THE NERVOUS SYSTEM

The nervous system primarily consists neurons and neuroglia. The functional unit of the nervous system are the neurons. A neuron can be defined as a nerve cell. The unique structure of **neurons** makes them specialized for receiving and transmitting electrical impulses throughout the body. The neuron acts like a miniature self-contained information processor. It receives inputs, processes information, and generates outputs.

Neuron as the functional unit of nervous system was demonstrated by R.Y. Cajal while the nerve cell or the neuron was first described by Camillo Golgi in 1873.

3.1Structure of neuron

The membrane, which surrounds the nerve cell, is made up of a double layer of lipid and contains protein molecules that play many important roles in transporting and blocking substances from coming in and out of the cell. A neuron has three main functional parts: the structure most associated with receiving signal is the dendrite, the body or soma , which accumulates signals coming from the input (dendrites) and which produces at the axonal hillock a series of bursts (impulses) when the accumulated signal reaches a critical threshold. These impulses are propagated to other neurons through an output called axon.

The structure of neuron is described below:

a) Neurocyton

The cell body (soma or neurocyton or perikaryon) contains a granular cytoplasm due to the presence of basophilic granules called Nissl's bodies. Nucleus is single and centrally located. Other cell organelles present are mitochondria, Golgi apparatus, ribosomes, endoplasmic reticulum , neurofibrillae and centrioles. The Nissl's granules which are sometimes referred to as chromatophilic substances are composed of ribonucleoproteins are produced in the nucleus and play important role in. these granules are present all over the neuron except the axon and axon hillock. The ribosomes are sometimes independent free floating structures in the cytoplasm of the cell (outside the nucleus), and sometimes connected to larger structures called endoplasmic reticulum. In the former case the ribosomes create proteins which are used inside the cell, and in the latter case they create proteins which are used in the cell membrane or transferred out of the cell. The materials that are transported out of the cell, are usually packaged by the Golgi apparatus. The Golgi apparatus packages the products of protein synthesis and the products are then transferred to the cell membrane where the package merges with the membrane and its contents are released outside the cell in a process referred to as exocytosis.

b) Dendrites

The dendrite is typically a short, abundantly branched, slender cytoplasmic processes (extension) of the cell body that primarily receives stimuli into the neuron. Infact, neural signals most often are received by specialized areas on the dendrites called dendridic spines.

c) Axon

The **axon** is typically a long, slender process of the cell body that sends nerve impulses. It emerges from the cell body at the cone-shaped axon hillock of the soma. Nerve impulses arise in the trigger zone, generally located in the initial segment, an area just outside the axon hillock.

Axoplasm The cytoplasm of the axon, the **axoplasm,** is rich in ultra-thin and delicate neurofibrils that transmit nerve signals. It surrounded by its electrically excitable plasma membrane, the **axolemma.** The membrane is made up of a double layer of lipid and contains protein molecules that play many important roles in transporting and blocking substances from coming in and out of the cell.

Collateral An axon may branch along the lengths to form small and delicate side branches called axon collaterals. These branches may return to merge with the main axon or terminate into a synapse.

Telodendria At its end, each axon or axon collateral usually forms numerous minute branches called **telodendria**. Most of these branches terminate in bulb-shaped structures called synaptic knobs (synaptic end bulbs or terminal buttons). The synaptic knobs contain neurotransmitters, chemicals that transmit nerve impulses to a muscle or another neuron. The long nerve fiber, the *axon*, transfers the signal from the cell body to another nerve or to a muscle cell. Mammalian axons are usually about 1 - 20 µm in diameter. Some axons in larger animals may be several meters in length.

Myelin or Medullary sheath The axon of many neurons may be wrapped around with an insulating layer of a fatty sheath called the myelin or medullary sheath. The "wrapping" is not continuous but interrupted at regular intervals by small spaces called the *nodes of Ranvier* (named for the French anatomist Louis Antoine Ranvier, 1834-1922, who observed them in 1878). The part of the axon between two successive Nodes of Ranvier is called internode. Myelin is secreted by *Schwann cells* in PNS (named for the German physiologist Theodor Schwann, 1810-1882, who first observed the myelin sheath in 1838). Each Schwann cell consist of single nucleus, little cytoplasm and cell membrane. In the CNS myelin is secreted by cells called oligodendrocytes. The main function of the myelin sheath is to speed the neural signal.

When the axon is not wrapped by a myelin sheath it is said to be non-myelinated nerve cell.

Neurilemma Outside the cell membrane of the Schwann cell there is an inelastic layer known as neurilemma which is continuous over the nodes of Ranvier. Neurilemma is absent in myelinated cells of CNS.

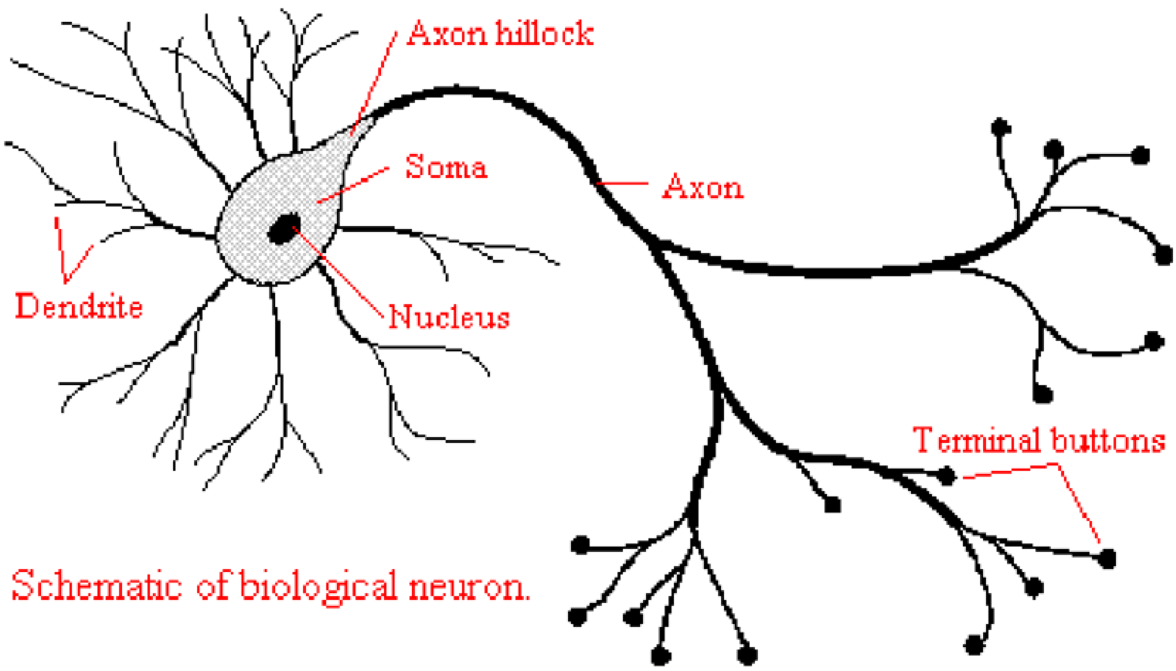


Figure 3.1: Structure of a biological neuron. Functionally there are four main elements: (1) a soma collecting the signal coming through (2) dendrites (input fibres) and distributing the signal further through (3) axons (output fibres). An axon from one neuron is connected to the dendrites of another neuron through (4) synapses (or terminal buttons), which represent the main memory of the neurons.

Types of neurons

A. Classification on the basis of function

a) Sensory neurons (**afferent** neurons): Sensory neurons transmit sensory impulses from the skin and other sensory organs or from various places within the body toward the central nervous system (CNS), which consists of the brain and spinal cord. Most sensory neurons are pseudounipolar.

b) Motor neurons (**efferent** neurons): Motor neurons transmit nerve impulses from the CNS toward effectors, target cells that produce some kind of response. Effectors include muscles, sweat glands, and many other organs. They are multipolar, each with one axon and several dendrites.

c) Association neurons (**interneurons):** The large group of neurons which do not form connections with sensory receptors or muscles or glands, but just with other neurons, are called interneurons. They are usually located in the CNS and transmit impulses from sensory neurons to motor neurons. They are multipolar. More than 90 percent of the neurons of the body are association neurons.

B. Classification on the basis of structure

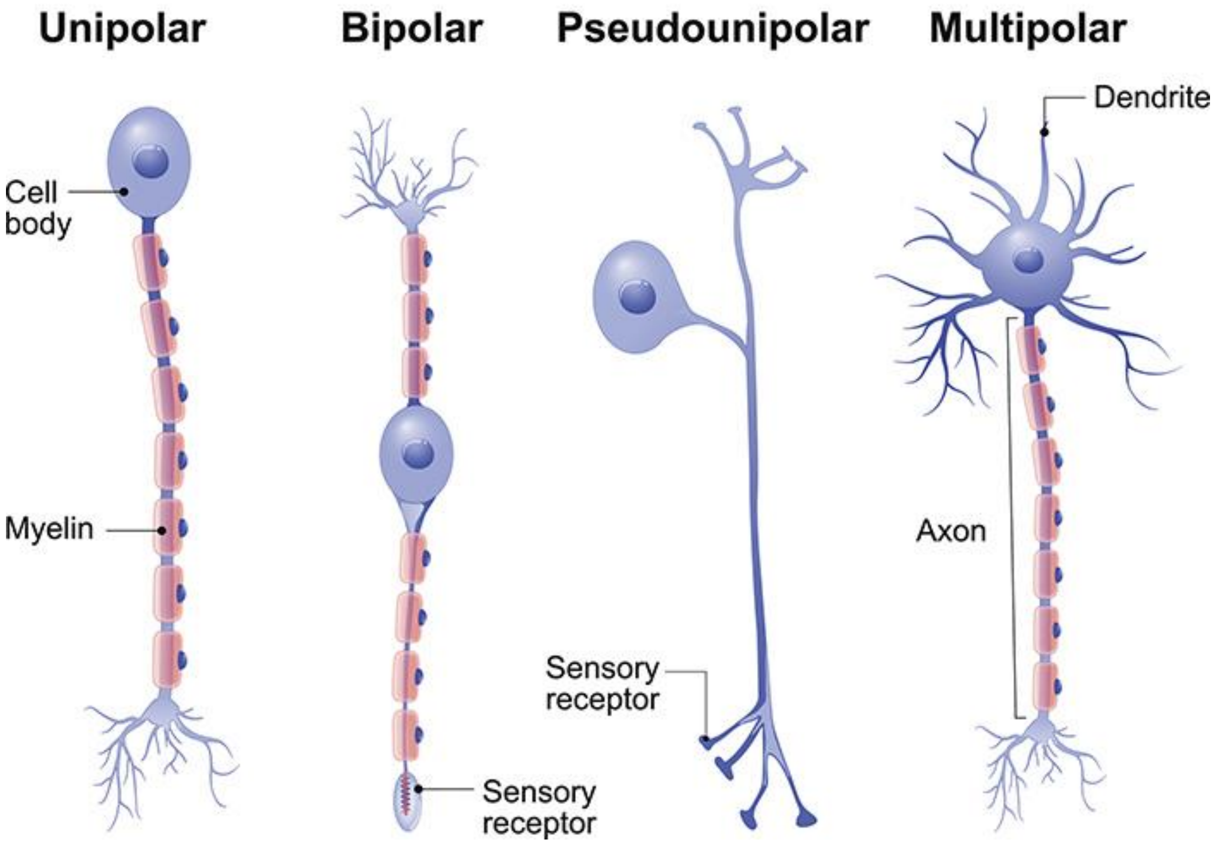
a) Non-polar neurons

b) Unipolar neurons have one process of emerging from the cell body that branches, T-fashion, into two processes. Both processes function together as a single axon. Dendrites emerge from one of the terminal ends of the axon. The trigger zone in a unipolar neuron is located at the junction of the axon and dendrites. Unipolar neurons are mostly sensory neurons.

c) Bipolar neurons have one axon and one dendrite. They emerge from opposite sides of the cell body. Bipolar neurons are found only as specialized sensory neurons in the eye, ear, or olfactory organs.

d) *Multipolar neurons* have one axon and several to numerous dendrites. Most neurons are of this type.

In the brain, the distinction between types of neurons is much more complex as there is a huge variety of neurons that exist in the brain.



Notes

A nerve fiber is an axon.

A nerve is a bundle of nerve fibers in the peripheral nervous system (PNS). Most nerves contain both sensory and motor fibers. Cell bodies are usually grouped into separate bundles called ganglia.

Supporting Cells

Although neurons are typically defined as nerve cells, they are not actually the only cells in the nervous system. In fact, they are supported by a large number of other cells apply named supporting cells or neuroglia. Glia are non-neuronal cells (i.e. not nerves) of the brain and nervous system. There are a variety of subtypes of glial cells, including astrocytes, oligodendrocytes, and microglia, each of which is specialised for a particular function.

Glia, unlike neurons, cannot generate action potentials, and because of this, were previously thought to be little more than housekeepers that ensured neurons could function properly. Hence the name glia is derived from glue as these cells were originally believed to keep the neurons glued together. This view is now shifting, and astrocytes in particular are recognised as key components of synapses that can influence how we process information. Glial cells are found in the CNS and PNS.

Glial cells of the Central Nervous system (CNS)

In the CNS Neuroglia can be broadly classified into two types - **Microglia and Macroglia**

A. Microglia

Microglia are the brain's immune cells, serving to protect it against injury and disease. Microglia identify when something has gone wrong and initiate a response that removes the toxic agent and/or clears away the dead cells. Thus, microglia are the brain's protectors. Microglia also contribute to the synaptic 'pruning' process by eating up the synapses which are not necessary.

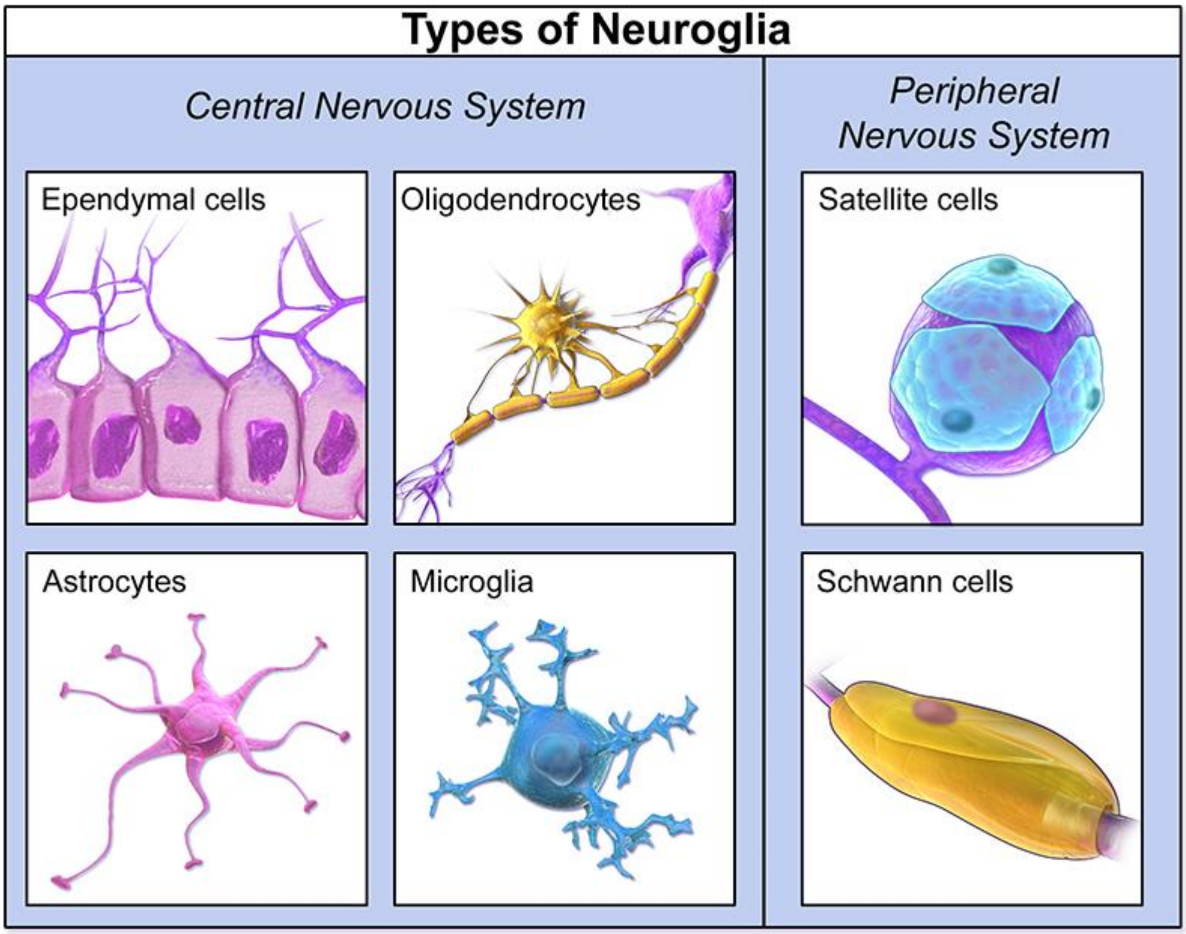
B. Macroglia

a) **Astrocytes**: Astrocytes are star-shaped cells that maintain a neuron's working environment. They do this by controlling the levels of neurotransmitter around synapses, controlling the concentrations of important ions like potassium, and providing metabolic support. astrocytes have the ability to sense neurotransmitter levels in synapses, and can respond by releasing molecules that directly influence neuronal activity, thereby astrocytes can modulate how neurons communicate.

b) **Oligodendrocytes**: Oligodendrocytes provide support to axons of neurons in the central nervous system, particularly those that travel long distances within the brain. They produce a fatty substance called myelin, which is wrapped around axons as a layer of insulation. Similar in function to insulation layers around power cables, the myelin sheath allows electrical messages to travel faster, and gives white matter its name—the white is the myelin wrapped around axons.

c) **Ependymal cells**: Ependymal cells line the spinal cord and ventricles of the brain. They are involved in secreting cerebrospinal fluid (CSF).

d) **Radial glia**: Radial glial cells are multi-purpose precursor cells involved in most aspects of nervous system development in vertebrates and can generate neurons and neuroglia.



Major types of glial cells in the nervous system. (Image courtesy: Blausen.com staff / CC BY 3.0 via Commons.)

Glial cells of the Peripheral Nervous System (PNS)

a) **Schwann cells**: Similar to oligodendrocytes in the central nervous system, Schwann cells myelinate neurons in the peripheral nervous system. They have phagocytic activity and help in regeneration of neurons in the peripheral nervous system.
b) **Satellite cells**: Satellite cells surround neurons in the sensory, sympathetic and parasympathetic ganglia and help regulate the chemical environment. They may also contribute to chronic pain.
c) **Enteric glial cells**: Enteric glial cells are found in the nerves in the digestive system.

Properties of nerve fibres

The nervous tissue has some unique properties

1. Excitability: When a stimulus (mechanical, thermal, electrical or chemical in nature) is applied there is a change in the electrical activity of the membrane from its resting state to an excited state
2. Conductivity: it is the ability to transmit impulses all along the whole length of axon without any change in the amplitude of the axon potential. The way the conduction of the action potential occurs along the nerve fiber depends on whether it’s myelinated or unmyelinated.
3. Adaptation: During the passage of a constant current, a nerve fiber does not get excited.