The capabilities of the upper extremity are varied and impressive. With the same basic anatomical structure of the arm, forearm, hand, and fingers, major league baseball pitchers hurl fastballs at 40 m/s, swimmers cross the English Channel, gymnasts perform the iron cross, travelers carry briefcases, seamstresses thread needles, and students type on computer keyboards. This chapter reviews the anatomical structures enabling these different types of movement and examines the ways in which the muscles cooperate to achieve the diversity of movement of which the upper extremity is capable.

**STRUCTURE OF THE SHOULDER**

The shoulder is the most complex joint in the human body, largely because it includes five separate articulations: the glenohumeral joint, the sternoclavicular joint, the acromioclavicular joint, the coracoclavicular joint, and the scapulothoracic joint. The glenohumeral joint is the articulation between the head of the humerus and the glenoid fossa of the scapula, which is the ball-and-socket joint typically considered to be the major shoulder joint. The sternoclavicular and acromioclavicular joints provide mobility for the clavicle and the scapula—the bones of the shoulder girdle.

**Sternoclavicular Joint**

The proximal end of the clavicle articulates with the clavicular notch of the manubrium of the sternum and with the cartilage of the first rib to form the sternoclavicular joint. This joint provides the major axis of rotation for movements of the clavicle and scapula (Figure 7-1). The sternoclavicular (SC) joint is a modified ball and socket, with frontal and transverse plane motion freely permitted and some forward and backward sagittal plane rotation allowed. A fibrocartilaginous articular disc improves the fit of the articulating bone surfaces and serves as a shock absorber. Rotation occurs at the SC joint during motions such as shrugging the shoulders, elevating the arms above the head, and swimming. The close-packed position for the SC joint occurs with maximal shoulder elevation.

**Acromioclavicular Joint**

The articulation of the acromion process of the scapula with the distal end of the clavicle is known as the acromioclavicular joint. It is classified as an
irregular diarthrodial joint, although the joint's structure allows limited motion in all three planes. There is a significant amount of anatomical variation in the acromioclavicular (AC) joint from individual to individual, with as many as five different morphological types identified (60). Rotation occurs at the AC joint during arm elevation. The close-packed position of the AC joint occurs when the humerus is abducted to 90°.

**Coracoclavicular Joint**

The coracoclavicular joint is a synechosis, formed where the coracoid process of the scapula and the inferior surface of the clavicle are bound together by the coracoclavicular ligament. This joint permits little movement. The coracoclavicular and acromioclavicular joints are shown in Figure 7-2.

**Glenohumeral Joint**

The glenohumeral joint is the most freely moving joint in the human body, enabling flexion, extension, hyperextension, abduction, adduction, horizontal abduction and adduction, and medial and lateral rotation of the humerus (Figure 7-3). The almost hemispherical head of the humerus has three to four times the amount of surface area as the shallow glenoid fossa of the scapula with which it articulates. The glenoid fossa is also less curved than the surface of the humeral head, enabling the humerus to move linearly across the surface of the glenoid fossa in addition to its extensive rotational capability (61). There are anatomical variations in the shape of the glenoid fossa from person to person, with an oval or
FIGURE 7-2
The acromioclavicular and coracoclavicular joints.

FIGURE 7-3
The glenohumeral joint.

- The extreme mobility of the glenohumeral joint is achieved at the expense of joint stability.

**glenoid labrum**
rim of soft tissue located on the periphery of the glenoid fossa that adds stability to the glenohumeral joint

**rotator cuff**
broad of tendons of the subscapularis, supraspinatus, infraspinatus, and teres minor, which attach to the humeral head

egg-shaped cavity in about 45% of the population and a pear-shaped cavity in the remaining 55% (63). With passive rotation of the arm, large translations of the humeral head on the glenoid fossa are present at the extremes of the range of motion (38). The muscle forces during active rotation tend to limit ranges of motion at the shoulder, thereby limiting the humeral translation that occurs (38).

The glenoid fossa is encircled by the glenoid labrum, a lip composed of part of the joint capsule, the tendon of the long head of the biceps brachii, and the glenohumeral ligaments. This rim of dense collagenous tissue is triangular in cross-section and is attached to the periphery of the fossa. The labrum deepens the fossa and adds stability to the joint. The capsule surrounding the glenohumeral joint is shown in Figure 7-4. Several ligaments merge with the glenohumeral joint capsule, including the superior, middle, and inferior glenohumeral ligaments on the anterior side of the joint and the coracohumeral ligament on the superior side.

The tendons of four muscles also join the joint capsule. These are known as the rotator cuff muscles because they contribute to rotation of the humerus and because their tendons form a collagenous cuff around the glenohumeral joint. These include supraspinatus, infraspinatus, teres
minor, and subscapularis, and are also sometimes referred to as the SITS muscles after the first letter of the muscles' names. Supraspinatus, infraspinatus, and teres minor participate in lateral rotation, and subscapularis contributes to medial rotation. The muscles of the lateral rotator group exchange muscle bundles with one another, which increases their ability to quickly develop tension and functional power (28). The rotator cuff surrounds the shoulder on the posterior, superior, and anterior sides. Tension in the rotator cuff muscles pulls the head of the humerus toward the glenoid fossa, contributing significantly to the joint's minimal stability. It has been shown that the rotator cuff muscles and the biceps are activated to provide shoulder stability prior to motion of the humerus (13). Negative pressure within the capsule of the glenohumeral joint also helps to stabilize the joint (31). The joint is most stable in its close-packed position, when the humerus is abducted and laterally rotated.

**Scapulothoracic Joint**

Because the scapula can move in both sagittal and frontal planes with respect to the trunk, the region between the anterior scapula and the thoracic wall is sometimes referred to as the scapulothoracic joint. The muscles attaching to the scapula perform two functions. First, they can contract to stabilize the shoulder region. For example, when a suitcase is lifted from the floor, the levator scapula, trapezius, and rhomboids develop tension to support the scapula, and in turn the entire shoulder, through the acromioclavicular joint. Second, the scapular muscles can facilitate movements of the upper extremity through appropriate positioning of the glenohumeral joint. During an overhand throw, for example, the rhomboids contract to move the entire shoulder posteriorly as the humerus is horizontally abducted and externally rotated during the preparatory phase. As the arm and hand then move forward to execute the throw, tension in the rhomboids is released to permit forward movement of the glenohumeral joint.

**Bursae**

Several small, fibrous sacs that secrete synovial fluid internally in a fashion similar to that of a joint capsule are located in the shoulder region.
These sacs, known as bursae, cushion and reduce friction between layers of collagenous tissues. The shoulder is surrounded by several bursae, including the subscapularis, subcoracoid, and subacromial.

The subscapularis and subcoracoid bursae are responsible for managing friction of the superficial fibers of the subscapularis muscle against the neck of the scapula, the head of the humerus, and the coracoid process. In 28% of studied cases, these two bursae physically merge into a single wide bursa (11). Given that the subscapularis undergoes significant changes in orientation during movements of the arm at the glenohumeral joint, especially where the upper portion of the muscle coils around the coracoid process, the role of these bursae is important.

The subacromial bursa lies in the subacromial space, between the acromion process of the scapula and the coracoacromial ligament (above) and the glenohumeral joint (below). This bursa cushions the rotator cuff muscles, particularly the supraspinatus, from the overlying bony acromion (Figure 7-5). The subacromial bursa may become irritated when repeatedly compressed during overhead arm action.

MOVEMENTS OF THE SHOULDER COMPLEX

Although some amount of glenohumeral motion may occur while the other shoulder articulations remain stabilized, movement of the humerus more commonly involves some movement at all three shoulder joints (Figure 7-6). Elevation of the humerus in all planes is accompanied by approximately 55° of lateral rotation (71). As the arm is elevated in both abduction and flexion, rotation of the scapula accounts for part of the total humeral range of motion. Although the absolute positions of the humerus and scapula vary due to anatomical variations among individuals, a general pattern persists (27). During about the first 30° of humeral elevation, the contribution of the scapula is only about one-fifth that of the glenohumeral joint (61). As elevation proceeds beyond 30°, the scapula rotates approximately 1° for every 2° of movement of the humerus (18, 33, 67). This important coordination of scapular and humeral movements, known as scapulohumeral rhythm, enables a much greater range of motion at the shoulder than if the scapula were fixed. During the first 90° of arm elevation (in sagittal, frontal, or diagonal planes), the clavicle is also elevated through approximately 35–45° of motion at the sternoclavicular joint (61). Rotation at the acromioclavicular joint occurs during the first 30° of humeral elevation and again as the arm is moved from 135° to maximum
elevation (40). Positioning of the humerus is further facilitated by motions of the spine. When the hands support an external load, the orientation of the scapula and the scapulohumeral rhythm are altered, with muscular stabilization of the scapula reducing scapulothoracic motion as dynamic scapular stabilization provides a platform for upper extremity movements (41). Generally, scapulohumeral relationships are more fixed when the arm is loaded and engaged in purposeful movement as compared to when the arm is moving in an unloaded condition (12).

The movement patterns of the scapula are also different in children and in the elderly. As compared to adults, children receive a greater contribution from the scapulothoracic joint during humeral elevation (15). With aging, there is a lessening of scapular rotation, as well as posterior tilt, with glenohumeral abduction (21). Abnormal motion of the scapula may contribute to a variety of shoulder pathologies, including shoulder impingement, rotator cuff tears, glenohumeral instability, and stiff shoulders (48).

**Muscles of the Scapula**

The muscles that attach to the scapula are the levator scapula, rhomboids, serratus anterior, pectoralis minor, and subclavius, and the four parts of the trapezius. Figures 7-7 and 7-8 show the directions in which these muscles exert force on the scapula when contracting. Scapular muscles have two general functions. First, they stabilize the scapula so that it forms a rigid base for muscles of the shoulder during the development of tension. For example, when a person carries a briefcase, the levator scapula, trapezius, and rhomboids stabilize the shoulder against the added weight. Second, scapular muscles facilitate movements of the upper extremity by positioning the glenohumeral joint appropriately. For example, during an overhand throw, the rhomboids contract to move the entire shoulder posteriorly as the arm and hand move posteriorly during the preparatory phase. As the arm and hand move anteriorly to deliver the throw, tension in the rhomboids subsides to permit forward movement of the shoulder, facilitating outward rotation of the humerus.
Muscles of the Glenohumeral Joint

Many muscles cross the glenohumeral joint. Because of their attachment sites and lines of pull, some muscles contribute to more than one action of the humerus. A further complication is that the action produced by the development of tension in a muscle may change with the orientation of the humerus because of the shoulder's large range of motion. With the basic instability of the structure of the glenohumeral joint, a significant portion of the joint's stability is derived from tension in the muscles and

- The development of tension in one shoulder muscle must frequently be accompanied by the development of tension in an antagonist to prevent dislocation of the humeral head.