SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

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DEPARTMENT OF BIOMEDICAL ENGINEERING

19BMB302 - BIOMEDICAL SIGNAL PROCESSING

III YEAR/ V SEMESTER

Unit IV : BIOSIGNALS AND THEIR CHARACTERISTICS

- Source of Bioelectric potential
- Resting and action potential
- Propagation of action potentials in
- Characteristics of biomedical signals
- The ECG-Cardiac electrophysiology
- Relation of ECG components to cardiac events
- Clinical applications

- The human central nervous system (CNS) contains about 100 billion neurons.
- 40% of the human genes participate, at least to a degree, in its formation.

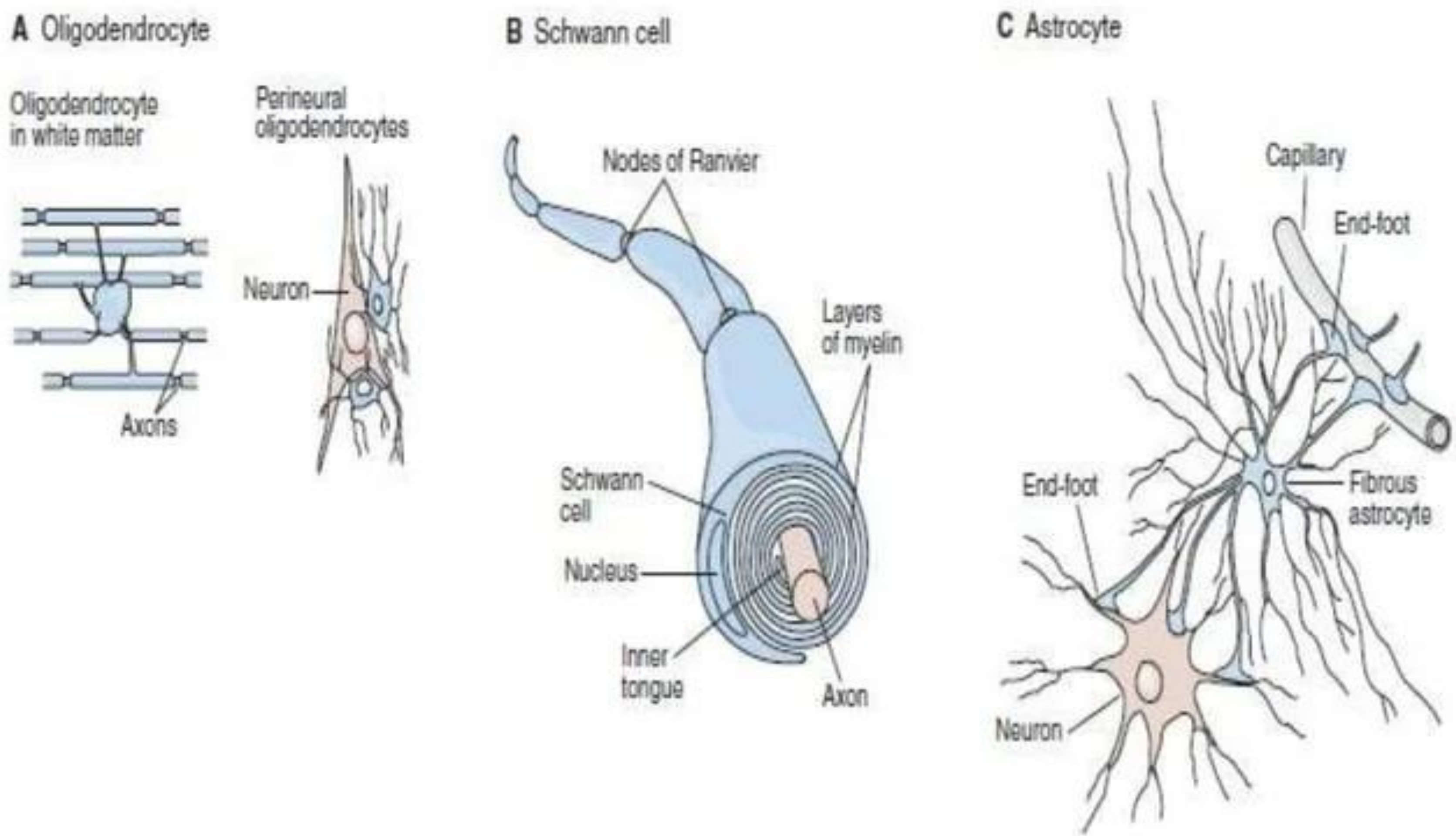
CELLULAR ELEMENTS IN THE CNS

- **GLIAL CELLS**
- the word *glia is* Greek for *glue.*
- *Theses cells are recognized for* their role in communication within the CNS in partnership with neurons.
- Unlike neurons, glial cells continue to undergo cell division in adulthood and their ability to proliferate is particularly noticeable after brain injury (eg, stroke).

- two major types of glial cells in the vertebrate nervous system:
- **microglia and macroglia**
- Microglia are scavenger cells that resemble tissue macrophages and remove debris resulting from injury, infection, and disease.

- three types of macroglia:
- **oligodendrocytes,**
- **Schwann cells,**
- **astrocytes .**
- **Oligodendrocytes** and **Schwann cells are involved in myelin formation around** axons in the CNS and peripheral nervous system, respectively.

- Astrocytes, which are found throughout the brain, are of two subtypes.
- **Fibrous astrocytes, which contain many** intermediate filaments, are found primarily in white matter.
- **Protoplasmic astrocytes are found in gray matter and have a** granular cytoplasm.
- Both types send processes to blood vessels, where they induce capillaries to form the tight junctions making up the **blood–brain barrier.**


A Oligodendrocyte
Oligodendrocyte in white matter
Perineural oligodendrocytes
Neuron
Axons
B Schwann cell
Nodes of Ranvier
Layers of myelin
Schwann cell
Nucleus
Inner tongue
Axon
C Astrocyte
Capillary
End-foot
End-foot
Fibrous astrocyte
Neuron

EXCITATION & CONDUCTION

- Nerve cells respond to electrical, chemical, or mechanical stimuli.
- Two types of physicochemical disturbances are produced:

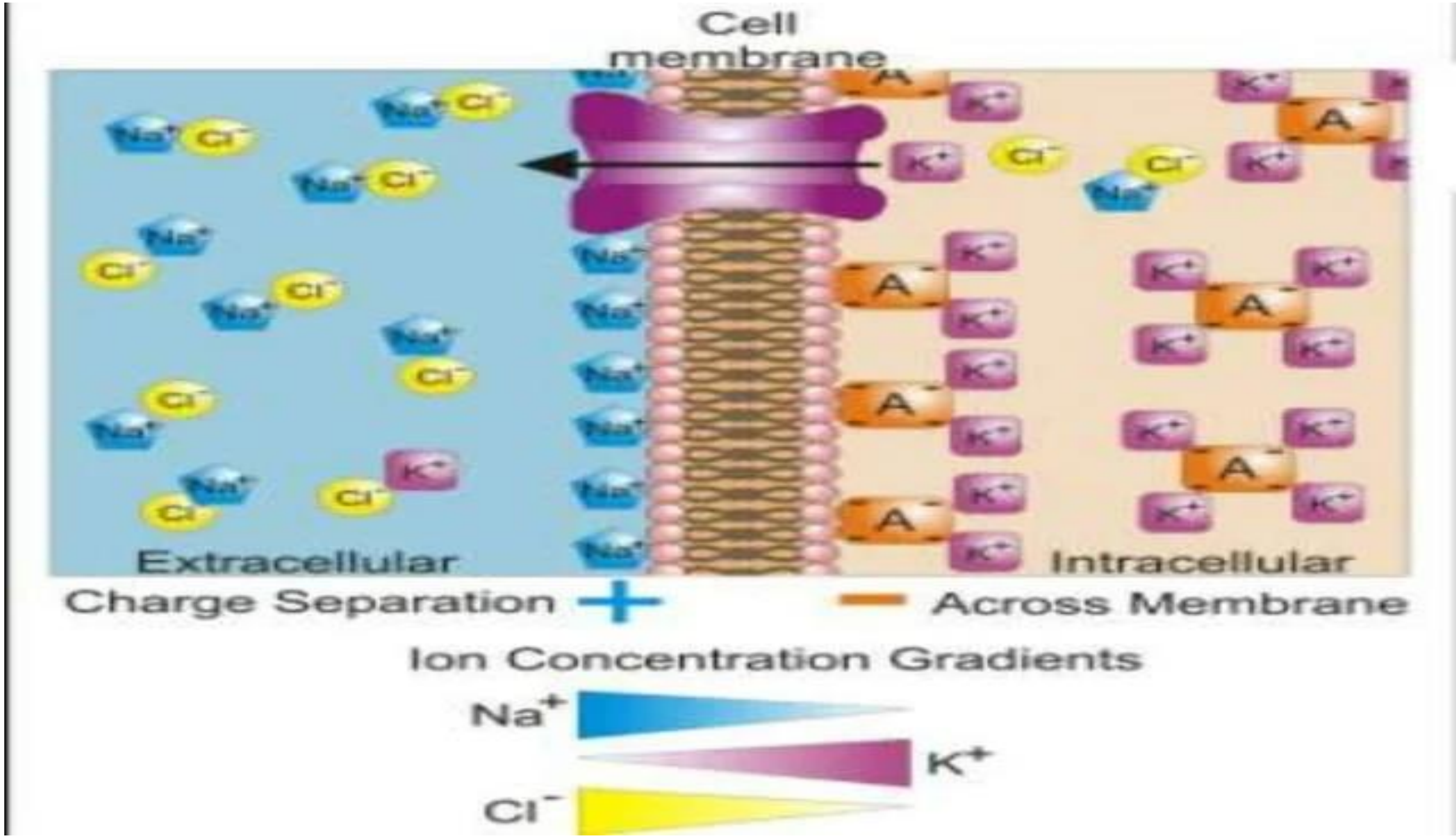
- local, nonpropagated potentials called, depending on their location, **synaptic, generator, or electrotonic potentials;**

- **Propagated** potentials, the **action potentials (or nerve impulses).**

RESTING MEMBRANE POTENTIAL

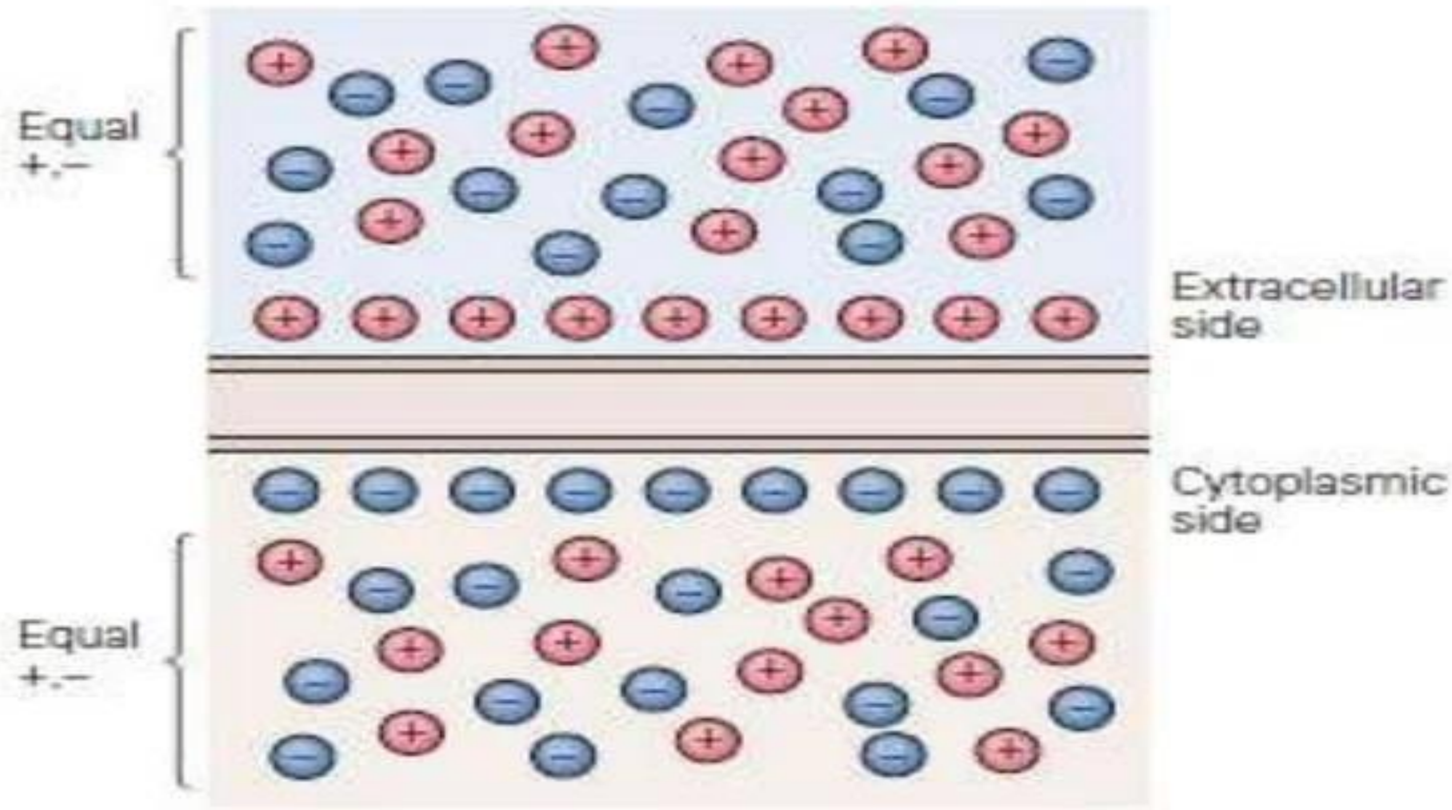
- **Resting Membrane Potential** (RMP) is the voltage (charge) difference across the cell **membrane** when the cell is at **rest**.
- In neurons, the **resting membrane potential is usually** about –70 mV, which is close to the equilibrium potential for K+.
- **Because there are more open K+** channels than Na + channels at rest, the membrane permeability to K+ is greater.

- The resting membrane potential represents an equilibrium situation at which the driving force for the membrane-permeant ions down their concentration gradients across the membrane is equal and opposite to the driving force for these ions down their electrical gradients.



Cell membrane
Extracellular
Intracellular
Charge Separation
Across Membrane
Ion Concentration Gradients
Na+
K+
Cl-

A membrane potential results from separation of positive and negative charges across the cell membrane.



Action Potential

- A momentary change in electrical potential associated with the passage of an impulse along the membrane of a muscle cell or nerve cell.
- An **Action potential** is the neurons way of transporting electrical signals from one cell to the next.

- Action potentials are the primary electrical responses of neurons and other excitable tissues, and they are the main form of communication within the nervous system.
- They are due to changes in the conduction of ions across the cell membrane.
- The electrical events in neurons are rapid, being measured in **milliseconds (ms) ; and the potential changes are small, being** measured in **millivolts (mV).**

How an action potential is generated?

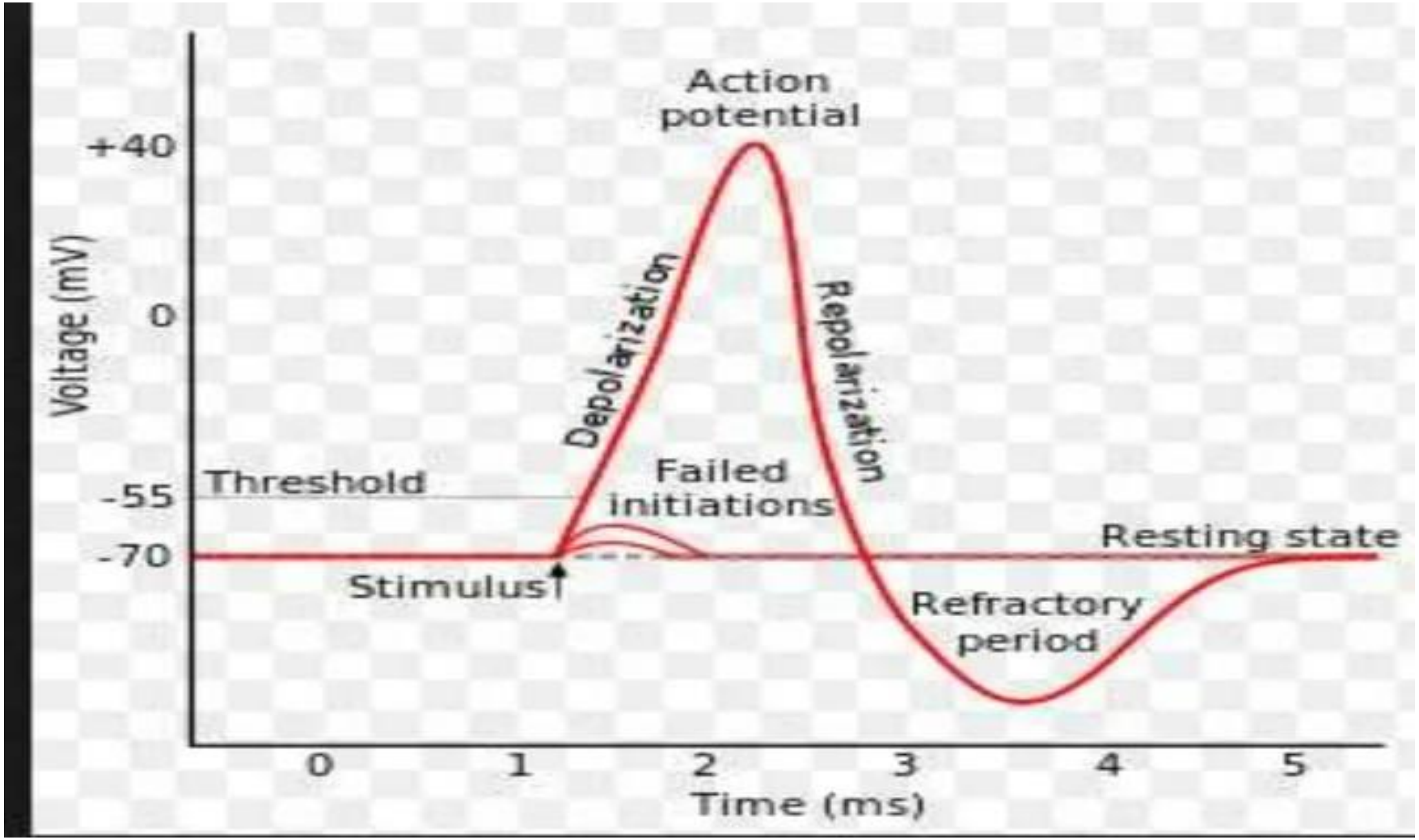
- A neuron that emits an **action potential** is often said to "fire".
- **Action** potentials are **generated** by special types of voltage-gated ion channels embedded in a cell's plasma membrane. ..
- The rapid influx of sodium ions causes the polarity of the plasma membrane to reverse, and the ion channels then rapidly inactivate.
- Thus, the sodium channel activation moves in a wave-like fashion: .

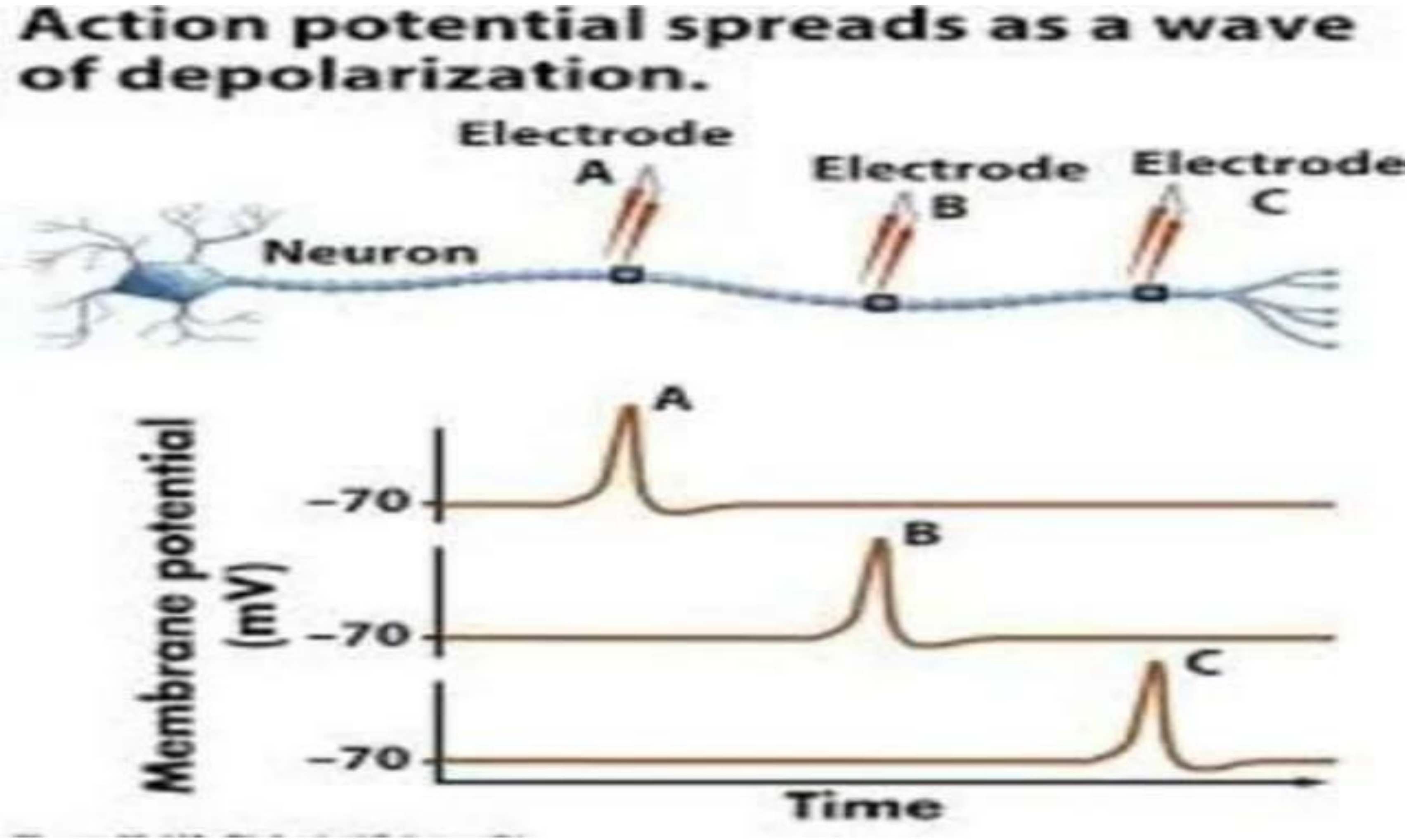
How an action potential is propagated?

- The **action potential** is **propagated** down the length of the neuron, from its input source at the dendrites, to the cell body, and then down the axon to the synaptic terminals

How does a stimulus trigger an action potential?

- The **stimulus triggers an action potential** in the cell membrane of the nerve cell, and that **action potential** provides the **stimulus** for a neighboring segment of the cell membrane.

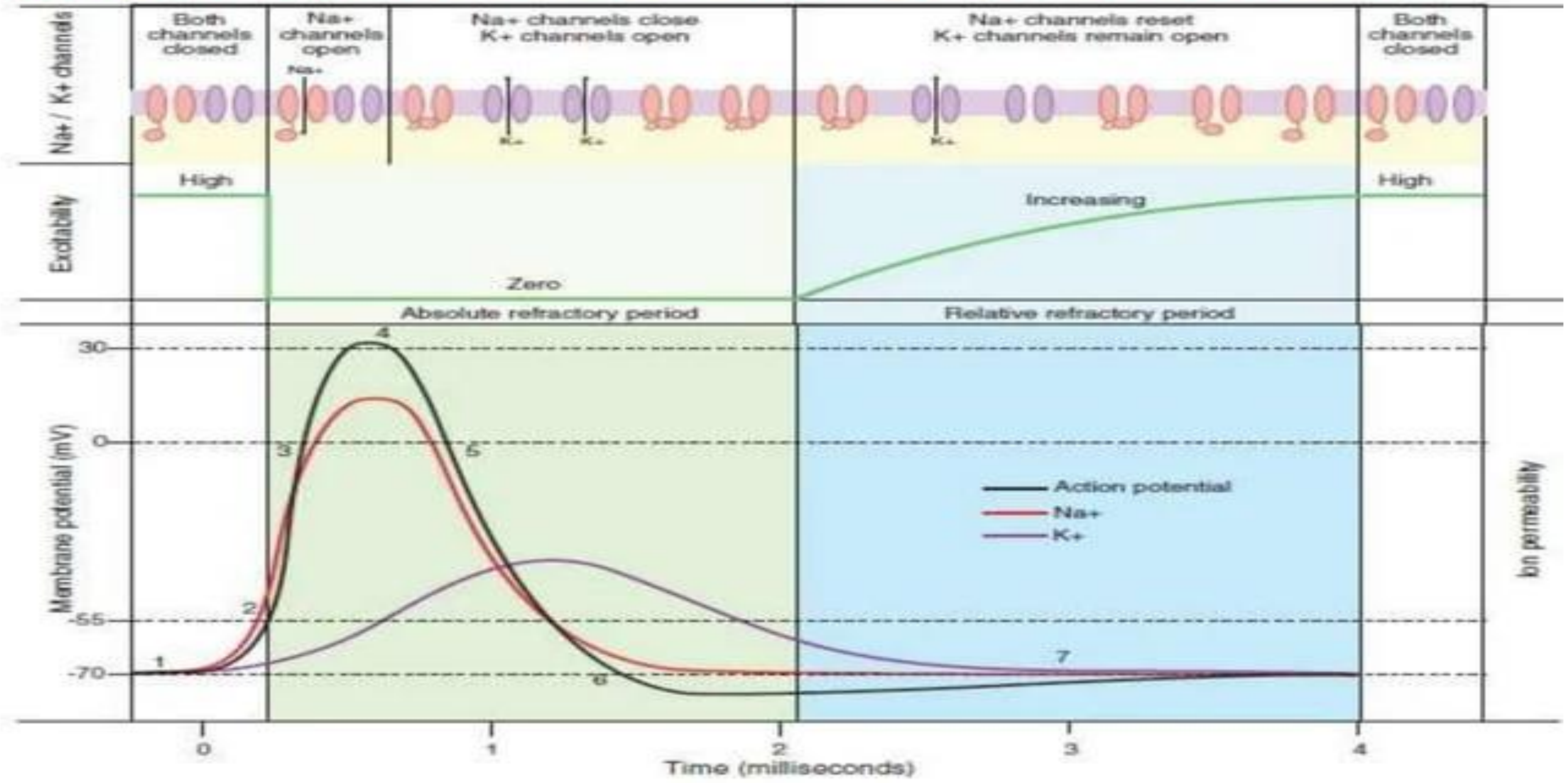

Action potential
+40
0
-55
-70
Voltage (mV)
Depolarization
Repolarization
Threshold
Failed initiations
Resting state
Stimulus
Refractory period
0
1
2
3
4
5
Time (ms)


Action potential spreads as a wave of depolarization.
Electrode A
Electrode B
Electrode C
Neuron
A
B
C
-70
-70
-70
Membrane potential (mV)
Time

IONIC FLUXES DURING THE ACTION POTENTIAL

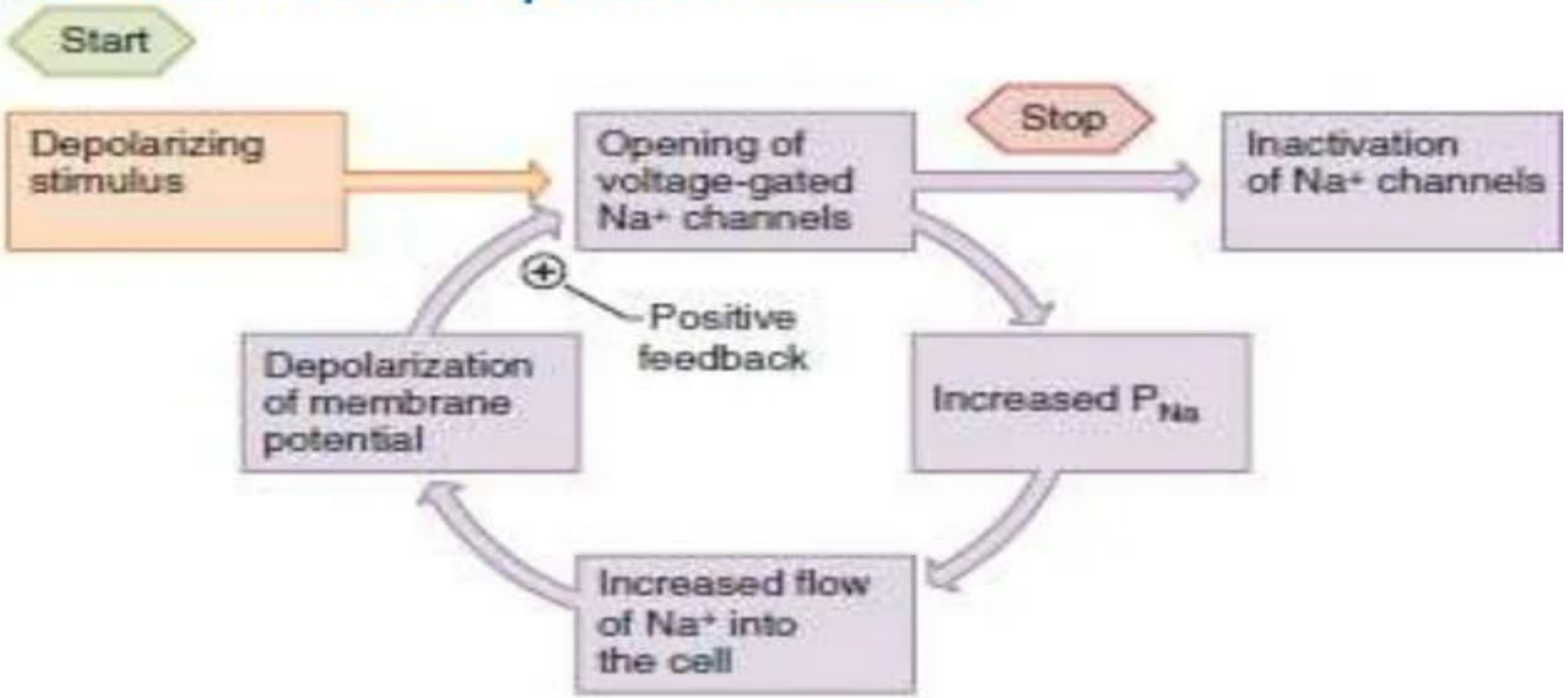
- The conductance of an ion is the reciprocal of its electrical resistance in the membrane and is a measure of the membrane permeability to that ion.
- In response to a depolarizing stimulus, some of the voltage-gated Na+ channels open and Na + enters the cell and the membrane is brought to its **threshold potential and the voltage-gated Na+** channels overwhelm the K + and other channels.

Changes in membrane potential and relative membrane permeability to Na + and K + during an action potential.

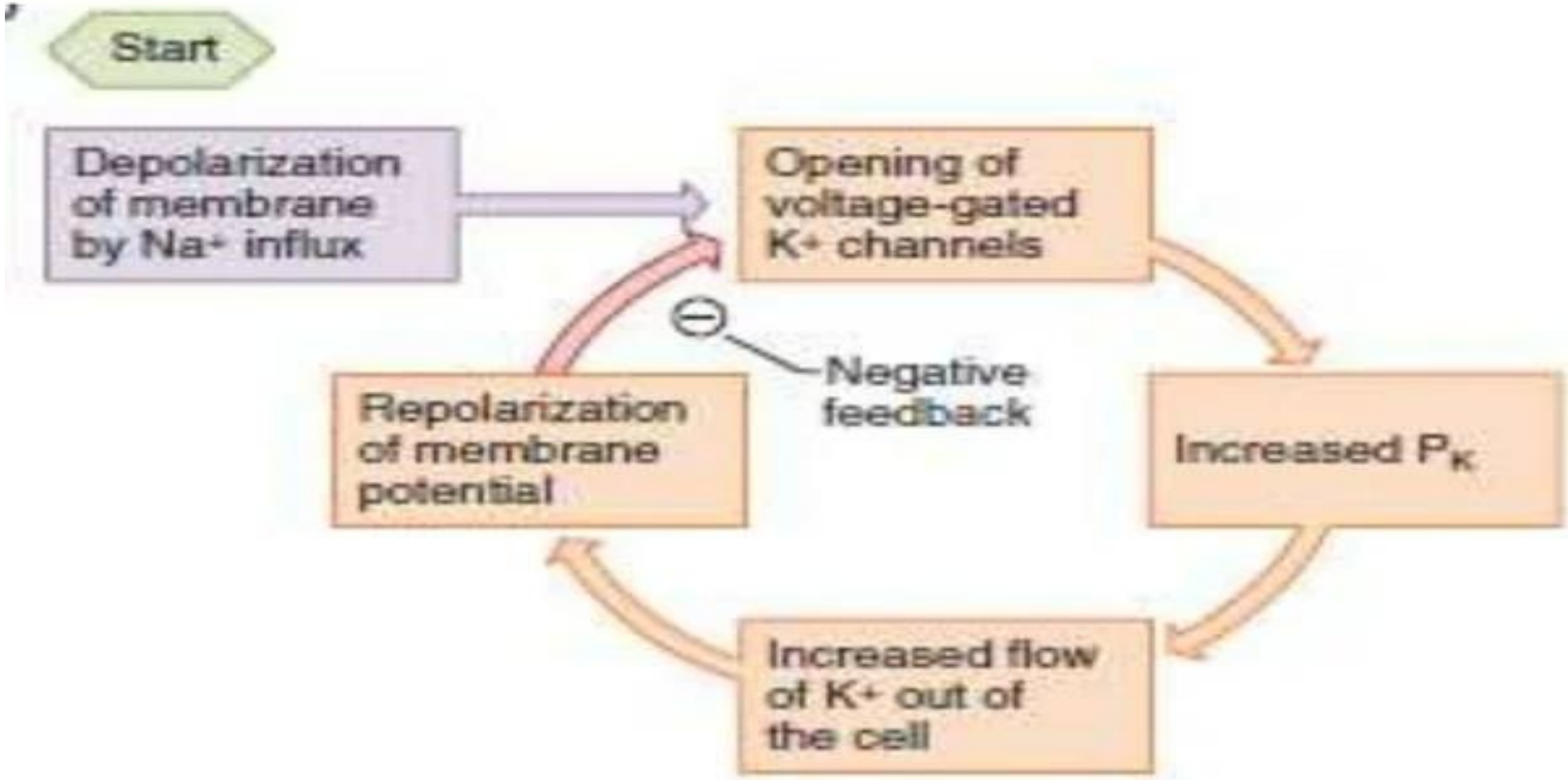


Feedback control in voltage-gated ion channels in the membrane.

Na + channels exert positive feedback.

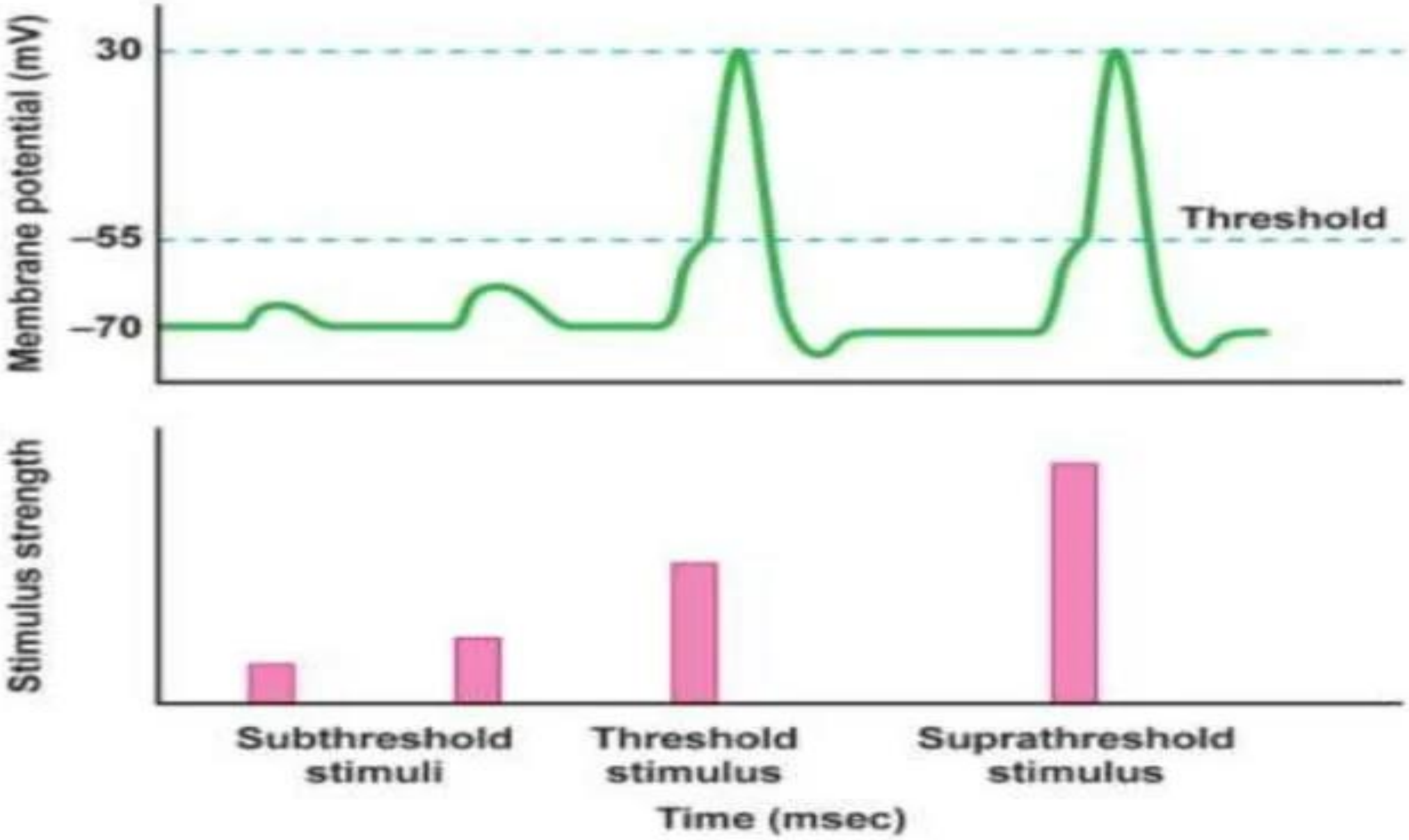


K + channels exert negative feedback



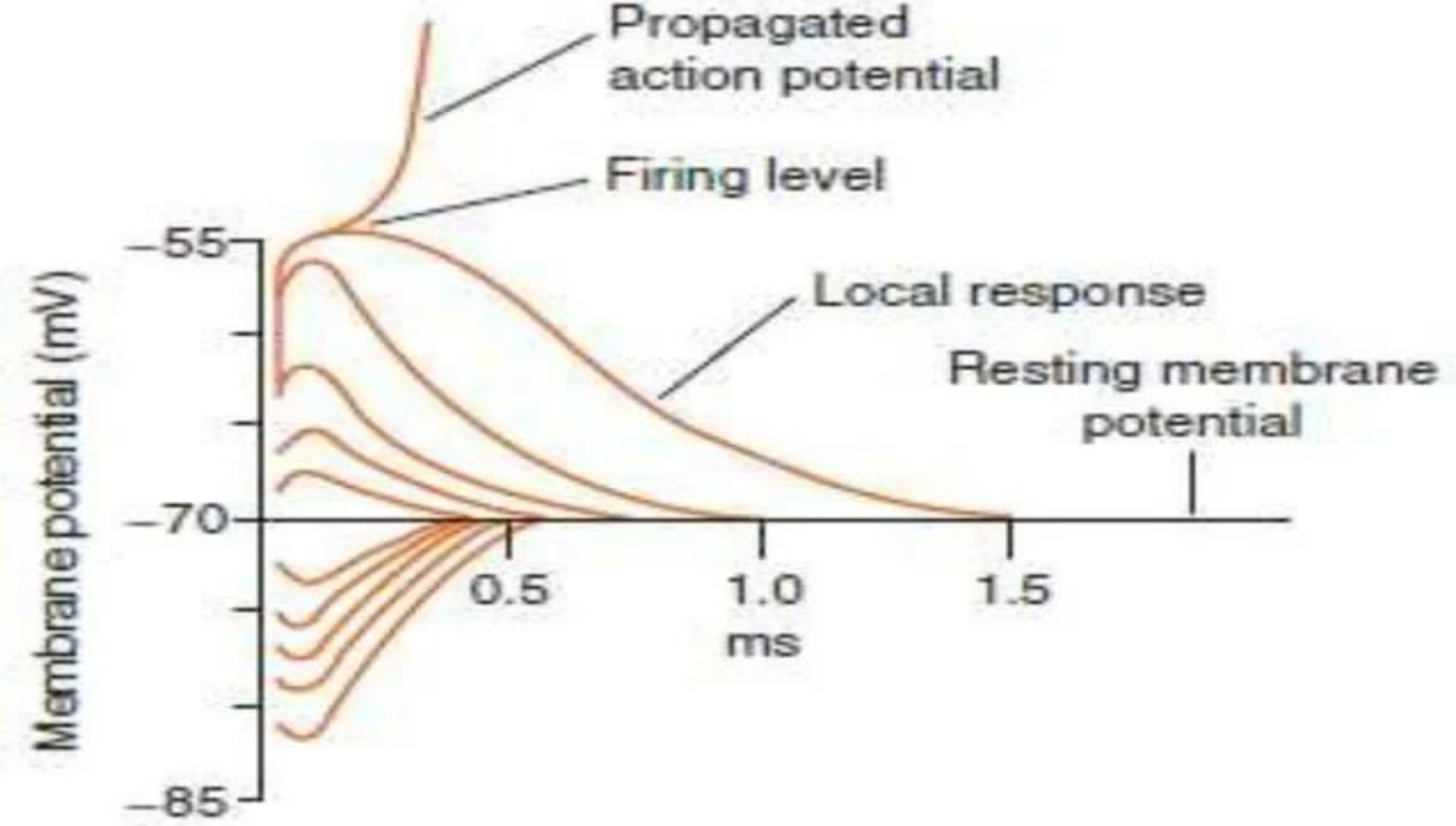
ALL-OR-NONE ACTION POTENTIALS

- The **all-or-none law** is the principle that the strength by which a nerve or muscle fiber responds to a stimulus is independent of the strength of the stimulus.
- If that stimulus exceeds the threshold **potential**, the nerve or muscle fiber will give a complete response; otherwise, there is no response.


Membrane potential (mV)
30
–55
–70
Threshold
Stimulus strength
Subthreshold stimuli
Threshold stimulus
Suprathreshold stimulus
Time (msec)

ELECTROTONIC POTENTIALS, LOCAL RESPONSE, & FIRING LEVEL

- A non-propagated local **potential**, resulting from a local change in ionic conductance.
- Although subthreshold stimuli do not produce an action potential, they do have an effect on the membrane potential.
- This can be demonstrated by placing recording electrodes within a few millimeters of a stimulating electrode and applying subthreshold stimuli of fixed duration.
- Application of such currents leads to a localized depolarizing potential change that rises sharply and decays exponentially with time.



Propagated
action potential
Firing level
Local response
Resting membrane
potential
Membrane potential (mV)
–55
–70
–85
0.5
1.0
1.5
ms

CHANGES IN EXCITABILITY DURING ELECTROTONIC POTENTIALS & THE ACTION POTENTIAL

- During the action potential, as well as during electrotonic potentials and the local response, the threshold of the neuron to stimulation changes.
- Hyperpolarizing responses elevate the threshold, and depolarizing potentials lower it as they move the membrane potential closer to the firing level.

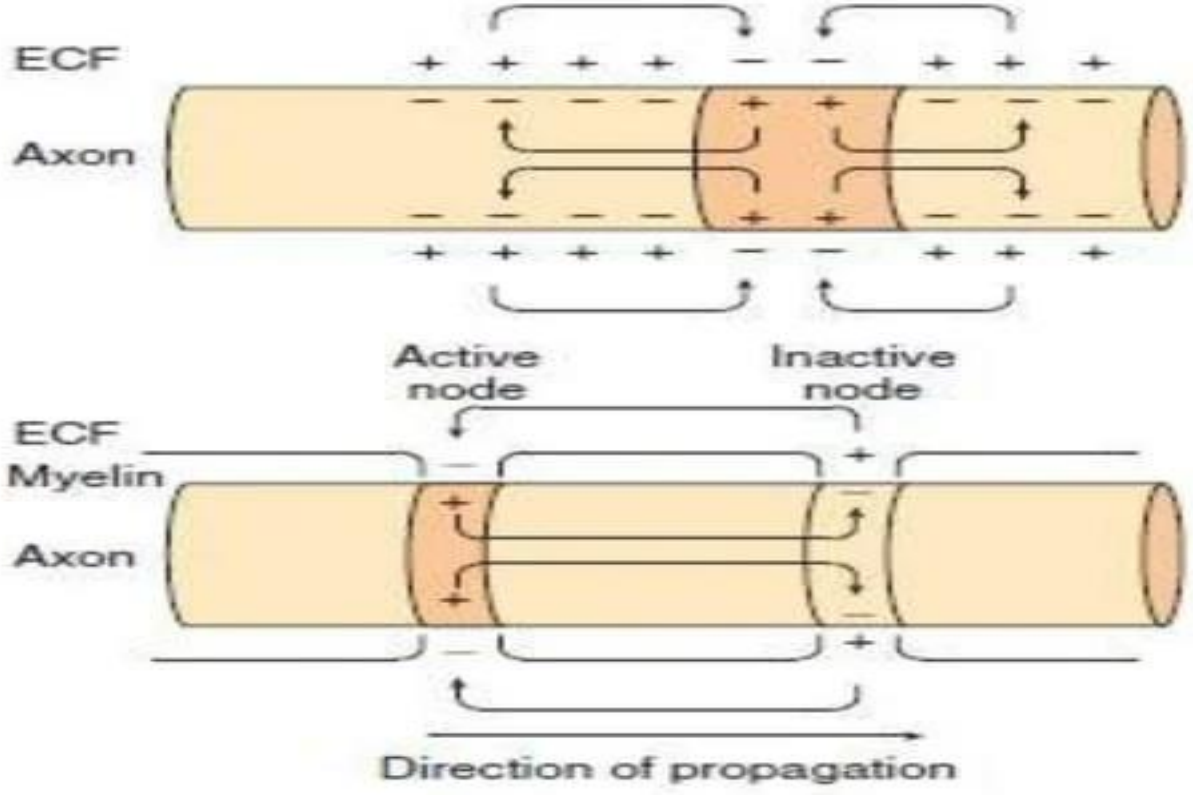
CONDUCTION OF THE ACTION POTENTIAL

- The nerve cell membrane is polarized at rest, with positive charges lined up along the outside of the membrane and negative charges along the inside. During the action potential, this polarity is abolished and for a brief period is actually reversed.
- **Positive charges from the membrane ahead of** and behind the action potential flow into the area of negativity represented by the action potential ("current sink").

- By drawing off positive charges, this flow decreases the polarity of the membrane ahead of the action potential.
- Such electrotonic depolarization initiates a local response, and when the firing level is reached, a propagated response occurs that in turn electrotonically depolarizes the membrane in front of it.

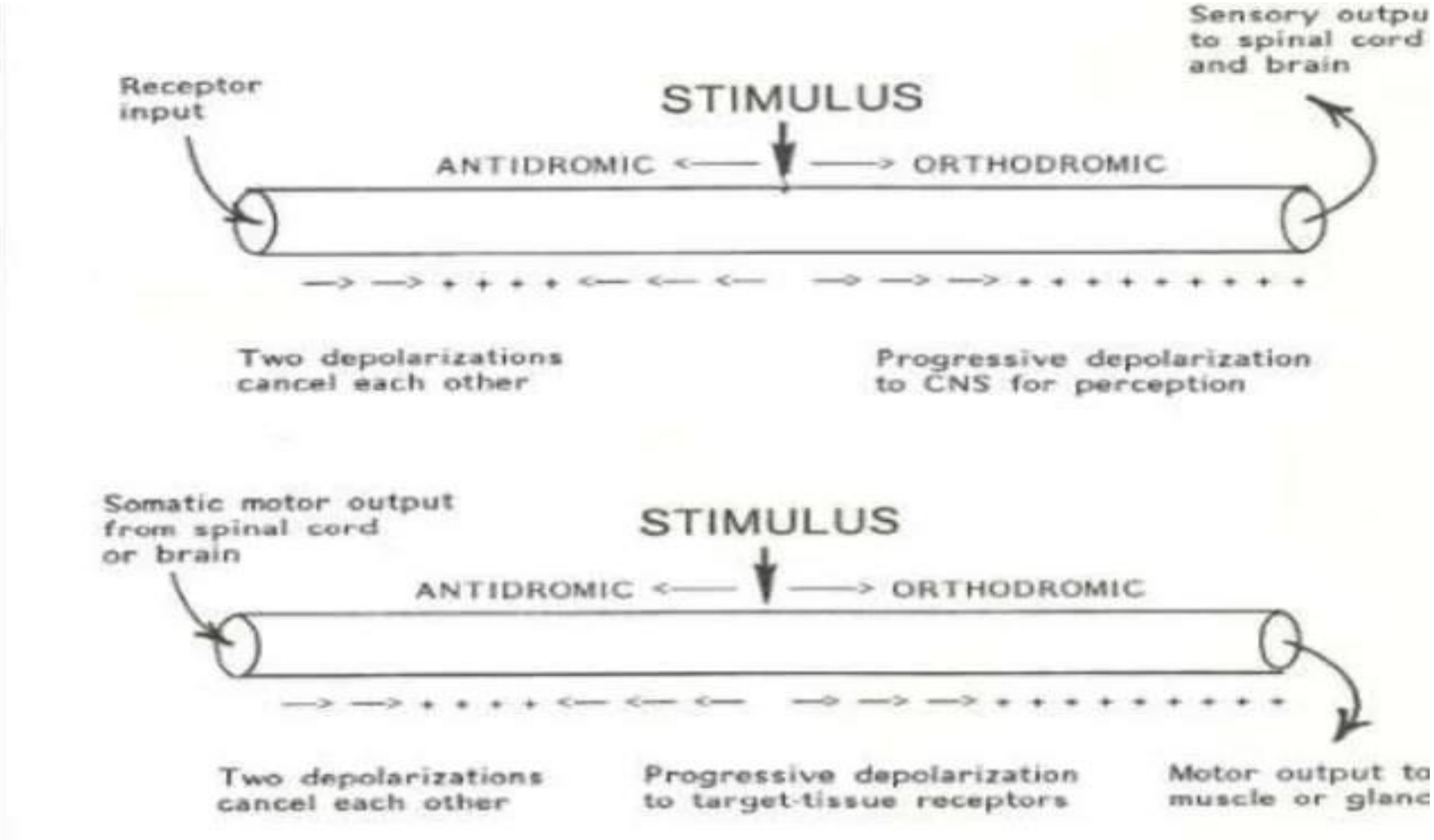
- The spatial distribution of ion channels along the axon plays a key role in the initiation and regulation of the action potential.
- Voltage-gated Na + channels are highly concentrated in the nodes of Ranvier and the initial segment in myelinated neurons.

Local current flow (movement of positive charges) around an impulse in an axon. Top: Unmyelinated axon.
Bottom: Myelinated axon.



ORTHODROMIC & ANTIDROMIC CONDUCTION

- An axon can conduct in either direction.
- When an action potential is initiated in the middle of the axon, two impulses traveling in opposite directions are set up by electrotonic depolarization on either side of the initial current sink.
- In the natural situation, impulses pass in one direction only, ie, from synaptic junctions or receptors along axons to their termination.
- Such conduction is called **orthodromic. Conduction** in the opposite direction is called **antidromic.**


Receptor input
STIMULUS
Sensory outpu to spinal cord and brain
ANTIDROMIC
ORTHODROMIC
Two depolarizations cancel each other
Progressive depolarization to CNS for perception
Somatic motor output from spinal cord or brain
STIMULUS
ANTIDROMIC
ORTHODROMIC
Two depolarizations cancel each other
Progressive depolarization to target-tissue receptors
Motor output to muscle or glanc

Thank You!