# NERVE IMPULSE

**PRODUCTION AND PROPAGATION OF NERVE IMPULSE :**

- Like muscle cells, neurons are also electrically excitable. The neurons in the body are connected with one another.
- Axon of the nerve cell is the nerve fibre. The cytoplasm of the nerve fibre is **axoplasm** and the membrane surrounding it is **axolemma.**
- Neurons communicate with one another using **action potentials,** which are used for short and long distance communications with in the body.
- Production of these action potentials depends on two basic features of neuron: the existence of resting membrane potential and presence of specific types of ion channels across the axolemma.
- Separation of positive and negative charges by axolemma is a form of **potential energy.**
- Two main channels are the leakage channels and voltage gated channels.
- A plasmamembrane has more potassium leakage channels than the sodium leakage channels. So plasmamembrane is more permeable to potassium a the resting state.
- Voltage gated channels of sodium have two gates : activation gate and inactivation gate.
- Potassium channels have only one gate.
- Voltage gated channels cause action potentials.

**1. Resting membrane potential :**

- The resting membrane potential exists because of a small buildup of negative ions in the axoplasm and the equal buildup of positive ions in the extra cellular fluid (ECF).
- Such separation of positive and negative charges is a form of **potential energy.**
- If the difference in charge is more across the axolemma, the membrane potential is larger. This difference close to the axolemma is calle axolemma, the membrane potential is larger.
- This difference close to the axolemma is called **resting membrane potential.**
- The resting membrane potential is maintained due to two conditions : unequal distribution of ions across the axolemma and variable permeability of axolemma.
- ECF contains large amounts of sodium ions. The axoplasm contains a large amount of diffusible potassium ions and nondiffusible organic phosphates and complex organic molecules.
- These nondiffusible ions and molecules cause the resting membrane potential.
- Most of the solutes in ECF and axoplasm are electrolytes. Neurilemma is moderately permeable to $Na^+$ but 50 to 100 time more permeable to $K^+$.
- Concentration of $Na^+$ ions in ECF is about 10 times more in ECF than in axoplasm.
- The concentration of $K^+$ ions in axoplasm is about 30 times more in axoplasm than in ECF.
- There is a slow influx of $Na^+$ ions into the axoplasm, and continuous outflux of $K^+$ from axoplasm through leakage channels during the resting state.
- In the resting state activation gate of sodium channel is closed, inactivation gate is opened.
- Gated channels of potassium are closed.
- The average resting membrane potential is –70 mV on inner side of the membrane.
- Hence, at the resting state the axolemma is polarised.

**2. Generation of Action potential**

- Action potential arises according to the "**all-or-none principle"**. When depolarisation reaches threshold level, the voltage gated channels open and the same amplitude of action potential is generated.
- There is no change in the amplitude beyond the threshold stimulus.
- At the threshold level the membrane potential changes from –70 to –55.
- When any stimulus depolarises the membrane to the threshold level, voltage gated $Na^+$ channels open causing the influx of $Na^+$ ions.
- The influx of $Na^+$ ions changes the membrane potential from –55 to +45 mV.
- At the peak of the action potential, called **spike potential,** the inside is +45 mV.
- This phase is called **depolarising phase.**
- During the depolarising phase both gates of sodium channel are opened and the potassium channel is closed.
- Depolarising phase is followed by the **repolarising phase.**
- In the repolarising phase activation gate of sodium channel is opened and the inactivation gate is closed.
- Potassium channels are opened. $K^+$ ions leave the axoplasm and cause the inside of the cell more negative than the outside.
- During **hyperpolarisation** phase both gates of the sodium channels are closed.
- Potassium channels are remained opened. The membrane potential becomes –90 mV inside.
- During repolarisation and hyperpolarisation inactivation gates of $Na^+$ are closed.
- So neuron is insensitive to the stimulus. This period is called **refractory period.**

- This hyperpolarisation is followed by **resting state.** In the resting state potassium channels are closed.
- Inactivation gates of $Na^+$ channels are opened, activation gates are closed.

**3. Conduction of action potentials :**

- Action potentials travel along an axon, as they are self propagating. An action potential is a localised event.
- Following are the characteristic of nerve impulse conduction.
- A wave of depolarisation cannot induce another action potential behind it, but propagates only in the forward direction. Because behind it is in a refractory period.
- The speed of the transmission is directly proportional to the diameter of the axon.
- In medullated nerve fibres the relay of impulses jumps from node to node. This is called **salutatory transmission** of impulses.
- This is about 50 times faster than the impulse conducted in non-medullated fibres.

**Signal transmission at synapse:**

- Synapse is a place where axon terminals (presynaptic neuron) of one nerve fibre lie close to the dendrites of the adjacent neurons (postsynaptic neuron).
- These junctions are called **synapses.**
- These ensure one way or unidirectional transmission of impulses. The process of chemical transmission across synapse was discovered by Henry Dale (1936).
- He found that a synaptic knob contains many mitochondria and many synaptic vesicles which are filled with a chemical that transmits impulses to post synaptic neurons.
- The chemical transmitters are called **'neuro transmitters'.**
- Neurotransmitters are produced by exocytosis by synaptic vesicles
- Synaptic activity is a short lived activity as the **neuro transmitters** are hydrolysed very soon by enzymes.
- The repolarisation of the postsynaptic membrane thus is soon restored.
- At these synaptic junctions acetylcoline is secreted by axon terminal ends. This accumulates on the cavity of the synapse and causes depolarisation in the dendrites of the next neuron.
- To ensure that the synapse is ready for the passage of next impulse, act of moving the acetylcholine is done by **cholinesterase.**
- The cholinesterase is found in high concentrations in the synaptic fluid. It degrades acetylecholine into acetylene and choline.
- Neuro transmitters are excitatory or inhibitory in action.
- excitatory neurotransmitters depolarise the post synaptic membranes causing excitatory post synaptic potential (EPSP).
- Post synaptic regeneration of action potential is inhibited by inhibitory neurotransmitters called inhibitory post synaptic potentials (IPSPs)
- Acetylcholine is the common neuro transmitter. Other neurohumors secreted by the presynaptic membrane fibres, are **norepinephrine, dopamine** etc. These are excitatory in function.
- They transmit the action potential to the postsynaptic membrane at the synapse. The neurotransmitters like glycine, Gamma Aminobutyric Acid (GABA), serotonin etc., are inhibitory in function. Inhibitory post synaptic potentials (IPSPs)

A neuron receives inputs from many synapses and the integration of these inputs is known as **Summation**

Summation occurs at Axon hillock
Summation from several presynaptic buttons is called **spatial summation**
Successive inputs from single presynaptic button is called **temporal summation**
Threshold is reached when the sum of all EPSPs exceeds sum of IPSPs thus generating an action potential