

Although they somewhat resemble neurons structurally (both cell types have cell extensions), glia are not able to transmit nerve impulses, a function that is highly developed in neurons. Another important difference is that glia never lose their ability to divide, whereas most neurons do. Consequently, most brain tumors are *gliomas*, or tumors formed by glial cells (neuroglia).

Supporting cells in the PNS come in two major varieties—Schwann cells and satellite cells (Figure 7.3e). **Schwann cells** form the myelin sheaths around nerve fibers that are found in the PNS. **Satellite cells** act as protective, cushioning cells.

Neurons

Anatomy

Neurons, also called **nerve cells**, are highly specialized to transmit messages (nerve impulses) from one part of the body to another. Although neurons differ structurally, they have many common features (Figure 7.4). All have a cell body, which contains the nucleus and is the metabolic center of the cell, and one or more slender processes extending from the cell body.

The **cell body** is the metabolic center of the neuron. It contains the usual organelles except for centrioles (which confirms the amitotic nature of most neurons). The rough ER, called **Nissl** (nis'l) **substance**, and **neurofibrils**, intermediate filaments that are important in maintaining cell shape, are particularly abundant in the cell body.

The armlike **processes**, or **fibers**, vary in length from microscopic to 3 to 4 feet. The longest ones in humans reach from the lumbar region of the spine to the great toe. Neuron processes that convey incoming messages (electrical signals) *toward* the cell body are **dendrites** (den'drītz), whereas those that generate nerve impulses and typically conduct them *away* from the cell body are **axons** (ak'sonz). Neurons may have hundreds of the branching dendrites (*dendr* = tree), depending on the neuron type, but each neuron has only one axon, which arises from a conelike region of the cell body called the **axon hillock**.

An occasional axon gives off a *collateral branch* along its length, but all axons branch profusely at their terminal end, forming hundreds to thousands of **axon terminals**. These terminals contain hundreds of tiny vesicles, or membranous sacs, that contain chemicals called **neurotransmitters**.

As we said, axons transmit nerve impulses away from the cell body. When these impulses reach the axon terminals, they stimulate the release of neurotransmitters into the extracellular space.

Each axon terminal is separated from the next neuron by a tiny gap called the **synaptic** (sī-nap'tik) **cleft**. Such a functional junction is called a **synapse** (*syn* = to clasp or join). Although they are close, neurons never actually touch other neurons. We will learn more about synapses and the events that occur there a bit later.

Most long nerve fibers are covered with a whitish, fatty material, called **myelin** (mi'ě-lin), which has a waxy appearance. Myelin protects and insulates the fibers and increases the transmission rate of nerve impulses. Axons outside the CNS are myelinated by **Schwann cells**, specialized supporting cells that wrap themselves tightly around the axon jelly-roll fashion (Figure 7.5). When the wrapping process is done, a tight coil of wrapped membranes, the **myelin sheath**, encloses the axon. Most of the Schwann cell cytoplasm ends up just beneath the outermost part of its plasma membrane. This part of the Schwann cell, external to the myelin sheath, is called the **neurilemma** (nu'rī-lem'mah, “neuron husk”). Since the myelin sheath is formed by many individual Schwann cells, it has gaps or indentations, called **nodes of Ranvier** (rahn-vēr), at regular intervals (see Figure 7.4).

Myelinated fibers are also found in the central nervous system. However, there it is oligodendrocytes that form CNS myelin sheaths (see Figure 7.3d). In contrast to Schwann cells, each of which deposits myelin around a small segment of one nerve fiber, the oligodendrocytes with their many flat extensions can coil around as many as 60 different fibers at the same time. Although the myelin sheaths formed by oligodendrocytes and those formed by Schwann cells are quite similar, the CNS sheaths lack a neurilemma. Because the neurilemma remains intact (for the most part) when a peripheral nerve fiber is damaged, it plays an important role in fiber regeneration, an ability that is largely lacking in the central nervous system.

Homeostatic Imbalance

The importance of the myelin insulation to nerve transmission is best illustrated by observing what happens when it is not there. In people with *multiple sclerosis (MS)*, the myelin sheaths around the fibers are gradually destroyed, converted to hardened

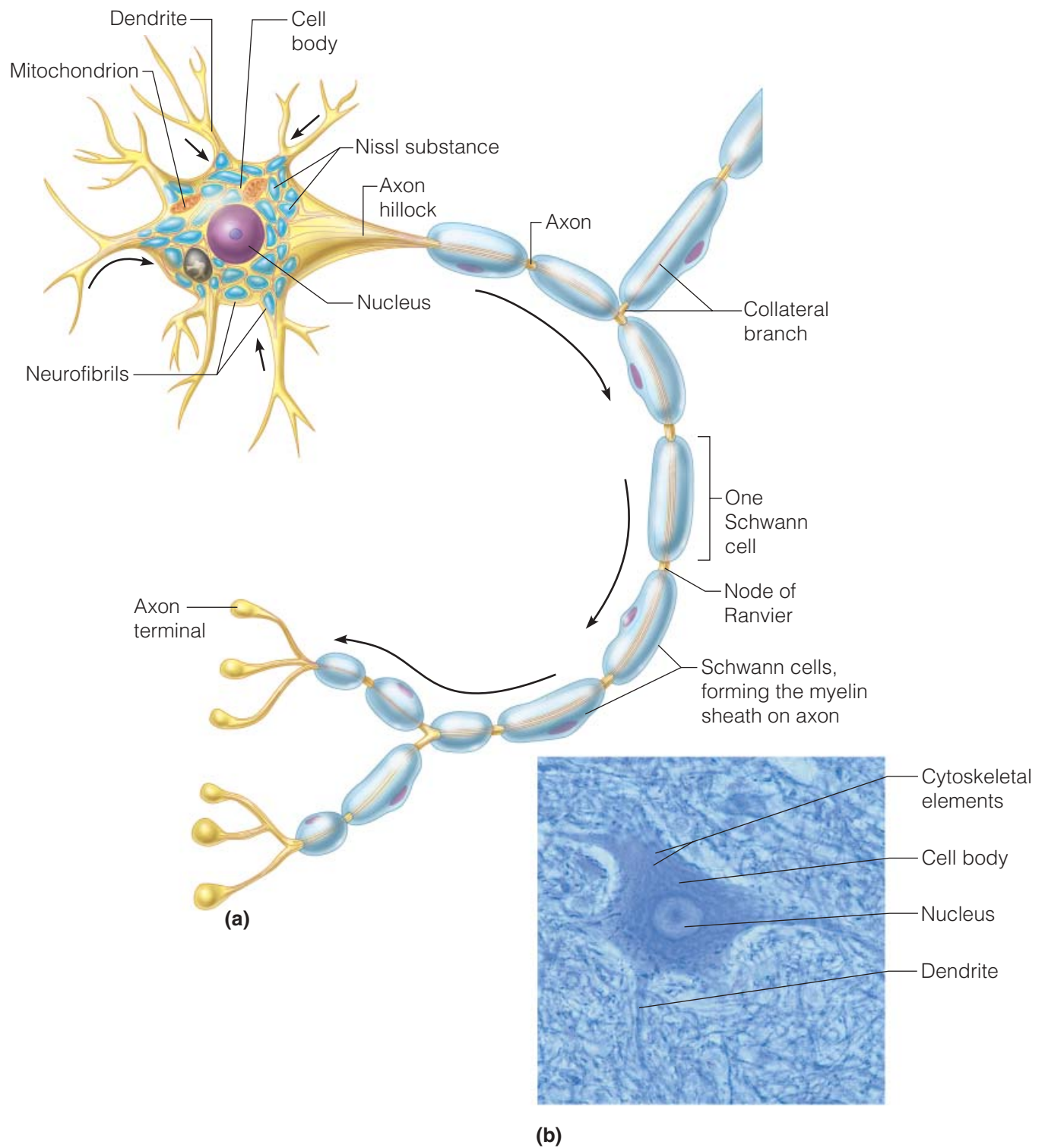


FIGURE 7.4 Structure of a typical motor neuron. (a) Diagrammatic view. (b) Photomicrograph (265×).

Q Why does the myelin sheath that is produced by Schwann cells have gaps in it?

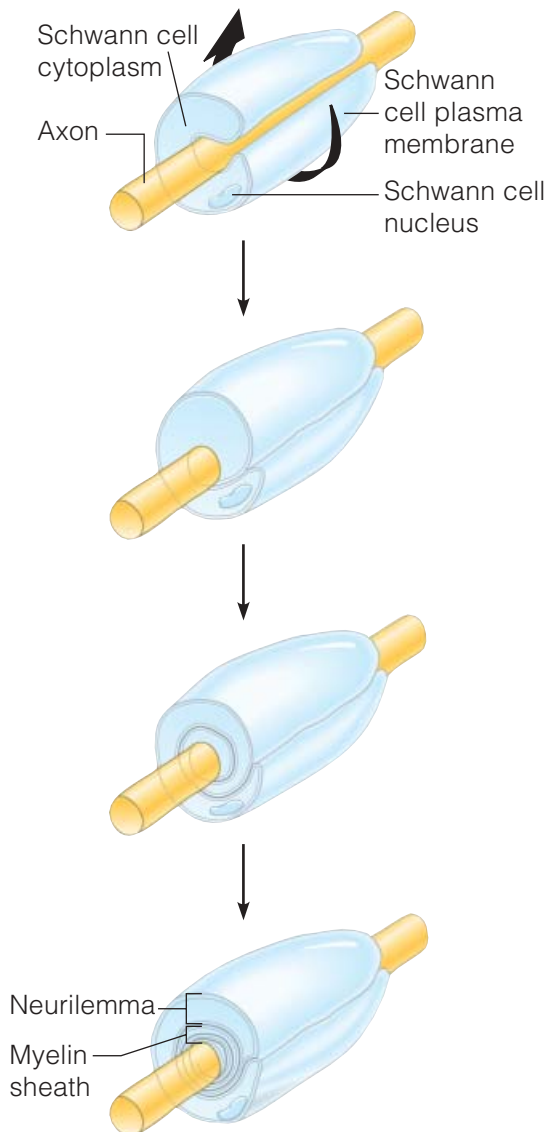


FIGURE 7.5 Relationship of Schwann cells to axons in the peripheral nervous system. As illustrated (top to bottom), a Schwann cell envelops part of an axon in a trough and then rotates around the axon. Most of the Schwann cell cytoplasm comes to lie just beneath the exposed part of its plasma membrane. The tight coil of plasma membrane material surrounding the axon is the myelin sheath. The Schwann cell cytoplasm and exposed membrane are referred to as the *neurilemma*.

A

Because the sheath is produced by several Schwann cells that arrange themselves end to end along the nerve fiber, each Schwann cell forming only one tiny segment of the sheath.

sheaths called *scleroses*. As this happens, the current is short-circuited, and the affected person loses the ability to control his or her muscles and becomes increasingly disabled. Multiple sclerosis is an autoimmune disease in which a protein component of the sheath is attacked. As yet there is no cure, but injections of interferon (a hormonelike substance released by some immune cells) and oral doses of bovine myelin appear to provide some relief. ▲

Clusters of neuron cell bodies and collections of nerve fibers are named differently when they are in the CNS than when they are part of the PNS. For the most part, cell bodies are found in the CNS in clusters called **nuclei**. This well-protected location within the bony skull or vertebral column is essential to the well-being of the nervous system—remember that neurons do not routinely undergo cell division after birth. The cell body carries out most of the metabolic functions of a neuron, so if it is damaged the cell dies and is not replaced. Small collections of cell bodies called **ganglia** (gang'le-ah; **ganglion**, singular) are found in a few sites outside the CNS in the PNS. Bundles of nerve fibers (neuron processes) running through the CNS are called **tracts**, whereas in the PNS they are called **nerves**. The terms *white matter* and *gray matter* refer respectively to myelinated versus unmyelinated regions of the CNS. As a general rule, the **white matter** consists of dense collections of myelinated fibers (tracts), and **gray matter** contains mostly unmyelinated fibers and cell bodies.

Classification

Neurons may be classified either according to how they function or according to their structure.

Functional Classification Functional classification groups neurons according to the direction the nerve impulse is traveling relative to the CNS. On this basis, there are sensory, motor, and association neurons (Figure 7.6). Neurons carrying impulses from sensory receptors (in the internal organs or the skin) to the CNS are **sensory**, or **afferent, neurons**. (*Afferent* literally means “to go toward.”) The *cell bodies* of sensory neurons are always found in a *ganglion* outside the CNS. Sensory neurons keep us informed about what is happening both inside and outside the body.

The *dendrite* endings of the sensory neurons are usually associated with specialized **receptors** that are activated by specific changes occurring

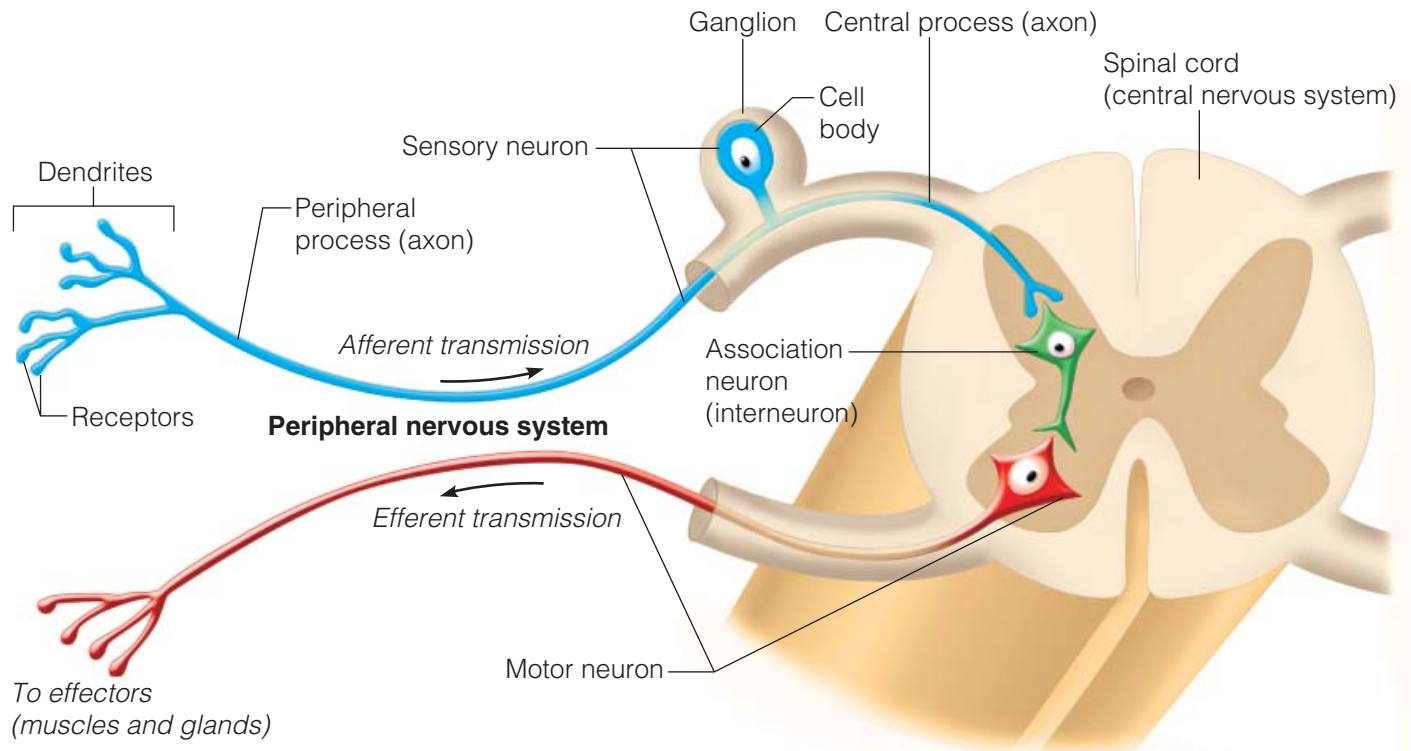


FIGURE 7.6 Neurons classified by function. Sensory (afferent) neurons conduct impulses from sensory receptors (in the skin, viscera, muscles) to the central nervous system; most cell bodies are in ganglia in the PNS. Motor (efferent) neurons transmit impulses from the CNS (brain or spinal cord) to effectors in the body periphery. Association neurons (interneurons) complete the communication pathway between sensory and motor neurons; their cell bodies reside in the CNS.

nearby. The very complex receptors of the special sense organs (vision, hearing, equilibrium, taste, and smell) are covered separately in Chapter 8. The simpler types of sensory receptors seen in the skin (**cutaneous sense organs**) and in the muscles and tendons (**proprioceptors** [pro"pre-o-sep'torz]) are shown in Figure 7.7. The pain receptors (actually bare dendrite endings) are the least specialized of the cutaneous receptors. They are also the most numerous, because pain warns us that some type of body damage is occurring or is about to occur. However, strong stimulation of any of the cutaneous receptors (for example, by searing heat, extreme cold, or excessive pressure) is also interpreted as pain.

The proprioceptors detect the amount of stretch, or tension, in skeletal muscles, their tendons, and joints. They send this information to the brain so

that the proper adjustments can be made to maintain balance and normal posture. *Propria* comes from the Latin word meaning "one's own," and the proprioceptors constantly advise our brain of our own movements.

Neurons carrying impulses from the CNS to the viscera and/or muscles and glands are **motor**, or **efferent**, **neurons** (see Figure 7.6). The cell bodies of motor neurons are always located in the CNS.

The third category of neurons is the **association neurons**, or **interneurons**. They connect the motor and sensory neurons in neural pathways. Like the motor neurons, their cell bodies are always located in the CNS.

Structural Classification Structural classification is based on the number of processes extending from

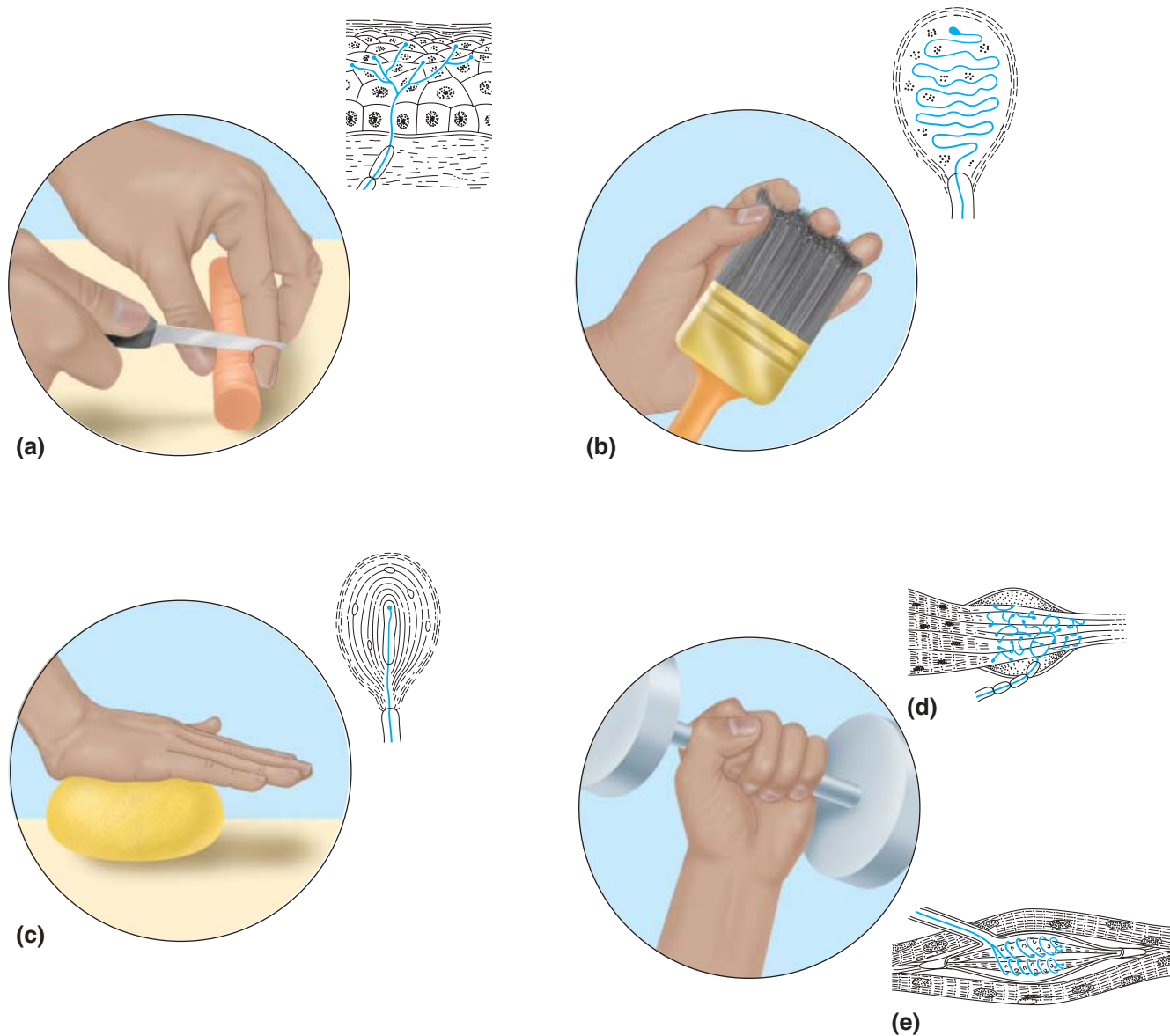


FIGURE 7.7 Types of sensory receptors. **(a)** Naked nerve endings (pain and temperature receptors). **(b)** Meissner's corpuscle (touch receptor). **(c)** Pacinian corpuscle (deep pressure receptor). **(d)** Golgi tendon organ (proprioceptor). **(e)** Muscle spindle (proprioceptor).

the cell body (Figure 7.8). If there are several, the neuron is a **multipolar neuron**. Since all motor and association neurons are multipolar, this is the most common structural type. Neurons with two processes—an axon and a dendrite—are called **bipolar neurons**. Bipolar neurons are rare in adults, found only in some special sense organs (eye, nose), where they act in sensory processing as receptor cells. **Unipolar neurons** have a single process emerging from the cell body. However,

it is very short and divides almost immediately into proximal (central) and distal (peripheral) processes. Unipolar neurons are unique in that only the small branches at the end of the peripheral process are dendrites. The remainder of the peripheral process and the central process function as axons; thus, in this case, the axon conducts nerve impulses both toward *and* away from the cell body. Sensory neurons found in PNS ganglia are unipolar.