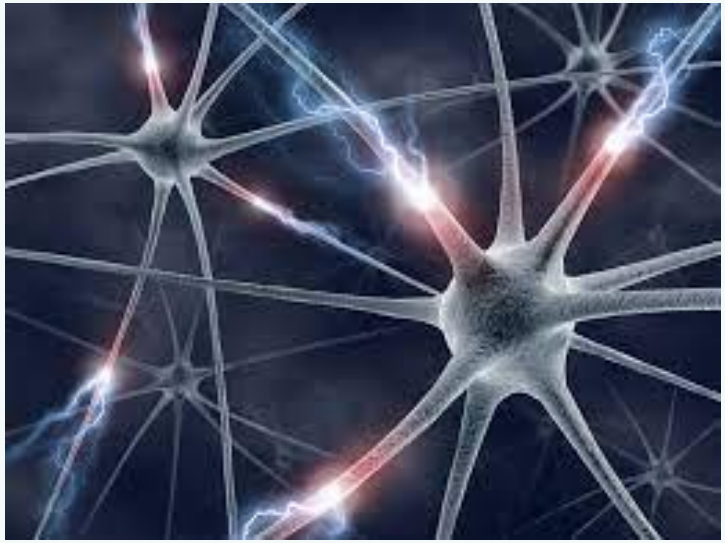

بسم الله الرحمن الرحيم


AD ASTRA
PER ASPERA

Ad Astra Per Aspera is a popular Latin phrase meaning
“to the stars through hardships”



Electrical Events During Neuronal Excitation And Inhibition

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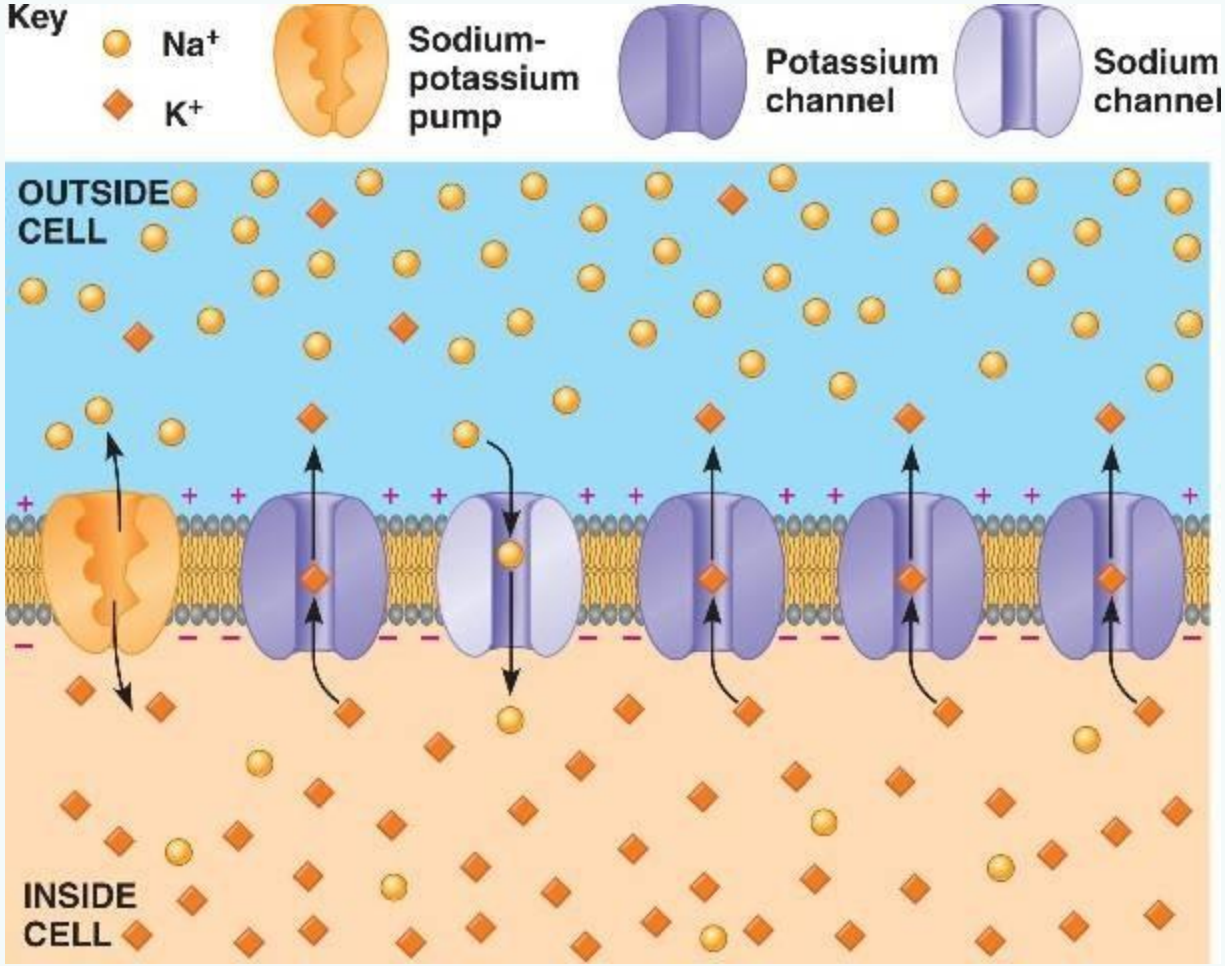
Learning Objectives

- Describe resting membrane potential of the neuronal soma.
- Describe Effect of Synaptic Excitation on the Postsynaptic Membrane—Excitatory Postsynaptic Potential.
- Describe Effect of Inhibitory Synapses on the Postsynaptic Membrane—Inhibitory Postsynaptic Potential.
- Describe Generation of Action Potentials in the Initial Segment of the Axon Leaving the Neuron—Threshold for Excitation.
- Describe the special characteristics of synaptic transmission.

Resting Membrane Potential


Key
Na+
K+
Sodium-potassium pump
Potassium channel
Sodium channel
OUTSIDE CELL
INSIDE CELL

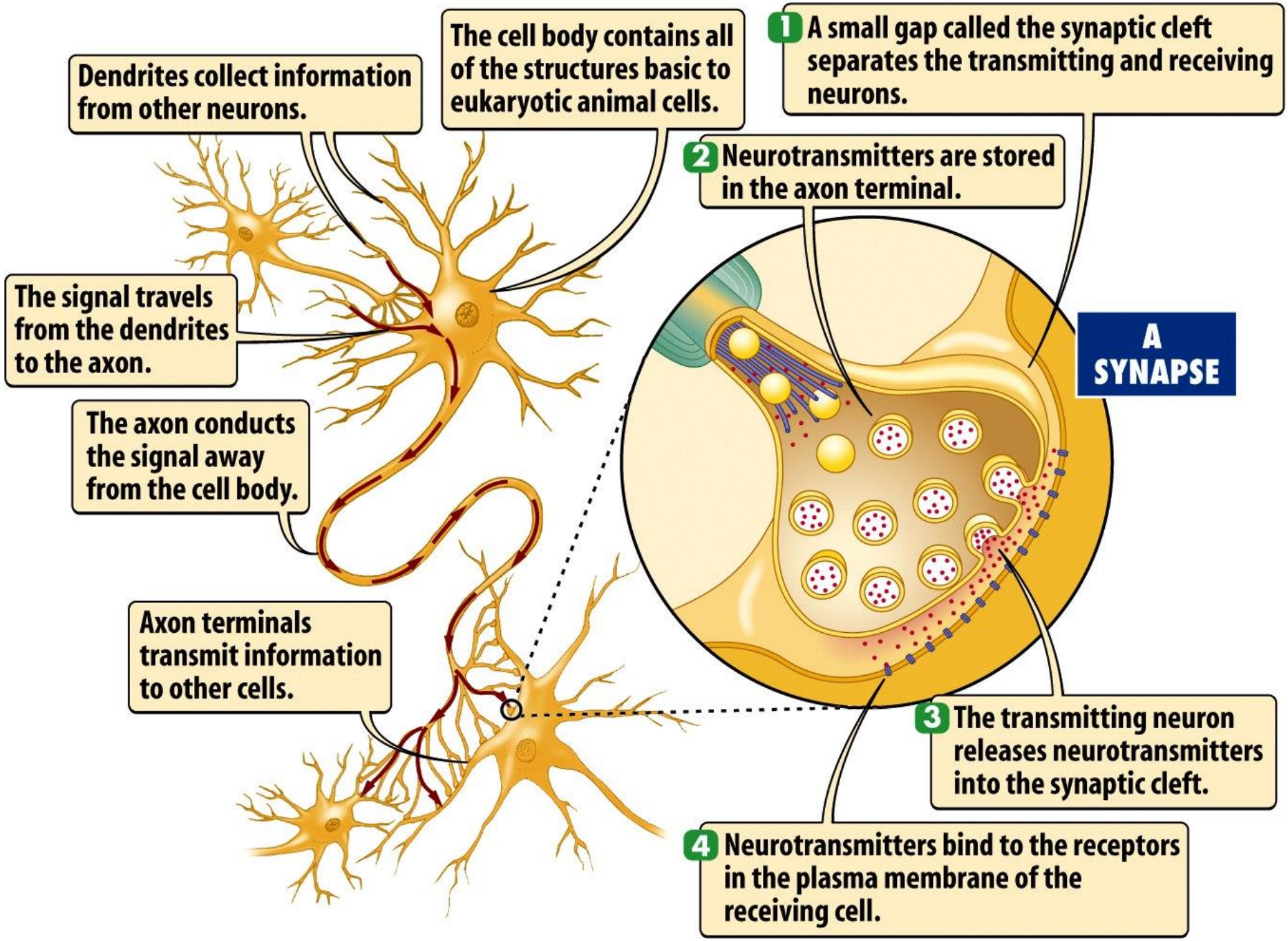
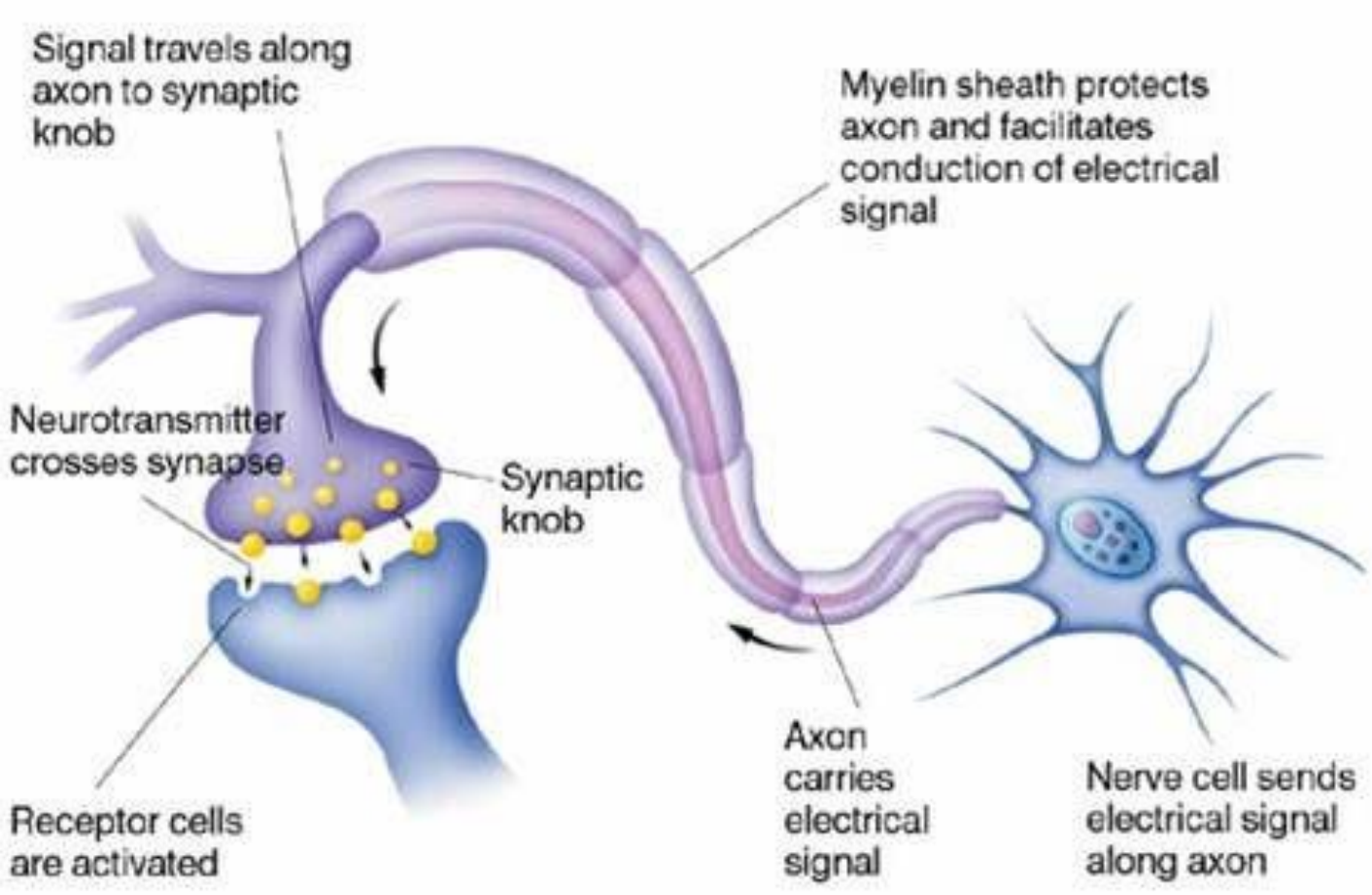


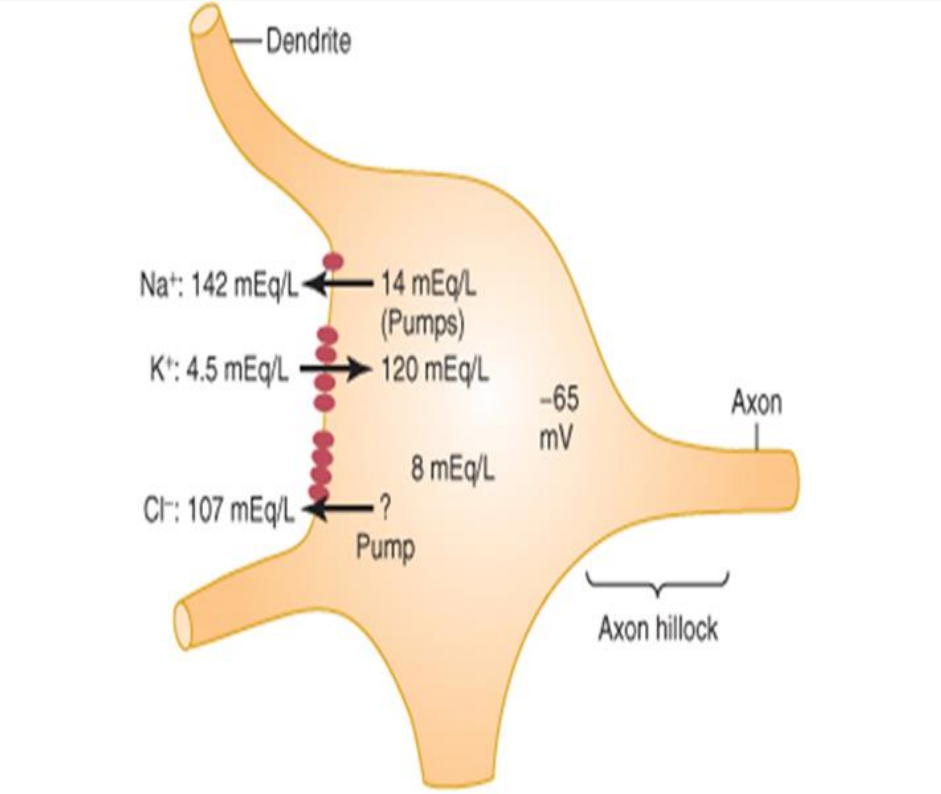
Figure 25-1a Discover Biology 3/e

Signal Transmission Along Axon

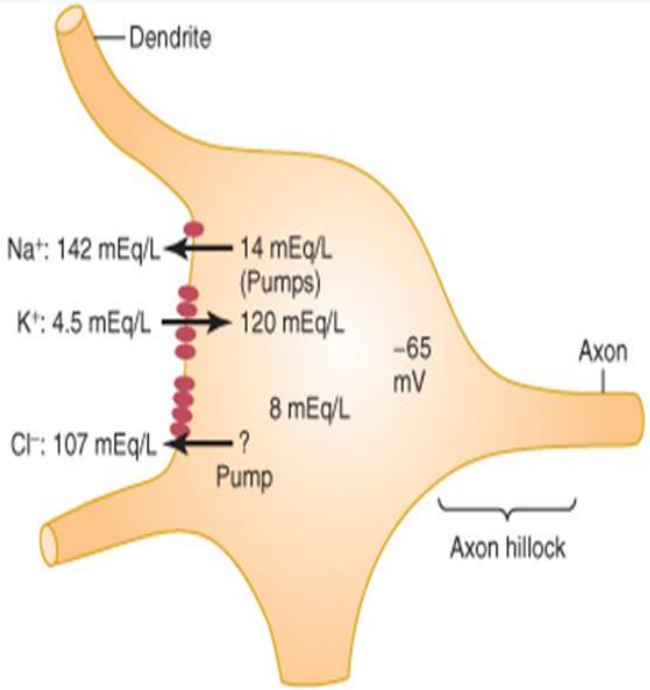


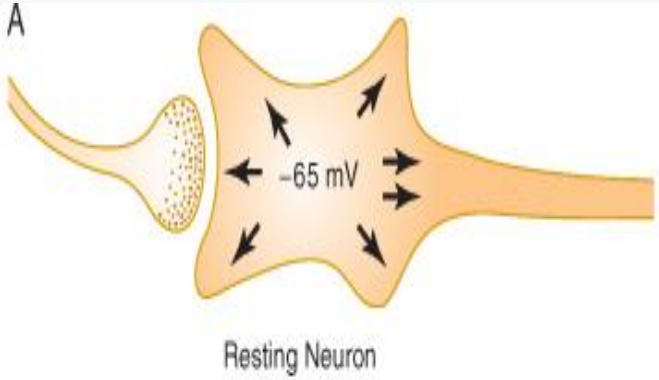
Resting Membrane Potential

- Resting Membrane potential in a spinal motor neuron is **-65mV** while
- In large peripheral nerve fiber → **-90mV**



Resting Neuronal Membrane





Concentration Differences of Ions

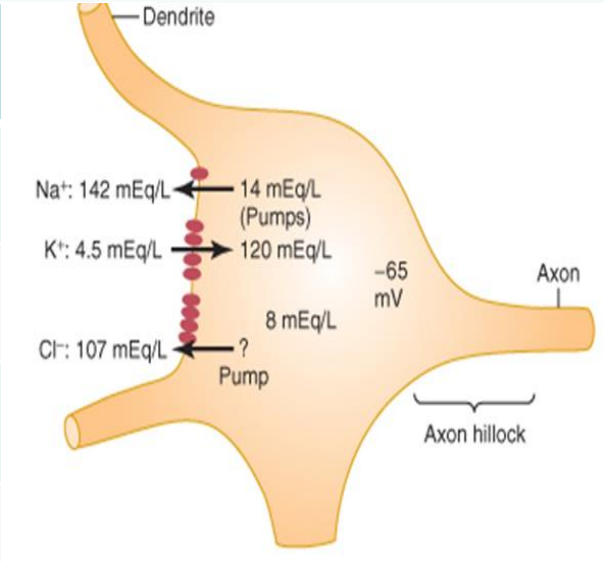
High in Extracellular Fluid	High Inside Neuron
• Sodium ions 142mEq/L • Chloride ions 107mEq/L	• Potassium 120mEq/L

Nernst Potential(EMF)

- It opposes the movement of ions on inside of membrane

- EMF (mV) = ± 61 x log [Concentration inside]
  Concentration outside

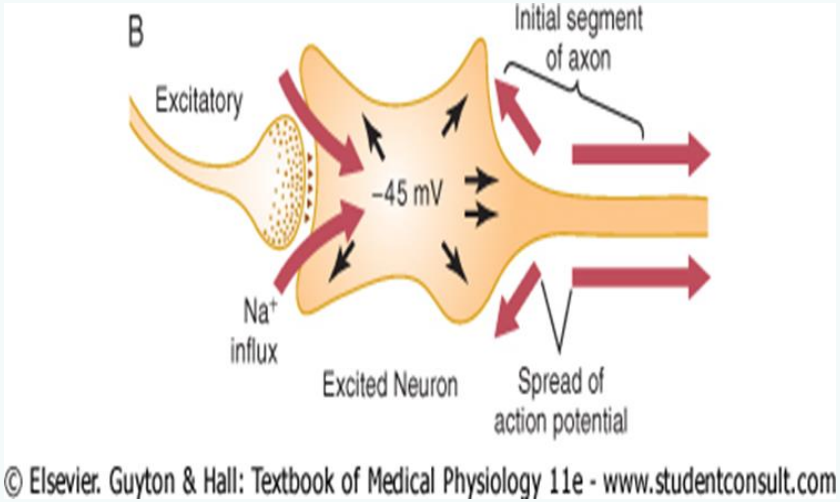
IONS	NERNST POTENTIAL
SODIUM	+ 61 mV
POTASSIUM	- 86 mV
CHLORIDE	- 70 mV



Excited & Inhibited Neuron

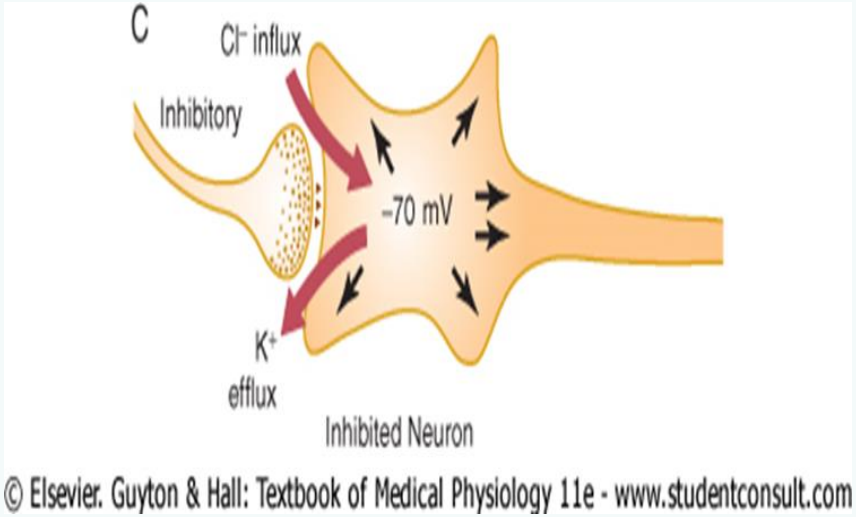
Excited

- Less negative voltage makes the neuron more excitable



Inhibited

- More negative voltage makes the neuron less excitable



Excitatory Post Synaptic Potential

Excitatory Post Synaptic Potential

- The positive increase in voltage above the normal resting neuronal potential is called EPSP, if high enough will elicit action potential in post synaptic neuron

- RMP has increased from -65 to -45 mV, a difference of **+20 mV** here is EPSP

- Results from discharge of many synaptic terminals (summation)

Excitatory Post Synaptic Potential

- Increased permeability to Na+

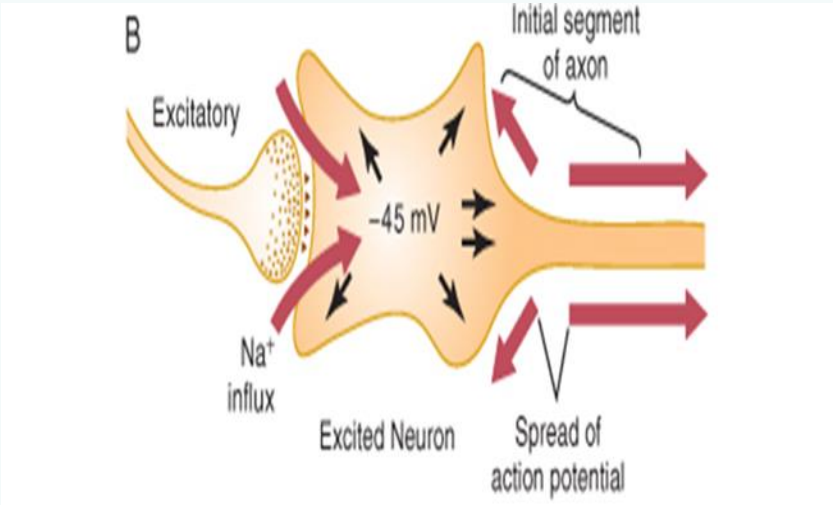
↓

-65mV → -45mV

EPSP

↓

Elicit Action Potential in postsynaptic neuron



Generation of Action Potentials

- EPSP when rises high enough → initiates action potential in neuron

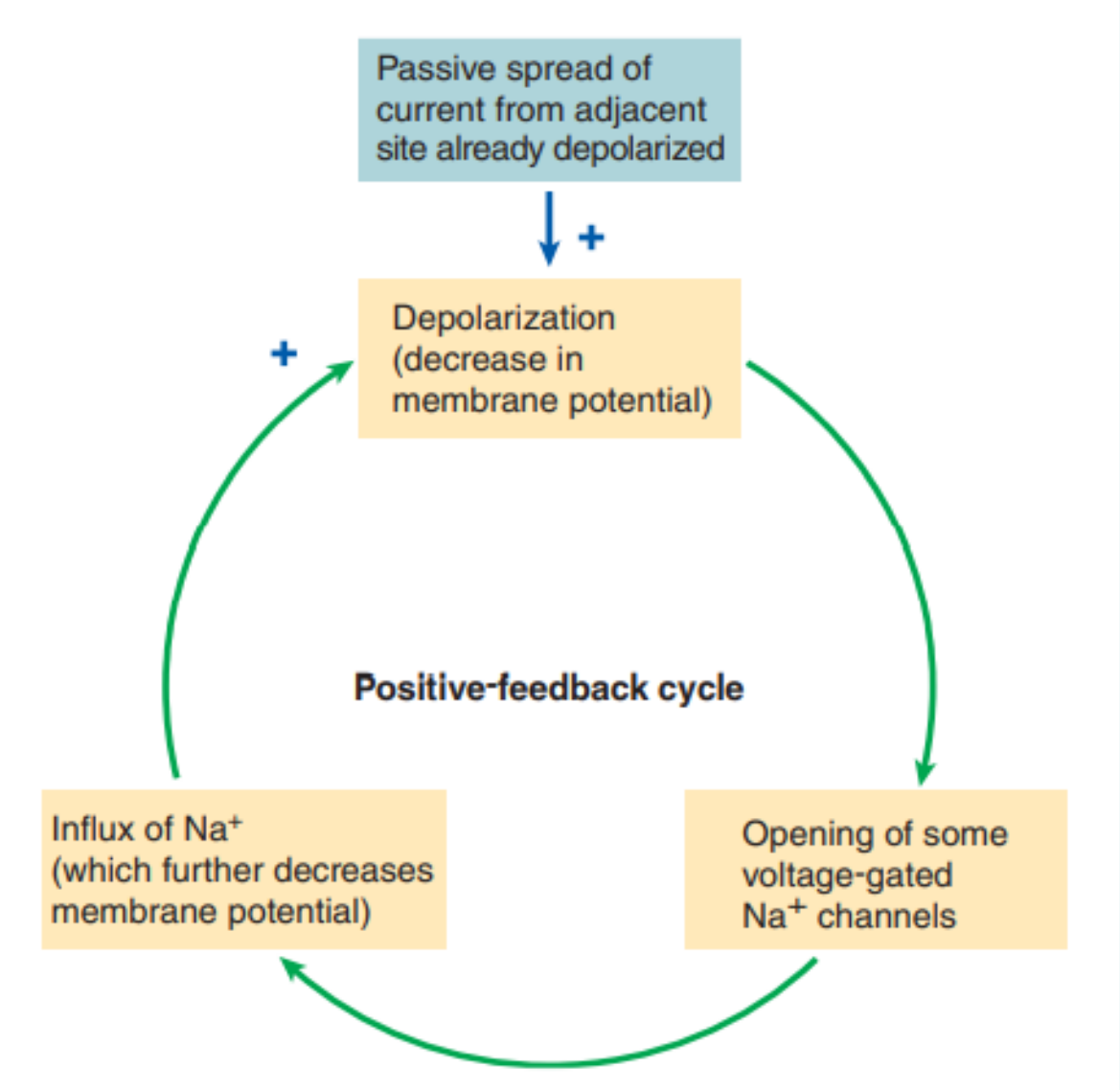
- Action potential **begins** in **initial segment of axon** where it leaves neuronal soma

- Membrane of initial segment of axon has

7 times greater voltage gated sodium channels as compared to soma

And **lower threshold** for excitation(+10 to +20mV)

Positive Feedback Cycle for Generation of Action Potential



MCQ

Initiation of action potential occurs at axon hillock because

A. Has no Nissl granules
B. Highest rate of conduction
C. Is non myelinated
D. lower threshold than rest of axon
E. Neurotransmitter is released here

Presynaptic & Post Synaptic Inhibition

Presynaptic Inhibition

- Release of inhibitory transmitter around presynaptic fibers mostly GABA

↓

Opening chloride ion channels

↓

inhibit synaptic transmission as neutralize the positive charged sodium ions

Inhibitory Post Synaptic Potential

- An **increase in negativity** beyond the normal resting membrane potential level is called an inhibitory postsynaptic potential **IPSP**

- -65 mV to -70 mV so

IPSP is -5 mV

Inhibitory Post Synaptic Potential

- **Cl-** Influx **+** **K+** Efflux

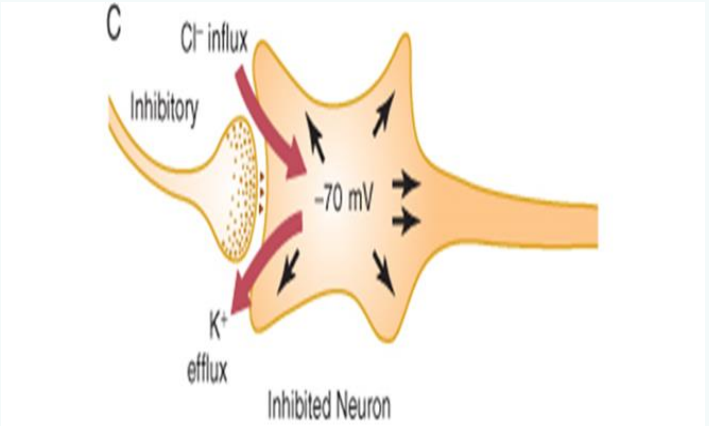
↓

Increase in intracellular negativity

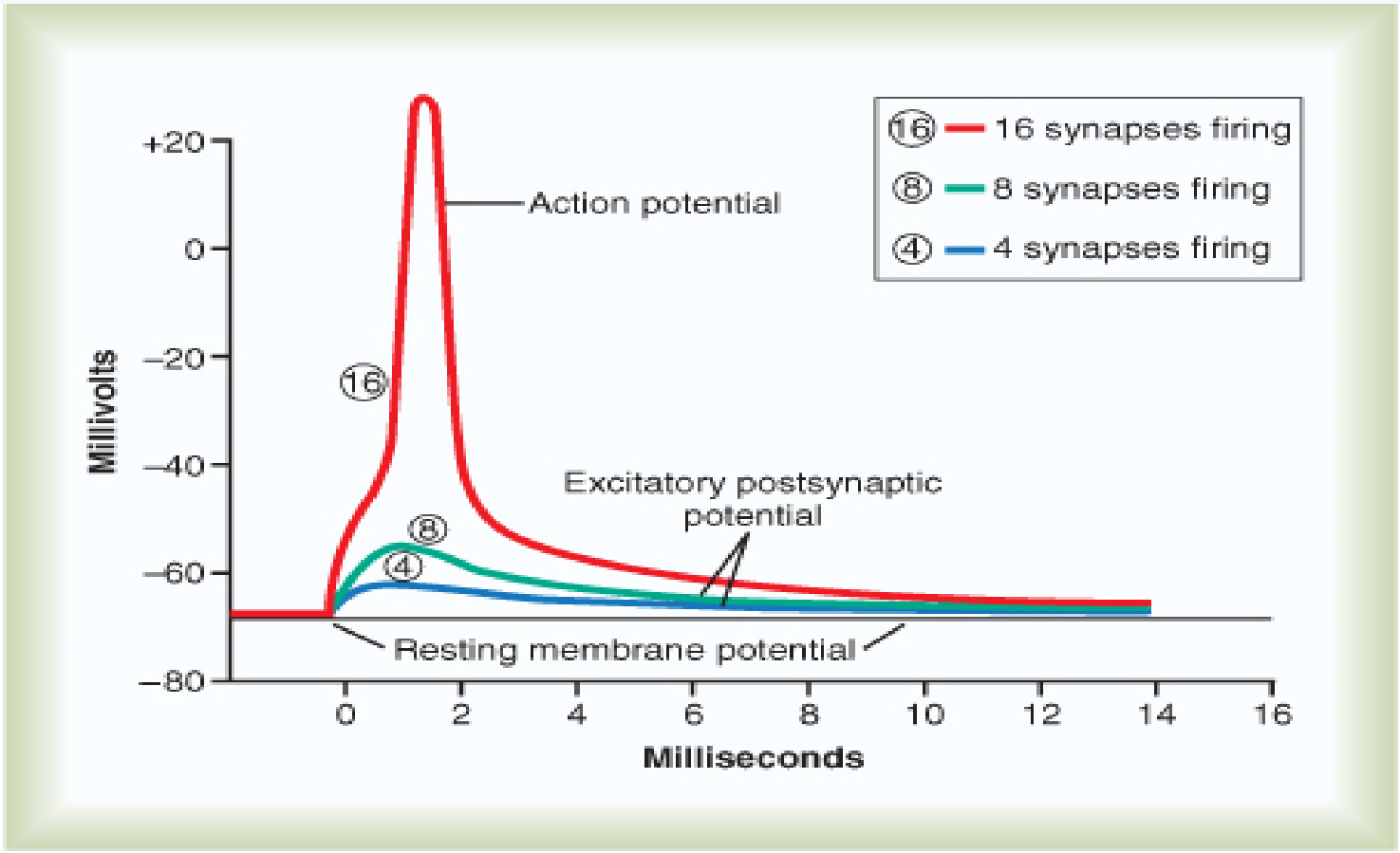
(Hperpolarization)

↓

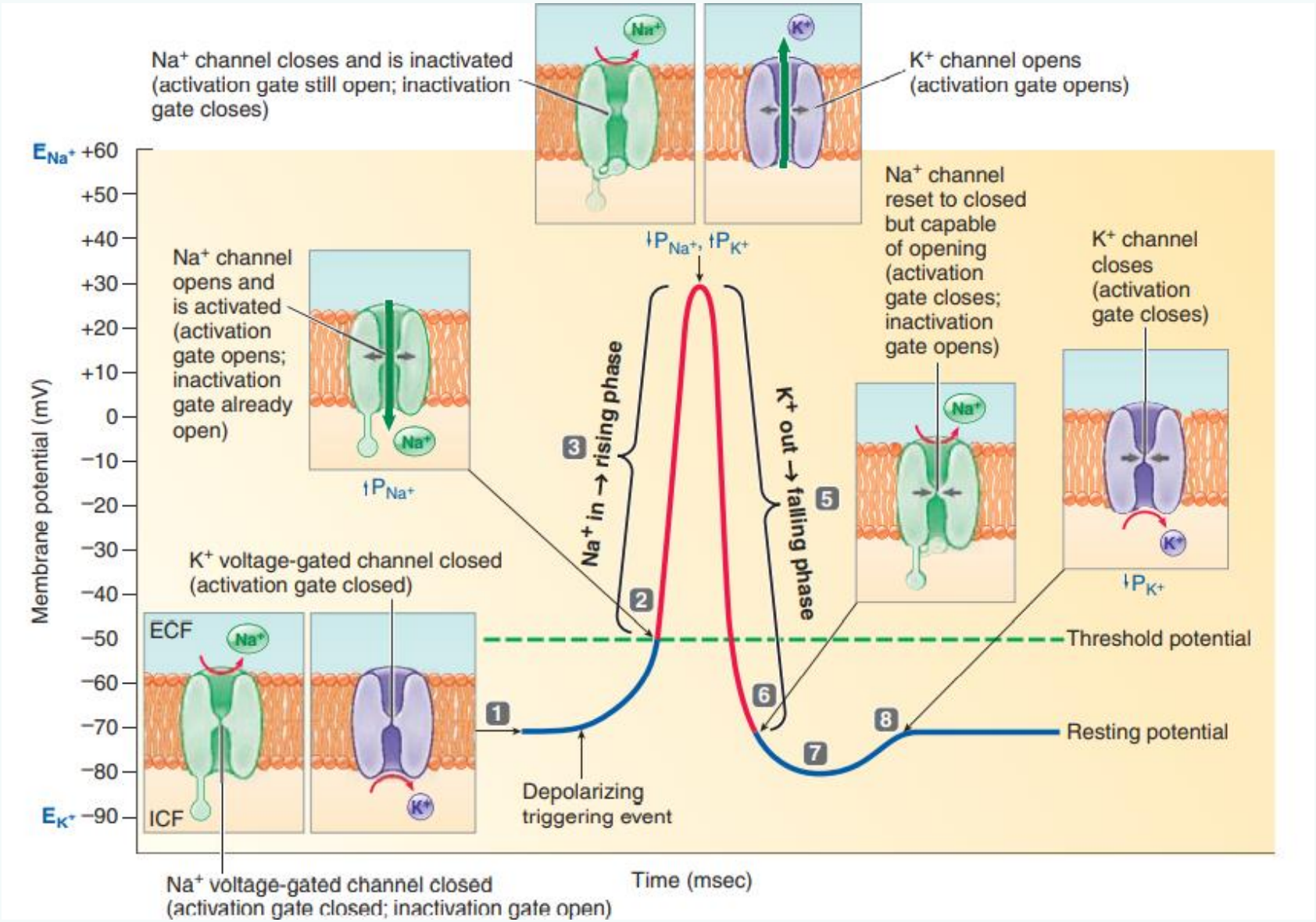
Neuronal inhibition



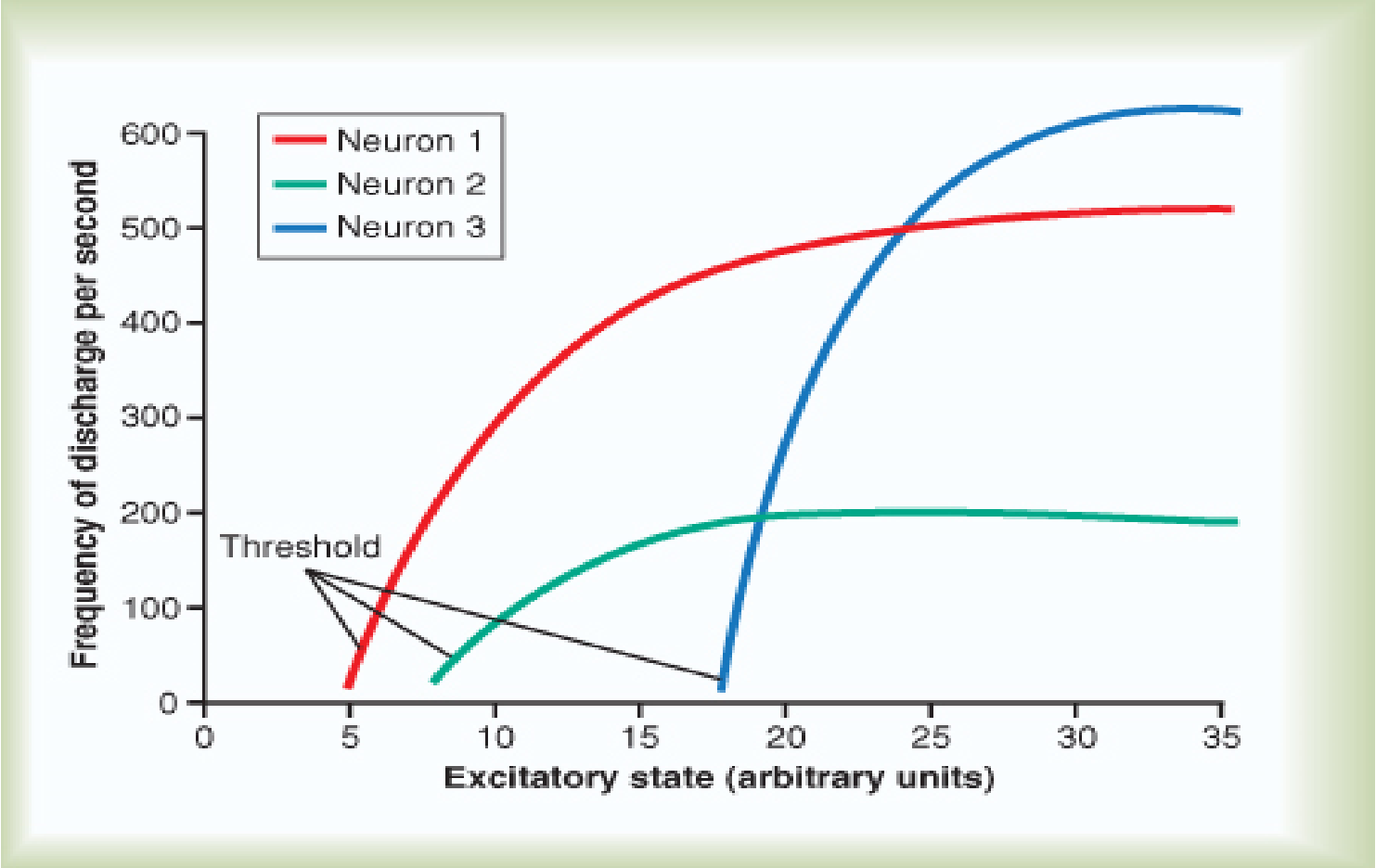
Time Course of Postsynaptic Potentials



Permeability Changes & Ion Fluxes During Action Potential



Response of Different Neurons to Different Levels of Excitatory State



Summation

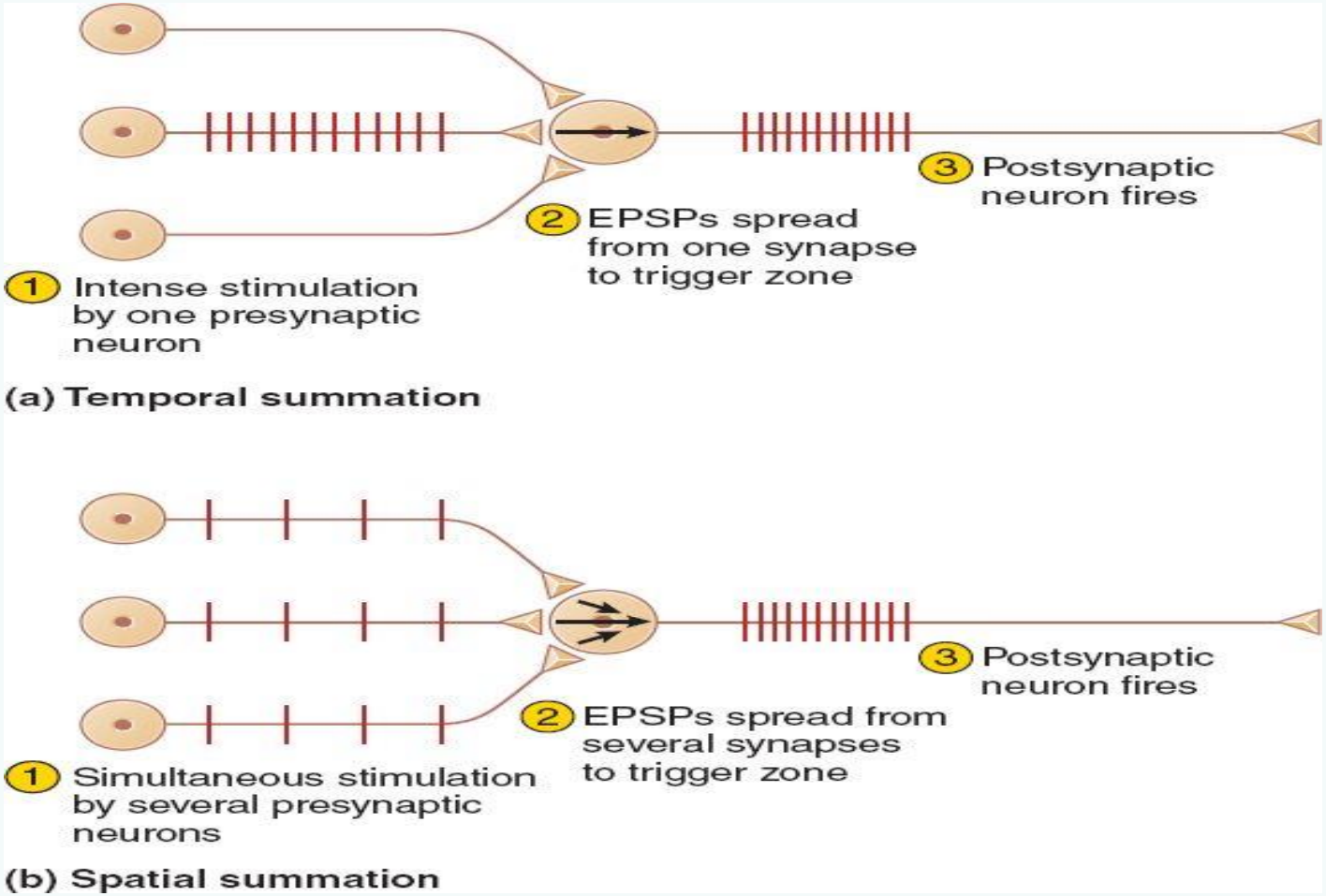
Summation

- the process that determines whether an action potential will be generated by the combined effects of excitatory and inhibitory signals

- may or may not reach the threshold voltage to trigger an action potential

- Amount of EPSP by one terminal is 0.5-1 mV and **10-20 mV** is required to reach threshold for excitation

Temporal And Spatial Summation



TEMPORAL SUMMATION
VERSUS
SPATIAL SUMMATION

TEMPORAL SUMMATION	SPATIAL SUMMATION
Sensory summation that involves the addition of single stimuli over a short period of time	Sensory summation that involves stimulation of several spatially separated neurons at the same time
A single presynaptic neuron is responsible for generating the action potential	Multiple presynaptic neurons are responsible for generating the action potential
One presynaptic neuron generates subthresholds over a certain period of time	Multiple presynaptic neurons generate subthresholds
A less efficient process as it takes time to generate an action potential	More efficient

Facilitation of Neurons

The summated postsynaptic potential is excitatory but not high enough to reach threshold for firing by postsynaptic neuron→

neuron is **FACILITATED**

Special Function of Dendrites

Special Function of Dendrites for Neuronal Excitation

- **Large spatial fields of Excitation of dendrites**

Anterior motor neuron (AMN) dendrites extend 500-1000 μm

80-95% of all AMN end on dendrites and 5-10% on soma

- **Electrotonic Conduction**

Dendrites mostly have few voltage gated Na+ Channels so fail to transmit action potentials

Transmit electrotonic current

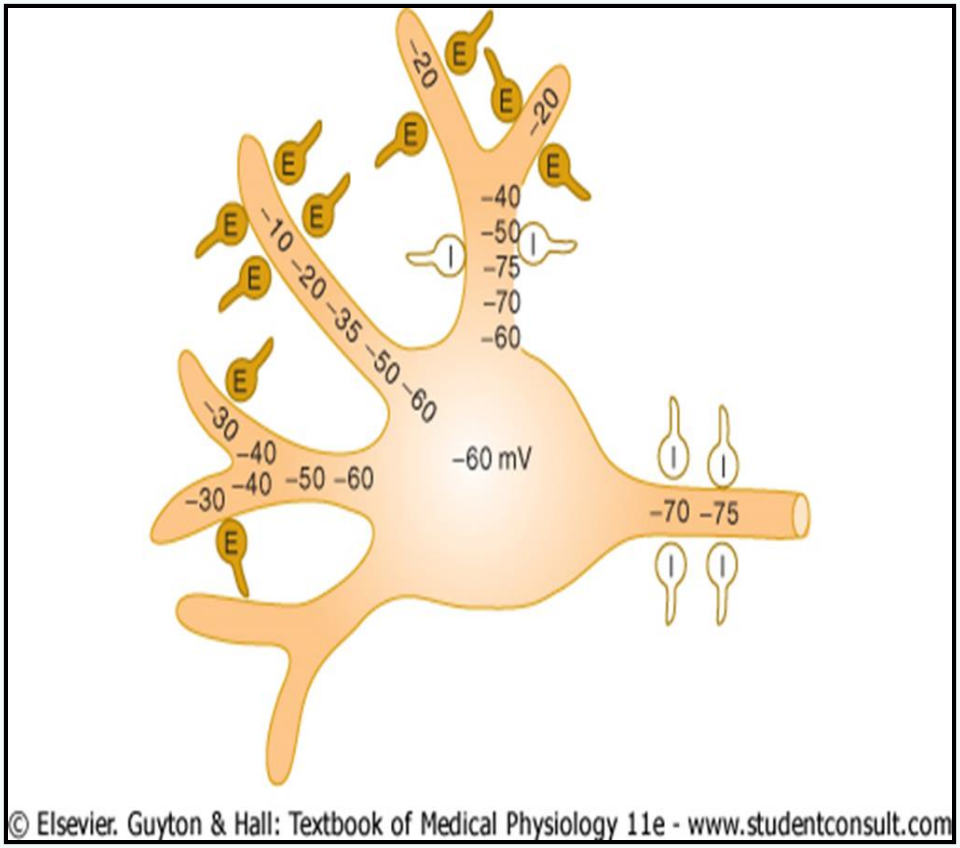
Stimulation of A Neuron By Presynaptic Terminals

Decremental conduction

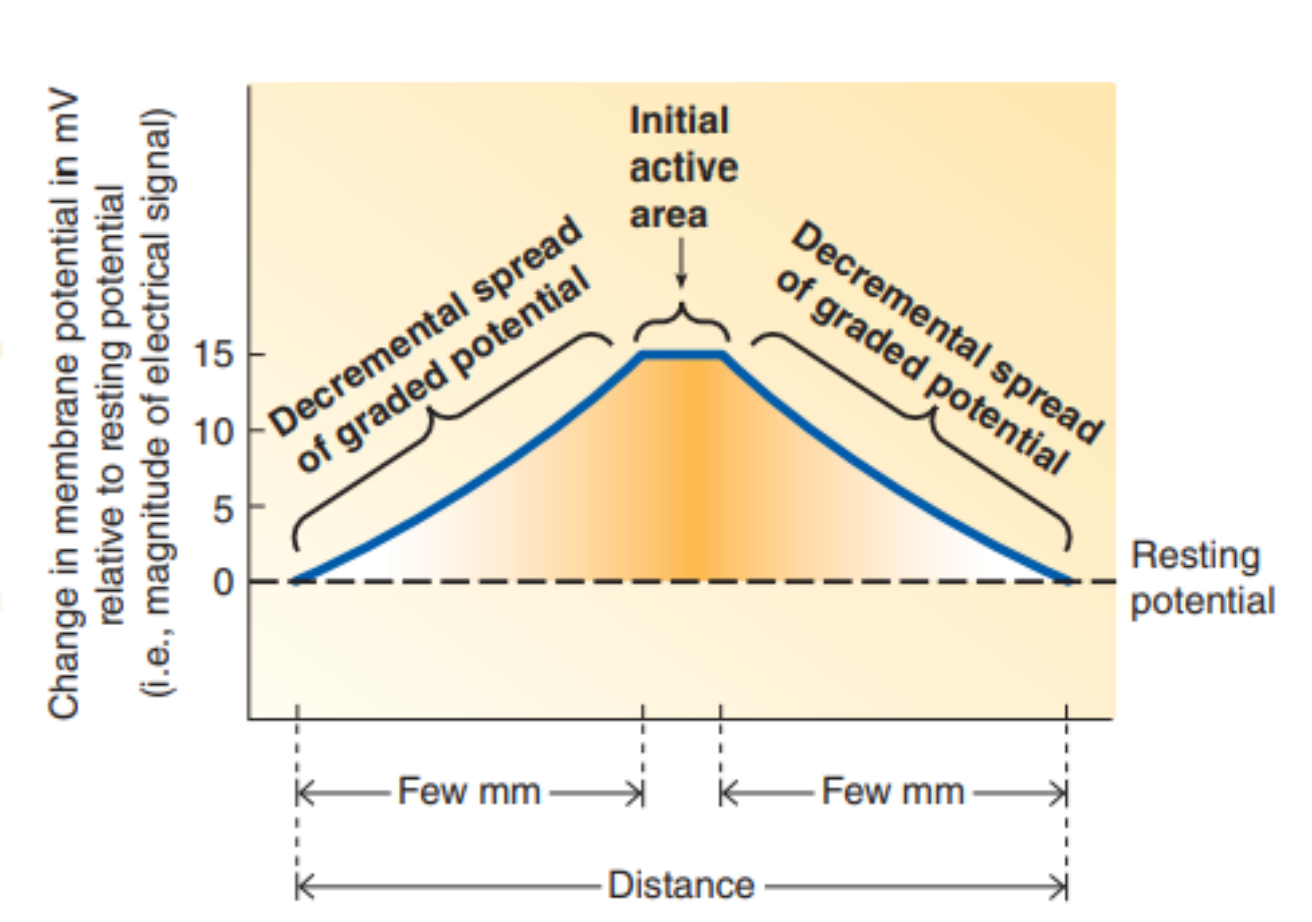
A large EPSP is lost as dendrites are

- Long
- Thin walled
- Leaky to K+ & Cl-

Farther the excitatory synapse from soma, greater will be the decrement and less excitation



Decremental Conduction



Property	Graded Potentials	Action Potentials
Triggering Events	Triggered by stimulus, by combination of neurotransmitter with receptor, or by inherent shifts in channel permeability	Triggered by depolarization to threshold, usually through passive spread of depolarization from adjacent area undergoing graded potential or action potential
Ion Movement Producing Change in Potential	Produced by net movement of Na^+, K^+, Cl^-, or Ca^{2+} across plasma membrane by various means	Produced by sequential movement of Na^+ into and K^+ out of cell through voltage-gated channels
Coding of Magnitude of Triggering Event	Graded potential change; magnitude varies with magnitude of triggering event	All-or-none membrane response; magnitude of triggering event coded in frequency rather than amplitude of action potentials
Duration	Varies with duration of triggering event	Constant
Magnitude of Potential Change with Distance from Initial Site	Decremental conduction; magnitude diminishes with distance from initial site	Propagated throughout membrane in undiminishing fashion; self-regenerated in neighboring inactive areas of membrane
Refractory Period	None	Relative, absolute
Summation	Temporal, spatial	None
Direction of Potential Change	Can be depolarization or hyperpolarization	Always depolarization and reversal of charges
Location	Occurs in specialized regions of membrane designed to respond to triggering event	Occurs in regions of membrane with abundance of voltage-gated Na^+ channels

Sherwood Physiology, Chapter 4, page 98

Special Characteristics of Synaptic Transmission

1. Fatigue
2. Effect of Acidosis and Alkalosis
3. Effect of Hypoxia
4. Effect of drugs
5. Synaptic Delay

Fatigue of Synaptic Transmission

- When excitatory synapses are rapidly stimulated, the number of discharges at first is great and the firing rate progressively decreases in next milliseconds/seconds

- **Protective mechanism** as in an Epileptic attack

Fatigue of Synaptic Transmission

Mechanism of Fatigue

1. Exhaustion of stores of neurotransmitters in synaptic terminals

2. Progressive inactivation of many postsynaptic membrane receptors

3. Slow development of abnormal ion concentrations in postsynaptic neuronal cells

Effect of Acidosis & Alkalosis on Synaptic Transmission

- **Alkalosis→ increases neuronal excitability**

An increase in arterial blood pH from

7.4 - 7.8/8 → epileptic seizures

- **Acidosis → depresses neuronal activity**

A fall in pH from **7.4 to below 7.0** → comatose state (diabetic/uremic acidosis)

Effect of Hypoxia on Synaptic Transmission

- Lack of oxygen supply for only a few seconds can cause complete in-excitability of some neurons

- If blood flow to brain is interrupted for a few seconds → unconsciousness

Effect of Drugs on Synaptic Transmission

- **Caffeine, Theophylline, Theobromine** in **coffee, tea, and cocoa** increase neuronal excitation by decreasing **excitatory threshold**

- **Strychnine** increases excitation of neurons by inhibiting action of **inhibitory transmitter** substances (glycine in spinal cord)

- **Anesthetics** increase the neuronal membrane **threshold** for excitation and may change physical characteristics of neuronal membranes → inhibition

Synaptic Delay

- Transmission of a neuronal signal from pre to post synaptic neuron takes a minimal period of **0.5 millisecond** called

Synaptic Delay

A video in collaboration between the Association of American Medical Colleges and Khan Academy

www.khanacademy.org

References

- Guyton and Hall
- Ganong’s Physiology
- Sherwood Physiology


QUESTIONS?
WHEN?
WHERE?
WHAT?
WHO?
HOW?
WHY?
Where?
What?
When?


Thank
you