The Muscular System

11

Learning Outcomes

These Learning Outcomes correspond by number to this chapter's sections and indicate what you should be able to do after completing the chapter.

- **11-1** Describe the **arrangement of fascicles** in the various types of muscles, and explain the resulting **functional differences**.
- **11-2** Describe the **classes of levers**, and explain how they make muscles more efficient.
- **11-3** Predict the **actions of a muscle** on the basis of its origin and insertion, and explain how **muscles interact** to produce or oppose movements.
- **11-4** Explain how the **name of a muscle** can help identify its **location, appearance, or function**.
- **11-5** Identify the principal **axial muscles** of the body, plus their origins, insertions, actions, and innervation.
- **11-6** Identify the principal **appendicular muscles** of the body, plus their origins, insertions, actions, and innervation, and compare the **major functional differences** between the upper and lower limbs.
- **11-7** Identify **age-related changes** of the muscular system.
- **11-8** Explain the **functional relationship** between the muscular system and other body systems, and explain the **role of exercise** in producing various responses in other body systems.

Clinical Notes

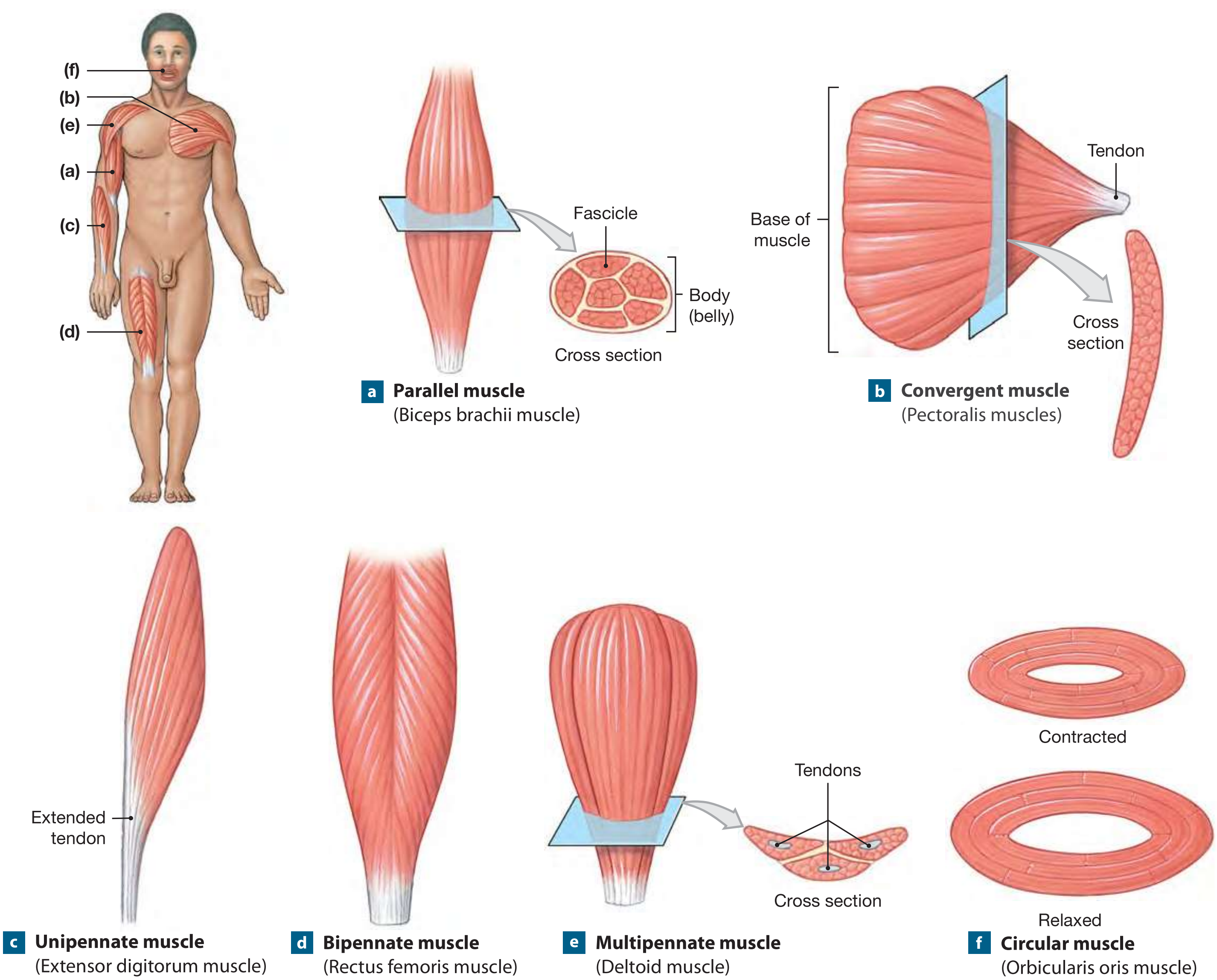
An Introduction to the Muscular System

This chapter describes the gross anatomy of the muscular system and considers functional relationships between muscles and bones of the body. Although most skeletal muscle fibers contract at similar rates and shorten to the same degree, variations in microscopic and macroscopic organization can dramatically affect the power, range, and speed of movement produced when muscles contract.

11-1 Fascicle arrangement is correlated with muscle power and range of motion

Muscle fibers in a skeletal muscle form bundles called *fascicles*. ⮌ p. 280 The muscle fibers in a single fascicle are parallel, but the organization of fascicles in skeletal muscles can vary, as can the relationship between the fascicles and the associated tendon. Based on the patterns of fascicle organization, skeletal muscles can be classified as *parallel muscles, convergent muscles, pennate muscles*, and *circular muscles* (**Figure 11–1**).

Figure 11–1 **Muscle Types Based on Pattern of Fascicle Organization.**



Parallel Muscles

In a **parallel muscle,** the fascicles are parallel to the long axis of the muscle. Most of the skeletal muscles in the body are parallel muscles. Some are flat bands with broad attachments *(aponeuroses)* at each end; others are plump and cylindrical, with tendons at one or both ends. In the latter case, the muscle is spindle shaped (**Figure 11–1a**), with a central **body,** also known as the *belly*. The *biceps brachii muscle* of the arm is a parallel muscle with a central body. When a parallel muscle contracts, it shortens and gets larger in diameter. You can see the bulge of the contracting biceps brachii muscle on the anterior surface of your arm when you flex your elbow.

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A skeletal muscle fiber can contract until it has shortened about 30 percent. Because the muscle fibers in a parallel muscle are parallel to the long axis of the muscle, when those fibers contract together the entire muscle shortens by about 30 percent. Thus, if the muscle is 10 cm (3.94 in.) long and one end is held in place, the other end will move 3 cm when the muscle contracts. The tension developed during this contraction depends on the total number of myofibrils the muscle contains. ⮌ p. 301 Because the myofibrils are distributed evenly through the sarcoplasm of each cell, we can use the cross-sectional area of the resting muscle to estimate the tension. For each 6.45 cm^2 (1 $in.^2$) in cross-sectional area, a parallel muscle can develop approximately 23 kg (50 lb) of isometric tension.

Convergent Muscles

In a **convergent muscle,** muscle fascicles extending over a broad area converge on a common attachment site (**Figure 11–1b**). The muscle may pull on a tendon, an aponeurosis, or a slender band of collagen fibers known as a **raphe** (RĀ-fē; seam). The muscle fibers typically spread out, like a fan or a broad triangle, with a tendon at the apex. Examples include the prominent *pectoralis muscles* of the chest. A convergent muscle is versatile, because the stimulation of different portions of the muscle can change the direction of pull. However, when the entire muscle contracts, the muscle fibers do not pull as hard on the attachment site as would a parallel muscle of the same size. This is because convergent muscle fibers pull in different directions, rather than all pulling in the same direction.

Pennate Muscles

In a **pennate muscle** (*penna*, feather), the fascicles form a common angle with the tendon. Because the muscle fibers pull at an angle, contracting pennate muscles do not move their tendons as far as parallel muscles do. But a pennate muscle contains more muscle fibers—and thus more myofibrils—than does a parallel muscle of the same size, and so produces more tension.

If all the muscle fibers are on the same side of the tendon, the pennate muscle is *unipennate*. The *extensor digitorum muscle*, a forearm muscle that extends the finger joints, is unipennate (**Figure 11–1c**). More commonly, a pennate muscle has fibers on both sides of the tendon. Such a muscle is called *bipennate*. The *rectus femoris muscle*, a prominent muscle that extends the knee, is bipennate (**Figure 11–1d**). If the tendon branches within a pennate muscle, the muscle is said to be *multipennate*. The triangular *deltoid muscle* of the shoulder is multipennate (**Figure 11–1e**).

Circular Muscles

In a **circular muscle,** or **sphincter** (SFINK-ter), the fascicles are concentrically arranged around an opening. When the muscle contracts, the diameter of the opening decreases. Circular muscles guard entrances and exits of internal passageways such as the digestive and urinary tracts. An example is the *orbicularis oris muscle* of the mouth (**Figure 11–1f**).

Checkpoint

1. **Based on patterns of fascicle organization, name the four classifications of skeletal muscle tissue.**
2. **Why does a pennate muscle generate more tension than does a parallel muscle of the same size?**
3. **Which type of fascicle arrangement would you expect in a muscle guarding the opening between the stomach and the small intestine?**

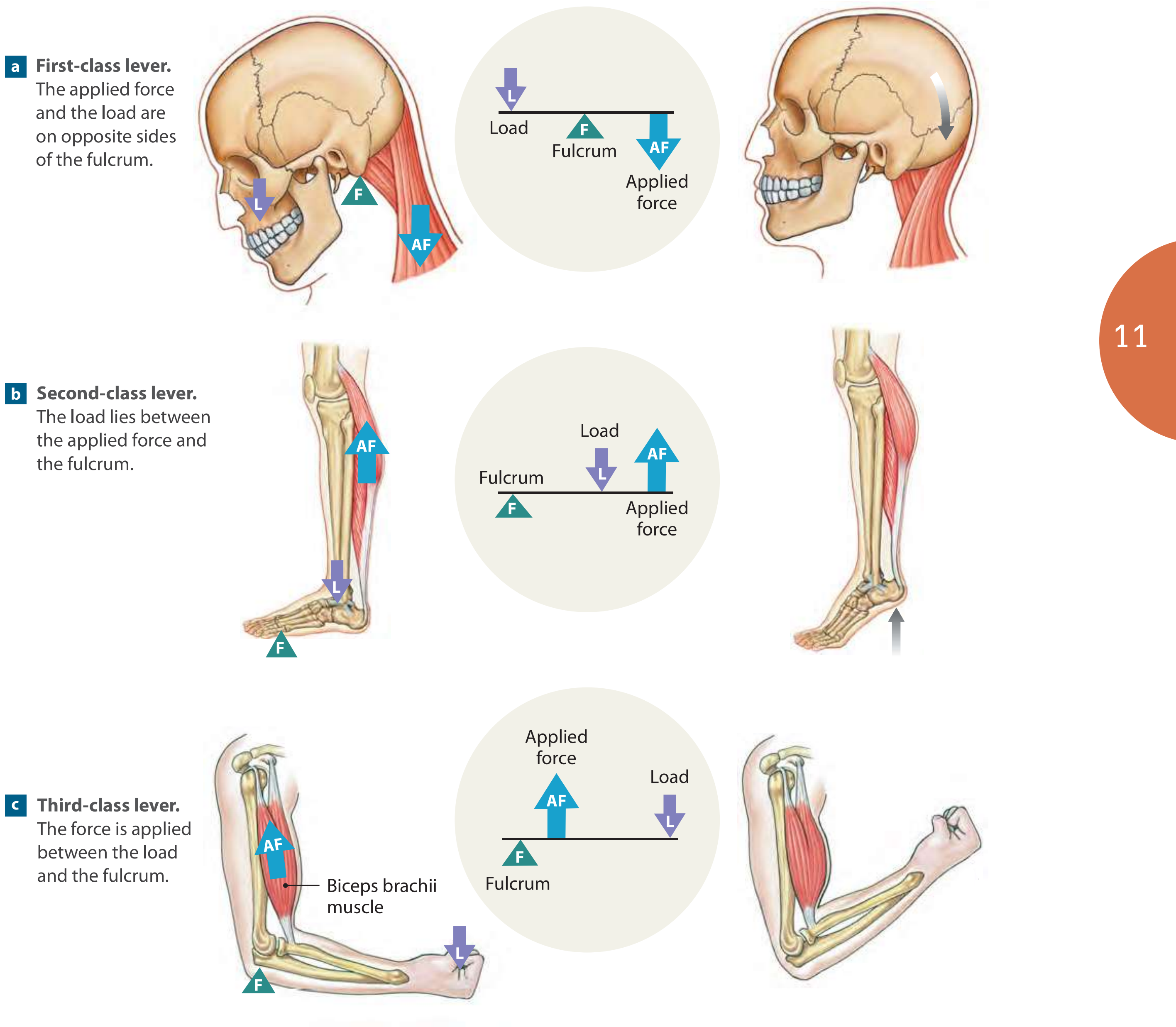
See the blue Answers tab at the back of the book.

11-2 ◗ The three classes of levers increase muscle efficiency

Skeletal muscles do not work in isolation. For muscles attached to the skeleton, the nature and site of the connection determine the force, speed, and range of the movement produced. These characteristics are interdependent, and the relationships can explain a great deal about the general organization of the muscular and skeletal systems.

Attaching the muscle to a lever can modify the force, speed, or direction of movement produced by muscle contraction. A lever is a rigid structure—such as a board, a crowbar, or a bone—that moves on a fixed point called the fulcrum. A lever moves when pressure called an applied force is sufficient to overcome any load that would otherwise oppose or prevent such movement. In the body, each bone is a lever and each joint is a fulcrum, and muscles provide the applied force. The load can vary from the weight of an object held in the hand to the weight of a limb or the weight of the entire body, depending on the situation. The important thing about levers is that they can change (1) the direction of an applied force, (2) the distance

Figure 11–2 **The Three Classes of Levers.**



and speed of movement produced by an applied force, and (3) the effective strength of an applied force.

There are three classes of levers, and examples of each are found in the human body (**Figure 11–2**). A seesaw or teeter-totter is an example of a **first-class lever.** In such a lever, the fulcrum (F) lies between the applied force (AF) and the load (L). The body has few first-class levers. One, involved with extension of the neck, is shown in **Figure 11–2a**.

In a **second-class lever** (**Figure 11–2b**), the load is located between the applied force and the fulcrum. A familiar example is a loaded wheelbarrow. The weight is the load, and the upward lift on the handle is the applied force. Because in this arrangement the force is always farther from the fulcrum than the load is, a small force can move a larger weight. That is, the effective force is increased. Notice, however, that when a force moves the handle, the load moves more slowly and covers a shorter distance. Thus the effective force is increased at the expense of speed and distance. The body has few second-class levers. Ankle extension (plantar flexion) by the calf muscles involves a second-class lever (**Figure 11–2b**).

Third-class levers are the most common levers in the body. In this lever system, a force is applied between the load

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and the fulcrum (**Figure 11–2c**). The effect is the reverse of that for a second-class lever: Speed and distance traveled are increased at the expense of effective force. In the example shown (the biceps brachii muscle, which flexes the elbow), the load is six times farther from the fulcrum than is the applied force. The effective force is reduced to the same degree. The muscle must generate 180 kg (396 lb) of tension at its attachment to the forearm to support 30 kg (66 lb) held in the hand. However, the distance traveled and the speed of movement are increased by that same 6:1 ratio: The load will travel 45 cm (almost 18 in.) when the point of attachment moves 7.5 cm (nearly 3 in.).

Although not every muscle operates as part of a lever system, the presence of levers provides speed and versatility far in excess of what we would predict on the basis of muscle physiology alone. Skeletal muscle fibers resemble one another closely, and their abilities to contract and generate tension are quite similar. Consider a skeletal muscle that can shorten 1 cm (0.39 in.) while it exerts a 10-kg (22-lb) pull. Without using a lever, this muscle would be performing efficiently only when moving a 10-kg (22-lb) weight a distance of 1 cm (0.39 in.). By using a lever, however, the same muscle operating at the same efficiency could move 20 kg (44 lb) a distance of 0.5 cm (0.2 in.), 5 kg (11 lb) a distance of 2 cm (0.79 in.), or 1 kg (2.2 lb) a distance of 10 cm (3.9 in.).

Checkpoint

4. **Define a lever, and describe the three classes of levers.**
5. **The joint between the occipital bone of the skull and the first cervical vertebra (atlas) is part of which class of lever system?**

See the blue Answers tab at the back of the book.

11-3 Muscle origins are at the fixed end of muscles, whereas insertions are at the movable end of muscles

This chapter focuses on the functional anatomy of skeletal muscles and muscle groups. You must learn a number of new terms, and this section attempts to help you understand them. Once you are familiar with the basic terminology, the names and actions of skeletal muscles are easily understood.

Origins and Insertions

In Chapter 10 we noted that when both ends of a myofibril are free to move, the ends move toward the center during a contraction. ⮌ p. 296 In the body, the ends of a skeletal muscle are always attached to other structures that limit their movement. In most cases one end is fixed in position, and during a contraction the other end moves toward the fixed end. The place where the fixed end attaches to a bone, cartilage, or connective tissue is called the **origin** of the muscle. The site where the movable end attaches to another structure is called the **insertion** of the muscle. The origin is typically proximal to the insertion. When a muscle contracts, it produces a specific **action,** or movement. Actions are described using the terms introduced in Chapter 9 (flexion, extension, adduction, and so forth).

As an example, consider the *gastrocnemius muscle*, a calf muscle that extends from the distal portion of the femur to the calcaneus. As **Figure 11–2b** shows, when the gastrocnemius muscle contracts, it pulls the calcaneus toward the knee. As a result, we say that the gastrocnemius muscle has its origin at the femur and its insertion at the calcaneus; its action can be described as "extension at the ankle" or "plantar flexion."

The decision as to which end is the origin and which is the insertion is usually based on movement from the anatomical position. Part of the fun of studying the muscular system is that you can actually do the movements and think about the muscles involved. As a result, laboratory activities focusing on muscle actions often resemble disorganized aerobics classes.

When the origins and insertions cannot be determined easily on the basis of movement from the anatomical position, other rules are used. If a muscle extends between a broad aponeurosis and a narrow tendon, the aponeurosis is the origin and the tendon is the insertion. If several tendons are at one end and just one is at the other, the muscle has multiple origins and a single insertion. These simple rules cannot cover every situation. Knowing which end is the origin and which is the insertion is ultimately less important than knowing where the two ends attach and what the muscle accomplishes when it contracts.

Most muscles originate at a bone, but some originate at a connective tissue sheath or band. Examples of these sheaths or bands include *intermuscular septa* (components of the deep fascia that may separate adjacent skeletal muscles), *tendinous inscriptions* that join muscle fibers to form long muscles such as the *rectus abdominis*, the interosseous membranes of the forearm or leg, and the fibrous sheet that spans the obturator foramen of the pelvis.

Actions

Almost all skeletal muscles either originate or insert on the skeleton. When a muscle moves a portion of the skeleton, that movement may involve flexion, extension, adduction, abduction, protraction, retraction, elevation, depression, rotation, circumduction, pronation, supination, inversion, eversion, lateral flexion, opposition, or reposition. (Before proceeding, you may want to review the discussions of planes of motion and **Figures 9–2** to **9–5**.) ⮌ pp. 258–262

Actions can be described in one of two ways. The first, used by most undergraduate textbooks and references such as *Gray's*

Anatomy, describes actions in terms of the bone or region affected. Thus, a muscle such as the biceps brachii muscle is said to perform "flexion of the forearm." The second way, of increasing use among specialists such as kinesiologists and physical therapists, identifies the joint involved. In this approach, the action of the biceps brachii muscle would be "flexion at (or of) the elbow." Both approaches are valid, and each has its advantages. In general, we will use the latter approach.

When complex movements occur, muscles commonly work in groups rather than individually. Their cooperation improves the efficiency of a particular movement. For example, large muscles of the limbs produce flexion or extension over an extended range of motion. Although these muscles cannot produce powerful movements at full extension due to the positions of the articulating bones, they are usually paired with one or more smaller muscles that provide assistance until the larger muscle can perform at maximum efficiency. At the start of the movement, the smaller muscle is producing maximum tension, while the larger muscle is producing minimum tension. The importance of this smaller "assistant" decreases as the movement proceeds and the effectiveness of the primary muscle increases.

Based on their functions, muscles are described as follows:

- An **agonist,** or **prime mover,** is a muscle whose contraction is mostly responsible for producing a particular movement. The biceps brachii muscle is an agonist that produces flexion at the elbow.
- An **antagonist** is a muscle whose action opposes that of a particular agonist. The *triceps brachii muscle* is an agonist that extends the elbow. It is therefore an antagonist of the biceps brachii muscle, and the biceps brachii is an antagonist of the triceps brachii. Agonists and antagonists are functional opposites; if one produces flexion, the other will produce extension. When an agonist contracts to produce a particular movement, the corresponding antagonist will be stretched, but it will usually not relax completely. Instead, it will contract eccentrically, with just enough tension to control the speed of the movement and ensure its smoothness. ⮌ p. 304 You may find it easiest to learn about muscles in agonist–antagonist pairs (flexors–extensors, abductors–adductors) that act at a specific joint. This method highlights the functions of the muscles involved, and it can help organize the information into a logical framework. The tables in this chapter are arranged to support such an approach.
- When a **synergist** (*syn-*, together + *ergon*, work) contracts, it helps a larger agonist work efficiently. Synergists may provide additional pull near the insertion or may stabilize the point of origin. Their importance in assisting a particular movement may change as the movement progresses. In many cases, they are most useful at the start, when the agonist is stretched and unable to develop maximum tension. For example, the *latissimus dorsi muscle* is a large trunk muscle that extends, adducts, and medially rotates the arm at the shoulder joint. A much smaller muscle, the *teres* (TER-ēz) *major muscle*, assists in starting such movements when the shoulder joint is at full flexion. Synergists may also assist an agonist by preventing movement at another joint, thereby stabilizing the origin of the agonist. Such synergists are called **fixators.**

Checkpoint

6. **Define the term *synergist* as it relates to muscle action.**
7. **The *gracilis muscle* is attached to the anterior surface of the tibia at one end, and to the pubis and ischium of the pelvis at the other. When the muscle contracts, flexion occurs at the hip. Which attachment point is considered the muscle's origin?**
8. **Muscle A abducts the humerus, and muscle B adducts the humerus. What is the relationship between these two muscles?**

See the blue Answers tab at the back of the book.

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11-4 ◗ Descriptive terms are used to name skeletal muscles

Except for the *platysma* and the *diaphragm*, the complete names of all skeletal muscles include the term *muscle*. Although the full name, such as the biceps brachii muscle, will usually appear in the text, for simplicity only the descriptive name (biceps brachii) will be used in figures and tables.

You need not learn every one of the approximately 700 muscles in the human body, but you will have to become familiar with the most important ones. Fortunately, the names anatomists assigned to the muscles include descriptive terms that can help you remember the names and identify the muscles. When faced with a new muscle name, it is helpful to first identify the descriptive portions of the name. The name of a muscle may include descriptive information about its location in the body, origin and insertion, fascicle organization, position, structural characteristics, and action.

Location in the Body

Table 11–1 includes a useful summary of muscle terminology, including terms that designate specific regions of the body. Regional terms are most common as modifiers that help identify individual muscles. In a few cases, a muscle is such a prominent feature of a body region that a name referring to the region alone

Table 11–1 Muscle Terminology

Terms Indicating Specific Regions of the Body	Terms Indicating Position, Direction, or Fascicle Organization	Terms Indicating Structural Characteristics of the Muscle	Terms Indicating Actions
Abdominis (abdomen)	Anterior (front)	**Nature of Origin**	**General**
Anconeus (elbow)	Externus (superficial)	Biceps (two heads)	Abductor
Auricularis (auricle of ear)	Extrinsic (outside)	Triceps (three heads)	Adductor
Brachialis (brachium)	Inferioris (inferior)	Quadriceps (four heads)	Depressor
Capitis (head)	Internus (deep, internal)		Extensor
Carpi (wrist)	Intrinsic (inside)	**Shape**	Flexor
Cervicis (neck)	Lateralis (lateral)	Deltoid (triangle)	Levator
Cleido-/-clavius (clavicle)	Medialis/medius (medial, middle)	Orbicularis (circle)	Pronator
Coccygeus (coccyx)	Oblique	Pectinate (comblike)	Rotator
Costalis (ribs)	Posterior (back)	Piriformis (pear-shaped)	Supinator
Cutaneous (skin)	Profundus (deep)	Platy- (flat)	Tensor
Femoris (femur)	Rectus (straight, parallel)	Pyramidal (pyramid)	
Genio- (chin)	Superficialis (superficial)	Rhomboid	**Specific**
Glosso-/-glossal (tongue)	Superioris (superior)	Serratus (serrated)	Buccinator (trumpeter)
Hallucis (great toe)	Transversus (transverse)	Splenius (bandage)	Risorius (a laughter)
Ilio- (ilium)		Teres (long and round)	Sartorius (like a tailor)
Inguinal (groin)		Trapezius (trapezoid)	
Lumborum (lumbar region)			
Nasalis (nose)		**Other Striking Features**	
Nuchal (back of neck)		Alba (white)	
Oculo- (eye)		Brevis (short)	
Oris (mouth)		Gracilis (slender)	
Palpebrae (eyelid)		Lata (wide)	
Pollicis (thumb)		Latissimus (widest)	
Popliteus (posterior to knee)		Longissimus (longest)	
Psoas (loin)		Longus (long)	
Radialis (radius)		Magnus (large)	
Scapularis (scapula)		Major (larger)	
Temporalis (temples)		Maximus (largest)	
Thoracis (thoracic region)		Minimus (smallest)	
Tibialis (tibia)		Minor (smaller)	
Ulnaris (ulna)		Vastus (great)	
Uro- (urinary)			

will identify it. Examples include the *temporalis muscle* of the head and the *brachialis* (brā-kē-A-lis) *muscle* of the arm.

Origin and Insertion

Many muscle names include terms for body places that tell you the specific origin and insertion of each muscle. In such cases, the first part of the name indicates the origin, the second part the insertion. The *genioglossus muscle*, for example, originates at the chin *(geneion)* and inserts in the tongue *(glossus)*. The names may be long and difficult to pronounce, but Table 11–1 and the anatomical terms introduced in Chapter 1 can help you identify and remember them. ⮌ pp. 16–22

Fascicle Organization

A muscle name may refer to the orientation of the muscle fascicles within a particular skeletal muscle. **Rectus** means "straight," and rectus muscles are parallel muscles whose fibers run along the long axis of the body. Because we have several rectus muscles, the name typically includes a second term that refers to a precise region of the body. For example, the *rectus abdominis muscle* is located on the abdomen, and the *rectus femoris muscle* on the thigh. Other common directional indicators include **transversus** and **oblique,** for muscles whose fibers run across (transversus) or at a slanting (oblique) angle to the longitudinal axis of the body.

Position

Muscles visible at the body surface are often called **externus** or **superficialis,** whereas deeper muscles are termed **internus** or **profundus.** Superficial muscles that position or stabilize an organ are called **extrinsic;** muscles located entirely within an organ are **intrinsic.**

Structural Characteristics

Some muscles are named after distinctive structural features. The biceps brachii muscle, for example, has two tendons of origin (*bi-*, two + *caput*, head); the triceps brachii muscle has three; and the *quadriceps* group, four. Shape is sometimes an important clue to the name of a muscle. For example, the *trapezius* (tra-PĒ-zē-us), *deltoid*, *rhomboid* (ROM-boyd), and *orbicularis* (or-bik-ū-LĀ-ris) muscles look like a trapezoid, a triangle, a rhomboid, and a circle, respectively. Many terms refer to muscle size. Long muscles are called **longus** (long) or **longissimus** (longest), and **teres** muscles are both long and round. Short muscles are called **brevis.** Large ones are called **magnus** (big), **major** (bigger), or **maximus** (biggest); small ones are called **minor** (smaller) or **minimus** (smallest).

Action

Many muscles are named *flexor*, *extensor*, *pronator*, *abductor*, and so on. These are such common actions that the names almost always include other clues as to the appearance or location of the muscle. For example, the *extensor carpi radialis longus muscle* is a long muscle along the radial (lateral) border of the forearm. When it contracts, its primary function is extension at the carpus (wrist).

A few muscles are named after the specific movements associated with special occupations or habits. The *sartorius* (sar-TOR-ē-us) *muscle*, the longest in the body, is active when you cross your legs. Before sewing machines were invented, a tailor would sit on the floor cross-legged, and the name of this muscle was derived from *sartor*, the Latin word for "tailor." The *buccinator* (BUK-si-nā-tor) *muscle* on the face compresses the cheeks—when, for example, you purse your lips and blow forcefully. *Buccinator* translates as "trumpet player." Another facial muscle, the *risorius* (ri-SOR-ē-us) *muscle*, was supposedly named after the mood expressed. However, the Latin word *risor* means "a laughter"; a more appropriate description for the effect would be "a grimace."

Axial and Appendicular Muscles

The separation of the skeletal system into axial and appendicular divisions provides a useful guideline for subdividing the muscular system as well:

1. The **axial muscles** arise on the axial skeleton. They position the head and spinal column and also move the rib cage, assisting in the movements that make breathing possible. They do not play a role in movement or support of either the pectoral or pelvic girdle or the limbs. This category includes approximately 60 percent of the skeletal muscles in the body.
2. The **appendicular muscles** stabilize or move components of the appendicular skeleton and include the remaining 40 percent of all skeletal muscles.

Figure 11–3 provides an overview of the major axial and appendicular muscles of the human body. These are superficial muscles, which tend to be rather large. The superficial muscles cover deeper, smaller muscles that cannot be seen unless the overlying muscles are either removed or *reflected*—that is, cut and pulled out of the way. Later figures that show deep muscles in specific regions will indicate whether superficial muscles have been removed or reflected.

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Paying attention to patterns of origin, insertion, and action, we will now study examples of both muscular divisions. As you examine the figures in this chapter, you will find that some bony and cartilaginous landmarks are labeled to provide orientation. These labels are shown in italics, to differentiate these landmarks from the muscles and tendons that are the primary focus of each figure. Should you need further review of skeletal anatomy, figure captions in this chapter indicate the relevant figures in Chapters 7, 8, and 9.

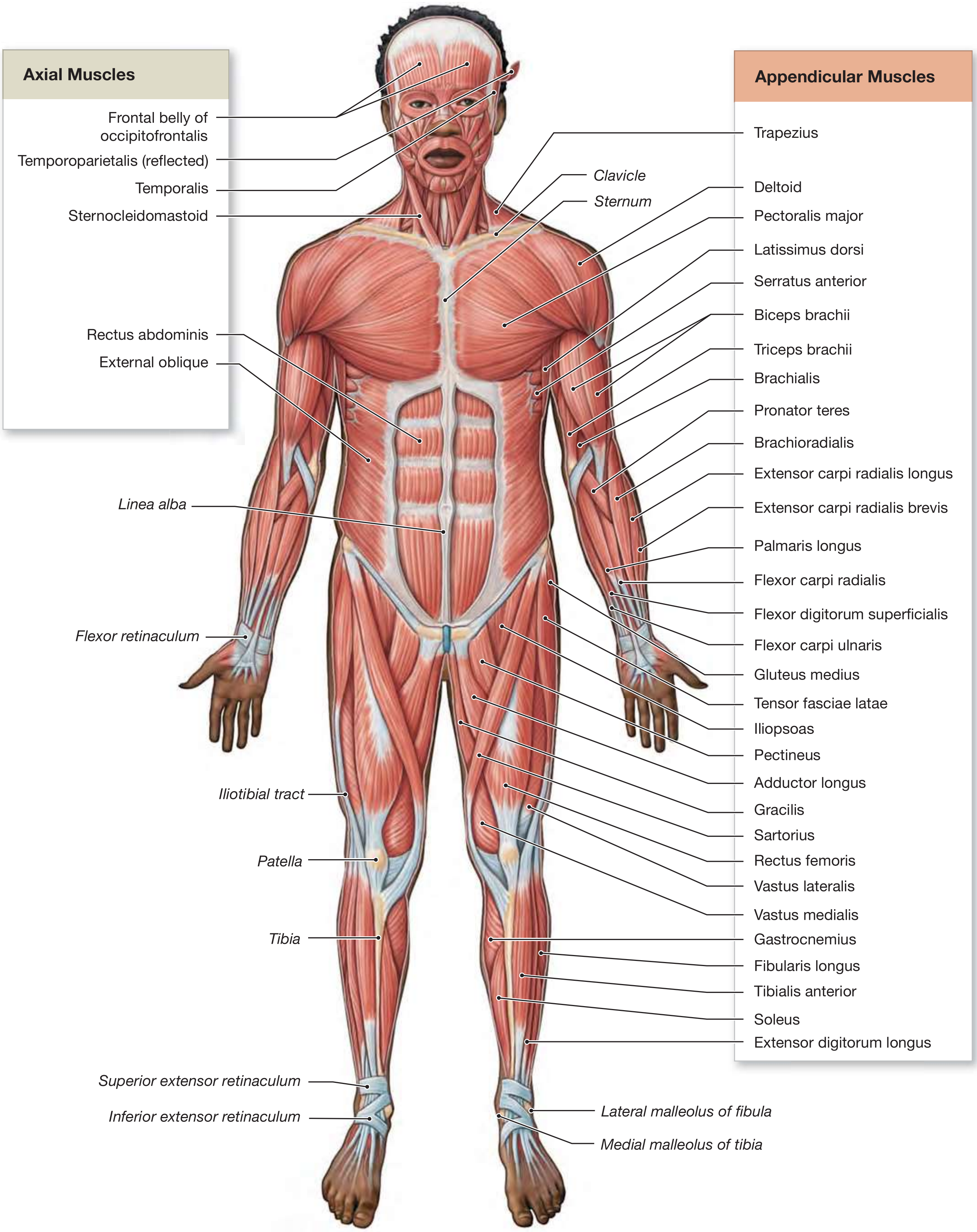
The tables that follow also contain information about the innervation of the individual muscles. **Innervation** is the distribution of nerves to a region or organ; the tables indicate the nerves that control each muscle. Many of the muscles of the head and neck are innervated by cranial nerves, which originate at the brain and pass through the foramina of the skull. Alternatively, spinal nerves are connected to the spinal cord and pass through the intervertebral foramina. For example, spinal nerve L_1 passes between vertebrae L_1 and L_2. Spinal nerves may form a complex network (a plexus) after exiting the spinal cord; one branch of this network may contain axons from several spinal nerves. Thus, many tables identify the spinal nerves involved as well as the names of the peripheral nerves.

Checkpoint

9. **Identify the kinds of descriptive information used to name skeletal muscles.**
10. **What does the name *flexor carpi radialis longus* tell you about this muscle?**

See the blue Answers tab at the back of the book.

Figure 11–3 **An Overview of the Major Skeletal Muscles.**



a An anterior view.
ATLAS: Plates 1a; 39a–d

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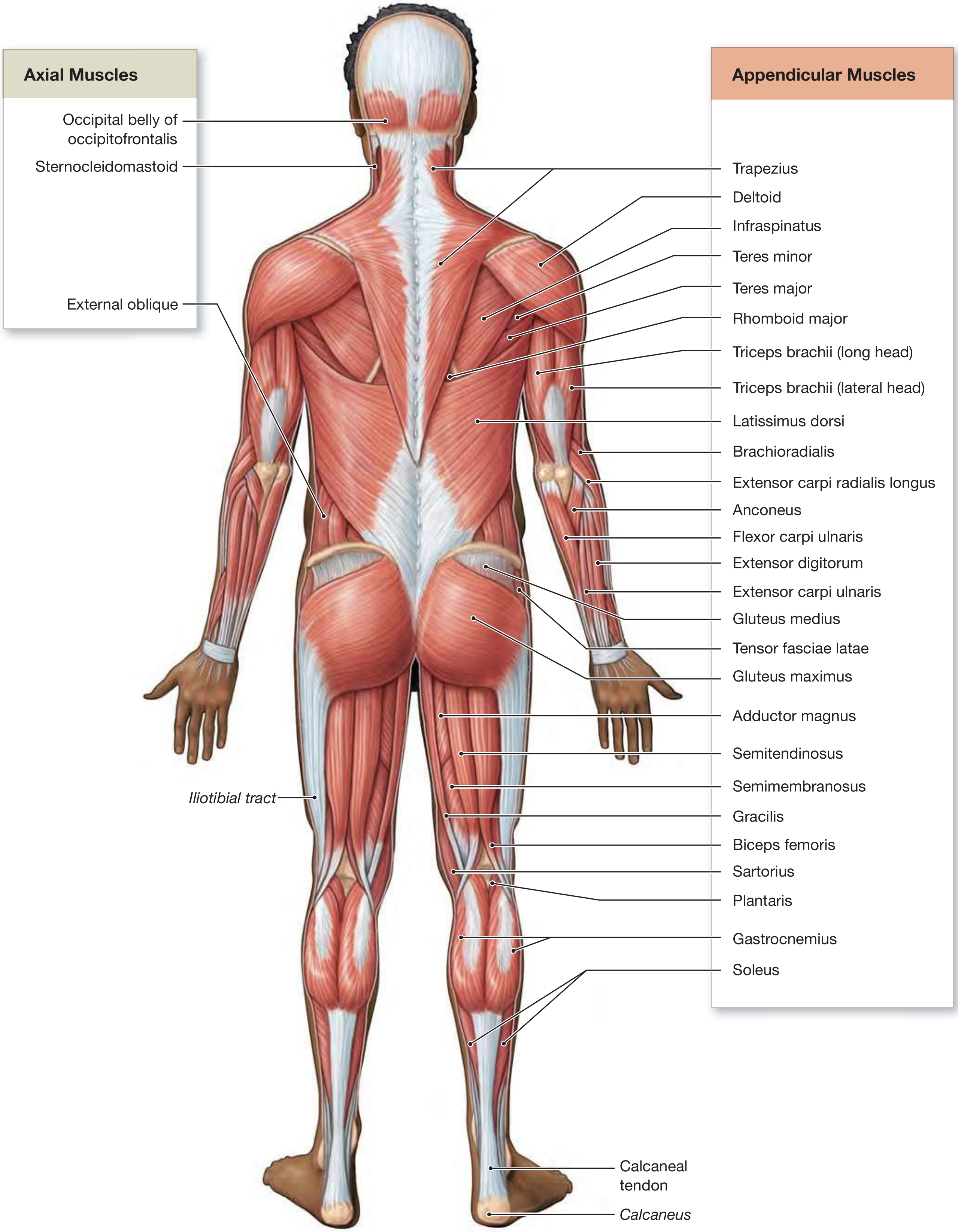
Figure 11–3 An Overview of the Major Skeletal Muscles (*continued*)



b A posterior view
ATLAS: Plates 1b; 40a,b

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11-5 ◗ Axial muscles are muscles of the head and neck, vertebral column, trunk, and pelvic floor

The axial muscles fall into logical groups on the basis of location, function, or both. The groups do not always have distinct anatomical boundaries. For example, a function such as extension of the vertebral column involves muscles along its entire length and movement at each of the intervertebral joints. We will discuss the axial muscles in four groups:

1. *The Muscles of the Head and Neck.* This group includes muscles that move the face, tongue, and larynx. They are responsible for verbal and nonverbal communication—laughing, talking, frowning, smiling, whistling, and so on. You also use these muscles while eating—especially in sucking and chewing—and even while looking for food, as some of them control your eye movements. The group does not include muscles of the neck that are involved with movements of the vertebral column.
2. *The Muscles of the Vertebral Column.* This group includes numerous flexors, extensors, and rotators of the vertebral column.
3. *The Oblique and Rectus Muscles.* This group forms the muscular walls of the thoracic and abdominopelvic cavities between the first thoracic vertebra and the pelvis. In the thoracic area the ribs separate these muscles, but over the abdominal surface the muscles form broad muscular sheets. The neck also has oblique and rectus muscles. Although they do not form a complete muscular wall, they share a common developmental origin with the oblique and rectus muscles of the trunk.
4. *The Muscles of the Pelvic Floor.* These muscles extend between the sacrum and pelvic girdle. The group forms the *perineum*, a muscular sheet that closes the pelvic outlet.

Muscles of the Head and Neck

We can divide the muscles of the head and neck into several functional groups. The *muscles of facial expression*, the *muscles of mastication* (chewing), the *muscles of the tongue*, and the *muscles of the pharynx* originate on the skull or hyoid bone. Muscles involved with sight and hearing also are based on the skull. Here, we will consider the *extrinsic eye muscles*—those associated with movements of the eye. We will discuss the intrinsic eye muscles, which control the diameter of the pupil and the shape of the lens, and the tiny skeletal muscles associated with the auditory ossicles, in Chapter 17. In the neck, the *extrinsic muscles of the larynx* adjust the position of the hyoid bone and larynx. We will examine the intrinsic laryngeal muscles, including those of the vocal cords, in Chapter 23.

Muscles of Facial Expression

The muscles of facial expression originate on the surface of the skull (**Figure 11–4** and **Table 11–2**). At their insertions, the fibers of the epimysium are woven into those of the superficial fascia and the dermis of the skin: Thus, when they contract, the skin moves.

The largest group of facial muscles is associated with the mouth. The **orbicularis oris** muscle constricts the opening, and other muscles move the lips or the corners of the mouth. The **buccinator** muscle has two functions related to eating (in addition to its importance to musicians). During chewing, it cooperates with the masticatory muscles by moving food back across the teeth from the *vestibule*, the space inside the cheeks. In infants, the buccinator provides suction for suckling at the breast.

Smaller groups of muscles control movements of the eyebrows and eyelids, the scalp, the nose, and the external ear. The **epicranium** (ep-i-KRĀ-nē-um; *epi-*, on + *kranion*, skull), or scalp, contains the **temporoparietalis** muscle and the **occipitofrontalis** muscle, which has a *frontal belly* and an *occipital belly*. The two bellies are separated by the **epicranial aponeurosis,** a thick, collagenous sheet. The **platysma** (pla-TIZ-muh; *platy*, flat) covers the anterior surface of the neck, extending from the base of the neck to the periosteum of the mandible and the fascia at the corner of the mouth. One of the effects of aging is the loss of muscle tone in the platysma, resulting in a looseness of the skin of the anterior throat.

Extrinsic Eye Muscles

Six **extrinsic eye muscles**, also known as the *oculomotor muscles*, originate on the surface of the orbit and control the position of each eye. These muscles, shown in **Figure 11–5** and detailed in **Table 11–3**, are the **inferior rectus, medial rectus, superior rectus, lateral rectus, inferior oblique,** and **superior oblique** muscles.

Muscles of Mastication

The muscles of mastication (**Figure 11–6** and **Table 11–4**) move the mandible at the temporomandibular joint (TMJ). The large **masseter** muscle is the strongest jaw muscle. The **temporalis** muscle assists in elevation of the mandible. You can feel these muscles in action by gritting your teeth while resting your hand on the side of your face below and then above the zygomatic arch. The **pterygoid** muscles, used in various combinations, can elevate, depress, or protract the mandible or slide it from side to side, a movement called *lateral excursion*. These movements are important in making efficient use of your teeth while you chew foods of various consistencies.

Figure 11–4 Muscles of Facial Expression. ATLAS: Plate 3a–d

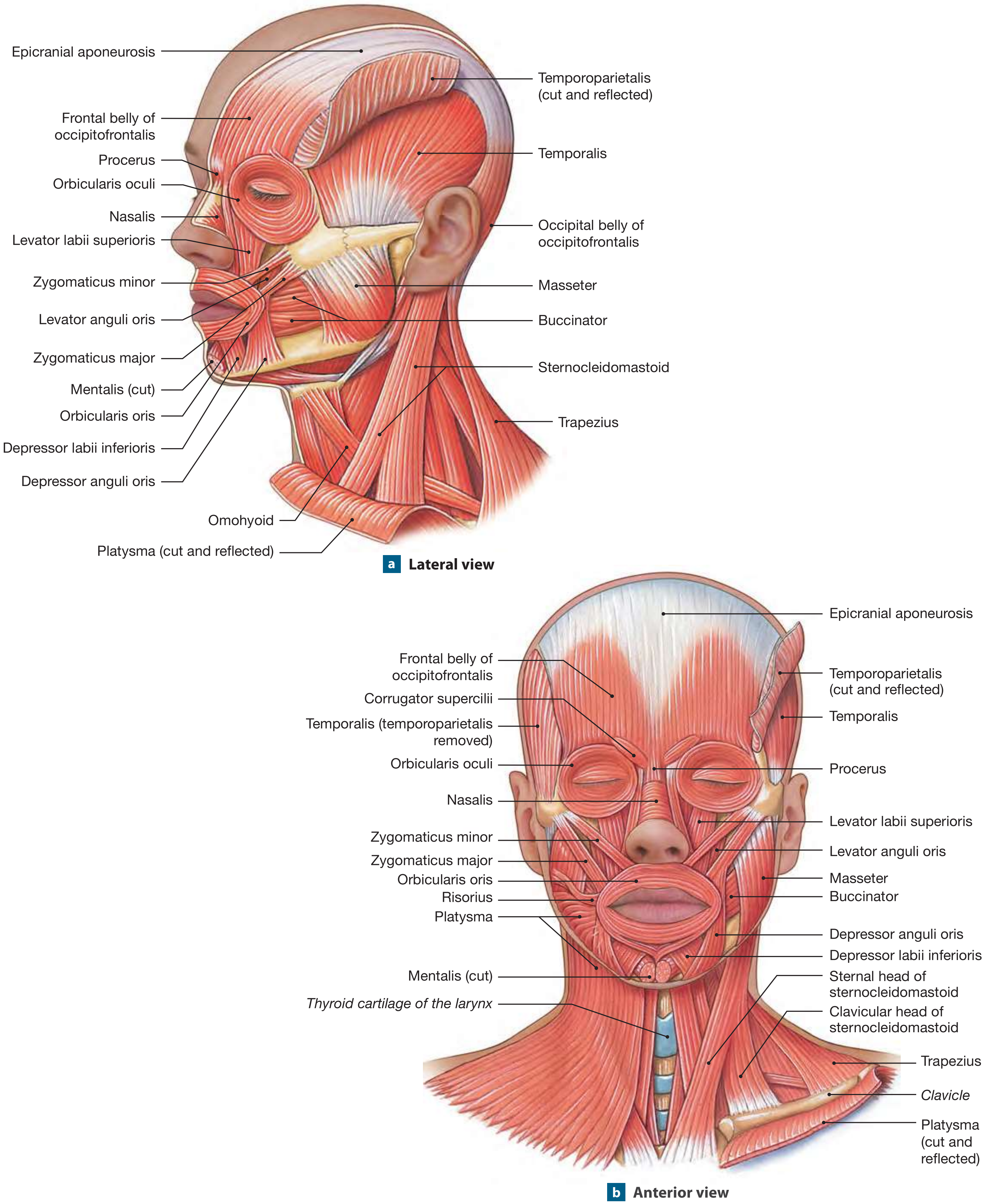

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Table 11–2 Muscles of Facial Expression (Figure 11–4)

Region and Muscle	Origin	Insertion	Action	Innervation
MOUTH				
Buccinator	Alveolar processes of maxilla and mandible	Blends into fibers of orbicularis oris	Compresses cheeks	Facial nerve (N VII)*
Depressor labii inferioris	Mandible between the anterior midline and the mental foramen	Skin of lower lip	Depresses lower lip	Facial nerve (N VII)
Levator labii superioris	Inferior margin of orbit, superior to the infra-orbital foramen	Orbicularis oris	Elevates upper lip	Facial nerve (N VII)
Levator anguli oris	Maxilla below the infra-orbital foramen	Corner of mouth	Elevates corner of mouth	Facial nerve (N VII)
Mentalis	Incisive fossa of mandible	Skin of chin	Elevates and protrudes lower lip	Facial nerve (N VII)
Orbicularis oris	Maxilla and mandible	Lips	Compresses, purses lips	Facial nerve (N VII)
Risorius	Fascia surrounding parotid salivary gland	Angle of mouth	Draws corner of mouth to the side	Facial nerve (N VII)
Depressor anguli oris	Anterolateral surface of mandibular body	Skin at angle of mouth	Depresses corner of mouth	Facial nerve (N VII)
Zygomaticus major	Zygomatic bone near zygomaticomaxillary suture	Angle of mouth	Retracts and elevates corner of mouth	Facial nerve (N VII)
Zygomaticus minor	Zygomatic bone posterior to zygomaticotemporal suture	Upper lip	Retracts and elevates upper lip	Facial nerve (N VII)
EYE				
Corrugator supercilii	Orbital rim of frontal bone near nasal suture	Eyebrow	Pulls skin inferiorly and anteriorly; wrinkles brow	Facial nerve (N VII)
Levator palpebrae superioris *(Figure 11–5)*	Tendinous band around optic foramen	Upper eyelid	Elevates upper eyelid	Oculomotor nerve (N III)**
Orbicularis oculi	Medial margin of orbit	Skin around eyelids	Closes eye	Facial nerve (N VII)
NOSE				
Procerus	Nasal bones and lateral nasal cartilages	Aponeurosis at bridge of nose and skin of forehead	Moves nose, changes position and shape of nostrils	Facial nerve (N VII)
Nasalis	Maxilla and alar cartilage of nose	Bridge of nose	Compresses bridge, depresses tip of nose; elevates corners of nostrils	Facial nerve (N VII)
EAR				
Temporoparietalis	Fascia around external ear	Epicranial aponeurosis	Tenses scalp, moves auricle of ear	Facial nerve (N VII)
SCALP (EPICRANIUM)				
Occipitofrontalis				
Frontal belly	Epicranial aponeurosis	Skin of eyebrow and bridge of nose	Raises eyebrows, wrinkles forehead	Facial nerve (N VII)
Occipital belly	Occipital bone and mastoid region of temporal bones	Epicranial aponeurosis	Tenses and retracts scalp	Facial nerve (N VII)
NECK				
Platysma	Superior thorax between cartilage of 2nd rib and acromion of scapula	Mandible and skin of cheek	Tenses skin of neck; depresses mandible	Facial nerve (N VII)

*An uppercase N and Roman numerals refer to a cranial nerve.

**This muscle originates in association with the extrinsic eye muscles, so its innervation is unusual.

Figure 11–5 **Extrinsic Eye Muscles.** ATLAS: Plates 12a; 16a,b

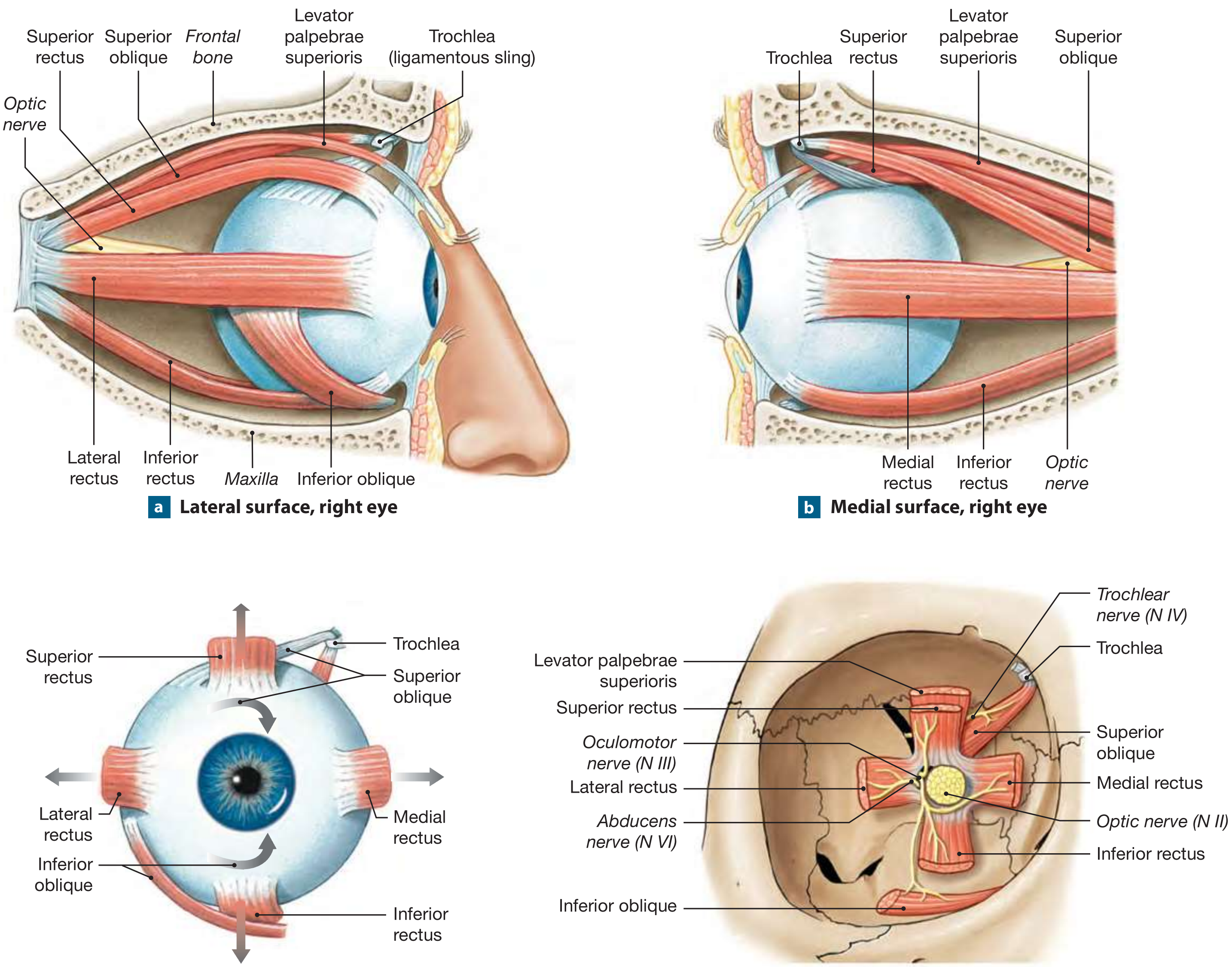

Table 11–3 Extrinsic Eye Muscles (Figure 11–5)

Muscle	Origin	Insertion	Action	Innervation
Inferior rectus	Sphenoid around optic canal	Inferior, medial surface of eyeball	Eye looks down	Oculomotor nerve (N III)
Medial rectus	Sphenoid around optic canal	Medial surface of eyeball	Eye looks medially	Oculomotor nerve (N III)
Superior rectus	Sphenoid around optic canal	Superior surface of eyeball	Eye looks up	Oculomotor nerve (N III)
Lateral rectus	Sphenoid around optic canal	Lateral surface of eyeball	Eye looks laterally	Abducens nerve (N VI)
Inferior oblique	Maxilla at anterior portion of orbit	Inferior, lateral surface of eyeball	Eye rolls, looks up and laterally	Oculomotor nerve (N III)
Superior oblique	Sphenoid around optic canal	Superior, lateral surface of eyeball	Eye rolls, looks down and laterally	Trochlear nerve (N IV)

Tips & Tricks

The medial and lateral *pteryg*oid muscles are named for their origin on the pterygoid ("winged") portion of the sphenoid bone. The *ptero*dactyl was a prehistoric winged reptile.

Muscles of the Tongue

The muscles of the tongue have names ending in *glossus*, the Greek word for "tongue." The **palatoglossus** muscle originates at the palate, the **styloglossus** muscle at the styloid process of the temporal bone, the **genioglossus** muscle at the chin, and the **hyoglossus** muscle at the hyoid bone (**Figure 11–7**). These muscles, used in various combinations, move the tongue in the delicate and complex patterns necessary for speech, and maneuver food within the mouth in preparation for swallowing (**Table 11–5**).

Muscles of the Pharynx

The muscles of the pharynx (**Figure 11–8** and **Table 11–6**) are responsible for initiating the swallowing process. The **pharyngeal constrictor** muscles (*superior*, *middle*, and *inferior*) move food into the esophagus by constricting the pharyngeal

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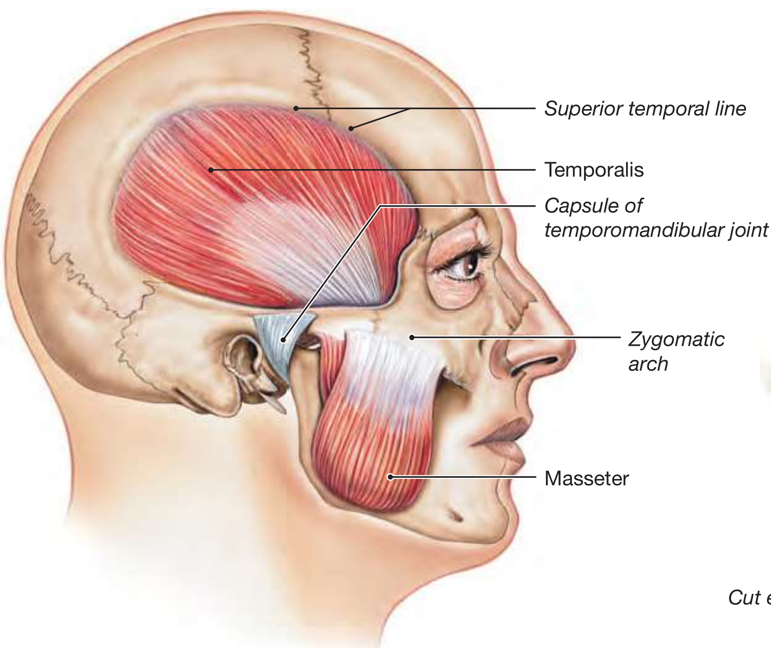
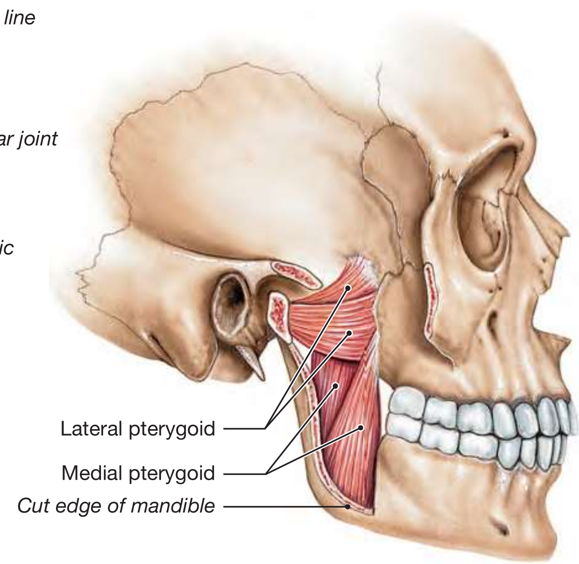
Figure 11–6 **Muscles of Mastication.** ATLAS: Plate 3c,d



a **Lateral view.** The temporalis muscle passes medial to the zygomatic arch to insert on the coronoid process of the manible. The masseter inserts on the angle and lateral surface of the mandible.



b **Lateral view, pterygoid muscles exposed.** The location and orientation of the pterygoid muscles can be seen after the overlying muscles, along with a portion of the mandible, are removed.

Table 11–4 Muscles of Mastication (Figure 11–6)

Muscle	Origin	Insertion	Action	Innervation
Masseter	Zygomatic arch	Lateral surface of mandibular ramus	Elevates mandible and closes the jaws	Trigeminal nerve (N V), mandibular branch
Temporalis	Along temporal lines of skull	Coronoid process of mandible	Elevates mandible	Trigeminal nerve (N V), mandibular branch
Pterygoids (medial and lateral)	Lateral pterygoid plate	Medial surface of mandibular ramus	*Medial*: Elevates the mandible and closes the jaws, or slides the mandible from side to side (lateral excursion)	Trigeminal nerve (N V), mandibular branch
			Lateral: Opens jaws, protrudes mandible, or performs lateral excursion	Trigeminal nerve (N V), mandibular branch

Figure 11–7 **Muscles of the Tongue.**

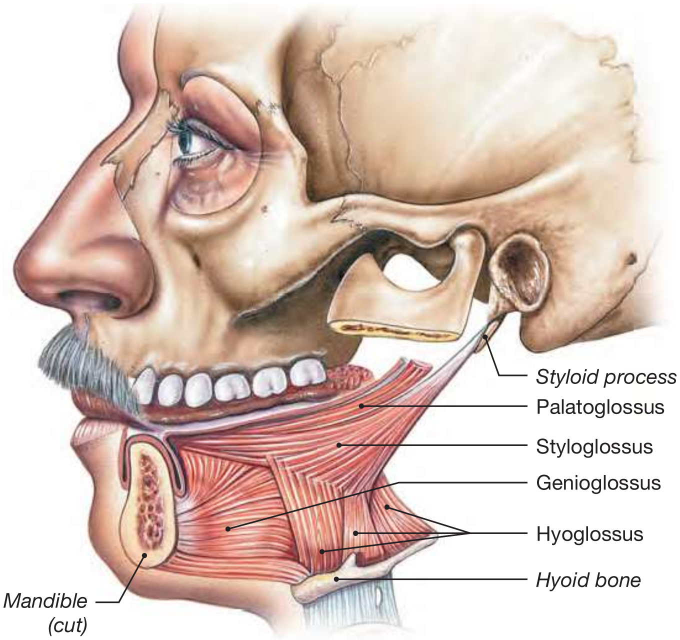
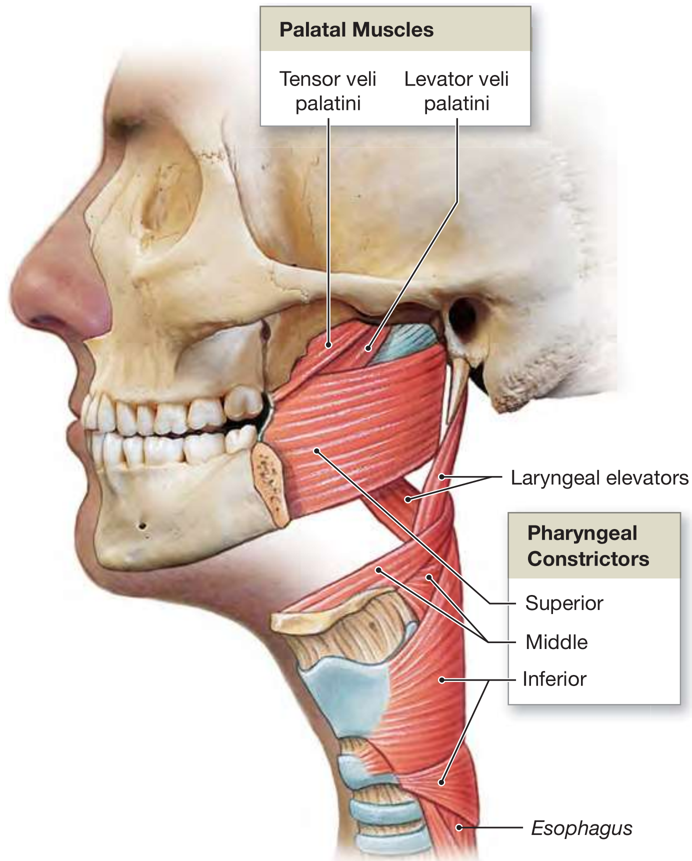


Figure 11–8 **Muscles of the Pharynx.** A lateral view.



walls. The **laryngeal elevator** muscles elevate the larynx. The two **palatal muscles**—the *tensor veli palatini* and the *levator veli palatini*—elevate the soft palate and adjacent portions of the pharyngeal wall and also pull open the entrance to the auditory tube. As a result, swallowing repeatedly can open the entrance to the auditory tube and help you adjust to pressure changes when you fly or dive.

Anterior Muscles of the Neck

The anterior muscles of the neck include (1) five muscles that control the position of the larynx, (2) muscles that depress the mandible and tense the floor of the mouth, and (3) muscles that provide a stable foundation for muscles of the tongue and pharynx (**Figure 11–9** and **Table 11–7**). The **digastric** (dī-GAS-trik) muscle has two bellies, as the name implies (*di-*, two + *gaster*, stomach). One belly extends from the chin to the hyoid bone; the other continues from the hyoid bone to the mastoid portion of the temporal bone. Depending on which belly contracts and whether fixator muscles are stabilizing the position of the hyoid bone, the digastric muscle can open the mouth by depressing the mandible, or it can elevate the larynx by raising the hyoid bone. The digastric muscle covers the broad, flat **mylohyoid** muscle, which provides a muscular floor to the mouth, aided by the deeper **geniohyoid** muscles that extend between the hyoid bone and the chin. The **stylohyoid** muscle forms a muscular connection between the hyoid bone and the styloid process of the skull. The **sternocleidomastoid**

Table 11–5 Muscles of the Tongue (Figure 11–7)

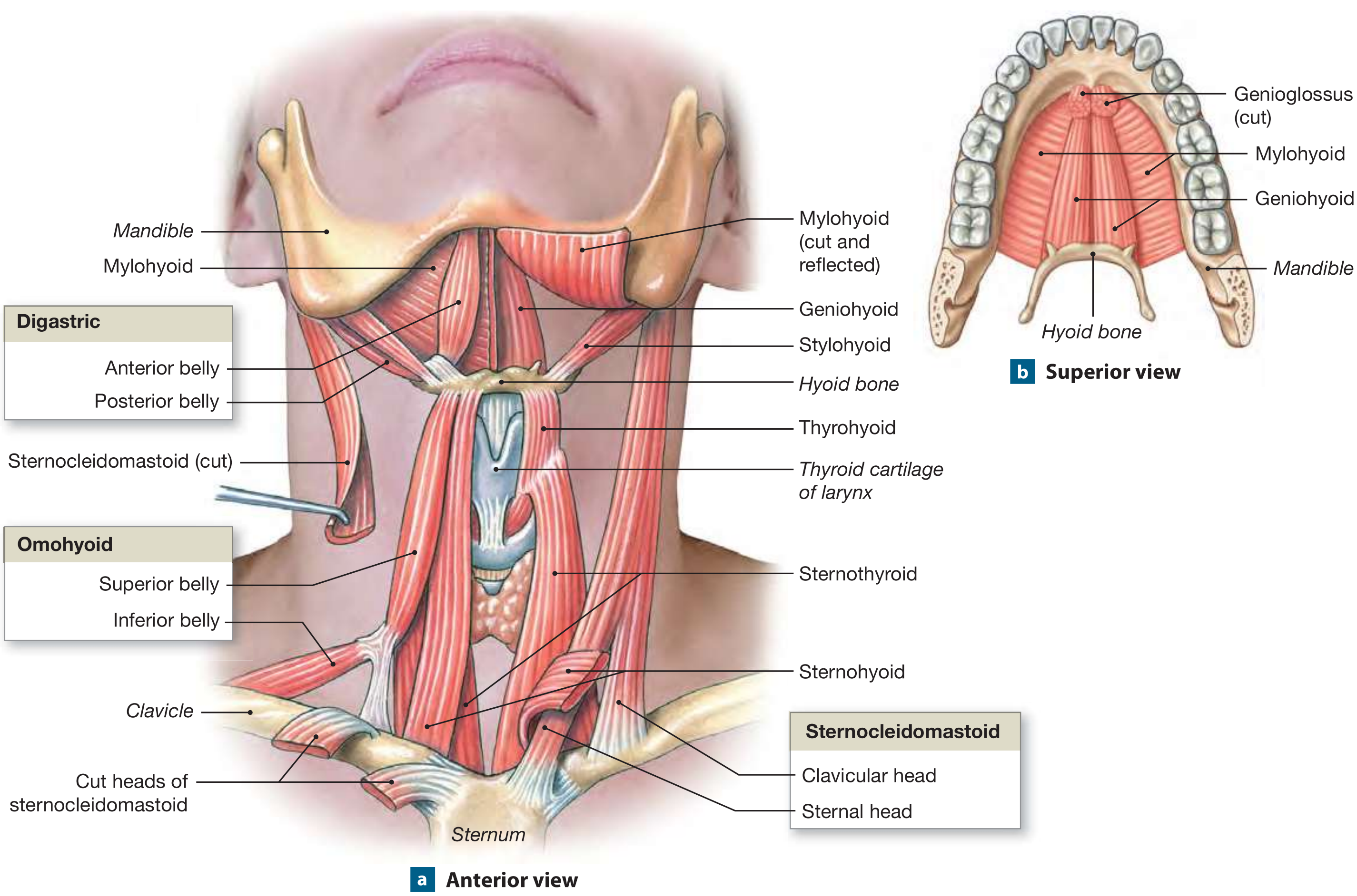
Muscle	Origin	Insertion	Action	Innervation
Genioglossus	Medial surface of mandible around chin	Body of tongue, hyoid bone	Depresses and protracts tongue	Hypoglossal nerve (N XII)
Hyoglossus	Body and greater horn of hyoid bone	Side of tongue	Depresses and retracts tongue	Hypoglossal nerve (N XII)
Palatoglossus	Anterior surface of soft palate	Side of tongue	Elevates tongue, depresses soft palate	Internal branch of accessory nerve (N XI)
Styloglossus	Styloid process of temporal bone	Along the side to tip and base of tongue	Retracts tongue, elevates side of tongue	Hypoglossal nerve (N XII)

Table 11–6 Muscles of the Pharynx (Figure 11–8)

Muscle	Origin	Insertion	Action	Innervation
PHARYNGEAL CONSTRICTORS				
Superior constrictor	Pterygoid process of sphenoid, medial surfaces of mandible	Median raphe attached to occipital bone	Constricts pharynx to propel bolus into esophagus	Branches of pharyngeal plexus (N X)
Middle constrictor	Horns of hyoid bone	Median raphe	Constricts pharynx to propel bolus into esophagus	Branches of pharyngeal plexus (N X)
Inferior constrictor	Cricoid and thyroid cartilages of larynx	Median raphe	Constricts pharynx to propel bolus into esophagus	Branches of pharyngeal plexus (N X)
LARYNGEAL ELEVATORS*				
	Ranges from soft palate, to cartilage around inferior portion of auditory tube, to styloid process of temporal bone	Thyroid cartilage	Elevate larynx	Branches of pharyngeal plexus (N IX and N X)
PALATAL MUSCLES				
Levator veli palatini	Petrous part of temporal bone; tissues around the auditory tube	Soft palate	Elevates soft palate	Branches of pharyngeal plexus (N X)
Tensor veli palatini	Sphenoidal spine; tissues around the auditory tube	Soft palate	Elevates soft palate	Trigeminal nerve (N V)

*Refers to the palatopharyngeus, salpingopharyngeus, and stylopharyngeus, assisted by the thyrohyoid, geniohyoid, stylohyoid, and hyoglossus muscles, discussed in Tables 11–5 and 11–7.

Figure 11–9 **Muscles of the Anterior Neck.** ATLAS: Plates 3a–d; 17; 18a–c; 25



a Anterior view

b Superior view

(ster-nō-klī-dō-MAS-toyd) muscle extends from the clavicle and the sternum to the mastoid region of the skull (**Figures 11–4** and **11–9**). The **omohyoid** (ō-mō-HĪ-oyd) muscle attaches to the scapula, the clavicle and first rib, and the hyoid bone. The other members of this group are strap-like muscles that extend between the sternum and larynx *(sternothyroid)* or hyoid bone *(sternohyoid)*, and between the larynx and hyoid bone *(thyrohyoid)*.

Muscles of the Vertebral Column

The muscles of the vertebral column are covered by more superficial back muscles, such as the trapezius and latissimus dorsi muscles (**Figure 11–3b**). The **erector spinae** muscles include superficial and deep layers. The superficial layer can be divided into **spinalis, longissimus,** and **iliocostalis** groups (**Figure 11–10** and **Table 11–8**). In the inferior lumbar and sacral regions, the boundary between the longissimus and iliocostalis muscles is indistinct. When contracting together, the erector spinae extend the vertebral column. When the muscles on only one side contract, the result is lateral flexion of the vertebral column.

Deep to the spinalis muscles, smaller muscles interconnect and stabilize the vertebrae. These muscles include the **semispinalis** group; the **multifidus** muscle; and the **interspinales, intertransversarii,** and **rotatores** muscles (**Figure 11–10**). In various combinations, they produce slight extension or rotation of the vertebral column. They are also important in making delicate adjustments in the positions of individual vertebrae, and they stabilize adjacent vertebrae. If injured, these muscles can start a cycle of pain → muscle stimulation → contraction → pain. Resultant pressure on adjacent spinal nerves can lead to sensory losses and mobility limitations. Many of the warm-up and stretching exercises recommended before athletic activity are intended to prepare these small but very important muscles for their supporting role.

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Table 11–7 Anterior Muscles of the Neck (Figure 11–9)

Muscle	Origin	Insertion	Action	Innervation
Digastric	Two bellies: *anterior* from inferior surface of mandible at chin; *posterior* from mastoid region of temporal bone	Hyoid bone	Depresses mandible or elevates larynx	*Anterior belly*: Trigeminal nerve (N V), mandibular branch *Posterior belly*: Facial nerve (N VII)
Geniohyoid	Medial surface of mandible at chin	Hyoid bone	As above and pulls hyoid bone anteriorly	Cervical nerve C_1 via hypoglossal nerve (N XII)
Mylohyoid	Mylohyoid line of mandible	Median connective tissue band (raphe) that runs to hyoid bone	Elevates floor of mouth and hyoid bone or depresses mandible	Trigeminal nerve (N V), mandibular branch
Omohyoid (superior and inferior bellies united at central tendon anchored to clavicle and first rib)	Superior border of scapula near scapular notch	Hyoid bone	Depresses hyoid bone and larynx	Cervical spinal nerves C_2–C_3
Sternohyoid	Clavicle and manubrium	Hyoid bone	Depresses hyoid bone and larynx	Cervical spinal nerves C_1–C_3
Sternothyroid	Dorsal surface of manubrium and first costal cartilage	Thyroid cartilage of larynx	Depresses hyoid bone and larynx	Cervical spinal nerves C_1–C_3
Stylohyoid	Styloid process of temporal bone	Hyoid bone	Elevates larynx	Facial nerve (N VII)
Thyrohyoid	Thyroid cartilage of larynx	Hyoid bone	Elevates thyroid, depresses hyoid bone	Cervical spinal nerves C_1–C_2 via hypoglossal nerve (N XII)
Sternocleidomastoid	Two bellies: *clavicular head* attaches to sternal end of clavicle; *sternal head* attaches to manubrium	Mastoid region of skull and lateral portion of superior nuchal line	Together, they flex the neck; alone, one side bends head toward shoulder and turns face to opposite side	Accessory nerve (N XI) and cervical spinal nerves (C_2–C_3) of cervical plexus

Figure 11–10 **Muscles of the Vertebral Column.**

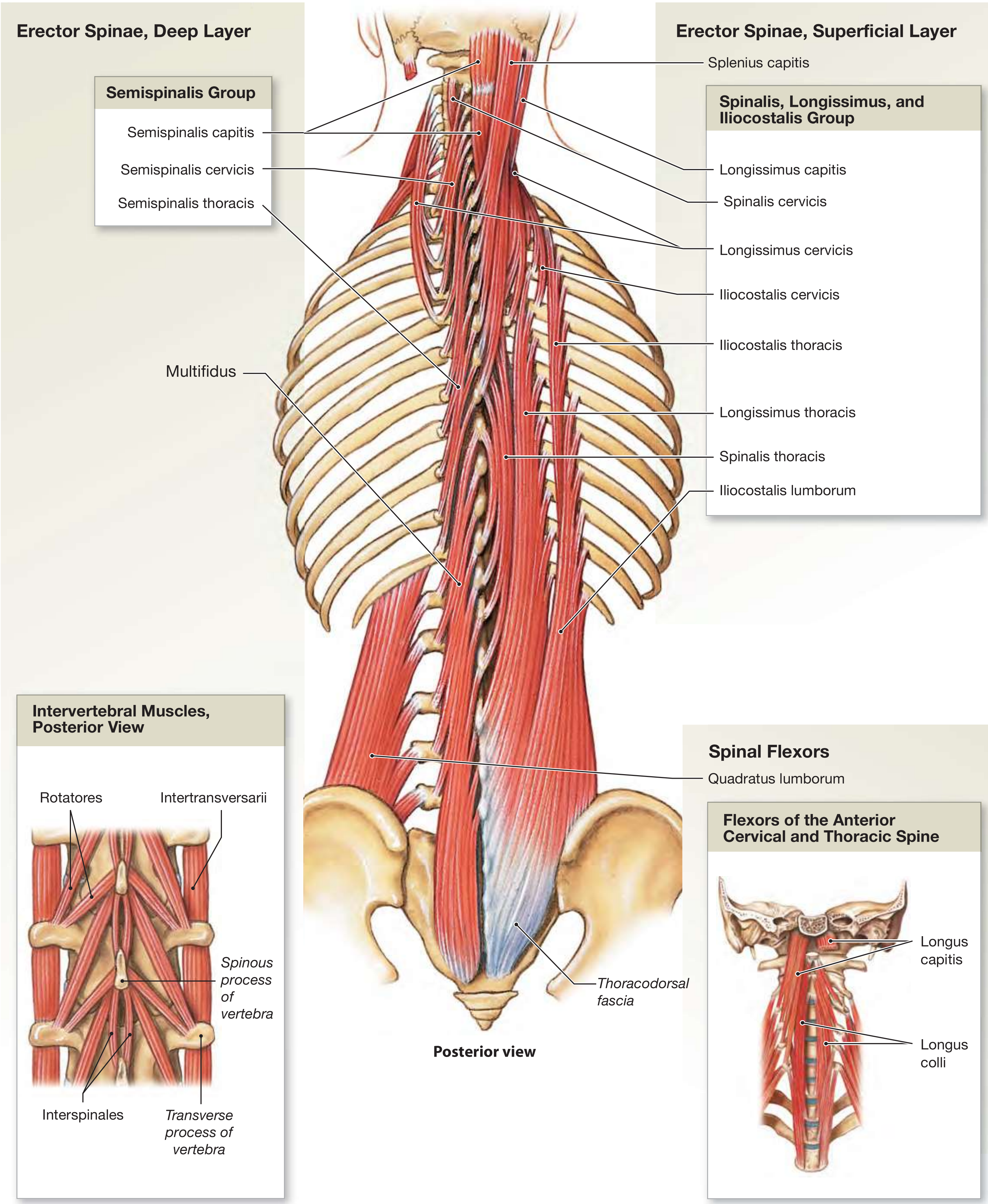

Table 11–8 Muscles of the Vertebral Column (Figure 11–10)

Group and Muscles	Origin	Insertion	Action	Innervation
SUPERFICIAL LAYER				
Splenius (**Splenius capitis, splenius cervicis**)	Spinous processes and ligaments connecting inferior cervical and superior thoracic vertebrae	Mastoid process, occipital bone of skull, and superior cervical vertebrae	Together, the two sides extend neck; alone, each rotates and laterally flexes neck to that side	Cervical spinal nerves
Erector spinae				
Spinalis group				
Spinalis cervicis	Inferior portion of ligamentum nuchae and spinous process of C_7	Spinous process of axis	Extends neck	Cervical spinal nerves
Spinalis thoracis	Spinous processes of inferior thoracic and superior lumbar vertebrae	Spinous processes of superior thoracic vertebrae	Extends vertebral column	Thoracic and lumbar spinal nerves
Longissimus group				
Longissimus capitis	Transverse processes of inferior cervical and superior thoracic vertebrae	Mastoid process of temporal bone	Together, the two sides extend head; alone, each rotates and laterally flexes neck to that side	Cervical and thoracic spinal nerves
Longissimus cervicis	Transverse processes of superior thoracic vertebrae	Transverse processes of middle and superior cervical vertebrae	Together, the two sides extend head; alone, each rotates and laterally flexes neck to that side	Cervical and thoracic spinal nerves
Longissimus thoracis	Broad aponeurosis and transverse processes of inferior thoracic and superior lumbar vertebrae; joins iliocostalis	Transverse processes of superior vertebrae and inferior surfaces of ribs	Extends vertebral column; alone, each produces lateral flexion to that side	Thoracic and lumbar spinal nerves
Iliocostalis group				
Iliocostalis cervicis	Superior borders of vertebrosternal ribs near the angles	Transverse processes of middle and inferior cervical vertebrae	Extends or laterally flexes neck, elevates ribs	Cervical and superior thoracic spinal nerves
Iliocostalis thoracis	Superior borders of inferior seven ribs medial to the angles	Upper ribs and transverse process of last cervical vertebra	Stabilizes thoracic vertebrae in extension	Thoracic spinal nerves
Iliocostalis lumborum	Iliac crest, sacral crests, and spinous processes	Inferior surfaces of inferior seven ribs near their angles	Extends vertebral column, depresses ribs	Inferior thoracic and lumbar spinal nerves
DEEP LAYER				
Semispinalis group				
Semispinalis capitis	Articular processes of inferior cervical and transverse processes of superior thoracic vertebrae	Occipital bone, between nuchal lines	Together, the two sides extend head; alone, each extends and laterally flexes neck	Cervical spinal nerves
Semispinalis cervicis	Transverse processes of T_1–T_5 or T_6	Spinous processes of C_2–C_5	Extends vertebral column and rotates toward opposite side	Cervical spinal nerves
Semispinalis thoracis	Transverse processes of T_6–T_{10}	Spinous processes of C_5–T_4	Extends vertebral column and rotates toward opposite side	Thoracic spinal nerves
Multifidus	Sacrum and transverse processes of each vertebra	Spinous processes of the third or fourth more superior vertebrae	Extends vertebral column and rotates toward opposite side	Cervical, thoracic, and lumbar spinal nerves
Rotatores	Transverse processes of each vertebra	Spinous processes of adjacent, more superior vertebra	Extends vertebral column and rotates toward opposite side	Cervical, thoracic, and lumbar spinal nerves
Interspinales	Spinous processes of each vertebra	Spinous processes of more superior vertebra	Extends vertebral column	Cervical, thoracic, and lumbar spinal nerves
Intertransversarii	Transverse processes of each vertebra	Transverse process of more superior vertebra	Laterally flexes the vertebral column	Cervical, thoracic, and lumbar spinal nerves
SPINAL FLEXORS				
Longus capitis	Transverse processes of cervical vertebrae	Base of the occipital bone	Together, the two sides flex the neck; alone, each rotates head to that side	Cervical spinal nerves
Longus colli	Anterior surfaces of cervical and superior thoracic vertebrae	Transverse processes of superior cervical vertebrae	Flexes or rotates neck; limits hyperextension	Cervical spinal nerves
Quadratus lumborum	Iliac crest and iliolumbar ligament	Last rib and transverse processes of lumbar vertebrae	Together, they depress ribs; alone, each side laterally flexes vertebral column	Thoracic and lumbar spinal nerves

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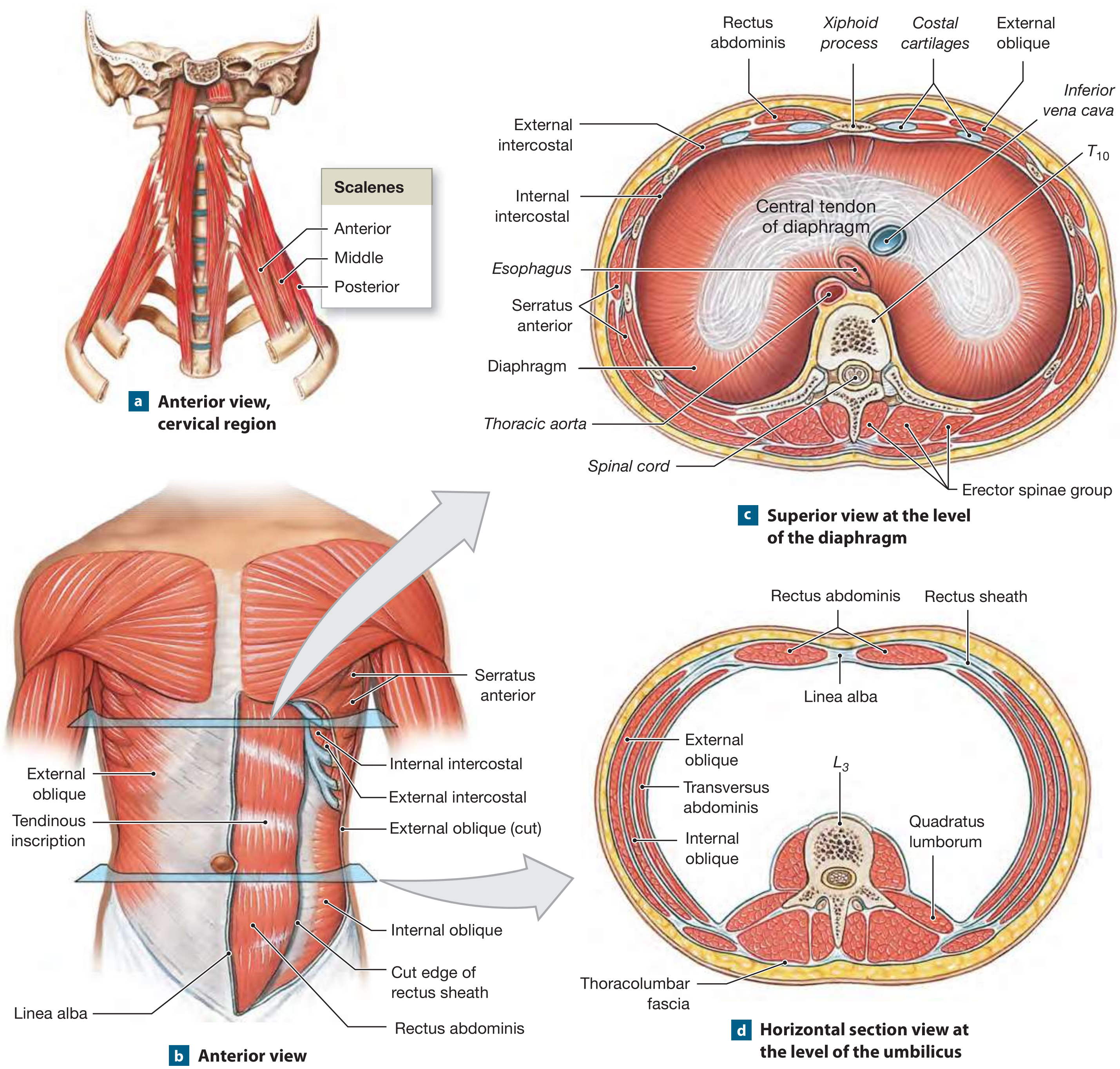
The muscles of the vertebral column include many posterior extensors, but few anterior flexors. The vertebral column does not need a massive series of flexor muscles, because (1) many of the large trunk muscles flex the vertebral column when they contract, and (2) most of the body weight lies anterior to the vertebral column, so gravity tends to flex the spine. However, a few spinal flexors are associated with the anterior surface of the vertebral column. In the neck, the **longus capitis** and the **longus colli** muscles rotate or flex the neck, depending on whether the muscles of one or both sides are contracting (**Figure 11–10**). In the lumbar region, the large **quadratus lumborum** muscles flex the vertebral column and depress the ribs (**Figure 11–10**).

Oblique and Rectus Muscles

The oblique and rectus muscles lie within the body wall, between the spinous processes of vertebrae and the ventral mid-

Figure 11–11 **Oblique and Rectus Muscles and the Diaphragm.** ATLAS: Plates 39b–d; 41a,b; 46



line (**Figures 11–3, 11–11,** and **Table 11–9**). The oblique muscles compress underlying structures or rotate the vertebral column, depending on whether one or both sides contract. The rectus muscles are important flexors of the vertebral column, acting in opposition to the erector spinae. The oblique and rectus muscle groups share embryological origins; we can divide these groups into cervical, thoracic, and abdominal regions.

The oblique group includes the **scalene** muscles of the neck (**Figure 11–11a**) and the **intercostal** and **transversus** muscles of the thorax (**Figure 11–11b, c**). The scalene muscles (*anterior*, *middle*, and *posterior*) elevate the first two ribs and assist in flexion of the neck. In the thorax, the oblique muscles extend between the ribs, with the **external intercostal** muscles covering the **internal intercostal** muscles. Both groups of intercostal muscles aid in respiratory movements of the ribs. A small **transversus thoracis** muscle crosses the inner surface of the rib cage and is separated from the pleural cavity by the parietal pleura, a *serous membrane*. ⮌ p. 131 The sternum occupies the place where we might otherwise expect thoracic rectus muscles to be.

The same basic pattern of musculature extends unbroken across the abdominopelvic surface (**Figure 11–11b, d**). Here, the muscles are called the **external oblique, internal oblique, transversus abdominis,** and **rectus abdominis** muscles (the "abs"). The rectus abdominis muscle inserts at the xiphoid process and originates near the pubic symphysis. This muscle is longitudinally divided by the **linea alba** (white

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Table 11–9 Oblique and Rectus Muscle Groups (Figure 11–11)

Group and Muscles	Origin	Insertion	Action	Innervation*
OBLIQUE GROUP				
Cervical region				
Scalenes (anterior, middle, and posterior)	Transverse and costal processes of cervical vertebrae	Superior surfaces of first two ribs	Elevate ribs or flex neck	Cervical spinal nerves
Thoracic region				
External intercostals	Inferior border of each rib	Superior border of more inferior rib	Elevate ribs	Intercostal nerves (branches of thoracic spinal nerves)
Internal intercostals	Superior border of each rib	Inferior border of the preceding rib	Depress ribs	Intercostal nerves (branches of thoracic spinal nerves)
Transversus thoracis	Posterior surface of sternum	Cartilages of ribs	Depress ribs	Intercostal nerves (branches of thoracic spinal nerves)
Serratus posterior superior *(Figure 11–13a)*	Spinous processes of C_7–T_3 and ligamentum nuchae	Superior borders of ribs 2–5 near angles	Elevates ribs, enlarges thoracic cavity	Thoracic nerves (T_1–T_4)
inferior	Aponeurosis from spinous processes of T_{10}–L_3	Inferior borders of ribs 8–12	Pulls ribs inferiorly; also pulls outward, opposing diaphragm	Thoracic nerves (T_9–T_{12})
Abdominal region				
External oblique	External and inferior borders of ribs 5–12	Linea alba and iliac crest	Compresses abdomen, depresses ribs, flexes or bends spine	Intercostal, iliohypogastric, and ilioinguinal nerves
Internal oblique	Thoracolumbar fascia and iliac crest	Inferior ribs, xiphoid process, and linea alba	Compresses abdomen, depresses ribs, flexes or bends spine	Intercostal, iliohypogastric, and ilioinguinal nerves
Transversus abdominis	Cartilages of ribs 6–12, iliac crest, and thoracolumbar fascia	Linea alba and pubis	Compresses abdomen	Intercostal, iliohypogastric, and ilioinguinal nerves
RECTUS GROUP				
Cervical region	*See muscles in Table 11–6*			
Thoracic region				
Diaphragm	Xiphoid process, cartilages of ribs 4–10, and anterior surfaces of lumbar vertebrae	Central tendinous sheet	Contraction expands thoracic cavity, compresses abdominopelvic cavity	Phrenic nerves (C_3–C_5)
Abdominal region				
Rectus abdominis	Superior surface of pubis around symphysis	Inferior surfaces of costal cartilages (ribs 5–7) and xiphoid process	Depresses ribs, flexes vertebral column, compresses abdomen	Intercostal nerves (T_7–T_{12})

*Where appropriate, spinal nerves involved are given in parentheses.

Clinical Note — Hernia

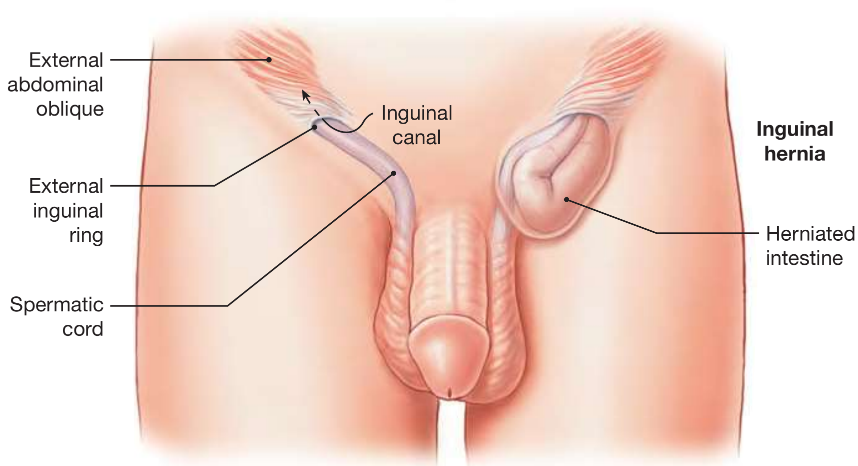
Protruding Organs

When the abdominal muscles contract forcefully, pressure in the abdominopelvic cavity can increase dramatically. That pressure is applied to internal organs. If the individual exhales at the same time, the pressure is relieved because the diaphragm can move upward as the lungs collapse. But during vigorous isometric exercises or when lifting a weight while holding one's breath, pressure in the abdominopelvic cavity can rise to 106 kg/cm^2, roughly 100 times the normal pressure. A pressure that high can cause a variety of problems, including hernias. A **hernia** develops when a visceral organ or part of an organ protrudes abnormally through an opening in a surrounding muscular wall or partition. There are many types of hernias; here we will consider only *inguinal* (groin) *hernias* and *diaphragmatic hernias*.

Late in the development of male fetuses, the testes descend into the scrotum by passing through the abdominal wall at the **inguinal canals.** In adult males, the sperm ducts and associated blood vessels penetrate the abdominal musculature at the inguinal canals as the *spermatic cords,* on their way to the abdominal reproductive organs. In an inguinal hernia, the inguinal canal enlarges and the abdominal contents, such as a portion of the greater omentum, small intestine, or (more rarely) urinary bladder, enter the inguinal canal. If the herniated structures become trapped or twisted, surgery may be required to prevent serious complications. Inguinal hernias are not always caused by unusually high abdominal pressures: Injuries to the abdomen or inherited weakness or distensibility of the canal can have the same effect.

The esophagus and major blood vessels pass through openings in the diaphragm, the muscle that separates the thoracic and abdominopelvic cavities. In a **diaphragmatic hernia** abdominal organs slide into the thoracic cavity. If entry is through the *esophageal hiatus,* the passageway used by the esophagus, a *hiatal hernia* (hī-Ā-tal; *hiatus,* a gap or opening) exists. The severity of the condition depends on the location and size of the herniated organ or organs. Hiatal hernias are very common, and most go unnoticed, although they may increase the severity of gastric acid entry into the esophagus (gastroesophogeal reflux disease, or GERD, commonly known as heartburn). Radiologists see them in about 30 percent of individuals whose upper gastrointestinal tracts are examined with barium-contrast techniques.

When clinical complications other than GERD develop, they generally do so because abdominal organs that have pushed into the thoracic cavity are exerting pressure on structures or organs there. Like inguinal hernias, a diaphragmatic hernia can result from congenital factors or from an injury that weakens or tears the diaphragm. If abdominal organs occupy the thoracic cavity during fetal development, the lungs may be poorly developed at birth.



line), a median collagenous partition (**Figure 11–3a**). The rectus abdominis muscle is separated into segments by transverse bands of collagen fibers called **tendinous inscriptions.** Each segment contains muscle fibers that extend longitudinally, originating and inserting on the tendinous inscriptions. Due to the bulging of enlarged muscle fibers between the tendinous inscriptions, bodybuilders often refer to the rectus abdominis as the "six-pack."

The Diaphragm

The term *diaphragm* refers to any muscular sheet that forms a wall. When used without a modifier, however, **diaphragm,** or

Clinical Note — Intramuscular Injections

Location, location, location: select **injection sites** with care

Drugs are commonly injected into muscle or adipose tissues rather than directly into the bloodstream (accessing blood vessels may be technically more complicated). An **intramuscular (IM) injection** introduces a fairly large amount of a drug, which will then enter the circulation gradually. The drug is introduced into the mass of a large skeletal muscle. Uptake is generally faster and accompanied by less tissue irritation than when drugs are administered *intradermally* or *hypodermally* (injected into the dermis or hypodermis layer, respectively). Depending on the size of the muscle, up to 5 mL of fluid may be injected at one time, and multiple injections are possible. A decision on the injection technique and the injection site is based on the type of drug and its concentration.

For IM injections, the most common complications involve accidental injection into a blood vessel or piercing of a nerve. The sudden entry of massive quantities of drug into the bloodstream can have fatal consequences, and damage to a nerve can cause motor paralysis or sensory loss. Thus, the site of the injection must be selected with care. Bulky muscles that contain few large vessels or nerves are ideal sites. The gluteus medius muscle or the posterior, lateral, superior part of the gluteus maximus muscle is commonly selected. The deltoid muscle of the arm, about 2.5 cm (1 in.) distal to the acromion, is another effective site. Probably most satisfactory from a technical point of view is the vastus lateralis muscle of the thigh; an injection into this thick muscle will not encounter vessels or nerves, but may cause pain later when the muscle is used in walking. This is the preferred injection site in infants before they start walking, as their gluteal and deltoid muscles are relatively small. The site is also used in elderly patients or others with atrophied gluteal and deltoid muscles.

diaphragmatic muscle, specifies the muscular partition that separates the abdominopelvic and thoracic cavities (**Figure 11–11b**). We include this muscle here because it develops in association with the other muscles of the chest wall. The diaphragm is a major muscle used in breathing.

Muscles of the Pelvic Floor

The muscles of the pelvic floor (**Figure 11–12** and **Table 11–10**) extend from the sacrum and coccyx to the ischium and pubis. These muscles (1) support the organs of the pelvic cavity, (2) flex the sacrum and coccyx, and (3) control the movement of materials through the urethra and anus.

The boundaries of the **perineum,** the muscular sheet that forms the pelvic floor, are formed by the inferior margins of the pelvis. A line drawn between the ischial tuberosities divides the perineum into two triangles: an anterior **urogenital triangle** and a posterior **anal triangle** (**Figure 11–12b**). The superficial muscles of the urogenital triangle are the muscles of the external genitalia. They cover deeper muscles that strengthen the pelvic floor and encircle the urethra. These muscles constitute the **urogenital diaphragm** (**Figure 11–12a**), a deep muscular layer that extends between the pubic bones.

An even more extensive muscular sheet, the **pelvic diaphragm,** forms the muscular foundation of the anal triangle (**Figure 11–12b**). This layer, covered by the urogenital diaphragm, extends as far as the pubic symphysis.

The urogenital and pelvic diaphragms do not completely close the pelvic outlet, because the urethra, vagina, and anus pass through them to open on the exterior. Muscular sphincters surround the passageways, and the external sphincters permit voluntary control of urination and defecation. Muscles, nerves, and blood vessels also pass through the pelvic outlet as they travel to or from the lower limbs.

Checkpoint

11. **Describe the location of axial muscles.**
12. **If you were contracting and relaxing your masseter muscle, what would you probably be doing?**
13. **Which facial muscle would you expect to be well developed in a trumpet player?**
14. **Why can swallowing help alleviate the pressure sensations at the eardrum when you are in an airplane that is changing altitude?**
15. **Damage to the external intercostal muscles would interfere with what important process?**
16. **If someone hit you in your rectus abdominis muscle, how would your body position change?**
17. **After spending an afternoon carrying heavy boxes from his basement to his attic, Joe complains that the muscles in his back hurt. Which muscles are most likely sore?**

See the blue Answers tab at the back of the book.

11

Figure 11–12 **Muscles of the Pelvic Floor.**

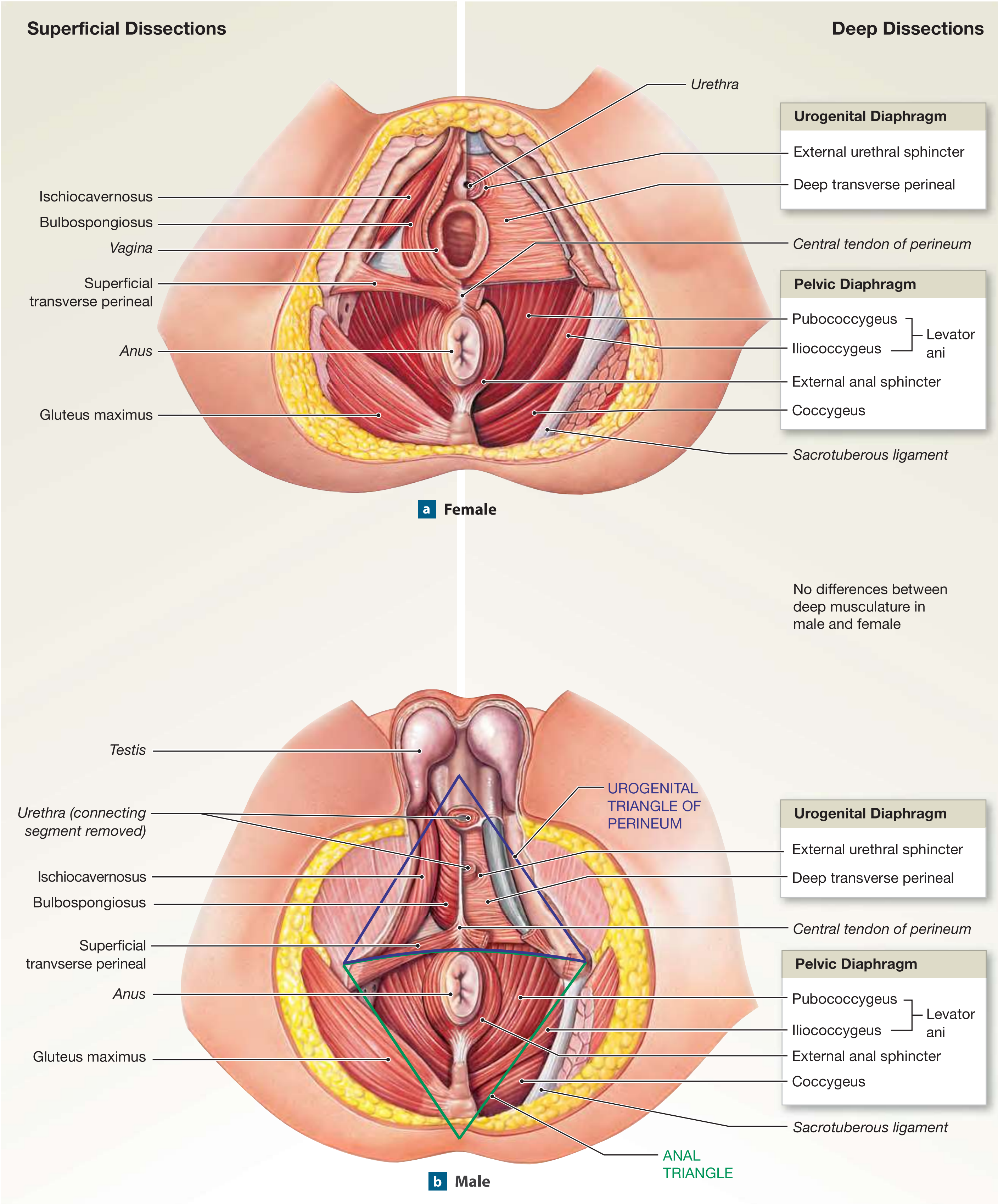


Table 11–10 Muscles of the Pelvic Floor (Figure 11–12)

Group and Muscle	Origin	Insertion	Action	Innervation*
UROGENITAL TRIANGLE				
Superficial muscles				
Bulbospongiosus				
Males	Collagen sheath at base of penis; fibers cross over urethra	Median raphe and central tendon of perineum	Compresses base and stiffens penis; ejects urine or semen	Pudendal nerve, perineal branch (S_2–S_4)
Females	Collagen sheath at base of clitoris; fibers run on either side of urethral and vaginal opening	Central tendon of perineum	Compresses and stiffens clitoris; narrows vaginal opening	Pudendal nerve, perineal branch (S_2–S_4)
Ischiocavernosus	Ischial ramus and tuberosity	Pubic symphysis anterior to base of penis or clitoris	Compresses and stiffens penis or clitoris	Pudendal nerve, perineal branch (S_2–S_4)
Superficial transverse perineal	Ischial ramus	Central tendon of perineum	Stabilizes central tendon of perineum	Pudendal nerve, perineal branch (S_2–S_4)
Deep muscles				
Urogenital diaphragm				
Deep transverse perineal	Ischial ramus	Median raphe of urogenital diaphragm	Stabilizes central tendon of perineum	Pudendal nerve, perineal branch (S_2–S_4)
External urethral sphincter				
Males	Ischial and pubic rami	To median raphe at base of penis; inner fibers encircle urethra	Closes urethra; compresses prostate and bulbo-urethral glands	Pudendal nerve, perineal branch (S_2–S_4)
Females	Ischial and pubic rami	To median raphe; inner fibers encircle urethra	Closes urethra; compresses vagina and greater vestibular glands	Pudendal nerve, perineal branch (S_2–S_4)
ANAL TRIANGLE				
Pelvic diaphragm				
Coccygeus	Ischial spine	Lateral, inferior borders of sacrum and coccyx	Flexes coccygeal joints; tenses and supports pelvic floor	Inferior sacral nerves (S_4–S_5)
Levator ani **Iliococcygeus**	Ischial spine, pubis	Coccyx and median raphe	Tenses floor of pelvis; flexes coccygeal joints; elevates and retracts anus	Pudendal nerve (S_2–S_4)
Pubococcygeus	Inner margins of pubis	Coccyx and median raphe	Tenses floor of pelvis; flexes coccygeal joints; elevates and retracts anus	Pudendal nerve (S_2–S_4)
External anal sphincter	Via tendon from coccyx	Encircles anal opening	Closes anal opening	Pudendal nerve, hemorrhoidal branch (S_2–S_4)

*Where appropriate, spinal nerves involved are given in parentheses.

11-6 Appendicular muscles are muscles of the shoulders, upper limbs, pelvic girdle, and lower limbs

The appendicular musculature positions and stabilizes the pectoral and pelvic girdles and moves the upper and lower limbs. There are two major groups of appendicular muscles: (1) *the muscles of the shoulders and upper limbs* and (2) *the muscles of the pelvis and lower limbs*. The functions and required ranges of motion are very different between these groups. In addition to increasing the mobility of the arms, the muscular connections between the pectoral girdle and the axial skeleton must act as shock absorbers. For example, while you jog, you can still perform delicate hand movements, because the muscular connections between the axial and appendicular components of the skeleton smooth out the bounces in your stride. In contrast, the pelvic girdle has evolved to transfer weight from the axial to the appendicular skeleton. Rigid, bony articulations are essential, because the emphasis is on strength rather than versatility, and a muscular connection would reduce the efficiency of the transfer. **Figure 11–13** provides an introduction to the organization of the appendicular muscles of the trunk. The larger appendicular muscles are often used as injection sites for medications.

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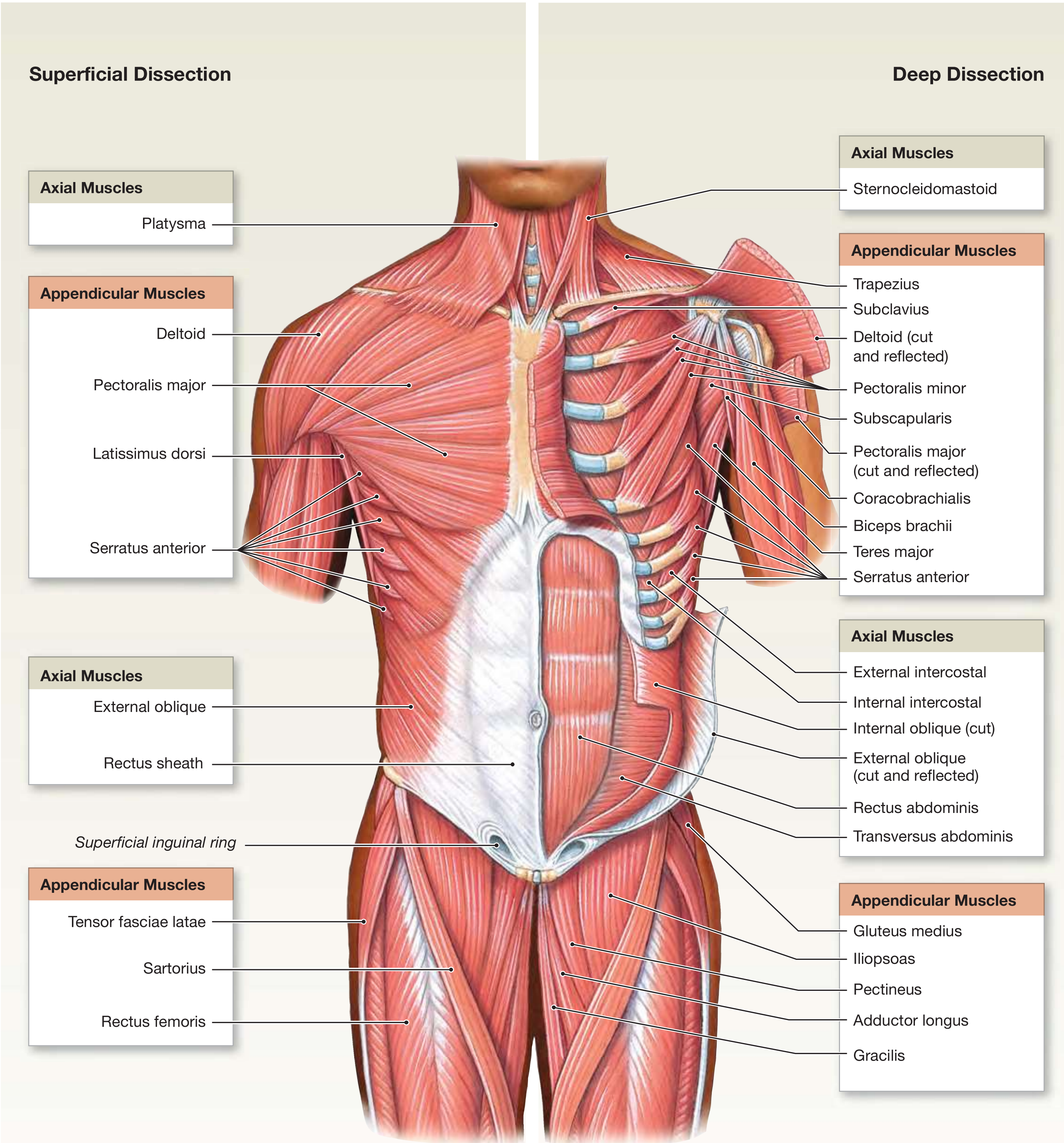
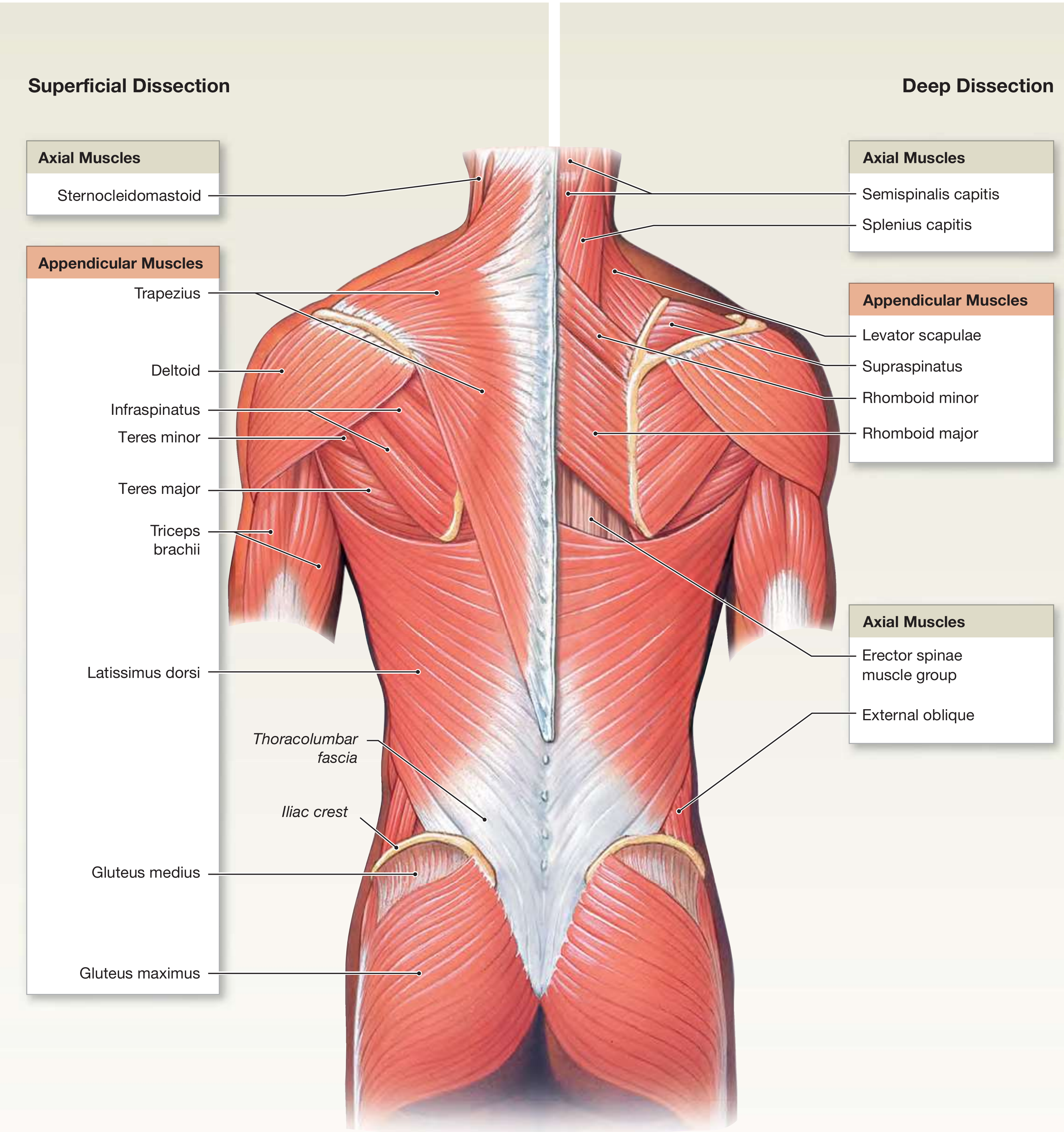
Figure 11–13 An Overview of the Appendicular Muscles of the Trunk.



a **Anterior view**
ATLAS: Plates 25; 39b

Figure 11–13 An Overview of the Appendicular Muscles of the Trunk (continued)



b Posterior view
ATLAS: Plate 40a,b

11

Muscles of the Shoulders and Upper Limbs

Muscles associated with the shoulders and upper limbs can be divided into four groups: (1) *muscles that position the pectoral girdle*, (2) *muscles that move the arm*, (3) *muscles that move the forearm and hand*, and (4) *muscles that move the hand and fingers*.

Muscles That Position the Pectoral Girdle

The large, superficial **trapezius** muscles, commonly called the "traps," cover the back and portions of the neck, reaching to the base of the skull. These muscles originate along the midline of the neck and back and insert on the clavicles and the scapular spines (**Figures 11–13** and **11–14**). The trapezius muscles are innervated by more than one nerve (**Table 11–11**), and specific regions can be made to contract independently. As a result, their actions are quite varied.

On the chest, the **serratus anterior** muscle originates along the anterior surfaces of several ribs (**Figures 11–3** and **11–14a,b**). This fan-shaped muscle inserts along the anterior margin of the vertebral border of the scapula. When the serratus anterior muscle contracts, it abducts (protracts) the scapula and swings the shoulder anteriorly.

Two other deep chest muscles arise along the anterior surfaces of the ribs on either side. The **subclavius** (sub-KLĀ-vē-us; *sub-*, below + *clavius*, clavicle) muscle inserts on the inferior border of the clavicle (**Figure 11–14a**). When it contracts, it depresses and protracts the scapular end of the clavicle. Because ligaments connect this end to the shoulder joint and scapula, those structures move as well. The **pectoralis** (pek-tō-RA-lis) **minor** muscle attaches to the coracoid process of the scapula. The contraction of this muscle generally complements that of the subclavius muscle.

Removing the trapezius muscle reveals the **rhomboid major, rhomboid minor,** and **levator scapulae** muscles (**Figure 11–14b**). These muscles are attached to the posterior surfaces of the cervical and thoracic vertebrae. They insert along the vertebral border of each scapula, between the superior and inferior angles. Contraction of a rhomboid muscle adducts (retracts) the scapula on that side. The levator scapulae muscle, as its name implies, elevates the scapula.

Muscles That Move the Arm

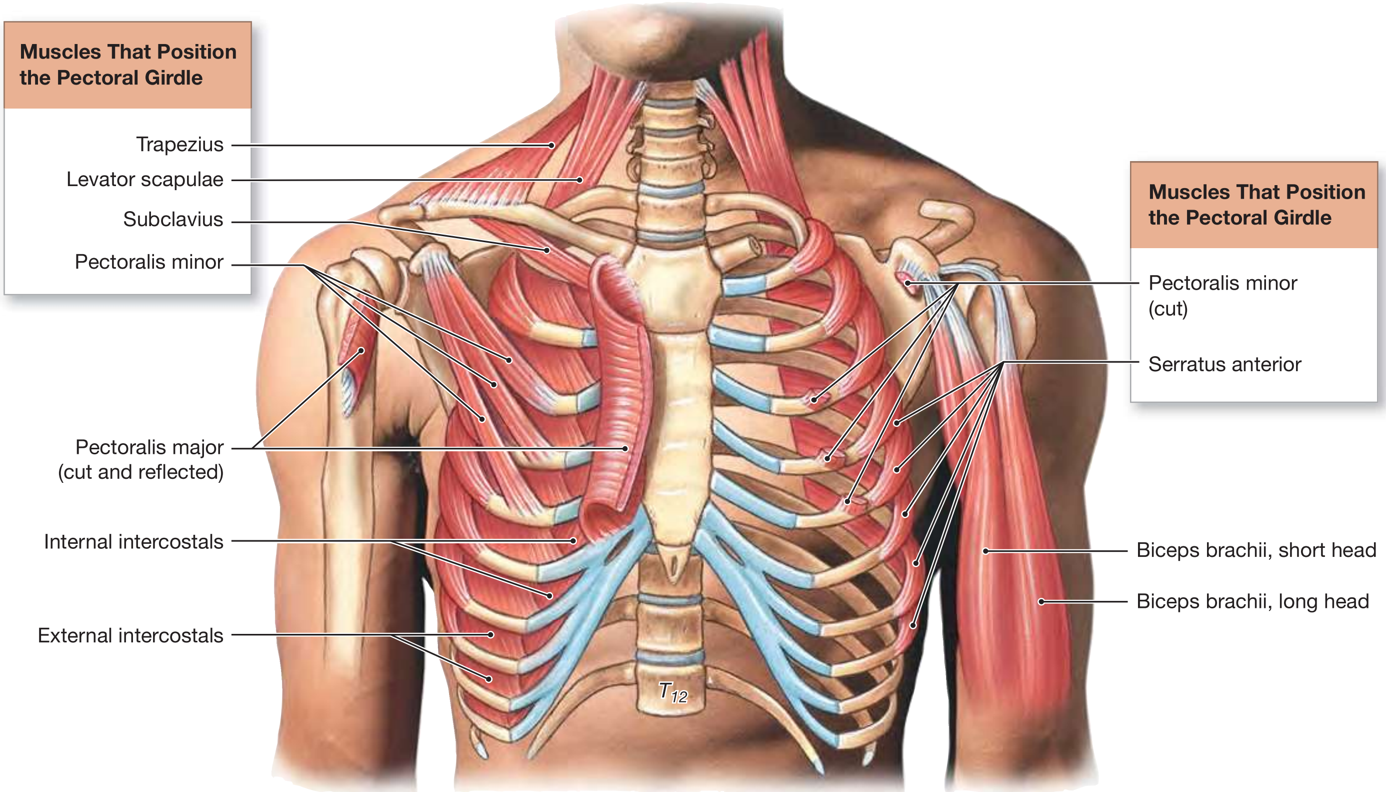
The muscles that move the arm (**Figures 11–13, 11–14,** and **11–15**) are easiest to remember when they are grouped by their actions at the shoulder joint (**Table 11–12**). The **deltoid** muscle is the major abductor, but the **supraspinatus** (soo-pra-spī-NĀ-tus) muscle assists at the start of this movement. The **subscapularis** and **teres major** muscles produce medial rotation at the shoulder, whereas the **infraspinatus** and the **teres minor** muscles produce lateral rotation. All these muscles originate on the scapula. The small **coracobrachialis** (KOR-uh-kō-brā-kē-A-lis) muscle is the only muscle attached to the scapula that produces flexion and adduction at the shoulder (**Figure 11–15a**).

Table 11–11 Muscles That Position the Pectoral Girdle (Figures 11–13, 11–14)

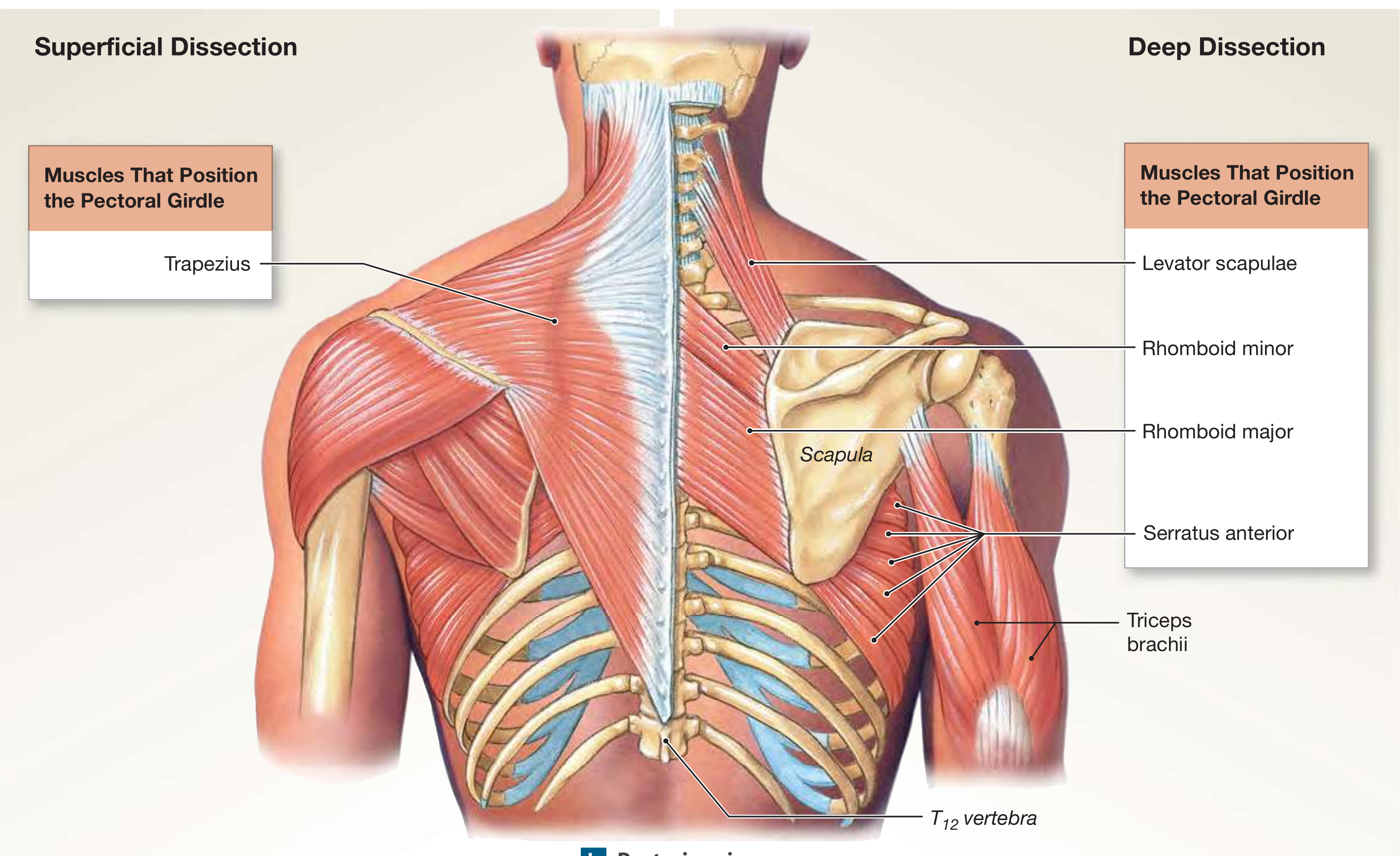
Muscle	Origin	Insertion	Action	Innervation*
Levator scapulae	Transverse processes of first four cervical vertebrae	Vertebral border of scapula near superior angle	Elevates scapula	Cervical nerves C_3–C_4 and dorsal scapular nerve (C_5)
Pectoralis minor	Anterior-superior surfaces of ribs 3–5	Coracoid process of scapula	Depresses and protracts shoulder; rotates scapula so glenoid cavity moves inferiorly (downward rotation); elevates ribs if scapula is stationary	Medial pectoral nerve (C_8, T_1)
Rhomboid major	Spinous processes of superior thoracic vertebrae	Vertebral border of scapula from spine to inferior angle	Adducts scapula and performs downward rotation	Dorsal scapular nerve (C_5)
Rhomboid minor	Spinous processes of vertebrae C_7–T_1	Vertebral border of scapula near spine	Adducts scapula and performs downward rotation	Dorsal scapular nerve (C_5)
Serratus anterior	Anterior and superior margins of ribs 1–8 or 1–9	Anterior surface of vertebral border of scapula	Protracts shoulder; rotates scapula so glenoid cavity moves superiorly (upward rotation)	Long thoracic nerve (C_5–C_7)
Subclavius	First rib	Clavicle (inferior border)	Depresses and protracts shoulder	Nerve to subclavius (C_5–C_6)
Trapezius	Occipital bone, ligamentum nuchae, and spinous processes of thoracic vertebrae	Clavicle and scapula (acromion and scapular spine)	Depends on active region and state of other muscles; may (1) elevate, retract, depress, or rotate scapula upward, (2) elevate clavicle, or (3) extend neck	Accessory nerve (N XI) and cervical spinal nerves (C_3–C_4)

*Where appropriate, spinal nerves involved are given in parentheses.

Figure 11–14 Muscles That Position the Pectoral Girdle.

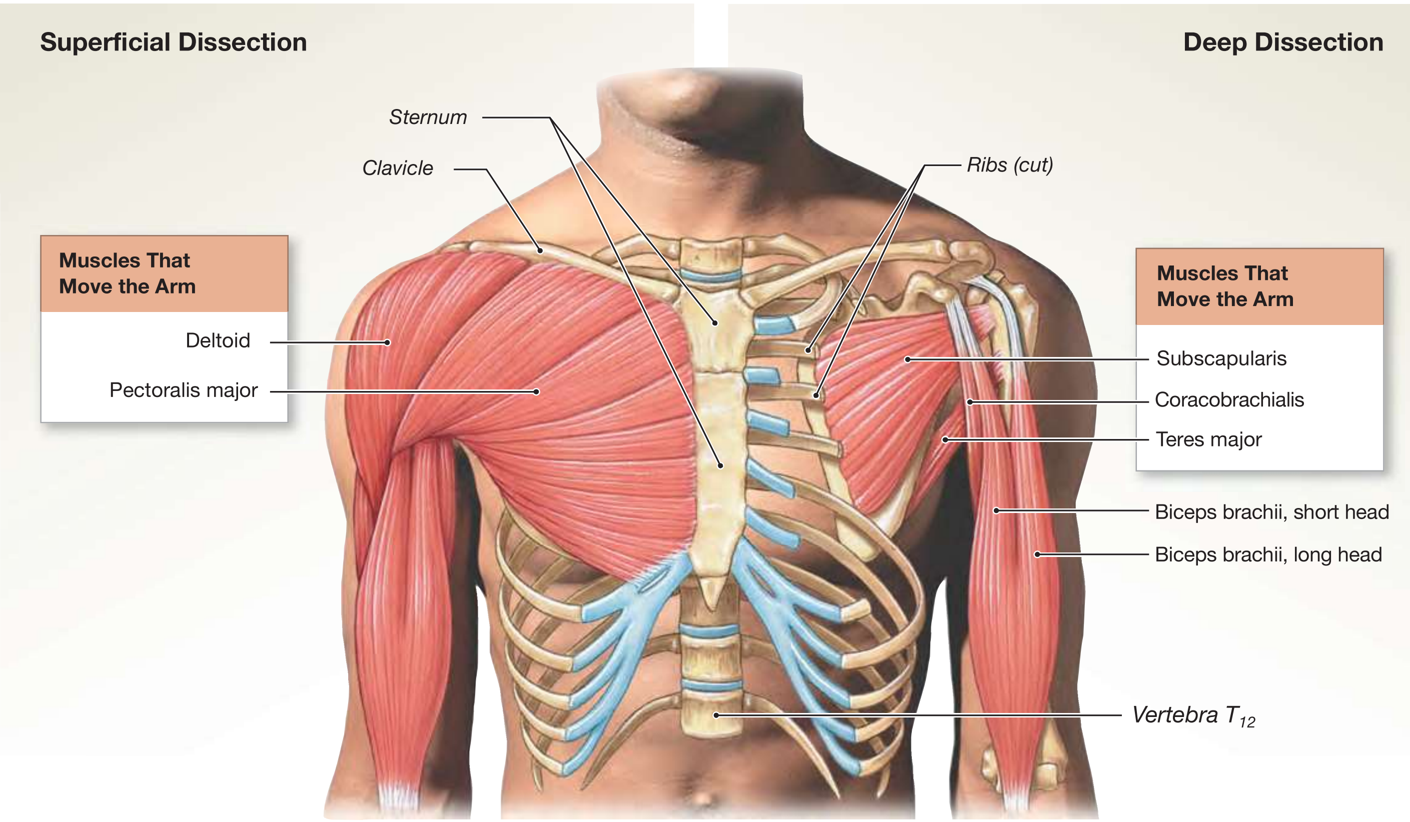


a **Anterior view**
ATLAS: Plates 39a-d; 40a–b

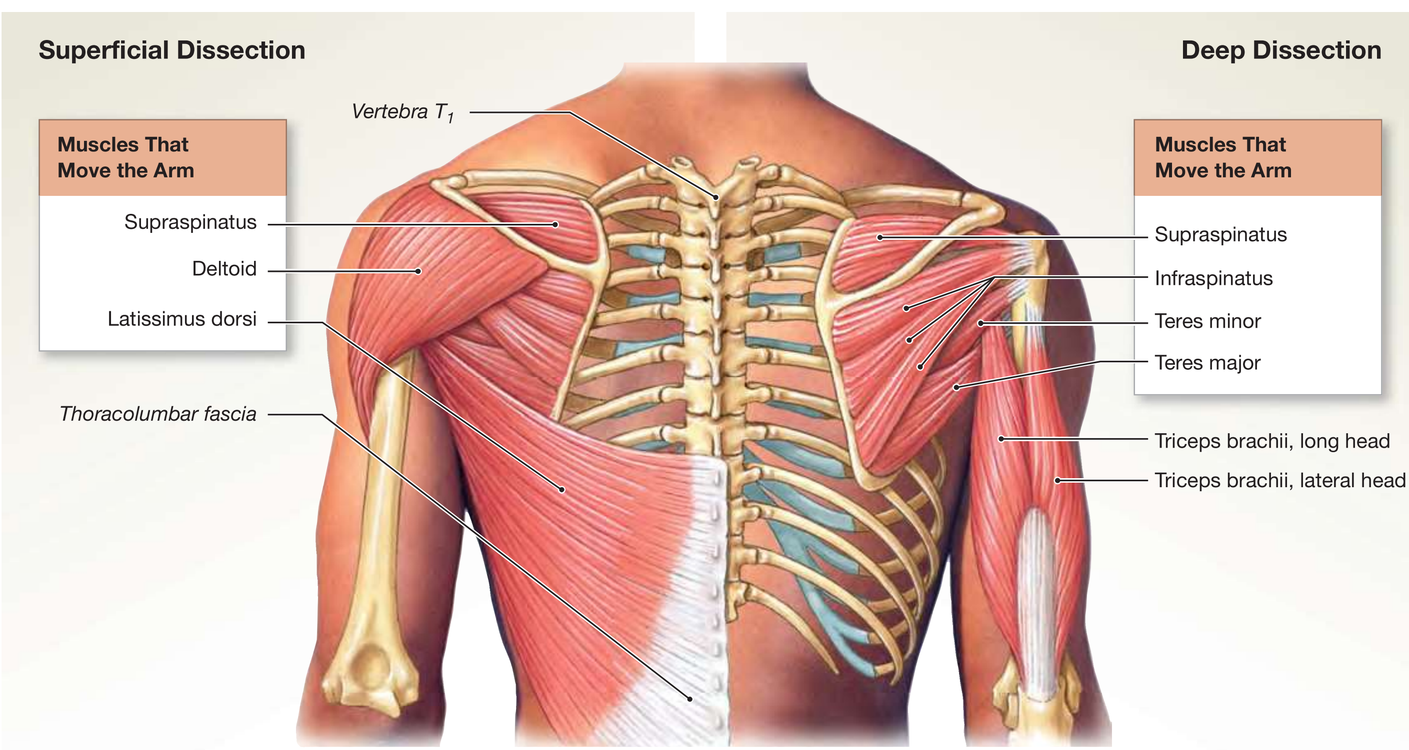


b **Posterior view**
ATLAS: Plates 27b; 40a–b

Figure 11–15 **Muscles That Move the Arm.** ATLAS: Plates 39a–d; 40a–b



a **Anterior view**



b **Posterior view**

Table 11–12 Muscles That Move the Arm (Figures 11–13 to 11–15)

Muscle	Origin	Insertion	Action	Innervation*
Deltoid	Clavicle and scapula (acromion and adjacent scapular spine)	Deltoid tuberosity of humerus	*Whole muscle*: abduction at shoulder; *anterior part*: flexion and medial rotation; *posterior part*: extension and lateral rotation	Axillary nerve (C_5–C_6)
Supraspinatus	Supraspinous fossa of scapula	Greater tubercle of humerus	Abduction at the shoulder	Suprascapular nerve (C_5)
Subscapularis	Subscapular fossa of scapula	Lesser tubercle of humerus	Medial rotation at shoulder	Subscapular nerves (C_5–C_6)
Teres major	Inferior angle of scapula	Passes medially to reach the medial lip of intertubercular groove of humerus	Extension, adduction, and medial rotation at shoulder	Lower subscapular nerve (C_5–C_6)
Infraspinatus	Infraspinous fossa of scapula	Greater tubercle of humerus	Lateral rotation at shoulder	Suprascapular nerve (C_5–C_6)
Teres minor	Lateral border of scapula	Passes laterally to reach the greater tubercle of humerus	Lateral rotation at shoulder	Axillary nerve (C_5)
Coracobrachialis	Coracoid process	Medial margin of shaft of humerus	Adduction and flexion at shoulder	Musculocutaneous nerve (C_5–C_7)
Pectoralis major	Cartilages of ribs 2–6, body of sternum, and inferior, medial portion of clavicle	Crest of greater tubercle and lateral lip of intertubercular groove of humerus	Flexion, adduction, and medial rotation at shoulder	Pectoral nerves (C_5–T_1)
Latissimus dorsi	Spinous processes of inferior thoracic and all lumbar vertebrae, ribs 8–12, and thoracolumbar fascia	Floor of intertubercular groove of the humerus	Extension, adduction, and medial rotation at shoulder	Thoracodorsal nerve (C_6–C_8)
Triceps brachii (long head)	*See Table 11–13*			

*Where appropriate, spinal nerves involved are given in parentheses.

11

Tips & Tricks

The supraspinatus and infraspinatus muscles are named for their origins above and below the spine of the scapula, respectively, not because they are located on the backbone.

The **pectoralis major** muscle extends between the anterior portion of the chest and the crest of the greater tubercle of the humerus. The **latissimus dorsi** (la-TIS-i-mus DOR-sē) muscle extends between the thoracic vertebrae at the posterior midline and the intertubercular groove of the humerus (**Figure 11–15b**). The pectoralis major muscle produces flexion at the shoulder joint, and the latissimus dorsi muscle produces extension. These muscles, commonly known as the "pecs" and the "lats," can also work together to produce adduction and medial rotation of the humerus at the shoulder.

Collectively, the supraspinatus, infraspinatus, teres minor, and subscapularis muscles and their associated tendons form the **rotator cuff.** Sports that involve throwing a ball, such as baseball or football, place considerable strain on the rotator cuff, and rotator cuff injuries are common.

Tips & Tricks

The acronym SITS is useful in remembering the four muscles of the rotator cuff.

Muscles That Move the Forearm and Hand

Although most of the muscles that insert on the forearm and hand originate on the humerus, the biceps brachii and triceps brachii muscles are noteworthy exceptions. The **biceps brachii** muscle and the *long head* of the **triceps brachii** muscle originate on the scapula and insert on the bones of the forearm (**Figure 11–16**). The triceps brachii muscle inserts on the olecranon. Contraction of the triceps brachii muscle extends the elbow, as when you do push-ups. The biceps brachii muscle inserts on the radial tuberosity, a roughened bump on the anterior surface of the radius. ⮌ p. 239 Contraction of the biceps brachii muscle flexes the elbow and supinates the forearm. With the forearm pronated (palm facing back), the biceps brachii muscle cannot function effectively. As a result, you are strongest when you flex your elbow with a supinated forearm; the biceps brachii muscle then makes a prominent bulge.

Figure 11–16 Muscles That Move the Forearm and Hand. Superficial muscles are shown in posterior and anterior views. Deeper muscles are shown in the sectional views and in *Figure 11–18*. **ATLAS: Plates 27a–c; 29a; 30; 33a–d; 37a,b**

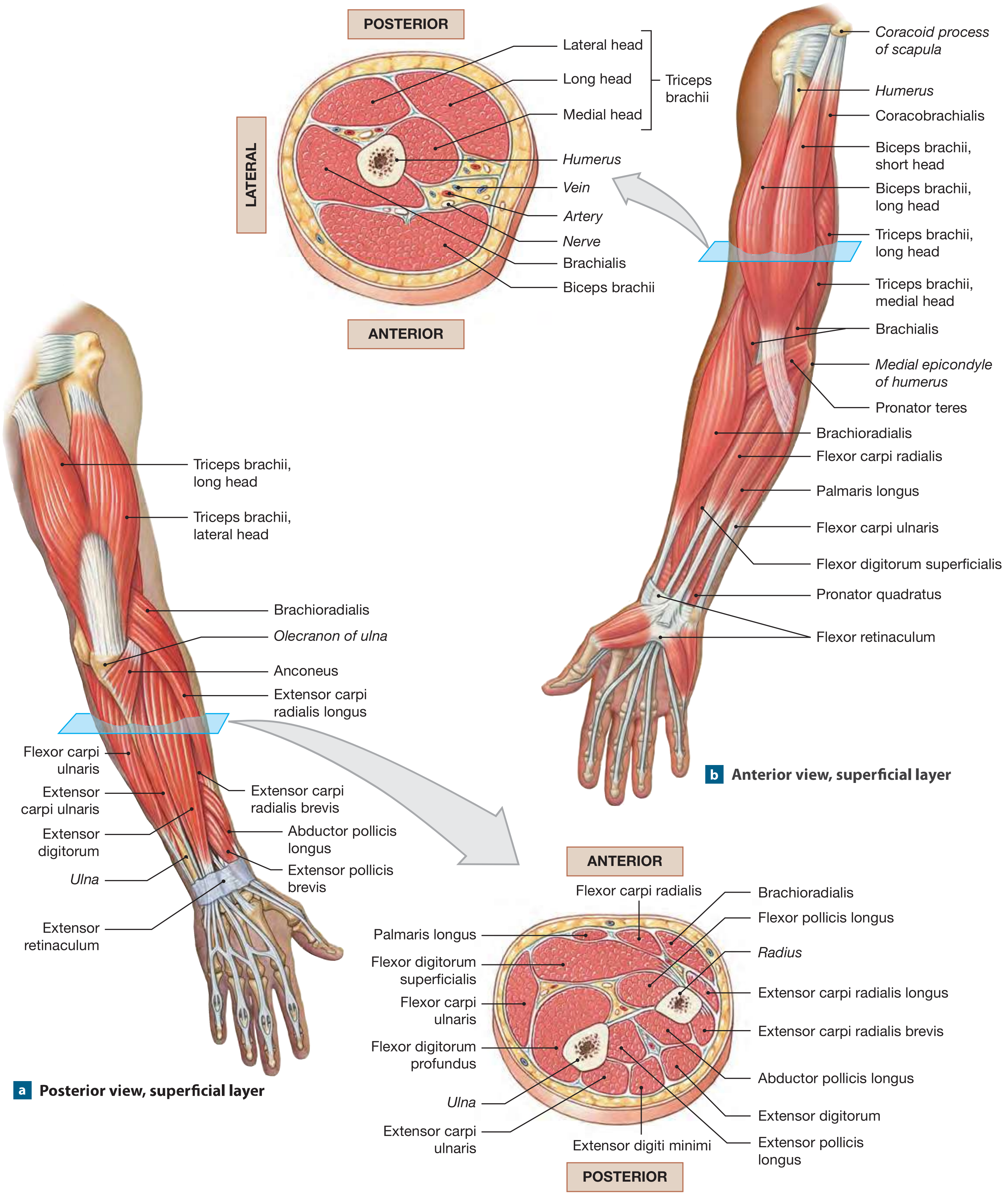


Table 11–13 Muscles That Move the Forearm and Hand (Figure 11–16)

	Muscle	Origin	Insertion	Action	Innervation
ACTION AT THE ELBOW					
Flexors	**Biceps brachii**	*Short head* from the coracoid process; *long head* from the supraglenoid tubercle (both on the scapula)	Tuberosity of radius	Flexion at elbow and shoulder; supination	Musculocutaneous nerve (C_5–C_6)
	Brachialis	Anterior, distal surface of humerus	Tuberosity of ulna	Flexion at elbow	Musculocutaneous nerve (C_5–C_6)and radial nerve (C_7–C_8)
	Brachioradialis	Ridge superior to the lateral epicondyle of humerus	Lateral aspect of styloid process of radius	Flexion at elbow	Radial nerve (C_5–C_6)
Extensors	**Anconeus**	Posterior, inferior surface of lateral epicondyle of humerus	Lateral margin of olecranon on ulna	Extension at elbow	Radial nerve (C_7–C_8)
	Triceps brachii				
	lateral head	Superior, lateral margin of humerus	Olecranon of ulna	Extension at elbow	Radial nerve (C_6–C_8)
	long head	Infraglenoid tubercle of scapula	Olecranon of ulna	As above, plus extension and adduction at the shoulder	Radial nerve (C_6–C_8)
	medial head	Posterior surface of humerus inferior to radial groove	Olecranon of ulna	Extension at elbow	Radial nerve (C_6–C_8)
PRONATORS/SUPINATORS					
	Pronator quadratus	Anterior and medial surfaces of distal portion of ulna	Anterolateral surface of distal portion of radius	Pronation	Median nerve (C_8–T_1)
	Pronator teres	Medial epicondyle of humerus and coronoid process of ulna	Midlateral surface of radius	Pronation	Median nerve (C_6–C_7)
	Supinator	Lateral epicondyle of humerus, annular ligament, and ridge near radial notch of ulna	Anterolateral surface of radius distal to the radial tuberosity	Supination	Deep radial nerve (C_6–C_8)
ACTION AT THE HAND					
Flexors	**Flexor carpi radialis**	Medial epicondyle of humerus	Bases of second and third metacarpal bones	Flexion and abduction at wrist	Median nerve (C_6–C_7)
	Flexor carpi ulnaris	Medial epicondyle of humerus; adjacent medial surface of olecranon and anteromedial portion of ulna	Pisiform, hamate, and base of fifth metacarpal bone	Flexion and adduction at wrist	Ulnar nerve (C_8–T_1)
	Palmaris longus	Medial epicondyle of humerus	Palmar aponeurosis and flexor retinaculum	Flexion at wrist	Median nerve (C_6–C_7)
Extensors	**Extensor carpi radialis longus**	Lateral supracondylar ridge of humerus	Base of second metacarpal bone	Extension and abduction at wrist	Radial nerve (C_6–C_7)
	Extensor carpi radialis brevis	Lateral epicondyle of humerus	Base of third metacarpal bone	Extension and abduction at wrist	Radial nerve (C_6–C_7)
	Extensor carpi ulnaris	Lateral epicondyle of humerus; adjacent dorsal surface of ulna	Base of fifth metacarpal bone	Extension and adduction at wrist	Deep radial nerve (C_6–C_8)

11

The biceps brachii muscle plays an important role in the stabilization of the shoulder joint. The short head originates on the coracoid process and provides support to the posterior surface of the capsule. The long head originates at the supraglenoid tubercle, inside the shoulder joint. ⮌ p. 235 After crossing the head of the humerus, it passes along the intertubercular groove. In this position, the tendon helps to hold the head of the humerus within the glenoid cavity while arm movements are under way.

More muscles are shown in **Figure 11–16** and listed in **Table 11–13**. As you study these muscles, notice that, in general, the extensor muscles lie along the posterior and lateral surfaces of the arm, whereas the flexors are on the anterior and medial surfaces. Connective tissue partitions separate major muscle groups, dividing the muscles into *compartments* formed by dense collagenous sheets.

The **brachialis** and **brachioradialis** (BRĀ-kē-ō-rā-dē-A-lis) muscles flex the elbow and are opposed by the **anconeus** muscle and the triceps brachii muscle, respectively.

The **flexor carpi ulnaris, flexor carpi radialis,** and **palmaris longus** muscles are superficial muscles that work together to produce flexion of the wrist. The flexor carpi radialis muscle flexes and *ab*ducts, and the flexor carpi ulnaris muscle flexes and *ad*ducts. *Pitcher's arm* is an inflammation at the origins of the flexor carpi muscles at the medial epicondyle of the humerus. This condition results from forcibly flexing the wrist just before releasing a baseball.

The **extensor carpi radialis** muscles and the **extensor carpi ulnaris** muscle have a similar relationship to that between the flexor carpi muscles. That is, the extensor carpi radialis muscles produce extension and *ab*duction, whereas the extensor carpi ulnaris muscle produces extension and *ad*duction.

The **pronator teres** and **supinator** muscles originate on both the humerus and ulna. These muscles rotate the radius without either flexing or extending the elbow. The **pronator quadratus** muscle originates on the ulna and assists the pronator teres muscle in opposing the actions of the supinator or biceps brachii muscles. The muscles involved in pronation and supination are shown in **Figure 11–17**. During pronation, the tendon of the biceps brachii muscle rotates with the radius. As a result, this muscle cannot assist in flexion of the elbow when the forearm is pronated.

11

Muscles That Move the Hand and Fingers

Several superficial and deep muscles of the forearm flex and extend the finger joints (**Figure 11–17** and **Table 11–14**). These large muscles end before reaching the wrist, and only their tendons cross the articulation, ensuring maximum mobility at both the wrist and hand. The tendons that cross the posterior and anterior surfaces of the wrist pass through **synovial tendon sheaths,** elongated bursae that reduce friction. p. 257

The muscles of the forearm provide strength and crude control of the hand and fingers. These muscles are known as the *extrinsic muscles of the hand*. Fine control of the hand involves small *intrinsic muscles*, which originate on the carpal and metacarpal bones. No muscles originate on the phalanges, and only tendons extend across the distal joints of the fingers. The intrinsic muscles of the hand are detailed in **Figure 11–18** and **Table 11–15**.

The fascia of the forearm thickens on the posterior surface of the wrist, forming the **extensor retinaculum** (ret-i-NAK-ū-lum; plural, *retinacula*), a wide band of connective tissue. The extensor retinaculum holds the tendons of the extensor muscles in place. On the anterior surface, the fascia also thickens to form another wide band of connective tissue, the **flexor retinaculum,** which stabilizes the tendons of the flexor muscles. Inflammation of the retinacula and synovial tendon sheaths can restrict movement and irritate the distal portions of the *median nerve*, a mixed (sensory and motor) nerve that innervates the hand. This condition, known as *carpal tunnel syndrome*, causes chronic pain.

Table 11–14 Muscles That Move the Hand and Fingers (Figure 11–17)

Muscle	Origin	Insertion	Action	Innervation
Abductor pollicis longus	Proximal dorsal surfaces of ulna and radius	Lateral margin of first metacarpal bone	Abduction at joints of thumb and wrist	Deep radial nerve (C_6–C_7)
Extensor digitorum	Lateral epicondyle of humerus	Posterior surfaces of the phalanges, fingers 2–5	Extension at finger joints and wrist	Deep radial nerve (C_6–C_8)
Extensor pollicis brevis	Shaft of radius distal to origin of adductor pollicis longus	Base of proximal phalanx of thumb	Extension at joints of thumb; abduction at wrist	Deep radial nerve (C_6–C_7)
Extensor pollicis longus	Posterior and lateral surfaces of ulna and interosseous membrane	Base of distal phalanx of thumb	Extension at joints of thumb; abduction at wrist	Deep radial nerve (C_6–C_8)
Extensor indicis	Posterior surface of ulna and interosseous membrane	Posterior surface of phalanges of index finger (2), with tendon of extensor digitorum	Extension and adduction at joints of index finger	Deep radial nerve (C_6–C_8)
Extensor digiti minimi	Via extensor tendon to lateral epicondyle of humerus and from intermuscular septa	Posterior surface of proximal phalanx of little finger (5)	Extension at joints of little finger	Deep radial nerve (C_6–C_8)
Flexor digitorum superficialis	Medial epicondyle of humerus; adjacent anterior surfaces of ulna and radius	Midlateral surfaces of middle phalanges of fingers 2–5	Flexion at proximal interphalangeal, metacarpophalangeal, and wrist joints	Median nerve (C_7–T_1)
Flexor digitorum profundus	Medial and posterior surfaces of ulna, medial surface of coronoid process, and interosseus membrane	Bases of distal phalanges of fingers 2–5	Flexion at distal interphalangeal joints and, to a lesser degree, proximal interphalangeal joints and wrist	Palmar interosseous nerve, from median nerve, and ulnar nerve (C_8–T_1)
Flexor pollicis longus	Anterior shaft of radius, interosseous membrane	Base of distal phalanx of thumb	Flexion at joints of thumb	Median nerve (C_8–T_1)

Figure 11–17 Muscles That Move the Hand and Fingers.

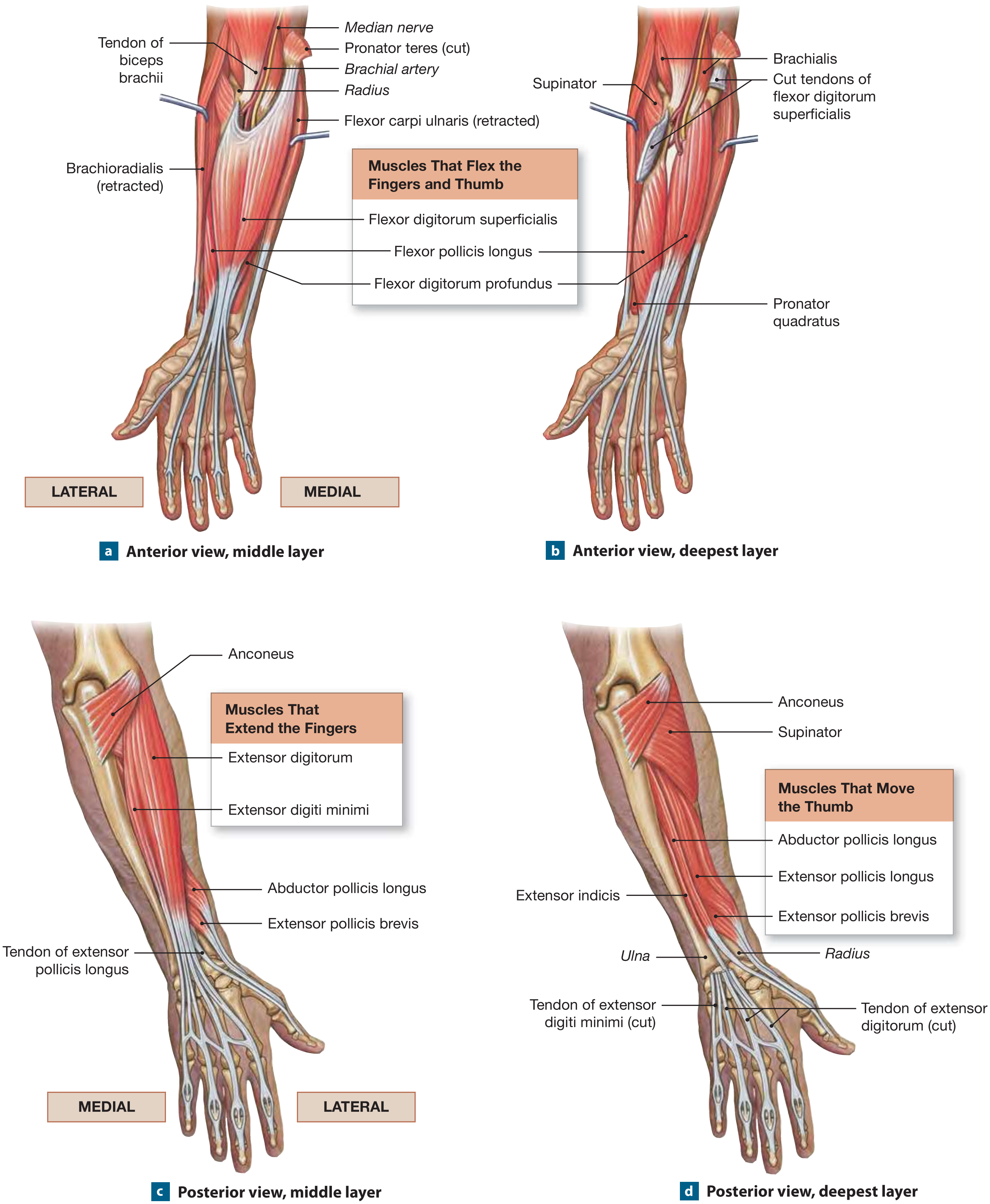
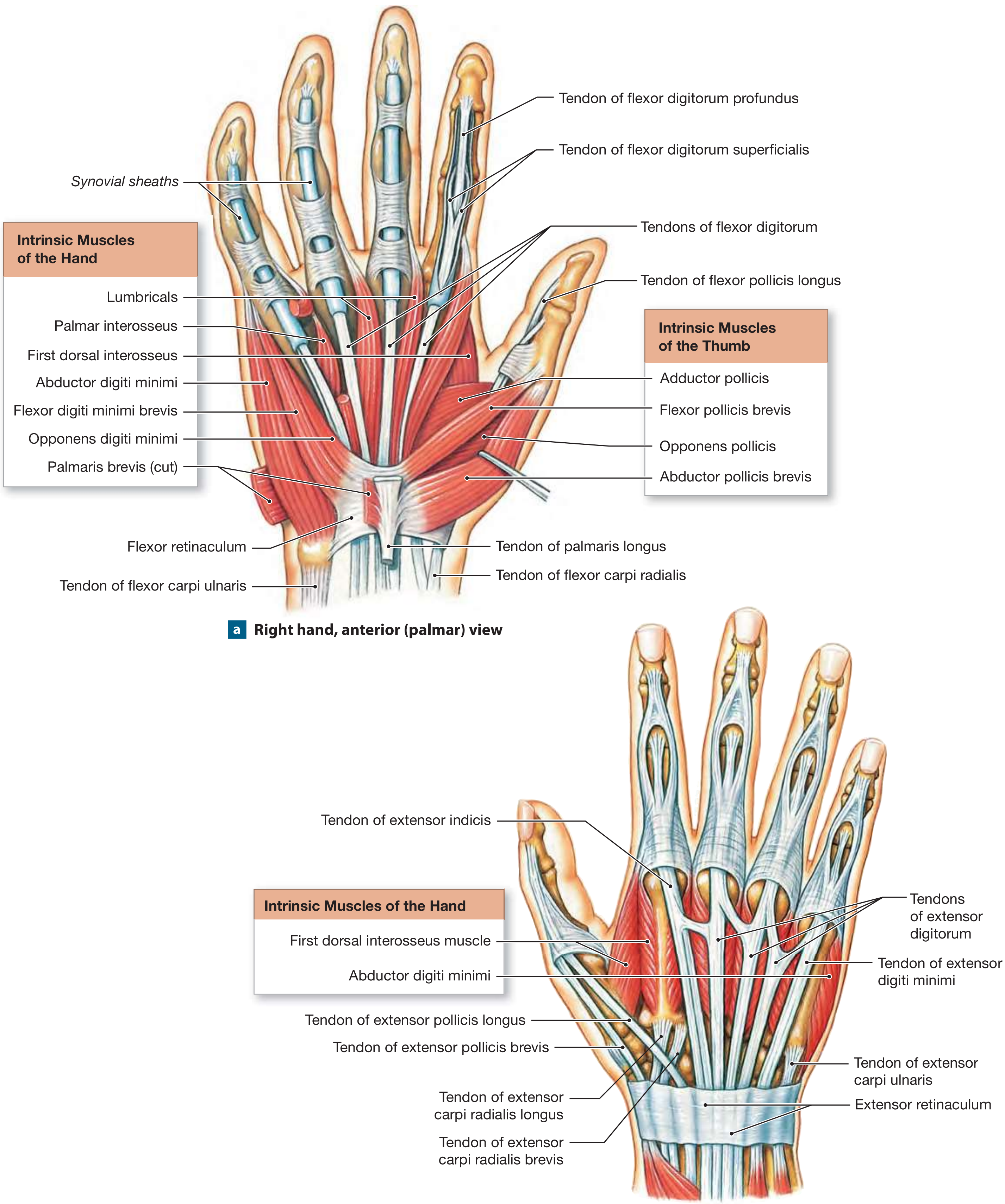


Figure 11–18 **Intrinsic Muscles of the Hand.** ATLAS: Plates 37b; 38c–f



a **Right hand, anterior (palmar) view**

b **Right hand, posterior view**

Table 11–15 Intrinsic Muscles of the Hand (Figure 11–18)

Muscle	Origin	Insertion	Action	Innervation
Palmaris brevis	Palmar aponeurosis	Skin of medial border of hand	Moves skin on medial border toward midline of palm	Ulnar nerve, superficial branch (C_8)
ADDUCTION/ABDUCTION				
Adductor pollicis	Metacarpal and carpal bones	Proximal phalanx of thumb	Adduction of thumb	Ulnar nerve, deep branch (C_8–T_1)
Palmar interosseus* (3–4)	Sides of metacarpal bones II, IV, and V	Bases of proximal phalanges of fingers 2, 4, and 5	Adduction at metacarpophalangeal joints of fingers 2, 4, and 5; flexion at metacarpophalangeal joints; extension at interphalangeal joints	Ulnar nerve, deep branch (C_8–T_1)
Abductor pollicis brevis	Transverse carpal ligament, scaphoid, and trapezium	Radial side of base of proximal phalanx of thumb	Abduction of thumb	Median nerve (C_6–C_7)
Dorsal interosseus (4)	Each originates from opposing faces of two metacarpal bones (I and II, II and III, III and IV, IV and V)	Bases of proximal phalanges of fingers 2–4	Abduction at metacarpophalangeal joints of fingers 2 and 4; flexion at metacarpophalangeal joints; extension at interphalangeal joints	Ulnar nerve, deep branch (C_8–T_1)
Abductor digiti minimi	Pisiform	Proximal phalanx of little finger	Abduction of little finger and flexion at its metacarpophalangeal joint	Ulnar nerve, deep branch (C_8–T_1)
FLEXION				
Flexor pollicis brevis	Flexor retinaculum, trapezium, capitate, and ulnar side of first metacarpal bone	Radial and ulnar sides of proximal phalanx of thumb	Flexion and adduction of thumb	Branches of median and ulnar nerves
Lumbrical (4)	Tendons of flexor digitorum profundus	Tendons of extensor digitorum to digits 2–5	Flexion at metacarpophalangeal joints 2–5; extension at proximal and distal interphalangeal joints, digits 2–5	No. 1 and no. 2 by median nerve; no. 3 and no. 4 by ulnar nerve, deep branch
Flexor digiti minimi brevis	Hamate	Proximal phalanx of little finger	Flexion at joints of little finger	Ulnar nerve, deep branch (C_8–T_1)
OPPOSITION				
Opponens pollicis	Trapezium and flexor retinaculum	First metacarpal bone	Opposition of thumb	Median nerve (C_6–C_7)
Opponens digiti minimi	Trapezium and flexor retinaculum	Fifth metacarpal bone	Opposition of fifth metacarpal bone	Ulnar nerve, deep branch (C_8–T_1)

*The deep, medial portion of the flexor pollicis brevis originating on the first metacarpal bone is sometimes called the *first palmar interosseus muscle*; it inserts on the ulnar side of the phalanx and is innervated by the ulnar nerve.

11

Muscles of the Pelvis and Lower Limbs

The pelvic girdle is tightly bound to the axial skeleton, permitting little movement. In our discussion of the axial musculature, we therefore encountered few muscles that can influence the position of the pelvis. The muscles that position the lower limbs can be divided into three functional groups: (1) *muscles that move the thigh*, (2) *muscles that move the leg*, and (3) *muscles that move the foot and toes*.

Muscles That Move the Thigh

Table 11–16 lists the muscles that move the thigh. **Gluteal muscles** cover the lateral surfaces of the ilia (**Figure 11–13a** and **Figure 11–19a,b,c**). The **gluteus maximus** muscle is the largest and most posterior of the gluteal muscles. Its origin includes parts of the ilium; the sacrum, coccyx, and associated ligaments; and the thoracolumbar fascia (**Figure 11–13**). Acting alone, this massive muscle produces extension and lateral rotation at the hip joint. The gluteus maximus shares an insertion with the **tensor fasciae latae** (FAH-shē-āy LAH-tāy) muscle, which originates on the iliac crest and the anterior superior iliac spine. Together, these muscles pull on the **iliotibial** (il-ē-ō-TIB-ē-ul) **tract**, a band of collagen fibers that extends along the lateral surface of the thigh and inserts on the tibia. This tract provides a lateral brace for the knee that becomes particularly important when you balance on one foot.

The **gluteus medius** and **gluteus minimus** muscles (**Figure 11–19a,b,c**) originate anterior to the origin of the gluteus maximus muscle and insert on the greater trochanter of the femur. The anterior gluteal line on the lateral surface of the ilium marks the boundary between these muscles.

Table 11–16 Muscles That Move the Thigh (Figure 11–19)

Group and Muscle	Origin	Insertion	Action	Innervation*
GLUTEAL GROUP				
Gluteus maximus	Iliac crest, posterior gluteal line, and lateral surface of ilium; sacrum, coccyx, and thoracolumbar fascia	Iliotibial tract and gluteal tuberosity of femur	Extension and lateral rotation at hip	Inferior gluteal nerve (L_5–S_2)
Gluteus medius	Anterior iliac crest of ilium, lateral surface between posterior and anterior gluteal lines	Greater trochanter of femur	Abduction and medial rotation at hip	Superior gluteal nerve (L_4–S_1)
Gluteus minimus	Lateral surface of ilium between inferior and anterior gluteal lines	Greater trochanter of femur	Abduction and medial rotation at hip	Superior gluteal nerve (L_4–S_1)
Tensor fasciae latae	Iliac crest and lateral surface of anterior superior iliac spine	Iliotibial tract	Flexion and medial rotation at hip; tenses fascia lata, which laterally supports the knee	Superior gluteal nerve (L_4–S_1)
LATERAL ROTATOR GROUP				
Obturators (externus and internus)	Lateral and medial margins of obturator foramen	Trochanteric fossa of femur (externus); medial surface of greater trochanter (internus)	Lateral rotation at hip	Obturator nerve (externus: L_3–L_4) and special nerve from sacral plexus (internus: L_5–S_2)
Piriformis	Anterolateral surface of sacrum	Greater trochanter of femur	Lateral rotation and abduction at hip	Branches of sacral nerves (S_1–S_2)
Gemelli (superior and inferior)	Ischial spine and tuberosity	Medial surface of greater trochanter with tendon of obturator internus	Lateral rotation at hip	Nerves to obturator internus and quadratus femoris
Quadratus femoris	Lateral border of ischial tuberosity	Intertrochanteric crest of femur	Lateral rotation at hip	Special nerve from sacral plexus (L_4–S_1)
ADDUCTOR GROUP				
Adductor brevis	Inferior ramus of pubis	Linea aspera of femur	Adduction, flexion, and medial rotation at hip	Obturator nerve (L_3–L_4)
Adductor longus	Inferior ramus of pubis anterior to adductor brevis	Linea aspera of femur	Adduction, flexion, and medial rotation at hip	Obturator nerve (L_3–L_4)
Adductor magnus	Inferior ramus of pubis posterior to adductor brevis and ischial tuberosity	Linea aspera and adductor tubercle of femur	Adduction at hip; superior part produces flexion and medial rotation; inferior part produces extension and lateral rotation	Obturator and sciatic nerves
Pectineus	Superior ramus of pubis	Pectineal line inferior to lesser trochanter of femur	Flexion, medial rotation, and adduction at hip	Femoral nerve (L_2–L_4)
Gracilis	Inferior ramus of pubis	Medial surface of tibia inferior to medial condyle	Flexion at knee; adduction and medial rotation at hip	Obturator nerve (L_3–L_4)
ILIOPSOAS GROUP				
Iliacus	Iliac fossa of ilium	Femur distal to lesser trochanter; tendon fused with that of psoas major	Flexion at hip	Femoral nerve (L_2–L_3)
Psoas major	Anterior surfaces and transverse processes of vertebrae (T_{12}–L_5)	Lesser trochanter in company with iliacus	Flexion at hip or lumbar intervertebral joints	Branches of the lumbar plexus (L_2–L_3)

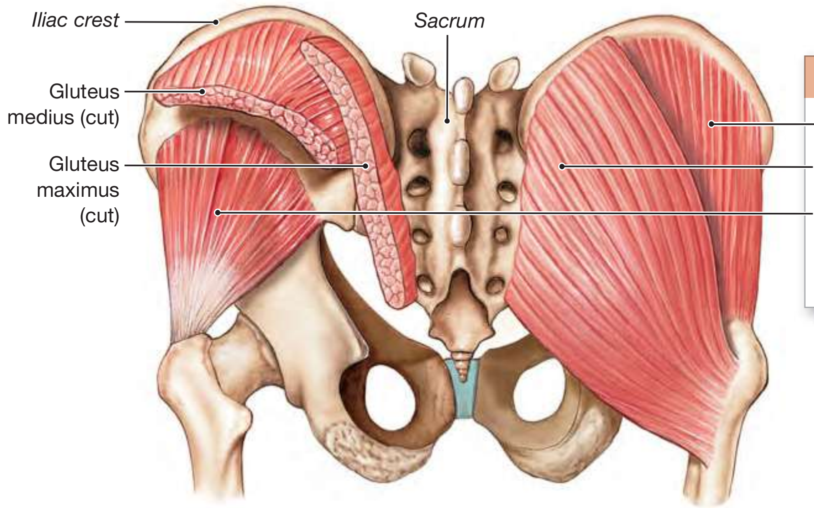
*Where appropriate, spinal nerves involved are given in parentheses.

11

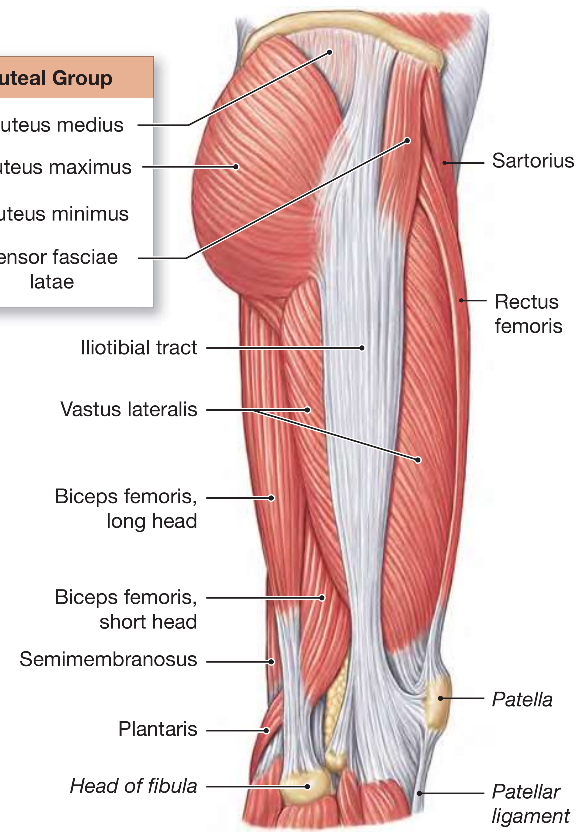
The **lateral rotators** originate at or inferior to the horizontal axis of the acetabulum. There are six lateral rotator muscles in all, of which the **piriformis** (pir-i-FOR-mis) muscle and the **obturator** muscles are dominant (**Figure 11–19c,d**).

The **adductors** (**Figure 11–19c,d**) originate inferior to the horizontal axis of the acetabulum. This muscle group includes the **adductor magnus, adductor brevis, adductor longus, pectineus** (pek-ti-NĒ-us), and **gracilis** (GRAS-i-lis) muscles. All but the adductor magnus originate both anterior and inferior to the joint, so they perform hip flexion as well as adduction. The adductor magnus muscle can produce either adduction and flexion or adduction and extension, depending on the region stimulated. The adductor magnus muscle can also produce medial or lateral rotation at the hip. The other muscles, which insert on low ridges along the posterior surface of the femur, produce medial rotation. When an athlete suffers a *pulled groin*, the problem is a *strain*—a muscle tear—in one of these adductor muscles.

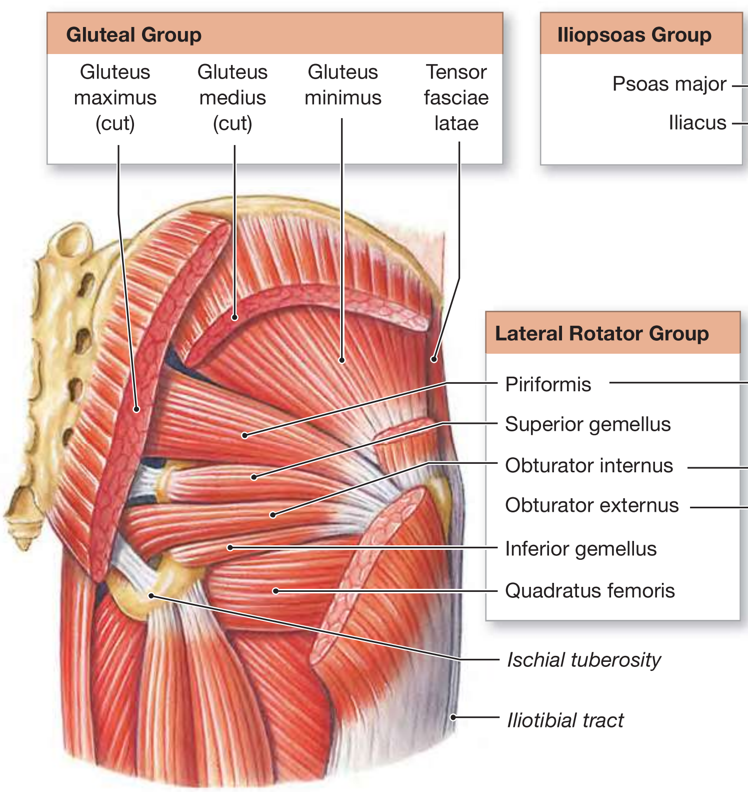
Figure 11–19 Muscles That Move the Thigh. ATLAS: Plates 68a–c; 72a,b; 73a,b



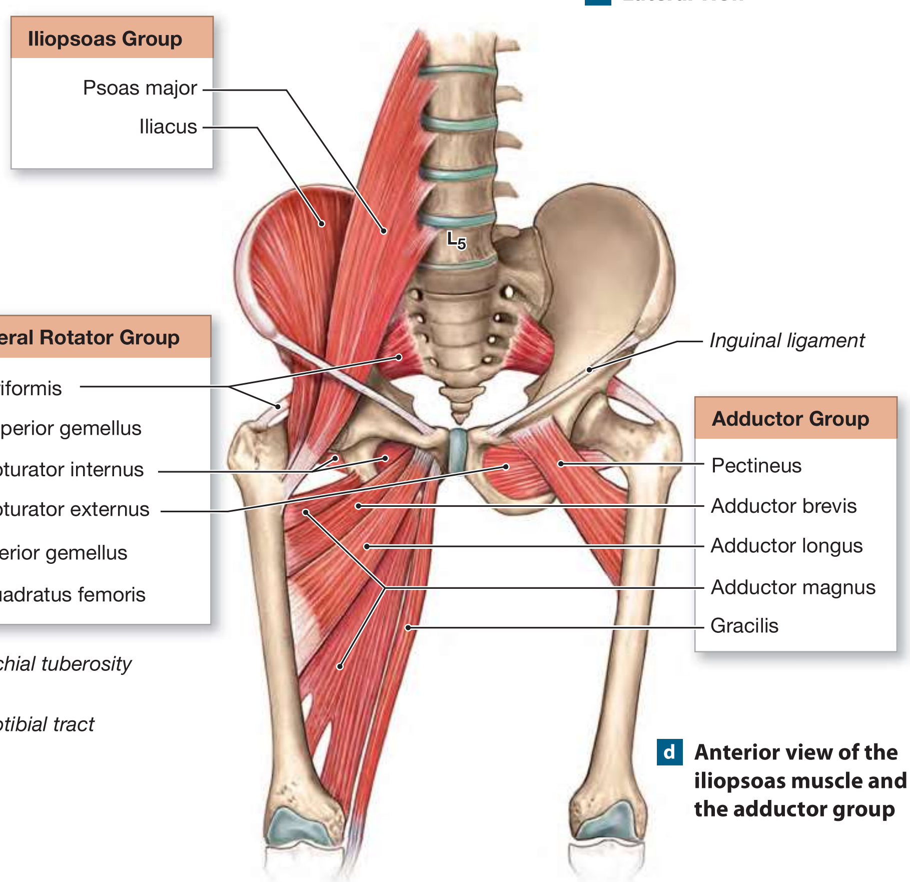
a Gluteal region, posterior view



b Lateral view



c Posterior view, deep muscles



d Anterior view of the iliopsoas muscle and the adductor group

A pair of muscles controls the internal surface of the pelvis. The large **psoas** (SŌ-us) **major** muscle originates alongside the inferior thoracic and lumbar vertebrae, and its insertion lies on the lesser trochanter of the femur. Before reaching this insertion, its tendon merges with that of the **iliacus** (il-Ī-ah-kus) muscle, which nestles within the iliac fossa. These two powerful hip flexors are often referred to collectively as the **iliopsoas** (il-ē-ō-SŌ-us) muscle.

Muscles That Move the Leg

As in the upper limb, muscle distribution in the lower limb exhibits a pattern: Extensor muscles are located along the anterior and lateral surfaces of the leg, and flexors lie along the posterior and medial surfaces (**Figure 11–20** and **Table 11–17**). As in the upper limb, sturdy connective tissue partitions divide the lower limb into separate muscular compartments. Although the flexors and adductors originate on the pelvic girdle, most extensors originate on the femoral surface.

The *flexors of the knee* include the **biceps femoris, semimembranosus** (sem-ē-mem-bra-NŌ-sus), **semitendinosus** (sem-ē-ten-di-NŌ-sus), and **sartorius** muscles (**Figure 11–20**). These muscles originate along the edges of the pelvis and insert on the tibia and fibula. The sartorius muscle is the only knee flexor that originates superior to the acetabulum, and its insertion lies along the medial surface of the tibia. When the sartorius contracts, it produces flexion at the knee and lateral rotation at the hip. This occurs when you cross your legs.

Because the biceps femoris, semimembranosus, and semitendinosus muscles originate on the pelvic surface inferior and posterior to the acetabulum, their contractions produce not only flexion at the knee, but also extension at the hip. These three muscles are often called the **hamstrings.** A *pulled hamstring* is a common sports injury caused by a strain affecting one of the hamstring muscles.

Tips & Tricks

To remember that three muscles make up the ***ham***strings, think "the three little pigs." These three muscles are portions of the cut of meat sold as ham.

The knee joint can be locked at full extension by a slight lateral rotation of the tibia. p. 270 The small **popliteus** (pop-LI-tē-us) muscle originates on the femur near the lateral condyle and inserts on the posterior tibial shaft (**Figure 11–21a**). When flexion is started, this muscle contracts to produce a slight medial rotation of the tibia that unlocks the knee joint.

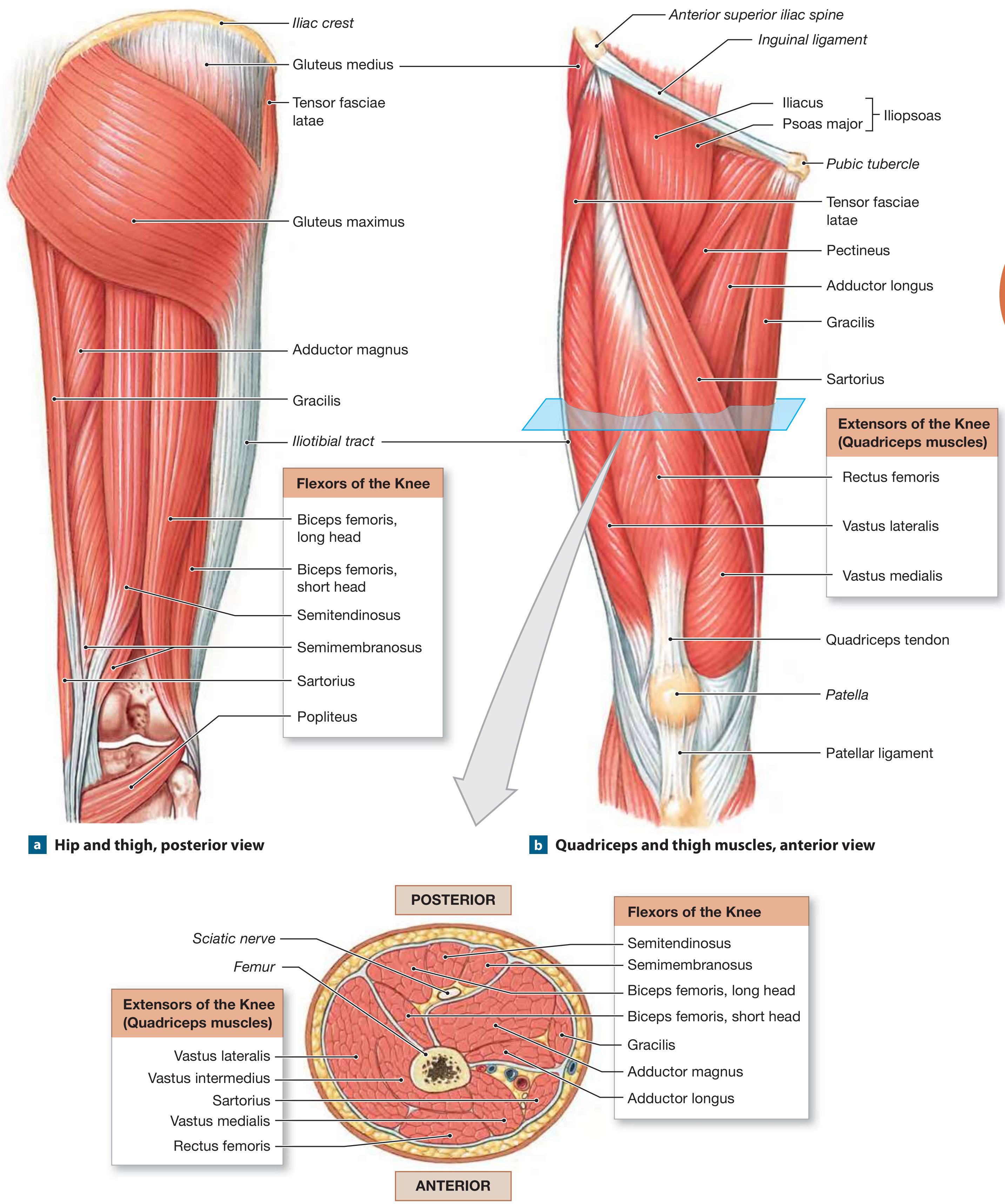
Collectively, four *knee extensors*—the three **vastus muscles,** which originate along the shaft of the femur, and the **rectus femoris muscle**—make up the **quadriceps femoris** (the "quads"). Together, the vastus muscles cradle the rectus femoris

Table 11–17 Muscles That Move the Leg (Figure 11–20)

Muscle	Origin	Insertion	Action	Innervation*
FLEXORS OF THE KNEE				
Biceps femoris	Ischial tuberosity and linea aspera of femur	Head of fibula, lateral condyle of tibia	Flexion at knee; extension and lateral rotation at hip	Sciatic nerve; tibial portion (S_1–S_3; to long head) and common fibular branch (L_5–S_2; to short head)
Semimembranosus	Ischial tuberosity	Posterior surface of medial condyle of tibia	Flexion at knee; extension and medial rotation at hip	Sciatic nerve (tibial portion; L_5–S_2)
Semitendinosus	Ischial tuberosity	Proximal, medial surface of tibia near insertion of gracilis	Flexion at knee; extension and medial rotation at hip	Sciatic nerve (tibial portion; L_5–S_2)
Sartorius	Anterior superior iliac spine	Medial surface of tibia near tibial tuberosity	Flexion at knee; flexion and lateral rotation at hip	Femoral nerve (L_2–L_3)
Popliteus	Lateral condyle of femur	Posterior surface of proximal tibial shaft	Medial rotation of tibia (or lateral rotation of femur); flexion at knee	Tibial nerve (L_4–S_1)
EXTENSORS OF THE KNEE				
Rectus femoris	Anterior inferior iliac spine and superior acetabular rim of ilium	Tibial tuberosity via patellar ligament	Extension at knee; flexion at hip	Femoral nerve (L_2–L_4)
Vastus intermedius	Anterolateral surface of femur and linea aspera (distal half)	Tibial tuberosity via patellar ligament	Extension at knee	Femoral nerve (L_2–L_4)
Vastus lateralis	Anterior and inferior to greater trochanter of femur and along linea aspera (proximal half)	Tibial tuberosity via patellar ligament	Extension at knee	Femoral nerve (L_2–L_4)
Vastus medialis	Entire length of linea aspera of femur	Tibial tuberosity via patellar ligament	Extension at knee	Femoral nerve (L_2–L_4)

*Where appropriate, spinal nerves involved are given in parentheses.

Figure 11–20 Muscles That Move the Leg. ATLAS: Plates 69a,b; 70b; 72a,b; 74; 76a,b; 78b–g



a Hip and thigh, posterior view

b Quadriceps and thigh muscles, anterior view

c Sectional view

muscle the way a bun surrounds a hot dog (**Figure 11–20c**). All four muscles insert on the patella via the quadriceps tendon. The force of their contraction is relayed to the tibial tuberosity by way of the patellar ligament. The rectus femoris muscle originates on the anterior inferior iliac spine and the superior acetabular rim—so in addition to extending the knee, it assists in flexion of the hip.

Tips & Tricks

Think of the quadriceps muscles as "the four at the fore."

11

Muscles That Move the Foot and Toes

The extrinsic muscles that move the foot and toes are shown in **Figure 11–21** and listed in **Table 11–18**. Most of the muscles that move the ankle produce the plantar flexion involved with walking and running movements. The **gastrocnemius** (gas-trok-NĒ-mē-us; *gaster*, stomach + *kneme*, knee) muscle of the calf is an important plantar flexor, but the slow muscle fibers of the underlying **soleus** (SŌ-lē-us) muscle are better suited for making continuous postural adjustments against the pull of gravity. These muscles are best seen in posterior and lateral views (**Figure 11–21a,b**). The gastrocnemius muscle arises from two heads located on the medial and lateral epicondyles of the femur just proximal to the knee. The *fabella*, a sesamoid bone, is occasionally present within the lateral head of the gastrocnemius muscle. The gastrocnemius and soleus muscles share a common tendon, the **calcaneal tendon,** commonly known as the *Achilles tendon*.

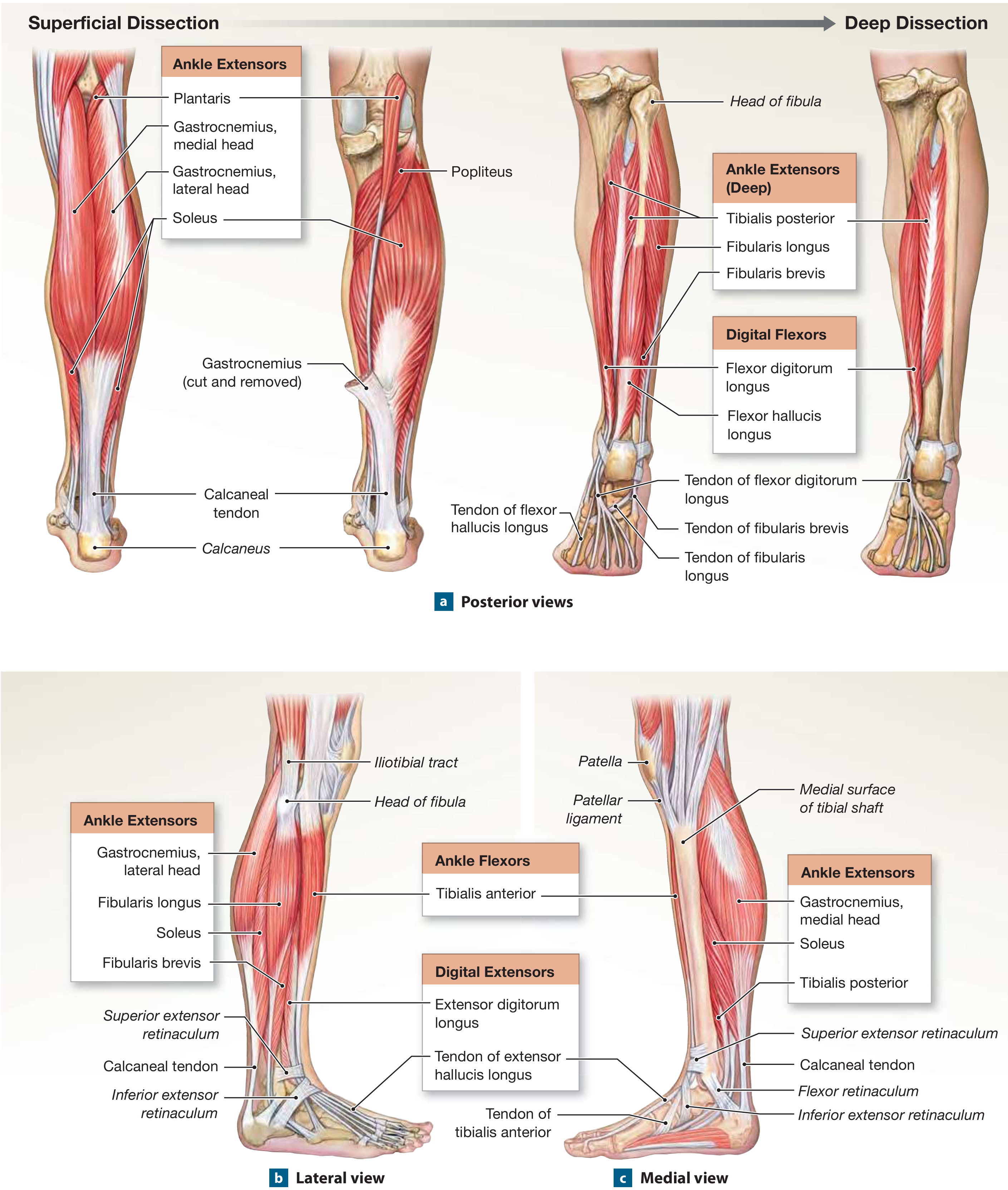
Tips & Tricks

The soleus is so named because it resembles the flat-bodied fish we call sole.

Table 11–18 Extrinsic Muscles That Move the Foot and Toes (Figure 11–21)

Muscle	Origin	Insertion	Action	Innervation
ACTION AT THE ANKLE				
Flexors (Dorsiflexors)				
Tibialis anterior	Lateral condyle and proximal shaft of tibia	Base of first metatarsal bone and medial cuneiform bone	Flexion (dorsiflexion) at ankle; inversion of foot	Deep fibular nerve (L_4–S_1)
Extensors (Plantar flexors)				
Gastrocnemius	Femoral condyles	Calcaneus via calcaneal tendon	Extension (plantar flexion) at ankle; inversion of foot; flexion at knee	Tibial nerve (S_1–S_2)
Fibularis brevis	Midlateral margin of fibula	Base of fifth metatarsal bone	Eversion of foot and extension (plantar flexion) at ankle	Superficial fibular nerve (L_4–S_1)
Fibularis longus	Lateral condyle of tibia, head and proximal shaft of fibula	Base of first metatarsal bone and medial cuneiform bone	Eversion of foot and extension (plantar flexion) at ankle; supports longitudinal arch	Superficial fibular nerve (L_4–S_1)
Plantaris	Lateral supracondylar ridge	Posterior portion of calcaneus	Extension (plantar flexion) at ankle; flexion at knee	Tibial nerve (L_4–S_1)
Soleus	Head and proximal shaft of fibula and adjacent posteromedial shaft of tibia	Calcaneus via calcaneal tendon (with gastrocnemius)	Extension (plantar flexion) at ankle	Sciatic nerve, tibial branch (S_1–S_2)
Tibialis posterior	Interosseous membrane and adjacent shafts of tibia and fibula	Tarsal and metatarsal bones	Adduction and inversion of foot; extension (plantar flexion) at ankle	Sciatic nerve, tibial branch (S_1–S_2)
ACTION AT THE TOES				
Digital flexors				
Flexor digitorum longus	Posteromedial surface of tibia	Inferior surfaces of distal phalanges, toes 2–5	Flexion at joints of toes 2–5	Sciatic nerve, tibial branch (L_5–S_1)
Flexor hallucis longus	Posterior surface of fibula	Inferior surface, distal phalanx of great toe	Flexion at joints of great toe	Sciatic nerve, tibial branch (L_5–S_1)
Digital extensors				
Extensor digitorum longus	Lateral condyle of tibia, anterior surface of fibula	Superior surfaces of phalanges, toes 2–5	Extension at joints of toes 2–5	Deep fibular nerve (L_4–S_1)
Extensor hallucis longus	Anterior surface of fibula	Superior surface, distal phalanx of great toe	Extension at joints of great toe	Deep fibular nerve (L_4–S_1)

Figure 11–21 **Extrinsic Muscles That Move the Foot and Toes.** ATLAS: Plates 81a,b; 82a,b; 84a,b



The term "Achilles tendon" comes from Greek mythology. Achilles was a warrior who was invincible but for one vulnerable spot: the calcaneal tendon. Outside mythology, damage to the calcaneal tendon isn't a fatal problem. Although it is among the largest, strongest tendons in the body, its rupture is common. The applied forces increase markedly during rapid acceleration or deceleration; sprinters can rupture the calcaneal tendon pushing off from the starting blocks, and the elderly often snap this tendon during a stumble or fall. Surgery may be necessary to reposition and reconnect the broken ends of the tendon to promote healing.

Deep to the gastrocnemius and soleus muscles lie a pair of **fibularis** muscles, or *peroneus* muscles (**Figure 11–21a,b**). The fibularis muscles produce eversion and extension (plantar flexion) at the ankle. Inversion is caused by the contraction of the **tibialis** (tib-ē-A-lis) muscles. The large **tibialis anterior** muscle (**Figure 11–21b,c**) flexes the ankle and opposes the gastrocnemius muscle.

Important digital muscles originate on the surface of the tibia, the fibula, or both (**Figure 11–21a,b,c**). Large synovial tendon sheaths surround the tendons of the tibialis anterior, **extensor digitorum longus,** and **extensor hallucis longus** muscles, where they cross the ankle joint. The positions of these sheaths are stabilized by superior and inferior **extensor retinacula** (**Figure 11–21b,c**).

Intrinsic muscles of the foot originate on the tarsal and metatarsal bones (**Figure 11–22** and **Table 11–19**). Their contractions move the toes and maintain the longitudinal arch of the foot. ⮌ p. 248

Checkpoint

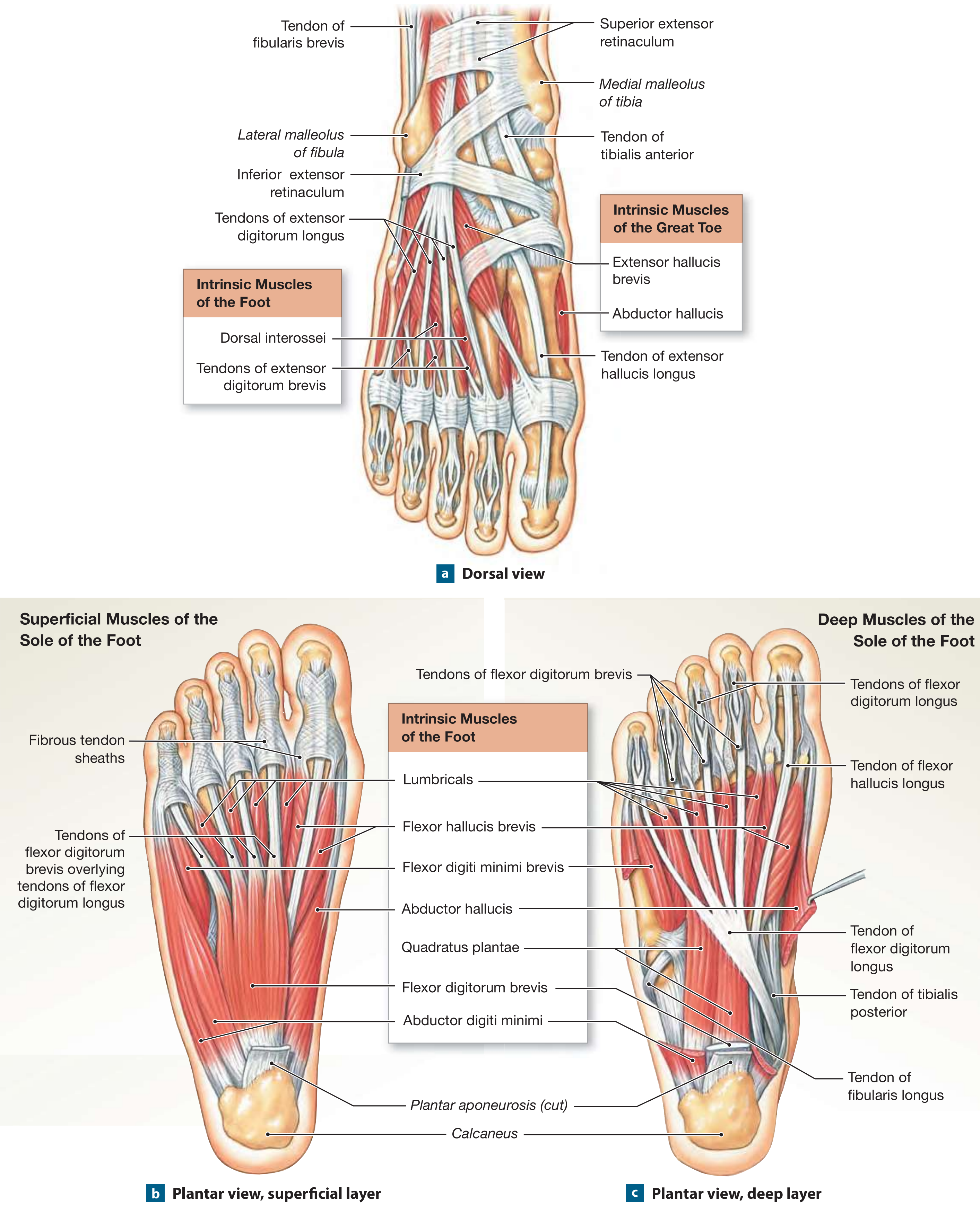
18. **Shrugging your shoulders uses which muscles?**
19. **Baseball pitchers sometimes suffer from rotator cuff injuries. Which muscles are involved in this type of injury?**
20. **An injury to the flexor carpi ulnaris muscle would impair which two movements?**
21. **Which leg movement would be impaired by injury to the obturator muscle?**
22. **To what does a "pulled hamstring" refer?**
23. **How would a torn calcaneal tendon affect movement of the foot?**

See the blue Answers tab at the back of the book.

Table 11–19 Intrinsic Muscles of the Foot (Figure 11–22)

Muscle	Origin	Insertion	Action	Innervation
FLEXION/EXTENSION				
Flexor hallucis brevis	Cuboid and lateral cuneiform bones	Proximal phalanx of great toe	Flexion at metatarsophalangeal joint of great toe	Medial plantar nerve (L_4–L_5)
Flexor digitorum brevis	Calcaneus (tuberosity on inferior surface)	Sides of middle phalanges, toes 2–5	Flexion at proximal interphalangeal joints of toes 2–5	Medial plantar nerve (L_4–L_5)
Quadratus plantae	Calcaneus (medial, inferior surfaces)	Tendon of flexor digitorum longus	Flexion at joints of toes 2–5	Lateral plantar nerve (L_4–L_5)
Lumbrical (4)	Tendons of flexor digitorum longus	Insertions of extensor digitorum longus	Flexion at metatarsophalangeal joints; extension at proximal interphalangeal joints of toes 2–5	Medial plantar nerve (1), lateral plantar nerve (2–4)
Flexor digiti minimi brevis	Base of metatarsal bone V	Lateral side of proximal phalanx of toe 5	Flexion at metatarsophalangeal joint of toe 5	Lateral plantar nerve (S_1–S_2)
Extensor digitorum brevis	Calcaneus (superior and lateral surfaces)	Dorsal surfaces of toes 1–4	Extension at metatarsophalangeal joints of toes 1–4	Deep fibular nerve (L_5–S_1)
Extensor hallucis brevis	Superior surface of anterior calcaneus	Dorsal surface of the base of proximal phalanx of great toe	Extension of great toe	Deep fibular nerve (L_5–S_1)
ADDUCTION/ABDUCTION				
Adductor hallucis	Bases of metatarsal bones II–IV and plantar ligaments	Proximal phalanx of great toe	Adduction at metatarsophalangeal joint of great toe	Lateral plantar nerve (S_1–S_2)
Abductor hallucis	Calcaneus (tuberosity on inferior surface)	Medial side of proximal phalanx of great toe	Abduction at metatarsophalangeal joint of great toe	Medial plantar nerve (L_4–L_5)
Plantar interosseus (3)	Bases and medial sides of metatarsal bones	Medial sides of toes 3–5	Adduction at metatarsophalangeal joints of toes 3–5	Lateral plantar nerve (S_1–S_2)
Dorsal interosseus (4)	Sides of metatarsal bones	Medial and lateral sides of toe 2; lateral sides of toes 3 and 4	Abduction at metatarsophalangeal joints of toes 3 and 4	Lateral plantar nerve (S_1–S_2)
Abductor digiti minimi	As above	Lateral side of proximal phalanx, toe 5	Abduction at metatarsophalangeal joint of toe 5	Lateral plantar nerve (L_4–L_5)

Figure 11–22 **Intrinsic Muscles of the Foot.** ATLAS: Plates 84a; 85a,b; 86c; 87a–c; 89



11

11-7 With advancing age, the size and power of muscle tissue decrease

The effects of aging on the muscular system can be summarized as follows:

- *Skeletal Muscle Fibers Become Smaller in Diameter.* This reduction in size reflects a decrease in the number of myofibrils. In addition, the muscle fibers contain smaller ATP, CP, and glycogen reserves and less myoglobin. The overall effect is a reduction in skeletal muscle size, strength, and endurance, combined with a tendency to fatigue quickly. Because cardiovascular performance also decreases with age, blood flow to active muscles does not increase with exercise as rapidly as it does in younger people. These factors interact to produce decreases of 30–50 percent in anaerobic and aerobic performance by age 65.
- *Skeletal Muscles Become Less Elastic.* Aging skeletal muscles develop increasing amounts of fibrous connective tissue, a process called **fibrosis.** Fibrosis makes the muscle less flexible, and the collagen fibers can restrict movement and circulation.
- *Tolerance for Exercise Decreases.* A lower tolerance for exercise results in part from tiring quickly and in part from reduced thermoregulation described in Chapter 5. p. 160 Individuals over age 65 cannot eliminate the heat their muscles generate during contraction as effectively as younger people can and thus are subject to overheating.
- *The Ability to Recover from Muscular Injuries Decreases.* The number of satellite cells steadily decreases with age, and the amount of fibrous tissue increases. As a result, when an injury occurs, repair capabilities are limited. Scar tissue formation is the usual result.

To be in good shape late in life, you must be in *very* good shape early in life. Regular exercise helps control body weight, strengthens bones, and generally improves the quality of life at all ages. Extremely demanding exercise is not as important as regular exercise. In fact, extreme exercise in the elderly can damage tendons, bones, and joints.

Checkpoint

24. **Describe general age-related effects on skeletal muscle tissue.**
25. **Define fibrosis.**

See the blue Answers tab at the back of the book.

11-8 Exercise produces responses in multiple body systems

To operate at maximum efficiency, the muscular system must be supported by many other systems. The changes that occur during exercise provide a good example of such interaction. As noted earlier, active muscles consume oxygen and generate carbon dioxide and heat. The effects of exercise on various body systems include the following:

- *Cardiovascular System:* Blood vessels in active muscles and the skin dilate, and heart rate increases. These adjustments accelerate oxygen and nutrient delivery to and carbon dioxide removal from the muscle, and bring heat to the skin for radiation into the environment.
- *Respiratory System:* Respiratory rate and depth of respiration increase. Air moves into and out of the lungs more quickly, keeping pace with the increased rate of blood flow through the lungs.
- *Integumentary System:* Blood vessels dilate, and sweat gland secretion increases. This combination increases evaporation at the skin surface and removes the excess heat generated by muscular activity.
- *Nervous and Endocrine Systems:* The above responses of other systems are directed and coordinated through neural and endocrine (hormonal) adjustments in heart rate, respiratory rate, sweat gland activity, and mobilization of stored nutrient reserves.

Even when the body is at rest, the muscular system has extensive interactions with other systems. **Figure 11–23** summarizes the range of interactions between the muscular system and other vital systems studied so far.

Checkpoint

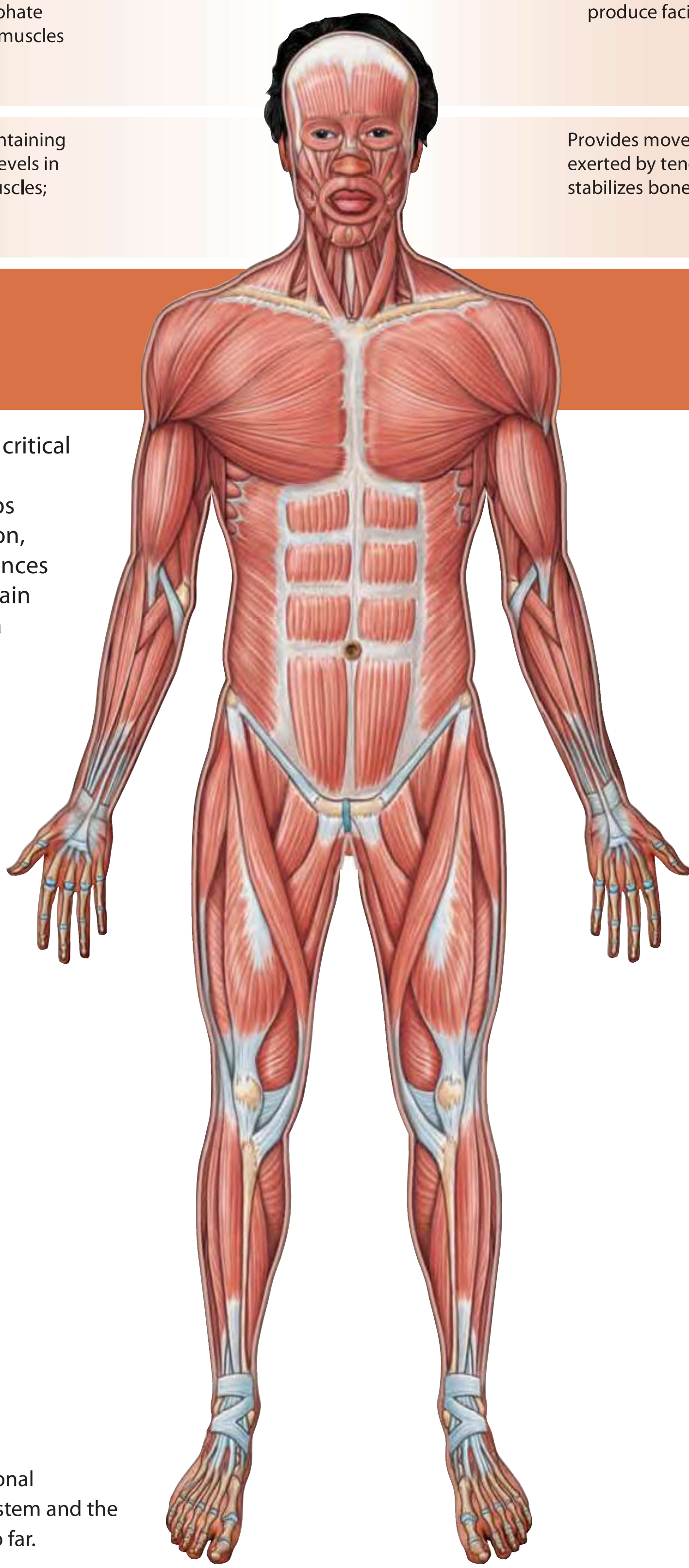
26. **What major function does the muscular system perform for the body as a whole?**
27. **Identify the physiological effects of exercise on the cardiovascular, respiratory, and integumentary systems, and indicate the relationship between those physiological effects and the nervous and endocrine systems.**

See the blue Answers tab at the back of the book.

SYSTEM INTEGRATOR

Body System → Muscular System		Muscular System → Body System	
Integumentary	Removes excess body heat; synthesizes vitamin D_3 for calcium and phosphate absorption; protects underlying muscles	Skeletal muscles pulling on skin of face produce facial expressions	Integumentary Page 165
Skeletal	Provides mineral reserve for maintaining normal calcium and phosphate levels in body fluids; supports skeletal muscles; provides sites of attachment	Provides movement and support; stresses exerted by tendons maintain bone mass; stabilizes bones and joints	Skeletal Page 275

The MUSCULAR System



The muscular system performs six critical functions for the human body. It produces skeletal movement, helps maintain posture and body position, supports soft tissues, guards entrances and exits to the body, helps maintain body temperature, and serves as a store of nutrient reserves.

Nervous Page 543
Endocrine Page 632
Cardiovascular Page 759
Lymphatic Page 807
Respiratory Page 857
Digestive Page 910
Urinary Page 992
Reproductive Page 1072

Figure 11–23 diagrams the functional relationships between the muscular system and the other body systems we have studied so far.

Related Clinical Terms

charley horse: Common name for a muscle spasm, especially in the leg.
compartment syndrome: A condition in which increased pressure within the muscle compartment of a limb produces ischemia or “blood starvation.”
fibromyositis: Chronic illness characterized by widespread musculoskeletal aches, pains, and stiffness, and soft tissue tenderness.
groin pull: An injury that is due to a strain of the muscles of the inner thigh.
impingement syndrome: Pain on elevation of the shoulder due to an injured or inflamed tendon or bursa coming into contact with the overlying acromial process.
physical therapist: Healthcare professional who uses specially designed exercises and equipment to help patients regain or improve their physical abilities.
plantar fascitis: Inflammation of the plantar fascia causing foot or heel pain.
shin-splints: Pain along the shinbone (tibia) caused by an overload on the tibia and connective tissues that connect muscle to the bone.
tenosynovitis: Inflammation of a tendon and the sheath that covers it.
torticollis: A shortening or contraction of the muscles of the neck resulting in the head being tipped to one side with the chin turned to the other side.

Chapter Review

Study Outline

11-1 ◗ Fascicle arrangement is correlated with muscle power and range of motion p. 323

1. Structural variations among skeletal muscles affect their power, range, and speed of movement.
2. A muscle can be classified as a **parallel muscle, convergent muscle, pennate muscle,** or **circular muscle (sphincter)** according to the arrangement of fibers and fascicles in it. A pennate muscle may be *unipennate*, *bipennate*, or *multipennate*. *(Figure 11–1)*

11-2 ◗ The three classes of levers increase muscle efficiency p. 324

3. A **lever** is a rigid structure that moves around a fixed point called the **fulcrum.** Levers can change the direction and effective strength of an applied force, and the distance and speed of the movement such a force produces.
4. Levers are classified as **first-class, second-class,** or **third-class levers.** Third-class levers are the most common levers in the body. *(Figure 11–2)*

11-3 ◗ Muscle origins are at the fixed end of muscles, whereas insertions are at the movable end of muscles p. 326

5. Each muscle can be identified by its *origin*, *insertion*, and *action*.
6. The site of attachment of the fixed end of a muscle is called the **origin;** the site where the movable end of the muscle attaches to another structure is called the **insertion.**
7. The movement produced when a muscle contracts is its **action.**
8. According to the function of its action, a muscle can be classified as an **agonist,** or **prime mover;** an **antagonist;** a **synergist;** or a **fixator.**

11-4 ◗ Descriptive terms are used to name skeletal muscles p. 327

9. The names of muscles commonly provide clues to their body region, origin and insertion, fascicle organization, position, structural characteristics, and action. *(Table 11–1)*
10. The **axial musculature** arises on the axial skeleton; it positions the head and spinal column and moves the rib cage. The **appendicular musculature** stabilizes or moves components of the appendicular skeleton. *(Figure 11–3)*
11. **Innervation** refers to the distribution of nerves that control a region or organ, including a muscle.

11-5 ◗ Axial muscles are muscles of the head and neck, vertebral column, trunk, and pelvic floor p. 332

12. The axial muscles fall into logical groups on the basis of location, function, or both.
13. The main muscles of facial expression are the **orbicularis oris, buccinator,** and **occipitofrontalis** muscles and the **platysma.** *(Figure 11–4; Table 11–2)*
14. Six extrinsic eye muscles (*oculomotor muscles*) control eye movements: the **inferior** and **superior rectus** muscles, the **lateral** and **medial rectus** muscles, and the **inferior** and **superior oblique** muscles. *(Figure 11–5; Table 11–3)*
15. The muscles of mastication (chewing) are the **masseter, temporalis,** and **pterygoid** muscles. *(Figure 11–6; Table 11–4)*
16. The muscles of the tongue are necessary for speech and swallowing and assist in mastication. They are the **palatoglossus, styloglossus, genioglossus,** and **hyoglossus** muscles. *(Figure 11–7; Table 11–5)*
17. The muscles of the pharynx constrict the pharyngeal walls **(pharyngeal constrictors),** elevate the larynx **(laryngeal elevators),** or raise the soft palate **(palatal muscles).** *(Figure 11–8; Table 11–6)*
18. The anterior muscles of the neck control the position of the larynx, depress the mandible, and provide a foundation for the muscles of the tongue and pharynx. The neck muscles include the **digastric** and **sternocleidomastoid** muscles and seven muscles that originate or insert on the hyoid bone. *(Figure 11–9; Table 11–7)*
19. The superficial muscles of the spine can be classified into the **spinalis, longissimus,** and **iliocostalis** groups. *(Figure 11–10; Table 11–8)*

20. Other muscles of the spine include the **longus capitis** and **longus colli** muscles of the neck, the small intervertebral muscles of the deep layer, and the **quadratus lumborum** muscle of the lumbar region. *(Figure 11–10; Table 11–8)*
21. The oblique muscles include the **scalene** muscles and the **intercostal** and **transversus** muscles. The **external** and **internal intercostal** muscles are important in respiratory (breathing) movements of the ribs. Also important to respiration is the **diaphragm.** *(Figures 11–10, 11–11; Table 11–9)*
22. The **perineum** can be divided into an anterior **urogenital triangle** and a posterior **anal triangle.** The pelvic floor consists of the **urogenital diaphragm** and the **pelvic diaphragm.** *(Figure 11–12; Table 11–10)*

11-6 Appendicular muscles are muscles of the shoulders, upper limbs, pelvic girdle, and lower limbs p. 347

23. The **trapezius** muscle affects the positions of the shoulder girdle, head, and neck. Other muscles inserting on the scapula include the **rhomboid, levator scapulae, serratus anterior, subclavius,** and **pectoralis minor** muscles. *(Figures 11–13, 11–15; Table 11–11)*
24. The **deltoid** and the **supraspinatus** muscles are important abductors. The **subscapularis** and **teres major** muscles produce medial rotation at the shoulder; the **infraspinatus** and **teres minor** muscles produce lateral rotation; and the **coracobrachialis** muscle produces flexion and adduction at the shoulder. *(Figures 11–13, 11–14, 11–15; Table 11–12)*
25. The **pectoralis major** muscle flexes the shoulder joint, and the **latissimus dorsi** muscle extends it. *(Figures 11–13, 11–14, 11–15; Table 11–12)*
26. The actions of the **biceps brachii** muscle and the **triceps brachii** muscle (long head) affect the elbow joint. The **brachialis** and **brachioradialis** muscles flex the elbow, opposed by the **anconeus** muscle. The **flexor carpi ulnaris, flexor carpi radialis,** and **palmaris longus** muscles cooperate to flex the wrist. The **extensor carpi radialis** muscles and the **extensor carpi ulnaris** muscle oppose them. The **pronator teres** and **pronator quadratus** muscles pronate the forearm and are opposed by the **supinator** muscle. *(Figures 11–15 to 11–18; Tables 11–13 to 11–15)*
27. **Gluteal muscles** cover the lateral surfaces of the ilia. The largest is the **gluteus maximus** muscle, which shares an insertion with the **tensor fasciae latae.** Together, these muscles pull on the **iliotibial tract.** *(Figures 11–13, 11–19; Table 11–16)*
28. The **piriformis** muscle and the **obturator** muscles are the most important **lateral rotators.** The **adductors** can produce a variety of movements. *(Figure 11–19; Table 11–16)*
29. The **psoas major** and **iliacus** muscles merge to form the **iliopsoas** muscle, a powerful flexor of the hip. *(Figures 11–19, 11–20; Table 11–16)*
30. The flexors of the knee include the **biceps femoris, semimembranosus,** and **semitendinosus** muscles (the three **hamstrings**) and the **sartorius** muscle. The **popliteus** muscle unlocks the knee joint. *(Figures 11–20, 11–21; Table 11–17)*
31. Collectively, the knee extensors are known as the **quadriceps femoris.** This group consists of the three **vastus** muscles (intermedius, lateralis, medialis) and the **rectus femoris** muscle. *(Figure 11–20; Table 11–17)*
32. The **gastrocnemius** and **soleus** muscles produce plantar flexion (ankle extension). A pair of **fibularis** muscles produces eversion as well as extension (plantar flexion) at the ankle. *(Figure 11–21; Table 11–18)*
33. Smaller muscles of the calf and shin position the foot and move the toes. Muscles originating at the tarsal and metatarsal bones provide precise control of the phalanges. *(Figure 11–22; Table 11–19)*

11-7 With advancing age, the size and power of muscle tissue decrease p. 368

34. With advanced age, the size and power of all muscle tissues decrease. Skeletal muscles undergo **fibrosis,** the tolerance for exercise decreases, and repair of injuries slows.

11-8 Exercise produces responses in multiple body systems p. 368

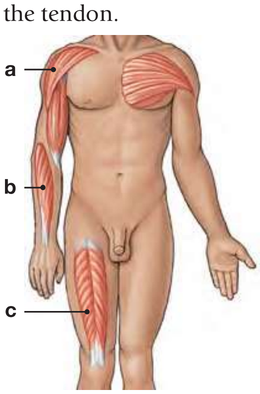
35. Exercise illustrates the integration of the muscular system with the cardiovascular, respiratory, integumentary, nervous, and endocrine systems. *(Figure 11–23)*

Review Questions

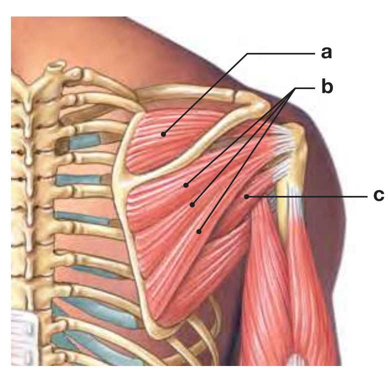
See the blue Answers tab at the back of the book.

LEVEL 1 Reviewing Facts and Terms

1. Name the three pennate muscles in the following figure, and for each muscle indicate the type of pennate muscle based on the relationship of muscle fibers to the tendon.
(a) ____________
____
(b) ____________
____
(c) ____________
____



2. Label the three visible muscles of the rotator cuff in the following posterior view of the deep muscles that move the arm.
(a) ____________
(b) ____________
(c) ____________



3. The bundles of muscle fibers within a skeletal muscle are called
   (a) muscles.
   (b) fascicles.
   (c) fibers.
   (d) myofilaments.
   (e) groups.
4. Levers make muscle action more versatile by all of the following, *except*
   (a) changing the location of the muscle's insertion.
   (b) changing the speed of movement produced by an applied force.
   (c) changing the distance of movement produced by an applied force.
   (d) changing the strength of an applied force.
   (e) changing the direction of an applied force.
5. The more movable end of a muscle is the
   (a) insertion.
   (b) belly.
   (c) origin.
   (d) proximal end.
   (e) distal end.
6. The muscles of facial expression are innervated by cranial nerve
   (a) VII.
   (b) V.
   (c) IV.
   (d) VI.
7. The strongest masticatory muscle is the ___________ muscle.
   (a) pterygoid
   (b) masseter
   (c) temporalis
   (d) mandible
8. The muscle that rotates the eye medially is the ___________ muscle.
   (a) superior oblique
   (b) inferior rectus
   (c) medial rectus
   (d) lateral rectus
9. Important flexors of the vertebral column that act in opposition to the erector spinae are the ___________ muscles.
   (a) rectus abdominis
   (b) longus capitis
   (c) longus colli
   (d) scalene
10. The major extensor of the elbow is the ___________ muscle.
    (a) triceps brachii
    (b) biceps brachii
    (c) deltoid
    (d) subscapularis
11. The muscles that rotate the radius without producing either flexion or extension of the elbow are the ___________ muscles.
    (a) brachialis and brachioradialis
    (b) pronator teres and supinator
    (c) biceps brachii and triceps brachii
    (d) a, b, and c
12. The powerful flexors of the hip are the ___________ muscles.
    (a) piriformis
    (b) obturator
    (c) pectineus
    (d) iliopsoas
13. Knee extensors known as the quadriceps consist of the
    (a) three vastus muscles and the rectus femoris muscle.
    (b) biceps femoris, gracilis, and sartorius muscles.
    (c) popliteus, iliopsoas, and gracilis muscles.
    (d) gastrocnemius, tibialis, and peroneus muscles.
14. List the four fascicle organizations that produce the different patterns of skeletal muscles.
15. What is an aponeurosis? Give two examples.
16. Which four muscle groups make up the axial musculature?
17. What three functions are accomplished by the muscles of the pelvic floor?
18. On which bones do the four rotator cuff muscles originate and insert?
19. What three functional groups make up the muscles of the lower limbs?

LEVEL 2 Reviewing Concepts

20. Of the following actions, the one that illustrates that of a second-class lever is
    (a) knee extension.
    (b) ankle extension (plantar flexion).
    (c) flexion at the elbow.
    (d) a, b, and c.
21. Compartment syndrome can result from all of the following *except*
    (a) compressing a nerve in the wrist.
    (b) compartments swelling with blood due to an injury involving blood vessels.
    (c) torn ligaments in a given compartment.
    (d) pulled tendons in the muscles of a given compartment.
    (e) torn muscles in a particular compartment.
22. A(n) ___________ develops when an organ protrudes through an abnormal opening.
23. Elongated bursae that reduce friction and surround the tendons that cross the dorsal and ventral surfaces of the wrist form ___________.
24. The muscles of the vertebral column include many dorsal extensors but few ventral flexors. Why?
25. Why does a convergent muscle exhibit more versatility when contracting than does a parallel muscle?
26. Why can a pennate muscle generate more tension than can a parallel muscle of the same size?
27. Why is it difficult to lift a heavy object when the elbow is at full extension?
28. Which types of movements are affected when the hamstrings are injured?

LEVEL 3 Critical Thinking and Clinical Applications

29. Mary sees Jill coming toward her and immediately contracts her frontalis and procerus muscles. She also contracts her right levator labii muscles. Is Mary glad to see Jill? How can you tell?
30. Mary's newborn is having trouble suckling. The doctor suggests that it may be a problem with a particular muscle. What muscle is the doctor probably referring to?
    (a) orbicularis oris
    (b) buccinator
    (c) masseter
    (d) risorius
    (e) zygomaticus
31. While unloading her car trunk, Amy pulls a muscle and as a result has difficulty moving her arm. The doctor in the emergency room tells her that she pulled her pectoralis major. Amy tells you that she thought the pectoralis major was a chest muscle and doesn't understand what that has to do with her arm. What would you tell her?

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