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The nervous system

- Components :- Brain, spinal cord, nerves, sensory receptors.
- Responsible for :-
  - sensory perceptions, mental activities, stimulating muscle movement, secretⁿ of many glands.
- Subdivisions -
  1. Central nervous system (CNS)
     Brain and spinal cord
  2. Peripheral nervous system (PNS)
     Cranial nerves and spinal nerves.
- Brain and spinal cord connected by
- Subcategories of PNS
  1. Sensory or afferent
  2. motor or efferent
- Divisions
  - Somatic nervous
  - Autonomic nervous
    - Sympathetic
    - Parasympathetic
    - Enteric

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Neurons

- Functional unit of nervous system
- Have capacity to produce action potential
  - electrical excitability
- cell body (cyton)
- Dendrites — Conducts impulses towards the cell body
  - Typically short, highly branched and unmyelinated
  - surfaces specialised for contact with other neurons.

- Axons :- Conduct impulses away from cellbody
  - Long, thin cylindrical process of cell
  - Arises at axon hillock
  - Impulses arise from initial segment
  - side branches (collaterals) end in fine processes called axon terminals.
  - Swollen tips c/d synaptic end bulbs contain vesicles filled with neurotransmitters

- Functional classification of Neurons
- Sensory neurons
  Transport sensory informatⁿ from skin, muscles, joints, sense organs and Viscera to CNS.
- Motor (efferent) neurons
  - send motor nerve impulse to muscles and glands

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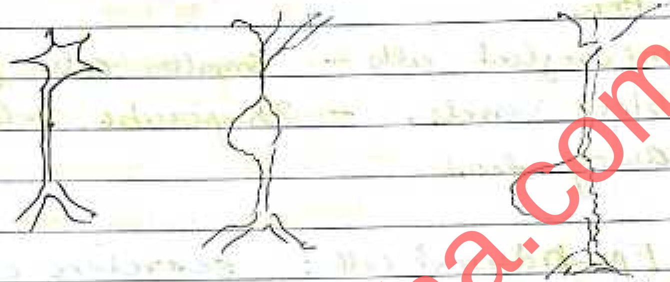
- Inter neurons (association) neuron.
- connect sensory to motor neurons
- : 90% in the body of neurons.

Structural classification of Neurons



Based on no. of processes found on cell body

- multipolar - several dendrites and one axon. most common
- Bipolar neurons - one main dendrite and one axon
  - found in retina, sinus, ear & olfactory
- unipolar neurons - one process only (develops from a bipolar)
  - are always sensory neurons

Neuroglial cells

- Half of the vol. of the CNS
- smaller cells than neurons
- cells are of 4 types -

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① Astrocytes
- Star-shaped cells.
- form blood-brain barrier

② oligodendrocytes – most common glial cell
- forms the myelin sheath around axon.
- CNS

③ microglial cells – smaller cells found near blood vessels. – Phagocytic role – clear away dead

④ Ependymal cell : secretory cell.
secreate the cerebrospinal fluid (CSF)

⑤ Satellite cells found in PNS. They surround the cell body and provide support.

⑥ Schwann cell : In the PNS, schwann cells produce myelin sheath.

All Axons are surrounded by lipid and protein covering called myelin sheath produced from schwann cells. The myelinated fibres appears white. The myelin acts as a electric insulator and speeds the conductn of nerve impulses. The gaps b/w two myelin sheath is known as nodes of Ranvier.

Neural Signals

2. All cells have an electrical potential or Voltage across their P.M. known as resting membrane potential
1. membrane potentials arise from differences in ion concⁿ b/w a cell's contents and the extracellular fluid.
3. The charge outside is designated as zero, so the minus sign indicates that the cytoplasm inside is -vely charged compared to the extracellular fluid.

The resting membrane potential is maintained due to –

(a) There are Na-K ATPase Pump in the membrane. These moves 3-Na^+ ions outside and 2 K^+ ion inside, thus maintaining the concⁿ gradient. (b) As the no. of open K^+ channels are greater than the Na^+ ion channels, more K goes out, thus making the inside more -ve.

Nature of Neural Signals

Ion channel :- integral transmembrane protein that allows a specific ion to cross the membrane

- may be passive all the time or it may be gated, requiring stimulus to change into an open conformation.
- Is selective for a specific ion, such as Na^+, K^+, and Cl^-

It may be of two types :-

① Gated Ion channel

- Ligated-gated
- open or closed in response to Ligand binding to receptor as ACh

Voltage-gated
- open and closed in response to small voltage changes.

② Passive Ion channels or Non-gated or leaked "
- always open and responsible for permeability
- specific for one type of ion although not absolute

Resting membrane potential :-
- Neurons have a selectively permeable membrane. During resting condn membrane is :
  - Permeable to K^+ (channels are open)
  - Impermeable to Na^+ (closed)
- Diffusion force pushes K^+ out (concn gradient)
- This creates a +vely charged extra-cellular space.
- Electrostatic force pushes the K^+ in. Thus, there is a "dynamic eqm" with zero net movement of ions. The resting membrane potential is -ve (-60mV)

Electric signals are produced whenever there is change in resting membrane potential. The changes can be of 4 types—

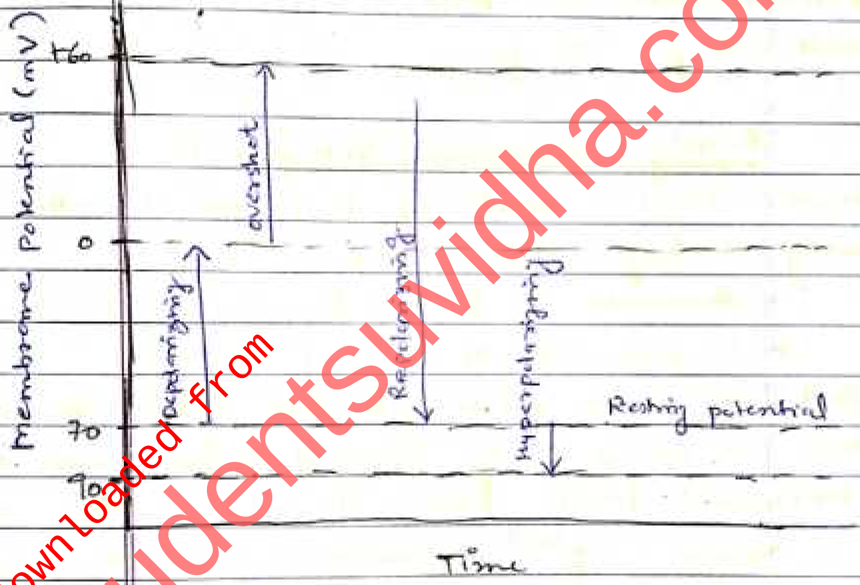
ⓐ Depolarising phase : when the membrane is less -ve than resting level.

ⓑ Overshoot - membrane reverses polarity and the inside becomes +ve relative to the exterior.

(3) Hyperpolarized : when the membrane becomes more -ve than resting

(4) Repolarized : It returns the membrane potential to resting level.

Polarized membrane has diff. net charge inside and outside.



- **Graded potential**

The change in potential takes place over small region of the plasma membrane. The +ve ions inside the membrane moves to the adjacent -ve charges. After a small region is depolarised local currents are produced the +ve charges inside the membrane moves to the -ve charges adjacent to that region. On the other hand, the +ve charges on the outside of the membrane moves towards the -ve charges of the adjacent region.

- **Action potential**

A rapid change in the membrane potential of certain cells such as neuron, muscle cell etc is known as action potential. The voltage gated Na^+ K^+ channels plays an impt role. Although these channel looks similar there are 2 impt differences —

- Na channels are faster to respond to the membrane depolarisation.
- Na channels have an extra intracellular structure known as inactivation gate. This blocks the channel shortly soon after depolarises open it limiting the Na flux.

- **Four stages of an action potential**

- Rising stage — Na^+ channels are open. (Voltage gated channel)

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* Depolarising phase – membrane reverses polarity. The Na activation gates open ; Na rushes in. K gates remain closed . membrane reaches threshold potential .
- Entry of Na leads to opening of more Na gates.
- overshoots and memb. becomes +ve inside
- When mem. potential reaches peak ; the Na^+ inactivation gates close.

* Repolarizing phase – returns the mem. potential to resting level ; inactivation gates close Na^+ channel and the K^+ channel open.

* Hyperpolarization phase – Na channel remain close but K^+ channel remain open since the inactivation gate take long to respond.

Role of gated ion channels in the action potential:

Step 1:- Depolarisation by some stimulus leads to the opening of the voltage gated Na^+ channels & the membrane soon reaches a threshold potential.

Step 2:- A +ve feedback loop is set . The Na^+ entry opens even more Na^+ gated channels and the membrane becomes more depolarized.

Step 3: It overshoots and membrane becomes +ve inside.

Step 4: When membrane potential reaches the peak, the Na^+ permeability declines due to inactivation gate. (Voltage gated channel)

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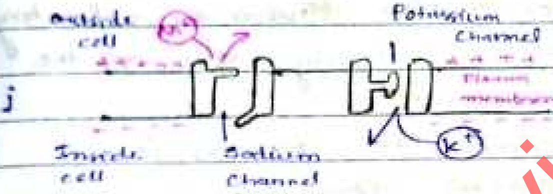
Step 5: The slow K^+ channel open and K goes out of the cells, thereby repolarising the membrane.

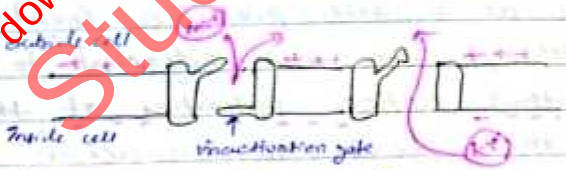
Step 6: Repolarization leads to closure of both Na & K gated channel. However, the K channels are slow to close and hence the membrane gets hyperpolarized with +ve charges.

Finally, when voltage gated K^+ channels close, the resting membrane potential is stored.

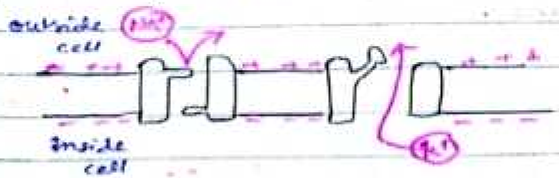


(1) Resting state

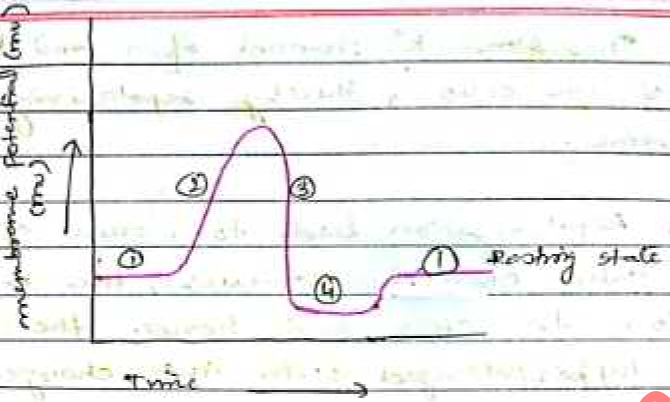
(2) Depolarizing phase



(3) Repolarizing phase state



(4) Overshoot

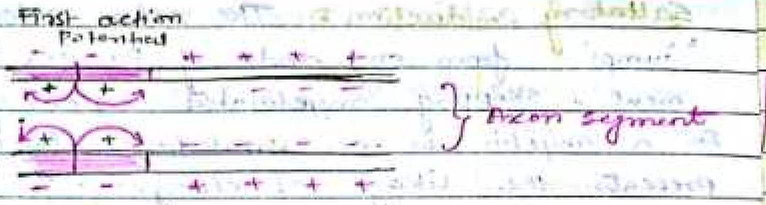


Refractory Period :- Sensitivity of axon to further stimulation decreases for a time known as refractory period. Na^+ channels are already open or the inactivation gates are closed.

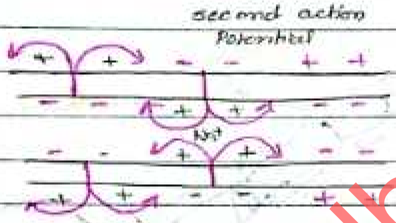
- During Refractory period the neuron is insensitive to depolarizing stimuli.
- **All or none** :- If the stimulus is below threshold, no action potential is generated. If it is higher than threshold, then action potential is not be higher.

Action potential propagation :-

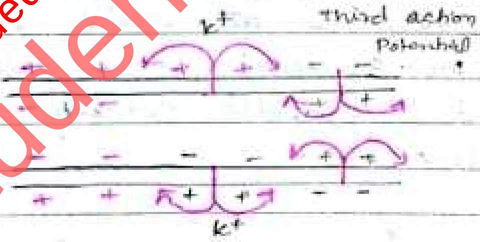
The action potential at a site produces local current that depolarize the site adjacent to it this produces another action potential at the next site. It thus, leads to an action potential propagation along the entire length of the membrane.



① An action potential is generated as Na ions flow inward across the membrane at one location.



② The depolarisation of the 1st action potential has spread to the neighbouring region of the membrane, depolarizing it and initiating a second action potential. At the site of the first action potential ; the membrane is repolarising as K^+ flows outward.



③ A 3rd action potential follows in sequence, with repolarizing in its wake. In this way, local currents of ions across the plasma membrane give rise to a nerve impulse that passes along the axon.

Propagation of the action Potential

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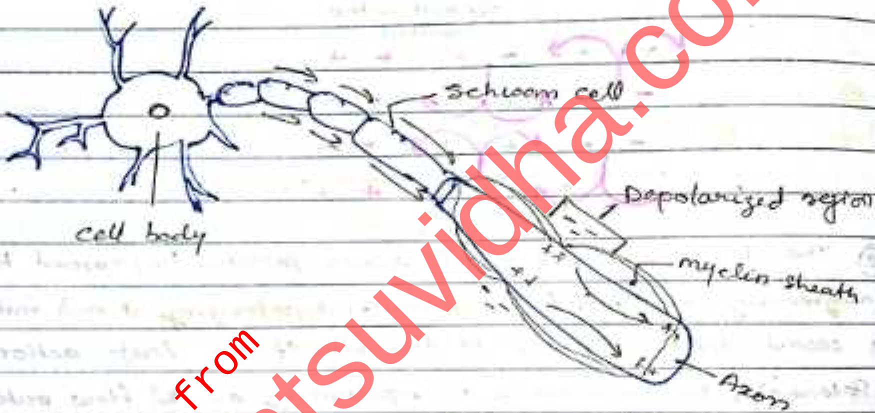
Action Potential "travel"

Saltatory conduction : The action potential "jumps" from one node of Ranvier to the next, skipping myelinated regions of membrane. As a myelin is an insulator. Therefore it prevents the likage of charges.

- Myelin thus, affects the speed. If myelin is lost as in multiple sclerosis the impulse propagation is drastically slowed down.



Synapsis: The synapse is the junction between two neurons at which electrical activity of pre-synaptic neuron alters the electrical and metabolic activity of post synaptic neuron.

Synapsis appear in many form :-

Convergence when many pre-synaptic neuron affect one post-synaptic neuron.

Divergence when a single pre-synaptic neuron affect many post-synaptic neuron.

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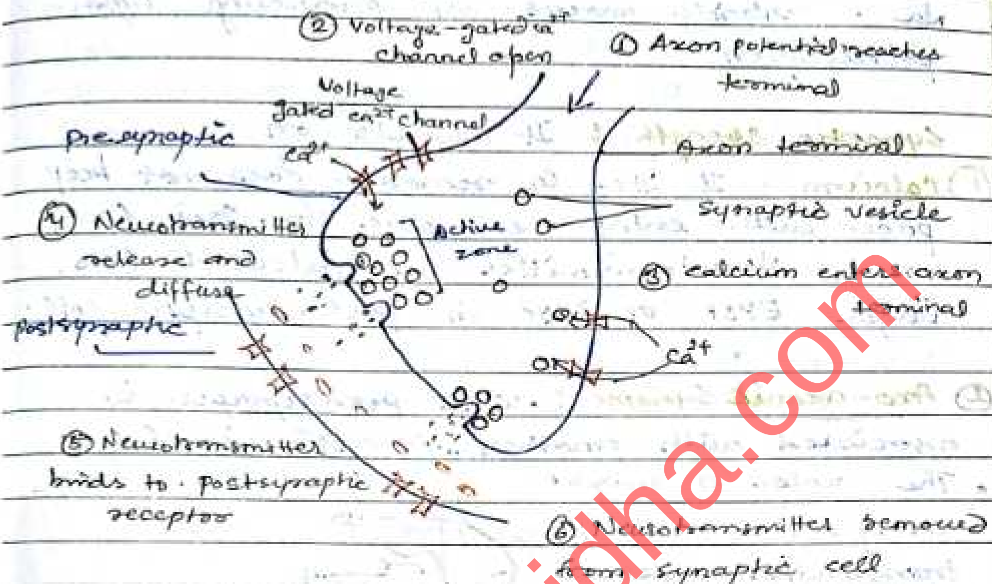
Mechanism of Neurotransmitter Release



Activation of the post-synaptic cell :

The neurotransmitter bind to receptors which may contain ion channel or may be coupled to ion channel. These are ligand gated channel.

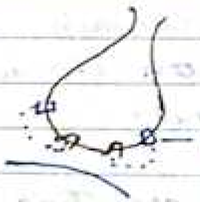
There are two types of chemical synapse :-
① Excitated : The post synaptic neuron is depolarized. In this, the Na^{++} and K^+ ion channels open. Na moves in and some K^+ moves out, but it is less compared to Na. This potential change is excitatory post synaptic potential [EPSP]
② Inhibitory chemical synapse : In this the hyper polarising potenential is generated known as IPSP.

In this, chloride and K ion channel open, not Na. chloride moves in producing hyper-polarisation

synaptic strength : It depends on
① calcium : If the Ca removal does not keep pace with entry then due to ↑sed Ca more Neurotransmitter are released thus, larger EPSP or IPSP in post-synaptic cell.

② Axo-axonic Synapse : when pre-synapse is associated with another synaptic ending.
• The neuron A might change the amt of transmitter released by B in response to action potential.

③ Sometimes the neurotransmitter acts on autoreceptors and provide feedback mechanism.



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Post synaptic mechanism for synaptic strength:

① Types of receptors :
② No. of receptors
③ De-sensitization of receptors

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Neurotransmitters & Neuromodulators

Neuromodulators regulate the post-synaptic response to a neurotransmitter or they may regulate the synthesis, release, reuptake or metabolism of ~~neutro~~ neuro-transmitters.

Chemical messengers released by neurons are ~~chl~~ neurotransmitters. e.g Acetylcholine, some neuro peptides, catacolamines.

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