



(Objective Checklist, continued)

### **CENTRAL NERVOUS SYSTEM (pp. 235–249)**

- Identify and indicate the functions of the major regions of the cerebral hemispheres, diencephalon, brain stem, and cerebellum on a human brain model or diagram.
- Name the three meningeal layers, and state their functions.
- Discuss the formation and function of cerebrospinal fluid and the blood-brain barrier.
- Compare the signs of a CVA with those of Alzheimer's disease; of a contusion with those of a concussion.
- Define *EEG*, and explain how it evaluates neural functioning.
- List two important functions of the spinal cord.
- Describe spinal cord structure.

### **PERIPHERAL NERVOUS SYSTEM (pp. 249–263)**

- Describe the general structure of a nerve.
- Identify the cranial nerves by number and by name, and list the major functions of each.
- Describe the origin and fiber composition of (a) ventral and dorsal roots, (b) the spinal nerve proper, and (c) ventral and dorsal rami.
- Discuss the distribution of the dorsal and ventral rami of spinal nerves.
- Name the four major nerve plexuses, give the major nerves of each, and describe their distribution.
- Identify the site of origin, and explain the function of the sympathetic and parasympathetic divisions of the autonomic nervous system.
- Contrast the effect of the parasympathetic and sympathetic divisions on the following organs: heart, lungs, digestive system, blood vessels.

### **DEVELOPMENTAL ASPECTS OF THE NERVOUS SYSTEM (pp. 263–266)**

- List several factors that may have harmful effects on brain development.
- Briefly describe the cause, signs, and consequences of the following congenital disorders: spina bifida, anencephaly, and cerebral palsy.
- Explain the decline in brain size and weight that occurs with age.
- Define *senility*, and list some possible causes.

You are driving down the freeway, and a horn blares on your right. You swerve to your left. Charlie leaves a note on the kitchen table: “See you later—have the stuff ready at 6.” You know that the “stuff” is chili with taco chips. You are dozing, and your infant son makes a soft cry. Instantly, you awaken. What do all these events have in common? They are all everyday examples of the functioning of your nervous system, which has your body cells humming with activity nearly all the time.

The **nervous system** is the master controlling and communicating system of the body. Every thought, action, and emotion reflects its activity. Its signaling device, or means of communicating with body cells, is electrical impulses, which are rapid and specific and cause almost immediate responses.

To carry out its normal role, the nervous system has three overlapping functions (Figure 7.1): (1) Much like a sentry, it uses its millions of sensory receptors to *monitor changes* occurring both

inside and outside the body. These changes are called *stimuli*, and the gathered information is called **sensory input**. (2) It *processes and interprets* the sensory input and makes decisions about what should be done at each moment—a process called **integration**. (3) It then *effects a response* by activating muscles or glands (effectors) via **motor output**. An example will illustrate how these functions work together. When you are driving and see a red light just ahead (sensory input), your nervous system integrates this information (red light means “stop”) and sends motor output to the muscles of your right leg and foot, and your foot goes for the brake pedal (the response).

The nervous system does not work alone to regulate and maintain body homeostasis; the endocrine system is a second important regulating system. While the nervous system controls with rapid electrical nerve impulses, the endocrine system organs produce hormones that are released into the blood. Thus, the endocrine system typically brings about its effects in a more leisurely way.

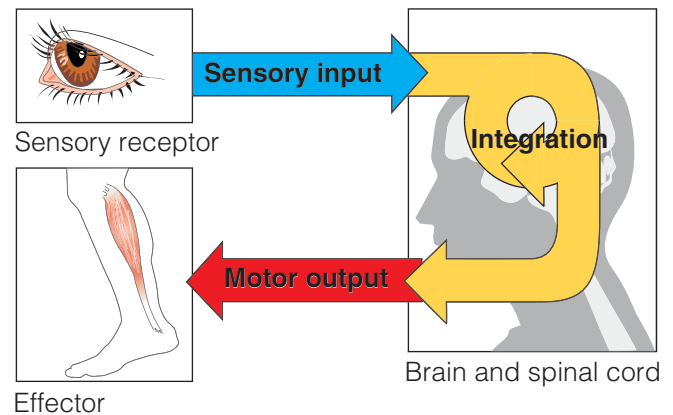
## Organization of the Nervous System

We have only one nervous system, but, because of its complexity, it is difficult to consider all its parts at the same time. So, to simplify its study, we divide it in terms of its structures (structural classification) or in terms of its activities (functional classification). Each of these classification schemes is described briefly below, and their relationships are illustrated in Figure 7.2. It is not necessary to memorize this whole scheme now, but as you are reading the descriptions, try to get a “feel” for the major parts and how they fit together. This will make your learning task easier as you make your way through this chapter. Later you will meet all these terms and concepts again and in more detail.

### Structural Classification

The structural classification, which includes all nervous system organs, has two subdivisions—the central nervous system and the peripheral nervous system (see Figure 7.2).

The **central nervous system (CNS)** consists of the brain and spinal cord, which occupy the dorsal body cavity and act as the integrating and



**FIGURE 7.1** The nervous system's functions.

command centers of the nervous system. They interpret incoming sensory information and issue instructions based on past experience and current conditions.

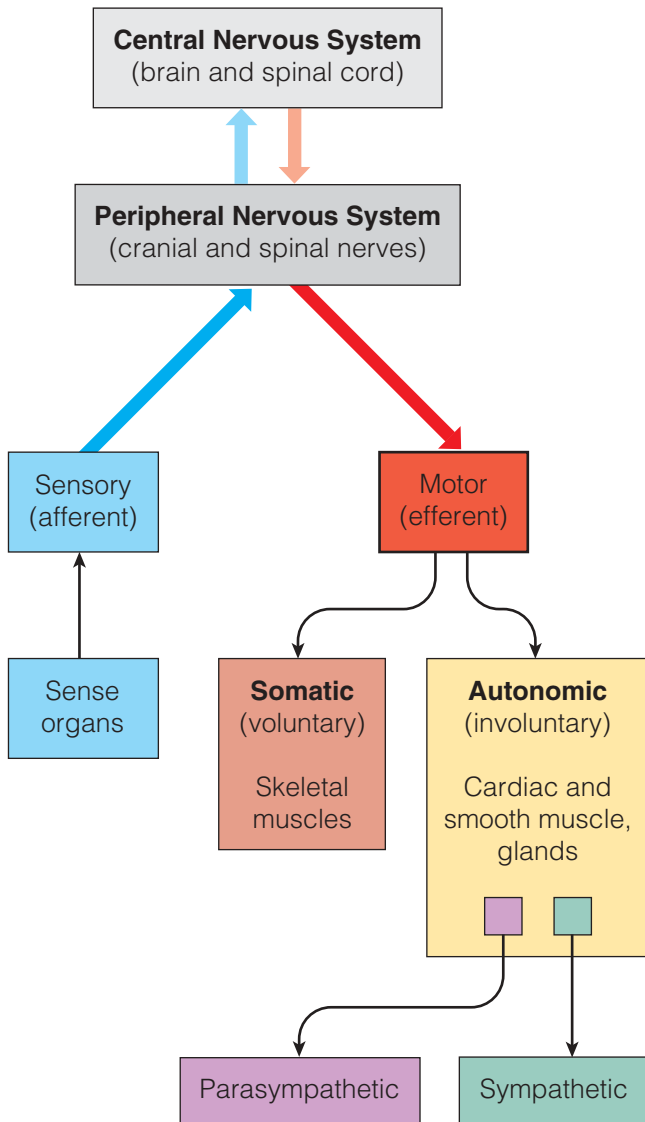
The **peripheral** (pě-rif'er-al) **nervous system (PNS)**, the part of the nervous system outside the CNS, consists mainly of the nerves that extend from the brain and spinal cord. *Spinal nerves* carry impulses to and from the spinal cord. *Cranial* (kra'ne-al) *nerves* carry impulses to and from the brain. These nerves serve as communication lines. They link all parts of the body by carrying impulses from the sensory receptors to the CNS and from the CNS to the appropriate glands or muscles.

The organs making up the CNS and PNS are discussed at length later in this chapter.

### Functional Classification

The functional classification scheme is concerned only with PNS structures. It divides them into two principal subdivisions (see Figure 7.2).

The **sensory**, or **afferent** (af'er-ent), **division** consists of nerve fibers that convey impulses to the central nervous system from sensory receptors located in various parts of the body. Sensory fibers delivering impulses from the skin, skeletal muscles, and joints are called *somatic* (*soma* = body) *sensory* (afferent) *fibers*, whereas those transmitting impulses from the visceral organs are called *visceral sensory fibers*, or *visceral afferents*. The sensory division keeps the CNS constantly informed of events going on both inside and outside the body.



**FIGURE 7.2 Organization of the nervous system.** Organizational flowchart showing that the central nervous system receives input via sensory fibers and issues commands via motor fibers. The sensory and motor fibers together form the nerves that constitute the peripheral nervous system.

The **motor**, or **efferent** (ef'er-rent), **division** carries impulses *from* the CNS to effector organs, the muscles and glands. These impulses activate muscles and glands; that is, they *effect* (bring about) a motor response.

The motor division in turn has two subdivisions (see Figure 7.2):

1. The **somatic** (so-mat'ik) **nervous system** allows us to consciously, or voluntarily, control

our skeletal muscles. Hence, this subdivision is often referred to as the **voluntary nervous system**. However, not all skeletal muscle activity controlled by this motor division is voluntary. Skeletal muscle reflexes, like the stretch reflex for example, are initiated involuntarily by these same fibers.

2. The **autonomic** (aw"to-nom'ik) **nervous system (ANS)** regulates events that are automatic, or involuntary, such as the activity of smooth and cardiac muscles and glands. This subdivision, commonly called the **involuntary nervous system**, itself has two parts, the *sympathetic* and *parasympathetic*, which typically bring about opposite effects. What one stimulates, the other inhibits. These will be described later.

Although it is simpler to study the nervous system in terms of its subdivisions, you should recognize that these subdivisions are made for the sake of convenience only. Remember that the nervous system acts as a coordinated unit, both structurally and functionally.

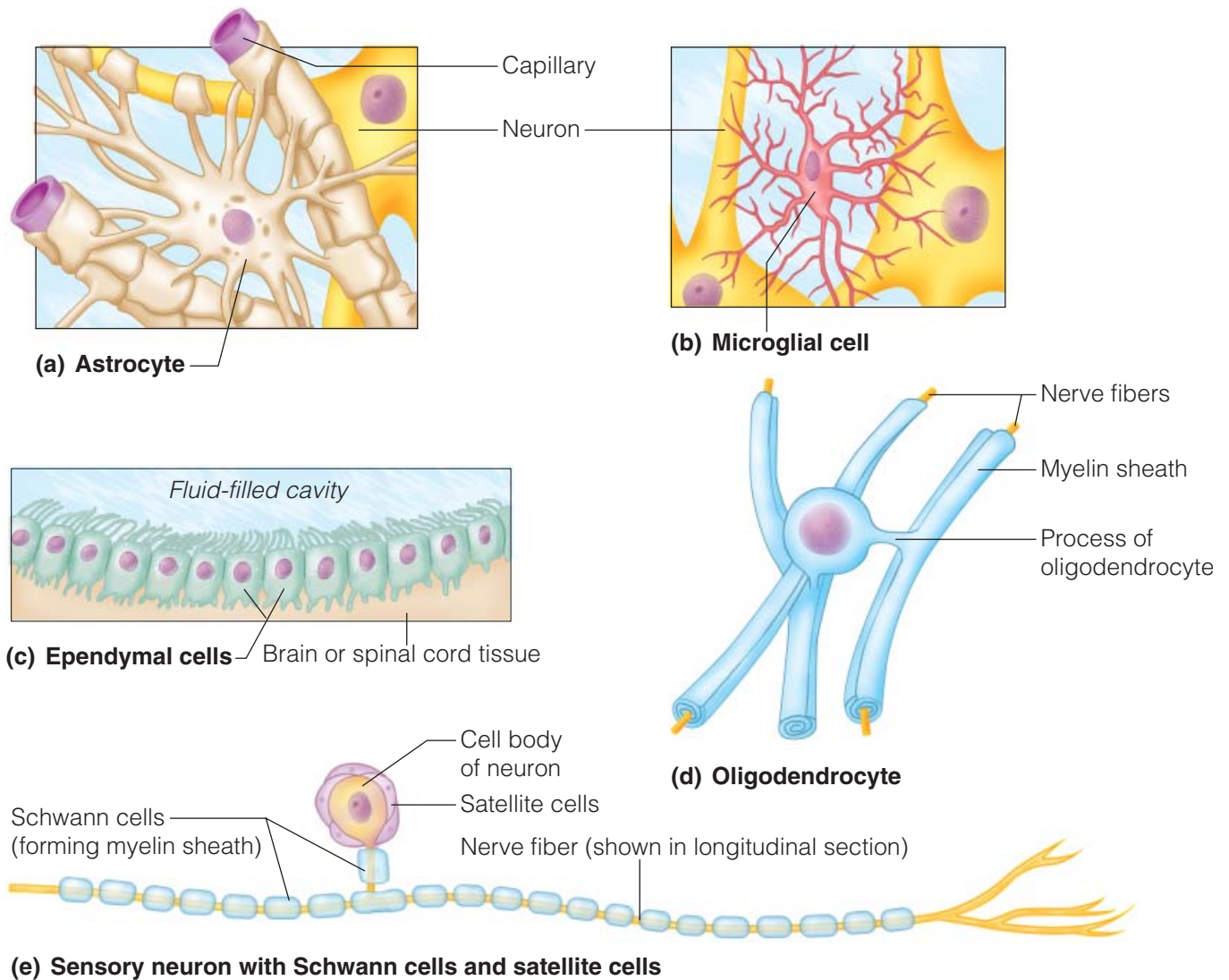
## Nervous Tissue: Structure and Function

Even though it is complex, nervous tissue is made up of just two principal types of cells—*supporting cells* and *neurons*.

### Supporting Cells

Supporting cells in the CNS are “lumped together” as **neuroglia** (nu-rog'le-ah), literally, “nerve glue.” Neuroglia includes many types of cells that generally support, insulate, and protect the delicate neurons (Figure 7.3). In addition, each of the different types of neuroglia, also simply called **glia** (gle'ah) or glial cells, has special functions. The CNS glia include:

- **Astrocytes:** abundant star-shaped cells that account for nearly half of the neural tissue. Their numerous projections have swollen ends that cling to neurons, bracing them and anchoring them to their nutrient supply lines, the blood capillaries (Figure 7.3a). Astrocytes form a living barrier between capillaries and neurons and play a role in making exchanges between the two. In this way, they help protect the neurons from harmful substances that might be in the



**FIGURE 7.3 Supporting (glial) cells of nervous tissues.** Astrocytes (a) form a living barrier between neurons and capillaries in the CNS. Microglia (b) are phagocytes, whereas ependymal cells (c) line the fluid-filled cavities of the CNS. The oligodendrocytes (d) form myelin sheaths around nerve fibers in the CNS. (e) The relationship of Schwann cells (myelinating cells) and satellite cells to a neuron in the peripheral nervous system.

blood. Astrocytes also help control the chemical environment in the brain by picking up excess ions and recapturing released neurotransmitters.

- **Microglia** (mi-krog'le-ah): spiderlike phagocytes that dispose of debris, including dead brain cells and bacteria (Figure 7.3b).
- **Ependymal** (ě-pen'dī-mal) **cells**: these glial cells line the cavities of the brain and the spinal

cord (Figure 7.3c). The beating of their cilia helps to circulate the cerebrospinal fluid that fills those cavities and forms a protective cushion around the CNS.

- **Oligodendrocytes** (ol'ī-go-den'dro-sītz): glia that wrap their flat extensions tightly around the nerve fibers, producing fatty insulating coverings called *myelin sheaths* (Figure 7.3d).



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