

PHYSIOLOGY



Lec: 13

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Lectures Objectives

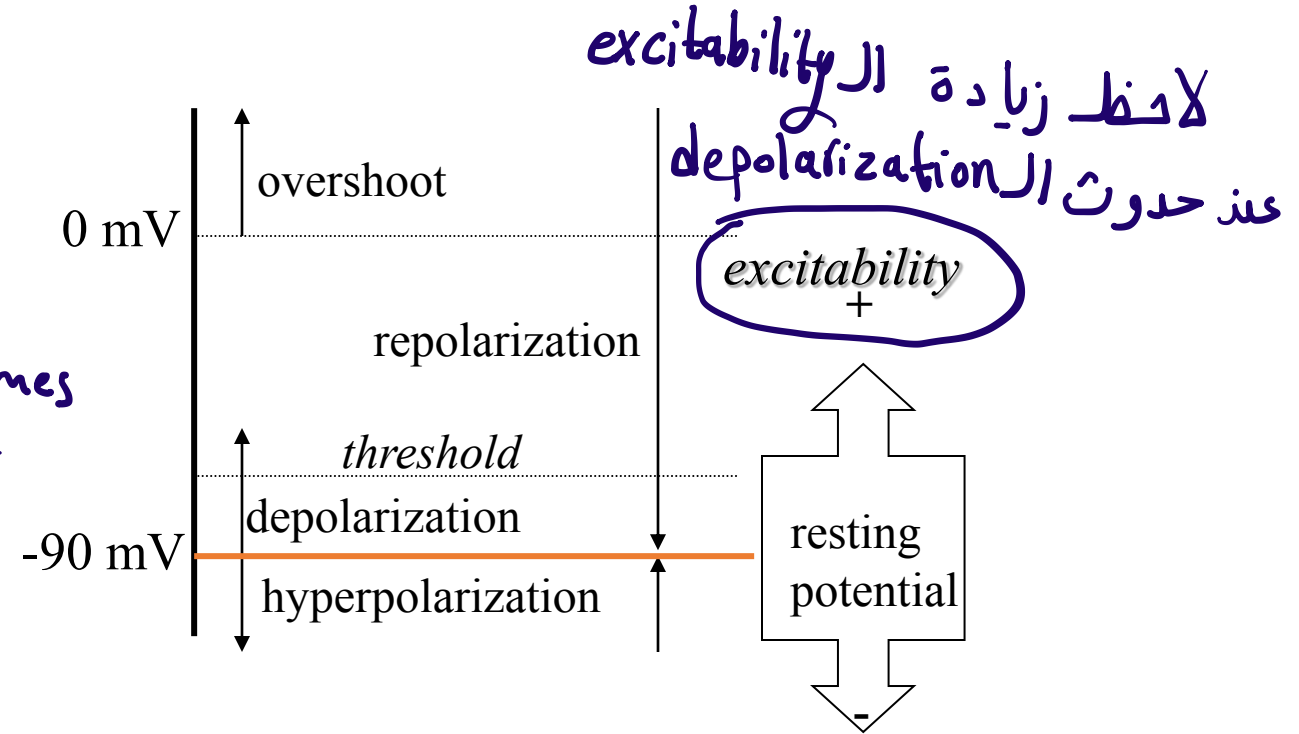
- Define the nerve action potential and properties
- Describe the activation of action potentials and describe the ionic basis of action potential .
- Describe the membrane currents underlying action potentials.
- Describe the activity of channels producing action potentials.
- Define threshold of for 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

* الرسومات جدًا مهمة
الدكتور حكما ممكن يجيبهم

Action potentials : Terminology

• *There are some terms that need to be understood & remembered:*

- **Depolarization**
- **Hyperpolarization**
- **Overshoot** → membrane potential becomes positive
 - means positive to 0 mV
- **Repolarization**
 - towards resting potential
- **Excitability**
- **Threshold** (for action potential generation)



* When depolarization happens, the cell becomes more excited

Action Potential : Terminology

- Depolarization is the process of making the membrane potential less negative (تقليل السالبة داخل الخلية)
- 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 (لجوا الخلية influx)
- 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. (لبرا الخلية reflux)

* ال influx يقلل السالبة داخل الخلية ← depolarize
* ال reflux يزيد السالبة داخل الخلية ← repolarization (في بعض الحالات يحدث hyperpolarization)

What is an action potential → overshoot is the peak of action potential

تتضمن خلية القلب

ظاهرة

• 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.

→ اوضحها برسمها

• Action potentials are the basic mechanism for transmission of information in the nervous system and in all types of muscle

→ طريقة لنقل المعلومات

• Triggered by application of an appropriate stimulus

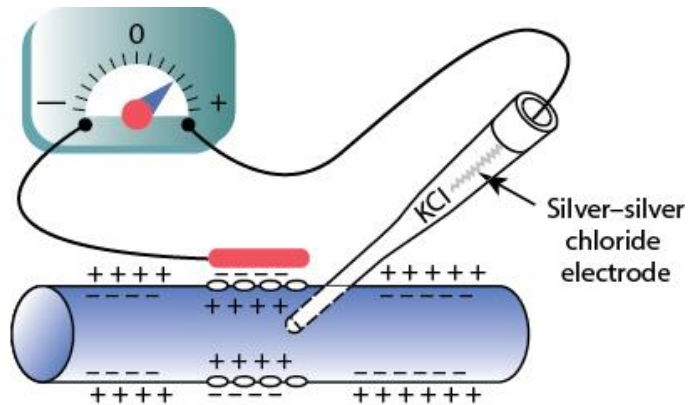
• For example: application of an electrical current to the nerve cells axons

شحنة كهربائية

لازم يكون فيه مُحفز

تعتبر مُحفز

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



ex. RMP \rightarrow -90 mV
 بهير -95 mV ويرجع بعدها طبيعي

(موجوده الحالة في الرسومات بالاسلايدات اللي قدام) \uparrow

action potential ال اعلى نقطة يوصلها ال overshoot هي ال

less negative \leftarrow

\rightarrow more negative \rightarrow

في بعض الحالات تزيد السالبة عن

ال RMP

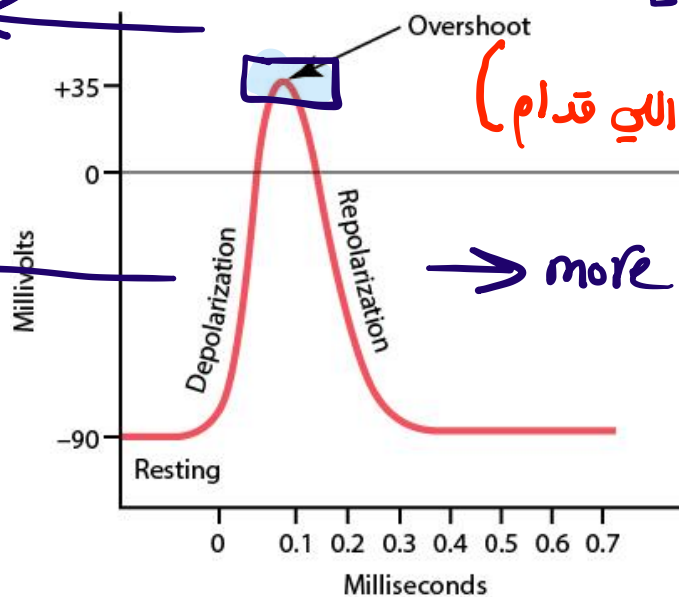


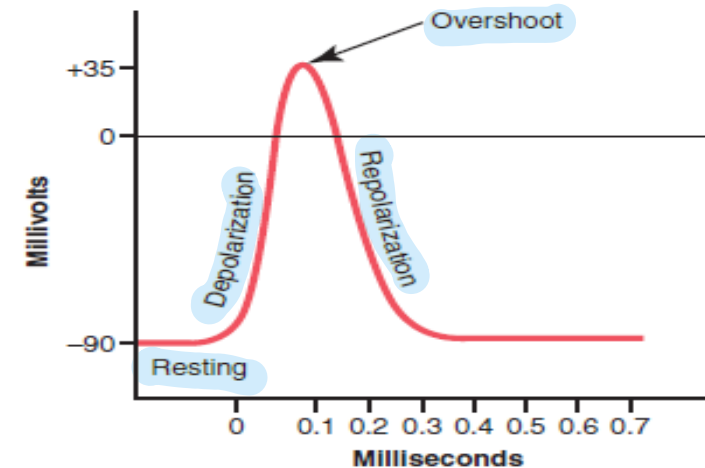
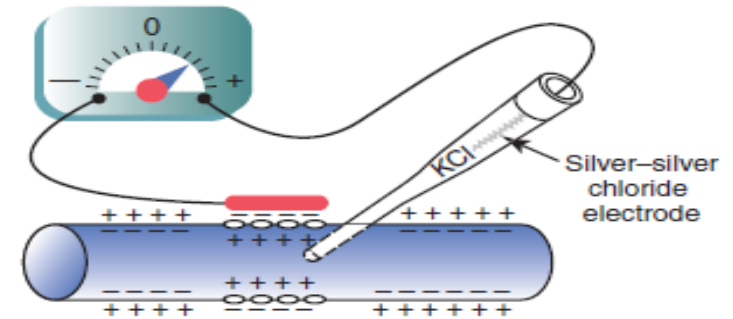
Figure 5-6

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

٣ مراحل
↓

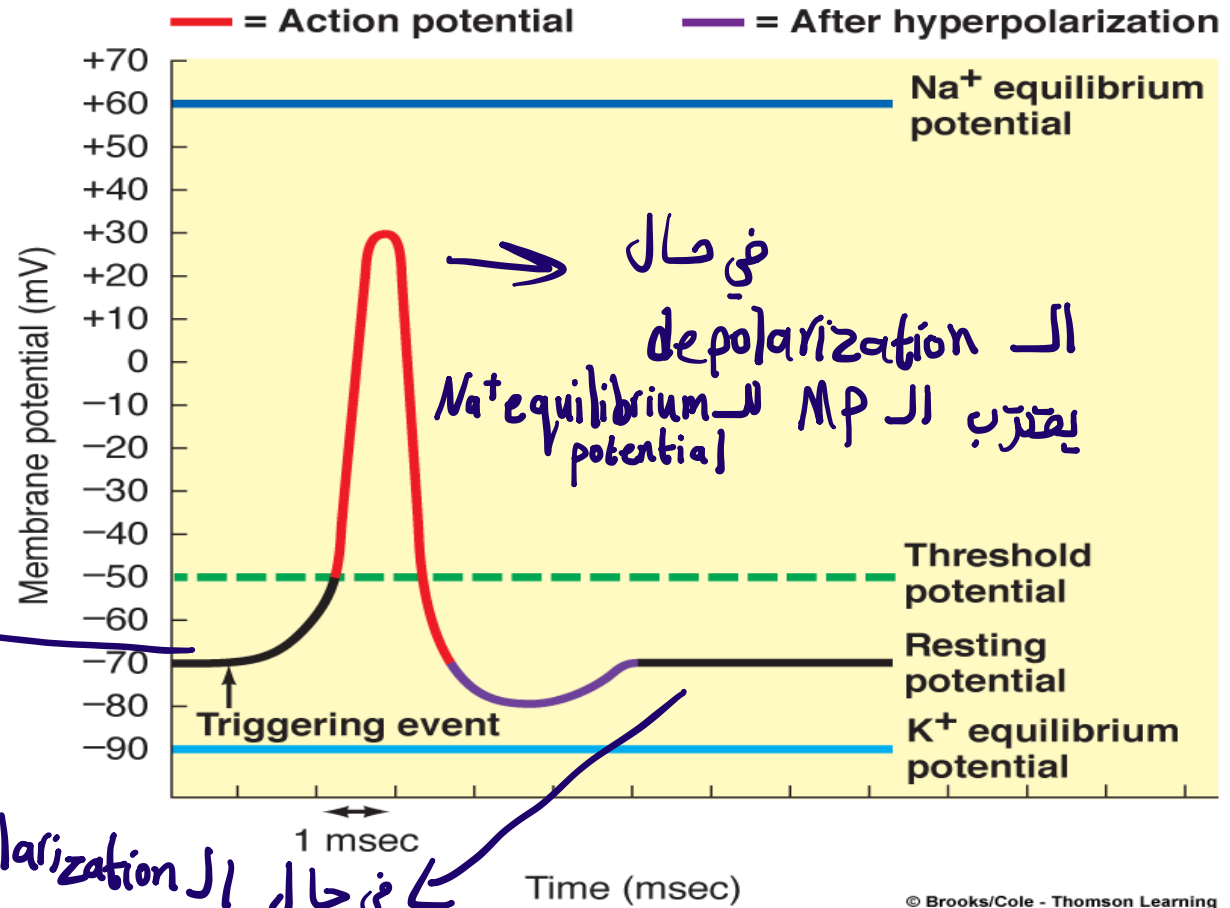
Stages of action potential

- ① Resting Stage::
Membrane is polarized
- ② Depolarization Stage
- ③ Repolarization Stage



Initiation of Action Potential

← رحالة اللى حكيت عنها فوق



MP → membrane potential

caused by a stimulus

في حال الـ depolarization الـ MP الـ Na⁺ equilibrium potential يقترب

في حال الـ repolarization الـ MP الـ K⁺ equilibrium potential يقترب

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. *resting stage → polarized*
- **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. *overshoot → become over zero*
- **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,

influx
of Na^+

من

efflux
of K^+

تُفتح قنوات للصوديوم فيدخل لل icf وتقل السالبة بالداخل

في ال hyperpolarization تُغلق قنوات الصوديوم وتُفتح قنوات البوتاسيوم بشكل اكبر ~ يخرج البوتاسيوم إلى الخارج فتزيد السالبة داخل الخلية

مهم فكرة إنه يحدث كل هذه

الخطوات في الخلايا العصبية بأقل من msec

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.

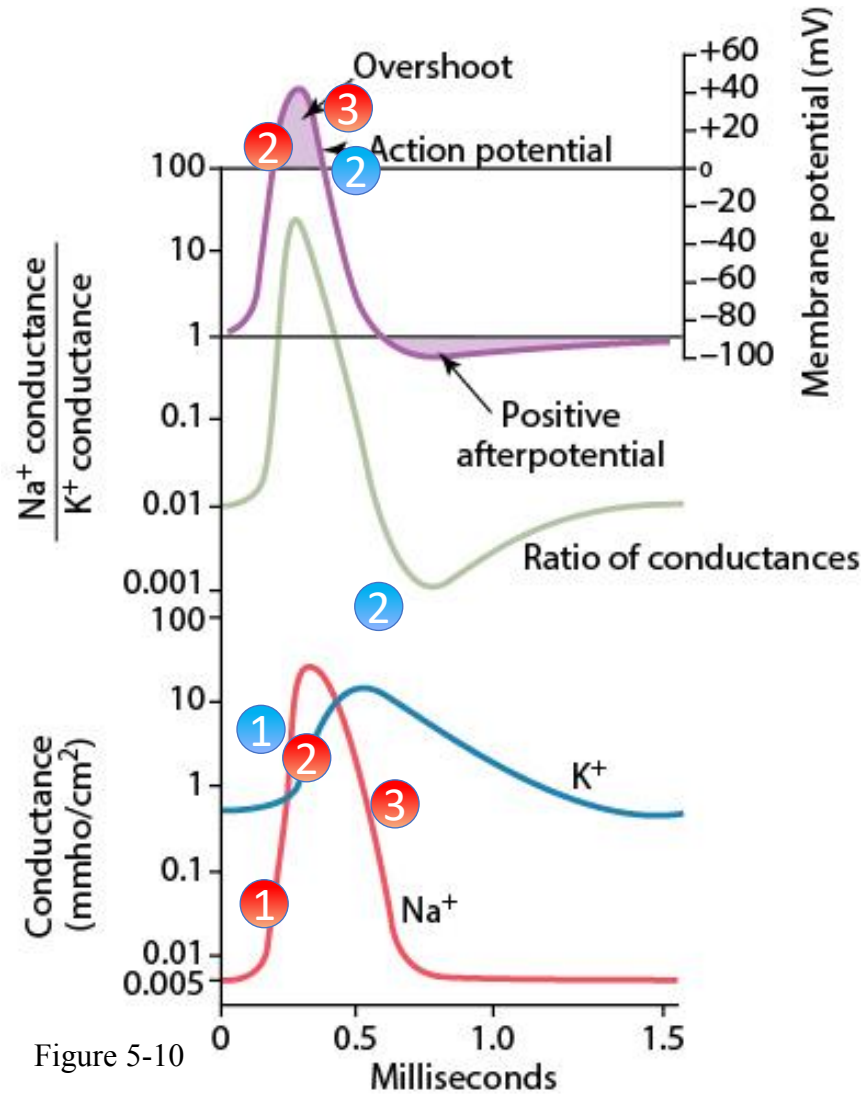


Figure 5-10

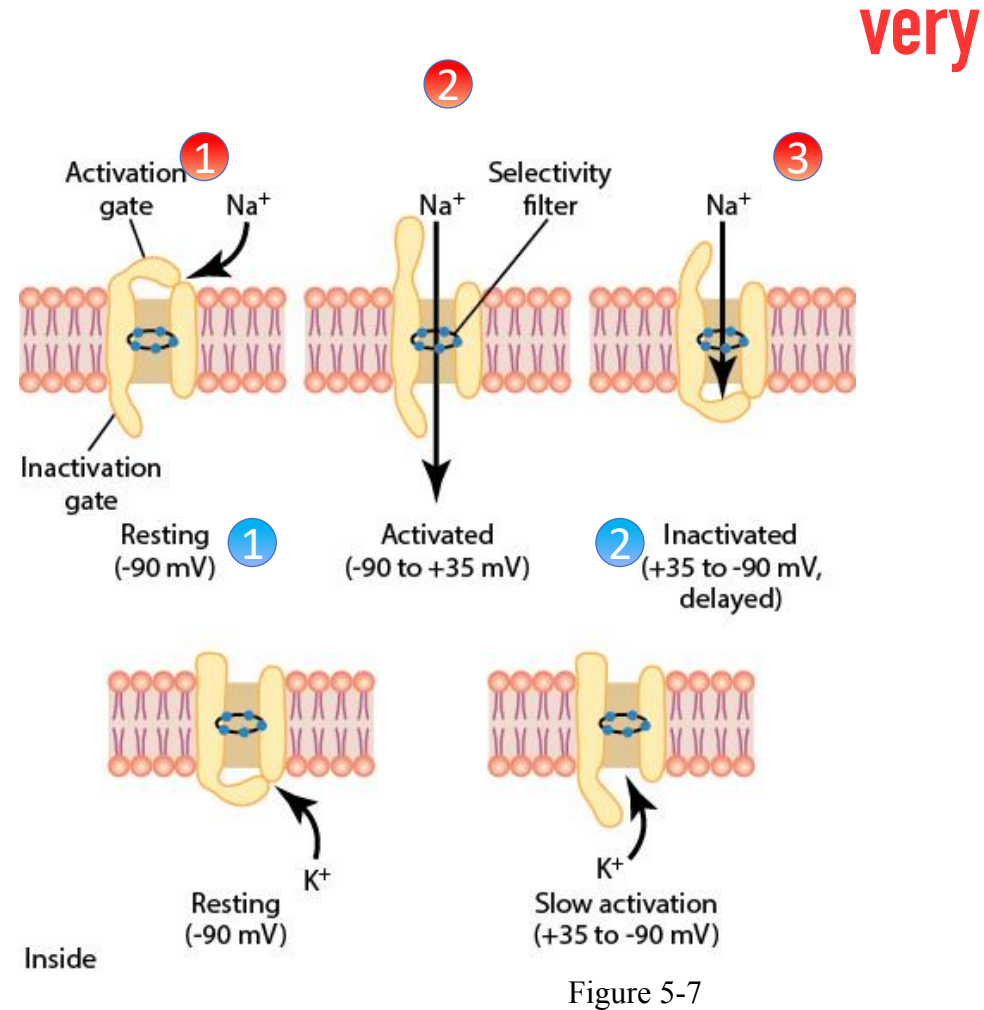


Figure 5-7

The absolute and relative refractory periods during an action potential

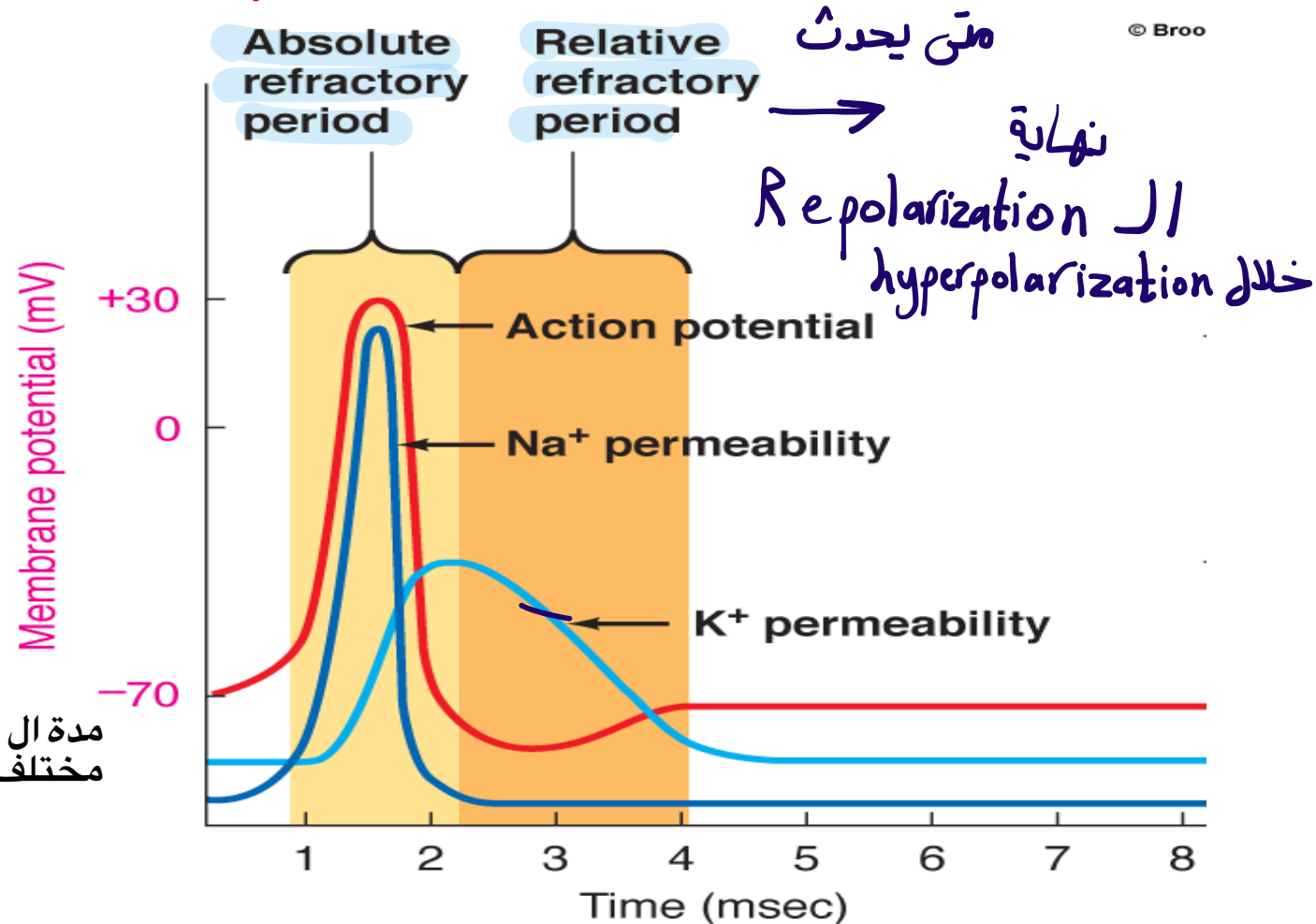
refractory period is a period of time that unresponsiveness happens for the second stimulus even if it was larger than the first stimulus

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

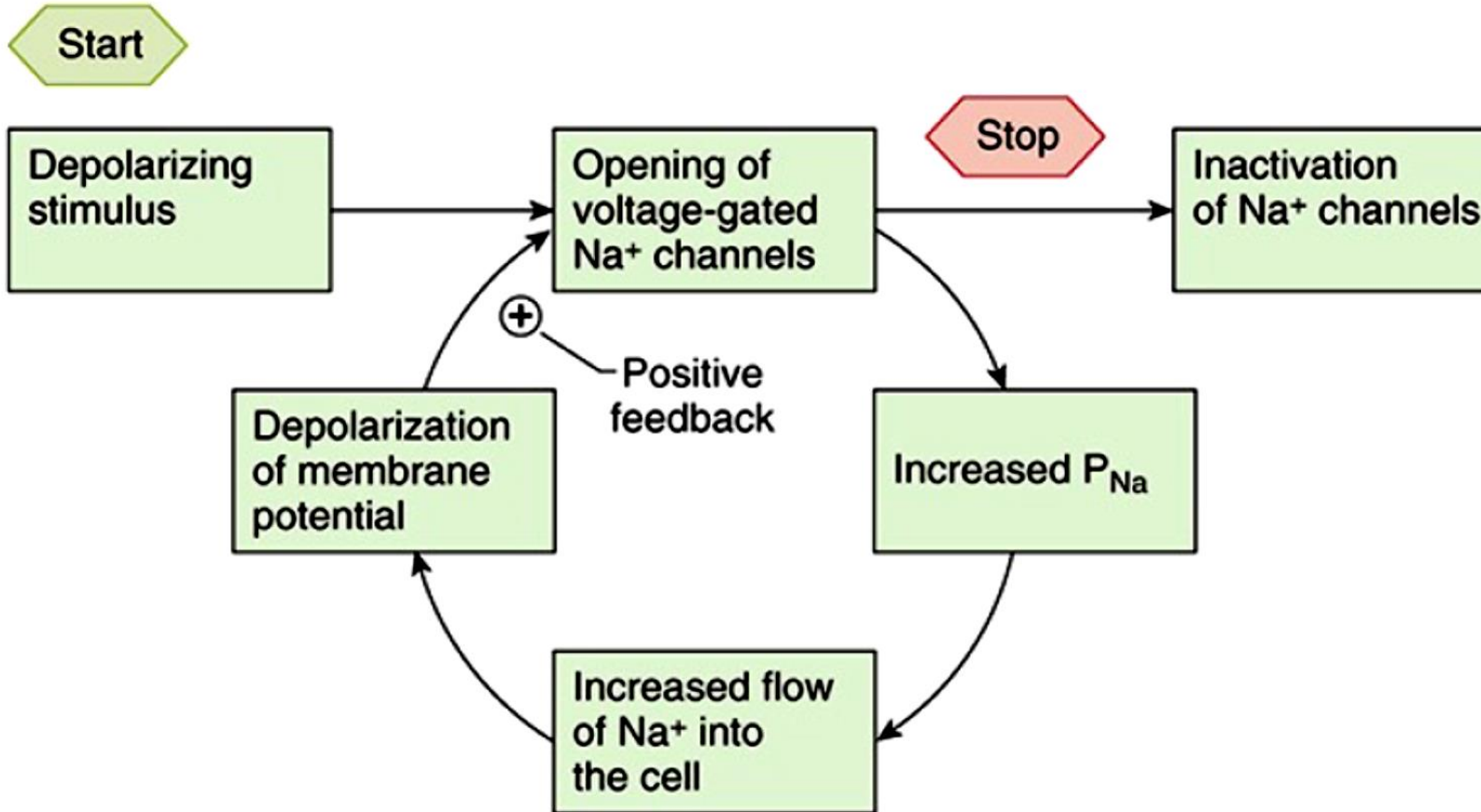
مدة ال refractory period في مختلف الخلايا: (عند البحث في قوقل نجد ان القيم مختلف لكن المهم الفكرة وليس الارقام)

3 msec in nerve cells
300 msec in cardiac cells

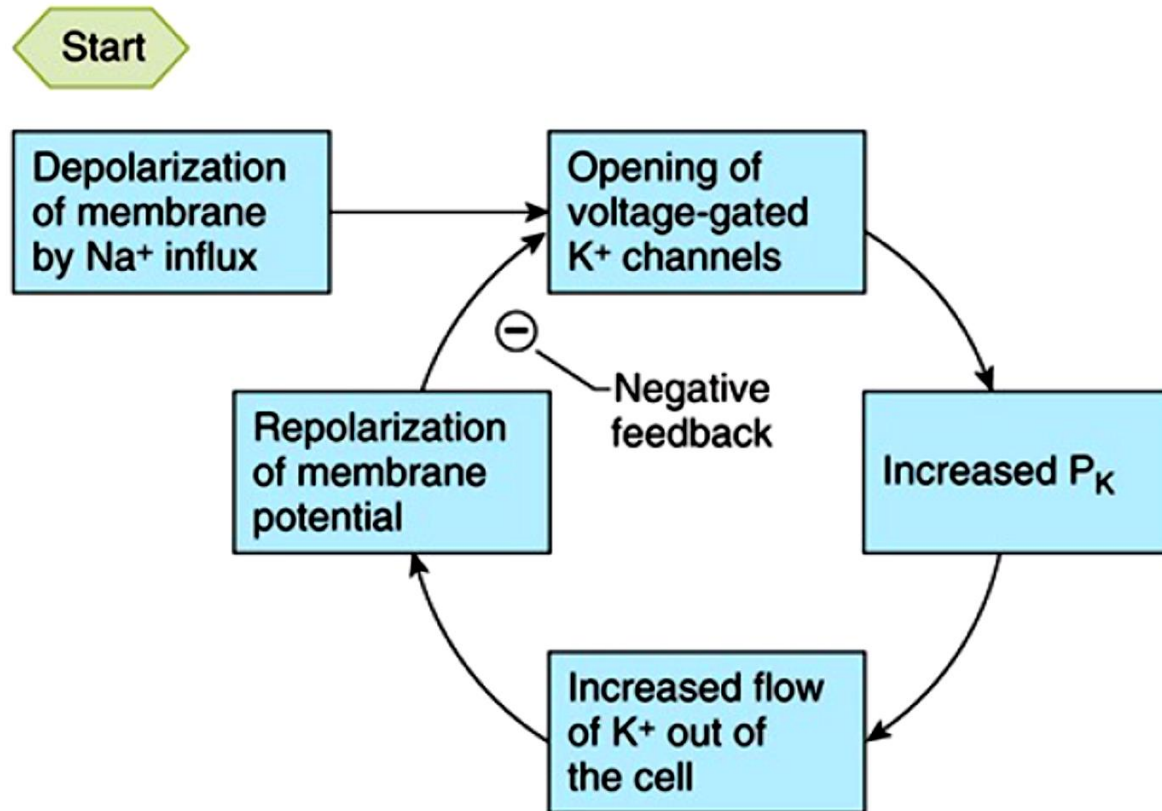


INITIATION OF THE ACTION POTENTIAL

Positive-Feedback Cycle Opens the Sodium Channels.



K channels exert negative feedback and cause repolarization



مو موجوده في الكتاب

Properties of action potentials

ينقل الإشارة

• Action potentials:

- are all-or-none events → مرة بهير مرة لا
 - ❑ threshold voltage (usually 15 mV positive to resting potential) → of the stimulus

on its own

- Self-propagation

no need for a stimulus

- are initiated by depolarization
 - ❑ action potentials can be induced in nerve and muscle by extrinsic (percutaneous) stimulation

- have constant amplitude سعة
 - ❑ APs do not summate - information is coded by frequency not amplitude.

- have constant conduction velocity سرعة توصيل

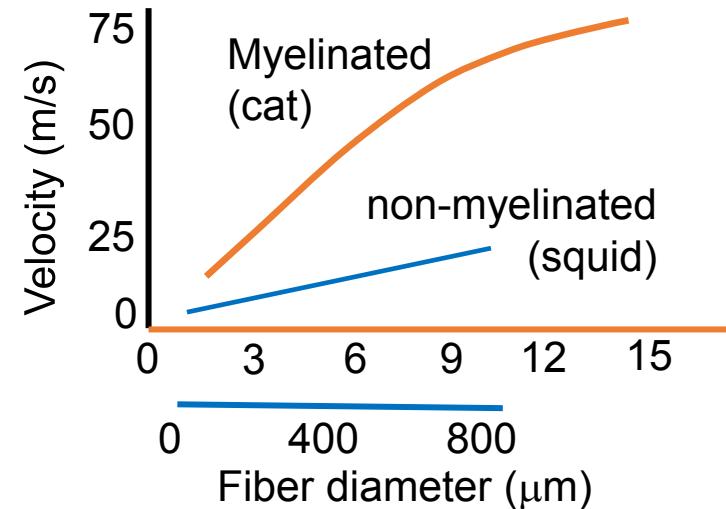
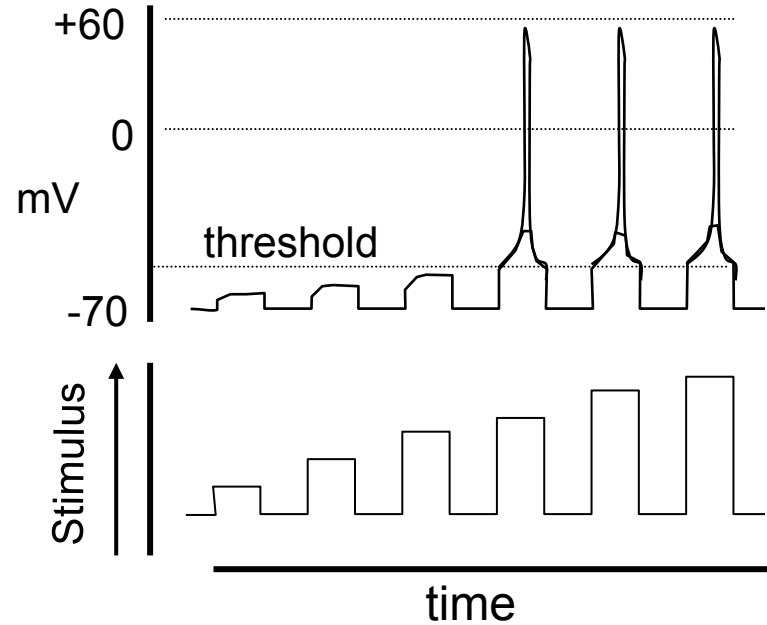
- ❑ True for given fiber.
- ❑ Fibers with large diameter conduct faster than small fibers. As a general rule:

faster

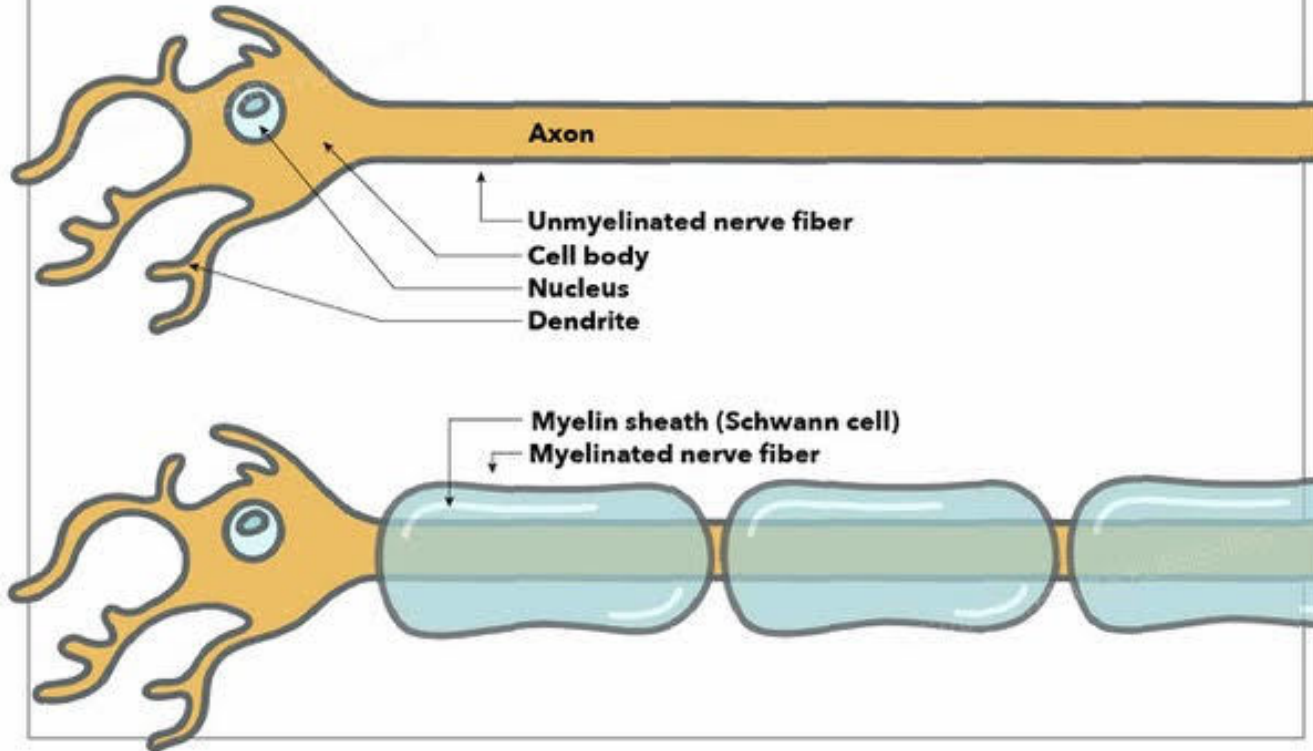
slower

- ❑ **myelinated** fiber diameter (in mm) x 4.5 = velocity in m/s.

- ❑ Square root of **unmyelinated** fiber diameter = velocity in m/s



Unmyelinated Nerve Fibers



جهد العتبة ←
stimulus لـ

Threshold for Initiation of the Action Potential.

velocity of AP is measured by m/s

وهو المطلوب لحدوث الـ AP

- An action potential will not occur until the initial rise in membrane potential is great enough to create the positive feedback described in the preceding paragraph.
- This occurs when the number of sodium ions entering the fiber (inward Na⁺ current) becomes greater than the number of potassium ions (K outward current) leaving the fiber.
- A sudden rise in membrane potential of 15 to 30 millivolts is usually required.
- For example, a sudden increase in the membrane potential in a large nerve fiber from -90 millivolts up to about -65 millivolts usually causes the explosive development of an action potential. This level of -65 millivolts is said to be the *threshold* for stimulation.
- If net inward current is less than net outward current, the membrane will not be depolarized to threshold and no action potential will occur (All-or-none response)

All or none principle of action potential

action potential

يوجد شروط لحدوث الـ

they occur once the voltage exceeds a threshold level

- Once an action potential has been elicited at any point on the membrane of a normal fiber, the depolarization process travels over the entire membrane if conditions are right, but it does not travel at all if conditions are not right. This principle is called the *all-or-nothing principle*, and it applies to all normal excitable tissues. [Occasionally, the action potential reaches a point on the membrane at which it does not generate sufficient voltage to stimulate the next area of the membrane. When this situation occurs, the spread of depolarization stops.]

(action potential doesn't happen)

Re-establishing sodium and potassium ionic gradients after action potentials are completed—importance of energy metabolism

معلومات كلها مطلوبة

- Very small amount of Na enters the cells and very small amount of K leaves the cell during an action potential
- Indeed, 100,000 to 50 million impulses can be transmitted by large nerve fibers before the concentration differences reach the point that action potential conduction ceases.
- Even so, with time, it becomes necessary to re-establish the sodium and potassium membrane concentration differences, which is achieved by action of the Na⁺-K⁺ pump in the same way as described previously for the original establishment of the resting potential

يعطيكم العافية وخليكم زي

