23A-2 Objectives

- Identify the two major divisions of the nervous system
- List and summarize the functions of the seven regions of the brain
- List and describe the functions of the peripheral nervous system's divisions
- Differentiate between spinal nerves and cranial nerves

23A-2 Divisions of the Nervous System

In general, the nervous system has two major divisions. The **central nervous system (CNS)** consists of the brain and spinal cord. The **peripheral nervous system (PNS)** is the remainder of the nervous system that carries information between the CNS and the rest of the body.

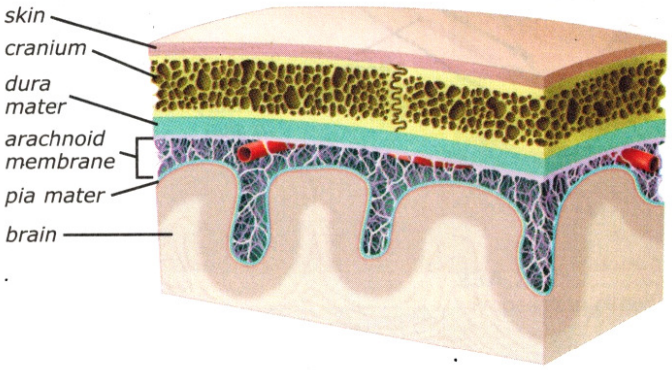
The Central Nervous System

The brain is one of the first organs to form in the human embryo. After about eighteen days of development, a group of cells (neuroblasts) forms the *neural plate*. This grows and eventually becomes a hollow, tubular mass of tissue. The anterior region enlarges and forms the major parts of the brain; the remainder becomes the spinal cord. The inside space increases in size and forms the **ventricles** (spaces inside the brain) and the central canal of the spinal cord.

Coverings of the Central Nervous System

The brain and spinal cord are covered by three protective coverings called **meninges*** (muh NIN jeez). Starting with the external covering and moving inward, they are as follows:

- **Dura mater***—a thick, tough membrane that may contain blood vessels. In the skull it is tightly bound to the inner surface of the cranium.
- **Arachnoid*** (uh RAK noyd) **membrane**—a thin, delicate, cobweblike membrane that forms many small spaces by its attachment to the pia mater.
- **Pia mater***—a thin membrane on the surface of the spinal cord and brain. This membrane contains many small blood vessels.



23A.4
The meninges are located between the cranium and the brain.

The **cerebrospinal*** (SEH ree bro SPY nul) **fluid** flows through the spaces between the pia mater and the arachnoid membrane. It also fills the ventricles of the brain and central canal of the spinal cord. The cerebrospinal fluid filters from the blood in the ventricles, passes over the central nervous system, and then returns to the blood. It nourishes the cells of the brain and spinal cord and protects these delicate organs by suspending them in a watery cushion.

The meninges surround the spinal cord down to the level of the coccyx. Examination of the cerebrospinal fluid can help to identify infections in the central nervous system. Physicians obtain a sample by performing a spinal tap—an insertion of a syringe needle between the lower lumbar vertebrae and withdrawal of 1–2 mL of cerebrospinal fluid. Since the spinal cord usually ends above this level, there is little chance of injury to the spinal cord by the needle. The fluid is examined under a microscope; the presence of erythrocytes, bacteria, or viruses in the fluid clearly indicates infection or tissue damage.

The Brain

The adult human **brain** accounts for only about 2% of body weight (about 1.36 kg), but it receives about 20% of the blood volume pumped by the heart. The natural color of the brain surface is pinkish gray and red. Blood gives the red color. The gray is characteristic of tissue composed primarily of cell bodies and dendrites and gives the *gray matter* its name. The deeper tissue of the brain is mostly *white matter* composed of myelinated axons.

* **meninges:** (Gk. MENIX, membrane)

dura mater: dura (L. DURA, hard) + mater (MATER, mother)

arachnoid: (Gk. ARAKHNOEIDES, cobweblike)

pia mater: pia (L. PIA, tender) + mater (mother)

cerebrospinal: cerebro- (brain) + -spinal (L. SPINA, the human spine)

The brain is subdivided into seven regions: the cerebrum, thalamus, hypothalamus, midbrain, pons, medulla oblongata, and cerebellum.

The **cerebrum** is divided sagittally into two large irregularly folded lumps. Each half of the cerebrum is termed a *hemisphere*. A thick layer of white matter connects the hemispheres, allowing communication between them. The ridged or raised areas of the brain are *gyri* (JYE RYE) (*sing.* gyrus). The deeper, depressed areas are *fissures*.

The gray matter surfaces of the *cerebral hemispheres* appear "wrinkled," making it possible to have more neurons in the gray matter. The **cerebral cortex** (outer gray matter) is only 2.5–4.0 mm thick, but it contains 12–15 billion neurons (approximately 75% of all neuron cell bodies in the nervous system). Generally speaking, the cerebral cortex is responsible for conscious activities. Researchers have mapped the various lobes according to their specific functions. Neurosurgeons use such information to determine which regions are diseased.

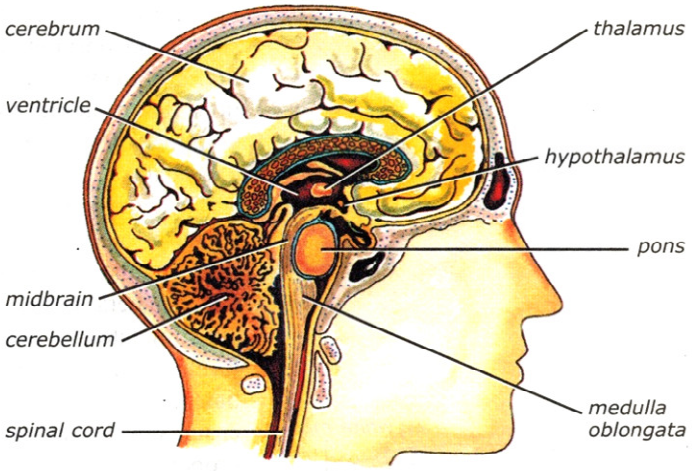
The **thalamus*** is composed of two oval gray masses near the center of the brain, connected at the middle by a bundle of white matter. The thalamus receives general sensations and quickly decides which impulses are important enough to be relayed to the parietal lobe. The thalamus is the first part of the brain that is aware of changes in the environment. The thalamus also helps to keep a person awake and alert.

The **hypothalamus*** weighs only about 4 g, yet it controls many involuntary activities, such as regulation of body temperature, blood volume, and fluid balance. It also has some control over appetite and emotional expression. It also controls hormone release by the *pituitary gland* and forms two hormones itself. The hypothalamus functions in both the nervous system and endocrine system.

The **midbrain** is located between the thalamus and the pons. Many motor impulses transmitted from the pons and the cerebellum to the cerebrum pass through the midbrain. In it are centers for controlling body movements and posture, especially controlling the head in relation to the rest of the body and space. Other midbrain centers are involved with vision and hearing reflexes.

The **pons*** is a bulging structure located between the medulla and the midbrain. It is composed almost entirely of white matter that carries information from one side of the brain to the other. With the medulla, the pons controls involuntary respiration. It also contains reflex centers that control chewing, facial expression, response to sounds, and eyeball movement.

The **medulla oblongata** is continuous with the spinal cord and functions primarily as a relay center between the spinal cord and the brain. Centers for the control of respiration, blood vessel diameter (blood pressure), and heart



23A.5
Cross section of the human brain

Lobes of the Cerebrum

Brains differ in specific features, but the arrangement of the major fissures is quite uniform. Normally the cerebrum is divided by fissures into lobes that are named for the skull bones that cover those areas.

- The **frontal lobe** is responsible for mental functions, such as reasoning, planning, and memorizing. It also controls the ability to communicate verbally and starts the commands for voluntary body movements.
- The **parietal lobe** is responsible for sensations, such as pain, pressure, touch, and temperature. This information is directed to the frontal lobe, which determines what to do about it. The parietal lobe also responds to muscle tension, sensing the position of the body. For example, an expert skydiver knows his body position while he moves through the air because of impulses sent to his parietal lobe.
- The **occipital lobe** is involved primarily in vision and memory of objects and symbols. A severe blow to the head may cause the sensation of seeing "stars" because it stimulates the neurons leading from the eyeballs to the occipital lobe. Nerve impulses from these fibers are interpreted as visual impulses by the occipital lobe.
- The **temporal lobe** perceives the sensations of hearing and smell. It also provides the ability to remember the pronunciation of words and the melody of songs that one has heard and stores memories of both sight and sound.

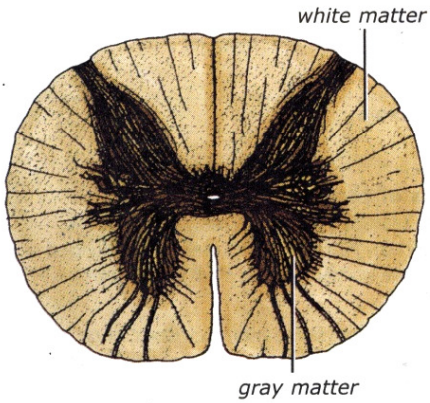
thalamus: (Gk. THALAMOS, inner chamber)

hypothalamus: hypo- (beneath) + -thalamus (inner chamber)

pons: (L. PONS, bridge)

rate are in the medulla. Therefore, injuries to the medulla may result in a *coma** (unconscious state) or death. Its reflex centers control sneezing, coughing, swallowing, and vomiting. Other factors, however, stimulate these actions. For example, something has to irritate the stomach before a person will vomit. Some cough medicines work by dulling the sensitivity of the medulla oblongata.

The **cerebellum**, the second largest part of the brain, is located inferior and posterior to the cerebrum. Similar to the cerebrum, it has two hemispheres joined in the middle and folds of gray matter that cover a mass of white matter. In general terms, the cerebellum monitors and adjusts body activities that are stimulated by other brain regions. It functions totally at the subconscious level; therefore, it stimulates no voluntary movements. Other brain regions initiate the movements, but the cerebellum regulates their quickness and force. It ensures that a movement goes where it should at the proper time and with the proper strength.



23A.6
Cross section of the spinal cord

The Spinal Cord

The **spinal cord**, the second major division of the central nervous system, is continuous with the medulla and usually extends down to the first or second lumbar vertebra. It relays messages between the peripheral parts of the body and the brain. It is a cylindrical mass of nervous tissue composed of thirty-one segments with one pair of spinal nerves originating from each segment.

In a transverse section the spinal cord appears as two masses of tissue joined by a narrow bridge of tissue with a tiny canal in the middle. The abundant nerves that branch from the cervical and lumbar regions make these areas of the spinal cord the thickest.

The spinal cord is white matter in the outer regions and gray matter in the center. The H- or butterfly-shaped central gray matter is mostly interneurons and the cell body portions of sensory and motor neurons. The white matter is myelinated axons arranged vertically. It is similar to a mass of communication cables, all insulated by the myelin sheaths. Some of the axon bundles carry impulses to the brain; others carry impulses only away from the brain. For example, pain impulses pass along only certain axons, while impulses to muscles pass along other axons.

* **coma:** (Gk. KOMA, deep sleep)

Facets of Biology — Spinal Cord Injuries

Each year approximately 11 000 people sustain injuries to their spinal cords. Of those injured, 80% are males between the ages of sixteen and thirty. Sometimes the results are only temporary; other times the victim sustains permanent injuries that may drastically change his life. In the United States over 450 000 people are living with permanent spinal cord injuries (SCI).

Injury can result when the spinal cord is pinched, torn, or severed. The body responds to injury by inflammation. Since the spinal cord is enclosed within the vertebral column, inflammation increases the pressure placed against the spinal cord and actually reduces the blood flow. The neurons begin to die and there is a loss of function. The amount of damage and loss of function depends on the location and

Causes of Spinal Cord Injuries	
Vehicular	44%
Motor vehicles	35%
Motorcycles	6%
All-terrain vehicles	0.2%
Violence	29%
Falls	21%
Sports	6%

severity of the injury. Forty-five percent of SCI result in loss of function that is complete—there is no function below the level of the injury on both sides. A person with incomplete loss of function maintains some sensory and motor ability below the injury.

People who sustain spinal cord injuries must receive special care. At the scene of the accident, they must be carefully strapped to the stretcher to prevent further injury. If possible, they should be taken to hospitals that specialize in treating this type of injury. Medications are given to reduce the amount of swelling, and sometimes surgery is needed. Sometimes full function returns after the swelling has resolved. Researchers are investigating several potential treatments, such as the use of stem cells to regenerate damaged spinal cord cells, nerve cell transplants, and medications to enhance nerve growth.

As with many types of injuries, recovery depends on the extent of the injury. Today, 83% of those who survive the first twenty-four hours are still alive ten years later. Despite their physical limitations, many SCI survivors lead active lives. Technological advances in wheelchair materials, construction, and mobility have allowed even greater freedom of activity.

New technology has improved the mobility and quality of life for people with SCI.

An injury such as this changes a person's life forever. How would you respond if you, someone in your family, or one of your friends sustained a spinal cord injury that resulted in permanent loss of function? It would probably test your faith in God and you would have many questions, especially, "Why did this happen?" While it is not necessarily a sin to ask God why, Christians must realize that God often calls His children to face difficulties without revealing His specific purposes. This truth is well illustrated in the life of Job. This man suffered a great deal in the will of God, yet God never told him why. Nevertheless, the suffering that Job experienced was very valuable. He did not come to know why he suffered. He came to know something far better: "I have heard of thee by the hearing of the ear: but now mine eye seeth thee" (Job 42:5). A believer who goes through this type of trial can take comfort in knowing that God is never taken by surprise. He is all knowing and completely sovereign (Job 42:2). Knowing this, one should ask, "How can God be glorified by this injury and my testimony?" Even in the face of a life-changing injury, a believer can know that he can do all things through Christ who strengthens him (Phil. 4:13) and that even this injury will in time prove to be an evidence of God's goodness and love (Rom. 8:28).

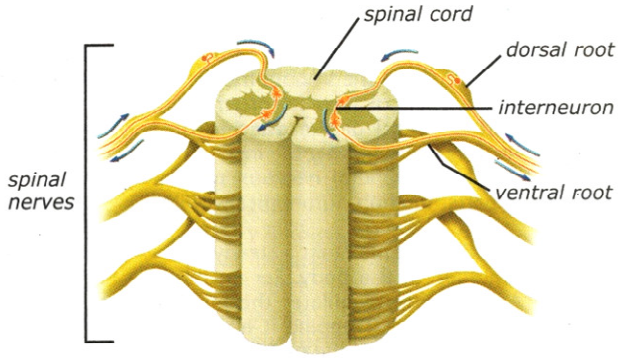
The Peripheral Nervous System

The peripheral nervous system is divided into two parts: the sensory and motor divisions. The **sensory division** contains all of the receptors and nerve fibers that carry information from the body to the central nervous system (brain and spinal cord).

The **motor division** carries information from the CNS to the rest of the body, allowing the body to react to the information received through the sensory system. It is composed of two independent divisions—the *somatic system* and the *autonomic system*. The somatic system is connected to the skeletal muscles and can be controlled. It is sometimes called the voluntary nervous system. This system also includes reflex arcs that can function automatically as protective reactions or to maintain balance. The autonomic system acts independently and without conscious effort. For example, no one needs to remind himself to breathe or digest his lunch—it happens automatically.

Twelve pairs of peripheral nerves, called **cranial* nerves**, originate directly from the brain. Most of these nerves control the sensations and movements of the head and neck. Scientists classify cranial nerves by their general function—*sensory*, *motor*, or *mixed* (containing both sensory and motor fibers)—and name them according to their function or the general distribution of their fibers.

Thirty-one pair of **spinal nerves** originate in the spinal cord and branch out to both sides of the body. These are also mixed nerves. The spinal nerves consist of a dorsal root that contains neurons that carry signals to the CNS, and a ventral root that carries information from the CNS to the effector



23A.7
Basic spinal nerve anatomy

* **cranial:** (Gk. KRANION, skull)

organs. As they are relayed to the brain, all impulses enter the spinal cord through the dorsal roots of the spinal nerves. Impulses from the brain exit through the spinal cord's ventral roots as they deliver the stimuli to the rest of the body.

Table 23A-1 Summary of the Cranial Nerves

Number	Name	Type	Function
I	Olfactory	Sensory	Smell
II	Optic	Sensory	Vision
III	Oculomotor	Motor	Movement of eyelid and eyeball (adjusts lens to focus vision, constricts pupil)
IV	Trochlear	Motor	Movement of eyeball
V	Trigeminal	Motor	Chewing
		Sensory	Face and teeth
VI	Abducens	Motor	Movement of eyeball
VII	Facial	Motor	Facial expression, secretion of saliva
		Sensory	Taste
VIII	Auditory	Sensory	Hearing, equilibrium
IX	Glossopharyngeal	Motor	Swallowing, secretion of saliva
		Sensory	Taste
X	Vagus	Motor	Controls movement of most digestive and respiratory organs, regulates heart action
		Sensory	Carries sensations from the same organs it provides with motor control
XI	Spinal accessory	Motor	Head and shoulder movement
XII	Hypoglossal	Motor	Tongue movement

Cranial nerves can be identified either by name or number. The number indicates the order in which the nerves arise from the brain, moving from anterior to posterior.

The Nervous System, Part 2

1. What are the two main divisions of the nervous system? What is in each division?
2. Name the layers of the meninges from the outside of the skull to the inside.
3. What is the function of cerebrospinal fluid?
4. List the seven regions of the brain and the function of each region.
5. What is the primary cause of spinal cord injuries?
6. List the two parts of the PNS. Which part takes sensory information to the brain? Which takes signals from the brain to muscles and organs?
7. How many cranial nerves are there? From where do they originate?
8. How many spinal nerves are there? From where do they originate?