<u>Unit 7: Nervous System</u>

Ms. Randall

<u>Essential Questions:</u>

- How does the nervous system work to convey information and support homeostasis?

<u>Unit Objectives:</u>

- Identify the three key functions of the nervous system.
- Differentiate between the central and peripheral nervous systems.
- Describe the role of neurons.
- Describe the variety and function of neuroglia.
- Describe a synapse, including the electrical and chemical events at and across the presynaptic and postsynaptic membranes.
- Identify the two parts of the CNS and identify the protective structures.
- Describe the function of reflex arcs.
- Characterize the function and location of the autonomic nervous system.
- Differentiate between the anatomical locations and functions of the sympathetic and parasympathetic nervous systems.

<u>Unit Vocabulary:</u>

Efferent
Afferent
Central nervous system
Cerebral Hemispheres
Peripheral nervous system
Cerebral Cortex
Thalamus
Somatic Nervous System
Hypothalamus
Autonomic Nervous System
Sympathetic
Pineal gland
Parasympathetic
Midbrain
Neuroglia (glia cells)
Medulla Oblongata
Cerebellum

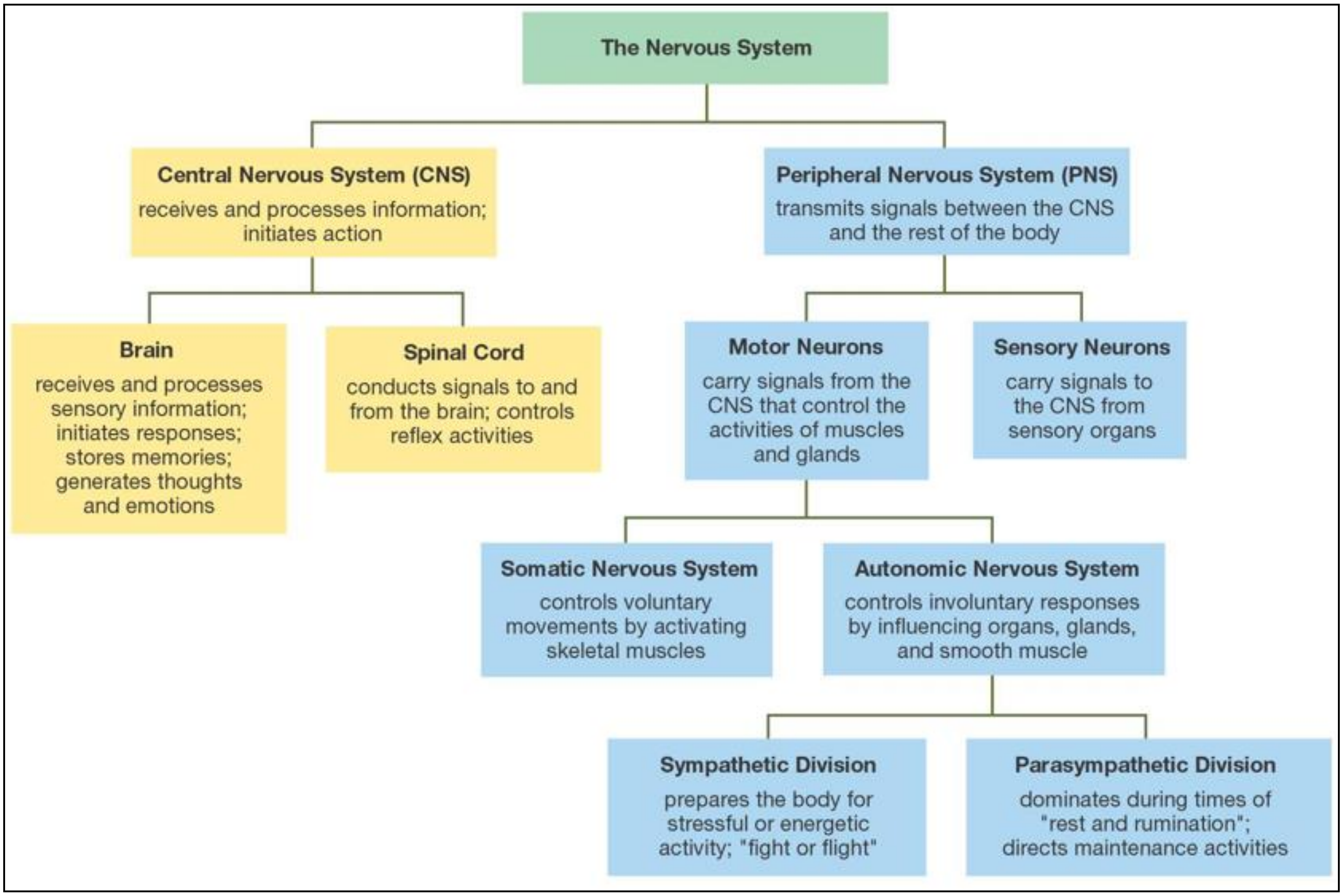
Schwann Cells
Cell Body
Dendrites
Axon
Meninges
Myelin Sheath
Dura Mater
Cerebrospinal fluid
Sensory neurons
Spinal Cord
Motor neurons
Interneurons
Multiple sclerosis
Chemical synapse
Synaptic cleft
Acetylcholine

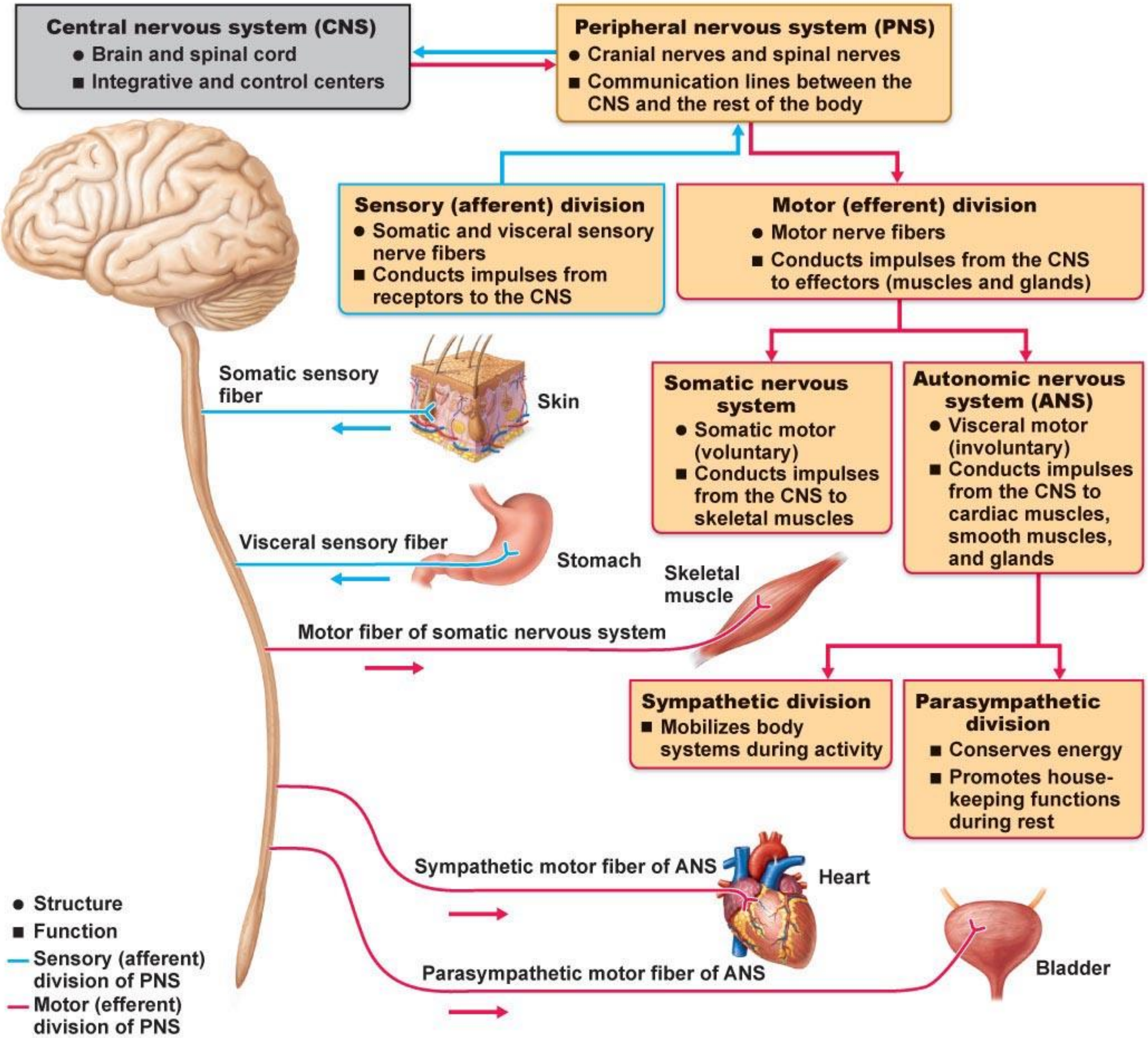
Lesson 1: Functions of the Nervous system

Objective:

- To explain the general functions of the nervous system
- To describe the general structure of a neuron
- To describe the function of neuroglia in the central nervous system

The nervous system allows organisms to sense, organize, and react to information in the environment. The basic unit of the nervous system is the **neuron**. **Synapses** form between the neurons, allowing them to communicate with other neurons or other systems in the body. The nervous system has several subdivisions.





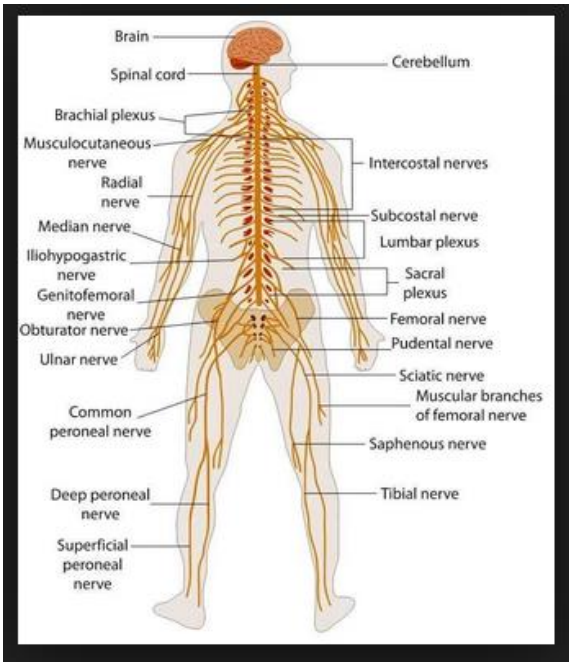
The **Peripheral Nervous System(PNS)** includes a large system of nerves that are linked to the brain and spinal cord. It is comprised of afferent sensory receptors, which process changes in internal and external stimuli and communicate that information to the **Central Nervous System(CNS).** The efferent PNS can be further subdivided into the **Autonomic nervous system** and **the Somatic nervous system.**

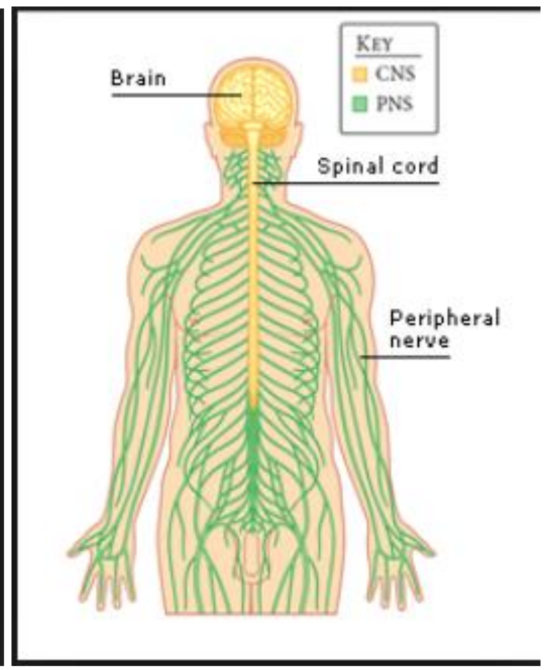
The **Autonomic nervous system** regulates *involuntary* actions such as internal-organ function and blood-vessel movement. It supplies nerves to ("innervates") cardiac and smooth muscle tissue. The autonomic nervous system is made of two components, which work in opposition to one another: The **Sympathetic nervous system**, responsible for the body's "fight-or-flight" response to danger, and the **Parasympathetic nervous system**, which calms the body back down.

The **Somatic nervous system** controls *voluntary* movements such as those in the skin, bones, joints, and skeletal muscles. Both systems within the PNS work together with the CNS to regulate bodily function and provide reactions to external stimuli.

The **Central Nervous System** includes the **spinal cord** and the **brain.** The **brain** is the body's main control center. The main function of the CNS is the integration and processing of sensory information. It synthesizes sensory input to compute an appropriate motor response, or output.

The general flow of information is that the **PNS** takes in information through **sensory neurons**, then sends it to the **CNS** to be processed. After processing, the **CNS** "tells" the **PNS** what to do—what muscles to flex, whether the lungs need more oxygen, which limbs need more blood, any number of biological processes—and the **PNS** makes it happen through muscle control. The neurons responsible for taking information to the **CNS** are known as **afferent neurons**, while the neurons that carry the responses from the CNS to the PNS are known as **efferent neurons.**

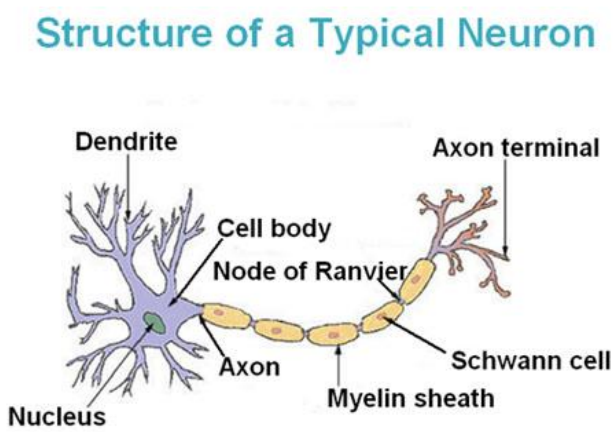


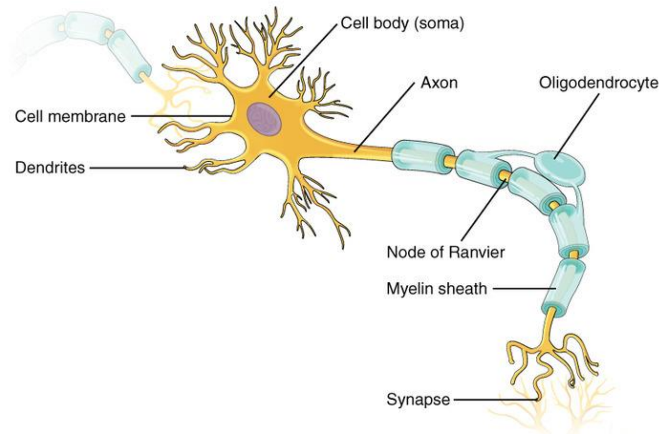


Structures of a Neuron

Neurons are specialized cells that transmit chemical and electrical signals to facilitate communication between the brain and the body. The neuron is the basic building block of the brain and central nervous system. The brain is made up entirely of **neurons** and **glial cells**, which are non-neuronal cells that provide structure and support for the neurons. Nearly 86 billion neurons work together within the nervous system to communicate with the rest of the body. They are responsible for everything from consciousness and thought to pain and hunger. There are three functional classifications of neuron: **sensory neurons, motor neurons,** and **interneurons.**

In addition to having all the normal components of a cell (nucleus, organelles, etc.) neurons also contain unique structures for receiving and sending the electrical signals that make neuronal communication possible.





The above images show the basic structural components of an average neuron, including the **dendrite, cell body, nucleus, Node of Ranvier, myelin sheath, Schwann cell,** and **axon terminal.**

Dendrite

Dendrites are branch-like structures extending away from the cell body, and their job is to receive messages from other neurons and allow those messages to travel to the cell body. Although some neurons do not have any dendrites, other types of neurons have multiple dendrites. Dendrites can have small protrusions called **dendritic spines,** which further increase surface area for possible connections with other neurons.

Cell Body

Like other cells, each neuron has a **cell body (or soma)** that contains a nucleus, smooth and rough endoplasmic reticulum, Golgi apparatus, mitochondria, and other cellular components.

Axon

An **axon**, at its most basic, is a tube-like structure that carries an *electrical impulse* from the cell body (or from another cell's dendrites) to the structures at opposite end of the neuron—**axon terminals**, which can then pass the impulse to another neuron. The cell body contains a specialized structure, the **axon hillock**, which serves as a junction between the cell body and the axon.

Synapse

The **synapse** is the chemical junction between the axon terminals of one neuron and the dendrites of the next. It is a gap where specialized chemical interactions can occur, rather than an actual structure.

Function of a Neuron

The specialized structure and organization of neurons allows them to transmit signals in the form of electric **impulses** from the brain to the body and back. Individually, neurons can pass a signal all the way from their own dendrites to their own axon terminals; but higher-level neurons are organized in long chains, allowing them to pass signals very quickly from one to the other. One neuron's axon will connect chemically to another neuron's dendrite at the synapse between them. Electrically charged chemicals flow from the first neuron's axon to the second neuron's dendrite, and that signal will then flow from the second neuron's dendrite, down its axon, across a synapse, into a third neuron's dendrites, and so on.

This is the basic chain of neural signal transmission, which is how the brain sends signals to the muscles to make them move, and how sensory organs send signals to the brain. It is important that these signals can happen quickly, and they do. Think of how fast you drop a hot potato—before you even realize it is hot. This is because the sense organ (in this case, the skin) sends the signal "This is hot!" to neurons with very long axons that travel up the spine to the brain. If this didn't happen quickly, people would burn themselves.

Dendrites, cell bodies, axons, and synapses are the basic parts of a neuron, but other important structures and materials surround neurons to make them more efficient.

Myelin Sheath

Some axons are covered with **myelin**, a fatty material that wraps around the axon to form the myelin sheath. This external coating functions as insulation to minimize dissipation of the electrical signal as it travels down the axon. Myelin's presence on the axon greatly increases the speed of conduction of the electrical signal, because the fat prevents any electricity from leaking out. This insulation is important, as the axon from a human motor neuron can be as long as a meter—from the base of the spine to the toes. Periodic gaps in the myelin sheath are called **nodes of Ranvier**. At these nodes, the signal is "recharged" as it travels along the axon.

Neuroglial Cells

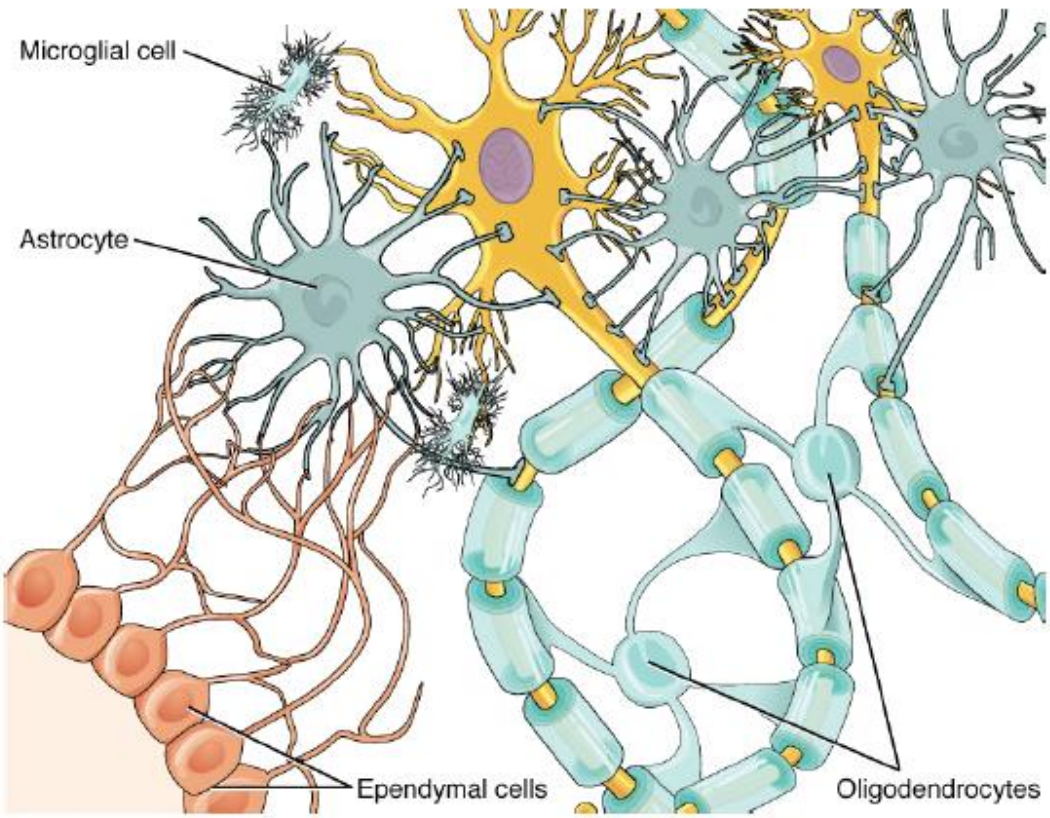
The myelin sheath is not actually part of the neuron. Myelin is produced by **glial cells** (or simply glia, or "glue" in Greek), which are non-neuronal cells that provide support for the nervous system. **Glia** function to hold neurons in place (hence their Greek name), supply them with nutrients, provide insulation, and remove pathogens and dead neurons. In the central nervous system, the glial cells that form the myelin sheath are called **oligodendrocytes**; in the peripheral nervous system, they are called **Schwann cells**. The various types of neuroglia and their functions and associated systems are located in the charts below.

Glial Cell Types by Location and Basic Function

CNS glia	PNS glia	Basic function
Astrocyte	Satellite cell	Support
Oligodendrocyte	Schwann cell	Insulation, myelination
Microglia	-	Immune surveillance and phagocytosis
Ependymal cell	-	Creating CSF

Table 8–1 NEUROGLIA

Name	Function
Oligodendrocytes	• Produce the myelin sheath to electrically insulate neurons of the CNS.
Microglia	• Capable of movement and phagocytosis of pathogens and damaged tissue.
Astrocytes	• Support neurons, help maintain K^+ level, contribute to the blood–brain barrier.
Ependyma	• Line the ventricles of the brain; many of the cells have cilia; involved in circulation of cerebrospinal fluid.



Lesson 2: The Synapse

Objective:

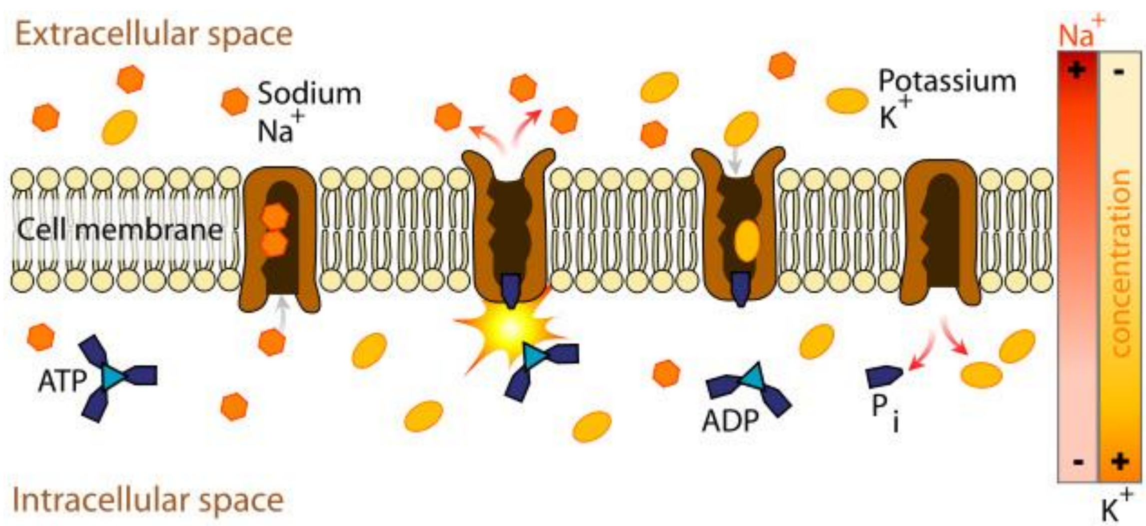
- To explain how information passes from one neuron to another
- To compare and contrast types of synaptic transmissions
- To describe the general ways, the nervous system processes information.

Nerve Impulses

Nerve impulses are electrical in nature. They result from a difference in electrical charge across the **plasma membrane** of a **neuron.** How does this difference in electrical charge come about? The answer involves **ions**, which are electrically charged atoms or molecules.

Resting Potential

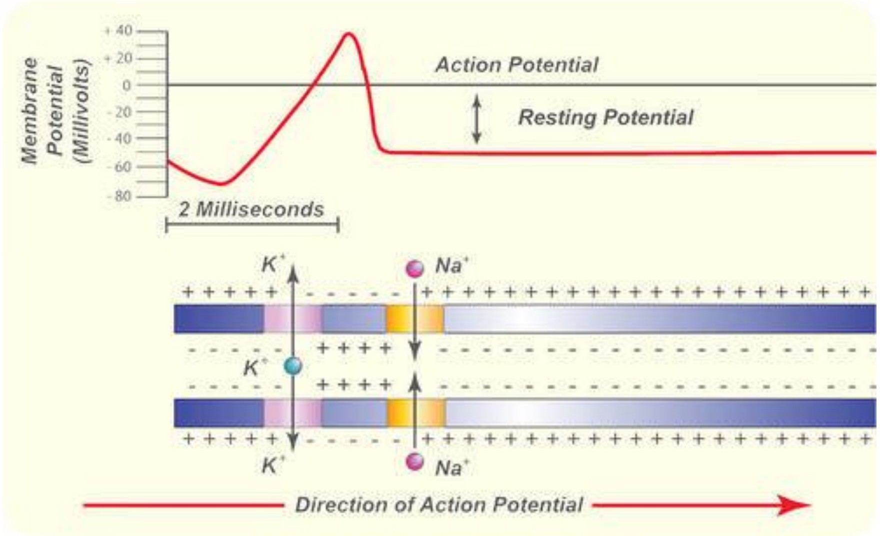
When a **neuron** is not actively transmitting a nerve impulse, it is in a resting state, ready to transmit a **nerve impulse**. During the resting state, a **sodium-potassium pump** located in the plasma membrane maintains a difference in charge across the cell membrane. It uses **energy** in **ATP** to pump **sodium ions** (Na^+) out of the cell and **potassium ions** (K^+) into the cell. As a result, the inside of the neuron is negatively charged compared to the extracellular fluid surrounding the neuron. This is due to many more positively charged ions outside the cell compared to inside the cell. This difference in electrical charge is called the **resting potential.**



[Figure1]

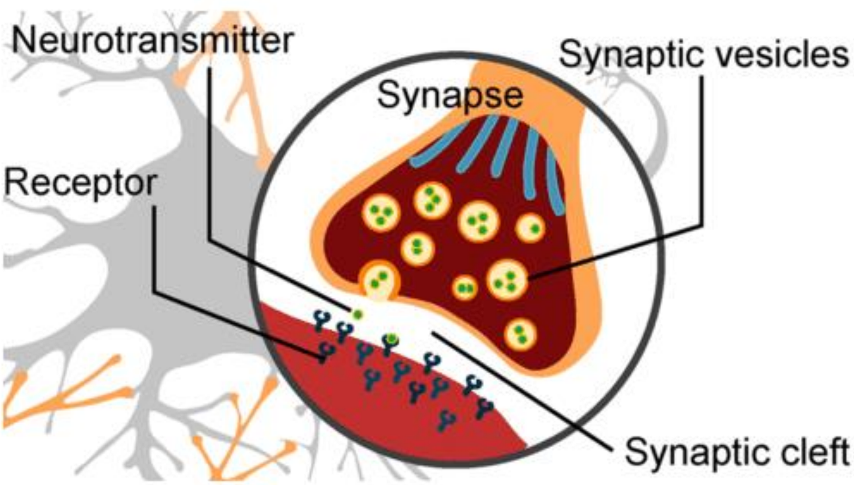
Action Potential

A **nerve impulse** is a sudden reversal of the electrical charge across the membrane of a resting neuron. The reversal of charge is called an **action potential.** It begins when the neuron receives a chemical signal from another cell. The signal causes gates in sodium ion channels to open, allowing positive sodium ions to flow back into the cell. As a result, the inside of the cell becomes positively charged compared to the outside of the cell. This reversal of charge ripples down the axon very rapidly as an electric current.



In neurons with **myelin sheaths**, ions flow across the membrane only at the nodes between sections of myelin. As a result, the action potential jumps along the axon membrane from node to node, rather than spreading smoothly along the entire membrane. This increases the speed at which it travels.

The place where an axon terminal meets another cell is called a **synapse**. The axon terminal and other cell are separated by a narrow space known as a **synaptic cleft.** When an action potential reaches the axon terminal, the axon terminal releases molecules of a chemical called a **neurotransmitter**. The neurotransmitter molecules travel across the synaptic cleft and bind to **receptors** on the membrane of the other cell. If the other cell is a neuron, this starts an action potential in the other cell.



Chemical vs. Electrical Synapse

Chemical Synapse: The first is the chemical synapse (as mentioned previously) in with the electrical activity in the presynaptic neuron triggers the release of chemical messengers, the **neurotransmitters.** The neurotransmitters diffuse across the synapse and bind to the specialized receptors of the postsynaptic cell. The neurotransmitter then either **excites or inhibits** the postsynaptic neuron. Excitation leads to the firing of an action potential while inhibition prevents the propagation of a signal.

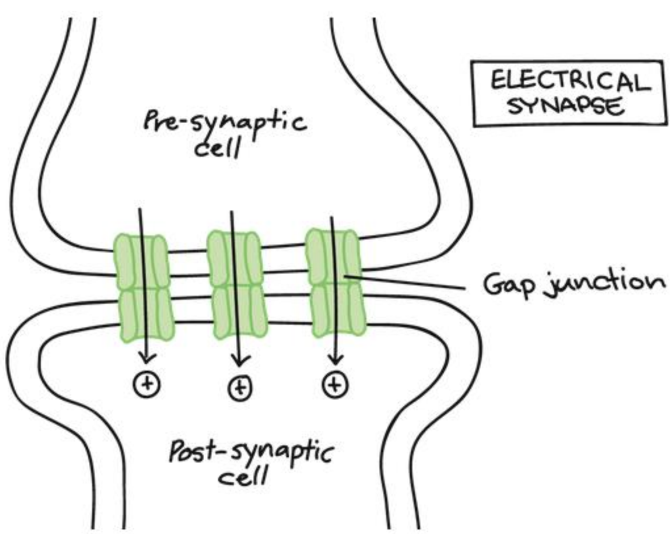
Table 1. Neurotransmitters

Neurotransmitter	Function	Location
Acetylcholine	muscle control, memory	CNS and/or PNS
Serotonin	intestinal movement, mood regulation, sleep	gut, CNS
Dopamine	voluntary muscle movements, cognition, reward pathways	hypothalamus
Norepinephrine	fight or flight response	adrenal medulla
GABA	inhibits CNS	brain
Glutamate	generally an excitatory neurotransmitter, memory	CNS, PNS

Electrical Synapses: In this type, two neurons are connected by specialized channels known as **gap junctions.** Electrical synapses allow electrical signals to travel quickly from the presynaptic cell to the postsynaptic cell, rapidly speeding up the transfer of signals. The gap between electrical synapses is much smaller than that of a chemical synapse (about 3.5 nanometers compared to 20 nanometers). The special protein channels that connect the two cells make it possible for the positive current from the presynaptic neuron to flow directly into the postsynaptic cell.

Electrical synapses transfer signals much faster than chemical synapses. While the speed of transmission in chemical synapses can take up to several milliseconds, the transmission at electrical synapses is nearly instantaneous. Where chemical synapses can be excitatory or inhibitory, electrical synapses are excitatory only.

While electrical synapses have the advantage of speed, the strength of a signal diminishes as it travels from one cell to the next. Because of this loss of signal strength, it requires a very large presynaptic neuron to influence much smaller postsynaptic neurons. Chemical synapses may be slower, but they can transmit a message without any loss in signal strength. Very small presynaptic neurons are also able to influence even very large postsynaptic cells



Lesson 3: Central Nervous System

Objective:

- Identify the components of the central nervous system
- Identify locations and basic function of the different parts of the brain
- Identify locations and basic function of the different parts of the spinal cord

The central nervous system (CNS) is made up of the **brain** and spinal cord and is covered with three layers of protective coverings called **meninges**. The outermost layer is the **dura mater**. The primary function for this thick layer is to protect the brain and spinal cord. The dura mater also contains vein-like structures that carry blood from the brain back to the heart. The middle layer is the web-like **arachnoid mater**. The last layer is the **pia mater,** which directly contacts and covers the brain and spinal cord like plastic wrap. The space between the arachnoid and pia maters is filled with **cerebrospinal fluid (CSF)**. CSF is produced by a tissue called **choroid plexus** in fluid-filled compartments in the CNS called **ventricles**. The brain floats in CSF, which acts as a cushion and shock absorber and makes the brain neutrally buoyant. CSF also functions to circulate chemical substances throughout the brain and into the spinal cord.

The brain is the part of the central nervous system that is contained in the cranial cavity of the skull. It includes the cerebral cortex, limbic system, basal ganglia, thalamus, hypothalamus, and cerebellum.

Cerebral Cortex

The outermost part of the brain is a thick piece of nervous system tissue called the **cerebral cortex**, which is folded into hills called **gyri** and valleys called **sulci**. The cortex is made up of two hemispheres—right and left—which are separated by a large sulcus. A thick fiber bundle called the **corpus callosum** connects the two hemispheres and allows information to be passed from one side to the other. Although there are some brain functions that are localized more to one hemisphere than the other, the functions of the two hemispheres are largely redundant.

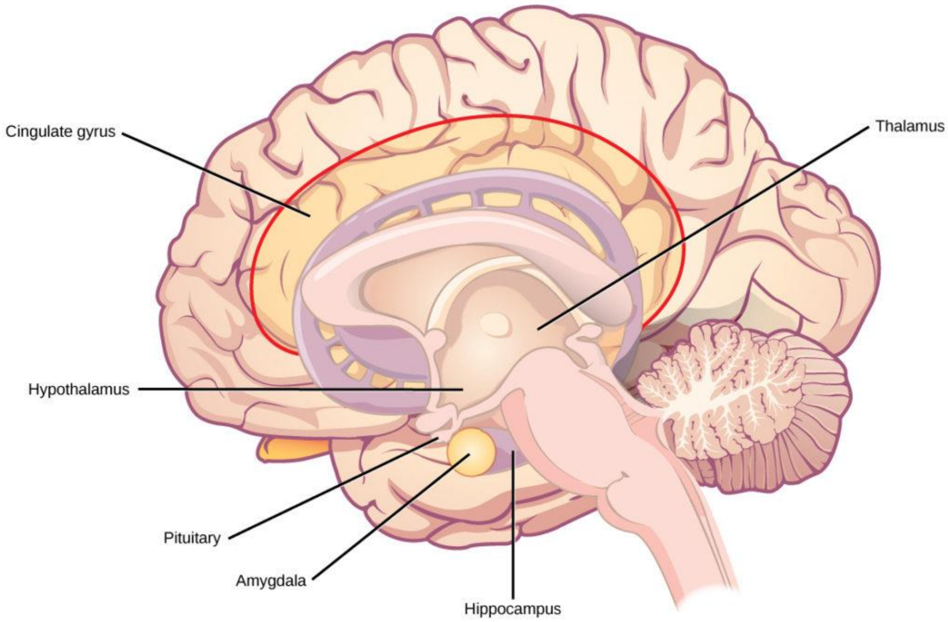
Each cortical hemisphere contains regions called **lobes** that are involved in different functions. Each hemisphere of the cerebral cortex can be broken down into four functionally and spatially defined lobes: frontal, parietal, temporal, and occipital.

The **frontal lobe** is located at the front of the brain, over the eyes. This lobe contains the olfactory bulb, which processes smells. The frontal lobe also contains the motor cortex, which is important for planning and implementing movement. Neurons in the frontal lobe also control cognitive functions like maintaining attention, speech, and decision-making. The **parietal lobe** is located at the top of the brain. Neurons in the parietal lobe are involved in speech and reading. Two of the parietal lobe's main functions are processing **somatosensation**—touch sensations like pressure, pain, heat, cold—and processing **proprioception**—the sense of how parts of the body are oriented in space. The **occipital lobe** is located at the back of the brain. It is primarily involved in vision—seeing, recognizing, and identifying the visual world. The **temporal lobe** is located at the base of the brain by your ears and is primarily involved in processing and interpreting sounds. It also contains the **hippocampus,** a structure that processes memory formation.

Basal Ganglia

Interconnected brain areas called the **basal ganglia** (or **basal nuclei**), play important roles in movement control and posture. Damage to the basal ganglia, as in Parkinson's disease, leads to motor impairments like a shuffling gait when walking. The basal ganglia also regulate motivation.

Thalamus



The **thalamus** acts as a gateway to and from the cortex. It receives sensory and motor inputs from the body and receives feedback from the cortex. This feedback mechanism can modulate conscious awareness of sensory and motor inputs depending on the attention and arousal state of the animal. The thalamus helps regulate consciousness, arousal, and sleep states. A rare genetic disorder called fatal familial insomnia causes the degeneration of thalamic neurons and glia. This disorder prevents affected patients from being able to sleep, among other symptoms, and is eventually fatal.

Hypothalamus

Below the thalamus is the **hypothalamus**. The hypothalamus controls the endocrine system by sending signals to the pituitary gland, a pea-sized endocrine gland that releases several different hormones that affect other glands as well as other cells. This relationship means that the hypothalamus regulates important behaviors that are controlled by these hormones. The hypothalamus is the body's thermostat—it makes sure key functions like food and water intake, energy expenditure, and body temperature are kept at appropriate levels. Neurons within the hypothalamus also regulate circadian rhythms, sometimes called sleep cycles.

Limbic System

The **limbic system** is a connected set of structures that regulates emotion, as well as behaviors related to fear and motivation. It plays a role in memory formation and includes parts of the thalamus and hypothalamus as well as the hippocampus. One important structure within the limbic system is a temporal lobe structure called the **amygdala**. The two amygdala are important both for the sensation of fear and for recognizing fearful faces. The **cingulate gyrus** helps regulate emotions and pain.

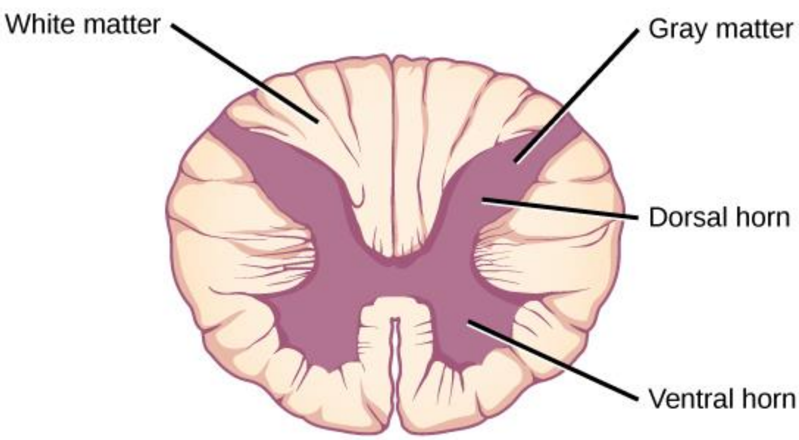
Cerebellum

The **cerebellum** sits at the base of the brain on top of the brainstem. The cerebellum controls balance and aids in coordinating movement and learning new motor tasks.

Brainstem

The **brainstem** connects the rest of the brain with the spinal cord. It consists of **the midbrain, medulla oblongata,** and **the pons**. Motor and sensory neurons extend through the brainstem allowing for the relay of signals between the brain and spinal cord. Ascending neural pathways cross in this section of the brain allowing the left hemisphere of the cerebrum to control the right side of the body and vice versa. The brainstem coordinates motor control signals sent from the brain to the body. The brainstem controls several important functions of the body including alertness, arousal, breathing, blood pressure, digestion, heart rate, swallowing, walking, and sensory and motor information integration.

Connecting to the brainstem and extending down the body through the spinal column is the **spinal cord**. The spinal cord is a thick bundle of nerve tissue that carries information about the body to the brain and from the brain to the body. The spinal cord is contained within the bones of the vertebrate column but can communicate signals to and from the body through its connections with spinal nerves (part of the peripheral nervous system). A cross-section of the spinal cord looks like a white oval containing a gray butterfly-shape, as illustrated in. Myelinated axons make up the "**white matter"** and neuron and glial cell bodies make up the "**gray matter."** Gray matter is also composed of interneurons, which connect two neurons each located in different parts of the body. Axons and cell bodies in the dorsal (facing the back of the animal) spinal cord convey mostly sensory information from the body to the brain. Axons and cell bodies in the ventral spinal cord primarily transmit signals controlling movement from the brain to the body.



The spinal cord also controls motor reflexes. These reflexes are quick, unconscious movements—like automatically removing a hand from a hot object. Reflexes are so fast because they involve local synaptic connections. For example, the knee reflex that a doctor tests during a routine physical is controlled by a single synapse between a sensory neuron and a motor neuron. While a reflex may only require the involvement of one or two synapses, synapses with interneurons in the spinal column transmit information to the brain to convey what happened (the knee jerked, or the hand was hot).

<u>**Lesson 4: Peripheral Nervous System**</u>

Objective:

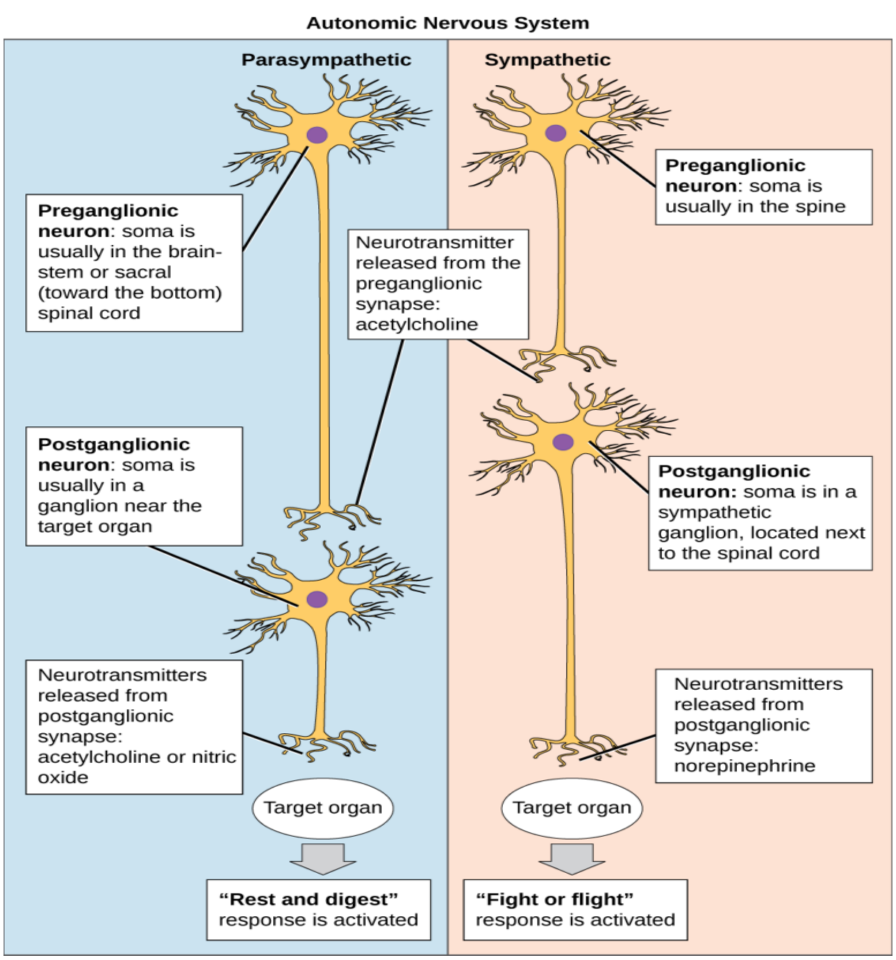
- Describe the organization and functions of the sympathetic nervous systems
- Describe the organization and functions of the parasympathetic nervous systems
- Describe the organization and function of the sensory-somatic nervous system

The **Peripheral nervous system** (PNS) is the connection between the central nervous system and the rest of the body. The CNS is like the power plant of the nervous system. It creates the signals that control the functions of the body. The PNS is like the wires that go to individual houses. Without those “wires,” the signals produced by the CNS could not control the body (and the CNS would not be able to receive sensory information from the body either).

The PNS can be broken down into the **autonomic nervous system**, which controls bodily functions without conscious control, and the **somatic nervous system**, which transmits sensory information from the skin, muscles, and sensory organs to the CNS and sends motor commands from the CNS to the muscles.

Autonomic Nervous System

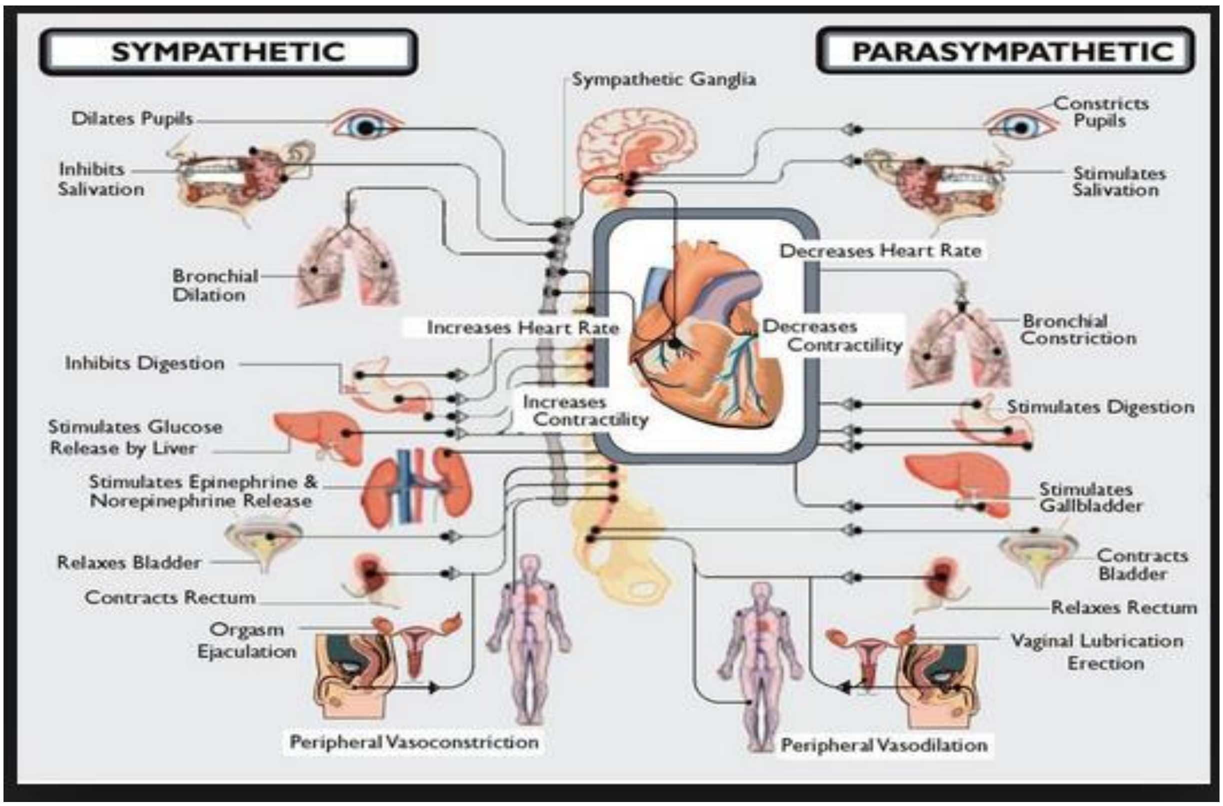
In the **autonomic nervous system**, a preganglionic neuron of the CNS synapses with a postganglionic neuron of the PNS. The postganglionic neuron, in turn, acts on a target organ. Autonomic responses are mediated by the **sympathetic and the parasympathetic systems**, which are **antagonistic** to one another. The sympathetic system activates the “fight or flight” response, while the parasympathetic system activates the “rest and digest” response.



The autonomic nervous system serves as the relay between the CNS and the internal organs. It controls the lungs, the heart, smooth muscle, and exocrine and endocrine glands. The autonomic nervous system controls these organs largely without conscious control; it can continuously monitor the conditions of these different systems and implement changes as needed. Signaling to the target tissue usually involves two synapses: a preganglionic neuron (originating in the CNS) synapses to a neuron in a ganglion that, in turn, synapses on the target organ. There are two divisions of the autonomic nervous system that often have opposing effects: the sympathetic nervous system and the parasympathetic nervous system.

Sympathetic Nervous System

The **sympathetic nervous system** is responsible for the “fight or flight” response that occurs when an animal encounters a dangerous situation. One way to remember this is to think of the surprise a person feels when encountering a snake (“snake” and “sympathetic” both begin with “s”). Examples of functions controlled by the sympathetic nervous system include an accelerated heart rate and inhibited digestion. These functions help prepare an organism’s body for the physical strain required to escape a potentially dangerous situation or to fend off a predator.



Most preganglionic neurons in the sympathetic nervous system originate in the spinal cord. The axons of these neurons release **acetylcholine** on postganglionic neurons within sympathetic ganglia (the sympathetic ganglia form a chain that extends alongside the spinal cord). The acetylcholine activates the postganglionic neurons. Postganglionic neurons then release **norepinephrine** onto target organs. As anyone who has ever felt a rush before a big test, speech, or athletic event can attest, the effects of the sympathetic nervous system are quite pervasive. This is both because one preganglionic neuron synapses on multiple postganglionic neurons, amplifying the effect of the original synapse, and because the adrenal gland also releases norepinephrine (and the closely related hormone epinephrine) into the blood stream. The physiological effects of this norepinephrine release include dilating the trachea and bronchi (making it easier for the animal to breathe), increasing heart rate, and moving blood from the skin to the heart, muscles, and brain (so the animal can think and run). The strength and speed of the sympathetic response helps an organism avoid danger.

Parasympathetic Nervous System

While the sympathetic nervous system is activated in stressful situations, the **parasympathetic nervous system** allows an animal to “rest and digest.” The parasympathetic system’s functions conserve energy: slowing down the heart rate, reducing contractile forces of both cardiac and gastrointestinal muscle, and reducing conduction velocity of the sinoatrial node and atrioventricular node.

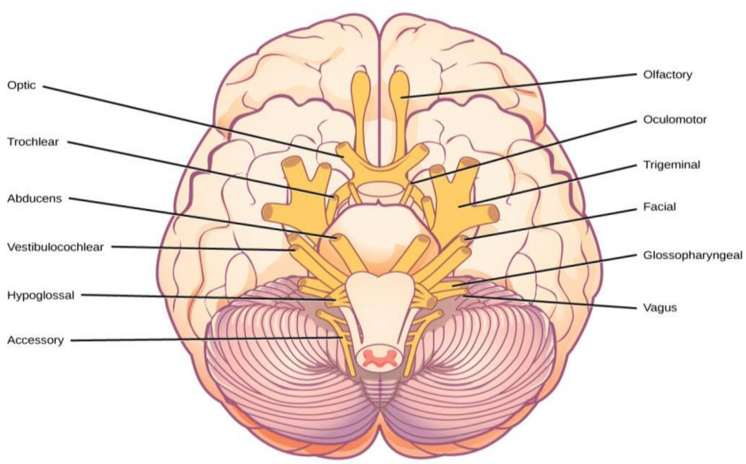
Parasympathetic preganglionic neurons have cell bodies located in the brainstem and in the sacral (toward the bottom) spinal cord. The axons of the preganglionic neurons release acetylcholine on the postganglionic neurons, which are generally located very near the target organs. Most postganglionic neurons release acetylcholine onto target organs, although some release nitric oxide. Acetylcholine acts on two types of receptors, the muscarinic and nicotinic cholinergic receptors. Most transmissions occur in two stages: When stimulated, the preganglionic neuron releases acetylcholine at the ganglion, which acts on nicotinic receptors of postganglionic neurons. The postganglionic neuron then releases acetylcholine to stimulate the muscarinic receptors of the target organ.

The parasympathetic nervous system resets organ function after the sympathetic nervous system is activated. Effects of acetylcholine release on target organs include slowing of heart rate, lowered blood pressure, and stimulation of digestion.

Somatic Nervous System

The somatic nervous system is made up of cranial and spinal nerves and contains both sensory and motor neurons. **Sensory neurons** transmit sensory information from the skin, skeletal muscle, and sensory organs to the CNS. Motor neurons transmit messages about desired movement from the CNS to the muscles to make them contract. Without its sensory-somatic nervous system, an animal would be unable to process any information about its environment (what it sees, feels, hears, and so on) and could not control motor movements. Unlike the autonomic nervous system, which has two synapses between the CNS and the target organ, sensory and motor neurons have only one synapse—one ending of the neuron is at the organ and the other directly contacts a CNS neuron**. Acetylcholine** is the main neurotransmitter released at these synapses.

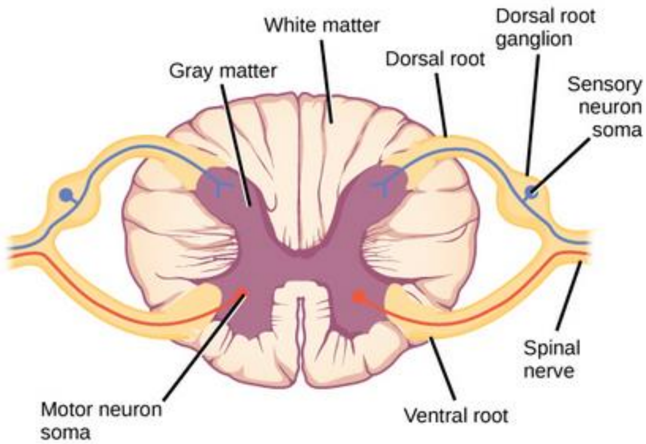
Humans have 12 **cranial nerves**, nerves that emerge from or enter the skull (cranium), as opposed to the spinal nerves, which emerge from the vertebral column.



Some cranial nerves transmit only sensory information. For example, the olfactory nerve transmits information about smells from the nose to the brainstem. Other cranial nerves transmit almost solely motor information. For example, the oculomotor nerve controls the opening and closing of the eyelid and some eye movements. Other cranial nerves contain a mix of sensory and motor fibers. For example, the glossopharyngeal nerve has a role in both taste (sensory) and swallowing (motor).

Spinal nerves transmit sensory and motor information between the spinal cord and the rest of the body. Each of the 31 spinal nerves (in humans) contains both sensory and motor axons. The sensory neuron cell bodies are grouped in structures called **dorsal root ganglia.**

Each sensory neuron has one projection—with a sensory receptor ending in skin, muscle, or sensory organs—and another that synapses with a neuron in the dorsal spinal cord. **Motor neurons** have cell bodies in the ventral gray matter of the spinal cord that project to muscle through the ventral root. These neurons are usually stimulated by **interneurons** within the spinal cord but are sometimes directly stimulated by sensory neurons.



Cross Section of Spinal Cord

<u>Lesson 5: Reflex Arcs</u>

Objective:

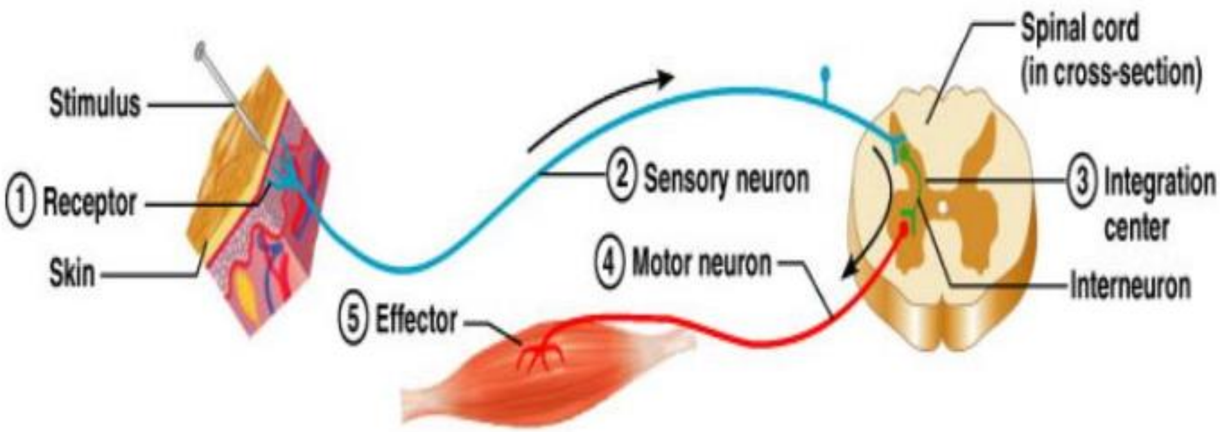
- To describe the function of each part of a reflex arc
- To explain two reflex examples

A **reflex action** is an involuntary and nearly instantaneous movement in response to a stimulus. When a person accidentally touches a hot object, they automatically jerk their hand away without thinking. A reflex does not require any thought input.

The path taken by the nerve impulses in a reflex is called a **reflex arc.** In higher animals, most **sensory neurons** do not pass directly into the brain, but synapse in the spinal cord. This characteristic allows reflex actions to occur relatively quickly by activating spinal motor neurons without the delay of routing signals through the brain, although the brain will receive sensory input while the reflex action occurs.

Most reflex arcs involve only three neurons. The stimulus, such as a needle stick, stimulates the pain receptors of the skin, which initiate an impulse in a **sensory neuron**. This travels to the spinal cord where it passes, by means of a synapse, to a connecting neuron called an **interneuron** situated in the spinal cord.

The **interneuron** in turn makes a synapse with one or more **motor neurons** that transmit the impulse to the muscles of the limb causing them to contract and pull away from the sharp object. Reflexes do not require involvement of the brain, although in some cases the brain can prevent reflex action.



Types of Reflex Arcs

There are two types of reflex arcs: the **autonomic reflex arc**, affecting inner organs, and the **somatic reflex arc,** affecting muscles. When a reflex arc consists of only two neurons, one sensory neuron, and one motor neuron, it is defined as monosynaptic.

Monosynaptic refers to the presence of a single chemical synapse. In the case of peripheral muscle reflexes (patellar reflex, Achilles reflex), brief stimulation to the muscle spindle results in the contraction of the agonist or effector muscle.

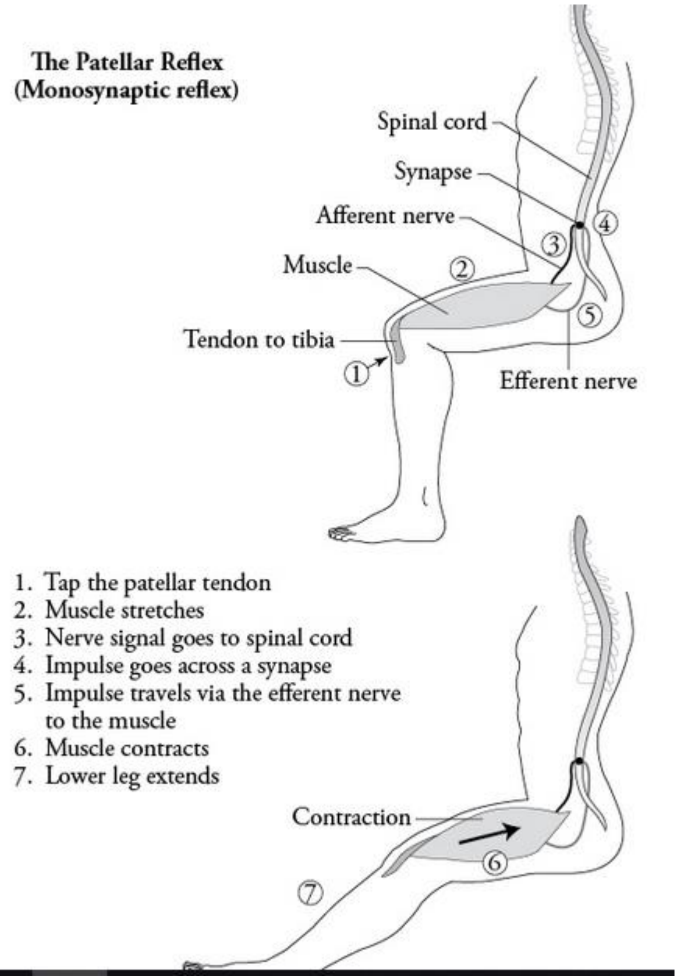
By contrast, in polysynaptic reflex arcs, one or more interneurons connect afferent (sensory) and efferent (motor) signals. For example, the withdrawal reflex is a spinal reflex intended to protect the body from damaging stimuli. It causes the stimulation of sensory, association, and motor neurons.

Reflex actions can be understood by the following examples:

- Moving away your hand after touching a hot object. This is a reflex action and is immediate. You don't think twice before removing your hand from the hot object. You feel the burn and immediately the action is taken.
- The act of breathing. You don't breathe and think. Breathing comes naturally. Controlling the breathing would need a lot of effort. Otherwise, it's involuntary and done unconsciously.
- When a doctor taps his patient's knee with a small mallet, the immediate reflex action is the jerking of the knee upwards. The knee jerk reaction is very natural. The patient doesn't think before doing it.
- Reflexes can be like lifting your foot automatically as soon as something gets stuck on your foot. We don't think whether we should lift up our foot. It's quick, sudden and immediate.
- When something gets on in our eyes, we blink furiously to try and remove it. This is a reflex action. We don't blink out of our own will. It just happens.

TABLE 11.2 | Parts of a Reflex Arc

Part	Description	Function
Receptor	The receptor end of a dendrite or a specialized receptor cell in a sensory organ	Sensitive to a specific type of internal or external change
Sensory neuron	Dendrite, cell body, and axon of a sensory neuron	Transmits nerve impulse from the receptor into the brain or spinal cord
Interneuron	Dendrite, cell body, and axon of a neuron within the brain or spinal cord	Serves as processing center; conducts nerve impulse from the sensory neuron to a motor neuron
Motor neuron	Dendrite, cell body, and axon of a motor neuron	Transmits nerve impulse from the brain or spinal cord out to an effector
Effector	A muscle or gland	Responds to stimulation by the motor neuron and produces the reflex or behavioral action


The Patellar Reflex
(Monosynaptic reflex)
Spinal cord
Synapse
Afferent nerve
Muscle
Tendon to tibia
Efferent nerve
1
2
3
4
5
1. Tap the patellar tendon
2. Muscle stretches
3. Nerve signal goes to spinal cord
4. Impulse goes across a synapse
5. Impulse travels via the efferent nerve to the muscle
6. Muscle contracts
7. Lower leg extends
Contraction
6
7