HUMAN ANATOMY

THE NERVOUS SYSTEM

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Organization of the Nervous System

With a mass of only **2 kg**, about 3% of the total body weight, the nervous system is one of the **smallest** and yet the **most complex** of the body systems.
This intricate network of **billions** of neurons and even more neuroglia is organized into **two** main **subdivisions**:

- the **central** nervous system and
- the **peripheral** nervous system.

Central Nervous System

The central nervous system (**CNS**)consists of the **brain** and **spinal cord.**
The **brain** is the part of the CNS that is **located** in the **skull** and contains about **85 billion** neurons.
The **spinal cord** is connected to the brain through the **foramen magnum** of the occipital bone and is **encircled** by the bones of the **vertebral column**.
The **spinal cord** contains about **100 million** neurons.
The **CNS processes** many different kinds of incoming **sensory information**.
It is also the source of **thoughts**, **emotions**, and **memories**.
Most **signals** that stimulate **muscles** to contract and **glands** to secrete originate in the CNS.

Peripheral Nervous System

The peripheral nervous system (**PNS**) consists of **all** nervous tissue **outside** the CNS.
Components of the PNS include **nerves**, **ganglia**, **enteric plexuses**, and **sensory receptors**.
A **nerve** is a **bundle** of hundreds to thousands of **axons** plus associated connective tissue and blood vessels that **lies outside** the brain and spinal cord.
12 pairs of **cranial** nerves emerge from the brain and **31 pairs** of **spinal** nerves emerge from the spinal cord.
Each nerve follows a defined path and serves a specific region of the body.
Ganglia are small masses of nervous tissue, consisting primarily of **neuron** cell **bodies**, that are located **outside** of the **brain** and **spinal cord**.
Ganglia are **closely associated** with **cranial** and **spinal nerves**.
Enteric plexuses are extensive networks of neurons located in the **walls of organs** of the gastrointestinal tract.
The neurons of these **plexuses** help **regulate** the **digestive** system.
The term **sensory** receptor refers to a structure of the nervous system that **monitors changes** in the external or internal **environment**.
Examples of **sensory receptors** include **touch** receptors in the **skin**, **photoreceptors** in the **eye**, and **olfactory** receptors in the **nose**.

The PNS is divided into
a **somatic nervous system** (SNS)(soma=body),
an **autonomic nervous system** (ANS) (auto=self), and
an **enteric nervous system** (ENS) (enteron=intestines).

The **SNS** consists of;

(1) **sensory neurons** that convey information to the CNS from somatic receptors in the head, body wall, and limbs and from receptors for the special senses of vision, hearing, taste, and smell, and

(2) **motor neurons** that conduct impulses from the CNS to skeletal muscles only.

Because these motor responses can be consciously controlled, the action of this part of the PNS is **voluntary**.

The **ANS** consists of;

(1) **sensory neurons** that convey information to the CNS from autonomic sensory receptors, located primarily in visceral organs such as the stomach and lungs, and

(2) **motor neurons** that conduct nerve impulses from the CNS to smooth muscle, cardiac muscle, and glands.

Because its **motor** responses are not normally under **conscious** control, the action of the ANS is **involuntary**.

The **motor** part of the **ANS** consists of two branches,

a. **the sympathetic division** and
b. **the parasympathetic division.**

With a few exceptions, **effectors receive** nerves from **both** divisions, and usually the two divisions have **opposing actions**.

For example, **sympathetic** neurons **increase** heart rate, and **parasympathetic** neurons **slow it down**.

In general, the **sympathetic** division helps **support** exercise or **emergency actions**, the "**fight or-flight**" responses, and the **parasympathetic** division takes care of "**rest-and-digest**" activities.

The operation of the **ENS**, the "brain of the gut," is involuntary.

Once considered part of the ANS, the ENS consists of over 100 million neurons in enteric plexuses that extend most of the length of the gastrointestinal (GI) tract.

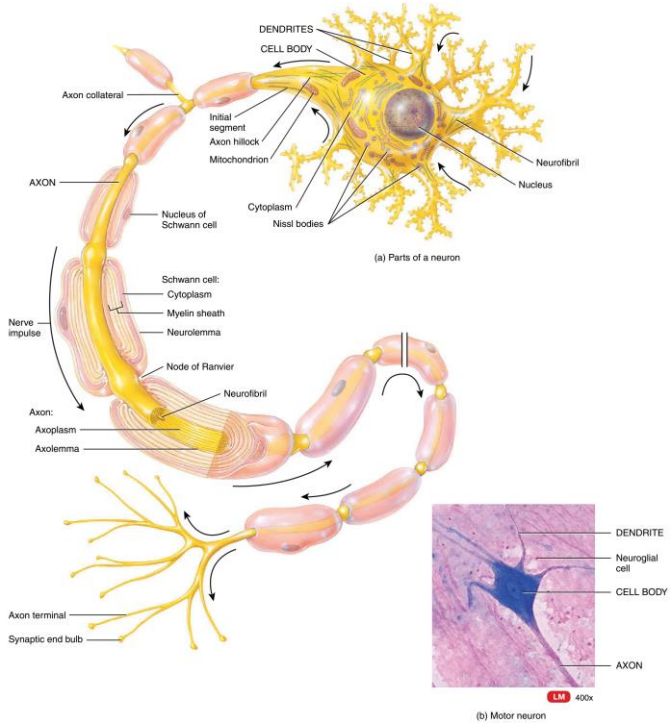
Many of the neurons of the enteric plexuses function independently of the ANS and CNS to some extent, although they also communicate with the CNS via sympathetic and parasympathetic neurons.

Sensory neurons of the ENS monitor chemical changes within the GI tract as well as the stretching of its walls.

Enteric motor neurons govern contractions of GI tract smooth muscle to propel food through the GI tract, secretions of GI tract organs (such as acid from the stomach), and activities of GI tract endocrine cells, which secrete hormones.

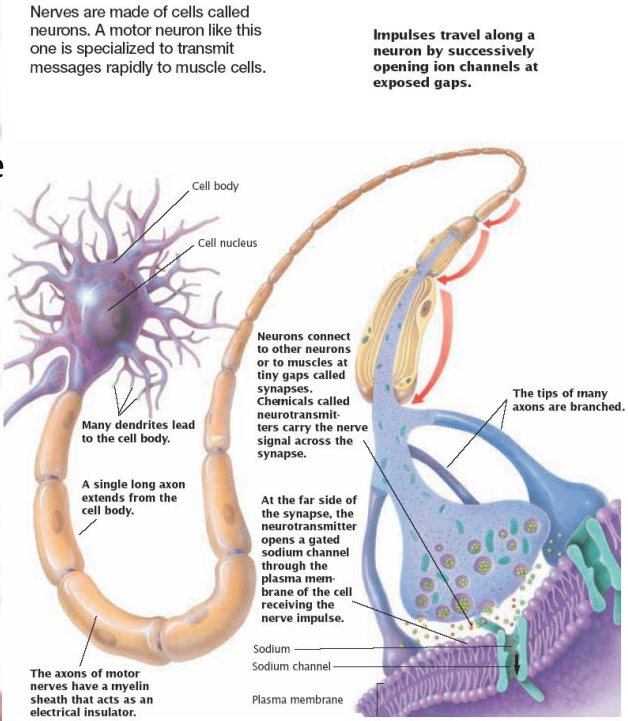
Neurons

- The nervous system contains a complex network of nerve cells, or **neurons.**
- Neurons are specialized cells that transmit information throughout the body.
- Neurons enable many important functions, such as movement, perception, thought, emotion, and learning.



Structure of Neurons

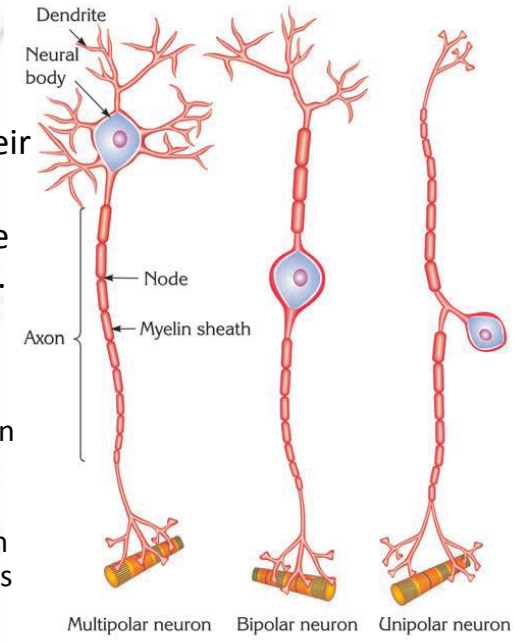
- **Dendrites** which extend from the cell body of the neuron, are the "antennae" of the neuron. Dendrites receive information from other cells.
- An **axon** is a long membrane-covered extension of the cytoplasm that conducts nerve impulses. The ends of an axon are called axon terminals.
- Bundles of axons are called **nerves.**



Classification of neurons

- Neurons are classified according to their projections and functions.

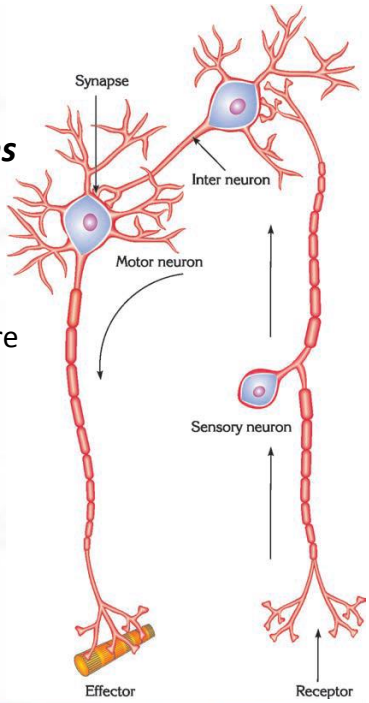
  Neurons are classified according to the shape and number of their extensions.
  - **Unipolar neuron:** Only **one** short projection **extend** from the cell body.
  - **Bipolar neuron: Two** parallel projections **extend** from the cell body, one is the axon and the other is the dendrite.
  - **Multipolar neuron:** There are **more than two** projections. Dendrites are short, thin and numerous. Generally only one axon is present.



Classification of neurons

Neurons are classified ***According to Their Functions*** into **three** groups:

- **Sensory neurons:** Sensory neurons transmit stimuli(Information gathered by receptors from sense organs or internal structures) from sensory organs such as the eye, ear, and skin to the CNS. Sensory neurons are usually unipolar or bipolar in structure.
- **Inter neurons:** Inter neurons are commonly found in the CNS. Their main function is interpretation of information. They are multipolar in structure.
- **Motor neurons:** Motor neurons transmit the impulses from the CNS to muscles or glands. Motor neurons are also multipolar.



Neurons, *continued*

Insulated Neurons

- Many neurons have a layer of insulation on their axon called a myelin sheath.
- The presence of myelin causes nerve impulses to move faster down the axon.
- The speed of impulse conduction is also related to axon diameter. A large-diameter axon conducts impulses faster than a small-diameter axon, assuming both axons are either myelinated or unmyelinated.

Neurons, *continued*

Neuron Function

- All cells have an electrical charge on the inside of the cell membrane that is different from the charge outside the cell.
- The difference in electrical charge across the cell membrane, called the **membrane potential,** results from the movement of ions into and out of the cell.
- This movement depends on the concentration of ions inside and outside the cell, the ability of the ions to diffuse across the membrane, and the ions' charge.

Neurons, *continued*

Resting Potential

- When a neuron is not conducting a nerve impulse, the neuron is said to be at rest.
- The membrane potential of a neuron at rest is called the **resting potential.**
- At the resting potential, the inside of the cell is negatively charged with respect to the outside of the cell.

Neurons, *continued*

Action Potential

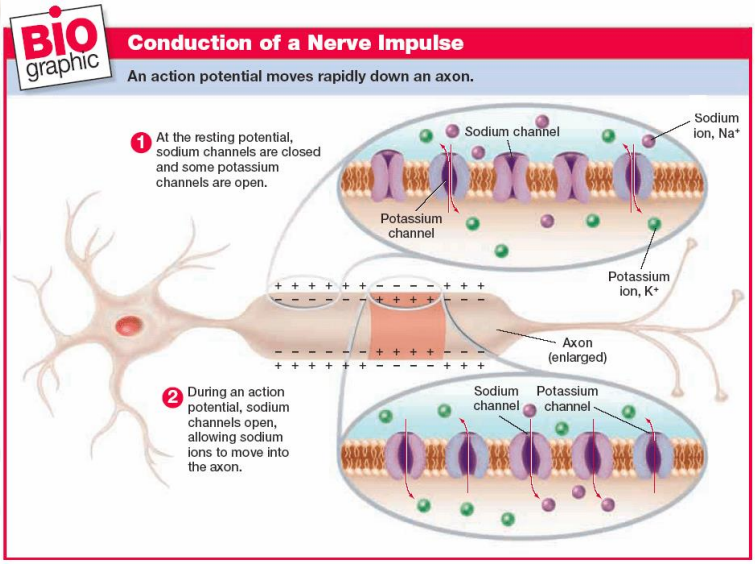
- When a neuron is conducting a nerve impulse, changes occur in the cell membrane of the neuron.
- A nerve impulse is also called an action potential. An **action potential** is a local reversal of polarity—from a negative charge to a positive charge—inside the neuron.
- An action potential moves down an axon like a flame burning down a fuse.

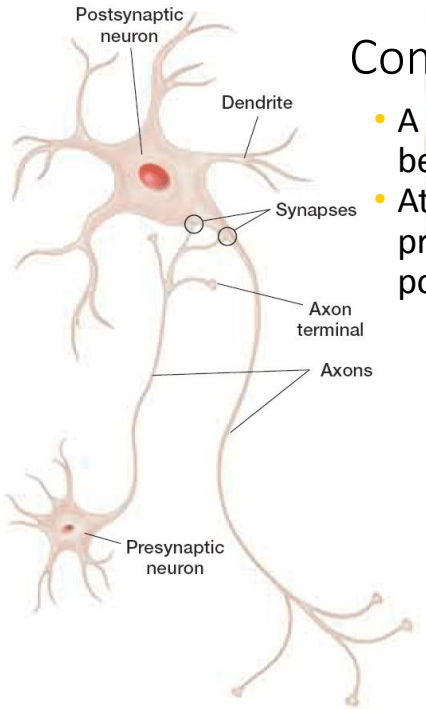
Conduction of a Nerve Impulse

Action Potential
An action potential moves rapidly down an axon:

Step 1 At the resting potential, the inside of the neuron is negatively charged with respect to the outside of the neuron.

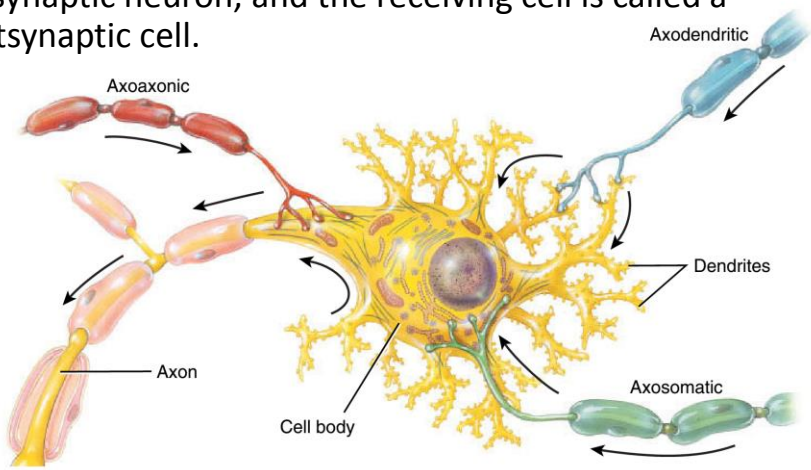
Step 2 During an action potential, sodium channels open, allowing sodium ions to move into the axon.





Communication Between Neurons

- A synapse is a junction at which signals are transmitted between a neuron and another cell.
- At a synapse, the transmitting neuron is called a presynaptic neuron, and the receiving cell is called a postsynaptic cell.



Communication Between Neurons, *continued*

- A junction at which a neuron meets another cell is called a **synapse.**
- When a nerve impulse arrives at an axon terminal of a presynaptic neuron, the impulse cannot cross the synaptic cleft.
- Instead, the impulse triggers the release of signal molecules called **neurotransmitters** into the synaptic cleft.

Communication Between Neurons, *continued*

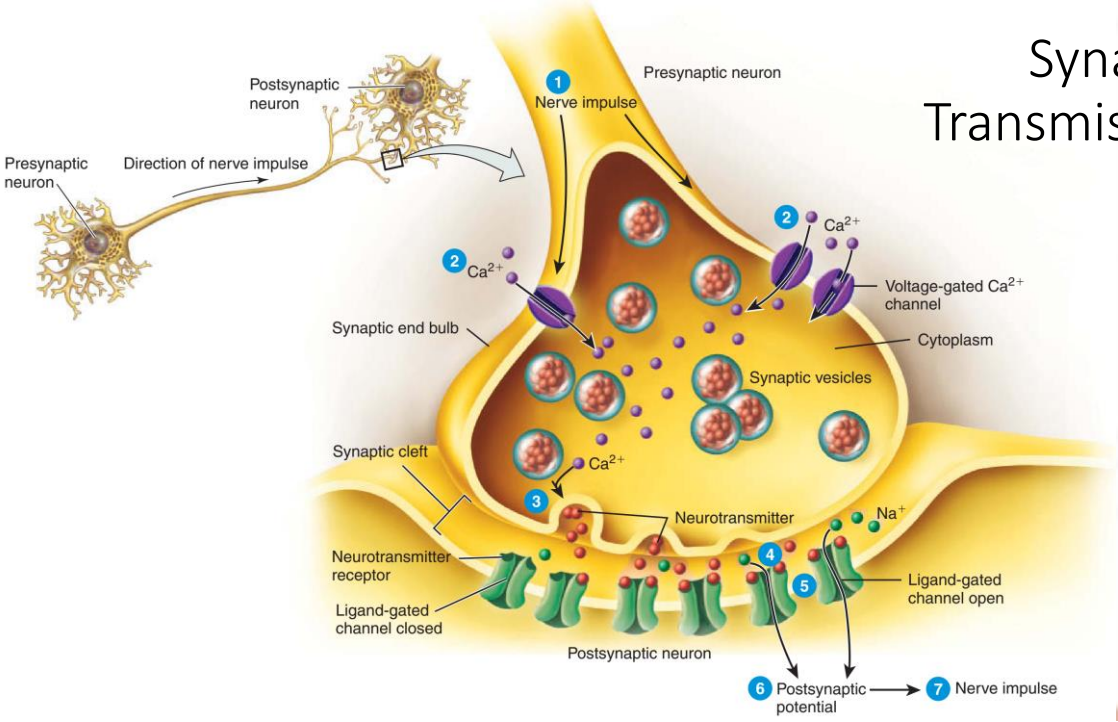
Release of Neurotransmitter

- A nerve impulse causes a presynaptic neuron to release neurotransmitter molecules into the synaptic cleft.
- When an action potential reaches an axon terminal of the presynaptic neuron, vesicles that contain neurotransmitter molecules fuse with the cell membrane.
- This releases neurotransmitter molecules into the synaptic cleft by exocytosis.

Some Neurotransmitters

Acetylcholine
Amino Acids
Biogenic Amines
Norepinephrine
Epinephrine
Dopamine
Serotonin
Purines
Nitric Oxide
Carbon Monoxide
Neuropeptides
Endorphins

Synaptic Transmission



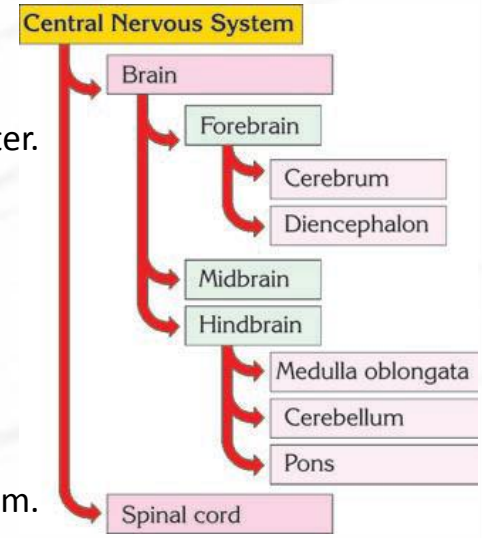
Central Nervous System

- Neurons are the most important cells of the nervous system. The functions of the nervous system depend on the complex interaction between billions of neurons.
- There are two main divisions of the nervous system—the central nervous system and the peripheral nervous system.
- The **central nervous system** (CNS) consists of the brain and the spinal cord. The CNS is the control center of the body.

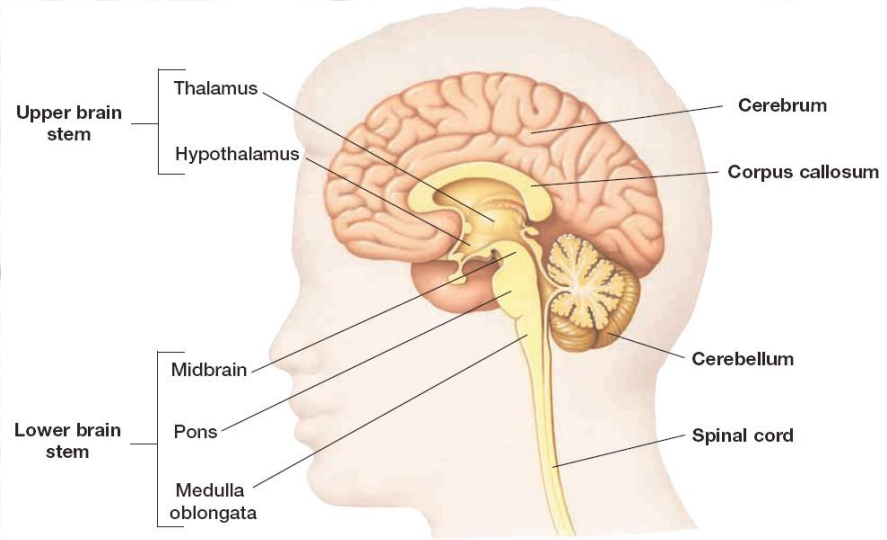
Central Nervous System, *continued*

Brain

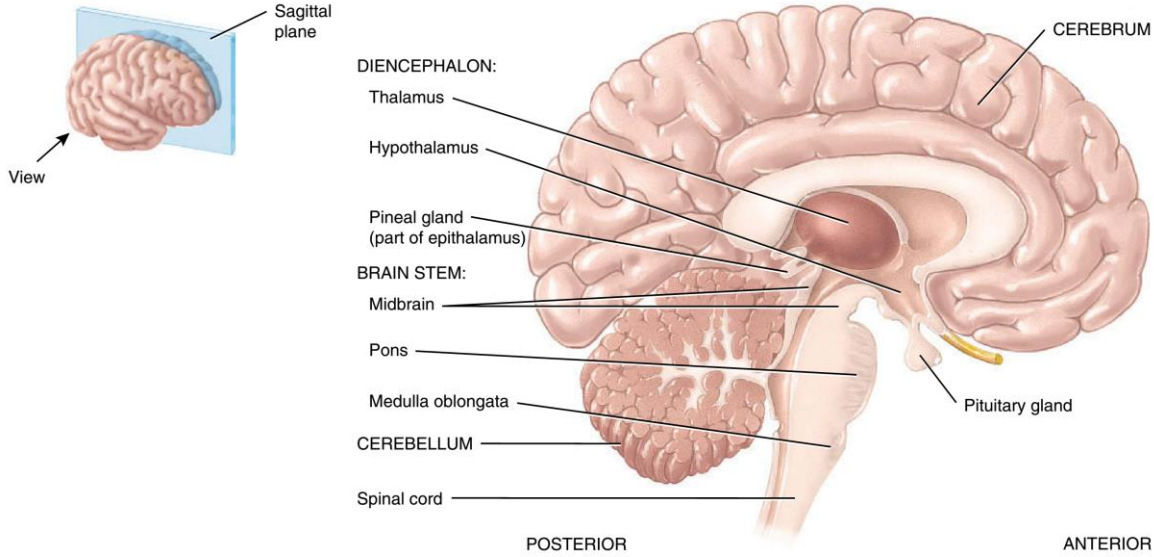
- The **brain** is the body's main processing center. Encased entirely within the skull, the brain contains about 100 billion neurons.
- Thoughts, feelings, emotions, behavior, perception, and memories are controlled by your brain.
- The brain consists of three major parts—the cerebrum, the cerebellum, and the brain stem.



Structure of the Human Brain

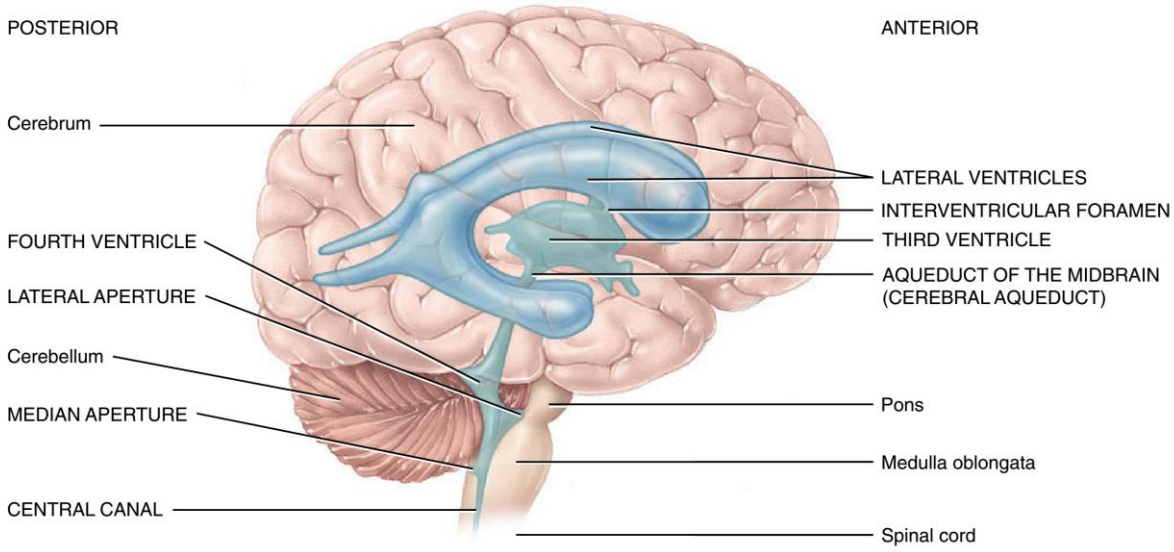


The four principal parts of the brain are the brain stem, cerebellum, diencephalon, and cerebrum.



(a) Sagittal section, medial view

Ventricles are cavities within the brain that are filled with cerebrospinal fluid.



Right lateral view of brain

Central Nervous System, *continued*

Brain: Cerebrum

- The **cerebrum** is the largest part of the brain.
- The capacity for learning, memory, perception, and intellectual function resides in the cerebrum.
- The cerebrum has a folded outer layer with many bumps and grooves. A long, deep groove down the center divides the cerebrum into right and left halves, or hemispheres.

Central Nervous System, *continued*

Brain: Brain Stem

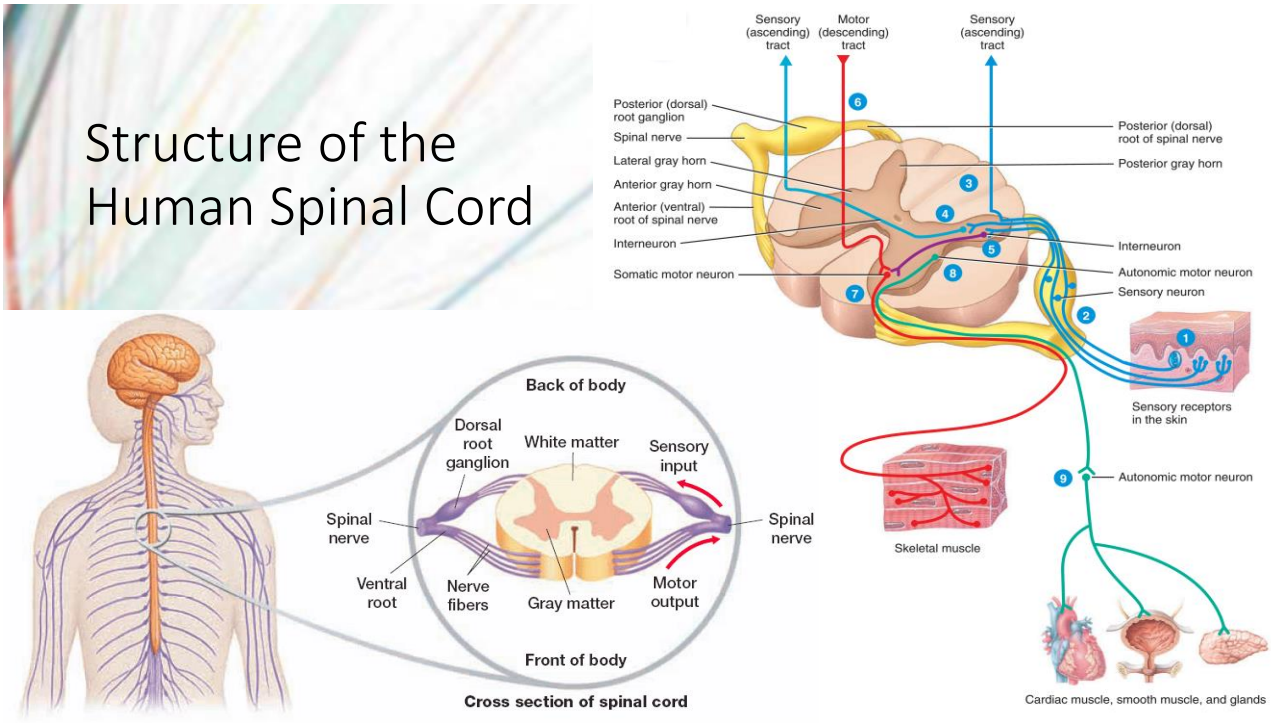
- At the base of the brain is the stalklike **brain stem.**
- The upper brain stem contains important relay centers that direct information to and from different parts of the brain. The **thalamus** is a critical site for sensory processing.
- The **hypothalamus,** along with the **medulla oblongata**, helps regulate many vital homeostatic functions, such as breathing and heart rate.

Central Nervous System, *continued*

Spinal Cord

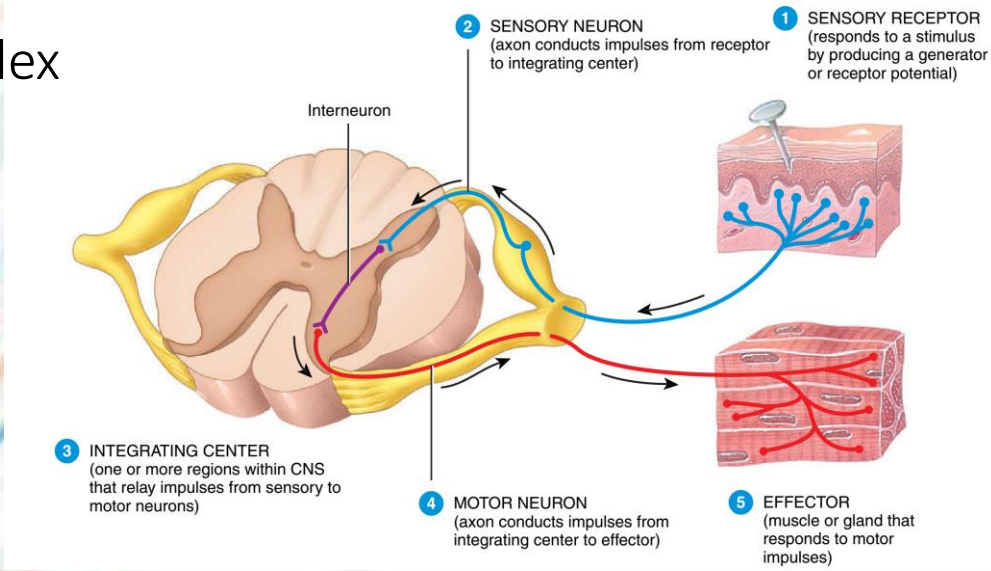
- The **spinal cord,** is a dense cable of nervous tissue that runs through the vertebral column.
- In addition to relaying messages, the spinal cord functions in reflexes. A **reflex** is a sudden, involuntary contraction of muscles in response to a stimulus.
- The spinal cord contains a core of gray matter covered by a white matter. Included in the gray matter are **interneurons** that link neurons together.

Structure of the Human Spinal Cord



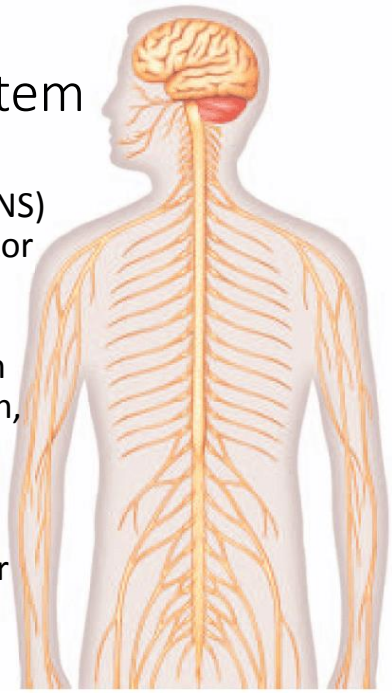
Reflex

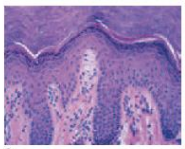
A reflex is a fast, predictable sequence of involuntary actions that occur in response to certain changes in the environment.

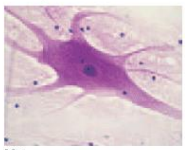


Peripheral Nervous System

- The **peripheral nervous system** (PNS) contains sensory neurons and motor neurons.
- **Sensory neurons** send information from sense organs, such as the skin, to the CNS.
- **Motor neurons** send commands from the CNS to muscles and other organs.




Sensory neuron


Motor neuron

The peripheral nervous system has two main types of neurons: sensory neurons and motor neurons. Sensory neurons send messages to the brain; motor neurons deliver messages to muscles and glands.

Peripheral Nervous System

- The peripheral nervous system connects the brain and the spinal cord to the rest of the body.
- In addition to the 31 pairs of spinal nerves, 12 pairs of cranial nerves connect the brain with areas in the head and neck.
- The PNS contains two principal divisions—the sensory division and the motor division.

Peripheral Nervous System, *continued*

Somatic Nervous System

- Most motor neurons that stimulate skeletal muscles are under our conscious control. These neurons are part of the somatic nervous system.
- Some activity in the somatic nervous system, such as spinal reflexes, is involuntary. A spinal reflex is a self-protective motor response.
- Spinal reflexes are extremely rapid because they usually involve the spinal cord but do not involve the brain.

Peripheral Nervous System, *continued*

Autonomic Nervous System

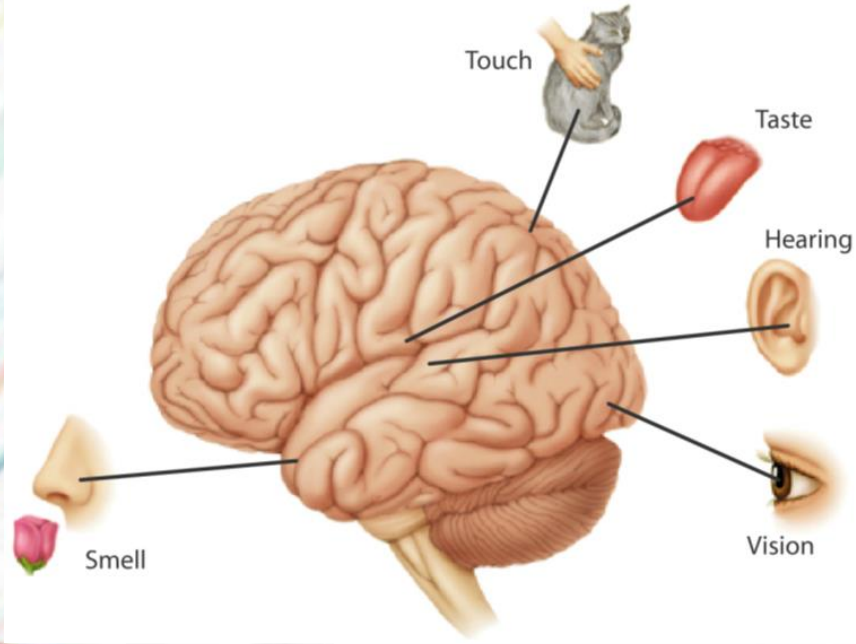
- Peripheral motor neurons that regulate smooth muscles do not require our conscious control. These neurons are part of the autonomic nervous system, which regulates heart rate and blood flow by controlling contractions of cardiac muscle in the heart and smooth muscle lining the walls of blood vessels.
- Two divisions of the autonomic nervous system—the parasympathetic division and the sympathetic division—maintain stability in the body by counterbalancing each other's effects.

Physiological Effects of the Autonomic Nervous System

Organ	Effect of sympathetic division	Effect of parasympathetic division
Eyes	Pupils dilate	Pupils constrict
Heart	Heart rate increases	Heart rate decreases
Lungs	Bronchioles dilate	Bronchioles constrict
Intestines	Gastric secretions decrease	Gastric secretions increase
Blood vessels	Blood vessels dilate	Little or none

Perception of Stimuli

- The perception of everything you respond to in the environment is made possible by sensory systems.
- Specialized neurons called **sensory receptors** detect sensory stimuli and then convert the stimuli to electrical signals, in the form of nerve impulses, that can be interpreted by the brain.
- Although sensory receptors are located throughout the body, they are most concentrated in the sense organs—the eyes, ears, nose, mouth, and skin.



Types of Sensory Receptors

Receptor type	Stimuli	Locations
Thermoreceptors	Temperature change	Skin, hypothalamus
Pain receptors	Tissue damage	All tissues and organs except the brain
Mechanoreceptors	Movement, pressure, tension	Skin, ears, muscles
Photoreceptors	Light	Eyes
Chemoreceptors	Chemical	Tongue, nose

Perception of Stimuli, *continued*

Sensory Receptors

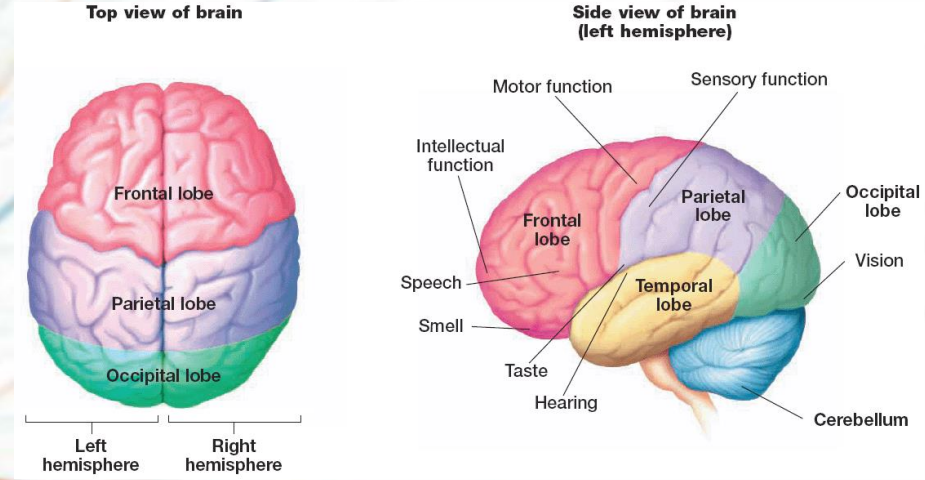
- Mechanoreceptors throughout the body respond to physical stimuli—such as pressure and tension—that cause distortion or bending of tissue.
- Thermoreceptors, located in the skin and hypothalamus, detect changes in temperature.
- Sensory receptors are located throughout the body, and sensory input from these receptors enters the central nervous system in an organized fashion.

Perception of Stimuli, *continued*

Processing of Sensory Information

- Many of the neurons in the cerebral cortex are responsible for processing incoming sensory information from the sense organs.
- The thalamus relays information from the sense organs to certain regions of the cerebral cortex.
- Sensory neurons from the different sense organs come together at certain regions in the cerebral cortex.

Processing Sites and Lobes of the Cerebral Cortex




QUESTIONS?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