Table 6.2	**The Five Golden Rules of Skeletal Muscle Activity**
1.	With a few exceptions, all skeletal muscles cross at least one joint.
2.	Typically, the bulk of a skeletal muscle lies proximal to the joint crossed.
3.	All skeletal muscles have at least two attachments: the origin and the insertion.
4.	Skeletal muscles can only pull; they never push.
5.	During contraction, a skeletal muscle insertion moves toward the origin.

There are five very basic understandings about gross muscle activity. I call these the *Five Golden Rules* of skeletal muscle activity because they make it easier to understand muscle movements and appreciate muscle interactions. These golden rules are summarized in **Table 6.2**.

Types of Body Movements

Every one of our 600-odd skeletal muscles is attached to bone, or to other connective tissue structures, at no fewer than two points. One of these points, the **origin,** is attached to the immovable or less movable bone (**Figure 6.12**). The **insertion** is attached to the movable bone, and when the muscle contracts, the insertion moves toward the origin. Some muscles have interchangeable origins and insertions. For example, the rectus femoris muscle of the anterior thigh crosses both the hip and knee joints. Its most common action is to extend the knee, in which case the proximal pelvic attachment is the origin. However, when the knee is bent (by other muscles), the rectus femoris can flex the hip, and then its distal attachment on the leg is considered the origin.

Generally speaking, body movement occurs when muscles contract across joints. The type of movement depends on the mobility of the joint and on where the muscle is located in relation to the joint. The most obvious examples of the action of muscles on bones are the movements that occur at the joints of the limbs. However, less freely movable bones are also tugged into motion by the muscles, such as the vertebrae's movements when the torso is bent to the side.

Q: *The other movement that the biceps brachii muscle (shown in this illustration) can bring about is to move the torso toward the bar when you chin yourself. Would the forearm still be the insertion for that movement?*

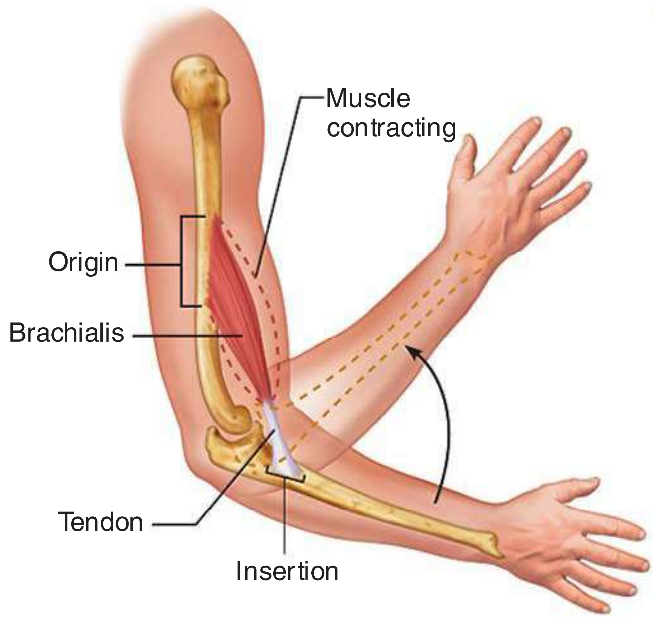

Figure 6.12 Muscle attachments (origin and insertion). When a skeletal muscle contracts, its insertion moves toward its origin.

Next we describe the most common types of body movements (**Figure 6.13**). Try to demonstrate each movement as you read the following descriptions:

- **Flexion.** Flexion is a movement, generally in the sagittal plane, that decreases the angle of the joint and brings two bones closer together (Figure 6.13a and b). Flexion is typical of hinge joints (bending the knee or elbow), but it is also common at ball-and-socket joints (for example, bending forward at the hip).
- **Extension.** Extension is the opposite of flexion, so it is a movement that increases the angle, or the distance, between two bones or parts of the body (straightening the knee or elbow). If extension is greater than 180° (as when you move your arm posteriorly beyond its normal anatomical position, or tip your head so that

A: *No, the insertion in this case would be its attachment to: the humerus, and the attachment on the forearm (which is held steady during this movement) is the origin.*

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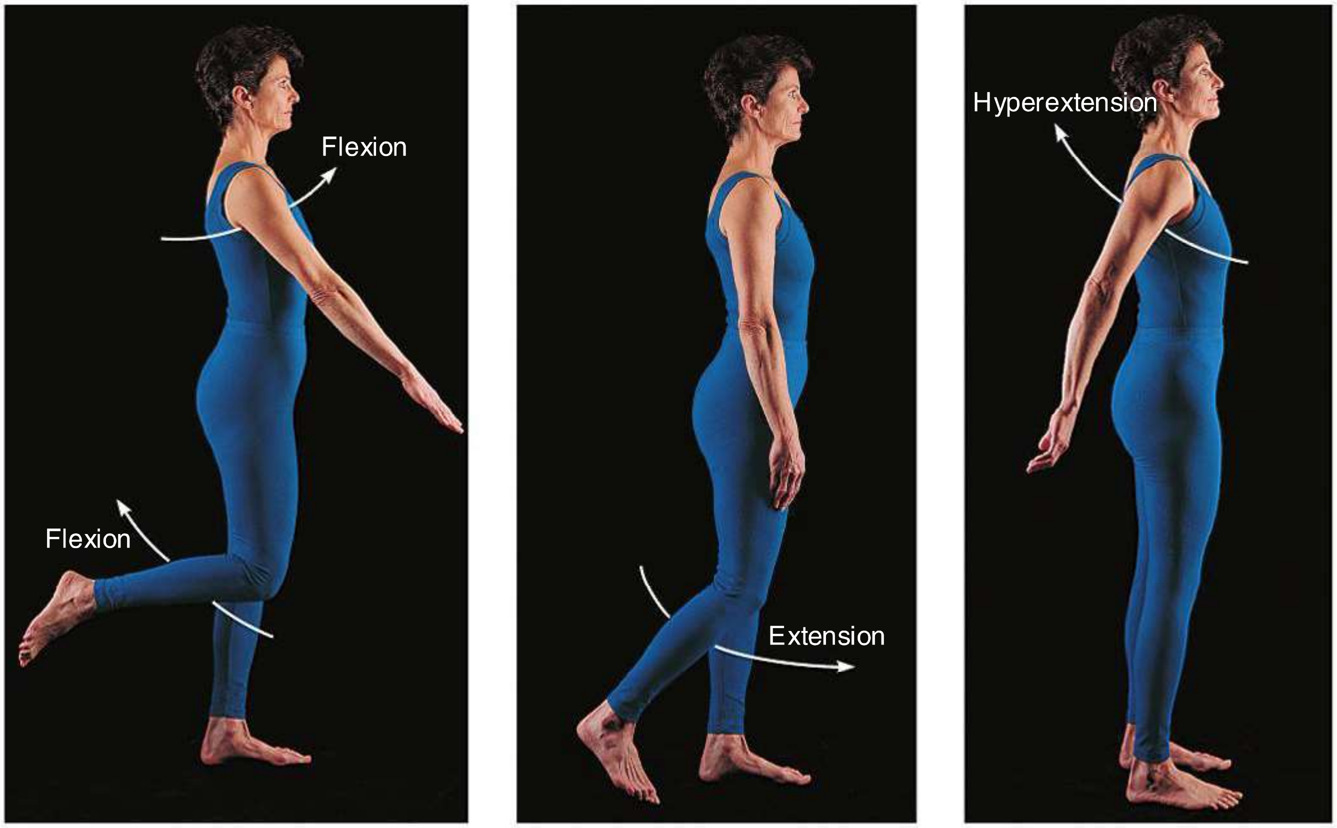
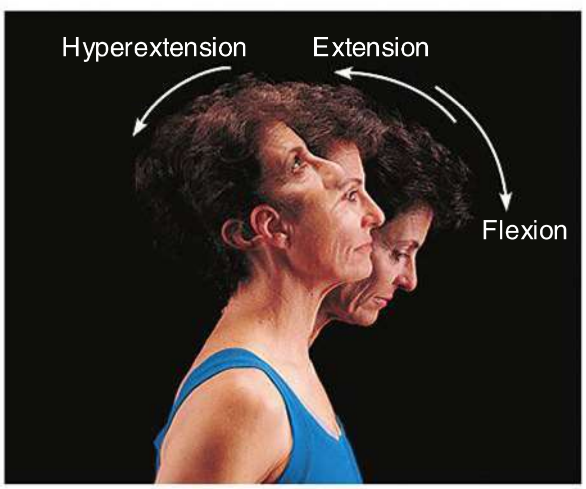
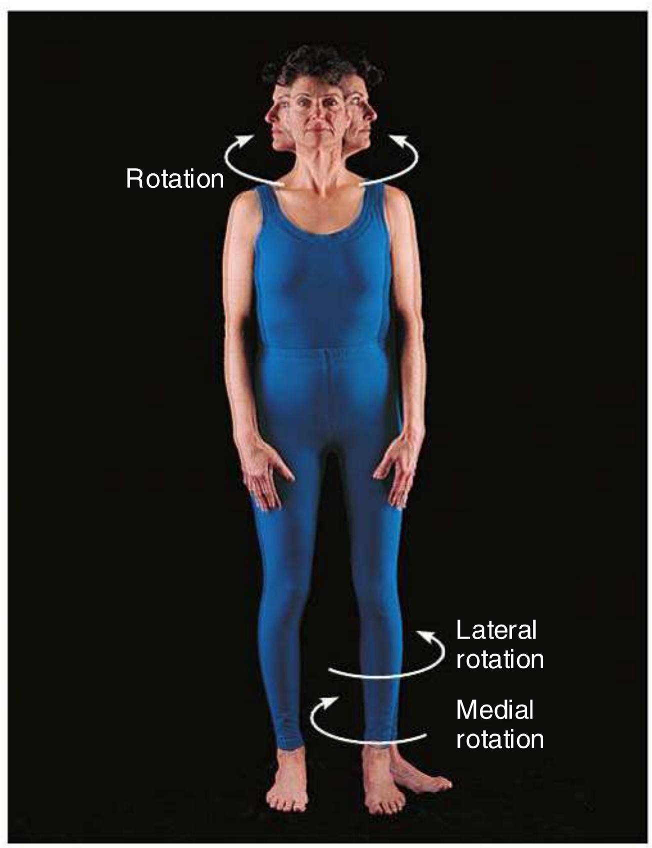


(a) Flexion and extension of the shoulder and knee



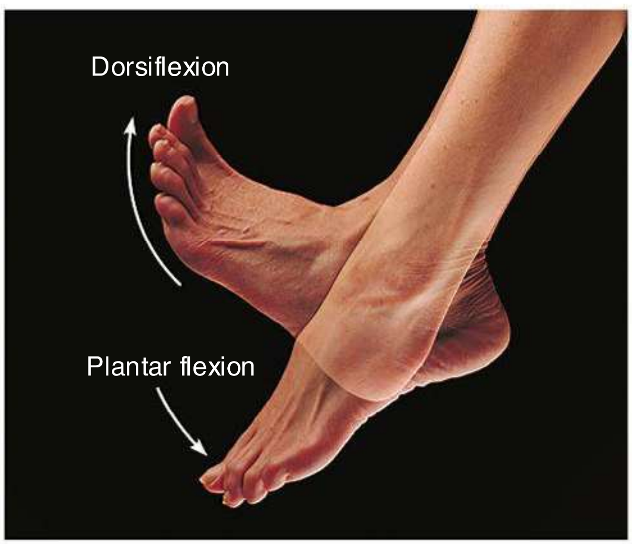
(b) Flexion, extension, and hyperextension



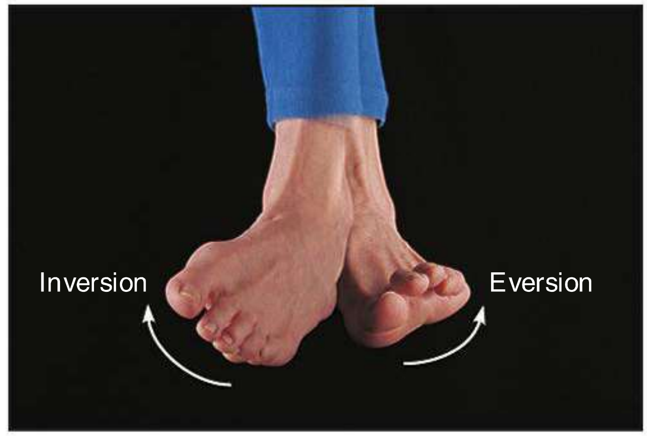
(c) Rotation

Figure 6.13 **Body movements.**

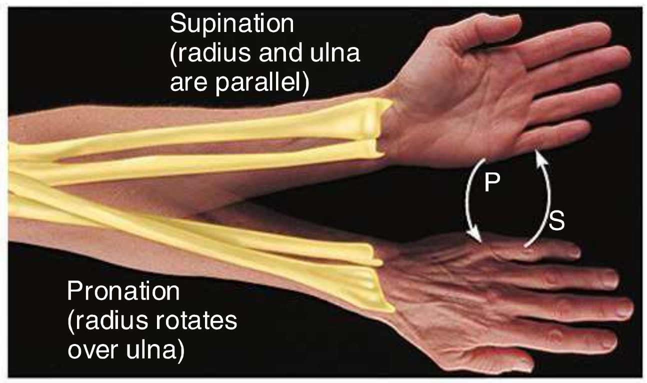
(d) Abduction, adduction, and circumduction



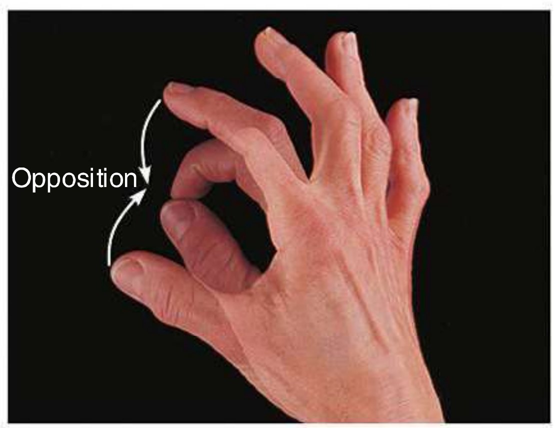
(e) Dorsiflexion and plantar flexion



(f) Inversion and eversion



(g) Supination (S) and pronation (P)



(h) Opposition

Figure 6.13 *(continued)*

your chin points toward the ceiling), it is hyperextension (Figure 6.13a and b).

- **Rotation.** Rotation is movement of a bone around its longitudinal axis (Figure 6.13c). Rotation is a common movement of ball-and-socket joints and describes the movement of the atlas around the dens of the axis (as in shaking your head "no").
- **Abduction.** Abduction is moving a limb away (generally on the frontal plane) from the midline, or median plane, of the body (Figure 6.13d). The terminology also applies to the fanning movement of the fingers or toes when they are spread apart.
- **Adduction.** Adduction is the opposite of abduction, so it is the movement of a limb toward the body midline (Figure 6.13d).
- **Circumduction.** Circumduction is a combination of flexion, extension, abduction, and adduction commonly seen in ball-and-socket joints such as the shoulder. The proximal end of the limb is stationary, and its distal end moves in a circle. The limb as a whole outlines a cone (Figure 6.13d).

Special Movements

Certain movements do not fit into any of the previous categories and occur at only a few joints. Some of these special movements are shown in Figure 6.13.

- **Dorsiflexion and plantar flexion.** Up and down movements of the foot at the ankle are given special names. Lifting the foot so that its superior surface approaches the shin (standing on your heels) is called dorsiflexion, whereas depressing the foot (pointing the toes) is called plantar flexion (Figure 6.13e). Dorsiflexion of the foot corresponds to extension of the hand at the wrist, whereas plantar flexion of the foot corresponds to flexion of the hand.
- **Inversion and eversion.** Inversion and eversion are also special movements of the foot (Figure 6.13f). To invert the foot, turn the sole medially. To evert the foot, turn the sole laterally.
- **Supination and pronation.** The terms *supination* (soo″pĭ-na′shun; "turning backward") and *pronation* (pro-na′shun; "turning forward") refer to movements of the radius around the ulna (Figure 6.13g). Supination occurs when the forearm rotates laterally so that the palm faces anteriorly, and the radius and ulna are parallel. Pronation occurs when the forearm rotates medially so that the palm faces posteriorly. Pronation brings the radius across the ulna so that the two bones form an X. A helpful memory trick: If you lift a cup of soup up to your mouth *on your palm,* you are supinating ("soup"-inating).
- **Opposition.** In the palm of the hand, the saddle joint between metacarpal 1 and the carpals allows opposition of the thumb (Figure 6.13h). This is the action by which you move your thumb to touch the tips of the other fingers on the same hand. This unique action makes the human hand a fine tool for grasping and manipulating things.

Interactions of Skeletal Muscles in the Body

Muscles can't push—they can only pull as they contract—so most often body movements result from two or more muscles acting together or against each other. Muscles are arranged in such a way that whatever one muscle (or group of muscles) can do, other muscles can reverse. In general, groups of muscles that produce opposite movements lie on opposite sides of a joint, as illustrated in **Figure 6.14**. Because of this arrangement, muscles are able to bring about an immense variety of movements.

The muscle that has the major responsibility for causing a particular movement is called the **prime mover.** (This physiological term has been borrowed by the business world to label a person who gets things done.) Muscles that oppose or reverse a movement are **antagonists** (an-tag′o-nists). When a prime mover is active, its antagonist is stretched and relaxed. Antagonists can be prime movers in their own right. For example, the biceps of the arm (prime mover of elbow flexion) is antagonized by the triceps (a prime mover of elbow extension).

Synergists (sin′er-jists; *syn* = together, *erg* = work) help prime movers by producing the same movement or by reducing undesirable movements. When a muscle crosses two or more joints, its contraction will cause movement in all the joints crossed unless synergists are there to stabilize them. For example, the finger-flexor

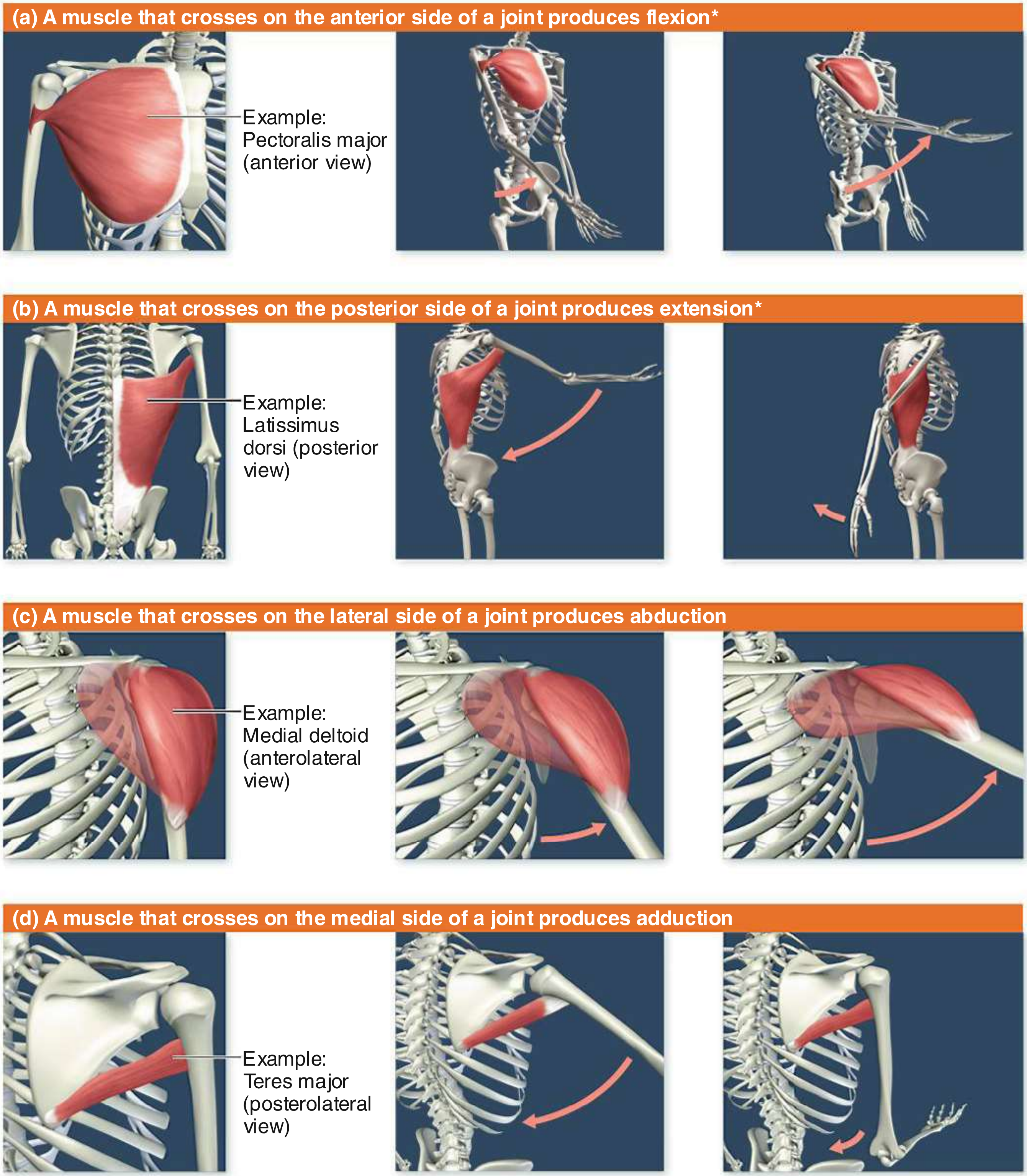


Figure 6.14 Muscle action. The action of a muscle can be inferred by the muscle's position as it crosses a joint. This generally does not apply to the knee and ankle because the lower limb is rotated during development. The muscles that cross these joints posteriorly produce flexion, and those that cross anteriorly produce extension.

muscles cross both the wrist and the finger joints. You can make a fist without bending your wrist because synergist muscles stabilize the wrist joints and allow the prime mover to act on the finger joints.

Fixators are specialized synergists. They hold a bone still or stabilize the origin of a prime mover so all the tension can be used to move the insertion bone. The postural muscles that stabilize the vertebral column are fixators, as are the muscles that anchor the scapulae to the thorax.

In summary, although prime movers seem to get all the credit for causing certain movements, the actions of antagonistic and synergistic muscles are also important in producing smooth, coordinated, and precise movements.

DID YOU GET IT?

15. What action is being performed by a person who sticks out his thumb to hitch a ride?

16. What actions take place at the neck when you nod your head up and down as if saying "yes"?

17. In what way are fixators and synergist muscles important?

For answers, see Appendix D.

Naming Skeletal Muscles

✓ List some criteria used in naming muscles.

Like bones, muscles come in many shapes and sizes to suit their particular tasks in the body. Muscles are named on the basis of several criteria, each of which focuses on a particular structural or functional characteristic. Paying close attention to these cues can greatly simplify your task of learning muscle names and actions:

- **Direction of the muscle fibers.** Some muscles are named in reference to some imaginary line, usually the midline of the body or the long axis of a limb bone. When a muscle's name includes the term *rectus* (straight), its fibers run parallel to that imaginary line. For example, the rectus femoris is the straight muscle of the thigh, or femur. Similarly, the term *oblique* as part of a muscle's name tells you that the muscle fibers run obliquely (at a slant) to the imaginary line.
- **Relative size of the muscle.** Such terms as *maximus* (largest), *minimus* (smallest), and *longus* (long) are often used in the names of muscles—for example, the gluteus maximus is the largest muscle of the gluteus muscle group.
- **Location of the muscle.** Some muscles are named for the bone with which they are associated. For example, the temporalis and frontalis muscles overlie the temporal and frontal bones of the skull, respectively.
- **Number of origins.** When the term *biceps, triceps,* or *quadriceps* forms part of a muscle name, one can assume that the muscle has two, three, or four origins, respectively. For example, the biceps muscle of the arm has two heads, or origins, and the triceps muscle has three.
- **Location of the muscle's origin and insertion.** Occasionally, muscles are named for their attachment sites. For example, the sternocleidomastoid muscle has its origin on the sternum (*sterno*) and clavicle (*cleido*) and inserts on the *mastoid* process of the temporal bone.
- **Shape of the muscle.** Some muscles have a distinctive shape that helps to identify them. For example, the deltoid muscle is roughly triangular (*deltoid* means "triangular").
- **Action of the muscle.** When muscles are named for their actions, terms such as *flexor, extensor,* and *adductor* appear in their names. For example, the adductor muscles of the thigh all bring about its adduction, and the extensor muscles of the wrist all extend the wrist.

Arrangement of Fascicles

Skeletal muscles consist of fascicles, but fascicle arrangements vary, producing muscles with different structures and functional properties. We describe the most common patterns of fascicle arrangement next.

The pattern is **circular** when the fascicles are arranged in concentric rings (**Figure 6.15d**). Circular muscles are typically found surrounding external body openings which they close by contracting. A general term for such muscles is *sphincters* ("squeezers"). Examples are the orbicularis muscles surrounding the eyes and mouth.

In a **convergent** muscle, the fascicles converge toward a single insertion tendon. Such a muscle is triangular or fan-shaped, such as the pectoralis major muscle of the anterior thorax (Figure 6.15a).

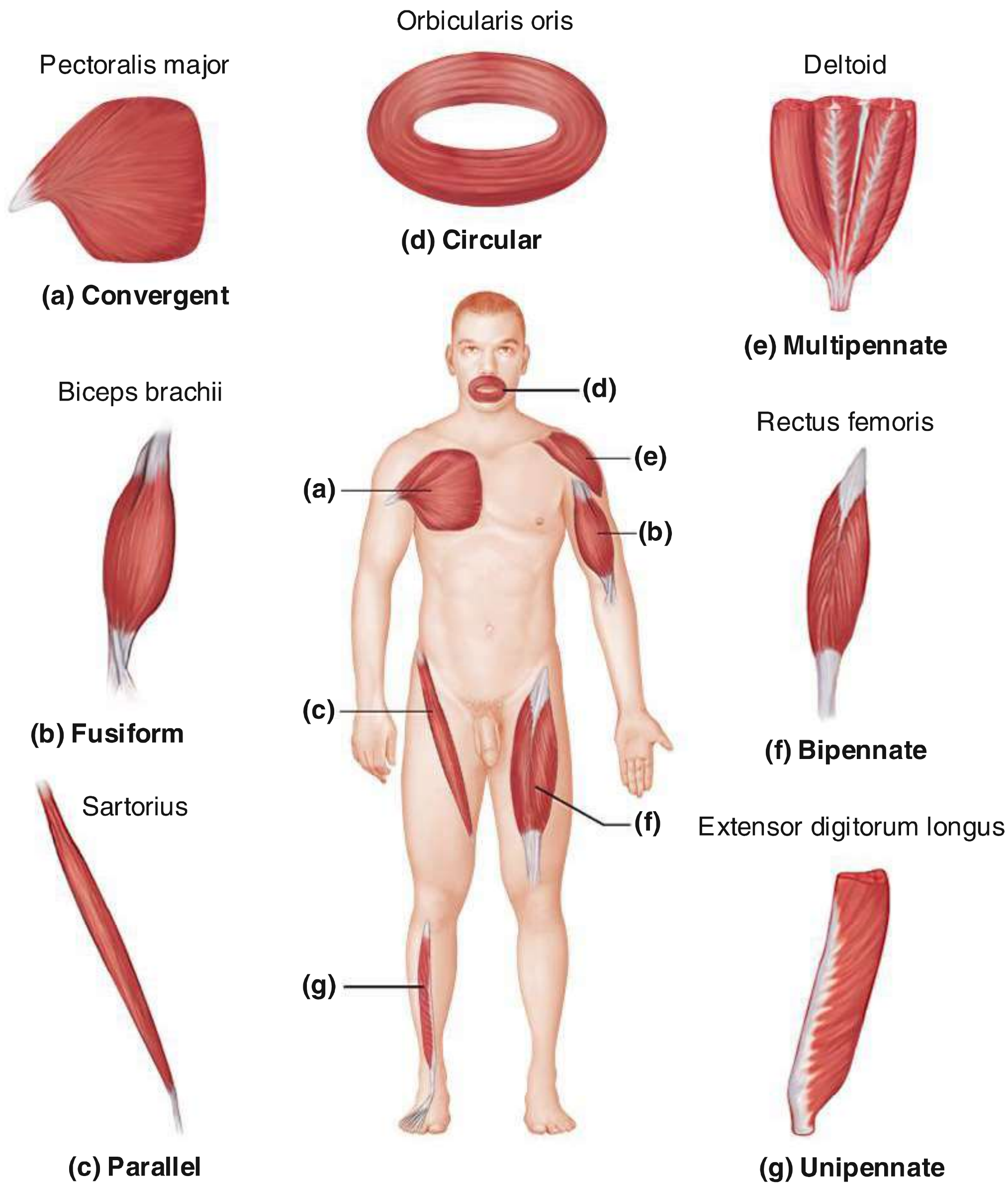


Figure 6.15 **Relationship of fascicle arrangement to muscle structure.**

In a **parallel** arrangement, the length of the fascicles run parallel to the long axis of the muscle. These muscles are straplike (Figure 6.15c). A modification of the parallel arrangement, called **fusiform,** results in a spindle-shaped muscle with an expanded belly (midsection), such as the biceps brachii muscle of the arm (Figure 6.15b).

In a **pennate** (pen′āt; "feather") pattern, short fascicles attach obliquely to a central tendon. In the extensor digitorum muscle of the leg, the fascicles insert into only one side of the tendon and the muscle is *unipennate* (Figure 6.15g). If the fascicles insert into opposite sides of the tendon or from several different sides, the muscle is *bipennate* (Figure 6.15f) or *multipennate* (Figure 6.15e), respectively.

A muscle's fascicle arrangement determines its range of motion and power. The longer and the more nearly parallel the fascicles are to a muscle's long axis, the more the muscle can shorten, but such muscles are not usually very powerful. Muscle power depends more on the total number of muscle cells in the muscle. The stocky bipennate and multipennate muscles, which pack in the most fibers, shorten very little but are very powerful.

A Closer Look

Are Athletes Looking Good and Doing Better with Anabolic Steroids?

Everyone loves a winner, and top athletes are popular and make lots of money. It is not surprising that some will grasp at anything to increase their performance—including "juice" (anabolic steroids). These hormones, variants of testosterone engineered by pharmaceutical companies, were introduced in the 1950s to treat victims of certain muscle-wasting diseases and anemia and to prevent muscle atrophy in patients immobilized after surgery. Testosterone is responsible for the increase in muscle and bone mass and other physical changes that occur during puberty and convert boys into men. Convinced that huge doses of the anabolic steroids could enhance masculinizing effects in grown men, many athletes were using them by the early 1960s, and the practice is still going strong today. In 2004, allegations of rampant steroid abuse by Barry Bonds of the San Francisco Giants and by other baseball players surfaced. Investigations of this so-called Balco Scandal have stunned fans of major league baseball. In October 2007, Marion Jones, one of the most celebrated female athletes of all time, admitted she was using performance-enhancing steroids when she won five gold medals in the 2000 Olympics, and in June 2010, Mark McGwire, another popular baseball star, finally admitted steroid use.

Steroid use today is not confined to athletes looking for an edge. Indeed, it is estimated that one out of every ten young men has tried steroids, and the practice is growing rapidly among young women.

The use of these drugs has been banned by most international athletic competitions, and users (and prescribing physicians or drug dealers) are naturally reluctant to talk about it. Nonetheless, there is little question that many professional bodybuilders and athletes competing in events that require great muscle strength (such as discus throwing and weight lifting) are heavy users. Sports figures such as football players have also admitted to using steroids to help them prepare for games. Advantages of anabolic steroids cited by athletes include increased muscle mass and strength, increased oxygen-carrying capacity of the blood (due to greater red blood cell volume), and an increase in aggressive behavior (the urge to "steamroller the other guy").

But do the drugs do all that is claimed for them? Research studies have reported increases in isometric strength and body weight in steroid users. Although these are results weight lifters dream about, there is hot dispute over whether the drugs also enhance the fine muscle coordination and endurance needed by runners and others.

One of the available androstenedione nutritional performance enhancers.

Do the claimed slight advantages conferred by steroid use outweigh the risks? Absolutely not! Physicians say that steroids cause bloated faces (a sign of steroid excess), shriveled testes, and infertility; damage the liver and promote liver cancer; and cause changes in blood-cholesterol levels (which may place long-term users at risk for coronary disease). Additionally, about one-third of anabolic steroid users develop serious psychiatric