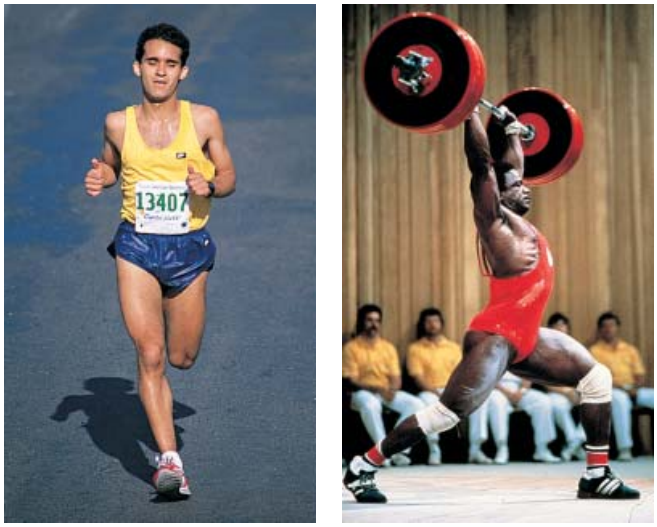


(a) (b)

FIGURE 6.11 The effects of aerobic training versus strength training. (a) A marathon runner. **(b)** A weight lifter.

and store more oxygen. However, aerobic exercise benefits much more than the skeletal muscles. It makes overall body metabolism more efficient, improves digestion (and elimination), enhances neuromuscular coordination, and makes the skeleton stronger. The heart enlarges (*hypertrophies*) so that more blood is pumped out with each beat, fat deposits are cleared from the blood vessel walls, and the lungs become more efficient in gas exchange. These benefits may be permanent or temporary, depending on how often and how vigorously one exercises.

Aerobic exercise does *not* cause the muscles to increase much in size, even though the exercise may go on for hours. The bulging muscles of a bodybuilder or professional weight lifter result mainly from **resistance,** or **isometric, exercises** (Figure 6.11b) in which the muscles are pitted against some immovable object (or nearly so). Resistance exercises require very little time and little or no special equipment. A few minutes every other day is usually sufficient. A wall can be pushed against, and buttock muscles can be strongly contracted even while standing in line at the grocery store. The key is forcing the muscles to contract with as much force as possible. The increased muscle size and strength that results is due mainly to enlargement of individual muscle cells (they make more contractile filaments), rather than an increase in their number. The amount of connective tissue that reinforces the muscle also increases.

Because endurance and resistance exercises produce different patterns of muscle response, it is important to know what your exercise goals are. Lifting weights will not improve your endurance for a marathon. By the same token, jogging will do little to improve your muscle definition for competing in the Mr. or Ms. Muscle contest, nor will it make you stronger for moving furniture. Obviously, the best exercise program for most people is one that includes both types of exercise.

Muscle Movements, Types, and Names

This section is a bit of a hodge-podge. It includes some topics that don't really fit together, but they don't fit anywhere else any better. For example, there are five very basic understandings about gross muscle activity. I call these the *Five Golden Rules* of skeletal muscle activity because until you understand them, comprehending muscle movements and appreciating muscle interactions is nearly impossible. These golden rules are summarized for your quick review 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 less than two points. One of these

TABLE 6.2 The Five Golden Rules of Skeletal Muscle Activity

1. With a few exceptions, all muscles cross at least one joint.
2. Typically, the bulk of the muscle lies proximal to the joint crossed.
3. All muscles have at least two attachments: the origin and the insertion.
4. Muscles can only pull; they never push.
5. During contraction, the muscle insertion moves toward the origin.

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.

The most common types of body movements are described next and shown in Figure 6.13. Try to demonstrate each movement as you read the following descriptions:

- **Flexion.** 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 (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 tip your head or your torso posteriorly so that 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).

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?*

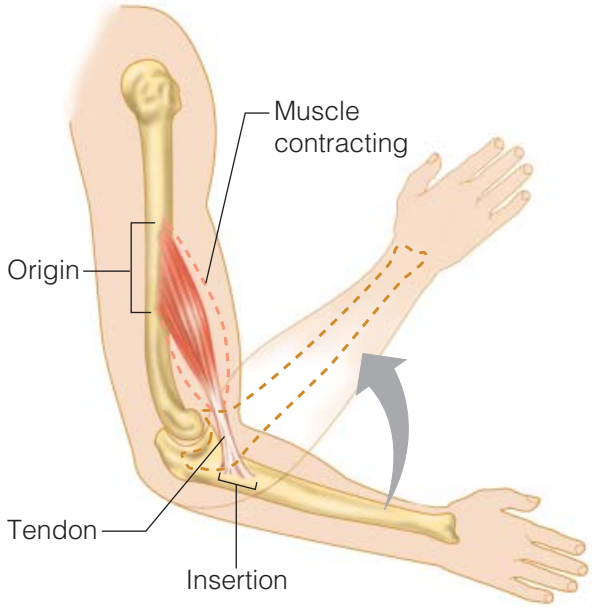
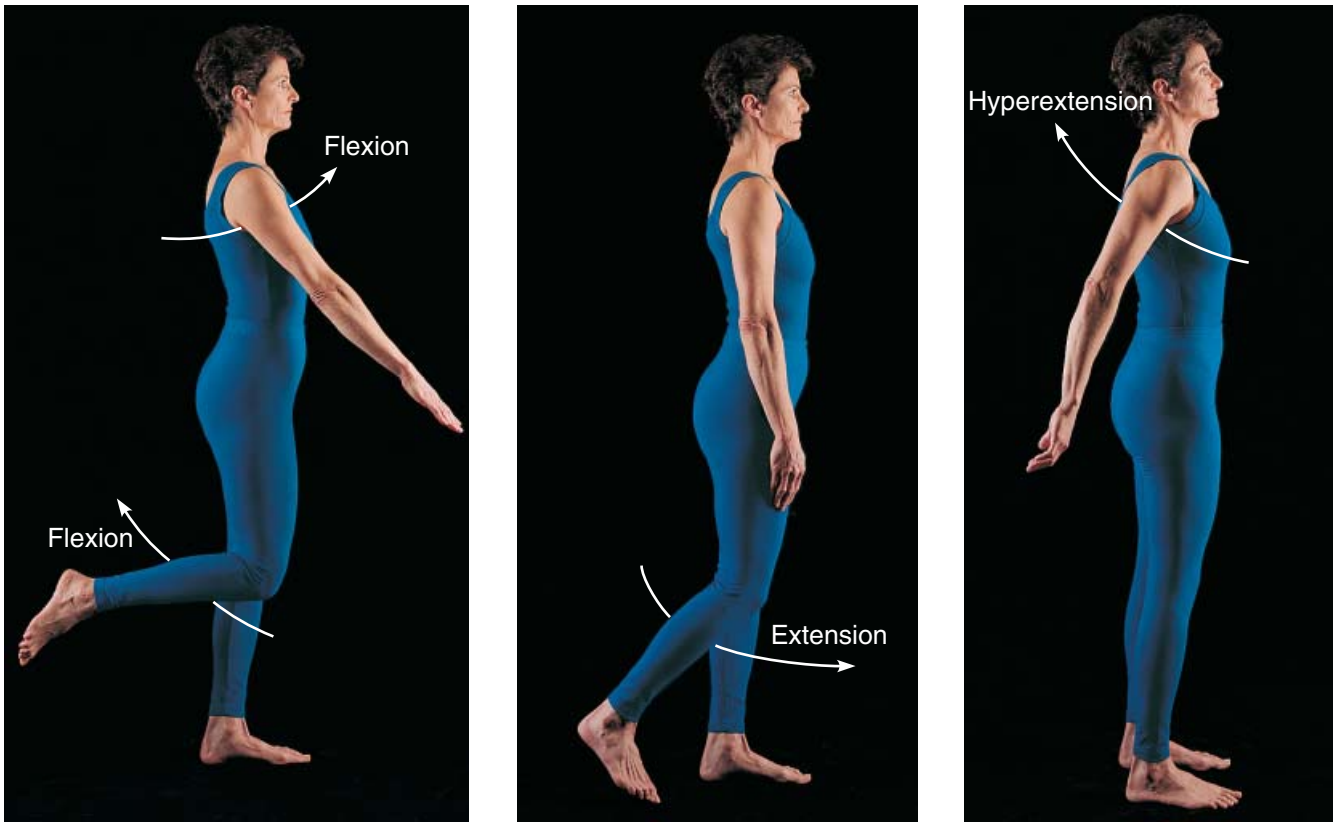


FIGURE 6.12 Muscle attachments (origin and insertion). When a skeletal muscle contracts, its insertion moves toward its origin.

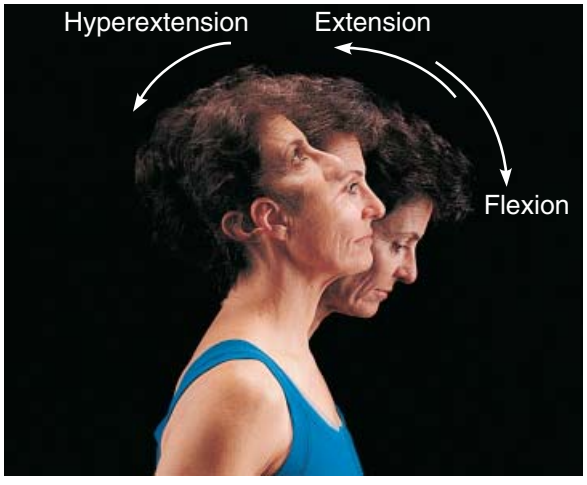
Special Movements

Certain movements do not fit into any of the previous categories and occur at only a few joints.

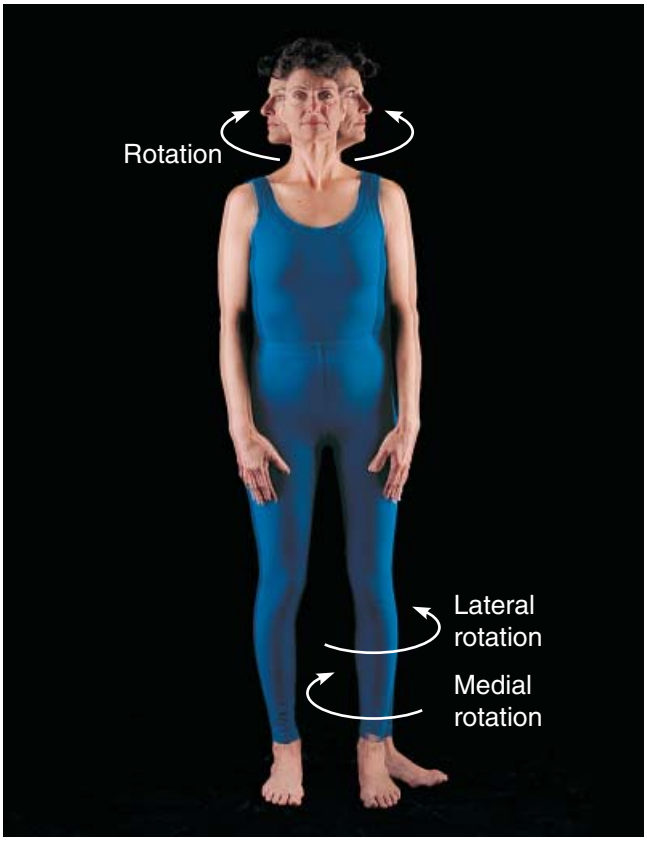
A *No, the insertion in this case would be its attachment to the humerus, and the attachment on the forearm (which is held steady during this movement) is the insertion.*



(a) Flexion and extension of the shoulder and knee

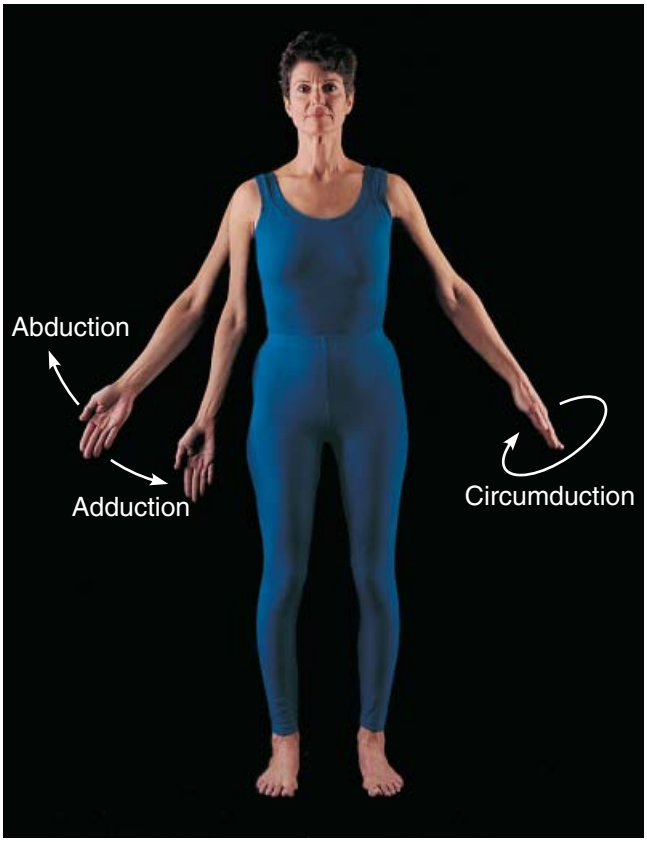


(b) Flexion, extension, and hyperextension

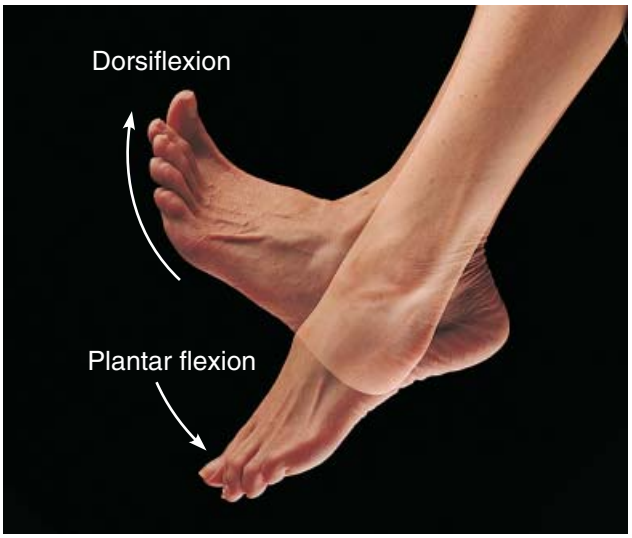


(c) Rotation

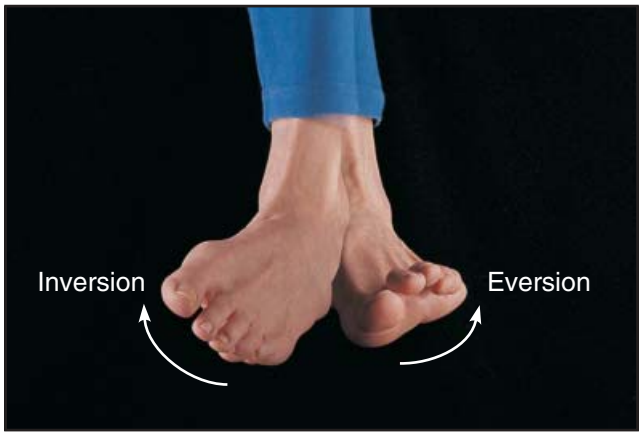
FIGURE 6.13 **Body movements.**



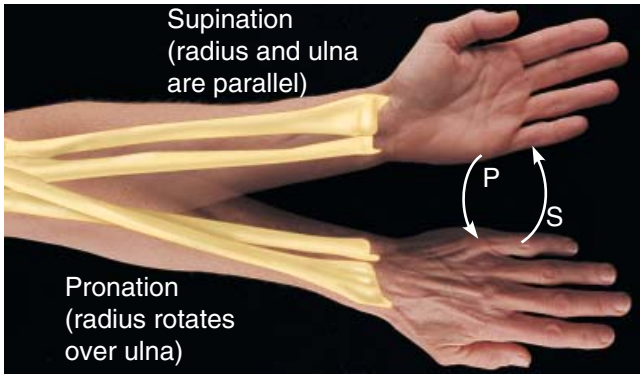
(d) Abduction, adduction, and circumduction



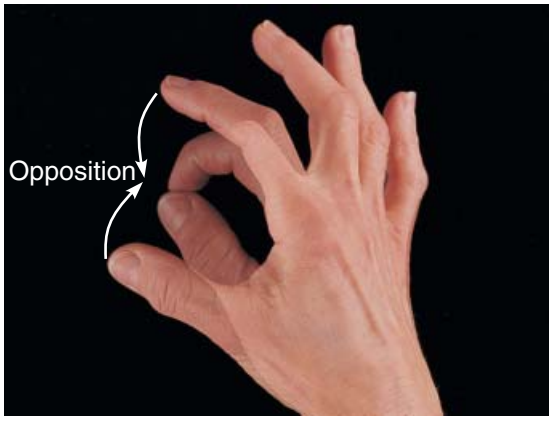
(e) Dorsiflexion and plantar flexion



(f) Inversion and eversion



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



(h) Opposition

FIGURE 6.13 (*continued*)

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. It is this unique action that makes the human hand such 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 are the result of the activity of 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. Because of this, 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 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 effecting smooth, coordinated, and precise movements.

Naming Skeletal 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