The Nervous System
Introduction, Spinal Cord, and Spinal Nerves

CHAPTER OBJECTIVES
After studying this chapter, you should be able to:

1. Name the major subdivisions of the nervous system.
2. Classify the different types of neuroglia cells.
3. List the structural and functional classification of neurons.
4. Explain how a neuron transmits a nerve impulse.
5. Name the different types of neural tissues and their definitions.
6. Describe the structure of the spinal cord.
7. Name and number the spinal nerves.
**KEY TERMS**

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INTRODUCTION

The nervous system is the body's control center and communication network. It directs the functions of the body's organs and systems. It allows us to interpret what is occurring in our external environment and helps us to decide how to react to any environmental change or stimulus by causing muscular contractions. It shares in the maintenance of homeostasis (the internal environment of our bodies) with the endocrine system by controlling the master endocrine gland (the pituitary) through the hypothalamus of the brain. See Concept Map 10-1: Spinal Cord and Spinal Nerves.

ORGANIZATION

The nervous system can be grouped into two major categories (Figure 10-1). The first is the central nervous system (CNS), which is the control center for the whole system. It consists of the brain and spinal cord. All body sensations and changes in our external environment must be relayed from receptors and sense organs to the CNS to be interpreted (what do they mean?) and then, if necessary, acted on (such as move away from a source of pain or danger).

The second major category is the peripheral nervous system (PNS), which is subdivided into several smaller units. This second category consists of all the nerves that connect the brain and spinal cord with sensory receptors, muscles, and glands.

The PNS can be divided into two subcategories: the afferent peripheral system, which consists of afferent or sensory neurons that convey information from receptors in the periphery of the body to the brain and spinal cord, and the efferent peripheral system, which consists of efferent or motor neurons that convey information from the brain and spinal cord to muscles and glands.

CONCEPT MAP 10-1. Spinal cord and spinal nerves.
The efferent peripheral system can be further subdivided into two subcategories. The first is the somatic nervous system, which conducts impulses from the brain and spinal cord to skeletal muscle, thereby causing us to respond or react to changes in our external environment. The second is the autonomic nervous system (ANS), which conducts impulses from the brain and spinal cord to smooth muscle tissue (like the smooth muscles of the intestine that push food through the digestive tract), to cardiac muscle tissue of the heart, and to glands (like the endocrine glands). The ANS is considered to be involuntary. The organs affected by this system receive nerve fibers from two divisions of the ANS: the sympathetic division, which stimulates or speeds up activity and uses norepinephrine (nor-ep-ih-NEH-frin) as a neurotransmitter, and the parasympathetic division, which stimulates or speeds up the body’s vegetative activities such as digestion, urination, and defecation and restores or slows down other activities. It uses acetylcholine (ah-seh-till-KOH-leen) as a neurotransmitter at nerve endings.

**CLASSIFICATION OF NERVE CELLS**

Nervous tissue consists of groupings of nerve cells or neurons (NOO-ronz) that transmit information called nerve impulses in the form of electrochemical changes. A nerve is a bundle of nerve cells or fibers. Nervous tissue is also composed of cells that perform support and protection. These cells are called neuroglia (n0o-ROWG-lee-ah) or glial (GLEE-al) cells (neuroglia means nerve glue). Over 60% of all brain cells are neuroglia cells.

**Neuroglia Cells**

There are different kinds of neuroglia cells, and, unlike neurons, they do not conduct impulses (Figure 10-2). Table 10-1 lists the types of neuroglia. Astrocytes are star-shaped cells that wrap around nerve cells to form a supporting network in the brain and spinal cord. They attach neurons to their blood vessels, thus helping regulate nutrients and ions that are needed by the nerve cells. Oligodendroglia (all-ih-goh-DEN-droh-GLEE-ah) look like small astrocytes. They also provide support by forming semirigid connective-like tissue rows between neurons in the brain and spinal cord. They produce the fatty myelin (MY-eh-lin) sheath on the neurons of the brain and spinal cord of the CNS. Microglia (my-KROWG-lee-ah) cells are small cells that protect the CNS and whose role is to engulf and destroy microbes like bacteria and cellular debris. Ependymal (eh-PIN-dih-mal) cells line the fluid-filled ventricles of the brain. Some
produce cerebrospinal fluid and others with cilia move the fluid through the CNS. Schwann cells form myelin sheaths around nerve fibers in the PNS.

## The Structure of a Neuron

Each nerve cell’s body contains a single nucleus (Figure 10-3). This nucleus is the control center of the cell. In the cytoplasm there are mitochondria, Golgi bodies, lysosomes, and a network of threads called neurofilaments that extend into the axon part of the cell, referred to as the fiber of the cell. In the cytoplasm of the cell body there is extensive rough endoplasmic reticulum (ER). In a neuron, the rough ER has ribosomes attached to it. These granular structures are referred to as Nissl (NISS-l) bodies, also called chromatophilic substance, and are where protein synthesis occurs.

There are two kinds of nerve fibers on the nerve cell: dendrites (DEN-drightz) and axons. Dendrites are short and branched, like the branches of trees. These are the receptive areas of the neuron and a multipolar neuron will have many dendrites. A nerve cell, however, will have only one axon, which begins as a slight enlargement of the cell body called the axonal hillock. The axon is a long process or fiber that begins singly but may branch and at its end has many fine extensions called axon terminals that contact with dendrites of other neurons. Numerous mitochondria and neurofilaments are in the axon.

### Table 10-1 Types of Neuroglia

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tr>
<td>Astrocytes</td>
<td>Star-shaped cells that function in the blood-brain barrier to prevent toxic substances from entering the brain</td>
</tr>
<tr>
<td>Oligodendroglia</td>
<td>Provide support and connection</td>
</tr>
<tr>
<td>Microglia</td>
<td>Involved in the phagocytosis of unwanted substances</td>
</tr>
<tr>
<td>Ependymal cells</td>
<td>Form the lining of the cavities in the brain and spinal cord</td>
</tr>
<tr>
<td>Schwann cells</td>
<td>Located only in the PNS and make up the neurilemma and myelin sheath</td>
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FIGURE 10-2. Types of neuroglia found in the CNS: astrocytes, oligodendroglia, microglia, and ependymal cells.
The large peripheral axons are enclosed in fatty myelin sheaths produced by the Schwann cells. These are a type of neuroglial cell that wrap tightly in layers around the axon, producing fatty sheets of lipoprotein. The portions of the Schwann cell that contain most of the cytoplasm of the cell and the nucleus remain outside of the myelin sheath and make up a portion called the neurilemma. Narrow gaps in the sheath are the nodes of Ranvier.

**Structural Classification of Neurons**

Cells that conduct impulses from one part of the body to another are called neurons. They may be classified by both function and structure. The structural classification consists of three types of cells. **Multipolar neurons** are neurons that have several (multi) dendrites and one axon. Most neurons in the brain and spinal cord are this type. The neuron studied in Chapter 5 is this type. Recall that the part of the neuron with the nucleus is called the cell body. The smaller extensions of the cell body are the dendrites, and the single long extension is called the axon. Single cells called Schwann cells, also called neurolemmocytes (noo-row-leh-MOH-sights), surround the axon at specific sites and form the fatty myelin sheath around the axons in the peripheral nervous system (Figure 10-4). Gaps in the myelin sheath are called nodes of Ranvier (NOHDZ of rahn-vee-A), also called neurofibral nodes. These gaps allow ions to flow freely from the extracellular fluids to the axons, assisting in developing action potentials for nerve transmission.

![Diagram of a neuron](image-url)
Bipolar neurons (see Figure 11-11 in Chapter 11) have one dendrite and one axon. They function as receptor cells in special sense organs. Only two (bi) processes come off the cell body. They are found in only three areas of the body: the retina of the eye, the inner ear, and the olfactory area of the nose. Unipolar neurons have only one process extending from the cell body. This single process then branches into a central branch that functions as an axon and a peripheral branch that functions as a dendrite. Most sensory neurons are unipolar neurons (see Figure 10-3). The branch functioning as an axon enters the brain or spinal cord; the branch functioning as a dendrite connects to a peripheral part of the body.

Functional Classification of Neurons

Nerve cells pick up various changes in the environment (stimuli such as changes in temperature or pressure) from receptors. Receptors are the peripheral nerve endings of sensory nerves that respond to stimuli. There are many different types of receptors. Our skin has an enormous number of such receptors. These receptors change the energy of a stimulus, like heat, into nerve impulses. The first nerve cell receiving this impulse directly from a receptor is called a sensory or afferent neuron. These neurons are of the unipolar type. The receptors are in contact with only one end of the sensory neuron (the peripheral process in the skin), thus ensuring a one-way transmission of the impulse. The central process of the sensory neuron goes to the spinal cord.

From the sensory neuron, the impulse may pass through a number of internuncial or association neurons. These are found in the brain and the spinal cord and are of the multipolar type. They transmit the sensory impulse to the appropriate part of the brain or spinal cord for interpretation and processing.

From the association or internuncial neurons, the impulse is passed to the final nerve cell, the motor or efferent neuron. The motor neuron is of the multipolar type. This neuron brings about the reaction to the original stimulus. It is usually muscular (like pulling away from a source of heat or pain) but it can also be glandular (like salivating after smelling freshly baked cookies).

THE PHYSIOLOGY OF THE NERVE IMPULSE

A nerve cell is similar to a muscle cell in that there are concentrations of ions on the inside and the outside of the cell membrane. Positively charged sodium (Na⁺) ions are in greater concentration outside the cell than inside. There is a greater concentration of positively charged potassium (K⁺) ions inside the cell than outside. This situation is maintained by the cell membrane’s sodium-potassium pump (Figure 10-5). In addition to the potassium ion, the inside of the fiber has negatively charged chloride (Cl⁻) ions and other negatively charged organic molecules. Thus, the nerve fiber has an electrical distribution as well, such that the outside is positively charged while the inside is negatively charged (Figure 10-6). This condition is known as the membrane or resting potential. Na⁺ and K⁺ ions tend to diffuse across the membrane but the cell maintains the resting potential through the channels of the sodium-potassium pump that actively extrudes Na⁺ and accumulates K⁺ ions.

When a nerve impulse begins, the permeability to the sodium (Na⁺) ions changes. Na⁺ rushes in, causing a change from a negative (-) to a positive (+) charge inside the nerve membrane. This reversal of electrical charge is called depolarization and creates the cell’s action potential. The action potential moves in one direction down the nerve fiber.
FIGURE 10-5. The sodium-potassium pump of a nerve cell’s membrane.

Now the potassium ions begin to move outside to restore the resting membrane potential. The sodium-potassium pump begins to function, pumping out the sodium ions that rushed in and pulling back in the potassium ions that moved outside, thus restoring the original charges. This is called repolarization, as shown in Figure 10-6, and the inside of the cell again becomes negative. This process continues along the nerve fiber acting like an electrical current, carrying the nerve impulse along the fiber. The nerve impulse is a self-propagating wave of depolarization followed by repolarization moving down the nerve fiber.
FIGURE 10-6. The electrical distribution surrounding a nerve fiber and transmission of a nerve impulse.
An unmyelinated nerve fiber conducts an impulse over its entire length, but the conduction is slower than that along a myelinated fiber. A myelinated fiber is insulated by the myelin sheath, so transmission occurs only at the nodes of Ranvier between adjacent Schwann cells. Action potentials and inflow of ions occur only at these nodes, allowing the nerve impulse to jump from node to node, and the impulse travels much faster. An impulse on a myelinated motor fiber going to a skeletal muscle could travel about 120 meters per second, while an impulse on an unmyelinated fiber would travel only 0.5 meter per second.

On any nerve fiber, the impulse will never vary in strength. If the stimulus or change in the environment is barely great enough to cause the fiber to carry the impulse, the impulse will be the same strength as one excited by a stronger stimulus. This is known as the all-or-none law, which states that if a nerve fiber carries any impulse, it will carry a full strength impulse.

**THE SYNAPTIC TRANSMISSION**

Synapses (sin-AP-seez) are the areas where the terminal branches of an axon (the axon terminals) are anchored close to, but not touching, the ends of the dendrites of another neuron. These synapses are one-way junctions that ensure that the nerve impulse travels in only one direction. This area is called a synaptic cleft. Other such areas of synapses are between axon endings and muscles or between axon endings and glands. An impulse continuing along a nerve pathway must cross this gap.

Transmission across synapses is brought about by the secretions of very low concentrations of chemicals called neurotransmitters that move across the gap. As the nerve impulse travels down the fiber, it causes vesicles in the axon endings of a presynaptic neuron to release the chemical neurotransmitter. Most of the synapses in our bodies use acetylcholine as the neurotransmitter. The acetylcholine allows the impulse to travel across the synaptic cleft to the postsynaptic neuron. However, it does not remain there because an enzyme in the cleft, acetylcholinesterase, immediately begins to break down the acetylcholine after it performs its function (Figure 10-7). The autonomic nervous system in addition uses adrenaline (also called epinephrine) as a transmitting agent. Many kinds of neurotransmitters are found in the nervous system. Some neurons produce only one type; others produce two or three. The best known neurotransmitters are acetylcholine and norepinephrine. Some others are serotonin (sayr-oh-TOH-nin), dopamine (DOH-pah-meen), and the endorphins (IN-DOHR-fin).
White matter forms nerve tracts in the CNS. The gray areas of the nervous system are called gray matter, consisting of nerve cell bodies and dendrites. It also can consist of bundles of unmyelinated axons and their neuroglia. The gray matter on the surface of the brain is called the cortex.

A nerve is a bundle of fibers located outside the CNS. Most nerves are white matter. Nerve cell bodies that are found outside the CNS are generally grouped together to form ganglia (GANG-lee-ah). Because ganglia are made up primarily of unmyelinated nerve cell bodies, they are masses of gray matter.

A tract is a bundle of fibers inside the CNS. Tracts run long distances up and down the spinal cord. Tracts are also found in the brain and connect parts of the brain with each other and parts of the brain with the spinal cord. Ascending tracts conduct impulses up the cord and are concerned with sensation. Descending tracts conduct impulses down the cord and are concerned with motor functions. Tracts are made of myelinated fibers and therefore are classified as white matter. Two other terms are of note: a nucleus is a mass of nerve cell bodies and dendrites inside the CNS, consisting of gray matter; horns are the areas of gray matter in the spinal cord.

THE SPINAL CORD

The spinal cord begins as a continuation of the medulla oblongata of the brainstem. Its length is approximately 16 to 18 inches. Its diameter varies at different levels because it is surrounded and protected by bone (the vertebrae) and by disks of fibrocartilage (the intervertebral disks). It is made up of a series of 31 segments, each giving rise to a pair of spinal nerves. In addition to the above protection, the spinal cord (as well as the brain) is further protected by the meninges (men-INS-jee), a series of connective tissue membranes. Those associated specifically with the spinal cord are called the spinal meninges (Figure 10-9).

The outermost spinal meninx is called the dura mater (DOO-rah-MATE-ehr), which means tough mother. It forms a tough outer tube of white fibrous connective tissue. The middle spinal meninx is called the arachnoid mater (ah-RACK-noyd MATE-ehr) or spider layer. It forms a delicate connective membranous tube inside the dura mater. The innermost spinal meninx is known as the pia mater (PEE-ah MATE-ehr) or delicate mother. It is a transparent fibrous membrane that forms a tube around and adheres to the surface of the spinal cord (and brain). It contains numerous blood vessels and nerves that nourish the underlying cells.

Between the dura mater and the arachnoid is a space called the subdural space, which contains serous
Some of the most commonly abused drugs that affect the CNS are depressants (“downers”), stimulants (“uppers”), and hallucinogens as well as the anabolic steroids.

One example of a depressant is Valium, which is prescribed in low doses to relieve tension. However, higher doses cause drowsiness, sedation, and loss of any pain sensations. Another group of depressants are the opiate drugs like codeine and heroin. Codeine can be prescribed by a doctor, but heroin has no legal use in the United States. These drugs act as sedatives and analgesics, which relieve pain in prescribed doses. However, they can cause psychological and physical dependency. They also produce a feeling of euphoria. Overuse can result in coma, convulsions, and respiratory problems that could lead to death. A drug derived from the hemp plant (Cannabis) is marijuana. It is not as potent as hashish. Hashish is made from the resin in the flowering tips of the hemp plant. This drug produces a state of euphoria free of anxiety and alters one’s perception of time and space. Marijuana has been prescribed for individuals with advanced stages of incurable diseases (e.g., certain cancers) and glaucoma of the eye. Higher doses can lead to hallucinations and respiratory problems.

Examples of stimulants to the CNS are cocaine, hallucinogens such as LSD (lysergic acid diethylamide), and amphetamines. Hallucinogens like LSD cause distortions in the five senses. The perceptions of sight, sound, smell, and taste are heightened and exaggerated. A person may have a sense of being able to do anything physically, leading to serious injury to oneself. Cocaine produces great psychological and physical dependence on the user. When inhaled it produces a quick state of euphoria. However, it causes changes in personality, seizures, and death from stroke or abnormal rhythms of the heart. Amphetamines overstimulate postsynaptic neurons, resulting in muscle spasms, restlessness, rapid heartbeat, and hypertension. This is a high price to pay for the feeling of euphoria and elation first produced. Death can result from respiratory or heart failure.

The anabolic steroids act like the male sex hormones and are commonly used by athletes because they cause skeletal muscle cells to increase in size. Athletes, like bodybuilders, can quickly increase their bulk, although this benefit has dangerous side effects. Taken in large doses, synthetic androgens or anabolic steroids have a negative feedback effect on the hypothalamus of the brain and the pituitary gland. This causes a reduction in gonadotropin-releasing hormone, luteinizing hormone, and follicle-stimulating hormone. As a result, the testes can atrophy and sterility will occur. The abuse of these steroids can also lead to liver problems, heart disease, and personality changes.

Functions of the Spinal Cord
A major function of the spinal cord is to convey sensory impulses from the periphery to the brain and to conduct motor impulses from the brain to the periphery. Ascending nerve tracts of the spinal cord carry sensory information from body parts to the brain, and descending tracts conduct motor impulses from the brain to muscles and glands. A second principal function is to provide a means of integrating reflexes. A pair of spinal nerves is connected to each segment of the spinal cord. Each pair of spinal nerves is connected to that segment of the cord by two pairs of attachments called roots (see Figure 10-9). The posterior or dorsal root is the sensory root and contains only sensory nerve fibers. It conducts impulses from the periphery (like the skin) to the spinal cord. These fibers extend into the posterior or dorsal gray horn of the spinal cord. The other point of attachment of the spinal nerve to the cord is the anterior or ventral root and this is the motor root. It contains motor nerve fibers only and conducts impulses from
The spinal cord extends down to the second lumbar vertebra. Yet spinal nerves, surrounded by the meninges, go all the way down to the end of the vertebral column. Because there is no spinal cord at the end of the vertebral canal, a needle can be inserted into the subarachnoid space in this area without damaging the spinal cord. This is done to perform a spinal tap and extract cerebrospinal fluid, which can then be examined for infectious organisms like those causing meningitis, or for detecting blood, in the case of a hemorrhage. A needle could also be inserted with an anesthetic agent to administer spinal anesthesia in this way. If a radiopaque substance is injected in this area, an X-ray can be taken of the spinal cord to detect any damage or defects in the cord.

**HEALTH ALERT**

The spinal cord extends down to the second lumbar vertebra. Yet spinal nerves, surrounded by the meninges, go all the way down to the end of the vertebral column. Because there is no spinal cord at the end of the vertebral canal, a needle can be inserted into the subarachnoid space in this area without damaging the spinal cord. This is done to perform a spinal tap and extract cerebrospinal fluid, which can then be examined for infectious organisms like those causing meningitis, or for detecting blood, in the case of a hemorrhage. A needle could also be inserted with an anesthetic agent to administer spinal anesthesia in this way. If a radiopaque substance is injected in this area, an X-ray can be taken of the spinal cord to detect any damage or defects in the cord.

**THE SPINAL NERVES**

The 31 pairs of spinal nerves arise from the union of the dorsal and ventral roots of the spinal nerves (see Figure 10-9). All the spinal nerves are mixed nerves because they consist of both motor and sensory fibers. Most of the spinal nerves exit the vertebral column between adjacent vertebrae. They are named and numbered according to the region and level of the spinal cord from which they emerge (Figure 10-10). There are 8 pairs of cervical nerves, 12 pairs of thoracic nerves, 5 pairs of
lumbar nerves, 5 pairs of sacral nerves, and a single pair of coccygeal nerves. The spinal nerves are also numbered according to the order (starting superiorly) within the region. Thus, the 31 pairs are C1 through C8 (cervical), T1 through T12 (thoracic), L1 through L5 (lumbar), S1 through S5 (sacral), and Cx (coccygeal).

SUMMARY OUTLINE

INTRODUCTION
1. The nervous system is the body’s control center and communication network.
2. It shares in the maintenance of homeostasis with the endocrine system.

ORGANIZATION
1. The central nervous system (CNS) consists of the brain and spinal cord.
2. The peripheral nervous system (PNS) consists of the afferent peripheral system (sensory neurons) and the efferent peripheral system (motor neurons).
3. The efferent peripheral system can be subdivided into the somatic nervous system, which sends signals to skeletal muscles, and the autonomic nervous system (ANS), which sends signals to cardiac and smooth muscles and glands.
4. The ANS has two divisions: the sympathetic division, which stimulates and speeds up activity, and the parasympathetic division, which restores or slows down certain activities but stimulates the body’s vegetative activities.

CLASSIFICATION OF NERVE CELLS
1. Neurons are nerve cells that transmit nerve impulses in the form of electrochemical changes.
2. A nerve is a bundle of nerve cells.
3. Neuroglia cells are nerve cells that support and protect the neurons.

Neuroglia Cells
1. Astrocytes are star-shaped cells that wrap around neurons for support in the brain and spinal cord and connect neurons to blood vessels.
2. Oligodendroglia look like small astrocytes. They form connective-like tissue rows for support and form the fatty myelin sheath on the neurons in the brain and spinal cord.
3. Microglia are small cells that do phagocytosis of microbes and cellular debris.
4. Ependymal cells line the fluid-filled ventricles of the brain. Some produce cerebrospinal fluid and others, with cilia, move it through the CNS.
5. Schwann cells form myelin sheaths around nerve fibers in the peripheral nervous system.
The Structure of a Neuron
1. A neuron is composed of a cell body with a nucleus and other intracellular organelles.
2. Dendrites are extensions of the cell body and are the receptive areas of the neuron.
3. An axon is a single long extension of the cell body that begins as a slight enlargement, the axon hillock. The axon may branch, but at its end there are many extensions called axon terminals.
4. On large peripheral axons, a Schwann cell produces a fatty myelin sheath that surrounds and insulates the axon. Narrow gaps in the sheath are called nodes of Ranvier.

Structural Classification of Neurons
1. Multipolar neurons have several dendrites coming off the cell body and one axon. Most neurons in the brain and spinal cord are multipolar neurons.
2. Bipolar neurons have one dendrite and one axon. They are found in the retina of the eye, the inner ear, and in the olfactory area of the nose.
3. Unipolar neurons have only one process extending from the cell body, which then branches into a central branch that functions as an axon and a peripheral branch that functions as a dendrite. Most sensory neurons are unipolar neurons.

Functional Classification of Neurons
1. Receptors detect stimuli in our environment.
2. Sensory or afferent neurons receive the impulse directly from the receptor site. They are unipolar neurons.
3. Internuncial or association neurons are found in the brain and spinal cord. They transmit the impulse for interpretation and processing. They are multipolar neurons.
4. Motor or efferent neurons bring about the reaction to the stimulus. They are multipolar neurons.

THE PHYSIOLOGY OF THE NERVE IMPULSE
1. A nerve cell fiber has a higher concentration of Na\(^+\) on the outside than inside and a higher concentration of K\(^+\) on the inside than on the outside. This is maintained by the sodium-potassium pump.
2. The nerve fiber has a negative electrical charge on the inside and a positive electrical charge on the outside.
3. This electrical ionic distribution is called the membrane or resting potential.
4. When a nerve impulse begins, the sodium ions (Na\(^+\)) rush in changing the inside electrical charge from negative to positive. This is the action potential called depolarization.
5. Potassium ions (K\(^+\)) move out to try to restore the resting membrane potential and the sodium-potassium pump operates to restore the original charge. This is repolarization and restores the fiber’s membrane to the original resting or membrane potential.
6. The nerve impulse is a self-propagating wave of depolarization followed by repolarization moving in one direction down the nerve fiber.
7. The all-or-none law states that if a nerve fiber carries any impulse, it will carry a full strength impulse.

THE SYNAPTIC TRANSMISSION
1. A synapse is an area where the terminal branches of an axon are close to but not touching the dendrites of another neuron.
2. When an impulse reaches the axon terminals, it triggers the release of a neurotransmitter like acetylcholine into the synaptic cleft, which allows the impulse to travel across the synapse.
3. Other neurotransmitters in the body are epinephrine or adrenaline, norepinephrine, serotonin, dopamine, and the endorphins.

THE REFLEX ARC
1. A reflex is an involuntary reaction to an external stimulus.
2. A reflex arc is the pathway that causes a reflex.
3. A reflex arc has five components: a sensory receptor in the skin; a sensory or afferent neuron; association or internuncial neurons in the spinal cord; a motor or efferent neuron; and an effector organ.

GROUPING OF NEURAL TISSUE
1. White matter refers to groups of myelinated axons from many neurons supported by neuroglia.
2. Gray matter consists of nerve cell bodies and dendrites, as well as groups of unmyelinated axons and their neuroglia.
3. A nerve is a bundle of fibers outside the CNS.
4. Ganglia are nerve cell bodies found outside the CNS.
5. A tract is a bundle of fibers inside the CNS.
6. A nucleus is a mass of nerve cell bodies and dendrites inside the CNS.
7. Horns are areas of gray matter in the spinal cord.

**THE SPINAL CORD**
1. The spinal cord is a continuation of the medulla oblongata.
2. The spinal cord is made of 31 segments, each giving rise to a pair of spinal nerves.
3. The spinal cord is protected by the spinal meninges.
4. The outermost spinal meninx is the dura mater or tough mother, the middle spinal meninx is the arachnoid mater or spider layer, and the innermost meninx is the pia mater or delicate mother.
5. Between the dura mater and the arachnoid is a space called the subdural space, which contains serous fluid.
6. Between the arachnoid and the pia mater is the subarachnoid space in which the cerebrospinal fluid circulates.

**FUNCTIONS OF THE SPINAL CORD**
1. The spinal cord conveys sensory impulses from the periphery to the brain (ascending tracts) and conducts motor impulses from the brain to the periphery (descending tracts).
2. The spinal cord also integrates reflexes.
3. Each pair of spinal nerves connects to a segment of the spinal cord by two points of attachments called the roots.
4. The posterior or dorsal root is sensory and connects with the posterior or dorsal gray horn of the spinal cord.
5. The anterior or ventral root is motor and connects with the anterior or ventral gray horn of the spinal cord.

**THE SPINAL NERVES**
1. There are eight pairs of cervical nerves (C1–C8).
2. There are 12 pairs of thoracic nerves (T1–T12).
3. There are five pairs of lumbar nerves (L1–L5).
4. There are five pairs of sacral nerves (S1–S5).
5. There is one pair of coccygeal nerves (Cx).

**REVIEW QUESTIONS**
1. Name the 31 spinal nerves and indicate how many there are of each.
2. Discuss the factors involved in the transmission of a nerve impulse.
3. Name and describe five types of neuroglia cells.
4. Classify the organization of the nervous system.
5. Name and describe the three types of structural neurons.
6. Explain how a reflex arc functions, and name its components.
7. Name the two functions of the spinal cord.

*Critical Thinking Questions*

**FILL IN THE BLANK**
Fill in the blank with the most appropriate term.
1. The central nervous system consists of the ______________ and the ______________.
2. The peripheral nervous system consists of the afferent system composed of ______________ neurons, and the efferent system composed of ______________ neurons.
3. The autonomic nervous system is divided into the ______________ division, which stimulates, and the ______________ division, which restores activities and stimulates vegetative functions.
4. The meninges have an outer meninx called the ______________, a middle meninx called the ______________ or spider layer, and an inner meninx called the ______________.
5. A ______________ is an area of gray matter in the spinal cord.
MATCHING

Place the most appropriate number in the blank provided.

1. Produce myelin sheath on neurons
2. Nerve cell bodies outside CNS
3. Engulf and destroy microbes
4. Bundles of fibers in the CNS
5. Attach neurons to their blood vessels
6. Unmyelinated axons and neuroglia
7. Coverings around brain and spinal cord
8. Gray matter in spinal cord
9. Reflex arc

10. Mass of nerve cell bodies and dendrites in CNS
11. Myelinated neurons
12. White matter in spinal cord

Three high school students are being evaluated by health care providers at a drug rehabilitation clinic that serves adolescents. Hector, a 15-year-old boy, appears agitated and restless. He tells his health care provider that he is having muscle spasms. Upon examination, the care provider notes that Hector has a rapid heart rate and a dangerously high blood pressure. Carolyn, a 16-year-old girl, is being reassessed following a visit to the emergency room last night. According to her ER records, Carolyn was at a party with her friends when she suddenly had a seizure. Her records also document that she had an abnormal heart rate upon admission. Dante, a 14-year-old boy, was also admitted to the ER the night before. Dante’s parents found him lying on the couch in a deep sleep. When they could not arouse their son, they rushed him to the hospital where he experienced a convulsion. Later that night, Dante’s parents discovered medication hidden in his room that his mother had used earlier, following major surgery.

Questions

1. What type of drug do you think Hector might be using?
2. What long-term problems can this type of drug cause?
3. What drug likely caused Carolyn’s seizure and abnormal heart rhythm?
4. How do users obtain the most dramatic “high” when using this drug?
5. What drug might have caused Dante’s symptoms?
6. Do you think the drug Dante used is legal or illegal, or does it depend on the circumstances?
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**LABORATORY EXERCISE:**

**THE NERVOUS SYSTEM**

**Materials needed:** Prepared microscope slides of neurons and neuroglia cells, anatomic model of the spinal cord, rubber mallet

1. Examine a prepared microscope slide of the crushed spinal cord of an ox. Study the parts of multipolar internuncial neurons, noting the following structures: the cell body with nucleus and dendrite extensions of the cell body; find axons with branches and axon terminals. Notice the small astrocytes and their stained nuclei scattered in the slide preparation.

2. Examine an anatomic model of a section of the spinal cord with attached spinal nerves. Study the dorsal and ventral gray horns of the cord. Note how the sensory dorsal posterior root of the spinal nerve enters the dorsal gray horn and how the motor ventral anterior root of the spinal nerve leaves the ventral gray horn of the cord.

3. Test the knee-jerk reflex on your lab partner by gently tapping the patellar tendon with a small rubber mallet. Note how the extension of the knee is completely involuntary and subconscious, illustrating the performance of the reflex arc.