MSS

physiology

LEC no.1

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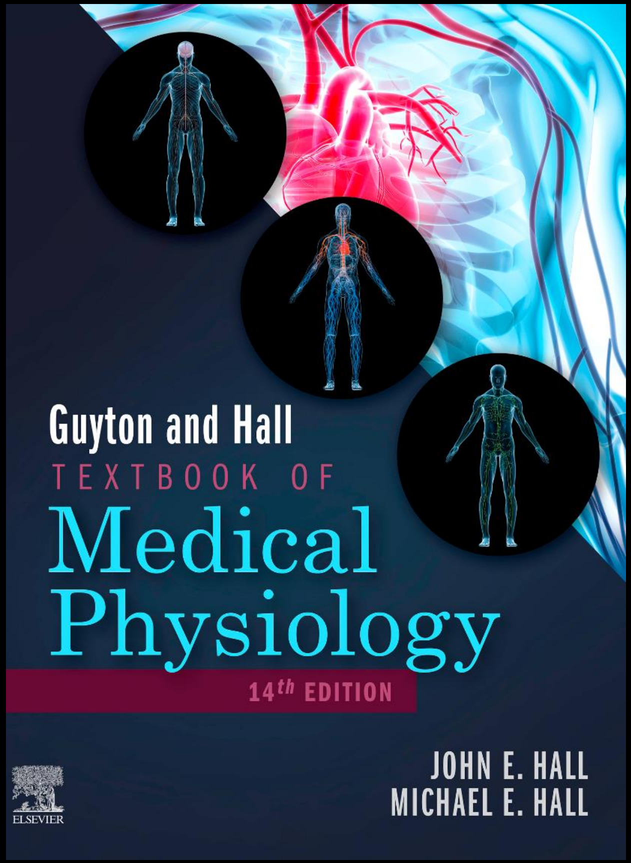
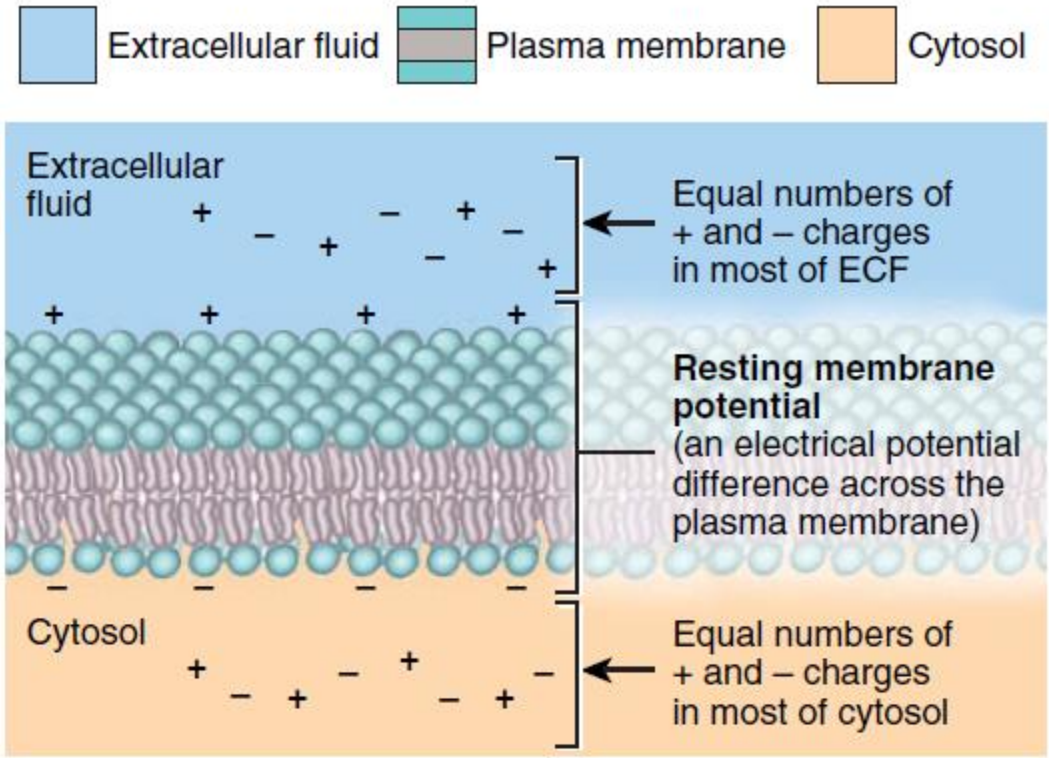


Chapter 6: Contraction of Skeletal Muscle

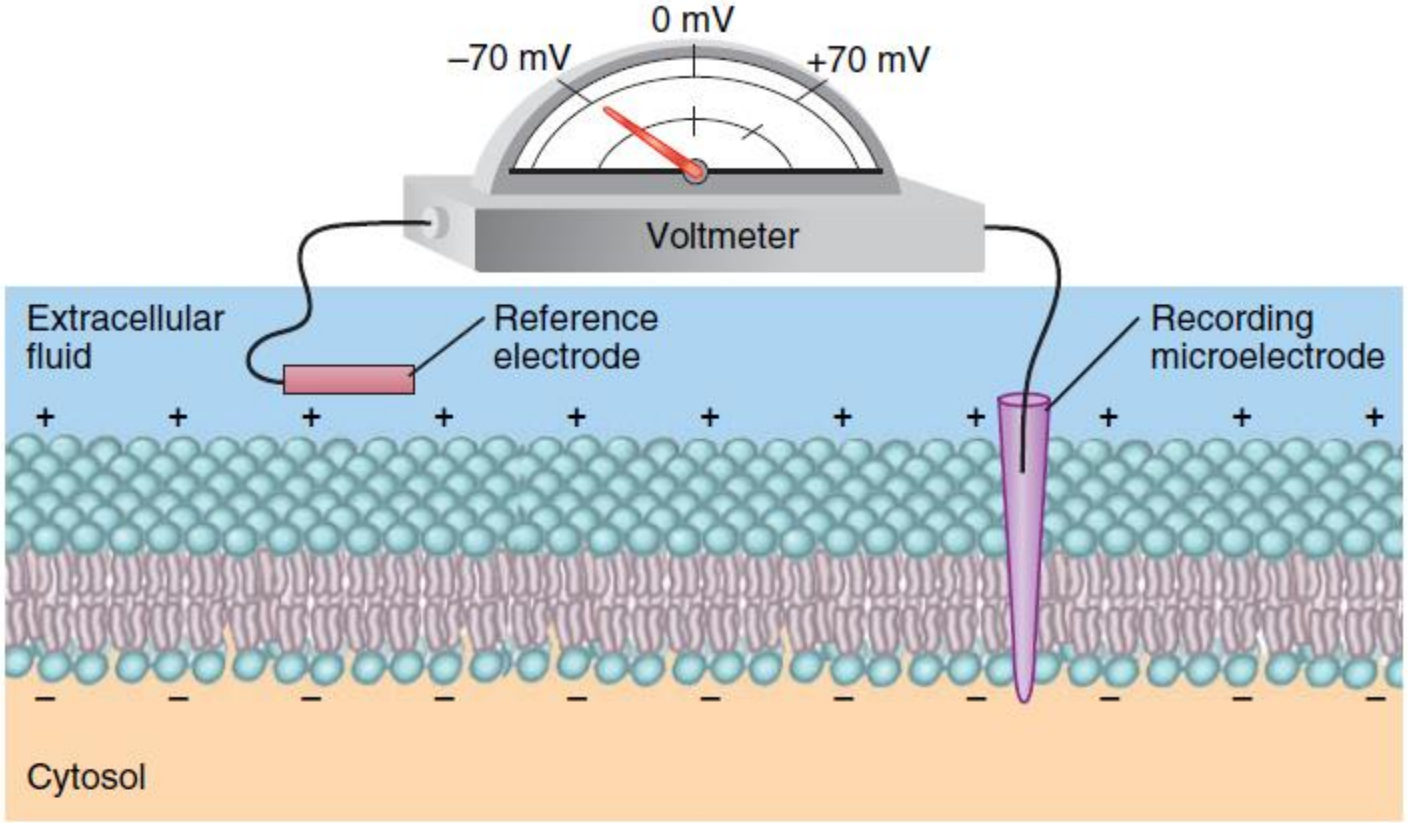
Chapter 7. Excitation of Skeletal Muscle: Neuromuscular Transmission and Excitation-Contraction Coupling

Revision

RESTING MEMBRANE POTENTIAL



(a) Distribution of charges that produce the resting membrane potential of a neuron



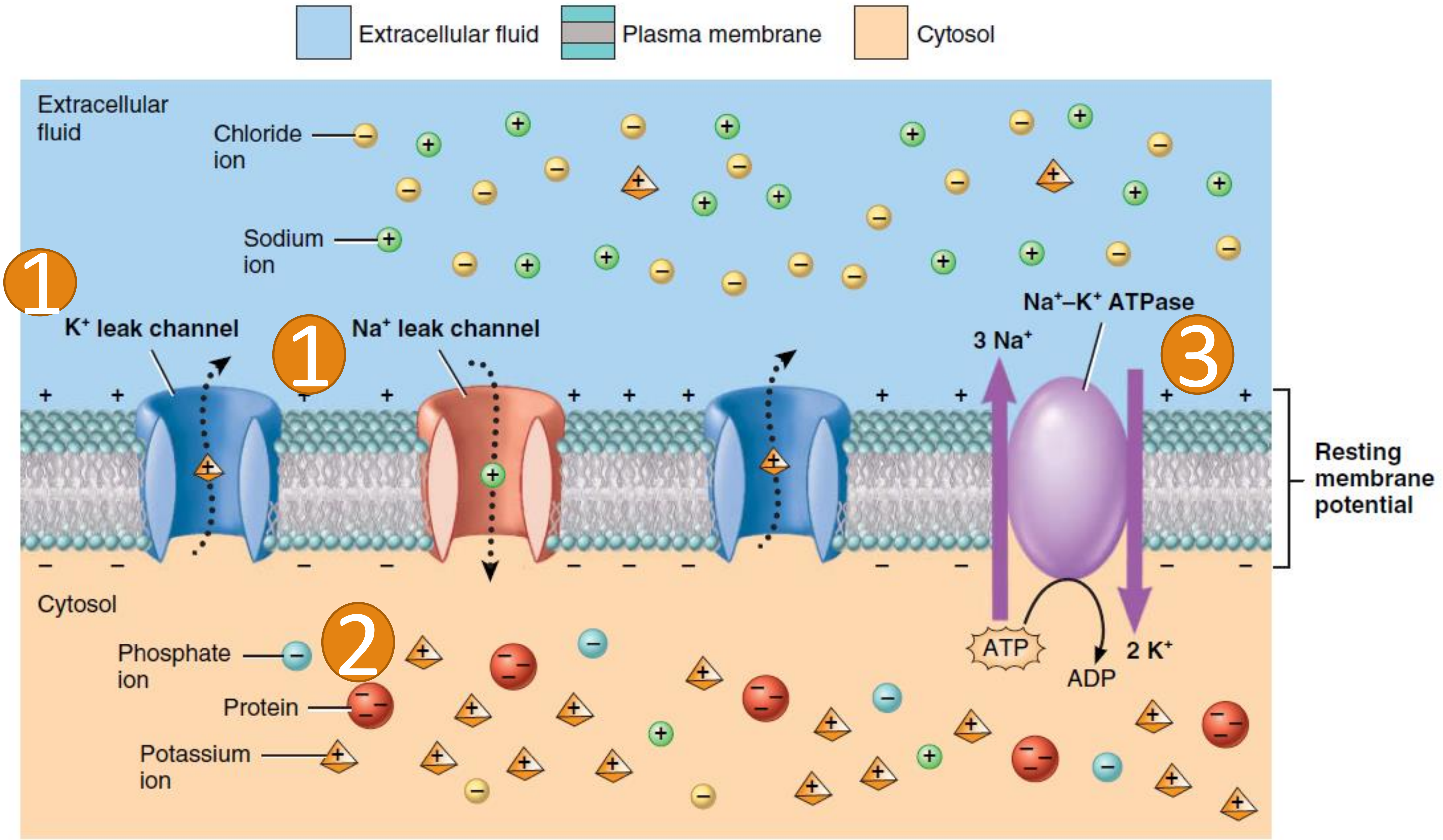
(b) Measurement of the resting membrane potential of a neuron

NOTES FOR CLARIFICATION :

The Factors that determine the resting membrane potential :

1. The anions (proteins) that are located intracellularly.
2. Sodium Na^+/ potassium K^+ pump
3. Concentration difference of sodium Na^+ and concentration difference of potassium K^+

For ex: if the resting membrane potential was –90mV is there any movement of sodium and potassium across membrane? YES, inside the cell there are more potassium ions and fewer sodium ions, while outside the cell there are more sodium ions and fewer potassium ions, this difference in ion concentration creates an electrical imbalance and unequal distribution of these ions across the cell membrane. **Leak channels** will allow the movement of Na^+ ions to intracellular fluid & efflux of K^+ ions to extracellular fluid so it's such a dynamic process, if there was an excessive disruption of charge the Na^+/k^+ pump will take the place and do the reverse what leak channels do.

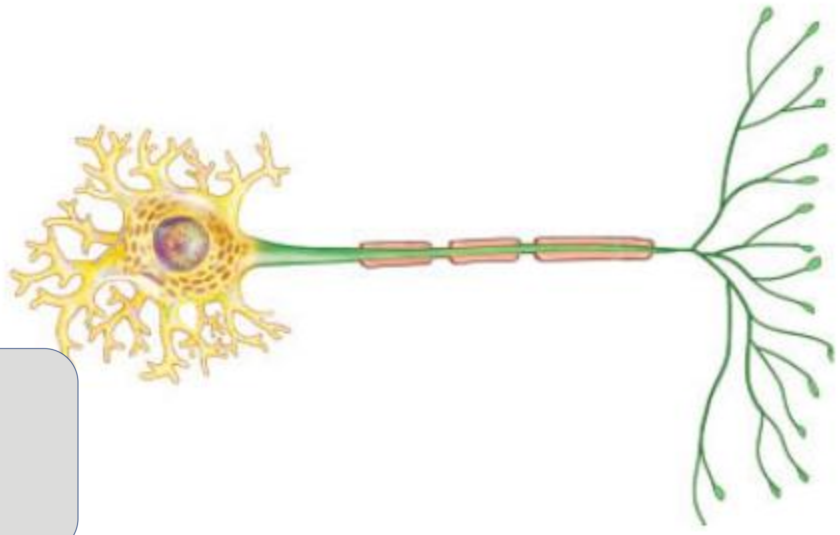


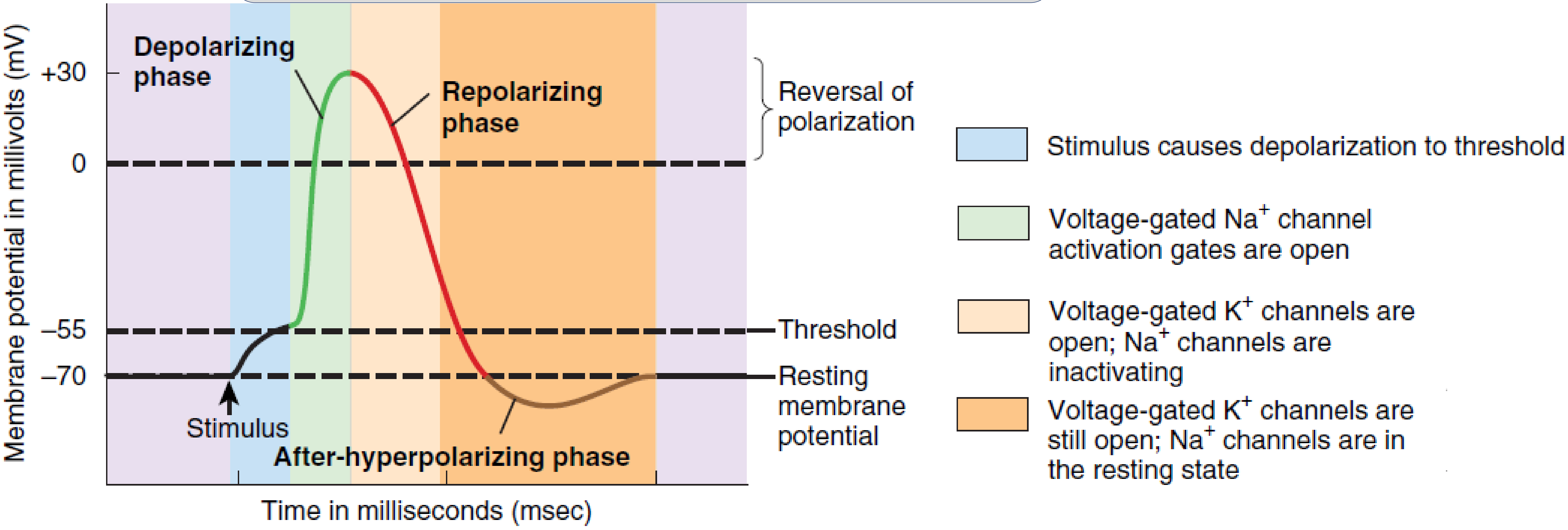
Extracellular fluid
Plasma membrane
Cytosol
Extracellular fluid
Chloride ion
Sodium ion
1
K⁺ leak channel
1
Na⁺ leak channel
Na⁺–K⁺ ATPase
3 Na⁺
3
Resting membrane potential
Cytosol
Phosphate ion
2
Protein
Potassium ion
ATP
ADP
2 K⁺

NERVE ACTION POTENTIAL

Rapid changes in the membrane potential that spread rapidly along the nerve fiber membrane.

Action potential starts at axon hillock (trigger zone) then propagates along the axon until it reaches the axon terminal.





NOTES FOR CLARIFICATION OF PREVIOUS SLIDE :

Just to be in case in this figure the **resting membrane potential is –70mV**

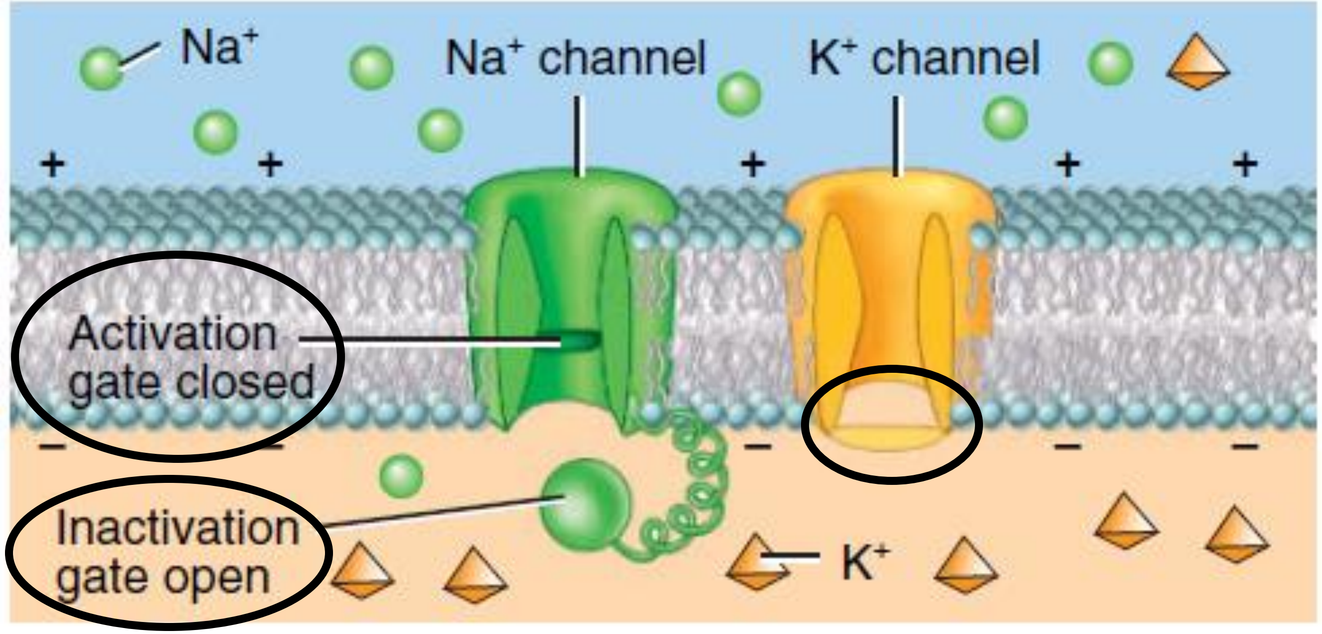
1. Its will remain –70mV until there is a certain type of stimulus, this stimulus should be strong enough to change the membrane potential to reach THRESHOLD which is –55mV so the amplitude of that stimulus is 15mV .

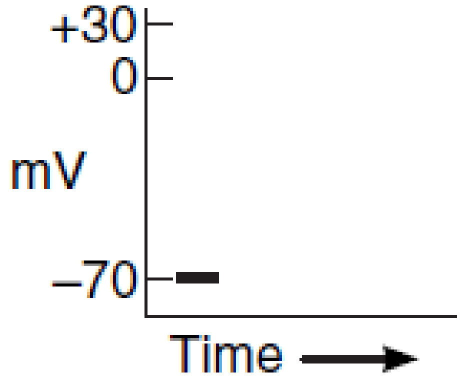
2. Depolarizing phase once it reaches –55mV there will be opening of voltage gated sodium channels, we know that the high concentration of Na+ is extracellular once these channels are open it will move down its concentration gradient from (extracellular ---> intracellular) and since Na+ has a positive charge, it's going to make the intracellular compartment more POSITIVE.

3. Repolarizing phase after the depolarizing phase the membrane potential will reach +30mV and there is will be opening of voltage gated potassium channels, normally the high concentration of K+ ions is intracellular, so there will be efflux down its concentration gradient from (intracellular ---> extracellular) and the intracellular will become more NEGATIVE (they actually start to open at -55mv but the process is very slow, their effect is not recognizable before the membrane potential reaches +30mv).

4. Hyperpolarizing phase a continuation or prolong opening of voltage gated potassium channels and the K+ ions will keep moving outside and the intracellular will become more & more NEGATIVE, even it can pass the resting membrane potential and the membrane potential will move below the resting membrane potential.

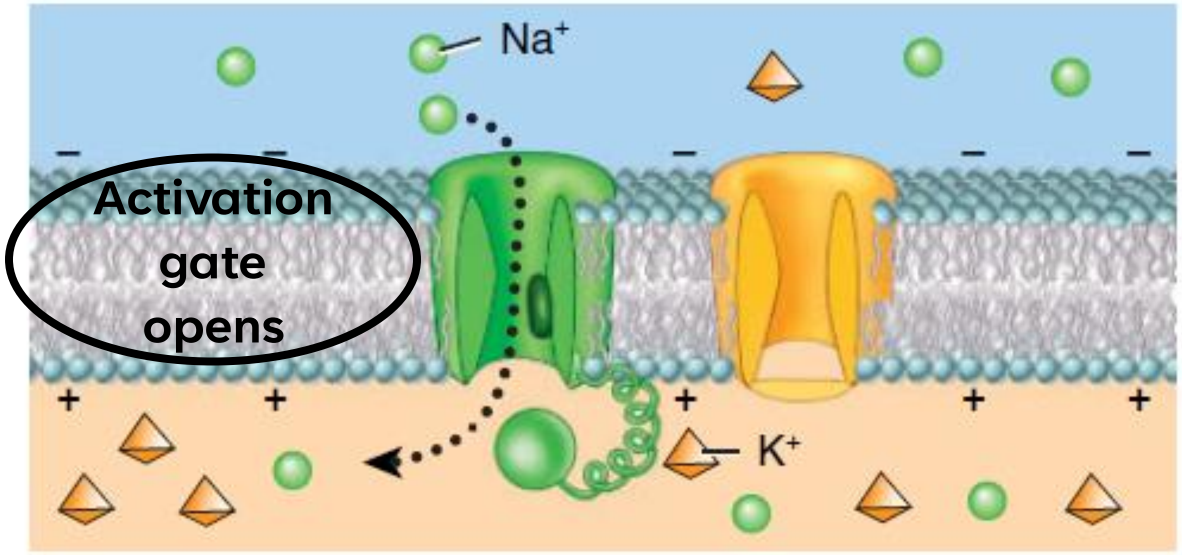
1. **Resting state:**
All voltage-gated Na^+ and K^+ channels are closed. The axon plasma membrane is at resting membrane potential: small buildup of negative charges along inside surface of membrane and an equal buildup of positive charges along outside surface of membrane.

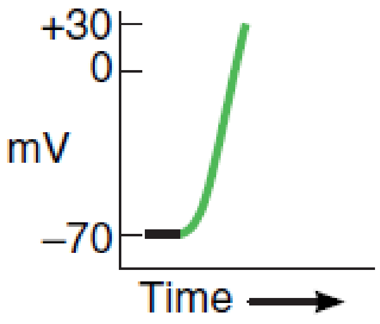




Na^+ channel has two gates, one called activation gate, and another called inactivation gate, **at resting** state K^+ channel **is closed** and Na^+ channel is **closed by activation gate**, so membrane potential is at -70.

2. **Depolarizing phase:**
When membrane potential of axon reaches threshold, the Na^+ channel activation gates open. As Na^+ ions move through these channels into the neuron, a buildup of positive charges forms along inside surface of membrane and the membrane becomes depolarized.

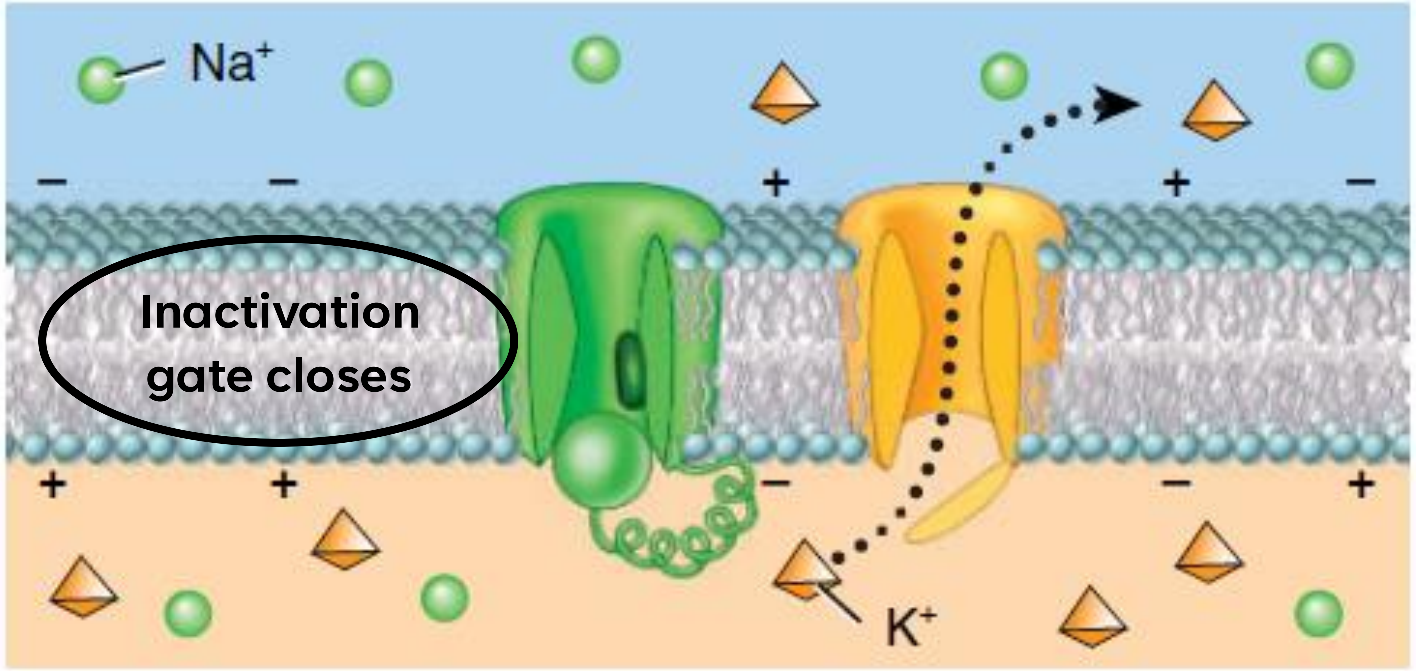




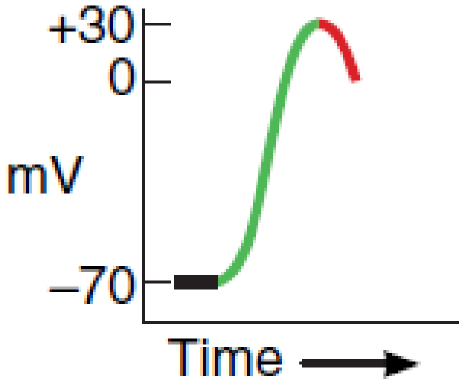
When the membrane is affected by a stimulus exceeding the threshold, Na^+ channel will open its **activation gate** allowing the **influx of Na^+**, increasing the membrane potential making the depolarizing phase.

The K^+ channel opens too but at a very slow rate. It allows **K^+ efflux** but not enough to stop the increase in membrane potential.

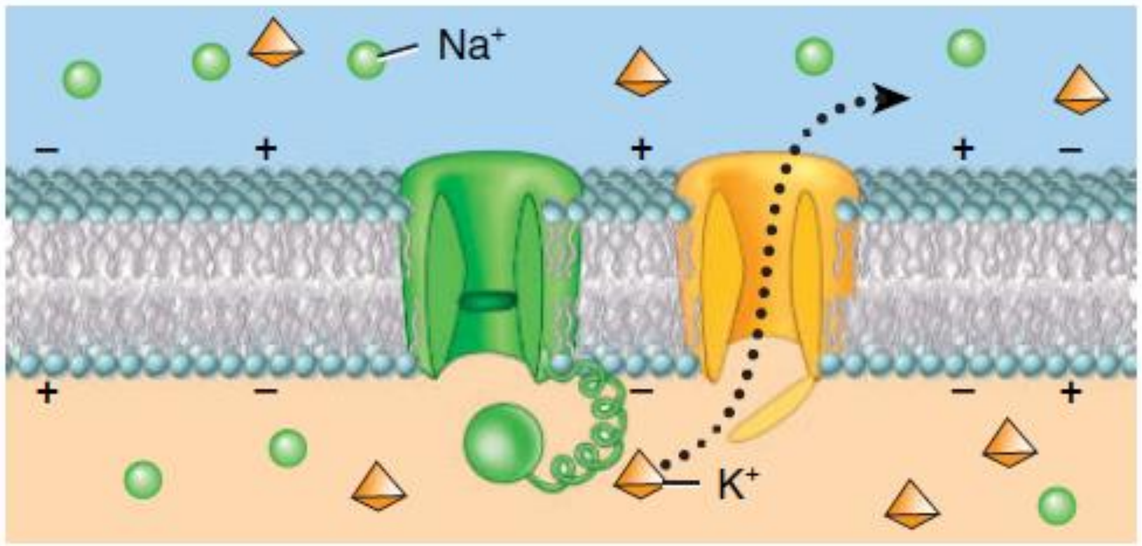
3. **Repolarizing phase begins:** Na^+ channel inactivation gates close and K^+ channels open. The membrane starts to become repolarized as some K^+ ions leave the neuron and a few negative charges begin to build up along the inside surface of the membrane.

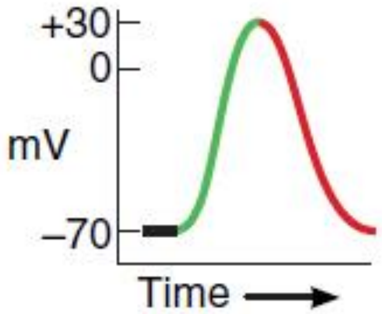


When membrane potential reaches +30 the **inactivation gate** will close the Na^+ channel stopping the Na+ influx, while the **K^+ efflux continues**, decreasing the membrane potential making the repolarizing phase.



4. Repolarization phase continues:
K^+ outflow continues. As more K^+ ions leave the neuron, more negative charges build up along inside surface of membrane.
K^+ outflow eventually restores resting membrane potential. Na^+ channel activation gates close and inactivation gates open. Return to resting state when K^+ gates close.





When the membrane potential goes below -70mv (resting potential) the Na^+ **activation gate will close** and **inactivation gate will open**, switching roles.

But the **K^+ channel will not close until almost -90**, the repolarizing phase continues.

The difference between activation gate and inactivation gate is that
Activation gate: opens when there is a stimulus.
Inactivation gate: remains closed despite the presence of a stimulus.
This allows refractory periods, which will be discussed.

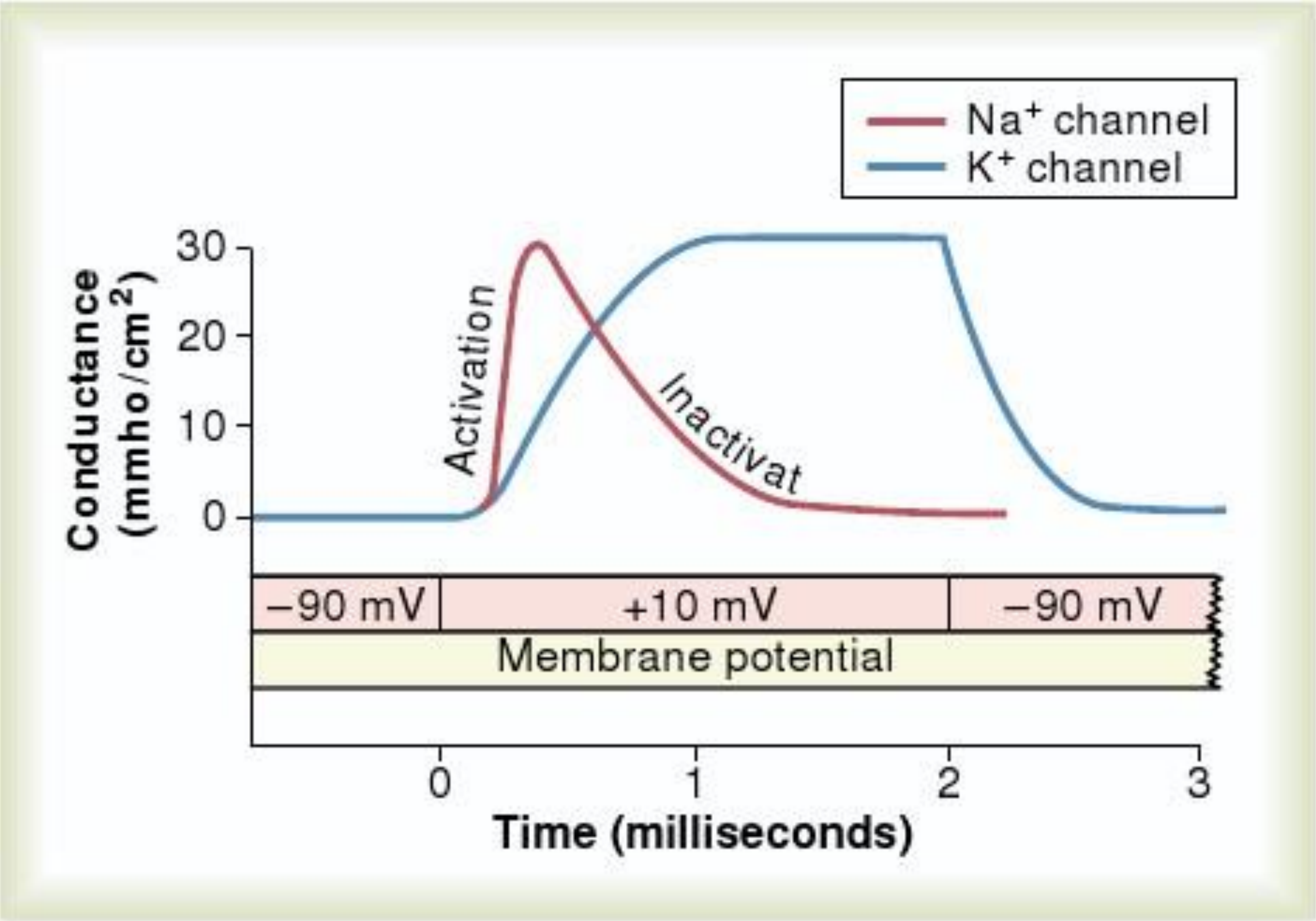
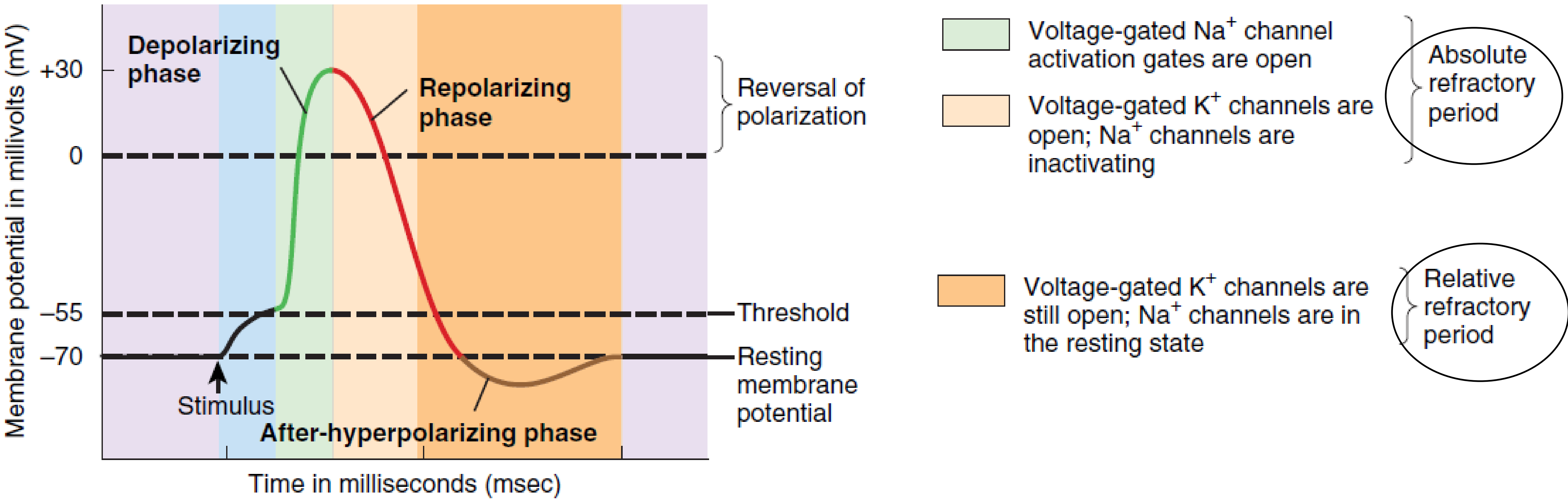


Figure 5–9

This figure shows how K+ channels open at depolarization phase but at a slower rate.

REFRACTORY PERIOD



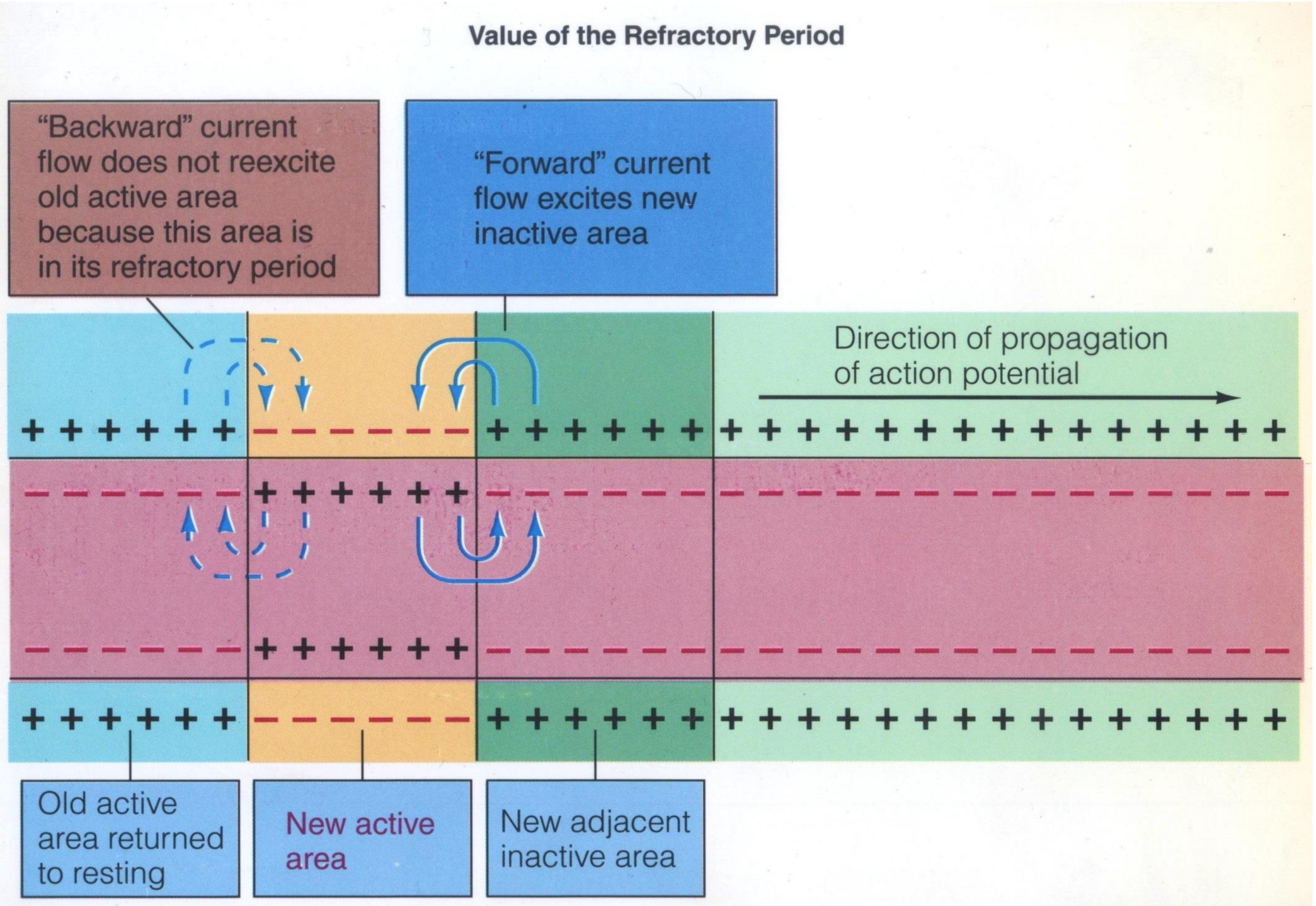
Refractory period is the phase where voltage gated channels are irresponsive to stimulus even if it's present, this prevents the overlapping of action potentials and makes them flow in one direction.

There are two types of refractory periods, relative and absolute.

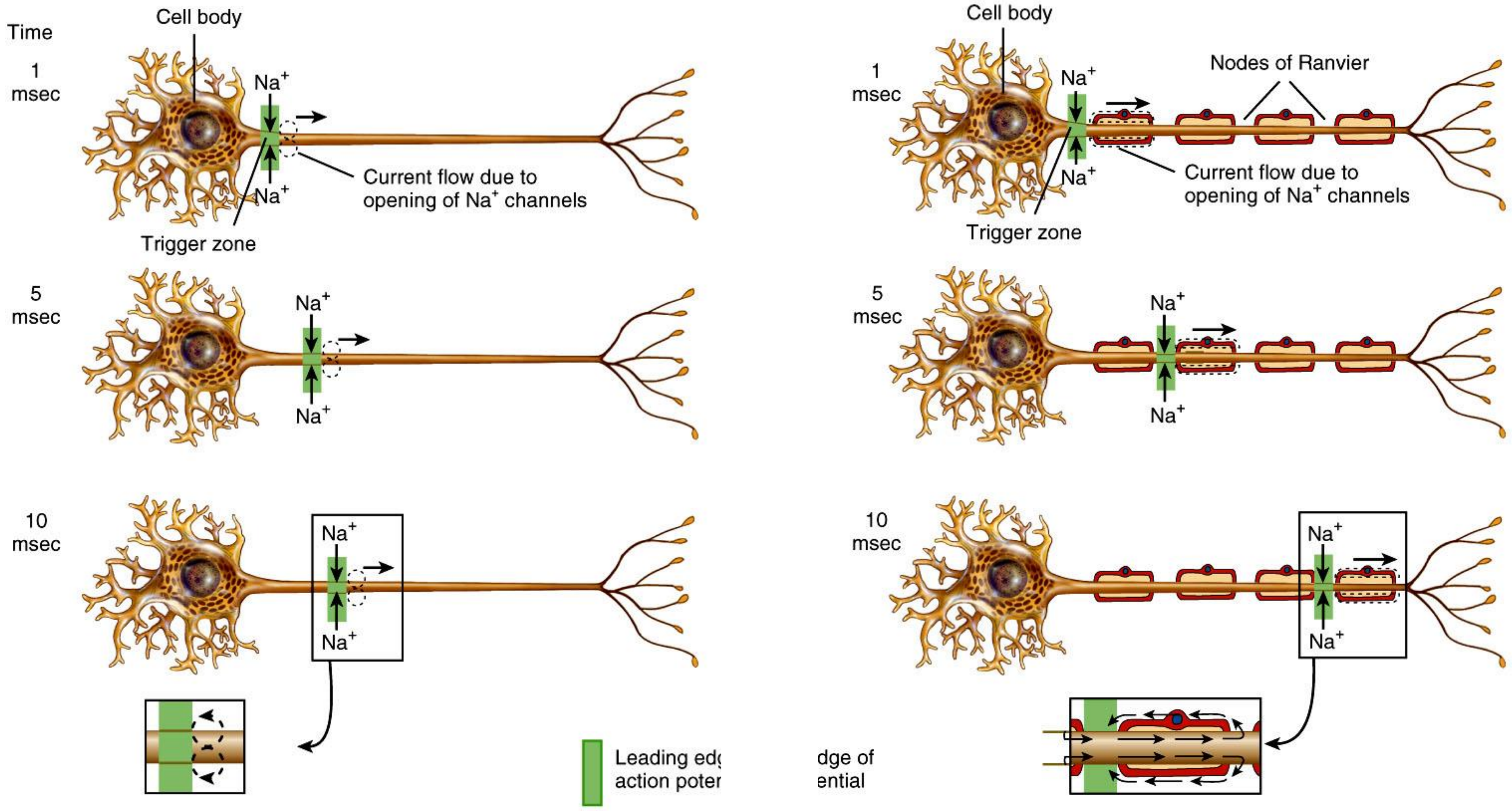
Relative refractory period : in **relative refractory period** the Na^+ voltage gated channel is **closed by the activation gate** but will not open even with a stimulus, unless the stimulus is **very strong**, then the activation gate **will open**, making action potential.

Absolute refractory period : in **absolute refractory period** the Na^+ voltage gated channel is **closed by the inactivation gate** and **will not open even when a very strong stimulus is present**. It only opens after the repolarization phase when membrane potential falls below -70mv, then the activation gate takes its place.

ACTION POTENTIAL PROPAGATION



TYPES OF ACTION POTENTIALS PROPAGATION



(a) Continuous conduction

(b) Saltatory conduction

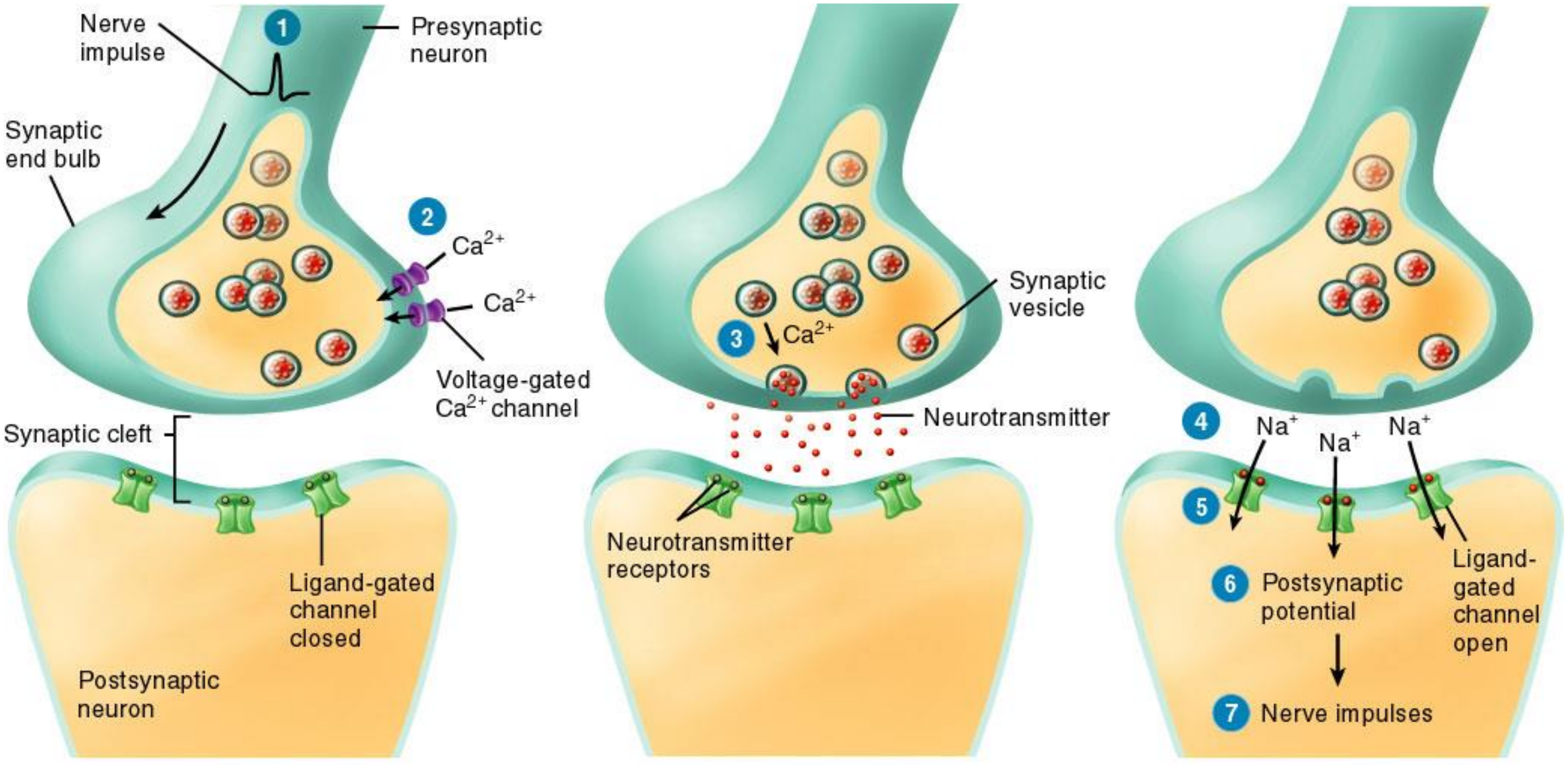
Figure 12.22 Tortora - PAP 12/e

There are two types of action potential propagation:

1- <u>**Continuous conduction**</u> : the action potential in one area activates the action potential in the next one, this type of conduction is **slow**, and it happens in **unmyelinated neurons**.

2- <u>**Saltatory conduction**</u> : this type is present in **myelinated neurons** where the action potential "**skips**" the myelinated areas, and only appear in nodes of Ranvier (unmyelinated areas) making the signal move **faster** along the axon.

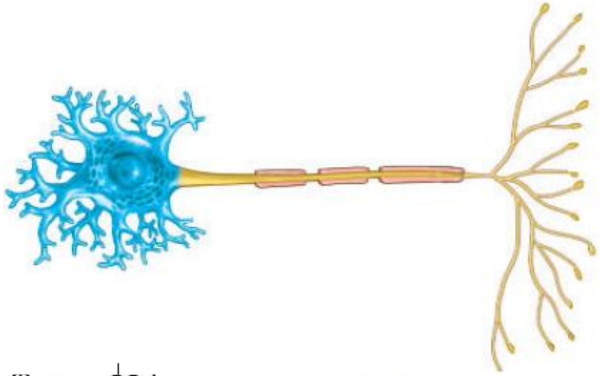
SIGNAL TRANSMISSION AT SYNAPSES



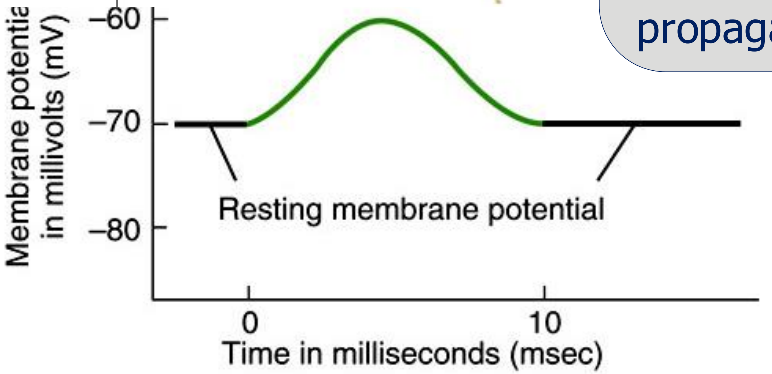
12.14

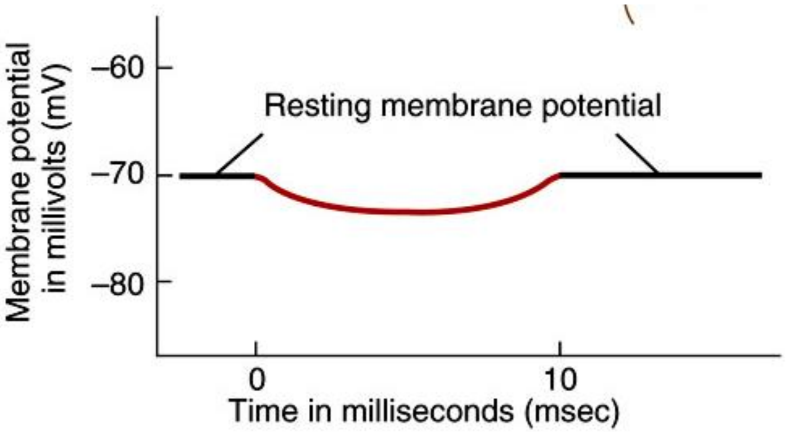
Action potential at synaptic bulb opens voltage gated Ca^{+2} channels resulting in influx of Ca++, higher intracellular concentration of calcium ions releases neurotransmitters to the synaptic cleft (exocytosis) activating the ligand gated Na^{+} channels at the post-synaptic neuron starting a post synaptic excitatory potential .

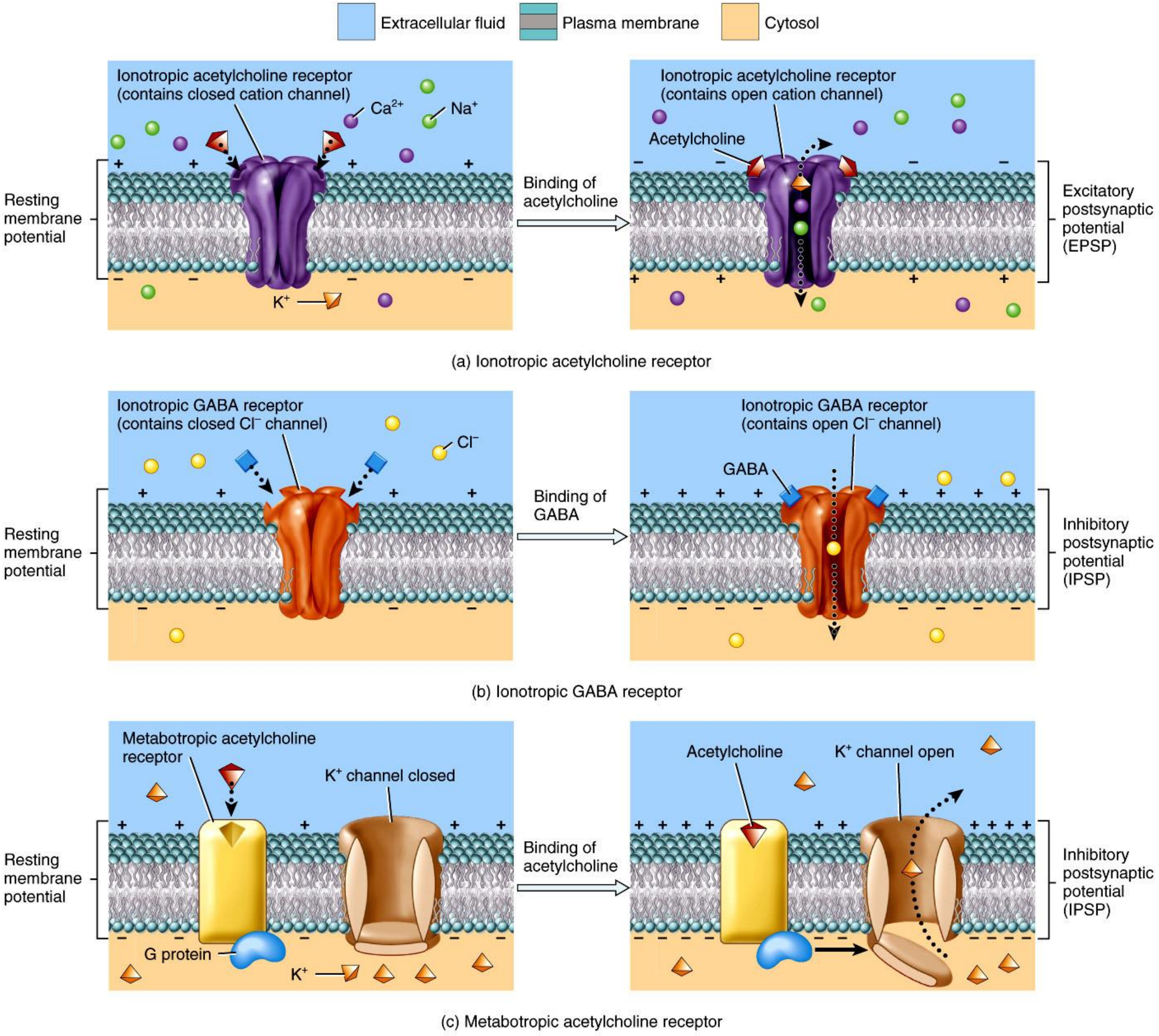
EXCITATORY AND INHIBITORY POSTSYNAPTIC POTENTIALS



In cell body: graded potentials
At axon hillock: graded potentials are added up, if they reach the threshold action potential starts and propagates along the axon.







PRESE

Figure 12.24 Tortora - PAP 12/e

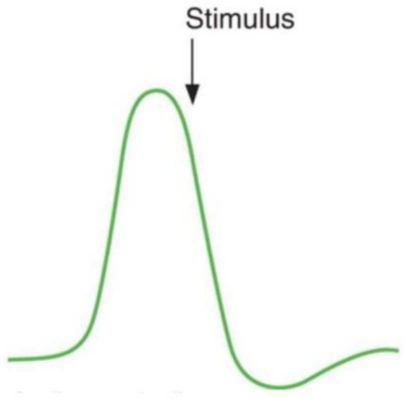
FURTHER EXPLANATION

Excitatory signals release excitatory neurotransmitters (**Ach** for example) activating **Na^+ channels** on the post-synaptic neuron allowing **Na^+ influx increasing its membrane potential**, creating excitatory post synaptic potentials, making it closer to the threshold potential.

Inhibitory signals release inhibitory neurotransmitters (**GABA** for example) activating **Cl^- channels** on the post-synaptic neuron allowing **Cl^- influx decreasing its membrane potential,** creating inhibitory post synaptic potentials, and pulling it away from the threshold potential.

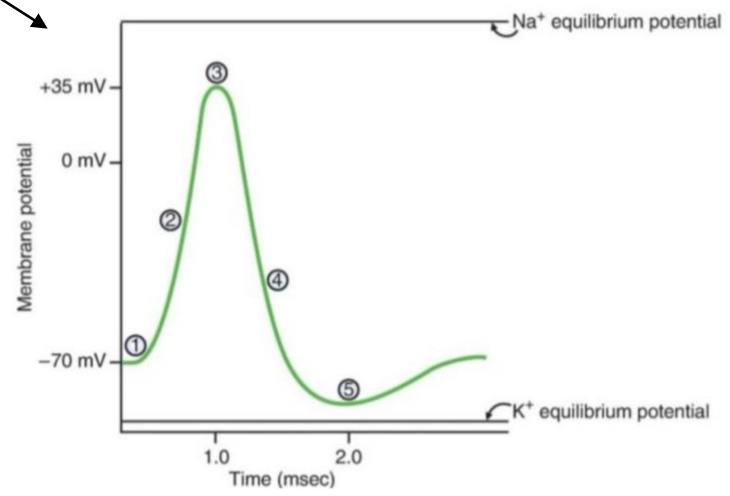
THE REST OF THE FILE WILL BE SOME KAHOOT QUESTIONS AND PAST PAPERS

1. During a nerve action potential, a stimulus is delivered as indicated by the arrow shown in the following figure. In response to the stimulus, a second action potential:



A. of smaller magnitude will occur
B. of normal magnitude will occur
C. Will not occur
D. will occur but will not have an overshoot
E. of normal magnitude will occur but will be delayed

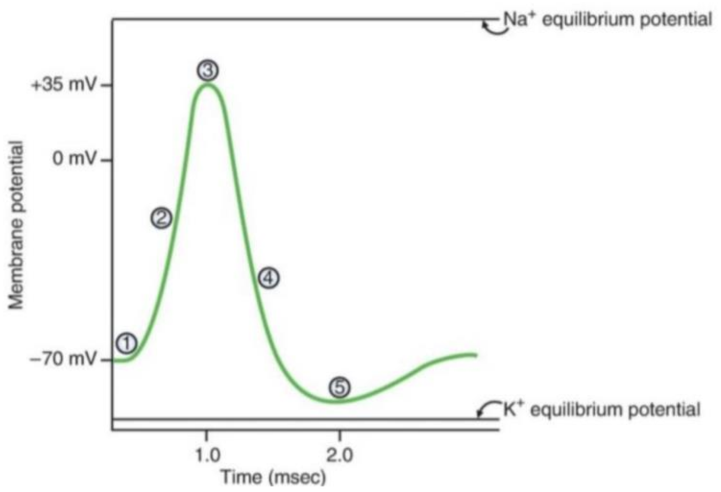
The following diagram of a nerve action potential applies to questions 2-4 :



2. At which labeled point on the action potential is K+ closest to electrochemical equilibrium?
A. 1
B. 2
C. 3
D. 4
E. 5

SOME KAHOOT QUESTIONS AND PAST PAPERS

The following diagram of a nerve action potential applies to questions 2-4 :



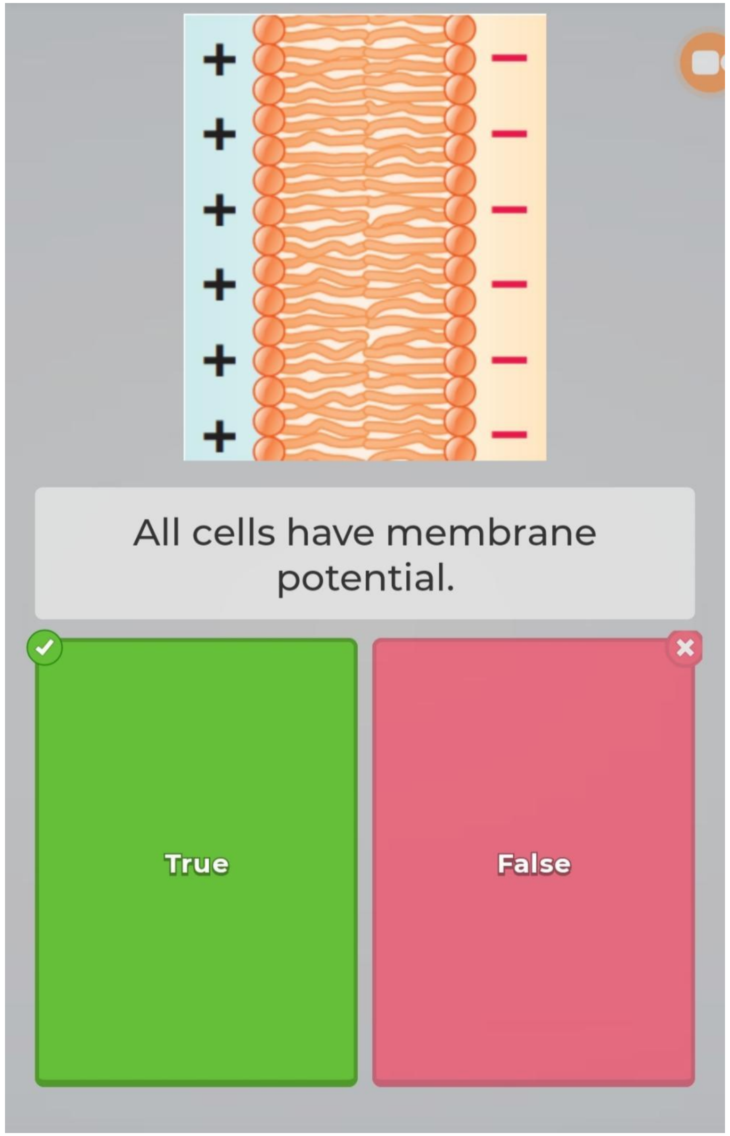
3. What process is responsible for the change in membrane potential that occurs between point 1 and point 3 :

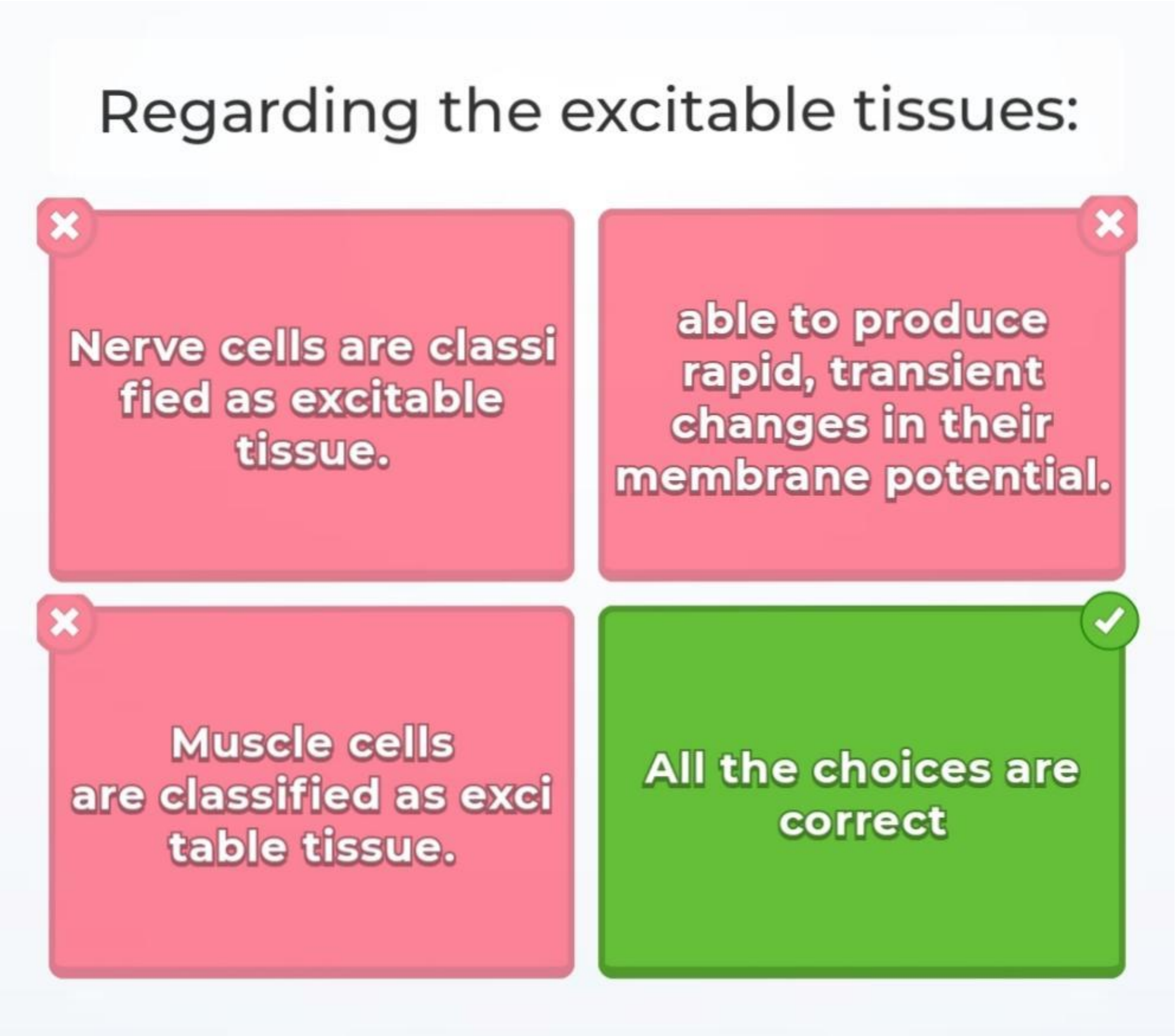
a. movement of Na+ into the cell
b. movement of Nat out of the cell
c. movement of K+ into the cell
d. movement of K+ out of the cell
e. activation of the Na+_K+ pump
f. inhibition of the Na+_K+ pump

4. What process is responsible for the change in membrane potential that occurs between point 3 and point 4:

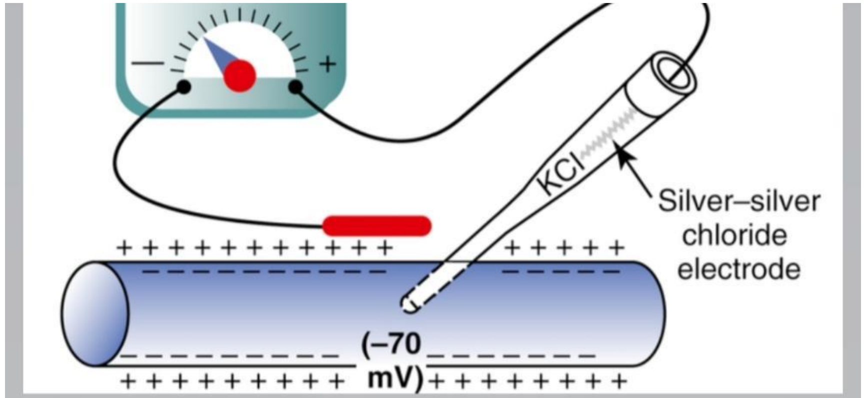
a. Movement of Nat into the cell
b. Movement of Nat out of the cell
c. Movement of K+ into the cell
d. Movement of K+ out of the cell
e. Activation of the Na+_K+ pump
f. Inhibition of the Na+_K+ pump

SOME KAHOOT QUESTIONS AND PAST PAPERS



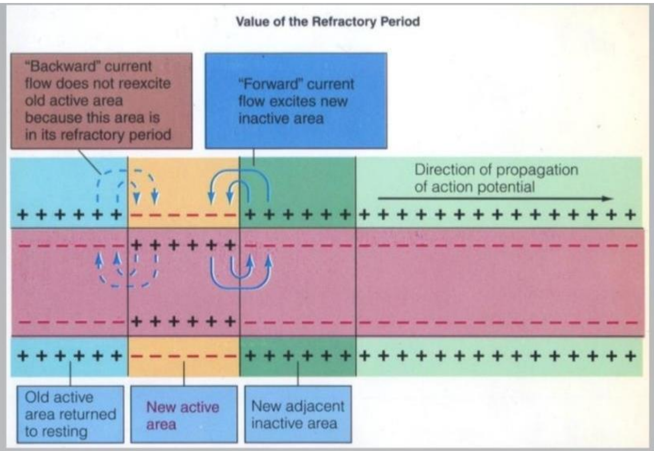


SOME KAHOOT QUESTIONS AND PAST PAPERS



The neuron's resting membrane potential is closer to:

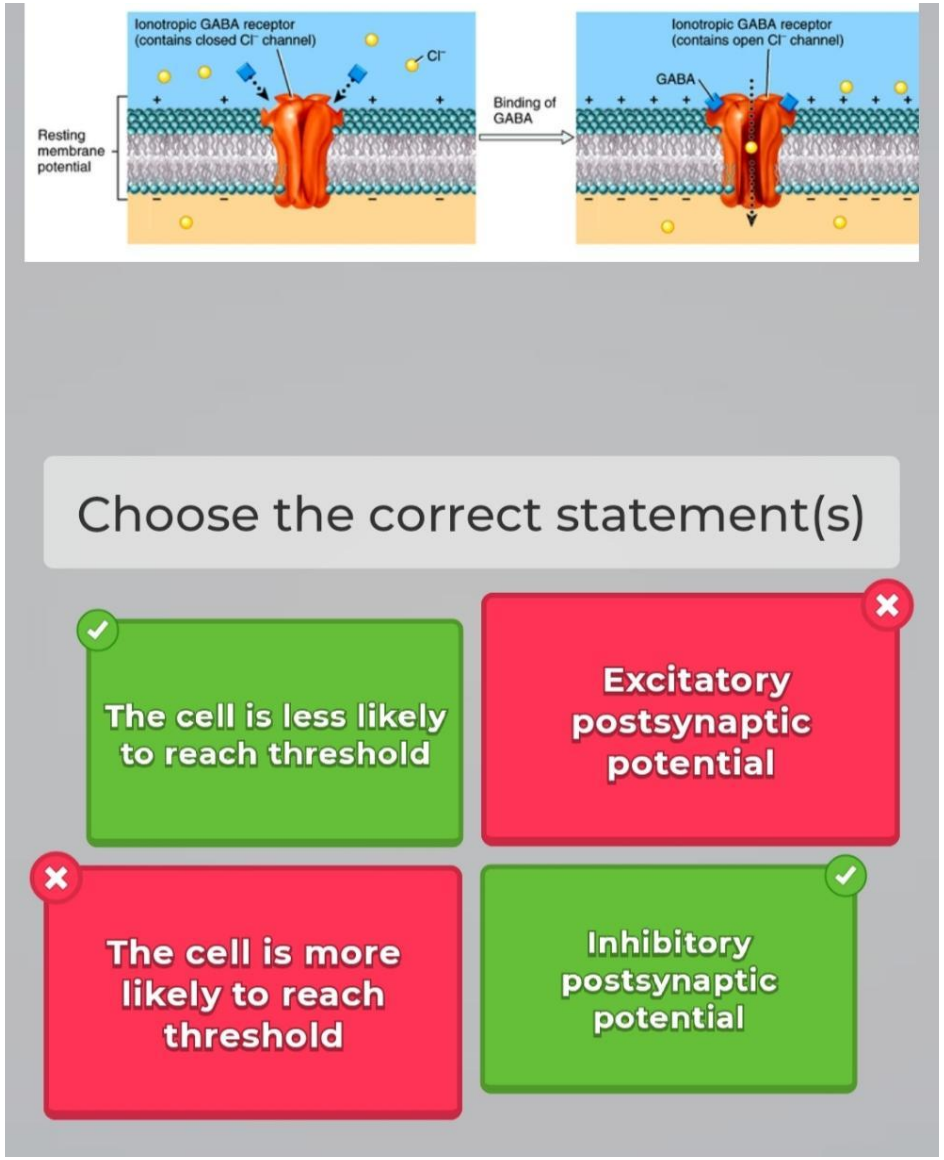
- equilibrium potential for Na+
- equilibrium potential for anions
- equilibrium potential for Cl-
- equilibrium potential for K+ ✓

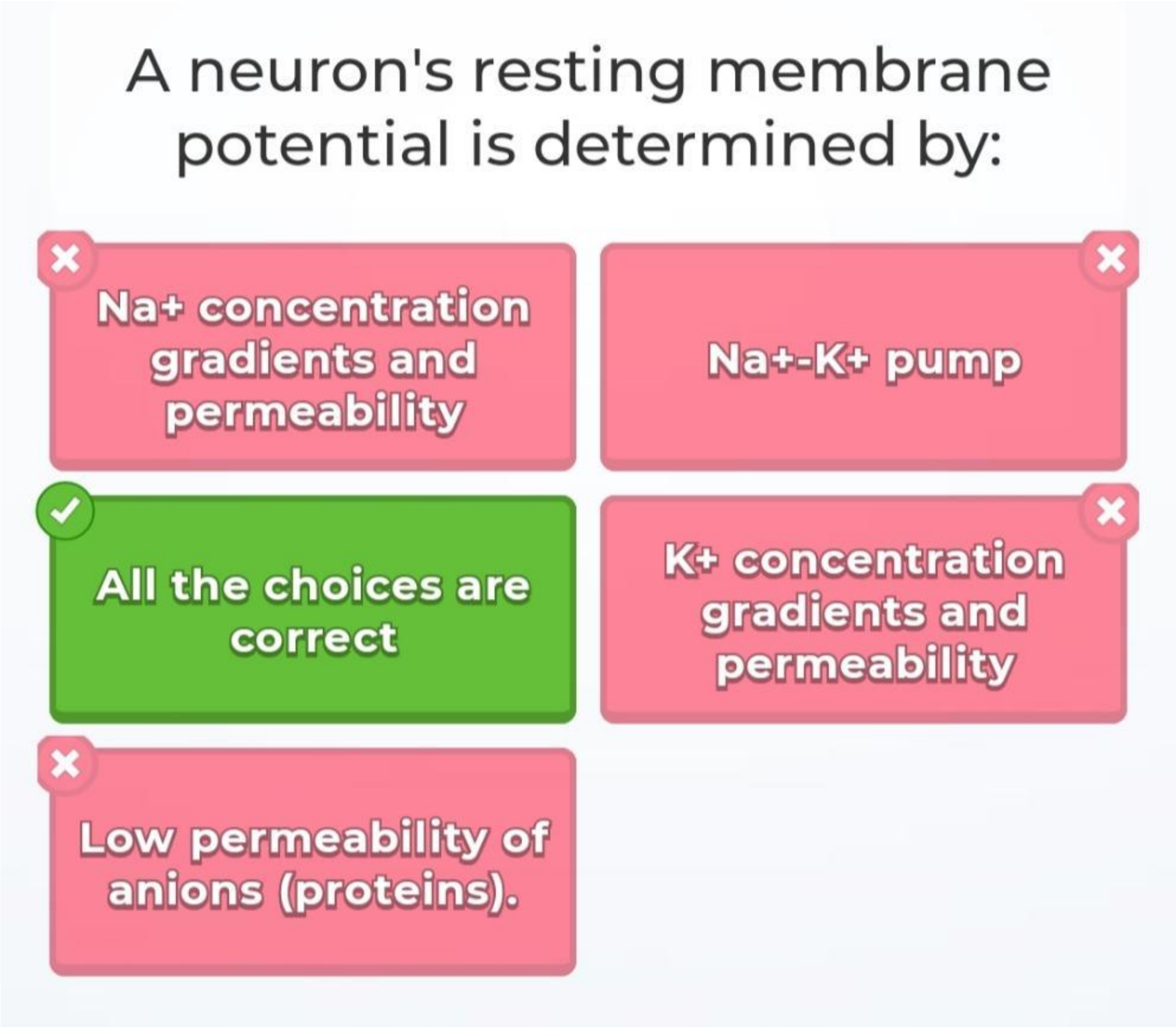


Action potential only propagates in the forward direction (cell body to terminals), which is due to:

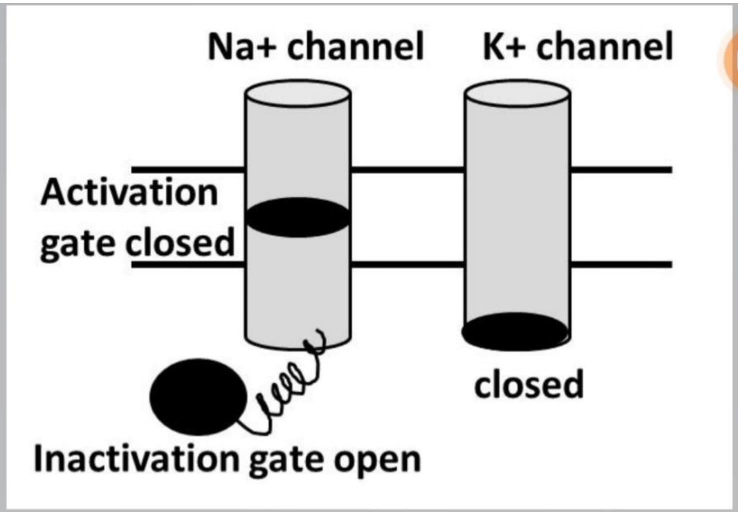
- Absence of K channels
- Absence of Na channels
- The old active area is now in the refractory period ✓
- Negative feedback mechanism

SOME KAHOOT QUESTIONS AND PAST PAPERS



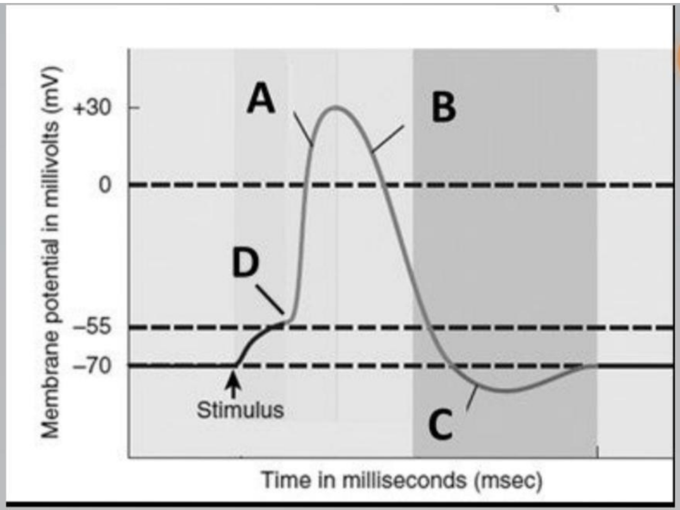


SOME KAHOOT QUESTIONS AND PAST PAPERS



These channels arrangement occurs at:

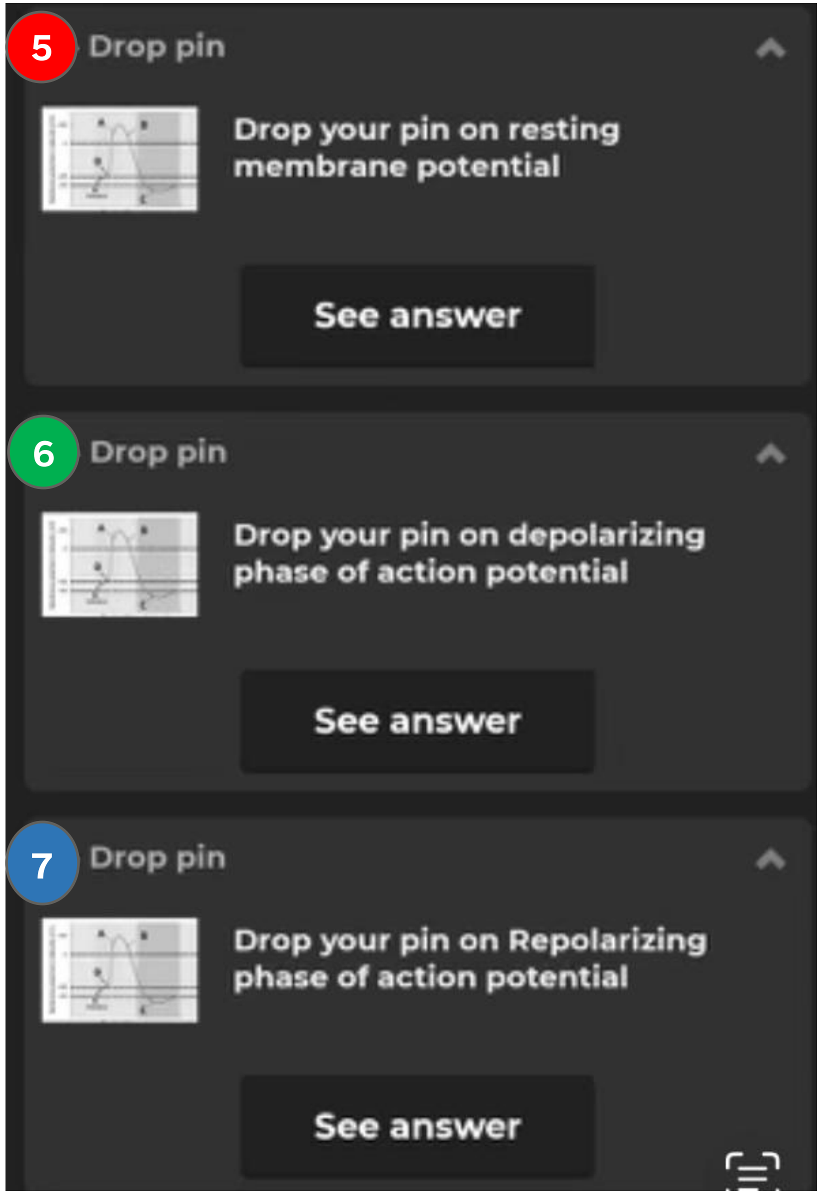
- Repolarizing phase ✗
- After hyperpolarization ✗
- Depolarizing phase ✗
- Resting phase ✓

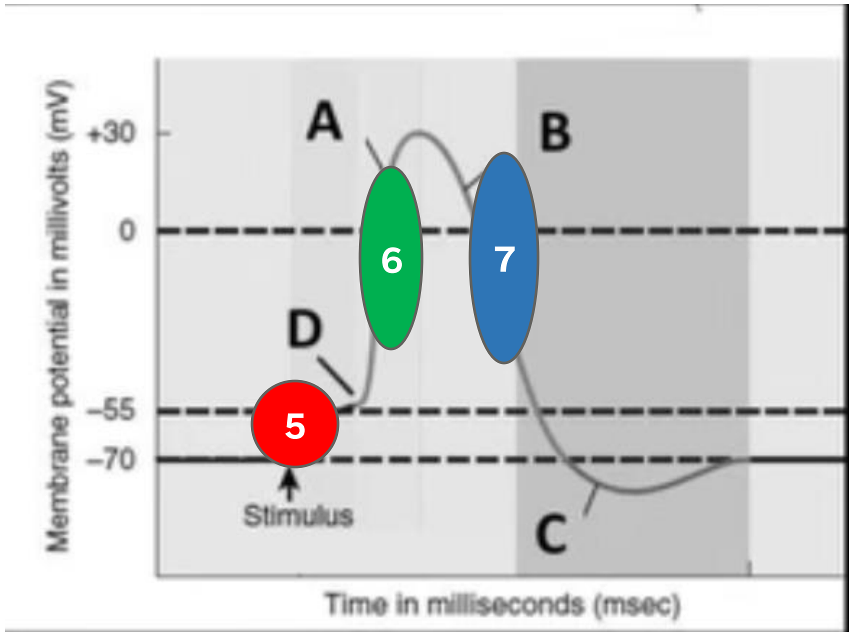


Threshold is

- - 70 ✗
- +30 ✗
- -90 ✗
- -55 ✓

SOME KAHOOT QUESTIONS AND PAST PAPERS





THANK YOU