CHAPTER 1

Introduction to the Nervous System

The human nervous system is an extremely efficient, compact, fast, and reliable computing system that performs at an incredible capacity. In fact, at this point it has the capability of performing tasks that are far beyond the abilities of any artificial intelligence as yet devised. The present textbook discusses not only the anatomy of the central nervous system but also its function, making it a textbook dealing with the subject of **neurobiology**. In case the reader wonders why one should study this subject matter, it should be recalled that it is our central nervous system more than anything else about us that makes us what we are, human beings.

The nervous system is subdivided, *morphologically*, into two compartments, the **central nervous system** (**CNS**) and the **peripheral nervous system** (**PNS**). The CNS is composed of the brain and spinal cord, whereas the PNS, as a physical extension of the CNS, is composed of ganglia as well as cranial and spinal nerve fibers. *Functionally*, the nervous system is also subdivided into two components, the **somatic nervous system**, which is under the individual's conscious control, and the **autonomic nervous system**, which controls the myriad of unconscious activities in conjunction with the voluntary nervous system. The autonomic nervous system is a tripartite organization, in that it has a **sympathetic**, a **parasympathetic**, and an **enteric** component. Simply stated, the first initiates the "flight or fight or freeze or fornicate" response, the second is concerned with the body's vegetative activities, whereas the enteric nervous system is involved in regulating the processes of digestion. It must be understood, however, that the interplay of these three systems maintains **homeostasis**. The autonomic nervous system acts upon three cell types to perform its functions, namely cells of glands, smooth muscle cells, and cardiac muscle cells. The nervous system has two other functional components, **sensory** and **motor**. The sensory component collects information and transmits it to the CNS (and is therefore called **afferent**), where the information is sorted, analyzed, and processed. Generally speaking, the motor component delivers the results of the analyses away from the CNS (and is therefore called **efferent**) to the effector organs, that is, muscles (all three types: skeletal, smooth, and cardiac) and glands, resulting in a response to the stimulus.

Discussion of the topics of neuroanatomy requires that the student be familiar with some of the specialized terminology

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Companion website: www.wiley.com/go/patestas/neuroanatomy3e

Terms	Definition
Arcuate	Arc-like, resembles a segment of a circle
Bilateral	On both sides
Bipolar neuron	A neuron with a single axon and a single dendrite; usually arising on opposite sides of the soma (e.g., neurons in the olfactory mucosa)
Brainstem	Originally this term referred to the entire brain with the exception of the telencephalon; currently, most neuroanatomists refer to the medulla oblongata, pons, and midbrain as the brainstem
Inferior	Toward the tail (proceeding to a lower position; the opposite of cranial)
Column	A large bundle (funiculus) of ascending or descending nerve fibers in the CNS, composed of several different fasciculi (e.g., posterior column of the white matter of the spinal cord)
Commissure	A bundle of nerve fibers that run horizontally, connecting the right and left sides of the central nervous system (e.g., anterior commissure)
Contralateral	The opposite side (e.g., in many instances the right side of the brain receives information from and controls the left side, *contralateral*, of the body)
Cortex	The periphery of a structure; the superficial layer, the opposite of the deep medulla
Decussation	The level in the central nervous system where paired fiber tracts cross from one side of the body to the other (e.g., pyramidal decussation)
Exteroceptor	A sensory receptor that provides information to the central nervous system concerning the external environment
Fasciculus	A bundle (tract) of ascending or descending nerve fibers within the central nervous system (e.g., cuneate fasciculus)
Fiber	A long, thin structure; refers to an axon or a collection of axons
Fovea	A depression or a pit (e.g., fovea centralis of the retina)
Funiculus	A large bundle (column) of ascending or descending nerve fibers in the CNS, composed of several different fasciculi (e.g., posterior funiculus of the white matter of the spinal cord)
Ganglion	A collection of nerve cell bodies in the peripheral nervous system (e.g., spinal ganglion [previously named "dorsal root ganglion"]; although it is used occasionally in reference to a collection of nerve cell bodies in the central nervous system, e.g., basal ganglia – not used in this textbook)
Glomerulus	Structures with a spherical configuration (e.g., synaptic glomeruli in the olfactory bulb)
Infundibulum	A funnel-like structure (e.g., infundibulum of the hypophysis)
Interoceptor	A sensory receptor that provides information to the central nervous system concerning the body's internal environment
Ipsilateral	The same side (e.g., in some instances the right side of the cerebellum receives information from and controls the right side, *ipsilateral*, of the body)
Lamina	A layer of a specific material such as the layering of nerve cell bodies in the spinal cord
Multipolar neuron	A neuron with a single axon and multiple dendrites (e.g., motor neuron)
Myelin	A fatty substance that surrounds certain axons; composed of spiral layers of the cell membranes of neurolemmocytes (eponym: Schwann cells) in the peripheral nervous system and of oligodendroglia in the central nervous system
Neurite	A collective term for axons and dendrites
Neuropil	A complex of axons, dendrites, and processes of neuroglia that form a web-like network in which nerve cell bodies of the gray matter are embedded
Nucleus	Core; in a cell it is the region of the cell that houses the chromosomes; in the central nervous system it is a collection of nerve cell bodies
Operculum	A cover or lid (e.g., parietal operculum of the cerebrum that overhangs and partially masks the insula)
Peduncle	A massive collection of nerve fiber bundles that connect the cerebrum and the cerebellum to the brainstem
Perikaryon	The cell body of a neuron (i.e., a neuron without its dendrites and axon); also referred to as soma
Plexus	The interwoven arrangements of nerve fibers that serve a specific region (e.g., brachial plexus, L. "braid")
Project	When one group of nerve cells relay their information to a second group of nerve cells, it is said that the first group "projects" to the second group (e.g., the hippocampal formation projects to the hypothalamus)
Proprioceptor	Sensory nerve endings in muscles, joints, and tendons that inform the central nervous system concerning the position and movements of the regions of the body in space (e.g., muscle spindle)
Pseudounipolar neurons	See unipolar neuron
Raphe	A seam or midline structure (e.g., raphe nuclei of the reticular formation)
Rostral	Toward the nose (proceeding toward a anterosuperior position; the opposite of inferior or caudal)
Tract	A bundle (fasciculus) of ascending or descending nerve fibers within the central nervous system (e.g., solitary tract)
Unipolar neuron	A neuron with an axon only, no dendrites. These are very rare in vertebrates. In fact, the term is being used to identify a special case of bipolar neurons (known as pseudounipolar neurons) whose axon and dendrite fuse with each other and form a single short process that bifurcates forming a central process (that enters the CNS) and a peripheral process that goes to a sensory receptor in the body

Table 1.1 ● Common terms in neuroanatomy.

of the subject matter. One of the problems that students have in studying neuroanatomy is that there may be numerous terms applied to the same or similar structures. It is important, therefore, to begin the discussion of this subject matter by listing and defining in Table 1.1 some, but not all, of the terminology the student will encounter.

CELLS OF THE CENTRAL NERVOUS SYSTEM

Neurons

Neurons are the functional units of the central nervous system

Neurons, the functional units of the nervous system, although of several types (unipolar [pseudounipolar], bipolar, and multipolar, detailed in Chapter 3), all have similar structures and functions. Their most important property is that they are capable of receiving, conducting, and transmitting electrochemical information to each other as well as to muscle cells and acinar cells of glands. Neurons (Fig. 1.1) have one or more processes, collectively known as **neurites**, which are of two types, one or more **dendrites** through which they receive information and a single process, known as an **axon**, through which they transmit information to other neurons and to effector organs. Hence, dendrites conduct information toward the **cell body**, whereas axons conduct information away from the cell body. Neurons usually communicate with each other as well as with other cells at **synapses** of which there are three types. If the axon of the first (presynaptic) neuron synapses with the dendrite of the second (postsynaptic) neuron, it is called an axodendritic synapse which is the most common. Synapses can also be axoaxonic (axon to axon) or axosomatic (presynaptic axon to postsynaptic cell body). **Neurotransmitter substances** are released from the axon terminal of the first neuron into the synaptic cleft and bind to receptor molecules on the surface of the second neuron (or muscle/myoepithelial cell/acinar cell). Neurotransmitter substances are recycled so that they may be used numerous times without having to resynthesize them. Neurons may also communicate with each other via **gap junctions** which are exceptionally small aqueous pores in the membranes of the soma and/or neurites of each of two adjacent cells. These pores are aligned with each other in such a way that they permit the movement of small secondary messenger molecules from the cytoplasm of one cell (the **signaling cell**) into the cytoplasm of the neighboring cell (the **target cell**), initiating a requisite response in the target cell.

Neuroglia

Neuroglia constitute several categories of non-neuronal cells, namely microglia, macroglia, and ependymal cells

Additional cells, known as **neuroglia**, constitute several categories of non-neuronal supporting cells. Those in the central nervous system are known as **ependymal cells**, **macroglia**, and **microglia**. The first two are derived from cells of the neural tube, whereas microglia are **macrophages** whose origins are monocyte precursors of the bone marrow.

Ependymal cells form a simple ciliated cuboidal epithelium that lines the central canal of the spinal cord and the ventricles of the brain. Additionally, these cells also participate in the formation of the choroid plexus, vascular tufts of tissue that manufacture cerebrospinal fluid (Fig. 1.2). **Macroglia** is a collective term for the protoplasmic astrocytes, fibrous astrocytes, and oligodendroglia. **Protoplasmic astrocytes** support neurons in the gray matter, form a subpial barrier, and envelop capillaries of the CNS (Fig. 1.3). Due to their

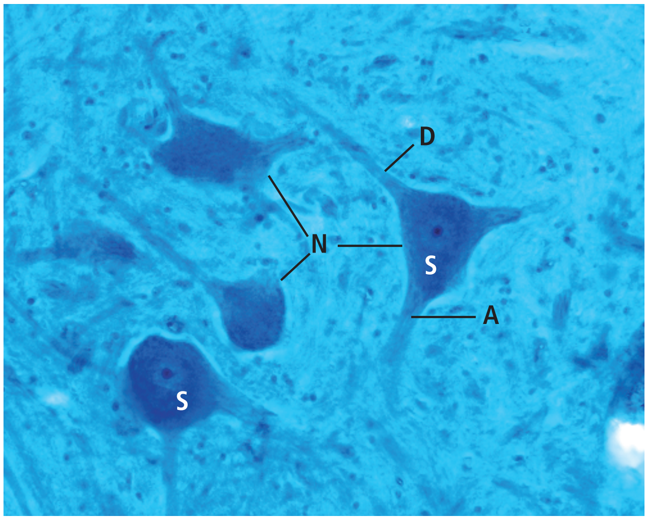

Figure 1.1 ● Observe the four multipolar neurons (N) from the anterior horn of the spinal cord. Note that each neuron has a cell body, also known as soma (S), and a number of processes, a single axon (A), and several dendrites (D). Collectively, axons and dendrites are known as neurites. Observe that the two neurons labeled with S display their large nucleus with prominent nucleoli. (Methylene blue, ×270).

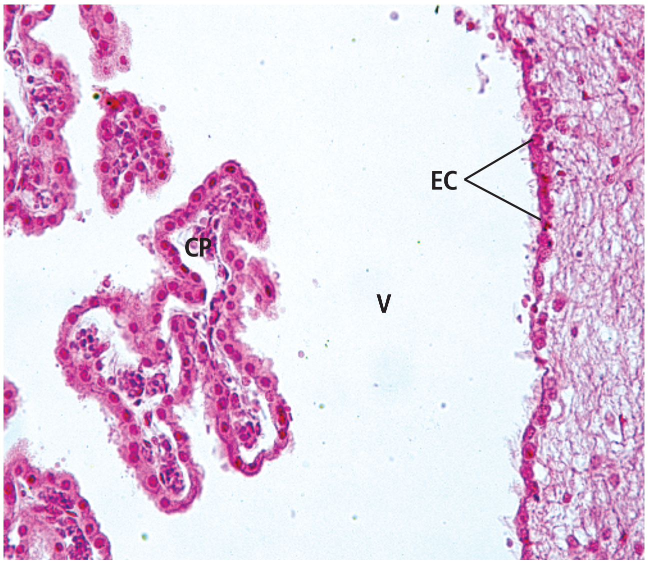

Figure 1.2 ● Note that ciliated cuboidal ependymal cells (EC) line the ventricle (V) of the brain. The structures on the left-hand side of the image are portions of choroid plexus (CP) which is responsible for manufacturing the cerebrospinal fluid. (Hematoxylin and Eosin; ×270).

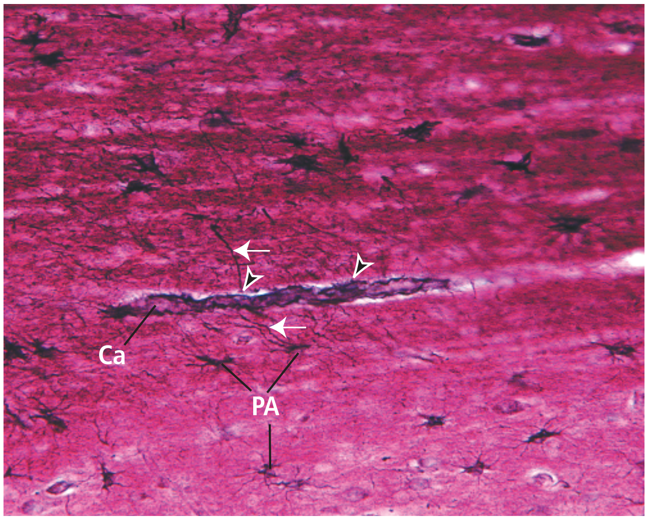

Figure 1.3 ● Note that the capillary (Ca), running horizontally through the middle of the image, is surrounded by a large number of protoplasmic astrocytes (PA) whose processes (arrows) extend to the blood vessel where they expand to form vascular feet (arrowheads), also known as pedicels. (Cerebral cortex, Cajal gold sublimate; ×270).

close relationship with blood vessels of the brain, they are responsible for the ability of endothelial cells of blood vessels to maintain the blood—brain barrier. **Fibrous astrocytes** are located in the white matter and appear to function in a similar fashion to protoplasmic astrocytes. Astrocytes also function in scavenging ions and neurotransmitter substances from the extracellular spaces. They also assist neurons in their role of transmitting impulses from one neuron to the other by regulating the presence of neurotransmitter substances as well as releasing **gliotransmitter substances** (e.g., adenosine triphosphate [ATP] and glutamate that appear to restrain synaptic transmission) in the vicinity of synapses.

Oligodendroglia form myelin sheaths around axons and also surround dendrites and cell bodies of neurons in the CNS. A single oligodendroglion can myelinate a single segment of several axons. **Neurolemmocytes (eponym: Schwann cells)** are located in the PNS, and they function in forming myelin around axons of the PNS. Unlike oligodendroglia, a single neurolemmocyte can myelinate a segment of only a single axon. It should be noted that the degree of myelination depends on the type of nerve fiber that is being myelinated, and the thicker the myelin sheath, the faster the axon can propagate the impulse.

CENTRAL NERVOUS SYSTEM

The central nervous system is composed of the large, superiorly situated brain and smaller, cylindrically shaped, inferiorly positioned spinal cord.

The **central nervous system** begins as a complex, hollow tube, whose superior end, the **brain**, is enlarged and folded in an elaborate manner, whereas its inferior end, the **spinal cord**, is a long, tubular structure (Fig. 1.4). The brain is housed in the cranial cavity and, at the foramen magnum, is continuous with the spinal cord, which is housed in the vertebral canal. The **posterior** surface of the spinal cord is closer to the lamina of the vertebral arch, whereas its **anterior** surface is closer to the bodies of the vertebrae. Since the CNS, as well as most of the body, is bilaterally symmetrical, the **sagittal** (midsagittal, according to some) plane bisects it into right and left halves. Positioning toward the sagittal plane is considered to be the **medial** direction, and away from the sagittal plane is the **lateral** direction.

Brain

The brain is subdivided into five regions: the telencephalon, diencephalon, mesencephalon, metencephalon, and myelencephalon

The **brain** is subdivided into five major regions, the largest being the **telencephalon**, which is composed of the cerebral hemispheres. The other four regions are: the **diencephalon**, whose component parts are the epithalamus, thalamus, hypothalamus, and subthalamus; the **mesencephalon**, consisting of the cerebral peduncles (tegmentum and crus cerebri) and the tectum (superior and inferior colliculi); the **metencephalon**, including the pons and cerebellum; and the **myelencephalon** (medulla oblongata). Frequently the medulla oblongata, mesencephalon, and the pons are collectively termed the **brainstem**. The lumen of the CNS is a narrow slit, which is known as the **central canal** in the spinal cord. However, the lumen is expanded into a system of dilated spaces, called **ventricles** in the brain, and these ventricles are filled with cerebrospinal fluid. Nine of the 12 pairs of **Cranial Nerves** (**CN**) emerge from the brain to supply motor, sensory, parasympathetic innervation, and proprioceptive information for the head and neck and much of the viscera of the body. Of the other three cranial nerves, one, the **optic nerve** (**CN II**), arises from the retina; one, the **olfactory nerve** (**CN I**), originates from the superior aspect of the nasal cavity; and one, the **accessory nerve** (**CN XI**), ascends from the superior cervical spinal cord.

Spinal cord

The spinal cord is a cylindrical structure whose neurons are arranged in such a fashion that the motor functions are anteriorly positioned and the sensory functions are posteriorly positioned

The **spinal cord** (Fig. 1.5) is concentric more or less cylindrical aggregate of nervous tissue, where a cylinder of white matter (neuronal cell bodies, myelinated axons and glia) surrounds a central cylinder of gray matter (neuronal cell bodies, myelinated axons and glia). Nerves emerging from the spinal cord supply motor, sensory, and autonomic (sympathetic, parasympathetic) fibers to the entire body below the head. The cell bodies of neurons of the spinal cord

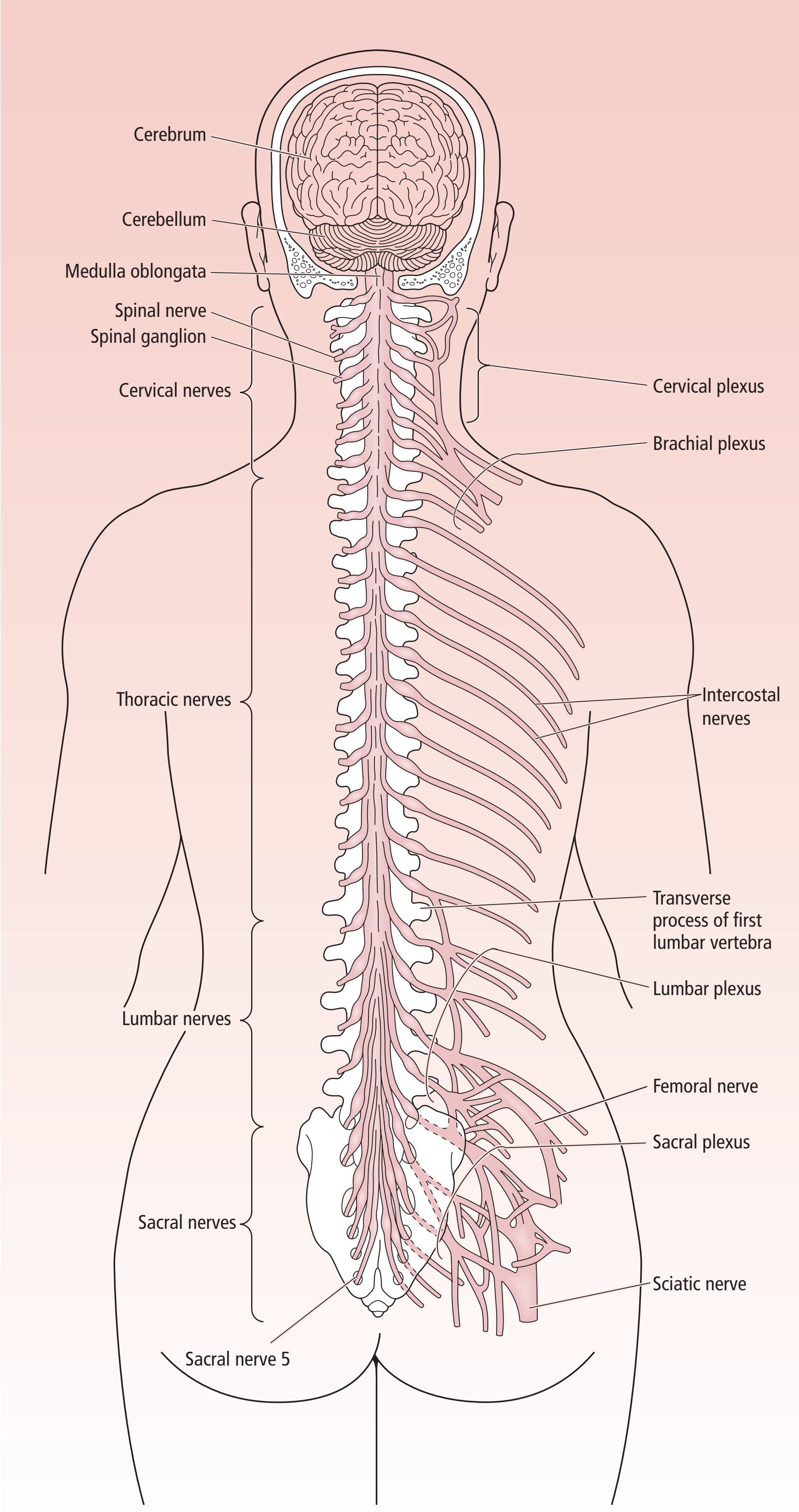

Figure 1.4 ● The brain, spinal cord, spinal nerves, and major somatic plexuses. Note that the back of the skull as well as the spinal processes of the vertebrae have been removed and that the dura mater and the arachnoid mater have been opened up so that the spinal cord may be viewed in its entire length.

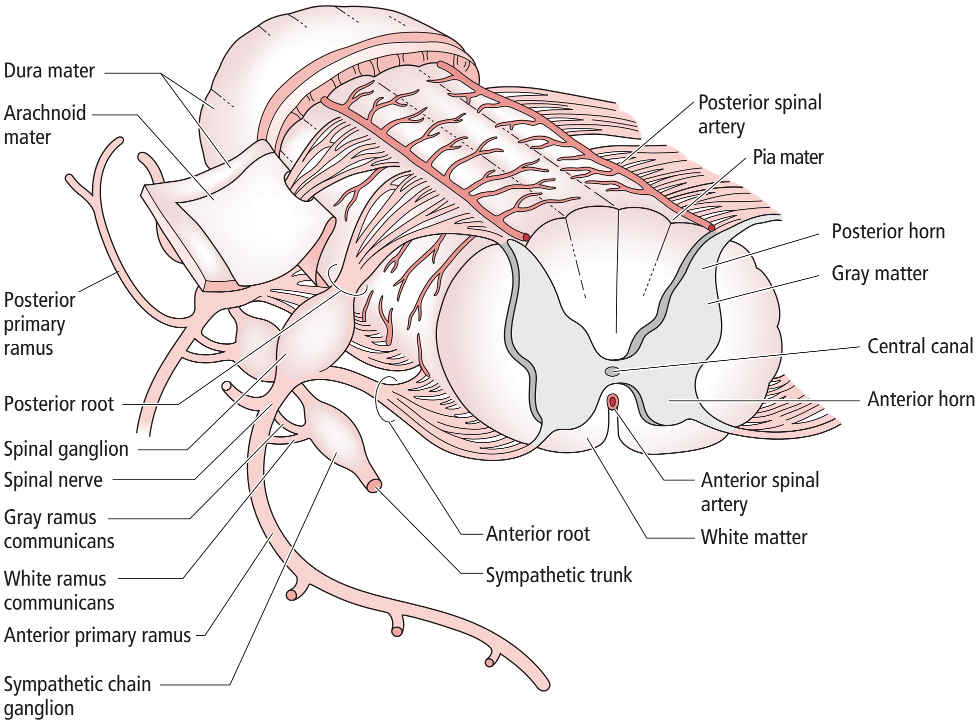

Figure 1.5 ● The spinal cord, its meninges, spinal nerves, and sympathetic chain ganglia.

are arranged in such a fashion that those concerned with somatic motor function are located in the **anterior horn**, and their axons leave via the anterior rootlets. These are accompanied by axons of the preganglionic sympathetic neurons, located in the **lateral horn** of the spinal cord gray matter in all the thoracic and upper two or three lumbar segments, and axons of preganglionic parasympathetic neurons located in the lateral horn of gray matter between the second and fourth sacral spinal cord levels. The **posterior horn** of the spinal cord is the location where central processes of unipolar neurons of posterior root ganglia enter the spinal cord, via posterior rootlets, bringing sensory information to the CNS. **Interneurons** connect two types of neurons to each other (e.g., unipolar sensory neurons of the posterior root ganglia to motor neurons of the anterior horn). Thus, interneurons have the capability of modulating (facilitating or inhibiting) a motor response to a sensory stimulus. For example, if one pricks one's finger the reflex response is to pull the finger away from the offending stimulus; however, if a health professional sticks one's finger for a blood test, the interneuron, receiving that information from higher levels in the central nervous system, inhibits the withdrawal of the finger.

The white matter of the spinal cord is composed of ascending and descending tracts of nerve fibers that connect regions of the CNS to each other. Anterior and posterior roots at each level of the spinal cord join one another to form the spinal nerves that leave the spinal cord at regular intervals, a condition that is indicative of its segmentation. Each posterior root displays a swelling, a spinal ganglion, housing the soma (cell bodies) of the unipolar (pseudounipolar) neurons.

Gray matter and white matter

Gray matter is composed of neuron cell bodies, clusters of which within the CNS are known as nuclei; white matter is recognized by the presence of myelinated axons

Gray matter is composed of neuronal cell bodies and their associated ganglia and can be arranged in layers (e.g., cortical gray matter) or in aggregations (e.g., subcortical nuclei). Neuronal cell bodies can be located in the CNS (brain and spinal cord gray matter) or in ganglia outside the CNS (e.g., spinal ganglia). There are two major categories of neurons, (1) those whose axons leave the CNS and (2) those whose axons remain within the CNS. The first group, called **principal cells** by some neuroanatomists, are generally motor neurons (somatic or autonomic); the second group, known as **interneurons** relay information from one neuron (or one group of neurons) to a second neuron (or second group of neurons) within the CNS (e.g., the interneuron of a reflex arc).

White matter is composed of neuroglia and processes of neurons, many of whose axons are wrapped in a myelin sheath, which in a living individual has a white color. These axons are collected into small bundles, known as **fasciculi**, or large bundles, called **funiculi** (L. *funiculus*, "cord"). Certain larger fiber bundles are named **tracts**, **brachia** (L. arm-like processes), **peduncles** (foot-like processes), or **capsules**, whereas axons that cross the midline to connect identical structures on opposing sides are known as **commissures**. The largest commissure of the CNS is the **corpus callosum**, which connects the two cerebral hemispheres of the brain. Axons that travel up or down the CNS and cross the midline from one side to the other are said to **decussate** at the point of crossing over.

PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system is a continuation of the CNS; it is composed of clusters of nerve cell bodies, known as ganglia, as well as of bundles of axons and central processes, known as nerves

The **peripheral nervous system** is composed of cranial nerves, spinal nerves, their associated ganglia, and nerve fibers and ganglia of the autonomic nervous system. It must be understood that the PNS is in physical continuity with the CNS; in fact, cell bodies of many of the nerve fibers (axons) of the PNS are located in the CNS.

Somatic nervous system

The somatic nervous system is composed of the 12 pairs of cranial nerves and their ganglia as well as of the 31 pairs of spinal nerves and their spinal ganglia

There are 12 pairs of cranial nerves, identified both by name as well as by Roman numerals I through XII. All cranial nerves, with the exception of the vagus (CN X), serve structures in the head and neck only. The vagus nerve innervates structures in the head and neck, but also serves many of the thoracic and abdominal viscera, for example, the heart and the gastrointestinal tract. Those cranial nerves that have sensory components possess sensory ganglia housing the cell bodies of unipolar (pseudounipolar) neurons whose single process bifurcates into a central and a peripheral process. The central process of a unipolar neuron enters the brain, whereas its peripheral process goes to a sensory receptor. There are no synapses occurring in these sensory ganglia.

There are 31 pairs of spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal), attesting to the segmentation of the spinal cord (see Fig. 1.4). The cell bodies of sensory neurons (unipolar neurons) are located in the spinal ganglia (sensory ganglia that were named "posterior root ganglia"). Again, it must be remembered that just as in the sensory ganglia of the cranial nerves there are *no synapses* occurring in the spinal ganglia. The single process of each neuron bifurcates, and the short central process joins other central processes to form posterior rootlets that enter the spinal cord. The peripheral process goes to a sensory receptor, which, when stimulated (see Chapter 3 for a thorough discussion of this progression), causes a change in the peripheral process that, as a consequence, conveys the information to the central process. This information is conveyed from the central process either to an interneuron (in a three-neuron reflex arc) or to a motor neuron in a two-neuron reflex arc, such as the patellar reflex. This reflex is activated when a gentle strike of the patellar tendon with a rubber hammer causes contraction of the muscle that kicks the foot forward. Although this description is true for reflex arcs, it must be realized that in most instances the incoming information is transmitted to higher levels in the brain and is processed either consciously or subconsciously, or both, rather than just relying on simple spinal reflex phenomena, which do not involve the brain. These motor neurons are multipolar neurons whose cell bodies are located in the anterior horn of the spinal cord and serve *skeletal muscle cells only*. Their axons leave via the anterior rootlets that join the posterior rootlets to form the **spinal nerve**.

Each spinal nerve bifurcates to form a smaller **posterior primary ramus** (**dorsal primary ramus**) and a larger **anterior primary ramus (ventral primary ramus)**. Posterior primary rami supply sensory and motor innervation to a small section of the back, whereas anterior primary rami supply the lateral and anterior portion of the neck, trunk, and limbs. Anterior rami that supply the thorax and abdomen usually remain as separate nerves, whereas those of the cervical and lumbosacral regions join each other to form **plexuses** from which individual nerve bundles arise to serve the head, neck (cervical plexus), and upper and lower extremities (brachial and lumbosacral plexuses, respectively). Each spinal nerve receives sensory information from the skin of the segment, or **dermatome**, of the body that it serves (see Chapter 5). The entire body is mapped into a number of dermatomes; however, there are overlaps in the innervation, so that a single dermatome is supplied by more than one spinal nerve. Such overlaps prevent the total anesthesia of a particular dermatome if the posterior rootlets of the spinal nerve supplying it are damaged.

Autonomic nervous system

The autonomic nervous system, controlled by the hypothalamus, regulates the activities of smooth muscle, cardiac muscle, and acinar cells of glands, and is divided into three components: the sympathetic, parasympathetic, and enteric nervous systems

The autonomic nervous system, controlled by the hypothalamus, is a motor system, but unlike somatic motor neurons, it does *not* serve skeletal muscle cells; instead, it innervates visceral muscle (cardiac muscle cells, smooth muscle cells) and secretory cells (acinar cells) of glands (see Chapter 10, Autonomic Nervous System). Additionally, whereas a somatic motor neuron **directly** innervates its muscle cell (Fig. 1.6), in the autonomic nervous system the neuron whose cell body is located in the CNS (**preganglionic** also known as **presynaptic neuron**) synapses with a second neuron (**postganglionic** also known as **postsynaptic neuron**) located in a ganglion in the PNS. It is the axon of the *postganglionic neuron* that synapses with the cardiac muscle cell, smooth muscle cell, or secretory cell of a gland. Thus, the autonomic nervous system is said to be a two-cell system, and synapses *always occur* within an autonomic ganglion (Fig. 1.6). There is an exception to that rule where the presynaptic fibers synapse with secretory cells in the medulla of the suprarenal gland, instructing them to release catecholamines. Those secretory cells act as postsynaptic neurons. The axon of the presynaptic neuron is myelinated and is known as the **presynaptic fiber**.

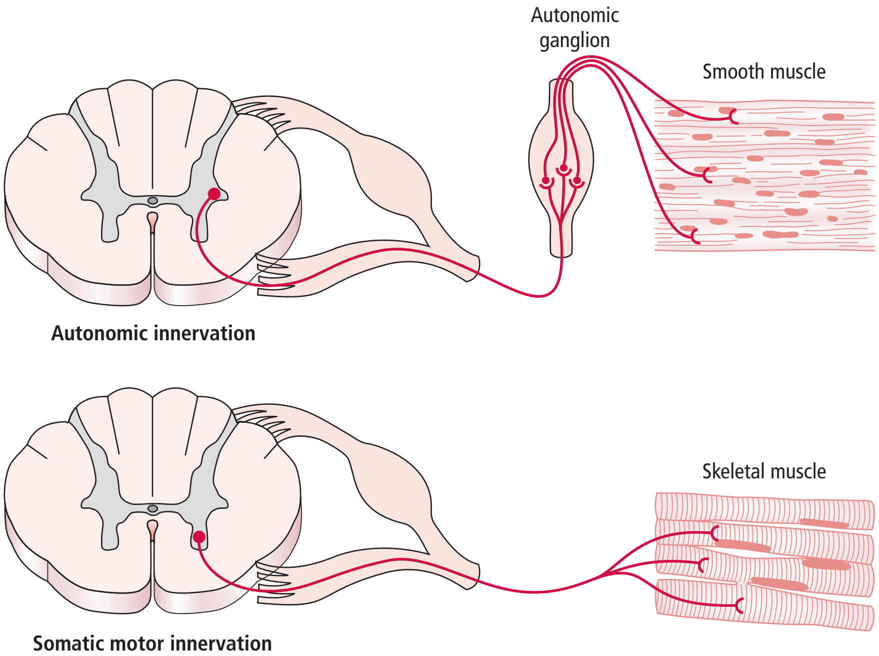

Figure 1.6 ● Diagram demonstrating the difference between autonomic innervation (top) and somatic motor innervation (bottom). Observe that two neurons are present in the autonomic supply, whereas a single motor neuron is present in the somatic motor system.

The axon of the postsynaptic neuron is not myelinated and is known as the **postsynaptic fiber**.

The autonomic nervous system is responsible for the maintenance of **homeostasis**, and is composed of three functional components: sympathetic, parasympathetic, and enteric. The **sympathetic** component prepares the body for the "four F's" (fight, flight, freeze, or fornicate), whereas the **parasympathetic** component prepares the body for a vegetative state (e.g., rest). The **enteric nervous system** is situated completely within the wall of the digestive tract and controls the entire process of digestion. Although the sympathetic and parasympathetic components of the autonomic nervous system do modulate its activities, the enteric nervous system can function quite well on its own if the connections of the sympathetic and parasympathetic components are cut off from it.

Cell bodies of **spinal sympathetic motor neurons** (**preganglionic sympathetic neurons**) are located in the lateral horn of the spinal cord gray matter in thoracic and upper lumbar spinal cord (T1 to L2, L3), whereas those of the **cranial parasympathetic motor neurons** (**presynaptic parasympathetic neurons**) are located in the brain (and their axons travel with CN III, VII, IX, and X) and the **spinal parasympathetic motor neurons** are in the lateral horn of gray matter in the sacral spinal cord (S2–S4). Postganglionic cell bodies of sympathetic neurons are usually located near the spinal cord, just lateral to the vertebral column, within the **paravertebral sympathetic ganglia**; or a little farther away, in **prevertebral ganglia**. The cell bodies of *postganglionic parasympathetic neurons*, however, are located in ganglia that are in the walls of the viscera being innervated, and are, therefore, said to be **intramural**.

The cell bodies of the sensory neurons that supply the viscera are located in the spinal ganglia of spinal nerves or in the sensory ganglia of cranial nerves, along with the somatic sensory neurons. However, their peripheral processes accompany the preganglionic autonomic fibers into their respective ganglia, but do *not* synapse in those ganglia. Moreover, these peripheral fibers continue to accompany the postganglionic autonomic fibers to the same destinations. In spite of their route, these sensory neurons are *not* considered to be a part of the autonomic nervous system. Sensory information relayed by these autonomic sensory nerves are not registered as part of the conscious experience, and even pain sensations are experienced as "referred pain" in somatic regions of the body (e.g., **angina pectoris**, where pain sensations arising in the heart muscle are experienced as pressure in the left side of the chest, neck, back, and arm, regions served by the same segmental spinal nerve).

QUESTIONS TO PONDER

1. What is the relationship between the central and peripheral nervous systems?

2. What is meant by the "fight, flight, freeze, or fornicate" response?

3. What single characteristic is the major difference between microglia and the other neuroglia of the central nervous system?

4. What is the major difference between a two-neuron reflex arc and a three-neuron reflex arc, aside from the simplistic fact that one has an extra neuron associated with it?