NEURAL CONTROL AND COORDINATION

NEURAL SYSTEM

Nervous System

- Functions of all organs or organ system of our body must be coordinated to main tan homeostasis or normal physiology of our body.
- In human body the neural system and the endocrine system jointly coordinate and integrate activities of all the organs so that they function in a synchronized fashion.
- Co-ordination is the process through which two or more organs interact & complement the functions of one another.
- For example, when we do physical exercises, the energy demand is increased for maintaining an increased muscular activity. The supply of oxygen is also increased. The increased supply of oxygen necessitates an increase in the rate of respiration, heart beat and increased blood flow via blood vessels.
- The neural system provides an organised network of point-to-point connections for a quick coordination.
- The endocrine system provides chemical integration through hormones.
- Nervous system and endocrine system are called Integrative system of the body.

	Neural Co-ordination	Endocrine Co-ordination (Chemical Co-ordination)
1.	Information passes as electrical impulses along nerve fibres.	Information passes as a chemical substance through the blood and lymph.
2.	There is rapid transmission of information	There is slow transmission of information.
3.	Response is immediate, very exact and short lived.	Response is usually slow, wide spread and long lasting.

- Nervous system offers high speed services but nerve fibres do not innervate all cells of the body and the cellular functions need to be continuously regulated, therefore a special kind of coordination and integration at the level of cells is provided by hormones.

Neural System

- The neural system of all animals is composed of highly specialised cells called neurons which can detect, receive and transmit different kinds of stimuli.
- The neural organisation is very simple in lower invertebrates.
  For example, in Hydra it is composed of a network of neurons.
- The neural system is better organised in insects, where a brain is present along with a number of ganglia and neural tissues.
- The vertebrates have a more developed neural system.

Human Neural System

The human neural system is divided into two parts:

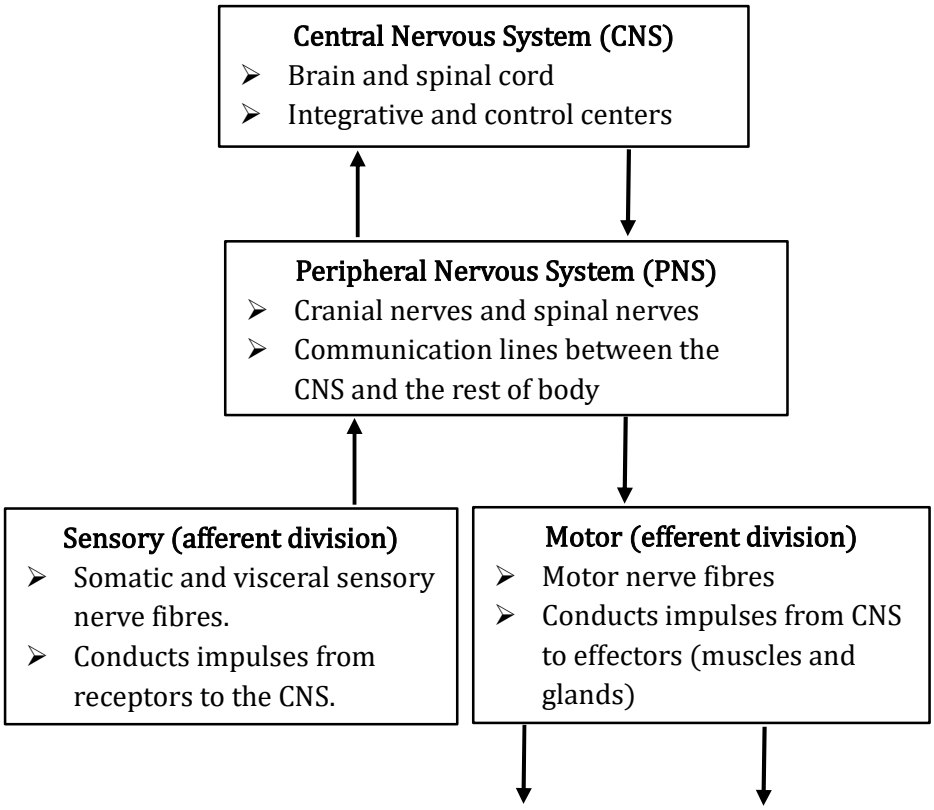
(i) Central neural system (CNS)

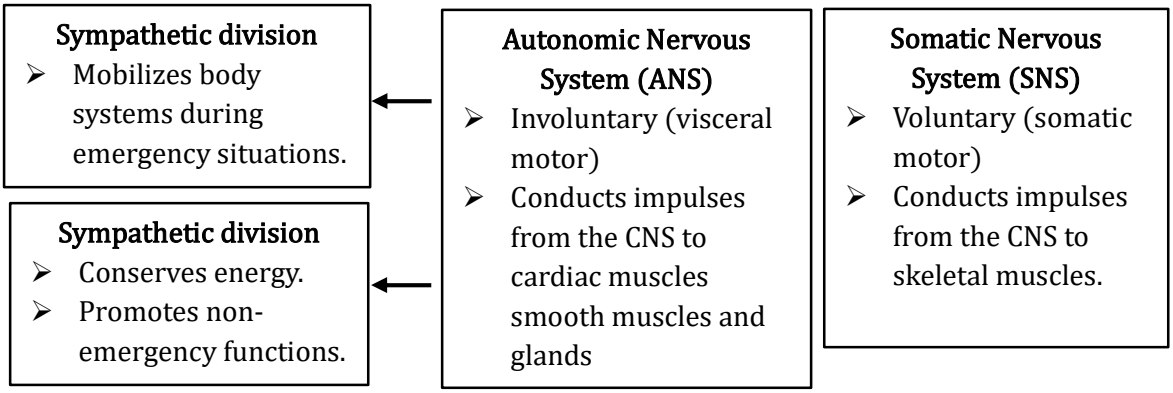
(ii) Peripheral neural system (PNS)

The CNS includes the brain and the spinal cord and is the site of information processing and control.

The PNS comprises of all the nerves of the body associated with the CNS (brain and spinal cord).

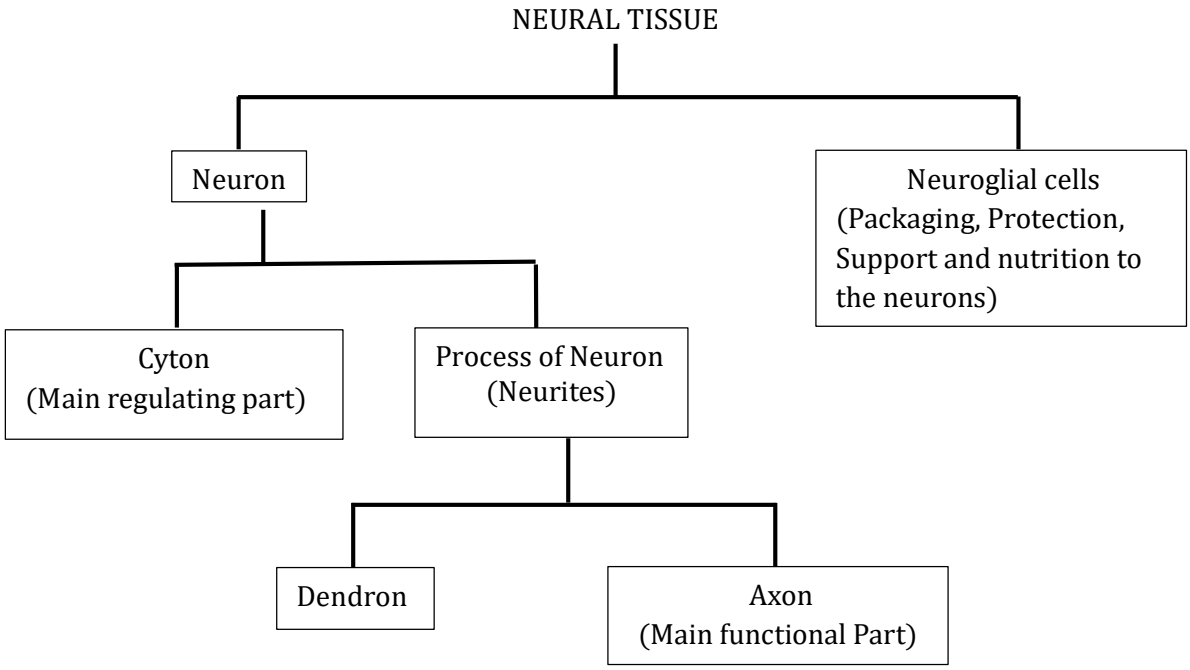
- The nerve fibres of the PNS are of two types:
  (a) Afferent fibres **(b)** Efferent fibres
- The afferent nerve fibres transmit impulses from tissues/organs to the CNS and the efferent fibres transmit regulatory impulses from the CNS to the concerned peripheral tissues/organs.
- The PNS is divided into two divisions:
  (a) Somatic neural system (SNS) **(b)** Autonomic neural system (ANS)
- The somatic neural system relays impulses from the CNS to skeletal muscles while the autonomic neural system transmits impulses from the CNS to the involuntary organs and smooth muscles of the body.
- The autonomic neural system is further classified into sympathetic neural system and parasympathetic neural system.





Nervous Tissue:

Nervous tissue originates from ectoderm and is specialized for receiving stimuli (Excitability), and transmit messages (conductivity).



- Neuron is the structural and functional unit of nervous system. It generates and transmits nerve impulses. It is the longest cell of the body.

Neuroglial cells:

These are supporting cells which form a packing substance around the neurons.
These are of three types.

(i) **Oligodendrocytes:** Formation of Myelin sheath around axons in CNS.
(ii) **Schwann cells:** Formation of Myelin sheath around axons in PNS.

(iii) **Astrocytes:** It forms blood brain barrier along with blood capillaries present in the brain. This barrier prevents the entry of neurotoxins from blood into tissues of brain.

(iv) **Microglial cells:** Smallest neuroglial cells, provide protection to tissue of brain by phagocytosis.

Melanogenesis

Axon of some neurons are covered by a layer of $\frac{\textbf{phospholipids}}{\textbf{sphingomyelin}}$ which is called as medullary sheath or myelin sheath.

- Myelin sheath is discontinuous around the Axon. These interruptions where Axon is uncovered by myelin sheath are called nodes of Ranvier.
- Myeline is a fatty material and acts as an electrical insulator in the same way as the rubber and plastic covering of electrical wiring.
- Myelin sheath acts as insulator and pervert's leakage of ions.

Peripheral nervous system (PNS):

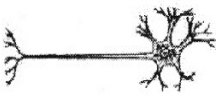
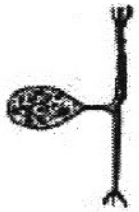
In the peripheral nerves, melanogenesis begins with the deposition of myelin sheath in concentric layer around the axon by Schwann cells. Myelin is covered by thin cytoplasm, nucleus and cell membrane of Schwann cells called neurilemma or sheath of Schwann cells. It encloses all nerve fibres in PNS.

Central nervous system (CNS):

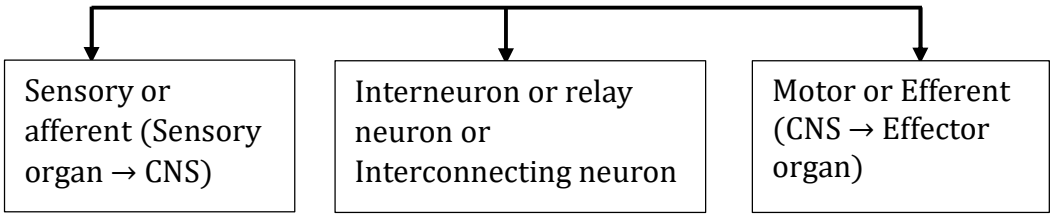
Neurilemma or Schwann cells are not present in CNS, therefore melanogenesis process occurs with the help of oligodendrocytes.

Types Of Neurons

(A) On The Basis of Structure

	A polar	Unipolar	Bipolar	Multipolar	Pseudo unipolar
Diagram					
Processes	Absent	Single	Two	Many	One
Axon	Absent	One	One	One	One
Dendron	Absent	Absent	One	Many	Absent
Examples	Hydra, Amacrine and horizontal cell of retina	Embryonic neurons	Olfactory epithelium, Retina	Most of the neurons in our body	Dorsal root ganglia of spinal cord

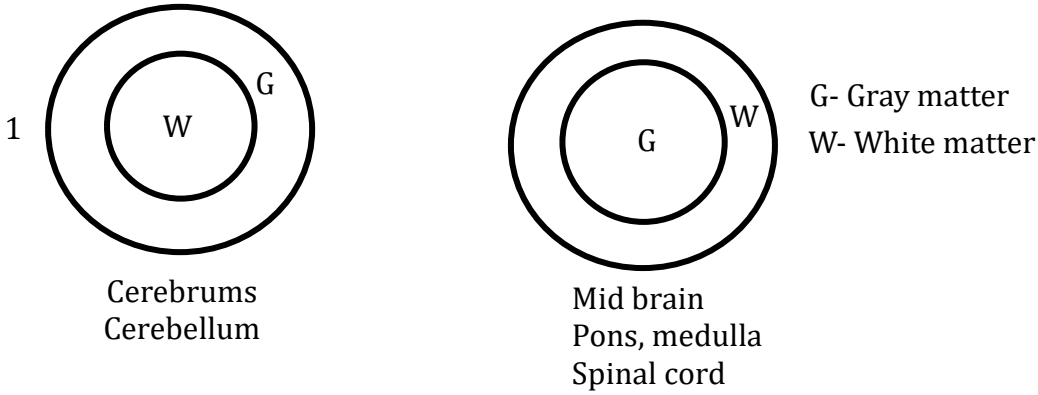
(B) On The Basis of Function



(C) On The Basis of Myelination

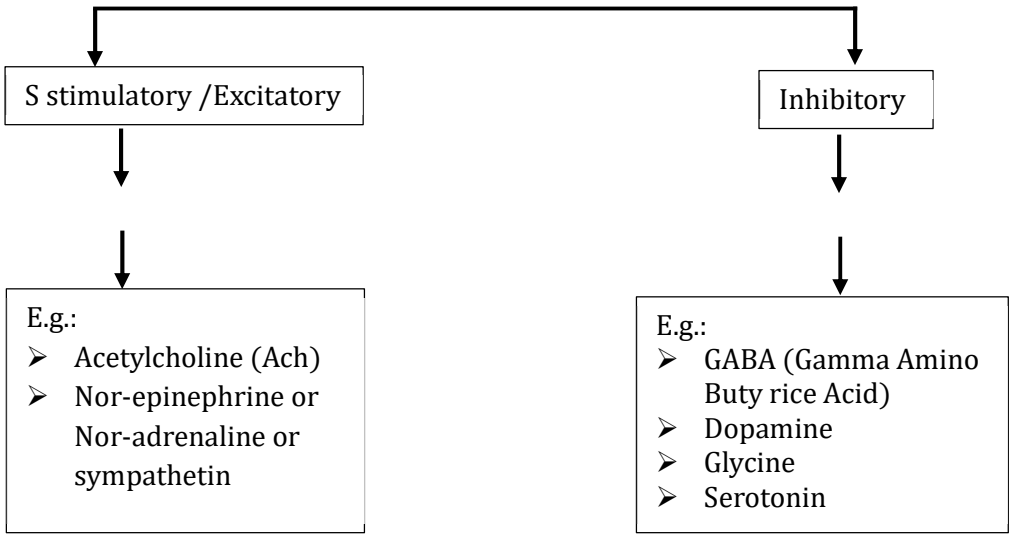
Gray matter: It is composed of nerve cells. It consists of cytons & non-myelinated nerve fibres (Gray fibers).

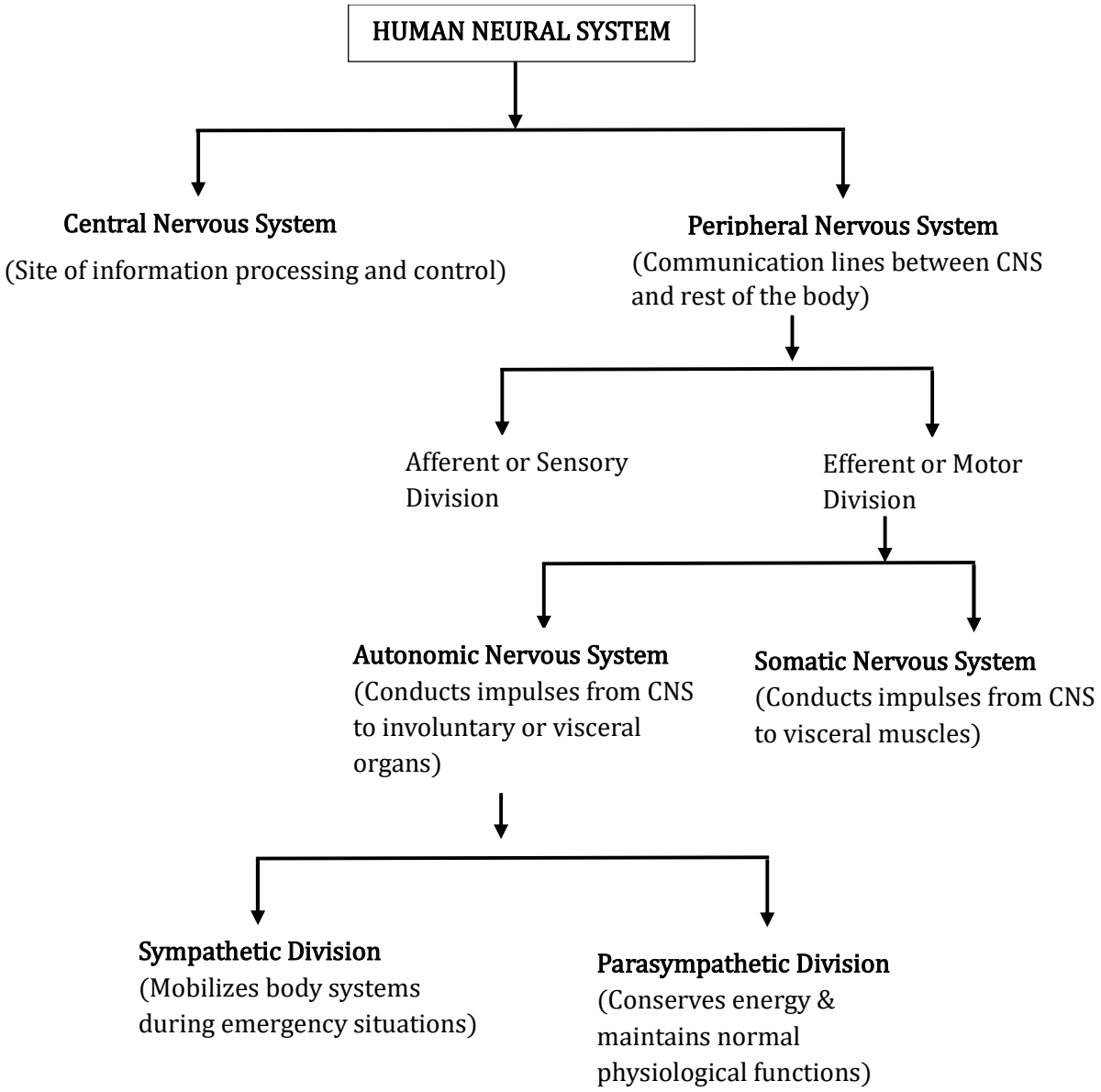
White matter: It contains myelinated nerve fibres (white fibres).



Neurons in which myelin sheath is present, are called myelinated or white nerve fibres. In some neurons where myelin sheath is absent, called as non-myelinated or gray nerve fibres.

(D) Type of Neurotransmitters





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- The PNS is divided into two divisions:
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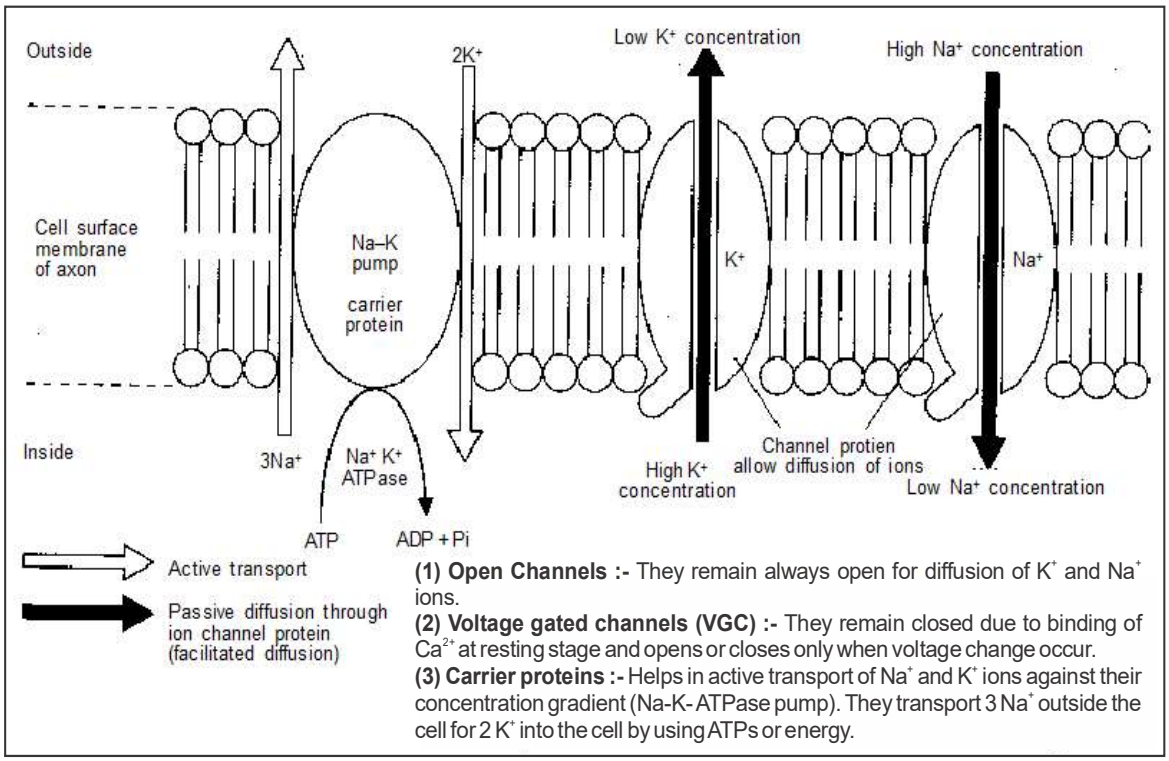
  - **(B)** Autonomic neural system (ANS)
- The somatic neural system relays impulses from the CNS to skeletal muscles while the autonomic neural system transmits impulses from the CNS to the involuntary organs and smooth muscles of the body.
- The autonomic neural system has two antagonistic units to regulate activities of visceral organs:
- sympathetic and parasympathetic system.
- Myelinated nerve fibres are found in spinal and cranial nerves. Unmyelinated nerve fibres is enclosed by a Schwann cell that does not form a myelin sheath around the axon, and is commonly found in autonomous and the somatic neural systems.

Generation And Conduction of Nerve Impulse

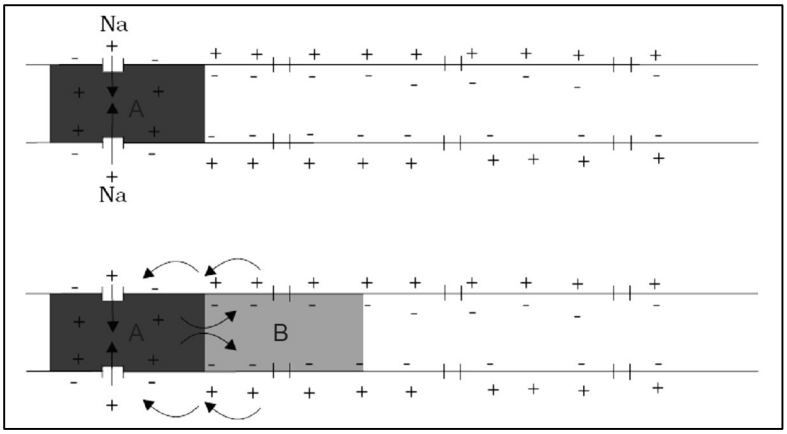


Excitable cells: Neurons are excitable cells because their membranes are in a polarized state due to differential concentration gradient of ions across membrane. Plasma membrane (Axolemma) contains different types of ion channels. This axolemma is selectively permeable to different ions.

1. **Resting State/Polarized State/Polarization:**
   - The fluid present outside the neuron (E.C.F.) contains high concentration of Na^+ and Cl^- ions while the axoplasm inside the axon contains high concentration of K^+ and negatively charged proteins, low concentration of Na^+ and thus forms a concentration gradient.

- When a neuron is not conducting any impulse (No stimulus or resting), the axonal membrane is comparatively more permeable to K^+ ions and nearly impermeable to Na^+ ions. The rate of diffusion is determined by the permeability of the membrane to the ions. Therefore, there would be greater loss of K^+ ions from the axon than Na^+ gain, this net loss of positive ions makes outer surface of membrane positively charged.
- Similarly, the membrane is impermeable to negatively charged proteins present in the axoplasm, so the inner surface of membrane becomes negatively charged. This membrane is said to be polarized.
- These ionic concentration gradient across the resting membrane are maintained by the active transport of ions by $Na^+ - K^+$ ATPase pump (carrier protein) which transports 3 Na^+ outwards for $2K^+$ into the cell.
- The potential difference across the membrane at rest is called "Resting membrane potential" (RMP = –70 mV, Range = –60 to –85 mV). The negative sign indicates that inner surface of membrane is more negatively charged relative to the outside.
- Overall, Active transport (mainly) and diffusion process are responsible for polarized state and maintaining resting potential (RMP) of neurons of our body.

2. Excited State/Depolarization:



Once the event of depolarization occurs, a nerve impulse or nerve impulse or spike is initiated. Action potential is another name of nerve impulse. This is generated by a change in the sodium ion channels. These channels, and some, of the potassium ion channels, are known as voltage gated channel, meaning they can be opened or closed with change in voltage. In resting state these channels are closed due to binding of Ca^{++}.

- A potential is generated and it cause sudden opening of the sodium gates. Opening of gates increases the permeability of the axon membrane to sodium ions which enter by diffusion. This increases the number of positive ions inside the axon.
- A change of +10 mV in potential difference from RMP through influx is sufficiently significant to trigger a rapid influx of Na^+ ions leading to generation of action potential. This change of +10 mV is called as threshold stimulus.
- At the point where membrane (Axolemma) is completely depolarized due to rapid influx of Na^+ ions, the negative potential is first cancelled out and becomes "0".

- Due to further entry of Na+, the membrane potential "over shoots" beyond the zero and becomes positive up to +30 to +45mV.
- This potential is called as action potential. In this state, the inner surface of axolemma becomes positively charged and outer surface becomes negatively charged. The rise in the stimulus-induced permeability to $Na^{\pm}$ is extremely short-lived. It is quickly followed by a rise in permeability to K^{+}.

3. Repolarization/Refractory Period:

- The rise in the stimulus induced permeability to Na^{+} is extremely short lived. It is quickly followed by a rise in permeability to K^{+} ions. Within a fraction of a second, K^{+} diffuses outside the membrane and restores the resting potential of the membrane at the site of excitation and the fiber becomes once more responsive to further stimulation.
- It means, after a fraction of second, the Na^{+} channels get closed and K^{+} channels (VGC) get open. Therefore, K^{+} diffuses outside the membrane rapidly. This rapid outflux of K^{+} (positive ions) makes inside of cell less positive or more negative and restores the resting potential of the membrane at the site of excitation and potential difference drops from +30 mV (AP) to –70 mV (RMP). This phenomenon is called repolarization. The neuron is now prepared to receive another stimulus and conduct it in the same manner.
- The time required for restoring resting potential or normal polarized state by an excited neuron is called refractory period, because during this period, the neuron is incapable of receiving another stimulus.
- The whole process of depolarization and repolarization is very fast. It takes only about 1-to-5-mile seconds.

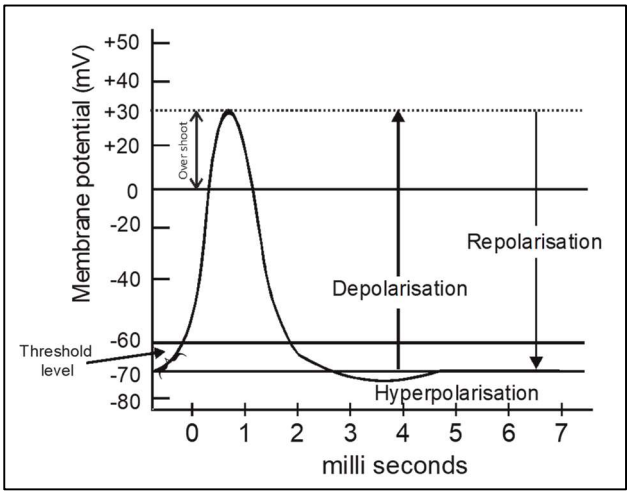


Figure: Action potential generation

Process	Na^{+} - K^{+} Pump	Passive diffusion	Na^{+} VGC	K^{+} VGC	Potential with value	Inside Charge after the event
Palarisation	3	3	X	X	RMP(-60 to -85 mV)	Negative

Depolarization	X	3	3	X	+30 to +45 mV	Positive
Repolarization	3	3	X	3	-70 mV	Negative
Hyperpolarization	3	3	X	3	-85 mV	Negative

- Open/Operating → 3 Closed → X