NERVOUS SYSTEM (NERVOUS TISSUE)

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CLASSIFICATION OF NEURONS

- STRUCTURAL CLASSIFICATION OF NEURONS
  (Based On No. Of Processes Extending From Cell Body)

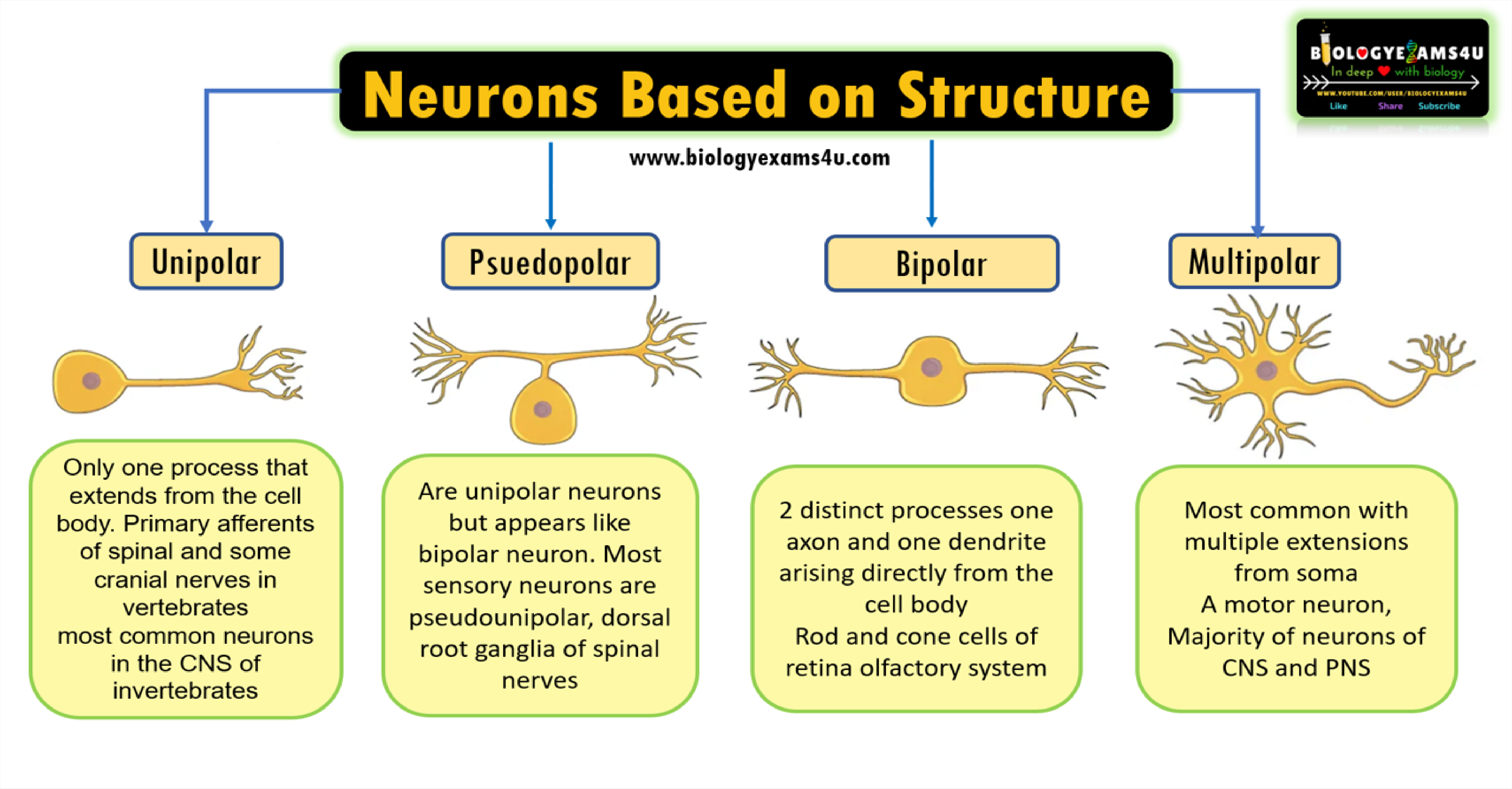
- STRUCTURAL CLASSIFICATION OF NEURONS
  (Based On Variation In Axons)

- Based on Function

- Based on presence or absence of myelin sheath

STRUCTURAL CLASSIFICATION OF NEURONS

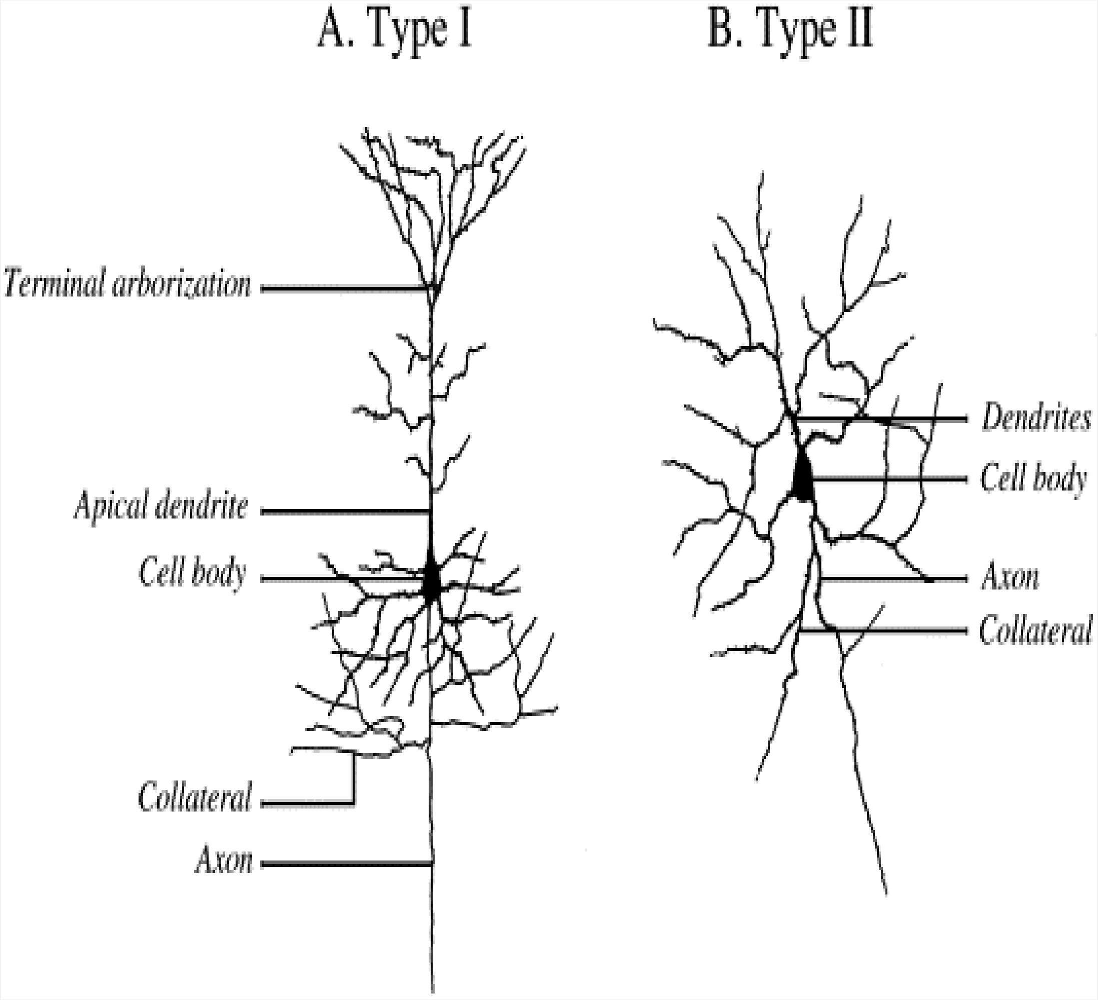
(Based On No. Of Processes Extending From Cell Body)



STRUCTURAL CLASSIFICATION OF NEURONS
(Based On Variation In Axons)

1. **Golgi type 1 neuron-** long axons, cell body of these neurons in CNS and axon reaches to remote peripheral organs (connect remote regions)- **motor neurons**

1. **Golgi type 2 neuron** –Axons are short and end near the cell body – **present in cerebral cortex and spinal cord (ie interneurons)**



Neurons Based on Function

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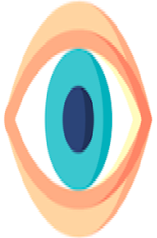
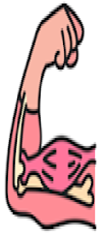
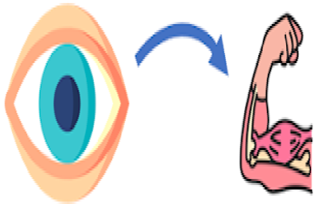
Afferent or Sensory Neuron	Efferent or Motor Neuron	Interneuron
		
These neurons detect stimuli from the environment, such as light, sound, and touch. They transmit this information to the central nervous system (CNS).	These neurons control the muscles and other organs of the body. They transmit signals from the CNS to the muscles, telling them to contract or relax.	These neurons connect sensory neurons and motor neurons. They help to process information and coordinate the activity of different parts of the nervous system.

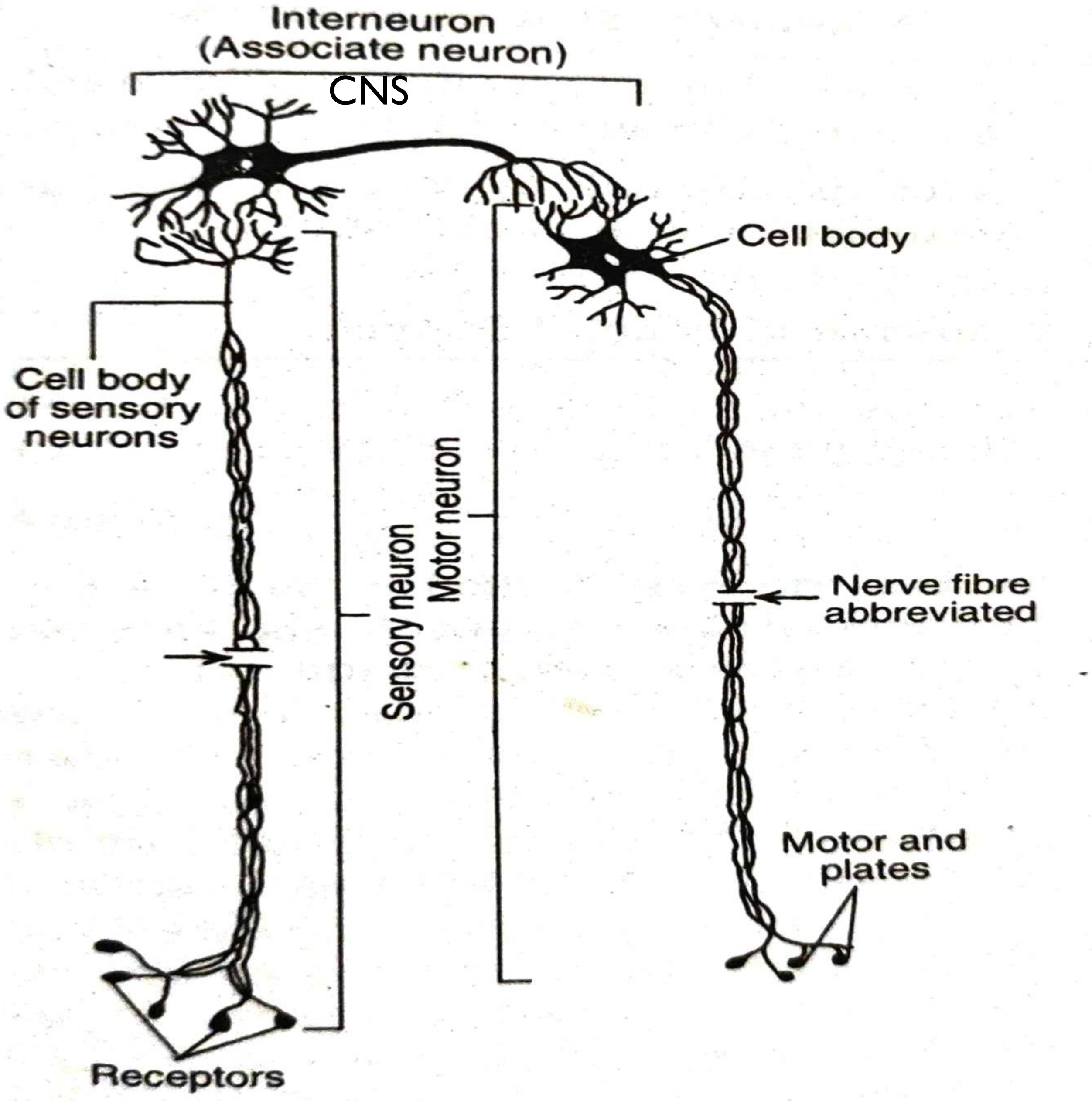
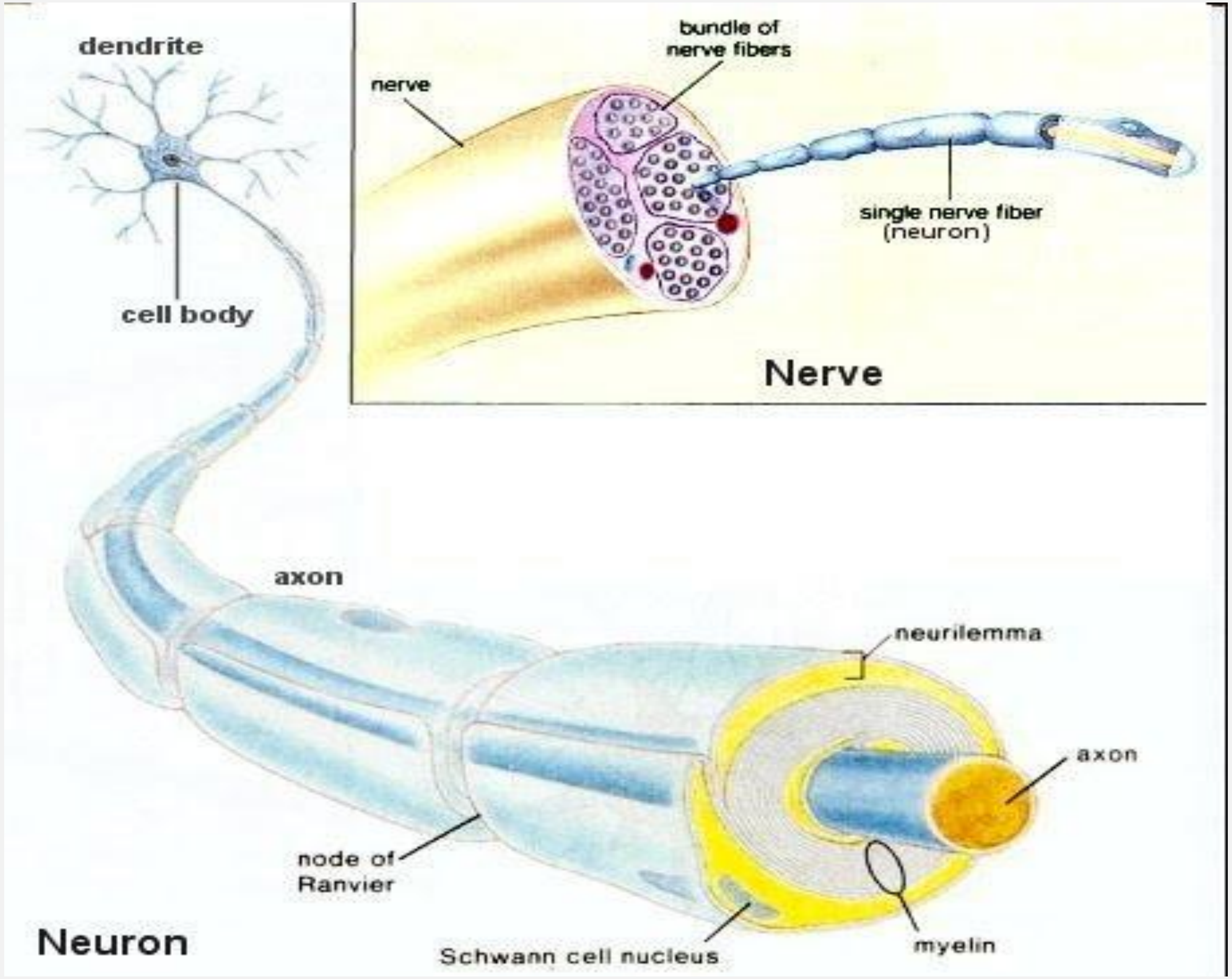


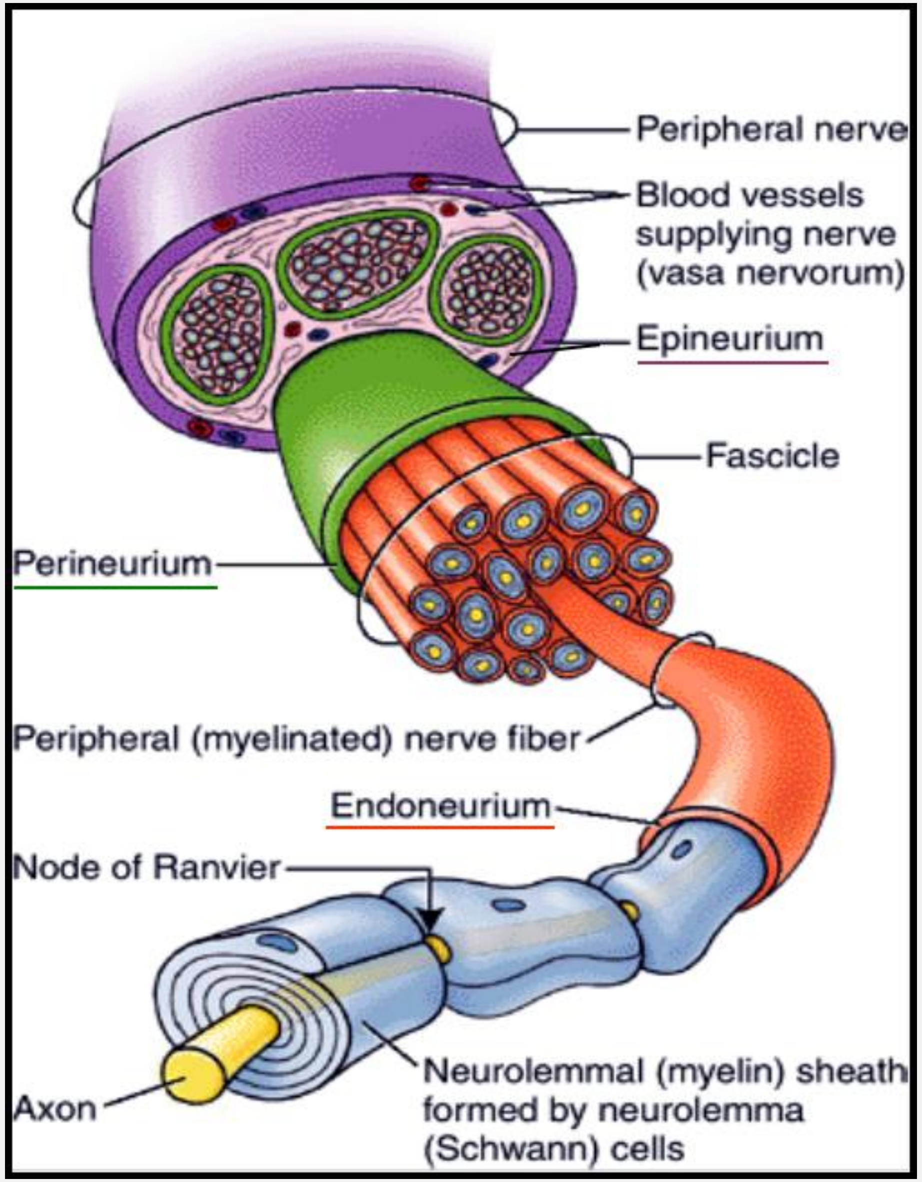
Fig 1(d).5: Diagrammatic representation of three types of neuron (basis of function).

MYELINATED NERVE FIBERS
VERSUS
UNMYELINATED NERVE FIBERS

MYELINATED NERVE FIBRE	NON MYELINATED NERVE FIBRE
Myelinated nerve fibers contain a myelin sheath around the nerve fiber	Unmyelinated nerve fibers do not contain a myelin sheath
White in color	Grey in color
Consist of nodes of Ranvier	Do not consist of nodes of Ranvier
Since transmission occurs only through nodes of Ranvier, the speed of transmission of nerve impulses is high	The speed of the transmission of the nerve impulses is low since these do not contain myelin sheaths
Long axon nerve fibers are myelinated	Short axon nerve fibers are unmyelinated
Myelin sheath prevents the loss of the impulse during conduction	Can lose the nerve impulse during conduction
Axon of this fibre is covered internally by myelin sheath and outwardly by Neurolemma	Axon is covered by neurolemma but myelin sheath is absent
Ion channels are concentrated at Nodes of Ranvier	Ion channels are spread throughout the axon
Conduction type is Saltatory Conduction	Conduction type is Continuous Conduction
Present within the White matter of brain, Spinal cord, cranial nerve and spinal nerve	Present within Gray matter of brain and spinal cord and autonomic nervous system

NEURON Vs NERVE FIBRE Vs NERVE



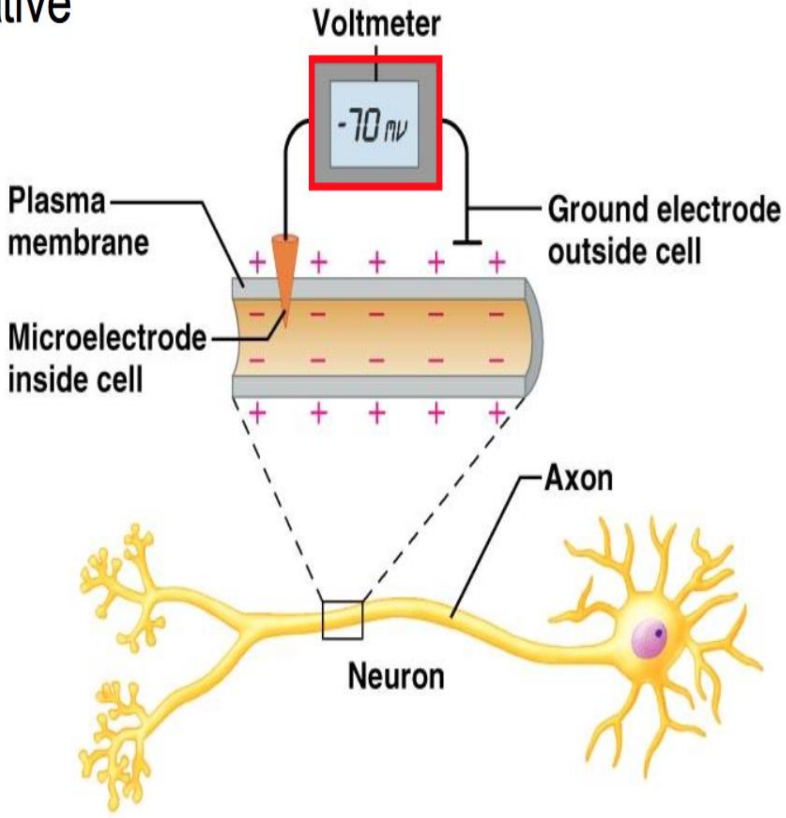


GENERATION OF NERVE IMPULSES AND PROPOGATION OF NERVE IMPULSE

NERVE CONDUCTION (2 MAIN PHASES)
RESTING POTENTIAL
ACTION POTENTIAL

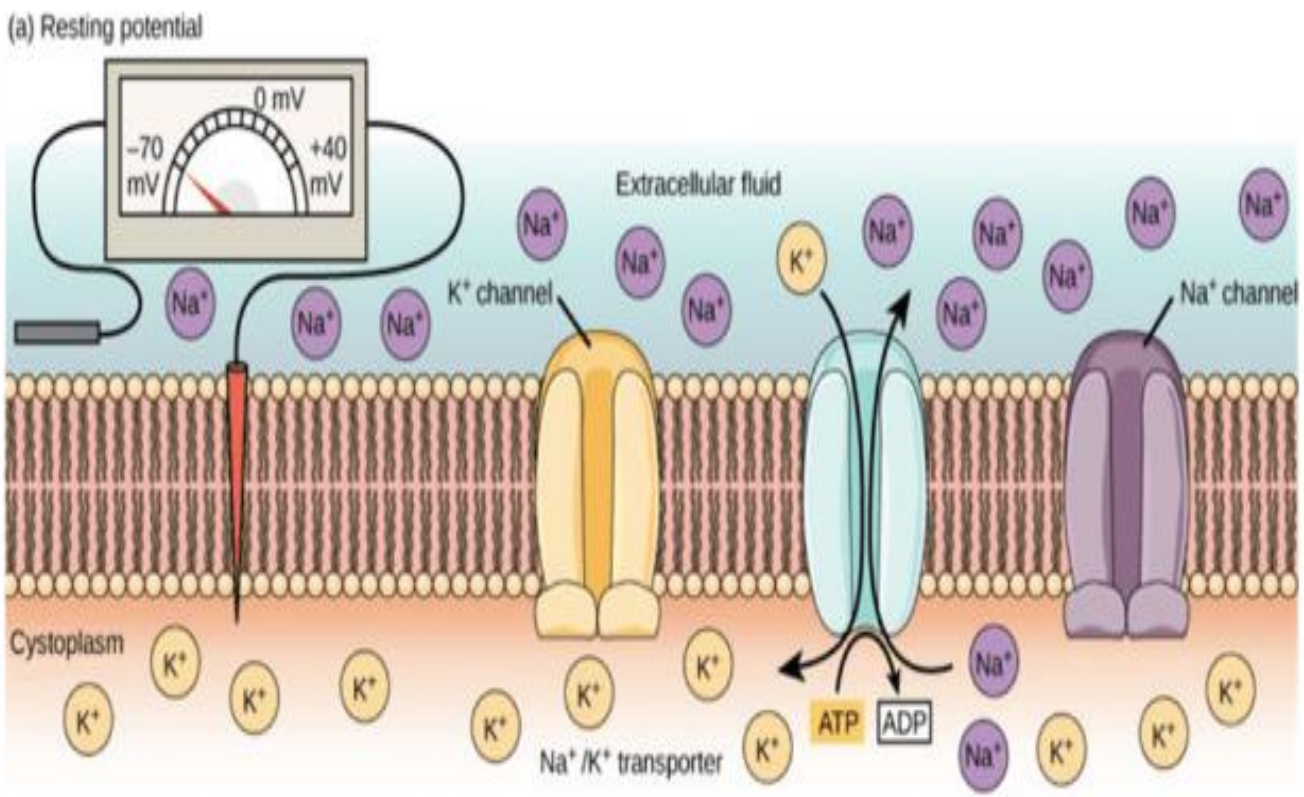
The Resting Membrane Potential

- *Usually* the cytoplasm is negative
  - (-20 to -110 mV; relative to the ECF = 0 mV)
- Depends upon ions present:
  - Permeability
  - Electrochemical gradients

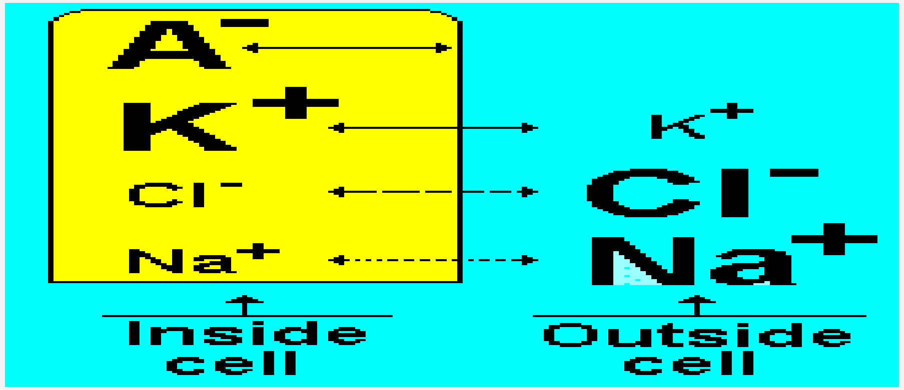


RESTING POTENTIAL

The **resting membrane potential of a cell** is defined as the difference in electrical potential across the plasma membrane when the cell is not stimulated or when the cell is in a state of relaxation.



At the resting potential, all voltage-gated Na⁺ channels and most voltage-gated K⁺ channels are closed. The Na⁺/K⁺ transporter pumps K⁺ ions into the cell and Na⁺ ions out.



- When a neuron is at rest, the resting potential of a neuron is typically -70 mV
- This shows **the surplus negative charged ions on the inner side of the membrane.**
- Typically, a higher level of potassium ion K+ is present inside the cell.
- At the exterior of the cell, the level of Sodium and Chloride ions (Na+ and Cl-) are in higher concentration.
- Unlike other cell types, neurons and muscle cells are capable of transitioning from a resting state to a more active one.

When at rest, the neuron is *negatively charged* relative to its environment. This is because of the following events:

i) At rest, the negatively charged ion -Cl^- and the positively charged ion, Na^+, cannot easily cross the plasma membrane of the neuron (*sodium channels* close)

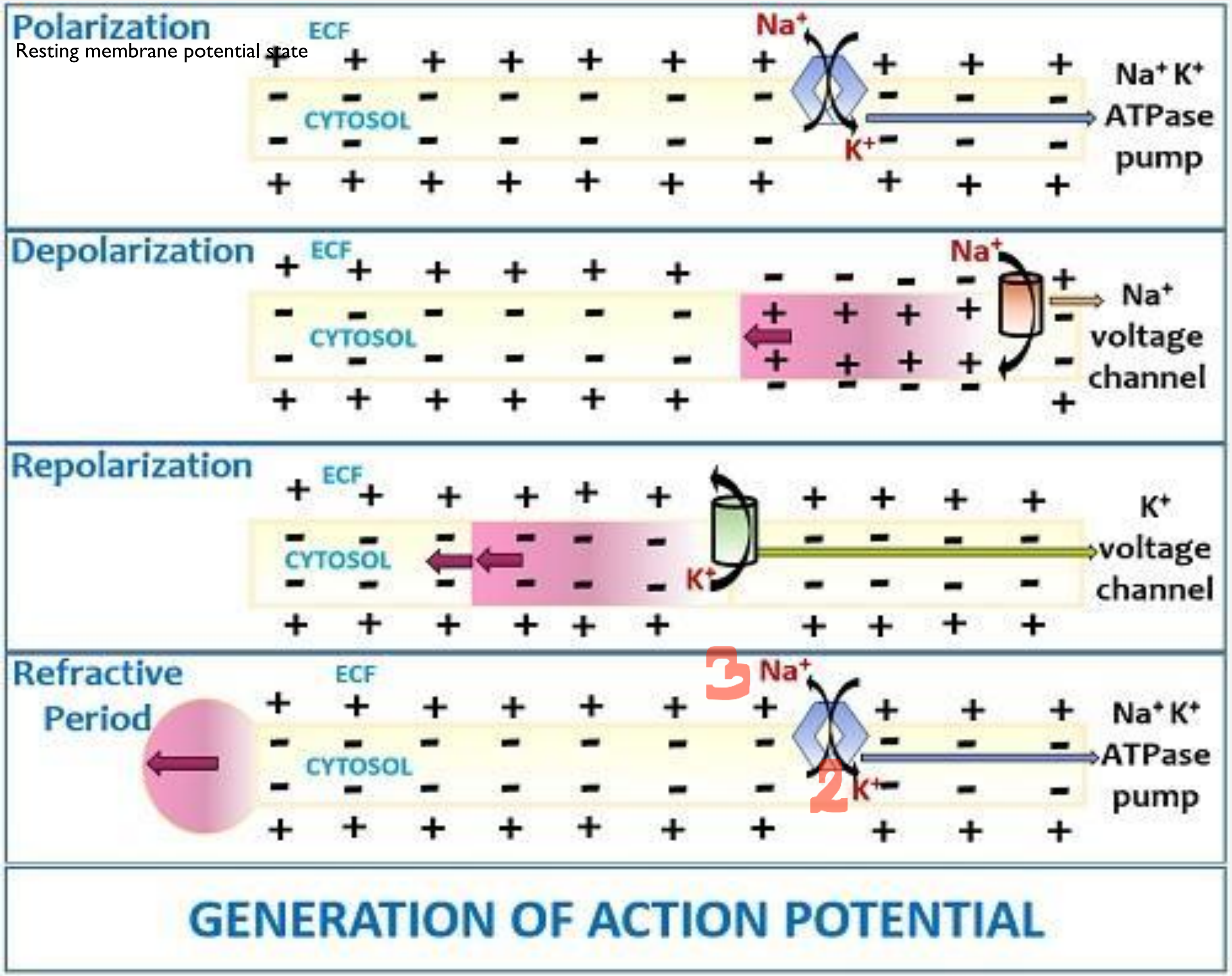
ii) Negatively charged proteins cannot readily leave the neuron as well. (Ie., UNEQUAL DISTRIBUTION OF IONS)

iii) A **membrane pump** moves *three* Na^+ out for every *two* K^+ entering the cell.

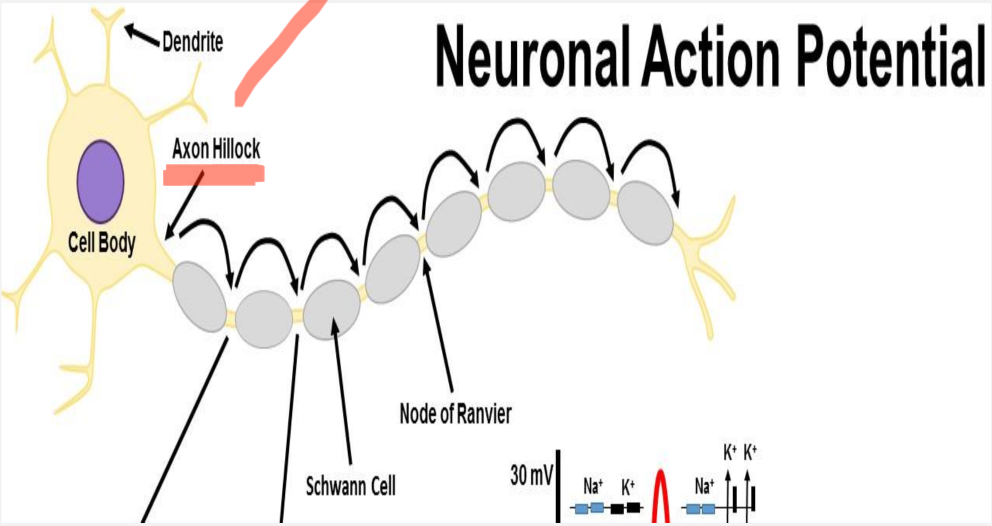
- As a result, more Na^+ ions are outside than inside and more K^+ ions inside than outside the cell.

- This leads to a *resting membrane potential* of about ***-70mV***, which means the inside of the neuron is about 70 mV less than its environment

ACTION POTENTIAL



ACTION POTENTIAL Begins at the Axon Hillock as a result of Depolarization

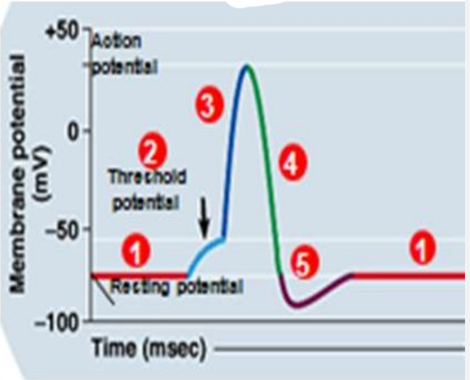


ACTION POTENTIAL: It is the change in electrical potential across the neuronal membrane.

Action potential carries the impulses from one neuron to the next neuron. Action potentials are all-or-none.

Steps in an Action Potential

1. **Resting potential** or Polarization **(-70 mV)**
   - Na+ outside, K+ inside
   - Channels closed
2. **Stimulus / Threshold** **(-50 mV)**
   - Some Na+ channels open
   - Na+ comes in
   - If **threshold** is passed they all open



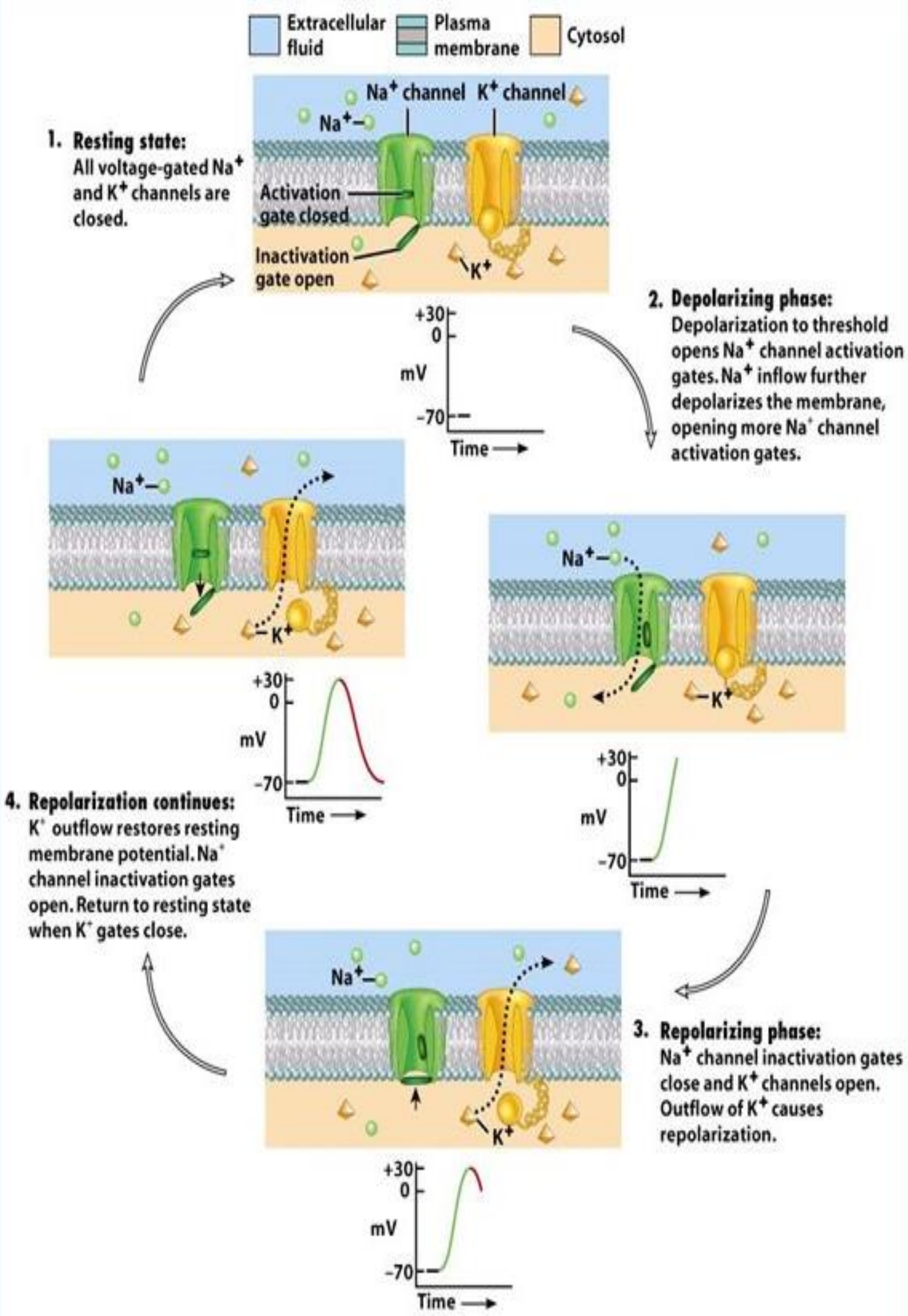
3. **Depolarization** **(+30 mV)**
   - Na+ channels open, Na+ comes in and the cell becomes positive
   - Chain reaction of Na+ channels opening down the axon
4. **Repolarization** **(-70 mV)**
   - Na+ channels close, K+ channels open
   - K+ moves out and the cell becomes negative

5. **Hyperpolarization or Undershoot & return to resting potential**

It makes the cell more negative than its typical resting membrane potential. As the action potential passes through, potassium channels stay open a little bit longer, and continue to let positive ions exit the neuron.

This means that the cell temporarily hyperpolarizes, or gets even more negative than its resting state **(-90mV)**

As the potassium channels close, the sodium-potassium pump works to reestablish the resting state by actively transporting **3 Na+ outside and 2K+ inside (ATP use)**

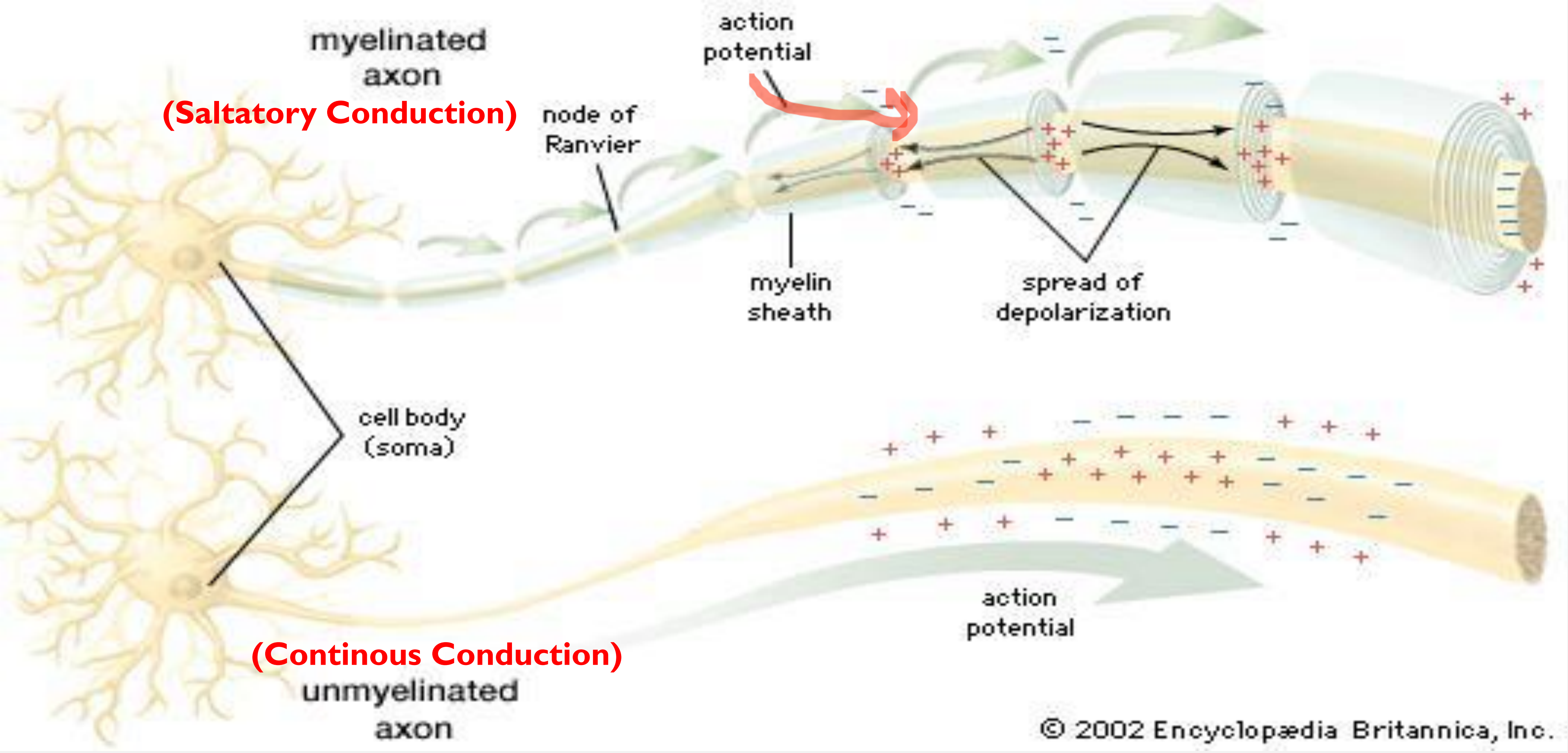


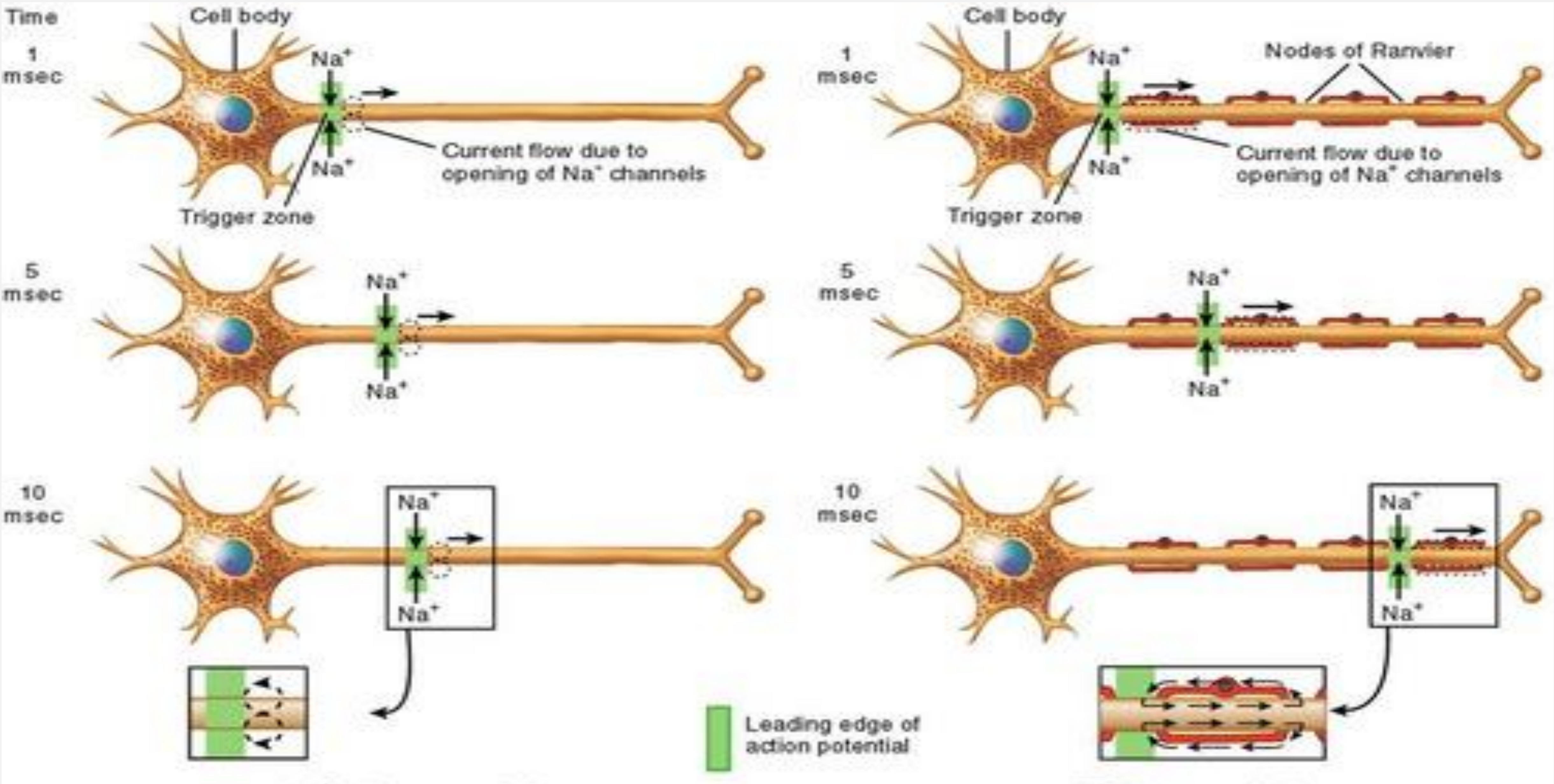
The Action Potential: Summarized

- Resting membrane potential is -70mV
- Depolarization is the change from -70mV to +30 mV
- Repolarization is the reversal from +30 mV back to -70 mV

PROPOGATION OF NERVE IMPULSE OR SIGNAL

1. MYELINATED NERVE FIBRE   2. NON-MYELINATED NERVE FIBRE

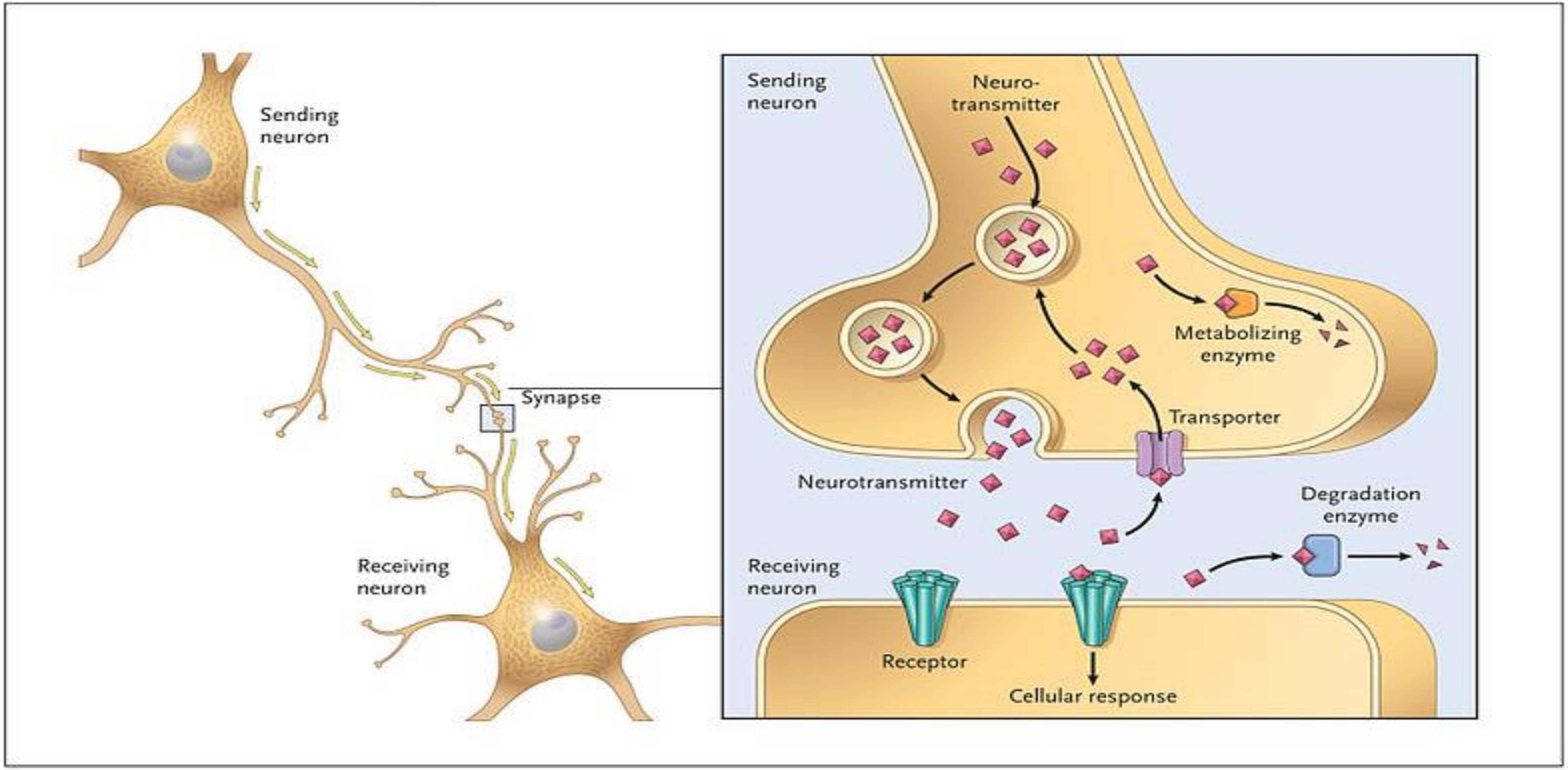




(a) Continuous conduction

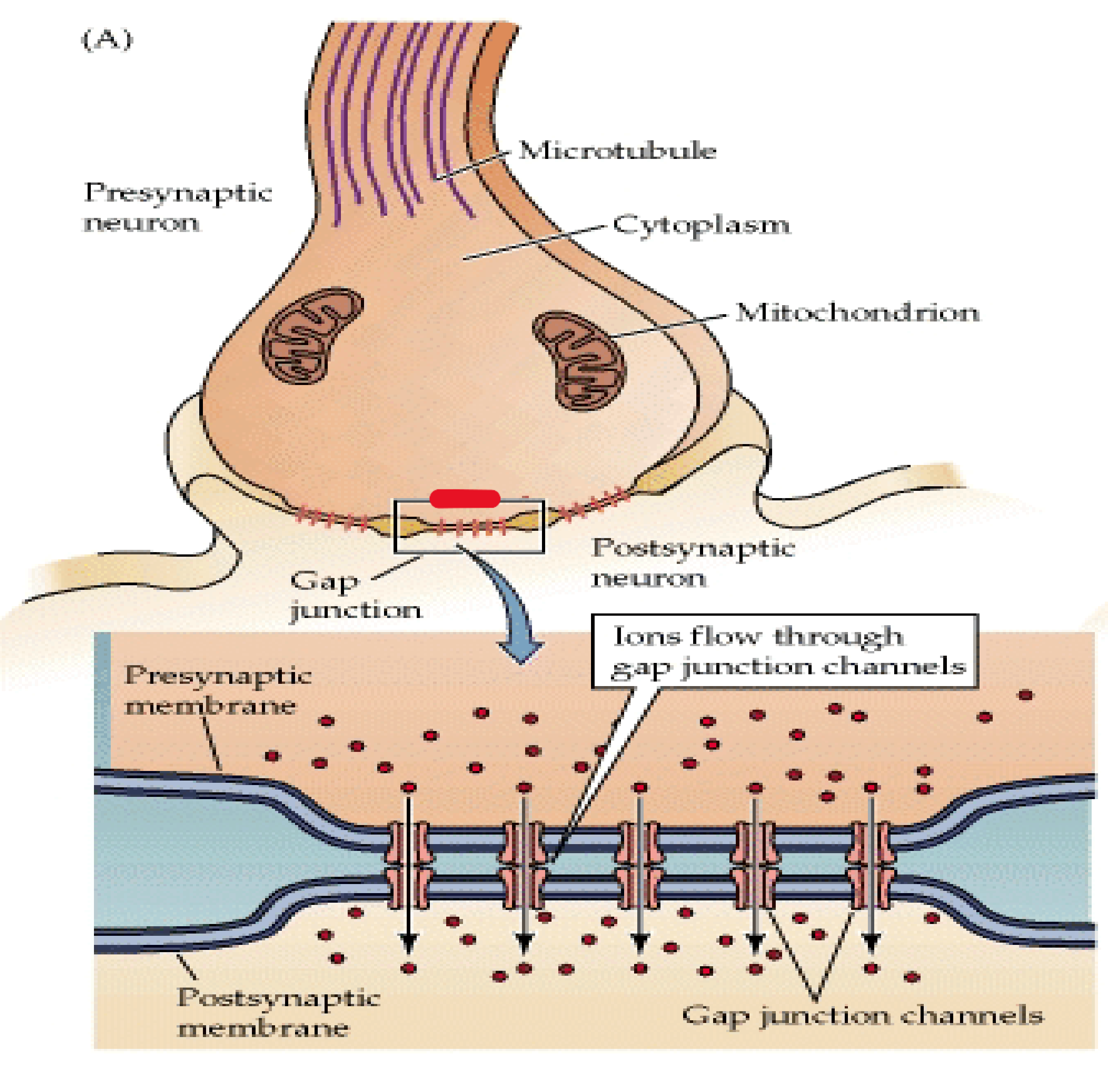
(b) Saltatory conduction

SYNAPSE

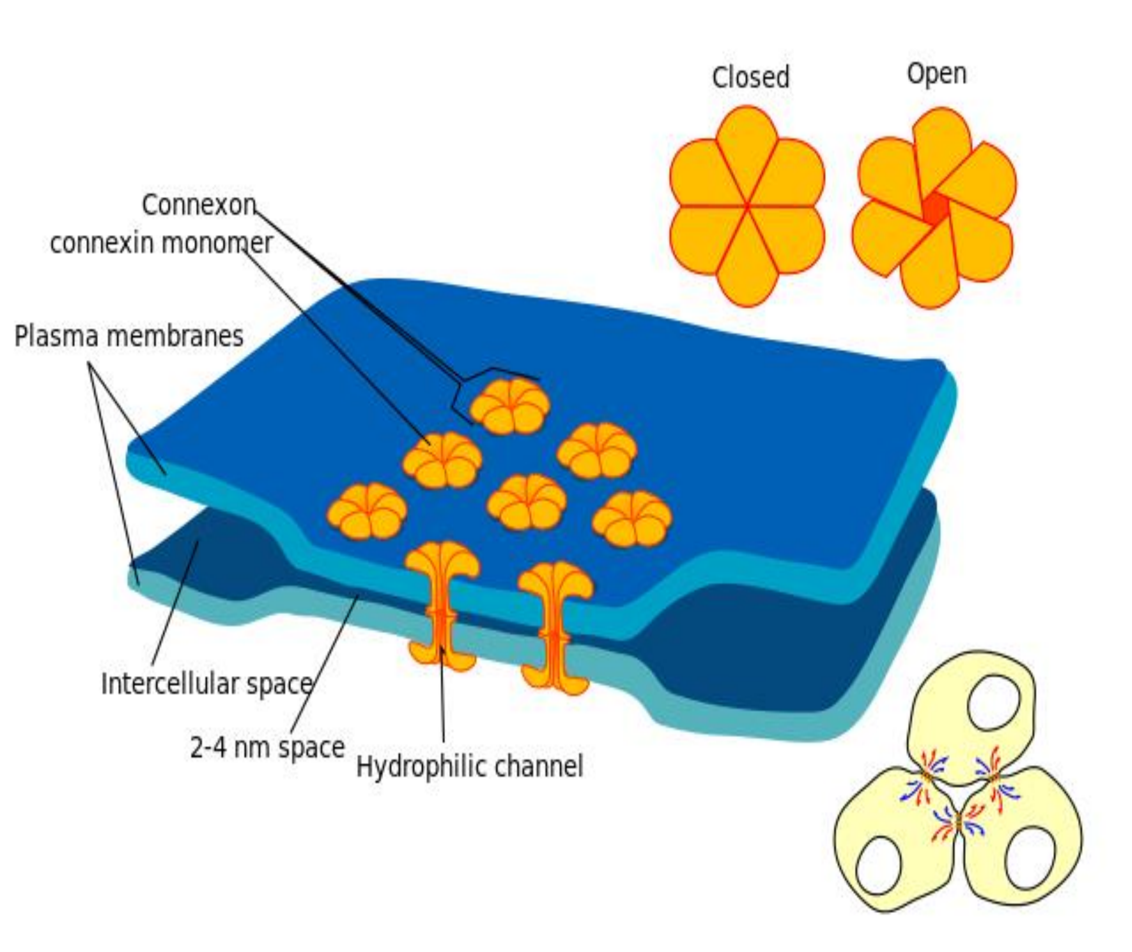

Sending neuron
Synapse
Receiving neuron
Sending neuron
Neuro-transmitter
Metabolizing enzyme
Transporter
Neurotransmitter
Degradation enzyme
Receiving neuron
Receptor
Cellular response

SYNAPSE

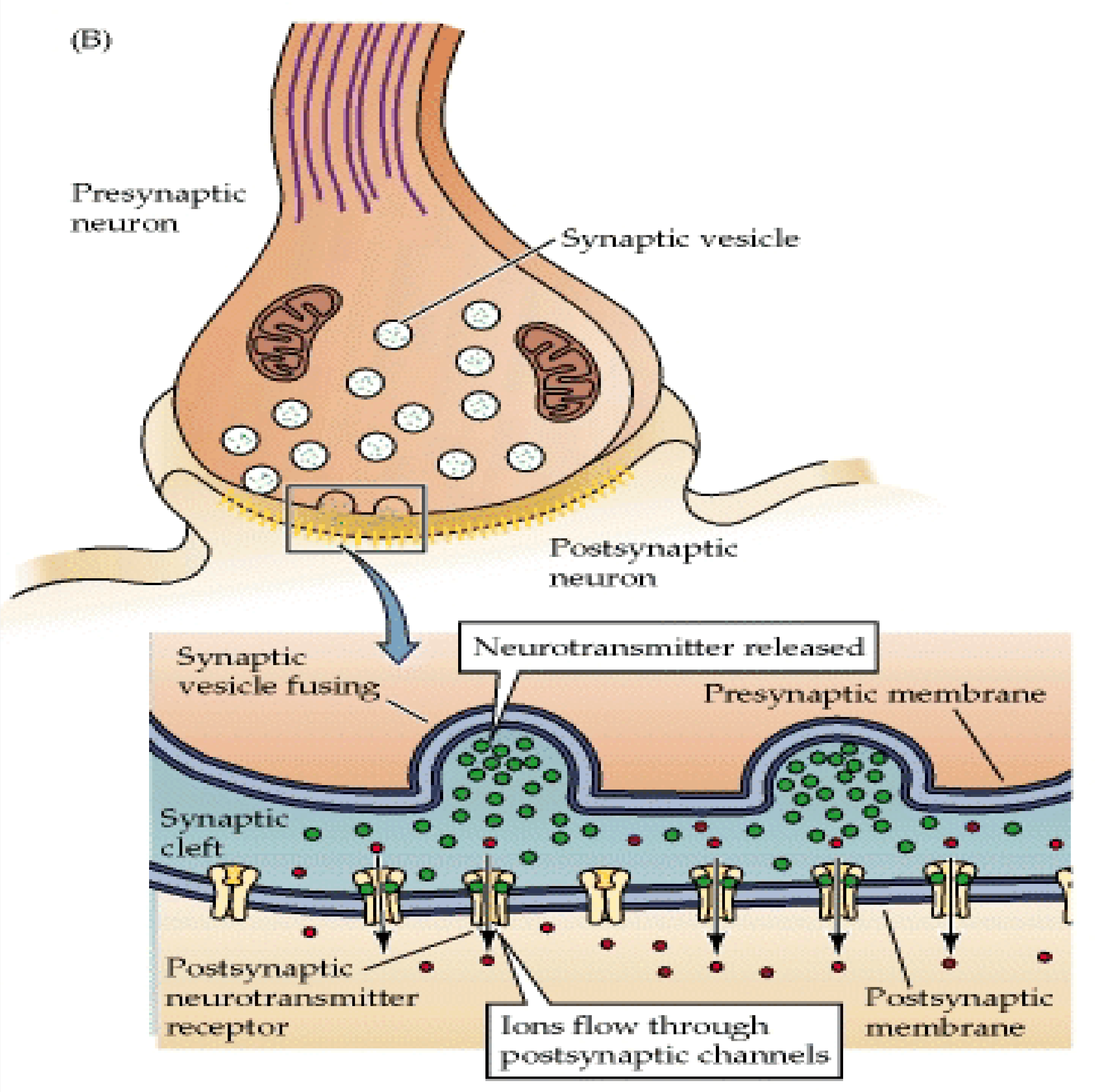
Synapse can be broadly classified into
A. Electrical Synapse
B. Chemical Synapse(Human CNS synapses)

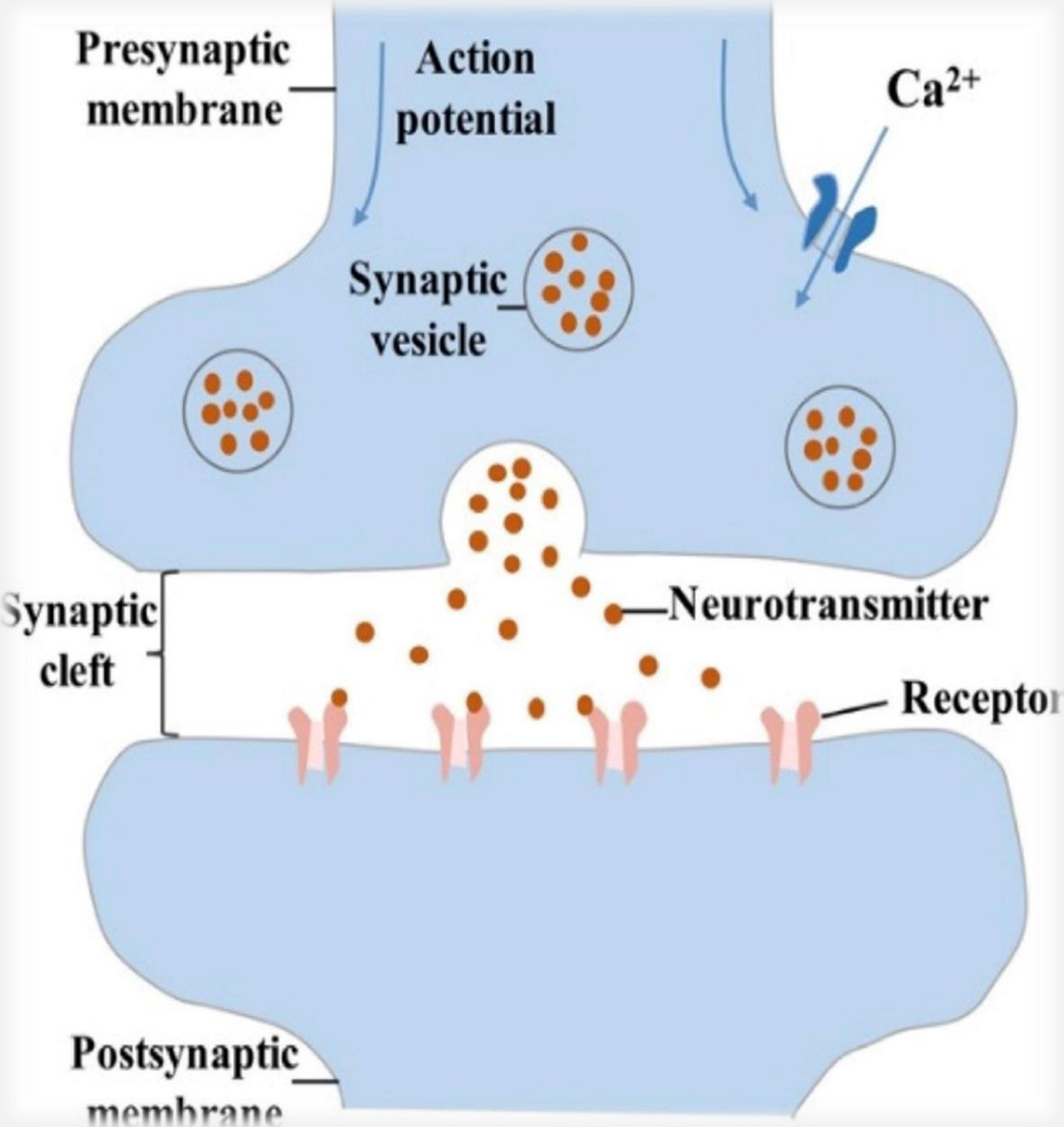


A. Electrical Synapse with connexon
(common in lower vertebrates and invertebrates, found in brains of mammals also)

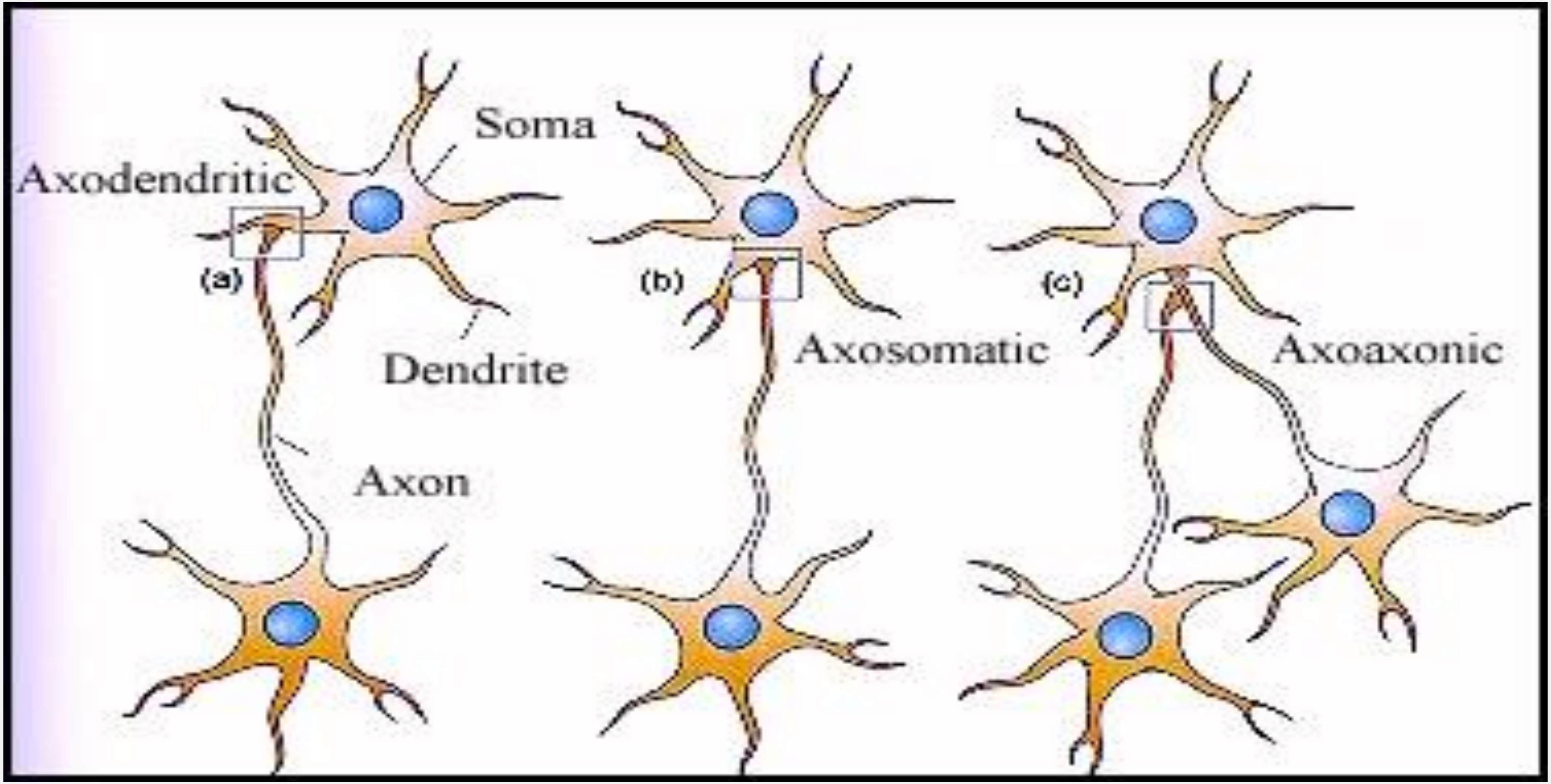


CHEMICAL SYNAPSE





CLASSIFICATION OF CHEMICAL SYNAPSE
(Based On Neuronal Elements Associated)



NEUROTRANSMITTER

- Neurotransmitters are chemical substances that transmit signals between neurons (nerve cells) or from neurons to muscles, glands, or other target cells. They are crucial for communication within the nervous system and influence various physical and psychological functions of the body.
- When a neuron is activated by an electrical signal (action potential), neurotransmitters are released from small sacs called synaptic vesicles in the neuron. These chemicals cross the synapse (the gap between neurons) and bind to receptors on the target neuron or cell. Once bound, neurotransmitters either stimulate (excitatory) or inhibit (inhibitory) the next neuron, influencing its electrical activity.

Types of Neurotransmitters:

Neurotransmitters can be broadly classified into two types **based on their effects on the target cells**. Each type plays a specific role in maintaining balance in the nervous system.

Functional Classification

Function	Examples
Excitatory (leads to depolarization)	Glutamate
	Aspartate
	Serotonin
	Histamine
	ATP, CO
Inhibitory (leads to hyperpolarization)	Glycine
	Gamma amino butyric acid (GABA)
	Taurine
Excitatory & Inhibitory (leads to depolarization and hyperpolarization depending on type of receptor)	Acetylcholine
	Epinephrine (Adrenaline)
	Dopamine
	Norepinephrine (Noradrenaline)
	NO
	Endorphins, enkephalins, substance P, cholecystokinin

1. Excitatory neurotransmitters: when released excitatory neurotransmitters have excitatory effects on the neuron. It stimulates a neuron that will fire an action potential (electrical signal), causing the target cell to become more active.

Mechanism of Action

When these excitatory neurotransmitters bind to their receptors on the postsynaptic neuron, **they often lead to the influx of positive ions (sodium)** into the neuron. **This depolarizes the neuron** and brings it **closer to the threshold for firing an action potential.**

Common Examples

Excitatory Neurotransmitters:

- **Glutamate: The most common excitatory neurotransmitter in the brain. It plays a key role in learning and memory.**
- **Aspartate: Another excitatory neurotransmitter, less abundant than glutamate but still important in brain regions. Binds with NMDA (N-Methyl D-Aspartate) Receptors which are crucial for synaptic plasticity learning and memory.**

2. Inhibitory neurotransmitters:

Inhibitory neurotransmitters **have inhibitory effects on the neuron.** It **decreases the likelihood that a neuron will fire an action potential**, calming the nervous system and **preventing overstimulation.**

Mechanism of Action

Inhibitory Neurotransmitters: when they bind to their receptors, these neurotransmitters often lead to the **influx of negative ions (like chloride) or the efflux of positive ions (like potassium)**. They make the **inside of the neuron more negative,** which makes it less likely to reach the threshold needed to trigger an action potential.

Eg: Inhibitory Neurotransmitters:

- **GABA** (Gamma-Aminobutyric Acid): **The primary inhibitory neurotransmitter** in the **brain**. It helps regulate anxiety and muscle tone.
- **Glycine:** Commonly **found in the spinal cord and brainstem**, it plays a crucial role in inhibiting motor neurons.

NEUROTRANSMITTERS

ADRENALINE
fight or flight

produced in stressful situations. Increases heart rate and blood flow, leading to physical boost and heightened awareness.

GABA
calming

Calms firing nerves in the central nervous system. High levels improve focus, low levels cause anxiety. Also contributes to motor control and vision.

NORADRENALINE
concentration

affects attention and responding actions in the brain. Contracts blood vessels, increasing blood flow.

ACETYLCHOLINE
learning

Involved in thought, learning and memory. Activates muscle action in the body. Also associated with attention and awakening.

DOPAMINE
pleasure

feelings of pleasure, also addiction, movement and motivation. People repeat behaviors that lead to dopamine release.

GLUTAMATE
memory

Most common neurotransmitter. Involved in learning and memory, regulates development and creation of nerve contacts.

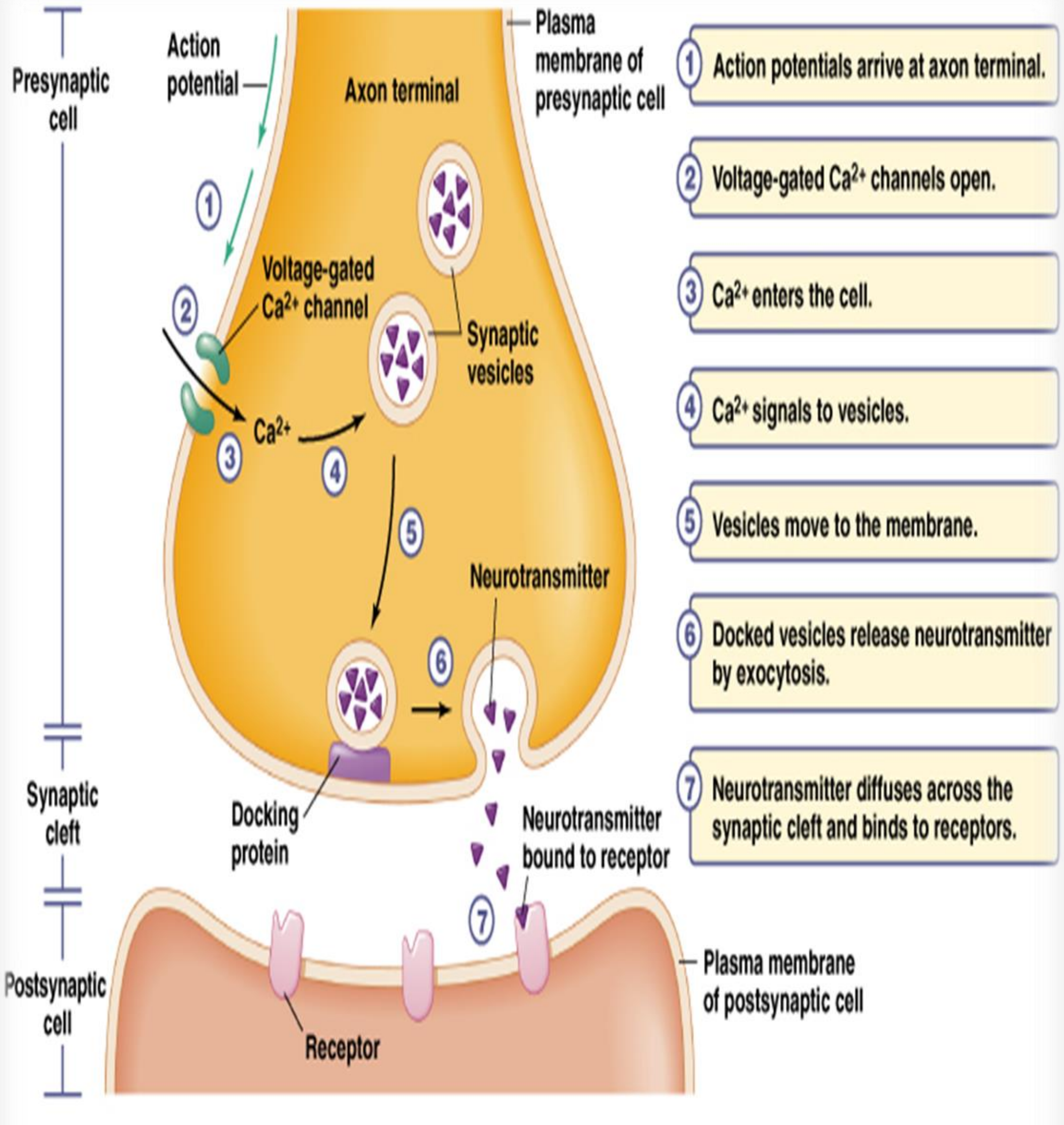
SEROTONIN
mood

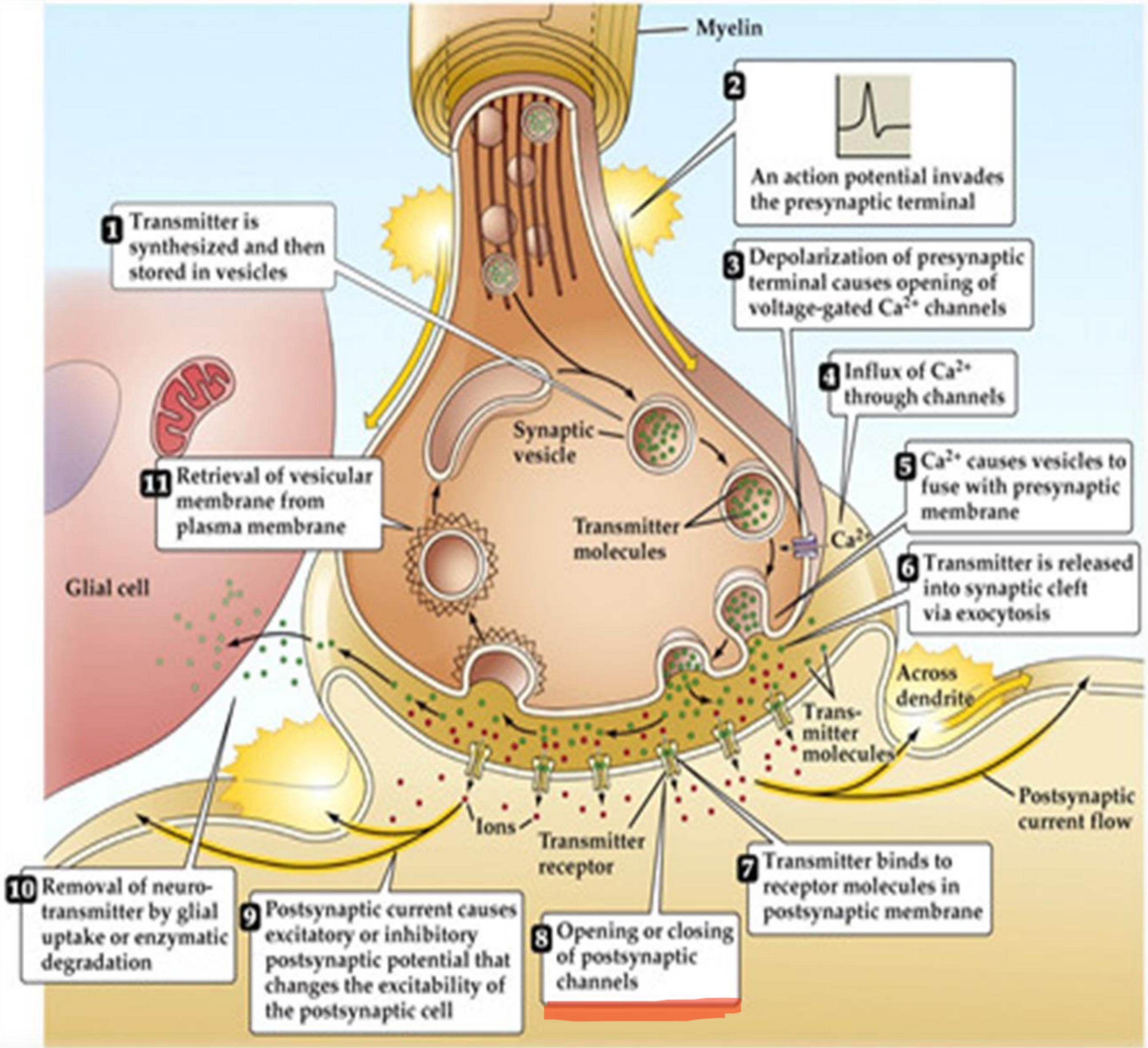
contributes to well-being and happiness. Helps sleep cycle and digestive system regulation. Affected by exercise and light exposure.

ENDORPHINS
euphoria

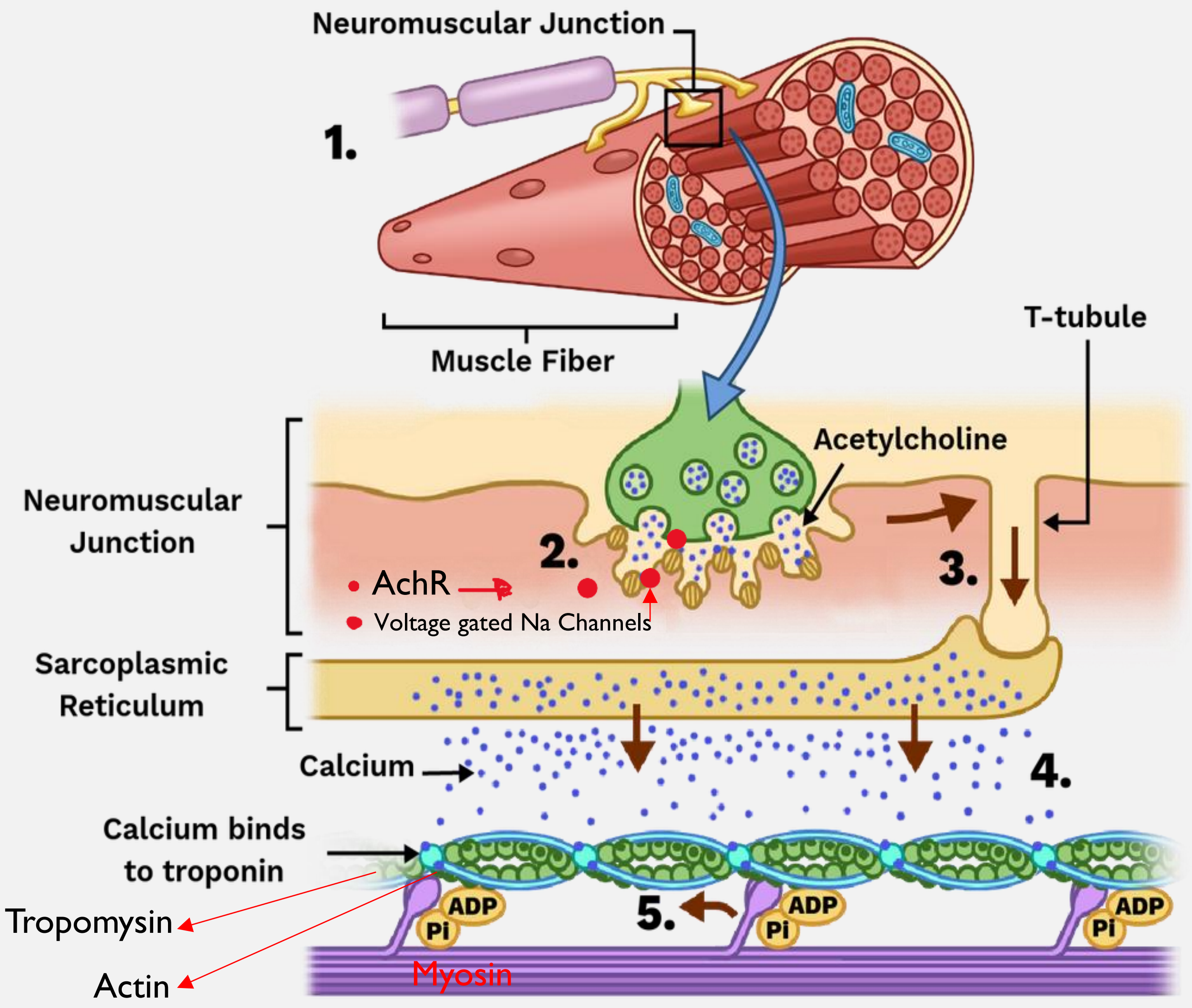
Released during exercise, excitement and sex, producing well-being and euphoria, reducing pain

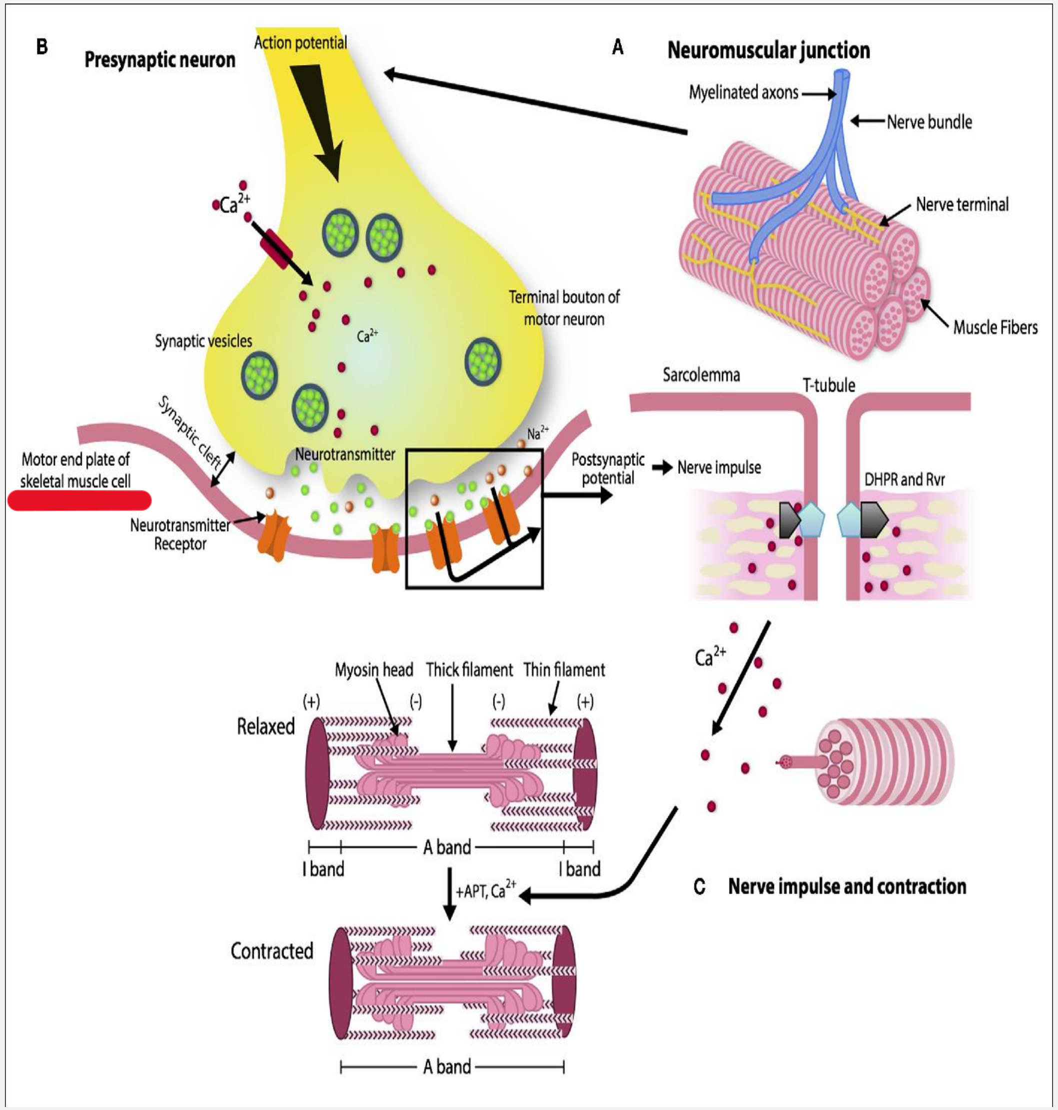
SYNAPTIC TRANSMISSION





NEUROMUSCULAR JUNCTION



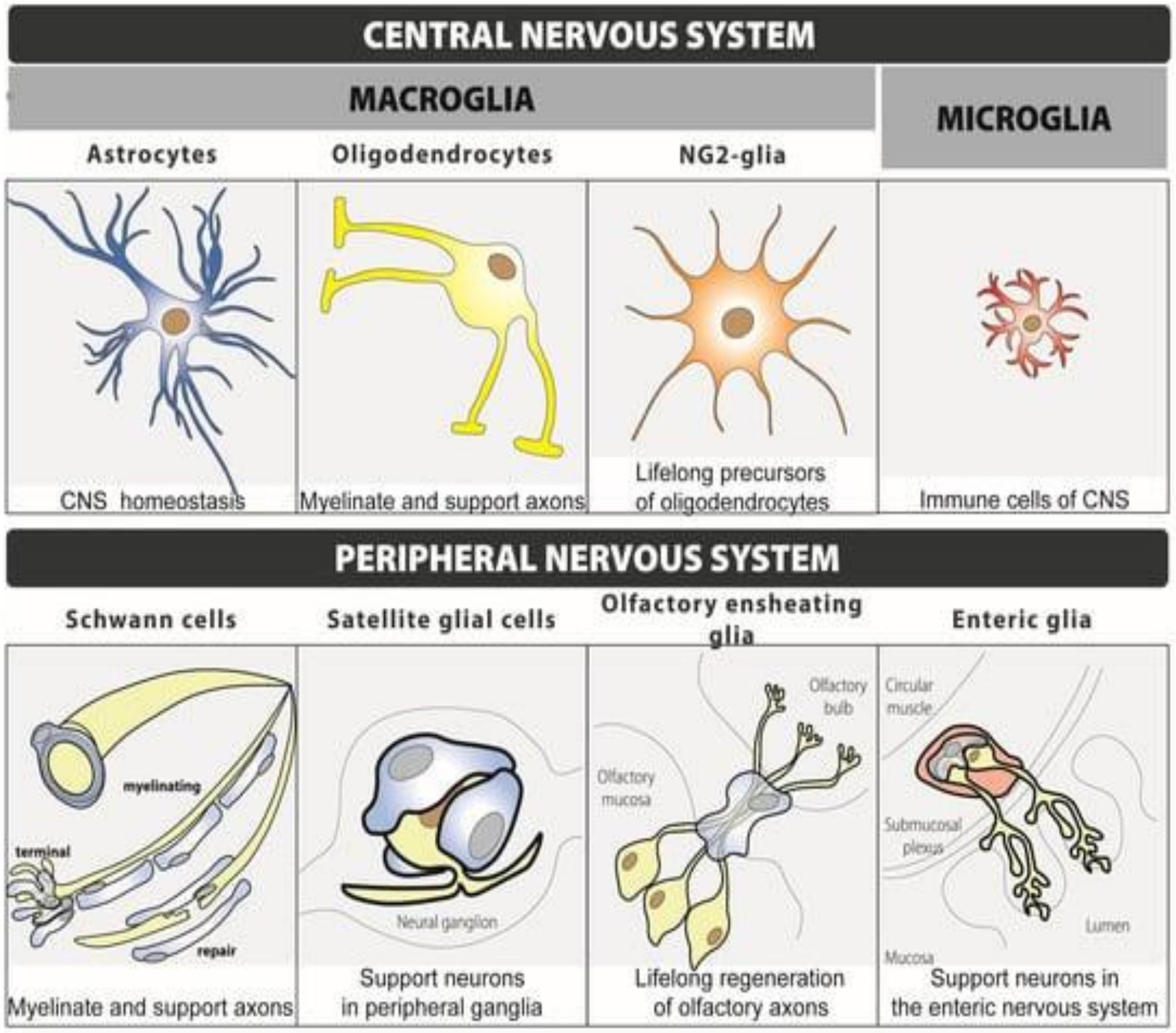


NEUROGLIA
OR
GLIAL CELLS

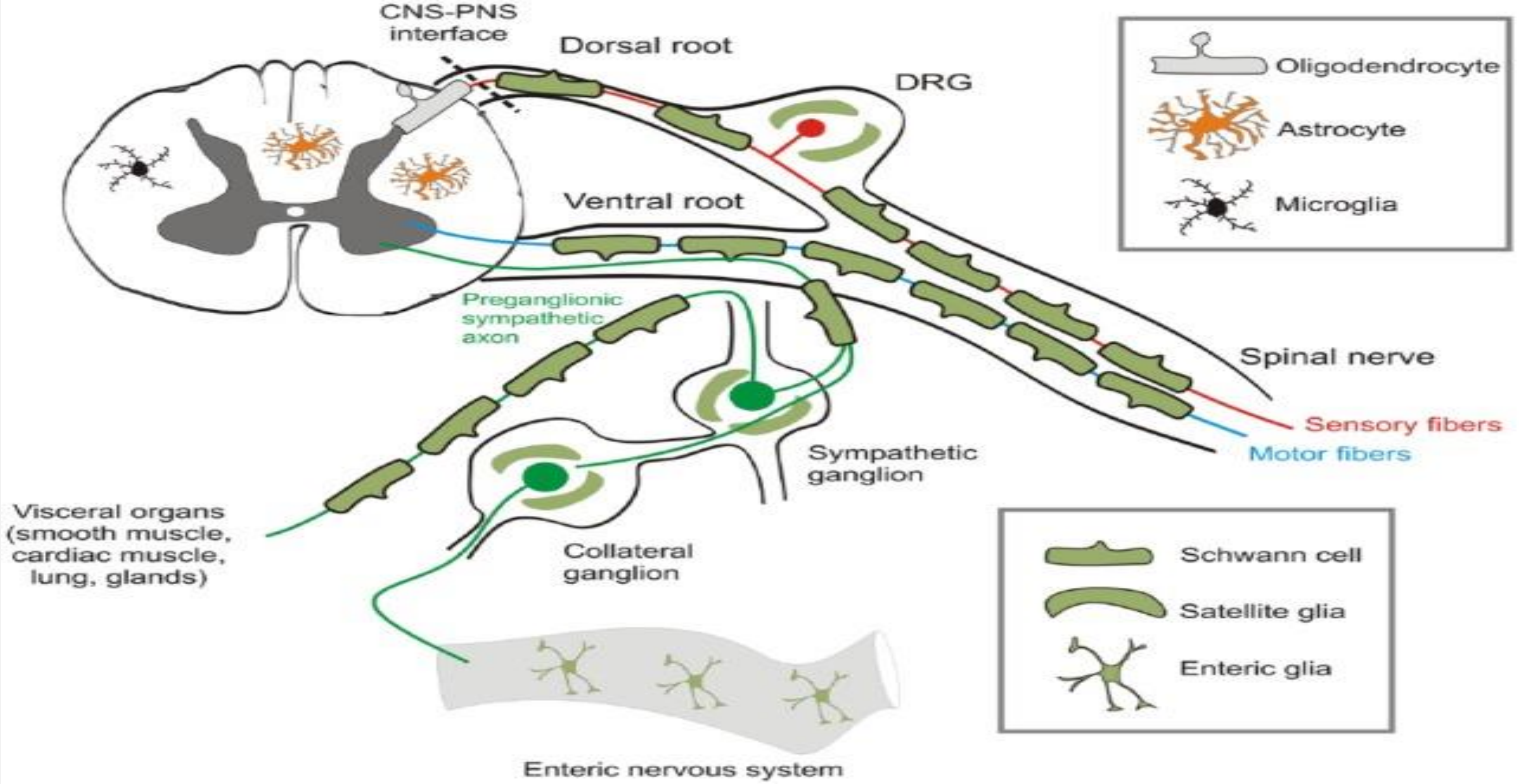
(Supporting Cell)

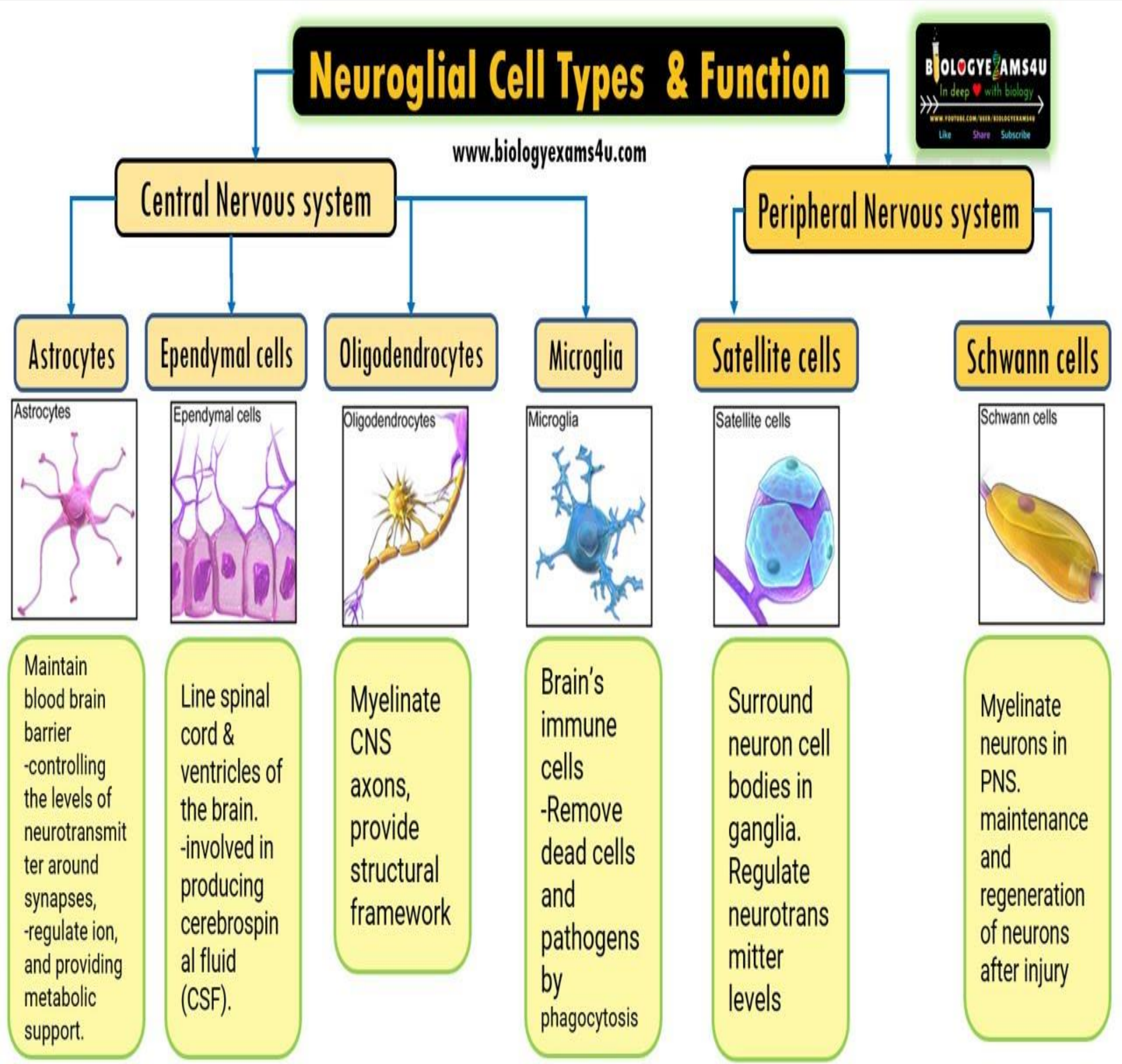
NEUROGLIA OR GLIAL CELLS- Supporting Cell

Neuroglia - Cells that provide metabolic support and immune protection for neurons. Neuroglia outnumber neurons by about 10:1 in the Central Nervous System. Neuroglia do not generate or conduct nerve impulses. However, unlike neurons, glial cells can regenerate if injured



NEUROGLIA OR GLIAL CELLS- Supporting Cell




Neuroglial Cell Types & Function
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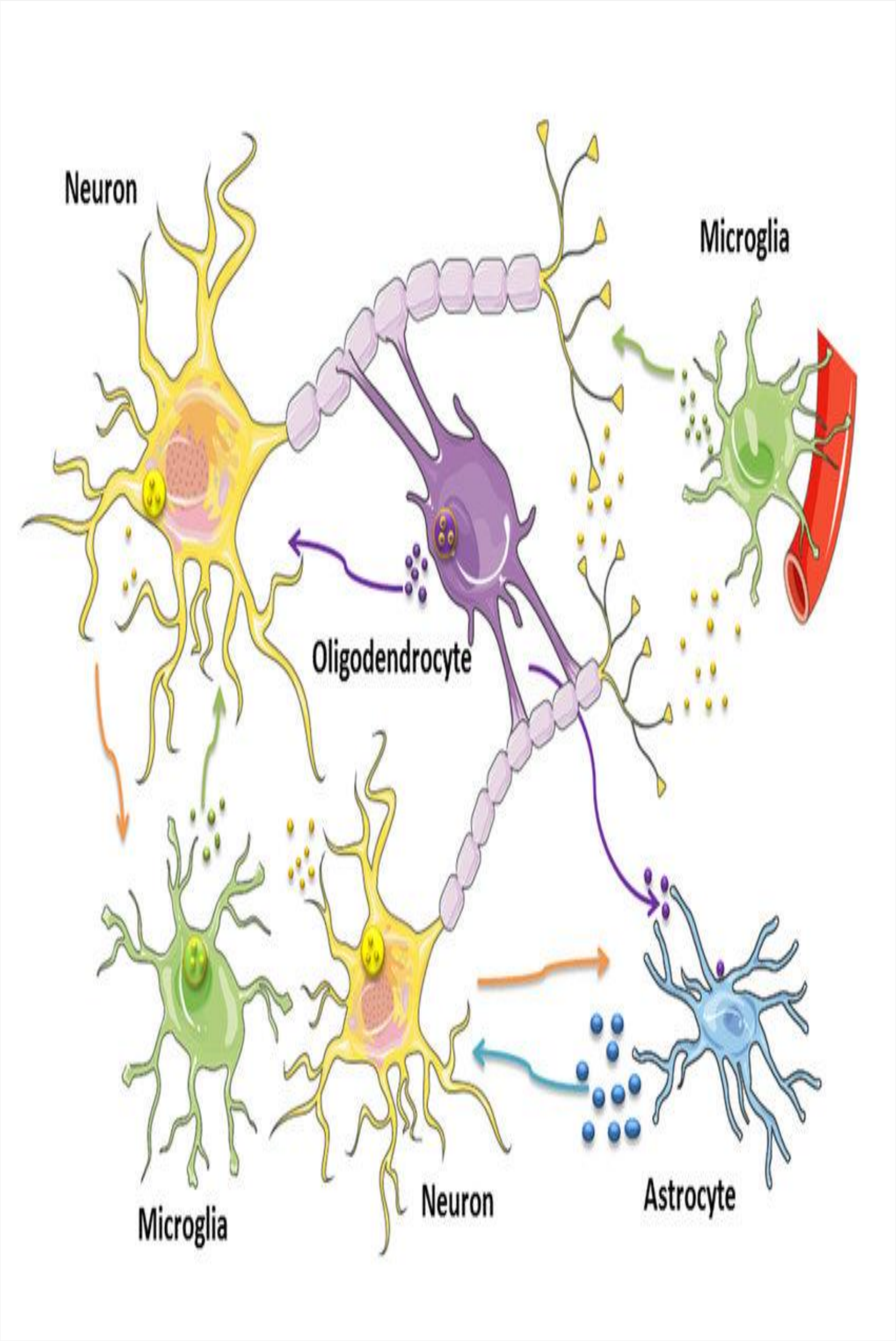
Central Nervous system
Peripheral Nervous system
Astrocytes
Ependymal cells
Oligodendrocytes
Microglia
Satellite cells
Schwann cells
Astrocytes
Ependymal cells
Oligodendrocytes
Microglia
Satellite cells
Schwann cells
Maintain blood brain barrier -controlling the levels of neurotransmitter around synapses, -regulate ion, and providing metabolic support.
Line spinal cord & ventricles of the brain. -involved in producing cerebrospinal fluid (CSF).
Myelinate CNS axons, provide structural framework
Brain's immune cells -Remove dead cells and pathogens by phagocytosis
Surround neuron cell bodies in ganglia. Regulate neurotransmitter levels
Myelinate neurons in PNS. maintenance and regeneration of neurons after injury


Neuron
Microglia
Oligodendrocyte
Microglia
Neuron
Astrocyte

NEUROGLIA CELLS IN CENTRAL NERVOUS SYSTEM

ASTROCYTES

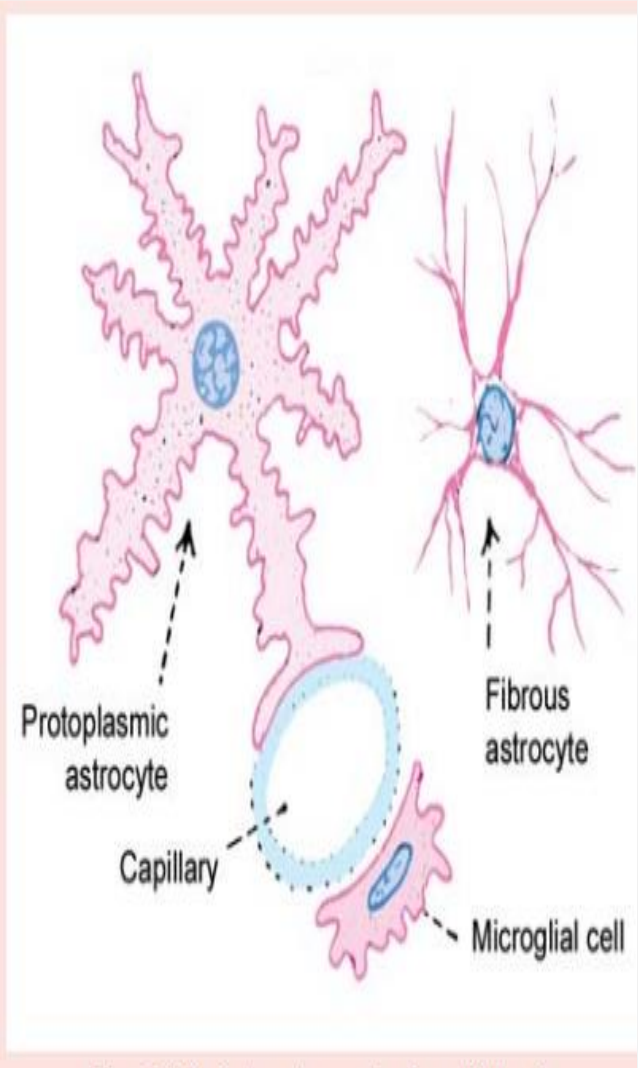
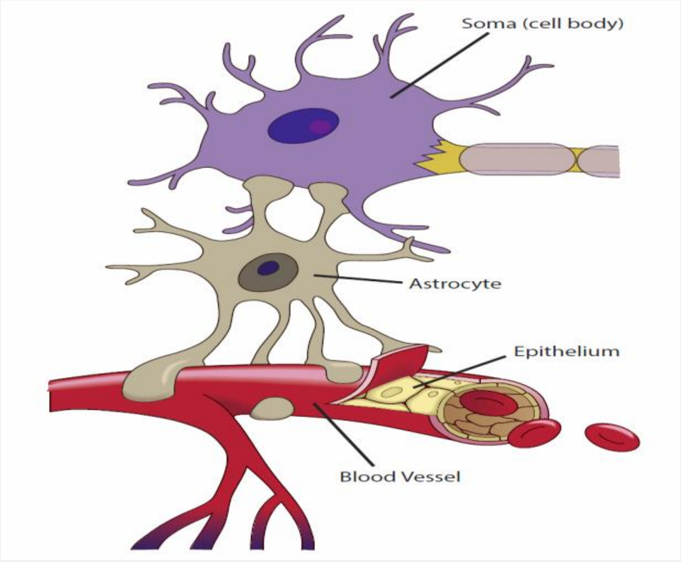


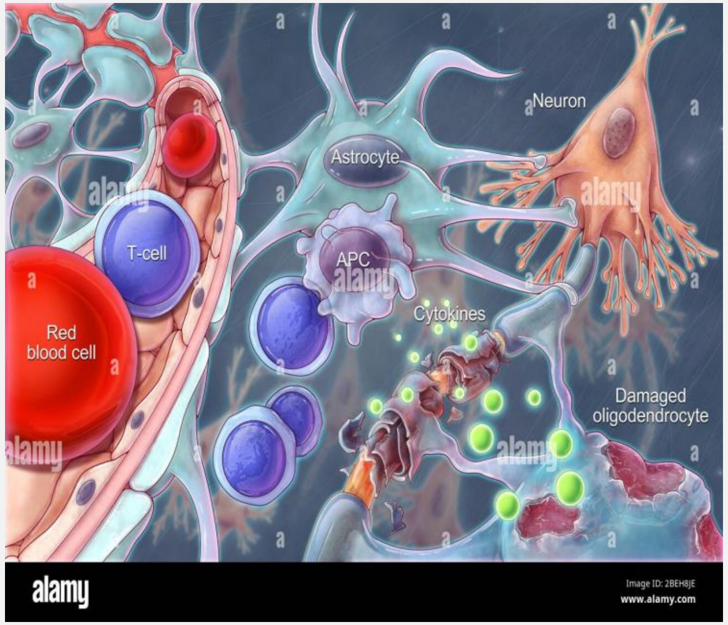
Fig. 1.23. Astrocytes and microglial cells.

- **They are star-shaped cells**
- **In expansion to blood vessels or in relation to surface of the brain.**
- ***Gliosomes* are present on the processes of astrocytes rich in mitochondria.**
- **In general, there are two types of astrocytes The processes of astrocytes are connected to those of other astrocytes through gap junction and communicate (calcium channels)**

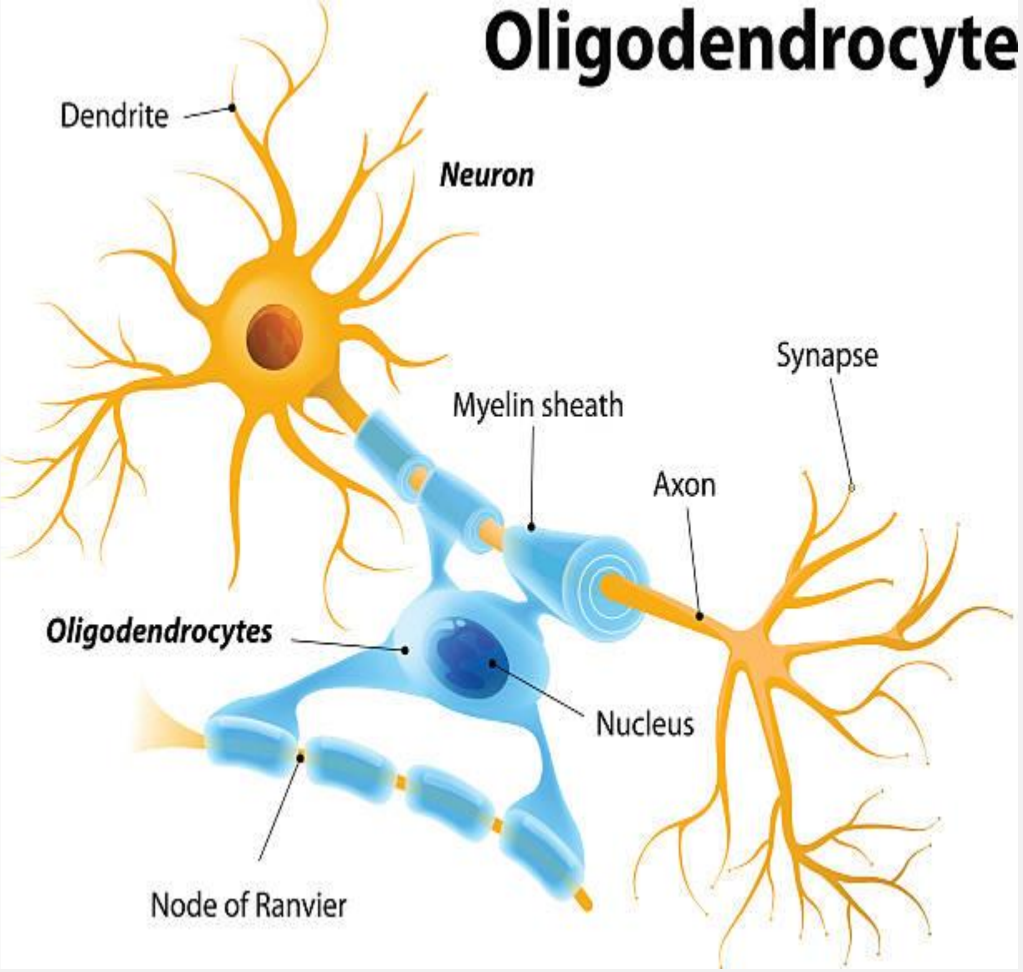
FUNCTION:

- ***Blood brain barrier***
- ***Structural integrity***
- ***metabolite exchange(glucose)***
- ***Removes excess glutamate from synapse***





OLIGODENDROCYTES

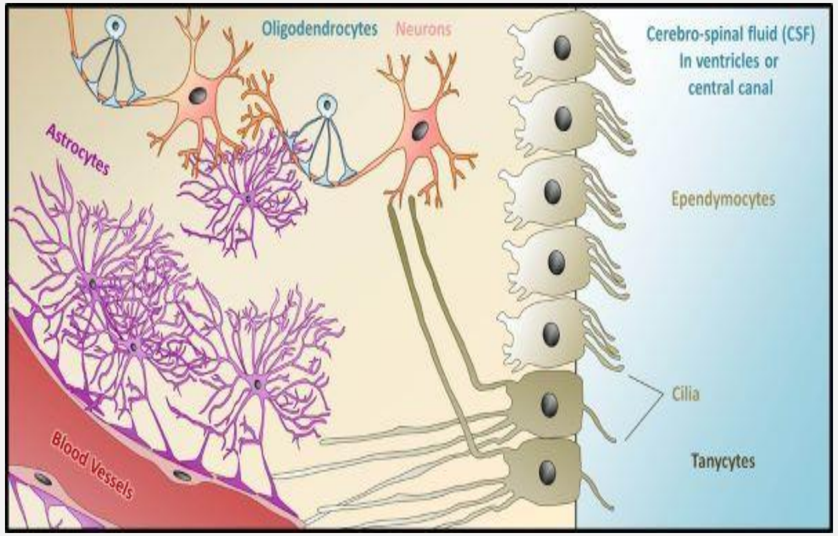


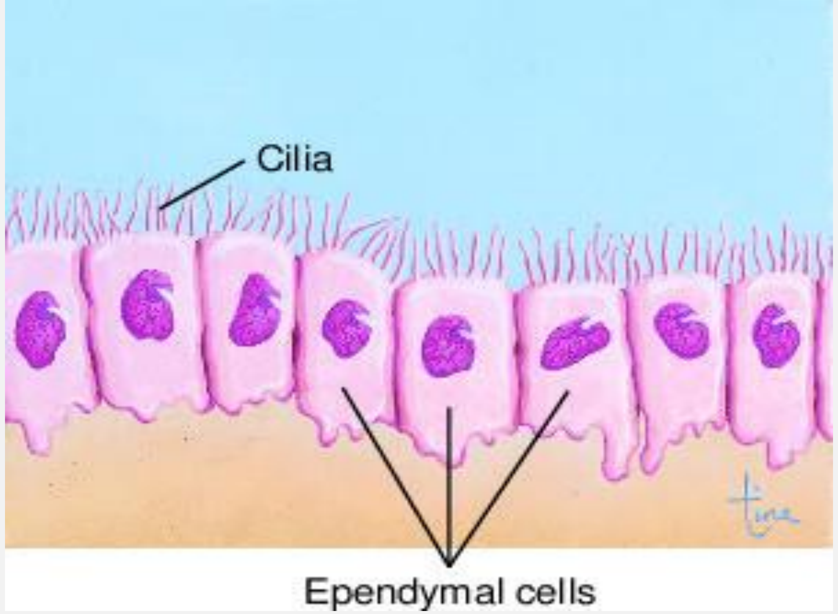
- **Oligodendrocytes have rounded or pear-shaped bodies with relatively few processes.**
- **The soma is small and the nucleus distinctive**
- **The dense cytoplasm stains darkly**
- **The processes extend to different axons and forms myelin sheath around them**

FUNCTION

- **Forms Myelin sheath**

EPENDYMAL CELLS





- Ependymal cells **similar in appearance to epithelial cells,** line the spinal cord and ventricular system of the brain.
- These cells contain cilia and has prominent nucleus.
- The ependymal cells are of three variants.
- The ependymocytes promote the free movement of molecules. It does so between the neurons and the cerebrospinal fluid.
- Tanycytes respond to alterations in the hormonal levels. It does within the blood-derived hormones.
- choroidal epithelial cells control the chemical composition of the **cerebrospinal fluid.**

FUNCTION:

- ***Production of CSF and its movement***
- ***Acts as barrier between CSF in the ventricular system and the brain***

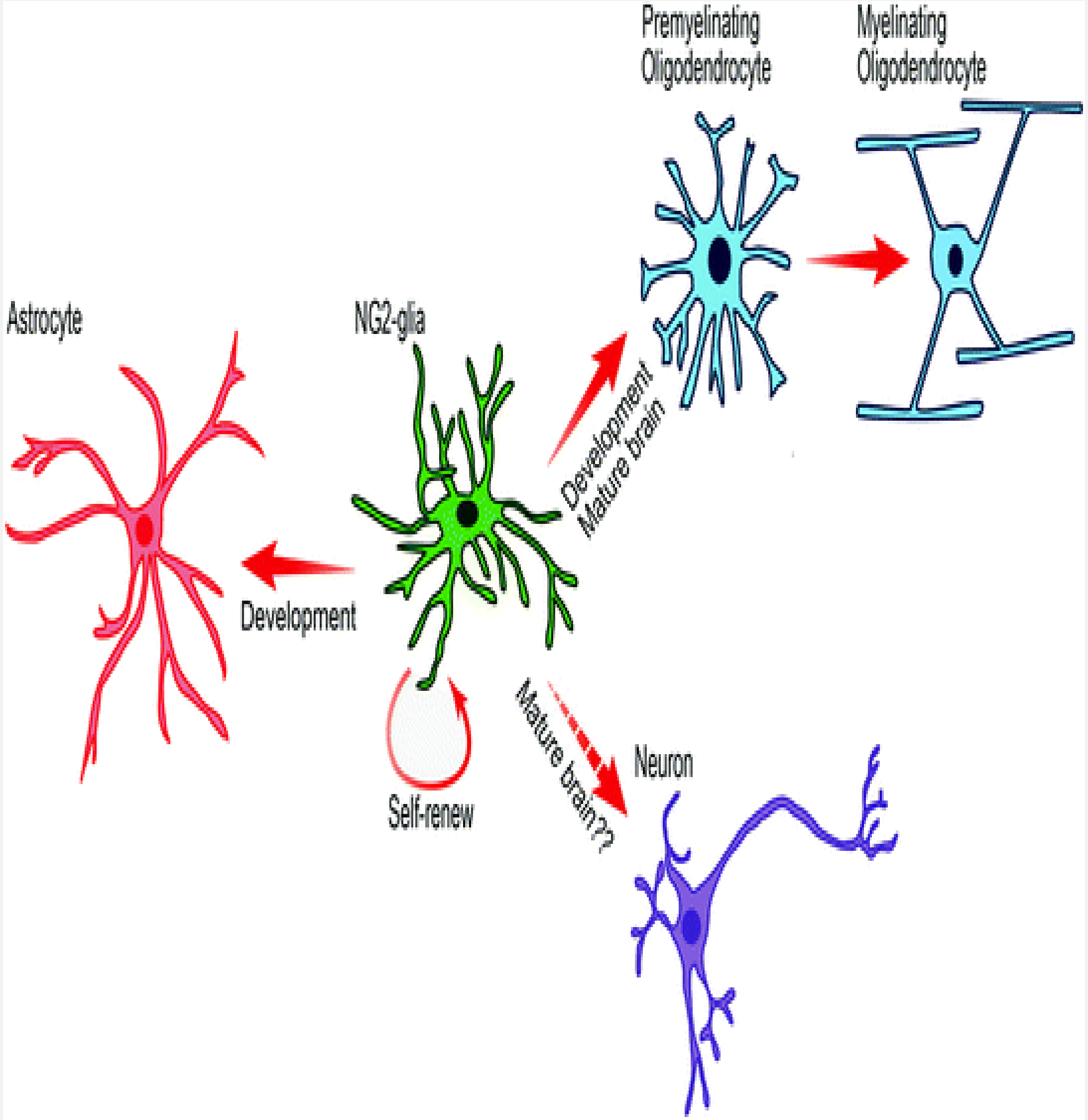
NG-2 GLIAL CELLS

NG-2 cells represent a resident **glial progenitor cell population** that exists throughout the Gray and white matter of the developing and mature mammalian CNS.

NG2-glia are defined by their expression of the chondroitin sulphate proteoglycan NG2 (**cspg4**)

2-8% of all the cells in the adult CNS.

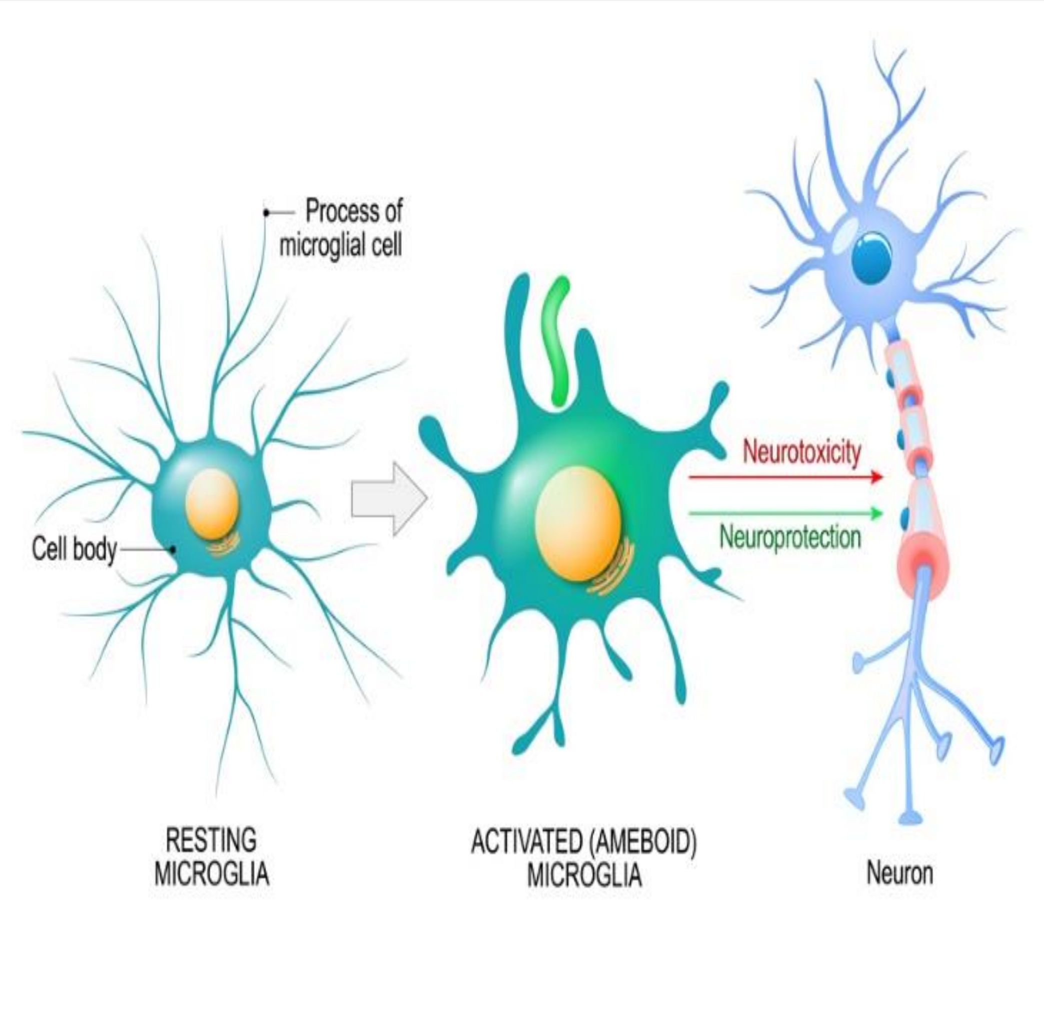
NG2 glia had large euchromatic nuclei with prominent nucleoli and thick and branched processes



Function

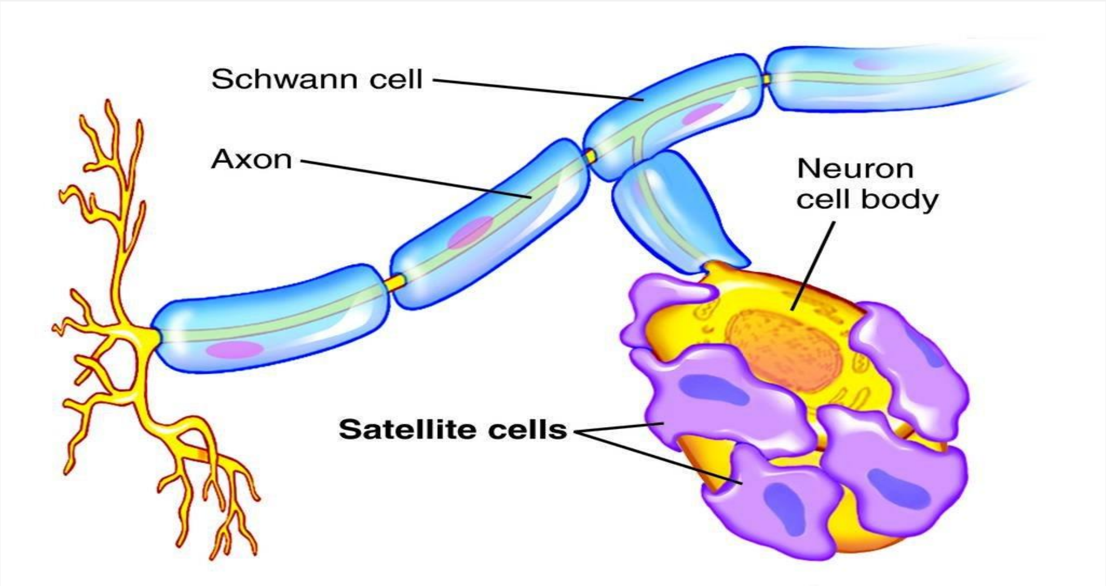
*These cells are often equated with **oligodendrocyte precursor cells (OPCs)** because of their ability to generate myelinating and non-myelinating oligodendrocytes.*

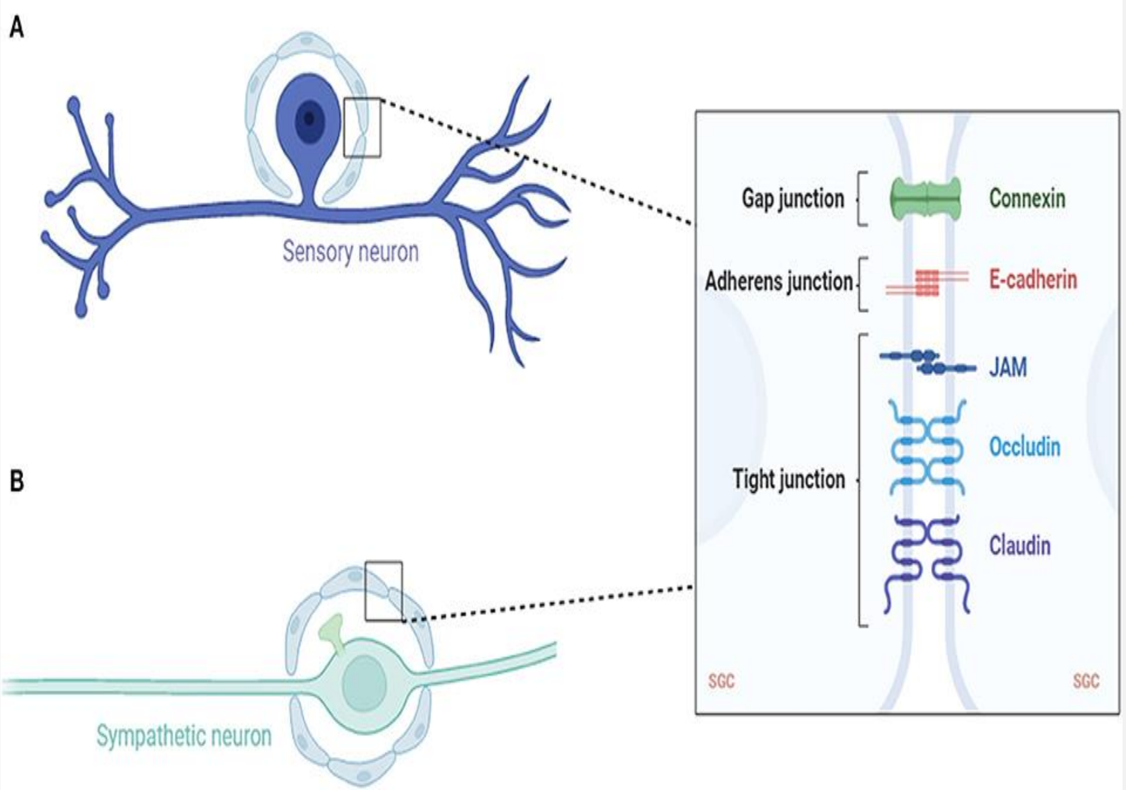
MICROGLIA OR SMALL GLIAL CELLS



- These are the **smallest neuroglial cells**.
- The cell body is flattened. The processes are short. These cells are frequently seen in relation to capillaries.
- **Function (macrophage-immune support)**: Its form tends to keep changing mainly after it has engulfed a foreign body. They are mobile within the brain and multiply when the brain is damaged.
- They became active after damage to nervous system tissue by trauma or disease.

NEUROGLIA CELLS
IN
PERIPHERAL NERVOUS SYSTEM





SATELLITE CELLS

- Satellite glial cells are small cells that surround **neurons cell body** in sensory, sympathetic, and parasympathetic ganglia, which are a cluster of nerve cell bodies outside CNS. **Like astrocytes**, they are interconnected by junctions.

Function:

They regulate the microenvironment around neurons

They provide structural support and respond to injury.

FUNCTION OF NEUROGLIA

FUNCTIONS OF NEUROGLIA

The following are the functions of neuroglia.

(1) They provide mechanical support to neurons.

(2) In view of their non-conducting nature they serve as insulators and prevent neuronal impulses from spreading in unwanted directions.

(3) They are believed to help neuronal function by playing an important role in maintaining a suitable metabolic environment for the neurons. They can absorb neurotransmitters from synapses thus terminating their action. It has been held that they play a role in maintaining the blood-brain barrier, but this view is open to question.

(4) They are responsible for repair of damaged areas of nervous tissue. Neuroglial cells proliferate in such regions (gliosis). These cells (specially microglia) may act as macrophages.

(Macrophages are cells that can engulf and destroy unwanted material).

(5) As mentioned above, oligodendrocytes provide myelin sheaths to nerve fibres within the central nervous system.

(6) Ependymal cells are concerned in exchanges of material between the brain and the cerebrospinal fluid.