
بسم الله الرحمن الرحيم

Muscle Action Potential

Learning Objective

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Learning outcomes

To describe the muscle action Potential

Generation of Resting Membrane Potential (-70mV)

Introduction:

Nerves and muscles are called **excitable tissue**

because they respond to:

a) Chemical.

b) Mechanical.

c) Electrical stimuli.

- Muscles demonstrate by **contraction,** while nerves by **integration and transmission**.

Electrical signals in neurons/ Muscle

- Production of signals depend on two basic features of the plasma membrane of excitable cells:

i) **Resting membrane potential.**

ii) **Ion channels.**

I) Ion channels:

- Ion channels open and close due to **the presence of (gates).**
- ***There are four kinds of ion channels:***

1 **leakage channels:** open and close randomly

2 **Voltage-gated channels:** opens to a change in Membrane Potential (voltage).

3 **Ligand-gated channels:** opens and close in response to chemical stimulus, such as Ach.

4 **mechanical gated channels:** open or close in response to mechanical stimulation, such as touch or tissue stretching.

II) Resting membrane potential(RMP):

- ***Definition:***

The difference in voltage across the cell membrane when a neuron or muscle cells is not producing an Action Potential.

- A typical value is: **-70 mV(-50 to -90)**
- A cell that exhibits a membrane potential is said to be ***polarized.***

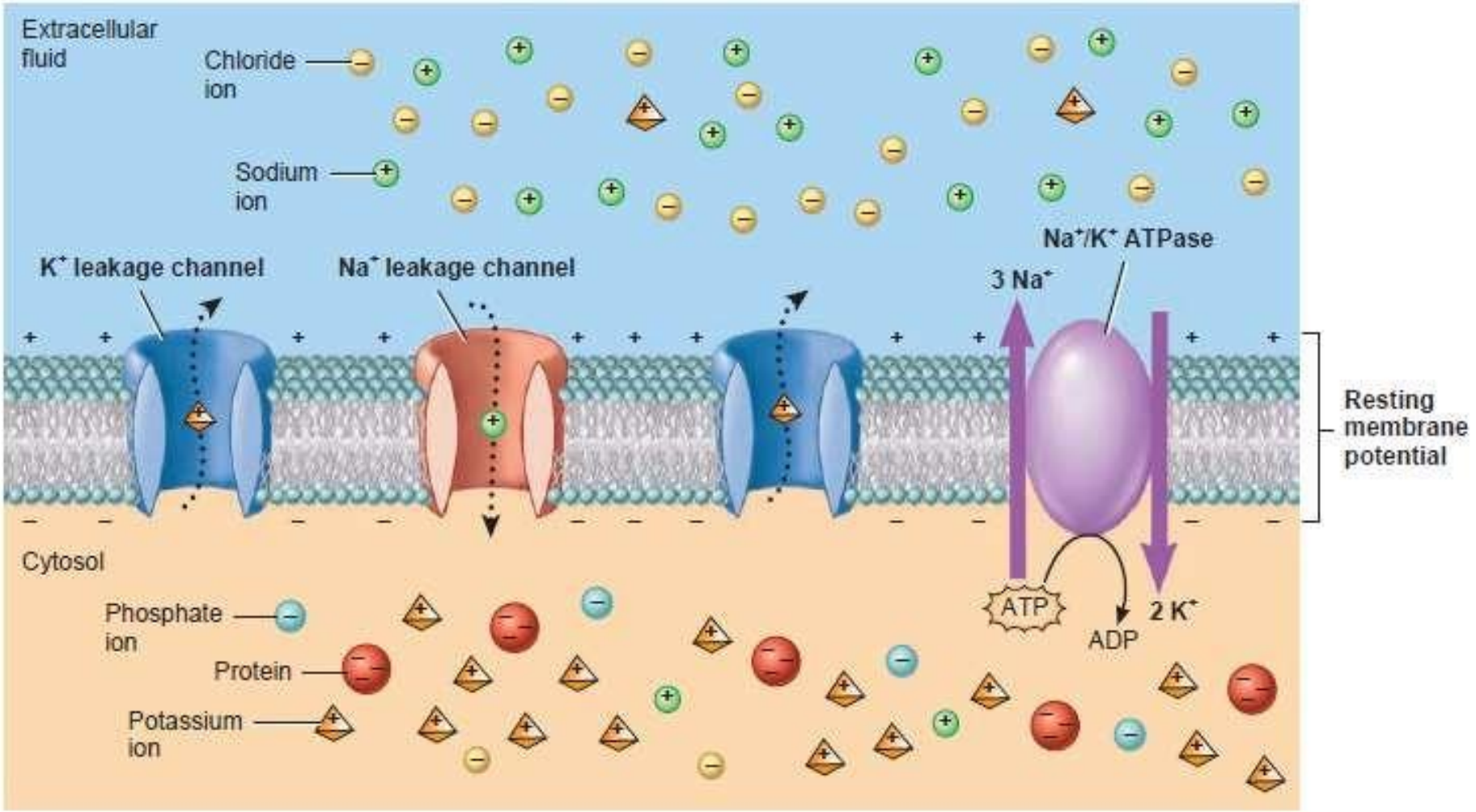
Why RMP is negative inside the cell relative to the outside?

- Because of the following:-

1- the resting membrane is **10-100 times more permeable to K+** than to Na+.

- K+ tends to leak out of the cell down its concentration gradient, carrying +ve charge with it, and unable to carry Cl- with it because Cl- has higher concentration outside.

2- The non-diffusible anion **(protein, sulphate and phosphate ions)** cannot leave the cell.


Extracellular fluid
Chloride ion
Sodium ion
K+ leakage channel
Na+ leakage channel
Na+/K+ ATPase
3 Na+
Resting membrane potential
Cytosol
Phosphate ion
Protein
Potassium ion
ATP
ADP
2 K+

Forces act on cell membrane atrest:

1. **Diffusion:** is the movement of molecules from a region of higher concentration to a region of lower concentration.
2. **Electrical gradient:** +ve ions move to the –ve area and –ve ions move to +ve area
3. **Active transport:** transport ions against their concentration gradient.Most important example is Na+_K+ pump(need energy); responsible transport of Na+ to the outside and K+ to the inside.

These forces are responsible for:

i- The maintenance of the RMP

ii- The development of the AP

iii- Bringing the cell back to its resting state after the AP is over.

The action potential(AP):

Definition: The AP **is a sudden reversal of membrane polarity by a stimulus.**

- **Importance:**

AP occurs in living organism to produce physiological effects such as:

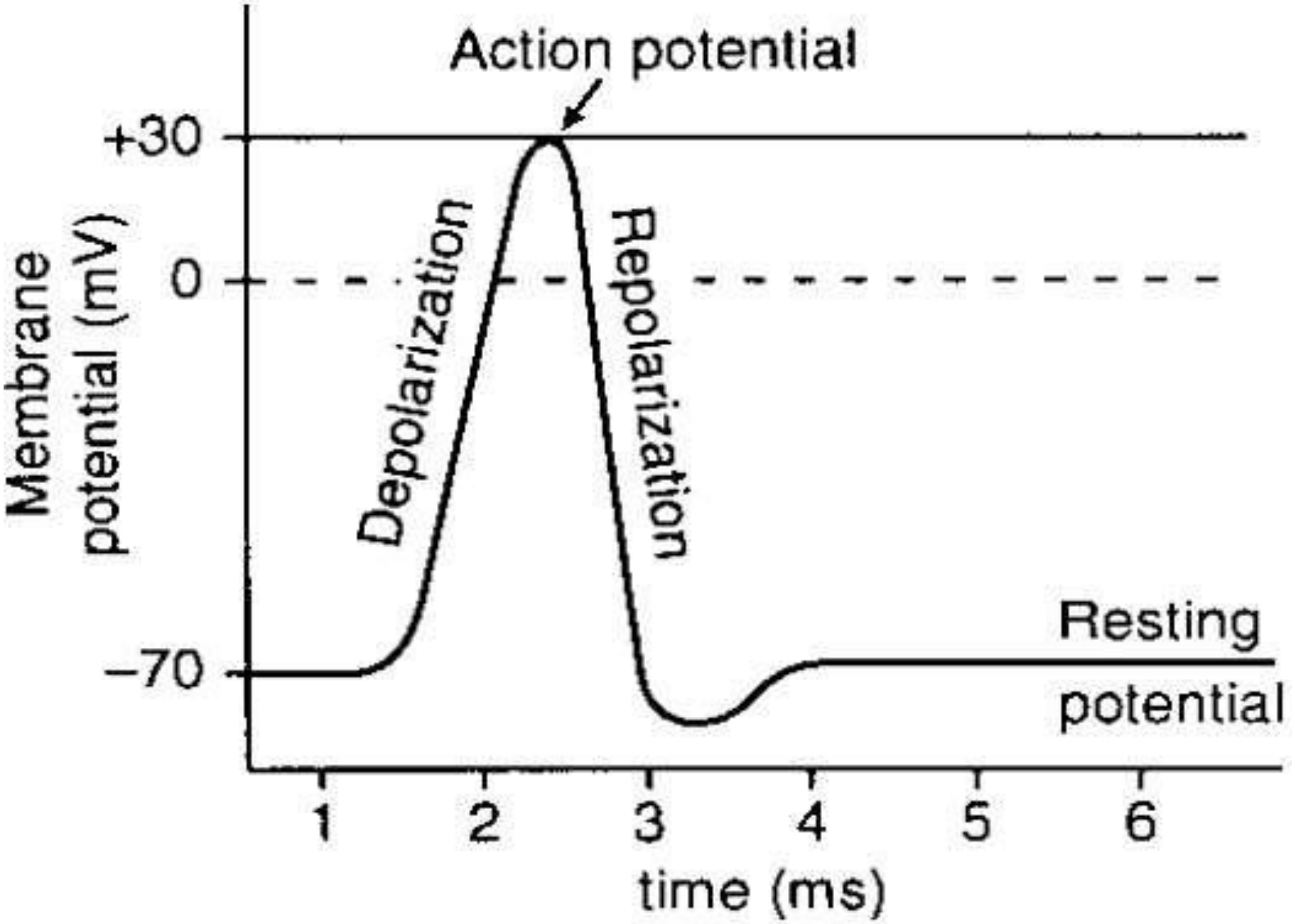
1. **Transmission of impulses along nerve fibers**
2. **Release of neurosecretions or chemical transmitters in synapses.**
3. **Contraction of muscle.**
4. **Activation or inhibition of glandular secretion.**

Development of the AP:

- When a cell membrane is stimulated by a physical or a chemical stimulus, **the cell membrane permeability to Na+ is dramatically increased.**
- Sodium channels open and the sodium ions rush through the channels to the inside the cell **causing the inside the membrane to become positive** with respect to the outside.
- This is called ***depolarization***.
- The membrane potential becomes **reversed and reaches +35 mV.**

Cont.

- Towards the end of depolarization, sodium permeability decreases and **pottasium permeability increases.**
- K+ions leave the cell down their concentration gradient, **causing the inside the membrane to return quickly to its original potential.**
- This is called ***repolarization.***
- The membrane potential is brought back to **-70 mV**


Action potential
+30
0
−70
Membrane potential (mV)
Depolarization
Repolarization
Resting potential
1
2
3
4
5
6
time (ms)

PROPAGATION OF THE ACTION POTENTIAL:

- An action potential elicited at any one point on an excitable membrane usually excites adjacent portions of the membrane, resulting in propagation of the action potential along the membrane.
- This transmission of the depolarization process along a nerve or muscle fiber is called a ***nerve or muscle impulse.***

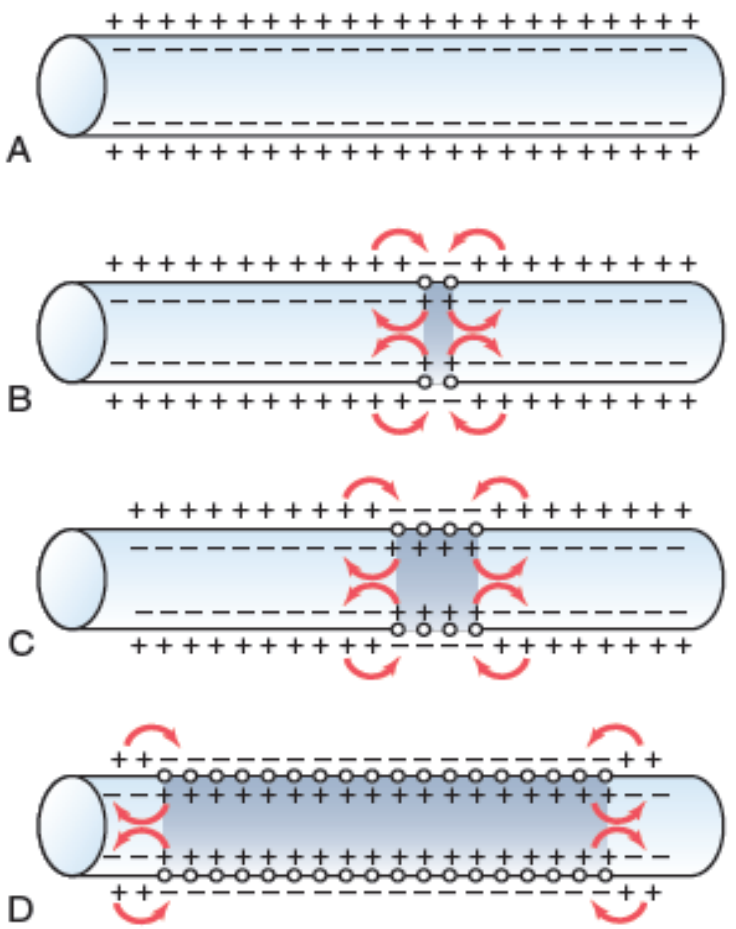


Figure 5-11. Propagation of action potentials in both directions along a conductive fiber.

Direction of Propagation:

- An excitable membrane **has no single direction of propagation,** but the action potential **travels in all directions away from the stimulus**—even along all branches of a nerve fiber—until the entire membrane has become depolarized.

Generation of action potential (AP):

The AP can be divided in five phases:

1. **The resting potential.**
2. **Threshold.**
3. **The rising phase.**
4. **The falling phase.**
5. **The recovery phase.**

1- Resting potential:

- When the neuron is at rest, **only a small of K+ channels are open**, permitting K+ ions to enter and exit the cell based onelectrochemical forces.

2 Threshold:

- As a depolarizing stimulus arrives the membrane, a **few Na+ channels open permitting Na+ ions to enter the neuron.**
- The increase in positive ions inside the cell depolarizes the membrane (making it less negative).

3 Rising phase:

- If the depolarization reaches the threshold potential, **additional voltage-gated Na+ channels open.**
- As positive Na+ ions rush in to the cell the voltage across the membrane rapidly **reverses and reaches its most positive value.**

4- Falling phase:

- At he peak of AP, two process occur simultaneously;

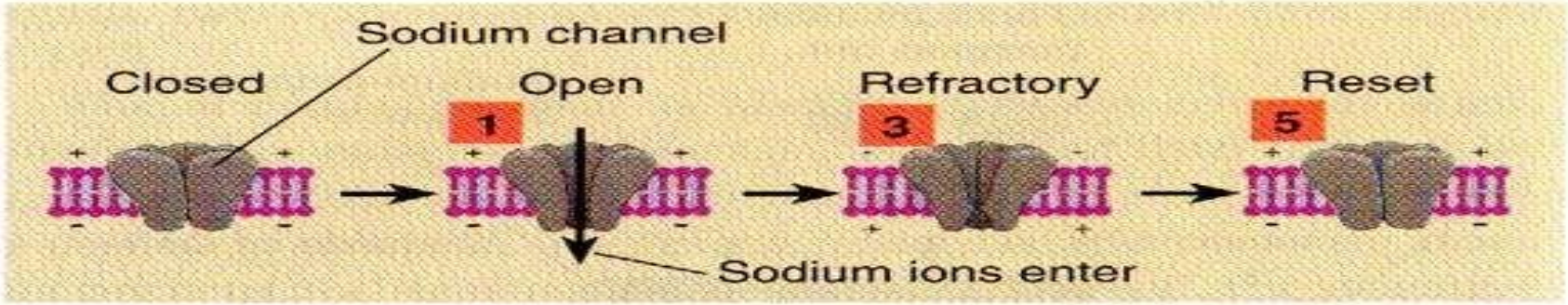
1. First: **many of the voltage-gated Na+ channels begin to close.**
2. Second: **many more k+ channel open, allowing positive charges to leave the cell**.

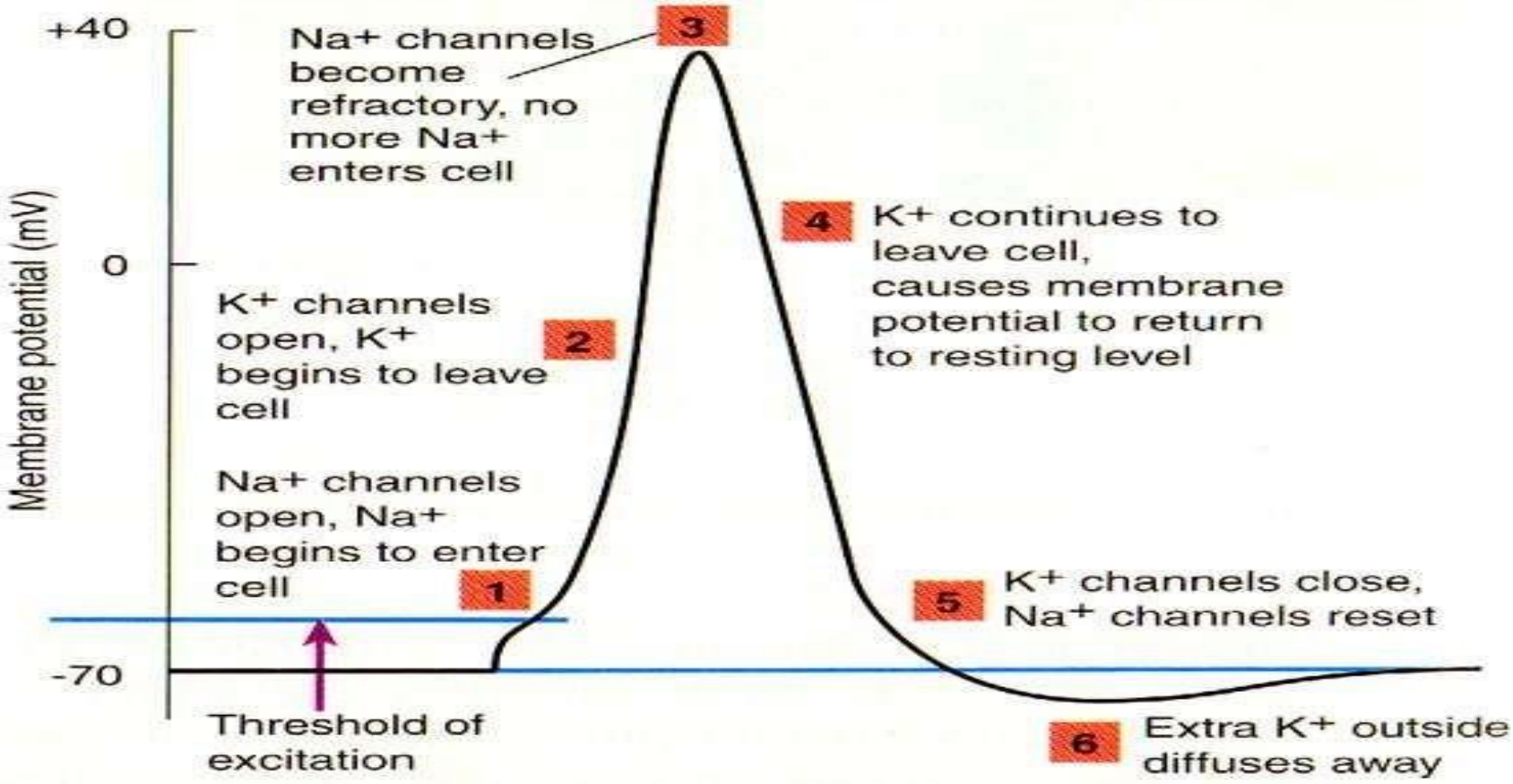
- This causes the Membrane Potential to begin to shift back toward the **Resting Membrane Potential.**
- As the Membrane Potential approaches the Resting Potential , **voltage-gated K+ channels are maximally activated and open.**

5- Recovery phase:

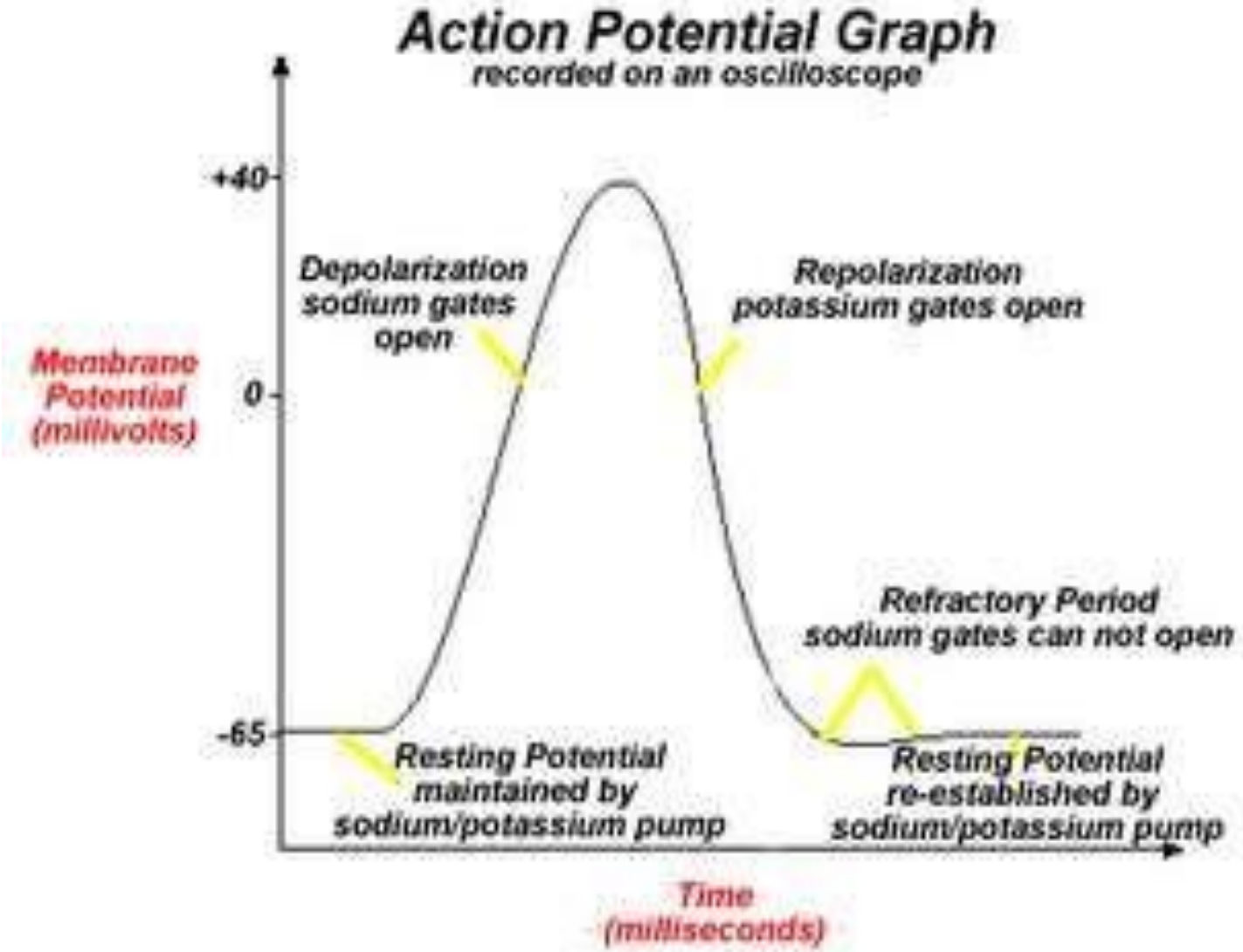
- This undershoot occurs because more K+ channels are open.
- The return to steady state continues as the additional K+ channels **that opened during the Action Potential now close.**
- The AP is now determined by the subset of the K+ channels that are normally open during the membrne's resting state.

AP


Sodium channel
Closed
Open
Refractory
Reset
1
3
5
Sodium ions enter


+40
0
-70
Membrane potential (mV)
Na+ channels become refractory, no more Na+ enters cell
3
4
K+ continues to leave cell, causes membrane potential to return to resting level
K+ channels open, K+ begins to leave cell
2
Na+ channels open, Na+ begins to enter cell
1
5
K+ channels close, Na+ channels reset
Threshold of excitation
6
Extra K+ outside diffuses away

Continue


Action Potential Graph
recorded on an oscilloscope
+40
0
-65
Membrane Potential (millivolts)
Depolarization sodium gates open
Repolarization potassium gates open
Refractory Period sodium gates can not open
Resting Potential maintained by sodium/potassium pump
Resting Potential re-established by sodium/potassium pump
Time (milliseconds)

All-or-Nothing Principle:

- Also called **All or None Law.**
- Applies to all normal **excitable tissues.**
- The depolarization process travels over the entire membrane if conditions are right, but it does not travel at all if conditions are not right.
- A law stating that certain structures, such as a neuron or a muscle fiber, either **respond completely** (all) or **not at all** (none) to a stimulus.
- **There is no partial nerve impulse in a neuron, or partial contraction of a fiber muscle.**
- If the stimulus is any strength above threshold, the nerve or muscle fiber will either give a complete response or no response.

Refractory period:

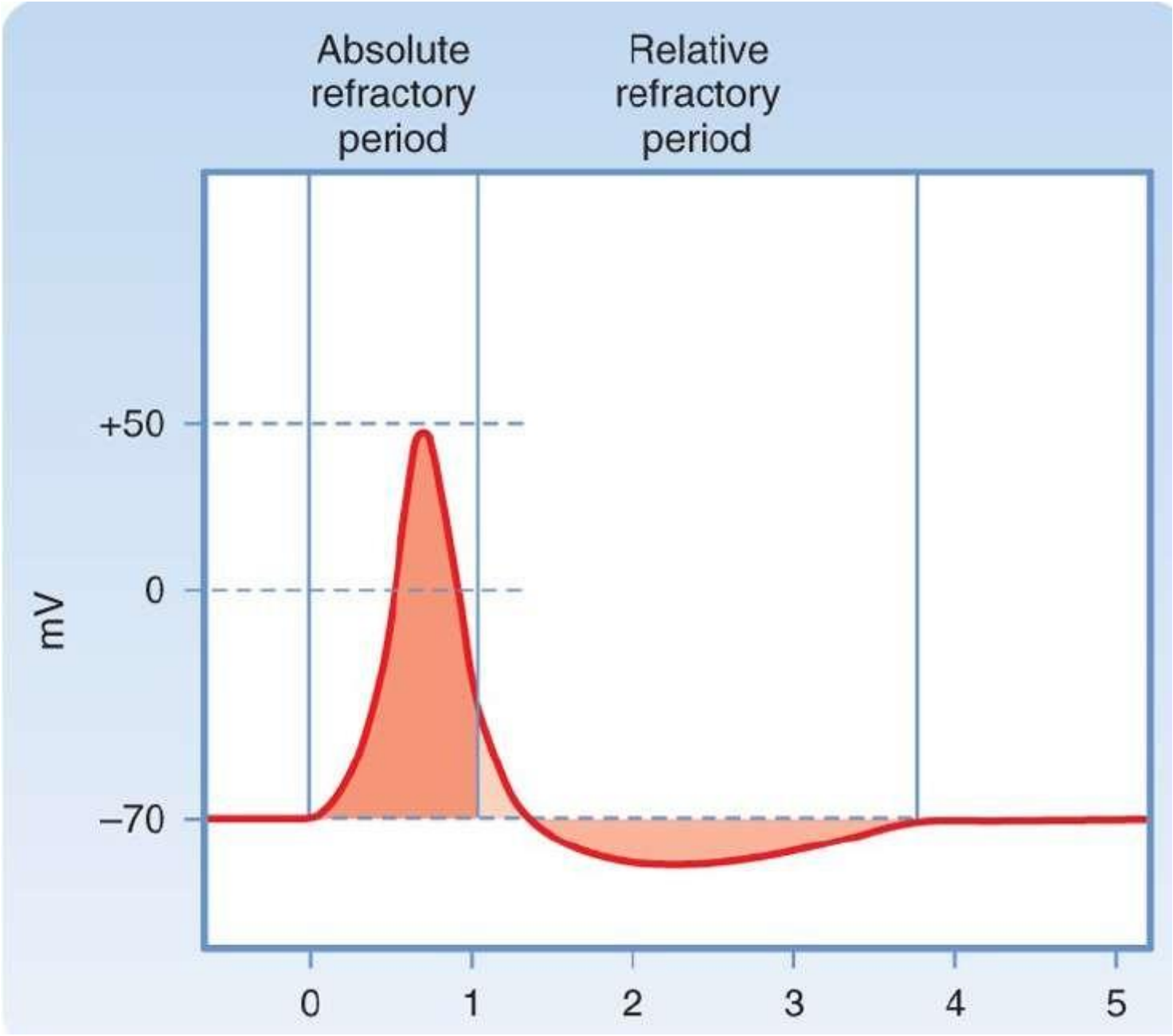
- It is the period which **an excitable cell cannot generate another AP in response to a *normal* threshold stimulus.**
- **Types of refractory period**:

1- Absolute refractory period: in which cannot initiate a second AP even a very strong stimulus.

- This period coincide with the period of voltage-gated Na+ channel activation gates are inactivating and cannot reopen; they first must return to the resting state.

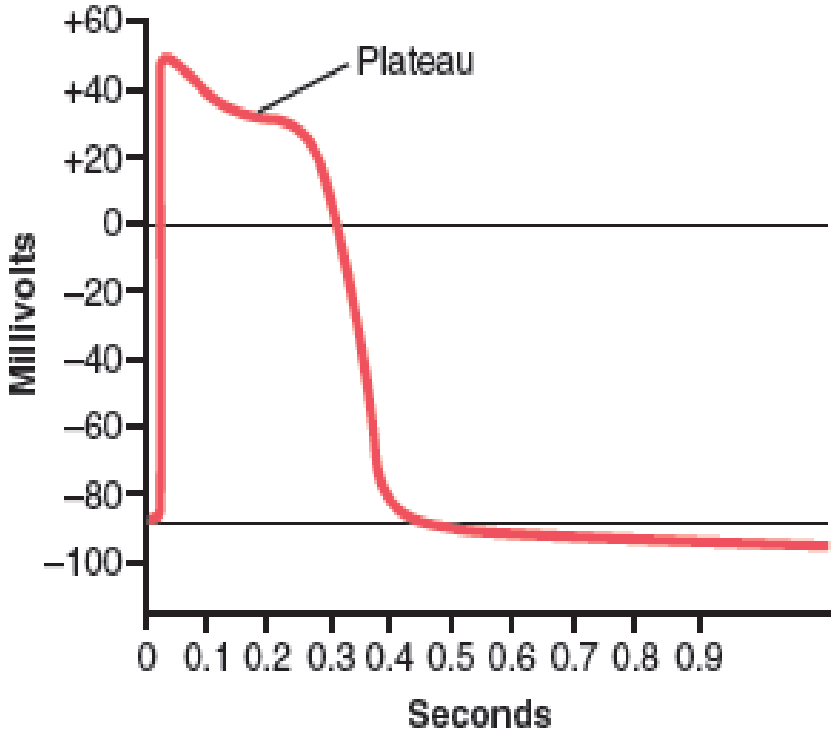
2- Relative refractory period: during which a second action potential can be evoked, but only if the stimulus strength is increased.

- It coincides with the period when the voltage-gated K+ channels are still open after inactivated Na+ channels have returned to their resting state.


Absolute refractory period
Relative refractory period
+50
0
−70
mV
0
1
2
3
4
5

PLATEAU IN SOMEACTIONPOTENTIALS:

- In some instances, the excited membrane does not repolarize immediately after depolarization; instead, **the potential remains on a plateau** near the peak of the spike potential for many milliseconds.
- This type **of action potential occurs in heart muscle fibers.**
- The plateau ends when the **calcium - sodium channels close** and **permeability to**



RHYTHMICITY OF SOME EXCITABLETISSUESREPETITIVE DISCHARGE

- Repetitive self-induced discharges occur normally in the heart, in most smooth muscle, and in many of the neurons of the central nervous system.
- These rhythmical discharges cause:

(1) Rhythmical beat of the heart,

(2) Rhythmical peristalsis of the intestines.

(3) Neuronal events as the rhythmical control of breathing.

- All other excitable tissues can discharge repetitively if the threshold for stimulation of the tissue cells is reduced to a low-enough level.
- Even large nerve fibers and skeletal muscle fibers, which normally are highly stable, discharge repetitively when they are placed in a solution that contains the drug *veratridine, which activates sodium ion channels, or* when the calcium ion concentration decreases below a critical value, which increases sodium permeability of the membrane.

CONDUCTIVITY:

- Conductivity is **the ability of nerve fibers to transmit the impulse from the area of stimulation to the other areas.**
- Action potential is transmitted through the nerve fiber as nerve impulse.
- Normally in the body, the action potential is transmitted through the nerve fiber in only one direction.
- In myelinated nerve fiber the conductivity of AP is **Saltatory or jumping conduction.**
- In Unmyelinated nerve fiber the conductivity of AP is **Continues conduction.**

Graded Potentials:

- **Graded potentials: are** changes in membrane potential that are confined to a relatively small region of the plasma membrane.
- Graded potentials are given various names related to the location of the potential or the function they perform.
- **Different types of graded potentials:**

1. Receptor potential.
2. Synaptic potential.
3. Pacemaker potential.