BASUDEV GODABARI DEGREE COLLEGE,KESAIBAHAL

DEPARTMENT OF ZOOLOGY

SELF STUDY MODULE

MODULE DETAILS –

.CLASS-3RD SEMESTER
.SUBJECTNAME- ZOOLOGY
.PAPER NAME-PHYSIOLOGY-CONTROLING & COORDINATING SYSTEM

UNIT-2-- STRUCTURE-

MUSCLE & NERVOUS SYSTEM
TOPIC-ORIGIN OF ACTION POTENTIAL & ITS PROPAGATION ACROSS NERVE FIBRE
PREPAIRED BY --BINOD BIHARI PRUSETH
DESIGNATION- LECTURER IN ZOOLOGY

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Propagation of nerve impulse

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

Nerve Impulse transmission along Neuron

The transmission of a nerve impulse along a neuron from one end to the other occurs as a result of electrical changes across the membrane of the neuron. The membrane of an unstimulated neuron is polarized—that is, there is a difference in electrical charge between the outside and inside of the membrane. The inside is negative with respect to the outside.

Polarization is established by maintaining an excess of sodium ions (Na^+) on the outside and an excess of potassium ions (K^+) on the inside. A certain amount of Na^+ and K^+ is always leaking across the membrane through leakage channels, but Na^+/K^+ pumps in the membrane actively restore the ions to the appropriate side.

The main contribution to the resting membrane potential (a polarized nerve) is the difference in permeability of the resting membrane to potassium ions versus sodium ions. **The resting membrane is much more permeable to potassium ions than to sodium ions resulting in slightly more net potassium ion diffusion (from the inside of the neuron to the outside) than sodium ion diffusion (from the outside of the neuron to the inside) causing the slight difference in polarity right along the membrane of the axon.**

Other ions, such as large, negatively charged proteins and nucleic acids, reside within the cell. It is these large, negatively charged ions that contribute to the overall negative charge on the inside of the cell membrane as compared to the outside.

In addition to crossing the membrane through leakage channels, ions may cross through **gated channels.** Gated channels open in response to neurotransmitters, changes in membrane potential, or other stimuli.

The following events characterize the transmission of a nerve impulse:

- **Resting potential.** The resting potential describes the unstimulated, polarized state of a neuron (at about –70 millivolts).

- **Graded potential.** A graded potential is a change in the resting potential of the plasma membrane in the response to a stimulus. A graded potential occurs when the stimulus causes Na^+ or K^+ gated channels to open. If Na^+ channels open, positive sodium ions enter, and the membrane depolarizes (becomes more positive). If the stimulus opens K^+ channels, then positive potassium ions exit across the membrane and the membrane **hyperpolarizes** (becomes more negative). A graded potential is a local event that does not travel far from its origin. Graded potentials occur in cell bodies and dendrites. Light, heat, mechanical pressure, and chemicals, such as neurotransmitters are examples of stimuli that may generate a graded potential (depending upon the neuron).

The following four steps describe the initiation of an impulse to the "resetting" of a neuron to prepare for a second stimulation:

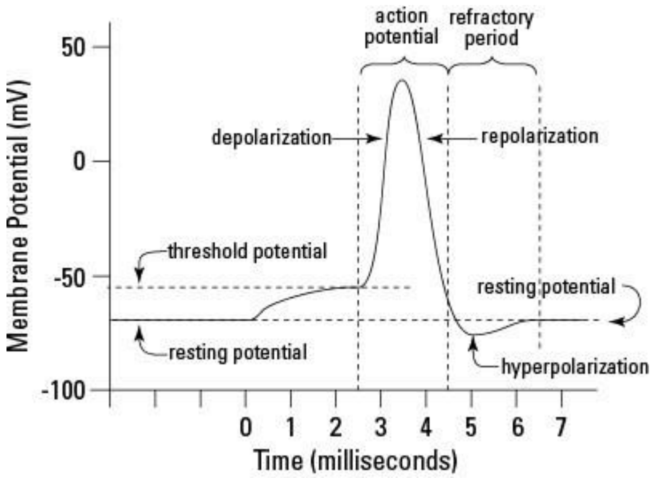
1. **Generation of action potential/ depolarization of axon:** Unlike a graded potential, an action potential is capable of traveling long distances. If a depolarizing graded potential is sufficiently large, Na^+ channels in the trigger zone open. In response, Na^+ on the outside of the membrane becomes depolarized (as in a graded potential). If the stimulus is strong enough—that is, if it is above a certain threshold level—additional Na^+ gates open, increasing the flow of Na^+ even more, causing an action potential, or complete depolarization (from –70 to about +30 millivolts). This in turn stimulates neighbouring Na^+ gates, farther down the axon, to open. In this manner, the action potential travels down the length of the axon as opened Na^+ gates stimulate neighbouring Na^+ gates to open. The action potential is an all-or-nothing event: When the stimulus fails to produce depolarization that exceeds the threshold value, no action potential results, but when threshold potential is exceeded, complete depolarization occurs.

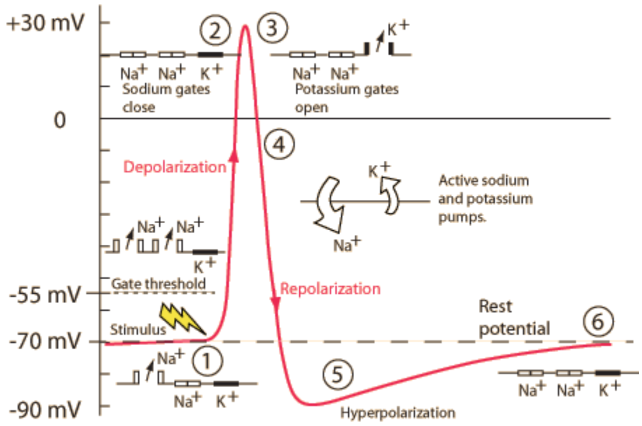
2. **Repolarization**: In response to the inflow of Na^+, K^+ channels open, this time allowing K^+ on the inside to rush out of the cell. The movement of K^+ out of the cell causes repolarization by restoring the original membrane polarization. Unlike the resting potential,

however, in repolarization the K^+ are on the outside and the Na^+ are on the inside. Soon after the K^+ gates open, the Na^+ gates close.

3. **Hyperpolarization:** By the time the K^+ channels close, more K^+ have moved out of the cell than is actually necessary to establish the original polarized potential. Thus, the membrane becomes hyperpolarized (about –80 millivolts).

4. **Refractory period**: With the passage of the action potential, the cell membrane is in an unusual state of affairs. The membrane is polarized, but the Na^+ and K^+ are on the wrong sides of the membrane. During this refractory period, the axon will not respond to a new stimulus. To re-establish the original distribution of these ions, the Na^+ and K^+ are returned to their resting potential location by Na^+/K^+ pumps in the cell membrane. Once these ions are completely returned to their resting potential location, the neuron is ready for another stimulus.





(Both the figures are showing transmission of nerve impulse)

Step	Voltage-gated ion channels	Ion permeability	Action potential curve
Resting state	all channels closed	no ion movement	flat
Depolarization	Na^+ channels open (activation gates)	Na^+ flows into cell	sharp upward spike
Repolarization	Na^+ channels inactivating (inactivation gates) K^+ channels open	K^+ flows out of cell	downward curve
Hyperpolarization	some K^+ channels remain open Na^+ channels reset (activation gates close & inactivation gates open)	some K^+ continues to flow out of cell	slight dip below resting membrane potential

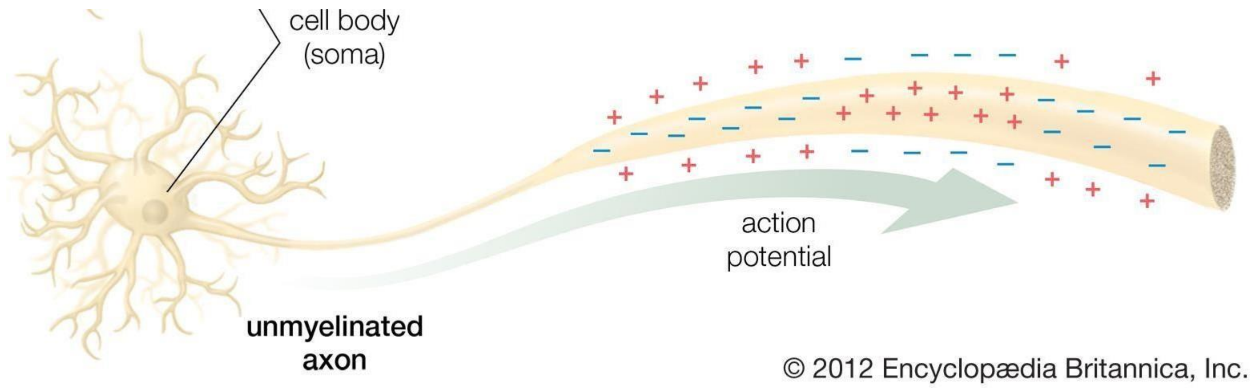
Conduction of the Action Potential along the Nerve Fiber

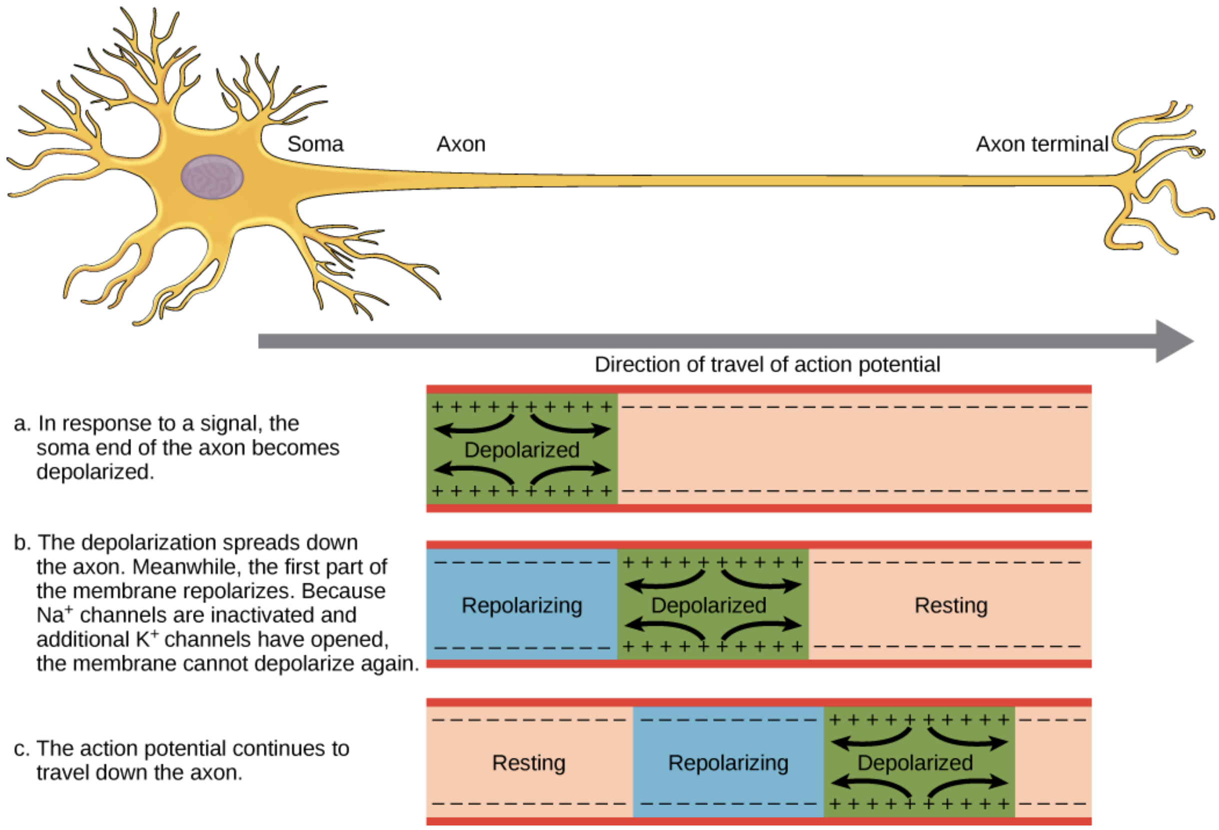
The way the conduction of the action potential occurs along the nerve fiber depends on whether it's myelinated or unmyelinated. Note: All muscle cells are unmyelinated, there is no insulation in muscle cells. Nerve cells could be either.

❖ Conduction along an Unmyelinated Nerve Fiber

Initially, a threshold stimulus creates an action potential. As the nerve fiber depolarizes, it triggers an increase in permeability of the **ligand-gated** sodium ion channels that causes sodium channels to open and sodium ions go into the nerve cell and reverse polarity because positively charged ions are flowing in. This action potential is going to be conducted along the length of the fiber by cause the next adjacent space to open **voltage-gated** sodium ion channels to open.

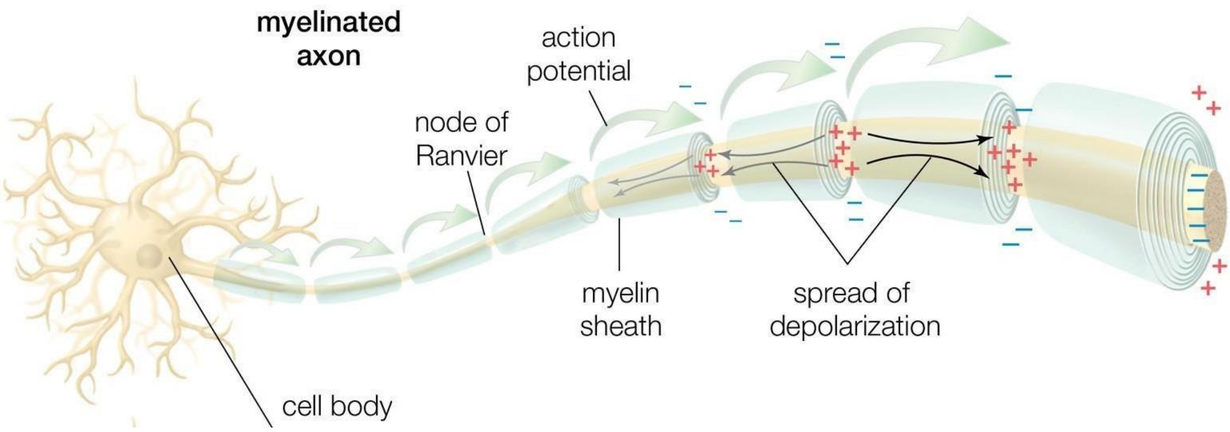
So as we go from left to right, sodium ions are entering the cell due to these voltage-gated sodium ion channels opening up and meanwhile, to the left of it, the potassium ions are going out. As the potassium ions go out, it repolarizes. This idea of sodium coming in and potassium going out, is going to repeat constantly so it appears to keep moving the electricity through the fiber.





❖ <u>Conduction along a Myelinated Nerve Fiber</u>

In myelinated nerve fibers, the depolarized Node of Ranvier triggers an increase in the permeability of the sodium ion channels (and thus depolarization) in the adjacent Node of Ranvier.



Above we see a myelinated neuron. If the myelinated cells are wrapped around interneurons, they are oligodendrocytes. If they're wrapped around neurons in the PNS they're called Schwaan cells. In either case there are these gaps called Nodes of Ranvier. The only place these potassium or sodium ions can enter or leave are from these spaces that are unmyelinated. Sodiums come in and potassiums going out just like an unmymelinated nerve fiber, except this signal seems to jump from one node to the next. This is called **saltatory conduction.**

Due to this skipping, saltatory conduction is up to 50 times faster than conduction through the fastest unmyelinated axons because they don't have to travel throughout every single space before moving to the next.

So in essence, the action potential is generated only at the nodes. The cell membrane below the myelin sheaths hardly have any sodium channels and are therefore not excitable anyway. Since the ionic currents are restricted to the nodes of Ranvier in the myelinated axons, this minimizes disturbances in the Na^+/K^+ concentration gradients which reduces the energy costs of the Na+/K+-ATP pump that have to restore ionic balance.