Origin of Nerve impulse

When a neurone is stimulated, the electrical activities of the neurone is changed which originates the nerve impulse. The electrical activity is changed throughout the cell membrane and can be recorded by Cathode Ray Oscilloscope (CRO). The CRO shows a positive deflection which is called "Action potential". This action potential then propagates through neurone.

In resting stage (when not stimulated), positive & negetive charged ions (Na^+, K^+, Cl^- etc.) remain distributed accross cell membrane in such a manner that when recorded the outside of membrane is more positively charged than inside. So, the resting membrane potential (RMP) is -70 mV. The concentration of Na^+ is more on the outside, but concentration of K^+ is 40 times higher on inside. Although K^+ is freely permeable through membrane. Na^+-K^+ ATPase pump is also very important in this RMP.

But in excited stage (when stimulated) a serise of events occur, and generates AP. It takes three stages –

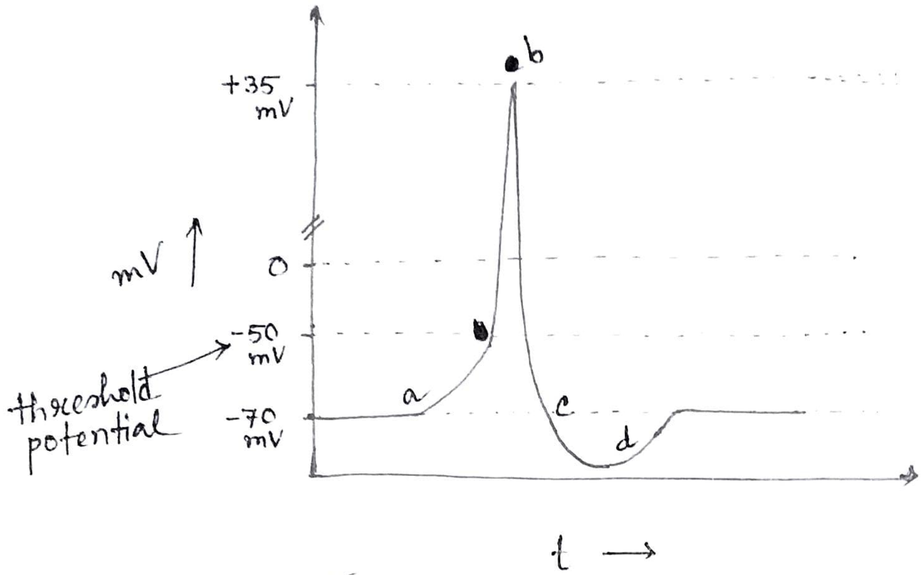
i) Phase I : Depolarization
ii) " II : Repolarization
iii) " III : Hyperpolarization

i) Phase I : There are numerous voltage-gated Na^+ channels on the cell membrane. When excited the membrane negetivity is reduced and suddenly reaches a firing level (threshold). In an instant the Na^+ channels are opend & Na^+ rushes to inside (Na^+ influx). The opening & closing of Na^+ gates is very fast, so they are called "fast Na^+ channels". Due to presence of huge Na^+s the inside of the cells now becomes positive, i.e, polarization is reversed, & the condition is called depolarization.

ii) Phase II : When the membrane potential rises from -70 mV towards '0', K^+ channels/gates open very slowly ("Slow K^+ gates"). Now K^+ comes out of the cell (K^+ efflux) and gradually the positivity of the cells begins to fall. The opening of K^+ gates are simultaneous with closing of Na^+ channels.

iii) Phase III : K^+ channels are slow to open & slow to close. So before closing excess K^+ ions come out (excess K^+ efflux) leaving the inside of the cell more negative than RMP.

After phase III, Na^+–K^+ ATPase pump is the only means to restore RMP. This pump uses ATP and pumps out 3 Na^+s in exchange of 2 K^+s & returns the membrane to its normal resting potential (–70 mV). This condition is called positive after potential.

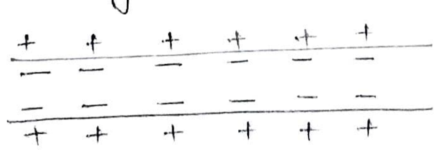


a – b → Phase I
b – c → Phase II
c → Phase III
d → after hyperpolarization / +ve after potential

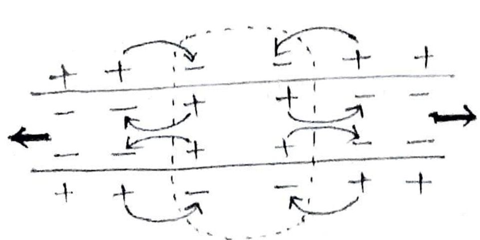
Fig: "Spike potential" (Action potential of neurone)

Propagation of nerve impulse :– The nerve impulse is propagated as a wave of depolarization. The nerve cell membrane is polarized at rest (–70 mV), but as soon as the nerve is excited, the membrane is depolarized. That is the electricity inside of the cell becomes more positive than outside. A local circuit of electricity is generated between the depolarised and the resting membrane. Then electricity flows from the depolarized to the resting membrane as shown below. Thus the local circuit of electricity excites the adjuscent membrane & the wave of depolarization current propagates through the nerve fiber. This type of propagation is seen in non-medullated fibers.

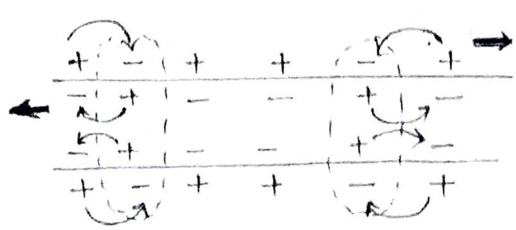
Resting ⇒



Threshold stimulus ⇒



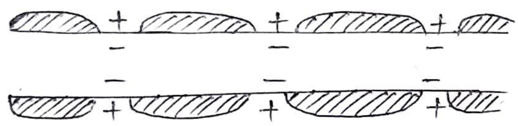
Replorization ⇒



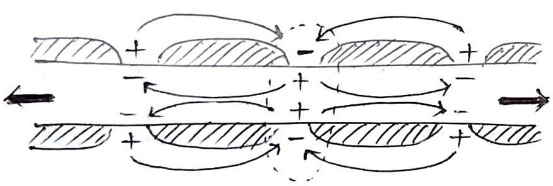
Saltatory Conduction :- Propagation of nerve impulse through medullated (myelinated) nerve fiber is called saltatory conduction. The myelin sheath is an effective insulator & inhibits electricity flow. So, ~~the depo~~ unlike non-medullated nerve fiber, the depolarization wave has to jump from one node of Ranvier to the next for the impulse to propagate.

When excited (stimulated), the ~~myeline~~ nodes of Ranvier are the only point to be depolarized, as the myeline sheath is non-conductant. The pattern of local circuit of electricity is same as non-medullated nerve, but here the depolarization current has to jump. Thus a local circuit is generated between adjacent nodes of Ranvier. This makes the velocity of propagation much more higher than that of non-medullated nerve fibers.

Resting ⇒



Threshold stimulus ⇒



Orthodromic & Antidromic Conduction :-

The action potential (wave of depolarization) can propagate to both direction of an axon, if the stimulus is applied at the middle. But normally, in living animals, propagation occurs unidirectionally, i.e from presynaptic to postsynaptic membrane, because at most of the synapses permit current ~~from~~ flow in one diretion and this type of unidirectional propagation is called Orthodromic conduction.

The AP propagates in both direction i.e from presynaptic to postsynaptic, as well as, post to presynaptic membrane, the impulse fails to ~~cond~~ cross the very first synapse it encounters in the opposite direction. This type of conduction is called antidromic conduction.

Current of injury :- If a nerve is injured, the injury acts as a stimulus and a steady electricity flow occurs from the injured spot to the uninjured spot. This is called current of injury / Demarkation current.

Synapse

Definition :- Synapse is the junctional region where one neurone ends (presynaptic) & another neurone begins (postsynaptic)

~~Structure~~ / **Types** :— According to the nature of connection, synapses can be classified as following —

i) Axosomatic → junction between axon & cell body (soma) 
ii) Axodendritic → " " axon & dendrites 
iii) Axoaxonic → " " axon & axon 

ALSO SEE PAGE 8

Structure :— Under electron microspcope, it can be seen that the terminal branches of the axon ("end brush") become dialated or expanded (synaptic knob). ~~This synaptic knobs acts are~~ The cell membrane of the synaptic knob is known as presynaptic membrane. ~~Thes~~ The cell mem. of postsynaptic region is known as postsynaptic membrane. There is gap of about 20-40 nm between these two membranes which is called synaptic cleft. The electrical impulse (AP) can not jump this gap and neurotransmitters (NT) are needed to carry through the electrical impulse as chemical impulse.

There are two major structures present in the ~~syng~~ synaptic knob — (i) huge number of synaptic vesicles, ii) mitochondria. The synaptic vesicles are of ~~two~~ three types —

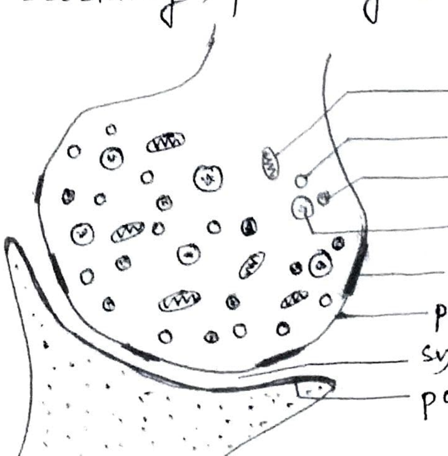
(a) Small vescicles with electron dense core :- contains acetyl choline, GABA, glutamate.

(b) Small clear vescicles :- contain catecholamines such as norepinephrine.

(c) Large vescicles with electron dense core :- contain neuropeptides.

Mitochondria helps in vescicle formation, docking, priming & energy ~~syp~~ supply.

The pre-synaptic membrane contains active zones, where neurotransmitters bind.



Mechanism of synaptic transmission :-

Since electricity or the wave of depolarization can not jump the synaptic cleft, certain chemical substances, called the neurotransmitters (NTs) take part in synaptic transmission. This change of electrical potential into chemical signal takes ~~Severlar~~ several steps —

i) Synaptic vescicles contain different types of NTs. Vescicles are formed by ~~from~~ budding off from ~~en~~ early endosomes. The protein & lipid contents are formed in neuronal soma. Vescicles travel to the axon. Neuropeptides ~~NTs~~ are also formed in the soma & are packaged inside the vesicles. But classic NTs are synthesized in the synaptic knob & are packaged by secondary active transport. The packaging of NTs require H^+ which is generated by V-type ATPase.

ii) Large vesicles can bind at any region of the presynaptic membrane, but ~~san~~ small vesicles only bind with a specific site called active zones. The vescicles first dock & then undergo priming process.

iii) When AP arrives at the synaptic knob, it causes several Ca^{2+} channels to open & the positive charge gradient triggers the fusion of docked vesicles with active zones. The release of NTs involve SNARE proteins (V- & t- SNAREs). The fusion of vescicles involve a zipper like interaction between Synaptobrevin (a V-SNARE) ~~&~~, Syntaxin and SNAP-25 (two t-SNAREs). Empty vescicles are coated with 'clethrine' & recycled back to early endosomes.

iv) Released NTs ~~co~~ cross the synaptic cleft and bind to the postsynaptic membrane which inturn increases the Na^+, K^+ permeability of the postsynaptic membrane. These ions again generate depolarization current or the Action potential, which can now propagate.

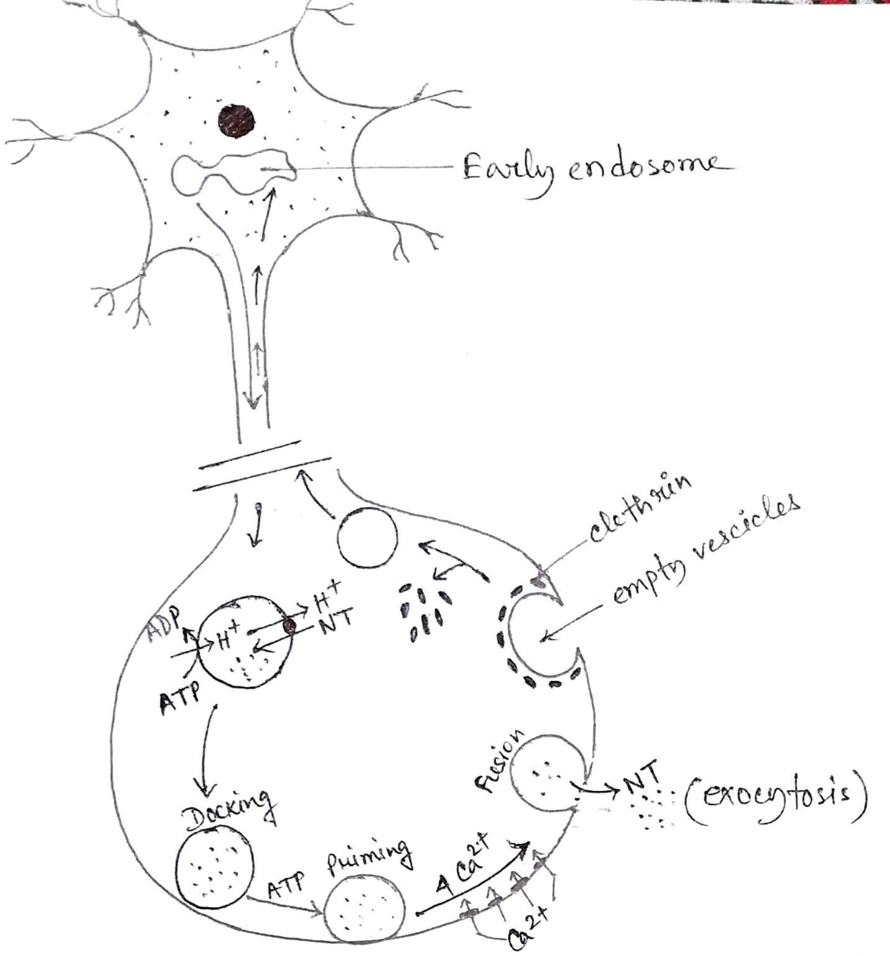


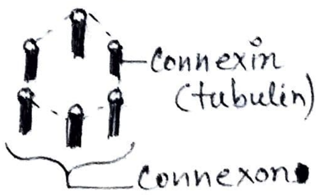
Fig : Process of NT release from presynaptic knob.

Types of synapes

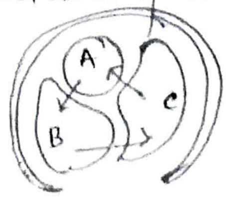
~~Motor Unit~~ :

1) Chemical Synapse → Simple chemical synapse (Type I and II)
   → Special " " (Neuro-muscular junction)

2) Electrical Synapse →
- transport ions and small molecules
- provide low resistant bridges → tube like structure called connexons.
- also known as gap junctions



3) According to organization →
   i) Reciprocal synapse ($A \rightleftharpoons B$)
   ii) Serial " ($A \rightarrow B \rightarrow C \rightarrow$)
   iii) Synaptic glomeruli → Complex structure of a clusture of neurones.



4) According to connection →