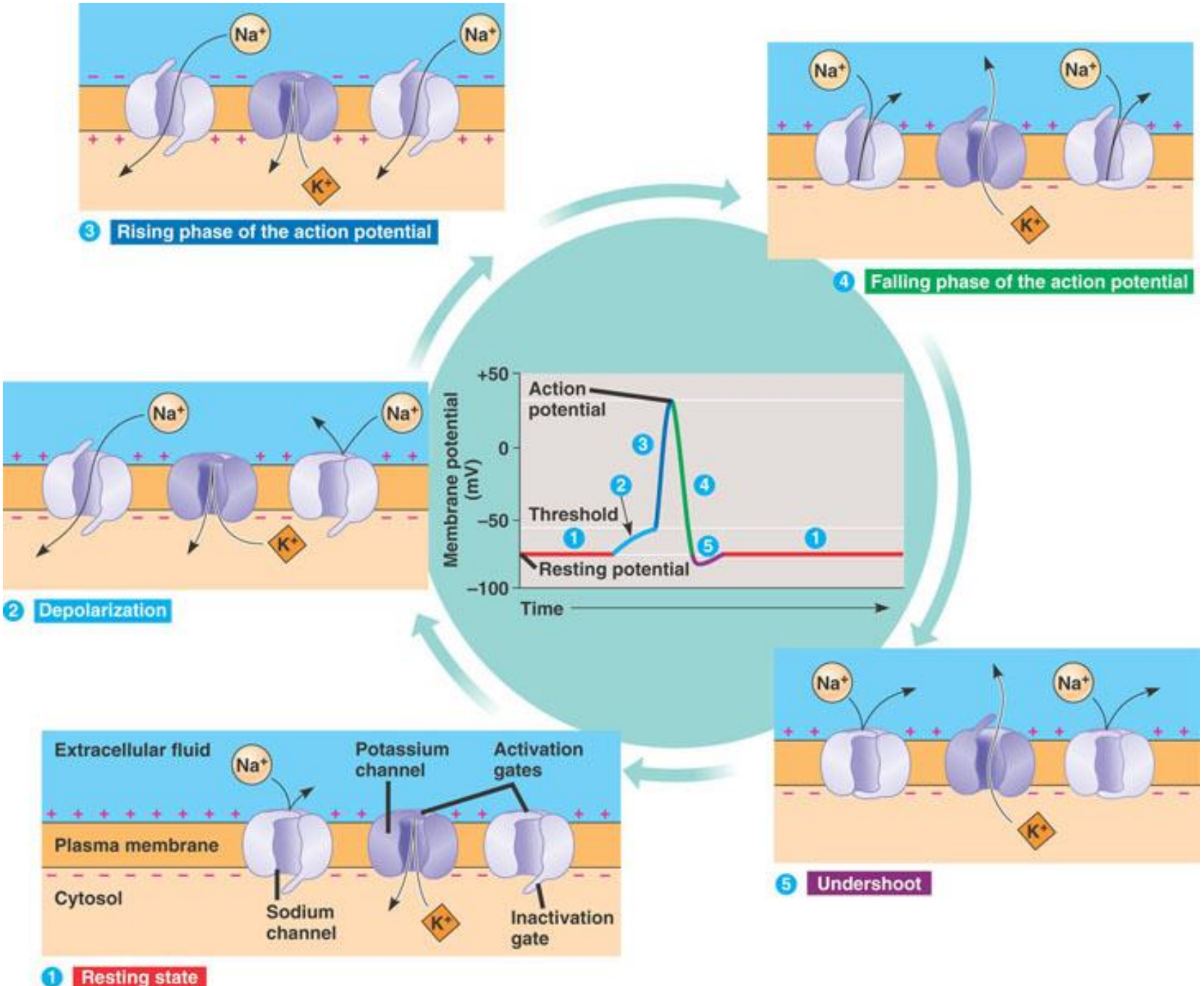
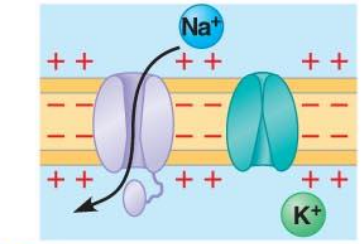
Transport of ions across plasma membranes

Plasma Membranes of Excitable tissues

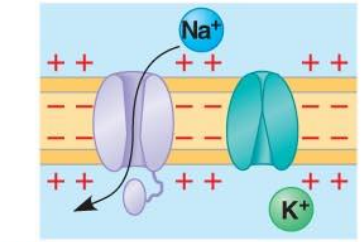
Ref: Guyton, 14th ed: 63-76. 13th ed: pp: 61-71. 12th ed: pp: 57-69,


Na+
Na+
K+
3 Rising phase of the action potential
4 Falling phase of the action potential
2 Depolarization
+50
0
−50
−100
Membrane potential (mV)
Action potential
Threshold
Resting potential
Time
1
2
3
4
5
5 Undershoot
Extracellular fluid
Plasma membrane
Cytosol
Potassium channel
Activation gates
Sodium channel
Inactivation gate
1 Resting state

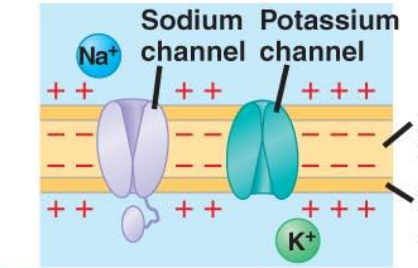
Generation of action potentials



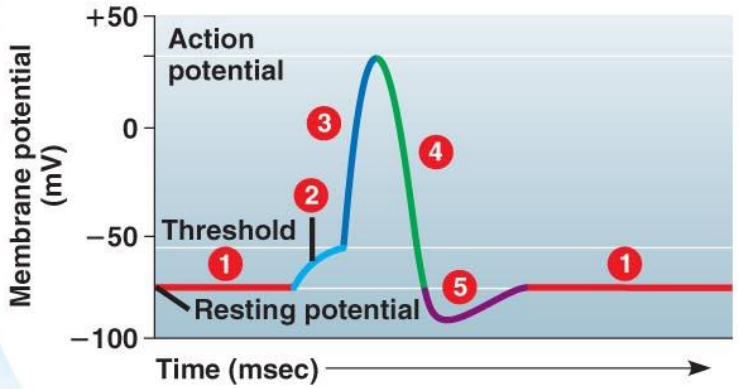
3 Additional Na^+ channels open, K^+ channels are closed; interior of cell becomes more positive.

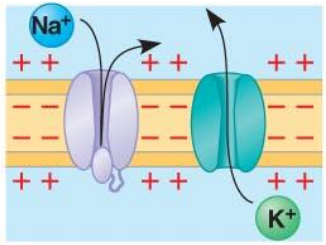


2 A stimulus opens some Na^+ channels; if threshold is reached, action potential is triggered.



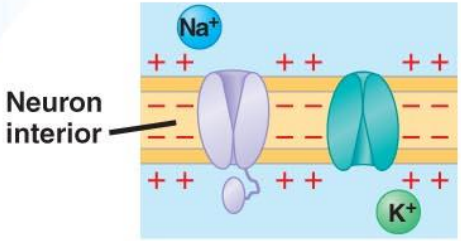
1 Resting state: voltage-gated Na^+ and K^+ channels closed; resting potential is maintained.





4 Na^+ channels close and inactivate. K^+ channels open, and K^+ rushes out; interior of cell more negative than outside.

5 The K^+ channels close relatively slowly, causing a brief undershoot.



1 Return to resting state.

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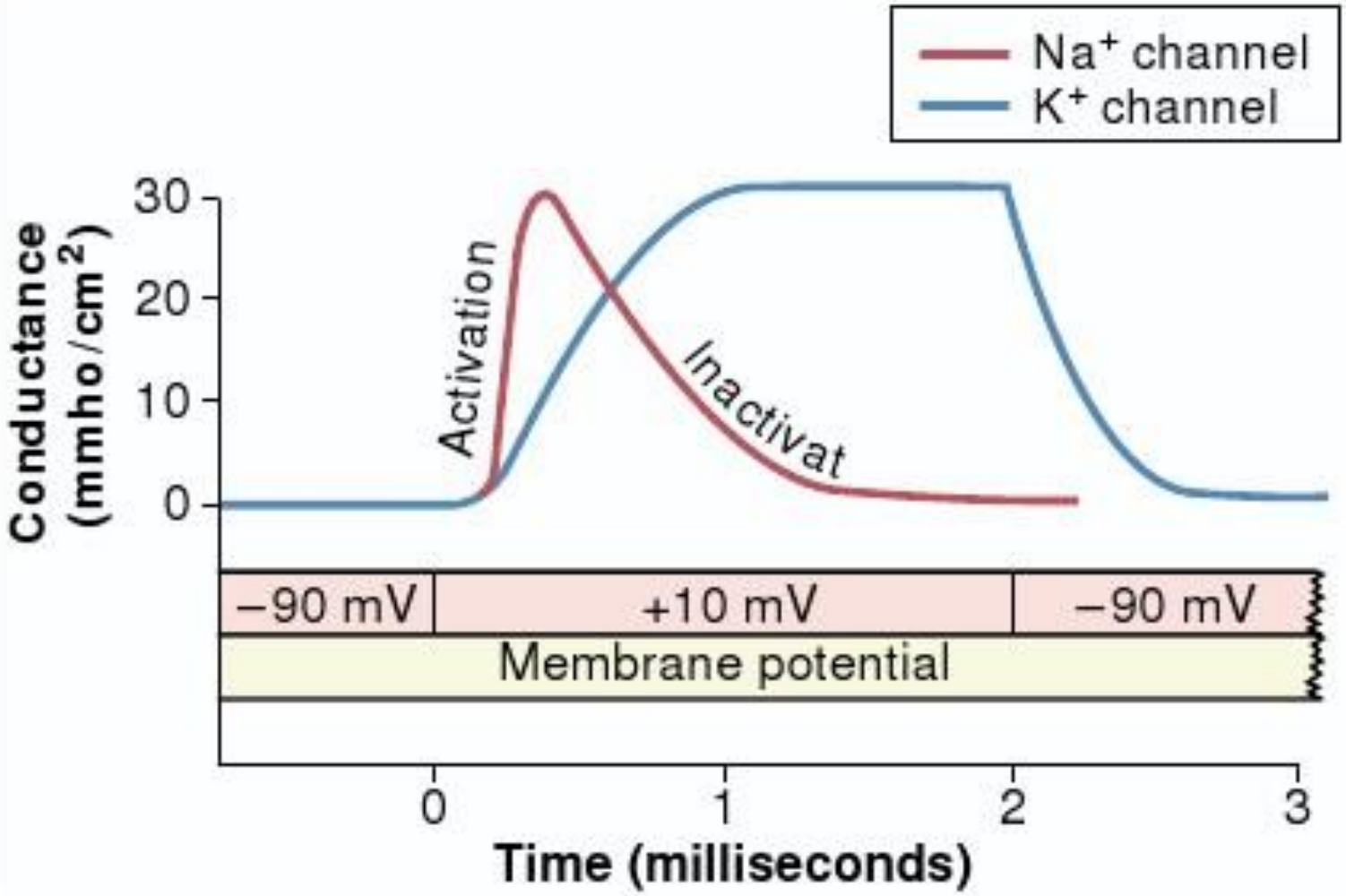
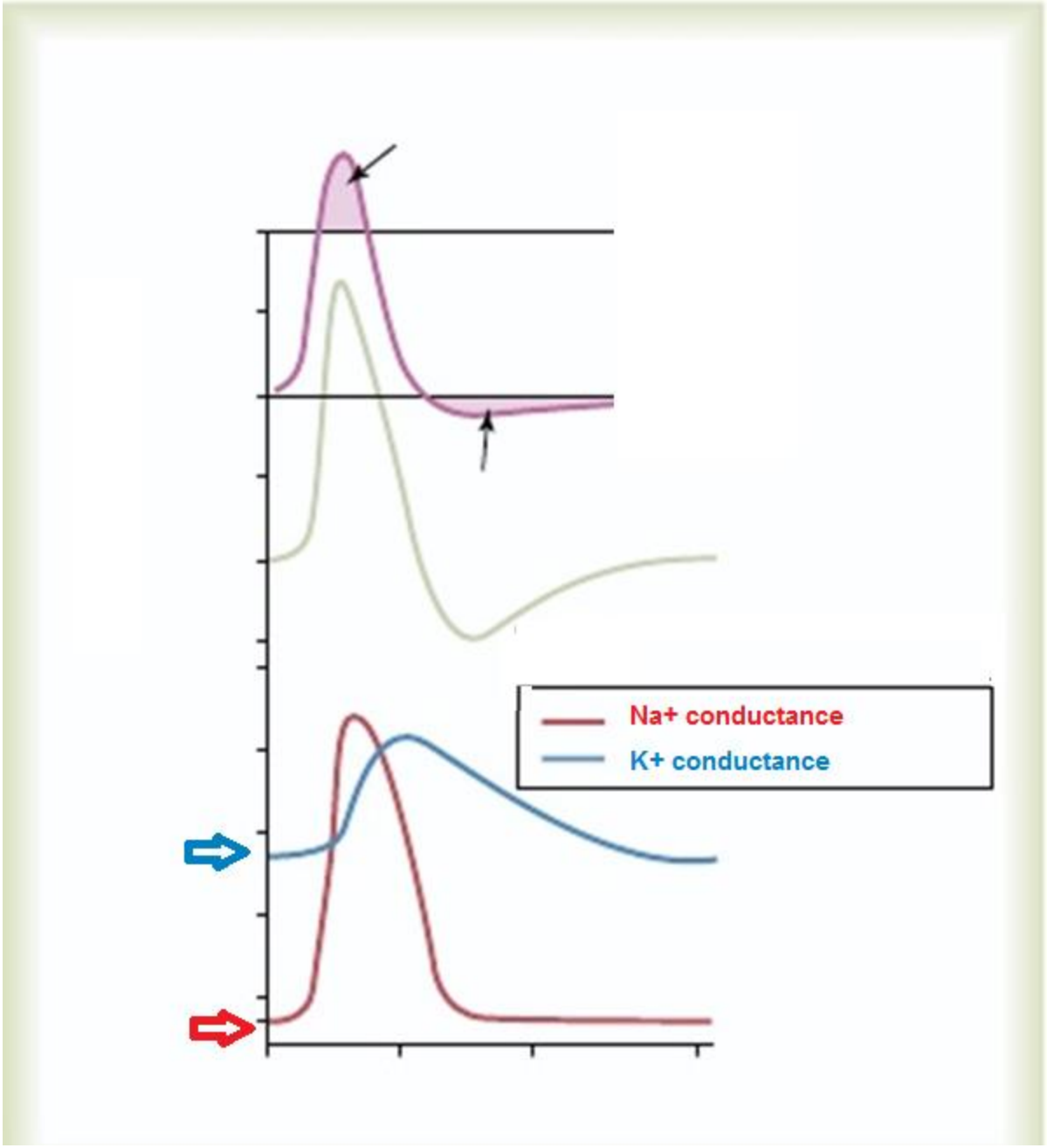
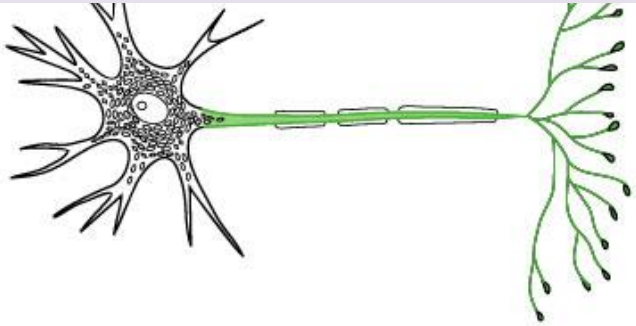

Na+ channel
K+ channel
Conductance (mmho/cm2)
30
20
10
0
Activation
Inactivat
−90 mV
+10 mV
−90 mV
Membrane potential
0
1
2
3
Time (milliseconds)

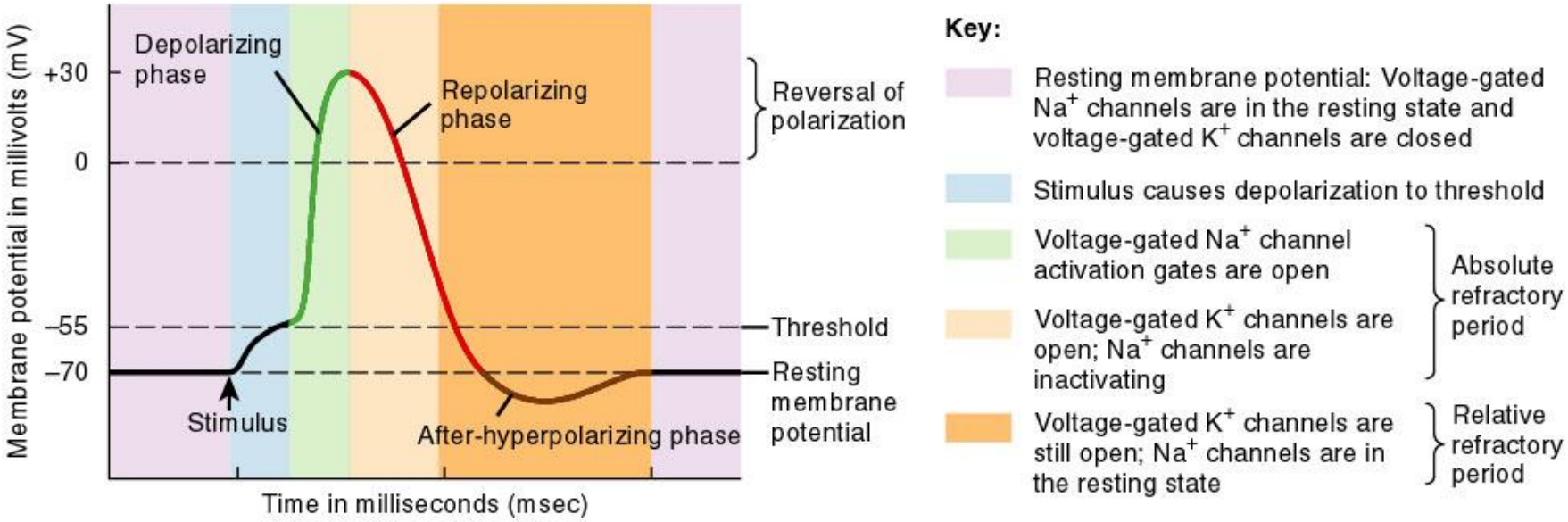
Figure 5–9

- Na+ and K+ conductance at resting potentials



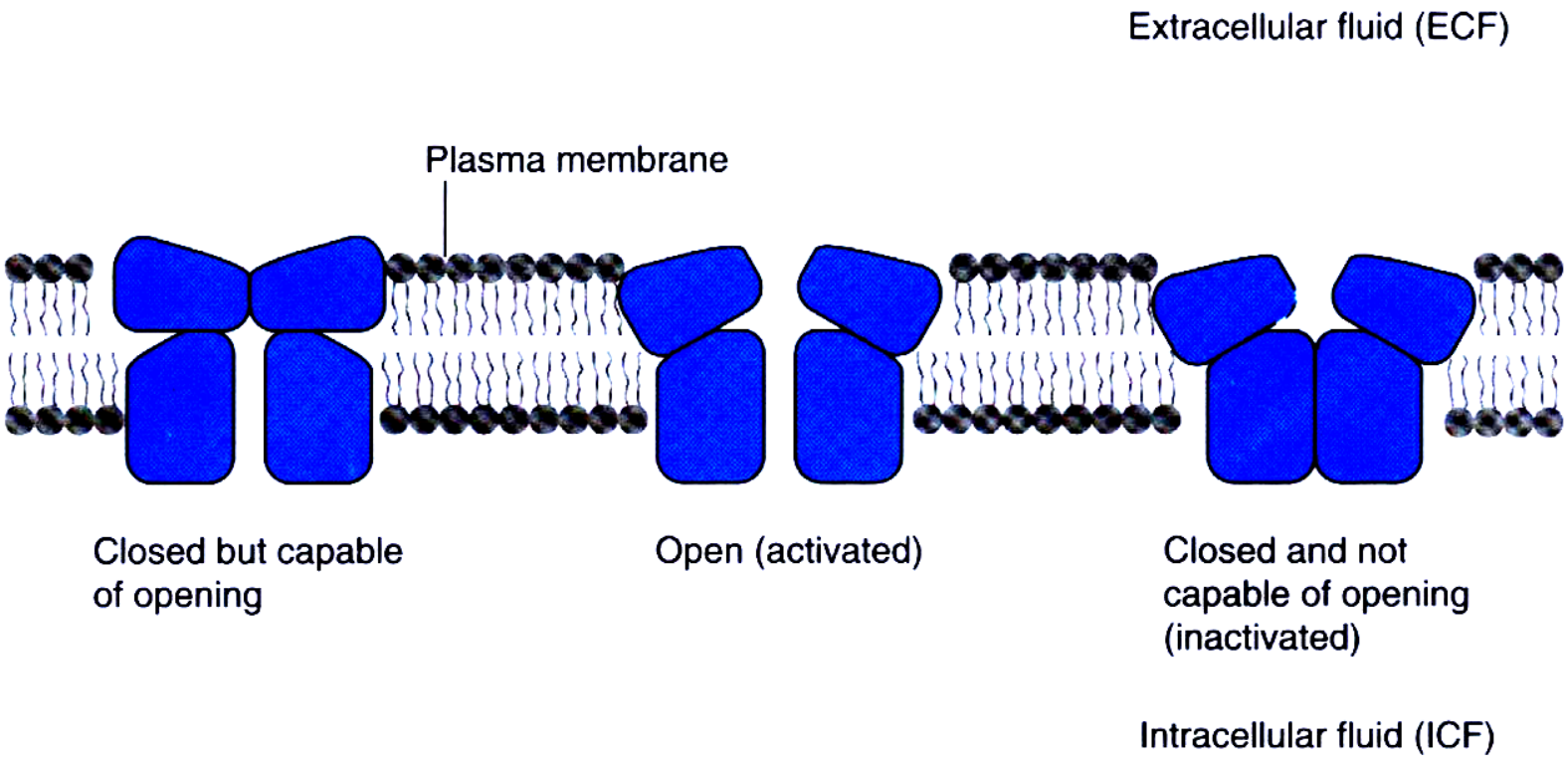
Refractory periods



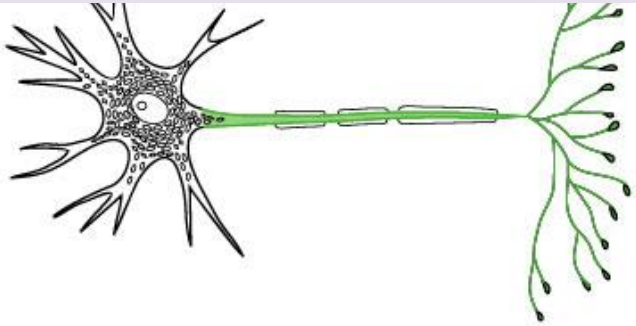


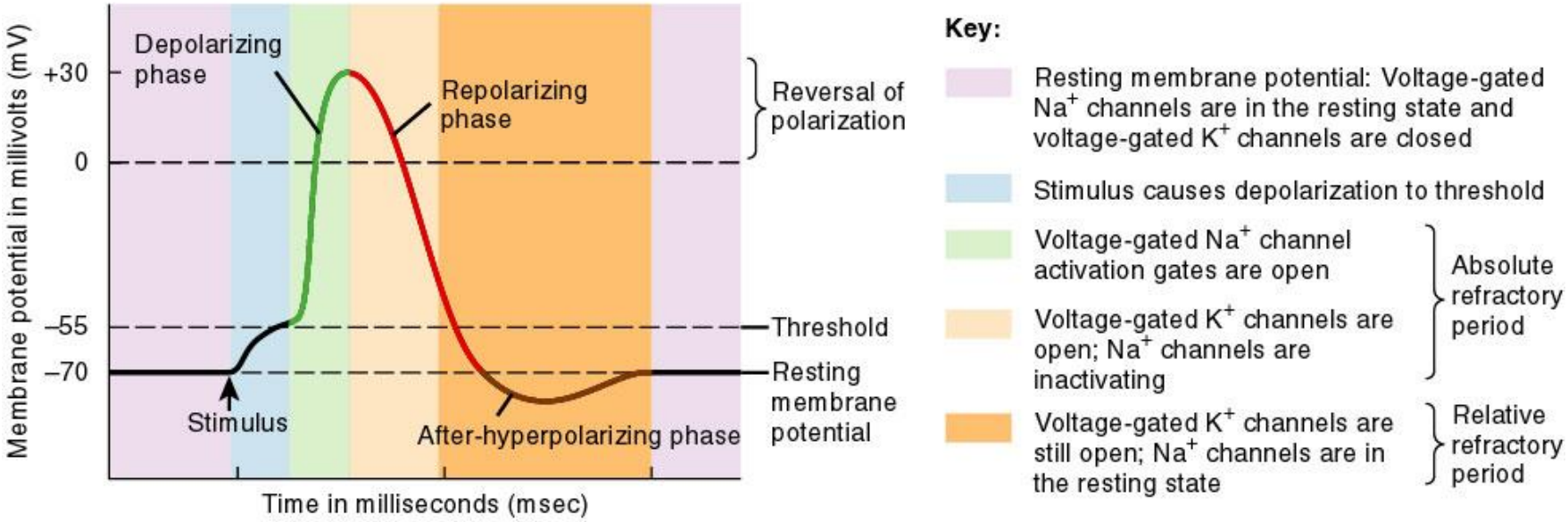
12.11

Refractory periods and Na+ Channels



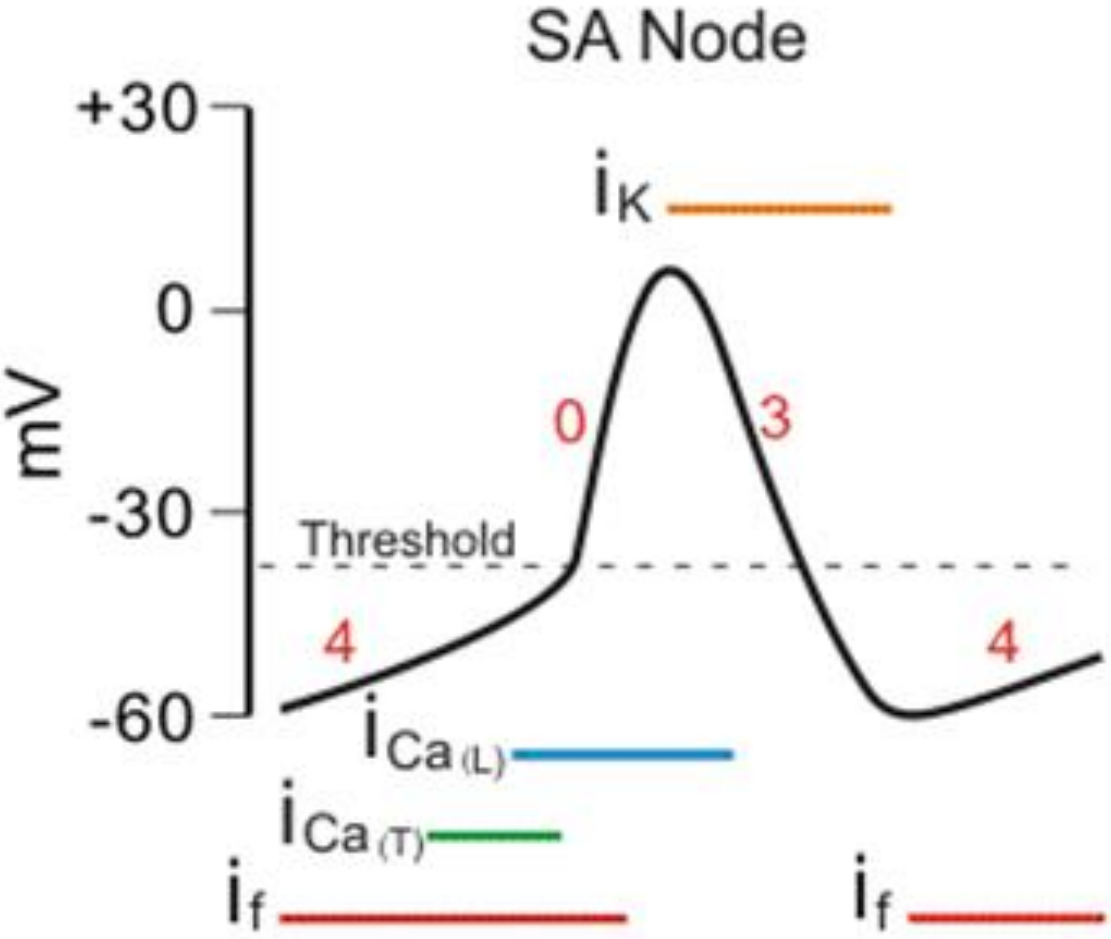
Refractory periods



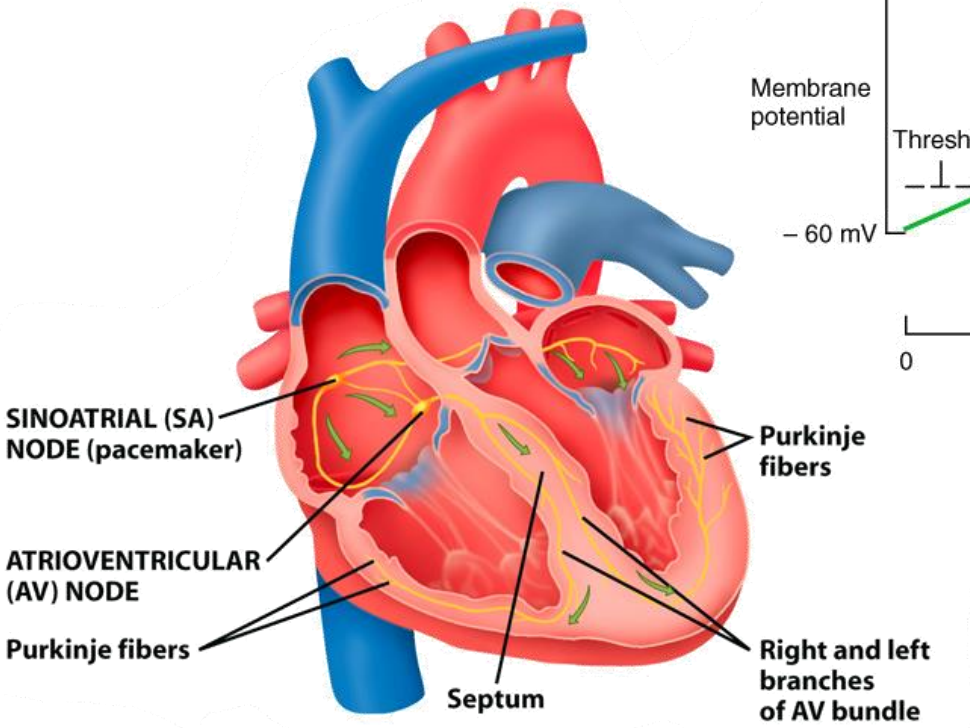


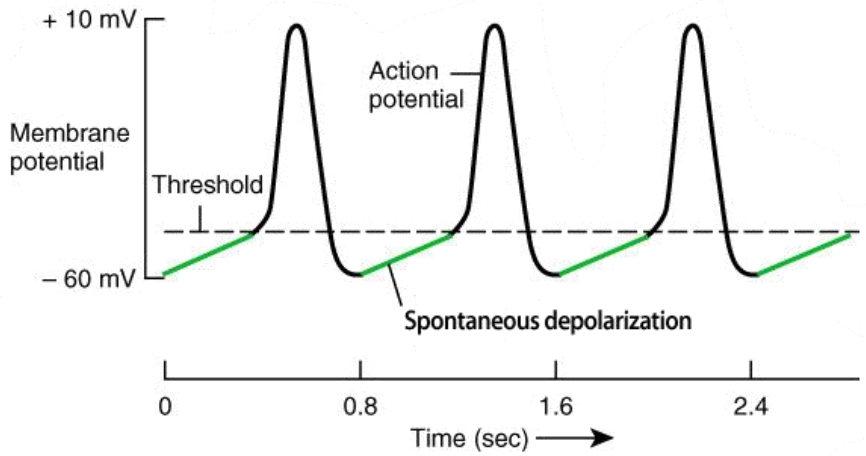
12.11

Involvement of other Ions in Action potential

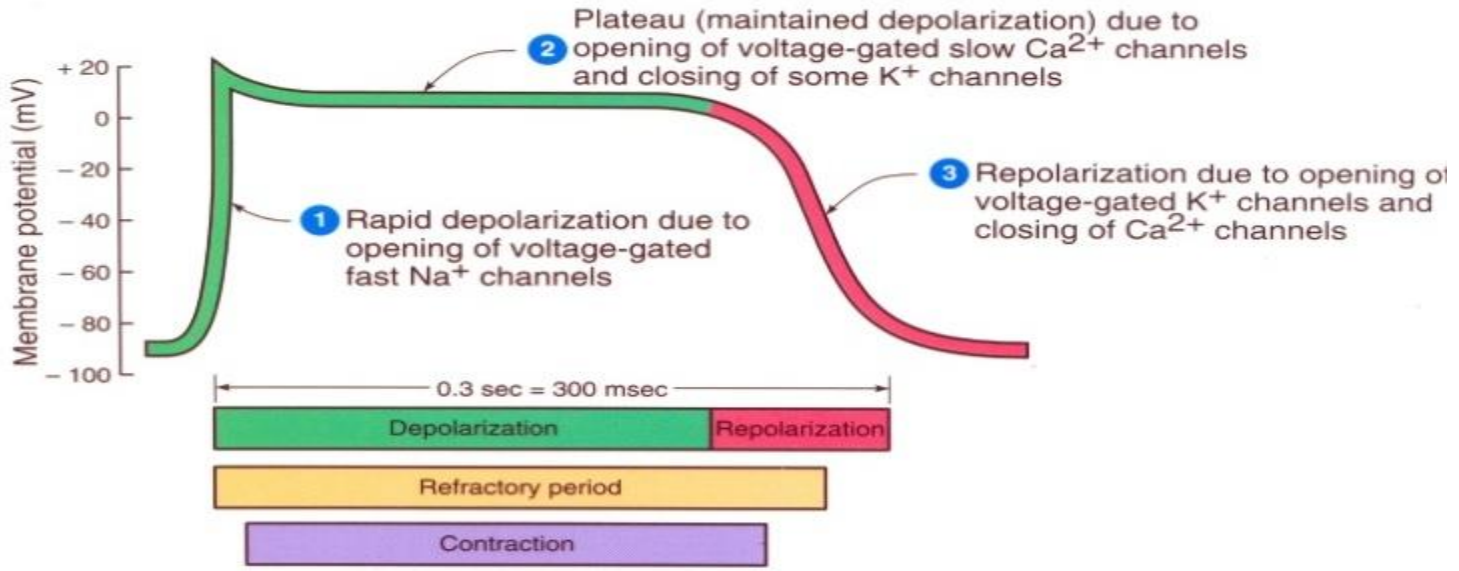

SA Node
+30
0
-30
-60
mV
Threshold
0
3
4
4
i_K
$i_{Ca\,(L)}$
$i_{Ca\,(T)}$
i_f
i_f

Cardiac Conduction

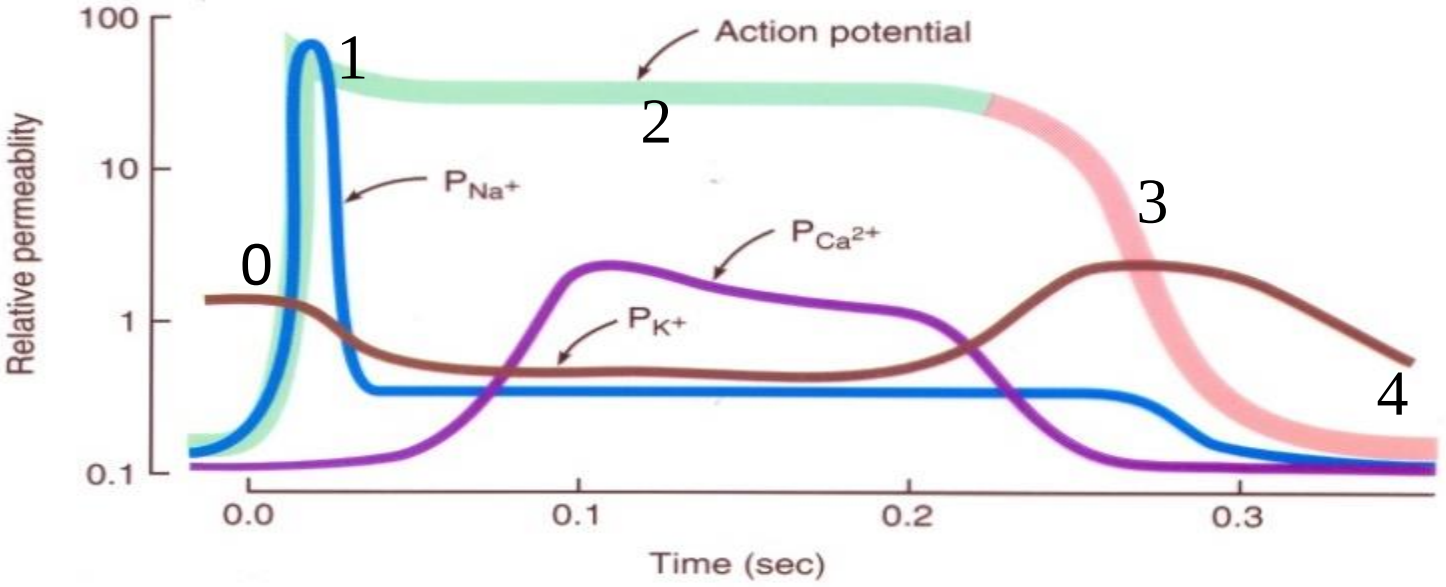




Generation of Action potential every 0.8 seconds, or 75 action potentials per minute at the SA node (**Pacemaker of the heart**)

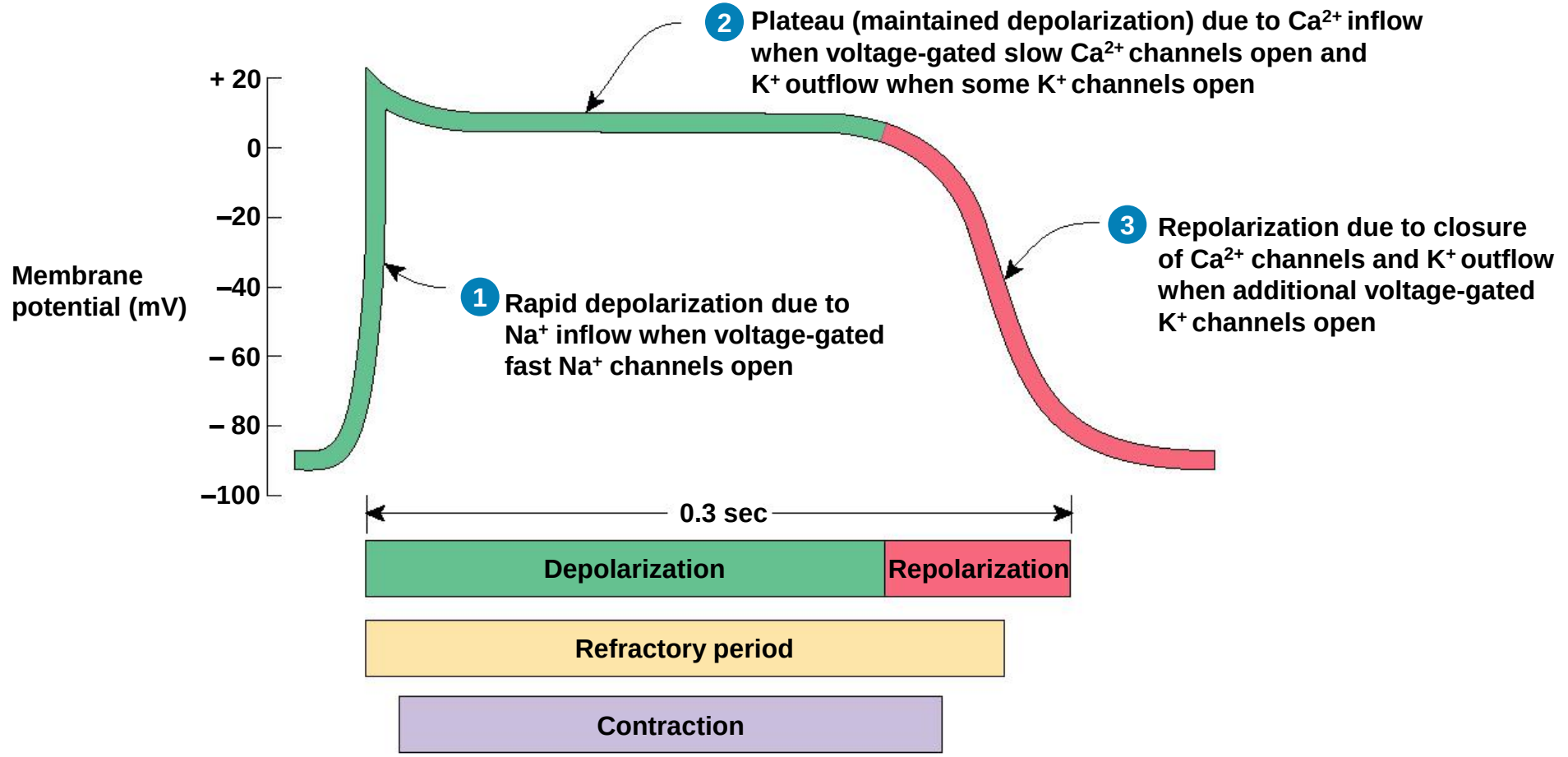


(a) Action potential, refractory period, and contraction

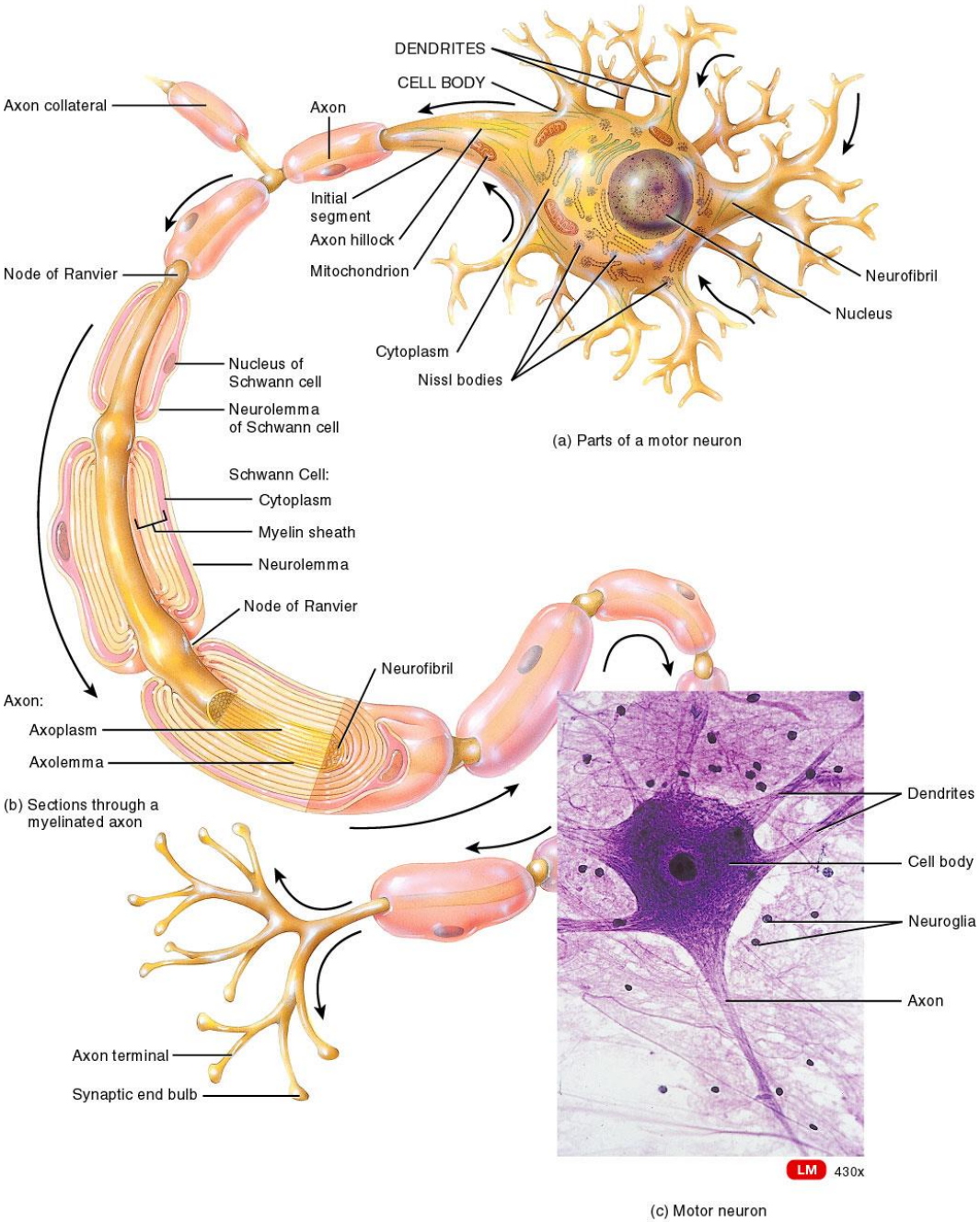


(b) Membrane permeability (P) changes

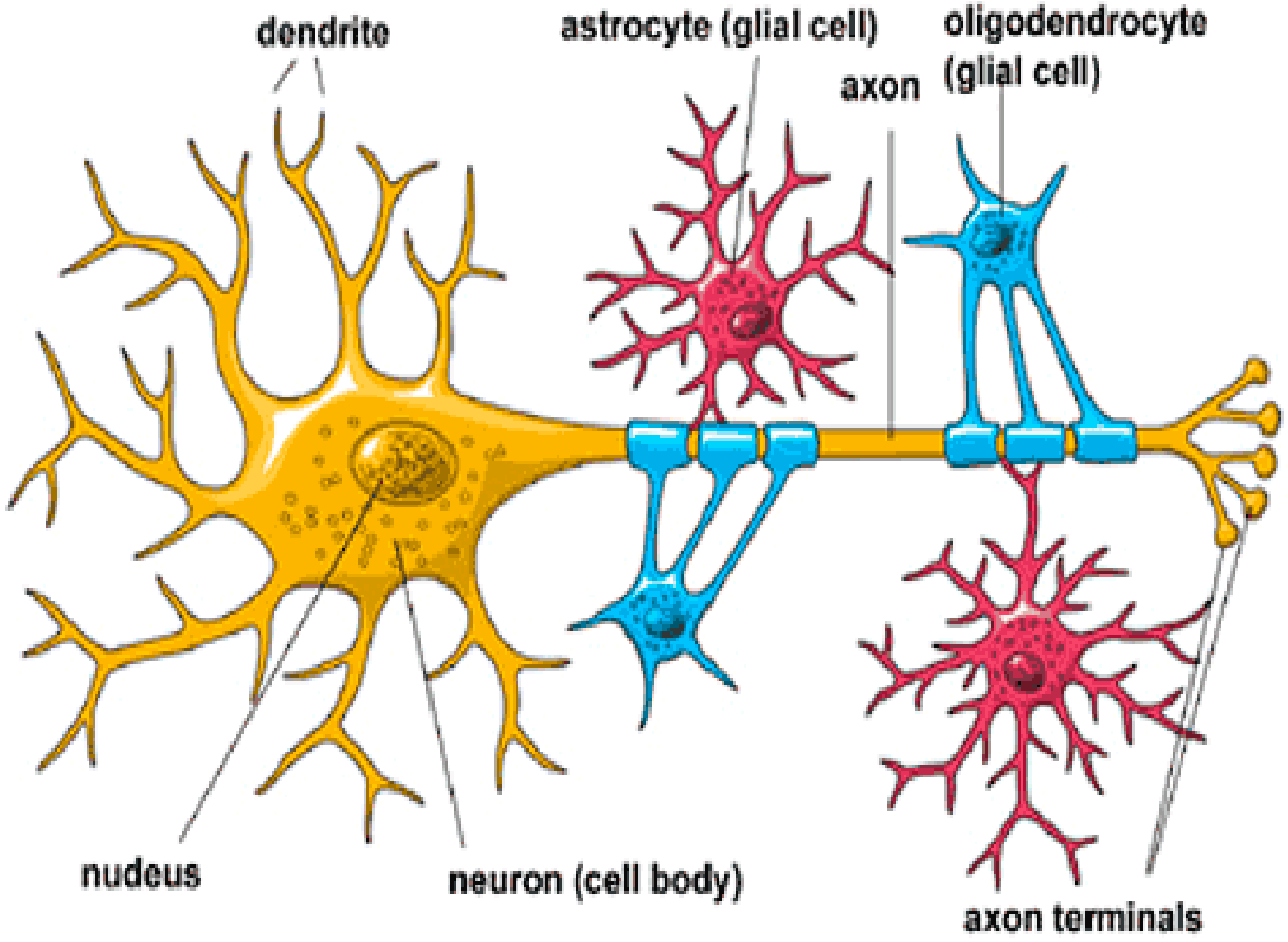
Cardiac Muscle Action Potential



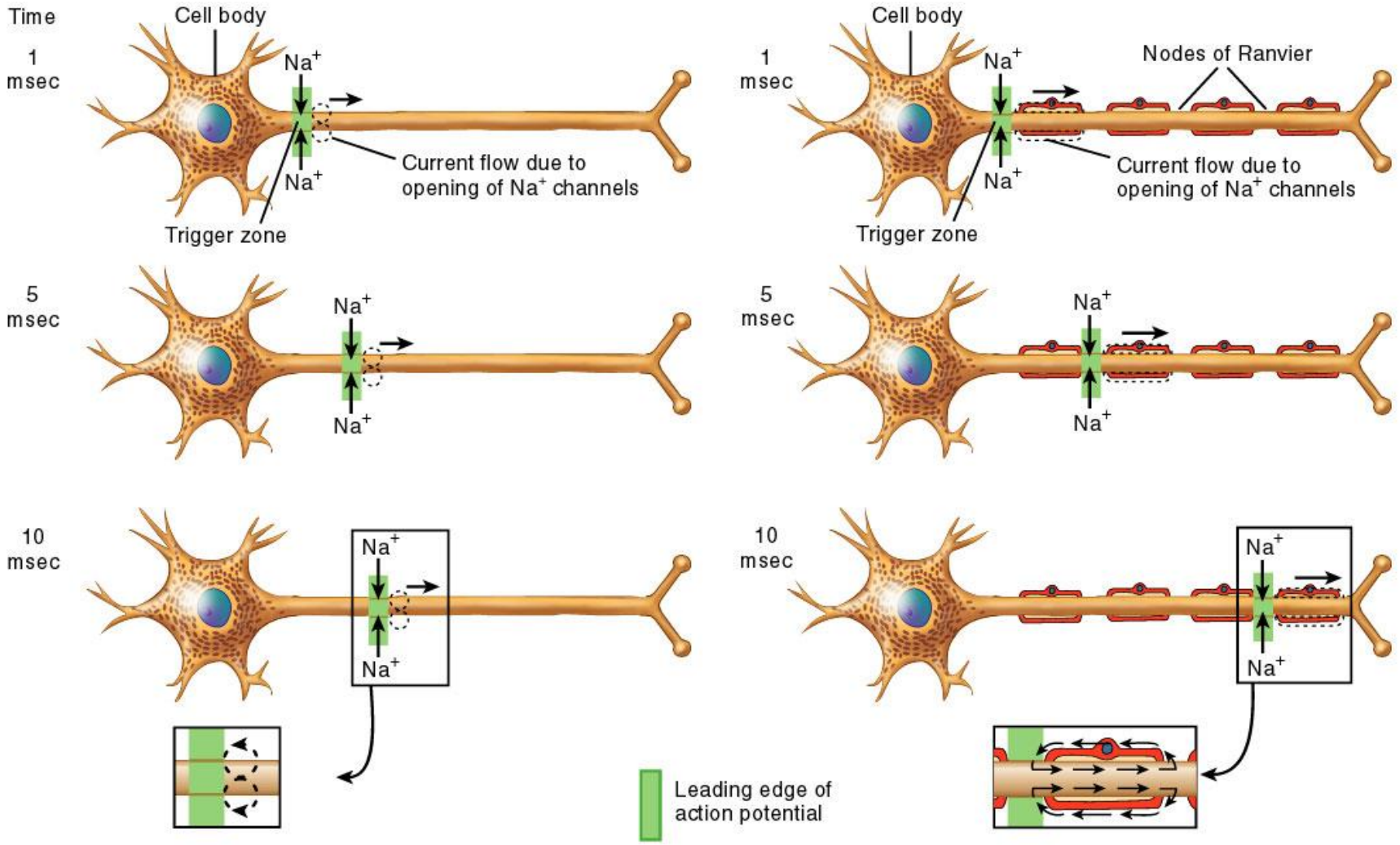
Generation of action potential at Neural cells


DENDRITES
CELL BODY
Axon collateral
Axon
Initial segment
Axon hillock
Mitochondrion
Node of Ranvier
Neurofibril
Nucleus
Cytoplasm
Nissl bodies
Nucleus of Schwann cell
Neurolemma of Schwann cell
(a) Parts of a motor neuron
Schwann Cell:
Cytoplasm
Myelin sheath
Neurolemma
Node of Ranvier
Neurofibril
Axon:
Axoplasm
Axolemma
(b) Sections through a myelinated axon
Dendrites
Cell body
Neuroglia
Axon
Axon terminal
Synaptic end bulb
LM 430x
(c) Motor neuron

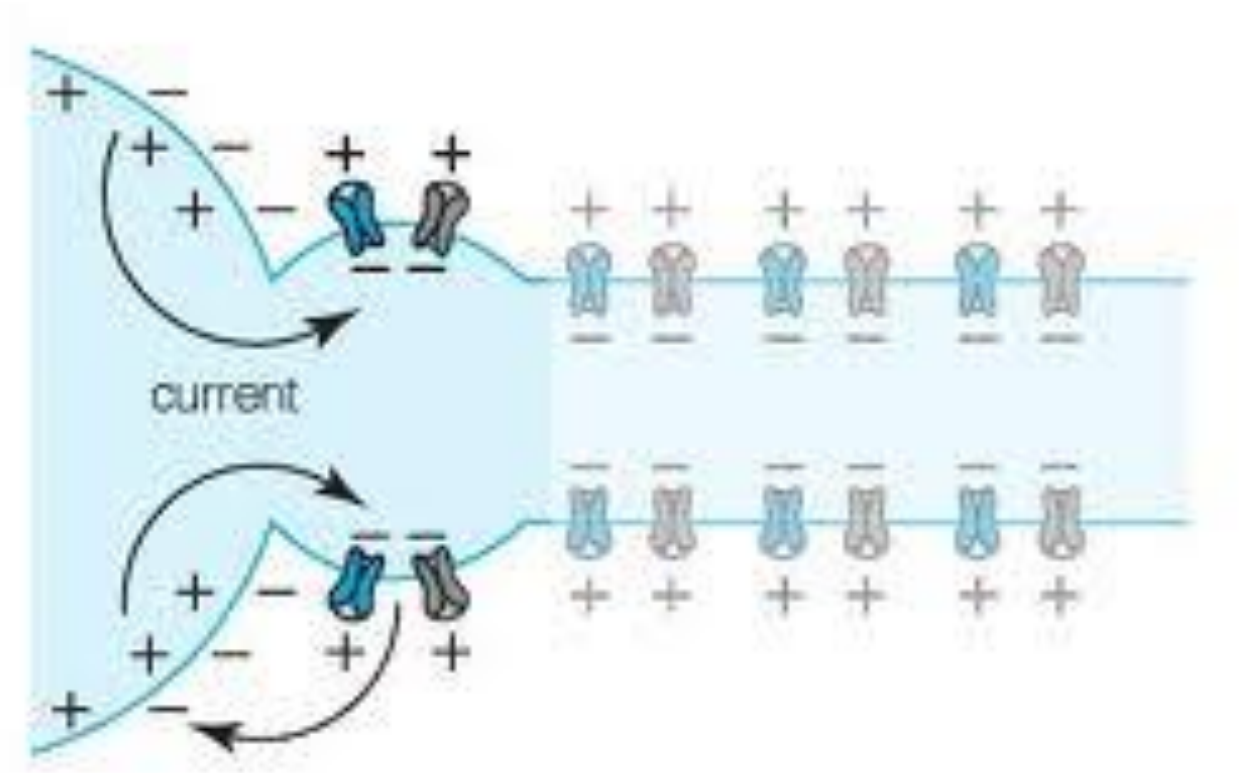
Supportive cells

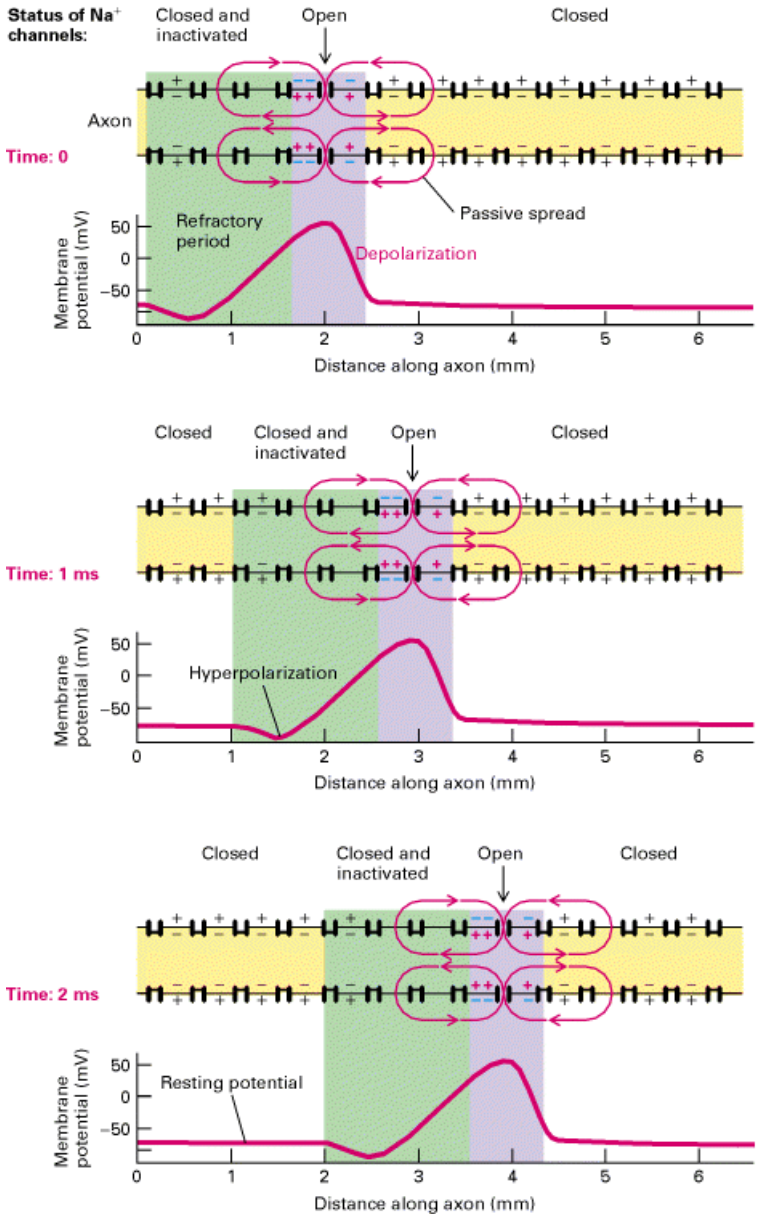


Conduction of impulse


Time
1 msec
5 msec
10 msec
Cell body
Na+
Current flow due to opening of Na+ channels
Trigger zone
Nodes of Ranvier
Leading edge of action potential
(a) Continuous conduction
(b) Saltatory conduction

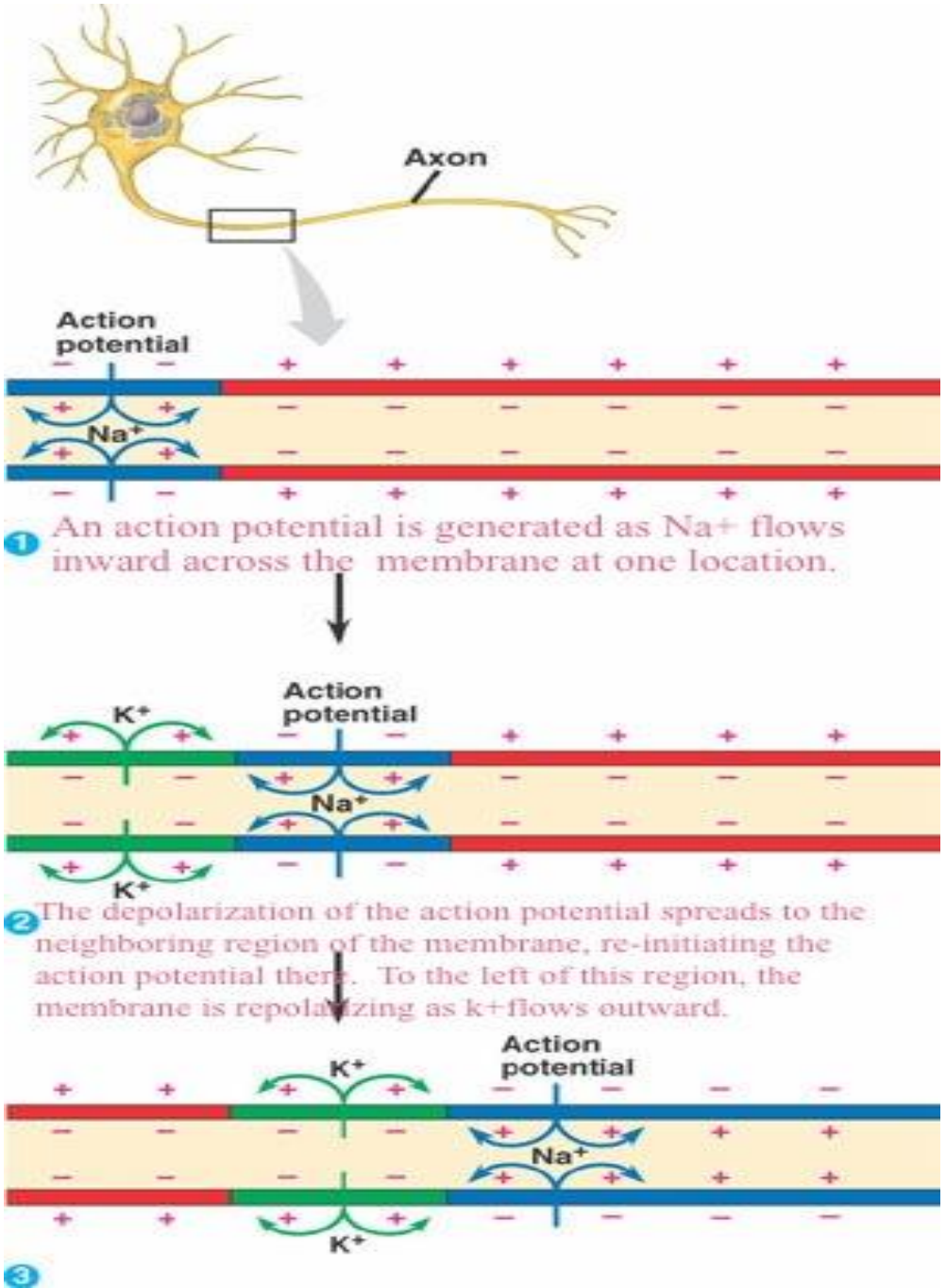
Action potentials





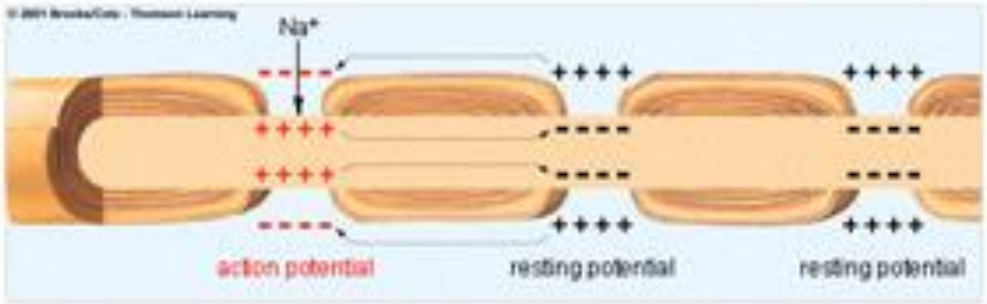
- Continuous Conduction in Unmyelinated axons

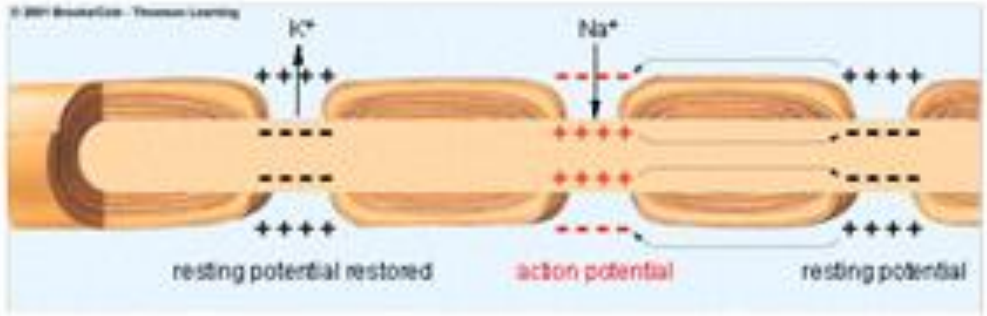
- Continuous Conduction in Unmyelinated axons



Myelin Sheath

Saltatory Conduction in Myelinated axons





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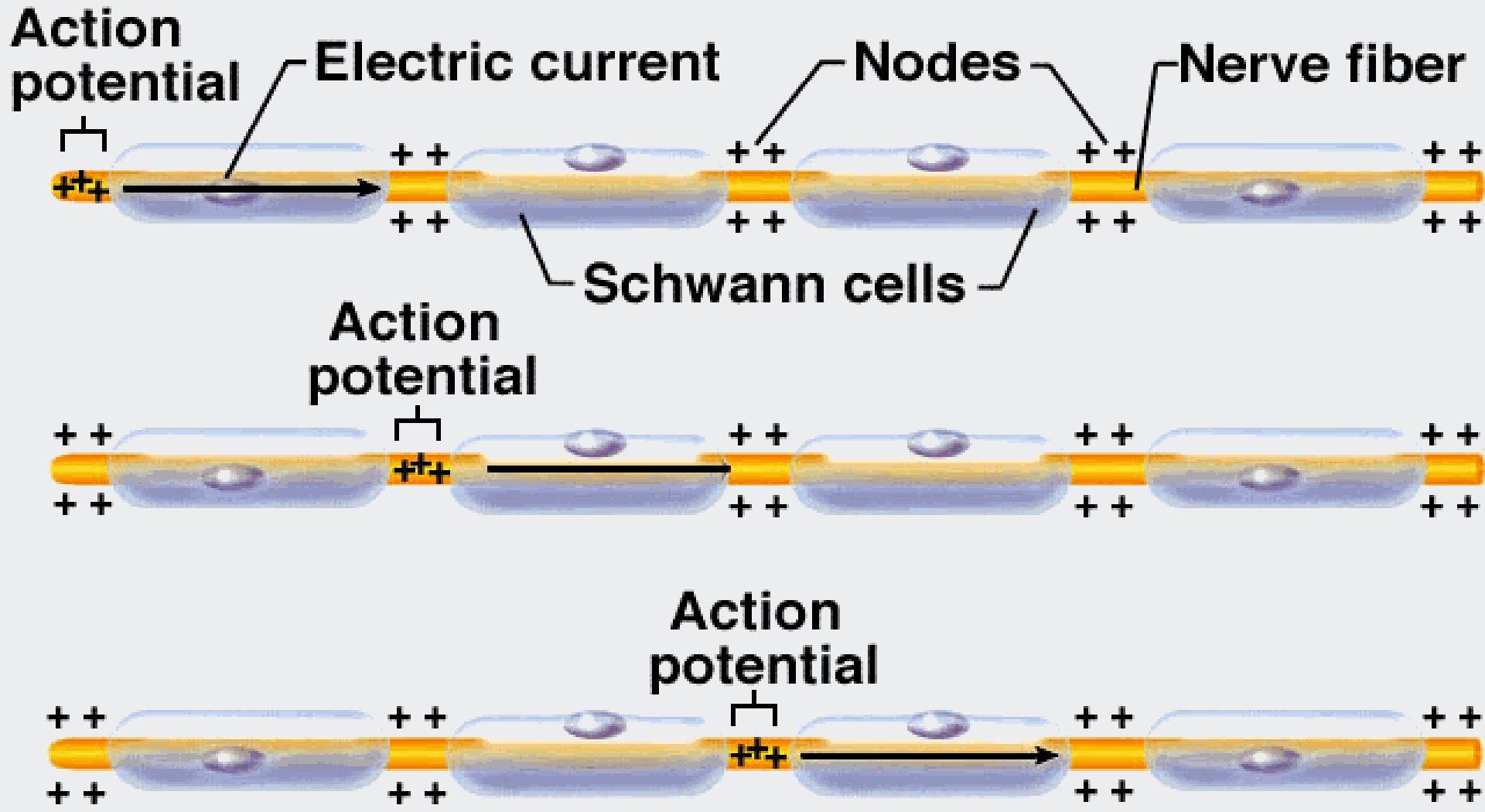
Nerve Impulse on Myelinated Fiber



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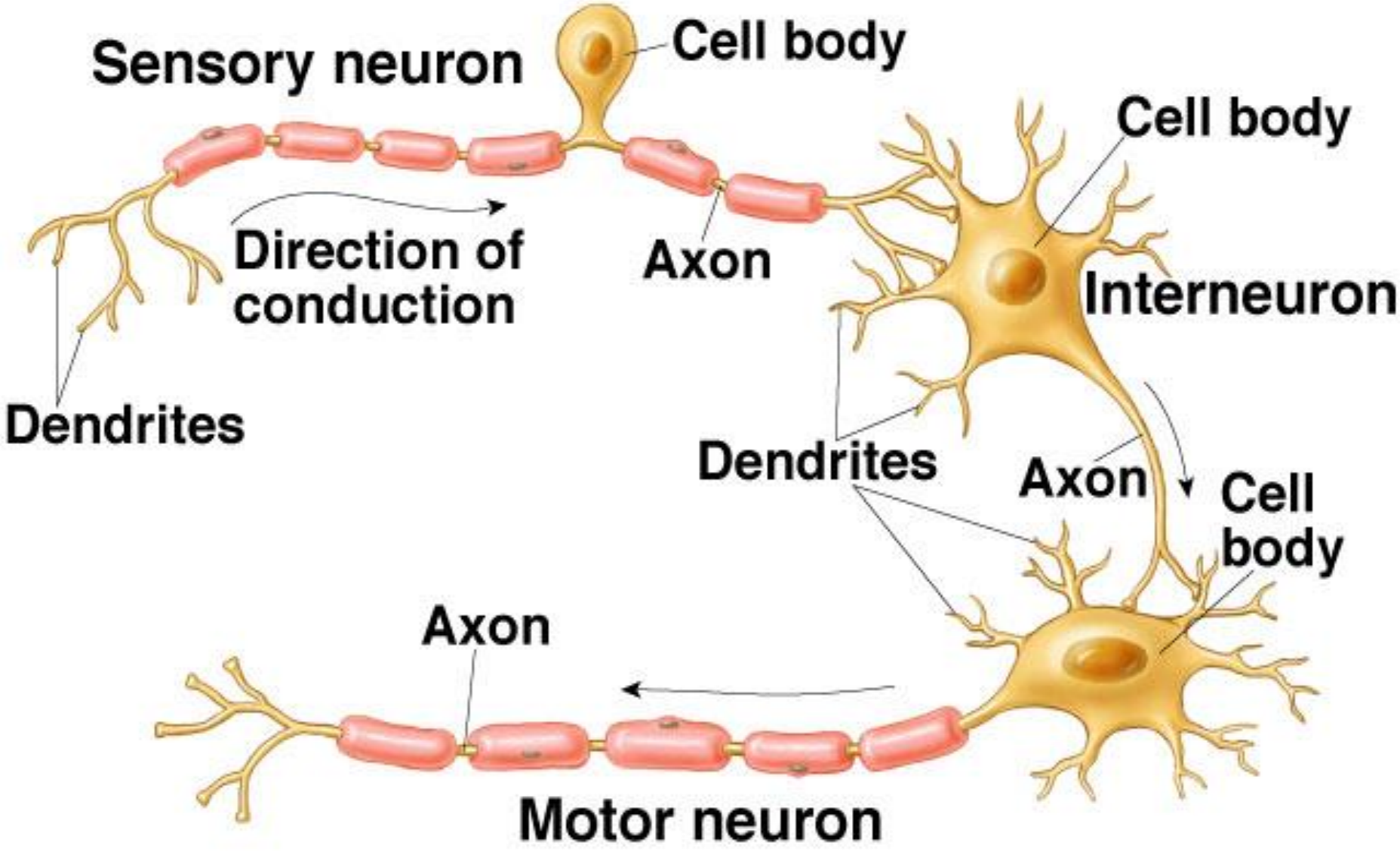


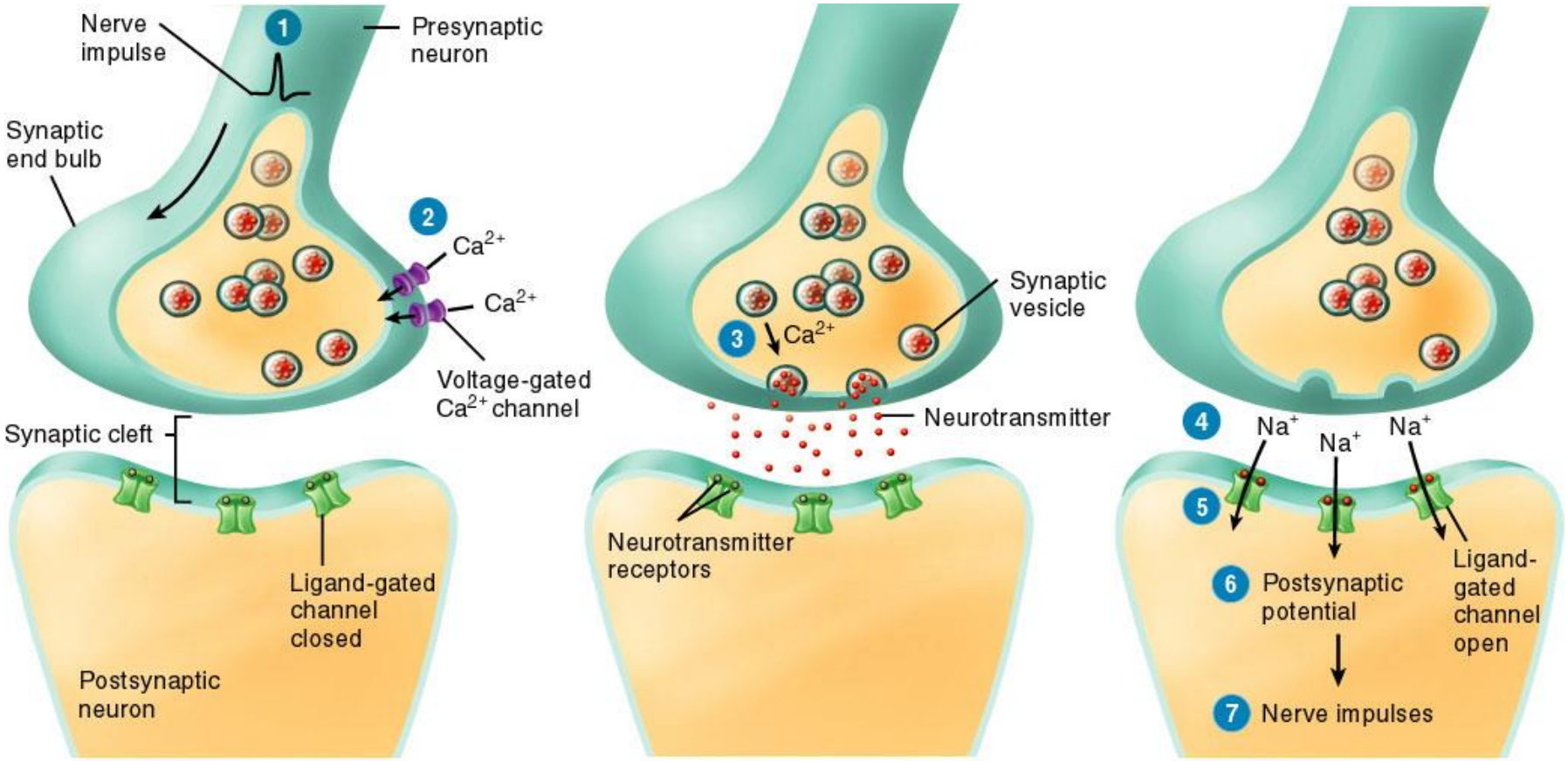
Question

- What is the importance of Refractory period at the nerve fiber??

Propagation of Action Potential

Saltatory *vs.* Continuous conduction

- https://www.youtube.com/watch?v=8yC--NvBn_M
- https://www.youtube.com/watch?v=RNdvrkolW0M
- https://www.youtube.com/watch?v=tOTYO5WrXFU


Nerve impulse
1
Presynaptic neuron
Synaptic end bulb
2
Ca^{2+}
Ca^{2+}
Voltage-gated Ca^{2+} channel
Synaptic cleft
Ligand-gated channel closed
Postsynaptic neuron
3
Ca^{2+}
Synaptic vesicle
Neurotransmitter
Neurotransmitter receptors
4
Na^{+}
Na^{+}
Na^{+}
5
6
Postsynaptic potential
Ligand-gated channel open
7
Nerve impulses

12.14

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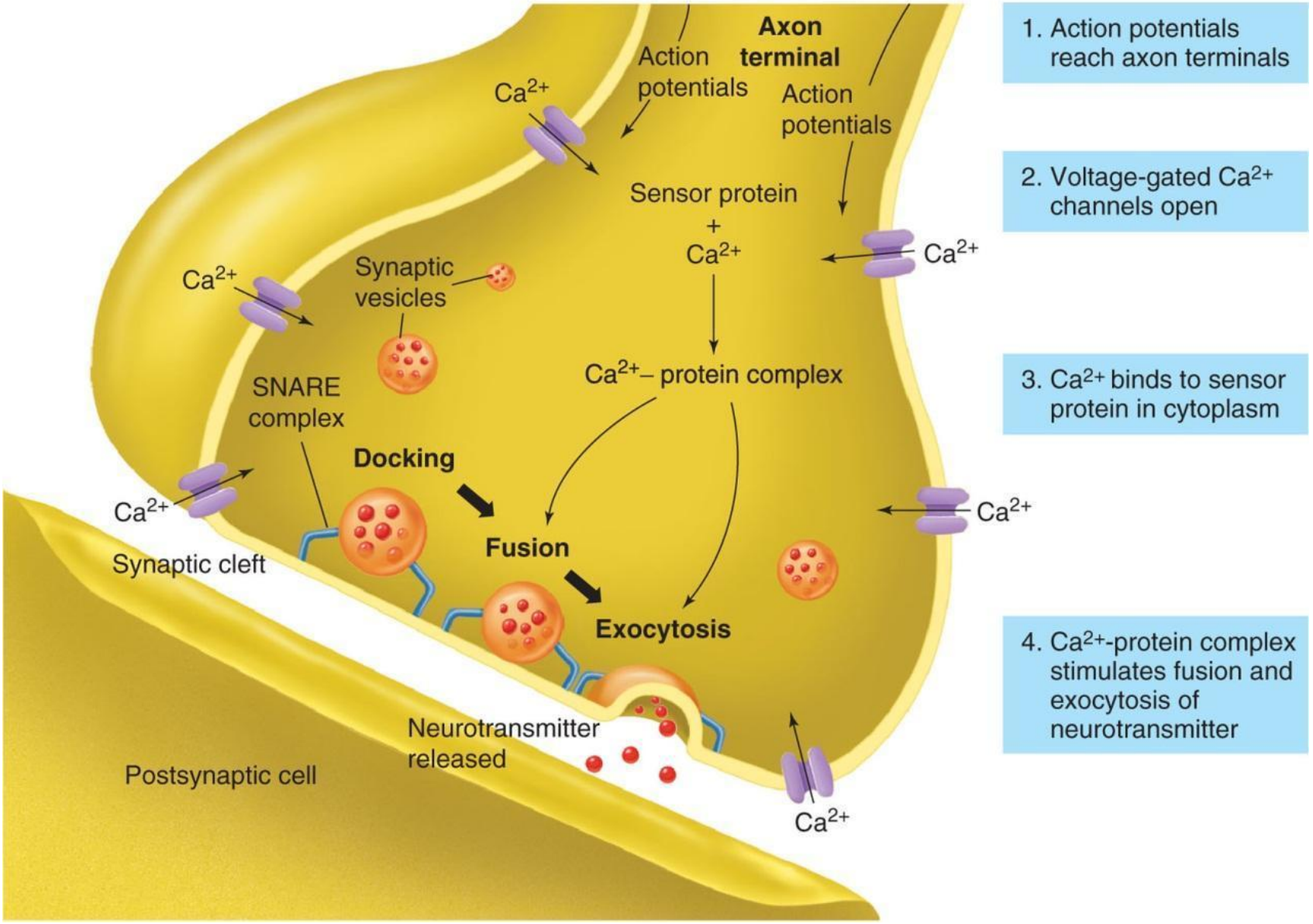
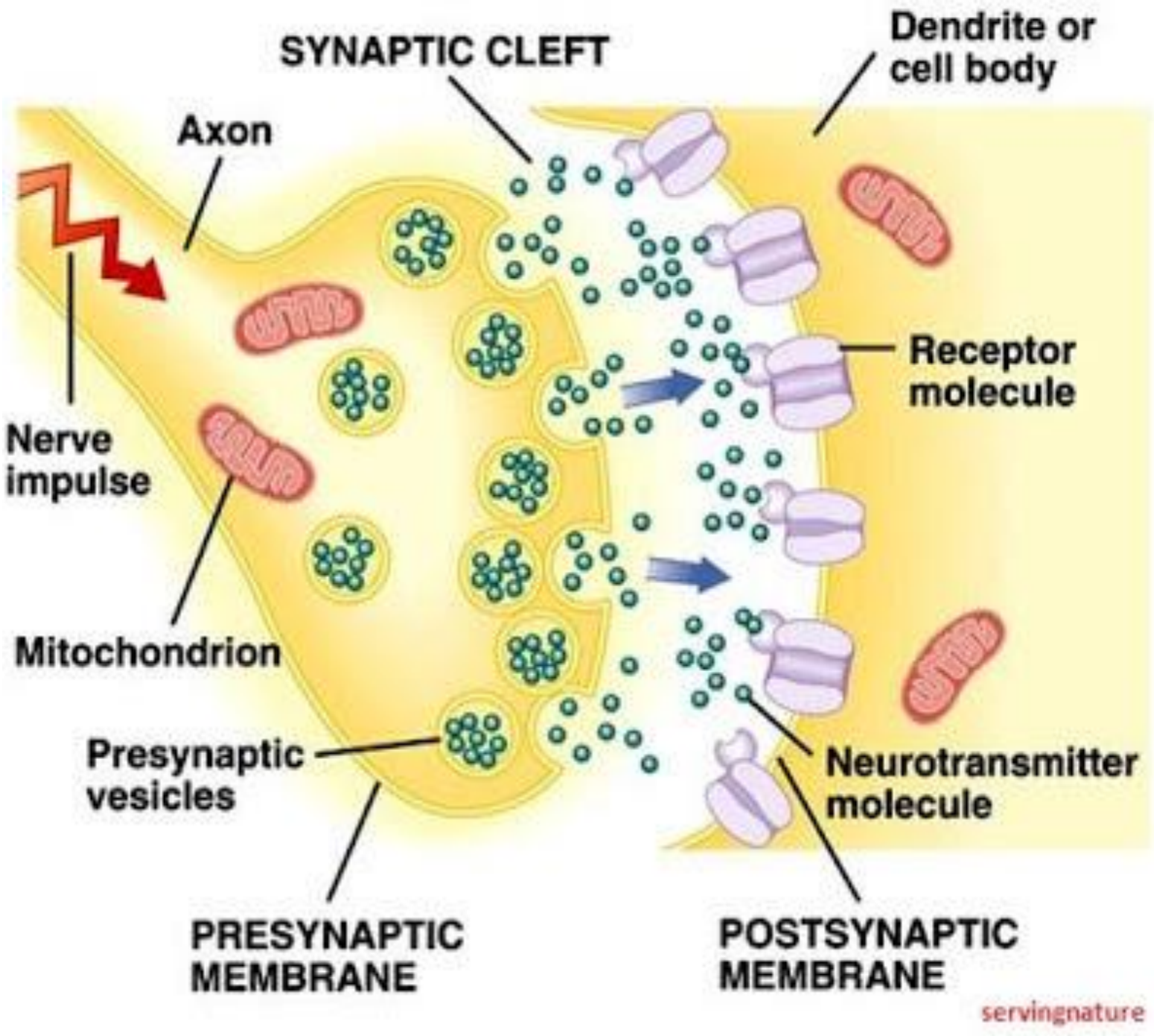
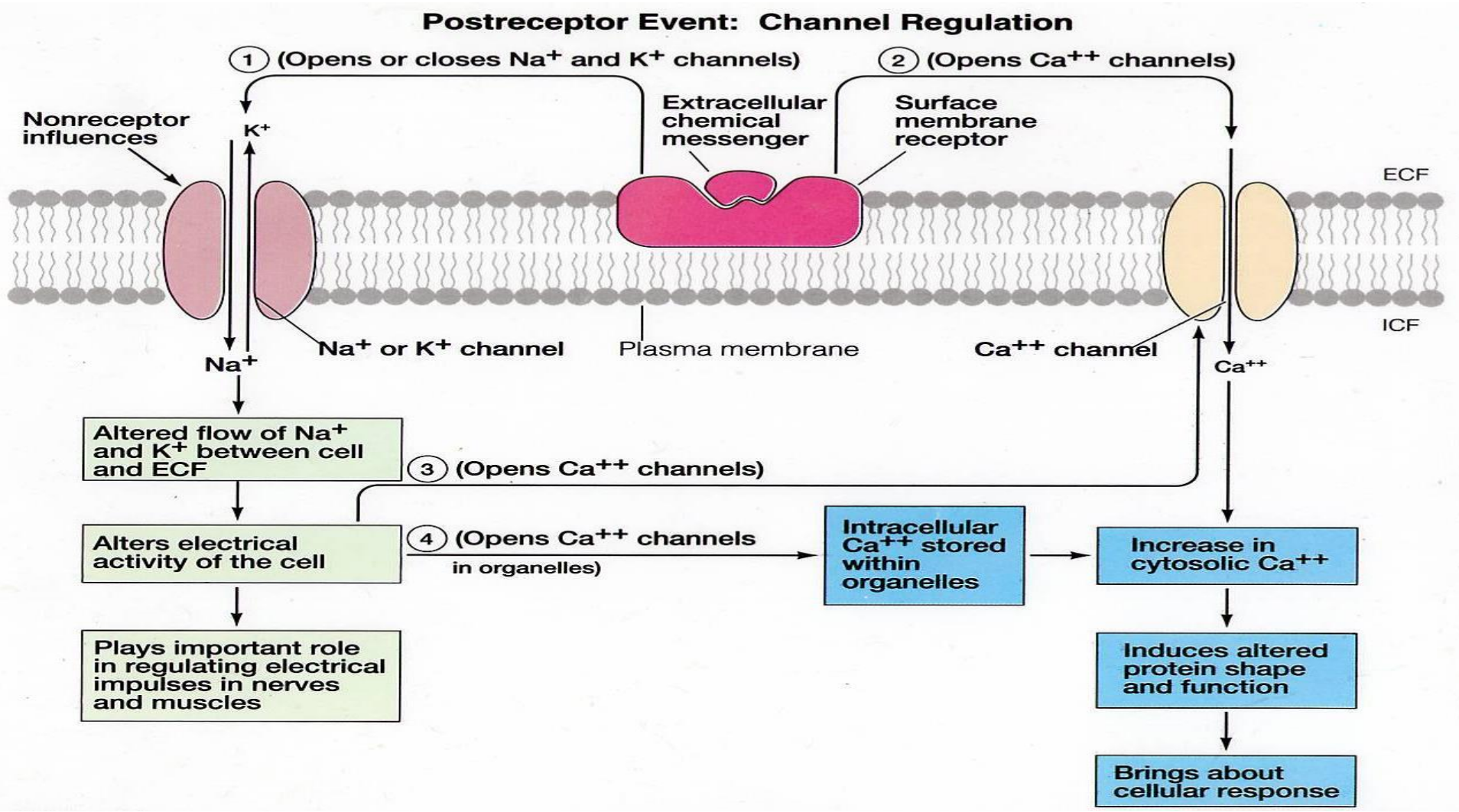
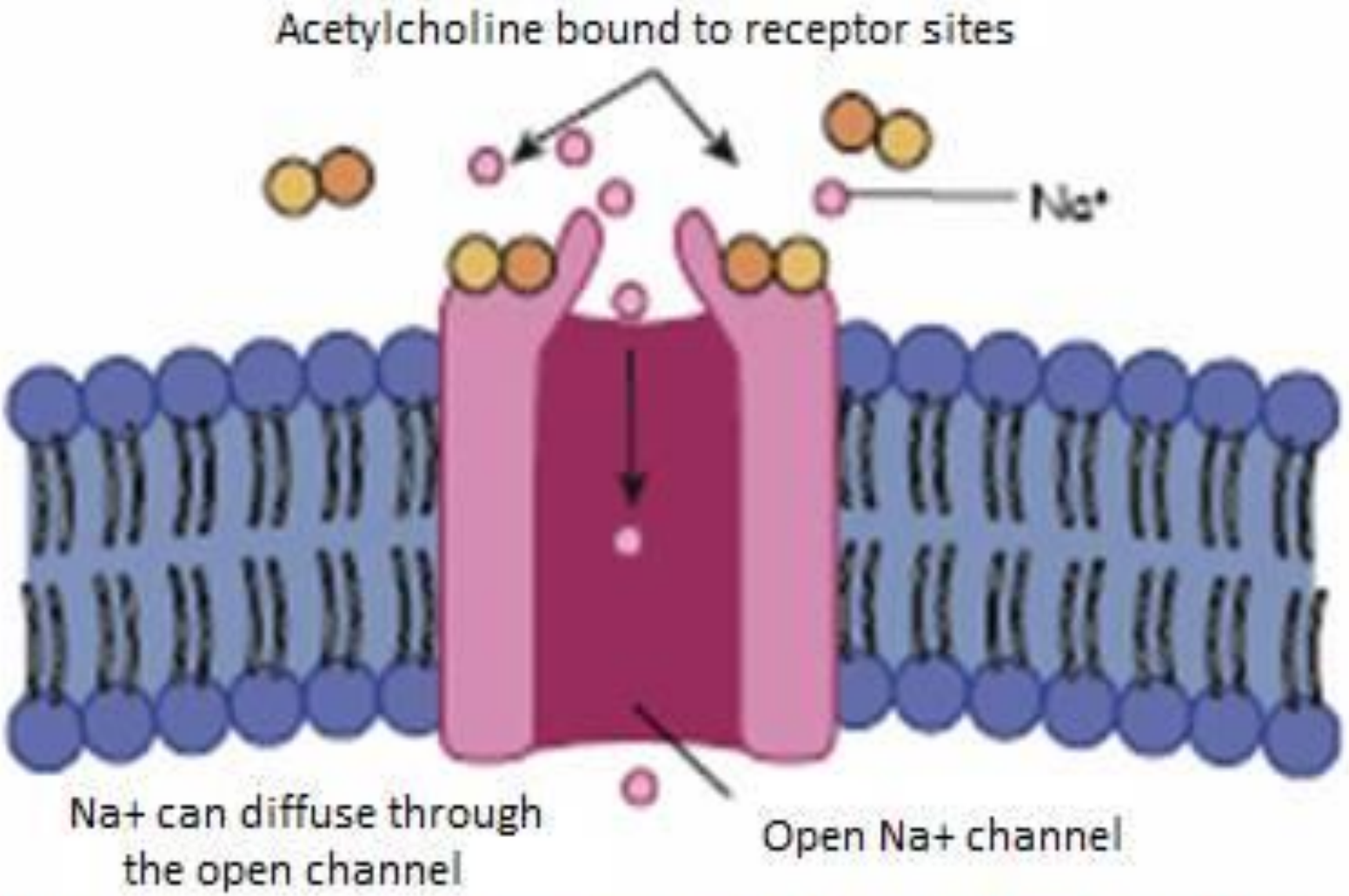



SYNAPTIC CLEFT
Dendrite or cell body
Axon
Receptor molecule
Nerve impulse
Mitochondrion
Presynaptic vesicles
Neurotransmitter molecule
PRESYNAPTIC MEMBRANE
POSTSYNAPTIC MEMBRANE
servingnature

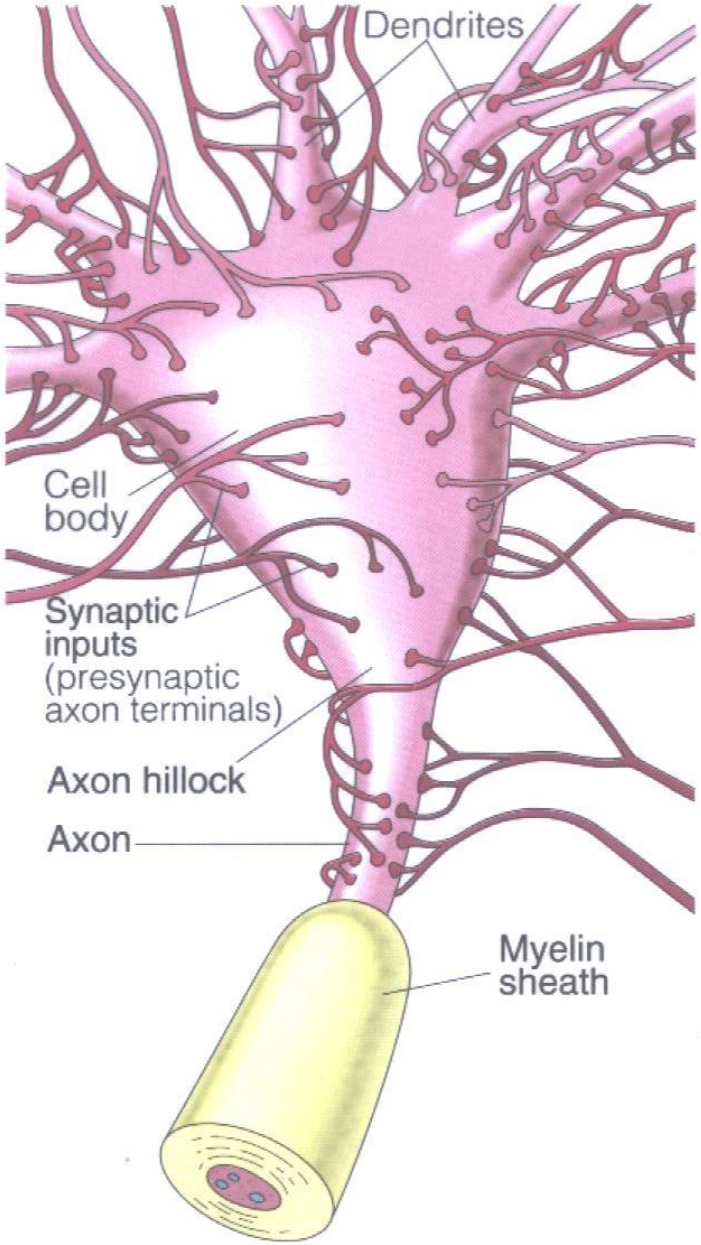
Chemical gated Channels

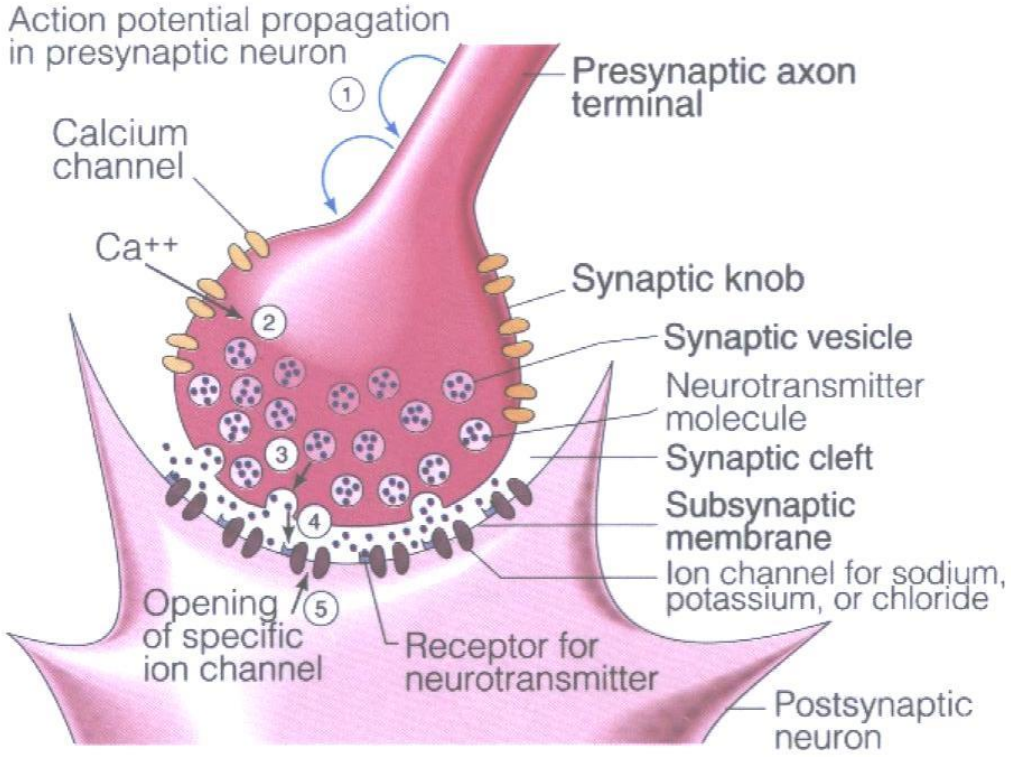


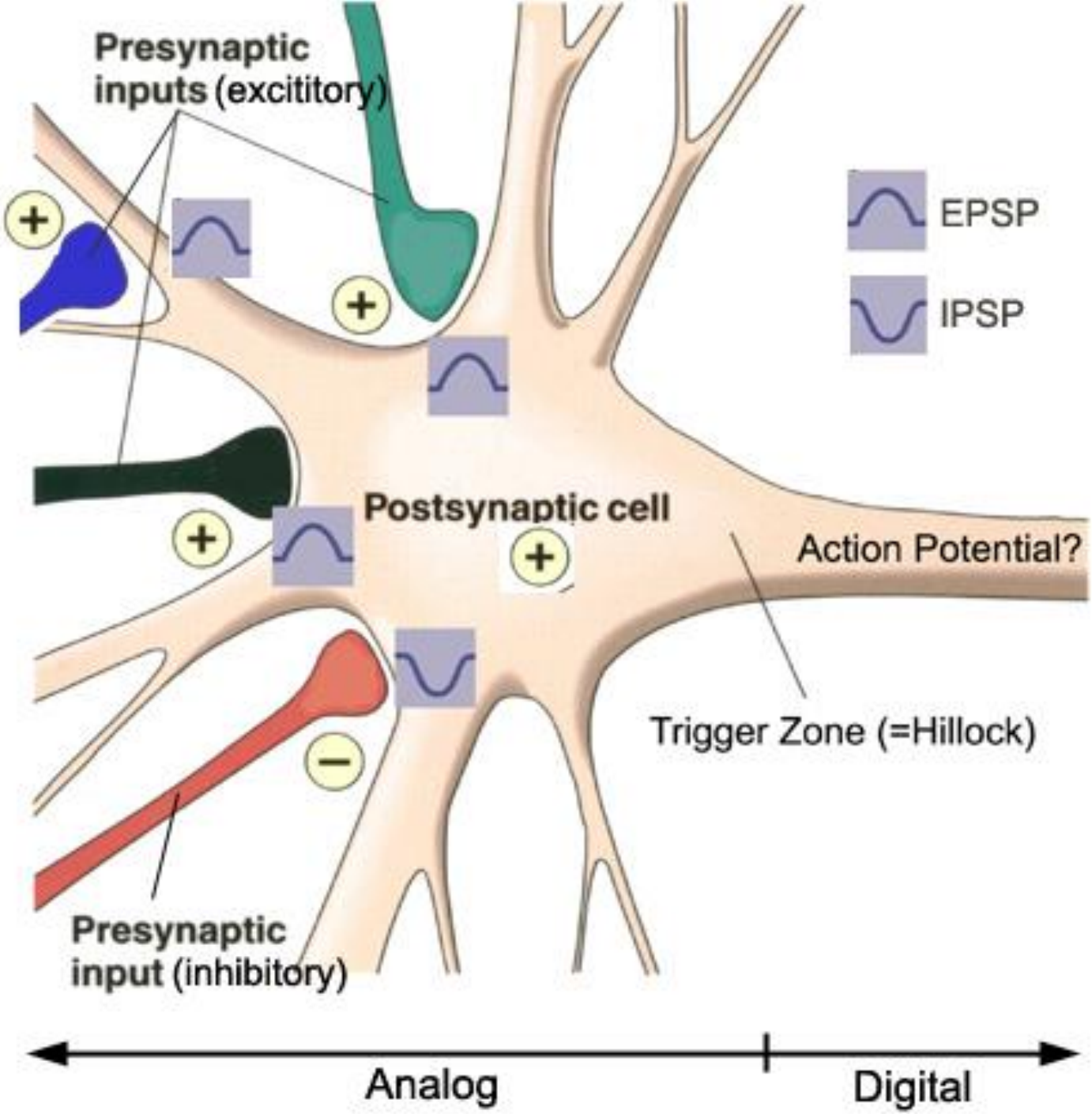


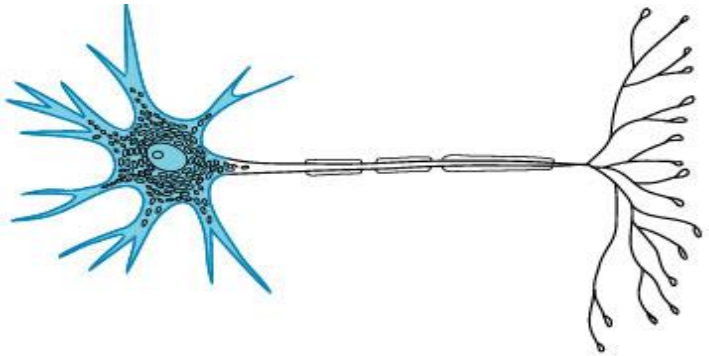
When 2 acetylcholine molecules bind to their receptor sites on the Na+ channel, the channel opens to allow Na+ to diffuse through the channel into the cell

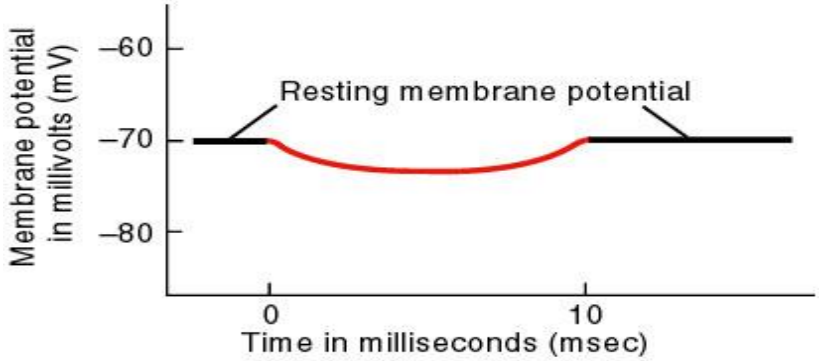
Synaptic Structure and Function



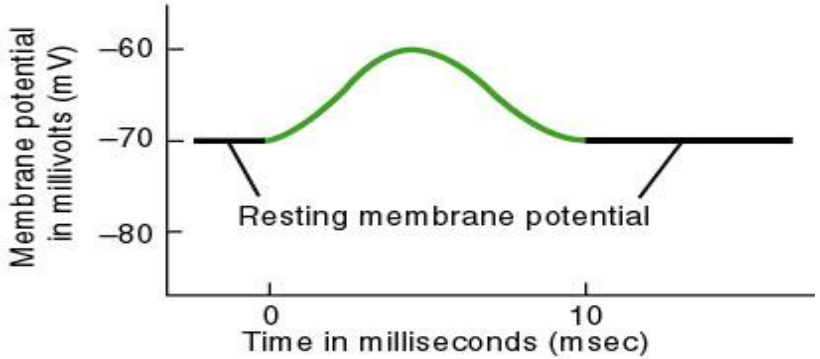



Presynaptic inputs (excititory)
EPSP
IPSP
Postsynaptic cell
Action Potential?
Trigger Zone (=Hillock)
Presynaptic input (inhibitory)
Analog
Digital





(a) Hyperpolarizing graded potential

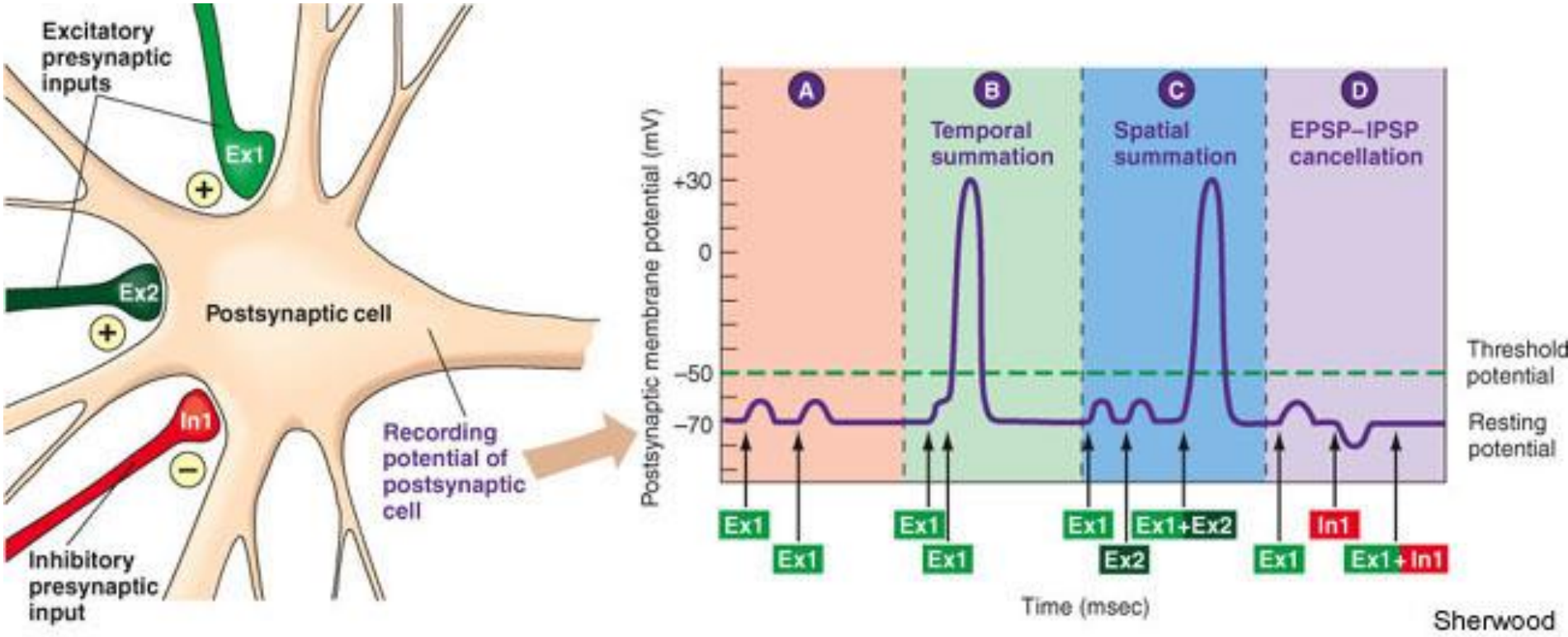


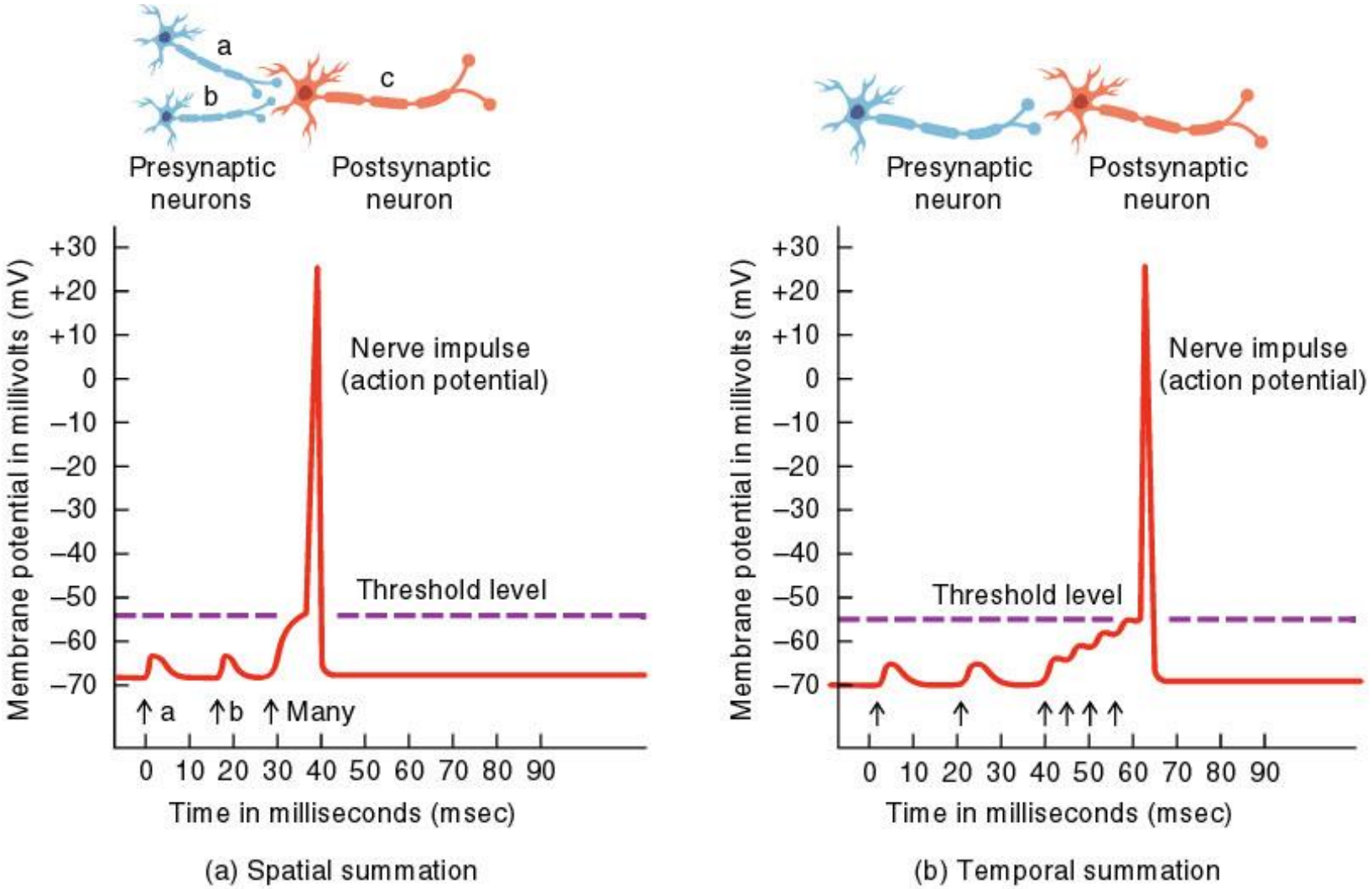
(b) Depolarizing graded potential

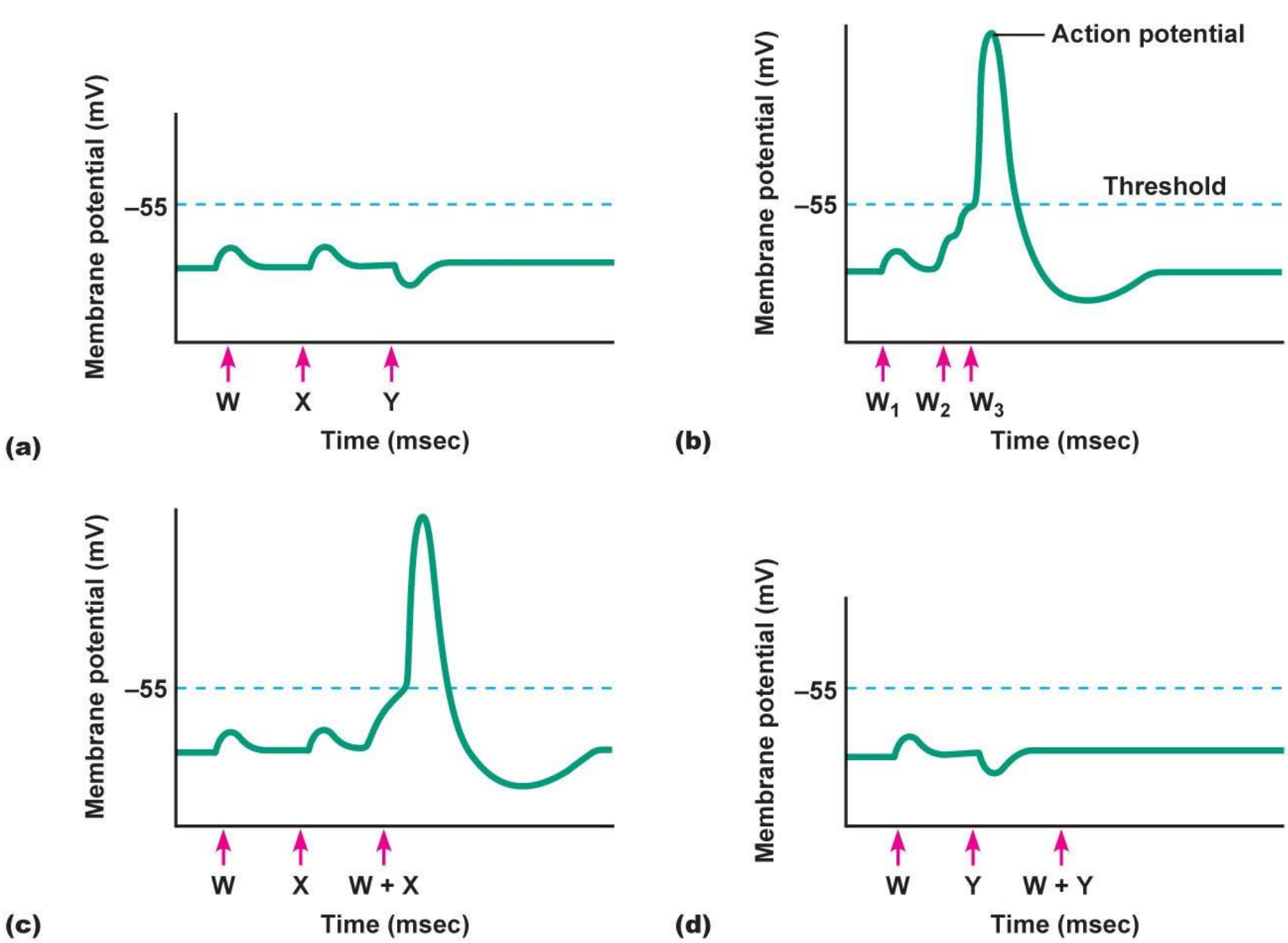
Generation of EPSP and IPSP

- https://www.youtube.com/watch?v=I7-PHiy8yCk

Summation of postsynaptic potentials




a
b
c
Presynaptic neurons
Postsynaptic neuron
Membrane potential in millivolts (mV)
+30
+20
+10
0
–10
–20
–30
–40
–50
–60
–70
Nerve impulse (action potential)
Threshold level
↑a ↑b ↑Many
0 10 20 30 40 50 60 70 80 90
Time in milliseconds (msec)
(a) Spatial summation
Presynaptic neuron
Postsynaptic neuron
Membrane potential in millivolts (mV)
Nerve impulse (action potential)
Threshold level
↑ ↑ ↑↑↑↑
0 10 20 30 40 50 60 70 80 90
Time in milliseconds (msec)
(b) Temporal summation



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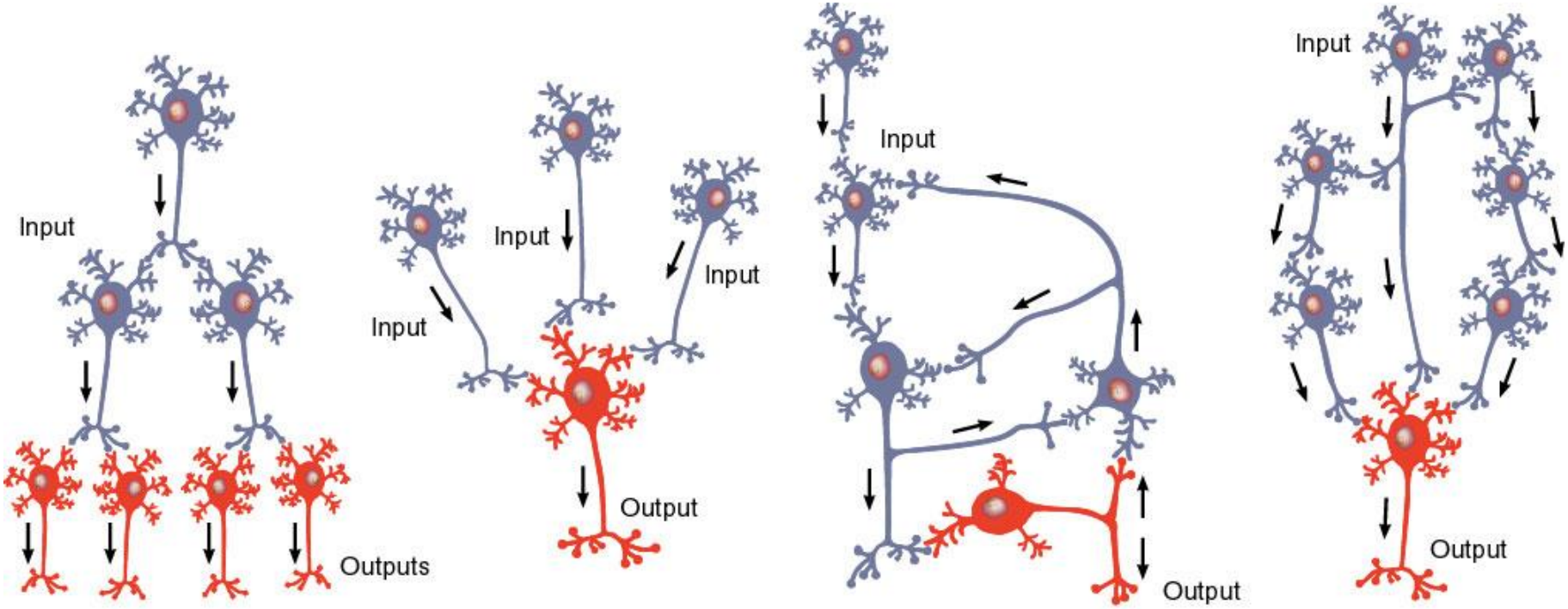
Synaptic organization



(a) Diverging circuit (b) Converging circuit (c) Reverberating circuit (d) Parallel after-discharge circuit

12.16

Question

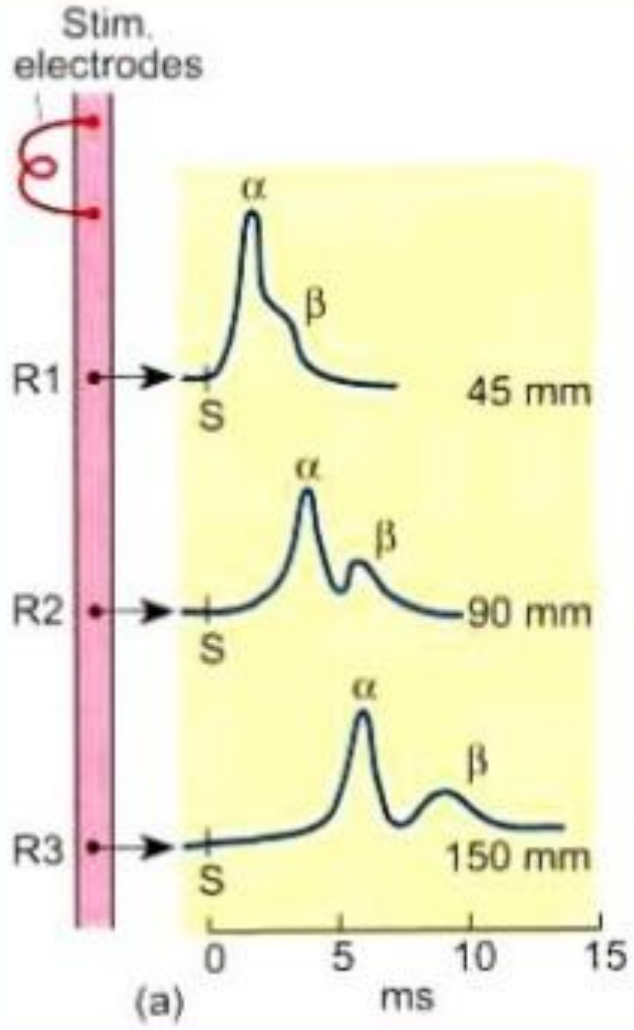
- Identify differences between Chemical and Electrical synapse?
- https://www.youtube.com/watch?v=OvVl8rOEncE

- What type of protein structure is involved in having electrical synapse?

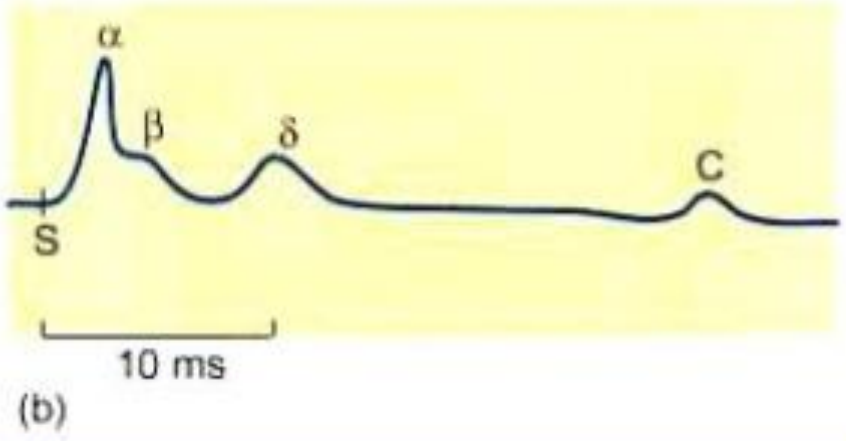
Monophasic action potential Vs Biphasic action potentials

https://www.youtube.com/watch?v=bEjpfnXgtUc

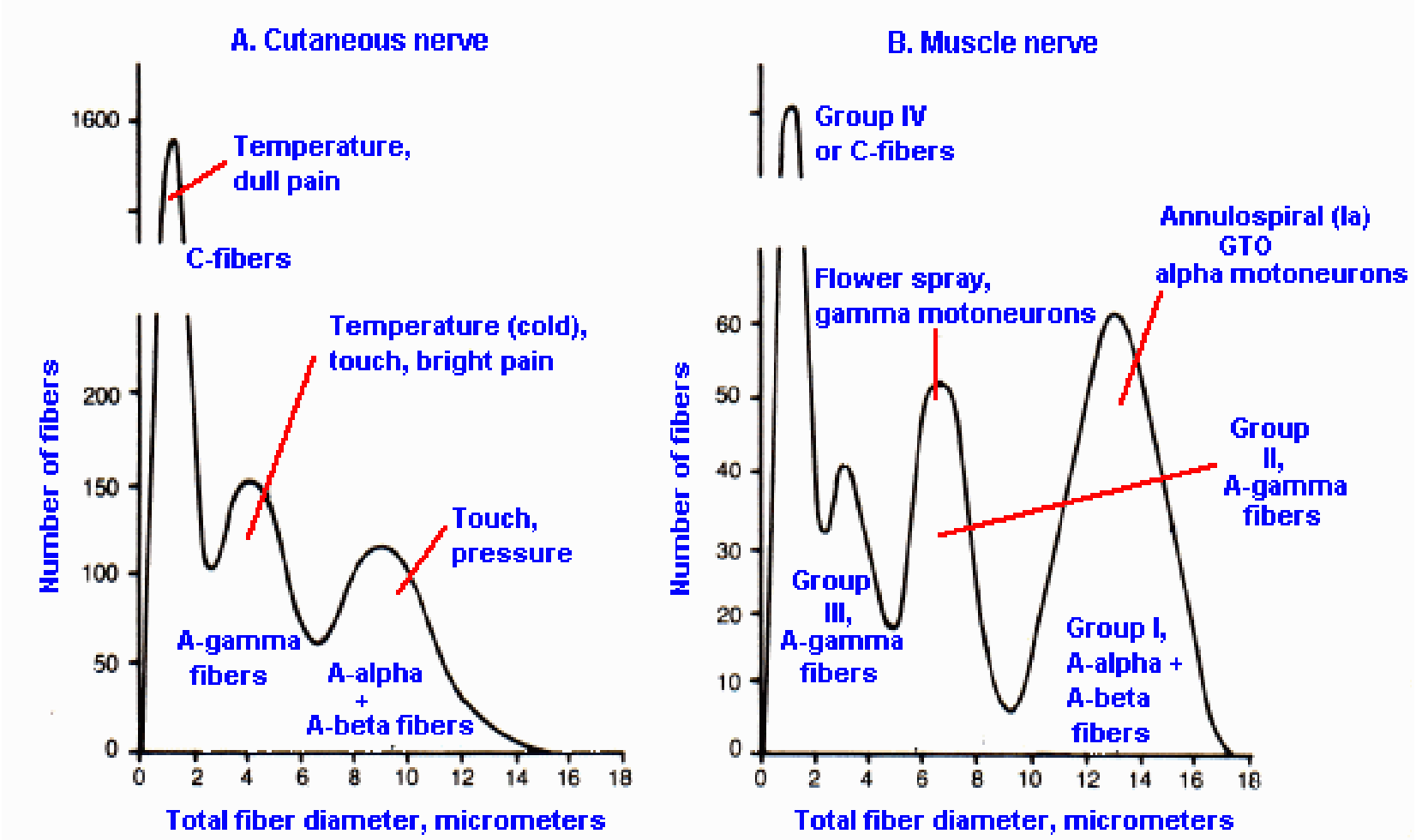
A compound action potential recorded at different points along an intact nerve



Each wave reflects the activity of a group of fibers with a similar conduction velocity.



Compound action potentials



Suggested Reading

- https://michaeldmann.net/mann12.html