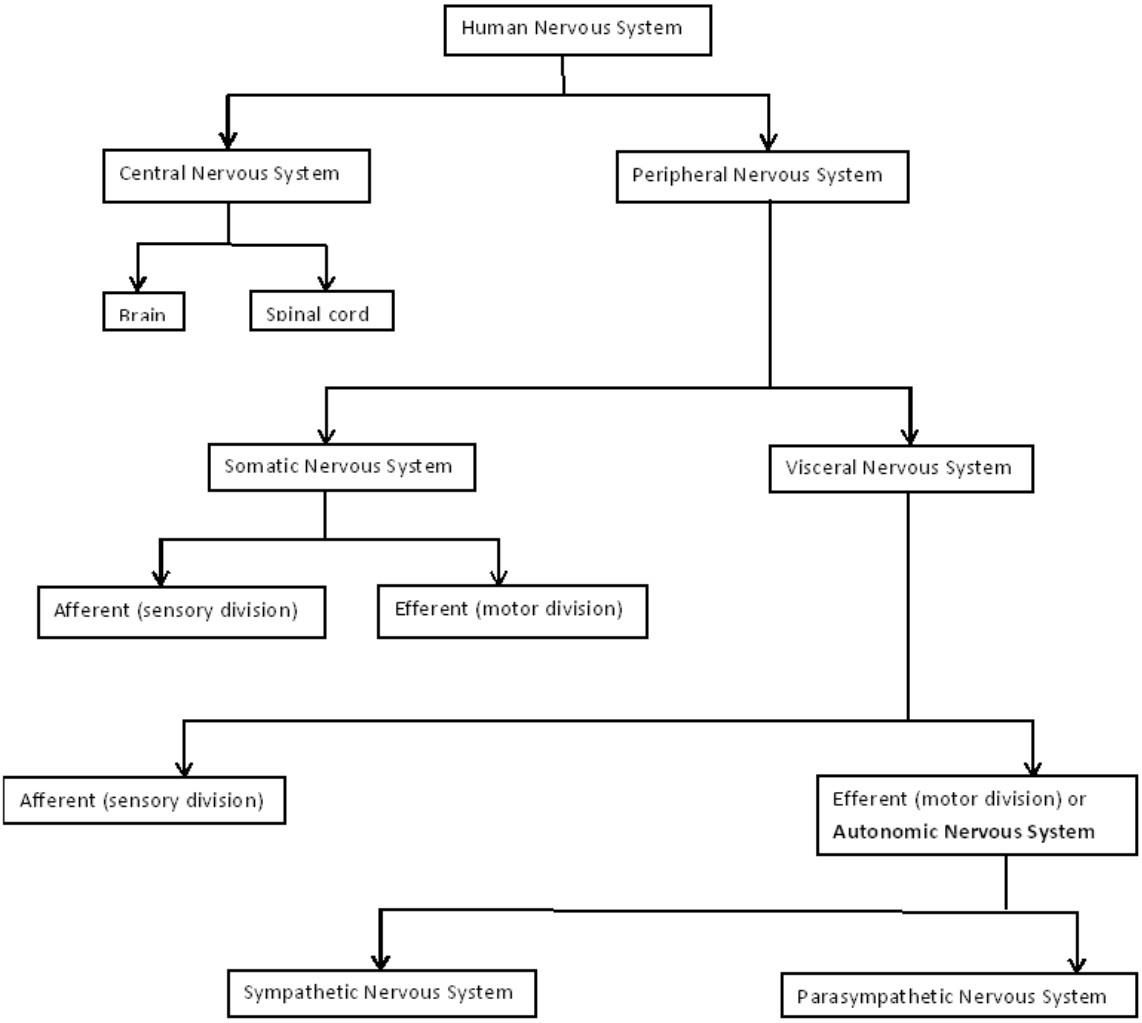
UNIT 1

ORGANIZATION OF NERVOUS SYSTEM



Central nervous system (CNS)

- It is the body's central controlling system and consists of the brain and the spinal cord.
- They are surrounded and protected by the skull and vertebral column respectively.
- It receives and interprets or integrates all stimuli and relays nerve impulses to muscles and glands, where the designated actions usually occur.

Peripheral nervous system (PNS):

- It consists of nerves and their fibers emerging from and going to the brain (cranial nerves) and spinal cord (spinal nerves).

- This system allows the brain and the spinal cord to communicate with the rest of the body.
- In terms of function, two types of nerve cells are present in the peripheral nervous system:
    - **Afferent or sensory nerves:** carry nerve impulses from sensory receptors in the body to the CNS.
    - **Efferent or motor nerves:** convey information away from the CNS to the effector organs (muscles and glands).

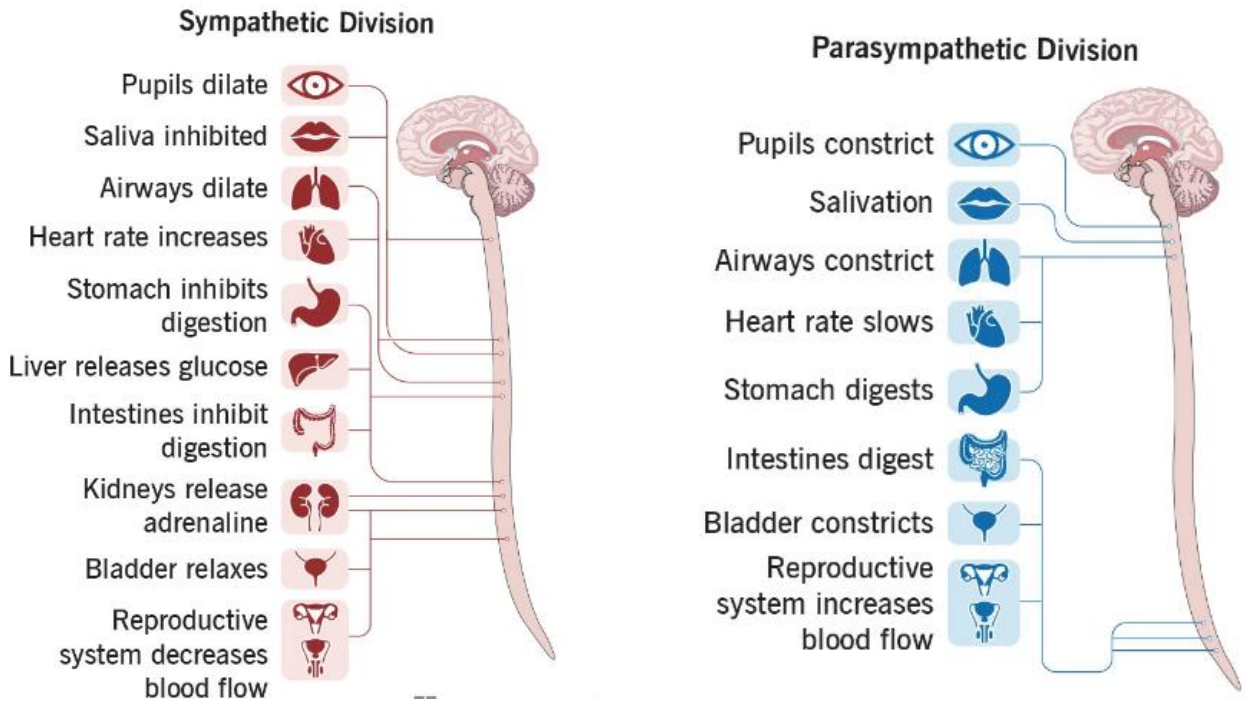
PNS is divided on a purely functional basis into the **somatic nervous system** and the **visceral nervous system.**

Somatic nervous system is further composed of afferent and efferent divisions.

1. **Somatic afferent (sensory) division**: consists of nerve cells that receive and process sensory input from the superficial organs like skin, skeletal muscles, tendons, joints, eyes, tongue, nose and ears and the input is conveyed to the spinal cord.
2. **Somatic efferent (motor) division**: consists of neuronal pathways that descend from the brain through the brain stem and spinal cord to influence the lower motor neurons of some cranial and spinal nerves. They always excite (never inhibit) the skeletal muscles to contract, i.e. regulates the voluntary contraction of skeletal muscles.
3. **Visceral nervous system** is also composed of afferent and efferent divisions.
    I. **Visceral afferent (sensory) division:** includes the neural structures involved in conveying sensory information from sensory receptors in the **visceral organs** (internal large body organs lying in the great body cavities) of the cardiovascular, respiratory, digestive, urinary and reproductive systems.
    II. **Visceral efferent (motor) division:** It is commonly known as **autonomous or autonomic nervous system (ANS)** and includes the neural structures involved in the motor activities that influence smooth muscles, cardiac muscles, and glands of the skin and viscera.

Autonomic nervous system is further divided into two sub-divisions:

a. **Sympathetic nervous system**
b. **Parasympathetic nervous system**



Autonomic nervous system

autonomic nervous system is a part of your overall nervous system that controls the automatic functions of your body that you need to survive.

Sympathetic

The sympathetic division of the autonomic nervous system influences the various organ systems of the body through connections emerging from the thoracic and upper lumbar spinal cord. It is referred to as the **thoracolumbar system** to reflect this anatomical basis.

Parasympathetic

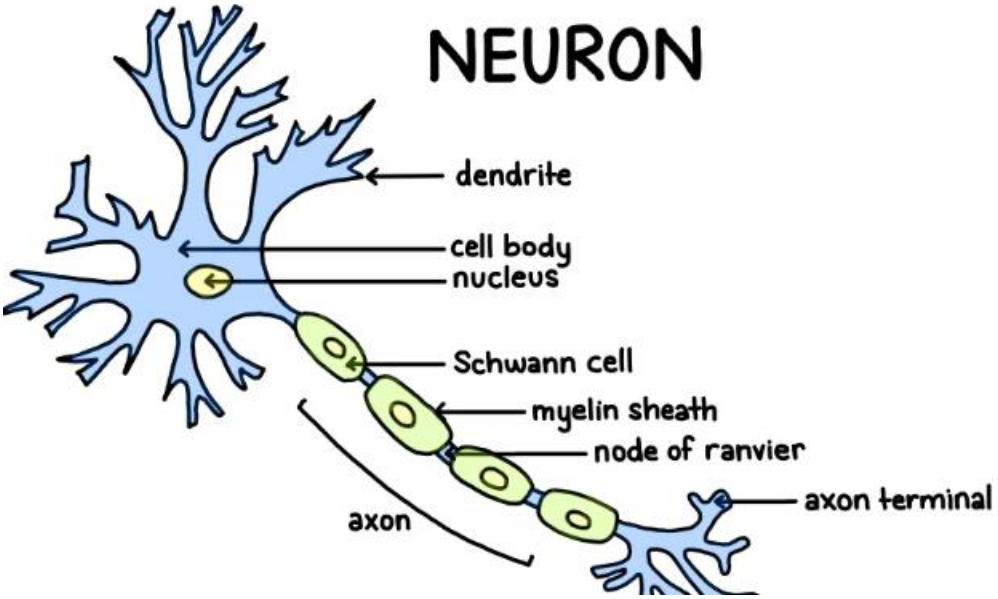
The parasympathetic division of the autonomic nervous system is named because its central neurons are located on either side of the thoracolumbar region of the spinal cord (*para–* = "beside" or "near"). The parasympathetic system can also be referred to as the **craniosacral system** (or outflow) because the preganglionic neurons are located in nuclei of the brain stem and the lateral horn of the sacral spinal cord.

The nervous system commands muscles, controls the functioning of all organs and provides information about the outside world through sensory information.

NEURON AND NEUROGLIA

Neuron:

- About 100 billions of neurons are present in nervous system.
- They are Specialised type of cell, they vary in shape and size, all neurons contains three principle parts- **cell body, dendrites and an axon**



Cell body

- Has a large nucleus, which contain prominent nucleolus, as well as other several structures (Nissl bodies, ER,lysosome, mitochondria, neuroflament), responsible for metabolism, growth and repair of neuron
- **Nissl bodies-** made up of RNA, RER and free ribosome, help in protein synthesis
- **Neurofilament and neurotubules** are thread like protein, runs parallel to long process
- **Neurofilament-** semisolid structure that provide skeletal framework to axon
- **Neurotubules-** transport intracellular proteins between cell body and the processes

Dendrites-

- Many thread cytoplasmic extension arises from cell body called dendrites
- It conducts nerve impulse toward the cell body
- They are myelinated and have Nissl's granule and neurofibril

Axon-

- Usually one of the cytoplasmic extension is long and unbranched called axon.

- It is covered by lipid sheath called **myelin sheath**
- **Myelin sheath** is formed by specialized non-neural cell called **schwann cell (neurolemmocytes)** in **PNS** and by **Oligodendrocytes** in **CNS**. The outer sheath of these cell is known as **neurolemma**
- It conduct nerve impulse away from cell body
- It lacks nissl's granules

Types of neuron:

I. Types of neuron based on structure-

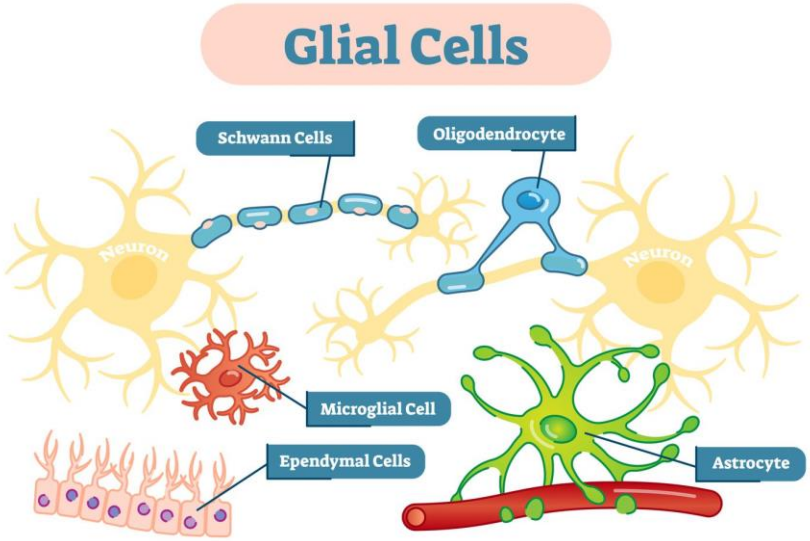
1. **Unipolar-** have single processes, very common sensory neuron in PNS,
2. **Bipolar-** two processes- a dendrires and an axon, eg. Retina, cochlea, smell receptor
3. Multi polar-many processes- many dendrites but one axon eg. Brain and spinal cord

II. Types of neuron based on function-

1. **General somatic afferent (sensory)-** carry sensory impulse from skin, skeletal muscles, joints and connective tissue to CNS
2. **General visceral afferent-** impulse from visceral organ to CNS
3. **General somatic efferent(motor)-** CNS to skeletal muscles
4. **General visceral efferent-** CNS to visceral organs
5. **Special visceral efferent-** brain to muscles of jaws, pharynx, facial expression, larynx
6. **Special afferent-** receptor cell (olfactory, optics, auditory, vestibule, gustation) to CNS

2. Neuroglia

- **Glial cells** are non conducting cells that protect and nurture as well as support cells of nervous tissue.
- There are **4 types** of neuroglia cells



i) Astrocytes–

- largest,most numerous glial cell, with long star like processes, help form the blood –brain barrier.
- **Function:** structural support, transport of substance between blood vessels and neurons, mop up excess ions (k) and neurotransmitters.

ii) Oligodendrocytes-

- relatively small, with several branching processes,found in grey and white matter of CNS,
- **function**: produce myelin sheath

iii) Microglial cell–

- smallest glial cell, cuboidal or columnar shaped, it is a macrophage, engulf damaged neuron

iv) Ependymal cell-

- elongated cell, arranged in single layer in inner lining of spinal cord and ventricle of brain.

CLASSIFICATION AND PROPERTIES OF NERVE FIBER

On the Basis of Conducting Velocity and Diameter Relation

On the basis of the mutual relation between the diameter of a nerve fibre and its nerve conduction velocity, the nerve fibres into three major groups: group A, group B and group C.

- **Group A Nerve Fibres:** Group A nerve fibres are heavily myelinated nerve fibres that are further subdivided into four types: alpha Aα; beta Aβ; gamma Aγ; and delta Aδ. The fibres with larger diameters and more myelination tend to transmit the impulses at a faster rate.
- **Group B Nerve Fibres:** Group B nerve fibres are less myelinated than group A, but more myelinated than group C nerve fibres. They include visceral nerves such as the vagus nerve.
- **Group C Nerve Fibres:** Group C nerve fibres are unmyelinated fibres that usually have a smaller diameter and low conduction velocity.

Fibre Type	Subtype	Radius (μm)	Conductance velocity (m/s)
A	Aα	12-20	70-120
	Aβ	5-12	30-70
	Aγ	3-6	15-30
	Aδ	2-5	12-30
B		<3	3-15
C	Dorsal horns	0.5-2	0.5-2
	Sympathetic	0.7-2.3	0.7-2.3

On the Basis of Presence of Myelin Sheath

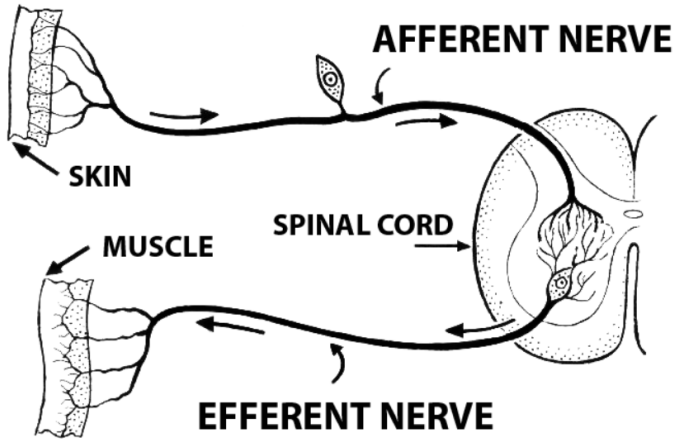
There are both myelinated and unmyelinated nerve fibres in the nervous system. Both the types of nerve fibres differ in their relative composition. Let us look at them.

- **Myelinated Nerve Fibres:** Myelinated nerve fibres are covered by a layer of insulating sheet called myelin sheath. In the peripheral nervous system, the myelin sheath is formed by the Schwann cells whereas in the central nervous system, the myelin sheaths are formed by the oligodendrocytes.
- **Non Myelinated Nerve Fibres:** Nonmyelinated nerve fibres are covered by cytoplasm of Schwann cells but the myelin is not secreted in such cases. They are commonly found in the autonomic nervous system.

On the Basis of Functional Relation to the Central Nervous System

On the basis of functional relation to the central nervous system, the nerve fibres are divided into afferent and efferent fibres. Let us look at them separately.

- **Afferent Nerve Fibres:** The peripheral nerve fibres receive impulses from different receptors of the body and transmits them to the central nervous system, these types of fibres are called afferent nerve fibres. These fibres are pseudounipolar in nature.
- **Efferent Nerve Fibres:** The fibres that carry nerve impulses away from the central nervous system to other effector organs such as glands and muscles are called efferent nerve fibres. Morphologically, they are multipolar in nature.



PROPERTIES OF NERVE FIBER

i. Excitability:

- When a stimulus is applied, the nerve fiber demonstrates a change in its electrical activity from its resting state.

ii. Conductivity:

- It is the ability of the nerve fiber to transmit impulses all along the whole length of axon without any change in the amplitude of the action potential. This type of conduction is termed as decrementless conduction.

iii. Refractory period (Fig. 2.13):

- It is the duration after an effective stimulus, when a second stimulus is applied, there will be no response for the second stimulus.

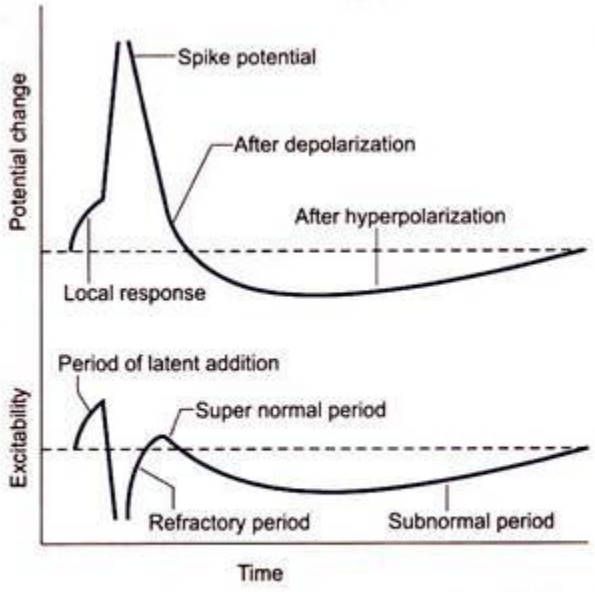


Fig. 2.13: Excitability of the nerve fiber during absolute and relative refractory periods

- a. From the time of the application of the stimulus till the initial one-third of the repolarization phase, the nerve fiber excitability will be zero and is completely refractory for the second stimulus. This duration is known as absolute refractory period.
- b. Relative refractory period is the duration after an effective stimulus, when a second stimulus, which is slightly above threshold, is applied there will be response for the second stimulus as well.

iv. All or none law:

- It states that, when the tissue is stimulated with threshold or more than threshold strength, the amplitude of response will remain the same but for a stimulus of less than threshold strength, there will not be any response.

All or none is obeyed by:

a. A single nerve fiber.

b. A single skeletal muscle fiber.

c. A motor unit.

d. Whole of cardiac muscle.

ELECTROPHYSIOLOGY AND NERVE IMPULSE CONDUCTION

- The intracellular and extracellular fluid in the nervous system contains many charged ions like Na+, K+, Ca++, Cl- etc.
- The presence of these ions imparts an electric potential inside the cell and outside the cell.
- Membrane Potential (Transmembrane Potential, Membrane Voltage) is the difference of voltage between inside the cell membrane and outside the cell membrane.
- The resting membrane potential is -70mv.
- Nerve impulse (Action Potential) is generated by a change in ion concentrations across the cell membrane.

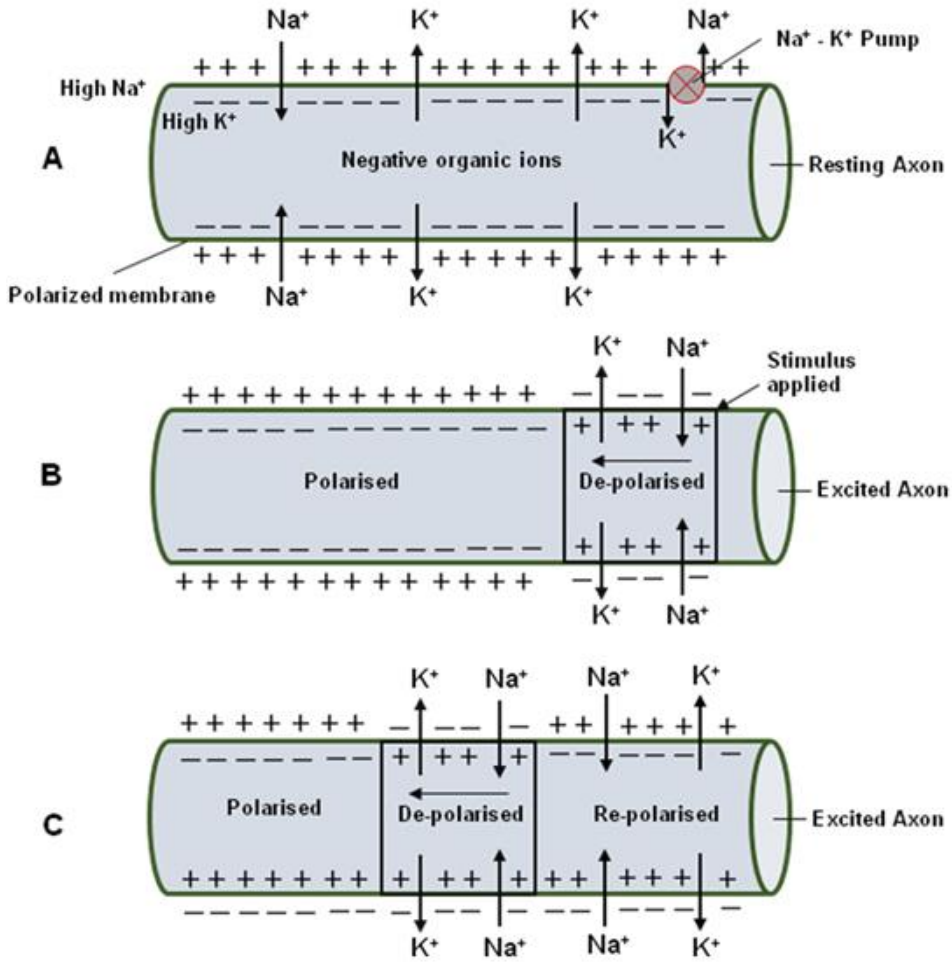
Nerve impulse: Nerve impulse is an overall physiological changes that occur in a neuron due mechanical, chemical or electrical disturbance created by a stimulus. It propagation through axon, synapse and neuromuscular junction is called Nerve Impulse conduction.

Nerve Impulse transmission along Neuron or Action Potential

Transmission of nerve impulse along nerve fibre can be summarized in three steps

1. Polarization (Resting Potential)
2. Depolarization (Action Potential)

3. Repolarization



Polarization (Resting potetential):

- A neuron at resting is electrically charged but not conducting.
- The Axoplasm or plasma membrane of a resting neuron is negatively charged as compared to the interstitial fluid.
- The potential difference measured at this stage is called **resting potential** which is about **-70mV**. The interstitial fluid has high concentration of Na+ ion which is about 16 times higher outside the neuron than inside neuron. Similarly, the axoplasm has high concentration of K+ ion which is about 25 times higher inside than in outer interstitial fluids.
- Due to difference in concentration of ions, Na+ ion tends to diffuse into the axoplasm and K+ ion tends to diffuse outside the axoplasm.

- The membrane of neuron at resting is more permeable to K+ ion than Na+ ion. So, K+ leaves the neuron faster than Na+ enter the neuron.
- The difference in permeability results in accumulation of high concentration of cation (+ve charged ion) outside the neuron compared to the concentration of cation inside.
- This state of resting neuron is called **Polarized state** and it is electro-negatively charged.

Depolarization (Action Potential):

- Any stimulus beyond the threshold can initiate an impulse.
- When such stimulus is applied in the resting neuron, it opens the sodium channel. Now the permeability of Na+ ion suddenly increases at the point of stimulus causing depolarization.
- The diffusion of Na+ ion increases by 10 times from outside to inside. As a result the axoplasm become positively charges, which is exact opposite to polarized state, so called as **depolarized state** or **reverse polarized state.**
- The depolarization of the membrane stimulates the adjacent voltage channel, so the action potential passes as a wave along the length of neuron.

Repolarization:

- When the concentration of Na+ ion inside axoplasm increases, the permeability to Na+ decreases and the sodium channel starts to close.
- The Na-K pump activates, so that Na+ are pumped out and K+ inside until the original resting potential is restored. The process is known as **repolarization** and it starts from the same point from where depolarization starts.
- The entire process of polarization, depolarization and repolarization occur within fraction of seconds. Now, again the neuron is read for another impulse.

Saltatory conduction:

- Transmission of nerve impulses is very rapid. However, nerve impulse conduction along unmyelinated neuron is slow than that of myelinated neuron. It is because, the myelin sheath act as insulator, so that the impulse have to jump from one node of Raniver to another.
- This speed up the conduction process, and this type of conduction is known as **Saltatory conduction.**

RECEPTOR

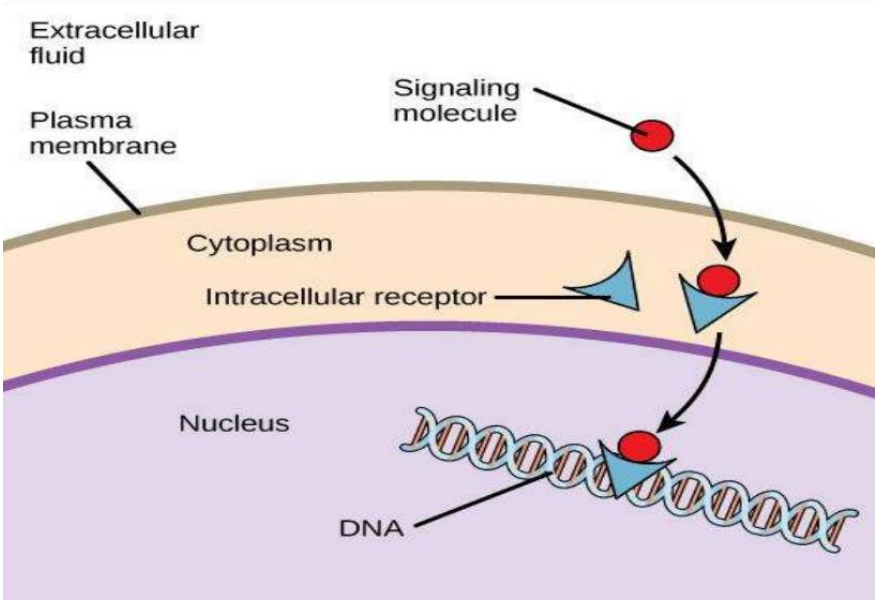
Receptors are protein molecules inside the target cell or on its surface that receive a chemical signal. Chemical signals are released by signaling cells in the form of small, usually volatile or soluble molecules called ligands. A ligand is a molecule that binds another specific molecule, in some cases, delivering a signal in the process. Ligands can thus be thought of as signaling molecules. Ligands and receptors exist in several varieties; however, a specific ligand will have a specific receptor that typically binds only that ligand.

Classification

There are 2 types of receptors.

Internal & Cell surface receptor.

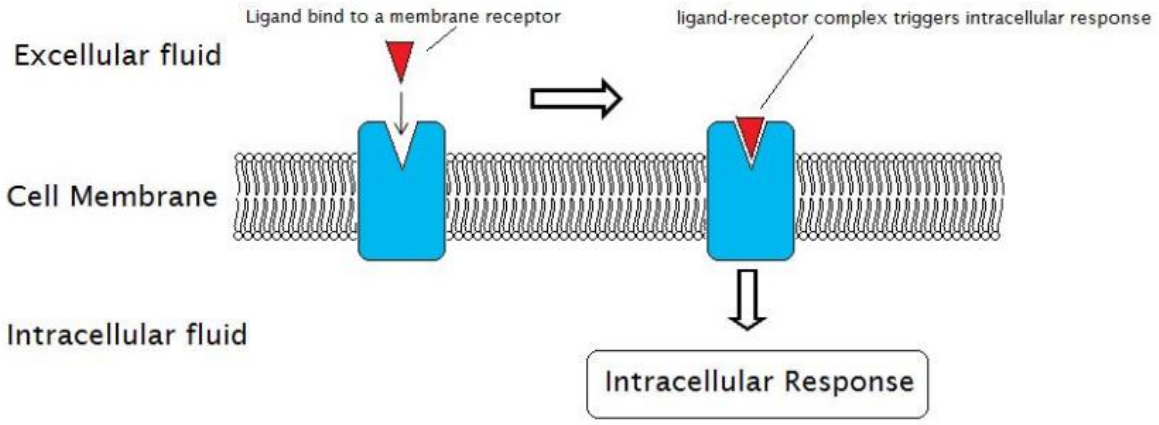
1. Internal /Intracellular/Cytoplasmic receptors :
    a. found in the cytoplasm of the cell.
    b. respond to hydrophobic ligand molecules.
    c. Hydrophobic signaling molecules typically diffuse across the plasma membrane.
    d. interact with intracellular receptors in the cytoplasm.



Cell-surface receptors

1. These are also known as **transmembrane receptors**, are proteins that are found attached to the cell membrane.

2. These receptors bind to external ligand molecules (ligands that do not travel across the cell membrane).
3. This type of receptor spans the plasma membrane and performs **signal transduction**, in which an extracellular signal is converted into an intercellular signal.
4. Ligands that interact with cell-surface receptors do not have to enter the cell that they affect. Cell-surface receptors are also called cell-specific proteins or markers because they are specific to individual cell types.
5. Each cell-surface receptor has three main components: an external ligand-binding domain, a hydrophobic membrane-spanning region, and an intracellular domain inside the cell.
6. The size and extent of each of these domains vary widely, depending on the type of receptor.



There are three general categories of cell-surface receptors:

A. Ion channel-linked receptors

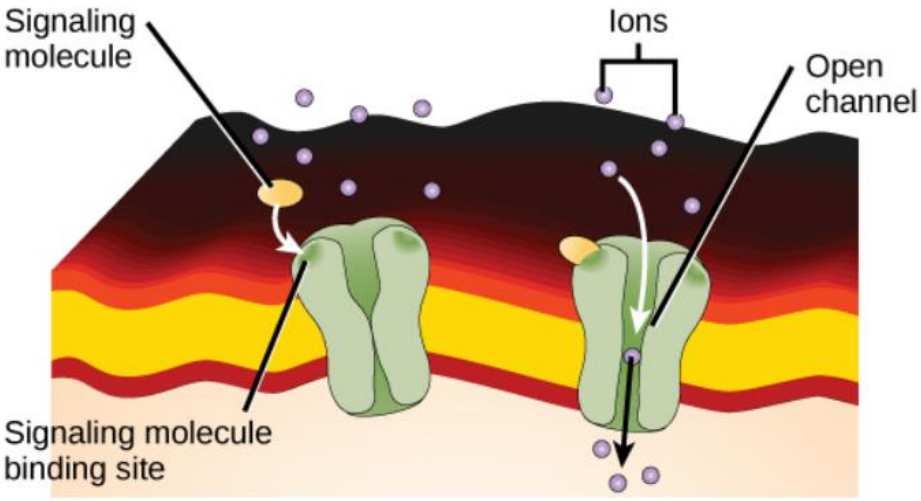
B. G-protein-linked receptors

C. Enzyme-linked receptors.

A. ION CHANNEL-LINKED RECEPTORS

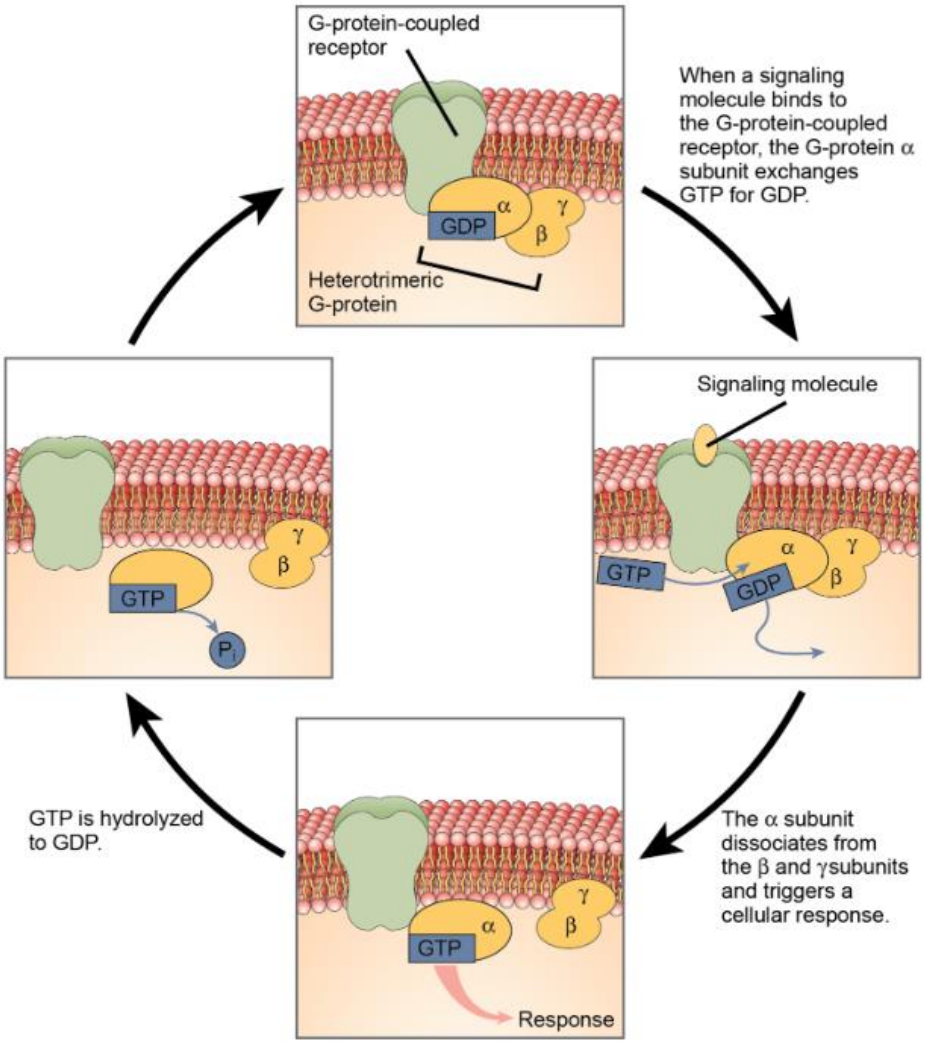
1. Ion channel-linked receptors bind a ligand and open a channel through the membrane that allows specific ions to pass through.
2. To form a channel, this type of cell-surface receptor has an extensive membrane-spanning region.

3. When a ligand binds to the extracellular region of the channel, there is a conformational change in the proteins structure that allows ions such as sodium, calcium, magnesium, and hydrogen to pass through.



B. G-PROTEIN-COUPLED RECEPTORS

1. They bind a ligand and activate a membrane protein called a G-protein.
2. The activated G-protein then interacts with either an ion channel or an enzyme in the membrane.
3. Before the ligand binds, the inactive G-protein can bind to a site on a specific receptor.
4. Once the G-protein binds to the receptor, the G-protein changes shape, becomes active, and splits into two different subunits.
5. One or both of these subunits may be able to activate other proteins as a result.



C. ENZYME-LINKED RECEPTORS

1. **Enzyme-linked receptors** are cell-surface receptors with intracellular domains that are associated with an enzyme.
2. In some cases, the intracellular domain of the receptor itself is an enzyme. Other enzyme-linked receptors have a small intracellular domain that interacts directly with an enzyme.
3. When a ligand binds to the extracellular domain, a signal is transferred through the membrane, activating the enzyme.
4. Activation of the enzyme sets off a chain of events within the cell that eventually leads to a response.

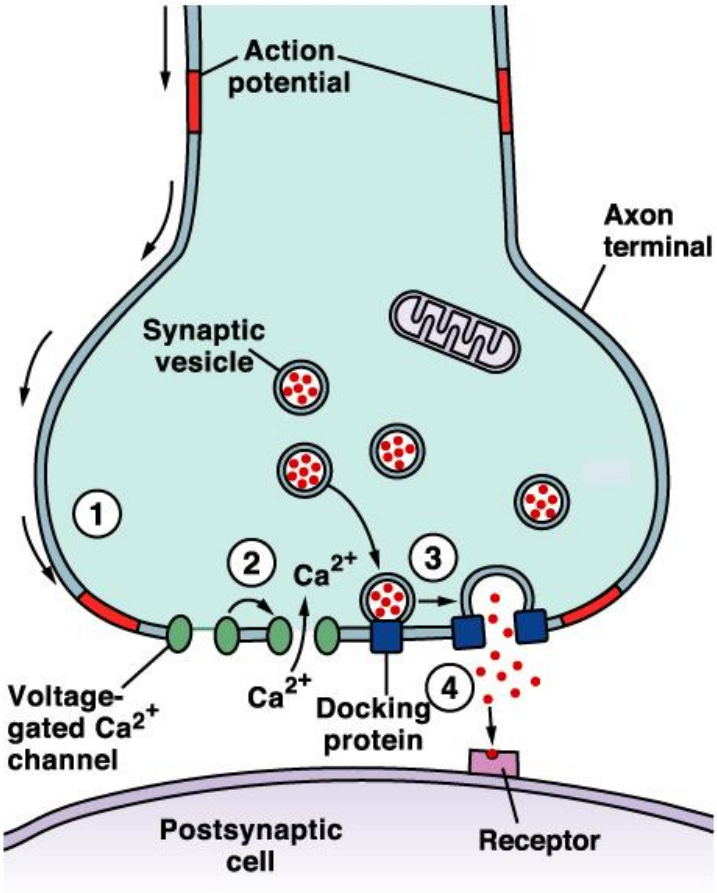
SYNAPSE

A synapse is the point of connection between two neurons or between a neuron and a target cell (such as a muscle or gland cell).

Structure

Synapses consist of

1. **presynaptic terminal (axon terminal) of one neuron,**
2. **synaptic cleft (a small gap),**
3. **postsynaptic membrane of the target cell.**



Neurotransmitters:

Communication at synapses occurs through chemical signals called neurotransmitters. The presynaptic neuron releases neurotransmitters into the synaptic cleft, and these molecules bind to receptors on the postsynaptic membrane.

Neurotransmitter Release:

When an action potential reaches the axon terminal of the presynaptic neuron, it triggers the release of neurotransmitters from synaptic vesicles into the synaptic cleft.

Receptor Binding:

Neurotransmitters diffuse across the synaptic cleft and bind to specific receptors on the postsynaptic membrane. This binding can result in excitatory or inhibitory effects on the postsynaptic cell.

Excitatory and Inhibitory Synapses:

Excitatory synapses increase the likelihood that the postsynaptic neuron will generate an action potential, while inhibitory synapses decrease this likelihood.

Reuptake and Enzymatic Degradation:

After neurotransmitters transmit their signals, they can be removed from the synaptic cleft through reuptake by the presynaptic neuron or enzymatic degradation in the synaptic cleft.

Plasticity

Synaptic plasticity refers to the ability of synapses to undergo changes in strength, which is crucial for learning and memory. Long-term potentiation (LTP) and long-term depression (LTD) are examples of synaptic plasticity.

Neuromuscular Junction

A specialized type of synapse called the neuromuscular junction connects motor neurons to muscle fibers, enabling the transmission of signals for muscle contraction.

Diseases and Disorders:

Dysfunction in synapses is associated with various neurological and psychiatric disorders, including Alzheimer's disease, Parkinson's disease, and schizophrenia.