

# CHAPTER 13

## NERVOUS SYSTEM

### **LEARNING OUTCOMES**

#### **13.1 Overview of the Nervous System**

1. Distinguish between the central nervous system and peripheral nervous system with regard to location and function.
2. List the three types of neurons and provide a function for each.
3. Summarize the activities that generate and propagate an action potential.
4. Explain the role of neurotransmitters and the process of synaptic integration.

#### **13.2 The Central Nervous System**

1. Identify the structures of the spinal cord, and provide a function for each.
2. Identify the structures of the brain, and provide a function for each.
3. Identify the lobes and major areas of the human brain.
4. Distinguish between the functions of the primary motor and the primary somatosensory areas of the brain.

#### **13.3 The Limbic System and Higher Mental Functions**

1. Identify the structures of the limbic system.
2. Explain how the limbic system is involved in memory, language, and speech.
3. Summarize the types of memory associated with the limbic system.

#### **13.4 The Peripheral Nervous System**

1. Describe the series of events during a spinal reflex.
2. Distinguish between the somatic and autonomic divisions of the peripheral nervous system.
3. Distinguish between the sympathetic and parasympathetic divisions of the autonomic division.

#### **13.5 Drug Therapy and Drug Abuse**

1. Explain the ways that drugs interact with the nervous system.
2. Classify drugs as to whether they have a depressant, stimulant, or psychoactive effect on the nervous system.
3. List the long-term effects of drug use on the body.

### **EXTENDED LECTURE OUTLINE**

#### **13.1 Overview of the Nervous System**

The nervous system has two major divisions, the central nervous system consisting of the brain and spinal cord, and the peripheral nervous system consisting of nerves. The nervous system has three specific functions: receive sensory input, perform information processing and integration, and generate motor output.

##### **Nervous Tissue**

The nervous system contains neurons that conduct impulses and neuroglial cells that service neurons.

##### **Anatomy of a Neuron**

Sensory neurons take information from sensory receptors to the central nervous system (CNS); interneurons occur within the CNS, and motor neurons take information from the CNS to effectors (muscles or glands) which carry out responses. Neurons are composed of dendrites, a cell body, and an axon. Long axons are covered by a myelin sheath.

##### **Myelin Sheath**

Long axons are covered by a myelin sheath formed by neuroglial cells called Schwann cells, interrupted by gaps called nodes of Ranvier. A myelin sheath gives nerve fibers their white, glistening appearance and plays an important role in nerve regeneration within the peripheral nervous system (PNS). Multiple sclerosis is a disease in which myelin breaks down.

##### **Physiology of a Neuron**

Nerve signals convey information within the nervous system.

##### **Resting Potential**

When an axon is not conducting a nerve impulse, the inside of an axon is negative (-65mV) compared to the outside. The sodium-potassium pump actively transports Na<sup>+</sup> out of an axon and K<sup>+</sup> to inside an axon. The resting potential is due to the leakage of K<sup>+</sup> to the outside of the neuron. The resting potential exists because the outside of the cell is more positive than the inside.

##### **Action Potential**

An action potential is a rapid change in polarity as the nerve signal occurs. It is an all-or-none phenomenon and occurs only when threshold is reached.

#### **Sodium Gates Open**

The gates of sodium channels open first and  $\text{Na}^+$  flows into the axon. The membrane potential depolarizes.

#### **Potassium Gates Open**

The gates of potassium channels open and  $\text{K}^+$  flows into the axon. The membrane potential repolarizes.

#### **Visualizing an Action Potential**

Researchers find it useful to plot the voltage changes over time.

#### **Propagation of an Action Potential**

The action potential occurs in each successive portion of an axon. A refractory period ensures that the action potential will not move backwards. In myelinated fibers the action potential only occurs at the nodes of Ranvier, jumping from one node to another. This is called saltatory conduction.

#### **The Synapse**

Transmission of the nerve impulse from one neuron to another takes place at a synapse when a neurotransmitter molecule is released from an axon bulb into a synaptic cleft. The binding of the neurotransmitter to receptors in the postsynaptic membrane causes either excitation or inhibition. Once a neurotransmitter has been released into a synaptic cleft and has initiated a response, it is removed from the cleft by enzymes.

#### **Neurotransmitter Molecules**

Two well known neurotransmitters are acetylcholine (Ach) and norepinephrine (NE) but at least 100 different neurotransmitters are known or suspected. Many drugs work by interfering with the action of neurotransmitters and others act by prolonging neurotransmitters.

#### **Synaptic Integration**

Excitatory signals have a depolarizing effect, and inhibitory signals have a hyperpolarizing effect on the postsynaptic membrane. Integration is the summing up of these signals. If the neuron receives more inhibitory than excitatory signals, the axon may not reach threshold. If a neuron receives more excitatory than inhibitory signals, it will transmit a signal.

### **13.2 The Central Nervous System**

The CNS consists of the spinal cord and brain, which are both protected by bone, meninges, and cerebrospinal fluid. The CNS receives and integrates sensory input and formulates motor output. The CNS is composed of short, nonmyelinated gray matter and myelinated tracts called white matter. The ventricles of the brain are reservoirs for cerebrospinal fluid.

#### **The Spinal Cord**

The spinal cord extends from the base of the brain and is located in the vertebral canal formed by the vertebrae.

#### **Structure of the Spinal Cord**

The gray matter of the spinal cord contains neuron cell bodies; the white matter consists of myelinated axons that occur in bundles called tracts. Because these tracts cross over, the left side of the brain controls the right side of the body and vice versa. The spinal cord also has a central canal.

#### **Functions of the Spinal Cord**

The spinal cord carries out reflex actions and sends sensory information to the brain and receives motor output from the brain. When the spinal cord is severed, a loss of sensation and motor control occurs in areas below the site of injury. If the spinal cord is severed in the thoracic area, paraplegia results. If the injury is in the neck region, quadriplegia results.

#### **Reflex Actions**

The spinal cord is the center for thousands of reflex arcs. Examples are when blood pressure falls, receptors in the carotid arteries and aorta generate nerve signals, which pass through sensory fibers to the cord then up to the cardiovascular center in the brain. Then nerve signals pass down to the spinal cord, where motor signals cause the constriction of blood vessels.

#### **The Brain**

The brain has four cavities called ventricles. The cerebrum can be associated with the two lateral ventricles, while the diencephalon can be associated with the third ventricle, and the brain stem and the cerebellum can be associated with the fourth ventricle.

### **The Cerebrum**

The cerebrum is the largest portion of the brain in humans. It is the last center to receive sensory input and carry out integration before commanding voluntary motor responses.

#### **Cerebral Hemispheres**

The cerebrum has two cerebral hemispheres connected by the corpus callosum. Sensation, reasoning, learning and memory, and also language and speech take place in the cerebrum. Each cerebral hemisphere contains a frontal, parietal, occipital, and temporal lobe, each of which is associated with particular functions.

#### **The Cerebral Cortex**

The cerebral cortex is a thin but highly convoluted outer layer of gray matter that covers the cerebral hemispheres. It is the region of the brain that accounts for sensation, voluntary movement, and all the thought processes we associate with consciousness.

#### **Primary Motor and Sensory Areas of the Cortex**

The primary motor area in the frontal lobe sends out motor commands to lower brain centers that pass them on to motor neurons. The primary somatosensory area in the parietal lobe receives sensory information from lower brain centers in communication with sensory neurons.

#### **Association Areas**

Association areas, where integration occurs, are located in all the lobes; the prefrontal area of the frontal lobe is especially necessary for higher mental functions. A visual association area occurs in the occipital lobe, and an auditory association area occurs in the temporal lobe. A momentary lack of oxygen at birth can cause cerebral palsy, characterized by spastic weakness of arms and legs.

#### **Processing Centers**

Processing centers of the cortex receive information from the other association areas and perform higher-level analytical functions. The prefrontal area in the frontal lobe uses information in the other association areas to plan our actions. The Broca's and Wernicke's areas are involved with understanding the written and spoken word and speaking and writing themselves.

#### **Central White Matter**

Most of the rest of the cerebrum is composed of white matter. Descending tracts from the primary motor area communicate with lower brain centers, and ascending tracts from lower brain centers send sensory information up to the primary somatosensory area.

### **Basal Nuclei**

Masses of gray matter deep within the white matter, called basal nuclei, integrate motor commands.

### **The Diencephalon**

The diencephalon encloses the third ventricle. Within the diencephalon, the hypothalamus controls homeostasis, and the thalamus specializes in sending sensory input, except for smell, to the cerebrum. The pineal gland of the diencephalon secretes melatonin.

### **The Cerebellum**

The cerebellum is separated from the brain stem by the fourth ventricle. The cerebellum receives sensory input from the eyes, ears, joints, and muscles about the present position of body parts, and it also receives motor output from the cerebral cortex about where these parts should be located. It then sends motor impulses by way of the brain stem to the skeletal muscles.

### **The Brain Stem**

The brainstem contains the midbrain, the pons, and the medulla oblongata. The midbrain relays impulses from the cerebrum and spinal cord or cerebellum and houses reflexes for visual, auditory, and tactile responses. The medulla oblongata and pons have reflex centers for vital functions, like breathing and the heartbeat.

#### **The Reticular Formation**

Within the reticular formation, a complex network of nuclei and fibers that extend the length of the brainstem called the reticular activating system arouses the cerebrum via the

thalamus and causes a person to be alert. General anesthetics artificially suppress the RAS.

### **13.3 The Limbic System and Higher Mental Functions**

The limbic system is intimately involved in our emotions and higher mental functions.

#### **Limbic System**

The limbic system is a functional grouping rather than an anatomical one. Within the limbic system, the hippocampus makes the prefrontal area aware of past experiences, and the amygdala causes such experiences to have emotions associated with them. Alzheimer disease is a brain disorder characterized by a gradual loss of memory.

#### **Higher Mental Functions**

##### **Memory and Learning**

Memory is the capacity to retain a thought or recall an event or other information from the past. Learning takes place when we retain and utilize past memories.

##### **Types of Memory**

Short-term memory and long-term memory are dependent upon the prefrontal area. Long-term memory includes semantic memory (numbers, words, etc.) and episodic memory (persons, events, etc.). Skill memory is involved in performing motor activities.

##### **Long-Term Memory Storage and Retrieval**

The hippocampus acts as a conduit for sending information to long-term memory and retrieving it once again. The amygdala adds emotional overtones, such as fear, to memories.

##### **Long-Term Potentiation**

On the cellular level, long-term potentiation, the release of more neurotransmitters than before due to continued stimulation over a short period of time, seems to be required for long-term memory.

##### **Language and Speech**

Language depends on semantic memory. Language and speech are dependent upon Broca's area (a motor speech area) and Wernicke's area (a sensory speech area) that are in communication. Interestingly enough, these two areas are located only in the left hemisphere.

### **13.4 The Peripheral Nervous System**

The peripheral nervous system contains only nerves (bundles of axons) and ganglia (cell bodies). There are cranial nerves and spinal nerves. Dorsal root ganglia contain the cell bodies of sensory neurons. 12 pairs of cranial nerves are concerned with the head, neck, and facial regions of the body. The vague nerve branches to most of the internal organs. The 31 pairs of spinal nerves are called mixed nerves because they contain both sensory and motor fibers. Each spinal nerve serves the region of the body in which it is found.

#### **Somatic System**

The nerves in the somatic system serve the skin, skeletal muscles, and tendons. The somatic system includes nerves that take sensory information from external sensory receptors to the CNS and motor commands away from the CNS to the skeletal muscles. Automatic responses to a stimulus in the somatic region are called reflexes.

##### **The Reflex Arc**

A reflex arc involves only the spinal cord. Sensory receptors in the skin generate nerve impulses that move along sensory fibers through the dorsal-root ganglia toward the spinal cord. Sensory neurons then pass signals on to many interneurons. Some of these interneurons synapse with motor neurons and nerve impulses travel along these motor fibers to an effector, bringing about a response to the stimulus. You do not feel pain until the brain receives the information and interprets it.

#### **Autonomic System**

The autonomic system regulates the activity of cardiac and smooth muscles and glands. The system is divided into the sympathetic and parasympathetic divisions. Reflex actions like the regulation of blood pressure, are completed by motor neurons in the autonomic system.

##### **Sympathetic Division**

The sympathetic division is associated with responses that occur during times of stress. The neurotransmitter released by the postganglionic axon is primarily norepinephrine (NE).

##### **Parasympathetic Division**

The parasympathetic system is associated with responses that occur during times of relaxation.

The neurotransmitter is acetylcholine (ACh).

### **The Somatic Versus the Autonomic Systems**

Table 13.1 on page 303 of the text summarizes the features and functions of the somatic motor pathway with the motor pathways of the autonomic system.

## **13.5 Drug Therapy and Drug Abuse**

Although neurological drugs are quite varied, each type has been found to either promote or prevent the action of a particular neurotransmitter or to impact the limbic system. Neuromodulators are naturally occurring molecules that block the release of a neurotransmitter or modify a neuron's response to a neurotransmitter. Drug abuse is apparent when a person takes a drug at a dose level and under circumstances that increase the potential for a harmful effect.

Table 13.2 on page 305 of the text summarizes drug influence on CNS.

### **Drug Mode of Action**

There are more than 100 known neurotransmitters. Dopamine plays a central role in the brain's regulation of mood and also helps us organize coordinated movements. Neuromodulators are naturally occurring molecules that block the release of a neurotransmitter or modify a neuron's response to a neurotransmitter. Endorphins serve as natural painkillers. Pharmaceuticals can either promote the action of a neurotransmitter, interfere with or decrease the action of a neurotransmitter, or replace or mimic a neurotransmitter or neuromodulator. The opiates bind to endorphin receptors.

### **Drug Abuse**

Drug abuse is linked to neurotransmitter levels. Dopamine is central to the brain's reward circuit. Drug abuse is when a person takes a dose level that increases the potential for a harmful effect. With physical dependence, the person becomes tolerant to the drug. Alcohol, drugs, and tobacco can all harm the developing embryo, fetus, or newborn.

### **Alcohol**

Alcohol is the most socially accepted form of drug use worldwide. Alcohol acts as a depressant and influences many brain regions and neurotransmitter systems. Alcohol has many known harmful effects on the body and brain. Consuming alcoholic energy drinks can cause users to drink more.

### **Nicotine**

Nicotine acts as a stimulant. In the CNS, nicotine causes neurons to release dopamine; in the PNS, nicotine mimics the activity of acetylcholine. Nicotine induces both physiological and psychological dependence. 70% of people who try smoking become addicted.

### **Cocaine and Crack**

Cocaine is a powerful stimulant, often sold as a potent extract termed "crack." Cocaine is highly addictive and overdosing is a real possibility.

### **Methamphetamine and Ecstasy**

Methamphetamine is available as either a powder (speed) or a crystal (crystal meth or ice). It is close in structure to amphetamine and attaches to the same receptors as dopamine and norepinephrine. After the initial rush, there is typically a state of high agitation that can, in some individuals, lead to violent behaviors. Ecstasy is the street name for MDMA, which is chemically similar to methamphetamine. It can interfere with temperature regulation, cause high blood pressure and seizures.

### **Heroin**

Heroin is derived from morphine and acts as a depressant in the nervous system. It results in a rush sensation and euphoric experience. Tolerance and dependence is common. There are available treatments for heroin addiction, such as methadone, which itself can be addictive.

### **Marijuana and K2**

Smoking a cigarette or "joint" of marijuana results in a mild euphoria along with alterations in vision and judgment. In heavy users, hallucinations, paranoia, and psychotic symptoms can result. In 1996, several states legalized marijuana for medical uses. A synthetic compound called K2, or Spice is more potent than THC, an ingredient in marijuana. There are reports of death in K2 users.