Medical Biology

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Nervous system

The nervous system is responsible for communication between different regions of the body, it is divided into:

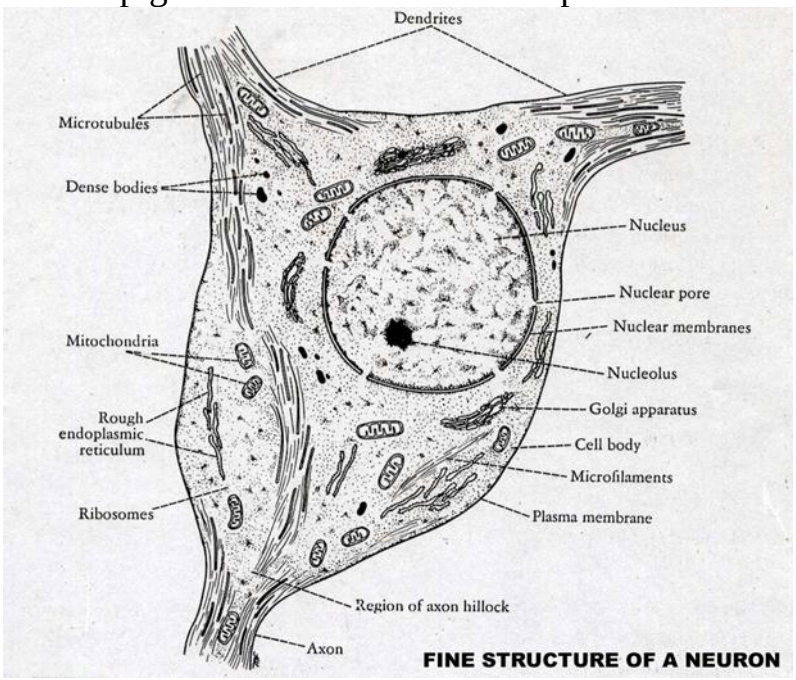
- **CNS (central nervous system) = brain + spinal cord**
- **PNS (peripheral nervous system) =nerves running between the CNS & other tissues.**

Nervous tissue consists of two major cell types:
neurons and neuroglia.

The Neuron:

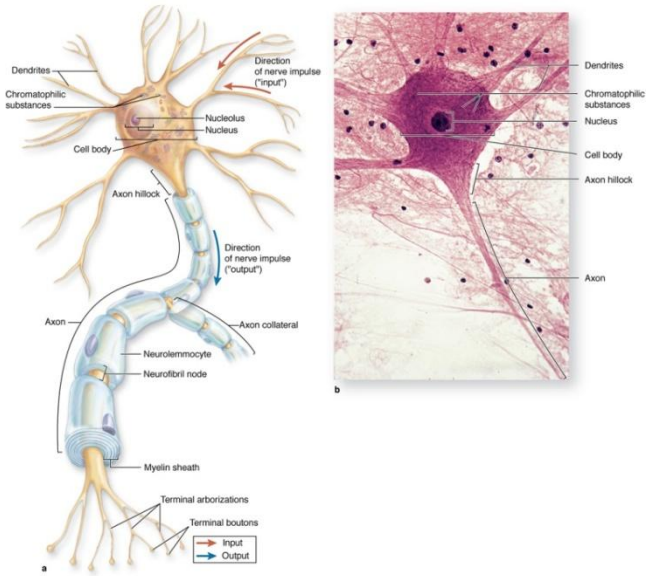
It is the main functional unit of the nervous system, it consists of:

- **Cell body (perikaryon):** containing the nucleus & most of the organelles.
  The neurons are highly metabolically active cells characterized by:
  - Large nucleus & central nucleolus.
  - The cytoplasm contains abundant lysosomes & rough endoplasmic reticulum (RER), Nissl substances (RER and free ribosomes also called chromatophilic substances), well developed Golgi & large no. of mitochondria to provide energy, inclusions of pigmented material such as lipofuscin.



- **Axon:** a single long process which conducts the electrical signals from the cell body of the neuron to other cells. Axons can range in length from 1 millimeter to as long as 1 meter. Sometimes axons branch into one or more collateral axons. Each axon may have several small branches at the end; these are called axon terminals. Axons are output channels. The conical region of an axon where it joins the cell body is called the axon hillock, this is the region where the signals that travel down the axon are generated. Near its end, an axon usually divides into several branches, each of which ends in a synaptic terminal. The site of communication between a synaptic terminal and another cell is called a synapse. At most synapses, information is passed from the transmitting neuron (the presynaptic cell) to the receiving cell (the postsynaptic cell) by means of chemical messengers called neurotransrnitters.

- **Dendrites:** Dendrites (from the Greek Dendron, tree) are short processes which receive the signals from the axons of other neurons by making synapse which allows direct communications between the cells. A single neuron can have anywhere from 1 to 20 dendrites, each of which can branch many times. Dendrites are input channels.
- **Terminal button:** is the branched terminal end of the axon. Many **neurotransmitters** are synthesized and stored in the axon terminals. Some are synthesized in the cell body and transported down the axon to the terminals. When released, neurotransmitters carry chemical messages between neurons and muscle fibers, which cause contract. They also carry messages to organs and glands that affect the function of all the body systems.



Unlike most other cells, neurons do not divide to reproduce themselves. Also, unlike most other cells, neurons are able to transmit an electrochemical signal. Neurons, on the other hand, are irregular in shape and have a number of extensions (sometimes called "processes") coming off them. This makes them look like a many-legged spider.

Types of the Neurons:

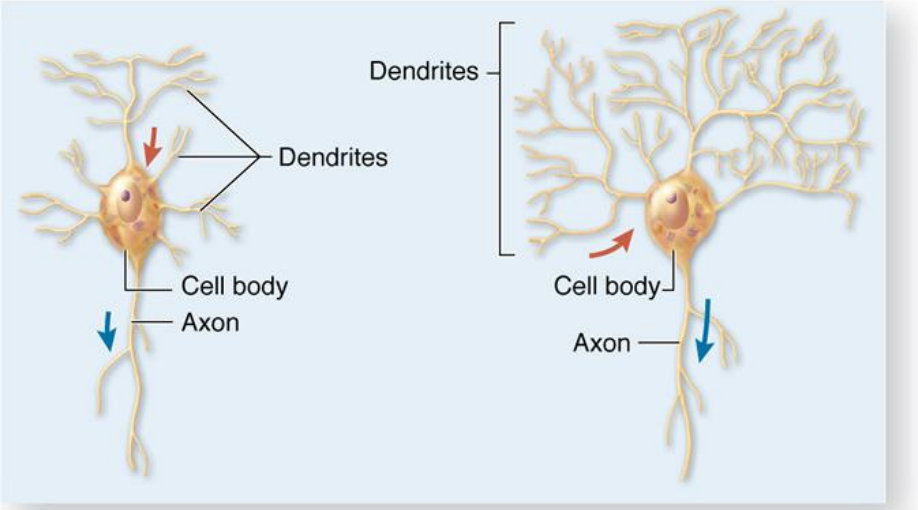
They are classified according to shape:

- **Multipolar (motor) neurons**: have large cell body + large axon + many dendritic processes.
- **Unipolar (pseudounipolar) (sensory):** cell body + one large process divided into 2 branches; one is axon & other is dendrite.
- **Bipolar:** simple cells provide local communications within the CNS having 2 main processes of equal size, one axon & other dendrite.

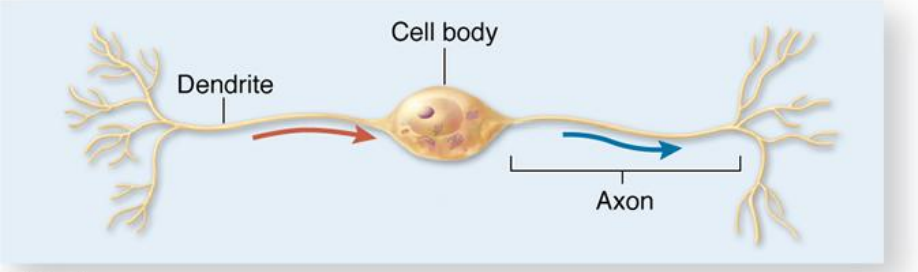
Neurons can be grouped into three general types:

1. Sensory neurons (afferent): transmit impulses from receptors to the CNS (such as somatic afferent fibers that transmit sensations of pain, temperature, touch & pressure from body surface). While visceral afferent transmits pain impulses from internal organs, mucous membranes, glands & blood vessels.
2. Motor neurons (efferent): transmit impulses from the CNS or ganglia to effectors cells. Somatic efferent neurons send voluntary impulses to skeletal muscles, while visceral efferent neurons transmit involuntary impulses to smooth muscle, cardiac conducting cells & glands.

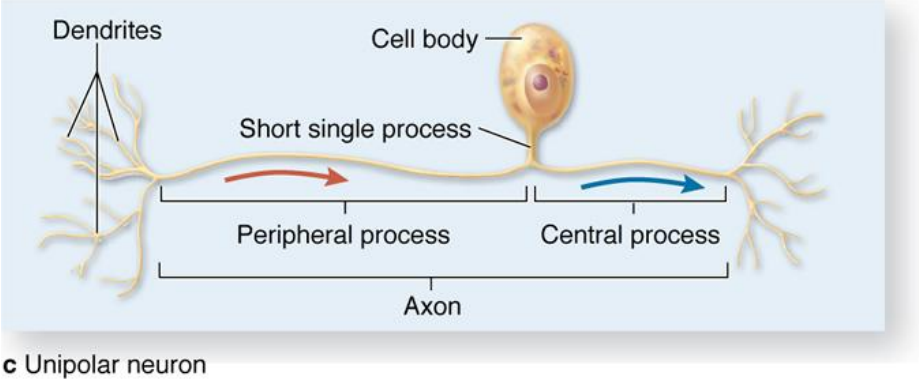
3. Interneurons: form communicating & integrating network between the sensory & motor neurons, it is estimated that 99.9% of all neurons belong to this integrating network.



a Multipolar neurons



b Bipolar neuron

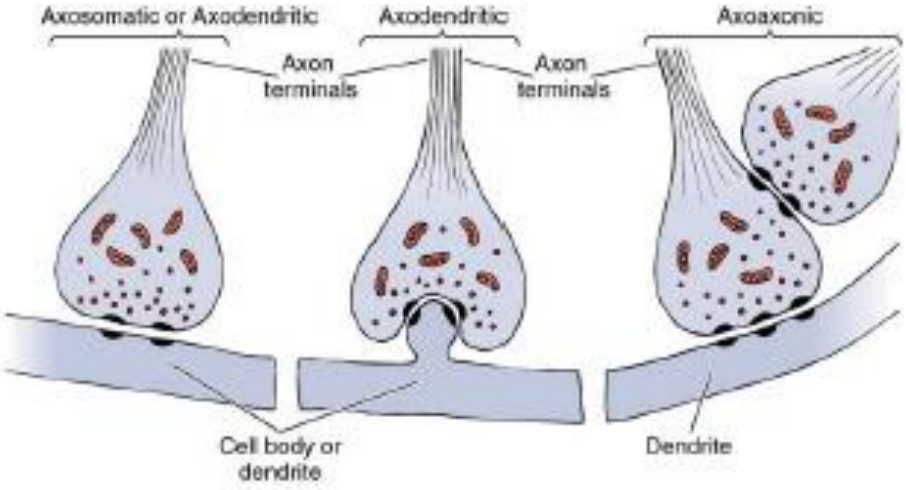


c Unipolar neuron

Synapses:

Synapses are the sites where 2 neurons contact each other. At synapses information is transmitted (in a unidirectional way) in the form of action potentials between two neurons (or between one neuron & other effector cell such as muscle or glandular cells). Synapse is formed by an axonal terminal (presynaptic terminal) that delivers the signal, a region on the surface of another cell at which a new signal is generated (postsynaptic terminal) & a thin intercellular space between them (synaptic cleft). An axon terminal may synapse with a cell body (axosomatic synapse), a dendrite (axodendritic synapse), or another axon (axoaxonic

synapse). In humans, synapses work by chemical molecules (neurotransmitters) released from presynaptic neuron terminals & affect the postsynaptic cell. This type is called a chemical synapse. On the other hand, action potential may be transmitted directly from the presynaptic cell to postsynaptic cell through gap junctions (electrical synapse) which are extremely rare in humans.



Neuroglia:

They outnumber neurons by about 10 to 1 in the brain, like neurons, glia (neuroglia) has many extensions coming off their cell bodies. Unlike neurons, however, glia probably does not send out electrochemical signals. Also, unlike neurons, glia is replaced constantly throughout a person's life. Most neurons are unable to survive alone for long; they require the nutritional support provided by the **neuroglial cells.** More than half the volume of the human nervous system is composed of supporting neuroglial cells.

In the brain & the spinal cord there are 4 types of supporting cells:

1. Astrocytes: stellate-shaped cells with fine processes radiating in all directions. Its roles are:

a. Astrocytes provide nutritional support to neurons and help keep most substances other than oxygen, carbon dioxide, glucose, and essential amino acids from entering the brain from the bloodstream.

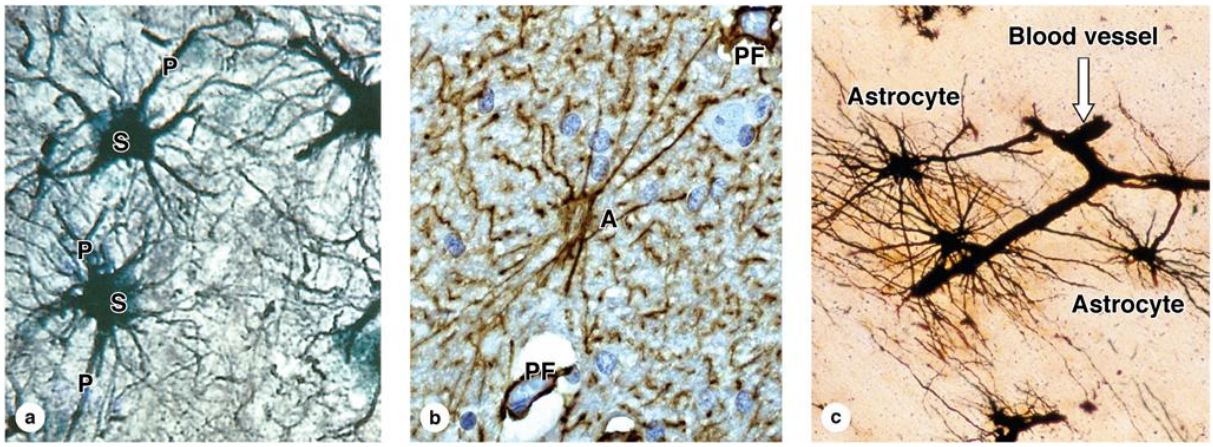
b. Astrocytes give structural support to hold neurons in place and also scavenge dead cells after an injury to the brain.

c. Processes from astrocytes called "end feet" adhere to the blood vessels of the brain and secrete chemical signals that induce (cause) the formation of tight junctions between the endothelial cells which line the blood vessels. As a result, substances from the extracellular fluid cannot move easily into these cells. Most large molecules cannot cross this blood-brain barrier. Small fat-soluble molecules and uncharged particles such as carbon dioxide and oxygen, however, diffuse easily across this barrier. So, astrocytes play a role in the formation of blood-brain barriers which prevent diffusion of substances between the blood & the brain.

Astrocytes are of 2 types:

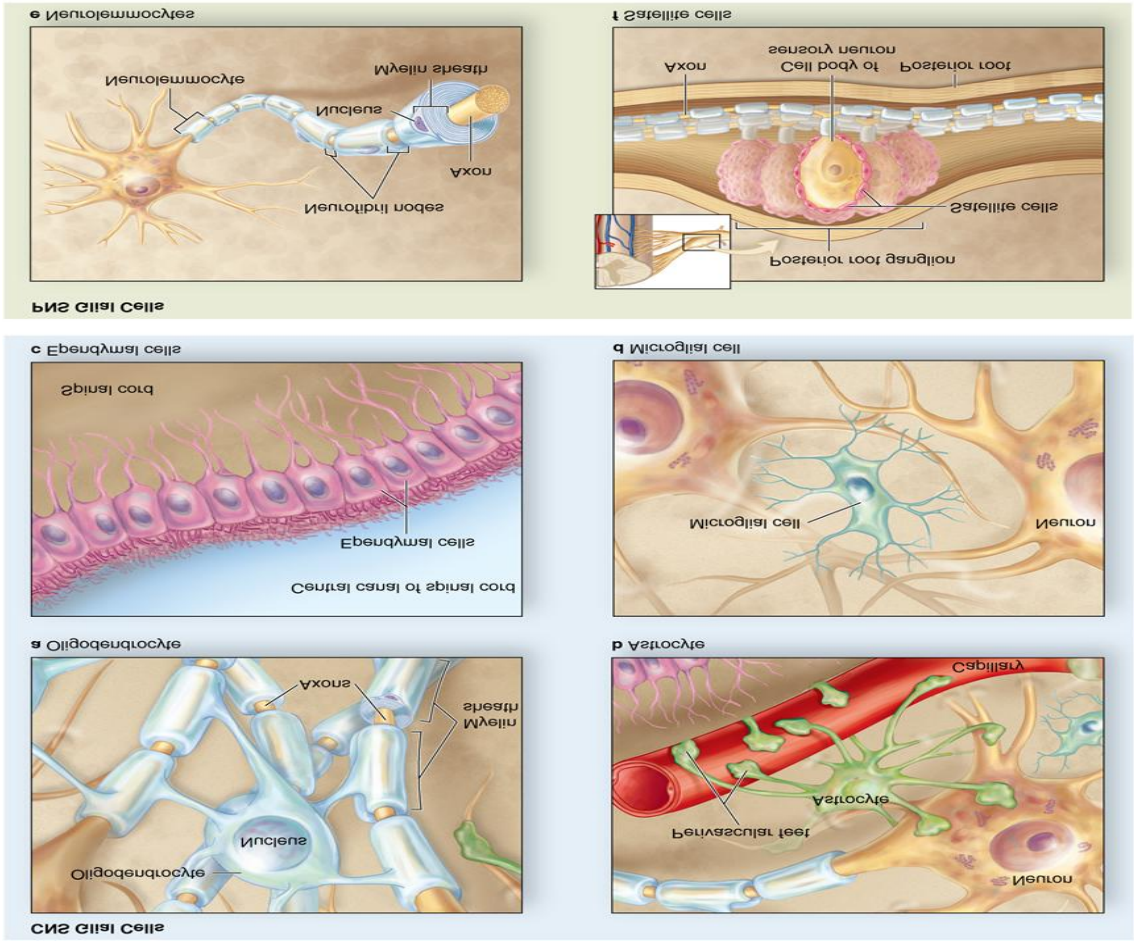
a. fibrous astrocytes found in the white matter of brain.

b. protoplasmic astrocytes found in the gray matter of brain.



2. Oligodendrocytes: round cells with few processes, these cells are located in both gray and white matter of CNS. They produce myelin within the CNS. In producing myelin, oligodendrocytes function similarly to the Schwann cells of the PNS, except that a single oligodendrocyte may wrap several axons with segments of myelin, whereas a single Schwann cell wrap only one axon with myelin.
3. Ependymal cells: are epithelial cells lining the cavities (ventricles) of the brain as a sheet of cuboidal cells many of which are ciliated & they are in contact with the Cerebrospinal fluid (CSF). Cerebrospinal fluid acts as a shock-absorbing cushion to protect the brain from blows to the head. In effect, this fluid makes the brain float inside the skull. The cerebrospinal fluid also removes waste products from the brain.
4. Microglia cells: are specialized macrophages forming the immune cells in the CNS.
In PNS:
5. Schwann cell (neurolemmocytes): are found only in PNS, they function to envelop the axon of many neurons with a sheath of fatty material called myelin, which acts as an electrical insulator. Schwann cells produce myelin in the PNS, while oligodendrocytes produce myelin in the CNS. During development, these cells wrap themselves around each axon several times to form a **myelin sheath,** an insulating covering consisting of multiple layers of membrane. Schwann cells also help repair damaged nerves outside the brain and spinal cord.
6. Satellite cells of ganglia: form a covering layer over the large neuronal cell bodies in PNS ganglia and exert trophic or supportive role.

Clinical Notes:
Most brain tumors are **astrocytoma** derived from fibrous astrocyte. These are distinguished pathologically by immunohistochemical methods.


e Neurolemmocytes
Neurolemmocyte
Myelin sheath
Nucleus
Axon
Neurofibril nodes
PNS Glial Cells
f Satellite cells
Axon
Cell body of sensory neuron
Posterior root
Satellite cells
Posterior root ganglion
c Ependymal cells
Spinal cord
Ependymal cells
Central canal of spinal cord
b Microglial cell
Microglial cell
Neuron
g Oligodendrocyte
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