PROPAGATION OF NERVE IMPULSE

ZOOLOGY GENERAL

(Paper G-CC-T-04)

FOURTH SEMESTER

Submitted by- SANGITA BASAK

DEPARTMENT OF ZOOLOGY

KRISHNATH COLLEGE, BERHAMPORE

Propagation of Nerve Impulse

❑ Introduction :

For receiving and interpreting stimuli specialised cells and tissues have evolved in many animals. From these specialised cells and tissues a system of control has been developed which regulates and integrates the activities of all other systems and organs of animals. This system is the nervous system whose basic units are the **neurones** or nerve cells. In spite of the wide diversity in size, position and structure nerve cells can be functionally distinguished into three regions, the **generator**, the **conductive** and the **transmissional regions**. The generator region is restricted to the dendrite, soma and collaterials. The conductive region is the axon, and the transmissional region comprises the nerve terminalis.

❑ Physiochemical background :

Impulse—It can be defined as the sum total of mechanical. chemical or elcetrical disturbance created by a stimulus in a neuron. Its propagation along the fibre is called the transmission.

Intratransmission of nerve :

Impulse—It is found that in a resting neurone there is a difference on etectrical charges or potential difference on either side of the membrane. This potential difference is known as **membrane potential** or resting potential. This is due to unequal distribution of Na^+ and K^+ outside and inside the cell. K^+ concentrations inside the neurone is 30 times greater than its outside. Similarly Na^+ are positive and develop a positive charge outside the membrane. Though K^+ are also positive and are actively transported to inside the cell there are insufficient K^+ to equalize the large number of non diffusable negative ions trapped in the cell. Thus the inside membrane has a negative charge. The difference of charge is known as **resting potential.** At rest the value of resting potential is –70mv. The membrane at this stage is said to be **polarised.**

❑ Resting membrane potential :

It is known that in all cell membranes, except in places of contact, there are equal number of positive and negative charges. This is called **electrical neutrality** i.e., to neutralize each positive charge there is a negative charge. When positive charges come out of the membrane to the outside then the inner side of the membrane of the neurone becomes negatively charged and the outside is the postively charged.

Like other cell membrane the Na^+ and K^+ move across the membrane of the neurone by sodium and potassium pump. By this pump three Na^+ ions come out of the membrane and two K^+ ions enter the cell. As a result there becomes a deficit of positive charges in the cytoplasm and negetive charges inside the cell membrane increase. This is called resting potential and it is –90 mv. Beside sodium–potassium pump Na^+ and K^+ ions also move across the membrane through protein channels formed by the leak protein.

❑ Nerve impulse and development of action potential :

When a nerve is excited at a point an impulse is generated and a change in the resting potential takes place. This change of resting potential is known as **action potential.** During the development of action potential the negetive potential of resting potential changes to positive potential and then again to negative potential as before. For conduction of impulse this action potential moves through the membrane to reach the terminal end.

Resting stage : Before the development of action potential the axon membrane lies at resting stage when the action potential of the axoplasm remains as –90mv. In resting stage the outside of the axon membrane bears +ve charges whereas the inside bear –ve charges. This condition is known as **polarised state.**

Depolarisation : During the development of action potential at a particular point on the axon membrane a great inflow of Na^+ ions from the outside of the membrane, takes place, As a result the resting potential –90 mv is disturbed and its gradually changes to zero and finally becomes postively charged. This process is known as **depolarisation.** In large nerve fibres the action potential may cross the zero level and becomes positively charged. The crossing of milivolt form zero to plus is known as **overshoot** . In cranial nerves and small nerves the value never crosses the zero level.

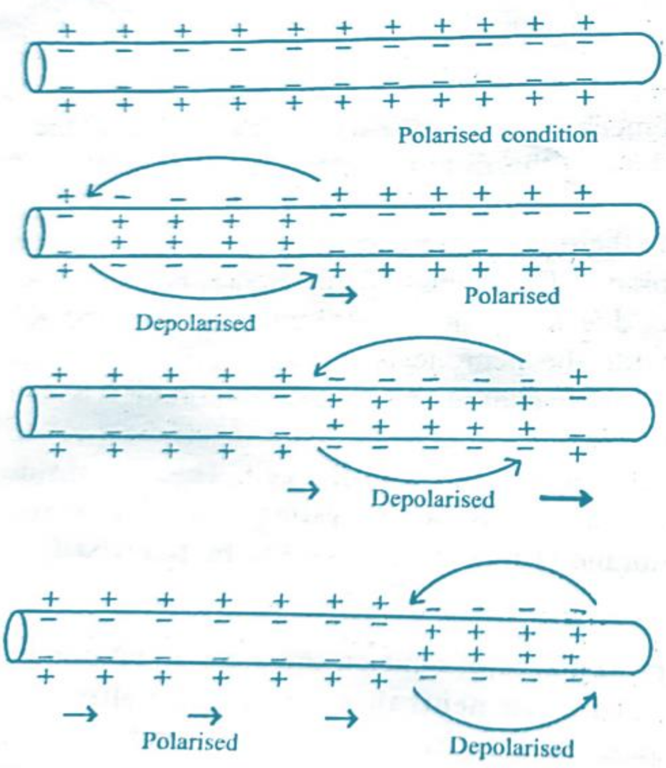

Fig. 27.1 : Local Circuit theory of nerve impulse propagation

Repolarization : Within fraction of seconds sodium channel is closed and potassium channel opens more than the normal. So by diffusion potassium comes out of the neurone through axon membrane and resting potential again returns. This is known as **repolarisation.** Due to exit of maximum number K^+ ions from the neurones the inside of the neurones become excessively negatively charged. This excess potential is known as **positive after potential.** The rise and fall of this potential is known as **spike potential.** The time taken to come to resting potential after spike potential is known as **negative after potential.**

Sodium and potassium channels : The passage of Na^+ and K^+ ions through the axial membrane takes place through different processess. They are (i) ATP dependent Na^+–K^+ pump in which in resting conditions $3Na^+$ ions move out and $2K^+$ ions move inside the cell.

(ii) Leak channels, for the passage of Na^+ and K^+ ions, are created within the protein molecules of the axon membrane.

(iii) Leak channels are opened or closed due to differential action potential and passage in or out of Na^+ and K^+ ions of the axon membrane is controlled by activation gate. If action potential ions within –70mv to –50mv the sodium activation gate opens and movement of Na^+ ions are greatly increased. When the action potential reaches to zero sodium gate is generally closed and potassium gate opens and potassium ions begin to flow in. Repolarization takes place and when the action potential reaches –90mv potassium gate is closed. Calcium ions also regulate the opening and closing of Na^+ channel. Even after repolarisation K^+ still flow outside and innerside of the membrane become more negative. This change is known as **positive after potential.**

Action potential—On receiving a stimulus or on exciting a neurone, the potential changes from the resting level (–90mv) to O, and then becomes +20 or +30 mv. This reversal of polarity is called **overshoot**. After this the potential sharply reverts to the resting level.

This rapidly moving change in the membrane potential is called an action potential. The entire event occurs in a milli second. The rise and fall of the action potential is the **spike potential**. The short phase of the action potential before reaching the resting level is **negative after potential.** For any neurone the spike is of constant magnitude and seems to pass unaltered along the length of the neurone.

Propagation of an Impulse—Various theories have been postulated to explain the propagation of a nerve impulse. The most important theories are—

(1) **Local circuit theory :** Propagation of a nerve, impulse depends on the flow of current in local circuits ahead of the active region, which depolarizes the resting membrane and causes in turn to become active. In both myelinated and non–myelinated fibres the principle is the same, i.e., polarization → depolarization → polarization, that the active region triggers the resting region ahead of it by causing an outword flow of electric current.

Saltatory Transmission : In myelinated nerve transmission of nerve impulses is somewhat different. The myeline sheath does not conduct an electric current. The sheath is interrupted at various intervals called **nodes of Ranvier**. Depolarization can occur only at these nodes. But beneath the myelin sheath depolarization is impossible. When an impulse is transmitted along a myelinated fibre, it depolarizes the membrane around the first node of Ranvier, spreads around the outside of the myelin sheath to the next node, and so on. This type of impulse transimission is called **saltatory transmission**, which is the charactristics of myelinated nerve fibres.

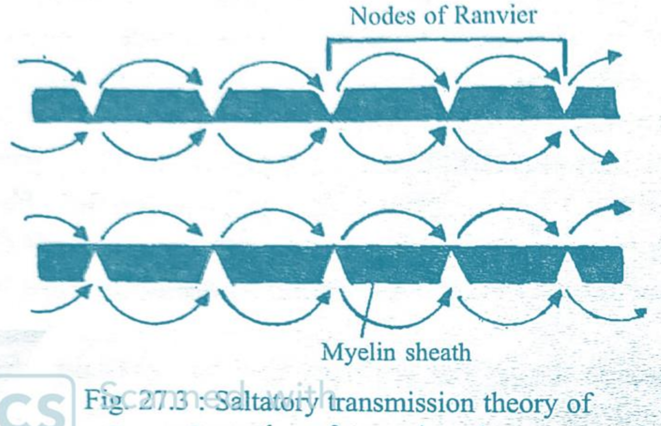

Fig. 27.3 : Saltatory transmission theory of propagation of nerve impulse