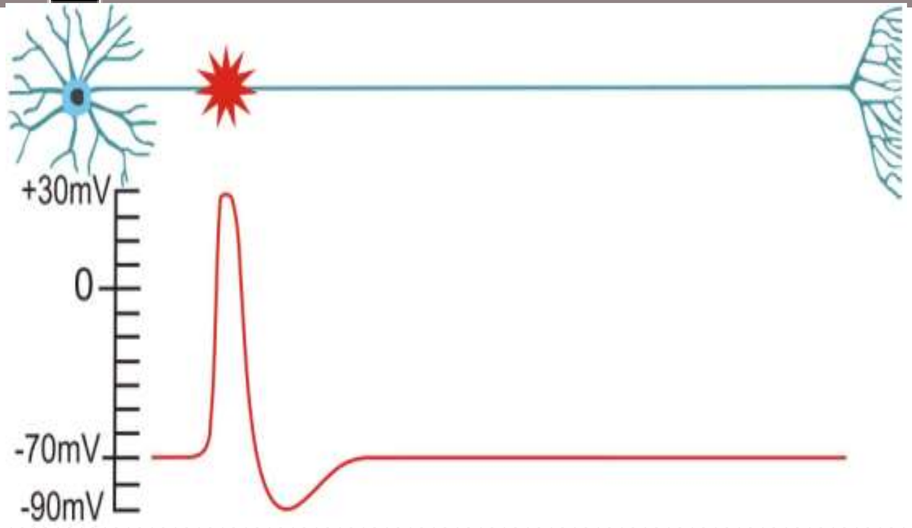
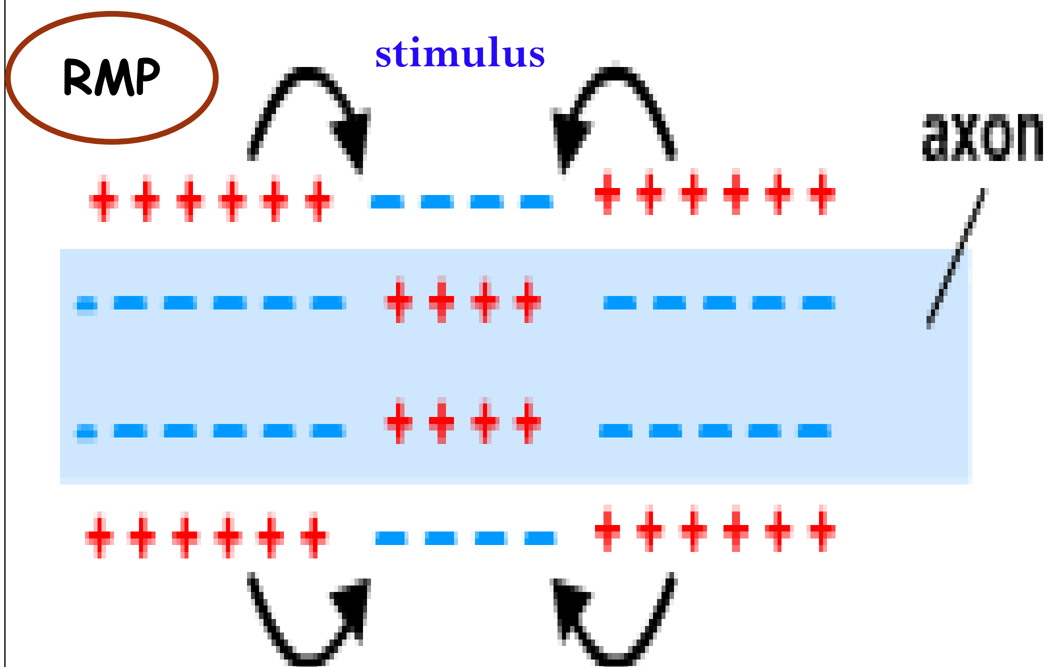
Action potential

BY
Dr. Nour A. Mohammed
Mut'ah school
of medicine

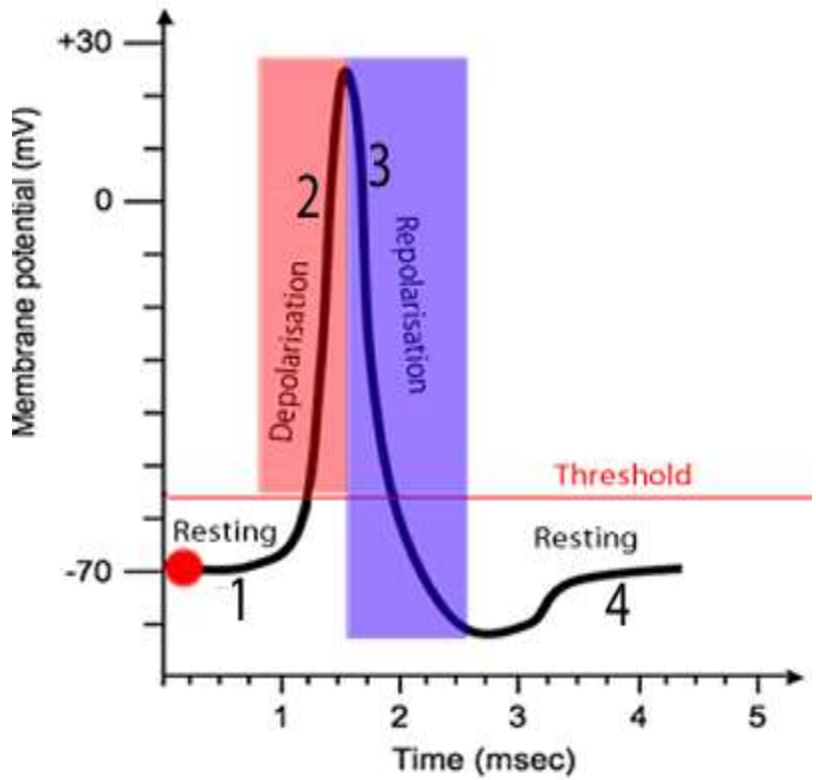


Definition

it is a **transient** change in the resting membrane potential as a result of application of a **threshold stimulus.**



depolarisation moves along the axon



Application of an adequate electric stimulus to the nerve fiber is followed by:

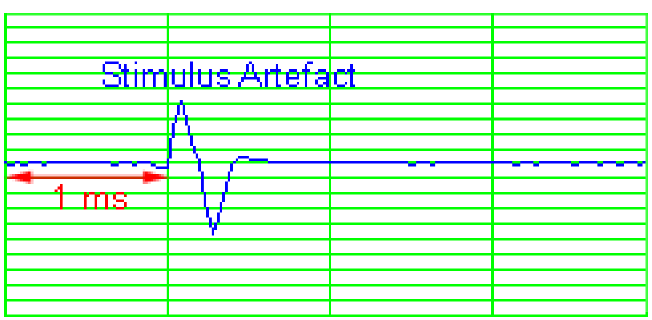
1) **Stimulus artifact √**
2) **Latent period √**
3) **Spike potential**
    a) Depolarization
    b) Repolarization
        - Rapid Repolarization
        - Slow Repolarization
        - Hyperpolarization

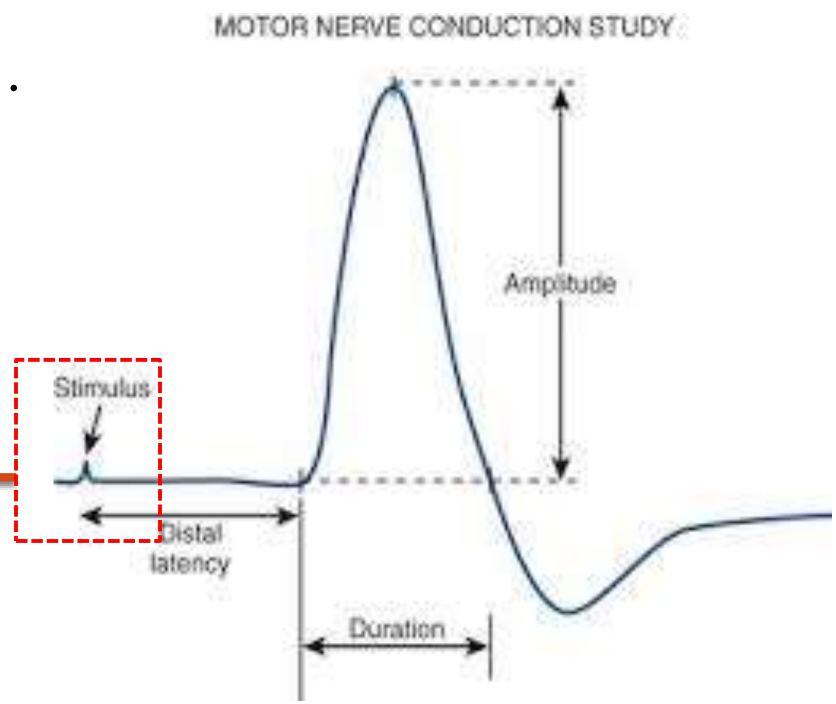
Stages of action potential:

(1) Stimulus artifact

- It is a short irregular deflection of the base line due to stimulus application.
- This is due to current leakage from the stimulating electrode to the recording electrode

(indicates beginning of stimulation).

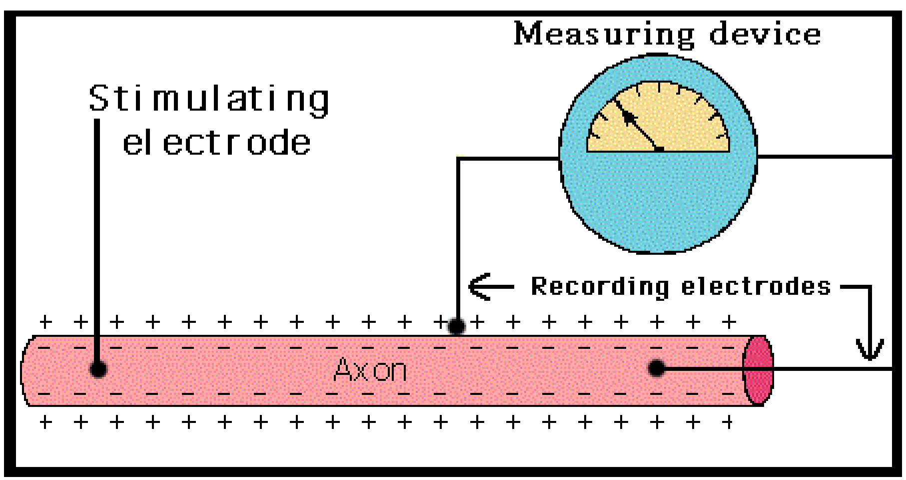


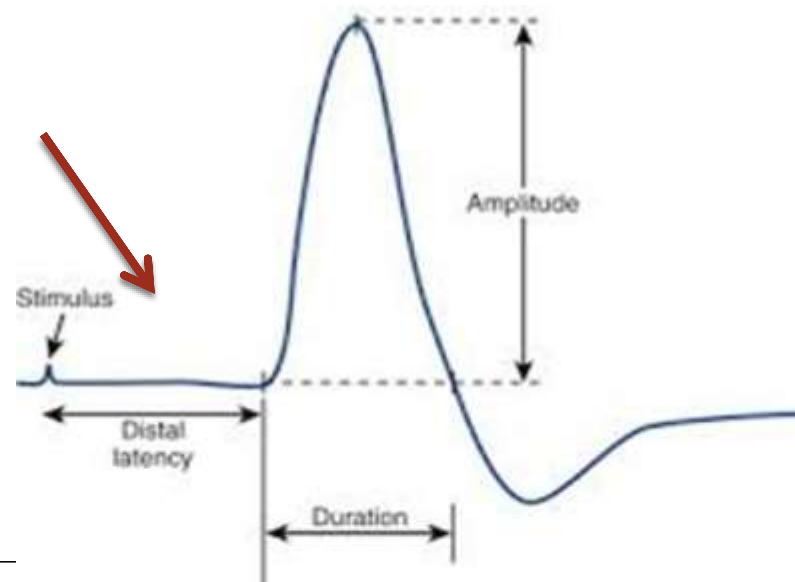


(2) Latent period

- It represents the time that the nerve impulse (**response**) takes to travel from the stimulating to recording electrode.
- It indicates the rate of conduction in the axon.

$$\text{Speed of conduction} = \frac{\textbf{\textit{Distance between electrodes}}}{\textbf{\textit{Latent period}}}$$

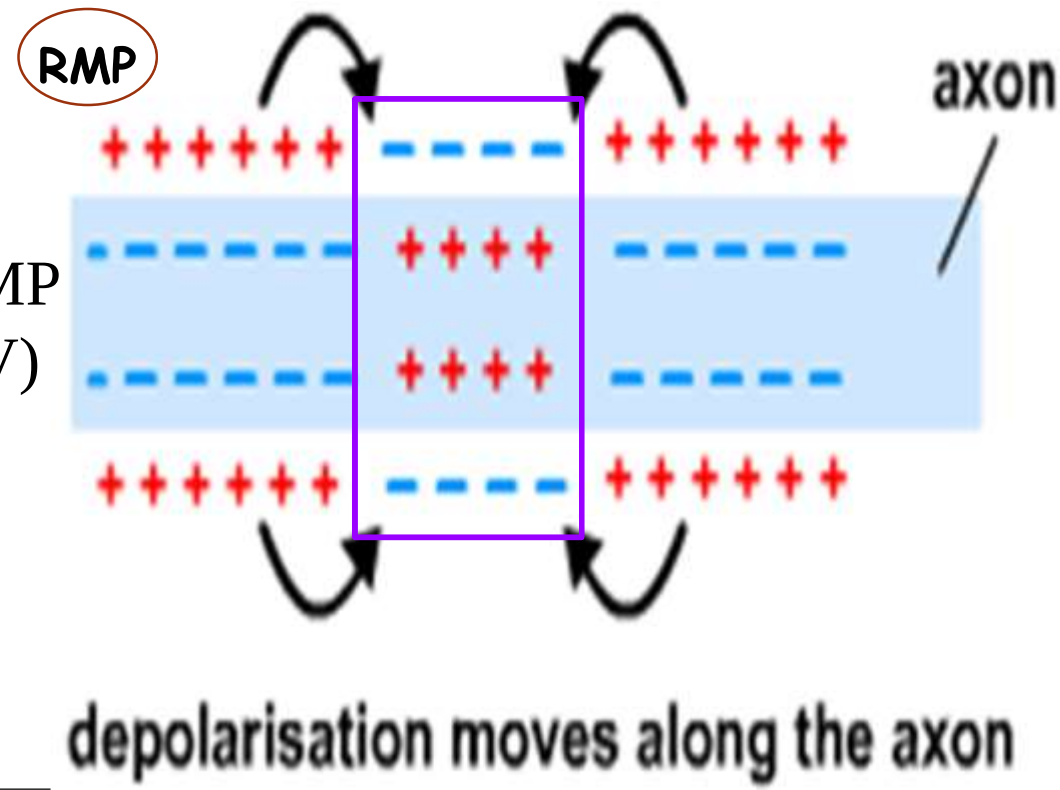




(3) Depolarization

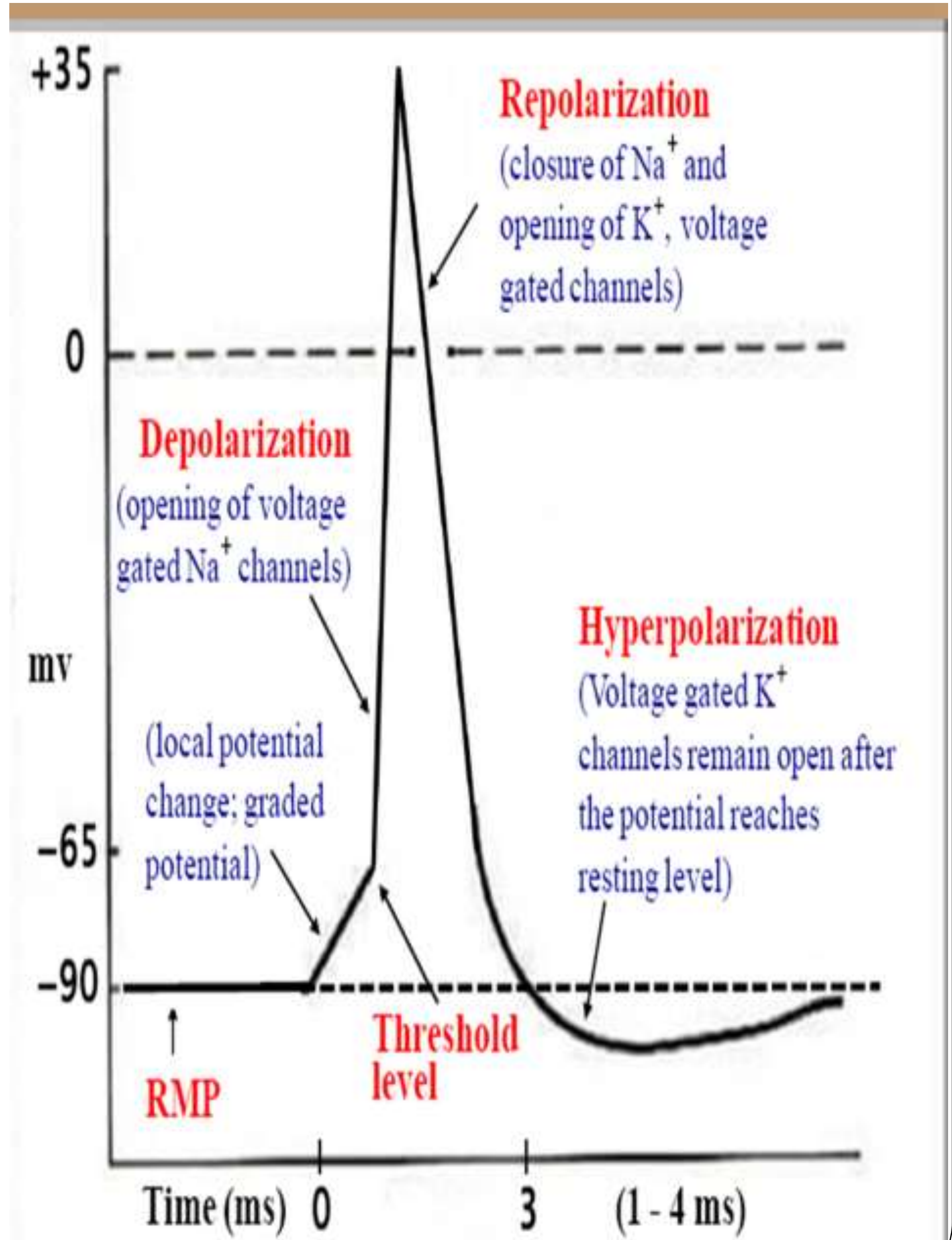
There is a rapid loss or (reversal) of polarity of the membrane. It is recorded as a rise of membrane potential in the positive direction.

- At first, there is a slow depolarization of 25 mV (RMP changes from –90 to –65 mV)



Depolarization steps:

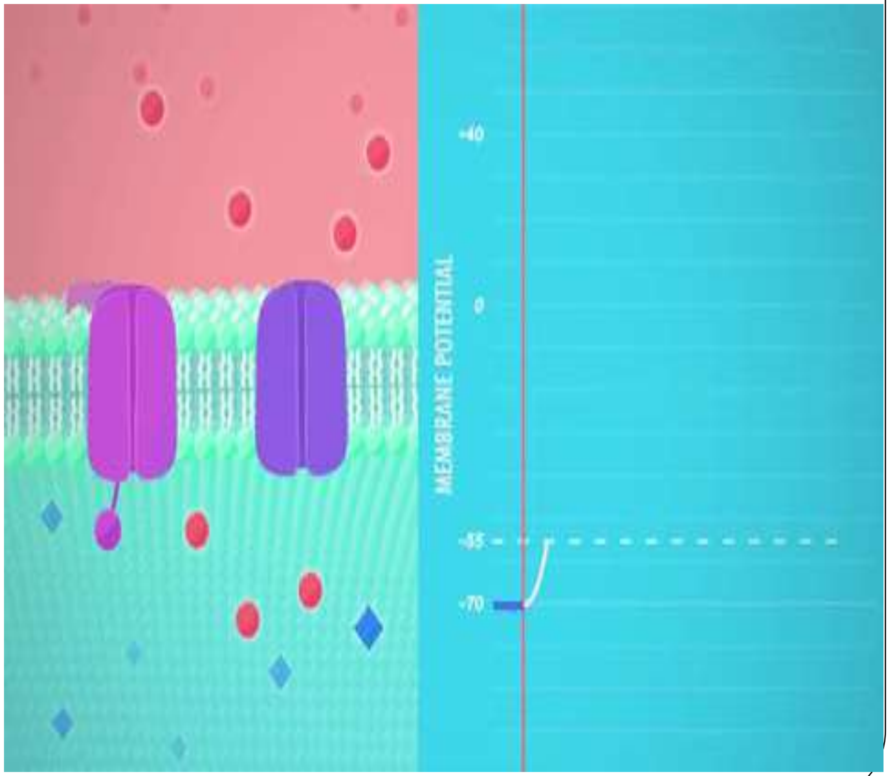
- At -65 mV (***Firing level***), the depolarization occurs rapidly till the potential reaches zero mV (no deference between inside and outside the cell membrane).
- Then, the inside becomes positive to the outside of the membrane i.e. reversal of polarity (**overshoot**) till +35 mV.



So, the magnitude of the depolarization phase equals 125 mV (from –90 to +35 mV).

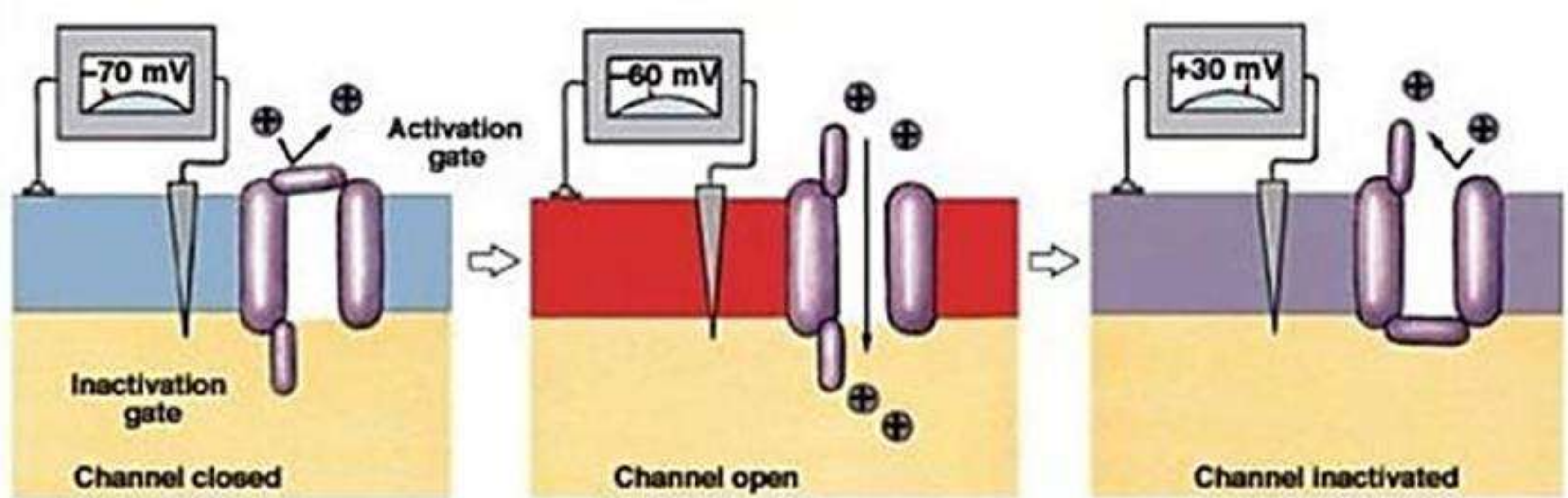
Cause of depolarization:

- ✓ The stimulus opens some Na+ channels allowing Na^+ to enter the cell.
- ✓ If the Na+ influx achieves threshold potential (the firing level) then additional Na+ gates open and depolarization will proceed rapidly.
- ✓ The flow of Na+ will cause more Na+ channels to open. (+ve feedback mechanism).

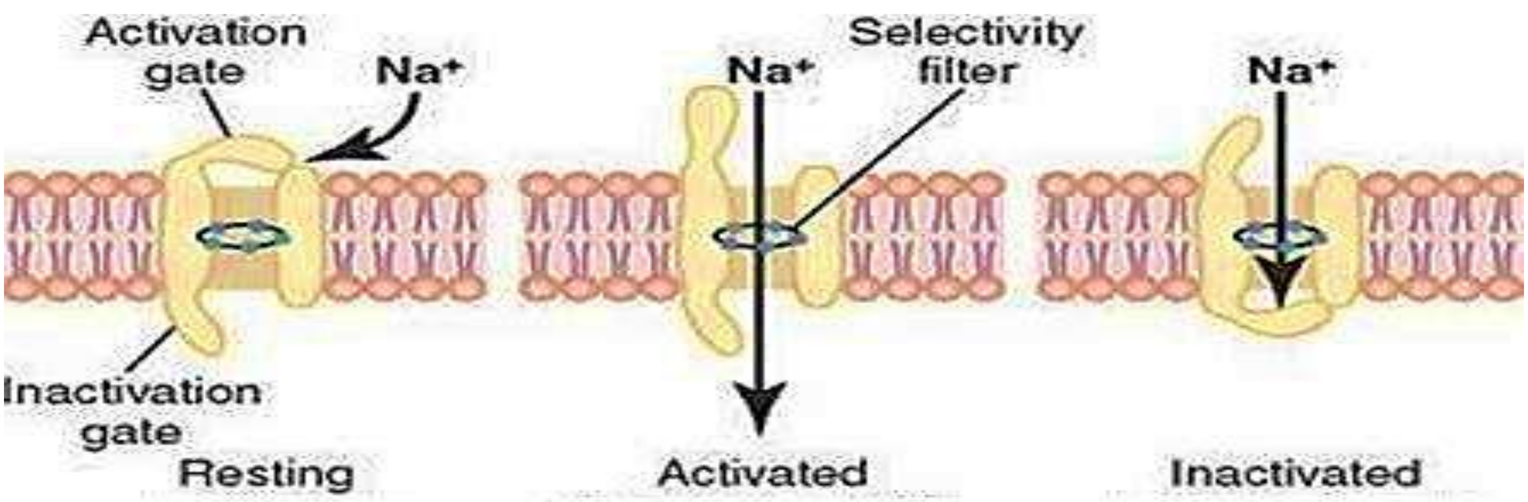


Changes in voltage-gated fast Na+ channels and Na+ permeability during action potential:

- **Outer gate (activation gate):** opens at the start of depolarization causing Na+ influx.
- **Inner gate (inactivation gate):** then closes, preventing further Na+ influx and causing Na+ channel inactivation.



- **During rest:** the activation gate is closed & the inactivation gate is opened → no Na+ permeability.
- **During activation:** change of membrane potential by 25 mV (from -90 to -65 mV) → the activation gate opens and Na+ permeability reaches maximum till the potential of +35 mV. Then the inactivation gate closes.

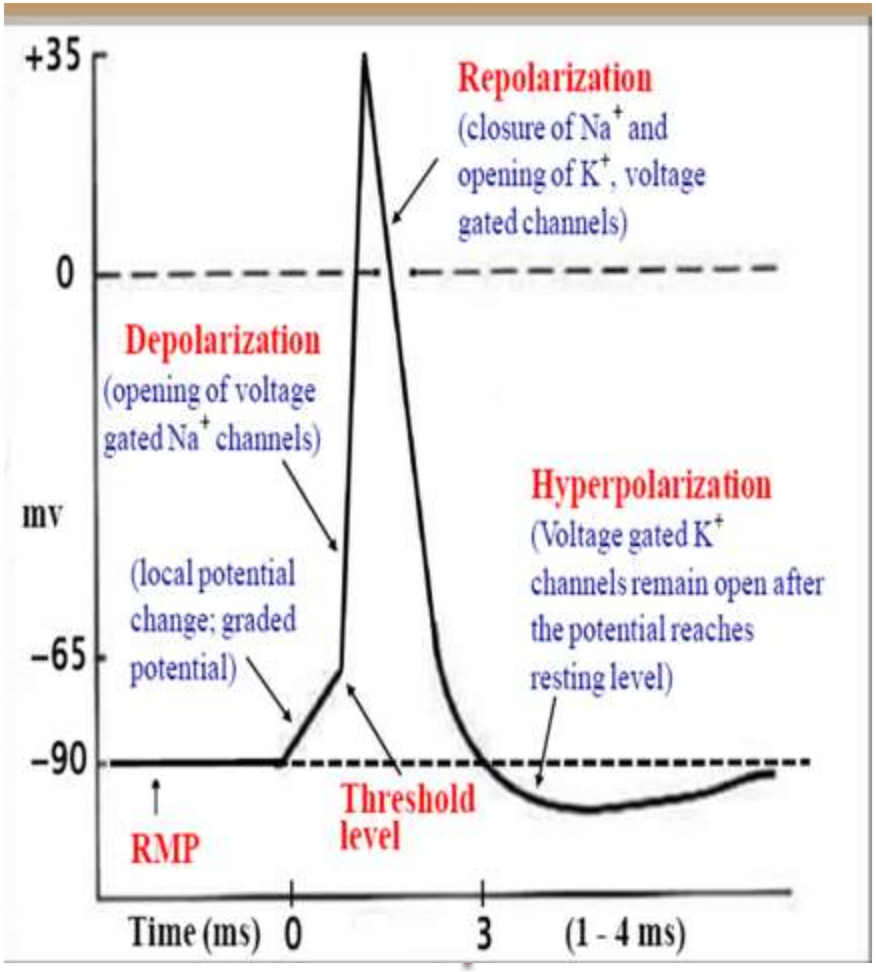


(4) Repolarization

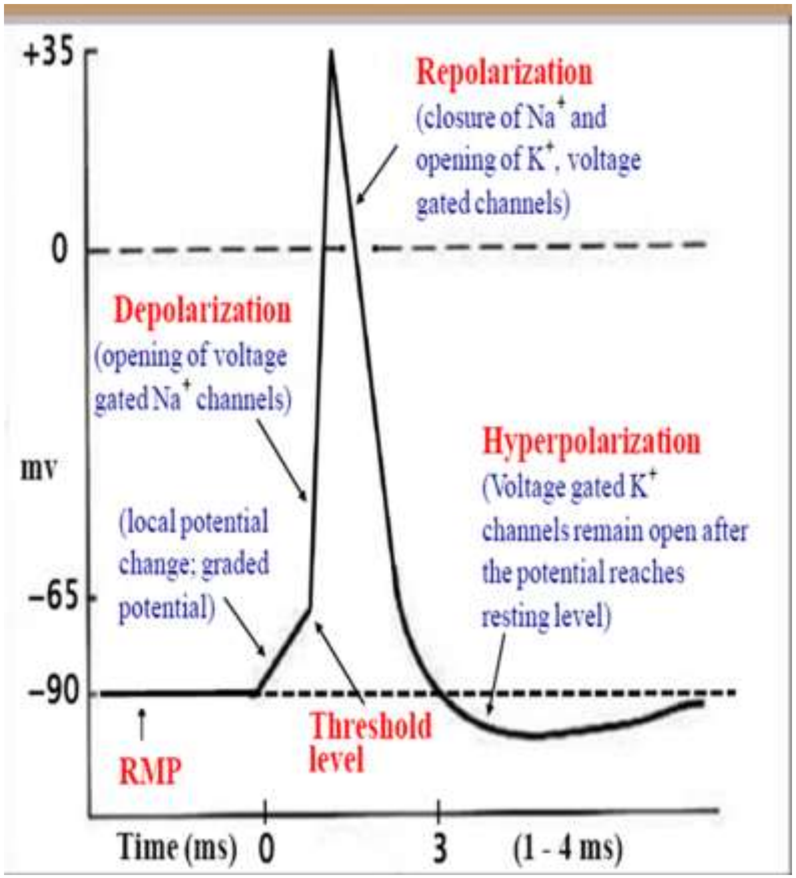
It is the return of the membrane potential to the resting state (from +35 to –90 mV).

It occurs in **3 steps:**

1. Rapid repolarization
2. Slow repolarization
3. Hyperpolarization.



1. Rapid repolarization:

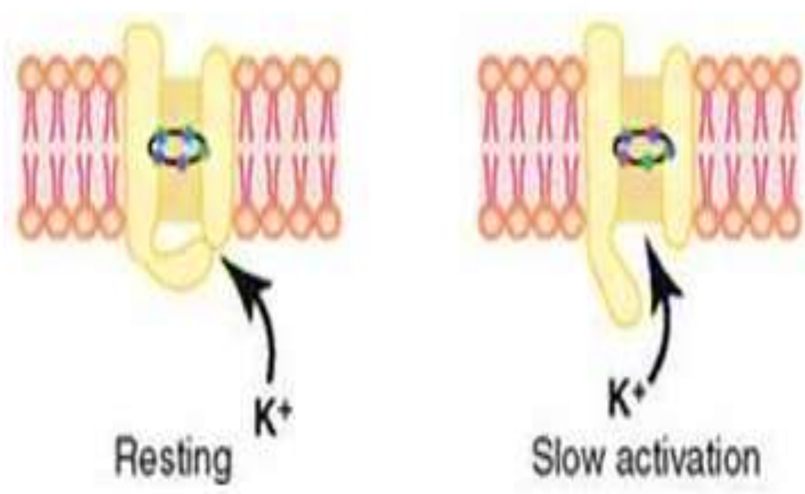


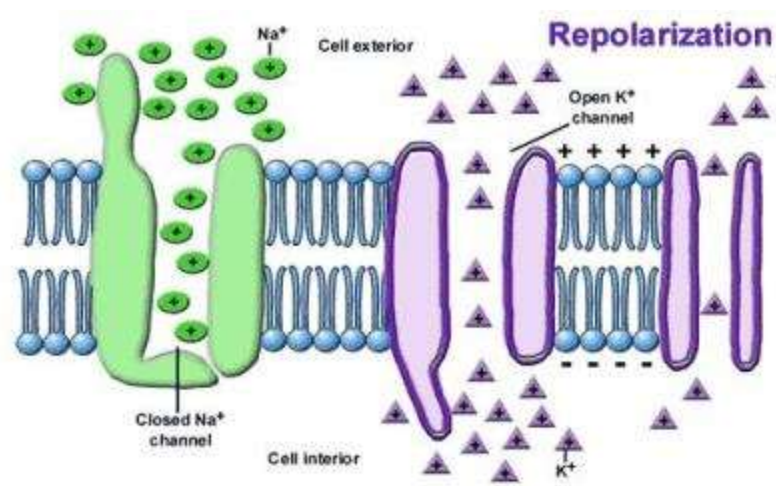
- During which the membrane restores 70% of its resting condition.
- ***Cause:***
- a) Inactivation of voltage gated Na+ channels so, Na+ influx stopped.
- b) Activation of voltage gated K+ channels so, K+ outflux increased.

Changes in voltage-gated K+ channels during action potential:

K+ channel has a single gate located on the inside of the membrane.

- ✦ **During rest:** the gate is closed.
- ✦ **During activation:** depolarization → slow opening of K+ channels which coincides to the closure of Na+ gates → repolarization.



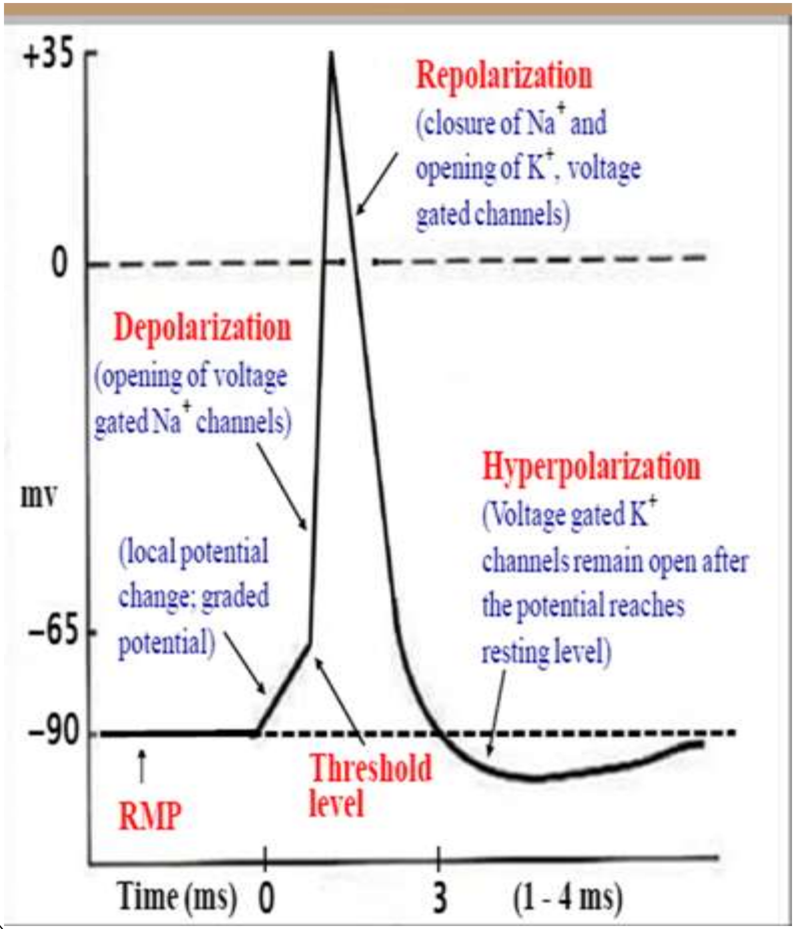


Note that:

K+ gates are stimulated by the same stimulus that stimulates Na+ channels but K+ channel are slow (take more time to open and close).

(2) Slow repolarization

After 70% of repolarization, the rate of repolarization becomes slow.

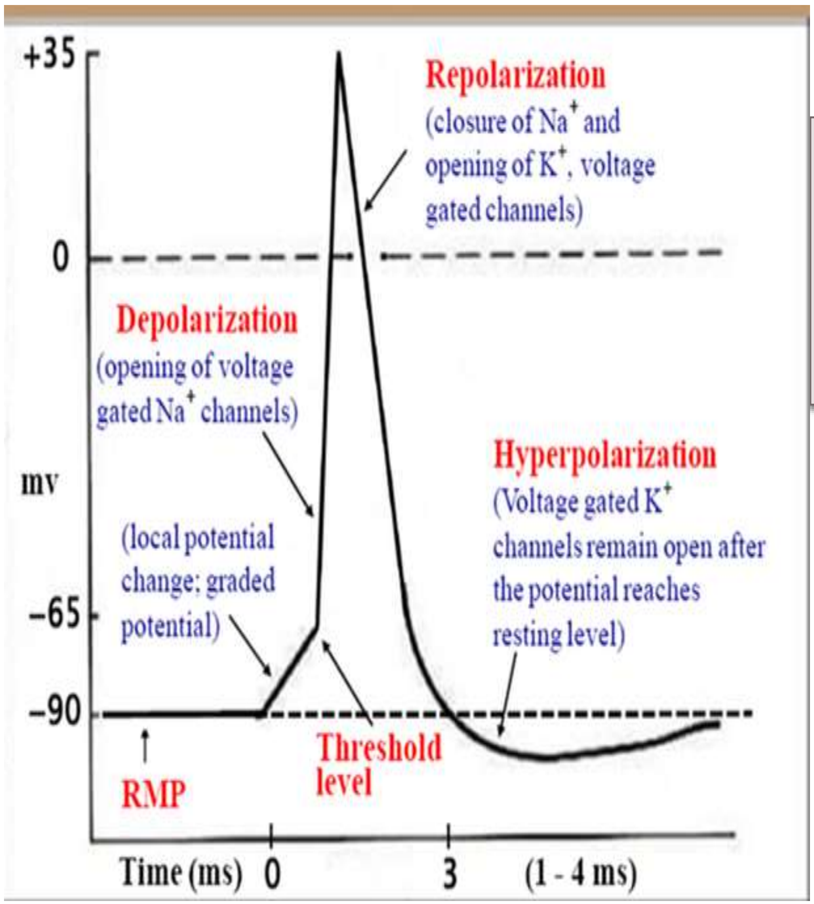


Cause:

Decrease in K+ gradient → slow K+ efflux → delayed repolarization.

(3) hyperpolarization

After reaching the RMP, there is an overshooting of about **1-2 mV** hyperpolarization, then the membranes returns to normal **RMP.**

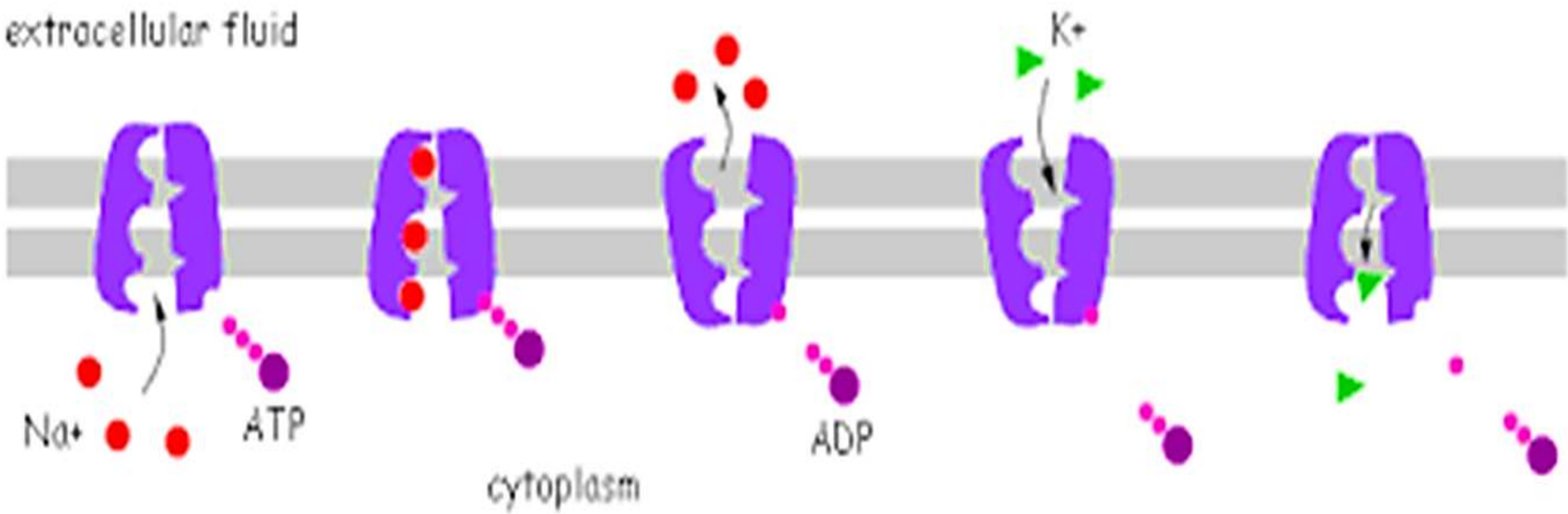


Cause: Delayed K+ channels closure

→ more K+ efflux

→ more hyperpolarization.

- Finally, ***Na*$^{+}$*- K*$^{+}$*pump*** helps to restore the normal ionic distribution of the RMP i.e., maintenance of Na^{+} (extra cellular) and K^{+} (intracellular)



Properties of action potential:

1) Caused by **threshold** stimulus *(or suprathreshold)*
2) Caused by ionic changes.
3) Conducted (propagates) in both directions.
4) Constant duration.
5) Obeys All or none law ⇨ can't be graded (constant amplitude).
6) Has Absolute Refractory Period ⇨ can't be summated.

Excitability changes:

At first, there is increase in excitability till the firing level then the following changes occur:

1- Absolute refractory period:

- No response to any stimulus (loss of excitability).
- Coincides with depolarization from the firing level till the first 1/3 of rapid repolarization.

2- Relative refractory period:

- Stronger stimulus $\rightarrow$ response (low excitability).

- Coincides with lower 2/3 of rapid repolarization.

3- Supernormal phase:

- Weak stimulus $\rightarrow$ response (high excitability).

- Coincides with the Slow repolarization

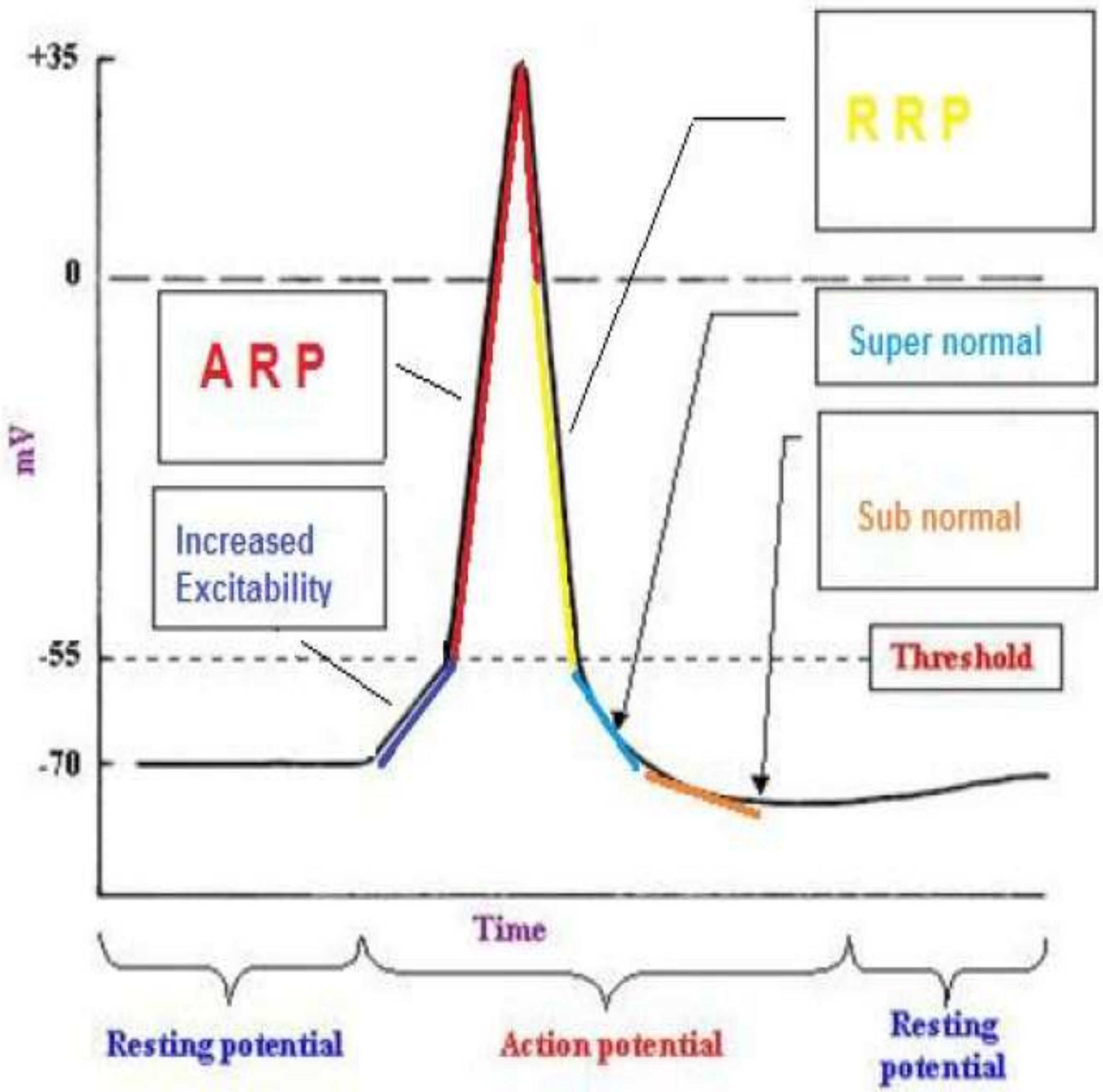
- During it, the membrane is partially depolarized and has low threshold for firing level.

4- Subnormal phase:

-Stronger stimulus → response (low excitability).

- Coincides with the hyperpolarization

- During it, the membrane is hyperpolarized with increase threshold for firing level and difficult stimulation.



+35
0
-55
-70
mV
RRP
ARP
Super normal
Increased Excitability
Sub normal
Threshold
Time
Resting potential
Action potential
Resting potential

Thank you