# Action potential

**BY**

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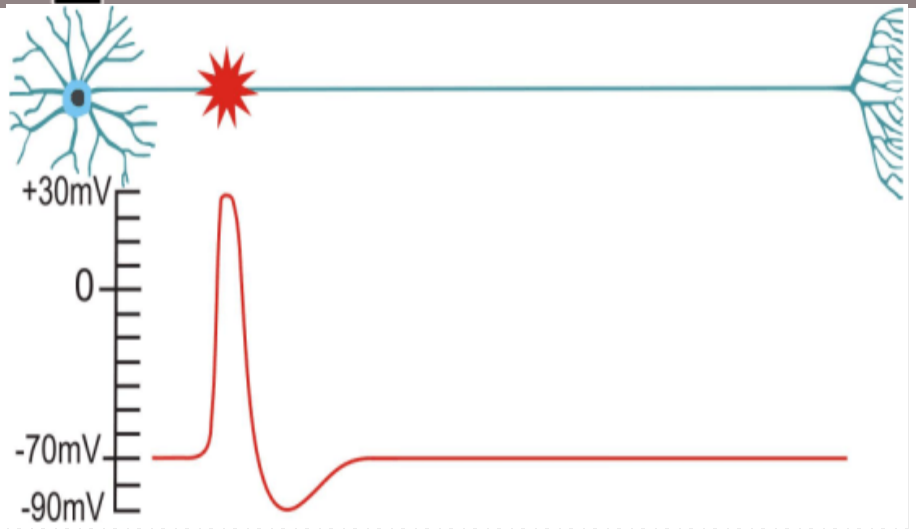
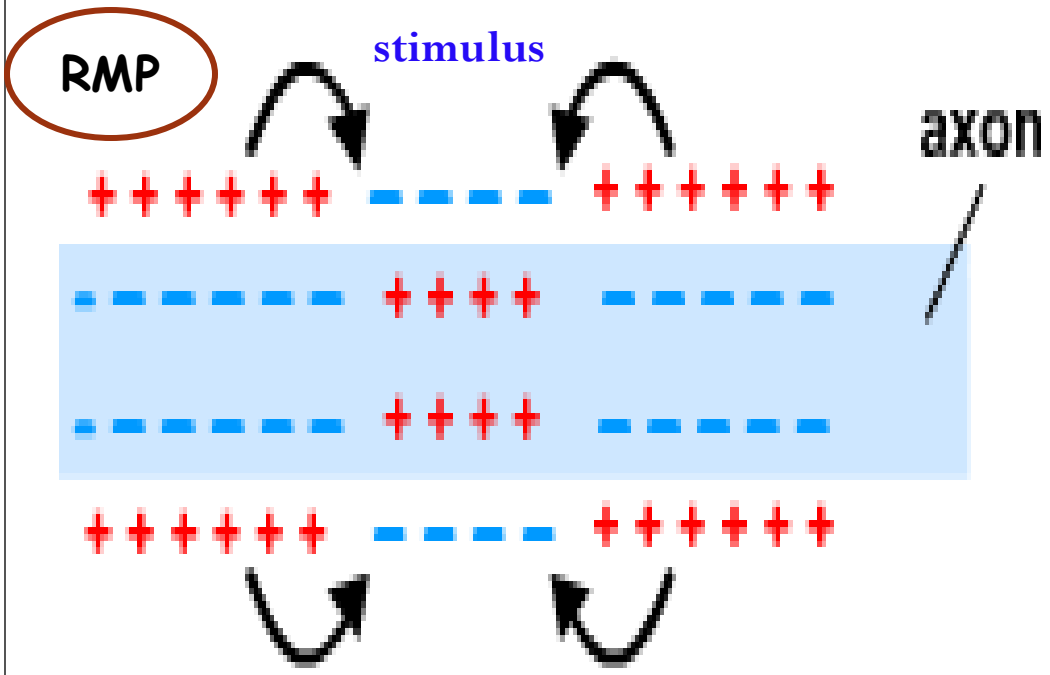
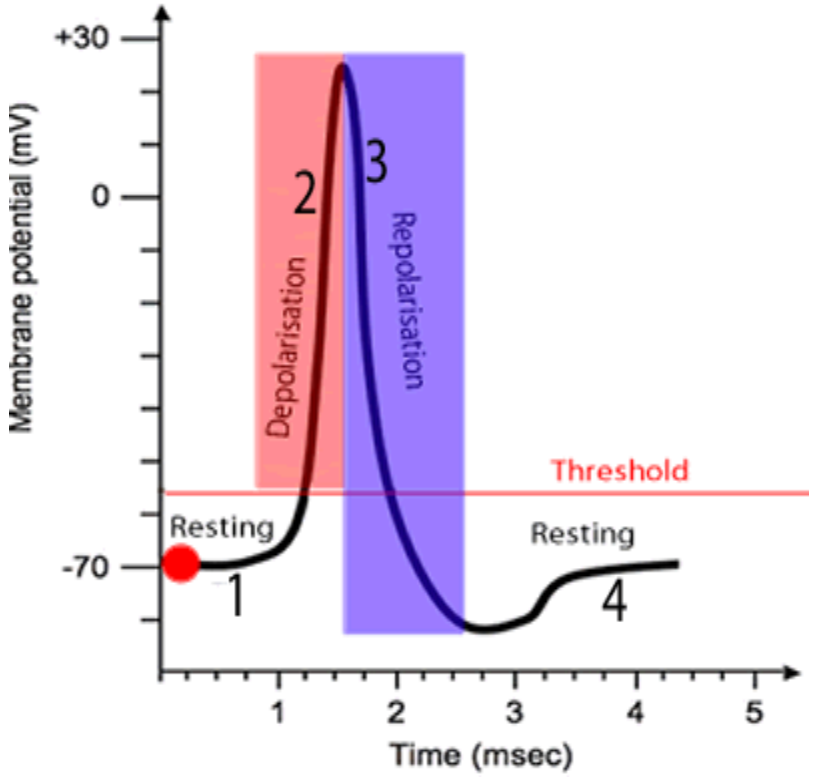


# Definition

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:

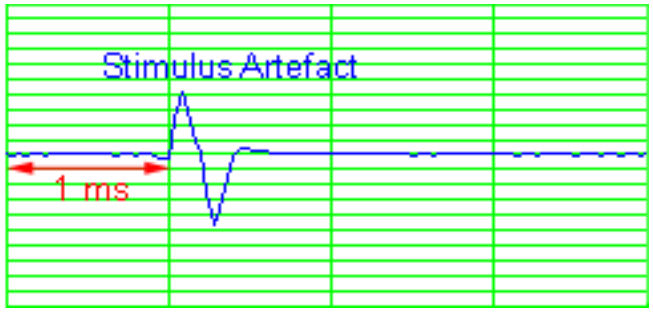
1) **Stimulus artifact** √
2) **Latent period** √
3) **Spike potential**
    a) Depolarization
    b) Repolarization
        - Rapid Repolarization
        - Slow Repolarization
        - Hyperpolarization

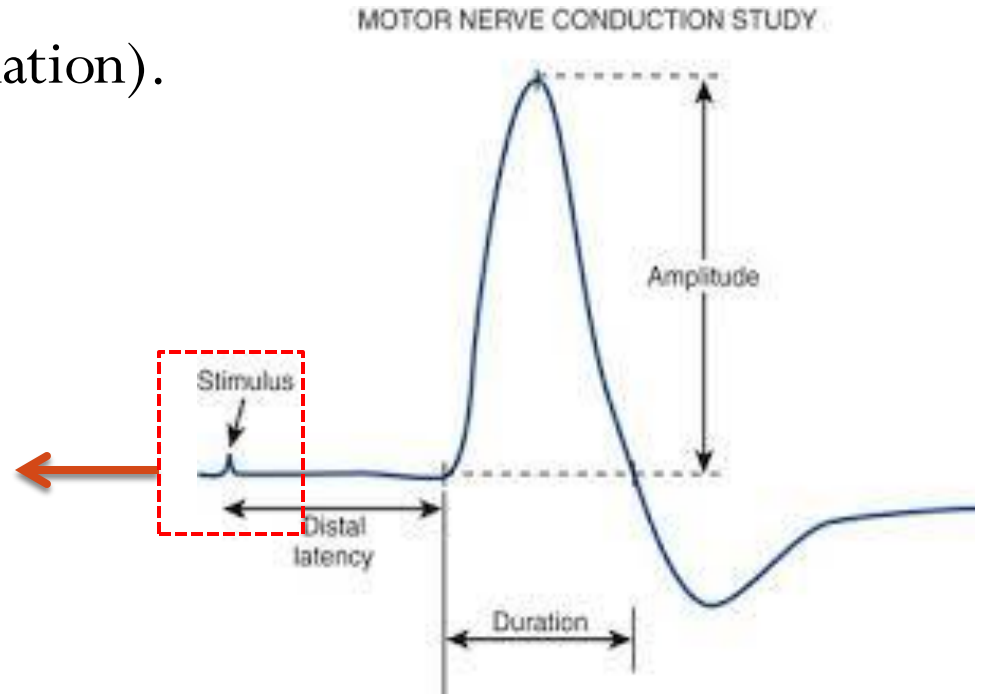
# Stages of action potential:

## (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).

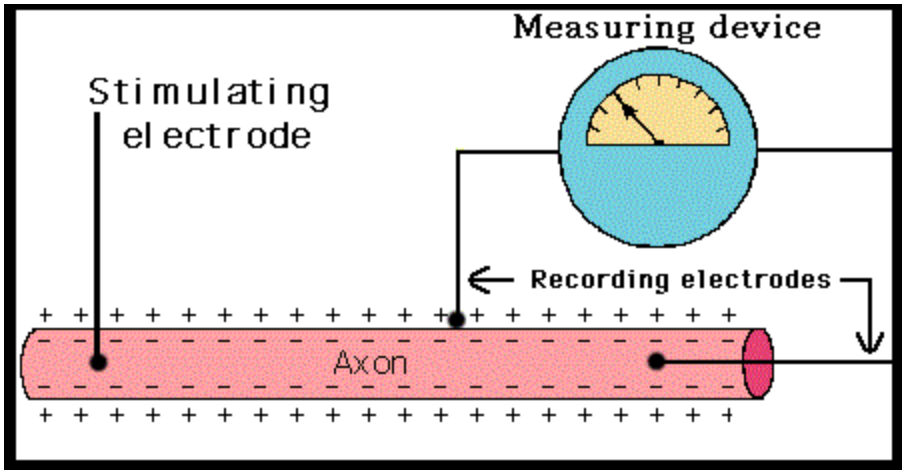


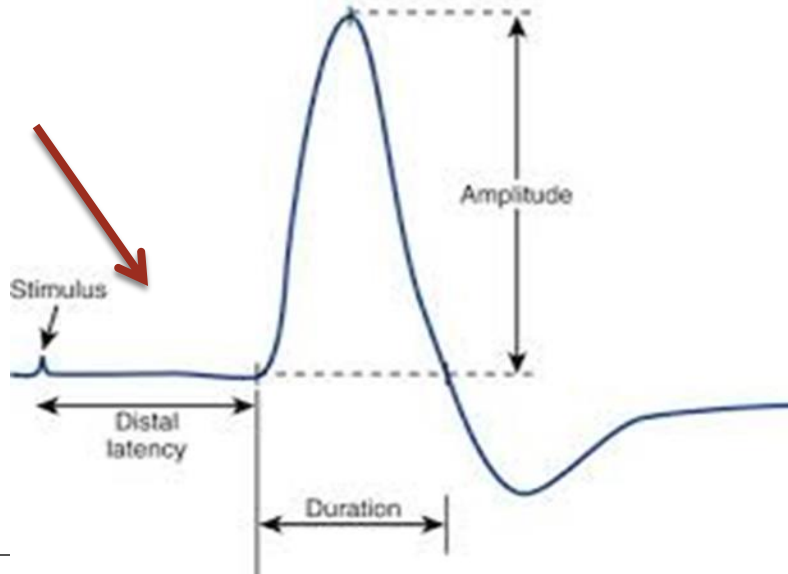



# (2) Latent period

- 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.

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



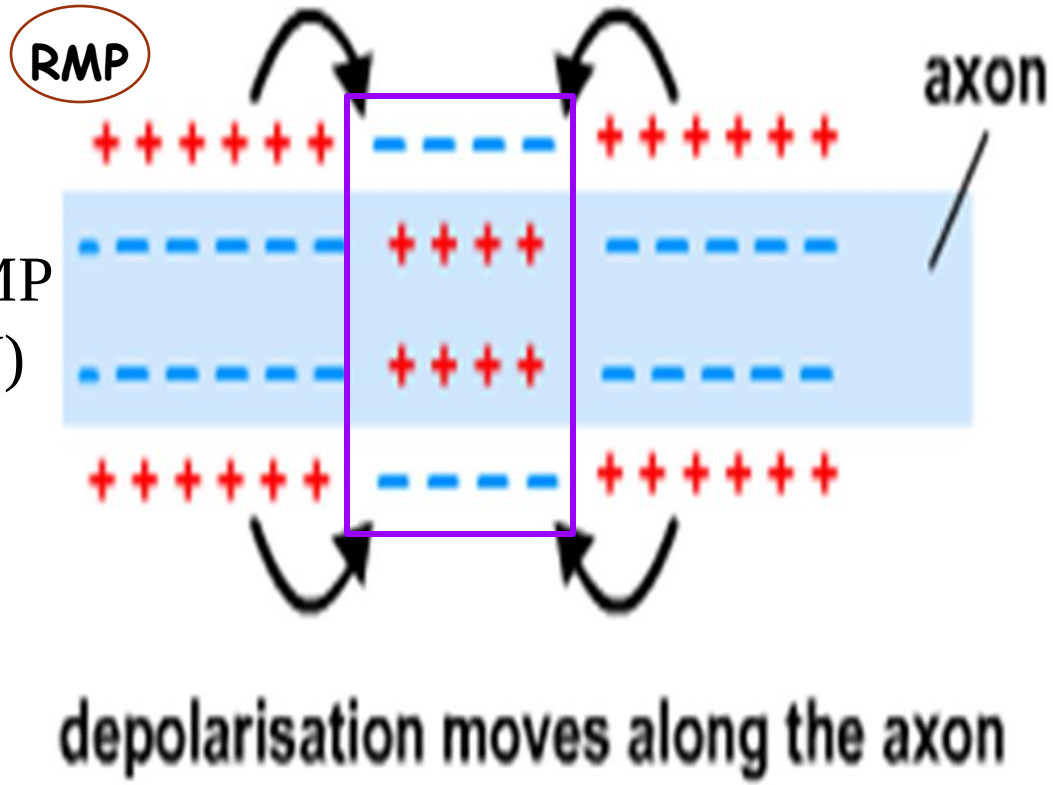



# (3) Depolarization

There is a rapid loss or (reversal) of polarity of the membrane.

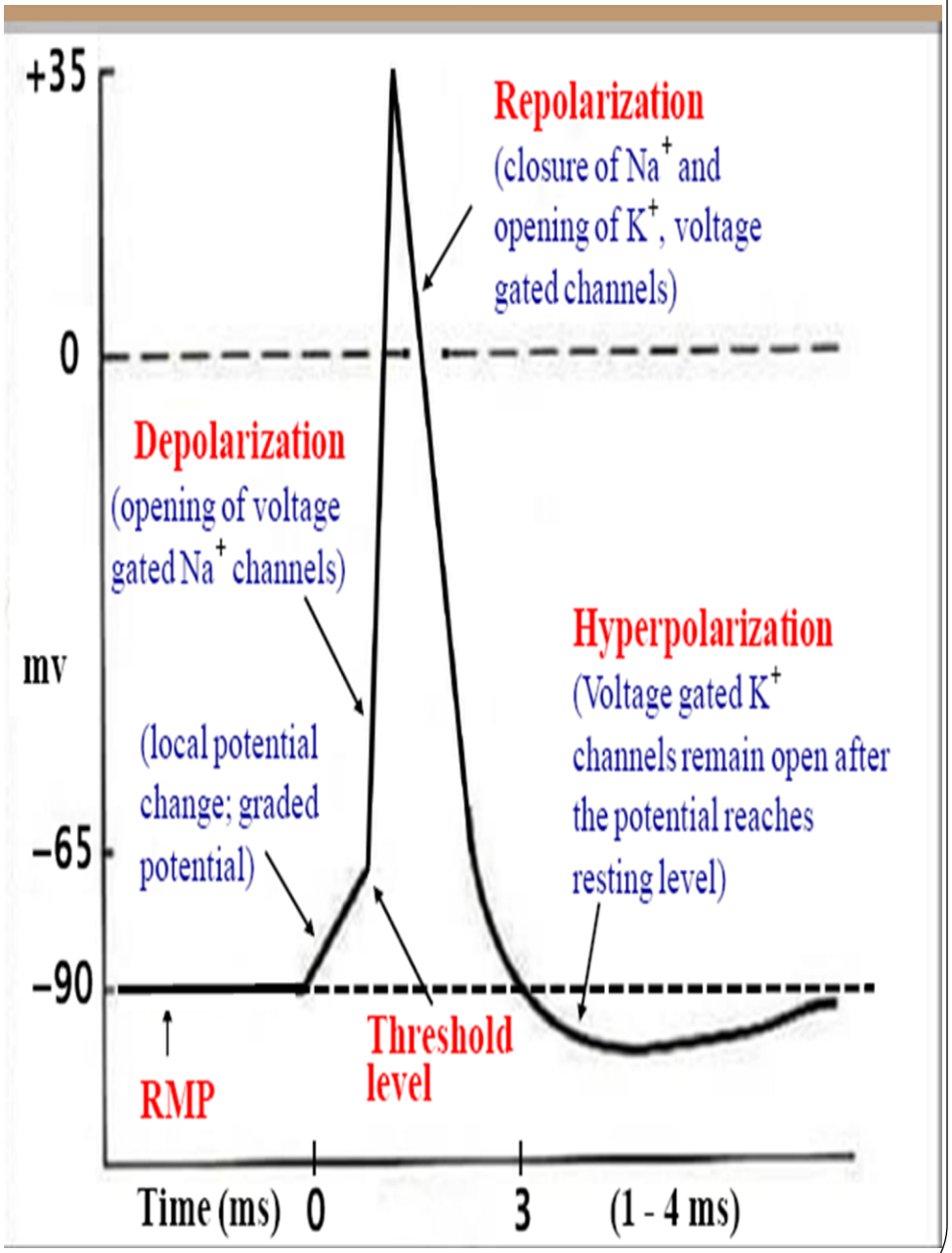
It is recorded as a rise of membrane potential in the positive direction.

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



# Depolarization steps:

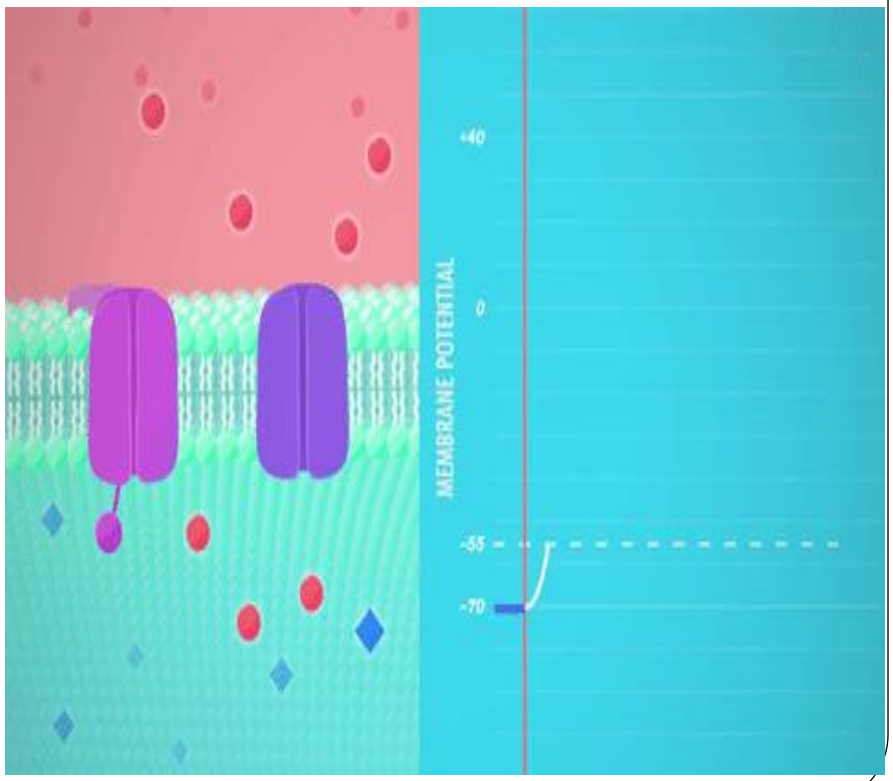
- At -65 mV (***Firing level***), the depolarization occurs rapidly till the potential reaches zero mV (no deference between inside and outside the cell membrane).
- Then, the inside becomes positive to the outside of the membrane i.e. reversal of polarity (**overshoot**) till +35 mV.



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

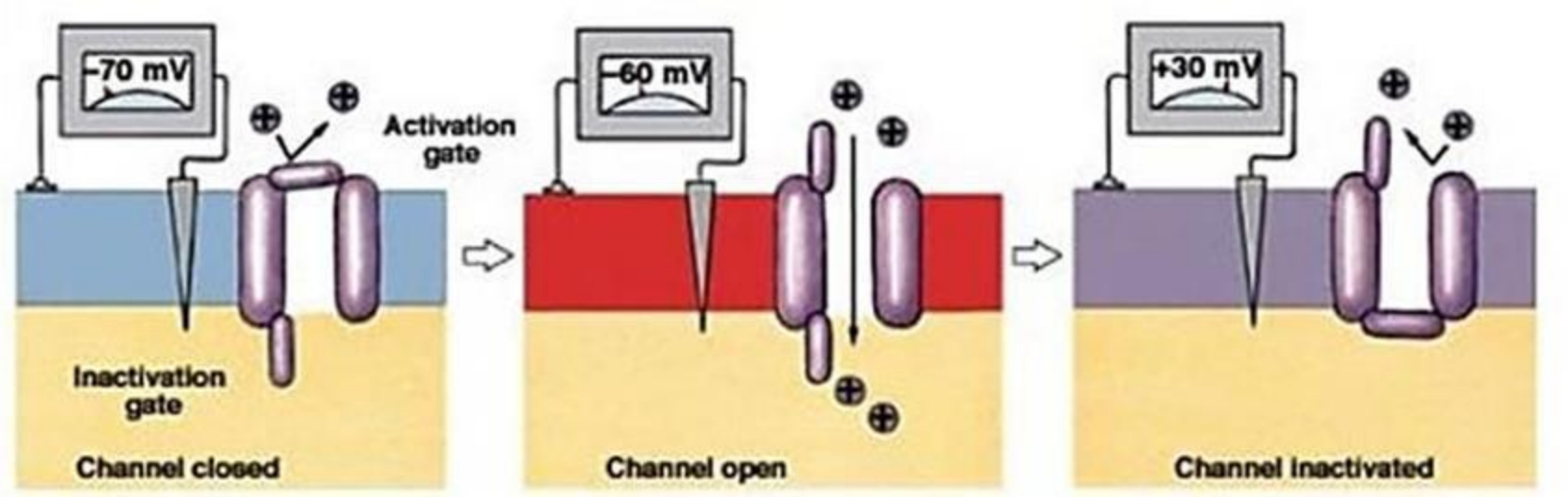
## Cause of depolarization:

- ✓ 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).

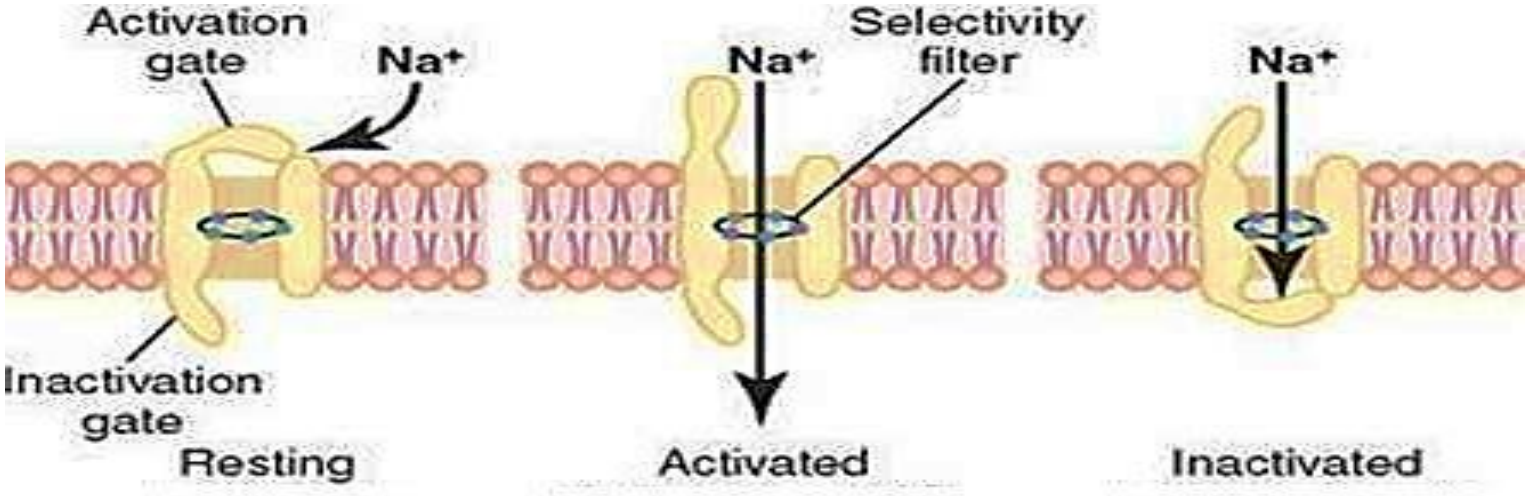


# Changes in voltage-gated fast Na+ channels and Na+ permeability during action potential:

- **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.

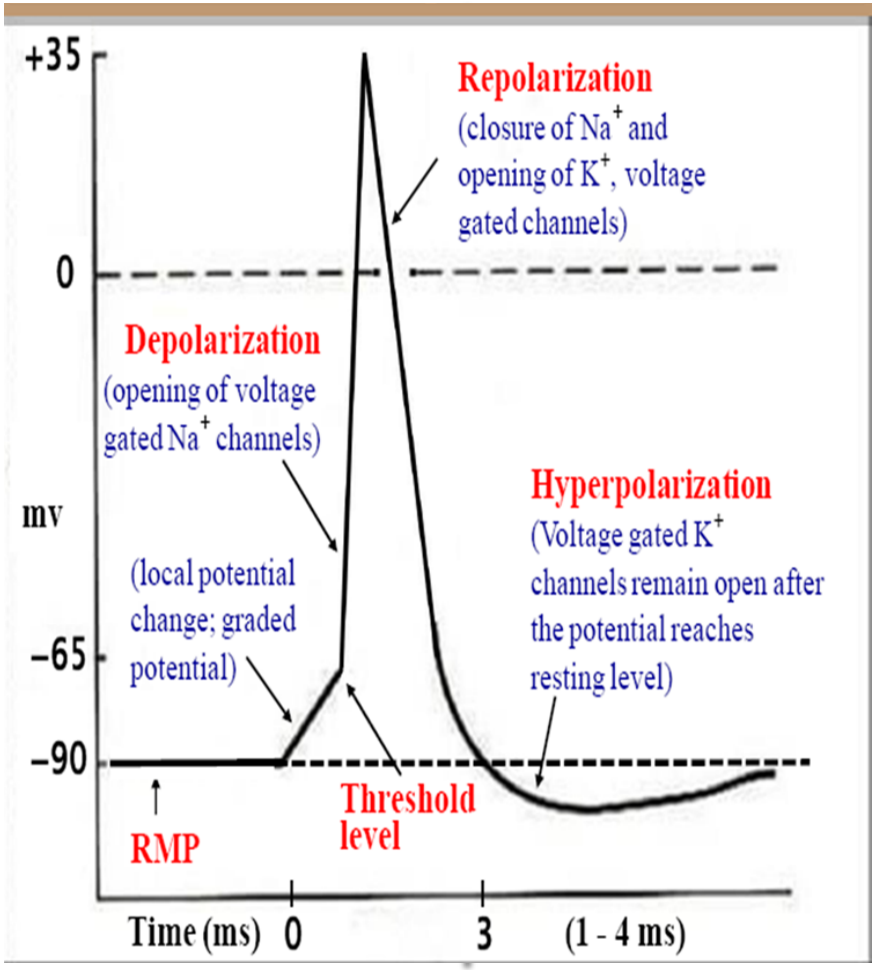


# (4) Repolarization

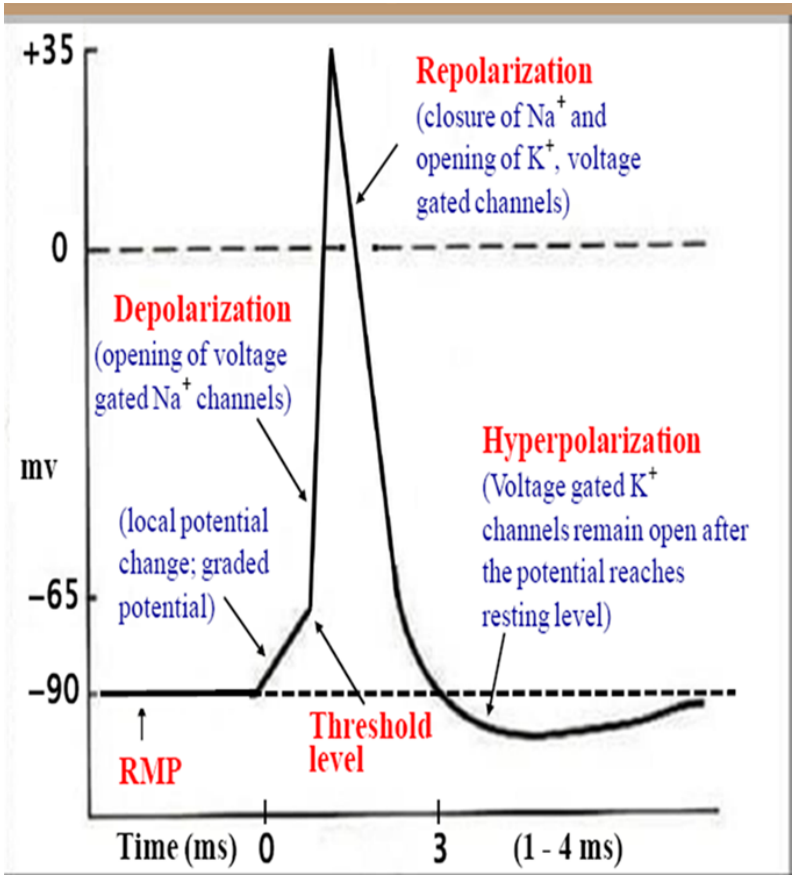
It is the return of the membrane potential to the resting state (from +35 to –90 mV).

It occurs in **3 steps:**

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



# 1. Rapid repolarization:

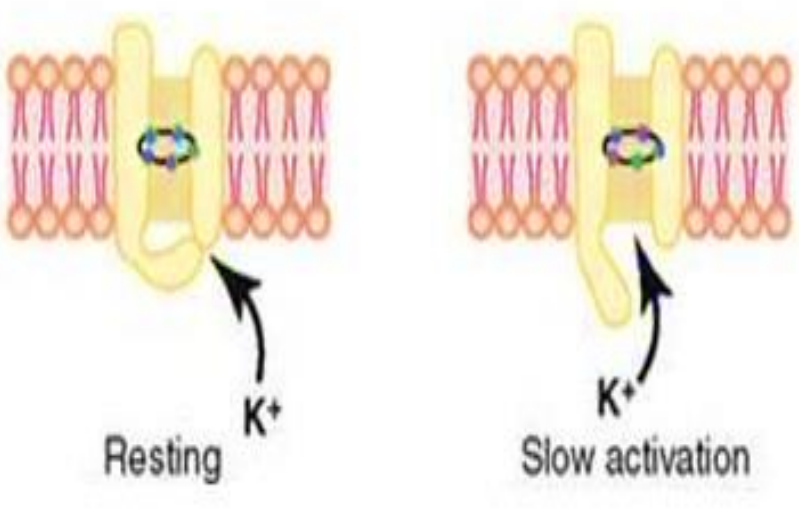


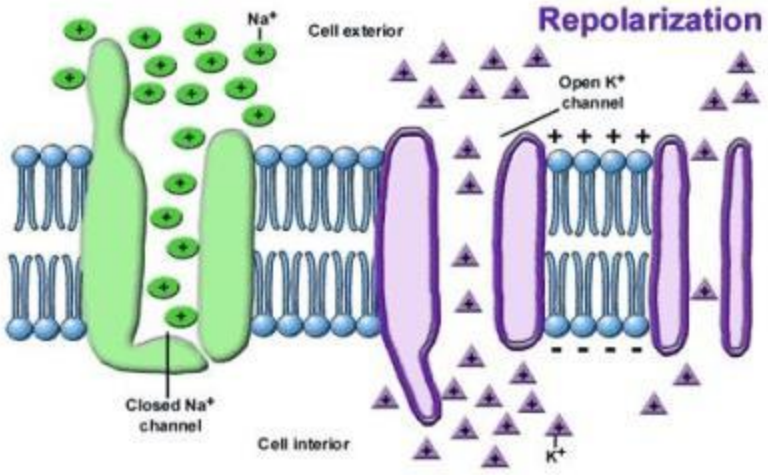

- During which the membrane restores 70% of its resting condition.
- ***Cause:***
- a) Inactivation of voltage gated Na+ channels so, Na+ influx stopped.
- b) Activation of voltage gated K+ channels so, K+ outflux increased.

# 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.



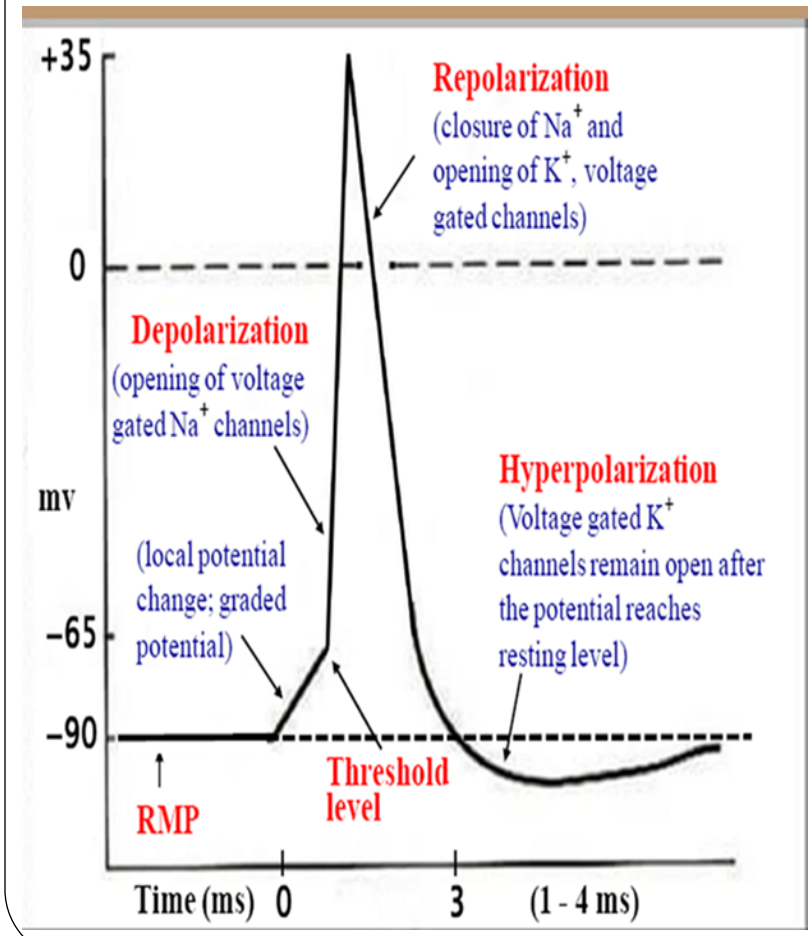



# Note that:

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.

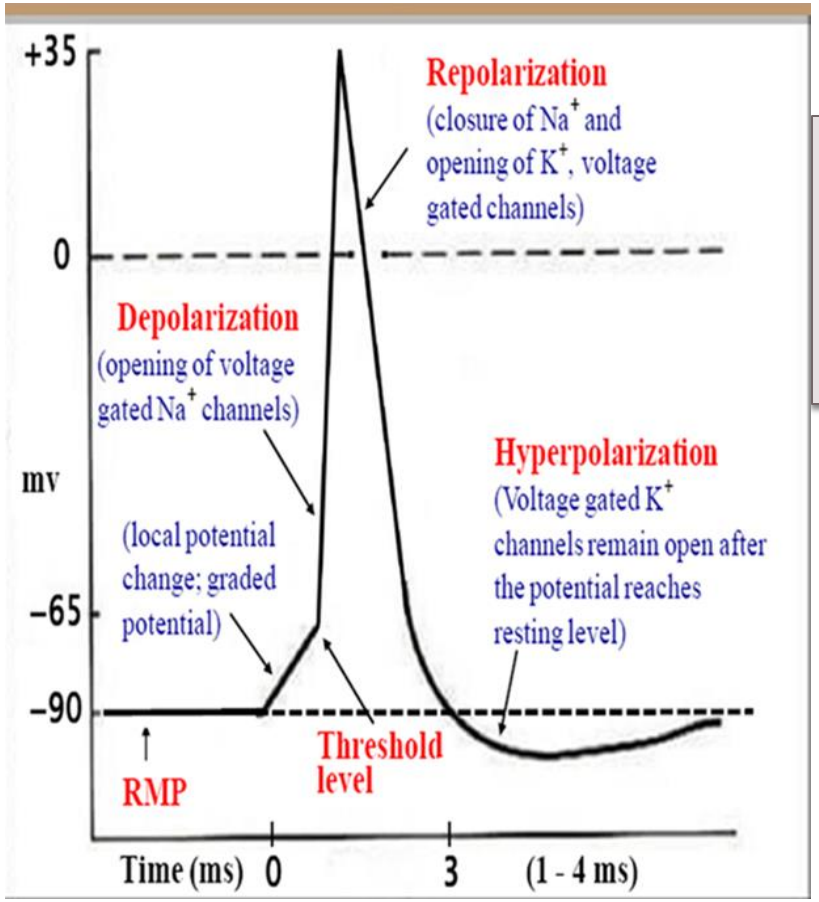



**Cause:**

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.**

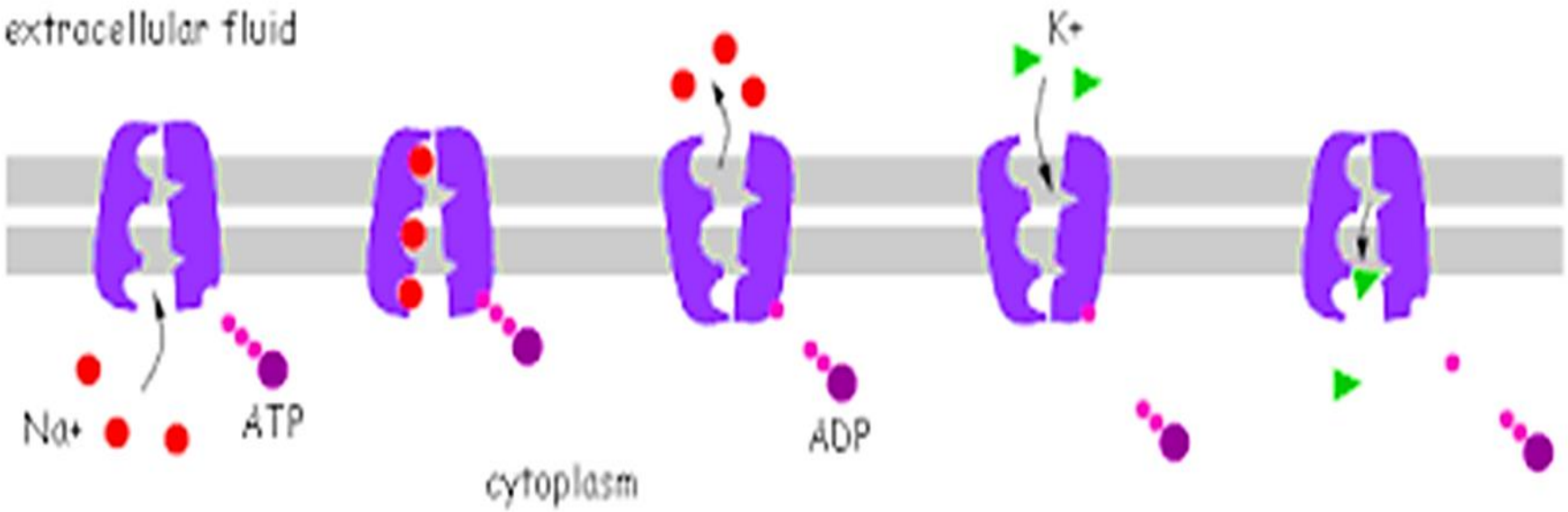



**Cause**: Delayed K+ channels closure

→ 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 → response (low excitability).

- Coincides with lower 2/3 of rapid repolarization.

## 3- Supernormal phase:

- Weak stimulus → response (high excitability).

- Coincides with the Slow repolarization

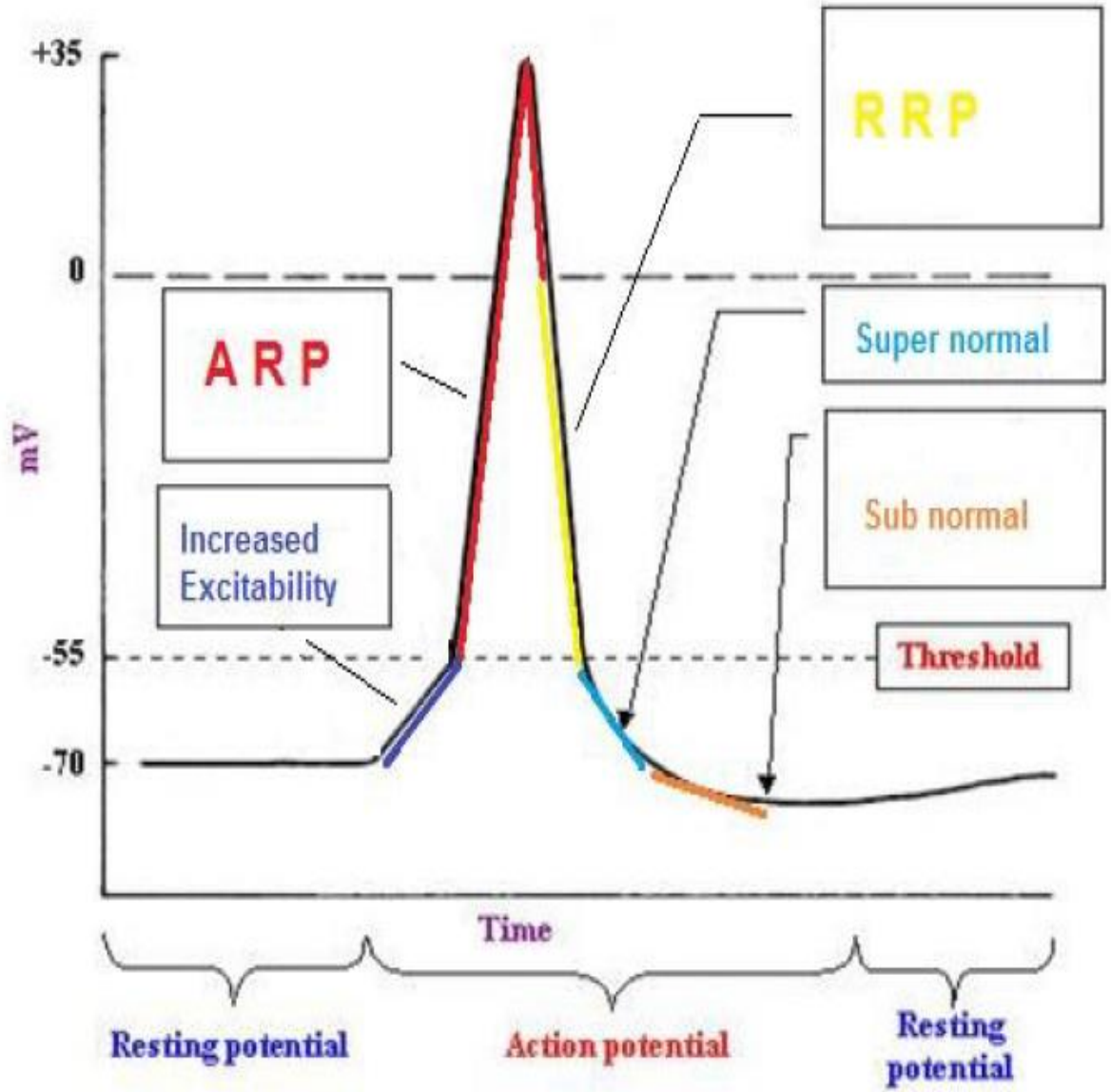
- During it, the membrane is partially depolarized and has low threshold for firing level.

## 4- Subnormal phase:

-Stronger stimulus → response (low excitability).

- Coincides with the hyperpolarization

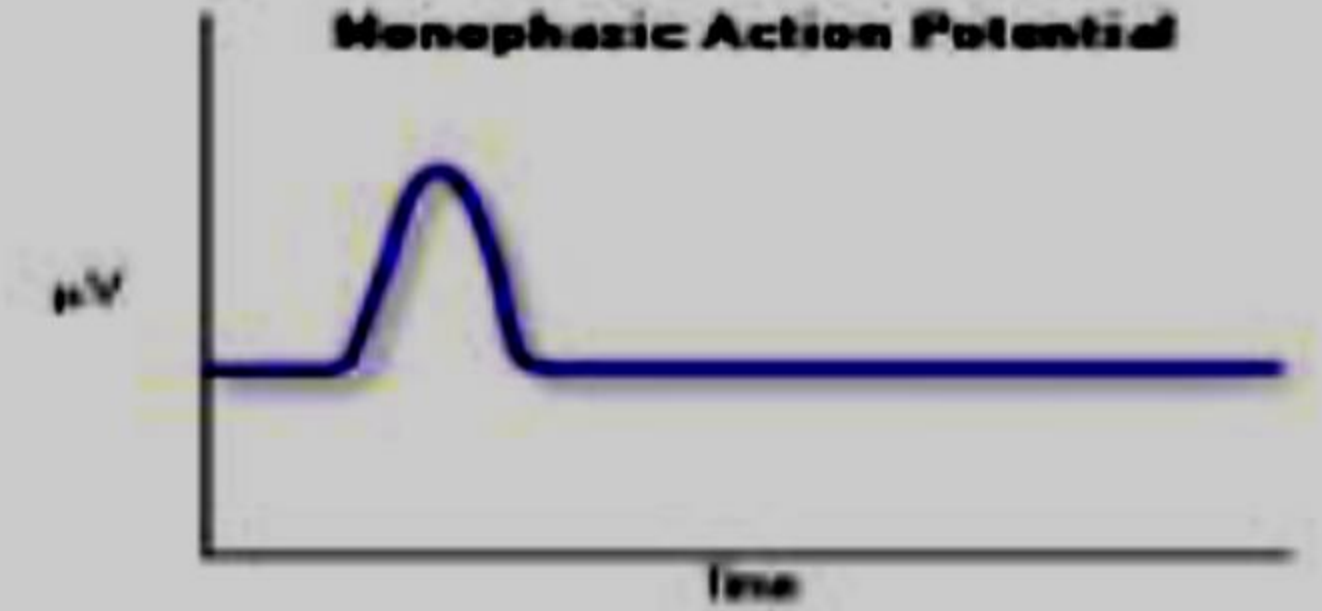
- During it, the membrane is hyperpolarized with increase threshold for firing level and difficult stimulation.


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

# Types of action potential:

## *1-Monophasic action potential:*

it is the recording of potential difference between inside and outside the nerve fiber membrane at one point.


Monophasic Action Potential
μV
Time

# 2- Biphasic action potential

It is the potential changes between 2 points (A & B) on the outer surface of the nerve fiber membrane by using 2 microelectrodes connected to galvanometer .

**The stimulus is applied near the A point.**

**- It consists of the following phases:**

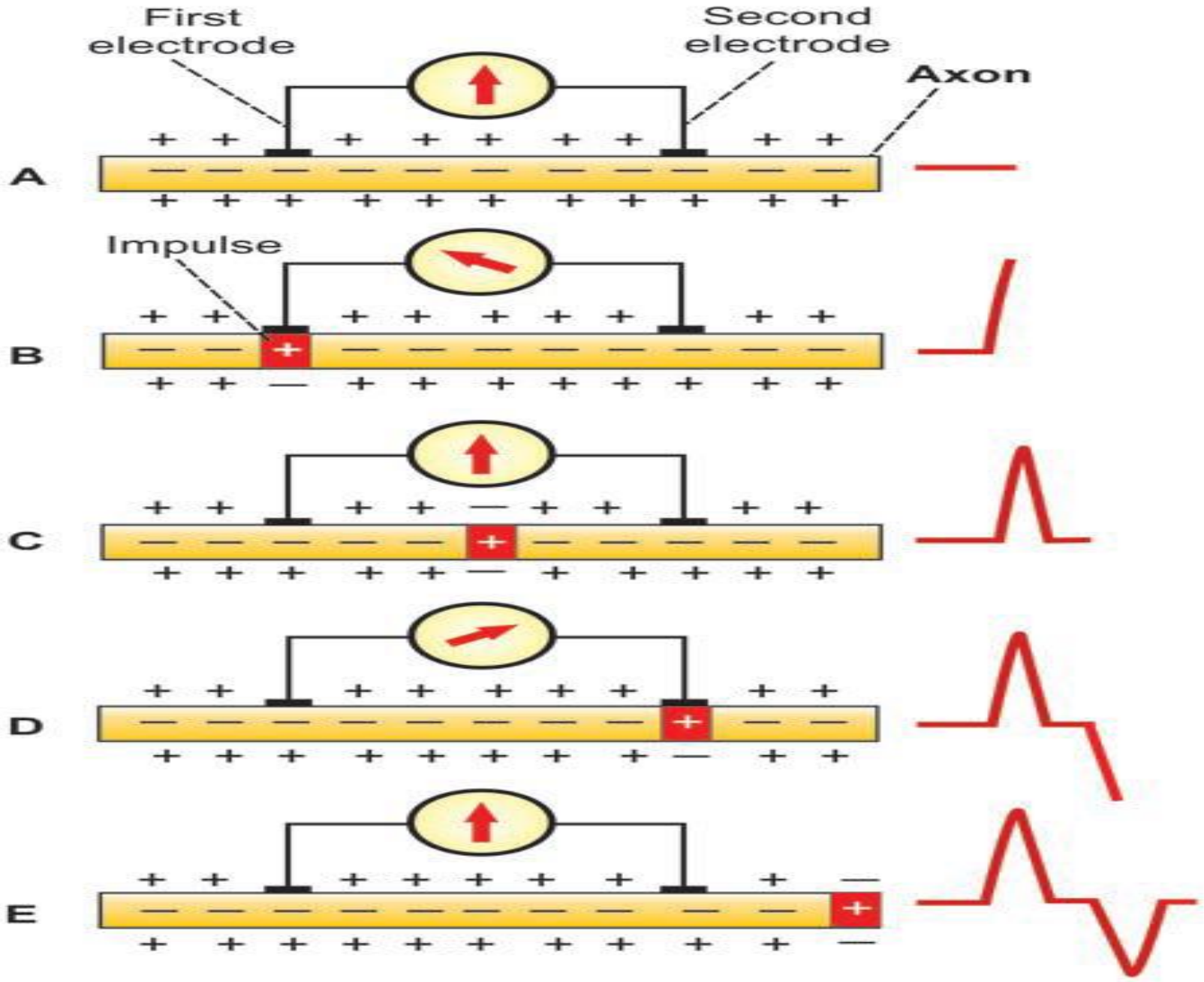
**1) At first, both (A) & (B) are +ve. So, no potential difference between A & B. (isoelectric).**

**2) When depolarization wave reach (A) it becomes (-ve) relative to (B) (+ve). So, deflection is recorded.**

**3) When the depolarization wave leaves (A) it repolarizes to (+ve). So, no potential difference between A & B. (isoelectric).**

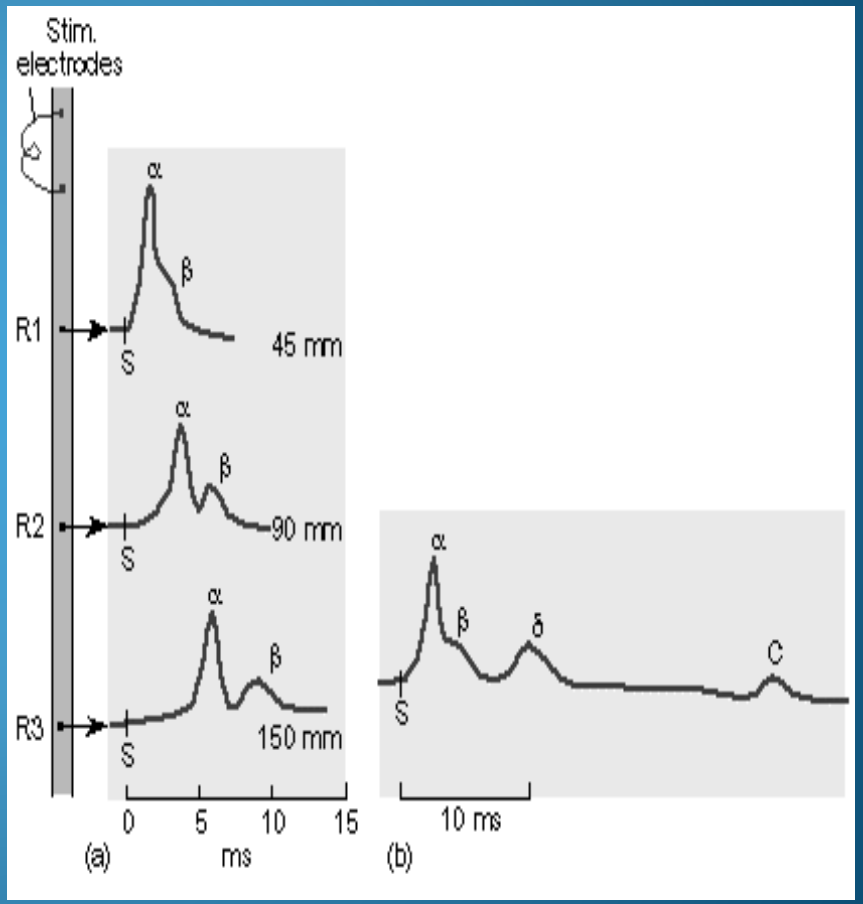
**4) When depolarization wave reach (B) it becomes (-ve) relative to (A) (+ve). So, deflection is recorded in the opposite direction.**

**5) When the depolarization wave leaves (B) it repolarizes to (+ve). So, no potential difference between A & B. (isoelectric).**


First electrode
Second electrode
Axon
A
Impulse
B
C
D
E

# 3-Compound action potential:

If a mixed nerve is stimulated → multiple peaks of action potentials as **the threshold** of stimulus, **distance from electrode** and **speed of conduction** vary from one fiber to another according to its thickness, till the maximal stimuli is reached, all nerve fibers are excited giving maximal response.



As the **mixed nerve** consisted of **many nerve fibers**, these fibers have different diameters and excitability.

- So, stimulation of the mixed nerve depends on the intensity of stimulus and is called the ***compound action potential*:**

1-Subthreshold stimulus → no response.

2-Threshold stimulus → potential changes of some more excitable fibers.

3-Suprathreshold stimulus → more fibers are excited with more response.

4-Maximal stimuli → all fibers are excited and give maximal response.

5-Supramaximal stimuli → the same maximal response.

# Action potential in skeletal muscle

Similar to the nerve with the following differences

| | Muscle | Nerve |
|---|---|---|
| - RMP | - 90 mV. | - 70 mV. to – 90 |
| - Firing level | - 70 mV. | - 55 mV or - 65 |
| - Overshoot | + 40 mV | + 35 mV |
| -Amplitude of A.P. | 130 mV | 105 mV or 125 |
| - Duration of spike P. | 2-4 msec | 2 msec |
| - Rate of conduction | 5 meter/sec | Variable |
| - Chronaxia | Long (less excitable) | Short (more excitable) |


Thank you