6.5 NEURONS AND SYNAPSES

Nervous system:

- Sensor → sensory input → integration → motor output → effector
- divided into central nervous system and peripheral nervous system.

Difference between CNS and PNS -

Central nervous system

- consists of Brain & Spinal cord
- neurons - relay neurons (interneurons)

Peripheral Nervous System

- consists of cranial, spinal and peripheral nerves
- neurons → sensory and motor

NEURONS

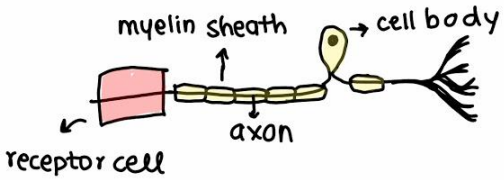
- they are specialised cells that function to transmit electrical impulses within the nervous system.

The nervous system converts sensory information into electrical impulses in order to rapidly detect and respond to stimuli.

Types of Neurons -

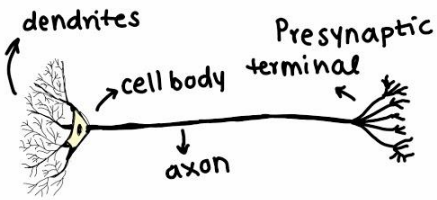
→ sensory neurons

- activated by sensory input (input can be physical or chemical)
- sensory receptors to the central nervous system.



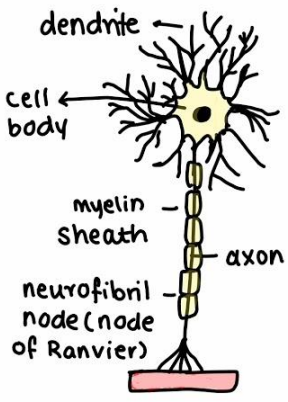
→ relay neurons

- transfers signals between sensory and motor neurons
- form a network of relay neurons within the CNS.



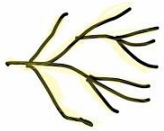
→ motor neurons

- connect to the muscle, glands and organs.
- CNS to effectors



STRUCTURE OF NEURON

→ dendrite:



→ short branched fibres

→ convert chemical information from other neurons into electrical signals.

→ axon:

→ elongated fibre

→ transmits electrical signals to terminal regions for communication with other neurons.

→ cell body (soma):

→ contains the nucleus and organelles

→ carries out essential metabolic processes for survival.

MYELIN SHEATH

It is an insulating layer present around the axon.

- It improves the conduction speed of electrical impulses along the axon.
- requires additional space and energy.

myelin

→ mixture of proteins and phospholipids that is produced by Schwann cells in the PNS and Oligodendrocytes in the CNS.

MYLENATION

- mylenation of nerve fibres allows for saltatory conduction.

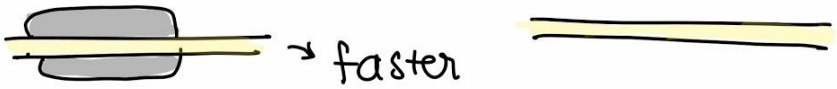
Unmylenated neurons → action potentials propagate sequentially along the axon in a continuous wave of depolarisation.

mylenated neurons → action potentials "hop" between the gaps in the myelin sheath called nodes of Ranvier.

This results in an increase in the speed of the electrical conduction by a factor of up to 100-fold.

white matter- regions of the nervous system composed of myelinated axon tracts.

grey matter- consists of neuronal cell bodies and dendrites, as well as support cells and synapses.

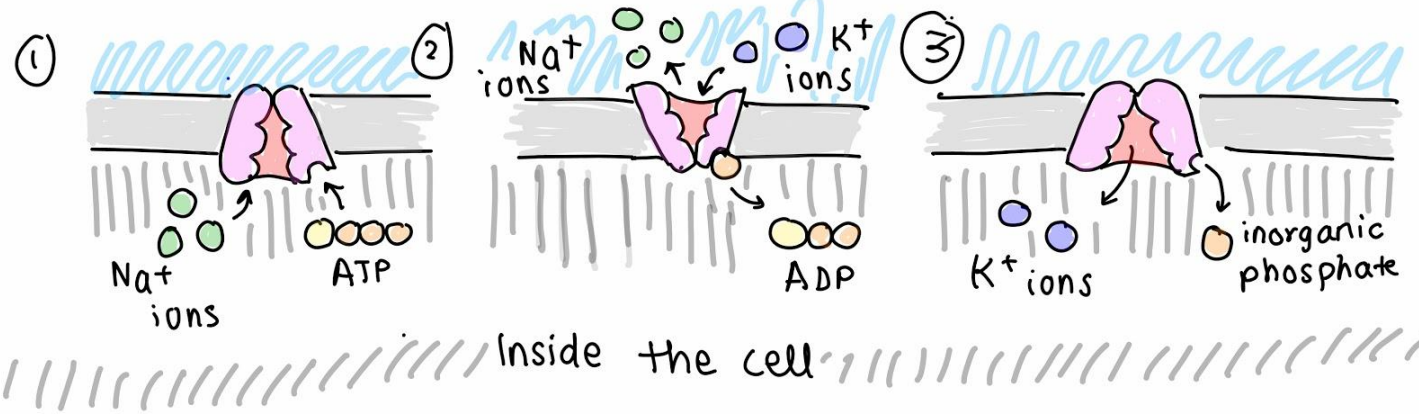


RESTING POTENTIAL

A resting potential is the difference in charge across the membrane when a neuron is not firing.

- neurons generate and conduct electrical signals by pumping positively charged ions (Na^+ & K^+) across their membrane.

Membrane potential: the unequal distribution of ions on different sides of the membrane creates a charge difference which is called a membrane potential.



The maintenance of a resting potential is an active process which is controlled by the sodium potassium pumps.

- transmembrane protein that actively exchanges sodium & potassium ions.
  - expels 3 Na^+ for every 2 K^+ ions admitted.
  - electrochemical gradient whereby the cell interior is relatively negative to the extracellular environment.

ACTION POTENTIAL

The reversal and restoration of the electrical potential across the plasma membrane of the cell.

- occur in 3 main stages- depolarisation, repolarisation and refractory period.

i) The action potential in one part of the neuron causes the action potential to develop in the next.

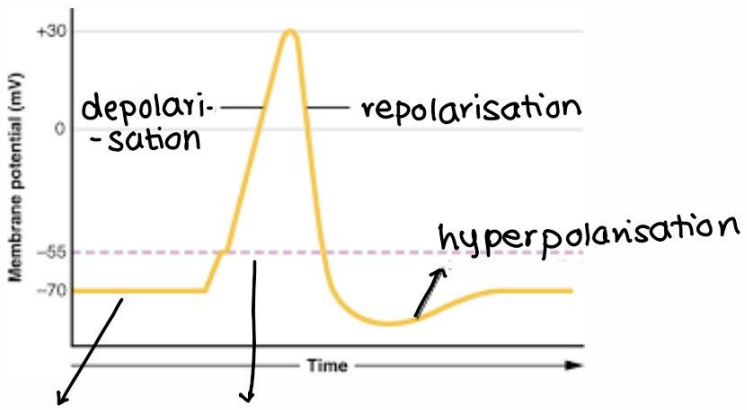
ii) Depolarisation - Sodium channels open quickly, Na^+ ions diffuse into the neuron (down the concentration gradient). Entry of these Na^+ ions causes a net positive charge.
it refers to a sudden change in membrane potential - usually from a relatively negative to to positive internal charge.

iii) Repolarisation - Potassium channel opens after short delay. The K^+ ions diffuse out Exit of positive ions causes the inside of the neuron to become negatively charged.
it refers to the restoration of a membrane potential by restoring a negative internal charge.

iv) Sodium potassium pump restores the original concentration gradient by pumping sodium out and potassium back in. The neuron gets prepared for the next impulse.

↳ Refractory period - period of time following a nerve impulse before the neuron is able to fire again.

Oscilloscope Trace of an Action potential



← Resting potential

Before the action potential occurs, the neuron should be in a state of rest (-70mV)

Threshold potential - an action potential of the same magnitude will always occur provided a minimum electrical stimulus is generated

↓

Threshold potential (-55 mV)

Oscilloscopes:

scientific instruments that are used to measure the membrane potential across a neuronal membrane.

SYNAPTIC TRANSFER

Synapses: junctions between neurons and between neurons and receptor or effector cells.

- neurons trasmit information across synapses by converting the electrical signal into a chemical signal.

Synaptic Transmission:

i) Nerve impulses reach the end of the pre-synaptic neuron.

ii) Calcium ions diffuse in through the calcium channels.

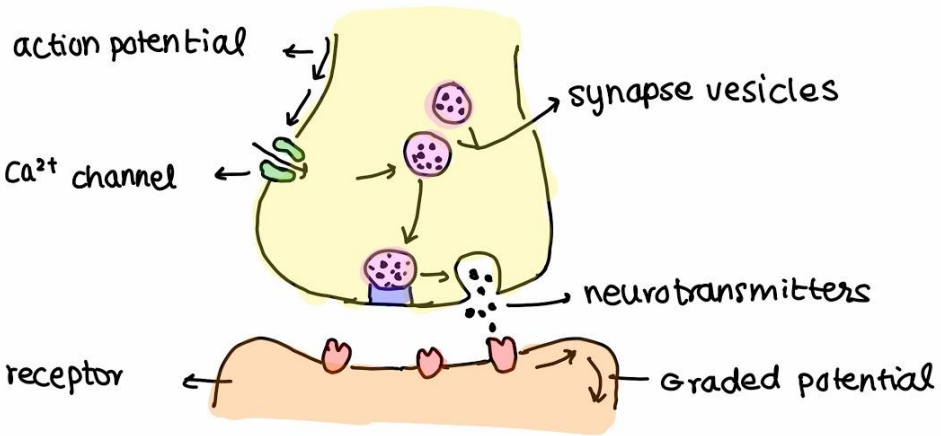
iii) Vesicles of neurotransmitters move to the membrane and release the contents.

iv) Neurotransmitters diffuse across the synaptic cleft and binds to the receptors.

v) Sodium ions enter the post synaptic neuron and cause depolarisation.

vi) The nerve impulses set off along the post synaptic neuron.

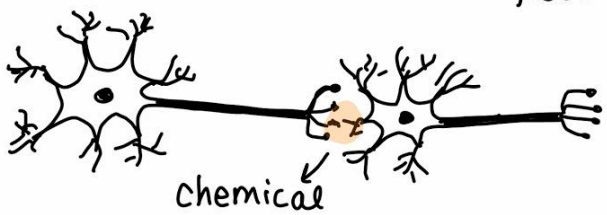
vii) Ca^{2+} ions are pumped out using ATP. Neurotransmitters are broken down in the synaptic cleft and reabsorbed into the vesicles.



NEUROTRANSMITTERS

They are chemical messengers released from neurons and function to transmit signals across the synaptic cleft.

- released in response to depolarisation of the axon of a pre-synaptic neuron.
- bind to the receptors on the post synaptic cells.



ACETYLCHOLINE

- released at the neuromuscular junctions and binds to the receptors on the muscle fibres.
- trigger muscle contraction

secretion and reabsorption:

- acetylcholine is produced in the pre-synaptic neuron

A + C → AC • choline, absorbed from the diet and acetyl, from aerobic respiration combine to form acetylcholine.

- it is loaded into vesicles and then released into the synaptic cleft.
- the receptors for acetylcholine in the post-synaptic membrane have a binding site to which the neurotransmitter will bind.
- it only binds with the receptor for a short time 

- Acetylcholinesterase enzyme is presented in the synaptic cleft which breaks down acetylcholine into acetyl and choline again.

NEONICOTINOIDS

↳ synthetic compounds similar to nicotine

- bind to the acetylcholine receptors in the cholinergic synapses in the CNS of insects.
- the enzyme cannot break neonicotinoids ∴ the binding is irreversable.
- acetylcholine isn't able to bind and the synaptic transmission is prevented.

→ consequence - paralysis / death of insects.

Advantage:

- can be used as pesticides - aren't harmful to humans

Disadvantage:

- honeys and other beneficial insects get effected too.