Bioelectric potentials: Action potential

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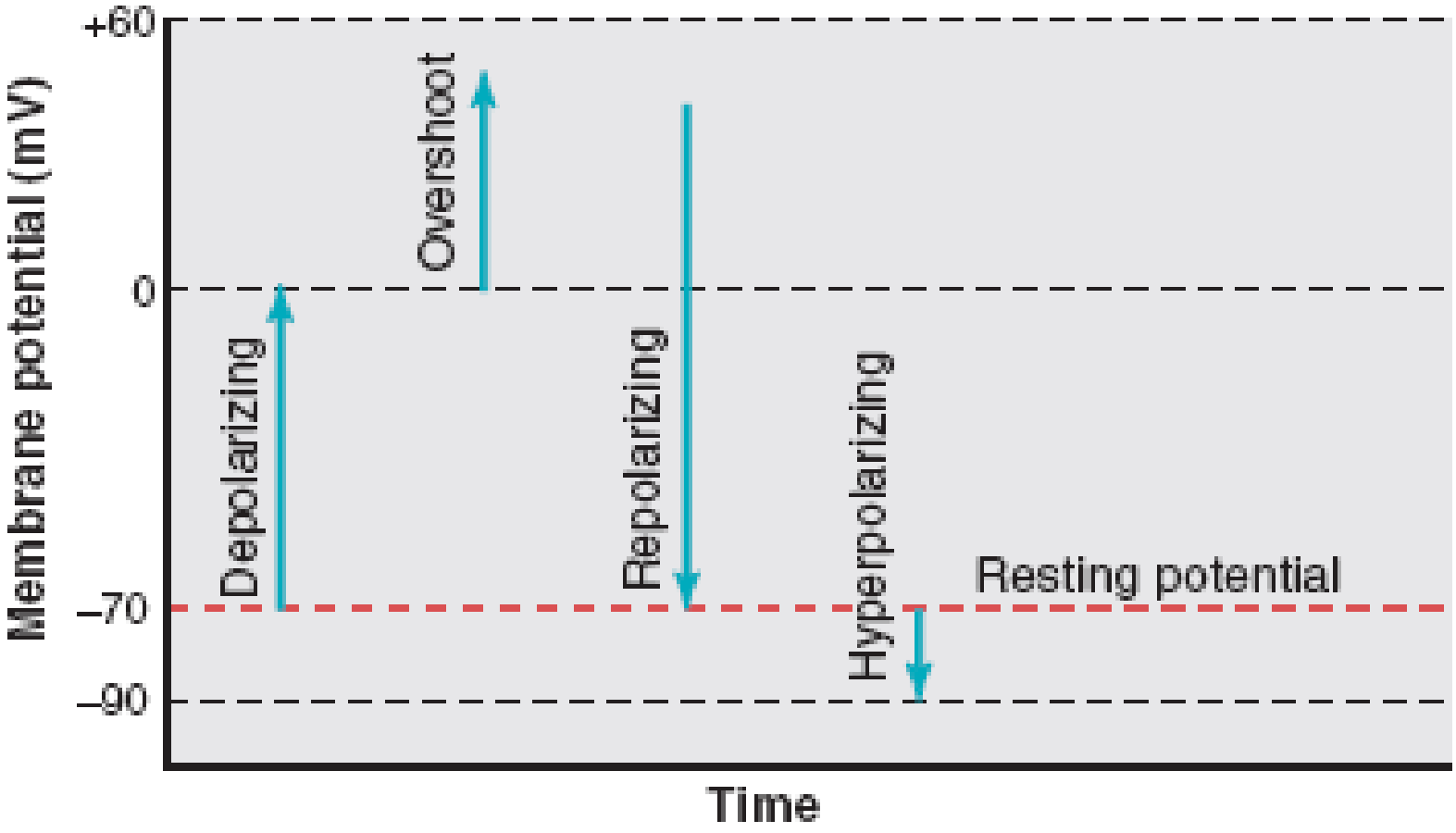
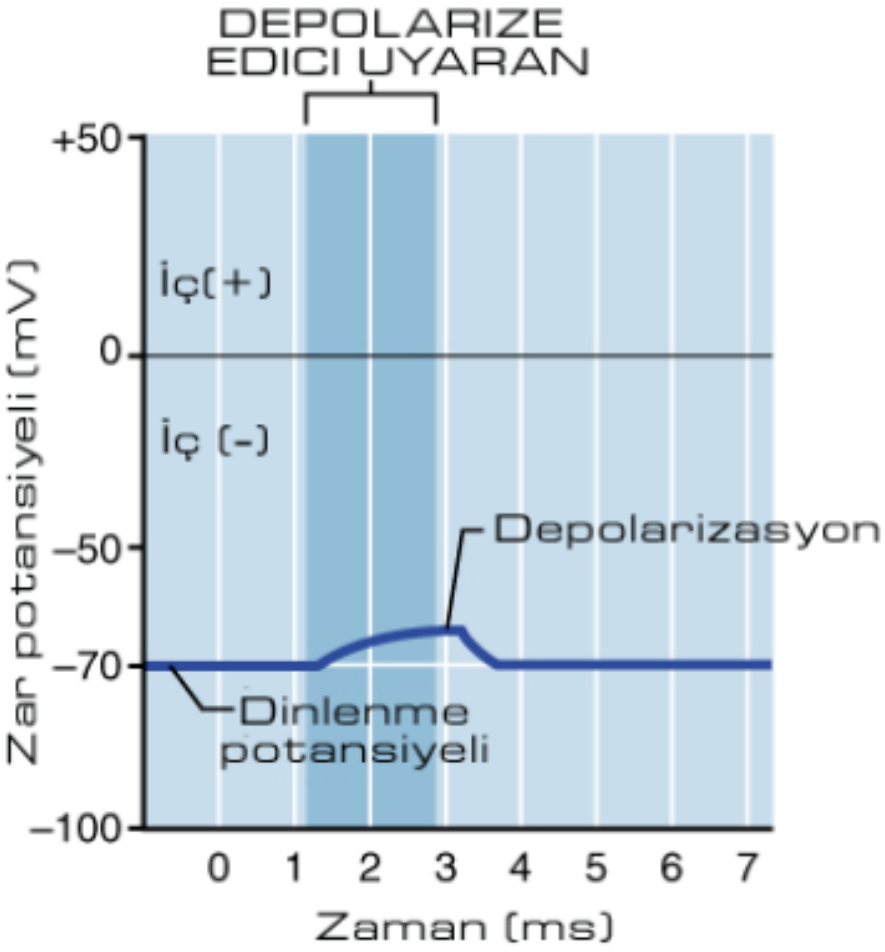
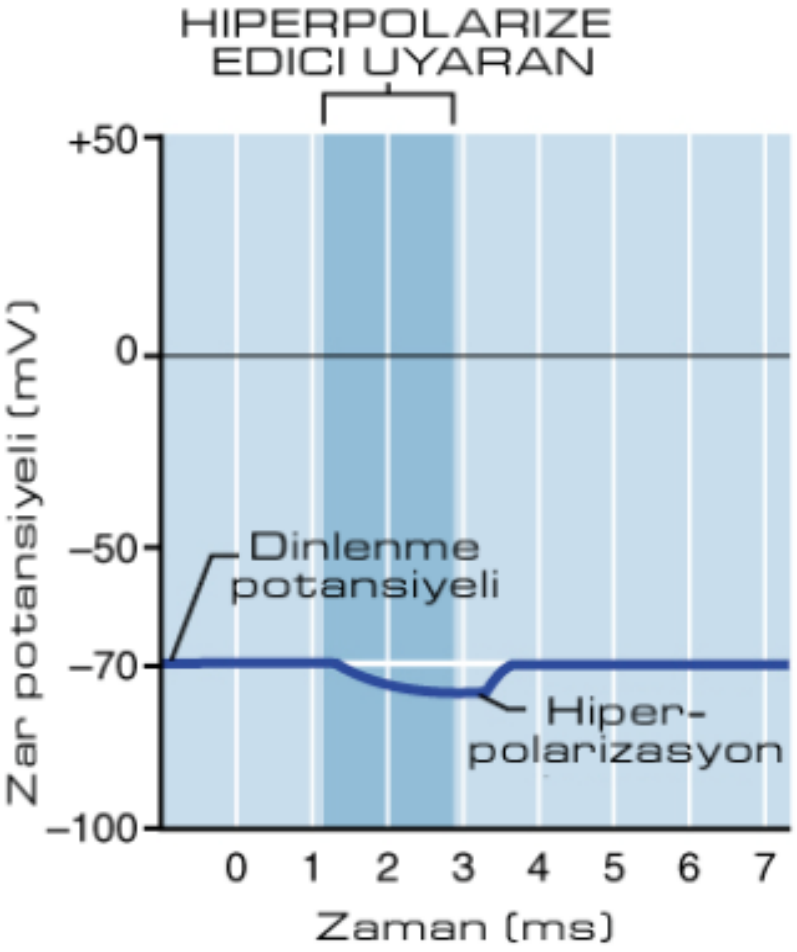
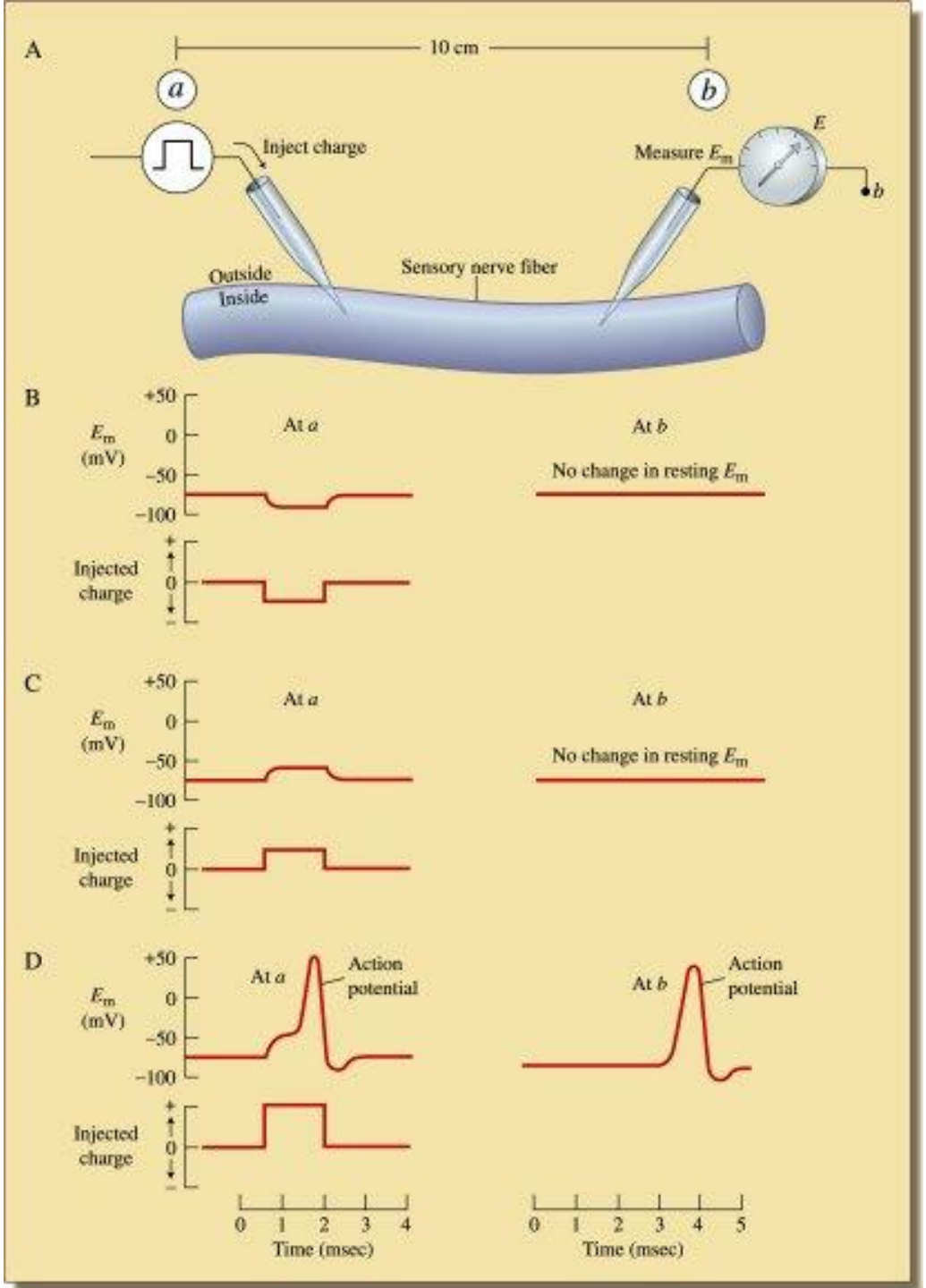
Terminology



Membrane potential changes



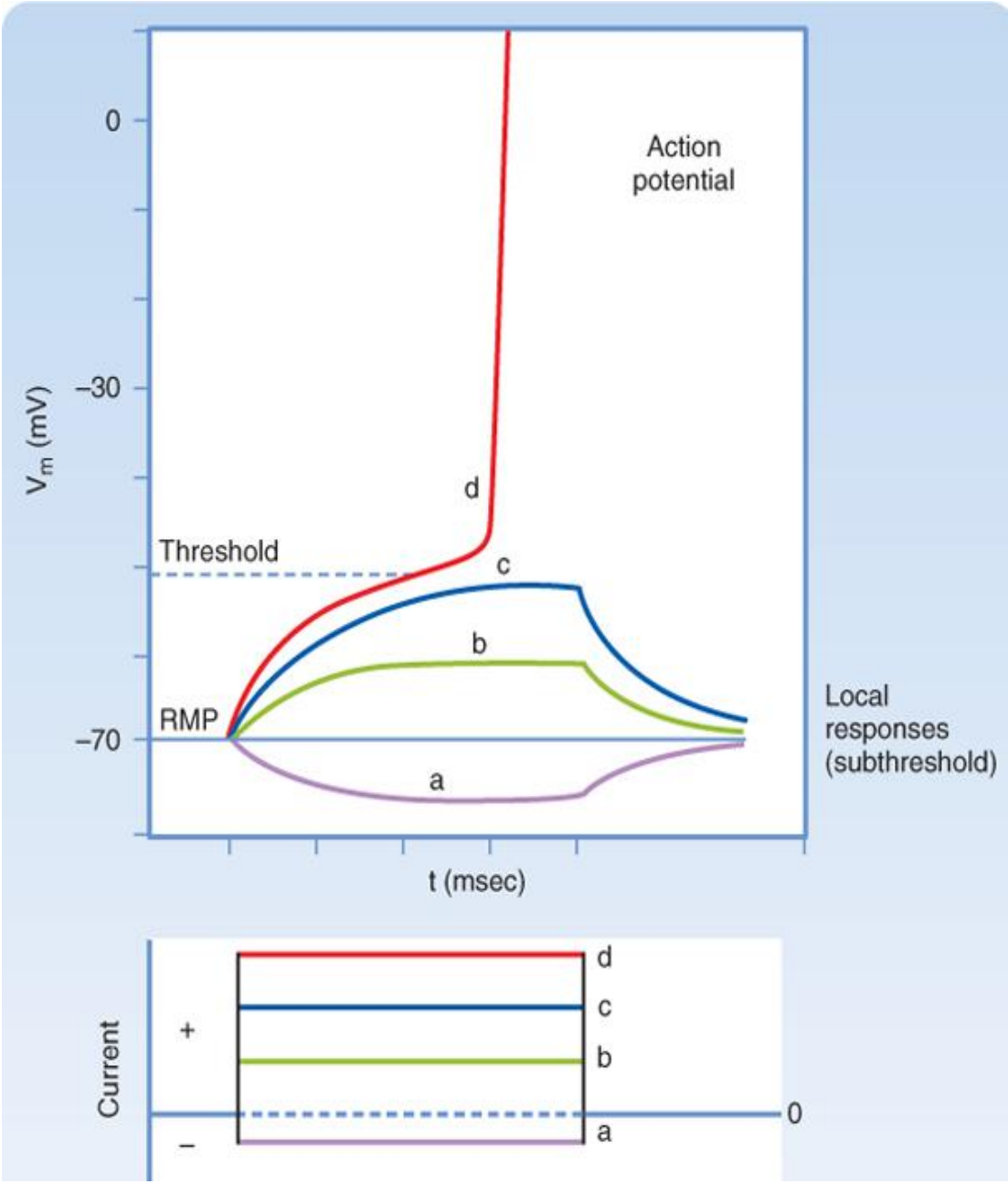




Stimulating electrode:
Introduces current that can depolarize or hyper-polarize

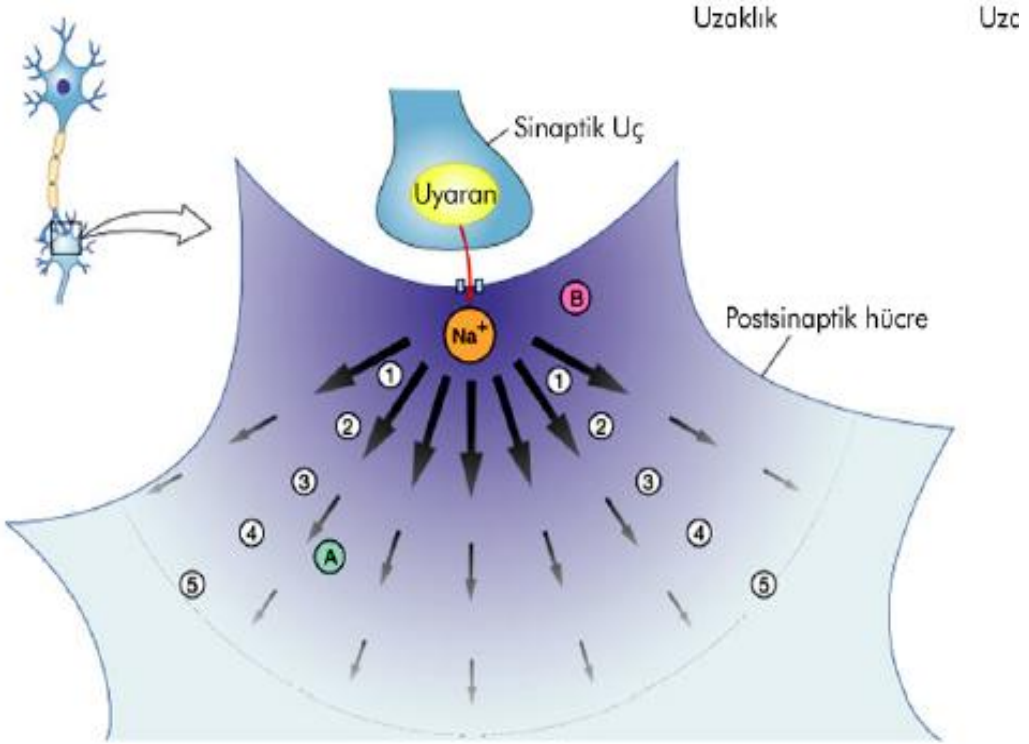
Recording electrode:
Records change in Potential of the membrane At a distance away

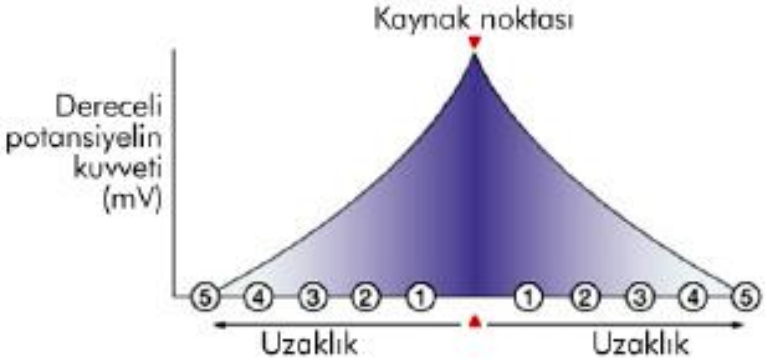
Membrane potential changes



Local potentials

- Different amp
- Amp ↓ by distance
- Different durations
- Summation
- Treshold Ø
- Excitatory
- Inhibitory

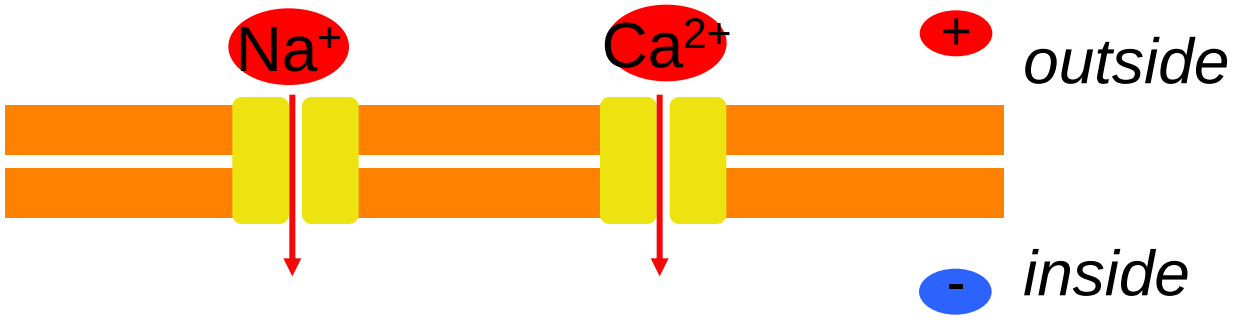




Receptor potentials
Synaptic potentials

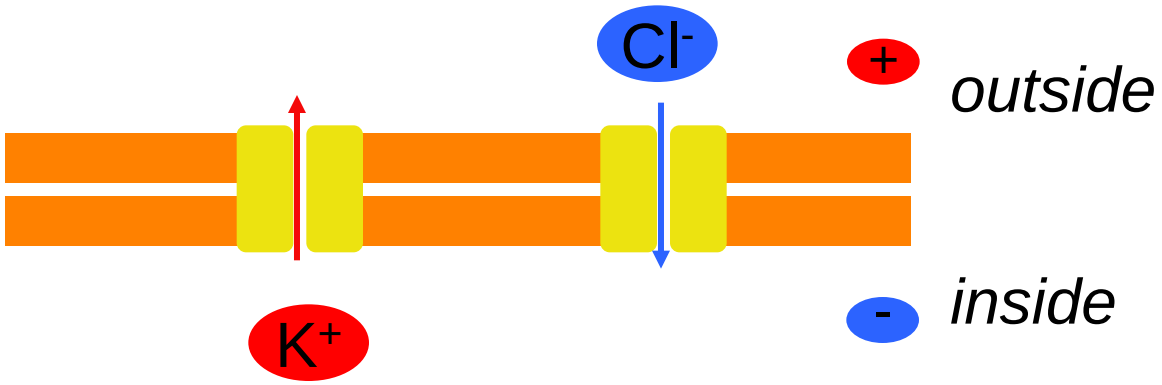
Excitatory postsynaptic potentials (EPSPs)

- Opening of ion channels which leads to **depolarization** makes an action potential *more likely*, hence "excitatory PSPs": **EPSPs.**
  - Inside of post-synaptic cell becomes **less negative**.
  - **Na^+ channels**
  - **Ca^{2+}** .



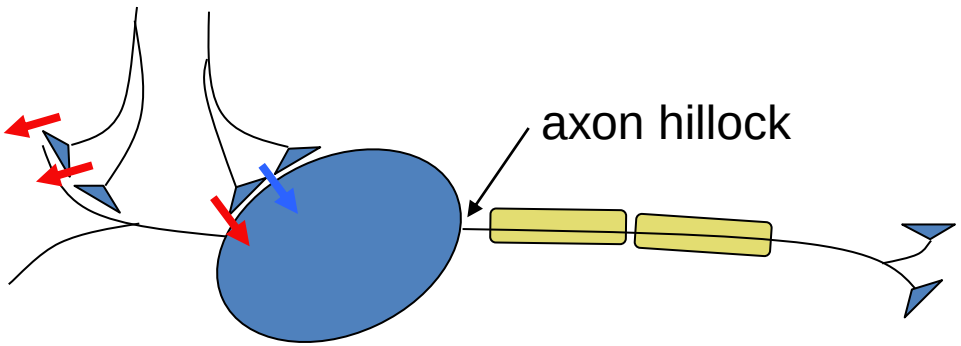
Inhibitory postsynaptic potentials (IPSPs)

- Opening of ion channels which leads to **hyperpolarization** makes an action potential *less likely*, hence "inhibitory PSPs": **IPSPs.**
  - Inside of post-synaptic cell becomes **more negative**.
  - **K^+**
  - **Cl^-** (if already depolarized)



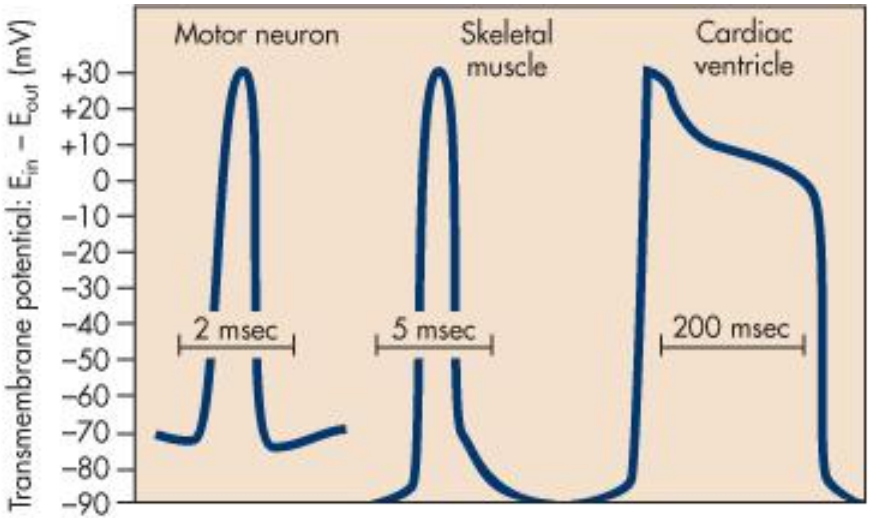
Integration of information

- PSPs are small. An individual EPSP will not produce enough depolarization to trigger an action potential.
- IPSPs will counteract the effect of EPSPs at the same neuron.
- **Summation** means the effect of many coincident IPSPs and EPSPs at one neuron.
- If there is sufficient depolarization at the **axon hillock**, an action potential will be triggered.

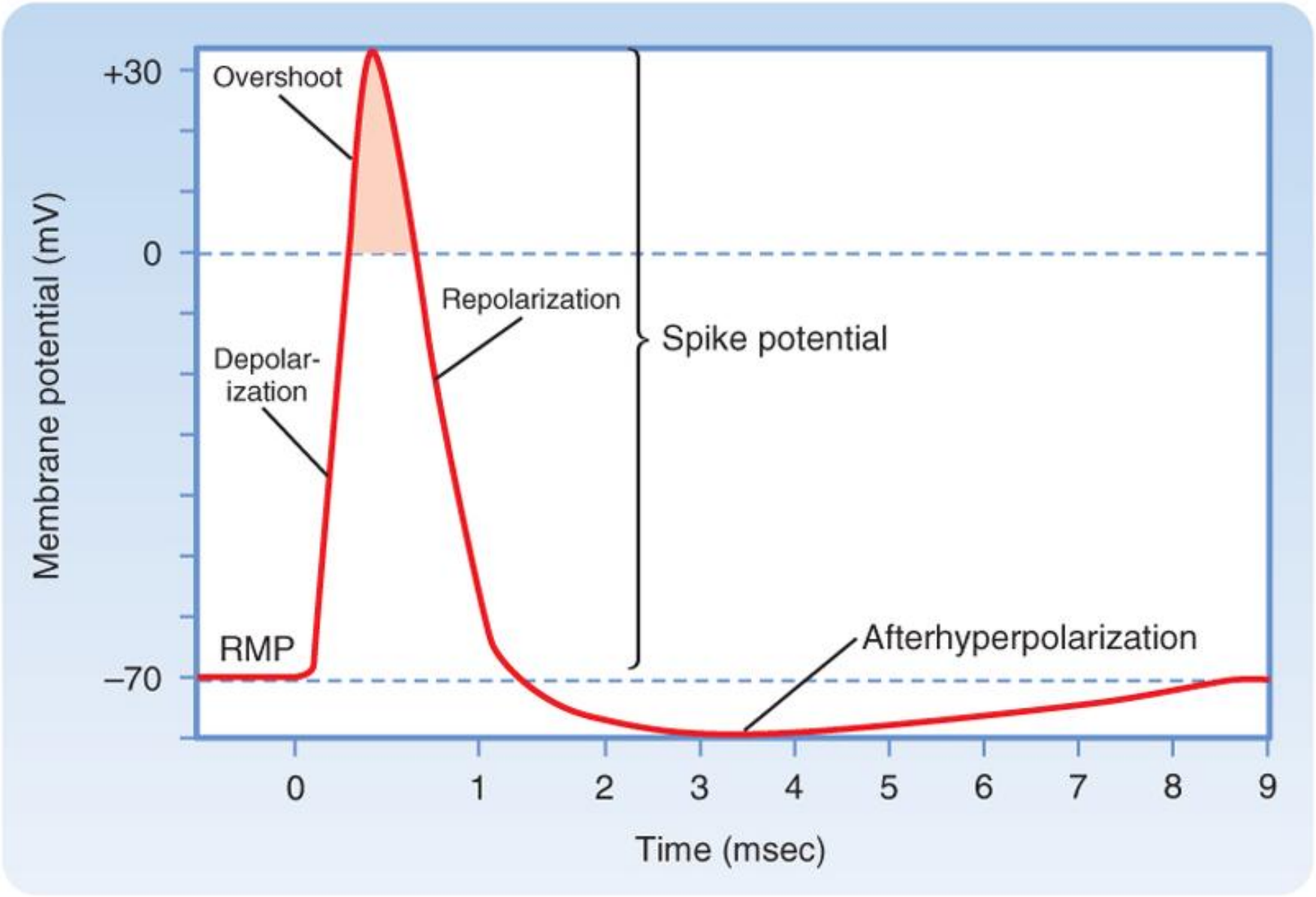


Action potentials

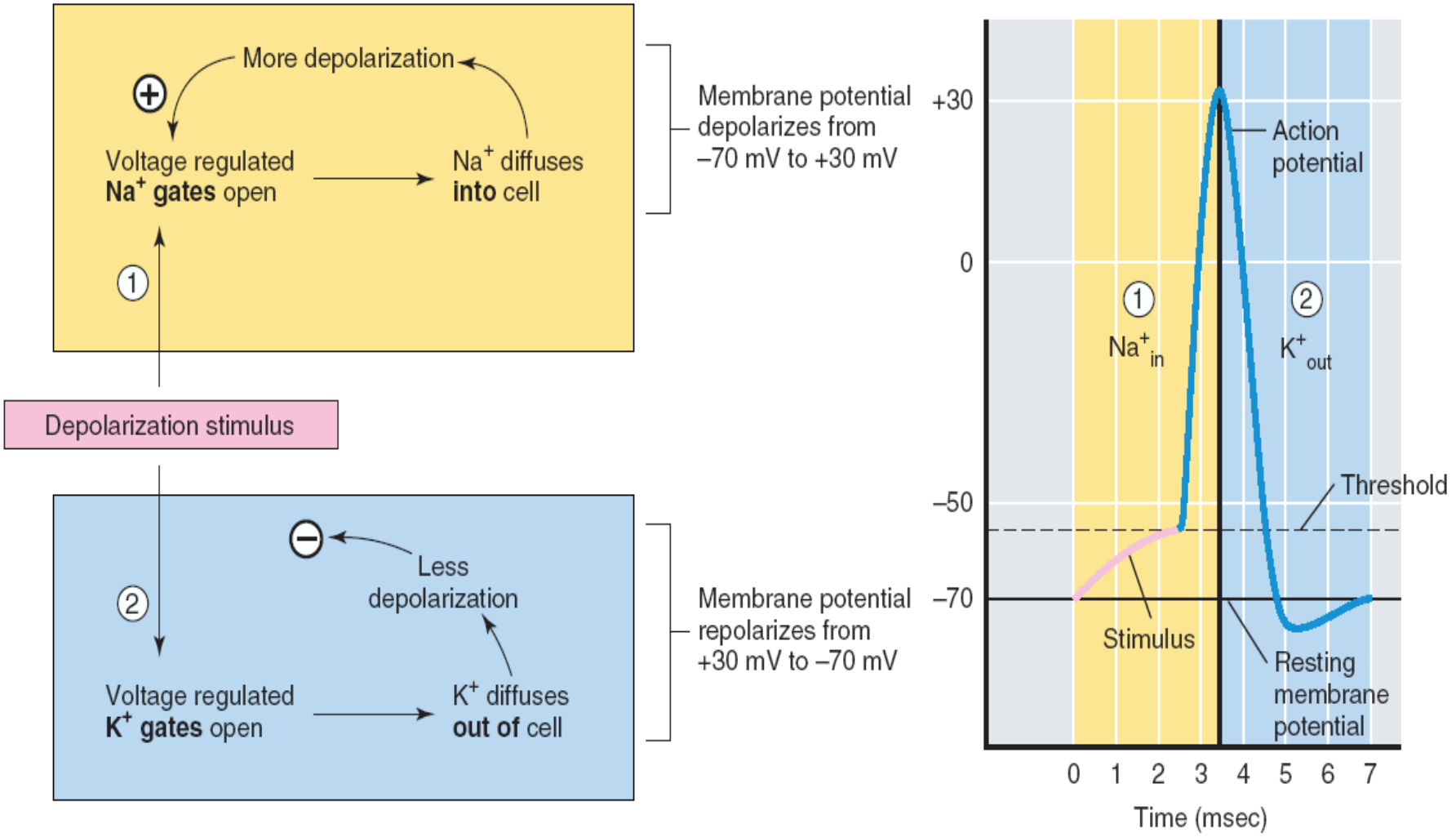
- Treshold (~ -55mV)
- Fixed amp
  - ✓ All or none
- Fixed duration
- Summation Ø
  - ✓ Refractory period
- Allways excitatory
- Voltage-gated ion channels



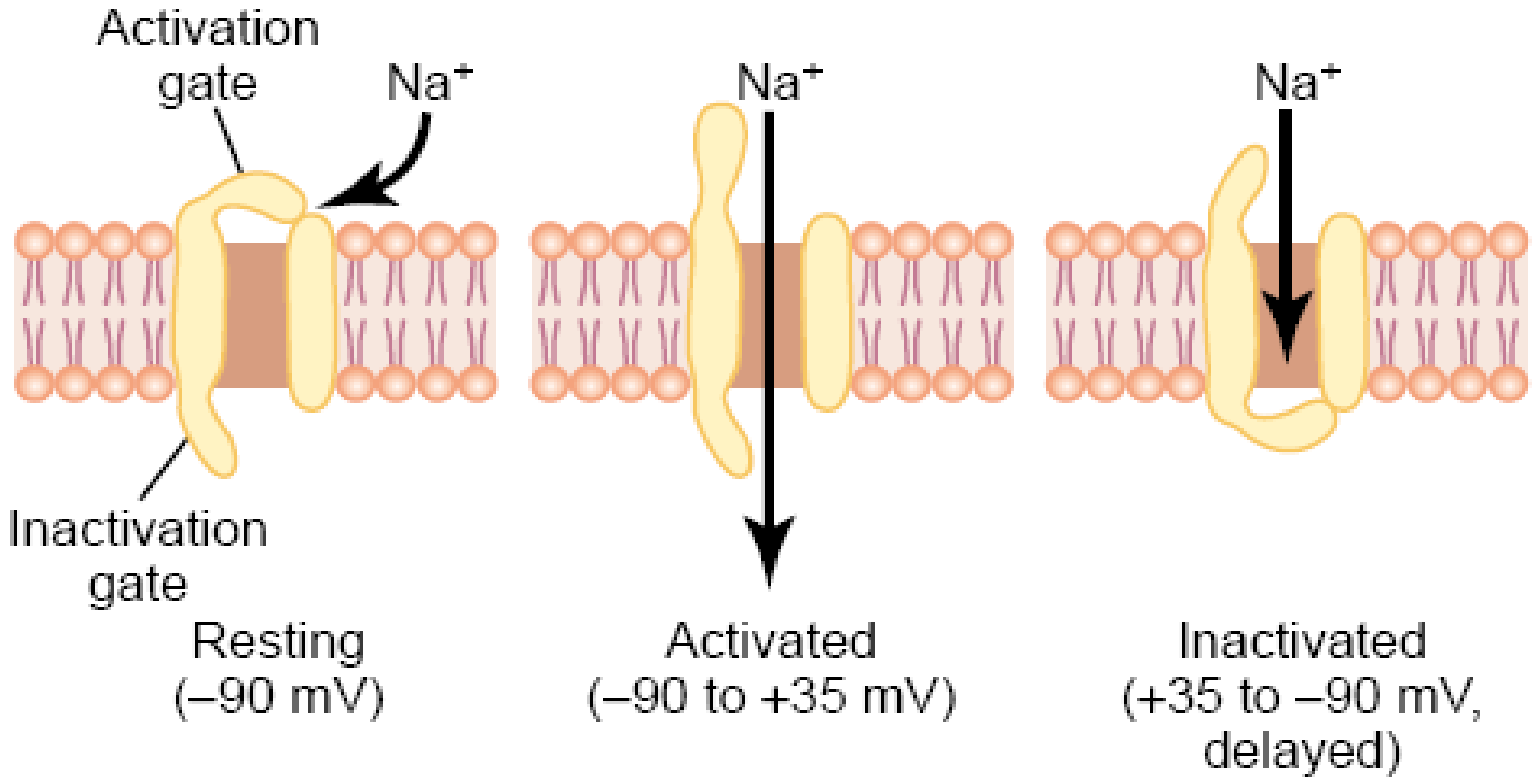
Action potentials

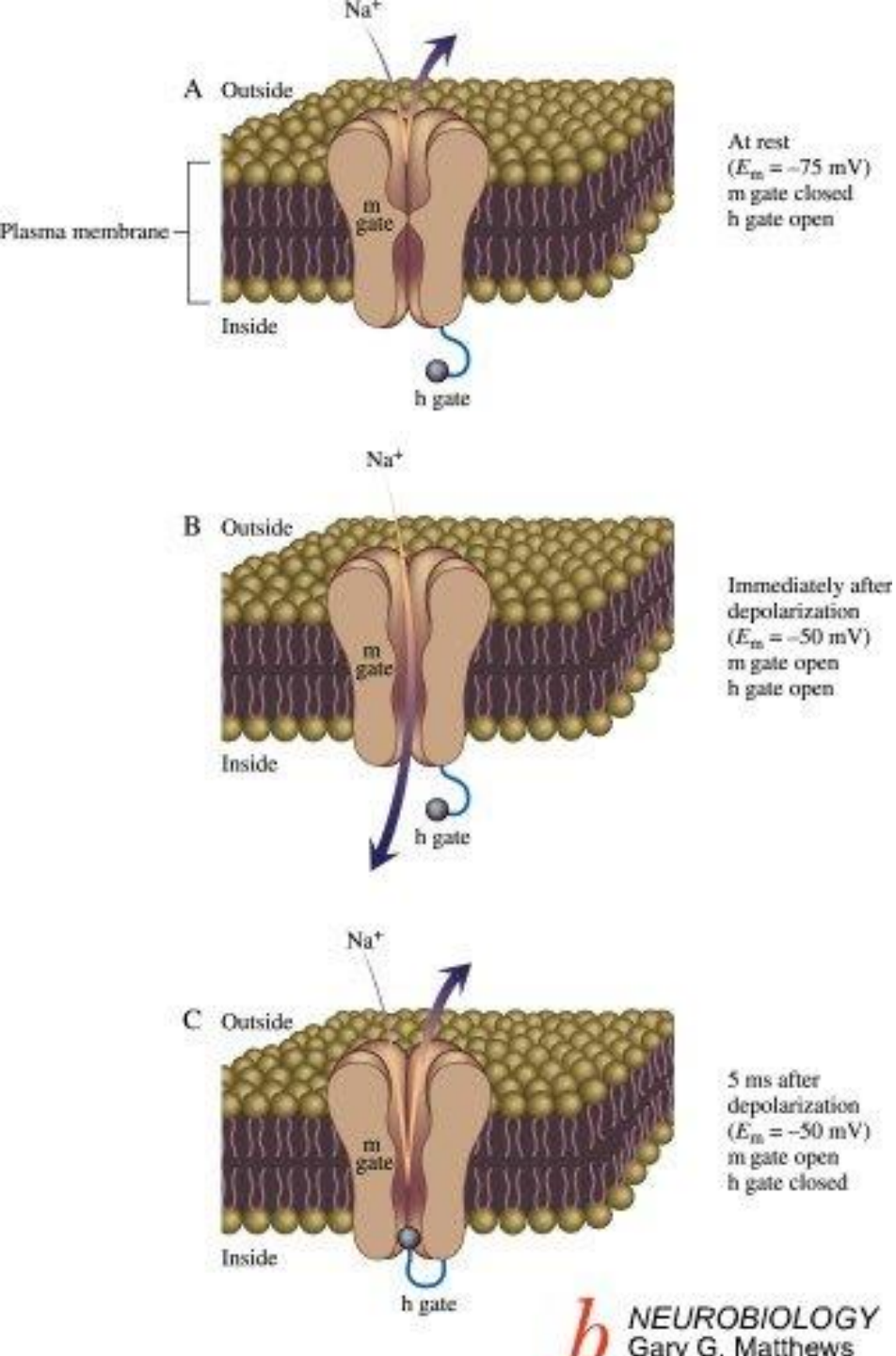


Action potentials



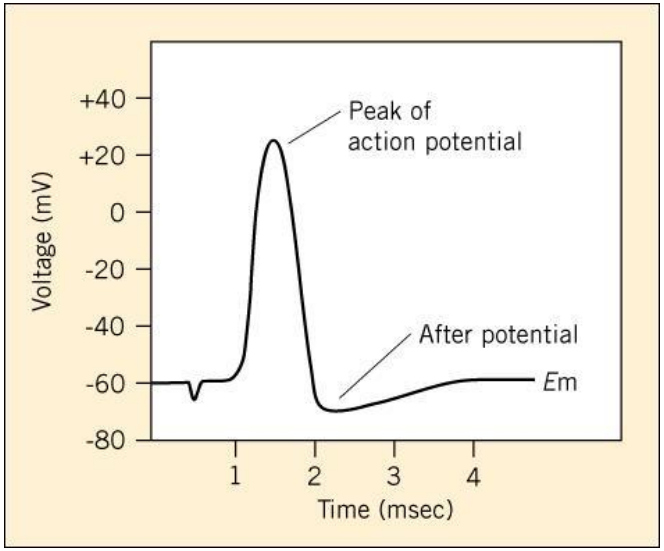
Voltage-gated Na^+ channels



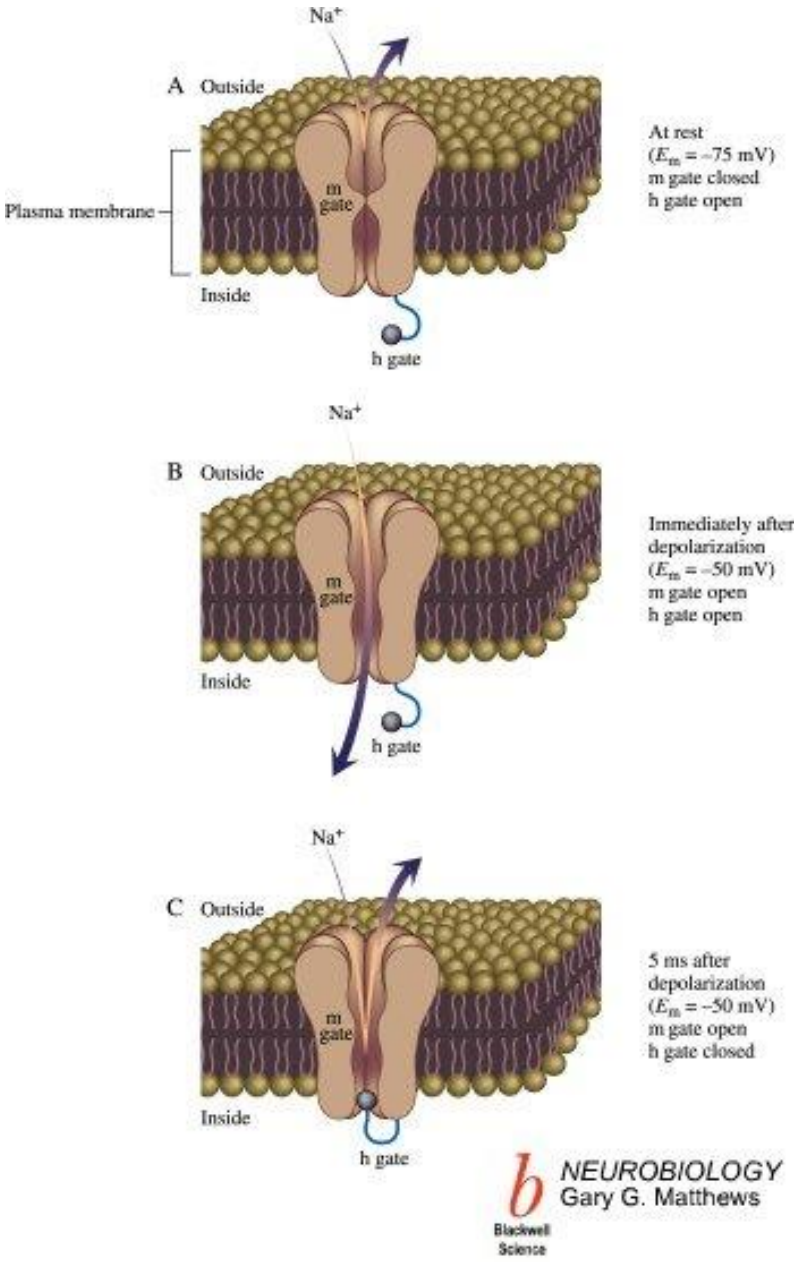


Regenerative Process:

Once one Na channel Opens, Na enters, Depolarizes membrane, More and more Na Channels open leading to More sodium influx & causes upward & depolarizing (more +) phase of the AP



Na Channel Gates



- M gate= **activation gate o**n Na channel; opens quickly when membrane is depolarized

- H gate- inactivation gate on Na channel; Closes slowly after membrane is depolarized

- causes the absolute refractory period for AP propagation

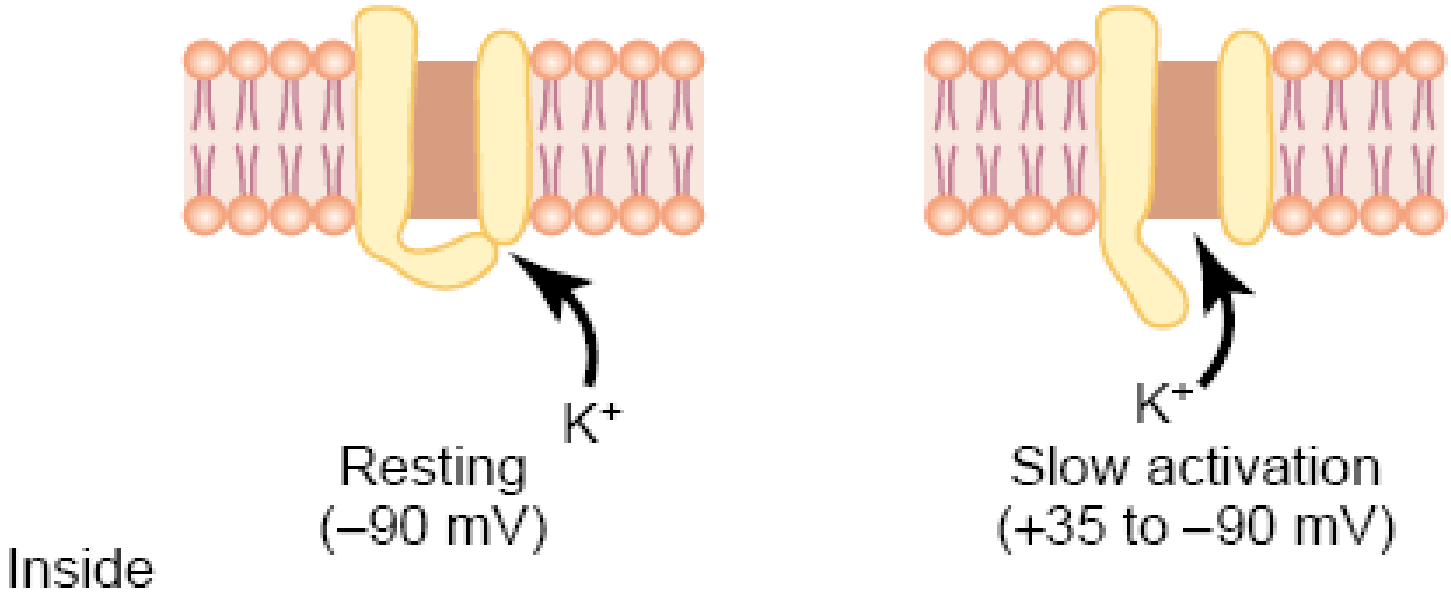
Voltage-gated Na^+ channels

Local anestetics (lidokain)

Tetrodotoxin

Pufferfish

Voltage-gated K^+ channels



Insulin deficiency→ Hyperkalemia →

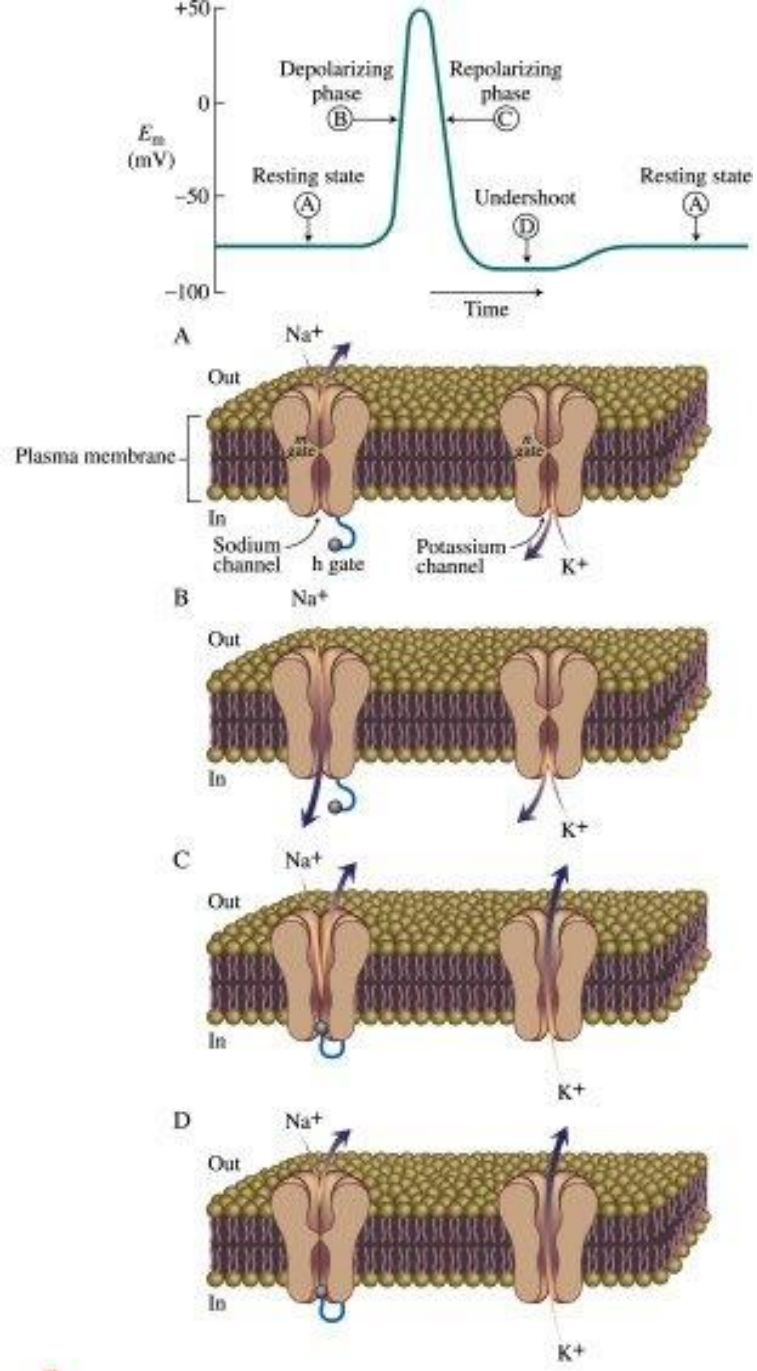
Depolarization → Excitability ?

Potassium Channel Property

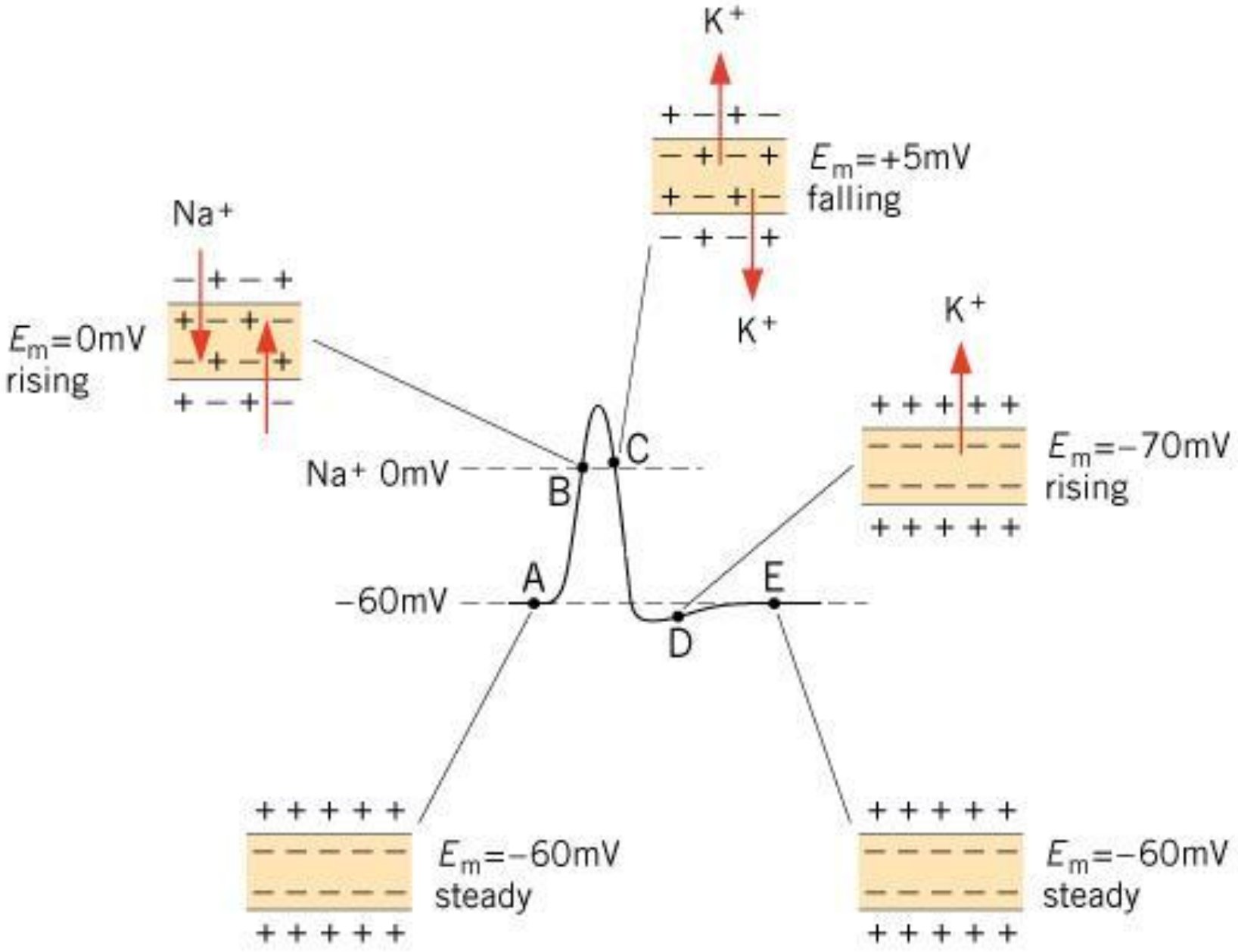
- K channels open with a delay and stay open for length of depolarization
- Repolarize the Vm toward to E_K which is why you have hyperpolarization.

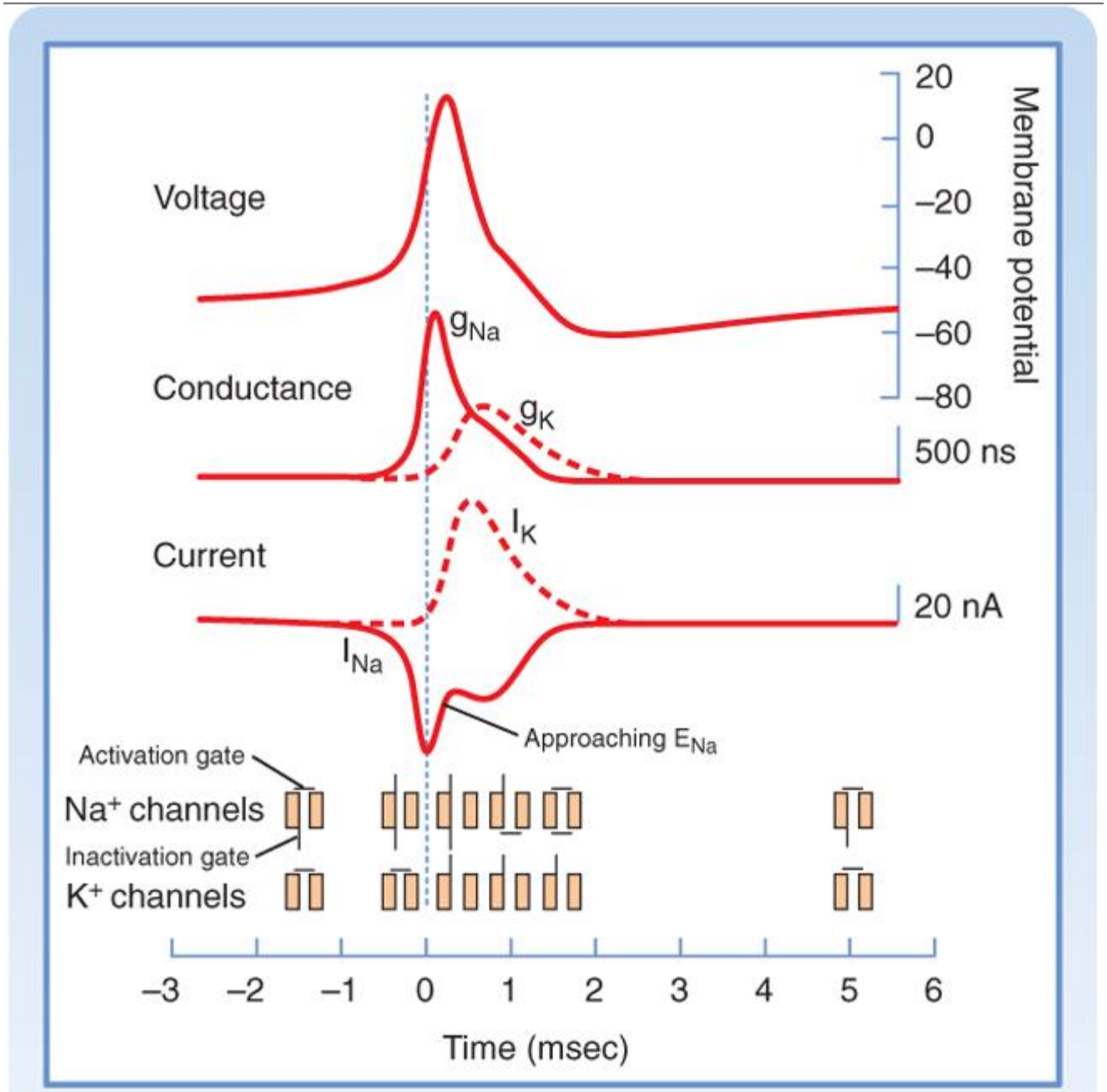
- Also called a delayed rectifier channel

Gate on the Delayed Rectifier Potassium Channel



- K channels have a single gate (n) that stays open as long as Vm is depolarized.
- n gate on K channels opens very slowly this allows the Vm to depolarize due to Na influx; Na and K currents do not offset each other right away


K+
Em=+5mV
falling
K+
Na+
Em=0mV
rising
K+
Em=−70mV
rising
Na+ 0mV
A
B
C
D
E
−60mV
Em=−60mV
steady
Em=−60mV
steady

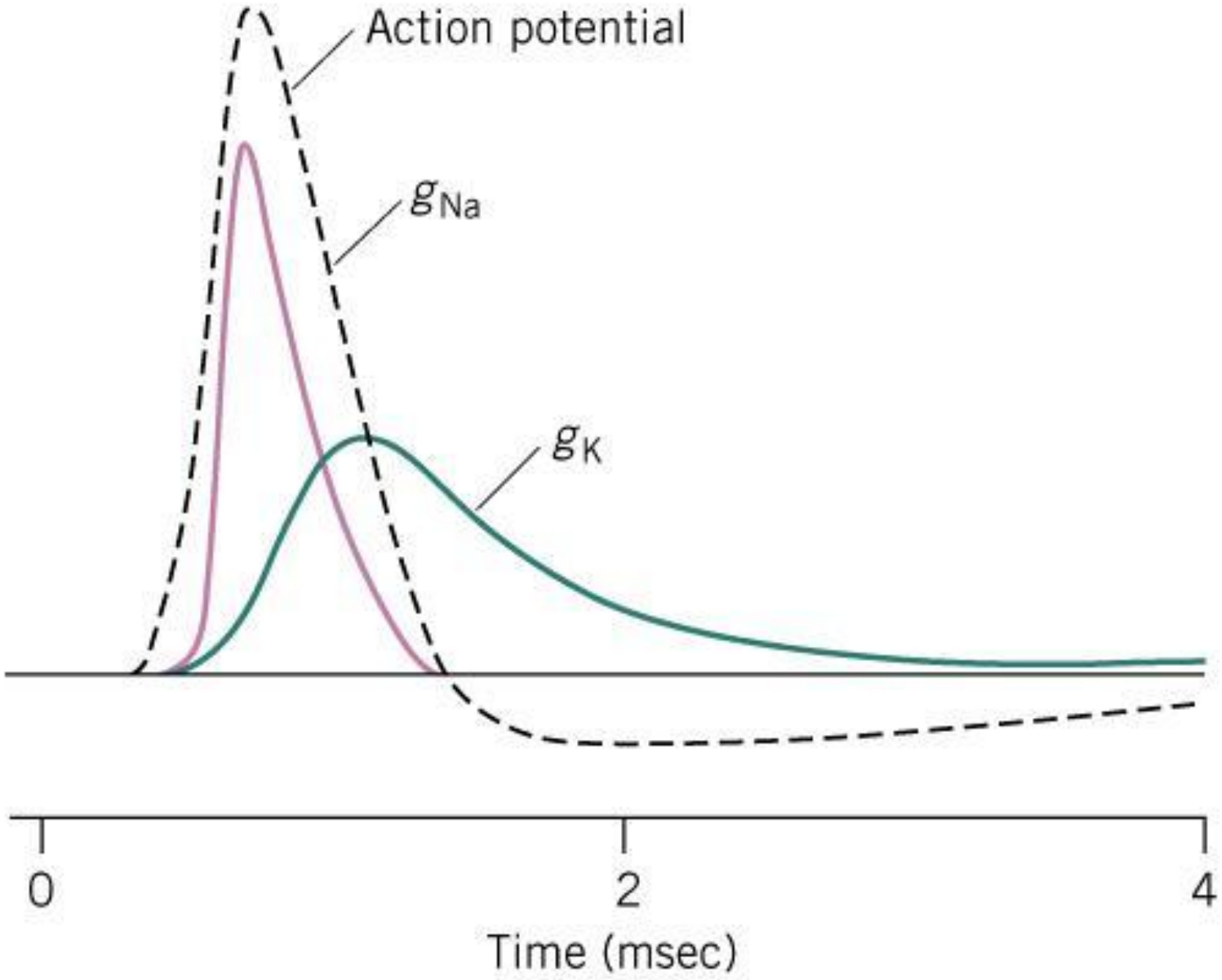

Voltage
Conductance
Current
g_{Na}
g_K
I_K
I_{Na}
20
0
–20
–40
–60
–80
Membrane potential
500 ns
20 nA
Approaching E_{Na}
Activation gate
Na^+ channels
Inactivation gate
K^+ channels
–3
–2
–1
0
1
2
3
4
5
6
Time (msec)

Conductance = g

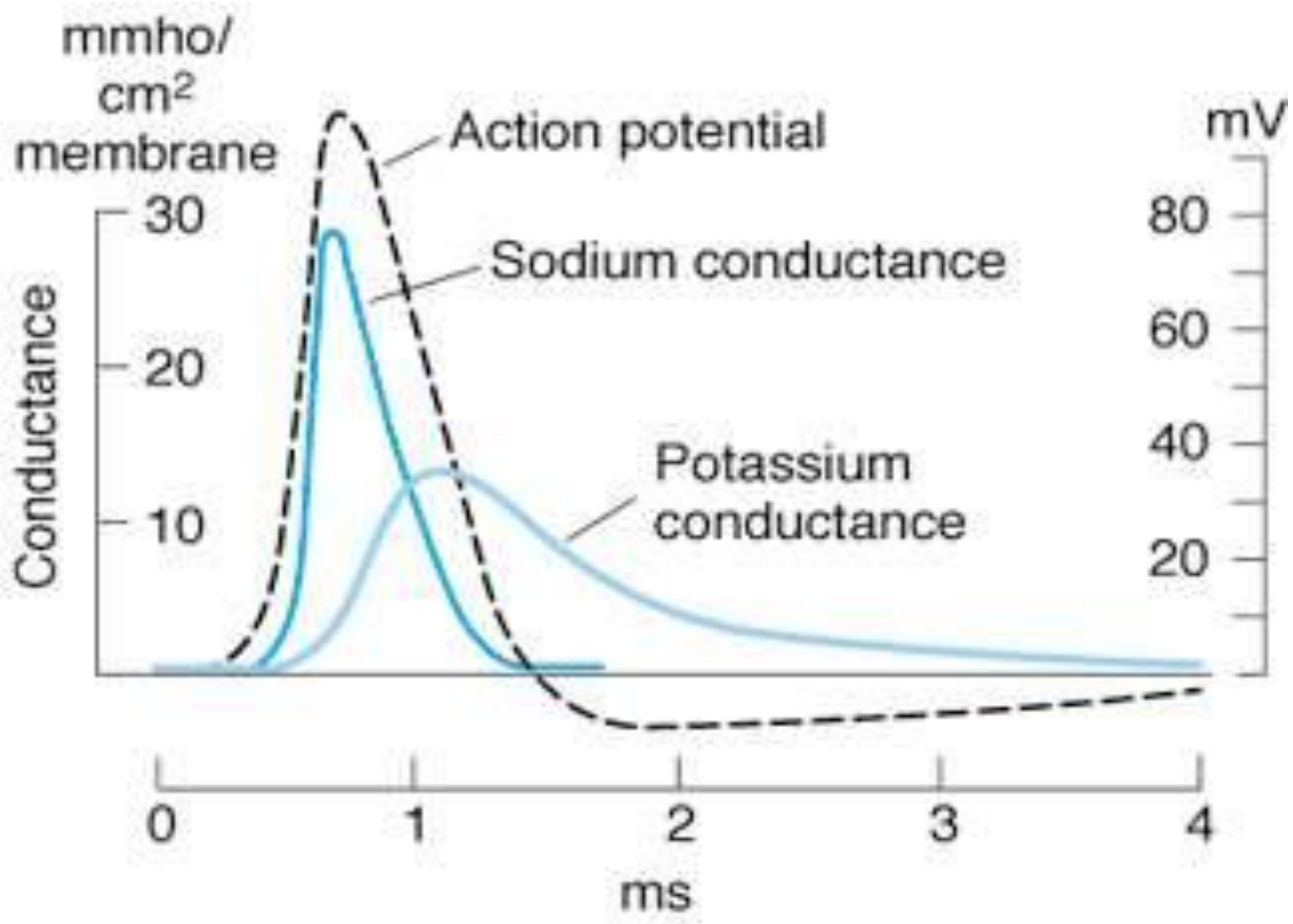
- How many charges (ions) enters or leaves cell (inverse of resistance)
- due to:
  - number of channels/membrane area
    - Highest density at axon hillock
  - number of open channels
  - ion concentration on either side of membrane
  - Measured in Siemens (S), in cells pS (pico; -12)

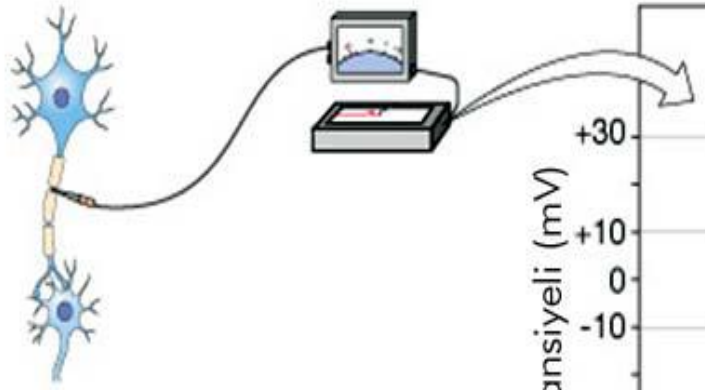
Ion Permeability

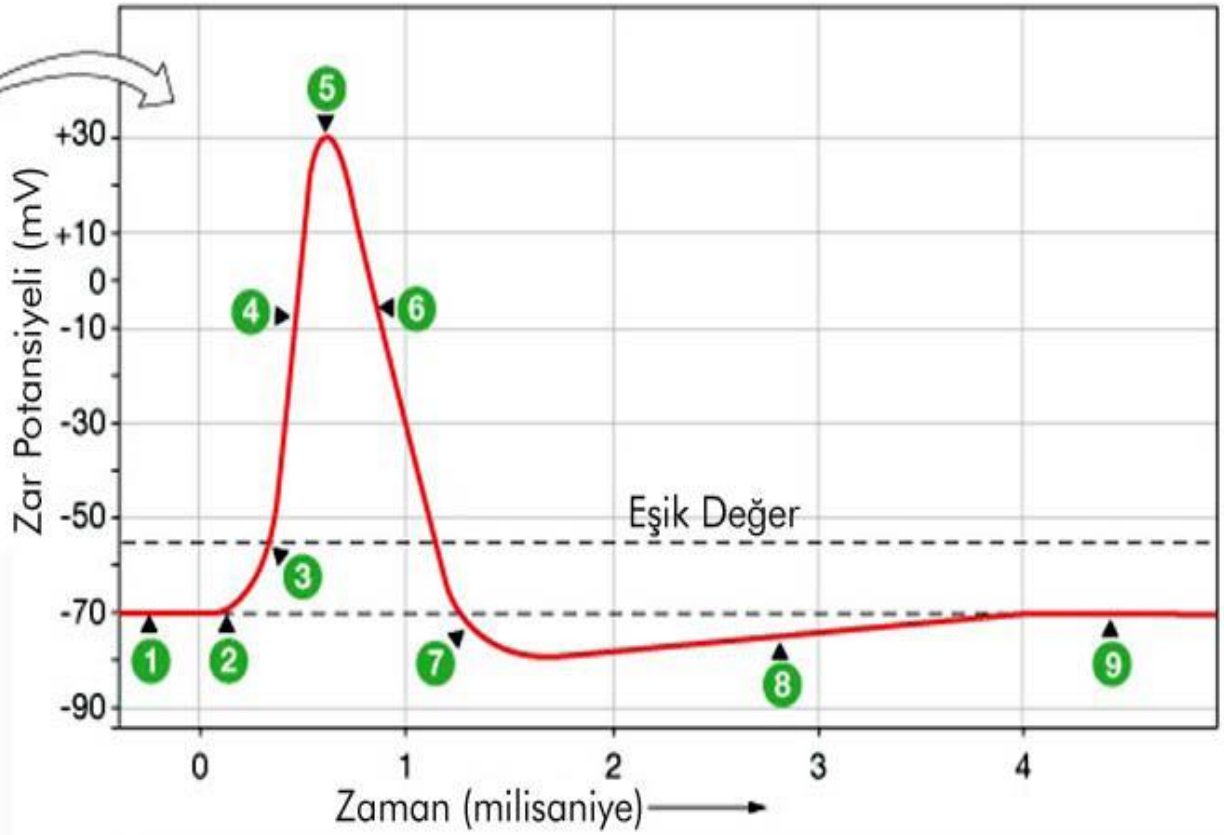
- Changes during action potential
- The plasma membrane becomes permeable to sodium ions
  - Permeability increases from 0.02 to 20=1000 fold increase
- Causes E_m to approach E_{na}


Action potential
g_{Na}
g_K
0
2
4
Time (msec)

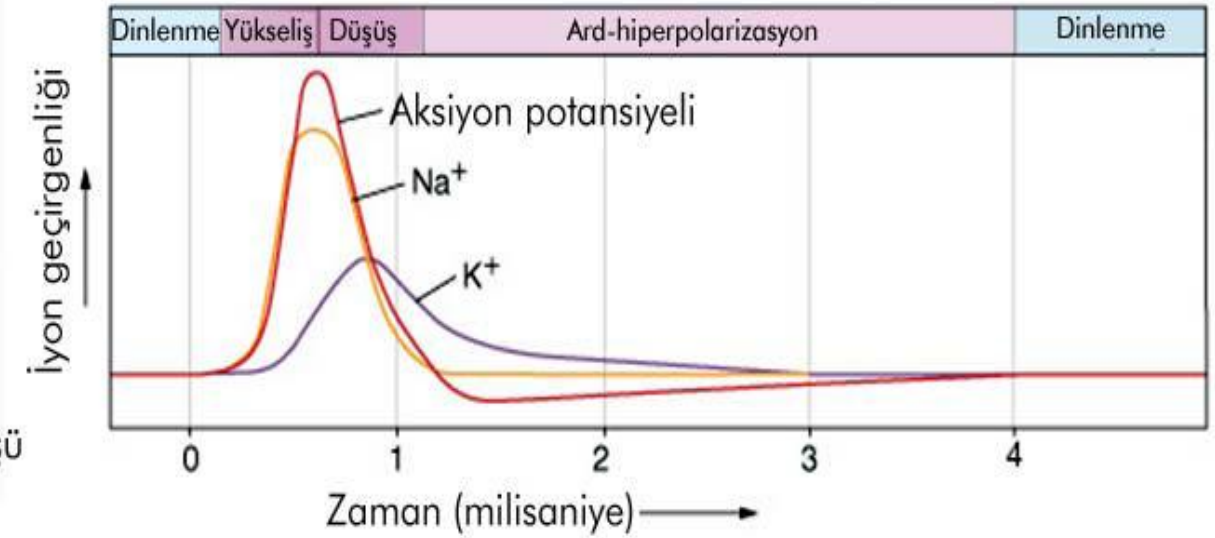
After hyperpolarization



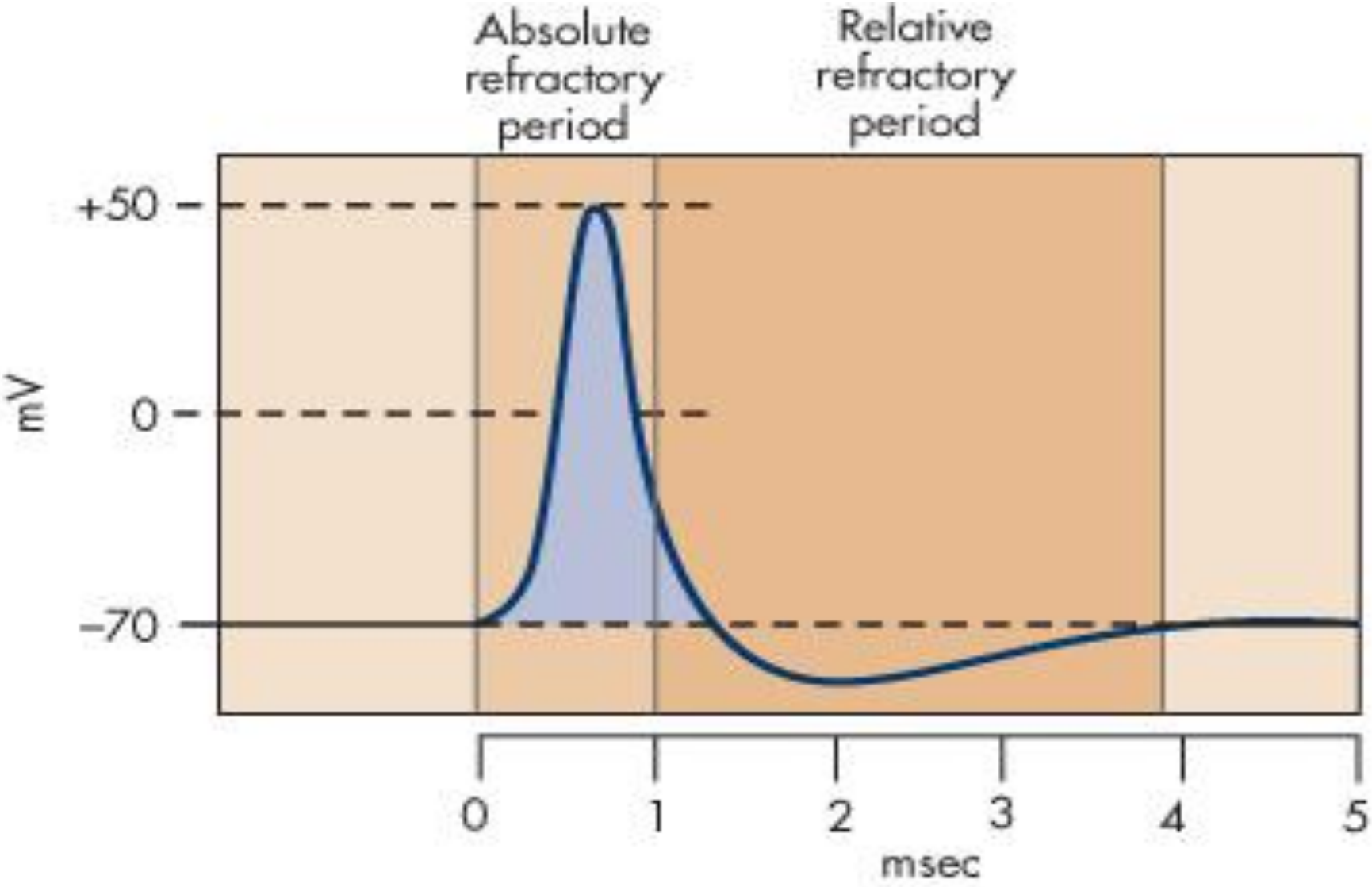




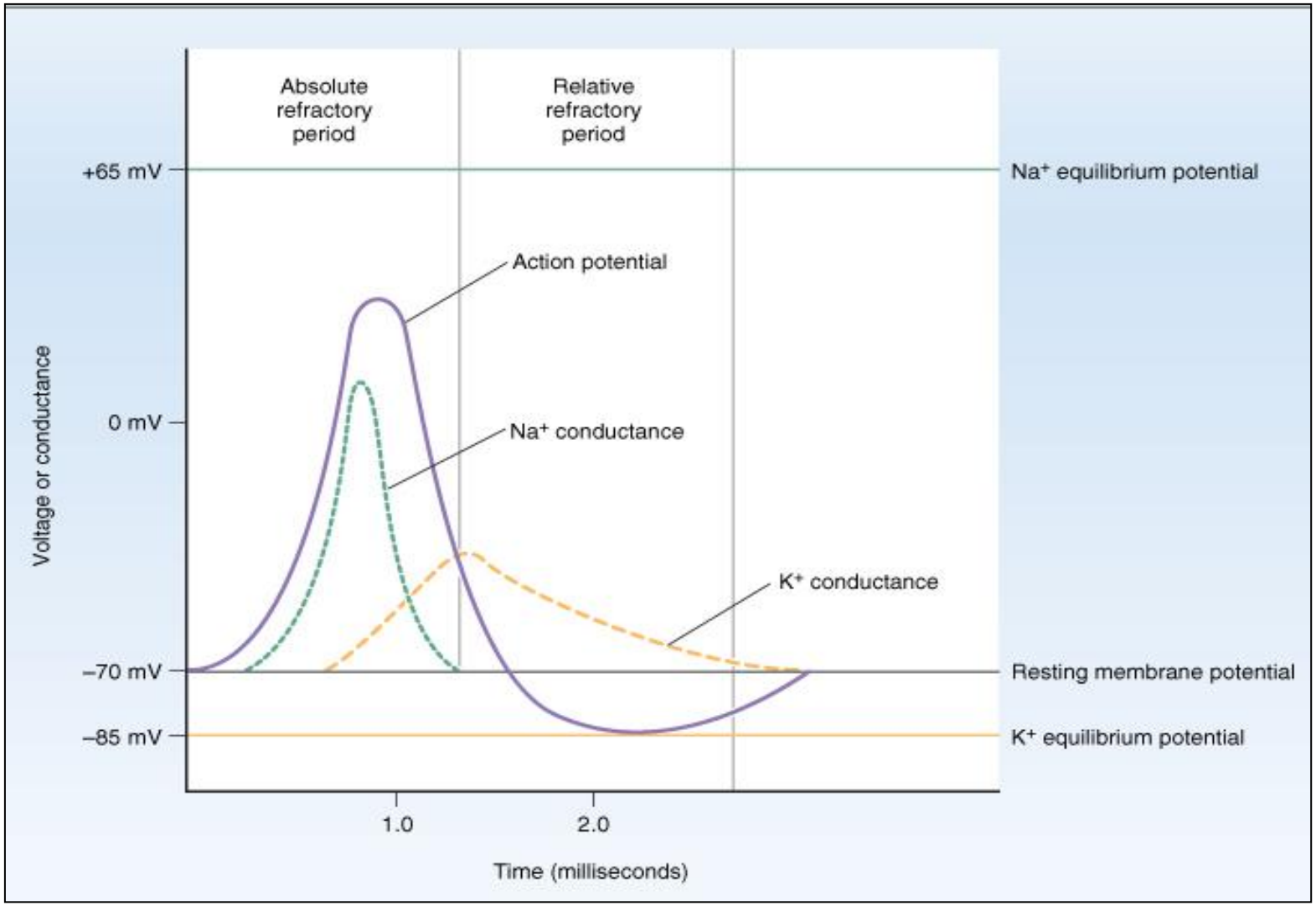
1. Dinlenme potansiyeli
2. Depolarizasyon
3. Voltaj kapılı hızlı sodyum kanallarının açılması, hücre içine Na girişi; voltaj kapılı K kanallarında yavaş açılma
4. Hızlı Na girişi ve depolarizasyon
5. Na kanallarının kapanması, yavaş K kanallarının açılması
6. Potasyumun HDS'ya hareketi
7. Potasyum kanallarının açık kalma dönemi (hiperpolarizasyon)
8. Voltaj kapılı potasyum kanallarının kapanması, K-sızma kanalları.
9. Hücrenin dinlenme durumuna dönüşü



Refractory period

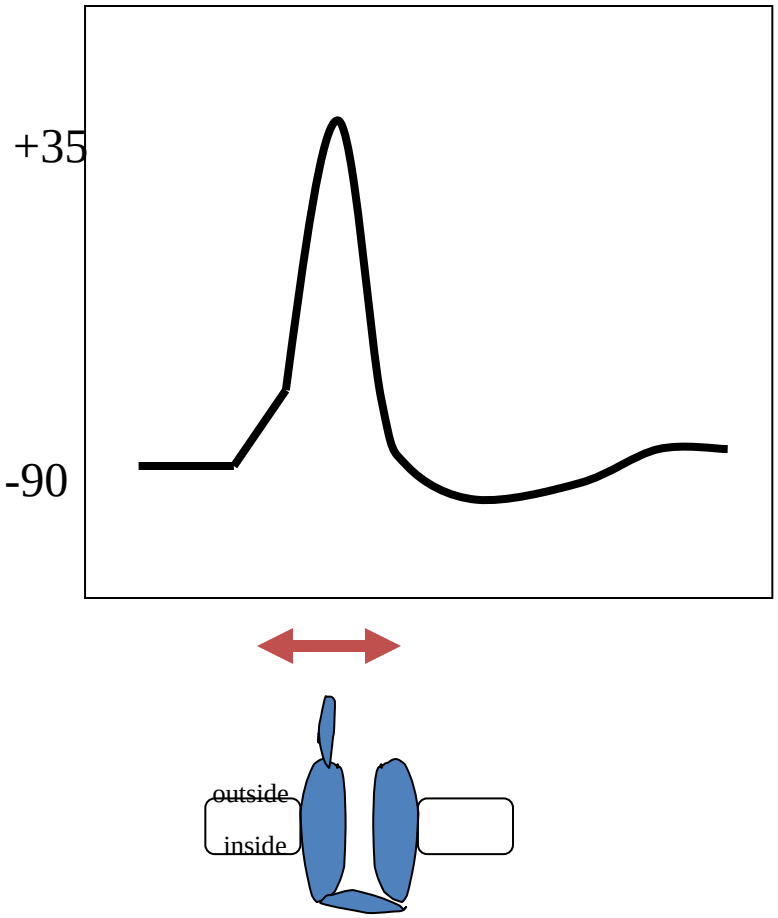


Refractory period due to Na channel inactivation and the high gk



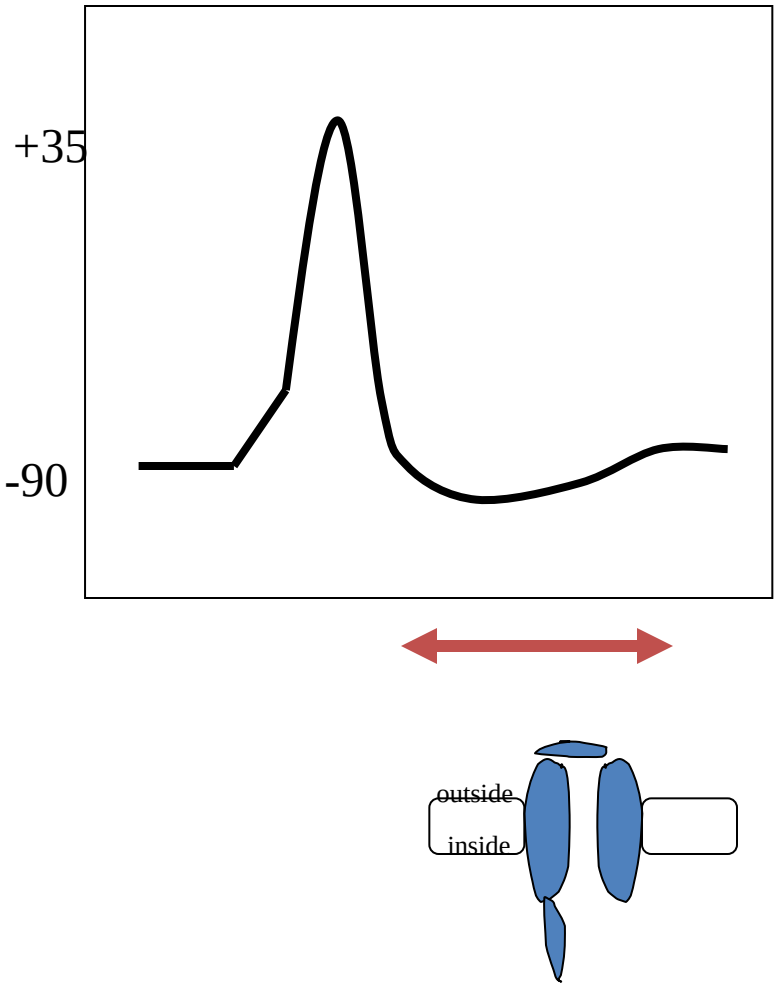
Refractory Period

- Absolute refractory period
  - During this period nerve membrane cannot be excited again
  - Because of the closure of inactivation gate

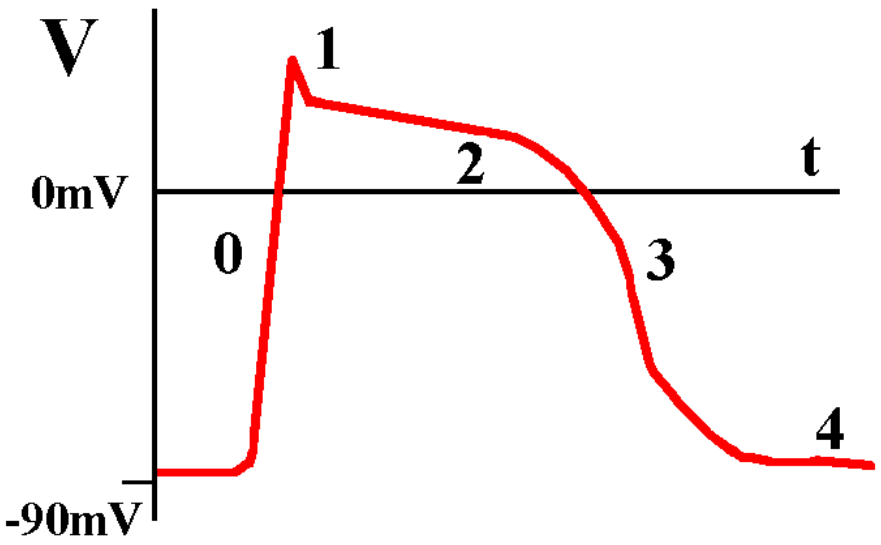


Refractory Period

- Relative refractory period
  - During this period nerve membrane can be excited by supra threshold stimuli
  - At the end of repolarisation phase inactivation gate opens and activation gate closes
  - This can be opened by greater stimuli strength



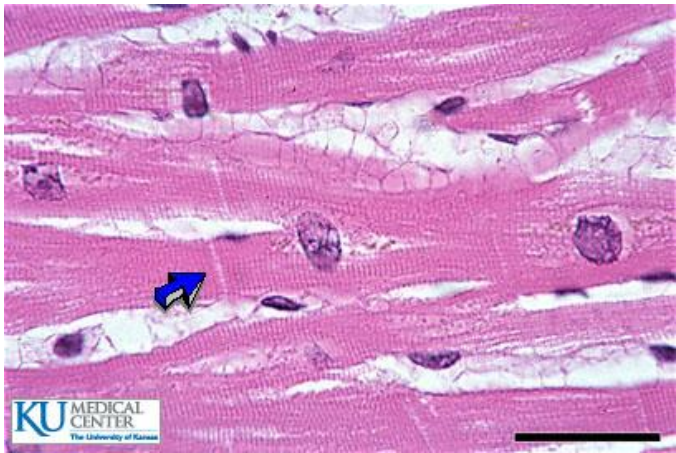
Cardiac muscle action potential



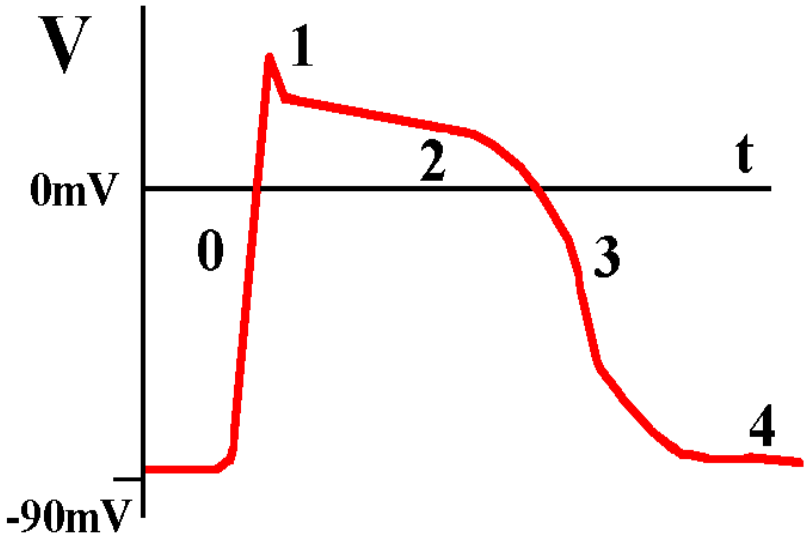
Phases

- 0: depolarisation
- 1: short repolarisation
- 2: plateau phase
- 3: repolarisation
- 4: resting

Duration is about 250 msec



Cardiac muscle action potential



Phases

0: Na+ influx through fast Na+ channels

1: K+ efflux, Cl- influx

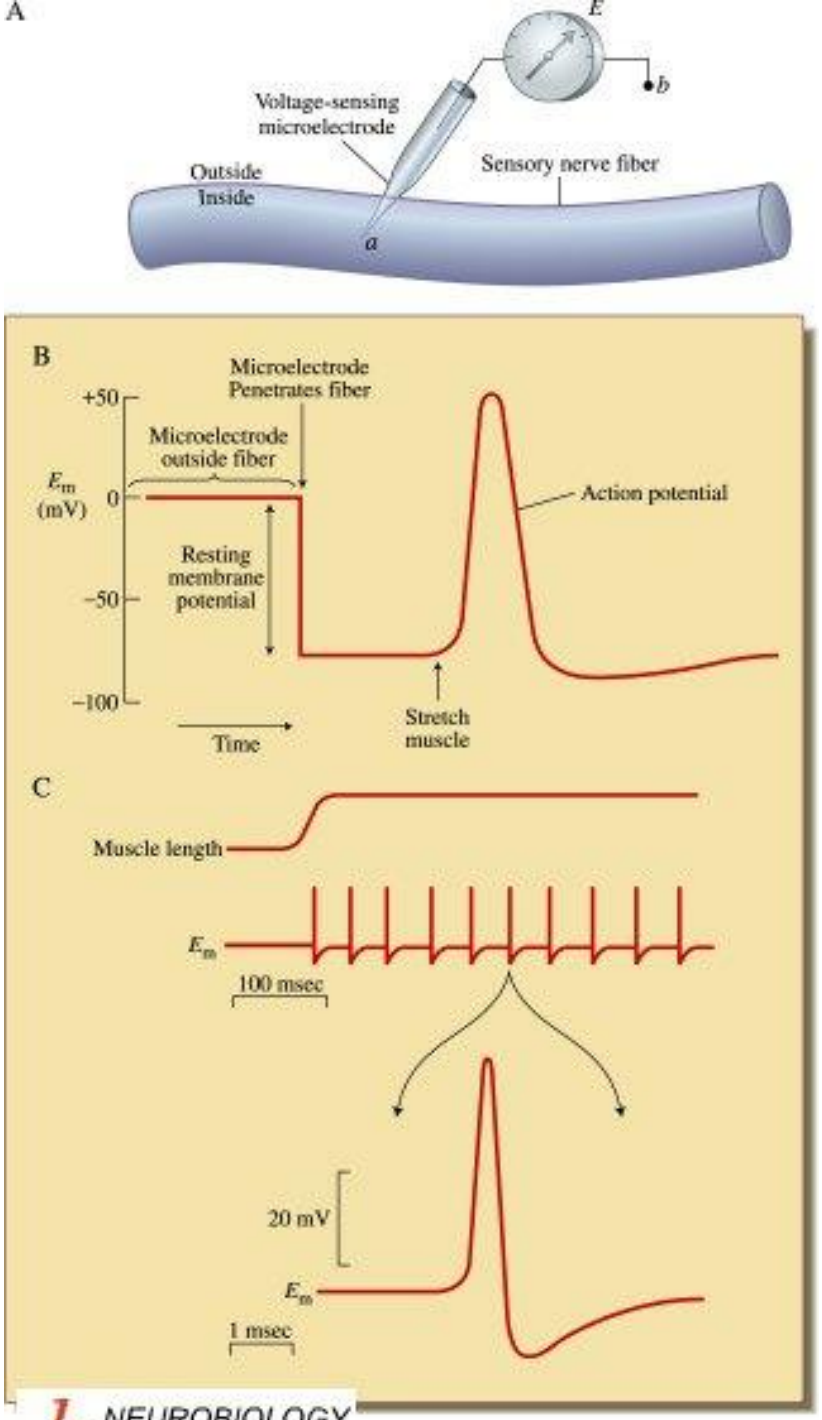
2: Ca++ influx through slow Ca++ channels - L type

3: K+ efflux

4: resting

Information Coding

- Is **NOT** in shape of action potential
- Is in the action potential frequency of firing — how many are triggered
- In the action potentials pattern or timing of propagation



Action Potential: a transient and rapid sequence of changes in the membrane potential

Action Potentials
Can travel up to
100 meters/second

Usually 10-20 m/s
0.1sec delay
between muscle and
sensory neuron
action potential