Introduction to Neurophysiology 4

Neuronal Membrane Potential

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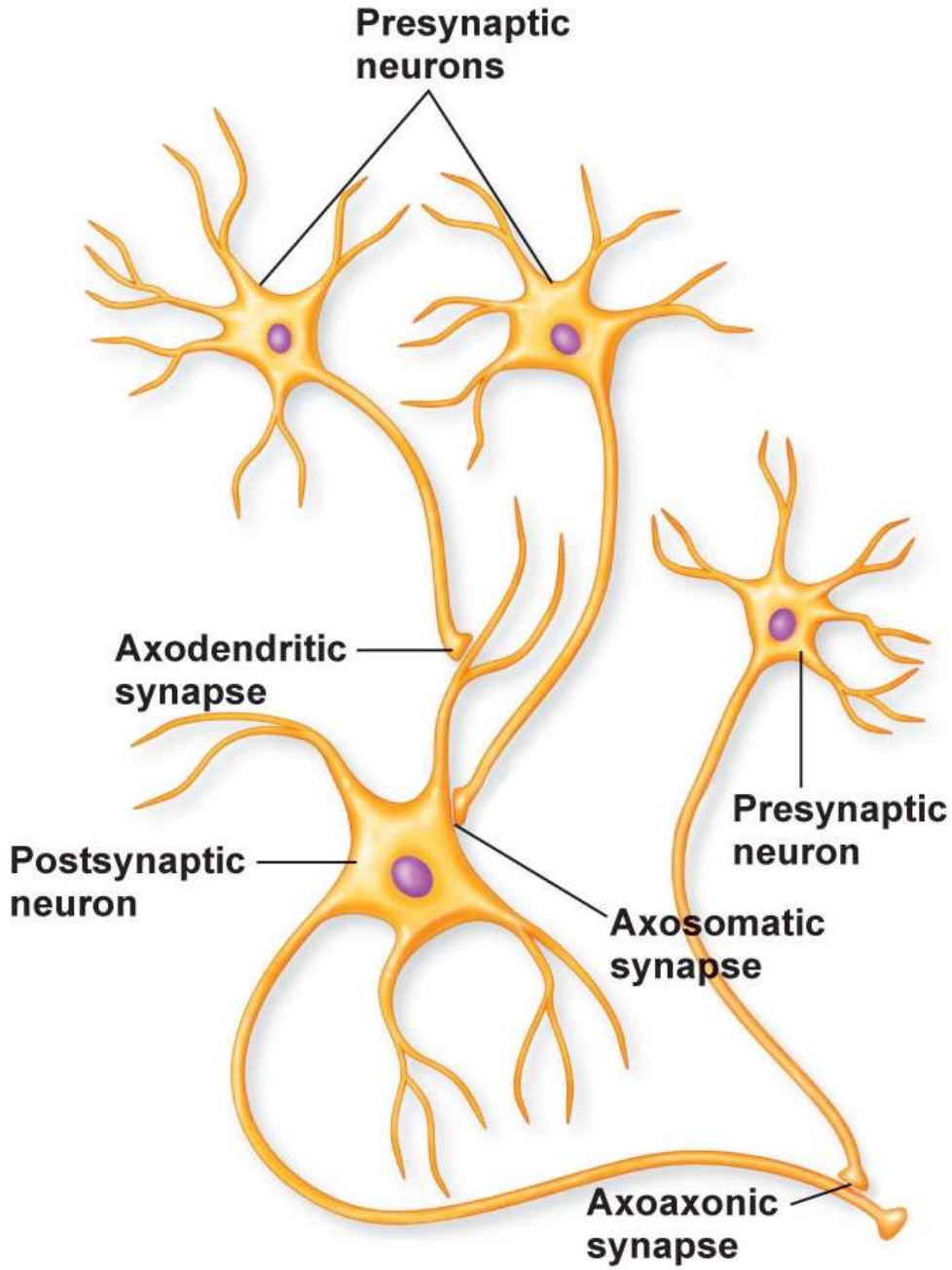
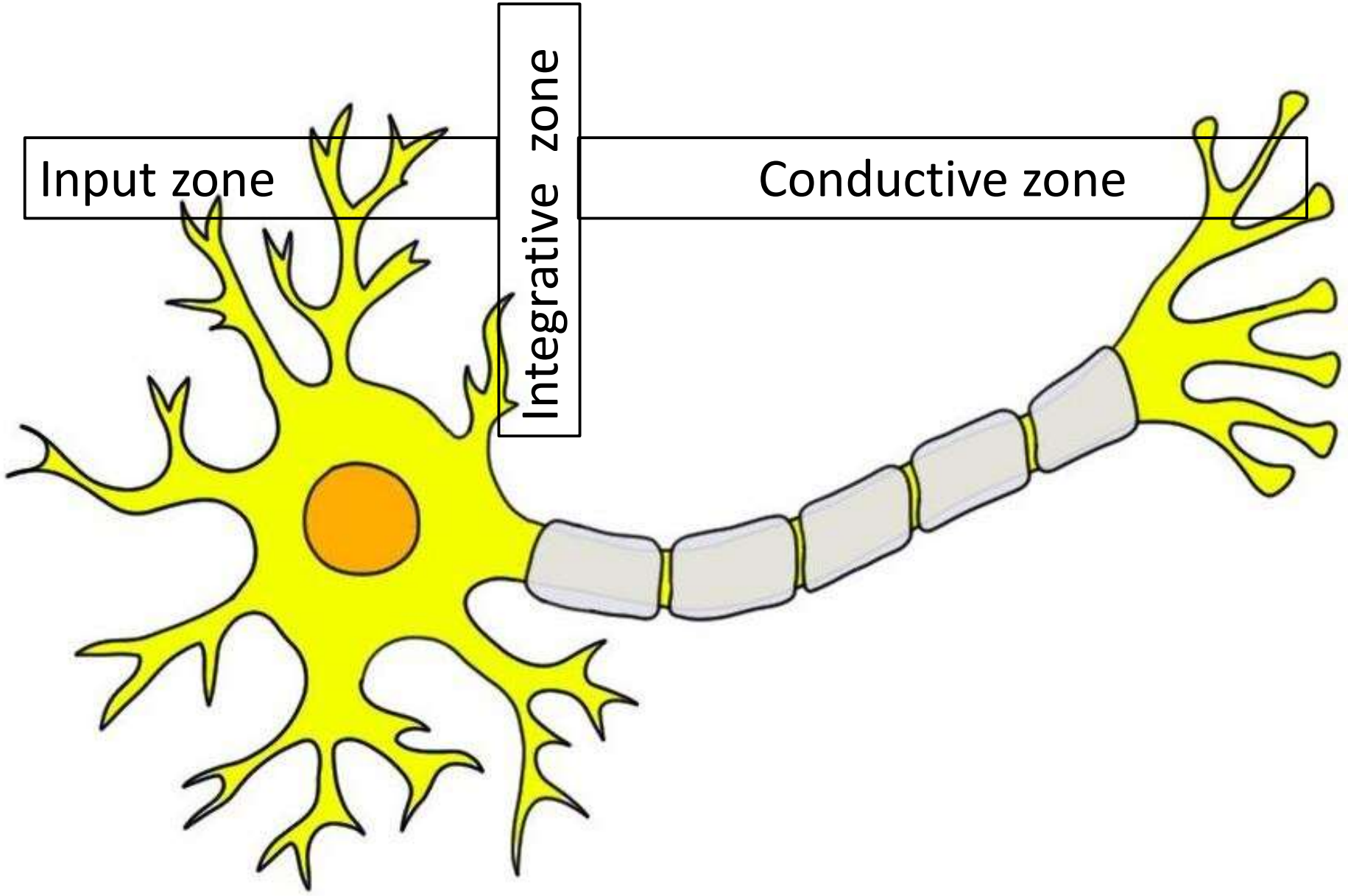

Presynaptic neurons
Axodendritic synapse
Postsynaptic neuron
Presynaptic neuron
Axosomatic synapse
Axoaxonic synapse



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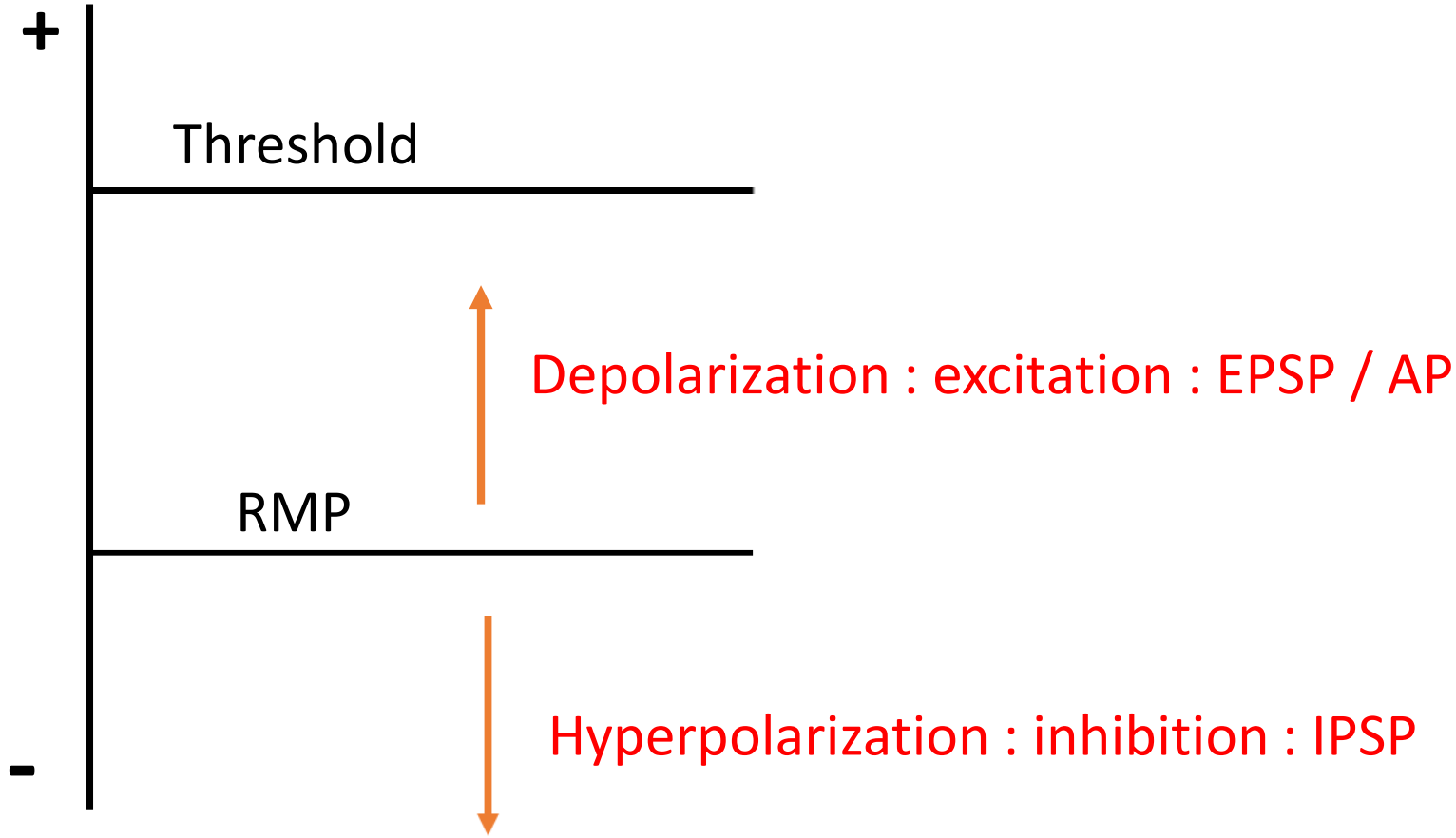
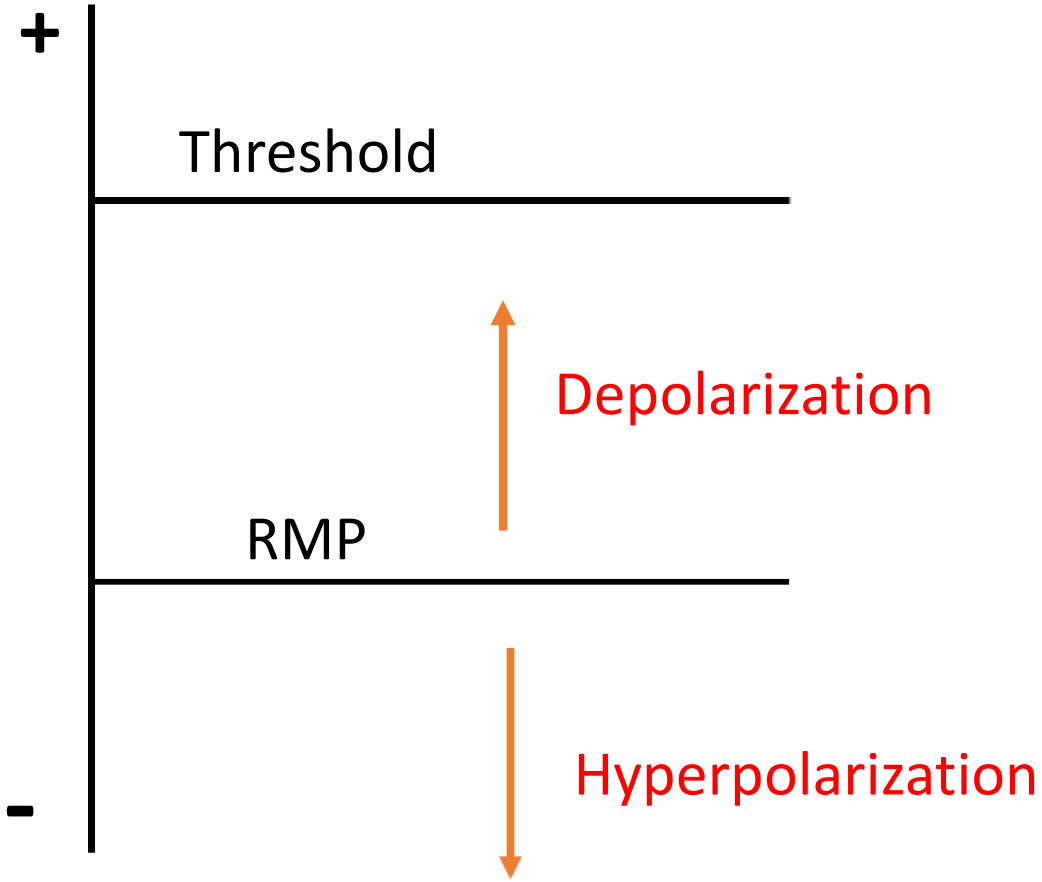
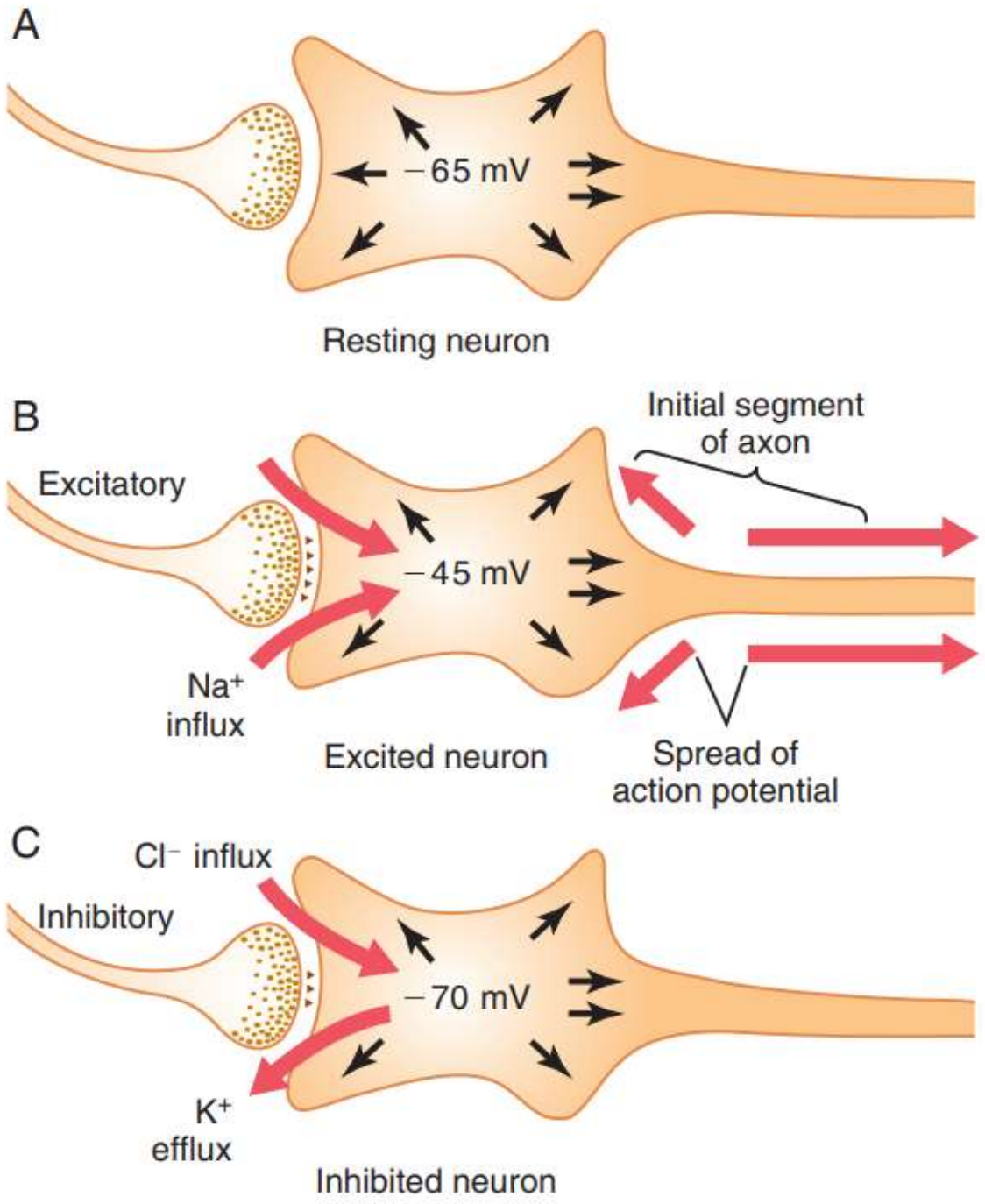
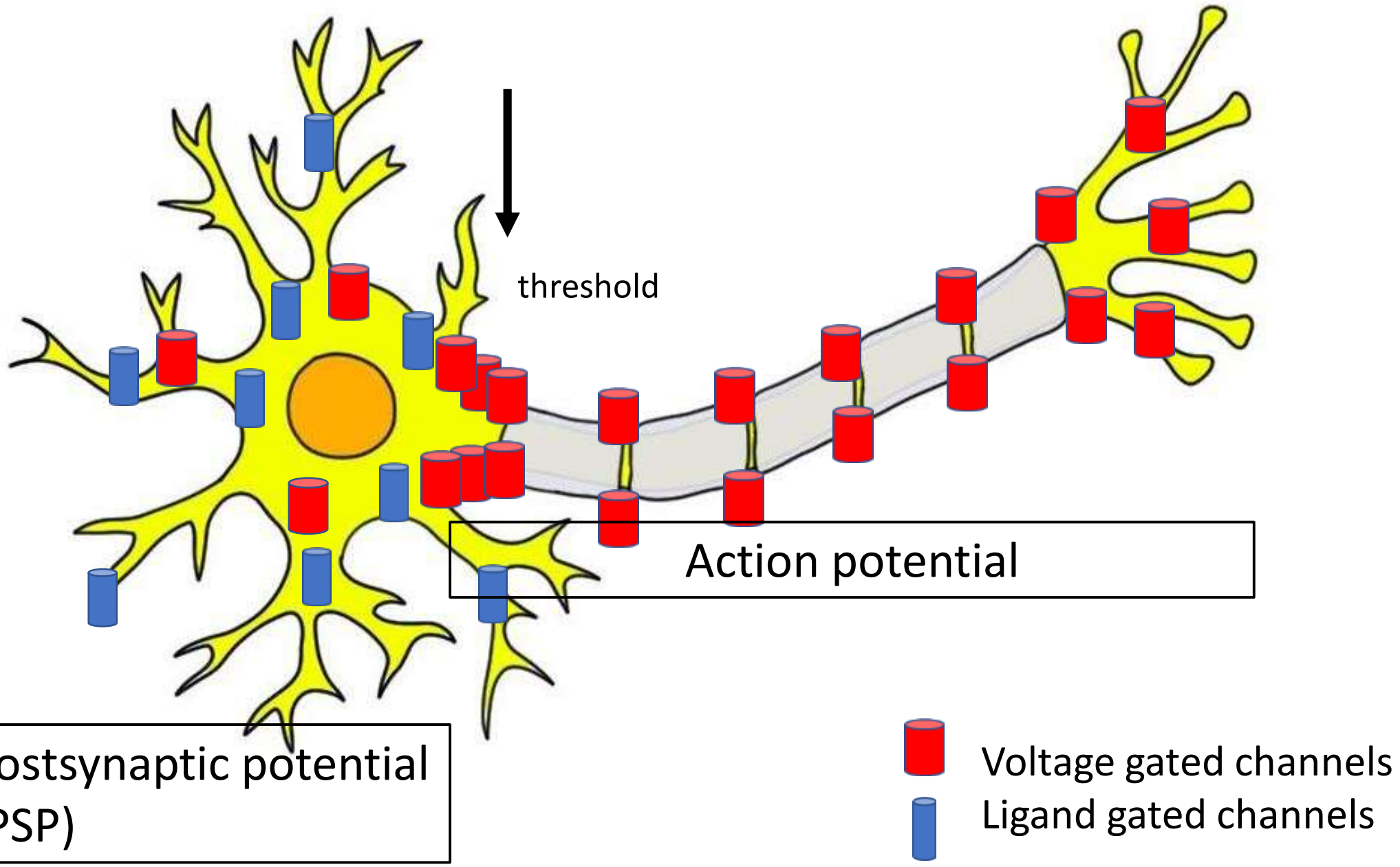

+
Threshold
Depolarization : excitation : EPSP / AP
RMP
Hyperpolarization : inhibition : IPSP
-


+
Threshold
Depolarization
RMP
Hyperpolarization
-


A
−65 mV
Resting neuron
B
Initial segment
of axon
Excitatory
−45 mV
Na+
influx
Excited neuron
Spread of
action potential
C
Cl− influx
Inhibitory
−70 mV
K+
efflux
Inhibited neuron


threshold
Action potential
Postsynaptic potential (PSP)
Voltage gated channels
Ligand gated channels

Action potential in the axon

Action potential does not begin adjacent to the excitatory synapses. Instead, it begins in the initial segment of the axon.

The main reason is that the soma has relatively few voltage gated sodium channels in its membrane, which makes it difficult for the EPSP to open the required number of sodium channels to elicit an action potential.

Action potential in the axon

- The membrane of the initial segment of the axon has 7 times as great a concentration of voltage-gated Na+ channels as does the soma and, therefore, can generate an action potential with much greater ease than can the soma.

- The threshold is lower in the axon initial segment than the soma.

Graded potential vs Action potential

Comparison of Graded Potentials and Action Potentials in Neurons

CHARACTERISTIC	GRADED POTENTIALS	ACTION POTENTIALS
Origin	Arise mainly in dendrites and cell body.	Arise at trigger zones and propagate along axon.

Excitatory postsynaptic potential (EPSP)

- This positive increase in voltage above the normal resting neuronal potential— that is, to a less negative value—is called the excitatory postsynaptic potential (or **EPSP)**, because if this potential rises high enough in the positive direction, it will elicit an action potential in the postsynaptic neuron, thus exciting it.

- EPSP is +20 millivolts means 20 millivolts more positive than the resting value.

Inhibitory postsynaptic potential (IPSP)

- Opening potassium or chloride channels.
- An increase in negativity beyond the normal resting membrane potential level is called an inhibitory postsynaptic potential (IPSP).
- IPSP is -20 millivolts means 20 millivolts more negative than the resting value.

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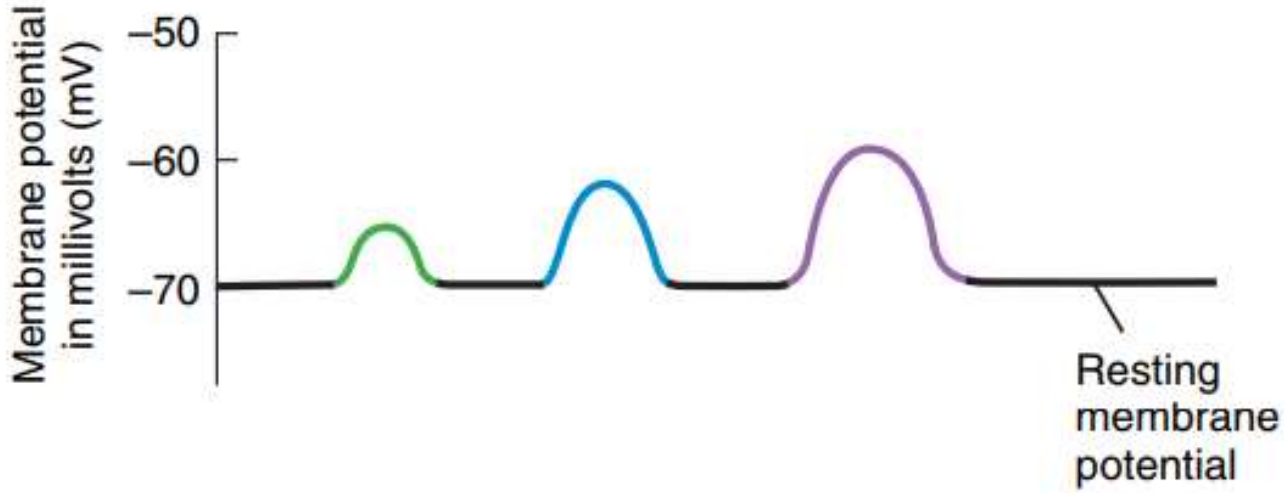
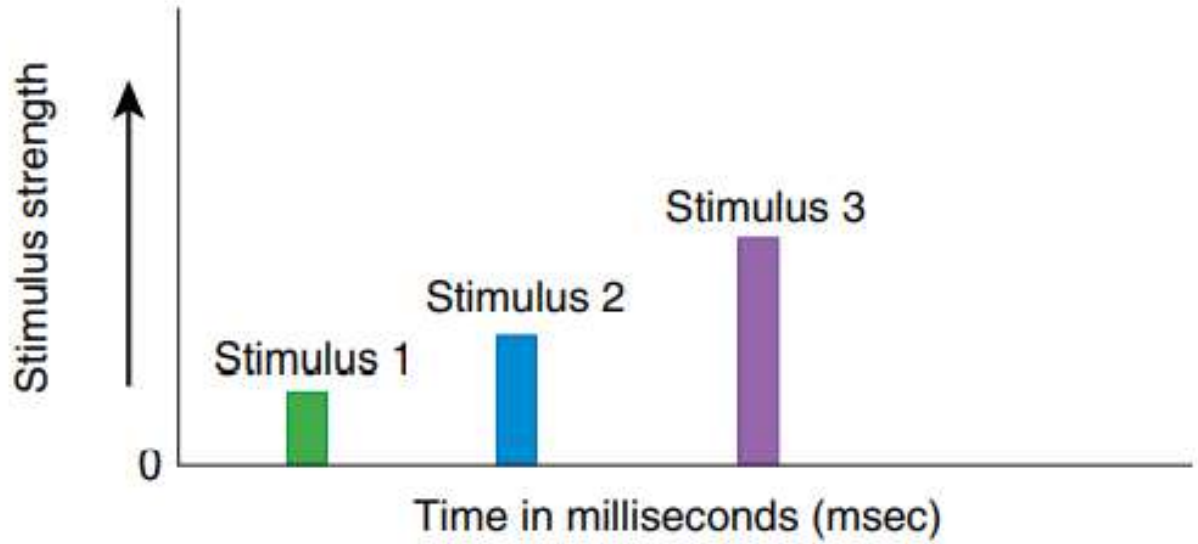
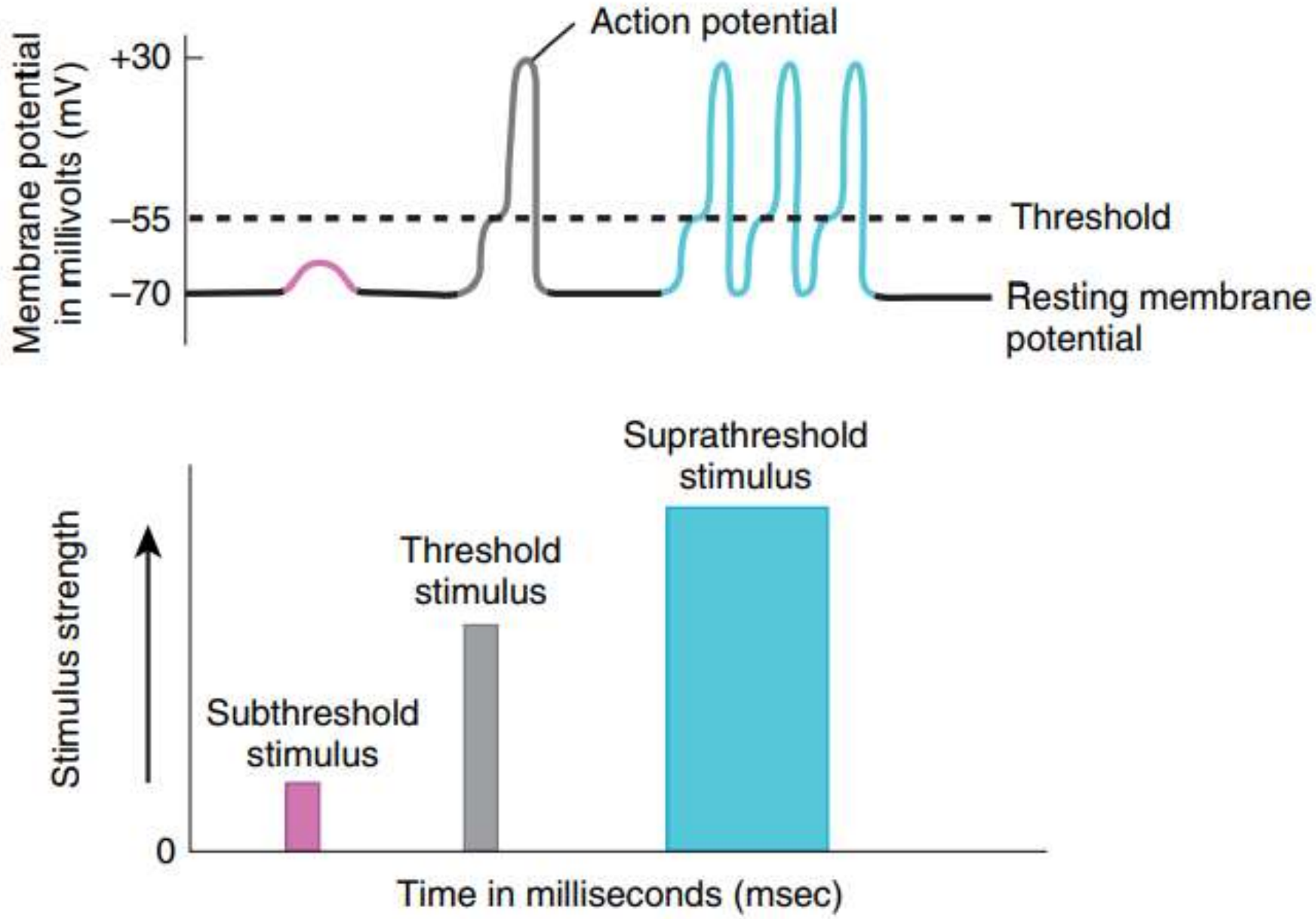
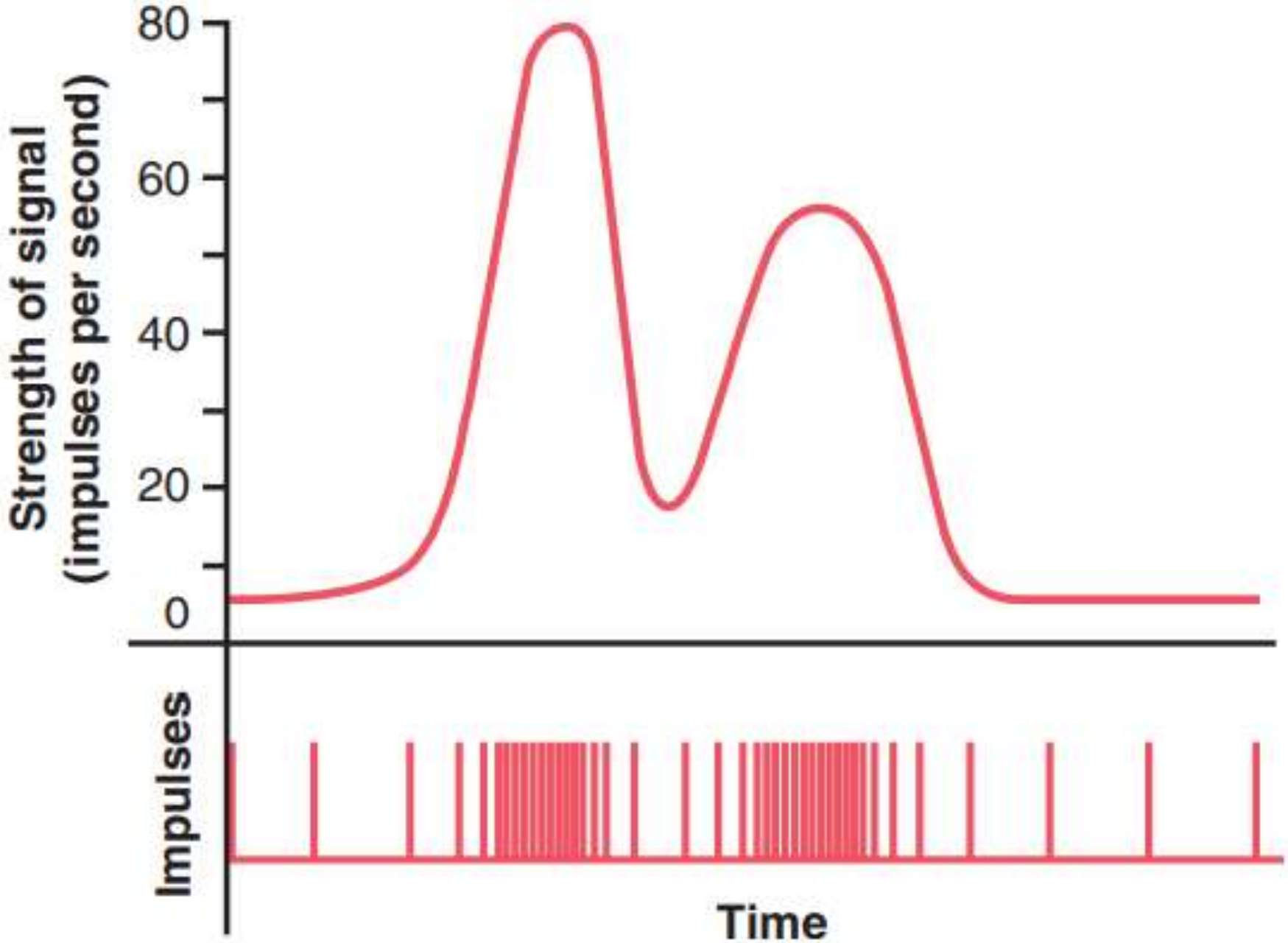
Amplitude (size)	Depending on strength of stimulus, varies from less than 1 mV to more than 50 mV.	All or none; typically about 100 mV.

The amplitude of a graded potential depends on the stimulus strength. The greater the stimulus strength, the larger the amplitude of the graded potential.






Action potential
Membrane potential in millivolts (mV)
+30
–55
–70
Threshold
Resting membrane potential
Suprathreshold stimulus
Threshold stimulus
Subthreshold stimulus
Stimulus strength
0
Time in milliseconds (msec)


Strength of signal
(impulses per second)
80
60
40
20
0
Impulses
Time

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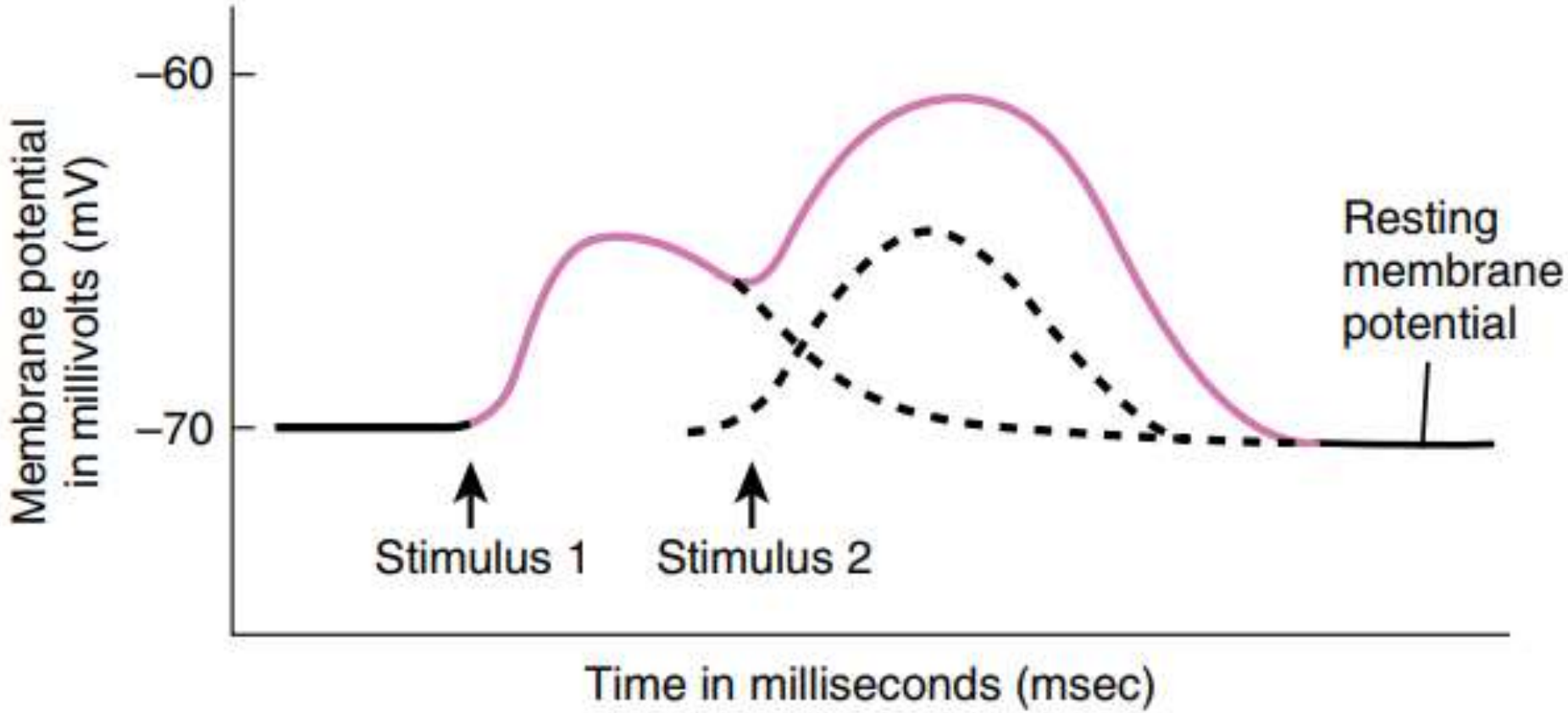
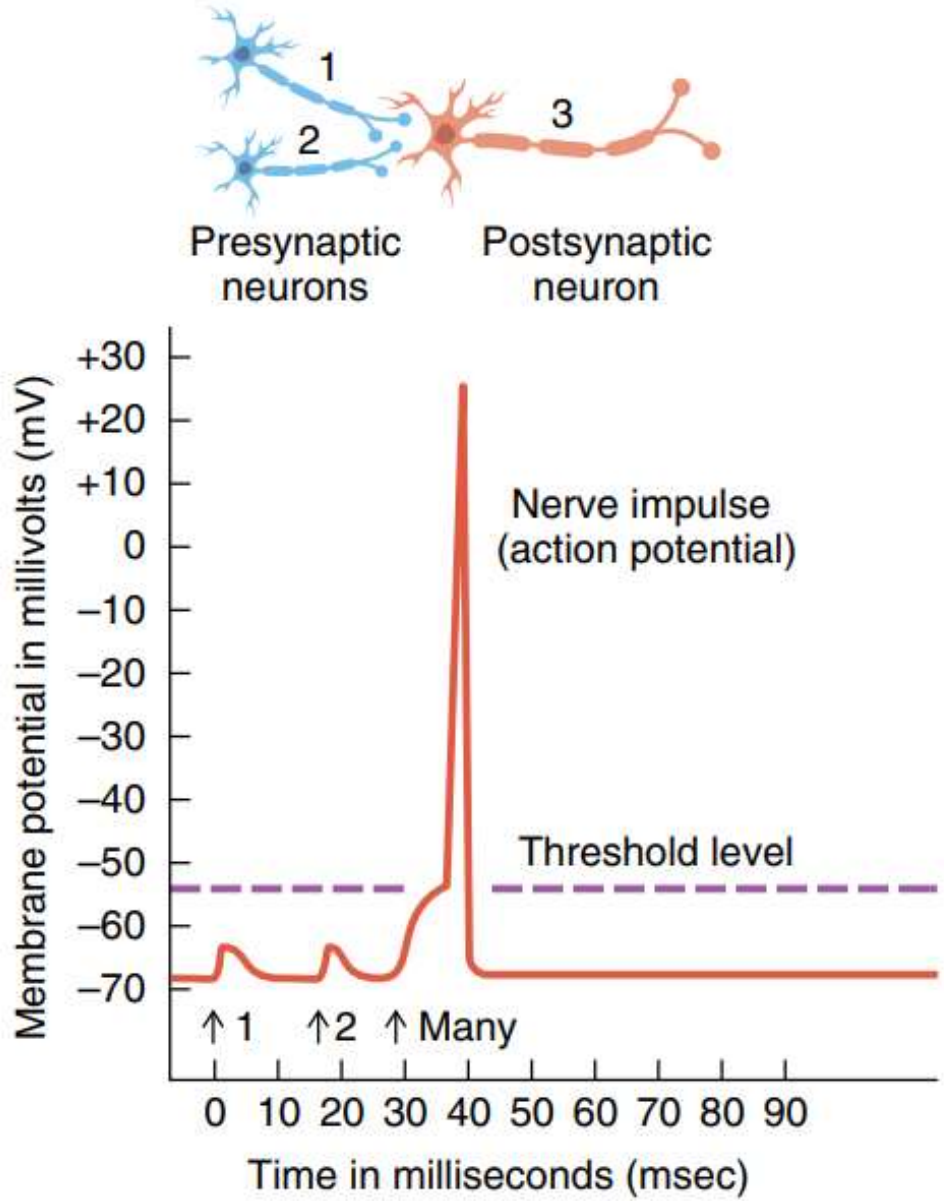
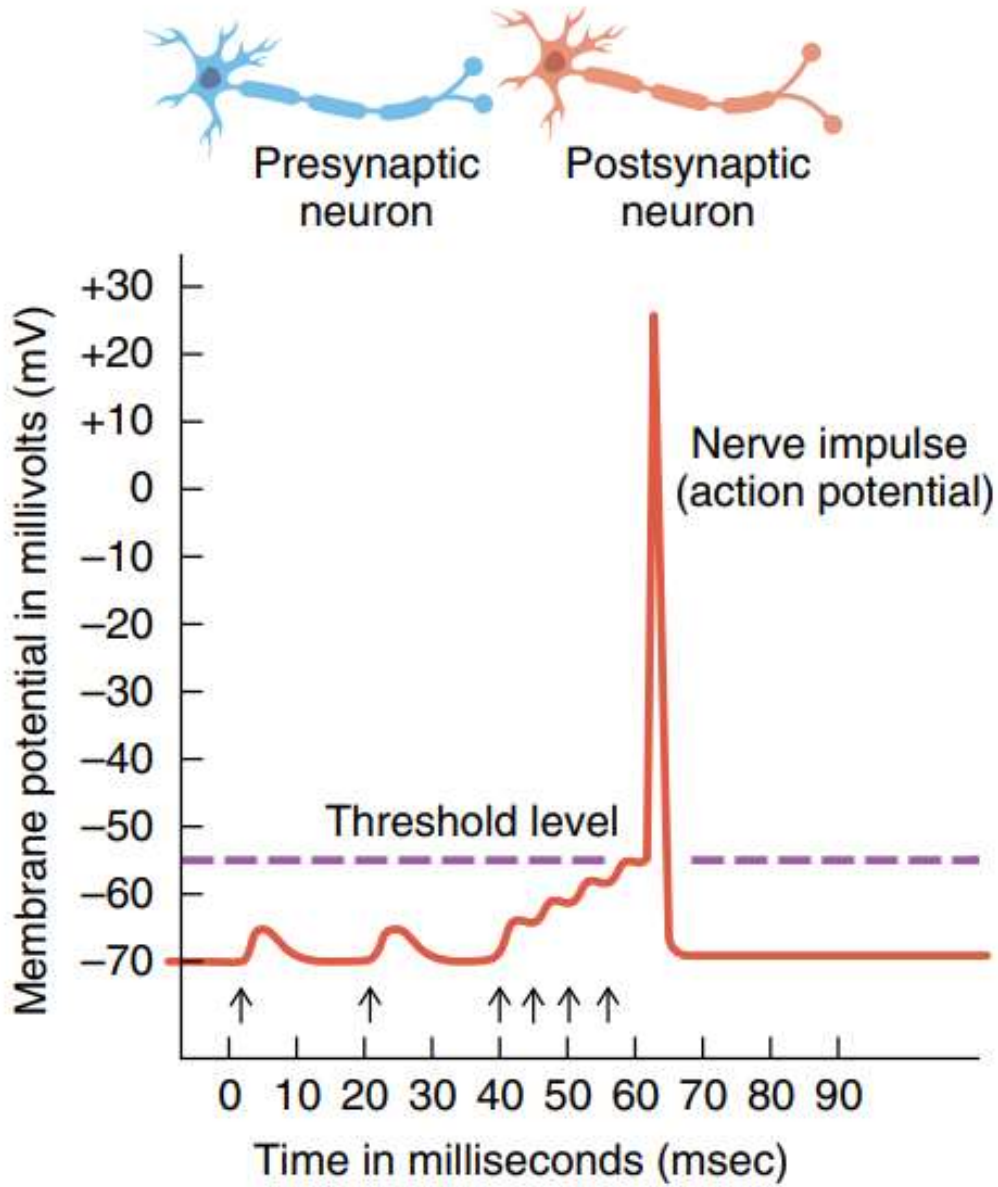
Refractory period	Not present; summation can occur.	Present; summation cannot occur.

Summation in graded potential

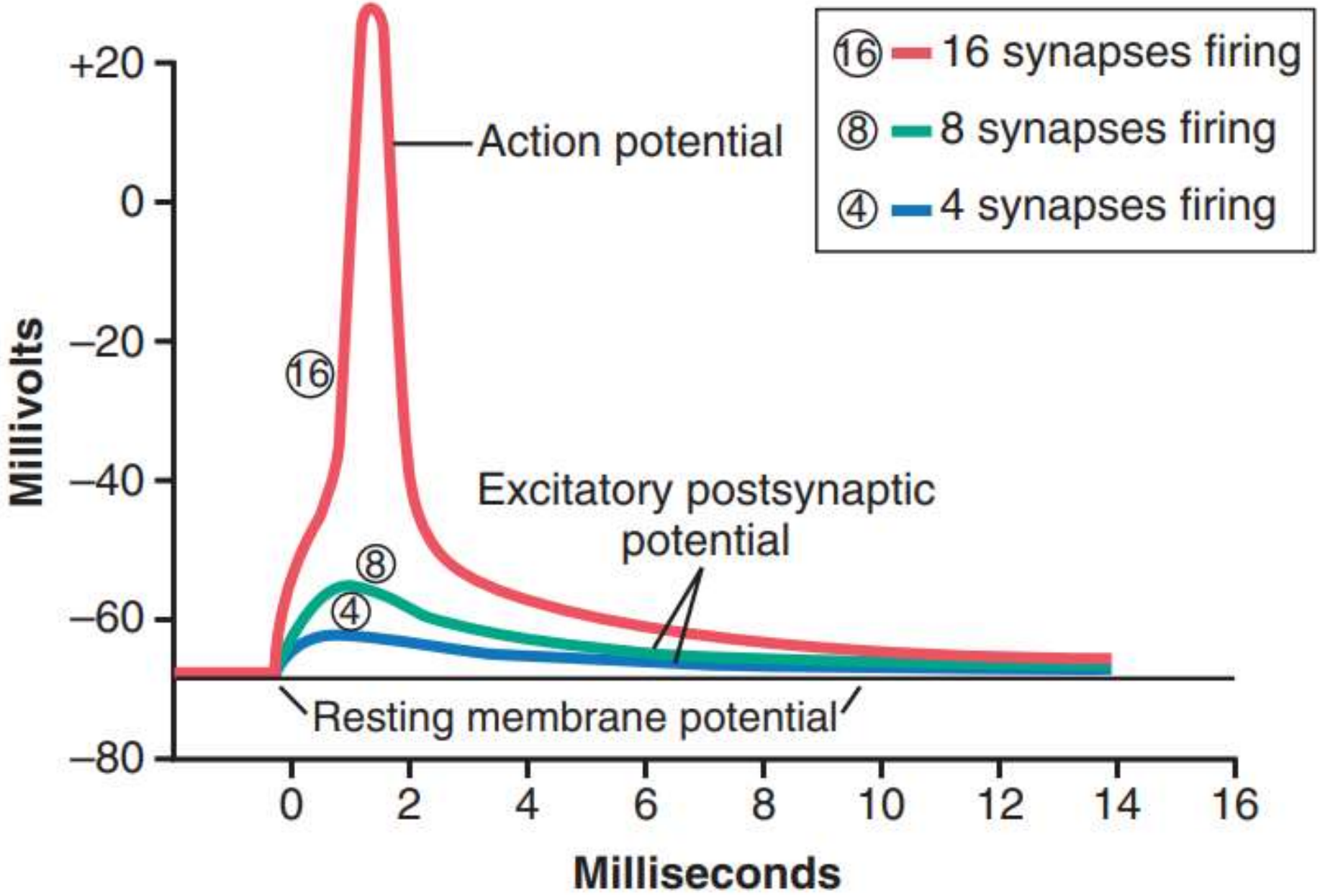




(a) Spatial summation



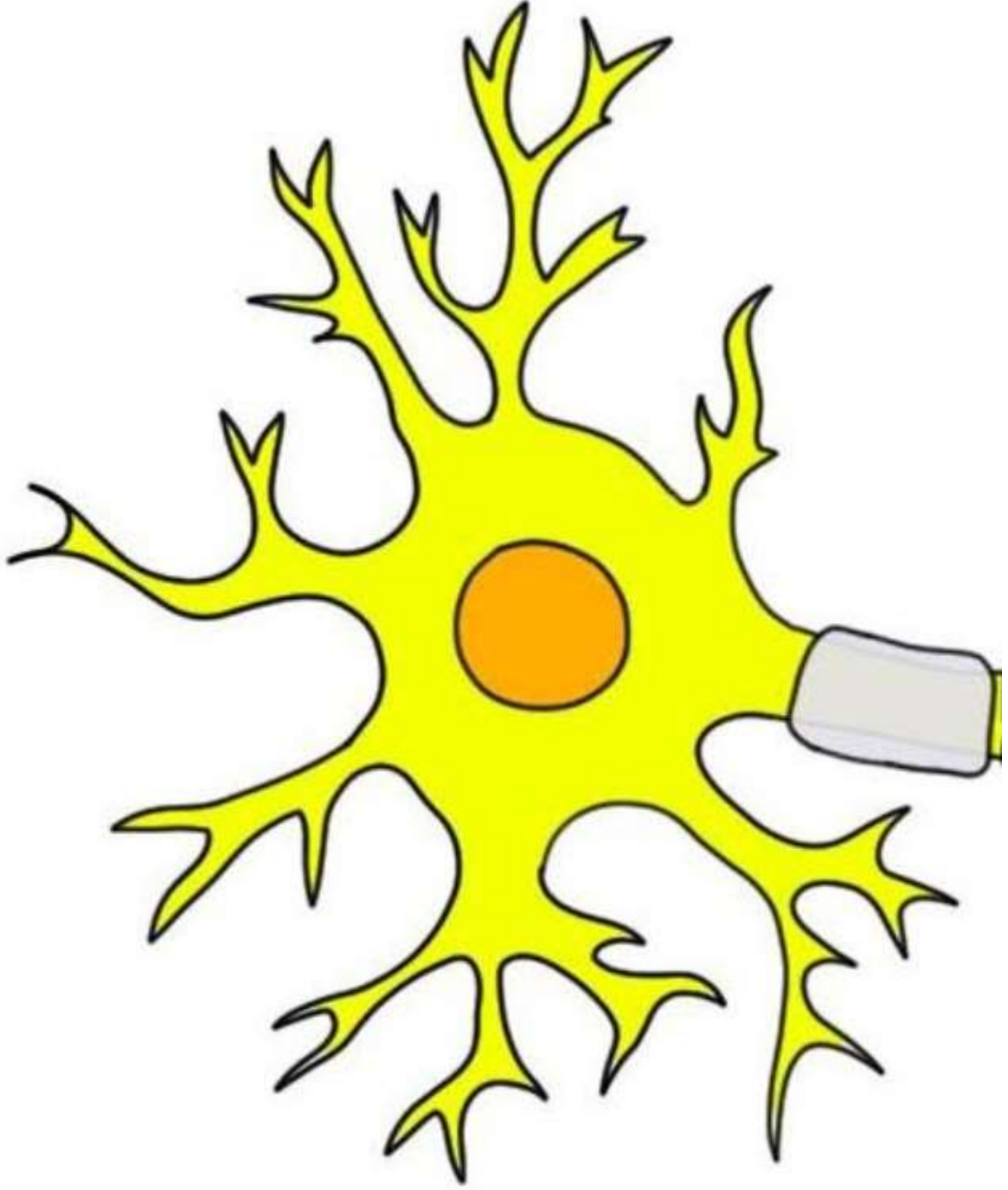
(b) Temporal summation


⑯ 16 synapses firing
⑧ 8 synapses firing
④ 4 synapses firing
Action potential
⑯
⑧
④
Excitatory postsynaptic potential
Resting membrane potential
+20
0
–20
–40
–60
–80
Millivolts
0
2
4
6
8
10
12
14
16
Milliseconds

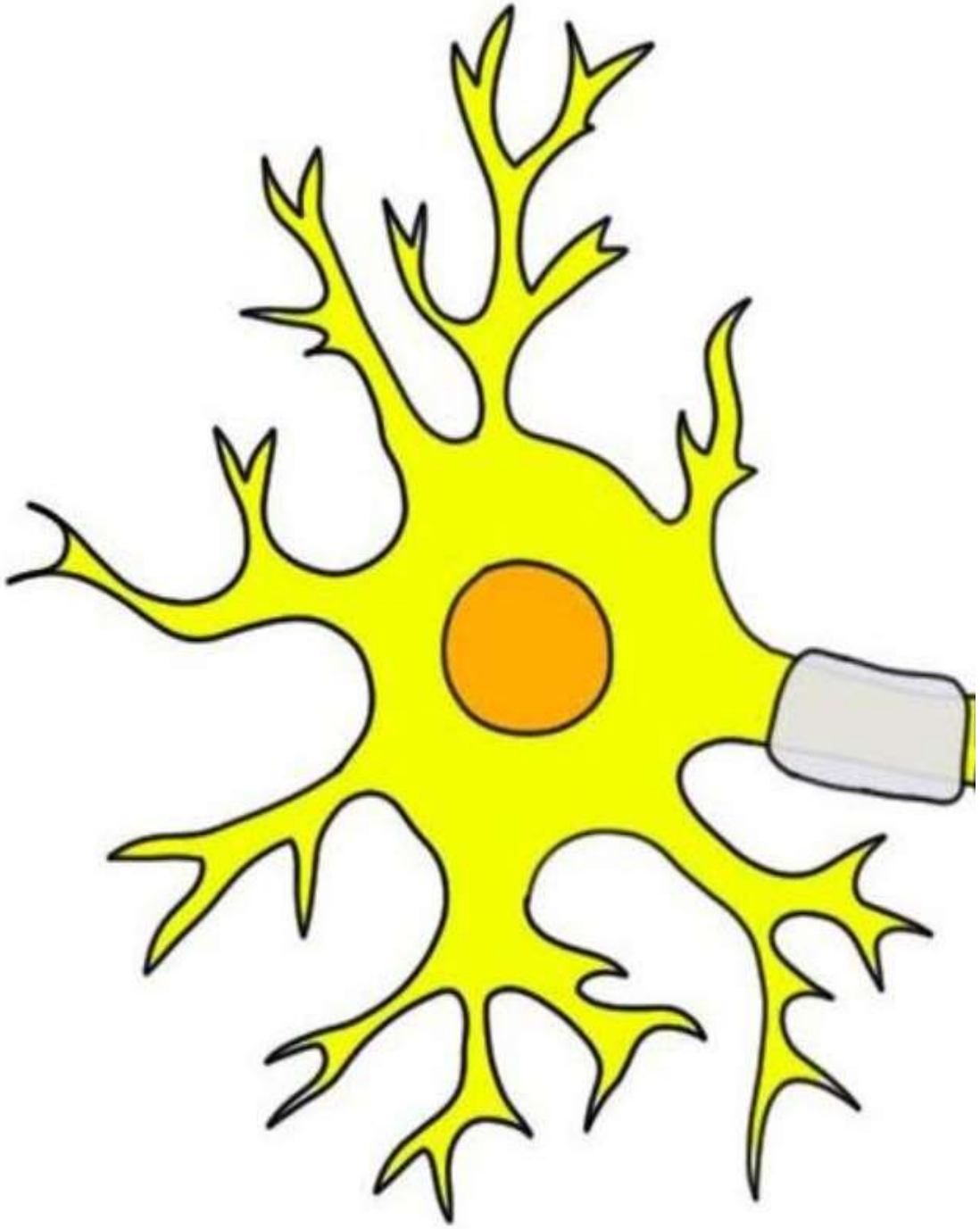
Dendrites:

Large spatial field of excitation.

A great opportunity for summation of signals from many neurons.

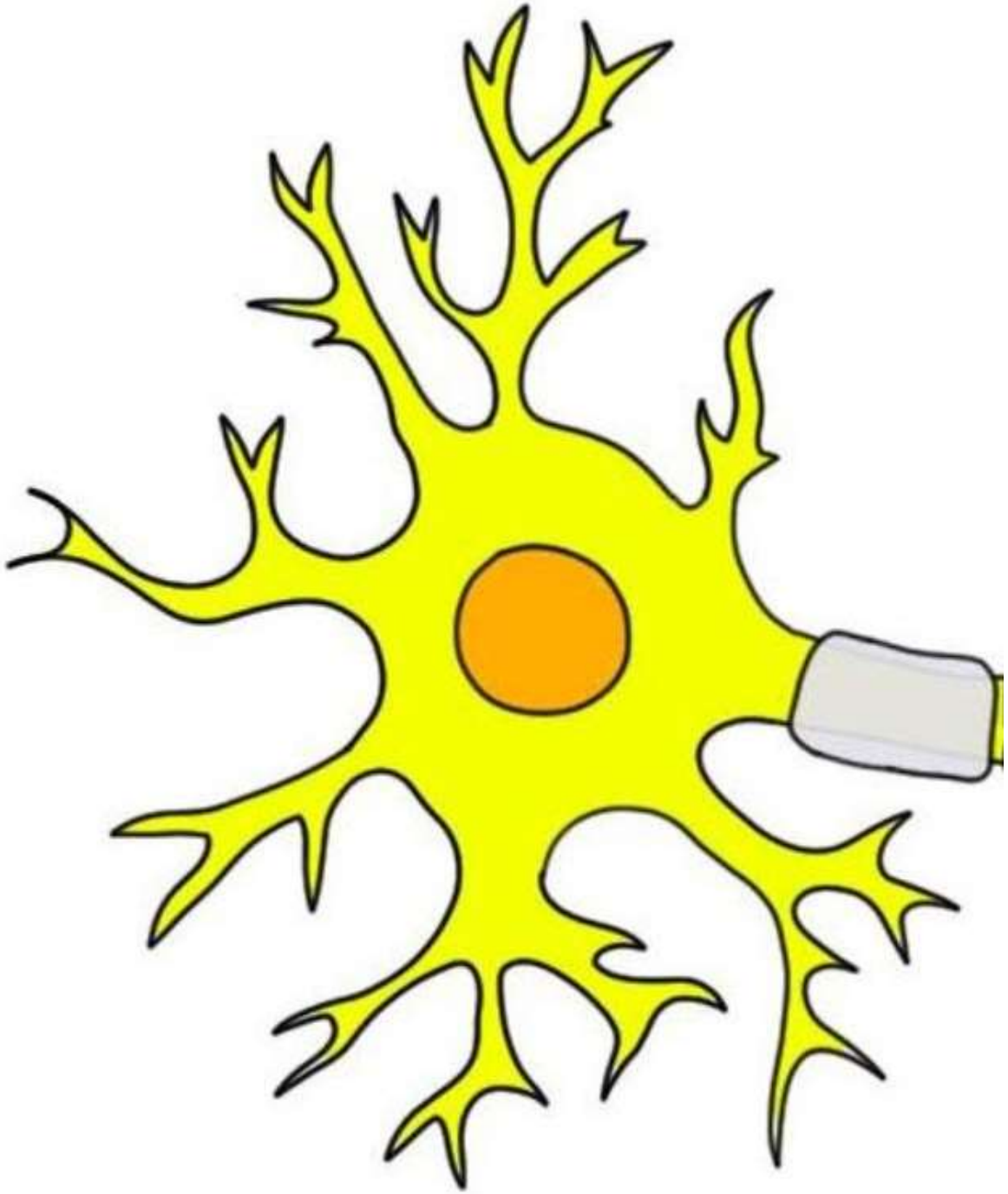


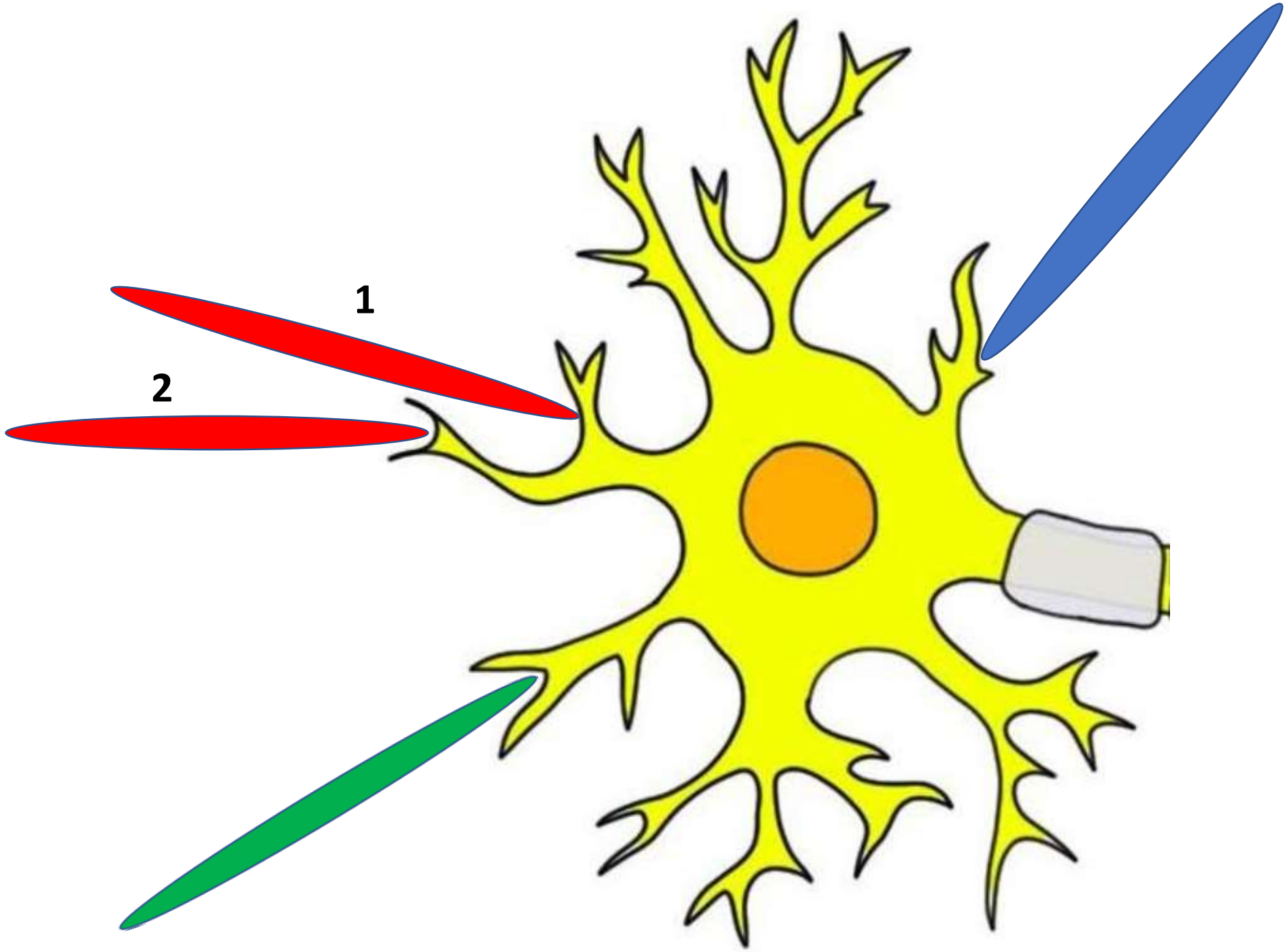
Most dendrites fail to transmit action potentials because their membranes have relatively few voltage-gated sodium channels.

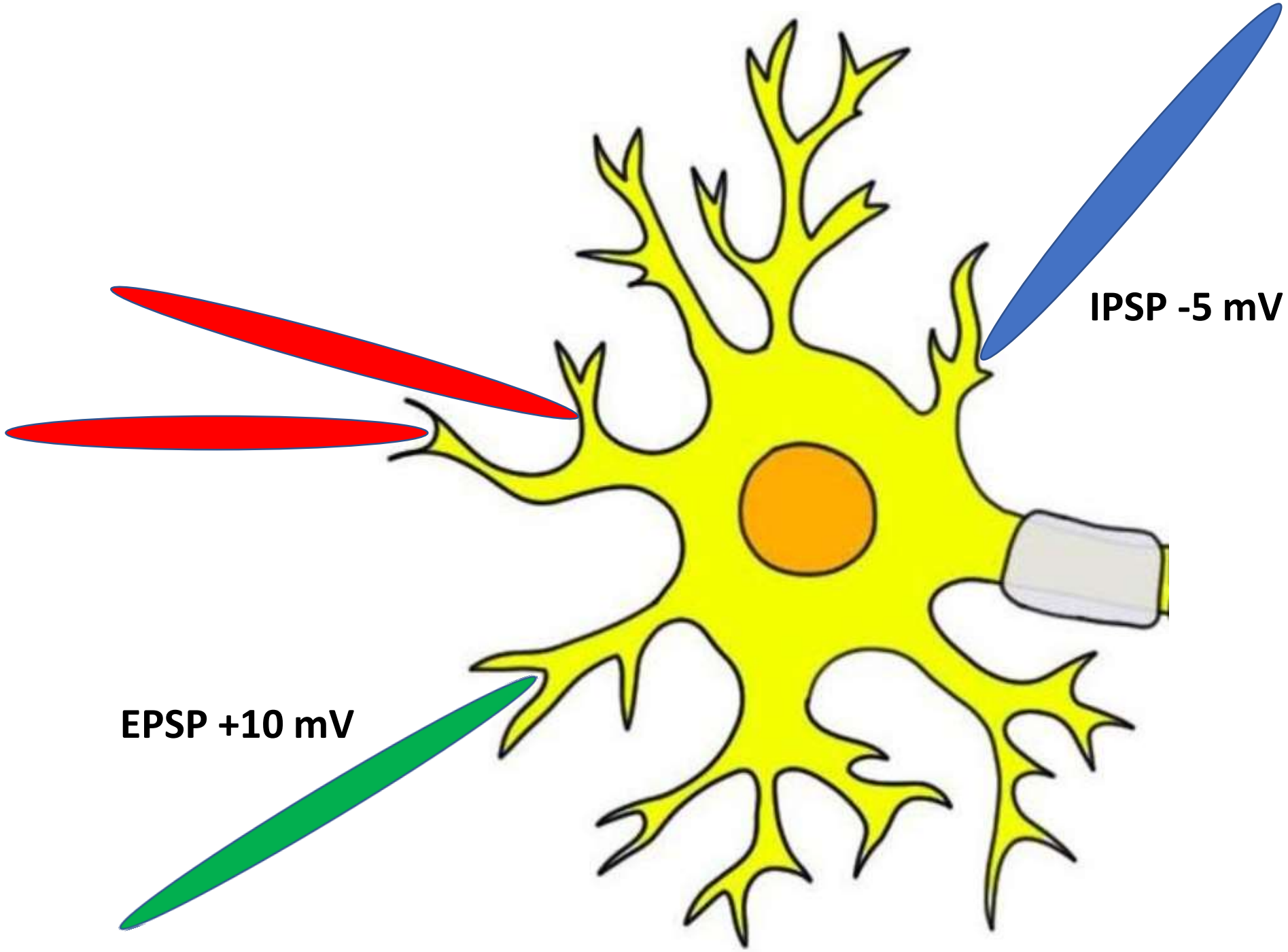


Decremental conduction

The synapses that lie near the soma have far more effect in causing neuron excitation or inhibition than those that lie far away from the soma.




1
2

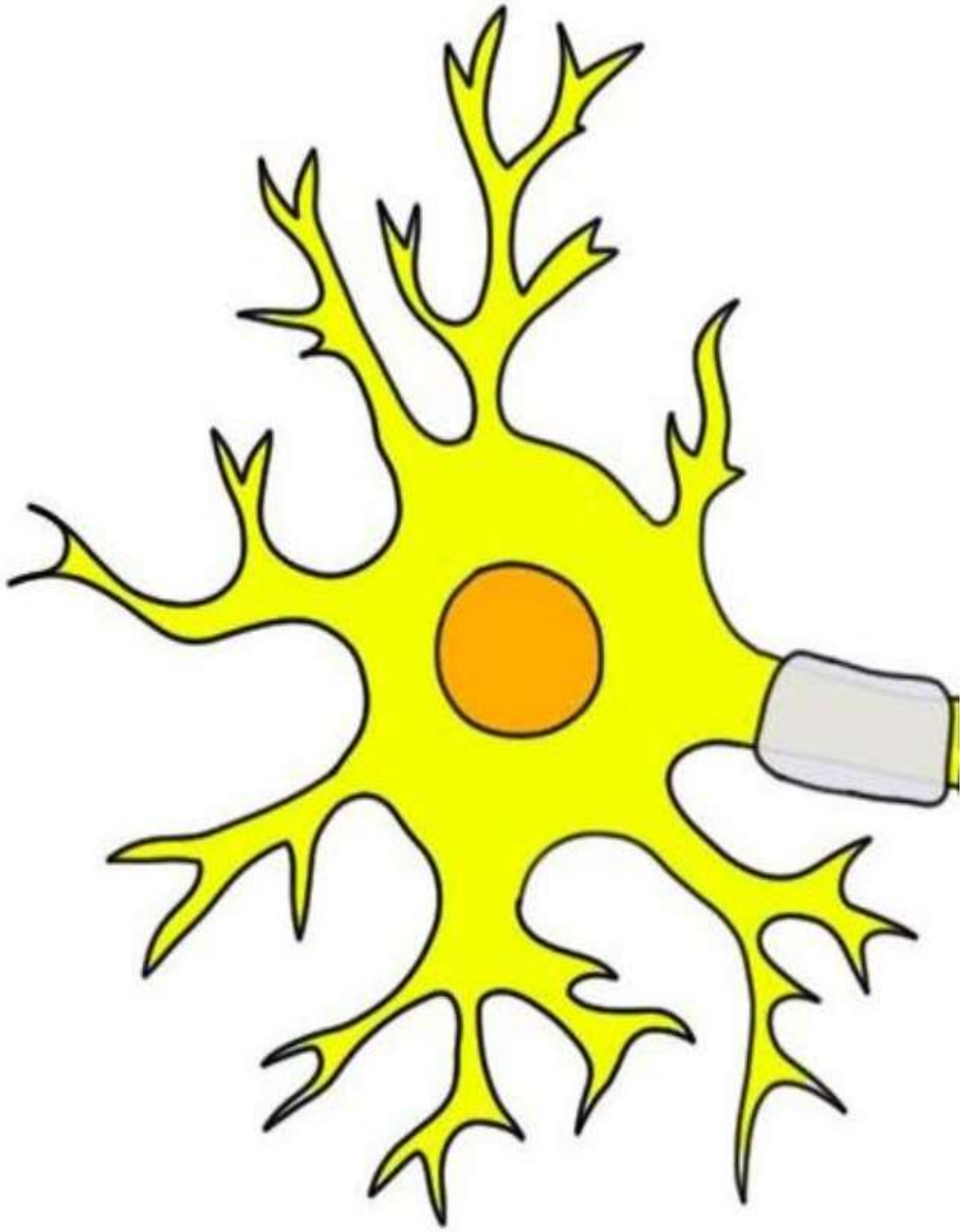

IPSP -5 mV
EPSP +10 mV

Soma:
uniform distribution of electrical potential:

Large diameter (less resistance to conductance).

Highly conductive electrolytic fluid.

(change in membrane potential will be transmitted equally to all parts of the soma.)



Resting membrane potential of neuronal soma

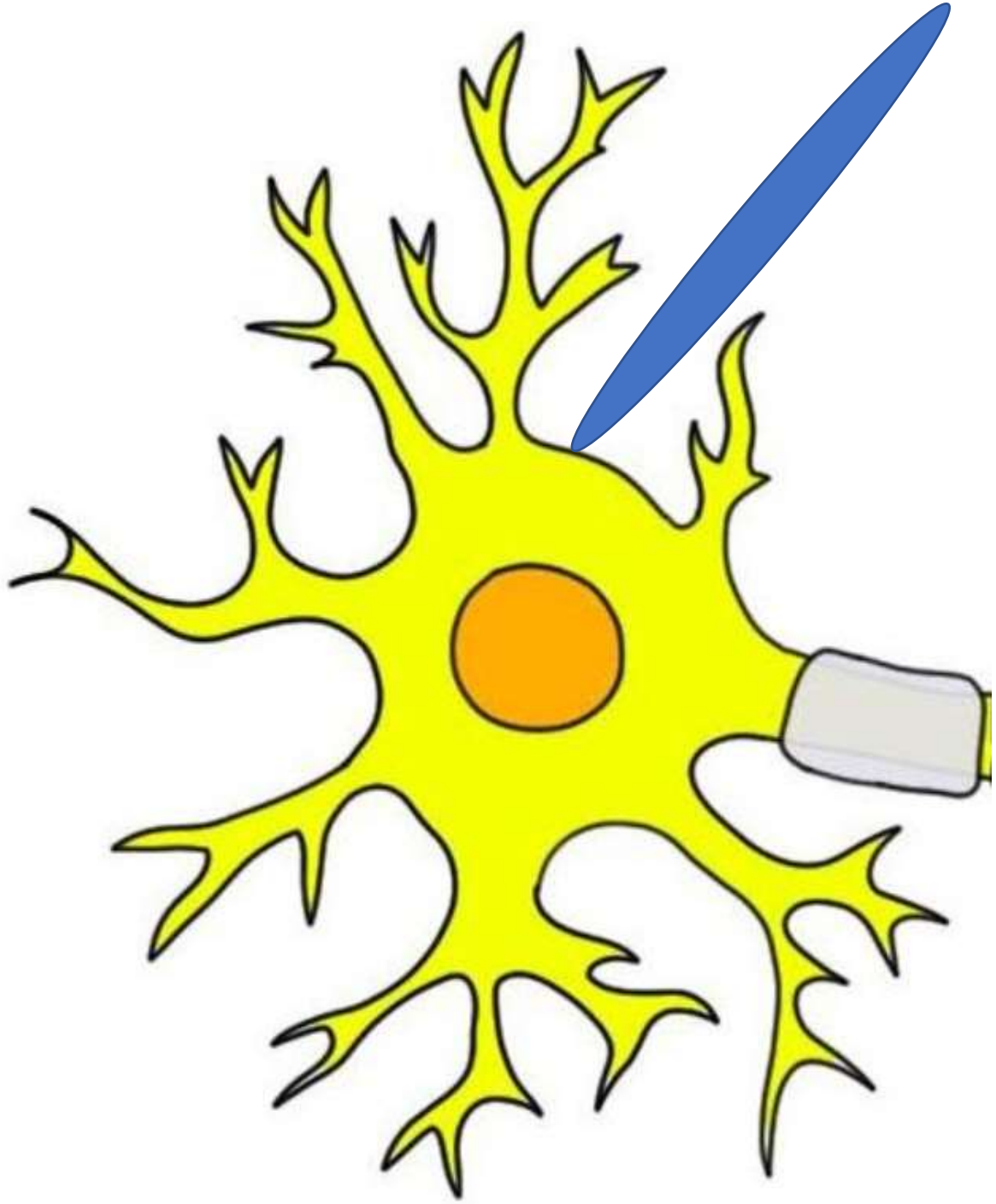
- Any change in potential in any part of the intra-somal fluid causes an almost exactly equal change in potential at all other points inside the soma.

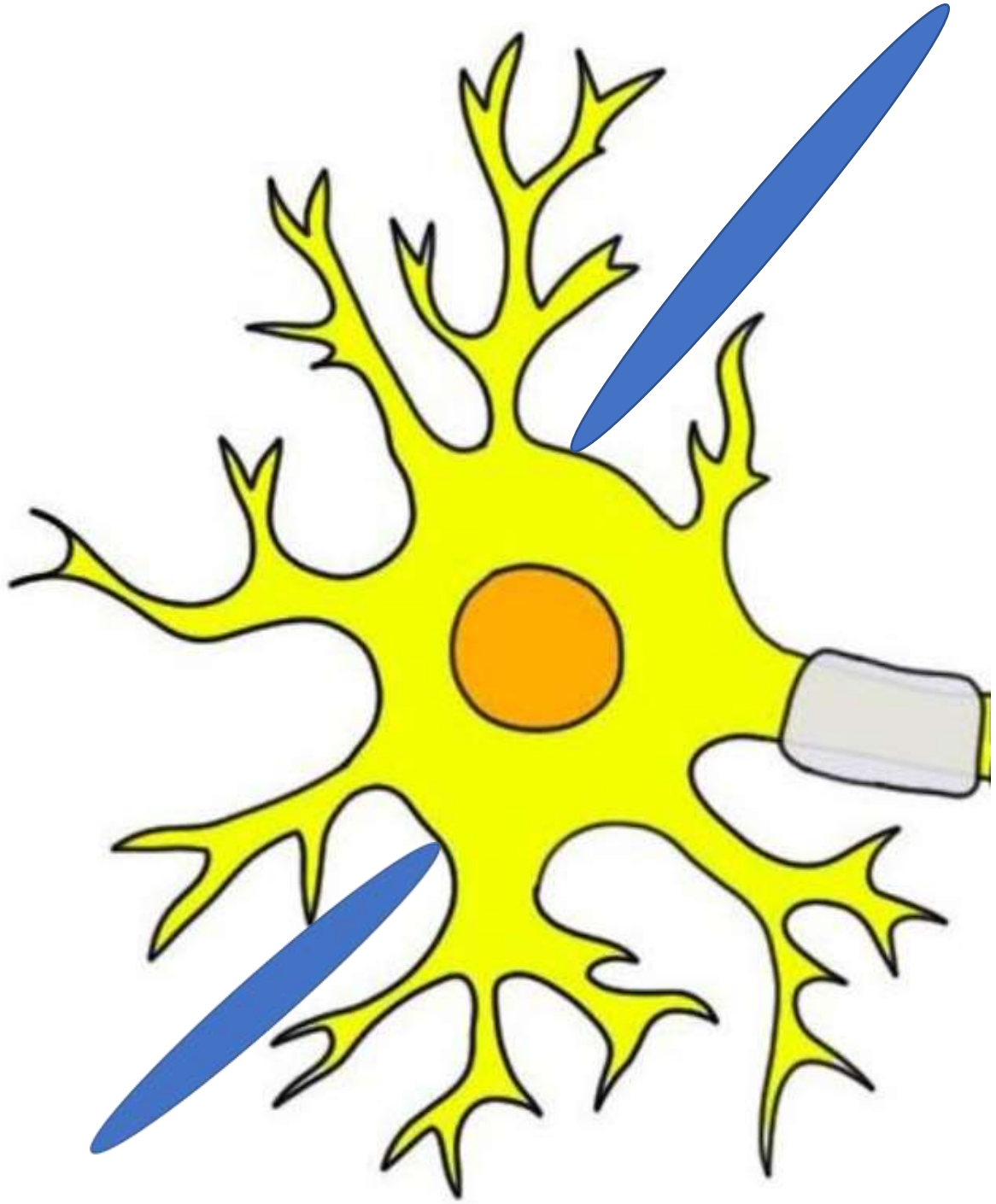
- This principle is important because it plays a major role in “summation” of signals entering the neuron from multiple sources.

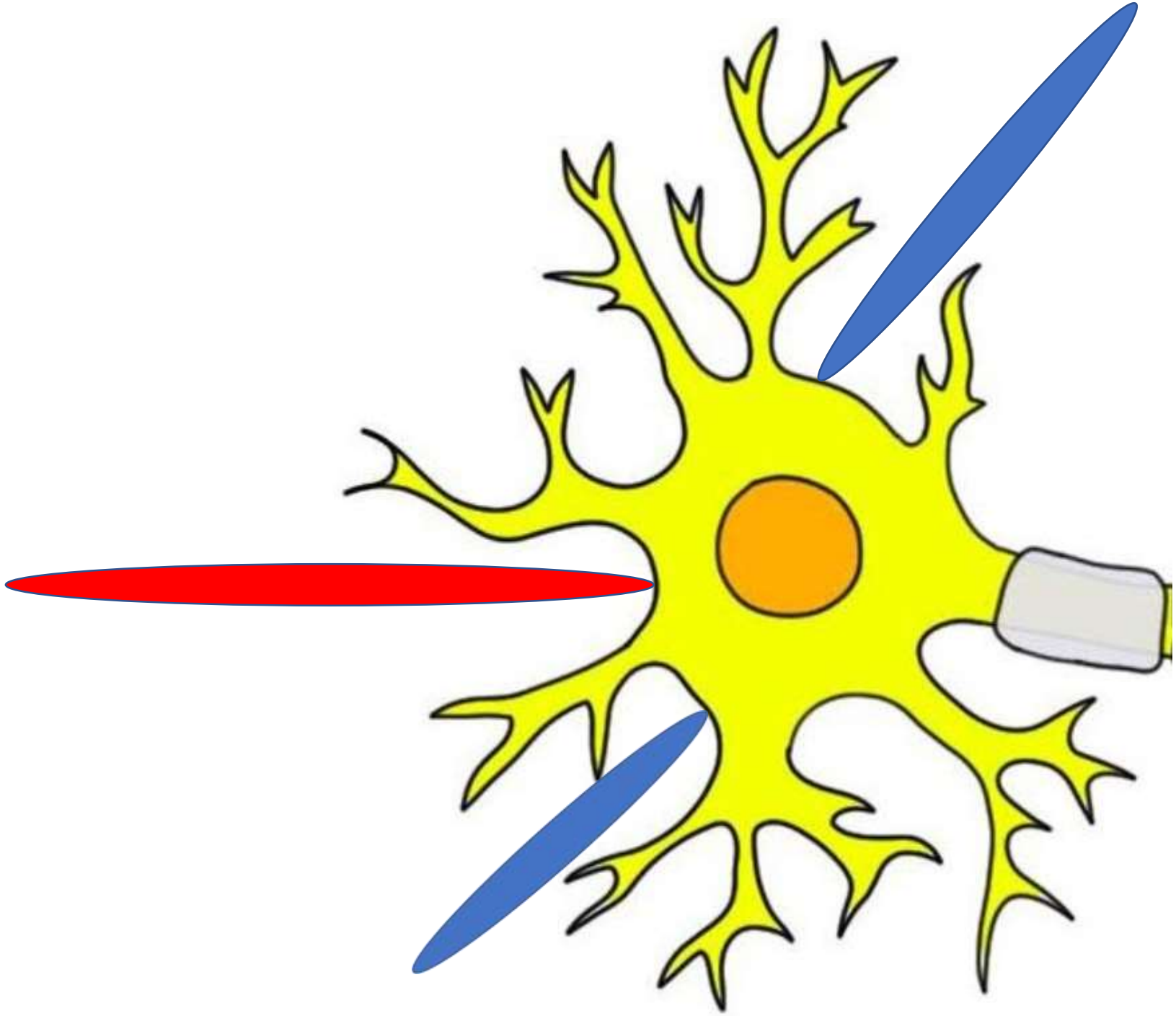
Summation in neurons

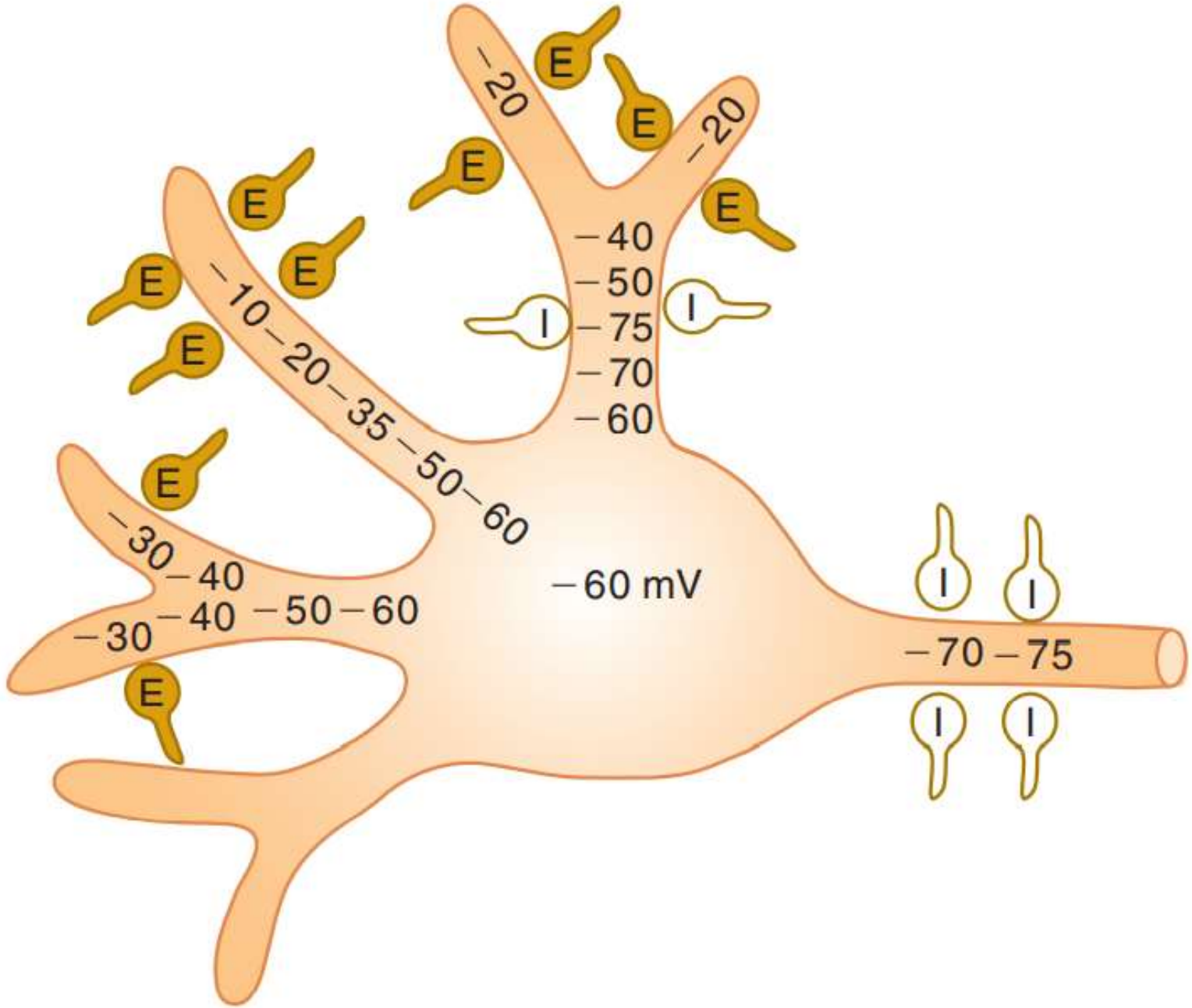
- Excitation of a single presynaptic terminal on the surface of a neuron almost never excites the neuron.

- The reason is that the amount of transmitter substance released by a single terminal to cause an EPSP is usually no greater than 0.5 to 1 millivolt, instead of the 10 to 20 millivolts normally required to reach threshold for excitation.








E
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I
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−20
−20
−40
−50
−75
−70
−60
−10
−20
−35
−50
−60
−30
−40
−50
−60
−30
−40
−60 mV
−70
−75

Presynaptic inhibition

- In addition to inhibition caused by inhibitory synapses operating at the neuronal membrane, which is called **postsynaptic inhibition**.

- **Presynaptic inhibition** is caused by release of an inhibitory substance onto the outsides of the presynaptic nerve fibrils before their own endings terminate on the postsynaptic neuron.
- In most instances, the inhibitory transmitter substance is GABA.
- This release has a specific effect of opening anion channels, allowing large numbers of Cl- ions to diffuse into the terminal fibril.

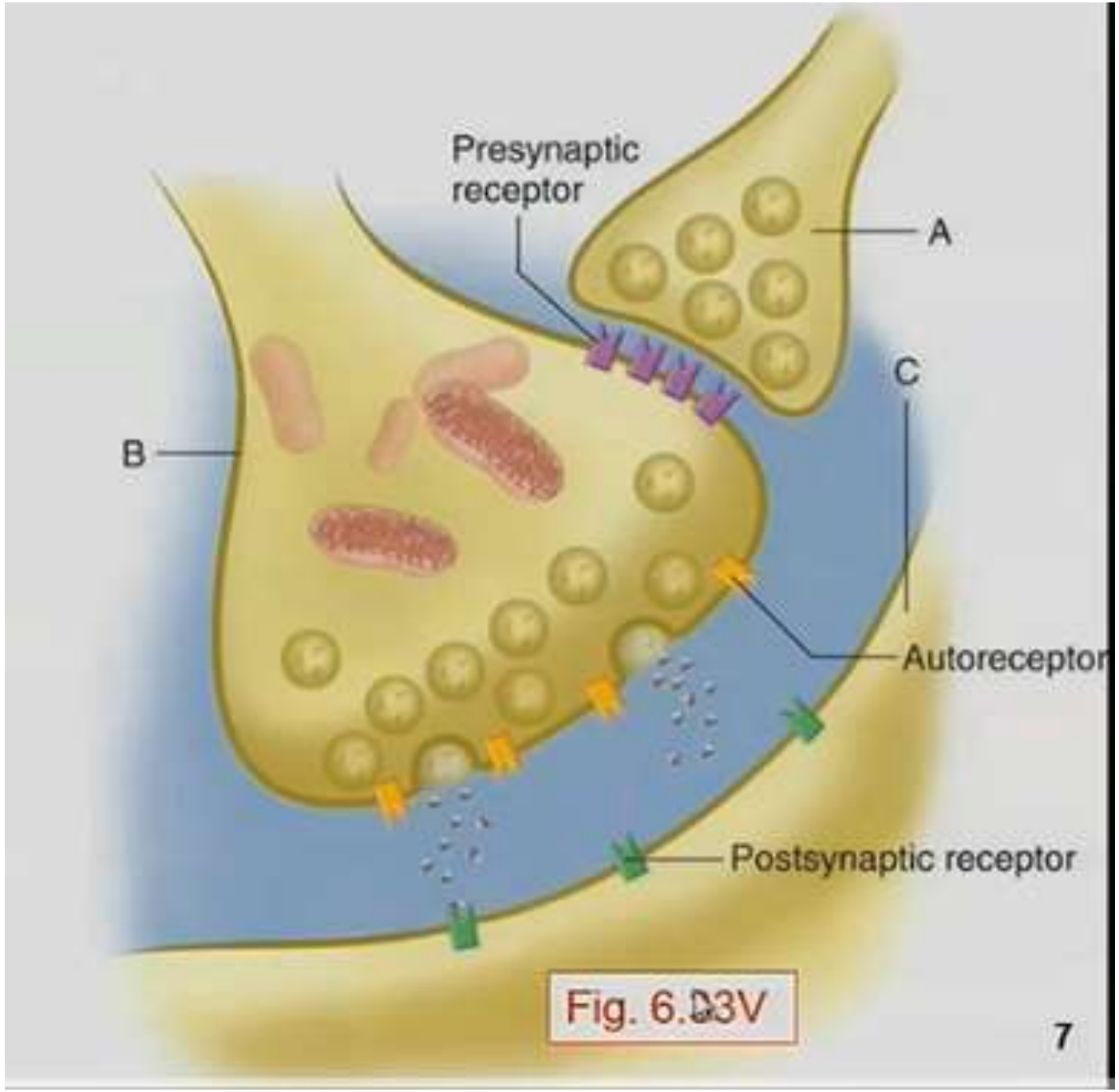

Presynaptic
receptor
A
C
B
Autoreceptor
Postsynaptic receptor

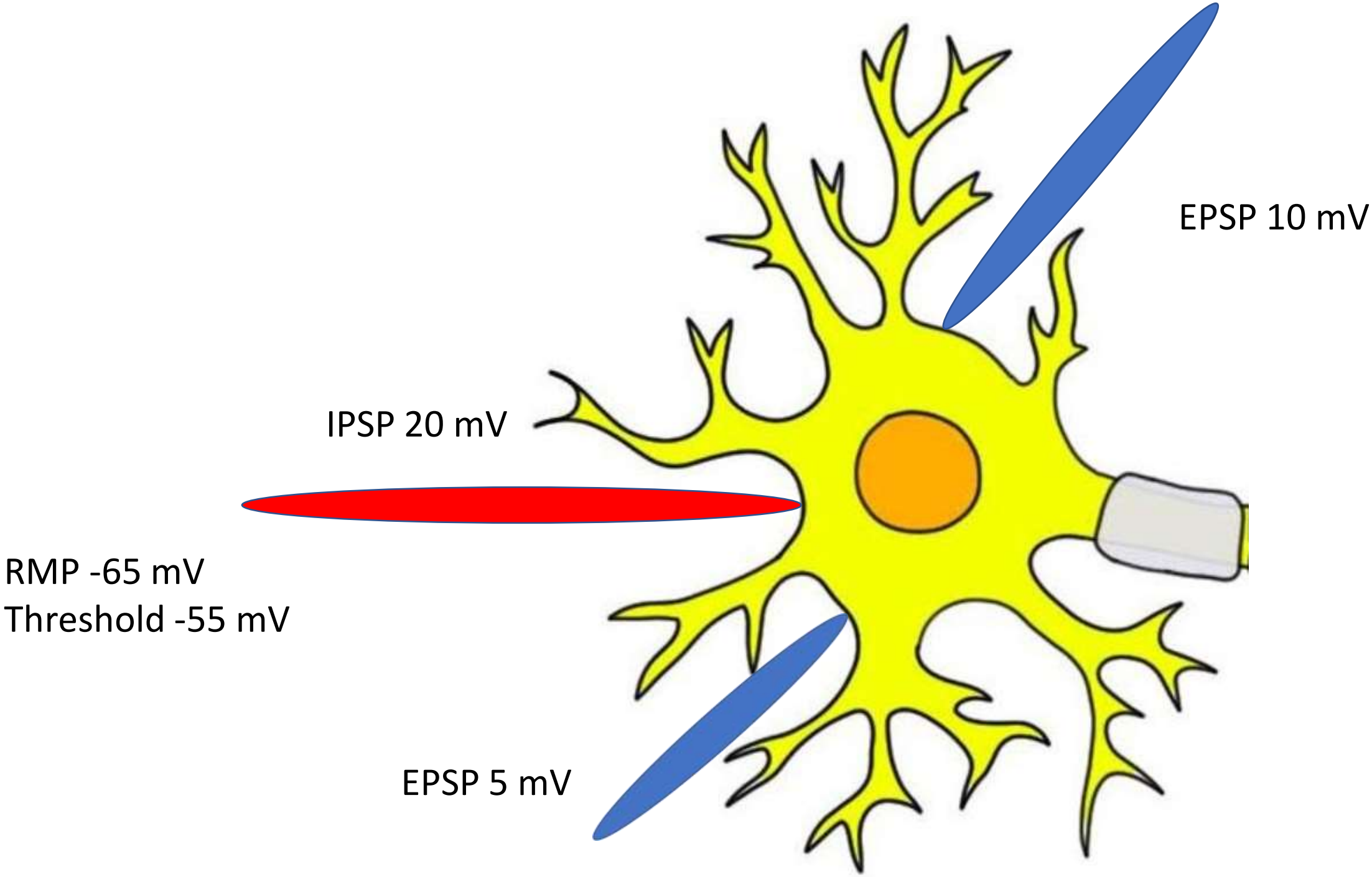
Fig. 6.13V

Presynaptic inhibition

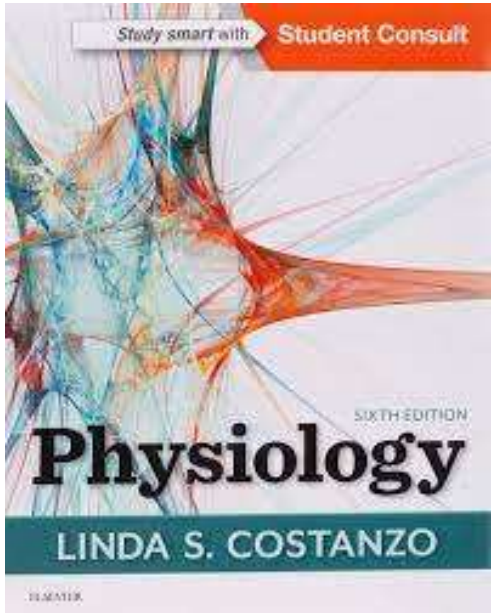
- Presynaptic inhibition occurs in many of the sensory pathways in the nervous system, such as, adjacent sensory nerve fibers often mutually inhibit one another, which minimizes sideways spread and mixing of signals in sensory tracts.

Facilitation of neurons

- Often the summated postsynaptic potential is excitatory but has not risen high enough to reach the threshold for firing by the postsynaptic neuron.
- When this situation occurs, the neuron is said to be facilitated.
- That is, its membrane potential is nearer the threshold for firing than normal but is not yet at the firing level.
- Consequently, another excitatory signal entering the neuron from some other source can then excite the neuron very easily.


EPSP 10 mV
IPSP 20 mV
RMP -65 mV
Threshold -55 mV
EPSP 5 mV

References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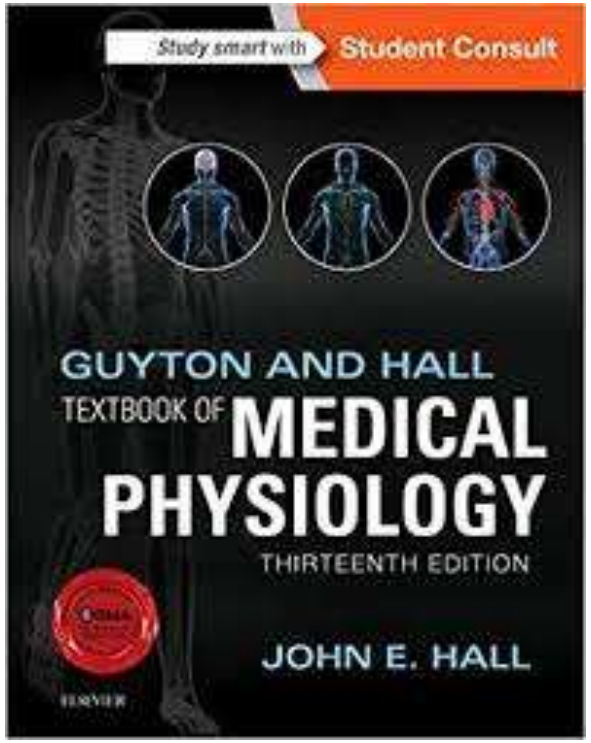
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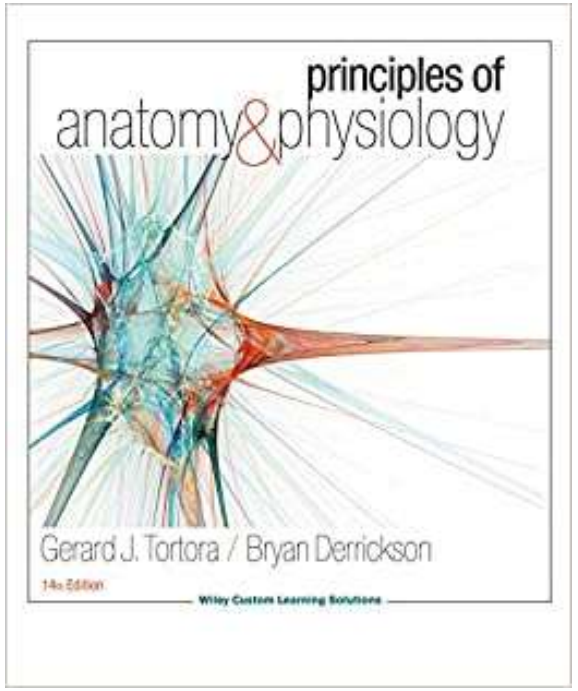
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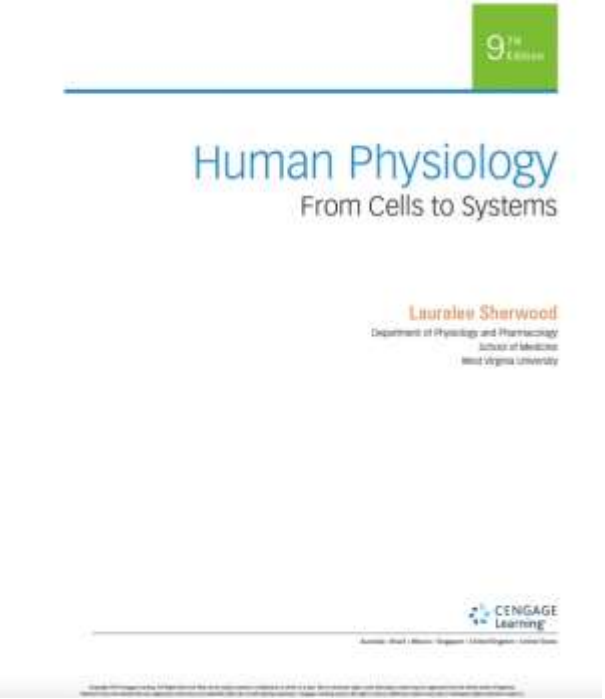
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Questions? Feedback?

Thank you