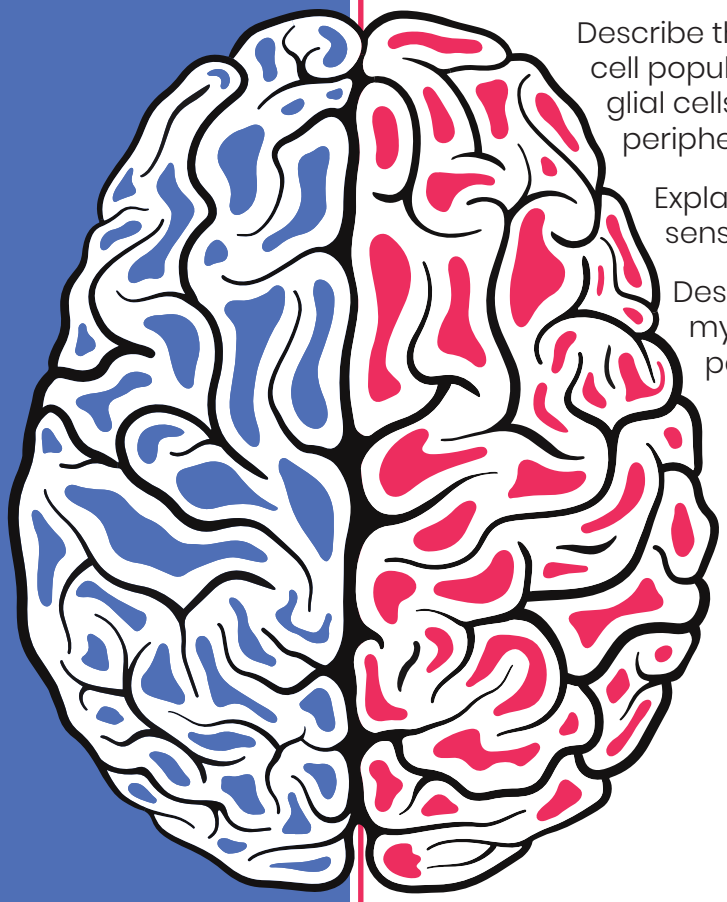
MEDICAL SCHOOL COMPANION

2

HISTOLOGY OF THE NERVOUS SYSTEM



Objectives

Describe the histological structure of the two main cell populations in the nervous system (neurons and glial cells) with their functions in the central and peripheral nervous systems.

Explain the different types of neurons used in sensory and motor pathways.

Describe the glia cells responsible for myelination of axons in the central and peripheral nervous system.

Explain the two types of axon transport (anterograde and retrograde) and the process of axon regeneration.

HISTOLOGY OF THE NERVOUS SYSTEM

The nervous system contains two main types of cells: neurons and glial or support cells.

Neurons

Neurons are the basic structural and functional units of the nervous system. They are responsible for (1) **the transfer of information** and (2) the **production of neurotransmitters** (excitatory and inhibitory). The many billions of neurons in the nervous system can be organized into three main types of neurons based on their cell shape and the number of processes (Fig. 2.1) as described below. Neurons communicate with each other via electrical (gap junctions) or chemical synapses, with chemical synapses being the most common type.

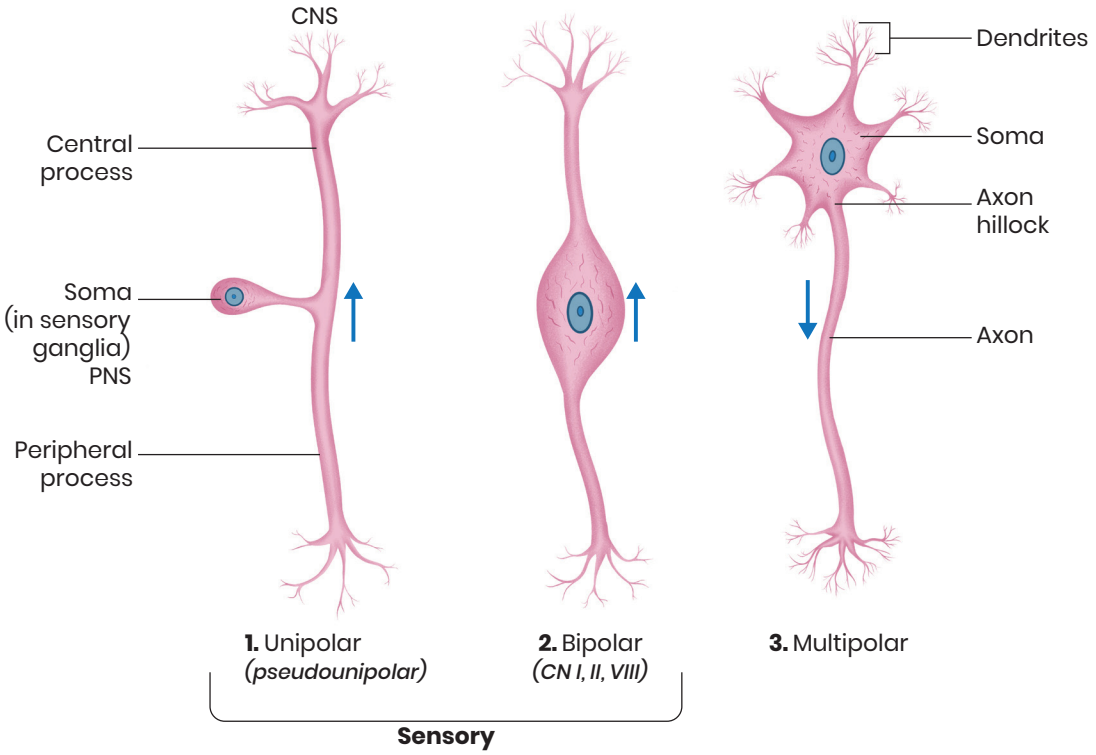


Figure 2.1 Types of Neurons

1. **Unipolar (pseudounipolar) neurons** are **sensory** in function and distribute in PNS within spinal and cranial nerves. The cell bodies of these neurons are located in **sensory ganglia** of the PNS. The peripheral processes of unipolar neurons course distally through the spinal and cranial nerves and receive sensory information from the sensory receptors located in the skin and muscles. . The unipolar neuron has a central process that courses through the dorsal root of the spinal nerves or the cranial nerves to enter the CNS.

2. **Bipolar neurons** are also sensory in function. They are only associated with three cranial nerves: CN II (retina); CN VIII (spiral and vestibular ganglia); and CN I (olfactory epithelium).

3. **Multipolar neurons** are motor or sensory in function. They are the most numerous and found throughout the nervous system. The cell bodies are located in spinal cord gray matter, brainstem motor nuclei, or in motor ganglia of PNS.

The structural organization of the multipolar neuron is illustrated in figure: 2.2:

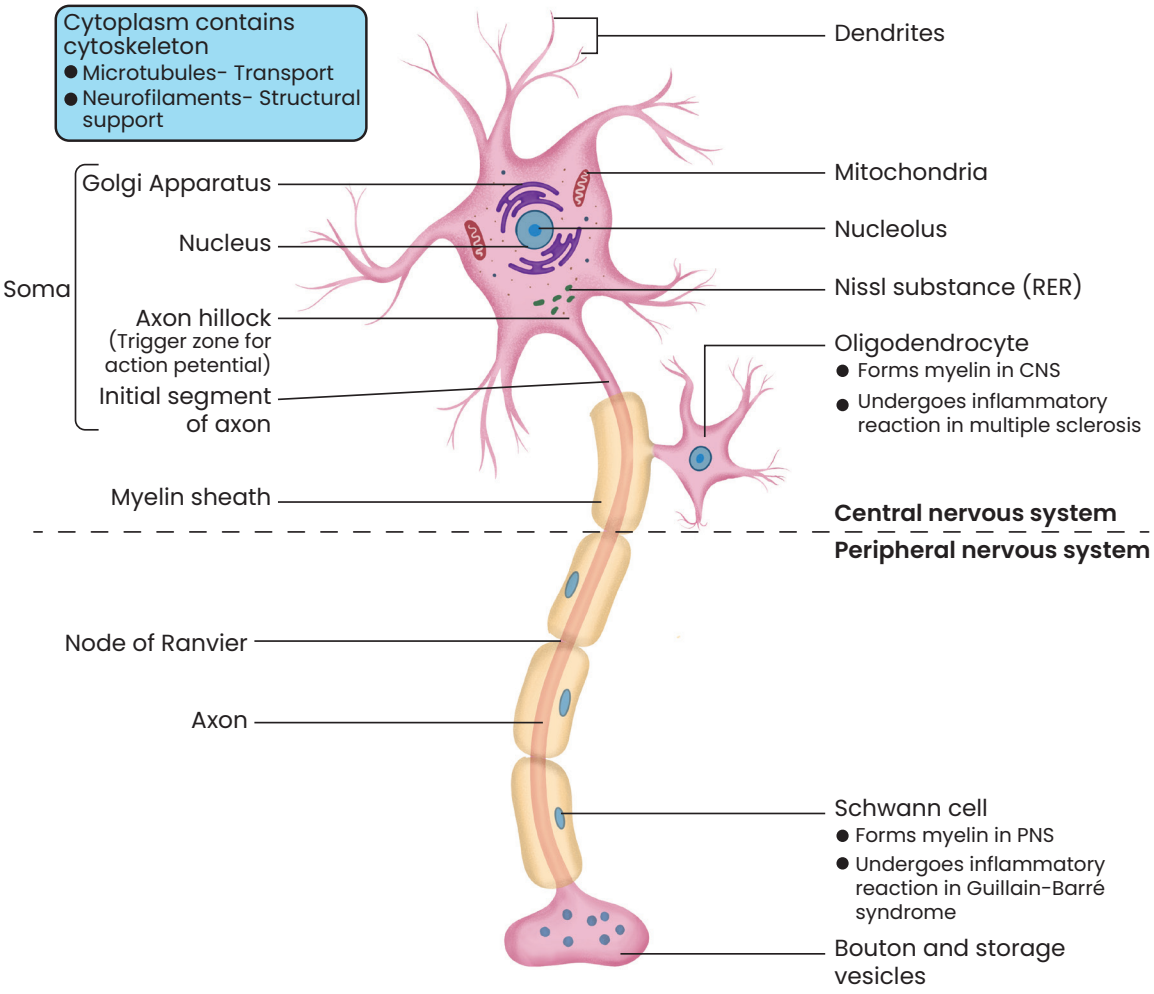


Figure 2.2 Structure of a Multipolar Neuron

1. **Dendrites** are receptive in function and make synaptic contact with many upstream neurons. They are multiple, highly branched, and represent tapered extensions from the cell membrane of the soma (cell body). Dendritic spines function to increase the surface area of the dendrites.

2. The **cell body** (soma) is the control center of the cell. It contains the nucleus (with nucleolus) and all of the classic organelles (Golgi apparatus, mitochondria, endoplasmic reticulum (Nissl substance), and cytoskeletal components (neurofilaments, microfilaments, and microtubules).

3. **Axons** have a uniform diameter and form a single extension from the cell body that can course great distances to end in a dilated bouton (contains storage vesicles for neurotransmitters). Note that the cytoplasm of the axon lacks **Golgi apparatus** and **Nissil substance,** thus proteins are not produced here. Axons form the conductive part of the neuron.

Glial Cells

Glial cells (neuroglia) comprise a very large population of cells in the CNS and PNS that are essential for normal neuron function. They form a structural support for the nervous system. Glia cells are active in cell division and mitosis throughout life and more so following pathology of the nervous system. Gliomas are some of the more common and deadly of the primary brain tumors in the CNS.

Some of the major types of glial cells are listed below. Most of these cells are in the CNS (derived from **neuroectoderm**) except for Schwann cells (derived from **neural crest cells**) that are located in the PNS.

1. **Astrocytes** are the largest and most numerous of the glial cells. They are critical for neuron function. Their primary functions include; (**1**) removal of neurotransmitters (glutamate and GABA) from the synaptic space, (**2**) removal of K^+ from the extracellular space, (**3**) provide foot plates that play a role in the blood-brain barrier along with tight junctions and basal lamina, and (4) forming scar tissue following neuronal pathology. Astrocytes contain **glial fibrillary acidic protein** (GFAP) used in pathology as a marker to identify tumor.
2. **Oligodendrocytes** are involved in CNS myelination of multiple axons (30-60 axons). These cells are injured in multiple sclerosis.
3. **Schwann cells** are involved in PNS myelination of axons**. Nodes of Ranvier** are gaps in the myelin sheath of a peripheral axon between adjacent Schwann cells that allow faster electrical impulse to move down the axon (saltatory conductions). Schwann cells only mylinate one segment of neurons between the nodes of Ranvier. These cells are damaged in Guillian-Barre syndrome.
4. **Microglia** are phagocytic cells that remove debris and invading bacteria in the nervous system. These develop from monocytes and migrate to injury site.
5. **Ependymal cells** line the ventricles. Specialized ependymal cells form the choroid plexus in the lateral, third and fourth ventricles and produce most of the CSF.

Axon Transport

Axonal transport (Fig. 2.3) is responsible for the movement of secretory products, organelles, and proteins from the cell body to axon terminal (**anterograde transport**) mediated by kinesin or from the distal axon terminal back to the cell body (**retrograde transport**) mediated by dyncin. Transport in either direction utilizes **microtubules** as a mechanism for transport. These two mechanisms and the proteins involved are shown in the figure below.

Retrograde transport is clinically important because it is involved in transporting pathological agents (polio, rabies viruses, herpes, and tetanus toxin) back towards the cell body where they become dormant until they are activated.

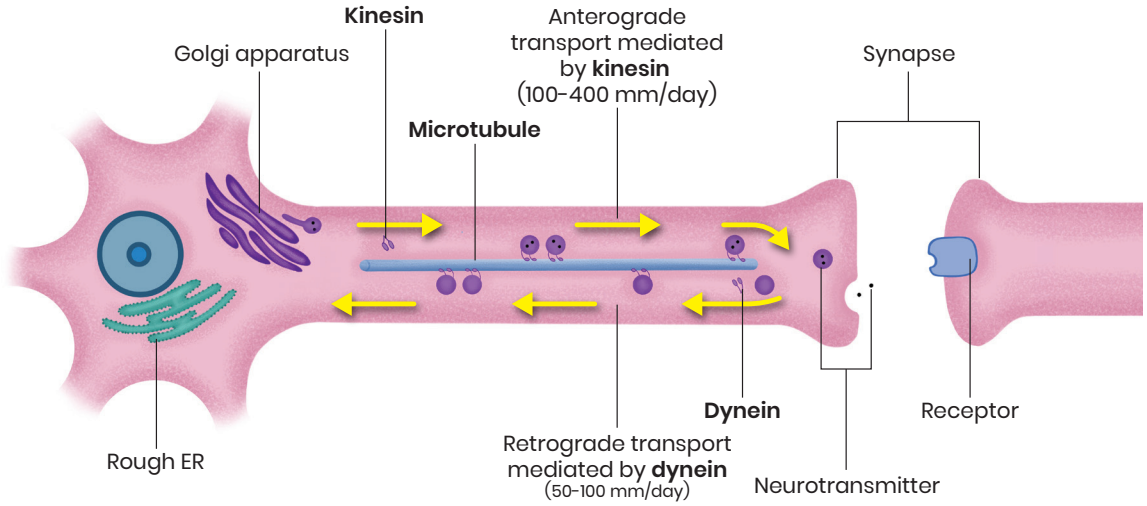


Figure 2.3 Axon Transport

Neuronal Regeneration

Damage to axons within the CNS or PNS by trauma or disease results in the removal of the axon distal to the lesion site by a process called **Wallerian (anterograde) degeneration**. This removal occurs via macrophages within 2-3 weeks in the PNS but takes considerably longer in the CNS (up to several months).

Regeneration

Axon regeneration is potentially **more successful** in the PNS over time (axon growth of 1-3 mm/day) but requires **intact Schwann** cells to provide the myelin sleeve that guides the direction of growth of the new axon.

Axon regeneration in the CNS is much **more limited**. Oligodendrites of the CNS do not support regeneration, and typically the neuron will die and be replaced by scar tissue laid down by the astrocytes.

Chromatolysis

The cell body of the damaged neurons undergo a process called **chromatolysis** which involves several changes within the cell body:

1. Nucleus moves to a peripheral location
2. Cell body enlarges and swells
3. RER is dispersed