Chapter 9
NERVOUS TISSUE

IN THIS CHAPTER:

- ✔ *The Nervous System*
- ✔ *Neurons and Neuroglia*
- ✔ *Physiology of Nerve Conduction*
- ✔ *Synapse and Synaptic Transmission*
- ✔ *Solved Problems*

The Nervous System

On the basis of structure, the nervous system is divided into the **central nervous system (CNS)** and the **peripheral nervous system (PNS)**. The CNS is composed of the *brain* and the *spinal cord*. The PNS is composed of *cranial nerves* from the brain and *spinal nerves* from the spinal cord. In addition, *ganglia*, clusters of cell bodies of neurons, and *plexuses*, networks of nerves, are found within the PNS.

The **autonomic nervous system (ANS)** is a functional division of the nervous system. Structures within the brain are ANS control centers, and specific nerves are the pathways for conduction of autonomic nerve impulses. The ANS functions automatically to speed up or slow down body activities.

Note!

Functions of the Nervous System

- Respond to internal and external stimuli.
- Transmit nerve impulses to and away from CNS.
- Interpret nerve impulses at the cerebral cortex.
- Assimilate experiences in memory and learning.
- Initiate glandular secretion and muscle contraction.
- Program instinctual behavior.

Neurons and Neuroglia

A **neuron** is a nerve cell found in both the CNS and the PNS. Although neurons vary considerably in size and shape, they are generally composed of a **cell body, dendrites,** and an **axon** (Figure 9-1).
At the ends of the branched axon are slight enlargements, **axon terminals,** that contain **synaptic vesicles** that produce and secrete *neurotransmitter chemicals* in the *synapses*.

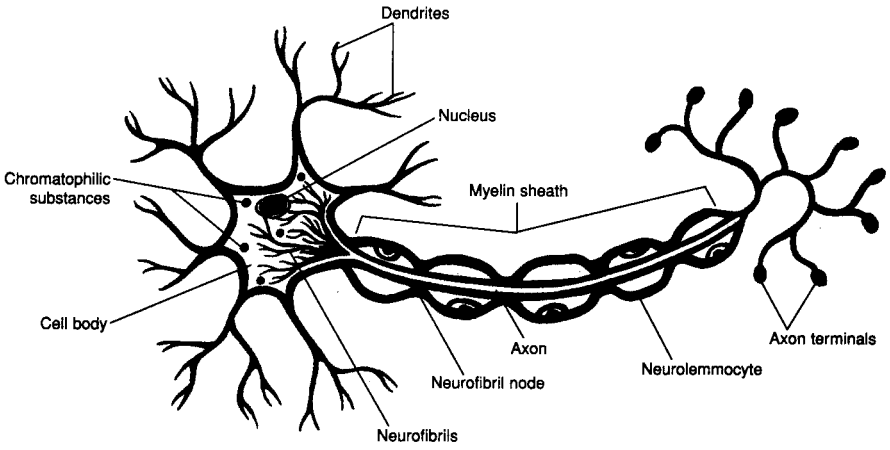

Figure 9-1. The structure of a neuron.

You Need to Know ✓

Types of Neurons

- **Sensory neurons:** transmit impulses **to** the CNS.
  somatic sensory: carry impulses from receptors in the skin, bones, muscles and joints.
  visceral sensory: carry impulses from the visceral organs.
- **Motor neurons:** transmit impulses **away** form the CNS.
  somatic motor: innervate skeletal muscles.
  visceral motor (autonomic motor): innervate cardiac muscle, smooth muscle, and glands.
- **Association neurons (interneurons):** conduct impulses from sensory to motor neurons.

Myelin is an insulating sheath of a fatlike lipid that wraps around the axon of many neurons. This sheath is produced by specific **neuroglia** cells. In the PNS, there are small gaps between segments of the sheath. The myelin sheath insulates nerve fibers and speeds up transmission of an impulse along the axon.

Neuroglia are specialized cells of the nervous support neurons. There are six different types of neuroglia, all mitotically divide, and are about five times more abundant than neurons.

Physiology of Nerve Conduction

In a non-conducting ("resting") neuron, a voltage, or **resting potential,** exists across the cell membrane. This resting potential is due to an imbalance of charged particles (ions) between the extracellular and the intracellular fluids. The mechanisms responsible for the membrane having a net positive charge on its outer surface and a net negative charge on its inner surface (Figure 9-2) are as follows:

1. A *sodium-potassium pump* actively transports sodium ions (Na+) to the outside and potassium ions (K+) to the inside, with three Na+ moved out for every two K+ moved in.

2. The cell membrane is more permeable to K+ than to Na+, so that the K+ , which is more concentrated inside the cell, diffuses outward faster than the Na+, which is more concentrated outside the cell, diffuses inward. Na+ and K+ move through the membrane using different channels.
3. The cell membrane is essentially impermeable to the large (negatively charged) anions that are present inside the neuron, therefore fewer negatively charged particles move out than positively charged particles.

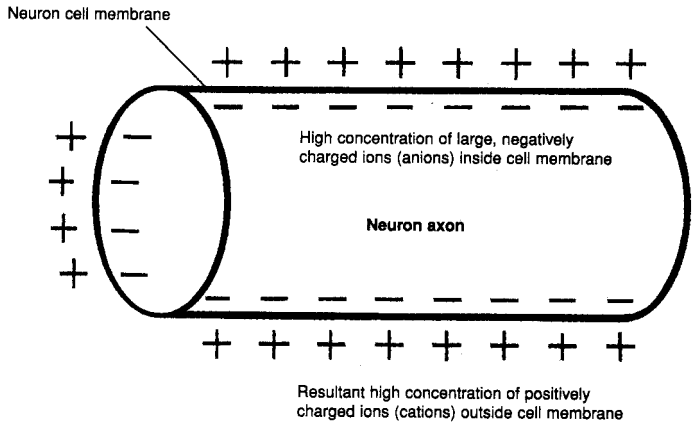

Figure 9-2. A segment of a neuron showing the location of charges.

Nerve impulses carry information from one point of the body to another by progression along the neuron membrane of an abrupt change in the resting potential. This "traveling disturbance," called an **action potential,** is described below.

1. A stimulus (chemical-electrical-mechanical) is sufficient to alter the resting membrane potential of a region of the membrane.
2. The membrane's permeability to sodium ions (Na+) increases at the point of stimulation.
3. Na+ rapidly moves into the cell through the membrane; the membrane becomes locally depolarized (membrane potential = 0).
4. Na+ continues to move inward; the inside of the membrane becomes positively charged relative to the outside (reverse polarization).

5. Reverse polarization at the original site of stimulation results in a local current that acts as a stimulus to the adjacent region of the membrane.
6. At the point originally stimulated, the membrane's permeability to sodium decreases, and its permeability to K+ increases.
7. K+ rapidly moves outward, again making the outside of the membrane positive in relation to the inside (repolarization).
8. N+ and K+ pumps transport Na+ back out of, and K+ back into the cell. The cycle repeats itself, traveling in this manner along the neuron membrane.

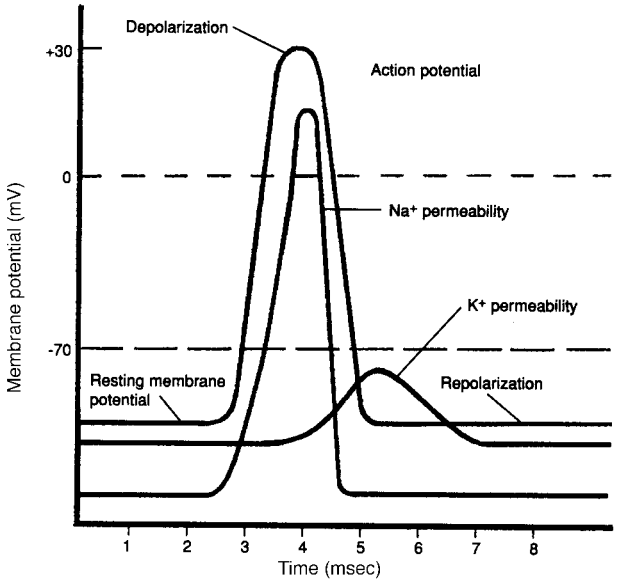

Figure 9-3. An action potential.

An action potential will be produced in response to a *threshold stimulus*. The resting membrane potential is about –70mV. If a stimulus raises the membrane potential –55 mV, a *threshold potential* has been reached, complete depolarization and repolarization occur, and an action potential is generated. (See Figure 9-3.)

All-or-None Law

A threshold stimulus evokes a maximal response and a sub-threshold stimulus evokes no response.

Synapse and Synaptic Transmission

A **synapse** is the specialized junction through which impulses pass from one neuron to another (*synaptic transmission*), via chemical messengers (**neurotransmitters**). Refer to Figure 9-4 and steps below.

1. An action potential reaches the axon terminal.
2. An influx of Ca2+ causes synapatic vesicles containing neurotransmitter to fuse with the presynaptic membrane.
3. Neurotransmitter is released by exocytosis into the synaptic cleft.
4. The neurotransmitter diffuses across the cleft to the postsynaptic membrane and bind to specific receptors located there.
5. The permeability of postsynaptic membrane is altered, initiating an impulse on the second neuron.
6. The neurotransmitter is removed from the synapse.

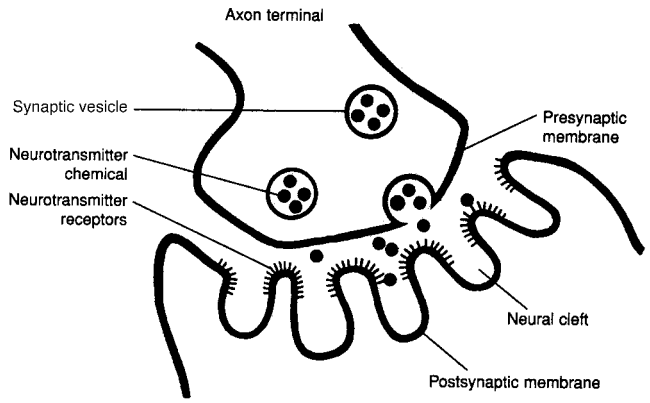

Figure 9-4. Synaptic transmission.

Neurotransmitters may be excitatory, causing the postsynaptic neuron to become active by producing an *excitatory postsynaptic potential* (EPSP), or may be inhibitory, preventing the postsynaptic neuron from becoming active by producing an *inhibitory postsynaptic potential* (ISPS).

Solved Problems

True or False

____ 1. There are basically only two different cell types in the nervous system. (**False**)
____ 2. A polarized nerve fiber has an abundance of sodium ions on the outside of the axon membrane. (**True**)
____ 3. All synapses are inhibitory. (**False**)
____ 4. The myelin sheath surrounds the dendrites. (**False**)
____ 5. Motor neurons convey information from receptors in the periphery to the CNS. (**False**)
____ 6. The sodium pumps operate by diffusion, and thus requires no ATP for its operation. (**False**)

Completion

1. Within the peripheral nervous system, myelin is formed by the _____. (**neurolemmocytes or Schwann cells**)
2. A junction between two neurons, where the electrical activity of the first influences the excitability of the second is called a _____. (**synapse**)
3. When an action potential depolarizes the synaptic knob, small quantities of transmitter substance are released into the _____ _____. (**synaptic cleft**)

Chapter 10
CENTRAL NERVOUS SYSTEM

IN THIS CHAPTER:

- ✔ *Brain*
- ✔ *Meninges*
- ✔ *Blood-Brain Barrier*
- ✔ *Neurotransmitters*
- ✔ *Spinal Cord*
- ✔ *Solved Problems*

The **central nervous system** (**CNS**) consists of the *brain* and *spinal cord*. The functions of the CNS include body orientation and coordination, assimilation of experiences (learning), and programming of instinctual behavior. The CNS contains gray and white matter. The **gray matter** consists of either nerve cell bodies and dendrites, or of unmyelinated axons and neuroglia. It forms the outer convoluted cerebral cortex and cerebellar cortex in the brain and forms the inner portion of the spinal cord. The **white matter** consists of aggregations of myelinated axons and forms nerve **tracts,** within the CNS.

Brain

There are five regions of the brain, some with multiple structures:

Brain region	Structures
Telencephalon	Cerebrum
Diencephalon	Thalamus, Hypothalamus, and Pituitary gland
Mesencephalon	Superior colliculus, Inferior colliculus, and Cerebral peduncles
Metencepahlon	Cerebellum and Pons
Myelencephalon	Medulla oblongata

Telencephalon—Cerebrum

The cerebrum consists of five paired lobes within two convoluted **cerebral hemispheres.** The hemispheres are connected by the **corpus callosum.** The cerebrum is responsible for higher functions, including perception of sensory impulses, instigation of voluntary movement, memory, thought, and reasoning. The outer convoluted surface, the **cerebral cortex,** is composed of gray matter. Elevated folds of the convolutions are the **gyri** (*gyrus*, singular) and the depressed grooves are the **sulci** (*sulcus*, singular). The convolutions greatly increase the surface area of the gray matter. Beneath the cerebral cortex is the thick white matter, the **cerebral medulla.**

You Need to Know ✓

5 Cerebral Lobes and Their Functions:

Frontal lobe	Voluntary control of skeletal muscles; personality; intellectual process; verbal communication.
Parietal lobe	Cutaneous and muscular sensations; understanding and utterance of speech.
Temporal lobe	Interpretation of auditory sensations; auditory and visual memory.
Occipital lobe	Integration of movements in focusing the eye; correlation of visual images with previous experiences; conscious seeing.
Insular	Memory; integration of other cerebral activities.

Diencephalon

The diencephalon, a major autonomic region of the forebrain, is almost completely surrounded by the cerebral hemispheres. It contains the:

- **Thalamus.** The thalamus is a paired organ immediately below the lateral ventricle. It is a relay center for all sensory impulses, except smell, to the cerebral cortex.
- **Hypothalamus.** The hypothalamus consists of several nuclei interconnected to other parts of the brain. Most of its functions relate to regulation of visceral activities including: cardiovascular regulation, body-temperature regulation, water and electrolyte balance, gastrointestinal activity and hunger, sleeping and wakefulness, sexual response, emotions, and control of endocrine functions through stimulation of the anterior pituitary.
- **Epithalamus.** The **pineal gland** extends from the epithalamus. It secretes the hormone *melatonin,* which may play a role in the onset of puberty.
- **Pituitary Gland.** The pituitary is divided into the anterior pituitary, the **adenohypophysis,** and the posterior pituitary, the **neurohypophysis**. This gland has endocrine functions.

Mesencephalon

The mesencephalon, or midbrain, is a short section of the brain stem between the diencephalon and the pons. It contains the **superior colliculi,** concerned with visual reflexes, the **inferior collicui,** responsible for auditory reflexes, and the **cerebral peduncles,** which contain sensory and motor fibers and are involved with coordinating reflexes.

Metencephalon

The metencephalon contains the:

- **Pons.** The pons consists of fiber tracts that relay impulses from one region of the brain to another. Many cranial nerves originate here. Also the *apneusitic* and *pneumotaxic* centers involved with regulating respiratory rate are located in the pons.
- **Cerebellum.** The cerebellum consists of two hemispheres and is responsible for involuntary coordination of skeletal-muscle contractions in response proprioreceptors within muscles, tendons, joints, and sensory organs.

Mylencephalon—Medulla oblongata

The medulla oblongata connects to the spinal cord and makes up much of the brain stem. It is composed primarily of white matter tracts that communicate between the spinal cord and the brain. Three areas that control autonomic functions are: the **cardiac center,** sending inhibitory and accelerator fibers to the heart; the **vasomotor center,** which causes the smooth muscle of arterioles to contract; and the **respiratory center,** which controls the rate and depth of breathing.

Ventricles of the brain

The ventricles of the brain consist of a series of cavities that are connected to one another and to the central canal of the spinal cord.

Lateral ventricles	Located in each cerebral hemisphere
Third ventricle	Located in the diencephalon
Fourth ventricle	Located in the brain stem

Meninges

Three connective tissue membranes cover the entire CNS.

The three meninges are (from outermost to innermost): **Dura mater, Arachoid, Pia mater.**

The dura mater forms a tough tubular sheath around the spinal cord. The **epidural space** is a vascular area between the sheath and the vertebral canal. It is the location where epidural anesthesia is injected. The **subarachnoid space** is located between the arachnoid and the pia mater. It contains *cerebrospinal fluid*. **Cerebrospinal fluid** (**CSF**) is a clear, lymph-like fluid produced continually by active transport of substances from blood plasma by specialized capillaries in the roof of the ventricles, the *choroid plexuses*. CSF forms a protective cushion around and within the CNS; it also buoys the brain. CSF circulates around the CNS through the ventricles of the brain, the central canal of the spinal cord, and the subarachnoid space.

Blood-Brain Barrier

The **blood-brain barrier (BBB)** is a structural arrangement of the capillaries that surround connective tissue and the vascular processes of *astrocytes* (a type of neuroglia in the CNS) that cling to the capillaries. The BBB selectively determines which substances can move from the blood plasma to the extracellular fluid of the brain. Fat-soluble compounds readily pass through the BBB, as do H_2O, O_2, CO_2, and glucose. Certain chemicals such as alcohol, nicotine, and anesthetics also readily pass through. Inorganic ions pass more slowly and other substances, such as macroproteins, lipids, certain toxins, and most antibiotics are restricted.

Neurotransmitters

There are over 200 neurotransmitters synthesized and secreted by neurons within the brain. The most important are listed below.

Neurotransmitter	**Function**
Acetylcholine	Transmits impulses across synapses
Epinephrin, norepinephrin	Arouse the brain and maintain alertness
Dopamine	Motor control
Gamma-aminobutyric acid (GABA)	Motor coordination through inhibition of certain neurons
Enkephalins, endorphins	Block transmission and perception of pain

Spinal Cord

The **spinal cord** extends through the vertebral canal of the vertebral column to the level of the first lumbar vertebra (L1). It is continuous with

the brain through the foramen magnum of the skull. The spinal cord consists of centrally located gray matter involved in reflexes, and peripheral ascending and descending tracts of white matter that conduct nerve impulses to and from the brain. Thirty-one pairs of spinal nerves arise from the spinal cord. The *gray matter* in cross section has a four-horned appearance (Figure 10-1). The **posterior** (*dorsal*) **horns** receive the axons of sensory fibers that enter the spinal cord; the **anterior** (*ventral*) **horns** contain the dendrites and cell bodies of motor neurons that leave the spinal cord. At the thoracic and lumbar level there are **lateral horns** that contain the preganglionic sympathetic neurons that leave via the anterior root. The *white matter* is composed primarily of myelinated fibers that form spinal tracts. The tracts are separated by the horns of gray matter into three regions: **posterior, lateral,** and **anterior funiculi.**

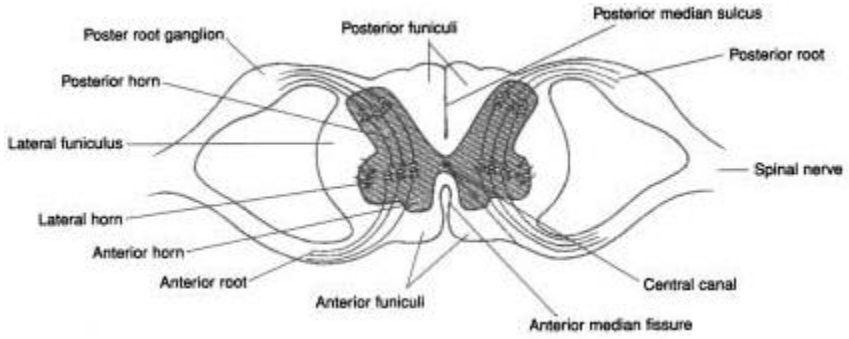

Figure 10-1. A cross section of the spinal cord.

Solved Problems

True or False

____ 1. The pineal gland, the hypothalmus , and the pituitary gland all have neuroendocrine functions. (**True**)

____ 2. The thalamus is an important relay center in that all sensory impulses (except olfaction) going to the cerebrum synapse there. (**True**)

____ 3. All ventricles of the brain are paired, except for the fourth. (**False**)