Chapter 9

The Nervous System: The Spinal Cord and Spinal Nerves
## Key Terms

<table>
<thead>
<tr>
<th>acetylcholine</th>
<th>motor</th>
<th>presynaptic</th>
</tr>
</thead>
<tbody>
<tr>
<td>action potential</td>
<td>nerve</td>
<td>receptor</td>
</tr>
<tr>
<td>afferent</td>
<td>nerve impulse</td>
<td>reflex</td>
</tr>
<tr>
<td>autonomic nervous system</td>
<td>neuritis</td>
<td>repolarization</td>
</tr>
<tr>
<td>axon</td>
<td>neuroglia</td>
<td>saltatory conduction</td>
</tr>
<tr>
<td>dendrite</td>
<td>neuron</td>
<td>sensory</td>
</tr>
<tr>
<td>depolarization</td>
<td>neurotransmitter</td>
<td>somatic nervous system</td>
</tr>
<tr>
<td>effector</td>
<td>norepinephrine</td>
<td>sympathetic nervous system</td>
</tr>
<tr>
<td>efferent</td>
<td>parasympathetic nervous system</td>
<td>synapse</td>
</tr>
<tr>
<td>ganglion</td>
<td>plexus</td>
<td>tract</td>
</tr>
<tr>
<td>interneuron</td>
<td>postsynaptic</td>
<td></td>
</tr>
</tbody>
</table>
Overview of the Nervous System

Learning Objective

1. Outline the organization of the nervous system according to structure and function.
Neurons and Their Functions

Learning Objectives

2. Describe the structure of a neuron.

3. Explain the construction and function of the myelin sheath.

4. Describe how neuron fibers are built into a nerve.
5. List four types of neuroglia in the central nervous system, and cite the functions of each.
The Nervous System at Work

Learning Objectives

6. Diagram and describe the steps in an action potential.

7. Explain the role of neurotransmitters in impulse transmission at a synapse.
The Spinal Cord

Learning Objective

8. Describe the distribution of gray and white matter in the spinal cord.
The Spinal Nerves

Learning Objective

9. Describe and name the spinal nerves and three of their main plexuses.
Reflexes

Learning Objectives

10. List the components of a reflex arc.

11. Define a simple reflex, and give several examples of reflexes.
The Autonomic Nervous System

Learning Objectives

12. Compare the locations and functions of the sympathetic and parasympathetic nervous systems.

13. Explain the role of cellular receptors in the action of neurotransmitters in the autonomic nervous system.
Clinical Aspects of the Spinal Cord and Spinal Nerves

Learning Objective

14. Describe eight disorders of the spinal cord and spinal nerves.
Learning Objective

15. Using the case study, describe the effects of demyelination on motor and sensory function.
Learning Objective

16. Show how word parts are used to build words related to the nervous system.
Overview of the Nervous System

Role of the Nervous System

- Coordinates all body systems.

- Detects and responds to stimuli.

- Brain and spinal cord act as switching centers.

- Nerves carry messages to and from centers.
Overview of the Nervous System (cont.)

**Structural Divisions**

- Central nervous system (CNS)
  - Brain
  - Spinal cord

- Peripheral nervous system (PNS)
  - Cranial nerves
  - Spinal nerves
What structures make up the central nervous system? The peripheral nervous system?
## Functional Divisions of the PNS

<table>
<thead>
<tr>
<th>Division</th>
<th>Control</th>
<th>Effectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Somatic nervous system</td>
<td>Voluntary</td>
<td>Skeletal muscle</td>
</tr>
<tr>
<td>Autonomic nervous system</td>
<td>Involuntary</td>
<td>Smooth muscle, cardiac muscle, and glands</td>
</tr>
</tbody>
</table>

*PNS* refers to the peripheral nervous system.
Overview of the Nervous System (cont.)

Checkpoints

9-1  What are the two divisions of the nervous system based on structure?

9-2  What division of the PNS is voluntary and controls skeletal muscles? What division is involuntary and controls smooth muscle, cardiac muscle, and glands?
Pop Quiz

9.1 Which division of the nervous system exclusively controls skeletal muscles?

A) Peripheral nervous system
B) Central nervous system
C) Somatic nervous system
D) Autonomic nervous system
Pop Quiz Answer

9.1 Which division of the nervous system exclusively controls skeletal muscles?

A) Peripheral nervous system
B) Central nervous system
C) Somatic nervous system
D) Autonomic nervous system
Neurons and Their Functions

Learning Objectives

2. Describe the structure of a neuron.

3. Explain the construction and function of the myelin sheath.

4. Describe how neuron fibers are built into a nerve.
Neurons and Their Functions (cont.)

Structure of a Neuron

- Neurons are the functional cells of the nervous system.
- They are highly specialized with a unique structure related to their function.
  - Cell body
    - Contains the nucleus and other organelles
  - Cell fibers
    - Dendrites carry impulses to cell body.
    - Axons carry impulses away from cell body.
How do you know the neuron shown here is a motor neuron? Is it part of the somatic or visceral nervous system? Explain.
Neurons and Their Functions (cont.)

Figure 9-3 Microscopic view of a neuron.

- Nucleus
- Nucleolus
- Axon
- Cell body
- Dendrite
Neurons and Their Functions (cont.)

The Myelin Sheath

• Some axons insulated and protected by a fatty myelin sheath.

• In the PNS, myelin sheath is formed by Schwann cells.
  – Outermost membrane of Schwann cell forms neurilemma.

• In the CNS, myelin sheath formed by oligodendrocytes.

• Myelinated axons make up white matter.

• Unmyelinated axons make up gray matter.
Figure 9-4 Formation of a myelin sheath.
## Types of Neurons

<table>
<thead>
<tr>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory (afferent) neurons</td>
<td>Conduct impulses to the spinal cord and brain</td>
</tr>
<tr>
<td>Motor (efferent) neurons</td>
<td>Carry impulses from the CNS to muscles and glands</td>
</tr>
<tr>
<td>Interneurons (central or association neurons)</td>
<td>Relay information from place to place within the CNS</td>
</tr>
</tbody>
</table>
Neurons and Their Functions (cont.)

Nerves and Tracts

- Nerve—fiber bundle within the PNS
- Tract—fiber bundle within the CNS
- Organized into fascicles
- Connective tissue layers
  - Endoneurium
  - Perineurium
  - Epineurium
Neurons and Their Functions (cont.)

**Figure 9-5** Structure of a nerve.

What is the deepest layer of connective tissue in a nerve? What is the outermost layer?
Neurons and Their Functions (cont.)

Checkpoints

9-3 What is the name of the neuron fiber that carries impulses toward the cell body? What is the name of the fiber that carries impulses away from the cell body?

9-4 What color describes myelinated fibers? What color describes the nervous system’s unmyelinated tissue?

9-5 What name is given to nerves that convey impulses toward the CNS? What name is given to nerves that transport away from the CNS?

9-6 What is a nerve? What is a tract?
Neurons and Their Functions (cont.)

Pop Quiz

9.2 Which fibers conduct impulses away from the cell body?

A) Dendrites
B) Axons
C) Cell bodies
D) Neurilemma
Pop Quiz Answer

9.2 Which fibers conduct impulses away from the cell body?

A) Dendrites
B) Axons
C) Cell bodies
D) Neurilemma
5. List four types of neuroglia in the central nervous system, and cite the functions of each.
Neuroglia (cont.)

Functions of Neuroglia

- Protect, support, and nourish nervous tissue
- Aid in cell repair
- Remove pathogens and impurities
- Regulate composition of fluid around cells

Examples of Neuroglia

- Schwann cells
- Astrocytes
- Oligodendrocytes
- Ependymal cells
Neuroglia (cont.)

Figure 9-6 Astrocytes, a type of neuroglia.
What is the name of the nervous system’s nonconducting cells, which protect, nourish, and support the neurons?
Neuroglia (cont.)

Pop Quiz

9.3  Which of the following is NOT an example of a neuroglial cell?

A) Neuron
B) Astrocyte
C) Schwann cell
D) All of the options are neuroglia.
Neuroglia (cont.)

Pop Quiz Answer

9.3 Which of the following is NOT an example of a neuroglial cell?

A) Neuron
B) Astrocyte
C) Schwann cell
D) All of the options are neuroglia.
The Nervous System at Work

Learning Objectives

6. Diagram and describe the steps in an action potential.

7. Explain the role of neurotransmitters in impulse transmission at a synapse.
The Nervous System at Work (cont.)

Overview

- The nervous system works by means of electric impulses sent along fibers and transmitted from cell to cell at highly specialized junctions called synapses.
The Nervous System at Work (cont.)

The Nerve Impulse

- Resting state
  - Plasma membrane is polarized
  - Leak channels
  - Sodium–potassium pump

- Action potential
  - Depolarization
  - Repolarization

- Role of myelin—saltatory conduction
The Nervous System at Work (cont.)

Figure 9-7 The action potential.

A

![Diagram of the action potential]

B

<table>
<thead>
<tr>
<th>Resting</th>
<th>Rising phase</th>
<th>Falling phase</th>
<th>Resting</th>
</tr>
</thead>
<tbody>
<tr>
<td>More Na⁺ outside; More K⁺ inside</td>
<td>Na⁺ enters</td>
<td>K⁺ leaves</td>
<td>Na⁺ and K⁺ concentrations restored</td>
</tr>
</tbody>
</table>

Stimulus

Time (msec)
What happens to the charge on the membrane at the point of an action potential?
Figure 9-9 Saltatory conduction.
The Nervous System at Work (cont.)

The Synapse

- Junction point for transmitting nerve impulse from neuron to another cell

- Basic structure
  - Axon (presynaptic cell)
    - Releases neurotransmitter, a chemical signal
  - Synaptic cleft
  - Dendrite (postsynaptic cell)
    - Binds neurotransmitter via receptors
The Nervous System at Work (cont.)

Examples of Neurotransmitters

- Norepinephrine
- Serotonin
- Dopamine
- Acetylcholine
Figure 9-10 A synapse.
The Nervous System at Work (cont.)

Checkpoints

9-8 What are the two stages of an action potential, and what happens during each?

9-9 What ions are involved in generating an action potential?

9-10 How does the myelin sheath affect conduction along an axon?

9-11 What is the junction between two neurons called?

9-12 As a group, what are all the chemicals that carry information across the synaptic cleft called?
9.4 Potassium channels open early in the action potential to cause membrane:

A) Depolarization
B) Potential
C) Repolarization
D) Degradation
The Nervous System at Work (cont.)

Pop Quiz Answer

9.4 Potassium channels open early in the action potential to cause membrane:

A) Depolarization
B) Potential
C) Repolarization
D) Degradation
The Spinal Cord

Learning Objective

8. Describe the distribution of gray and white matter in the spinal cord.
The Spinal Cord (cont.)

Overview

- Links the PNS and brain
- Helps coordinate impulses within the CNS
- Contained in and protected by vertebrae
The Spinal Cord (cont.)

Structure of the Spinal Cord

• Inner gray matter (unmyelinated axons)
  – Dorsal horn
  – Ventral horn
  – Gray commissure
  – Central canal

• Outer white matter (myelinated axons)
  – Posterior median sulcus
  – Anterior median fissure
  – Ascending and descending tracts
The Spinal Cord (cont.)

Checkpoints

9-13 How are the gray and white matter arranged in the spinal cord?

9-14 What is the purpose of the tracts in the spinal cord’s white matter?
The Spinal Cord (cont.)

Pop Quiz

9.5 What fluid is found in the central canal of the spinal cord?

A) Blood
B) Cerebrospinal fluid
C) Lymph
D) Saline
The Spinal Cord (cont.)

Pop Quiz Answer

9.5  What fluid is found in the central canal of the spinal cord?

A) Blood
B) Cerebrospinal fluid
C) Lymph
D) Saline
The Spinal Nerves

Learning Objective

9. Describe and name the spinal nerves and three of their main plexuses.
The Spinal Nerves (cont.)

- 31 pairs

- Each nerve attached to the spinal cord by two roots.
  - Dorsal root with dorsal root ganglion (sensory)
  - Ventral root (motor)

- Nerves near end of cord travel together in the cord until each exits from its respective intervertebral foramen.

- Mixed nerves contain both sensory and motor fibers.
The Spinal Nerves (cont.)

Figure 9-11 Spinal cord and spinal nerves.

Is the spinal cord the same length as the spinal column? How does the number of cervical vertebrae compare to the number of cervical spinal nerves?
The Spinal Nerves (cont.)

Branches of the Spinal Nerves

- Cervical plexus
  - Phrenic nerve

- Brachial plexus
  - Radial nerve

- Lumbosacral plexus
  - Sciatic nerve

- Dermatomes
The Spinal Nerves (cont.)

Figure 9-12 Dermatomes.

Which spinal nerves carry impulses from the skin of the toes? From the anterior hand and fingers?
The Spinal Nerves (cont.)

Checkpoints

9-15 How many pairs of spinal nerves are there?

9-16 What types of fibers are in a spinal nerve’s dorsal root? What types are in its ventral root?

9-17 What is the term for a network of spinal nerves?
The Spinal Nerves (cont.)

Pop Quiz

9.6 The phrenic nerve arises from the:

A) Brachial plexus
B) Lumbosacral plexus
C) Abdominal plexus
D) Cervical plexus
The Spinal Nerves (cont.)

Pop Quiz Answer

9.6 The phrenic nerve arises from the:
A) Brachial plexus
B) Lumbosacral plexus
C) Abdominal plexus
D) Cervical plexus
Reflexes

Learning Objectives

10. List the components of a reflex arc.

11. Define a simple reflex, and give several examples of reflexes.
## The Reflex Arc

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receptor</td>
<td>Detects stimulus</td>
</tr>
<tr>
<td>Sensory neuron</td>
<td>Transmits nerve impulses toward the CNS</td>
</tr>
<tr>
<td>Central nervous system</td>
<td>Coordinates nerve impulses and response is organized</td>
</tr>
<tr>
<td>Motor neuron</td>
<td>Transmits nerve impulses away from the CNS</td>
</tr>
<tr>
<td>Effector</td>
<td>Receives nerve impulses from the CNS and carries out response</td>
</tr>
</tbody>
</table>
Is this a somatic or an autonomic reflex arc? What type of neuron is located between the sensory and motor neuron in the CNS?
Reflex Activities

- Simple reflex
  - Characteristics
    - Rapid
    - Uncomplicated
    - Automatic
  - Types
    - Stretch reflex
    - Withdrawal reflex
What is the name for a pathway through the nervous system from a stimulus to an effector?
Reflexes (cont.)

Pop Quiz

9.7 What is the correct order of impulse conduction through a reflex arc?

A) Sensory neuron, receptor, effector, interneuron, motor neuron

B) Receptor, sensory neuron, interneuron, motor neuron, effector

C) Receptor, motor neuron, sensory neuron, interneuron, effector

D) Effector, sensory neuron, motor neuron, interneuron, receptor
Reflexes (cont.)

Pop Quiz Answer

9.7 What is the correct order of impulse conduction through a reflex arc?

A) Sensory neuron, receptor, effector, interneuron, motor neuron

B) Receptor, sensory neuron, interneuron, motor neuron, effector

C) Receptor, motor neuron, sensory neuron, interneuron, effector

D) Effector, sensory neuron, motor neuron, interneuron, receptor
Clinical Aspects of the Spinal Cord and Spinal

Learning Objectives

12. Compare the locations and functions of the sympathetic and parasympathetic nervous systems.

13. Explain the role of cellular receptors in the action of neurotransmitters in the autonomic nervous system.
The Autonomic Nervous System (cont.)

Function

- Regulates the action of glands, smooth muscles of hollow organs and vessels, and heart muscle

Structure

- Preganglionic neuron connects the spinal cord to ganglion.
- Postganglionic neuron connects ganglion to effector.
The Autonomic Nervous System (cont.)

Divisions of the Autonomic Nervous System

- Sympathetic nervous system
- Parasympathetic nervous system
The Autonomic Nervous System (cont.)

Functions of the Autonomic Nervous System

- Sympathetic nervous system
  - Fight-or-flight response

- Parasympathetic nervous system
  - Returns body to normal

- Systems generally have opposite effects on organ
Sympathetic Nervous System Anatomy

- Preganglionic neurons in thoracolumbar area

- Ganglia:
  - Sympathetic chain ganglia
  - Collateral ganglia

- Postganglionic neurons are adrenergic (norepinephrine)
The Autonomic Nervous System (cont.)

Parasympathetic Nervous System Anatomy

- Preganglionic neurons in craniosacral areas
- Terminal ganglia
- Postganglionic neurons are cholinergic (acetylcholine)
Which division of the autonomic nervous system has ganglia closer to the effector organ?
The Role of Cellular Receptors

• “Docking sites” on postsynaptic cell membranes

• Two types:
  - Cholinergic receptors
    • Nicotinic (bind nicotine) on skeletal muscle cells
    • Muscarinic (bind muscarine, a poison) on effector cells of the PNS
  - Adrenergic receptors
    • Found on receptor cells of the sympathetic nervous system
    • Bind norepinephrine, epinephrine
The Autonomic Nervous System (cont.)

Checkpoints

9-19  How many neurons are there in each motor pathway of the ANS?

9-20  Which division of the ANS stimulates a stress response? Which division reverses the stress response?
The Autonomic Nervous System (cont.)

Pop Quiz

9.8 Which of the following is NOT an action of the sympathetic nervous system?

A) Increase in blood pressure
B) Stimulation of skeletal muscle
C) Stimulation of the adrenal gland
D) Dilation of the pupils
The Autonomic Nervous System (cont.)

Pop Quiz Answer

9.8 Which of the following is NOT an action of the sympathetic nervous system?

A) Increase in blood pressure
B) Stimulation of skeletal muscle
C) Stimulation of the adrenal gland
D) Dilation of the pupils
Learning Objective

14. Describe eight disorders of the spinal cord and spinal nerves.
Medical Procedures Involving the Spinal Cord

- Lumbar puncture (spinal tap)
  - Cerebrospinal fluid (CSF) removed for testing
- Drug administration
  - Anesthetic (an epidural)
  - Pain medication
Clinical Aspects of the Spine and Spinal Nerves (cont.)

Figure 9-15 Lumbar puncture and epidural anesthesia.
Clinical Aspects of the Spinal Cord and Spinal Nerves (cont.)

Diseases and Other Disorders of the Spinal Cord

- Diseases
  - Multiple sclerosis (MS)
  - Amyotrophic lateral sclerosis
  - Poliomyelitis

- Tumors
Clinical Aspects of the Spinal Cord and Spinal Nerves (cont.)

Diseases and Other Disorders of the Spinal Cord (cont.)

• Injuries
  – Monoplegia
  – Diplegia
  – Paraplegia
  – Hemiplegia
  – Tetraplegia
Clinical Aspects of the Spinal Cord and Spinal Nerves (cont.)

Disorders of the Spinal Nerves

- Neuropathy
- Mononeuropathy
- Polyneuropathy
  - Tumors
  - Toxins
  - Infections
    - Herpes zoster
  - Autoimmune disorders
- Guillain-Barré syndrome
Figure 9-16 Carpal tunnel syndrome.
Clinical Aspects of the Spinal Cord and Spinal Nerves (cont.)

Checkpoints

9-21 What is removed in a lumbar puncture?

9-22 What is the meaning of the word root *plegia*?

9-23 What term is used for any disorder of the nerves?
Ms. L has been experiencing muscle weakness. Her physician informs her that she has abnormal antibodies attacking the myelin sheath around neurons in her central nervous system. The most likely diagnosis is:

A) Poliomyelitis
B) Multiple sclerosis
C) Amyotrophic lateral sclerosis
D) Peripheral neuropathy
Ms. L has been experiencing muscle weakness. Her physician informs her that she has abnormal antibodies attacking the myelin sheath around neurons in her central nervous system. The most likely diagnosis is:

A) Poliomyelitis
B) Multiple sclerosis
C) Amyotrophic lateral sclerosis
D) Peripheral neuropathy
Case Study

Learning Objective

15. Using the case study, describe the effects of demyelination on motor and sensory function.
Case Study (cont.)

- Damage to white matter tracts in the brain and spinal cord prevents the transmission of nerve impulse to and from the CNS and PNS.

  - Damage to sensory tracts leads to sensory deficits.

  - Damage to motor tracts leads to motor deficits.
16. Show how word parts are used to build words related to the nervous system.
# Word Anatomy (cont.)

<table>
<thead>
<tr>
<th>Word Part</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Role of the Nervous System</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>aut/o</td>
<td>self</td>
<td>The <em>autonomic</em> nervous system is automatically controlled and is involuntary.</td>
</tr>
<tr>
<td>-lemma</td>
<td>sheath</td>
<td>See below example.</td>
</tr>
<tr>
<td>neur/i</td>
<td>nerve, nervous tissue</td>
<td>The <em>neurilemma</em> is the outer membrane of the myelin sheath around an axon.</td>
</tr>
<tr>
<td>olig/o-</td>
<td>few, deficiency</td>
<td>An <em>oligodendrocyte</em> has few dendrites.</td>
</tr>
<tr>
<td>soma-</td>
<td>body</td>
<td>The <em>somatic</em> nervous system controls skeletal muscles that move the body.</td>
</tr>
</tbody>
</table>
## The Nervous System at Work

<table>
<thead>
<tr>
<th>Word Part</th>
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<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>de-</td>
<td>remove</td>
<td><em>Depolarization</em> removes the charge on the plasma membrane of a cell.</td>
</tr>
<tr>
<td>post-</td>
<td>after</td>
<td>The <em>postsynaptic</em> cell is located after the synapse and receives neurotransmitter from the presynaptic cell.</td>
</tr>
<tr>
<td>re-</td>
<td>again, back</td>
<td><em>Repolarization</em> restores the charge on the plasma membrane of a cell.</td>
</tr>
</tbody>
</table>
**Word Anatomy (cont.)**

<table>
<thead>
<tr>
<th>Word Part</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The Spinal Cord</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hemi-</td>
<td>half</td>
<td><em>Hemiplegia</em> is paralysis of one side of the body.</td>
</tr>
<tr>
<td>myel/o</td>
<td>spinal cord</td>
<td><em>Poliomyelitis</em> is an infectious disease that involves the spinal cord and other parts of the CNS.</td>
</tr>
<tr>
<td>para-</td>
<td>beyond</td>
<td><em>Paraplegia</em> is paralysis of both lower limbs.</td>
</tr>
<tr>
<td>plegia</td>
<td>paralysis</td>
<td><em>Monoplegia</em> is paralysis of one limb.</td>
</tr>
<tr>
<td>tetra-</td>
<td>four</td>
<td><em>Tetraplegia</em> is paralysis of all four limbs.</td>
</tr>
</tbody>
</table>