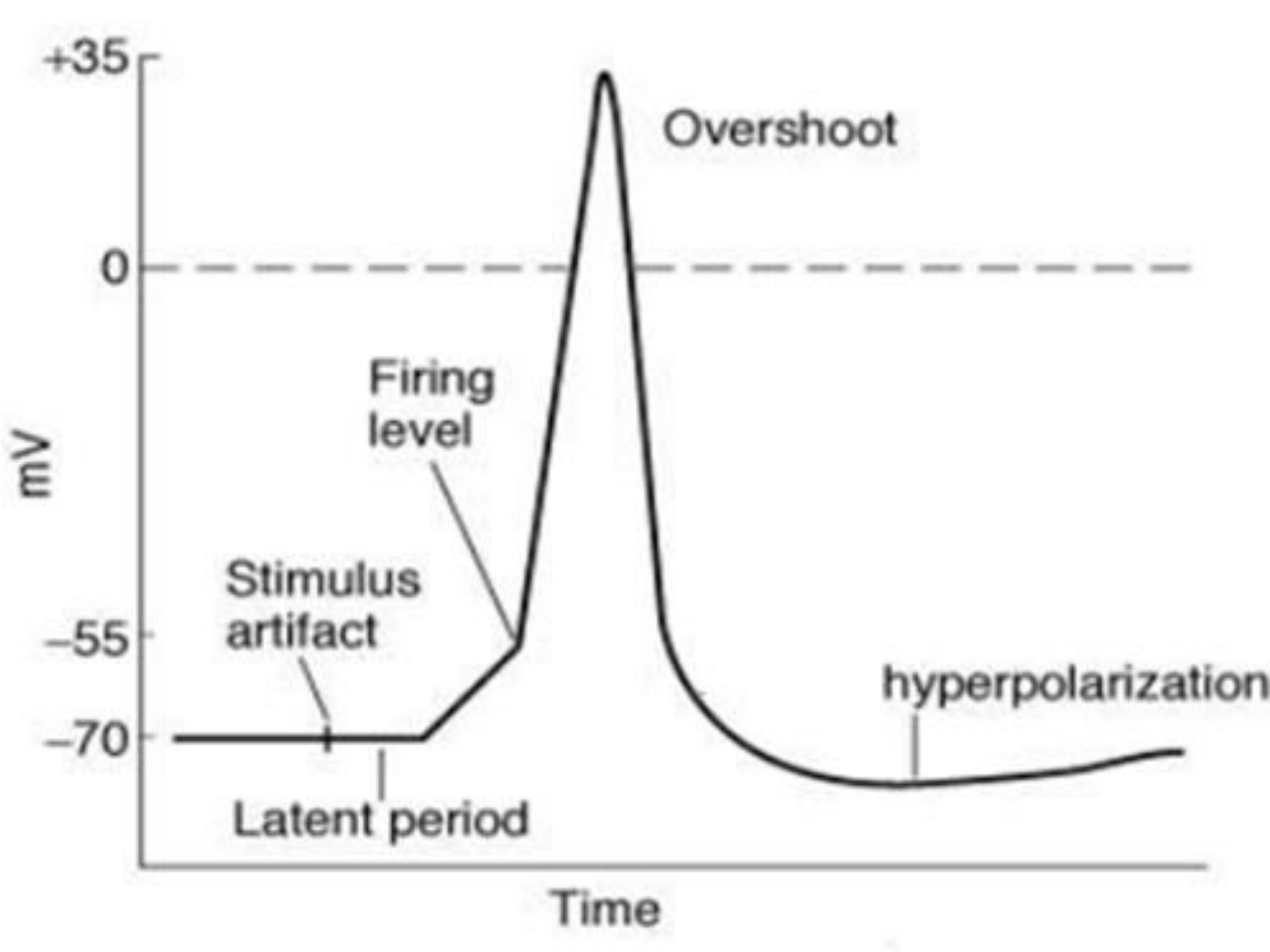
Action Potential

Action Potential

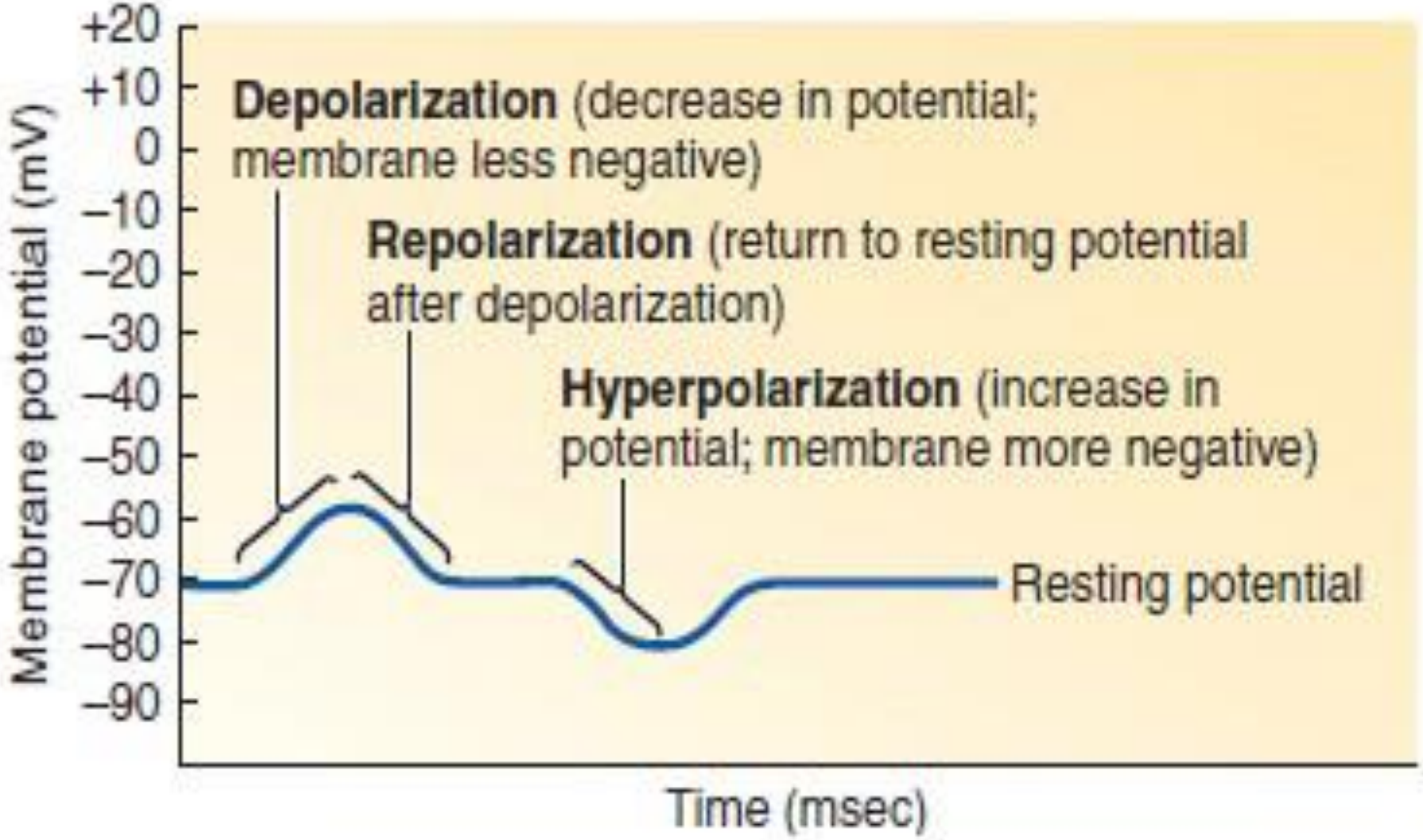
- An **action potential** is rapid depolarization followed by repolarization of membrane after a **threshold/supra-threshold stimulus** is applied to an excitable membrane **(nerve & muscle).**
- **Phases of action potential:**

1. Stimulus artifact
2. Latent period
3. Firing level/Threshold
4. Depolarization
5. Repolarization
6. Hyperpolarization

- Electrical signals are critical to the function of nervous system.


+35
0
–55
–70
mV
Overshoot
Firing level
Stimulus artifact
Latent period
hyperpolarization
Time

Types of changes in membrane potential



- Different kinds of stimuli may be utilized for excitation such as: **electrical,** mechanical, chemical, thermal, sound or light, etc.

Latent period:

- It is a time it takes the impulse to travel along the axon from site of stimulation to recording electrode.

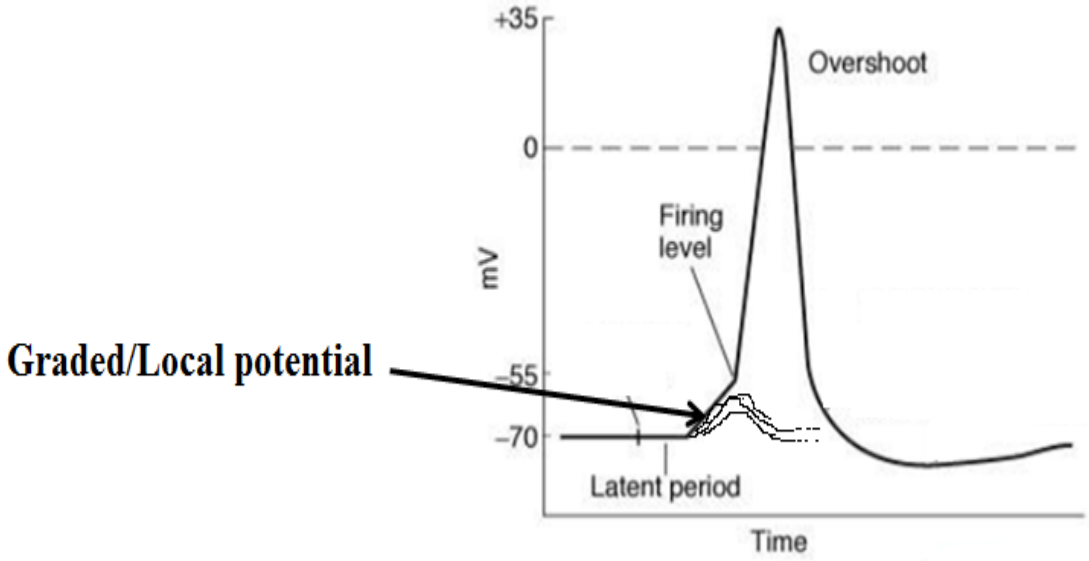
Threshold Potential (firing level):

- **It** refers to “magnitude” of depolarization of excitable membrane **at which membrane undergoes spontaneous changes in permeability** to different ions which leads to generation of an action potential.

- Threshold stimulus
- Depolarization
- Threshold potential
- Action potential

- subliminal stimulus (subthreshold)

Graded Depolarization



Graded Potential	Action potential
• It generated at the site of stimulation is called graded potential. • They serve as short distance signals & their strength decreases with distance & time. • These are not propagated.	• Action potential is rapid depolarization followed by repolarization of membrane after a **threshold/supra-threshold stimulus** is applied to an excitable membrane **(nerve & muscle).** • These potentials are propagated over long distances. • No decrement or change in size/shape of action potential.

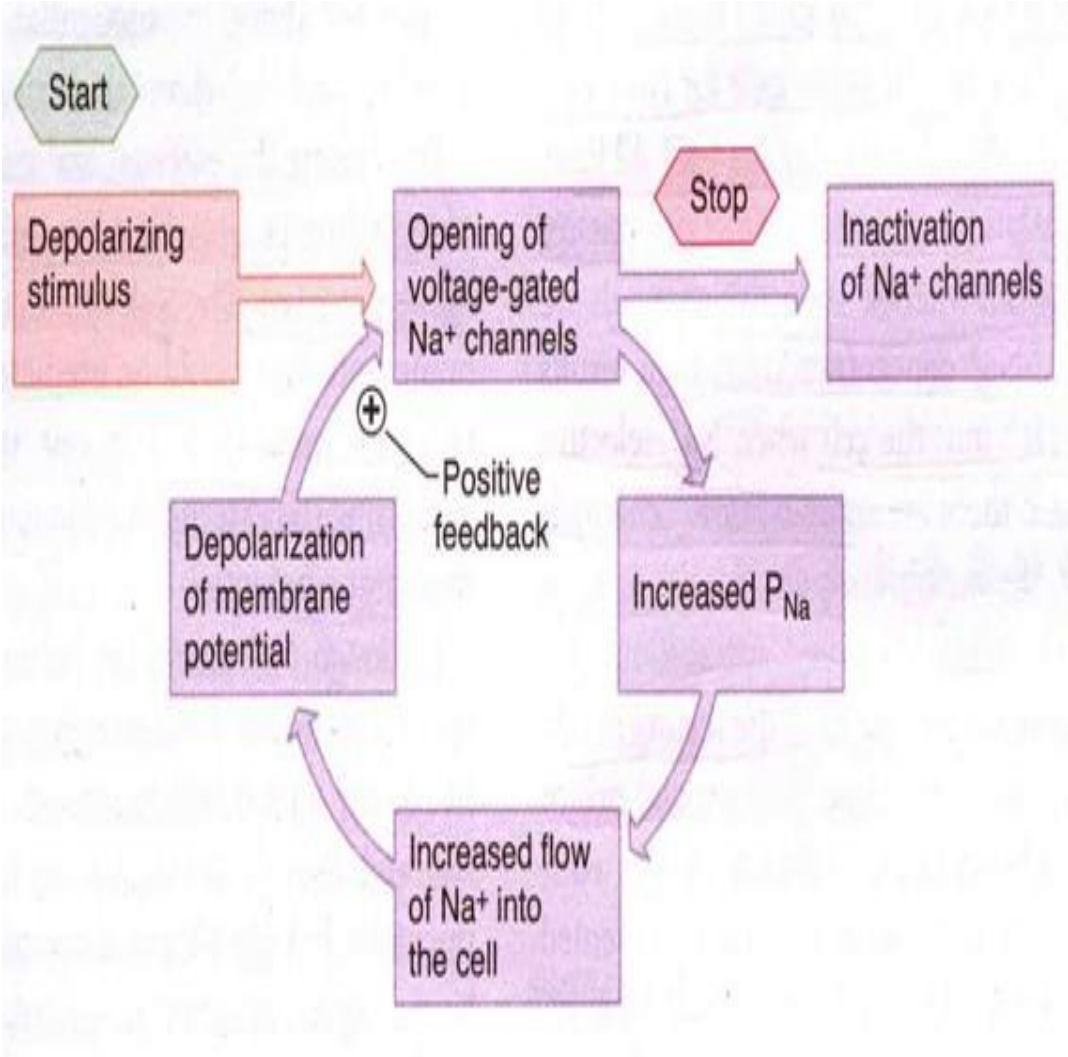
Graded potentials die out over short distances. However, when their magnitude is sufficient, they lead to generation of action potential.

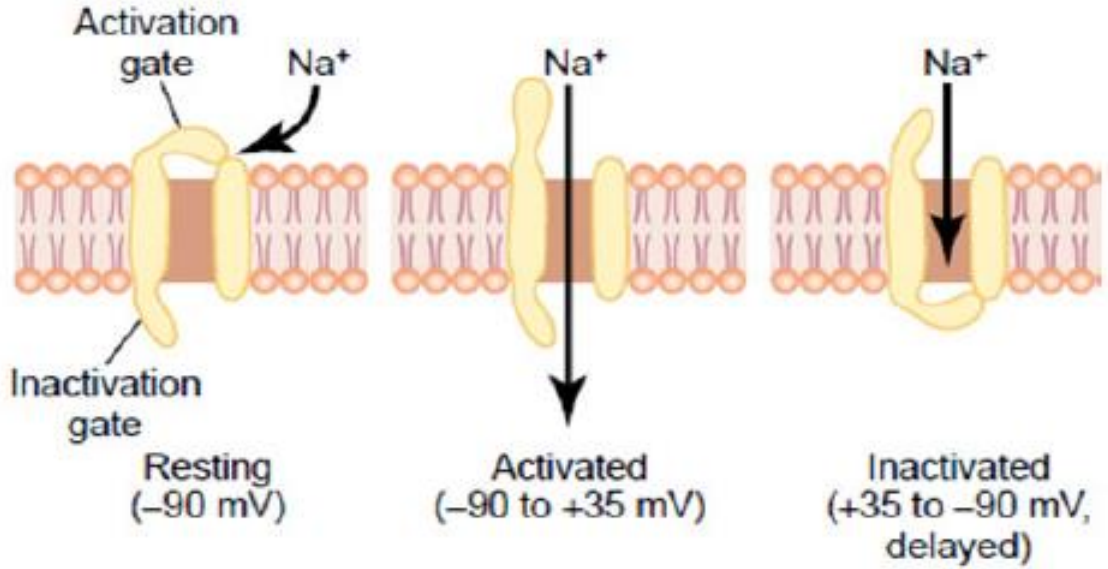
The following graded potentials:

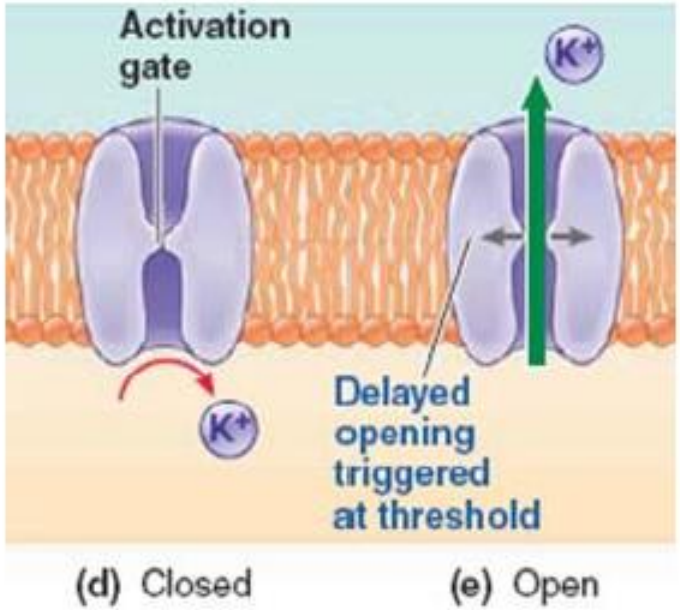
- ***Generator/receptor potential-*** *cutaneous sensory receptors,*
- ***End plate potential-*** *skeletal muscle.*
- ***Post synaptic potential-*** *synapse.*
- ***pacemaker potentials-*** *heart.*
- ***slow-wave potentials-*** *GI smooth muscle.*

Ionic basis of action potential

- Action potentials take place as a result of opening and subsequent closing of two specific types of channels.
- Na+ channels that are closed at resting membrane potential (RMP) open rapidly upon depolarization allowing Na+ entry that further depolarizes the membrane and potentiates additional Na+ channel opening **positive feedback.**

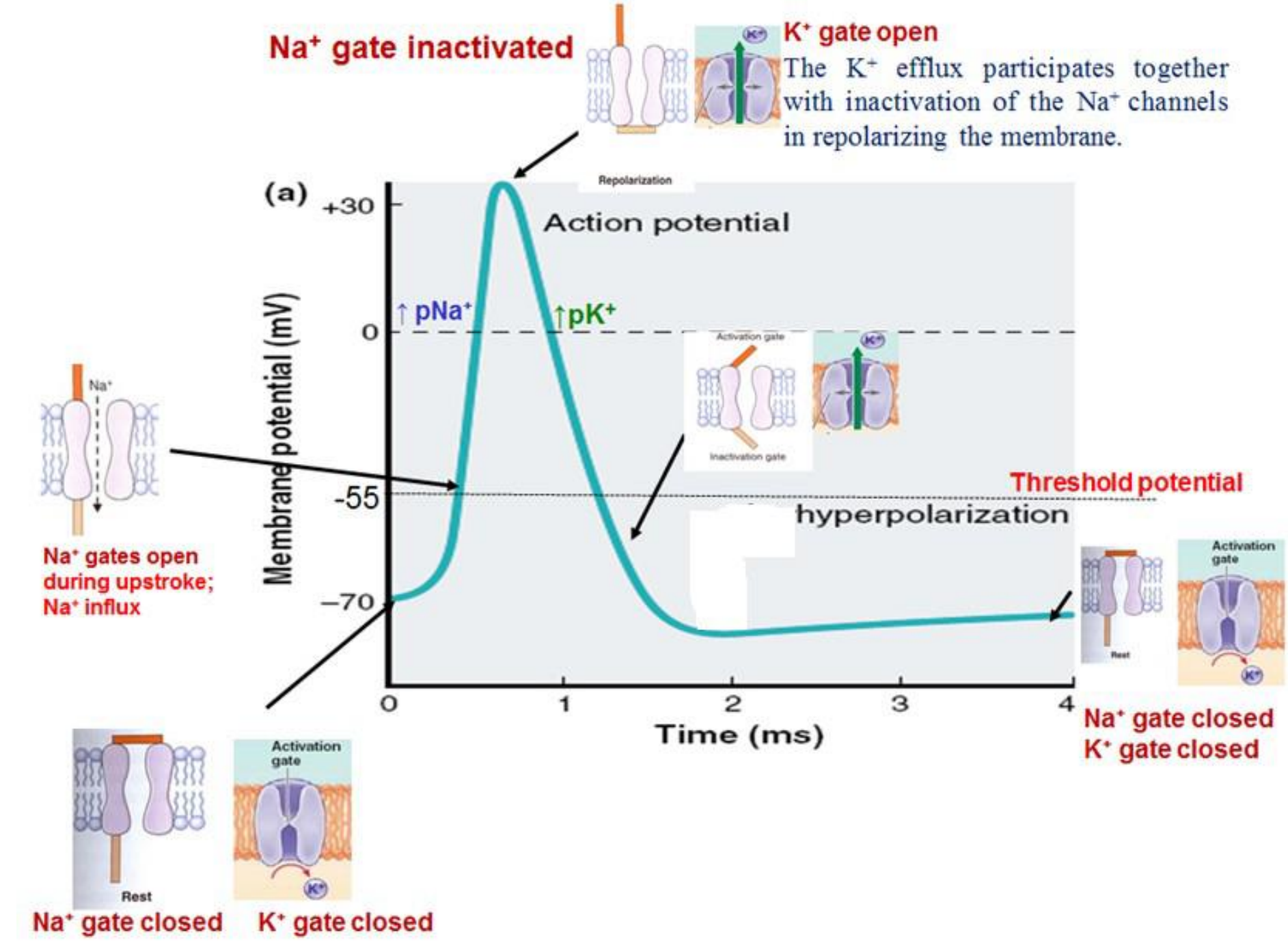






Voltage-gated Na^+ channels

Voltage-gated K^+ channels


Na⁺ gate inactivated
K⁺ gate open
The K⁺ efflux participates together with inactivation of the Na⁺ channels in repolarizing the membrane.
(a)
Repolarization
Action potential
+30
0
-55
–70
↑ pNa⁺
↑pK⁺
Membrane potential (mV)
Activation gate
Inactivation gate
Threshold potential
hyperpolarization
Na⁺
Na⁺ gates open during upstroke; Na⁺ influx
0
1
2
3
4
Time (ms)
Rest
Activation gate
Na⁺ gate closed
K⁺ gate closed
Rest
Activation gate
Na⁺ gate closed
K⁺ gate closed

Ionic basis of action potential

- Action potential generated by sequential changes in membrane permeability to ions (Na+ & K+).

A) Resting (polarized) state:

- At the resting state; inside of membrane is negative & outside is positive as K+ permeability is greater than Na+ permeability.

B) Depolarization:

- Depolarization state, Membrane becomes very permeable to Na+ ions, allowing tremendous numbers of positively charged Na+ ions to diffuse to interior of axon via **Voltage gated Na+ channels.**

C) **Repolarization:**

- It starts with **K+ efflux** due to opening of **voltage gated K+ channels** & decreases in further Na+ influx. It re-establishes the normal negative resting membrane potential (RMP).

D) Hyperpolarization:

- It is occurs due to **late closure of voltage gated K+ channels, more K+ efflux** {potential is even more negative than resting membrane potential (RMP)}.
- **The Na+-K+ pump gradually restores the concentration gradients of ions disrupted by action potential.**

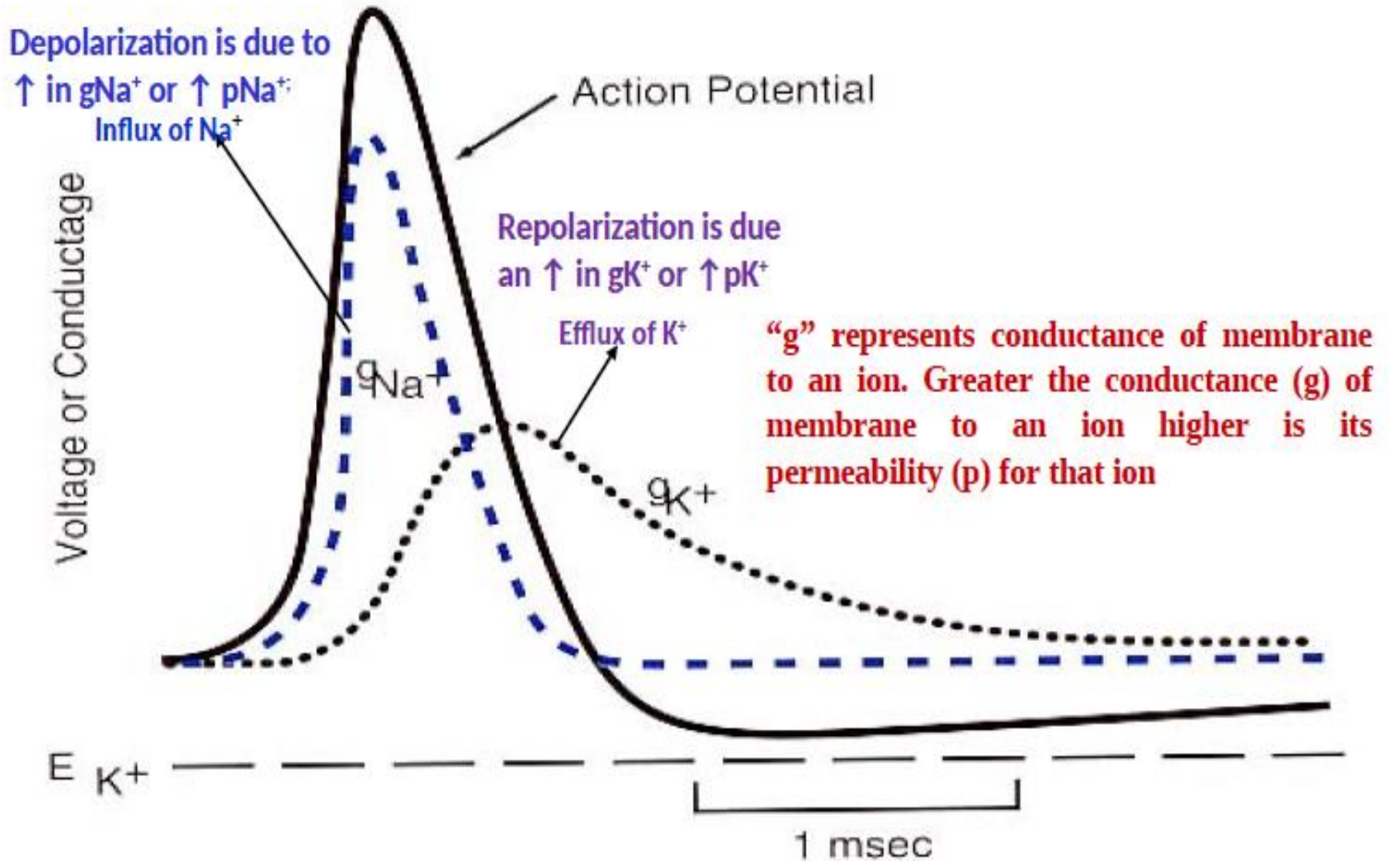


Figure: Time course of changes in **Na+-and K+** conductance that underlie the **nerve action potential**.

Duration of action potential

- Unlike variable duration of a graded potential, duration of an action potential is always the same in a given excitable cell.

– In a neuron, an action potential lasts for only 1 Millisecond (0.001 sec).

– It lasts longer in muscle, with the duration depending on muscle type (200 to 300 Millisecond in cardiac muscle cell).

Physiological effects of action potentials:

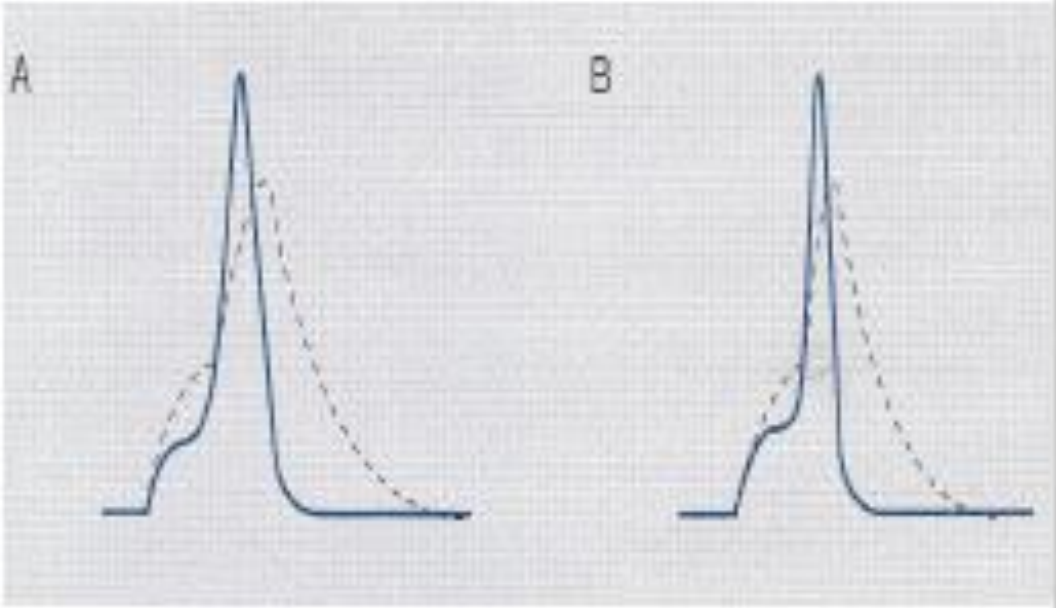
These include:

- Transmission of impulses along nerve fibers.
- Release of neurotransmitter or chemical transmitters in synapses
- Muscle contraction occurred.
- Activation or inhibition of glandular secretion.

Voltage gated Na^+ channels blocked by

A. Tetrodotoxin (TTX)

B. Local anesthetics (procaine, lidocaine)



Voltage gated K^+ channels blocked by

- Tetraethylammonium (TEA)