PHYSIOLOGY

Lec: 13

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General Physiology
Second Semester , 2024
Lecture 13 and 14
Part 1: Action potential of neurons
Ionic basis and properties of action potential
Part II Cardiac action potentials

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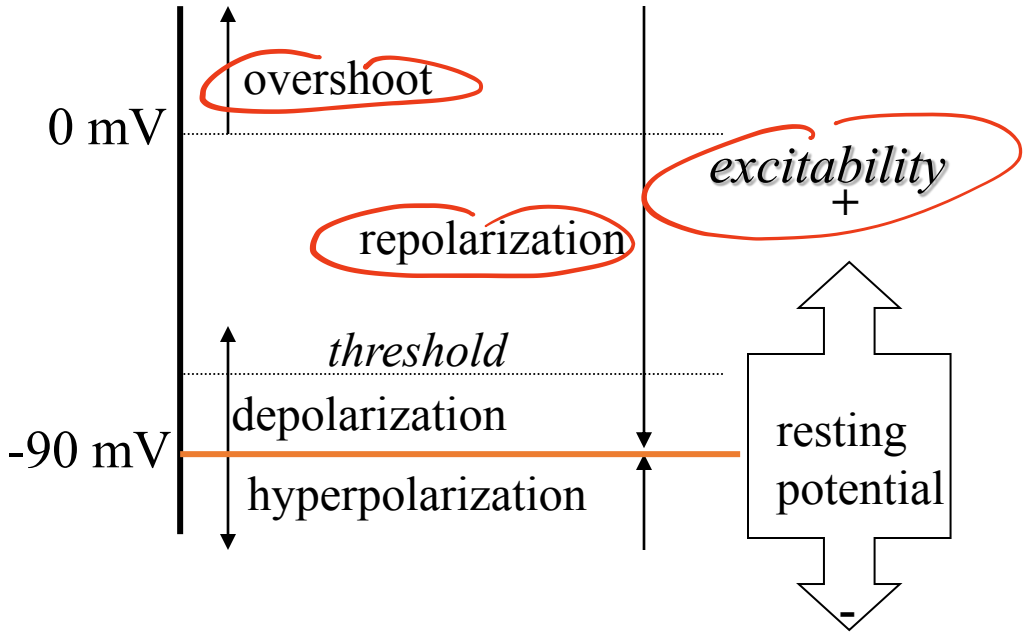
Lectures Objectives

- Define the nerve action potential and properties
- Describe the activation of action potentials and describe the ionic basis of action potential .
- Describe the membrane currents underlying action potentials.
- Describe the activity of channels producing action potentials.
- Define threshold of for initiation of action potential threshold and different phases of action potential , depolarization, overshoot , repolarization and refractory period.
- Explain the propagation of nerve impulse along axons membranes in myelinated and non myelinated nerve fibers
- Explain the consequences of myeline loss on nerve function and give example of demyelinated diseases
- Describe and explain actions of calcium, local anesthetics, and neurotoxins on action potentials.
- Define pacemaker potentials and identify phases of SA node action potential
- Identify phasis of action potential of cardiac muscles and compare neuronal action potential Skeletal muscles and cardiac muscle action potential

Action potentials : Terminology

↳ It's a rapid change of membrane potential

- ***There are some terms that need to be understood & remembered:***
  - **Depolarization** → لصار تقلل السالبة
  - **Hyperpolarization**
  - **Overshoot**
    - means positive to 0 mV
  - **Repolarization** → خروج الأيونات كانت داخلة
    - towards resting potential
  - **Excitability**
  - **Threshold** *(for action potential generation)*



*depolarization : The loss of membrane polarity by entering Na^+ to the inside ((changing in potential))

*repolarization : by closing Na^+ channel and opening the K^+ channel to be outside ((to the resting potential))

*Overshoot : when the inside of the cell becomes positive ((Above 0V))

The above of the mountain

* hyperpolarization: The excess open of K^+ channel and the K^+ will efflux out of the CM.

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*Excitability: The ability of the neuron to fire the Action potential

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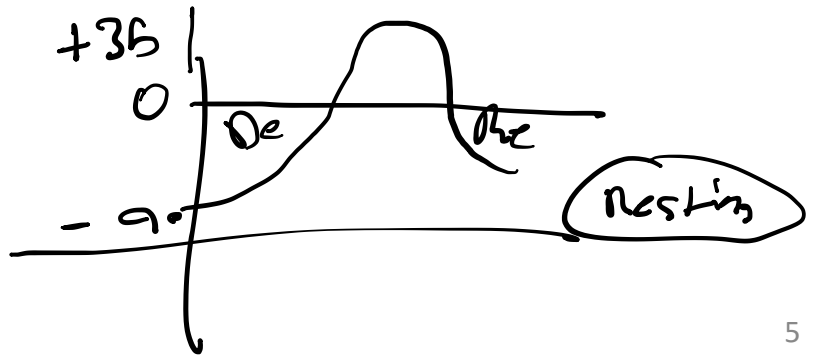
*Threshold: The min of action potential (V) the depolarization make

Action Potential : Terminology

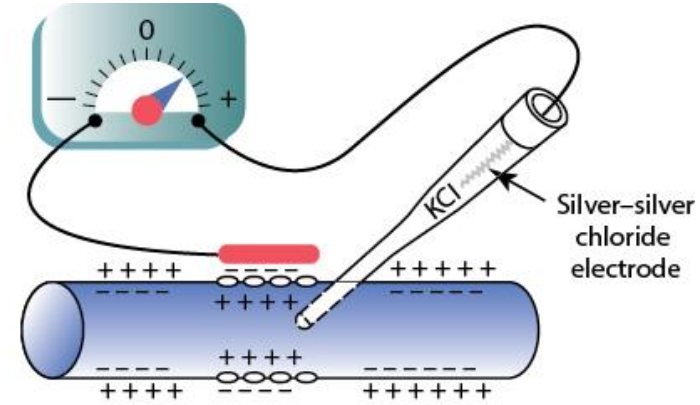
- Depolarization is the process of making the membrane potential less negative
- Hyperpolarization is the process of making the membrane potential more negative
- Inward current is the flow of positive charge into the cell. Thus, inward currents depolarize the membrane potential. An example of an inward current is the flow of Na+ into the cell during the upstroke of the action potential
- Outward current is the flow of positive charge out of the cell. Outward currents hyperpolarize the membrane potential. An example of an outward current is the flow of K+ out of the cell during the repolarization phase of the action potential.

What is an action potential

- The action potential is a phenomenon of excitable cells such as nerve and muscle and consists of a rapid depolarization (upstroke) followed by repolarization of the membrane potential.
- Action potentials are the basic mechanism for transmission of information in the nervous system and in all types of muscle
- Triggered by by application of an appropriate stimulus
- For example: application of an electrical current to the nerve cells axons



Intracellular recording of action in the axon of a nerve cell via microelectrodes



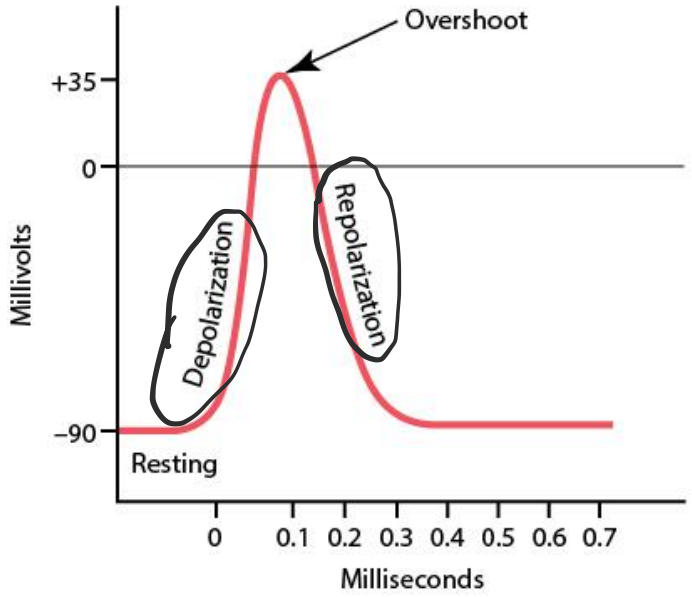


Figure 5-6

Schematic Diagram of action potential and membrane potential changes during the successive stages of action potential

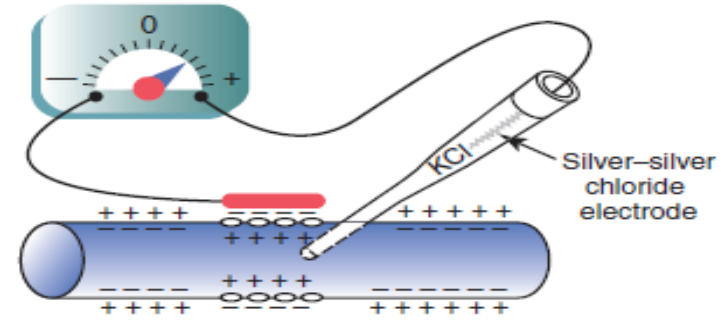
Stages of action potential

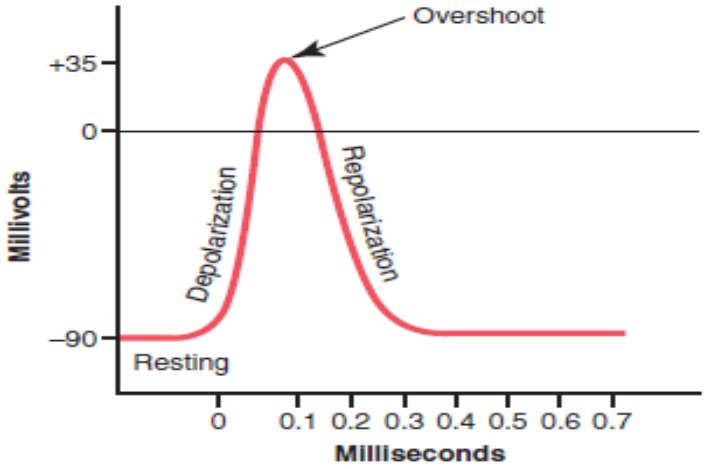
Resting Stage::

Membrane is polarized

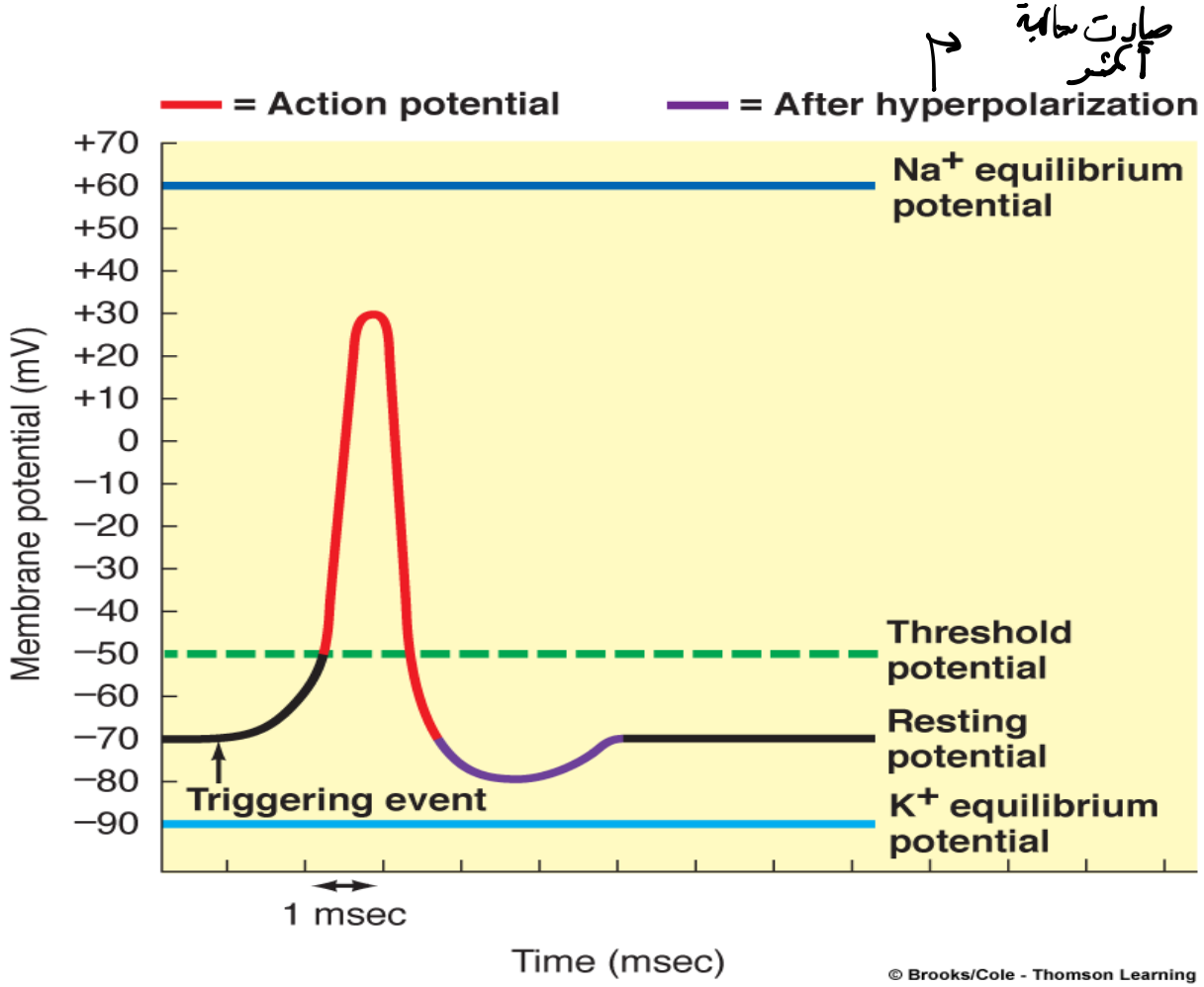
Depolarization Stage

Repolarization Stage





Initiation of Action Potential



NEURON ACTION POTENTIAL

Successive stages of the action potential

- **Resting Stage.** The resting stage is the resting membrane potential before the action potential begins. The membrane is said to be "polarized" during this stage because of the -70 millivolts negative membrane potential that is present.
- **Depolarization Stage.** The normal polarized state of −70 millivolts is immediately neutralized by the inflowing, positively charged sodium ions, with the potential rising rapidly in the positive direction—a process called *depolarization.* In large nerve fibers, the great excess of positive sodium ions moving to the inside causes the membrane potential to actually overshoot beyond the zero level and to become somewhat positive. In some smaller fibers, as well as in many central nervous system neurons, the potential merely approaches the zero level and does not overshoot to the positive state.
- At this time, the membrane suddenly becomes permeable to sodium ions, allowing positively charged sodium ions to diffuse to the interior of the axon. The normal "polarized" state of −90 millivolts is immediately neutralized by the inflowing positively charged sodium ions, with the potential rising rapidly in the positive direction in some nerve cells
- **Repolarization Stage.** Within a few msec after the membrane becomes highly permeable to sodium ions, the sodium channels begin to close and the potassium channels open to a greater degree than normal. Then, rapid diffusion of potassium ions to the exterior re-establishes the normal negative resting membrane potential.

الإجابة.

* في بعض الـ neurons أو الـ (central neurons) تحصل الـ overshot

الـ zero على الرغم من أنها تتصل في باقي العصبونات إلى أعلى من

الـ zero بقليل.

Changes in sodium and potassium conductance during the course of the action potential. Sodium conductance increases several thousand–fold during the early stages of the action potential, whereas potassium conductance increases only about 30-fold during the latter stages of the action potential and for a short period there after.

Conductance: a measure of how easily ions can cross the membrane (it is the inverse of the resistance).

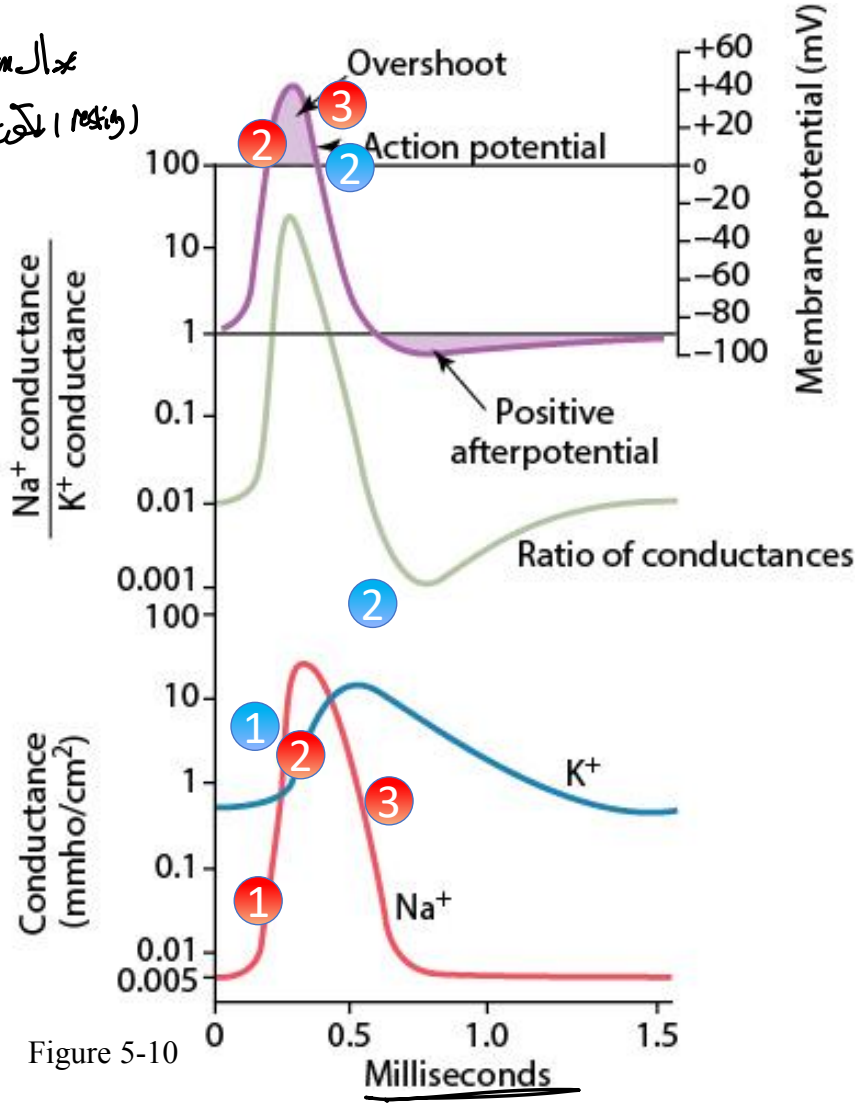


Figure 5-10

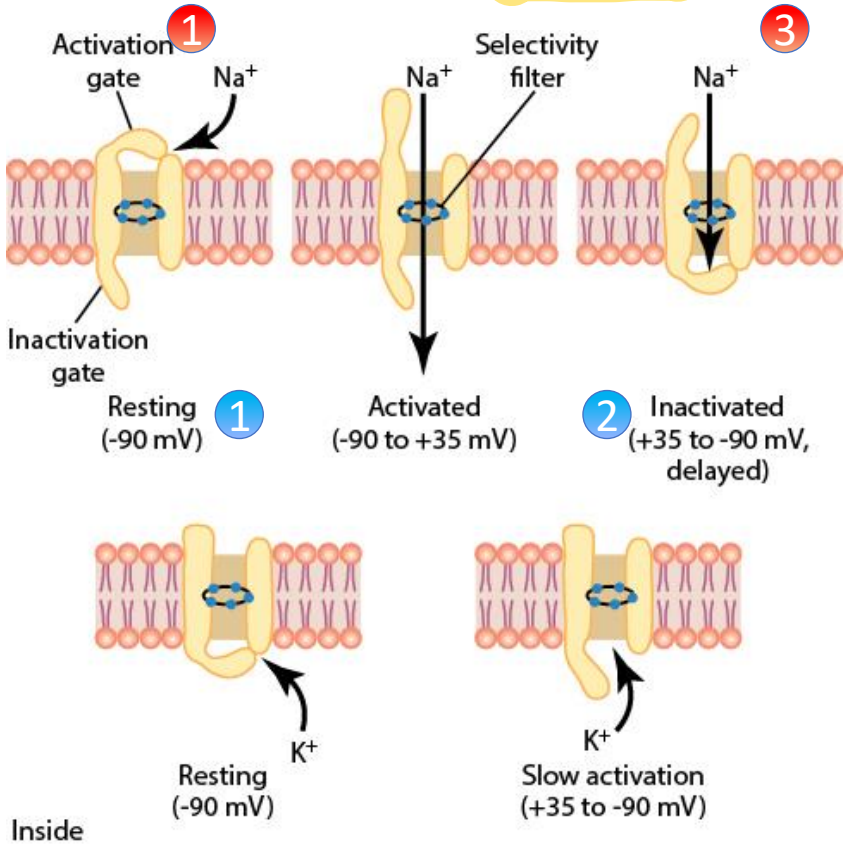
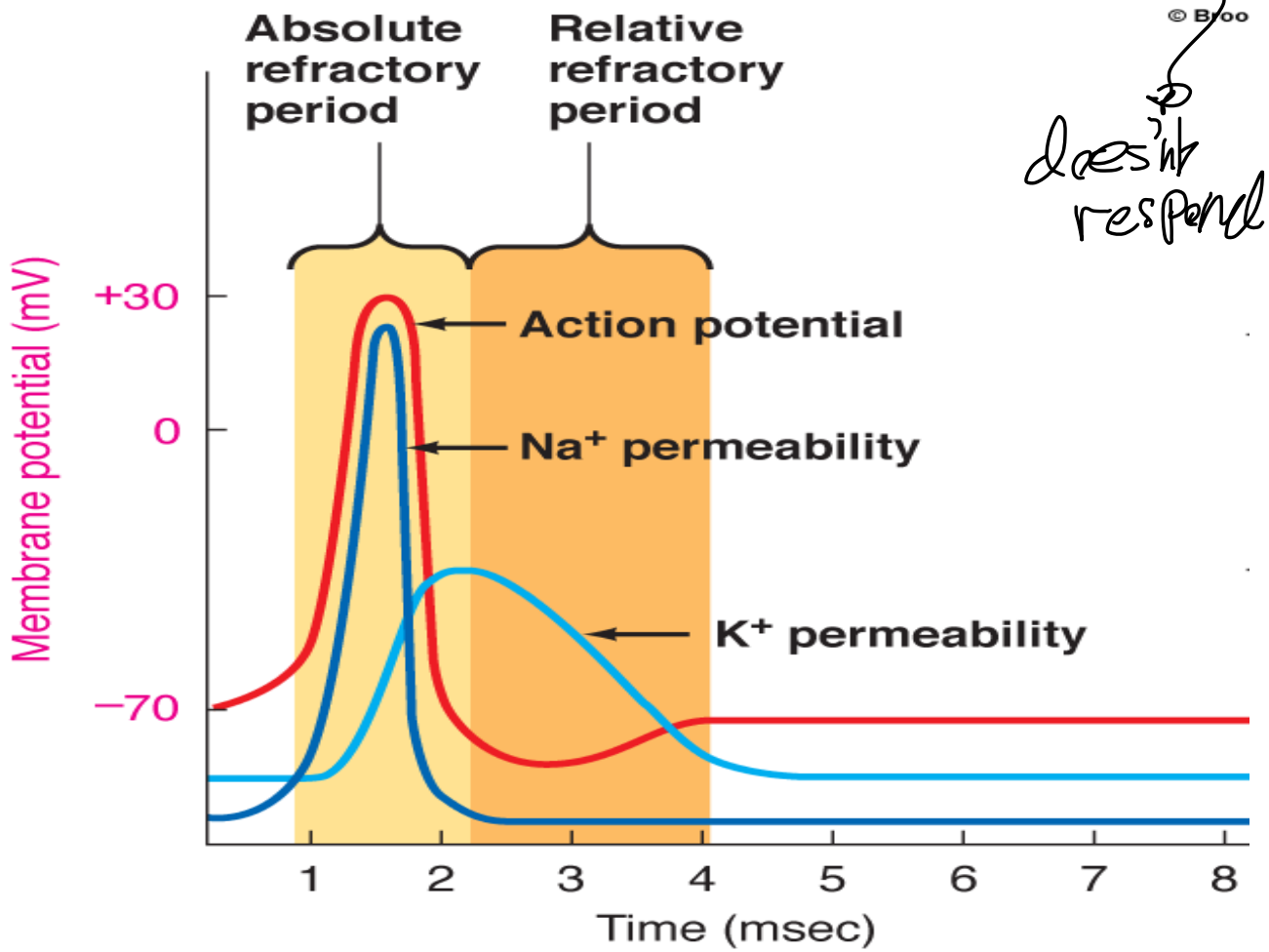


Figure 5-7

The absolute and relative refractory periods during an action potential

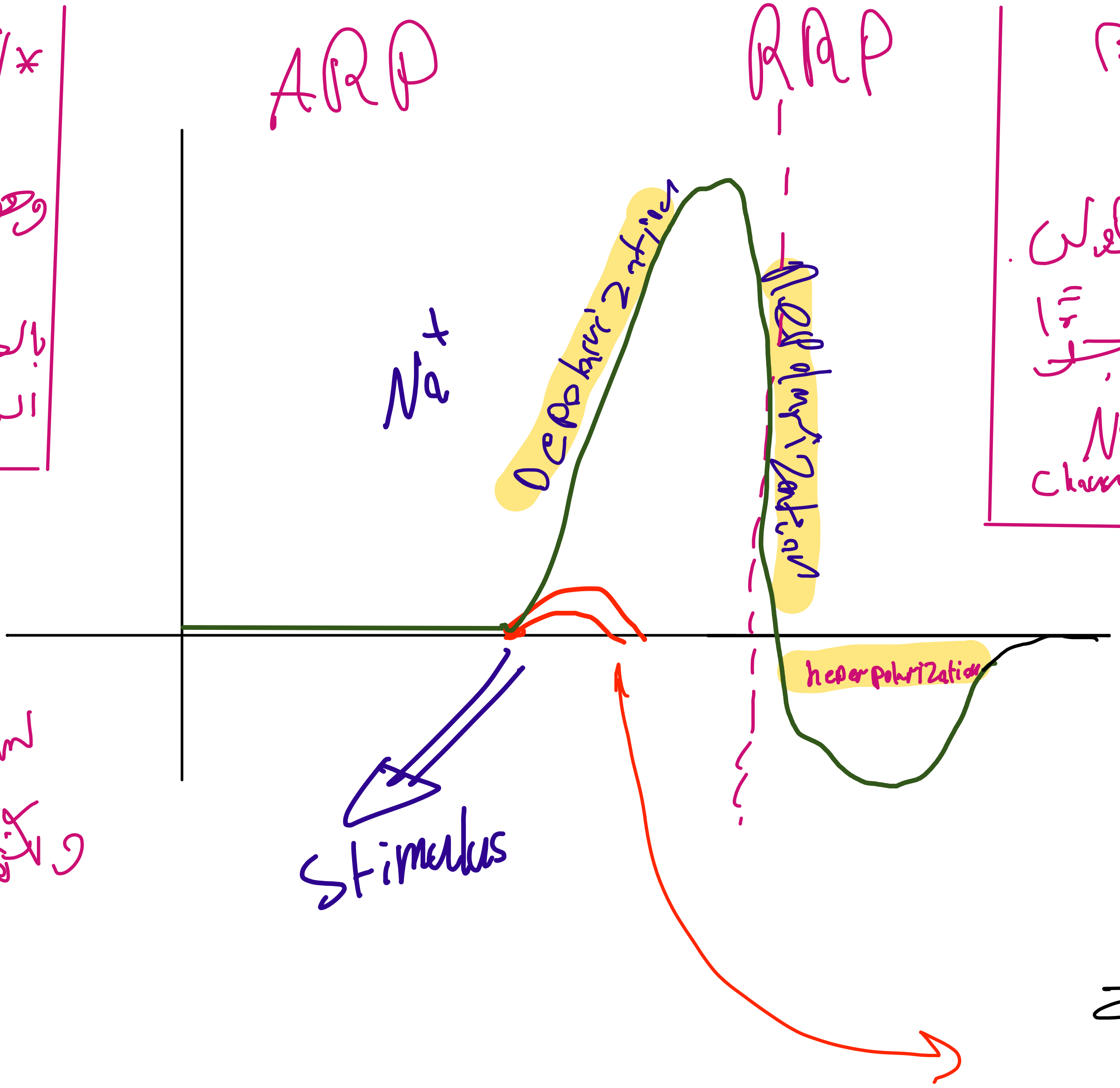
During the absolute refractory period no stimulus, however large, can elicit a second action potential.

During the relative refractory period a second action potential can be elicited but it requires a larger stimulus than that in the resting state



*الثاني حوار
relative
وهو الذي يسمح لـ 2nd
Action Potential
بالحدوث وبطريقة بسمح بوجود
الداخل ... 2nd.

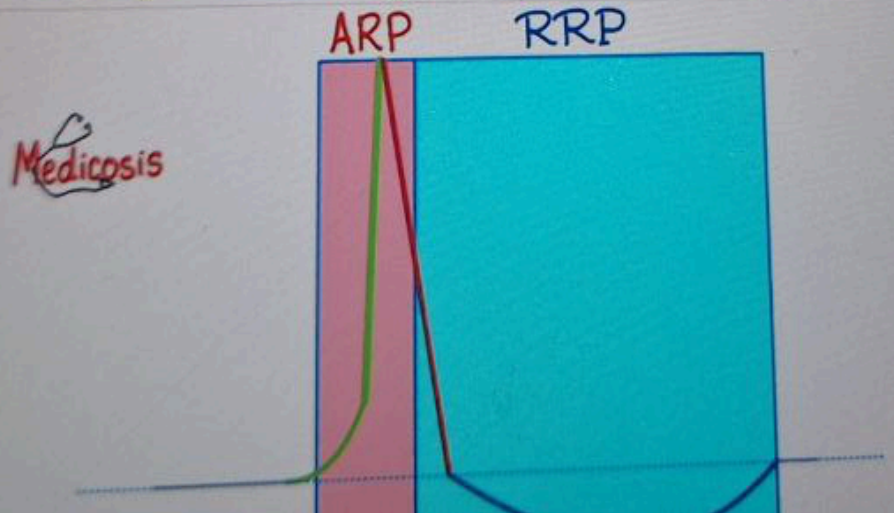
ويحدث
stimulus ع قوي
من الحالة الأولى لأنه
ما في حالة مقاومة
وانها نسبية = ((relative))



*الأول Absolute تغيير مدى
يحمل أي Action potential
مرة ثانية لأنه لما الـ الأول
ولو كان المحفز قوي جدا
ويتم عن طريق تعطيل الـ Na+
channel
فالذي يسمى بال
refractory.

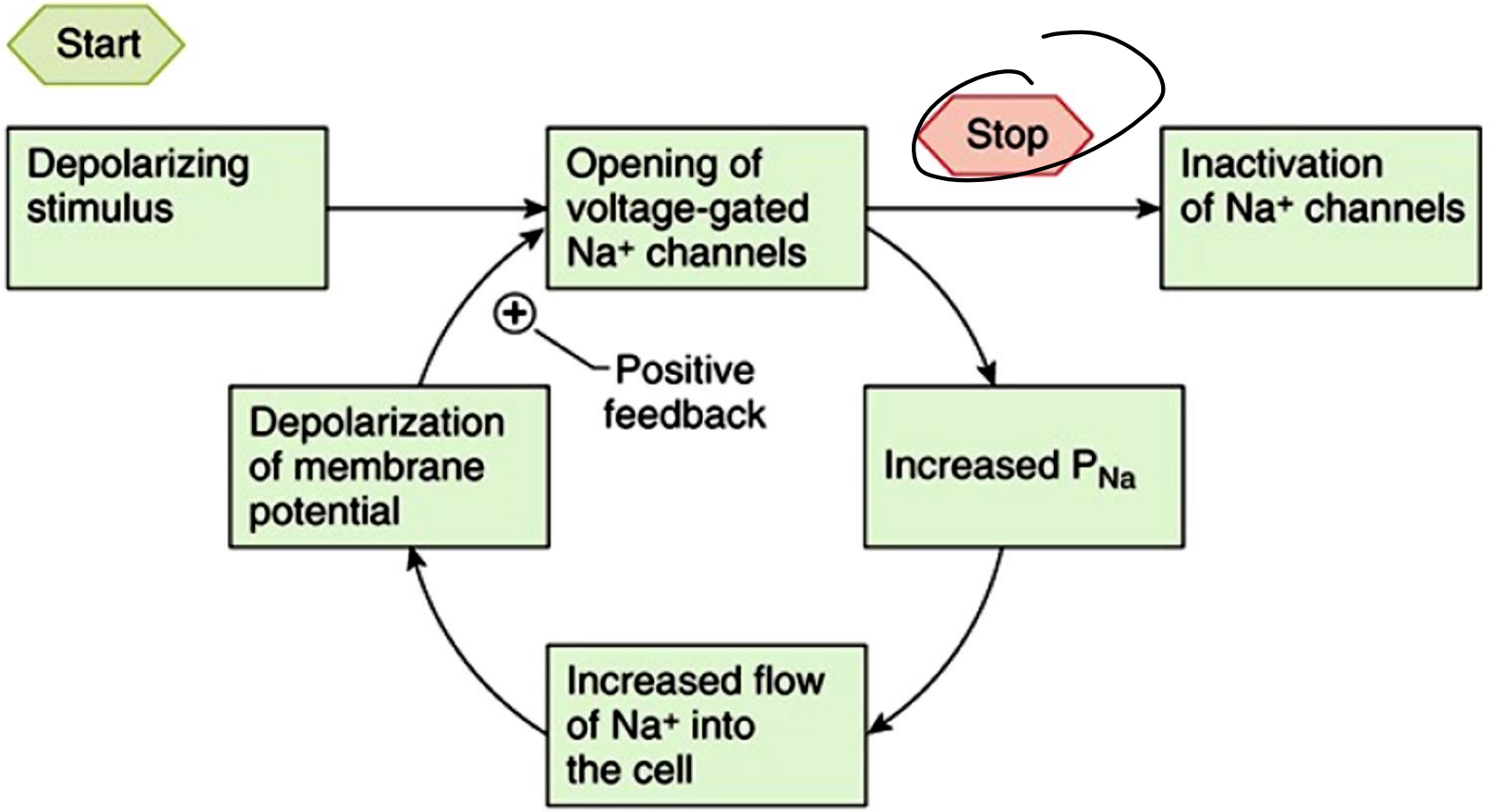
محاولات ناجحة

Medicosis

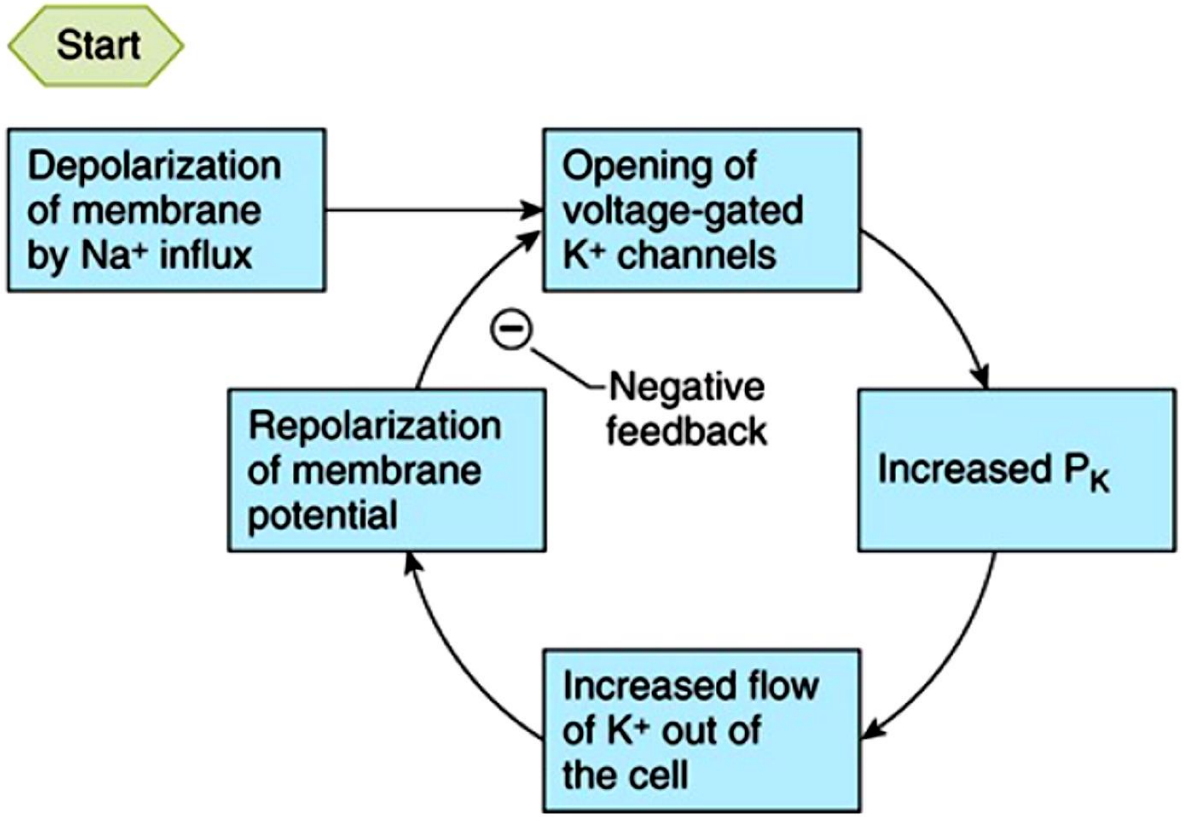
	Absolute Refractory Period (ARP)	Relative Refractory Period (RRP)
Def.	It's a period of time during which a 2nd Action Potential (AP) cannot occur no matter how strong the stimulus is.	It's a period of time during which a 2nd Action Potential (AP) can only occur with a stronger-than-normal stimulus.
Extent	From the firing level To the end of the early part of repolarization.	From The end of the ARP To The return of the membrane RMP.
Cause	Inactivation of Na^+ Channels. The inner gate is closed & can't open for sometimes.	Some Na^+ channels return to their resting state & can be activated.
Coincides with	The ascending limb & 1/3 of the descending limb	The rest of the descending limb
Graph		

INITIATION OF THE ACTION POTENTIAL

Positive-Feedback Cycle Opens the Sodium Channels.

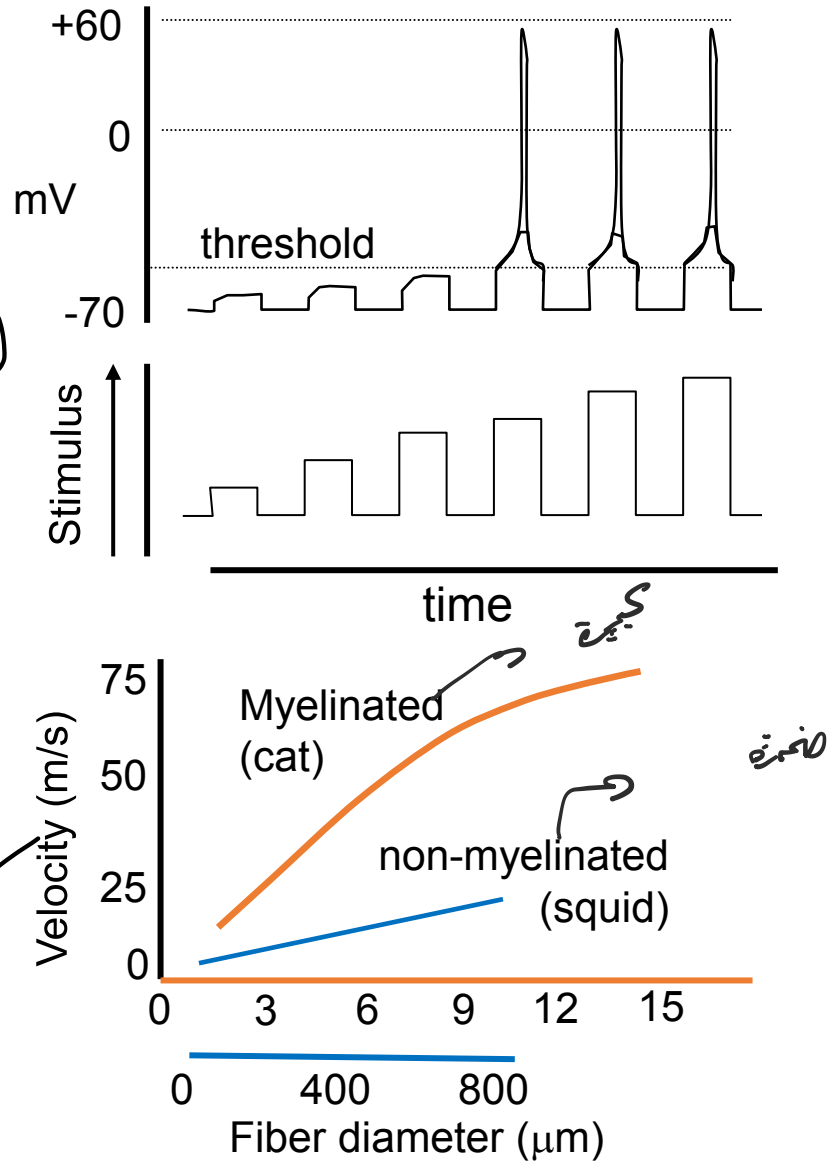


K channels exert negative feed back and cause repolarization



Properties of action potentials

- **Action potentials:**
  - **are all-or-none events**
    - threshold voltage (usually 15 mV positive to resting potential)
  - **Self-propagation**
  - **are initiated by depolarization**
    - action potentials can be induced in nerve and muscle by extrinsic (percutaneous) stimulation
  - **have constant amplitude**
    - APs do not summate - information is coded by frequency not amplitude.
  - **have constant conduction velocity**
    - True for given fiber.
    - Fibers with large diameter conduct faster than small fibers. As a general rule:
      - ***myelinated*** fiber diameter (in mm) x 4.5 = velocity in m/s.
      - Square root of ***unmyelinated*** fiber diameter = velocity in m/s



D

يا إما يحدث الـ Action Potential يا إما ما بيحدث

حسب الـ Stimulus إذا كان بيعمل depolarization لـ Na^+ channel

رح يصير الـ Action وإذا صار الـ Action ما رح يستجيب لـ Stimulus آخر حتى يخلص

((الخلاصة)) ← إذا بيمشي لحاله