Neuron physiology

Dr. Zainab Abbas Al-Mousawi

Neuron (also called **nerve cell**)

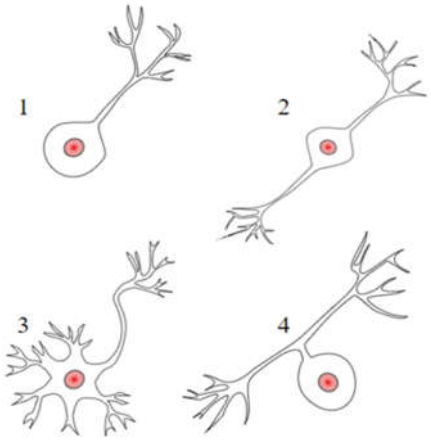
Neuron is a structural and functional unit of nervous system which generate electrical signals or impulses called **action potentials**, which allow them to quickly transmit information over long distances. Neuron is similar to any other cell in the body, having nucleus and all the organelles in cytoplasm. However, it is different from other cells by two ways:

1. Neuron has branches or processes called **axon** and **dendrites**
2. Neuron does not have centrosome. So, it cannot undergo division.

Classification of neuron

Depending upon the number of poles:

1. *Unipolar neurons*: single process
2. *Bipolar neurons*: 1 axon and 1 dendrite
3. *Multipolar neuron:* 1 axon and 2 or more dendrites.
4. pseudounipolar neuron



Depending upon the function:.

1. *Motor or Efferent Neurons*

The neurons which carry the **motor impulses** from central nervous system to peripheral effector organs like muscles, glands, blood vessels, etc. Generally, each motor neuron has a long axon and short dendrites (Most motor neurons are multipolar*)*.

2. *Sensory or Afferent Neurons*

Sensory or afferent neurons are the neurons which carry the **sensory impulses** from periphery to central nervous system. Generally, each sensory neuron has a short axon and long dendrites (Most sensory neurons are pseudounipolar*)*.

3. *Interneurons*

Interneurons are multipolar neuron, which are found only in the CNS, connect one neuron to another. Can serve as signal changers, they receive information from other neurons (either sensory neurons or interneurons) and transmit information to other neurons (either motor neurons or interneurons).

Depending upon the length of axon

1. *Golgi Type I Neurons*

Golgi type I neurons have **long axons.**

2. *Golgi Type II Neurons*

Neurons of this type have **short axons.**

Structure of neuron

Neuron is made up of three parts:

1. **Nerve cell body** (also called soma)
2. **Dendrites** are short processes transmits impulses towards the nerve cell body.
3. **Axon** is long processes arises from axon hillock of the nerve cell body and extends for a long distance away from the nerve cell body. Axon transmits impulses away from the nerve cell body. Dendrites and axons are usually called **nerve fibers.**

Glial Cells (or glia)

Glia one of the various types of neural tissue cells that provide support for the nervous system. Glia function to hold neurons in place, supply them with nutrients, provide insulation, and remove pathogens and dead neurons.

There are four main types of glial cells in the adult vertebrate nervous system. Three of these, **astrocytes, oligodendrocytes,** and **microglia**, are found only in the central nervous system (CNS). The fourth, the **Schwann cells**, are found only in the peripheral nervous system (PNS).

Some Axons of neurons are myelinated and other unmyelinated

Myelinated neuron wrapped by a white, fatty layer composed of lipid and lipoprotein called **myelin sheaths**, which is secreted by **Schwann cells**. Myelin sheaths shield the axon from extracellular fluid. There are short gaps between the myelin sheaths known as **nodes of Ranvier** where the axon is directly exposed to the surrounding extracellular fluid. Myelin sheath is responsible for white color of nerve fibers.

Functions of myelin sheath:

1. Faster conduction

Myelin sheath is responsible for faster conduction of impulse through the nerve fibers. In myelinated nerve fibers, the impulses jump from one node to another node. This type of transmission of impulses is called **saltatory conduction**

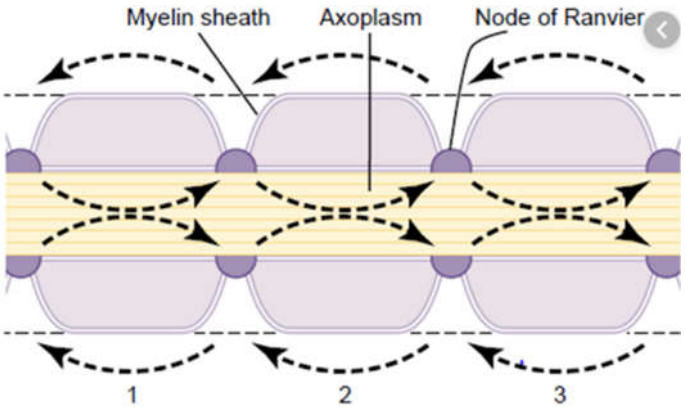


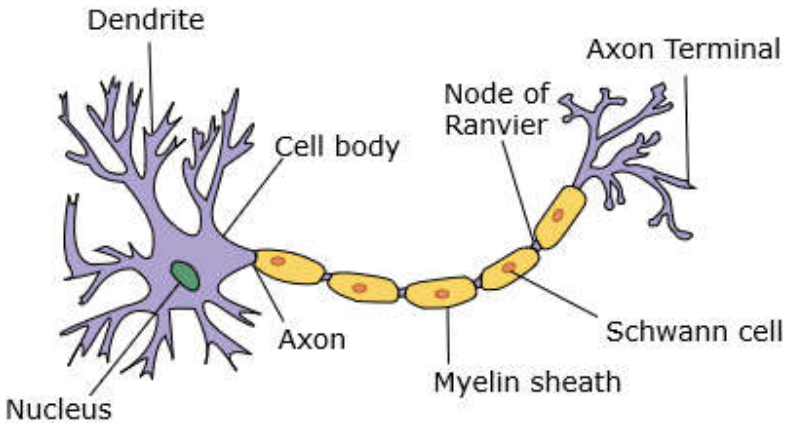
Figure 5–17

Saltatory conduction along a myelinated axon. Flow of electrical current from node to node is illustrated by the arrows.

2.Insulating capacity

Myelin sheath has a high insulating capacity. Because of this quality, myelin sheath restricts the nerve impulse within single nerve fiber and prevents the stimulation of neighboring nerve fibers.

Towards its end, the axon splits up into many branches and develops bulbous swellings known as **axon terminals** (or **nerve terminals**).



Resting membrane potential

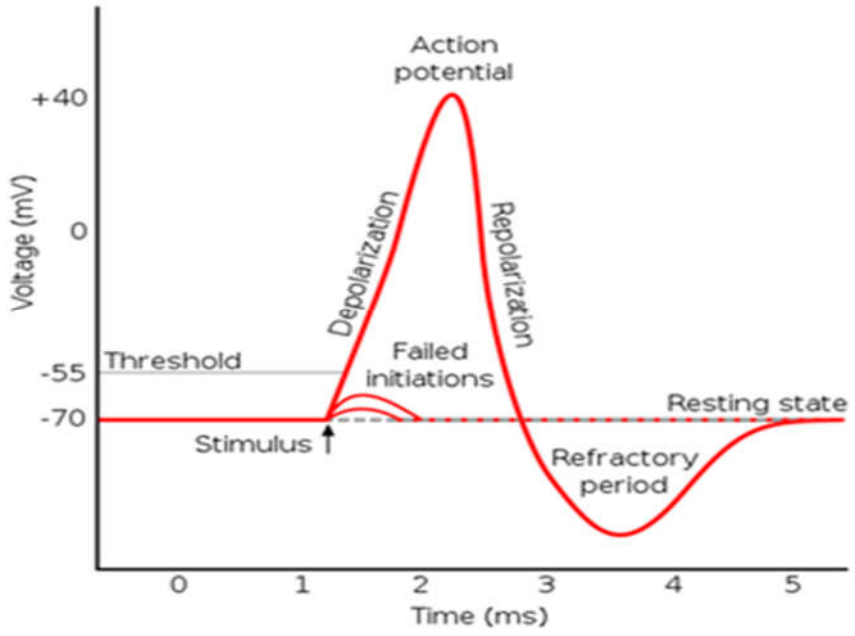
Resting membrane potential is the name for the electrical state when a neuron is not actively being signaled. A neuron at resting potential has a membrane with established amounts of sodium (Na+) and potassium (K+) ions on either side, leaving the inside of the neuron negatively charged relative to the outside the voltage of resting membrane is (-70). The causes of resting membrane potential are (Na+) and potassium (K+) ions channels (transport ion with concentration gradients) and Na- K ATPase pump (which pump 3 Na+ outside cell and 2 k+ inside the cells)

Action potential

The action potential is a rapid change in polarity that moves along the nerve fiber from neuron to neuron. unique to neurons and muscle fibers. In order for a neuron to move from resting potential to action potential—a short-term electrical change that allows an electrical signal to be passed from one neuron to another—the neuron must be stimulated by pressure, electricity, chemicals, or another form of stimuli. The level of stimulation that a neuron must receive to reach action potential is known as the **threshold** of excitation, and until it reaches that threshold, nothing will happen.

The action potential has several stages.

1. Stimulus starts the rapid change in voltage or action potential. when a raise the voltage of membrane above the threshold voltage (-55) start membrane depolarization.
2. Depolarization is caused by a rapid rise in membrane potential opening of sodium channels in the cellular membrane, resulting in a large influx of sodium ions.
3. Membrane Repolarization results from rapid sodium channel inactivation as well as a large efflux of potassium ions resulting from activated potassium channels.
4. Hyperpolarization is a lowered membrane potential caused by the efflux of potassium ions and closing of the potassium channels.
5. Resting state is when membrane potential returns to the resting voltage that occurred when Na-K ATPase pump sodium ions out of the cell and potassium ions in. This restores the original ion concentrations and readies the cell for a new action potential before the stimulus occurred.



special characteristic of signal transmission in a nerve trunk

1. Myelinated and unmyelinated nerve fibers

2. Solitary and continuous conduction
3. Summation and sub threshold potential
4. Absolute and relative refractory period

Main Difference between Myelinated and Unmyelinated Nerve Fibers

Myelinated	Unmyelinated
1.contain myelin sheath	don't contain myelin sheath
2.White color	Gray color
3.consist of node of Ranvier	not
4.solitary conduction (only in node of Ranvier)	continuous conduction
5.speed of impulses is high	low
6.long axon	Short axon
7. myelin sheath prevent loss of impulse	can lose impulse during conduction

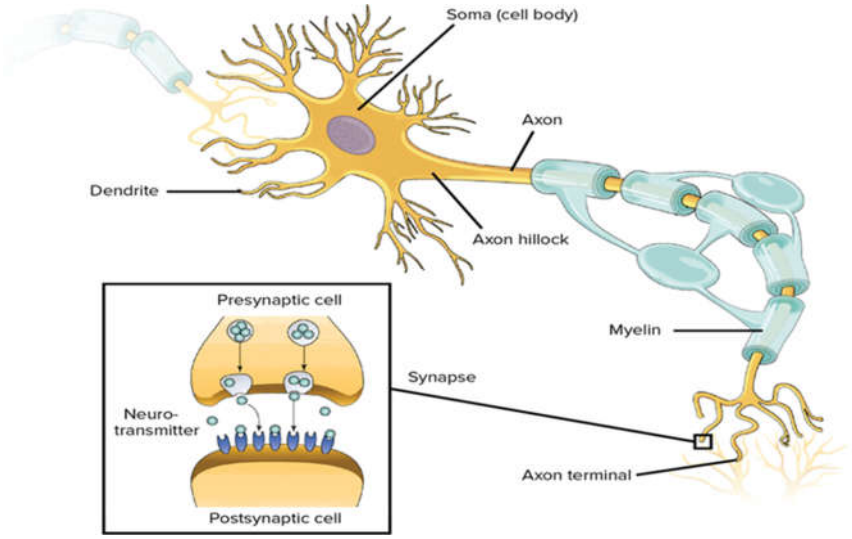
Summation: When one subliminal stimulus is applied, it does not produce any response in the nerve fiber because, the subliminal stimulus is very weak. However, if two or more subliminal stimuli are applied within a short interval of about 0.5 millisecond, the response is produced. It is because the subliminal stimuli are summed up together to become strong enough to produce the response.

Absolute Refractory period: time after the initiation of an action potential when another action potential cannot be generated

Relative Refractory period: time during the refractory period when a new action potential can only be initiated by a stronger stimulus than the current action potential because voltage-gated K+ channels are not closed.

Synapse

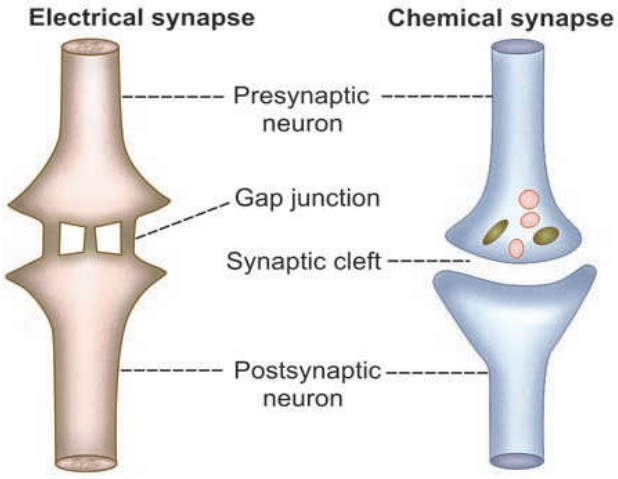
Synapse is the junction between two neurons (the nerve terminal and a dendrite or cell body of another neuron). The cell to which the axon terminal belongs (sending cell) is called the **presynaptic cell**, while the cell to which the dendrite or cell body belongs (receiving cell) is called the **postsynaptic cell.** The synaptic connections between neurons and skeletal muscle cells are generally called **neuromuscular junctions**, and the connections between neurons and smooth muscle cells or glands are known as **neuroeffector junctions**. The region between the pre- and postsynaptic membrane is very narrow.



Synapse is classified into two categories:

1. Electrical synapse: is the synapse in which the physiological continuity between the presynaptic and the post synaptic neurons is provided by **gap junction** between the two neurons. There is **direct exchange** of ions between the two neurons through the gap junction.

2. Chemical synapse: Chemical synapse is the junction between the presynaptic and the post synaptic neurons, through which the signals are transmitted by the release of chemical transmitter. In the chemical synapse, there is no continuity between the two neurons because of the presence of a space called **synaptic cleft** between the two neurons.



Neurotransmitter: is a chemical substance that acts as a **mediator** for the transmission of nerve impulse from one neuron to another neuron through a synapse.

classification of neurotransmitters

Depending upon chemical nature of neurotransmitters:

1. ***Amino Acids***

   Fast synaptic transmission such as GABA (Gamma-aminobutyric acid) and glutamate.

2. ***Amines*** (modified amino acids)

   Slow synaptic transmission such as noradrenaline, adrenaline, dopamine, serotonin and histamine.

3. ***Others***

   such substance is acetylcholine (Ach) and nitric oxide.

Depending upon function:

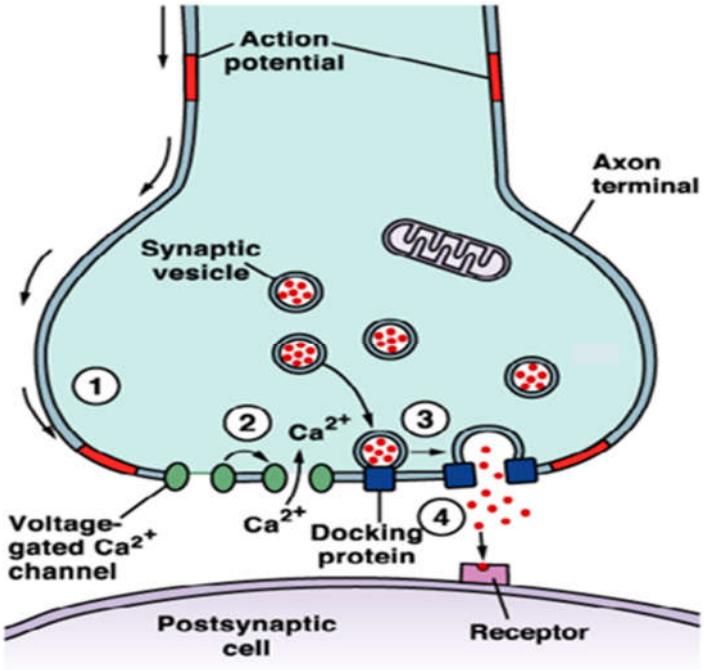
Some of the neurotransmitters cause excitation of postsynaptic neuron while others cause inhibition.

1. Excitatory neurotransmitters (acetylcholine and histamine).
2. Inhibitory neurotransmitters (GABA and dopamine).

(Adrenaline and noradrenaline act as excitatory and inhibitory neurotransmitter).

Transport and release of neurotransmitter

The neurotransmitter is produced in the cell body of the neuron and is transported through axon. At the axon terminal, the neurotransmitter is stored in small vesicles. Under the influence of a stimulus and action potential reaches the axon terminals, voltage-gated Ca^{2+} channels open and the concentration of Ca^{2+} increases inside the end bulb, The Ca^{2+} helps the merging of the vesicle with the presynaptic membrane so that these vesicles open and release the neurotransmitter into synaptic cleft. It binds to specific receptors on the surface of the postsynaptic cell.



Inactivation of neurotransmitter

After the finishing of the action, neurotransmitter is After the finishing of the action inactivated by four different mechanisms:

1. It diffuses out of synaptic cleft to the area where it has no action.
2. It is destroyed by specific enzymes.

3. It is removed by astrocytes.

4. It is reuptake into the axon terminal.

Acetylcholine

Acetylcholine (ACh) is synthesized from choline and acetyl coenzyme A in the cytoplasm of axon terminals and stored in synaptic vesicles. Ach can destroyed by the enzyme **acetylcholinesterase.** This enzyme is located on the pre- and postsynaptic membranes and rapidly destroys ACh, releasing choline. The choline is then transported back into the axon terminals where it is reused in the synthesis of new ACh. Acetylcholine is a major neurotransmitter in the peripheral nervous system, and it is also present in the brain. Nerve fibers that release ACh are called **cholinergic** fibers and the receptors which respond to the Ach called **cholinergic receptors**.

Cholinergic receptors are classified according to whether they are stimulated by the drug to:

1. Nicotinic receptors: nicotine, the chemical in tobacco, binds to the nicotinic receptor and activates it similarly to acetylcholine.

2. Muscarinic receptors: muscarine, a chemical product of certain mushrooms, binds to the muscarinic receptor

Catecholamines

Dopamine, norepinephrine (NE), and **epinephrine** are formed from the amino acid tyrosine Synthesis and release of the catecholamines from the presynaptic terminals and broken down in both the extracellular fluid and the axon terminal by enzymes such as monoamine oxidase. Nerve fibers that release epinephrine or norepinephrine came to be called **adrenergic** fibers. Norepinephrine-releasing fibers are also called **noradrenergic.** There are two major classes of receptors for norepinephrine and epinephrine:

1. Alpha-adrenergic receptors
2. Beta-adrenergic receptors