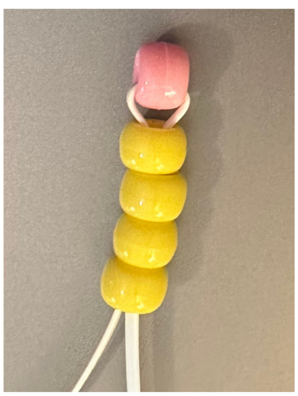
Adapted from: © 2000-2008, BrainU, University of Minnesota Department of Neuroscience in collaboration with the Science Museum of Minnesota. SEPA (Science Education Partnership Award) Supported by the National Center for Research Resources, a part of the National Institutes of Health.

Student Name: ____________________ **Date:** ______________

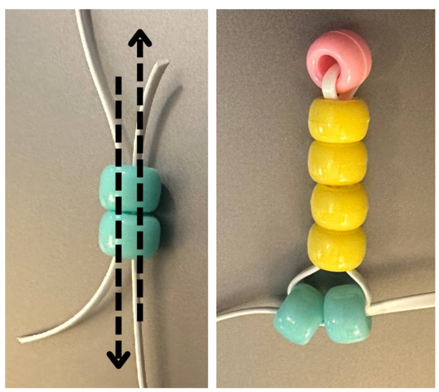
Bead Neuron: The ziplock should contain the correct number of beads for each of the parts of the neuron (see table below). Be sure you have the correct amount of beads for each part of the neuron, and record the color of the bead for each in the blank. To make the beaded neuron, string the beads using the directions and pattern in the diagrams below.

Dendrites = 20 ___________ beads	**Axon** = 7 ___________ beads
Cell Body = 6 ___________ beads	**Synaptic Terminal** = 2 ___________ beads
Nucleus = 1 ___________ bead	**Tip of Dendrite** = 5 ___________ beads

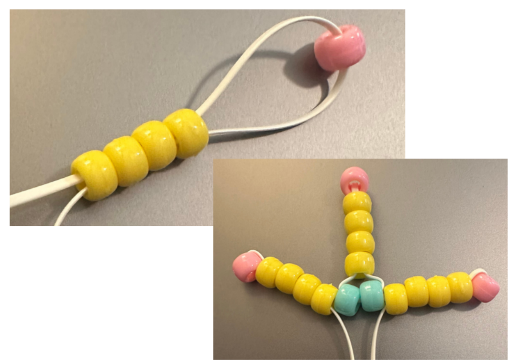
Step 1: Put one of the tip of the dendrite beads through the string and center in the middle. Take 4 dendrite beads and put both ends of the string through.



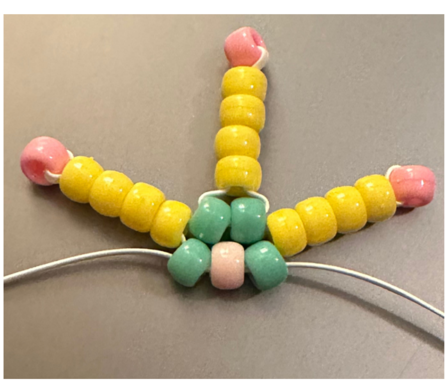
Step 2: Add 2 cell body beads and cross the string through both of the beads. Pull the string to adjust the beads toward the center of the neuron.



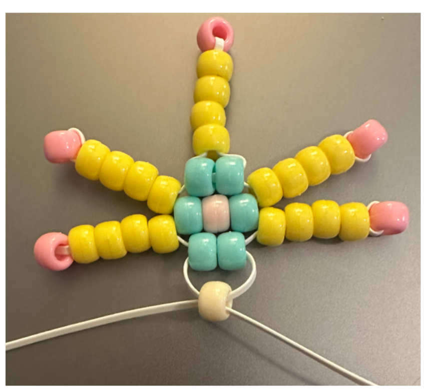
Step 3: String 4 dendrite beads followed by one tip of dendrite bead on one of the strings from the side. Take the end of the string and thread it back through just the 4 dendrite beads. Repeat with the string on the other side.



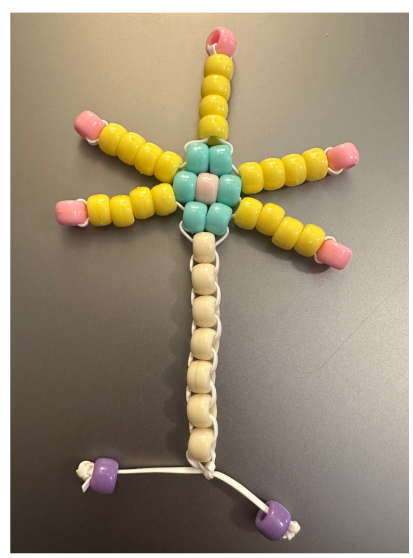
Step 4: Repeat the process in *step 2,* stringing the beads in order: one cell body bead, the nucleus, followed by another cell body bead. Cross the strings through all 3 beads and pull the string to position the beads.



Step 5: Repeat the process in *step 3,* adding one more dendrite on each side for a total of 5 dendrites. Cross the strings through one axon bead. Repeat 6 more times and tie a knot.



Step 6: Add the two synaptic terminal beads, one to each string. Tie a knot to secure the bead.

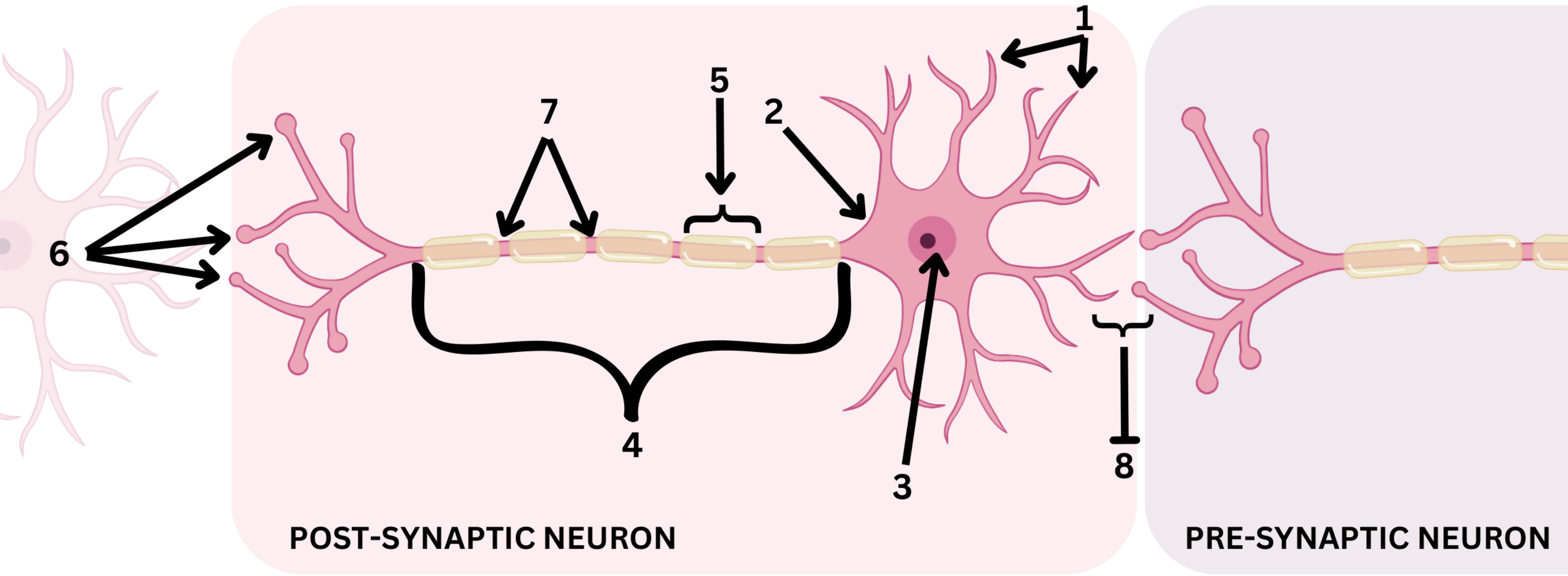


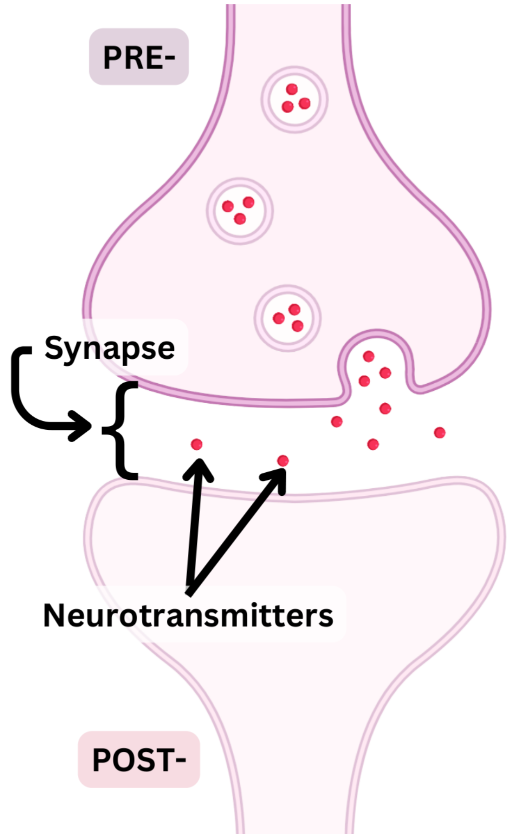
Iowa Neuropathology Resource Laboratory

NEURONS: STRUCTURES

Neurons are one type of cell within the brain, and there are on average 86 billions neurons in the primate (or human) brain. In order to communicate with one another, the neurons release chemicals called neurotransmitters that other neurons can recognize as signals for different actions. There are many different types of neurotransmitters, and each allows the neuron to communicate a different message, such as when to start or stop an action. Refer to the labeled neuron below, to learn the different structures of the neuron as well as read about the different types of neurons, and their different forms.

1.) Dendrites	3.) Nucleus	5.) Myelin Sheath	7.) Nodes of Ranvier
2.) Cell Body	4.) Axon	6.) Axon Terminal	8.) Synapse





The flow of the electrical signal or **action potential** travels from the **pre-synaptic** ("sending signal") **neuron** to the **post-synaptic** ("receiving signal") **neuron**.

Neurotransmitters are the molecular component of communication from the pre-synpatic neuron to the post-synpatic neuron. Examples of neurotransmitters include: Acetylcholine (Ach), Dopamine (DA), Serotonin (5HT), etc.

Neurotransmitter molecules transverse the extracellular space between the pre-synaptic neuron and post-synaptic neuron, called the **synapse**, and bind to receptors on the neighboring cell (onto **dendritic spines** - tiny projections on **dendrites**).

The signal is then generated and begins to travel down the neuron along the signal highway, called the **axon**. At the end of the of the axon are the **axon terminals** (synaptic terminals), where molecules/neurotransmitters are packaged into vesicles and exit the pre-synaptic neuron. They travel across the synapse, and enter the post-synaptic neuron. This is how signals are transmitted from neuron to neuron, and how the nervous system is able to communicate with itself.

Images from BioRender

STRUCTURES & FUNCTIONS

Dendrites

Dendrites are **branch-like** projections on neurons that **receive impulses** from the axon terminal of neighboring neurons. The dendrites are lined with the receptors called **dendritic spines**. Neurons can have hundreds of dendrites with varying numbers of spines, each having their own connection with other neurons. Dendrites are very malleable and can be subject to **growth/change** in connectivity as a function of learning and new experiences.

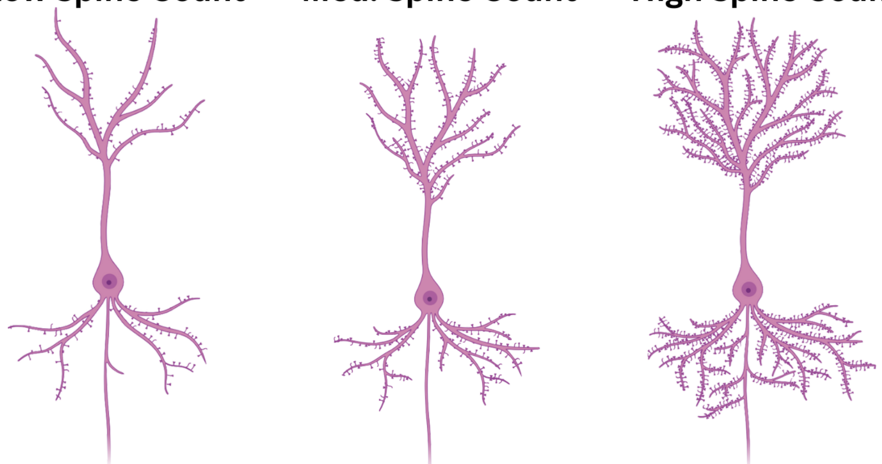
Cell Body & Nucleus

The cell body (otherwise known as the **soma**) contains many vital organelles, such as the **mitochondria** and the **nucleus**. The cell body helps **protect** the organelles inside from anything harmful in the extracellular (outside the cell) environment. The nucleus houses the nucleolus and contains **genetic information (chromosomes, ribosomes, RNA/DNA, etc.)**, which controls the neurons' activities. The cells' **protein production** is also guided and initiated by the nucleus.

Axon

Axons **carry electrical impulses**, also known as **action potentials**, which are the means of communication within the central and peripheral nervous system. The signal travels down the axon from the cell body to the axon terminal. Most neurons (typically) only have one axon. Axons can be **myelinated** which carry **FAST signals** from neuron to neuron, whereas **unmyelinated** axons conduct **SLOWER signals**.

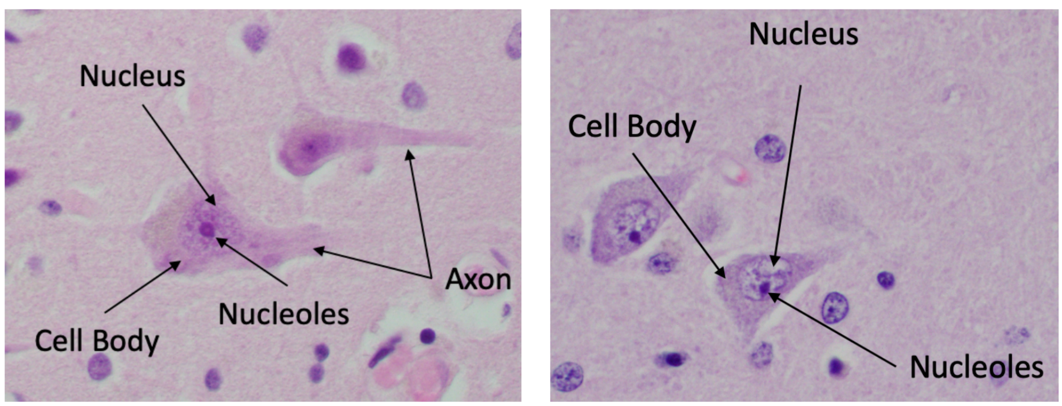
Low Spine Count | **Med. Spine Count** | **High Spine Count**



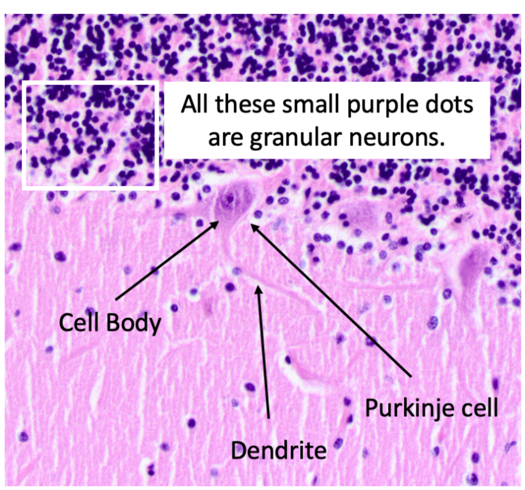
Low Dendritic Branching | **Med. Dendritic Branching** | **High Dendritic Branching**

Low Connectivity ⟶ **High Connectivity**

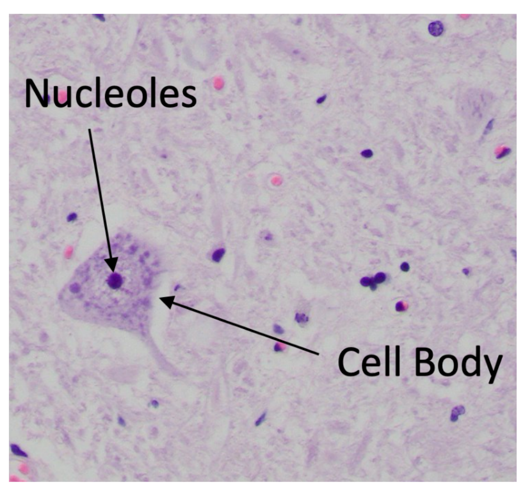
Cortical Neurons (Neurons Within Cortex)



Cerebellar Neurons (Purkinje Neuron) and Granular Cell Neurons



Motor Neurons (in Spinal Cord)



STRUCTURES & FUNCTIONS

Axon Terminal

Axon terminals are the site at which the **electrical impulses are converted into a chemical signal** (**neurotransmitter release**) from the pre-synaptic neuron. This happens through vesicles within the cell, which are packages of neurotransmitter that get released into the synapse. They travel to the post-synaptic/neighboring neuron, which generates a new signal that then spreads to the next neuron. This is how **communication between neurons** occurs.

Synapse

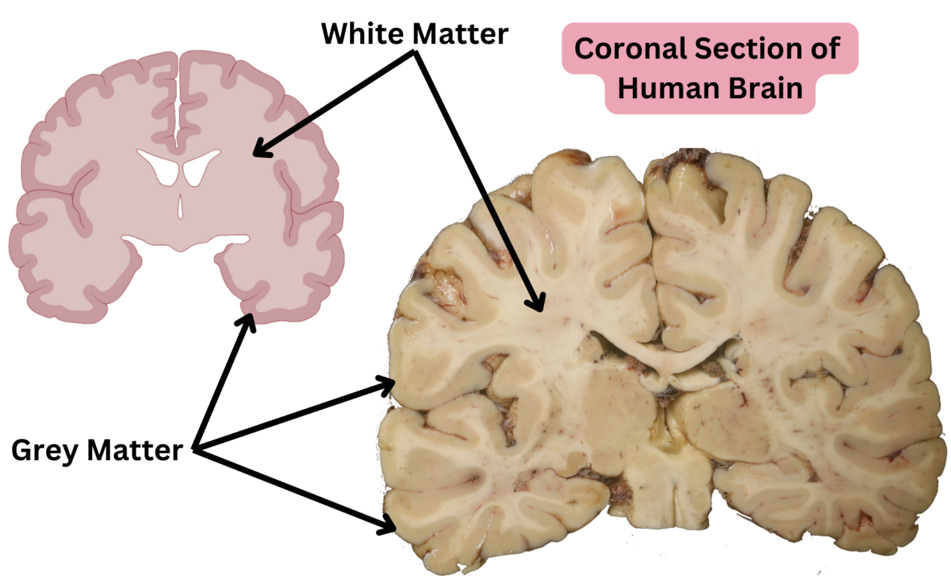
Also known as **synaptic cleft**, the synapse is the **extracellular space** between the pre-synaptic neuron and the post-sypnatic neuron where information is conveyed onto the dendrite of the neighboring neuron. Within the synaptic cleft are **proteins** that help with **diffusion** (getting things into and out of the cell membrane), **binding of neurotransmitters to receptors**, and **degradation** (or breakdown) of molecules.

Nodes of Ranvier

The nodes of Ranvier are **sections of unmyelinated axon** in **between sections of myelinated axon**. The ions responsible for regenerating the signal that travels down the axon are impermeable to the myelin sheath. At the nodes of Ranvier, there is a space between each myelin sheath which **allows for ions to pass through the membrane** into the axon to **regenerate the signal** so it can continue to transverse down the axon.

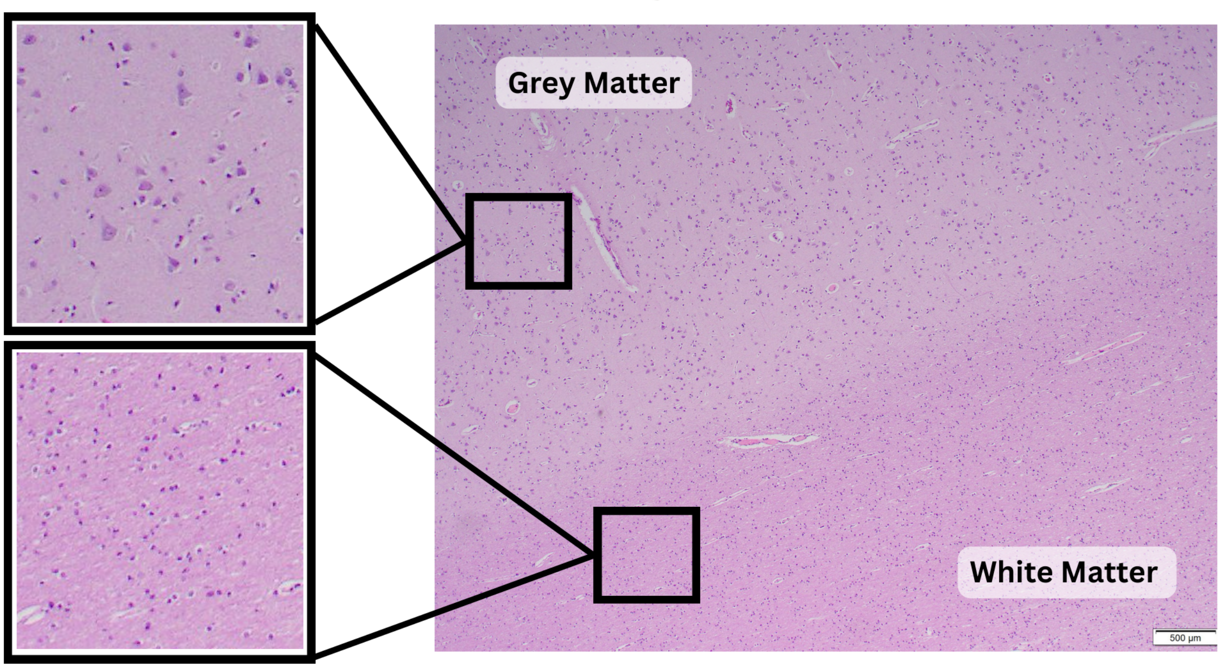
Myelin Sheath

Myelin sheaths are **insulating segments** on axons that allow electrical impulses to **travel quickly down the axon** to the next cell. Not all neurons have myelin, which results in slower signal conduction. **Damage** to myelin sheaths can **slow the neurons signal** impulse down as well. In the brain, **white matter** is made up of myelinated axons of the neurons, whereas the **grey matter** are cell bodies. This gives ***two distinct shades*** within the brain.



The **grey matter** (also called the cortex) is comprised of the **cell bodies** of the neurons, as well as other types of cells called glia.

The **white matter** is comprised of the **myelinated axons**. The small dots are glial cells called oligodendrocytes, which wrap myelin around the axon.



TYPES & FORMS OF NEURONS

Interneurons

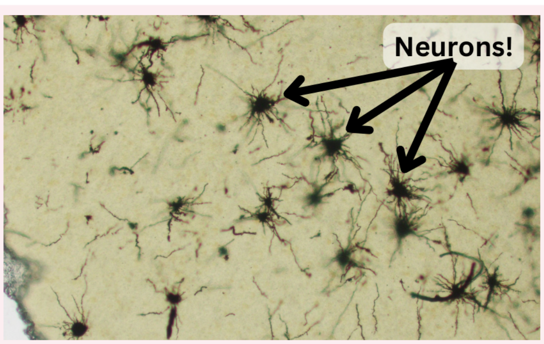
Cells that aid in the communication between sensory and motor neurons and carry both sensory information and aid in regulating motor activity. These neurons typically have relatively short axons and act as a relay for information.

Motor Neurons

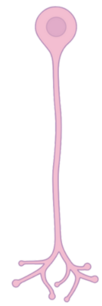
Motor neurons allow us to move, speak, swallow, and breathe. These cells transmit their signals from the central nervous system and innervate (control) muscles/organs in the peripheral nervous system for both involuntary and voluntary movements, etc.

Sensory Neurons

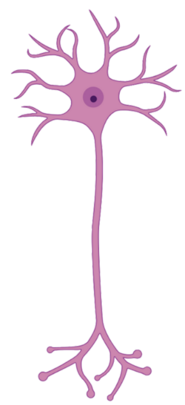
Sensory neurons are activated by sensory input from the environment. These cells transmit sensory signals from the peripheral nervous system to the central nervous system.



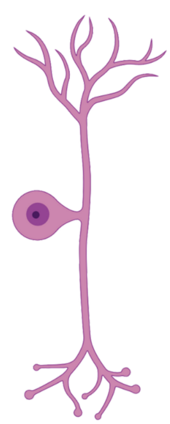
Golgi Staining is a silver staining method that is used to visualize **neurons**. This stain allows visualization of the the **entirety of the neuron**; the dendrites and their branching, the cell body, and the axon**.**



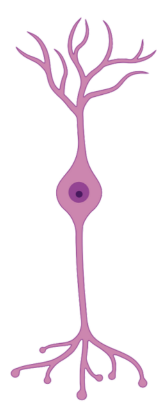
Unipolar Neuron



Multipolar Motor Neuron



Psuedounipolar Sensory Neuron



Bipolar Retinal Neuron

Unipolar

Unipolar neurons only have one projection extending out from the cell body. unipolar neurons are NOT present in vertebrates, but are commonly found in invertebrates like flies and other insects.

Multipolar

Multipolar neurons are the most common type of neuron within the central nervous system. They contain many branching dendrites but have only one axon.
Most interneurons and motor neurons are multipolar.

Psuedounipolar

Pseudounipolar neurons only have one axon but it splits into two branches extending from the cell body.
Most sensory neurons are pseudounipolar, containing one axon that splits and makes two connections; one to the dedrites to collect sensory information and the other to transmit information to the spinal cord.

Bipolar

Bipolar neurons have one axon, and one dendritic extension that project from the cell body.
Bipolar cells are most often found in sensory organs (ex. the retina, olfactory epithelium in nose, auditory system in ear).