Exercise 13

Histology of Nervous Tissue

Laboratory Objectives

On completion of the activities in this exercise, you will be able to:

- Explain the general organization of the nervous system.
- Recognize the important microscopic structures of a neuron.
- Explain the general structure and function of multipolar, bipolar, and unipolar neurons.
- Understand the functions of the neuroglia.
- Explain how an impulse is transmitted at a synapse.
- Identify important microscopic structures in the cerebrum and cerebellum.
- Identify important microscopic structures of the spinal cord.
- Understand how ventral and dorsal spinal roots give rise to a spinal nerve.
- Describe the organization of a peripheral nerve.

Materials

- Compound light microscopes
- Prepared microscope slides of the following nerve tissues:
  - Ox spinal cord smear
  - Cerebrum
  - Cerebellum
  - Spinal cord cross section with dorsal and ventral roots
  - Peripheral nerve cross section
- Anatomical models of a nerve cell and a synapse
- Colored drawing pencils

The nervous system provides the body with a means for maintaining homeostasis and ensuring that bodily functions are carried out efficiently. It performs this function by conducting electric impulses along nerve fibers to target organs. As a result of this electrical activity, the nervous system is able to control and integrate the activities of all the organs and organ systems. Neural responses occur quickly but have only short-term effects.

The nervous system is responsible for three basic functions.

- *Reception.* With the assistance of sensory receptors, it is able to detect changes that occur inside the body and in the surrounding environment.
- *Integration.* It is able to interpret and integrate sensory input by storing the information as memory and producing thoughts.
- *Response.* It is able to respond to the sensory input by initiating muscular contractions or glandular secretions.

The two major divisions of the nervous system (Figure 13.1) are the **central nervous system (CNS)** and the **peripheral nervous system (PNS)**. The central nervous system consists of the brain and the spinal cord. It is the control center for all nervous system function. All sensory information must be delivered to the CNS if it is to be detected and integrated. The CNS produces all motor impulses to muscles and glands. The peripheral nervous system comprises all nerves that connect the brain and spinal cord to muscles, glands, and receptors. Nerves connected to the brain are called **cranial nerves**; those connected to the spinal cord are **spinal nerves.** Cranial and spinal nerves convey sensory information from receptors (e.g., pain receptors in the skin) to the CNS, and transmit motor information from the CNS to **effector organs** (e.g., muscles and glands). Thus, the PNS can be divided into a **motor (efferent) division** with **motor (efferent) neurons**, and a **sensory (afferent) division** with **sensory (afferent) neurons.**

The motor, or efferent, division consists of two parts (Figure 13.1).

1. The **somatic nervous system** contains efferent neurons extending from the CNS to skeletal muscle (voluntary actions).
2. The **autonomic nervous system** contains efferent neurons extending from the CNS to smooth muscle, cardiac muscle, and glands (involuntary actions).

The sensory, or afferent, division contains three components (Figure 13.1).

1. Afferent neurons that receive stimuli from **somatic sensory receptors** that detect **general sensations** (touch, pressure, temperature, pain, and body position) in the skin, skeletal muscles, and joints.
2. Afferent neurons that receive stimuli from **visceral sensory receptors** that detect sensations in internal organs.
3. Afferent neurons that receive stimuli from **special sensory receptors** that detect **special sensations** (smell, taste, vision, hearing, equilibrium).

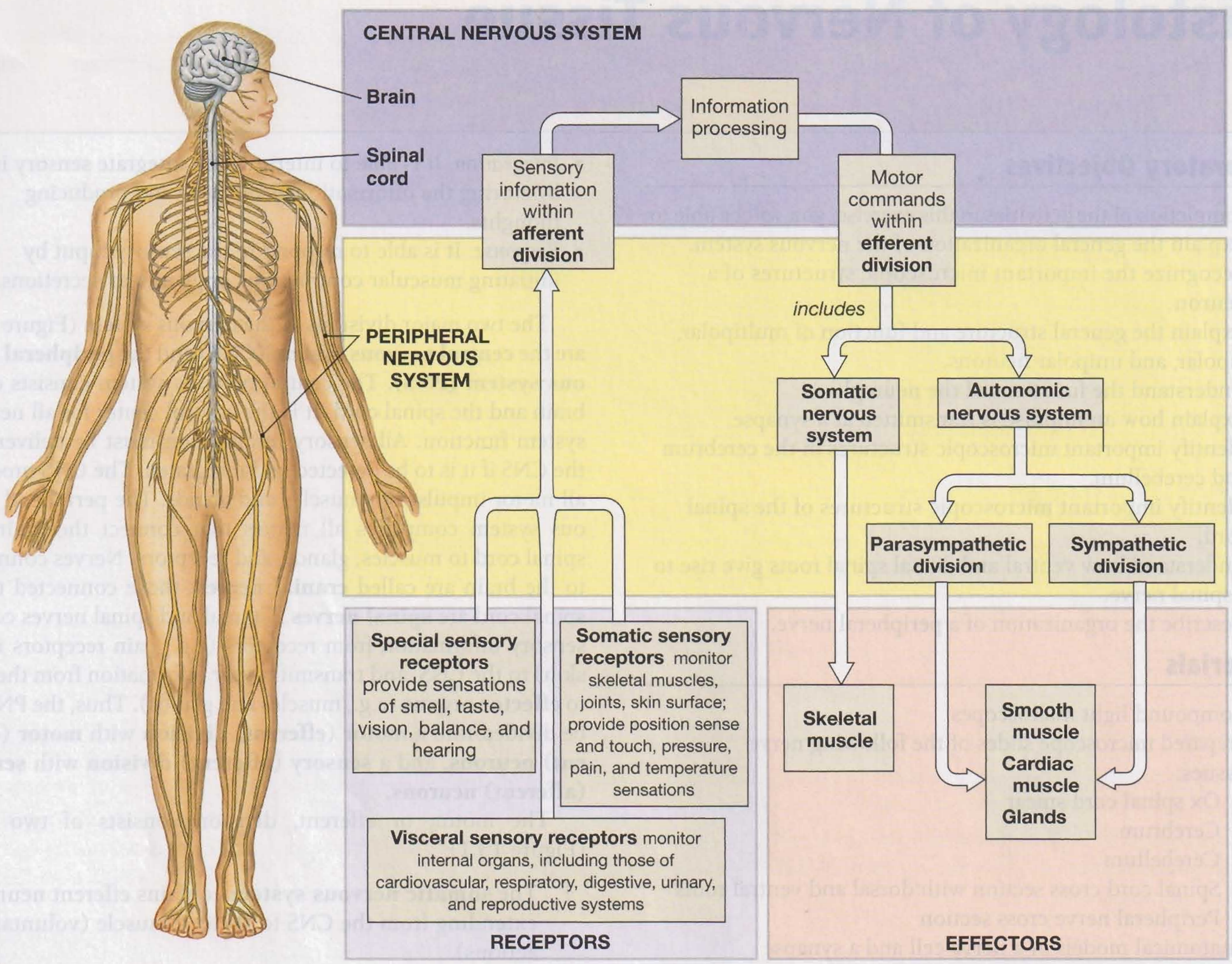


Figure 13.1 General organization of the nervous system. The central nervous system (CNS) includes the brain and spinal cord. The peripheral nervous system (PNS) includes the peripheral nerves (cranial and spinal nerves).

Cell Types in Nervous Tissue

The structural and functional unit of the nervous system is the **neuron**, or **nerve cell** (Figure 13.2). A typical neuron consists of a cell body that contains a large, round nucleus with a well-defined nucleolus. In the surrounding cytoplasm, the most prominent organelles include mitochondria, the Golgi apparatus, and clusters of free ribosomes and the rough endoplasmic reticulum (RER), known as **chromatophilic (Nissl) bodies**. The supporting cytoskeleton includes **neurofilaments** (intermediate filaments) and **neurotubules** (microtubules). In the CNS, neuron cell bodies are found in the surface layer of the cerebrum (**cerebral cortex**) and cerebellum (**cerebellar cortex**), and in deeper clusters called **nuclei** (singular = **nucleus**; not to be confused with the nucleus of a cell). In the PNS, neuron cell bodies are organized in clusters called **ganglia** (singular = **ganglion**).

WHAT'S IN A WORD The term *chromatophilic* is derived from Greek and means "color loving." The chromatophilic bodies in nerve cells readily stain with biological dyes and typically appear as dark blue or purplish structures.

Extending from the cell body are two types of cell processes: **dendrites** and **axons**. It is possible for neurons to possess many dendrites, but they usually have only one axon. The dendrites, along with the cell body, serve as contacts to receive impulses from other neurons. Usually, axons give off several collateral branches, each ending with a dilated region known as the **axon terminal** or **synaptic knob**. Axons can be quite variable in length. For example, the axons of the bipolar neurons in the retina of the eyeball are quite short; however, the axons of motor neurons that travel from the lumbar spinal cord to the foot can be greater than 1 meter (3 to 4 feet).

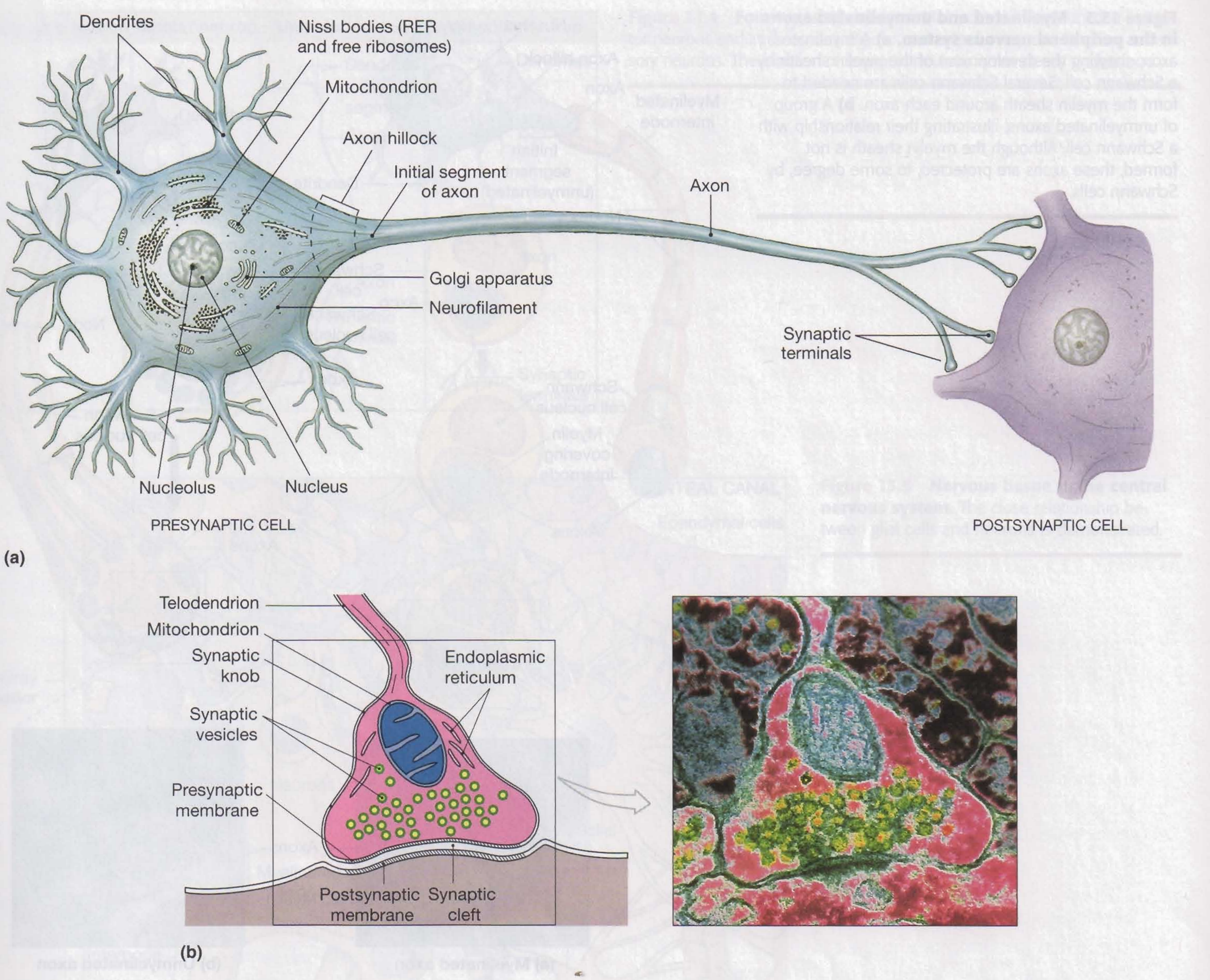
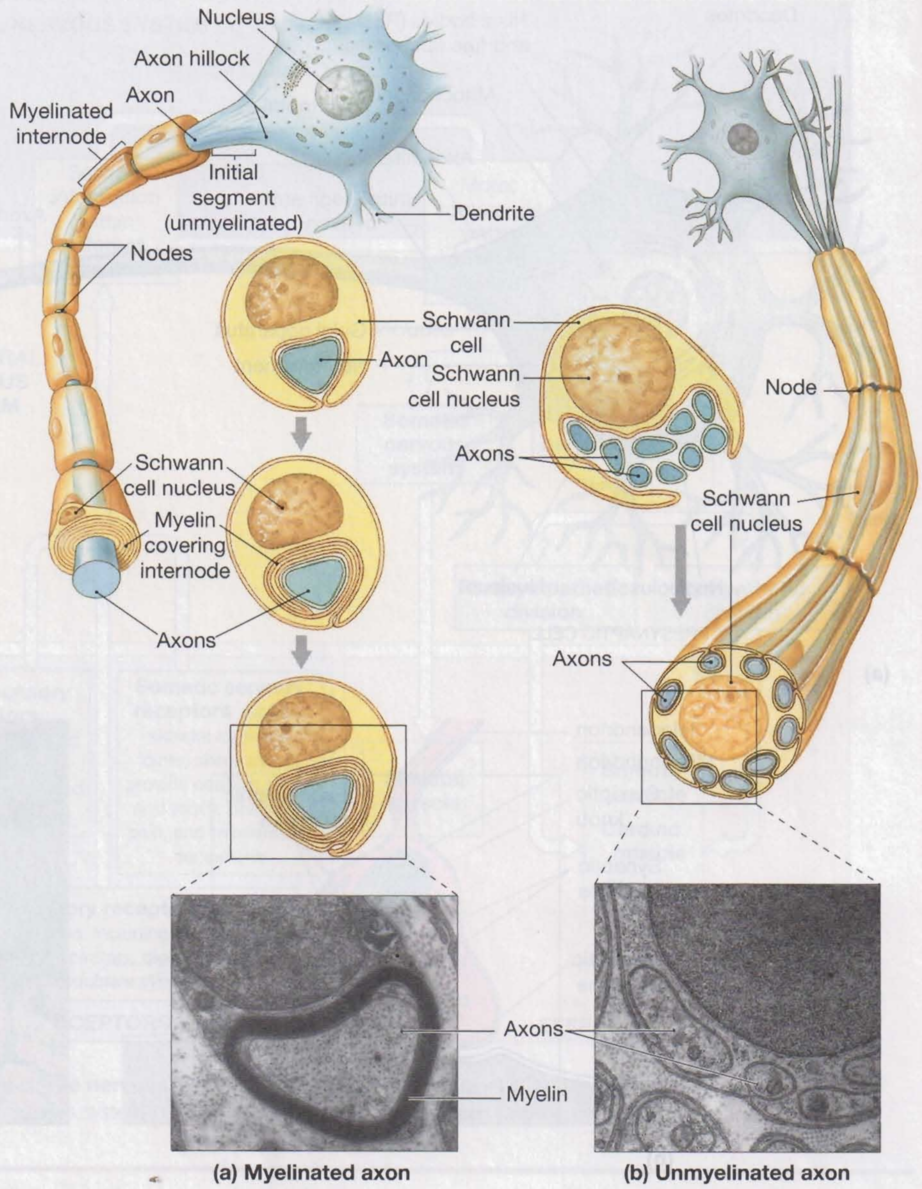


Figure 13.2 Synaptic connections between neurons. a) Generalized pattern showing the axon of a presynaptic cell forming synapses with the dendrites and cell body of a postsynaptic cell. **b)** Enlargement of a synapse between two neurons. The synapse is formed by the synaptic knob of a presynaptic neuron and a dendrite or the cell body of a postsynaptic neuron. Neurotransmitter is released by exocytosis from the presynaptic membrane, diffuses across the synaptic cleft, and attaches to receptors on the postsynaptic membrane.

Some axons are surrounded by a **myelin sheath** (Figure 13.3), which consists of several circular layers of fused cell membrane. Because of its high lipid content, the myelin sheath provides an insulating covering for nerve fibers, much like the insulation around electric wires in your home. The myelin sheath is produced by two types of cells. In the peripheral nervous system, it is produced by **neurolemmocytes (Schwann cells)**, and in the central nervous system by **oligodendrocytes**. Nerve fibers that are surrounded by myelin are called **myelinated fibers**; those without myelin are known as **unmyelinated fibers**. At regular intervals along a myelinated axon are small gaps in the myelin sheath. These interruptions are called **nodes of Ranvier**. The effect of the myelin sheath on the conduction of an electric impulse (action potential) will be studied later in this exercise.

Neurons are classified according to their function. As mentioned earlier, sensory (afferent) neurons conduct nerve impulses from sensory receptors, located in the body wall and internal organs (viscera), to the central nervous system. Motor (efferent) neurons conduct nerve impulses from the central

Figure 13.3 Myelinated and unmyelinated axons in the peripheral nervous system. a) A myelinated axon, showing the development of the myelin sheath by a Schwann cell. Several Schwann cells are needed to form the myelin sheath around each axon. **b)** A group of unmyelinated axons, illustrating their relationship with a Schwann cell. Although the myelin sheath is not formed, these axons are protected, to some degree, by Schwann cells.



nervous system to muscles or glands. A third type, **interneurons** or **association neurons**, form links between sensory and motor neurons. Interneurons also act as relay stations for the transmission of impulses from one part of the brain or spinal cord to another. The vast majority of neurons in the central nervous system are interneurons.

Neurons are also classified by the number of cell processes they possess (Figure 13.4). **Multipolar neurons** make up over 99% of nerve cells and include motor neurons and interneurons. They contain many cell processes—typically one axon and multiple dendrites. A small number of multipolar neurons contain only dendrites and are called **anaxonic neurons** (*anaxonic* means "no axon"). **Bipolar neurons** contain two cell processes: one axon and one dendrite. These cells are specialized sensory neurons; their locations are restricted to the retina of the eye, the inner ear, and the olfactory (sense of smell) epithelium in the upper nasal cavity. **Unipolar neurons** are the typical sensory neurons that transmit impulses from peripheral sensory receptors to the central nervous system. They possess only one cell process that divides into two branches: a peripheral branch that acts as a dendrite by transmitting impulses from a sensory receptor toward the cell body, and a central branch that acts as an axon by transmitting impulses to the central nervous system. When unipolar neurons first form, they have two distinct processes that fuse together as the cells mature. For this reason, they are sometimes called **pseudounipolar neurons** (*pseudo* means "false").

Other cells in the nervous system, the **neuroglia**, or **glial cells**, provide support and protection for neurons and other structures. Glial cells are more numerous than neurons. They have relatively small cell bodies from which cytoplasmic processes extend. The number of processes and the complexity of their branching patterns vary between the different cell types. Neuroglia are found in both the central nervous system

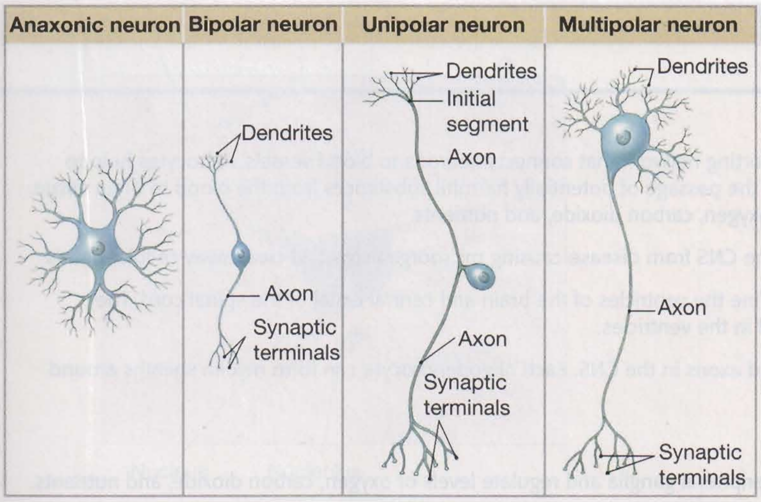


Figure 13.4 Four types of neurons. Multipolar neurons function as motor neurons and interneurons. Bipolar and unipolar neurons function as sensory neurons. The function of anaxonic neurons is not clearly understood.

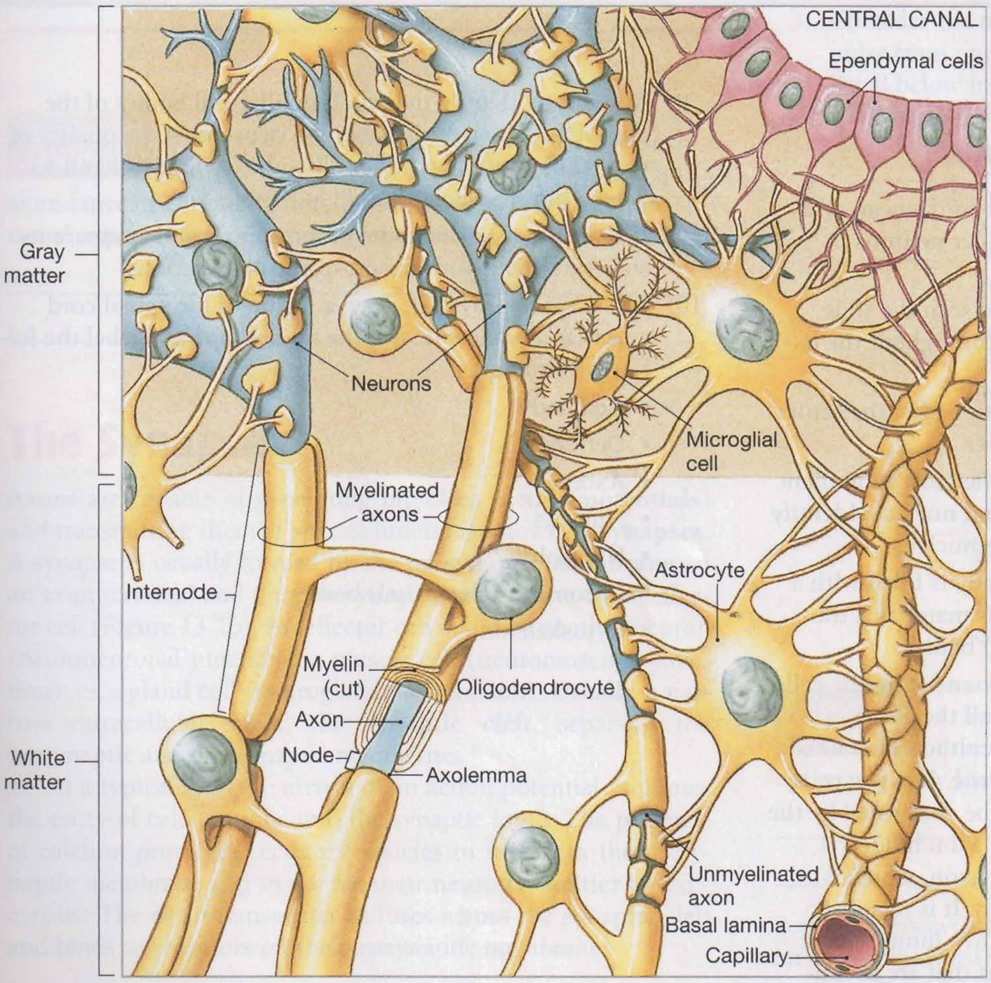


Figure 13.5 Nervous tissue in the central nervous system. The close relationship between glial cells and neurons is demonstrated.

(Figure 13.5) and the peripheral nervous system. The specific functions of each type are described in Table 13.1.

WHAT'S IN A WORD The word *glial* is derived from the Greek word *glia,* which means "glue." The name reflects the general function of the glial cells: sustaining and protecting neurons. ■

Because multipolar neurons are the most numerous, it is common to study the general structure of a neuron by observing these cells. The ox spinal cord is an excellent specimen, because the neurons are relatively large and structures are easy to identify with the light microscope.

Table 13.1 Neuroglia Cell Types

Cell type	Function
I. Neuroglia in the CNS	
1. Astrocytes	The cell processes of these cells form a supporting network that connects neurons to blood vessels. Astrocytes help to form the blood-brain barrier, which prevents the passage of potentially harmful substances from the blood to brain tissue. They also have a role in regulating levels of oxygen, carbon dioxide, and nutrients.
2. Microglial cells	These cells act as phagocytes. They protect the CNS from disease-causing microorganisms and clear away cellular debris.
3. Ependymal cells	These cells are modified epithelial cells that line the ventricles of the brain and central canal of the spinal cord. They facilitate the circulation of cerebrospinal fluid in the ventricles.
4. Oligodendrocytes	These cells produce the myelin sheath around axons in the CNS. Each oligodendrocyte can form myelin sheaths around several axons.
II. Neuroglia in PNS	
1. Satellite cells	These cells surround neuron cell bodies in peripheral ganglia and regulate levels of oxygen, carbon dioxide, and nutrients.
2. Neurolemmocyte (Schwann cell)	These cells produce the myelin sheath around axons in the PNS. Each neurolemmocyte forms a myelin sheath around only one axon.

ACTIVITY 13.1 Identifying Major Components of Multipolar Neurons

1. Obtain a prepared slide of an ox spinal cord smear, or a similar slide that demonstrates multipolar neurons (Figure 13.6).
2. View the slide under low power. As you scan the slide, note several large neurons distributed throughout the tissue specimen.
3. Move the slide so that a neuron is positioned in the center of the field of view. Switch to high power.
4. Identify the **cell body** of the neuron. The most prominent structure in this region is the large round nucleus. Identify the darkly stained nucleolus within the nucleus.
5. Notice that the cytoplasm in the cell body is filled with a darkly stained, granular substance. This material is the rough ER or the chromatophilic (Nissl) bodies.
6. Identify the many cell processes that extend from the cell body. One cell process is an axon, and all the other processes are dendrites. It is often difficult to determine whether a process is an axon or a dendrite. In a few cells, however, the presence of the axon can be confirmed by the identification of the **axon hillock**. The axon hillock is connected to the **initial segment** of an axon, which is where the axon arises from the cell body. It is relatively easy to identify because it has a distinctive funnel shape and lacks the dark-staining Nissl bodies that are prominent in the cell body and dendrites.
7. Attempt to identify bundles of filaments that travel through the cell body and extend into the dendrites and the axon. The filaments comprise the cytoskeleton and include neurotubules and neurofilaments. On your slide, you will not be able to differentiate between the two filament types.
8. Attempt to identify the much smaller cell bodies of the glial cells, which outnumber the neurons. If the quality of your slide is not good, the cell bodies will be difficult to detect, but the nuclei should be visible.
9. If available, study a model of the neuron and compare its structures with your miscroscopic observations.
10. In the space provided, draw a region of the spinal cord smear as you view it with the microscope and label the following structures.
    - Cell body
    - Dendrites
    - Axon
    - Nucleus
    - Nucleolus
    - Chromatophilic (Nissl) bodies
    - Cytoskeleton

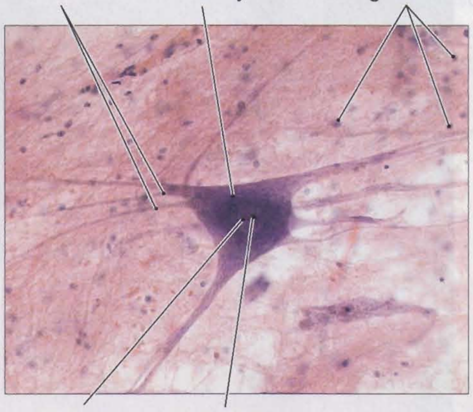


Figure 13.6 Multipolar neuron from an ox spinal cord smear. Multipolar neurons comprise the vast majority of neurons in the central nervous system.

QUESTION TO CONSIDER From your microscopic observations, you likely noticed that the cell bodies of neurons have an abundance of chromatophilic (Nissl) bodies. Provide a functional explanation for this structural feature.

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The Synapse

Axons are capable of generating impulses (**action potentials**) and transmitting them at special junctions known as **synapses**. A synapse is usually formed by the **presynaptic membrane** on an axon terminal and the **postsynaptic membrane** on an effector cell (Figure 13.2b). An effector cell could be another neuron (neuroneuronal junction), a muscle cell (neuromuscular junction), or a gland cell (neuroglandular junction). Usually, a narrow extracellular space, the **synaptic cleft**, separates the presynaptic and postsynaptic membranes.

At a typical synapse, arrival of an action potential promotes the entry of calcium ions into the synaptic knob. The presence of calcium promotes secretory vesicles to fuse with the presynaptic membrane and to release their neurotransmitter by exocytosis. The neurotransmitter diffuses across the synaptic cleft and binds to receptors on the postsynaptic membrane.

ACTIVITY 13.2 Examining the Synapse

1. If available in the laboratory, examine a model of a synapse. Alternatively, study figures of synapses in a histology atlas, your textbook, or Figure 13.2b in this exercise.
2. Identify the following structures.
   - The *axon,* also known as the *nerve fiber,* conducts *action potentials* toward the synapse. The cytoplasm of the axon (the **axoplasm**) contains numerous *neurofibrils* and *neurotubules,* components of the cytoskeleton. The axon is part of the *presynaptic neuron.*
   - The *synaptic knob* is the dilated termination of the axon. It contains numerous **mitochondria** and **secretory vesicles** filled with **neurotransmitter** molecules.
   - The *presynaptic membrane* is the cell membrane located at the end of the synaptic knob.
   - The *postsynaptic membrane* is the portion of the **postsynaptic neuron's** cell membrane adjacent to the synaptic cleft.
   - The *synaptic cleft* is the narrow space that separates the presynaptic and postsynaptic membranes.
3. Consider the mechanism for the transmission of an impulse from one neuron to another. Number the processes listed below in the order that they occur during synaptic transmission.

   ______ Neurotransmitter diffuses across the synaptic cleft.

   ______ Nerve impulse travels along the axon to the synaptic knob.

   ______ Secretory vesicles containing neurotransmitter fuse with the presynaptic membrane.

   ______ Neurotransmitter binds to receptors on the postsynaptic membrane.

   ______ Neurotransmitter released from the presynaptic membrane by exocytosis.

   ______ Action potential promotes the entry of calcium ions into the synaptic knob.

QUESTIONS TO CONSIDER 1. Synaptic knobs contain numerous mitochondria. Speculate on a reason why these organelles are strategically located in this region of a neuron.

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2. A neuron's cytoskeleton, particularly the neurotubules, plays an important role in transporting materials from the cell body to the axon terminals. Speculate on why this process, known as **axoplasmic transport**, is a vital activity for sustaining normal function at synapses.

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The Cerebrum

The cerebrum consists of two **cerebral hemispheres.** Similar to most regions of the brain, each cerebral hemisphere has two types of nervous tissue: **gray matter** and **white matter.** The gray matter consists of nerve cell bodies, dendrites, unmyelinated axons, and glial cells. It is located along the surface (cerebral cortex) and in deeper regions (nuclei). Immediately deep to the cerebral cortex is the white matter, which contains myelinated axons and glial cells. Bundles of axons in the white matter form fiber tracts that connect various brain regions.

ACTIVITY 13.3 Examining Microscopic Structure of the Cerebrum

1. Obtain a prepared slide of the cerebrum.
2. View the slide under low power. As you scan the slide, note two distinct regions (Figure 13.7a).
   - Along the surface is the layer of gray matter known as the cerebral cortex.
   - Deep to the cerebral cortex is the white matter.
3. In the cerebral cortex, identify the relatively large cell bodies of multipolar neurons and the nuclei of the much smaller glial cells, whose cell bodies are difficult to see. Note that the glial cells outnumber the neurons (Figure 13.7).
4. Move the slide so that a region of gray matter is in the center of the field of view. Switch to high power (Figure 13.7b). In the gray matter, you will see darkly stained cells throughout the field of view.
5. Scan the slide until you find a multipolar neuron, which has a relatively large cell body with the dark-staining Nissl bodies distributed throughout the cytoplasm. Depending on the section, the large nucleus with a distinct nucleolus may be identified.
6. Identify the many cell processes that extend from the cell body. One cell process is an axon, and all others are dendrites. If you are viewing a slide stained with hematoxylin and eosion (h & e), you might be able to confirm the presence of the axon by identifying the axon hillock.
7. Move the slide to a deeper area where very few cell bodies are present. This is the white matter, which contains mostly myelinated nerve fibers. You should be able to identify the nuclei of glial cells. Among the glial cells present here are the oligodendrocytes that produce the myelin sheath around axons in the central nervous system.
8. In the space provided, draw a region of the cerebrum as you view it with the microscope and label the following structures.
   - Gray matter in the cerebral cortex
   - Multipolar neurons
   - Glial cell nuclei (in both gray matter and white matter)
   - White matter deep to the cerebral cortex
   - Myelinated axons

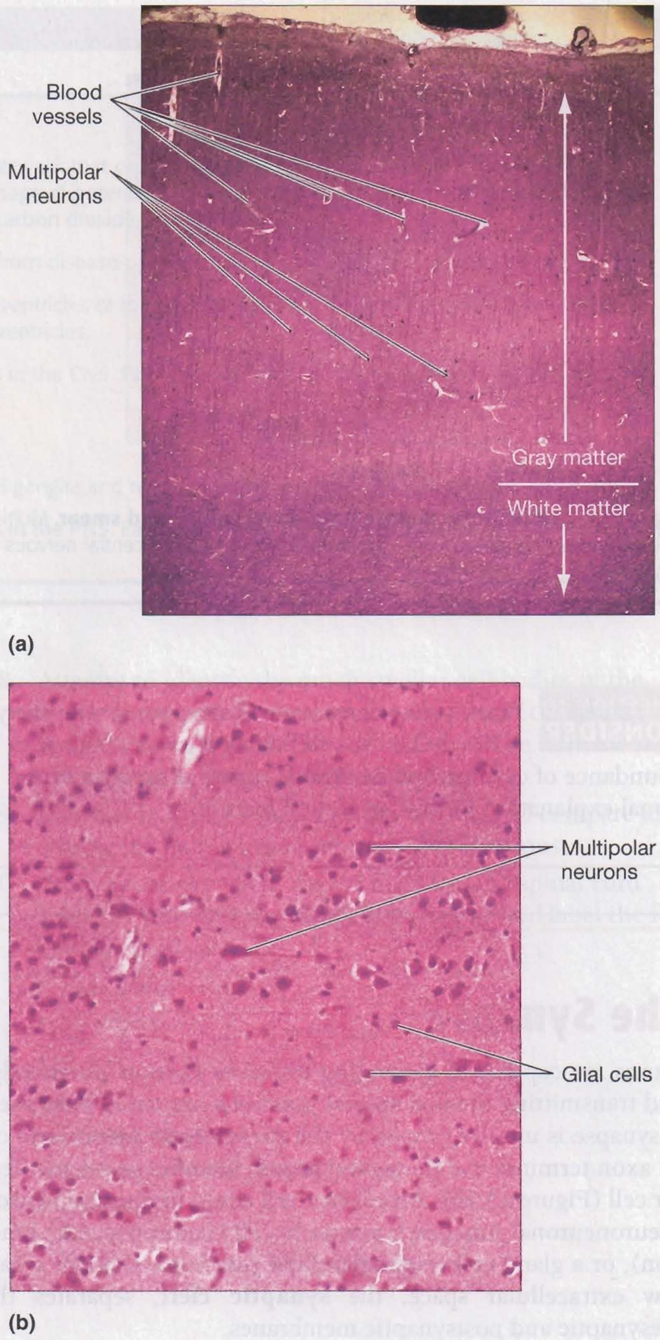

Figure 13.7 Light micrographs of nervous tissue in the cerebrum. a) Low-power view illustrating the relationship between the gray matter in the cerebral cortex and the deeper white matter (LM × 200); **b)** high-power view of the cerebral cortex illustrating multipolar neurons and the much smaller glial cells (LM × 200).

9. If available in your laboratory, obtain a slide of the cerebrum stained with silver. View the slide under low power. The slide has been specifically prepared to highlight nerve cells by staining them black against a light background (Figure 13.8). As you scan the slide, you will immediately notice the black-stained network of nerve cell processes.

In the white matter, you will see only nerve fibers, but if you move to an area of gray matter, you will see the cell bodies and numerous cell processes of multipolar neurons.

10. Place a region of gray matter containing several neurons in the center of the field of view and switch to high power. At this magnification, you can clearly see cell processes extending from all sides of the cell bodies (Figure 13.8).

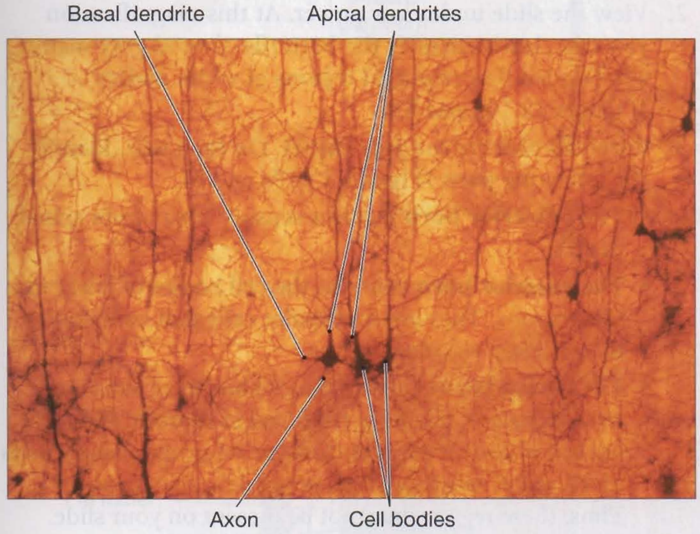

Figure 13.8 Multipolar neurons in the cerebral cortex, stained with silver. With this special preparation, the cell processes extending from the cell body and spatial arrangement of the neurons can be fully appreciated.

11. Slowly turn the fine adjustment knob of the microscope. Notice that the cells that you were viewing move out of focus but others at different depths of field come into focus. You can truly appreciate the three-dimensional quality of the structure you are viewing.

The Cerebellum

The arrangement of nervous tissue in the cerebellum is similar to what is seen in the cerebrum. The cerebellum consists of two **cerebellar hemispheres**. Each hemisphere contains a surface layer of gray matter, the **cerebellar cortex** (Figure 13.9), and a deep region of white matter called the **arbor vitae**. Deep to the arbor vitae are additional regions of gray matter known as the **cerebellar nuclei.**

ACTIVITY 13.4 Examining Microscopic Structure of the Cerebellum

1. Obtain a prepared slide of the cerebellum.
2. View the slide under low power. As you scan the slide, identify the outer layer of gray matter, the cerebellar cortex, and the deeper layer of white matter (Figure 13.9). This pattern is similar to what you saw in the cerebrum.
3. Try to identify the three layers of gray matter.
   - The relatively thick superficial **molecular layer** contains interneurons that interconnect the other neurons in the cerebellar cortex.

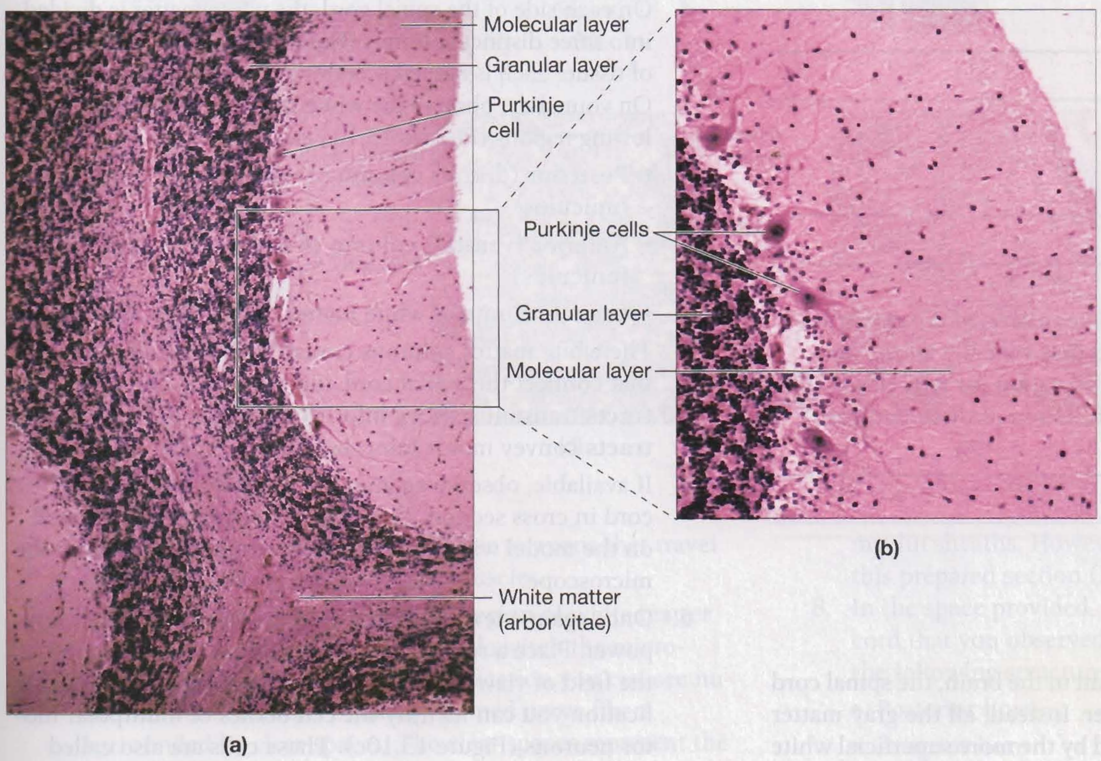

Figure 13.9 Light micrographs of nervous tissue in the cerebellum. a) Low-power view illustrating the relationship between the gray matter in the cerebellar cortex and the deeper white matter (arbor vitae) (LM × 100); **b)** higher power view of the cerebellar cortex. The three cellular layers including the large Purkinje cells can be seen (LM × 200).

- The thin **Purkinje cell layer** is occupied by multipolar neurons whose axons serve as a major output channel, transmitting information from the cortex to deeper cerebellar nuclei.
- The deep **granular layer** includes neurons that receive most of the information coming to the cerebellum from other brain areas.

4. Switch to high power. Within the molecular and granular layers, identify the cell bodies and cell processes (dendrites and unmyelinated axons) of small neurons.
5. The distinguishing structural feature in the cerebellum is the single row of large, flask-shaped **Purkinje cells** in the Purkinje cell layer (Figure 13.9b). Identify these multipolar cells on your slide.
6. In the space provided, draw a region of the cerebellum that you observed and label the following structures:
   - Cerebellar cortex
   - Purkinje cells
   - White matter

QUESTIONS TO CONSIDER 1. Compare the microscopic structure of the cerebrum with that of the cerebellum and identify similarities and differences (e.g., cell types and shapes, layering, or structural patterns of nervous tissue).

a. Similarities:

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b. Differences:

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2. From your light microscopic observations of the cerebrum and cerebellum, you likely noticed that virtually all the neurons are multipolar. Provide an explanation for why this is the case. (Hint: Consider the general function of these neurons.)

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The Spinal Cord

Unlike the cerebrum and cerebellum in the brain, the spinal cord lacks a cortical layer of gray matter. Instead, all the gray matter is deep and completely surrounded by the more superficial white matter. The gray matter is easy to identify because of its unique butterfly shape (Figures 13.10a and b).

ACTIVITY 13.5 Examining Microscopic Structure of the Spinal Cord

1. Obtain a slide of spinal cord tissue, viewed in cross section.
2. View the slide under low power. At this magnification you can clearly identify the butterfly-shaped gray matter, surrounded by peripheral regions of white matter (Figures 13.10a and b).
3. Carefully observe the gray matter. On each side, identify the following parts (Figures 13.10a and b).
   - The **posterior horn** receives sensory fibers from spinal nerves.
   - The **anterior horn** contains the cell bodies of *lower* motor neurons. They are multipolar cells that contribute motor fibers to spinal nerves.
   - The **lateral horns** contain the cell bodies of autonomic motor neurons. They are restricted to thoracic and lumbar spinal cord levels (sympathetic neurons) and portions of the sacral spinal cord (parasympathetic neurons). Thus, these regions may not be present on your slide.
   - The **gray commissure** is a narrow band of tissue that connects the gray matter on each side. The nerve fibers of interneurons pass through this area to relay impulses from one side of the cord to the other. The **central canal**, which contains cerebrospinal fluid, passes through the gray commissure.
4. On each side of the spinal cord, the white matter is divided into three distinct columns (**funiculi**; singular = **funiculus**) of tissue. Each is named according to its relative position. On your slide, observe the white matter and identify the following regions (Figures 13.10a and b).
   - Posterior (dorsal) column of white matter (posterior funiculus)
   - Anterior (ventral) column of white matter (anterior funiculus)
   - Lateral column of white matter (lateral funiculus)

   The white matter columns contain two types of fiber tracts that connect the spinal cord and the brain: The **ascending tracts** transmit sensory information while the **descending tracts** convey motor information.
5. If available, observe an anatomical model of the spinal cord in cross section. Correlate the structures illustrated on the model with what you have just observed under the microscope.
6. Once again, view the spinal cord cross section under low power. Place a region of the anterior horn in the center of the field of view and switch to high power. At this magnification you can identify the cell bodies of multipolar motor neurons (Figure 13.10c). These cells are also called

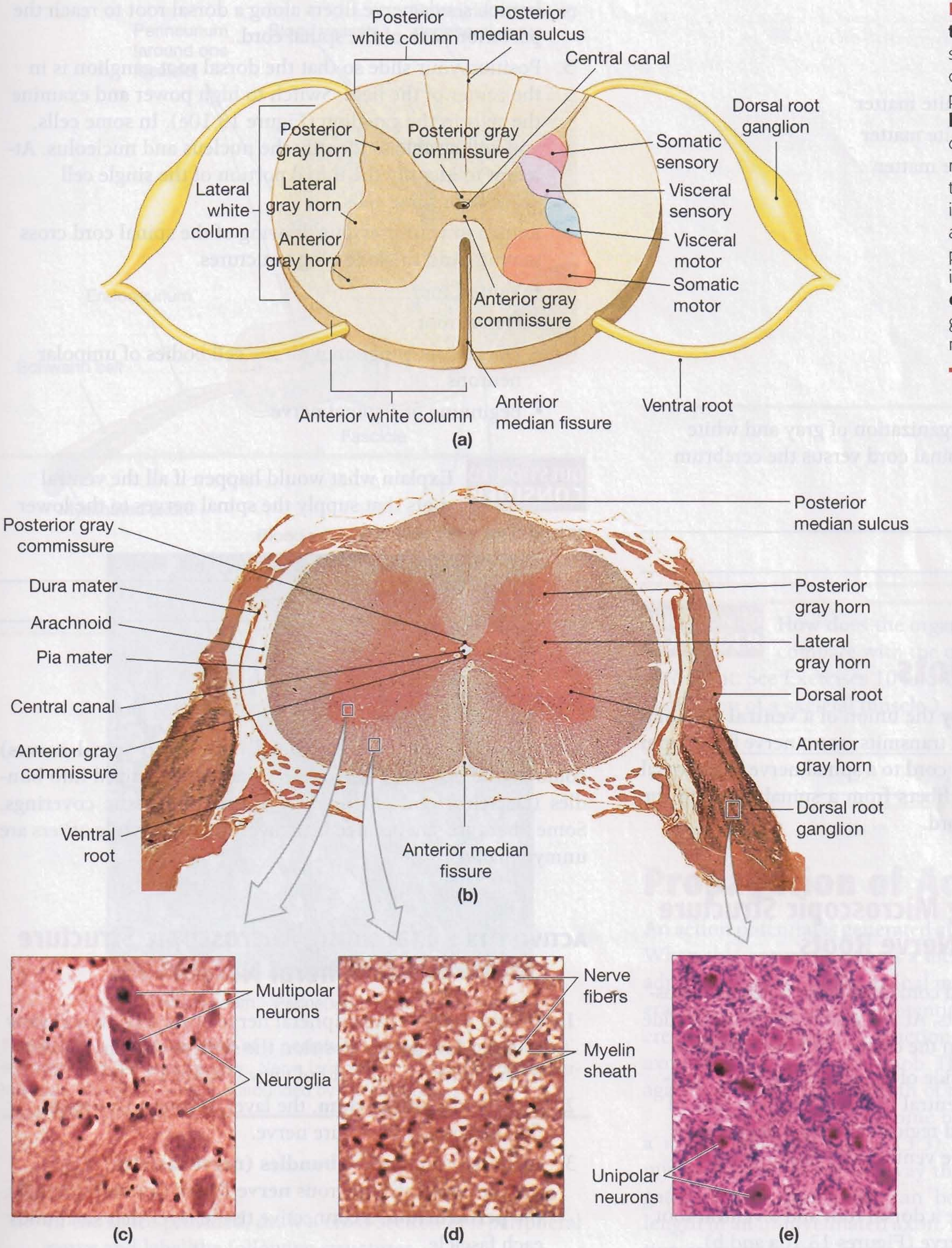


Figure 13.10 Microscopic structure of the spinal cord. a) Cross-sectional diagram, illustrating the deep gray matter horns and the superficial white matter columns; **b)** light micrograph of a spinal cord cross section with dorsal and ventral roots (LM × 40); **c)** high power of the gray matter in the anterior horn, illustrating multipolar motor neurons and glial cells (LM × 200); **d)** high power of the white matter, illustrating myelinated axons (LM × 200); **e)** high power of a dorsal root ganglion, illustrating unipolar sensory neurons (LM × 200).

lower motor neurons. They give rise to axons that travel in spinal nerves to reach skeletal muscles.

7. Switch back to low power. Place a region of white matter in the center of the field of view and switch the microscope to high power. At this magnification you can see numerous cross sections of darkly stained nerve fibers surrounded by clear spaces. The clear spaces represent the myelin sheaths. However, myelin is no longer present in this prepared section (Figure 13.10d).

8. In the space provided, draw a cross section of the spinal cord that you observed under the microscope and label the following structures.
   - Posterior horn
   - Anterior horn

- Lateral horn
- Gray commissure
- Central canal
- Posterior column of white matter
- Anterior column of white matter
- Lateral column of white matter

QUESTION TO CONSIDER Compare the organization of gray and white matter in the spinal cord versus the cerebrum and cerebellum.

Spinal Nerve Roots

Each spinal nerve is formed by the union of a **ventral root** and a **dorsal root**. The ventral root transmits motor nerve fibers from the anterior horn of the spinal cord to a spinal nerve. The dorsal root transmits sensory nerve fibers from a spinal nerve to the posterior horn of the spinal cord.

ACTIVITY 13.6 Examining Microscopic Structure of Spinal Nerve Roots

1. Obtain a slide of the spinal cord cross section that also illustrates the spinal nerve roots. At low power, position the slide so that the spinal cord is in the center of the field of view.
2. Move the slide to either side of the spinal cord and identify the dorsal root and ventral root. Along the course of the dorsal root is a dilated region called the **dorsal root ganglion** (see step 4). The ventral root does not have a comparable structure.
3. Locate the position where a dorsal root and a ventral root merge to form a spinal nerve (Figures 13.10a and b). Switch to high power and identify individual nerve fibers traveling along the nerve roots.
4. Switch back to low power and identify the dorsal root ganglion once again. Within the ganglion you will see numerous cell bodies of unipolar sensory neurons. These neurons contain one cell process that divides into two branches. One branch sends nerve fibers along a spinal nerve to reach peripheral sensory receptors. The other branch sends nerve fibers along a dorsal root to reach the posterior horn of the spinal cord.
5. Position your slide so that the dorsal root ganglion is in the center of the field. Switch to high power and examine the cells in the ganglion (Figure 13.10e). In some cells, you will be able to identify the nucleus and nucleolus. Attempt to identify the initial portion of the single cell process on some cells.
6. Return to your previous drawing of the spinal cord cross section. Add the following structures.
   - Ventral root
   - Dorsal root
   - Dorsal root ganglion with the cell bodies of unipolar neurons
   - Beginning of a spinal nerve

QUESTION TO CONSIDER Explain what would happen if all the ventral roots that supply the spinal nerves to the lower extremities were severed.

Peripheral Nerves

A typical peripheral nerve (cranial nerves and spinal nerves) contains thousands of nerve fibers that are organized into bundles (fascicles) and enclosed by connective tissue coverings. Some fibers are surrounded by a myelin sheath, while others are unmyelinated.

ACTIVITY 13.7 Examining Microscopic Structure of Peripheral Nerves

1. Obtain a slide of a peripheral nerve cross section and view it under low power. Position the slide so that the nerve is in the center of the field of view (Figure 13.11).
2. Identify the **epineurium**, the layer of connective tissue that surrounds the entire nerve.
3. Identify several **nerve bundles (nerve fasicles)**. Each bundle contains numerous **nerve fibers (axons)**. Identify the **perineurium**, a connective tissue layer that surrounds each fascicle.
4. Move the slide so that one nerve bundle is in the center of the field of view. Switch to high power so that you can identify individual nerve fibers. The fibers will appear as darkly stained circles. Identify myelinated nerve fibers. On the slide, these fibers are surrounded by a clear space. Due to the special preparation of the tissue, the myelin sheath is absent. Attempt to identify the **endoneurium**, the connective tissue layer that covers each nerve fiber.

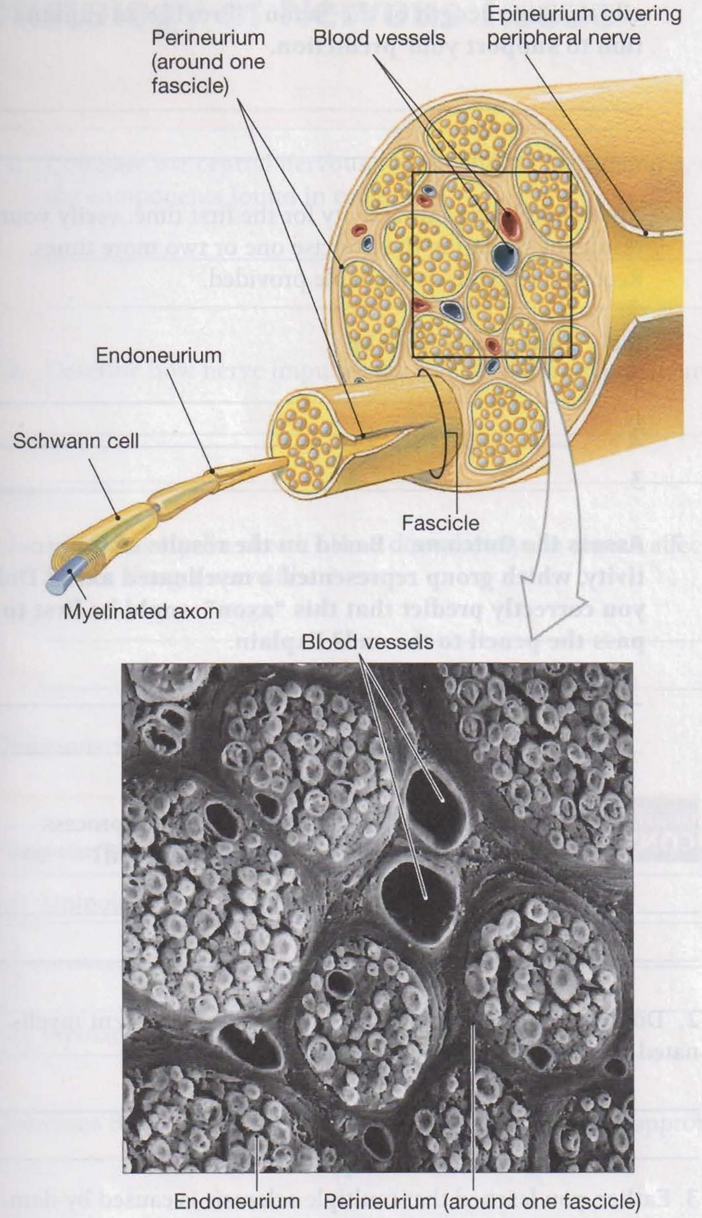


Figure 13.11 Cross section of a peripheral nerve. Each nerve fiber is surrounded by the endoneurium. Nerve fascicles are surrounded by the perineurium. The entire nerve is surrounded by the epineurium.

5. In the space provided, draw a cross section of a peripheral nerve and label the following structures.
   - Epineurium
   - Perineurium
   - Endoneurium
   - Nerve bundle (fascicle)
   - Nerve fiber (axon)
   - Clear space around some axons, where myelin sheath would be found

QUESTION TO CONSIDER How does the organization of a peripheral nerve compare with the organization of a skeletal muscle? (Hint: See Exercises 10 and 11 to review the levels of organization of a skeletal muscle.)

Propagation of Action Potentials

An action potential is generated at the initial segment of an axon. When this occurs, it creates a local current that depolarizes the adjacent segment of the axonal membrane, resulting in the generation of a second action potential. This process repeats itself to create a rapid succession of action potentials that move along the axon toward the synaptic knob. Thus, action potentials are propagated along the entire length of the axon.

As mentioned earlier, some nerve fibers are surrounded by a myelin sheath (Figure 13.3). The presence or absence of myelin will influence the way the action potentials are propagated. Action potentials can be generated along the entire length of an unmyelinated axon. Myelinated axons generate action potentials only at the nodes of Ranvier, where myelin is lacking. The insulating property of the myelin sheath inhibits the passage of sodium and potassium ions across the membrane, and it is that movement that creates the action potential. Thus, action potentials are not produced along the myelinated segments of the axon. Instead, they are transmitted by skipping from node to node. This type of transmission, known as **saltatory propagation**, is much faster than what occurs in an unmyelinated axon.

CLINICAL CORRELATION

Multiple sclerosis (MS) is a neurological disease that typically occurs in young adults. It is caused by the destruction of the myelin sheath around motor and sensory axons in the brain and spinal cord. The result is a progressive loss of motor and sensory function. Typical symptoms include muscle paralysis, impaired vision, loss of balance, slurred speech, and skin numbness. Multiple sclerosis is an autoimmune disease, which means that the affected individual's own immune system mistakenly attacks and destroys the myelin sheath. The severity and intensity of the disease varies among those who are affected.

Recent investigations suggest that MS could develop when the immune system confuses the myelin sheath proteins for viral proteins with similar amino acid sequences and attacks them. Treatment with interferons, antiviral proteins that are produced by cells in the immune system, has been successful in mitigating the symptoms of MS. However, there is currently no cure for the disease.

ACTIVITY 13.8 Demonstrating the Significance of the Myelin Sheath

1. Organize two groups of students. The first group will represent axon A and should include nine or ten students; the second group will represent axon B and should include four or five students.
2. Mark off a space in the laboratory or adjacent hallway that is 20 feet long.
3. The two groups should arrange themselves so that they form two parallel rows. The first person in each group represents the initial segment of an axon. They should be standing side by side at the zero mark. The last person in each group represents a synaptic knob. They should be standing side by side at the 20-foot mark. All other members in both groups should position themselves between the first and last persons so that there is an equal distance between each individual.
4. The first person in each group should hold a pencil. When the instructor gives the command to start, the students should hand the pencil down the line to the end. Members of axon A should be able to pass the pencil down the line without walking forward. Members of axon B will probably have to walk to the next person to pass the pencil.
5. **Form a Hypothesis** **Before you begin, predict which group (axon A or axon B) will be first to pass the pencil the entire length of the "axon." Provide an explanation to support your prediction.**

   ____

   ____

6. After completing this activity for the first time, verify your results by repeating the exercise one or two more times. Record the results in the table provided.

Trial	Faster "Axon" (A or B)
1	
2	
3	

7. **Assess the Outcome** **Based on the results of this activity, which group represented a myelinated axon? Did you correctly predict that this "axon" would be first to pass the pencil to the end? Explain.**

   ____

   ____

QUESTIONS TO CONSIDER

1. With regard to activity 13.8: What process does the passing of the pencil represent?

____

____

2. Do the individuals in the myelinated axon represent myelinated segments or nodes of Ranvier? Explain.

____

____

3. Earlier, you learned that multiple sclerosis is caused by damage to the myelin sheath around axons.
   - How will multiple sclerosis affect the transmission of action potentials along axons?
   - With regard to this activity, to demonstrate the effects of multiple sclerosis, would you add or subtract members of the myelinated axon? Explain.

____

____

Exercise 13 Review Sheet

Histology of Nervous Tissue

Name ______________________

Lab Section ______________________

Date

1. Compare the central nervous system and the peripheral nervous system by discussing the components found in each.

2. Describe how nerve impulses are transferred from one neuron to the next at a synapse.

3. What is a myelin sheath? How does the myelin sheath affect the conduction of impulses along a nerve fiber?

Questions 4–7: Fill in the blanks in the following table.

Types of Neurons		
Unipolar/Bipolar/Multipolar	**Sensory/Motor/Interneuron**	**Afferent/Efferent/Neither**
4. Unipolar		
5.	Motor	
6.		Neither
7. Bipolar		

Questions 8–12: Match the cell type in column A with the appropriate function in column B.

A

8. Ependymal cells ______
9. Astrocytes ______
10. Schwann cells ______
11. Microglial cells ______
12. Oligodendrocytes ______

B

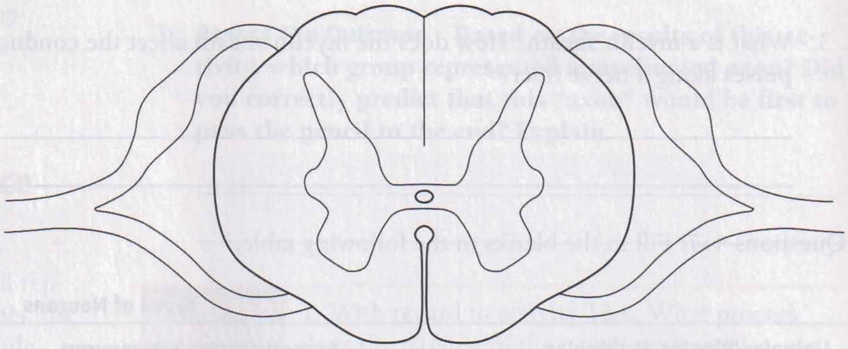
a. help to form the blood-brain barrier.
b. produce the myelin sheath in the PNS.
c. line the walls of ventricles in the brain.
d. serve as afferent neurons.
e. produce the myelin sheath in the CNS.
f. protect the CNS from disease-causing microorganisms.

Questions 13–14: Explain the difference between the following pairs of terms.

13. White matter and gray matter

14. Ganglion and nucleus

Questions 15–24: In the following diagram, identify structures by labeling with the color that is indicated.



Gray matter:

15. Anterior horn = green
16. Posterior horn = red
17. Lateral horn = yellow
18. Gray commissure = black

White matter:

19. Lateral columns = blue
20. Anterior column = purple
21. Posterior column = brown
22. Dorsal root ganglion = red
23. Dorsal root = yellow
24. Ventral root = red