
   K. deltoid
   L. masseter
   M. extensor digitorum
   N. latissimus dorsi
   O. pectoralis major

19. Match the following:

____ a. extend from the thick filaments	A. I band
____ b. contain myosin-binding site	B. synaptic vesicles
____ c. dense area that separates sarcomeres	C. myosin heads
____ d. contain acetylcholine	D. Z discs
____ e. striated zone of the sarcomere composed of thick and thin filaments	E. motor end plate
____ f. space between axon terminal and the sarcolemma	F. actin molecules
____ g. striated zone of the sarcomere composed of thin filaments only	G. A band
____ h. region of sarcolemma near the adjoining axon terminal	H. synaptic cleft

20. Matching the following:

____ a. works with prime mover to reduce unnecessary movement	A. insertion
____ b. muscle in a group that produces desired movement	B. origin
____ c. stationary end of a muscle	C. synergist
____ d. muscle that has an action opposite to that of another muscle	D. antagonist
____ e. helps stabilize the origin of the prime mover	E. prime mover
____ f. the end of a muscle attached to the movable bone	F. fixator

CRITICAL THINKING APPLICATIONS

1. The newspaper reported several cases of botulism poisoning following a fund-raiser potluck dinner for the local clinic. The cause appeared to be three-bean salad "flavored" with the bacterium *Clostridium botulinum*. What would be the result of botulism poisoning on muscle function?
2. Ali's nephew was squealing with laughter. She was entertaining him by sticking her thumb in her pursed lips, raising her eyebrows, pumping her arm up and down, and puffing her cheeks in and out. Name the muscles Ali was using to maneuver her face.
3. When her cast finally came off after six long weeks, Kate thought she'd be all set to rejoin her volleyball team, but now her left thigh is only half the size of her right. Explain what happened to her thigh and what she needs to do to get back in the game.
4. The coach of the track team has his athletes crosstraining. They ran 10 miles on Monday, then on Tuesday they lifted weights. How do these types of exercise affect the muscles?

ANSWERS TO FIGURE QUESTIONS

8.1 In order from the inside toward the outside, the connective tissue layers are endomysium, perimysium, and epimysium.

8.2 The A band is composed of thick filaments in its center and overlapping thick and thin filaments at each end; the I band is composed of thin filaments.

8.3 A band: myosin, actin, troponin, and tropomyosin. I band: actin, troponin, and tropomyosin.

8.4 The I bands disappear. The lengths of the thick and thin filaments do not change.

8.5 The motor end plate is the region of the sarcolemma near the axon terminal.

8.6 Binding of ATP to the myosin heads detaches them from actin.

8.7 The power stroke occurs during step 6.

8.8 Glycolysis, exchange of phosphate between creatine phosphate and ADP, and glycogen breakdown occur in the cytosol. Oxidation of pyruvic acid, amino acids, and fatty acids (aerobic cellular respiration) occurs in the mitochondria.

8.9 Sarcomeres shorten during the contraction period.

8.10 Fused tetanus occurs when the frequency of stimulation reaches 80 to 100 stimuli per second.

8.11 The walls of hollow organs contain visceral (single-unit) smooth muscle.

8.12 The prime mover or agonist produces the desired action.

8.13 The following are some possible responses (there are other correct answers): direction of fibers—external oblique; shape—deltoid; action—extensor digitorum; size—gluteus maximus; origin and insertion—sternocleidomastoid; location—tibialis anterior; number of origins—biceps brachii.

8.14 Smiling—zygomaticus major; pouting—platysma; squinting—orbicularis oculi.

8.15 The superior oblique passes through the trochlea.

8.16 The rectus abdominis aids in urination.

8.17 The diaphragm and external intercostals contract during normal quiet inhalation.

8.18 The pectoralis minor and serratus anterior have origins on the ribs; the trapezius, levator scapulae, and rhomboid major have origins on the vertebrae.

8.19 The pectoralis major and latissimus dorsi are muscles that cross the shoulder joint but do not originate on the scapula.

8.20 A compartment is a group of functionally related skeletal muscles in a limb, along with their blood vessels and nerves.

8.21 The median nerve is associated with the flexor retinaculum.

8.22 The iliocostalis, longissimus, and spinalis constitute the erector spinae.

8.23 Quadriceps femoris—rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius; hamstrings—biceps femoris, semitendinosus, semimembranosus.

8.24 Shinsplint syndrome affects the tibialis anterior.