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Department of Biomedical Engineering

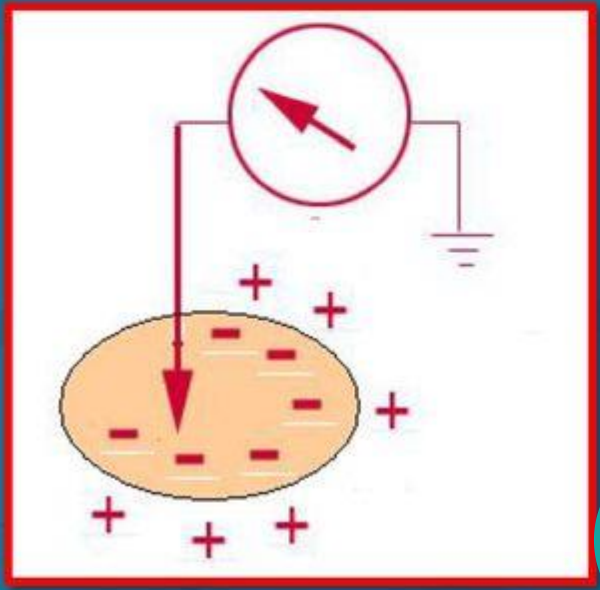
Course Name: 19BMT201 – Human Anatomy & Physiology

II Year : III Semester

Topic : UNIT 1- Cell membrane Potential & Action Potential

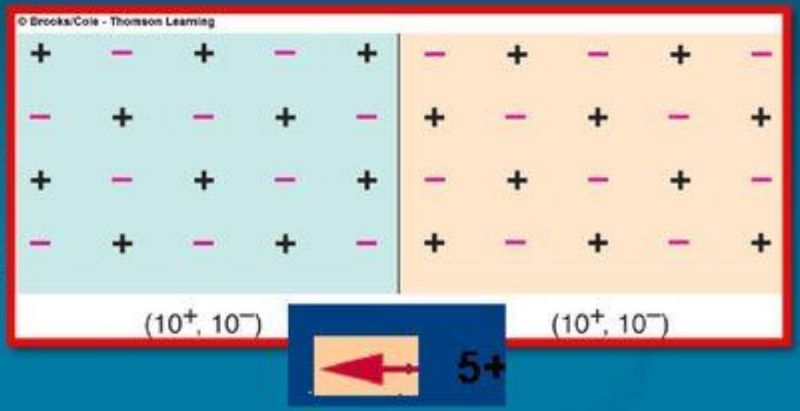
Membrane Potential

- Membrane potential: separation of opposite charges across the plasma membrane
  - difference in the relative number of **cations (+ve)** & **anions (-ve)** in the ICF & ECF
- These separation produce energy differences between inside and outside which called potential
- This energy is electrical energy and is measured by **Millivolts**

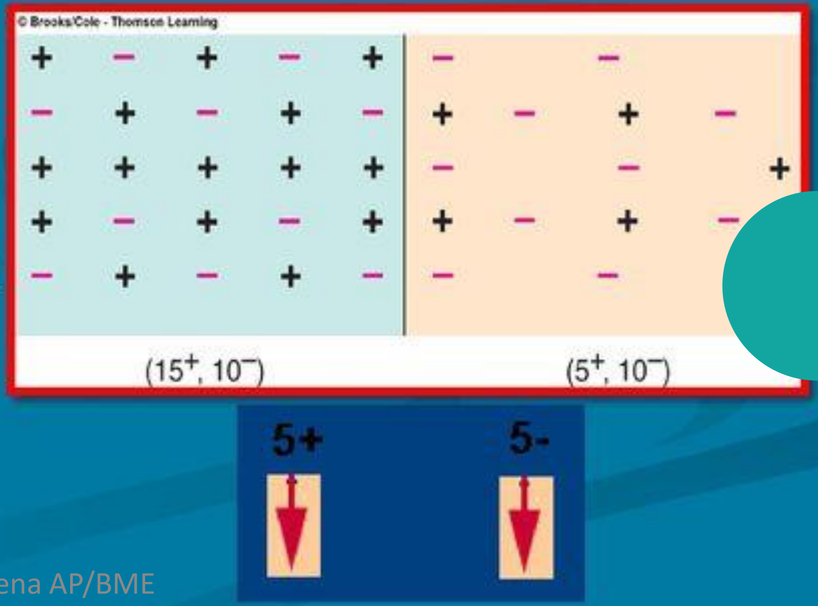


Membrane Potential

- **No membrane potential**
  ➔ An equal number of (+ve) and (-ve) charges are on each side of the membrane

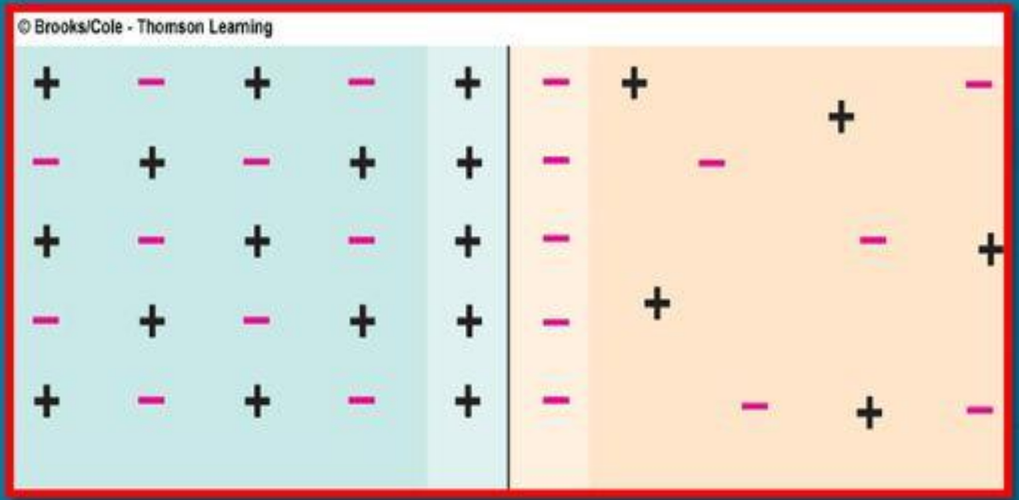


- **Membrane potential exist**
  ➔ Unequal number of (+ve) and (-ve) charges are on each side of the membrane



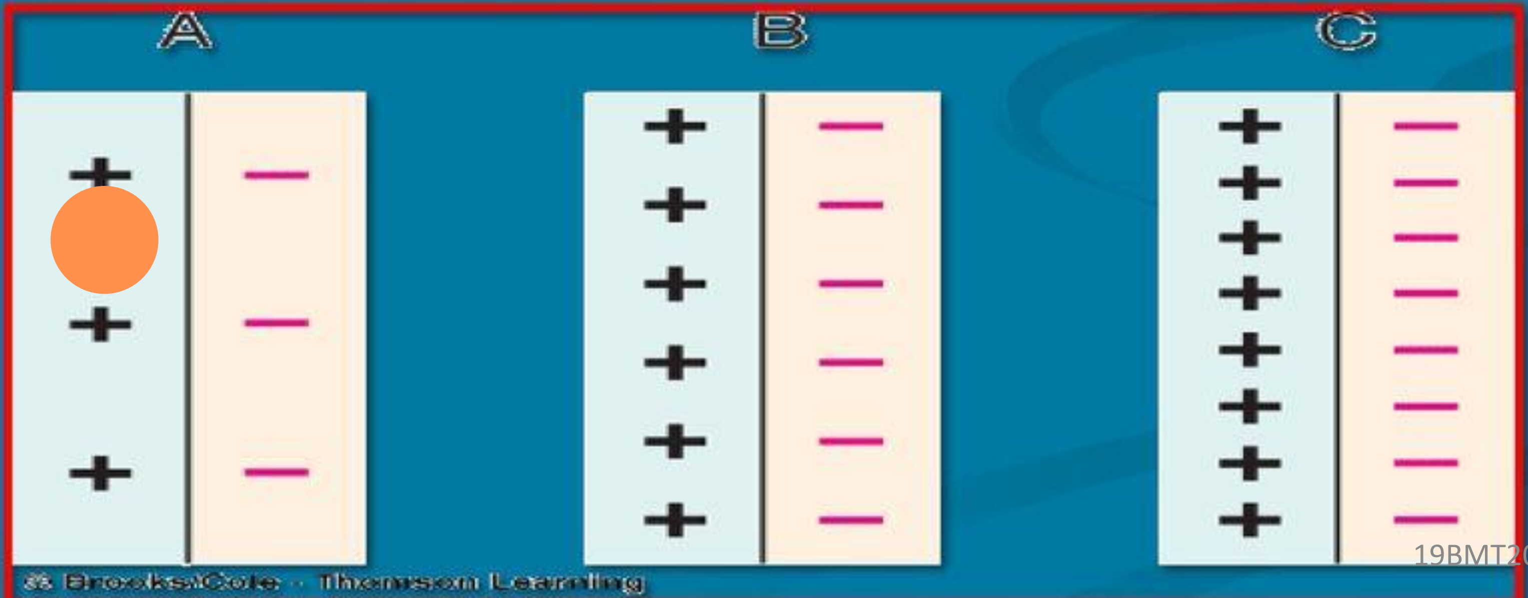
Membrane Potential

- Separated charges accumulated in a thin layer along the outer and inner surface of the plasma membrane



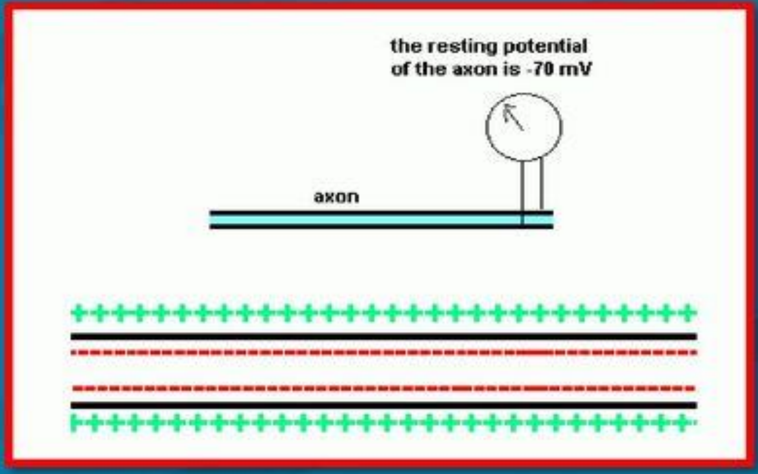
Membrane Potential

- The magnitude of the potential depends on the degree of separation of the opposite charges
- The greater the number of separated charges ➔ the larger potential



Resting Membrane Potential

- All plasma membrane of all living cells have **resting membrane potential**:
  - Varies in value according to the type of the cell:
    - Nerve cell → -70 mV
    - Skeletal and cardiac muscle → -80 to -90 mV
    - Smooth muscle → -60mV
  - The sign always represent the
    y of the excess charge
    e membrane
    e than outside



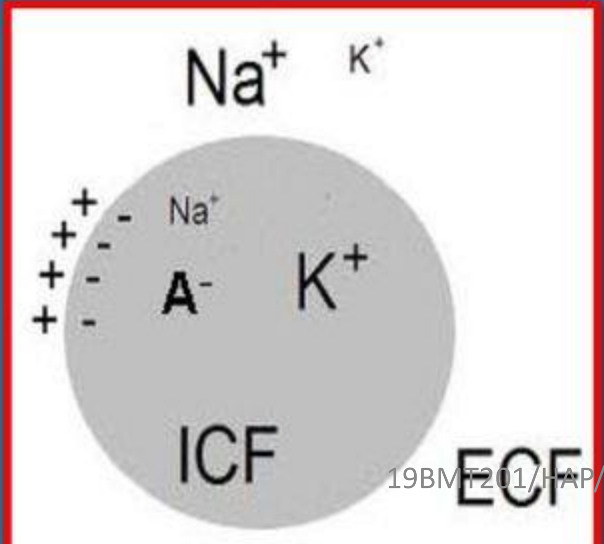
Resting Membrane Potential

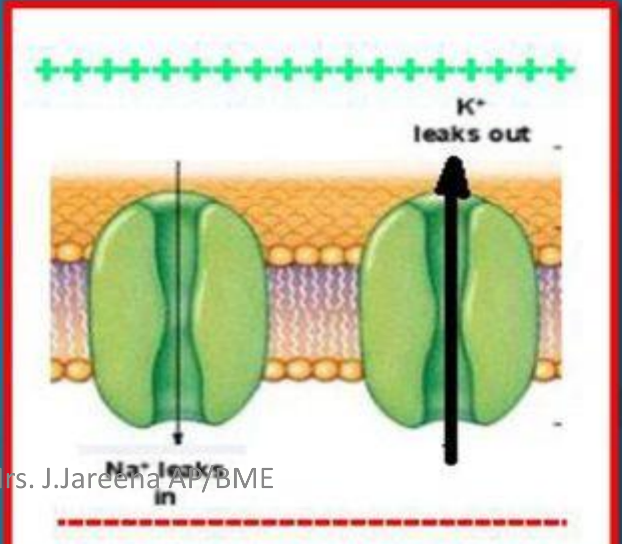
- In the body, the electrical charges are carried by ions
- The ions primarily responsible for the generation of resting membrane potential are:
  - Na^+
  - K^+
  - A^- (-ve charged intracellular proteins)

TABLE 3-3

Concentration and Permeability of Ions Responsible for Membrane Potential in a Resting Nerve Cell

ION	CONCENTRATION (millimoles/liter) Extracellular	CONCENTRATION (millimoles/liter) Intracellular	RELATIVE PERMEABILITY
Na^+	150	15	1
K^+	5	150	50–75
A^-	0	65	0

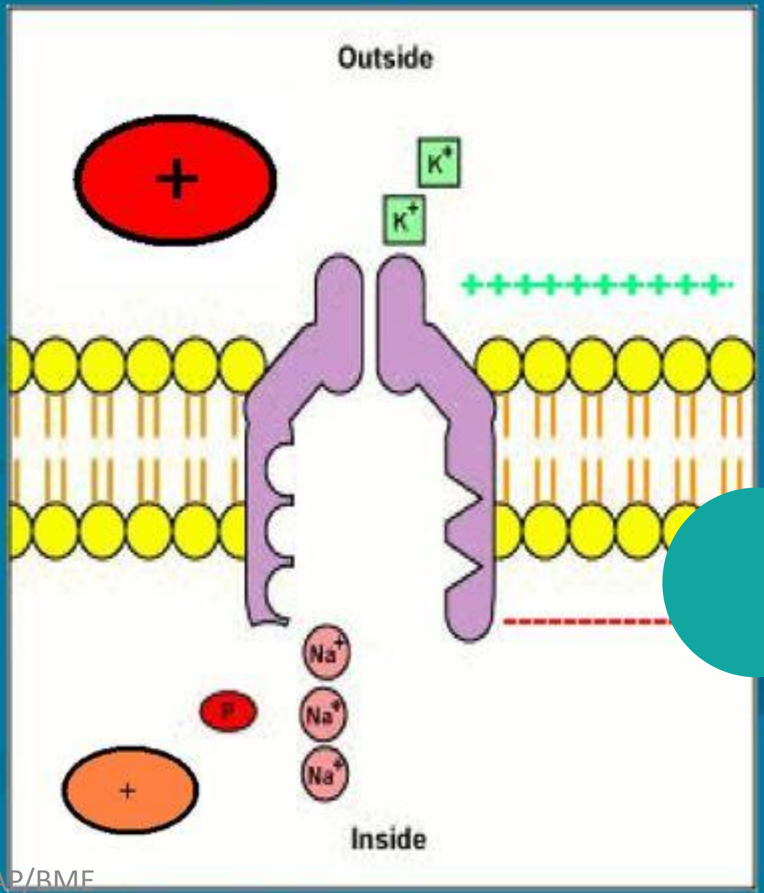




Resting membrane potential

- Unequal distribution of a key ions between ICF and ECF are maintained by Na^+ / K^+ pump:

  - •Active transport mechanism
  - •Pumps 3Na+ outside, 2K+ inside
  - •Maintains high [K+] inside the cell, high [Na+] outside
  - •Unequal transport generates a membrane potential
  - •Outside becoming more +ve than inside (more +ve are transported **out** than **in**)

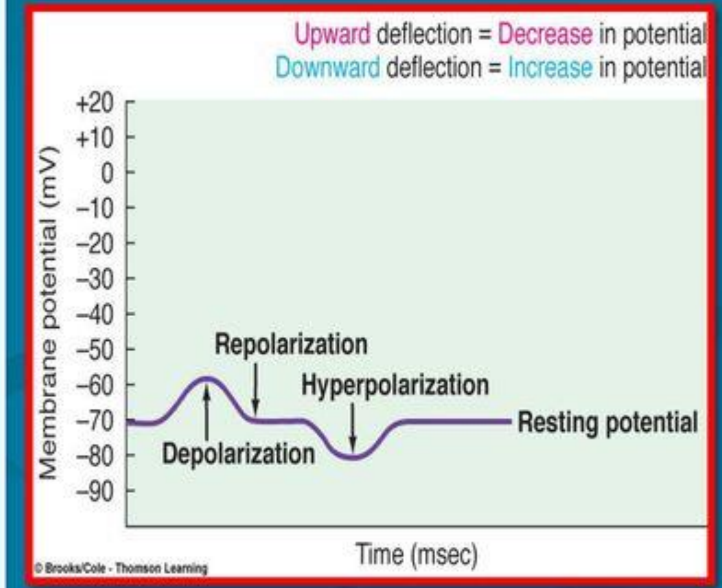


Changes in Resting Membrane Potential

- Excitable cell **(Nerve & muscle)** able to undergo transient, repaid changes in their resting membrane potential
- These changes serve as electrical signal:
  - Nerve cell: use electrical signal to receive, process, initiate, and transmit messages
  - Muscle: these electrical signals initiate contraction

Changes in Resting Membrane Potential

- **Polarization:** separation of opposite charge i.e. resting state (-ve inside compared with outside)
- **Depolarization:** decrease the negativity of the membrane (moving toward 0 mV)
- **Repolarization:** the membrane returns to resting potential
- **Hyperpolarization:** the membrane become more negative than at rest (increase negativity)



Changes in resting membrane potential

- Changes in membrane potential could be:
  - Graded potential
  - Action potential

Graded potentials are activated by the opening of mechanically or chemically gated channels and they travel over short distances.

Action potentials are generated by the opening of voltage-gated channels and travel over long distances

Action Potential- It is the rapid and transient change in a membrane potential which occurs when nerve cell membrane is stimulated.

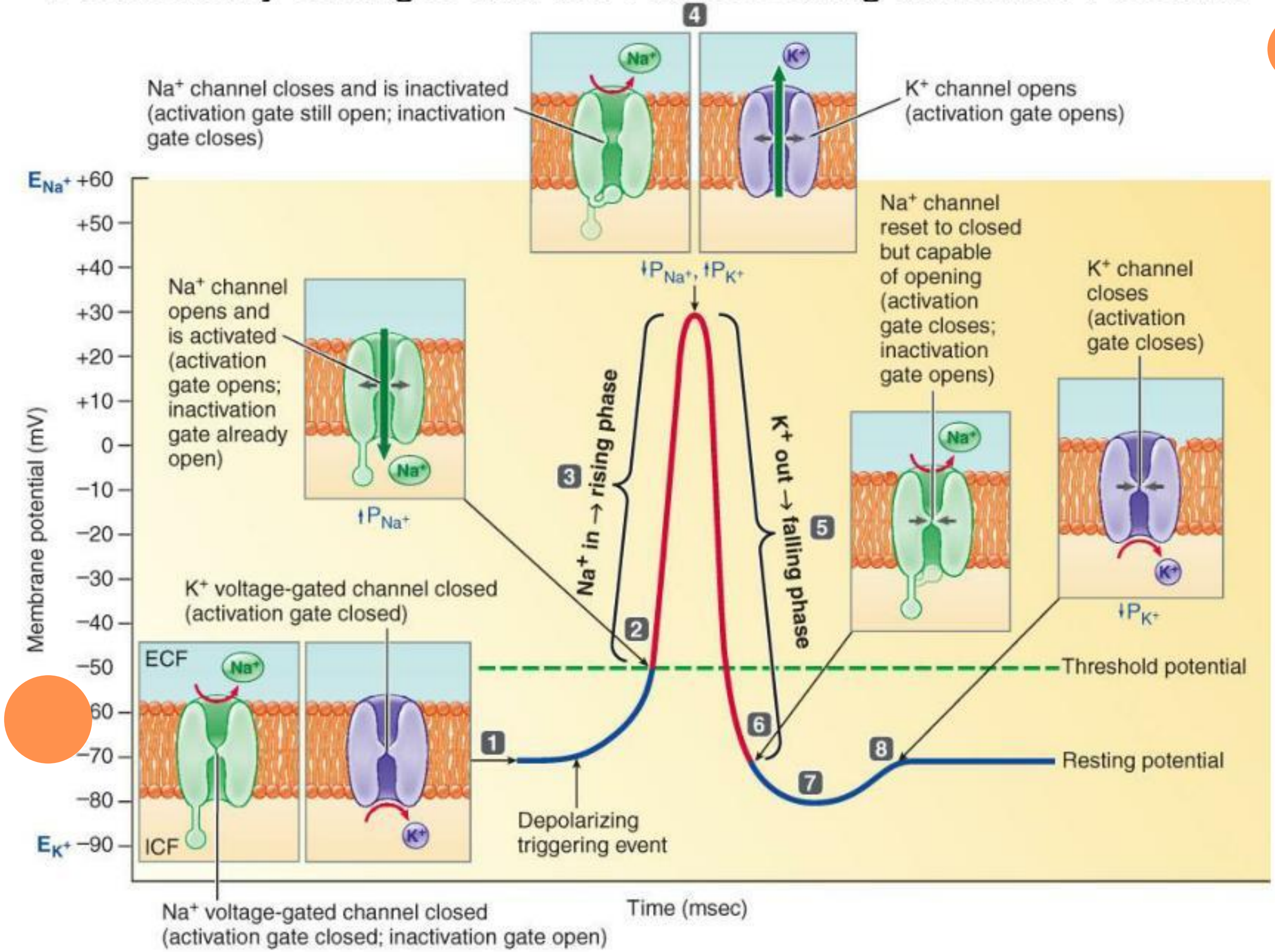
Action Potential Generation in a Nerve Cell

- **Resting potential:** The resting membrane potential in nerve cell averages around-70 m V. e.g. RMP of nerve is -90 m V, pacemaker is -60 m V and skeletal muscle averages to -83 m V.
- When a nerve cell is stimulated, the Na+ channels open. If the stimulus strength is adequate, the opening of the Na+ channels is sufficient to change the membrane potential from -70 m V up to -55 m V, the action threshold is reached.
- **Depolarization:** As the action threshold is reached more of the voltage-gated Na+ channels open. The Na+ influx drives and changes the membrane potential to about +30 m V. This process of change in membrane potential to positivity is called depolarization. The Na+ channels close and the K+ channels open. The K + channels are much slower to open and the depolarization gets completed.

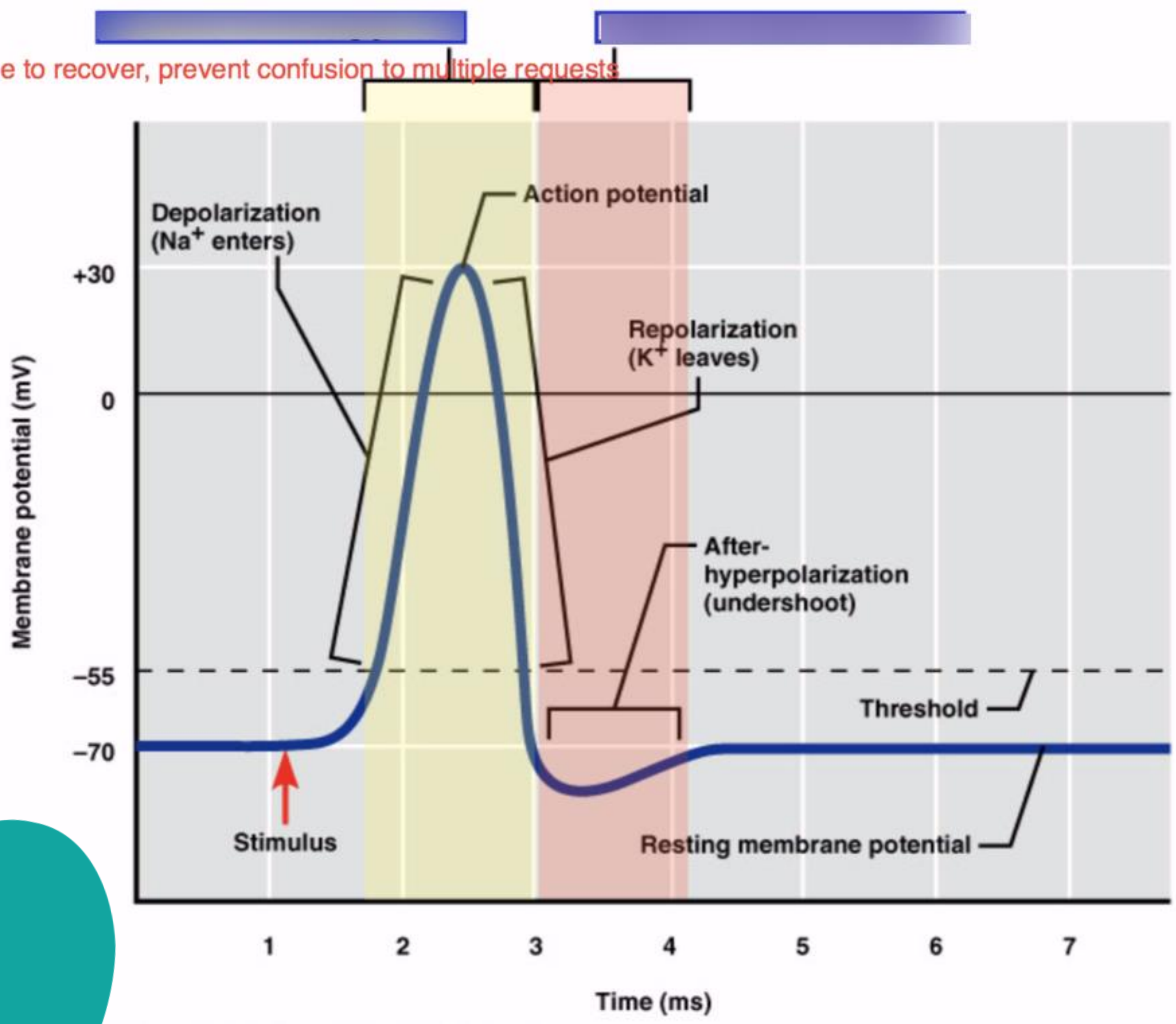
- **Repolarization:** The opening of **K** + channels open, the membrane begins to repolarize back toward its resting stage
- **Hyperpolarization:** The potential typically overshoots above the rest potential to about -90 m V. This leads to hyperpolarization. The process of hyperpolarization raises the threshold for any new stimulus and prevents the neuron from receiving another stimulus during this time.
- **Resting potential:** The Na+ /K+ pump eventually brings the membrane back to its resting state of-70 m V from hyperpolarized state.

Action Potentials

Permeability Changes and Ion Fluxes During an Action Potential



Time to recover, prevent confusion to multiple requests



The Refractory Period

- Two phases
  - Absolute refractory period
    - No stimulus of any strength will trigger AP
    - Lasts as long as Na^+ gates are open, then inactivated
  - Relative refractory period
    - Only especially strong stimulus will trigger new AP
    - K^+ gates are still open and any effect of incoming Na^+ is opposed by the outgoing K^+
    - Generally lasts until hyperpolarization ends
- **Only a small patch of neuron's membrane is refractory at one time (other parts of the cell can be stimulated)**

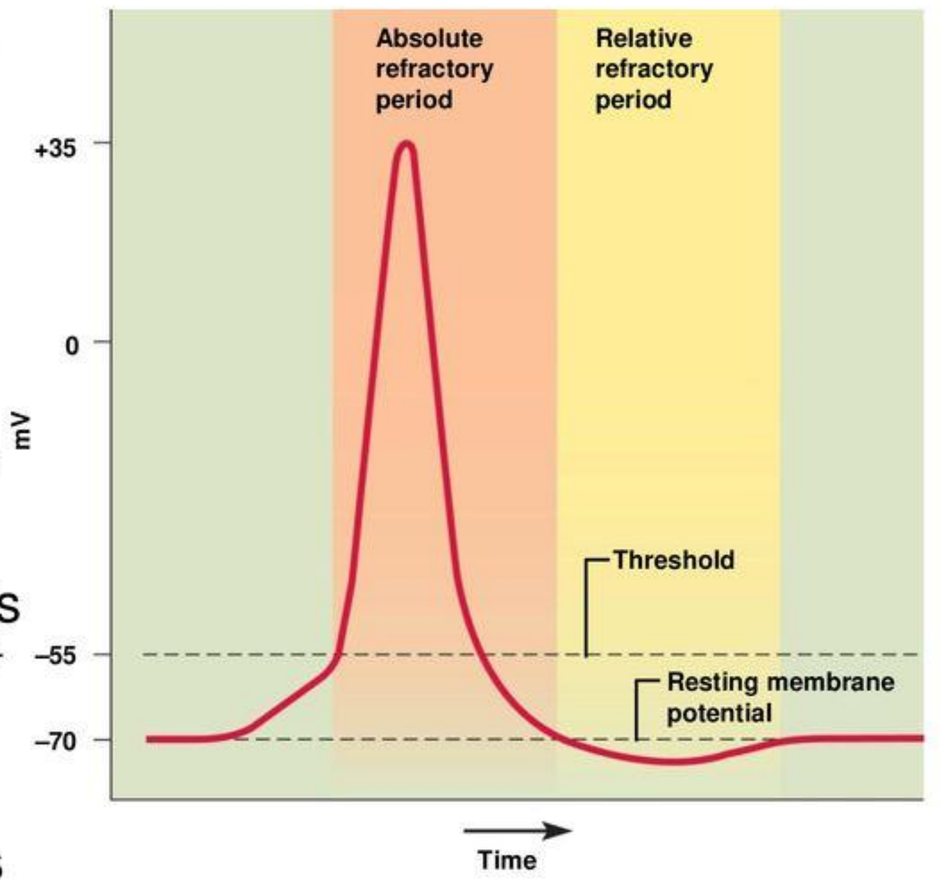


Figure 12.15

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