CHAPTER

1

Nervous Tissue

Learning Objective

After completing this lesson, the Reader should be able to understand:

- *Introduction*
- *Overview of nervous system*
- *Organization of nervous system*
- *Coverings of the Central Nervous System (CNS)*
- *Neurons*
- *Neuroglia*
- *Membrane potential*
- *Synapse*
- *Neurotransmitters*
- *Receptors*
- *Ligands*

1.1 Introduction

The nervous system is mainly composed of nerve cells neurons (electrically, excitable cells) and neuroglia (also called glia or glial cells). In other words, neurons and neuroglia are the main two nerve cells of the nervous system. The neurons and neuralgia are also of different types and these perform specialized functions to control the body functions. These cells are interconnected through synapses (specialized connections to communicate with cells). The nervous system has three main functions including sensory, integrative and motor functions **(Table 1-1)**.

1. **Sensory function:** The information is conveyed from the periphery to the brain through sensory neurons.
2. **Integrative function:** The information obtained from the periphery is perceived, analyzed (mainly in the cerebral cortex) and decisions are taken.
3. **Motor function:** The information is conveyed from the brain to the periphery through motor neurons.

Table 1-1 Functions of the nervous system

Sr. No.	Type of Functions	Comments
1	Sensory	Sensory or afferent neurons convey information from periphery to brain
2	Integrative	Inter-neurons interpret the information received from sensory neurons, decisions are taken
3	Motor	Motor or efferent neurons receive the information from inter-neurons and produce a response at the organ

Organization of the Nervous System

Based on structure, the nervous system is divided into two main subdivisions i.e. the central nervous system (CNS) and peripheral nervous system (PNS). The CNS consists of the brain and spinal cord. Further, the CNS has different centers, which carry out the various functions including sensory, motor and integration of data. These centers can be further divided into lower centers, including the spinal cord and brain stem, and higher centers, communicating with the brain via effectors (peripheral organs). The peripheral nervous system is composed of cranial nerves from the brain, spinal nerves from the spinal cord, ganglion, and plexuses **(Figure 1-1).** The peripheral nervous system is further subdivided into the somatic

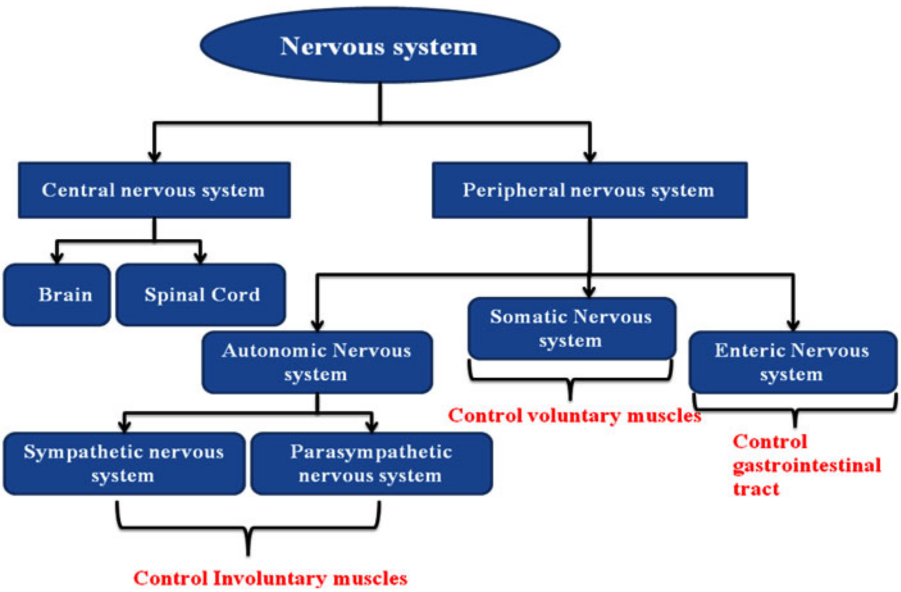


Figure 1-1. Classification of nervous system

nervous system (SNS), autonomic nervous system (ANS), and enteric nervous system (ENS). The function of the peripheral nervous system is to convey impulse to and from the CNS **(Table 1-2)**. The afferent nerves bring the information to the sensory neurons of CNS from the sensory receptors. On the other hand, the efferent nerves carry the information from the motor neurons of the CNS towards different peripheral tissues or organs. The somatic nervous system controls the voluntary (skeletal muscles) i.e. muscles which are under the control of the will of the person such as limbs. The autonomic nervous system is further divided into the sympathetic nervous system and the parasympathetic nervous system. The autonomic system controls the organs, which are not under the control of the will of the persons i.e. involuntary (smooth muscles and heart) such as the uterus, bronchi, blood vessels, etc. Another key difference between the autonomic and somatic nervous systems is that the autonomic nervous system uses two neurons between the CNS and target organ, while the somatic nervous system uses one neuron. Another system called the enteric nervous system innervates the visceral organs i.e. gastrointestinal tract, pancreas and gall bladder.

In the CNS, the collection of the neuron is called nuclei and the collection of the axon is called tracts. Whereas in the peripheral nervous system, the collection of the neuron is called ganglia and the collection of the axon is called nerves.

Table 1-2 Different types of the peripheral nervous system and their functions

Sr. No.	Types of Peripheral nervous system (PNS)	Functions
1	SNS (Somatic nervous system)	The nervous system controls the voluntary muscles (skeletal muscles). In other words, it controls the muscles that are under the control of the will of a person e.g. limbs
2	ANS (Autonomic nervous system)	The nervous system controls the involuntary muscles (smooth muscles and heart). In other words, it controls the muscles that are not under the control of the will of a person e.g. heart, uterus, bronchi, etc.
3	ENS (Enteric nervous system)	This is the local nervous system in the gastrointestinal tract. These monitor chemical changes within the GI tract, control stretching of its walls and control secretions from glands.

Coverings of the Central Nervous System (CNS)

The brain and spinal cord are protected by bones termed as cranium (cover brain) and vertebral column (surround spinal cord), respectively. The human cranium contains eight bones i.e. 1 frontal bone; 1 occipital bone; 2 parietal bones; 1 sphenoid bone; 2 temporal bones. Inner to the cranium and vertebral column, there are membranous coverings called meninges. The three protective membranes are **(Figure 1-2)**:

1. **Dura mater (Outer membrane):** It is the outermost layer of the meninges, which protects the brain and spinal cord. It is almost attached to the cranium.
2. **Arachnoid mater (Middle layer):** The arachnoid mater is the middle layer of the meninges, lying directly underneath the dura mater. There is a space between arachnoid and pia mater, which is termed as subarachnoid space and is filled with 'subarachnoid fluid'.
3. **Pia mater (Inner layer):** It is the innermost layer, which directly covers the brain and spinal cord.

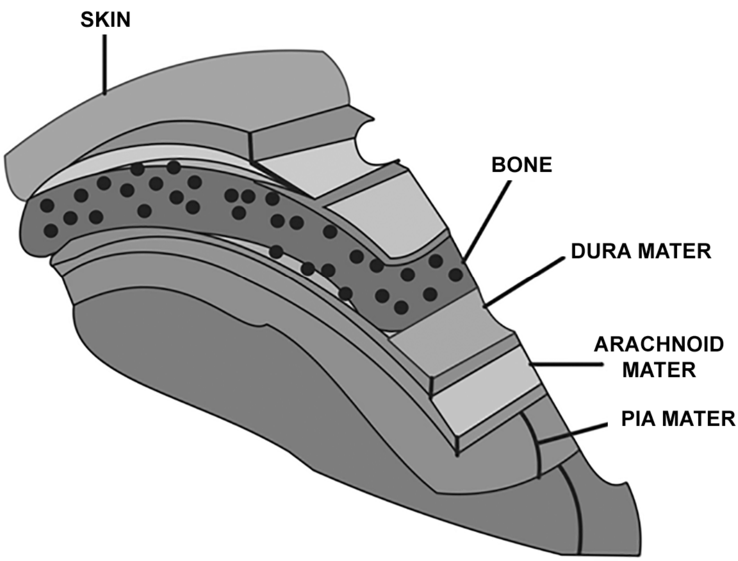


Figure 1-2 Protective coverings of the brain, including skin, a bony portion (cranium) and membranous coverings (meninges)

Neurons

Neurons are the basic functional units of the nervous system and are estimated to be as 100 billion in our nervous system. They generate electrical signals called action potentials, which assist them to rapidly transmit information over long distances. Neuron communicates with other cells in a unique way via specialized connections called synapses. Structurally, neuron consists of three parts a cell body, an axon and dendrites (**Figure 1-3**).

1. **Cell Body:** The cell body contains the nucleus, which serves as the control center of the cell. It is surrounded by the cytoplasm and it has typical cell organelles such as mitochondria, Golgi bodies, lysosomes, and extensive rough endoplasmic reticulum (ER). The rough ER has granular structures and these are referred to as Nissl bodies in neurons. These serve as a site of protein synthesis. Another important structure in the cytoplasm is the presence of neurofibril, which forms the cytoskeleton and provides support and shape to the cell. The cell body connects to the dendrites, which bring information to the neuron, and the axon, which sends information to other neurons.

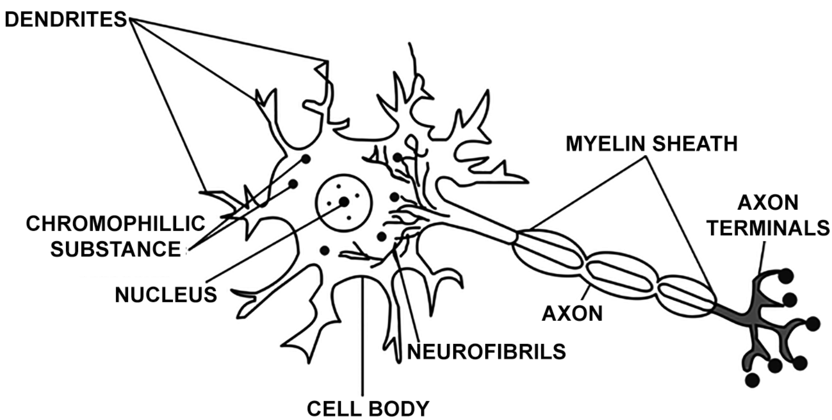


Figure 1-3 Structure of a Neuron

2. **Axon:** Usually, there is a single large branch of a neuron, which is termed as the axon and it is attached to the cell body at the axon hillock. The axon extends from the cell body and divided into many smaller branches (axon terminals) before ending at nerve terminals. The tips of the axon terminal swell into a bulb-like structure called synaptic end bulbs, which are filled with neurotransmitters. The cytoplasm of the axon is called axoplasm and is surrounded by the plasma membrane known as axolemma. The axoplasma also contain neurofibrils. Mostly, there is a single branch of axon; however, some branches may arise from the axon called axon collaterals (Figure 1-4). The main function of the axon is to transmit an electrochemical signal to other neurons.

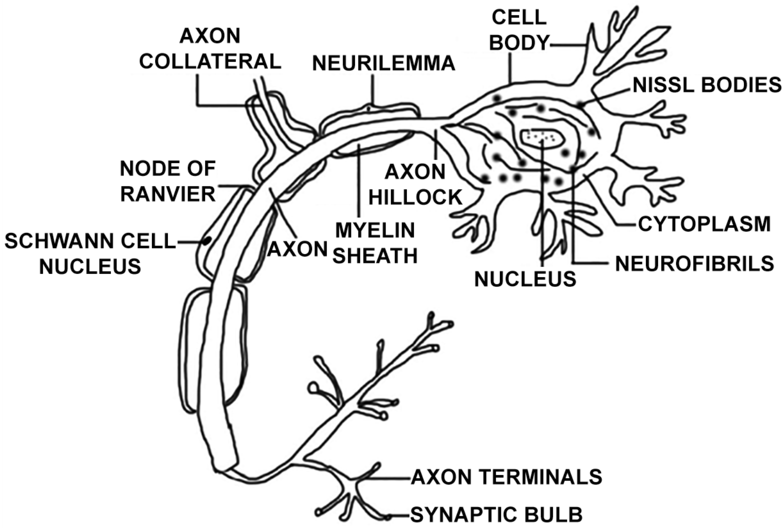


Figure 1-4 A detailed structure of a neuron

The longer axons are usually covered with a myelin sheath, which performs similar functions as insulation around an electrical wire. Moreover, due to the presence of myelin sheath, the speed of nerve conduction is increased. On the other hand, the nerve conduction velocity is significantly less in non-myelinated fibers (absence of myelin sheath). Myelin is a lipid-rich substance formed in the CNS by glial cells (oligodendrocytes) and in the peripheral nervous system by the Schwann cells **(Figure 1-5)**.

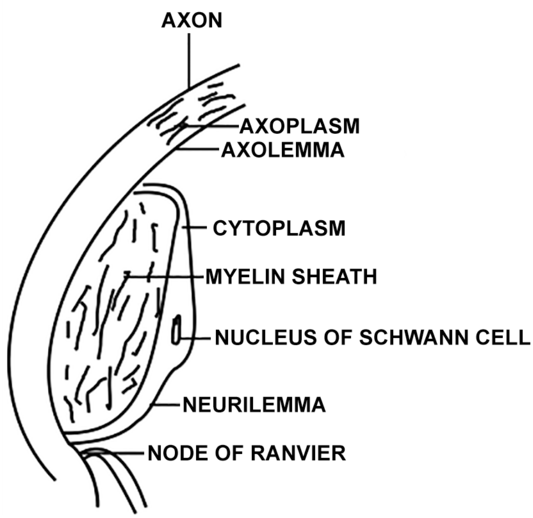


Figure 1-5 Magnified view of Schwann cells

The action potential propagation in myelinated neurons is much faster than in unmyelinated neurons due to saltatory conduction. In other words, there is the propagation of action potentials (by jumping) along the myelinated axons from one node of Ranvier to the next node of Ranvier. In unmyelinated neurons, action potential has to travel all along the axon; therefore, the conduction velocity of action potentials is relatively slow.

3. **Dendrites:** The neuron has a number of extensions called dendrites, which receive messages from other neurons. In other words, dendrites obtain information from surrounding neurons and convey to the cell body of its neurons. These are usually much smaller in length, not covered with myelin. In contrast to a single axon for a neuron, there are a number of dendrites connected to the cell body.

Table 1-3 Structural components of Neuron and its functions

Sr. No.	Structure	Function
1	Dendrites	These are branched, and provide a large surface area for receiving stimuli and passing impulses to the cell body
2	Chromatophillic substances (Nissil Body)	Layers of rough endoplasmic reticulum, whose function is protein synthesis
3	Neurofibrils	The filamentous strands of protein that support the cell body
4	Collateral branches (Axon Collaterals)	In some cases, there are extensions of the axon that may also transmit impulses
5	Axons	Conduct the impulse away from the cell body to another neuron or organ
6	Axon terminals	These enlargements at the ends of the branched axon; also contain synaptic vesicles that produce or secrete neurotransmitters into synapses
7	Microtubules	Minute channels that transport material within the cell

Table 1-4 Key differences between Axon and Dendrites

Sr. No.	Axons	Dendrites
1	Only one axon is present in a neuron	Usually multiple in number in a neuron
2	It carries nerve impulses away from the cell body	It carries nerve impulses to the cell body
3	Axon contains neurofibrils and no Nissl's granules.	Dendrites contain both neurofibrils and Nissl's granules

Table 1-4 *Contd...*

Sr. No.	Axons	Dendrites
4	Axon forms the efferent component of the impulse	Dendrites from the afferent component of the impulse
5	It is a thin, long process of uniform thickness and smooth surface	These are short, multiple processes, thickness diminishes as these divides repeatedly
6	The branches of the axon are fewer (axon collaterals) and at right angles to the axon.	The dendrites branch profusely and are present at different angles

Classification of Neurons

The neurons can be classified into two categories according to structure and function **(Table 1-5** and **Table 1-6)**.

Structural Classification

The neurons can be classified into three categories based on structure i.e. multipolar neurons, bipolar neurons, and unipolar neurons.

I. **Multipolar neurons:** These types of neurons have several dendrites and only one axon. The neurons of the brain and spinal cord come under this category.

II. **Bipolar neurons:** These types of neurons have one dendrite and one axon. These are found at the retina of the eye and olfactory area of the brain.

III. **Unipolar neurons (Pseudounipolar neuron):** In this neuron, only one process is attached to the cell body. These are the sensory neurons. Originally, they are developed as a bipolar neuron. However, during development, axons and dendrites fuse to form a single process.

Table 1-5 Structural classification of neuron

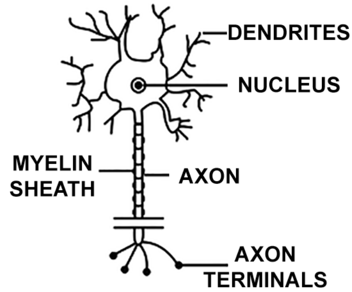
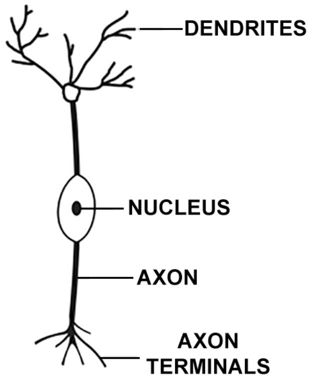
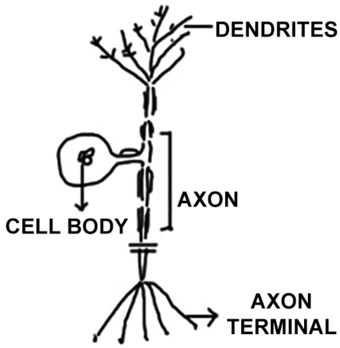
Sr. No.	Type of Neuron	Structure
1	Multipolar neurons (several dendrites and one axon)	

Table 1-5 *Contd...*

Sr. No.	Type of Neuron	Structure
2	Bipolar neurons (one dendrite and one axon)	
3	Unipolar neurons (only one process is attached to the cell body)	

Functional Classification

The neurons can be classified into three categories based on the direction of nerve impulse conduction i.e. afferent neurons, efferent neurons and interneurons **(Table 1-6).**

I. **Afferent neurons:** These neurons carry the signal from the periphery i.e. from the skin, muscles, joints, sense organs to the brain and spinal cord.

II. **Efferent neurons:** These neurons convey the motor nerve impulse from the CNS to peripheral organs. These can be subdivided into alpha or gamma motor neurons.

III. **Inter-neurons or association neurons:** These neurons carry nerve impulses from one neuron to another. Most neurons in the brain (90%) are association neurons.

Table 1-6 Structural classification of neuron

Sr. No.	Types of Neurons	
Based on structure		
1	Multipolar neurons	These have one axon, several dendrites
2	Bipolar neurons	These have one axon and one dendrite. Two cell processes are attached to the cell
3	Unipolar neurons	These have a single process attached to the cell body
Based on function		
1	Afferent neurons	Transmit nerve impulses from periphery to the spinal cord and brain
2	Efferent neurons	Conduct impulses away from the spinal cord or brain to peripheral organs
	Alpha motor neurons	Innervate and stimulates skeletal muscles
	Gamma motor neurons	Innervate specialized muscle tissue called muscle spindle
3	Association (Interneurons)	Conduct nerve impulses from one neuron to another neuron

Myelin sheath

Myelin sheath is a multilayered, lipid and protein covering that surrounds the axons. The nerve fibers that are surrounded by myelin sheath are called myelinated nerve fibers, while the nerve fibers that are not containing myelin sheath are called unmyelinated nerve fibers. Myelin sheath is produced by two types of neuroglia: neurolemmocytes and oligodendrocytes. In the peripheral nervous system, neurolemmocytes (Schwann cells) produce the myelin sheath. Structurally, the axon is surrounded by two layers: Inner layer which is made up of myelin sheath. It is a non-living deposition or covering; The Outer layer is a living layer that surrounds the inner layer. It contains the nucleus and cytoplasm of neurolemmocyte. This is also called neurolemma or sheath of Schwann **(Figure 1-6)**. When an axon is injured, the neurolemma helps in the regeneration of axon and myelin sheath. In the CNS, oligodendrocytes produce myelin sheath around the axons. In contrast to the peripheral nervous system, only the myelin sheath is present and neurolemma (living layer) is absent. If any injury takes place to the axon, then there is no regrowth after injury due to the absence of neurolemma. The amount of myelin increases from birth to maturity. The presence of myelin increases the speed of nerve impulse conduction. In the PNS, there are small gaps called nodes of Ranvier between segments of the sheath which are less in CNS **(Table 1-7)**.

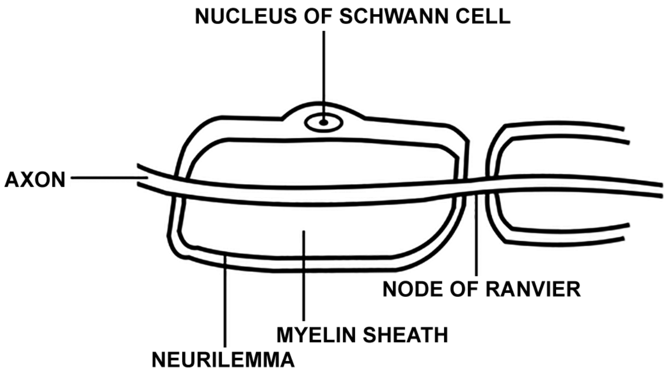


Figure 1-6 Typical structure of axon, myelin sheath, and nucleus of Schwann cell

Table 1-7 Key differences between myelin in CNS and PNS

Sr. No.	Myelin in CNS	Myelin in PNS
1	Formed by oligodendrocytes	Formed by Schwann cells
2	Neurolemma (living layer) is absent	Neurolemma is present
3	Fewer nodes of Ranvier	More nodes of Ranvier
4	Less regeneration after injury due to absence of neurolemma	More rapid regeneration after injury due to presence of neurolemma

Neuroglia

Neuroglia is also called glia or glial cells. These are the specialized cells of the nervous system. These physically and physiologically support, nourish, and protect the neurons and maintain homeostasis in the interstitial fluid. These are about half of the volume of CNS; smaller than neurons in size; but 5-50 times more in number. These cells can divide and multiply, but cannot propagate action potential. During an injury, these cells fill up space and help in healing. The neuroglial cells of the CNS include astrocytes, oligodendrocytes, microglial cells and ependymal cells **(Tables 1-8 and 1-9)**. In the PNS, two types of neuroglial cells are found i.e. neurolemmocytes (Schwann cells) and satellite cells.

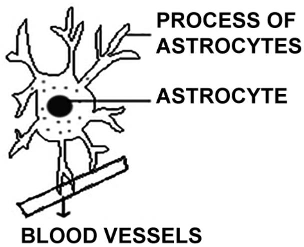
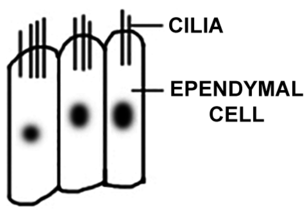
1. **Astrocytes (Astro-star; cytes-cell):** These are the cells, which are having a star-like structure and have many processes. These cells help in the metabolism of neurotransmitters, maintain the proper concentration of K+ ions, help in brain development, help in the formation of the blood-brain barrier, provides a link between neurons and blood vessels and regulates the entry of substances into the brain.

Table 1-8 The different types of neuroglia and its functions

Sr. No.	Types	Function
Neuroglia in the central nervous system		
1	Astrocytes	Star-shaped structure, largest, most numerous, many processes, forms structural support between capillaries and neurons within the CNS. These contribute to the blood-brain barrier (BBB) formation
	Protoplasmic astrocytes	Present in the gray matter; have short branches
	Fibrous astrocytes	Present in white matter; have long branches
2	Oligodendrocytes	Smaller, similar to astrocytes, fewer processes; form myelin sheath (multilayered protein and lipid layer) in CNS; guide development of neurons within the CNS
3	Microglia	Small, numerous spine-like projections, phagocytize pathogens and cellular debris within CNS
4	Ependymal cells	Cuboidal-columnar cells, line ventricles of the brain and central canal of the spinal cord; form CSF; form blood-CSF
Neuroglia in the peripheral nervous system		
5	Schwann cells	Forms myelin sheath, participate in axonal regeneration (more easily in PNS than CNS). Support ganglia within PNS
6	Satellite cells	Forms myelin within PNS; surround cells of PNS ganglia; regulate the exchange of material between neurons and interstitial fluid

2. **Oligodendrocytes: (Oligo-few; dendro-processes):** They are smaller in size as compared to astrocytes and also have few processes. They provide supports to neurons and produce myelin sheath.
3. **Microglial cells: (Micro-small; glia-adhere):** These are small phagocytic cells that are present in central nervous system. They protect by engulfing microorganism that enters the central nervous system.
4. **Ependymal cells:** They line the brain ventricles and they help in the formation of cerebrospinal fluid. The shape of ependymal cells varies. It can be ciliated squamous or columnar epithelial cells.
5. **Neurolemmocytes or Schwann cells:** These produce cells the myelin sheath and regulate the exchange of material between neurons and interstitial fluid.
6. **Satellite cells**: These cells provide supports to neurons present in ganglia.

Table 1-9 Structures of astrocytes, dendrites, and ependymal cells

Sr. No.	Neuroglia	Shape
1	Astrocytes (Star-shaped, many processes)	
2	Oligodendrocytes (Few processes attached to cell)	
3	Ependymal Cells	

Membrane Potential

There are various terms concerning voltage changes across the plasma membrane that need to be understood. These include the following:

1. **Resting membrane potential:** In the resting neuron, a resting membrane potential (potential difference) exists across the cell membrane. In other words, there is a potential difference across the cell membrane even in the resting state. This potential difference is due to the imbalance of charged particles across the cell membrane i.e. between the extracellular and intracellular fluids. Therefore, a cell membrane is said to be polarized (separation of charges). In the resting state, there is a net negative charge inside the cell (intracellular space) in comparison to the outside (extracellular space) (Figure 1-7).

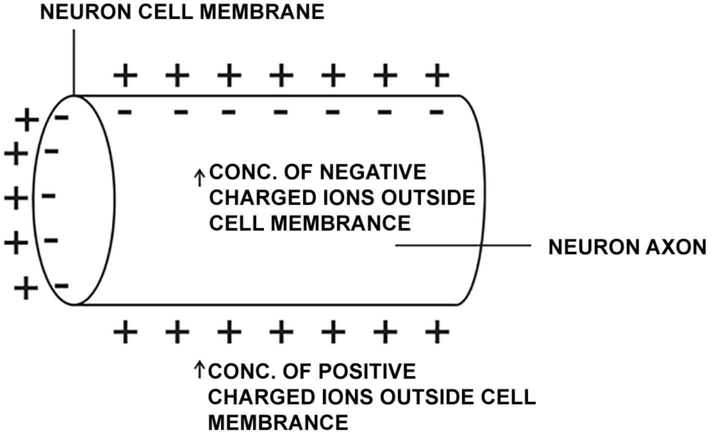


Figure 1-7 A segment of a neuron showing the separation of anions and cations across the cell membrane, leading to the development of net negative membrane potential (in the resting state) inside the cell.

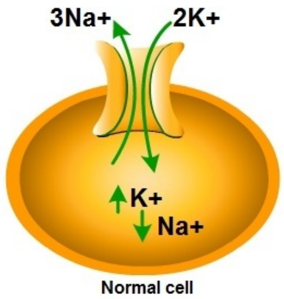


Figure 1-8 Normal functioning of Na+-K+ ATPase pump to pump three sodium outside the cell and pump two potassium ions inside the cells, leading to the development of resting membrane potential.

The resting membrane potential is around -70 to -80 MV (inside negative). The presence of a sodium-potassium pump (Na+-K+ ATPase pump) helps in maintaining the resting membrane potential. Indeed, this pump uses ATP (energy) to actively transport three sodium ions (Na+) ions from inside the cell to the outside. In return, two potassium ions (K+) are transported inside the cell from the outside **(Figure 1-8).** The net result is the movement of one extra positive ion outside the cell in each cycle and the continuation of this process leads to an accumulation of negative charge inside the cells.

2. **Action potential:** A rapid change in the membrane potential is termed as an action potential. In the resting state, the membrane potential is negative and in response to a stimulus, there is a rapid change in the membrane potential from negative to positive. Action potential comprises of depolarization

followed by repolarization (discussed below). An important point is that the events of depolarization and repolarization occur very rapidly **(Figure 1-9)**.

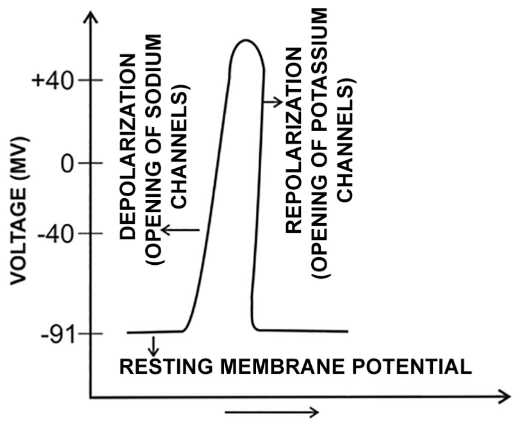


Figure 1-9 A Representation of action potential comprising of depolarization and repolarization

The action potential is a way of passing nerve impulses from one point to another point. In other words, the traveling disturbance in membrane potential is called the action potential. The following sequences are associated with action potential:

1. **Depolarization:** During depolarization, the membrane potential tends to increase and becomes less negative/zero or even positive. Depolarization means loss of the state of polarization, which occurs in a resting state. Actually, in response to a stimulus, there is the opening of fast operating, voltage-gated sodium channels, which allows the rapid movement of sodium ions from outside (present in excessive amount) to inside the cell (present in lesser amount). The net movement of positive sodium ions is responsible for the increase in membrane potential. This state ends with the closure of sodium channels, which are closed due to the development of positive membrane potential inside the cell (Figure 1-10).
2. **Repolarization:** Depolarization is rapidly followed by repolarization in which the membrane potential again becomes decreases from positive to negative. When the membrane potential becomes positive, there is a closure of sodium channels (discussed above) and the opening of voltage-gated potassium channels. This opening leads to the rapid movement of potassium ions from inside the cells (present in excessive amounts) to the outside (present in lower amount). The outward movement of positive ions decreases the membrane potential and inside membrane potential again becomes negative **(Figure 1-10)**.

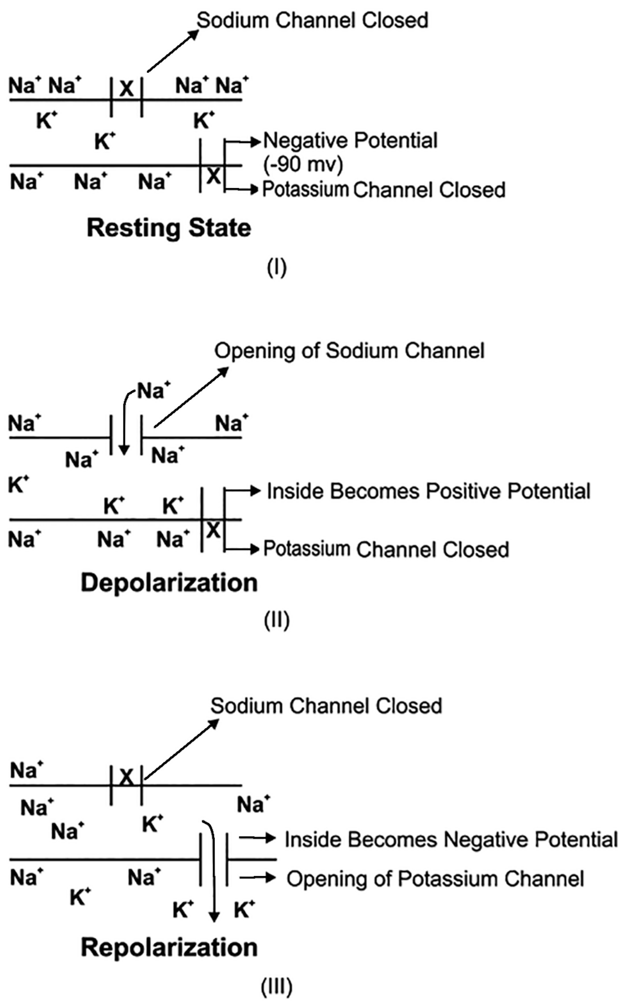


Figure 1-10 Schematic representation of events taking place in resting state (I), during depolarization (II) and repolarization (III)

A synapse is a specialized junction through which impulse passes from one neuron to another and the process of passage of impulses is termed as synaptic neurotransmission. In the nervous system, a synapse is formed between axon terminals of one neuron and dendrites of another neuron. Therefore, the impulse is passed from axon terminals (one neuron) to dendrites (another neuron) as synaptic neurotransmission **(Figure 1-11).** A typical synapse comprises of presynaptic membrane of axon terminal, synaptic/neural cleft (space) and postsynaptic membrane of the dendrite. An important point of the presynaptic and postsynaptic membrane is that these are expanded in the synaptic region to increase the surface area. Inside the presynaptic membrane, there are several synaptic vesicles, which store chemical messengers termed as neurotransmitters. On the other hand, there are specific receptors (depending on the type of neurotransmitter released) present on the postsynaptic membrane. The different steps involved in synaptic neurotransmission are as follows:

1. An action potential spreads over the axon terminal and depolarizes the presynaptic membrane
2. Depolarization of the presynaptic membrane is associated with an influx of calcium ions. The increase in calcium ions causes the movement of synaptic vesicles towards the presynaptic membrane. It is followed by the fusion of vesicles with the presynaptic membrane
3. It leads to release of neurotransmitters from the synaptic vesicles by exocytosis into the synaptic (neural) cleft
4. The neurotransmitter diffuses across the synaptic cleft to the postsynaptic membrane and binds to the specific receptor present on the postsynaptic membrane
5. The binding of the neurotransmitter to receptors leads to initiation of nerve impulse on the second neuron
6. The neurotransmitter is removed from the synapse by different methods including its enzymatic degradation or reuptake by a pump present on the presynaptic terminals

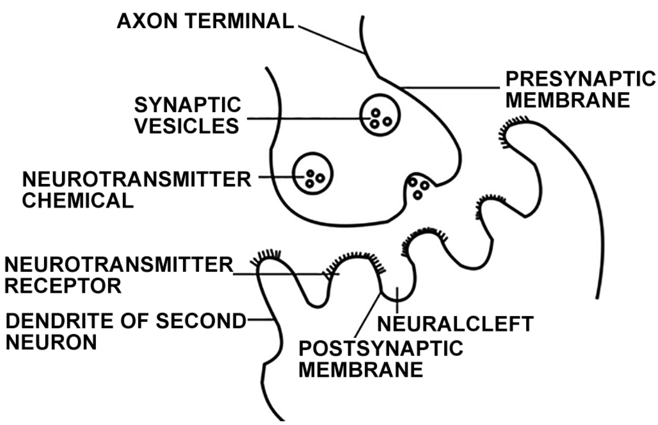


Figure 1-11 Schematic of synapse and synaptic transmission

Neurotransmitters

These are the chemicals that are normally stored inside the synaptic vesicles and released in the synaptic cleft to bind with receptors on the postsynaptic membrane to trigger the action potential. These are of various types depending on their chemical nature and functions performed. The common examples of neurotransmitters include acetylcholine, adrenaline, noradrenaline, dopamine, glutamate, histamine, serotonin (5-HT), GABA (gamma-aminobutyric acid) and bradykinin, etc. All these neurotransmitters perform different functions by activating on their specific receptors **(Table 1-10).** Based on their functions, neurotransmitters may be excitatory or inhibitory.

1. Excitatory neurotransmitters are those that produce excitation on the postsynaptic membrane. These act on the postsynaptic membrane and initiate the generation of excitatory postsynaptic potential (EPSP). Generally, there is the opening of sodium channels on the postsynaptic membrane after the binding of receptors with neurotransmitters. Examples of this type include glutamate.
2. Inhibitory neurotransmitters are those that produce inhibition on the postsynaptic membrane. These act on the postsynaptic membrane and initiate the generation of inhibitory postsynaptic potential (IPSP). Generally, there is an opening of chloride ion channels on the postsynaptic membrane after the binding of receptors with neurotransmitters. Examples of this type include GABA.

Table 1-10 Name of common neurotransmitters and their receptors

Sr. No.	Name of Neurotransmitters	Receptors
1	Acetylcholine	Muscarinic (M) and nicotinic (N) receptors
2	Adrenaline, noradrenaline	Alpha and beta receptors
3	Glutamate	NMDA and AMPA receptors
4	Dopamine	Dopamine (D) receptors
5	Histamine	Histamine (H) receptors

Receptors

Receptors are the molecules, mostly protein in nature, which receive the signals from the neurotransmitters or drugs and convert the signals into a biological response. In other words, neurotransmitters or drugs produce their effects on different tissues/organs by binding to their specific receptors. The agents that bind specifically to a receptor are termed as ligands. Receptors are located either on the plasma membrane or these are present inside the cells i.e. in the cytoplasm or nucleus **(Table 1-11)**.

1. **Receptors Present on Plasma Membrane:** Most of the receptors are located on the cell surface i.e. on the plasma membrane. The ligands for these receptors are generally hydrophilic (water-soluble). Examples: muscarinic receptors, nicotinic receptors, alpha receptors, beta receptors, dopamine receptors, etc.
2. **Intracellular Located Receptors located intracellularly:** Sometimes, receptors are located inside the cells i.e. in the cytoplasm. The ligands for these receptors are generally lipophilic. These ligands cross the plasma membrane and bind with cytoplasmic receptors. The ligand and receptor

complex moves to the nucleus and binds to specific DNA elements, termed as 'Response Elements'. Examples of such receptors include glucocorticoid receptors, mineralocorticoid receptors, thyroid receptors, estrogen receptors, testosterone receptors, and progesterone receptors.

Table 1-11 Name of common neurotransmitters and their receptors

Sr. No.	Cell Surface Receptors	Intracellular Receptors
1	Receptors are present on the cell surface	Receptors are located inside the cytoplasm
2	The ligands are hydrophilic	The ligands are lipophilic and cross the cell membrane to bind with cytoplasmic receptors
3	The response produced due to binding of the ligand with these receptors is generally quick	The response produced due to binding of the ligand with these receptors is generally slow
4	There is no alteration in transcription and protein synthesis	The binding of ligands with these receptors alters transcription and protein synthesis.
5	The examples of these receptors include: muscarinic receptors, nicotinic receptors, alpha receptors, beta receptors, dopamine receptors	The examples of these receptors include: glucocorticoid receptors, mineralocorticoid receptors, thyroid receptors, estrogen receptors, testosterone receptors, and progesterone receptors

Ligands

Receptors are very specific i.e. specific ligands can bind to specific receptors. The ligands can further be of different types, depending on whether they activate the receptors or they inhibit the receptors **(Table 1-12)**.

1. **Agonist:** It is a ligand that binds to the receptors and produces a biological response by inducing its activation. For example, acetylcholine is an agonist of muscarinic and nicotinic receptors; adrenaline and noradrenaline are agonists are alpha and beta receptors.
2. **Antagonist:** It is a ligand that binds to the receptor and prevents the actions of an agonist by inhibiting the binding of agonist to the receptor. In other words, antagonist inhibits the receptors and prevents agonist-induced activation of receptors. For example; atropine is an antagonist of muscarinic receptors and inhibits the actions of acetylcholine; beta receptor blockers inhibit beta receptors and inhibit the actions of adrenaline and noradrenaline.

Table 1-12 Types of ligands, depending on their ability to activate or inhibit the receptors

Sr. No.	Agonist	Antagonist
1	It binds to receptors and induces its activation	It binds to receptors but does not induce activation
2	It produces a biological response	It prevents the biological response of an agonist
3	Examples include acetylcholine as an agonist of muscarinic and nicotinic receptors; adrenaline and noradrenaline as agonists of alpha and beta receptors	Example include atropine as an antagonist of muscarinic receptors

1.2 Chapter at a Glance

Term	Description
Synapses	Specialized connections for communication
Sensory function	Information is conveyed from periphery to brain
Motor function	Information is conveyed from brain to periphery
ANS	Autonomic nervous system
ENS	Enteric nervous system
SNS	Somatic nervous system
Multipolar neurons	Neurons with several dendrites and only one axon.
Bipolar neurons:	Neurons with one dendrite and one axon
Ependymal cells	Line brain ventricles and forms the cerebrospinal fluid
Microglial cells	Small phagocytic cells
Action potential	A rapid change in the membrane potential
Neurotransmitters	Chemicals released in the synaptic cleft to trigger the action potential
EPSP	Excitatory postsynaptic potential
IPSP	Inhibitory postsynaptic potential
GABA	Gamma-aminobutyric acid
Agonist	The ligand binds to the receptors and produces a biological response
Antagonist	The ligand binds to a receptor and prevents actions of agonist

EXERCISES

Exercises

Multiple Choice Questions

1. Nervous system manly consists of
   (a) Spinal cord (b) Nerves
   (c) Brain (d) All of the above
2. A unit of Nervous system is
   (a) Spinal cord (b) Neuron
   (c) Brain (d) Nerves
3. Multipolar neurons have
   (a) Several dendrites and one axon
   (b) One dendrites and one axon
   (c) Only one process is attached to the cell body
   (d) None
4. Bipolar neurons have
   (a) Several dendrites and one axon
   (b) One dendrites and one axon
   (c) Only one process is attached to the cell body
   (d) None
5. Afferent neurons transmit nerve impulses from
   (a) From periphery to the spinal cord and brain
   (b) From spinal cord to periphery
   (c) Both a and b
   (d) None of the above
6. Which of the following neuroglial cell is not found in the CNS?
   (a) Astrocytes (b) Oligodendrocytes
   (c) Microglial cells (d) Neurolemmocytes
7. Which of the following neuroglial cells are found in the PNS?
   (a) Schwann cells (b) Satellite cells
   (c) Both a and b (d) None
8. Which of the following is not a feature of Myelin in CNS?
   (a) Formed by oligodendrocytes
   (b) Neurolemma is present
   (c) Fewer nodes of Ranvier
   (d) Less regeneration after injury
9. Efferent neurons
   (a) Conduct impulses away from the spinal cord or brain to peripheral organs
   (b) Conduct impulses to spinal cord or brain from peripheral organs
   (c) Both a and b
   (d) None of the above

10. Neuron communicates with other cells uniquely via specialized connections called
    (a) Neurofibril (b) Neurolemma
    (c) Synapses (d) None of the above

Short Answer Questions

1. Classify the nervous system..
2. What are the functions of the nervous system?
3. What are the coverings of the central nervous system?
4. Write about different types of the peripheral nervous system and their functions.
5. What are the different types of nerve cells?
6. What is an action potential?
7. Define the cell body, axon, and dendrites.
8. Define synapse.
9. What is the myelin sheath?
10. What are astrocytes?
11. What are Schwann cells?
12. What are oligodendrocytes?
13. What do you mean by depolarization and repolarization?
14. What is the resting membrane potential?
15. What are neurotransmitters?

Long Answer Questions

1. Explain the structural component of the neuron and its functions.
2. Explain the different types of neuroglial cell and their functions.
3. Write a note on action potential with all events taking placing during an action potential.
4. Write a note on synapse and synaptic transmission.
5. Write a note on the myelin sheath
6. Explain the differences between axons and dendrites.
7. Write the differences between myelin in CNS and PNS.
8. Write about common neurotransmitters and their receptors.
9. Write about depolarization and repolarization.
10. What are unipolar, multipolar and bipolar neurons?

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Answer Key MCQs

1. (d)	2. (b)	3. (a)	4. (b)	5. (a)
6. (d)	7. (c)	8. (b)	9. (a)	10. (c)