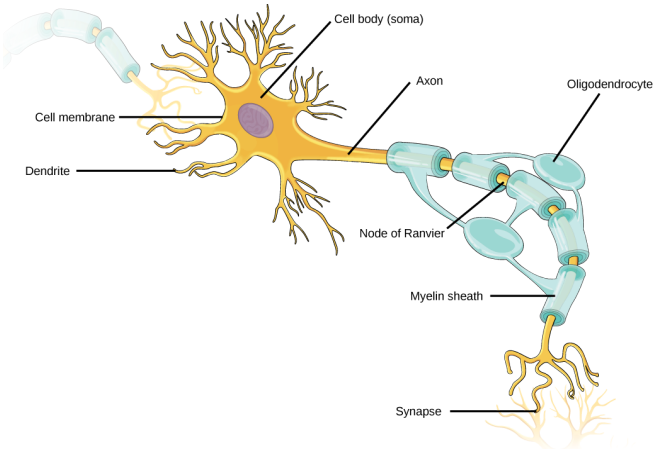
Chapter 8: The Nervous System

Objectives

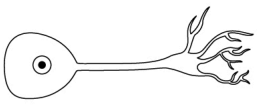
1. Define nerve, neuron, neuroglia, cephalization, ganglia, nerve cord, graded potential, trigger zone, threshold, action potential, synapse, synaptic cleft, neuromuscular junction, refractory period, neurotransmitter, reflex, blood-brain barrier, amyloid plaque
2. Describe a nerve net and name the organisms that use one
3. Name and describe the three types of neurons
4. Name and describe the divisions of the vertebrate nervous system
5. Name and describe the sections of a neuron
6. Identify a neuron as a sensory, inter, or motor neuron from a picture
7. Describe resting potential conditions
8. Describe the steps of signal sending
9. Describe the steps of signal receiving
10. Explain what happens when a cell receives signals from two different neurons
11. Name and describe the 6 main neurotransmitters
12. Name and describe diseases associated with improper neuron function
13. Name and describe the types of psychoactive drugs
14. Describe the structure of the spinal cord
15. Describe the steps of the patellar reflex
16. Name the three parts of the human brain once it is fully developed
17. Name and describe functions and subparts of the brainstem, cerebellum, and cerebrum
18. Name and describe the neuroglia of the CNS and PNS
19. Name and describe diseases associated with improper neuroglial function

Neurons and Glial Cells

- 8.1 Introduction
  - Sponges lack nervous systems
  - Nerve Net - a system of separate but connected nerve cells; exists in jellyfish
  - Nerves - nerve cells arranged in bundled fibers; exists in echinoderms
  - Platyhelminthes
    - Central Nervous System (CNS) - made up of a small "brain" and two nerve cords
    - Peripheral Nervous System (PNS) - a system of nerves that extend throughout the body
  - Insect Nervous System - contains a brain, ventral nerve cord, and ganglia
    - Ganglia - clusters of connected neurons
  - Invertebrate vs. Vertebrate
    - Vertebrate systems are more complex, centralized, and specialized
    - Vertebrates share a basic structure: a CNS that contains a brain and spinal cord and a PNS made up of peripheral sensory and motor nerves
    - Vertebrae are unique in that the nerve cords of many invertebrates are located ventrally whereas the vertebrate spinal cords are located dorsally
  - Neurons - specialized cells that can receive and transmit chemical or electrical signals
  - Glial Cells - cells that provide support functions for the neurons by playing an information processing role that is complementary to neurons
    - Recent evidence suggests glia may also usurp some of the neural signaling functions
- 8.1a: Neurons
  - Parts of a Neuron
    - Soma/Cell Body - contains a nucleus, smooth endoplasmic reticulum (SER), and rough endoplasmic reticulum (RER)
    - Dendrites - tree-like structures extending from the cell body to receive messages from other neurons
      - Dendritic Spines - small protrusions that increase surface area for synaptic connections
    - Synapses - specialized junctions that receive messages
    - Axon Hillock - receives and integrates signals from multiple synapses and serves as a junction between the cell body an an axon
    - Axon - tube like extension of the cell that propagates the integrated signal to axon terminals
    - Axon Terminals - specialized endings that synapse on other neurons, muscle, or target organs
      - Chemicals released on axon terminals allow signals to be communicated to other cells



  - Types of Neurons
    - Functional nature is dependent on structure



Unipolar neuron

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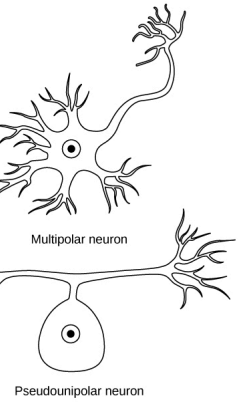
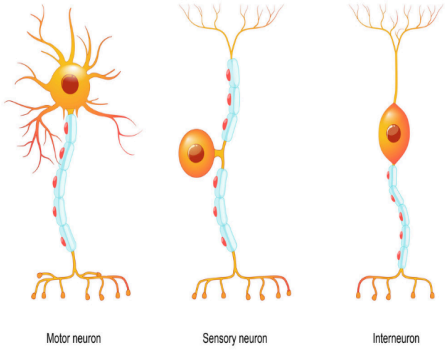
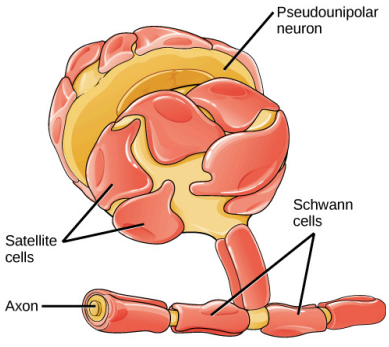
- There are 3 main categories of neuron cells based on **function**: sensory, interneurons, and motor neurons
  - Sensory Neurons - detect changes in the PNS and relay information to the CNS
  - Interneurons - relay information between different parts of the CNS
  - Motor Neurons - relay information from the CNS to the PNS
- There are 3 main categories of neuron cells based on **shape**: unipolar, bipolar, multipolar, and pseudounipolar
  - Unipolar - have only one structure that extends away from the soma; not found in vertebrates but in insects where they stimulate muscles or glands
  - Bipolar - has one axon and one dendrite extending from the soma
  - Multipolar - contains one axon and multiple dendrites; can be found in the central nervous system (brain and spinal cord)
    - Most common type of neuron
  - Pseudounipolar - has a single process that extends from the soma, like a unipolar cell, but this process later branches into two distinct structures, like a bipolar cell
    - Share characteristics with both unipolar and bipolar cells
      - Most sensory neurons are pseudounipolar and have an axon that branches into two extensions: one connected to dendrites that receive sensory information and another that transmits this information to the spinal cord

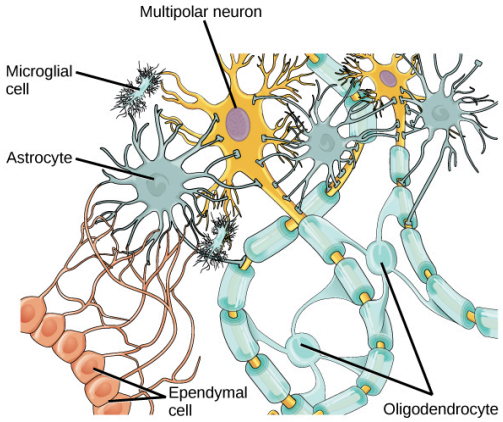




➢ 8.1b: Glia
- Glial cells outnumber neurons nearly 10:1
- Vital to neuron function
- Glia guide developing neurons to their destinations, buffer ions and chemicals that would otherwise harm neurons, and provide myelin sheaths around axons
  - Recently discovered that they play a role in responding to nerve activity and modulating communication between nerve cells
- Types of Glia
  - CNS has 4 major types: astrocytes, microglia, oligendrocytes, and ependymal cells
    - Astrocytes - make contact with both capillaries and neurons in the CNS; provide nutrients and other substances to neurons, regulate the concentrations of ions and chemicals in the extracellular fluid, provide structural support for synapses, and form the blood-brain barrier
      - Blood-Brain Barrier - a structure that blocks entrance of toxic substances into the brain
      - Become active in response to nerve activity, transmit calcium waves between astrocytes, and modulate the activity of surrounding synapses
    - Microglia - scavenge and degrade dead cells and protect the brain from invading microorganisms
    - Oligendrocytes - form sheaths around axons in the CNS to increase the speed of the signal
    - Ependymal Cells - line fluid-filled ventricles of the brain and the central canal of the spinal cord
      - Involved in the production of cerebrospinal fluid, which serves as a cushion for the brain, moves the fluid between the spinal cord and the brain
  - PNS has a single major type: Schwann cells
    - Schwann Cells - speed up signal transmission



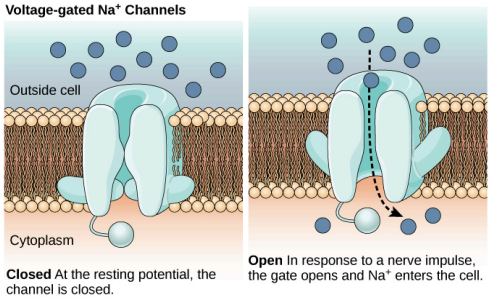
(b) Peripheral nervous system



(a) Central nervous system

How Neurons Communicate

➢ 8.2a: Nerve Impulse Transmission within a Neuron
- Signal exchange is made possible by the charged cellular membrane of each neuron
  - Charged Cellular Neuron - a voltage difference between the inside and the outside

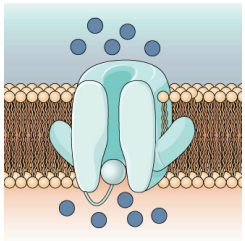


Closed At the resting potential, the channel is closed.

Open In response to a nerve impulse, the gate opens and Na^+ enters the cell.

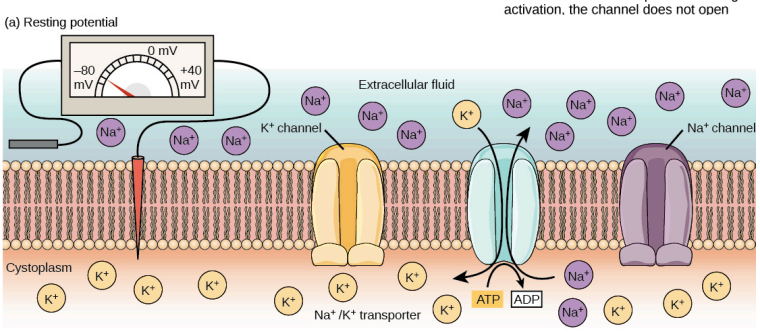
- The charge of this membrane can change in response to neurotransmitter molecules released from other neurons and environmental stimuli

- Neuronal Charged Membranes
  - The lipid bilayer membrane of a neuron does not allow charged particles to pass
  - Ion Channels - special proteins that span the membrane and allow ions to enter or exit the neuron
    - Have 3 configurations: open, closed, and inactive (needs to be activated in order to open and allow passage)
    - Voltage-Gated Ion Channels - ion channels that change their structure in response to voltage changes; regulate the relative concentrations of different ions inside and outside the cell
  - Membrane Potential - the difference in total charge between the inside and outside of the cell



Inactivated For a brief period following activation, the channel does not open

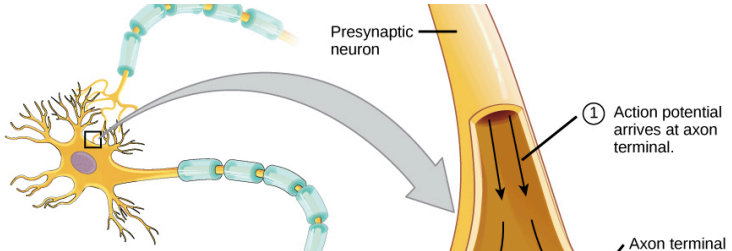
- Resting Membrane Potential
  - A neuron at rest has a negative charge compared to the surrounding area
  - Because ions cannot simply cross the membrane at will, there are different concentrations of several ions inside and outside the cell



At the resting potential, all voltage-gated Na^+ channels and most voltage-gated K^+ channels are closed. The Na^+/K^+ transporter pumps K^+ ions into the cell and Na^+ ions out.

- Action Potential - the transition from *55 mV to +40 mV
  - Neurons can receive input from other neurons
  - If the input is strong enough, the signal can be sent to downstream neurons
  - Transmission of signals between neurons is typically done by a chemical called a neurotransmitter
  - Signal transmission from dendrite to axon terminal (within the same neuron) is carried by a brief reversal of the resting membrane potential
    - When certain molecules bind to receptors located on a neuron's dendrites, ion channels open, allowing Na^+ ions to enter the neuron
    - The initial inflow of Na^+ is called graded potential
  - With enough Na^+, the neuron reaches its threshold potential
  - In response, the Na^+ channels in the axon hillock open, allowing even more Na^+ into the cell
  - All of the Na^+ ions entering the cell bring the neuron to a membrane potential of about +40 mV
  - An action potential occurs
  - Once the action potential is complete, the cell must now "reset" its membrane voltage back to the resting potential
    - Na^+ channels close and can't be reopened which marks the beginning of the neuron's refractory period (it can't produce another action potential because of it's Na^+ channels)
    - Voltage-gated K^+ channels open, allowing K^+ to leave the cell, causing the membrane potential to become negative again
    - Proteins swab K^+ from the outside to the inside by exchanging the K+ for Na+ ions
      - Na^+ leaves as K^+ enters, thereby returning the cell to resting potential
  - This process of generating an action potential and returning to resting potential happens down the length of a neuron
    - How signals are sent from one body location to another

➢ 8.2b: Synaptic Transmission
- Synapse - "gap"; the place where information is transmitted from one neuron to another; usually form between axon terminals and dendritic spines
- Chemical Synapse
  - When an action potential reaches the axon terminal it triggers Ca^{2+} channels to open
  - Ca^{2+} enter the cell and initiate small membrane-bound vesicles, called synaptic vesicles
    - Synaptic vesicles contain neurotransmitter molecules to be released from the cell
  - The neurotransmitter is released into the synaptic cleft—the extracellular space between the neuron and some second cell
  - The neurotransmitter diffuses across the synaptic cleft and binds to receptor proteins on the second cell's membrane



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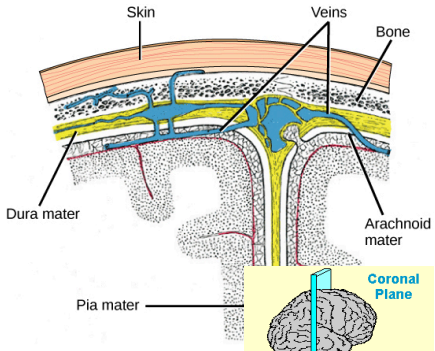
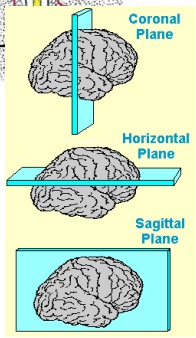
Chapter 8: The Nervous System

The Central Nervous System

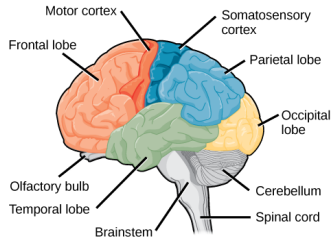
- 8.3 Introduction
  - CNS is made of the brain and spinal cord; covered with 3 layers of protective coverings called meninges
  - Brain floats in cerebrospinal fluid (CSF) that acts as a cushion, shock absorber, makes the brain neutrally buoyant, and circulates chemicals throughout the brain and to the spinal cord
  - Entire brain only contains ~8.5 TBSPs of CSF, but CSF is constantly being produced in the ventricles
    - Hydrocephalus/"Water Head" - condition in which a CSF-producing ventricle is blocked, and the brain is pushed against the skull, causing seizures, cognitive problems, and death is a shunt is not inserted



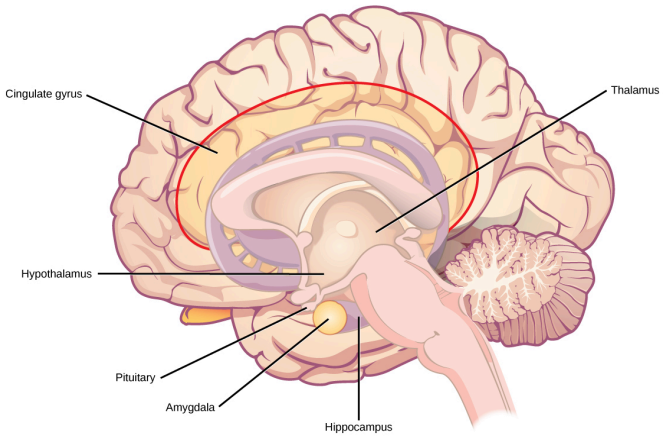
- 8.3a: Brain - part of the central nervous system, contained in the cranial activity of the skull; includes the cerebrum, cerebellum, and brainstem
  - Sectioning the Brain
    - Coronal Section - cuts the brain front to back
    - Horizontal Section - cuts the brian top to bottom
    - Sagittal Section - cuts the brain left to right



- 8.3a.1: Cerebrum - composed of the cerebral cortex, limbic system, basal ganglia, thalamus, hypothalamus
  - Cerebral Cortex - outermost part of the brain; thick slab of nervous system tissue
    - Folded into hills/gyri and valleys/sulci
    - Made of 2 hemispheres, divided by a large sulcus
  - Corpus Callosum - thick fiber bundle that connects the two hemispheres and allows information to be passed from one side to the other
    - Most functions are redundant in both hemispheres, though there are some localized functions
  - Lobes - regions in each cortical hemisphere that are involved in different functions
    - Frontal Lobe - located over the front of the bain, over the eyes; controls important cognitive skills
      - Olfactory Bulb - processes smells
      - Motor Cortex - important for planning and implementing movement
      - Control cognitive functions like maintaining attention, speech, and decision-making
    - Parietal Lobe - located at the top of the bain; involved in speech/reading, touch, and spatial orientation
      - Somatosensation - touch sensations like pressure, temperature, and pain
      - Proprioception - how the body is oriented
    - Occipital Lobe - located in the back of the brain; involved in seeing, recognizing, and identifying the visual input
    - Temporal Lobe - located at the base of the brain by the ears; primarily involved in processing and interpreting sounds
      - Hippocampus - processes memory formation



  - Basal Ganglia/Basal Nuclei - interconnected brain areas; involved in movement, posture, and motivation
  - Thalamus - acts as a gateway to and from the cortex; receives sensory and motor inputs from the body and also receives feedback from the cortex
    - Helps regulate consciousness, arousal, and sleep states
    - Feedback mechanism can modulate conscious awareness of sensory and motor inputs depending on the attention and arousal state of the organism
  - Hypothalamus - controls the endocrine system by sending signals to the pituitary gland
    - Pituitary Gland - a pea-sized endocrine gland that releases several different hormones that affect other glands as well as other cells
    - Because of this, the hypothalamus is able to regulate behaviors related to hormones
    - The body's thermostat—ensures 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



- Limbic System - connected set of structures that regulates emotion, behaviors related to fear and motivation, and memory formation; includes parts of the thalamus, hypothalamus, hippocampus, and amygdala
  - Amygdala - important for the sensation of fear and for recognizing fearful faces

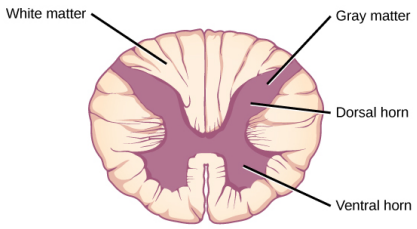
➢ 8.3a.2: Cerebellum - sits at the base of the brain on top of the brainstem; controls balance and aids in coordinating movement and learning new motor tasks

➢ 8.3a.3: Brainstem - connects the rest of the brain with the spinal cord and controls many involuntary responses; 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 here to allow the cerebrum's left hemisphere to control the right side of the body and vice versa
- 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

➢ 8.3b: Spinal Cord - connects to the brainstem and extends down the body, through the spinal column; thick bundle of nerve tissue that carries information about the body to the brain and from the brain to the body

- Contained within the bones of the vertebral column but is able to communicate signals to and from the body through its connections with spinal nerves (part of the PNS)
- Controls motor reflexes
  - Quick, unconscious movements because they involve local synaptic connections
- Spinal Cord Cross-Section
  - "White Matter" - made of myelinated axons
  - "Gray Matter" - made of neurons, glial cells, and interneurons that connect two neruons from different parts of the body

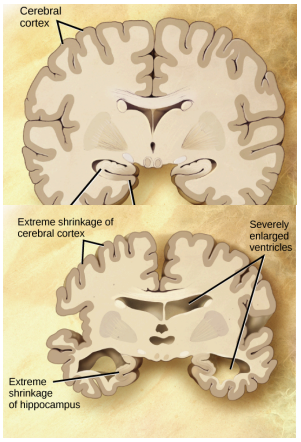


- Axons and cell bodies in the **dorsal** (facing the back of the animal) spinal cord convey mostly sensory information from the body to the brain
- Axons and cell bodies in the **ventral** (facing the front of the animal) spinal cord primarily transmit signals controlling movement from the brain to the body

Nervous System Disorders

➢ 8.4a: Neurodegenerative Disorders - illnesses characterized by a loss of nervous system functioning that are usually caused by neuronal death

- Alzheimer's Disease -
  - Most common cause of dementia
  - Symptoms
    - Memory loss
    - Confusion
    - Difficulty planning
    - Difficulty executing tasks
    - Poor judgement
    - Personality changes
  - Early Onset Alzheimer's
    - Caused by mutations in ⅓ known genes
  - Late Onset Alzheimer's
    - One particular gene, apolipoprotein E (APOE) has a variant (E4) that increases a carrier's likelihood of getting the disease
  - Treatment
    - No cure
    - Current treatments focus on managing the symptoms of the disease
    - Because decrease in the activity of cholinergic neurons (neurons that use the neurotransmitter acetylcholine) is common in Alzheimer's disease, several drugs used to treat the disease work by increasing acetylcholine neurotransmission, often by inhibiting the enzyme that breaks down acetylcholine in the synaptic cleft
    - Also treated with behavioral therapy



- Parkinson's Disease - causes the loss of dopamine neurons in the substantia nigra, a midbrain structure that regulates movement
  - Symptoms
    - Shaking limbs
    - Slowed movement
    - Changes in speech
    - Balance and posture issues
    - Rigid muscles
    - Hunched walk
  - Although some patients have a form of the disease known to be caused by a single mutation, for most patients the exact causes of Parkinson's disease remain unknown

- Treatment
  - No cure
  - Current treatments focus on managing the symptoms of the disease

➢ 8.4b: Neurodevelopmental Disorders - occur when the development of the nervous system is disturbed

- Autism Spectrum Disorder (ASD)
  - Characteristics and symptoms vary wildly
  - More prevalent in males than females
  - Treatment
    - Behavioral therapy
    - Interventions
    - Medications
- Attention Deficit Hyperactivity Disorder (ADHD) -
  - More prevalent in males than females
  - Symptoms
    - Lack of focus
    - Impulsivity
    - Hyperactivity
    - Executive function issues
- Mental Illness - nervous system disorders that result in problems with thinking, mood, or relating with other people
- Schizophrenia
  - Symptoms
    - Visual and auditory hallucinations
    - Delusions
    - Inappropriate and unregulated emotional responses
  - Treatment
    - No cure
    - Antipsychotic medications
- Major Depression - experienced a severely depressed mood lasting longer than two weeks along with other symptoms including a loss of enjoyment in activities that were previously enjoyed, changes in appetite and sleep schedules, difficulty concentrating, feelings of worthlessness, and suicidal thoughts
  - Causes are unknown
  - Treatment
    - Behavioral therapy
    - Antidepressants

➢ 8.4c: Other Neurological Disorders

- Epilepsy - characterized by recurrent seizures
  - Can be a symptom of another issue
  - Treatment
    - Anticonvulsant medications
    - Brain surgery
- Stroke - results when blood fails to reach a portion of the brain for a long enough time to cause damage
  - Treatments
    - Blood pressure medication
    - Physical therapy