Nervous System

TABLE 8-1 Synonyms in Neuroscience

TERM USED IN THIS BOOK	SYNONYM(S)
Action potential	Spike, nerve impulse, conduction signal
Autonomic nervous system	Visceral nervous system
Axon	Nerve fiber
Axonal transport	Axoplasmic flow
Axon terminal	Synaptic knob, synaptic bouton, presynaptic terminal
Axoplasm	Cytoplasm of an axon
Cell body	Cell soma, nerve cell body
Cell membrane of an axon	Axolemma
Glial cells	Neuroglia, glia
Interneuron	Association neuron
Rough endoplasmic reticulum	Nissl substance, Nissl body
Sensory neuron	Afferent neuron, afferent

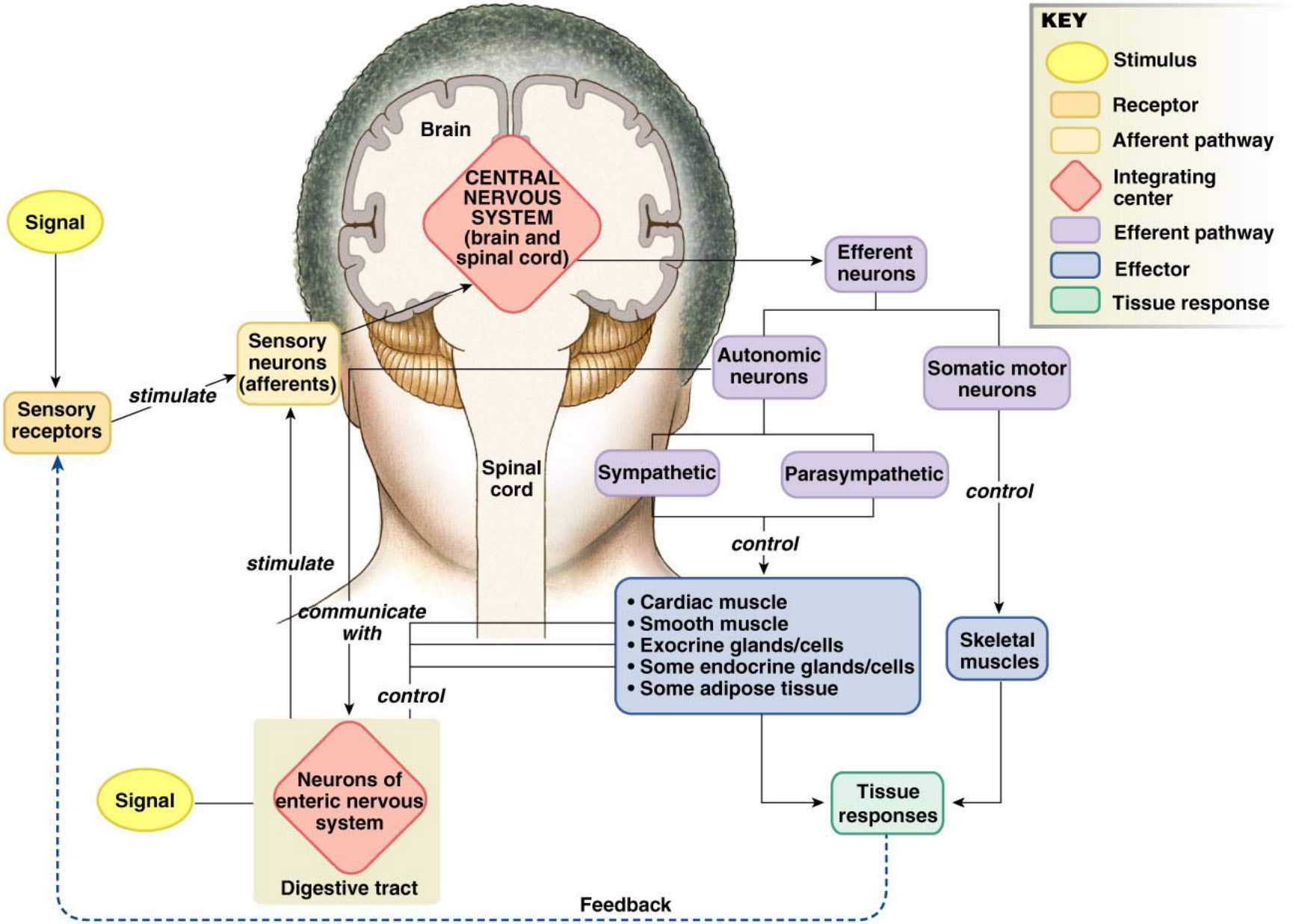
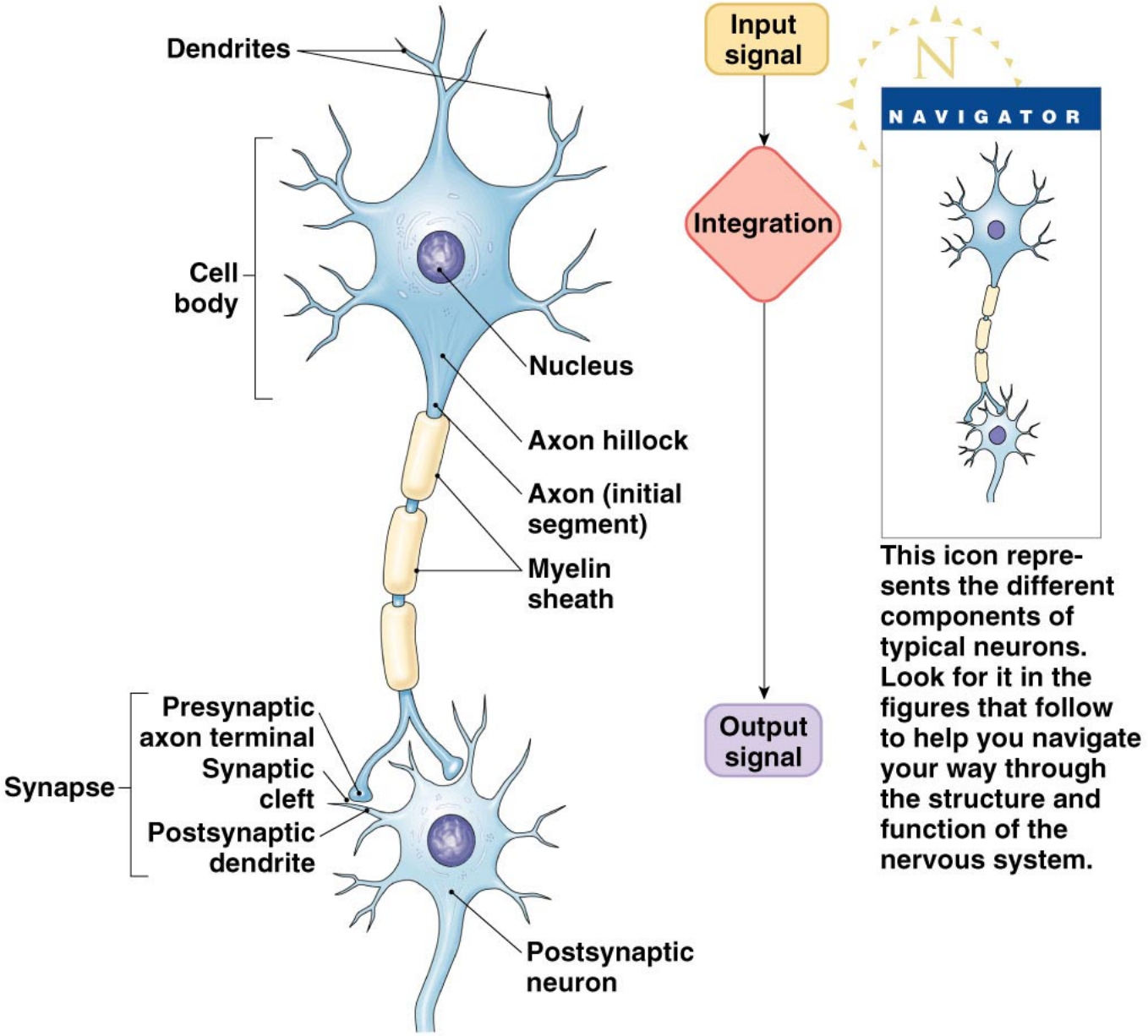


Figure 8-1



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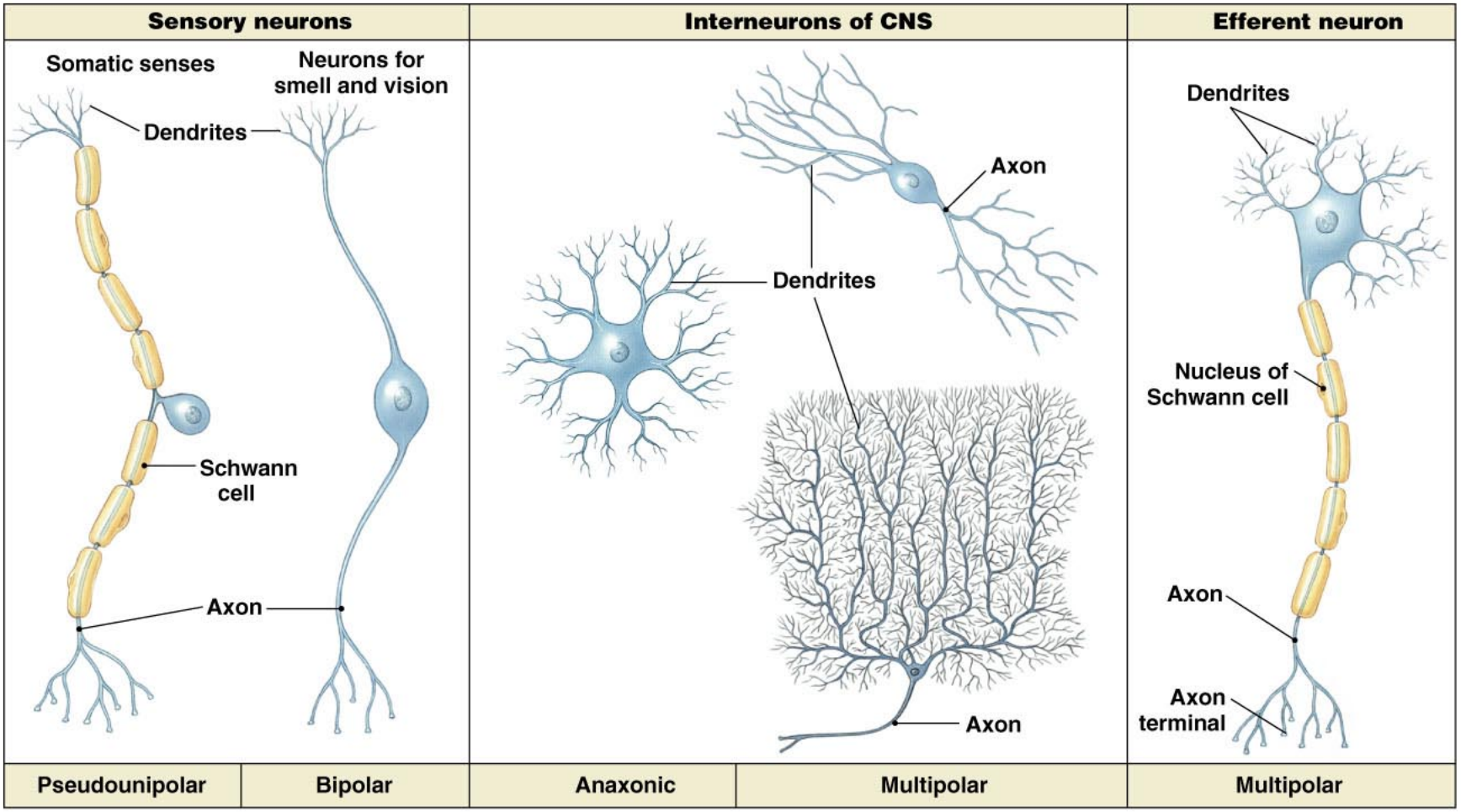


(a) Pseudounipolar neurons have a single process called the axon. During development, the dendrite fused with the axon.

(b) Bipolar neurons have two relatively equal fibers extending off the central cell body.

(c) Anaxonic CNS interneurons have no apparent axon.

(d) Multipolar CNS interneurons are highly branched but lack long extensions.

(e) A typical multipolar efferent neuron has five to seven dendrites, each branching four to six times. A single long axon may branch several times and end at enlarged axon terminals.

Figure 8-3 - Overview

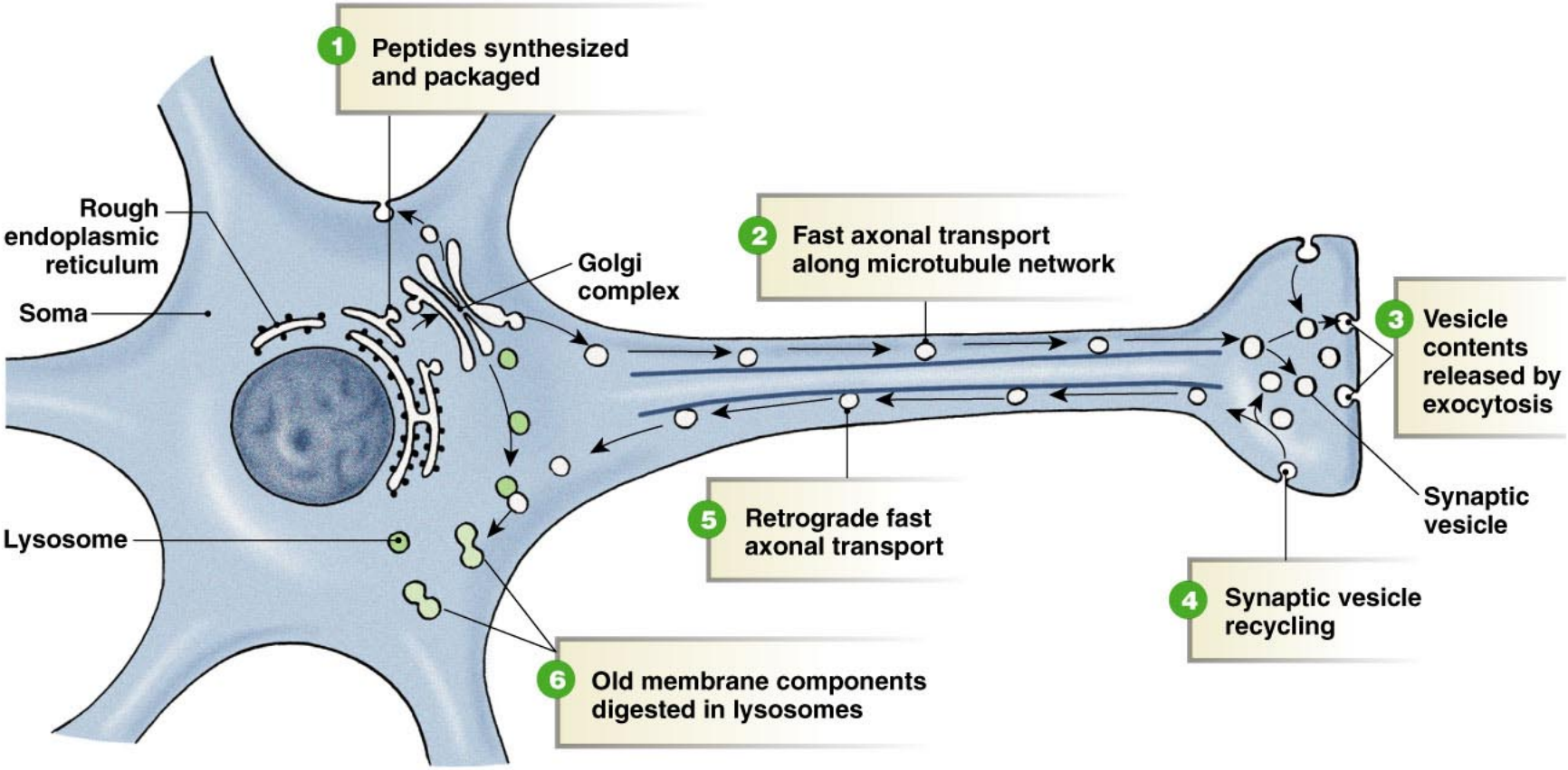


Figure 8-4

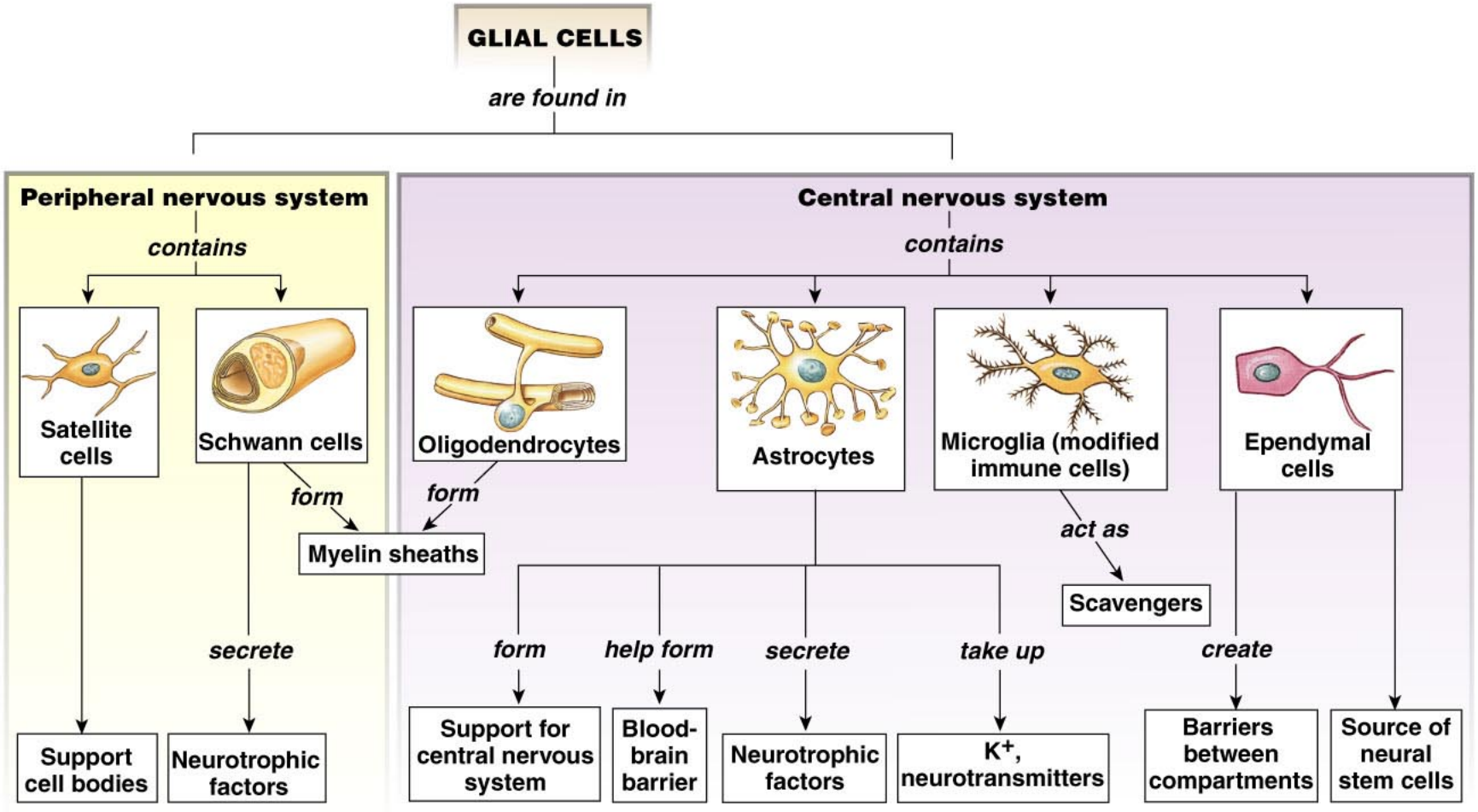


Figure 8-5 – Overview (1 of 3)

(a) Glial cells of the central nervous system

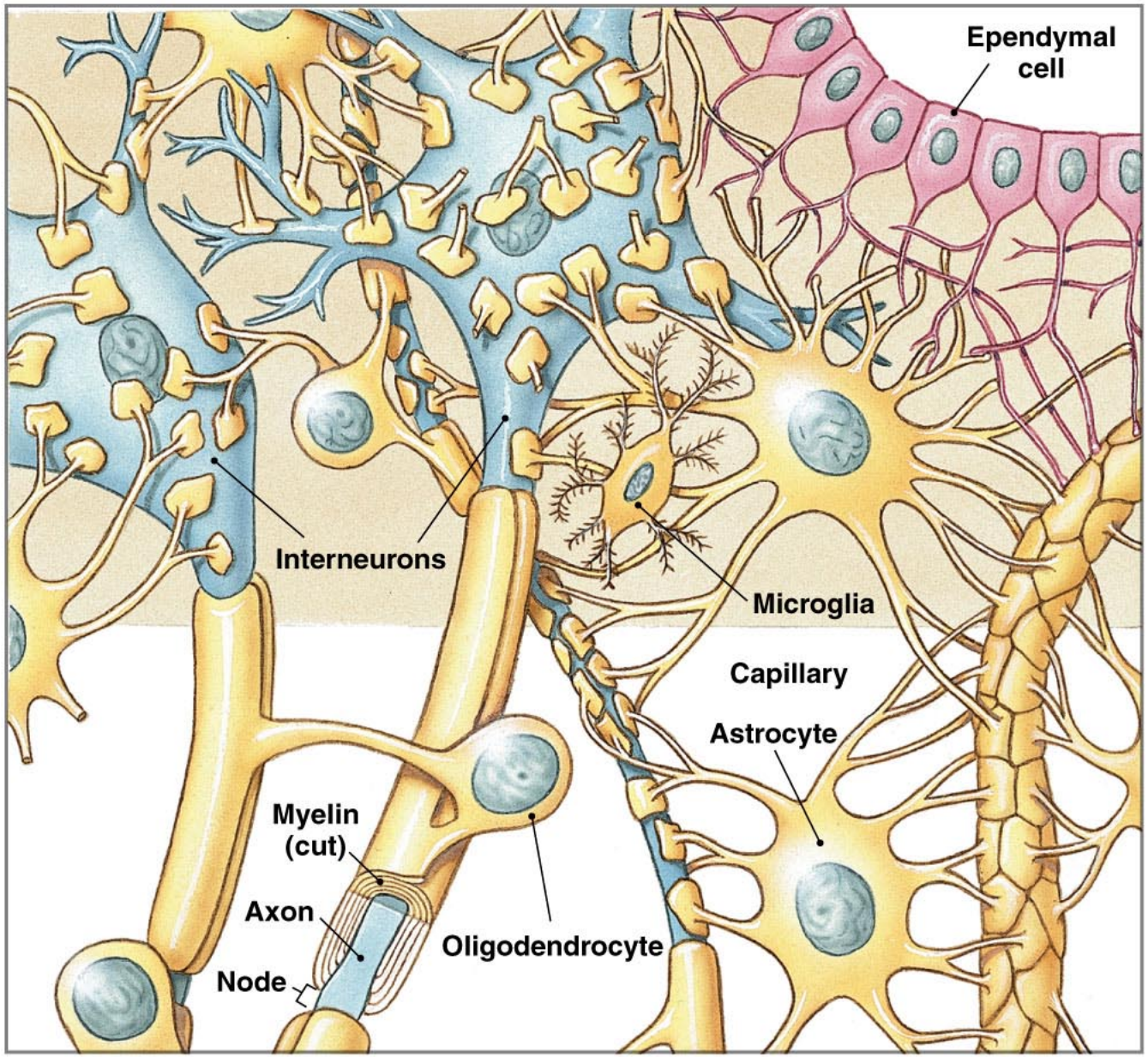


Figure 8-6a

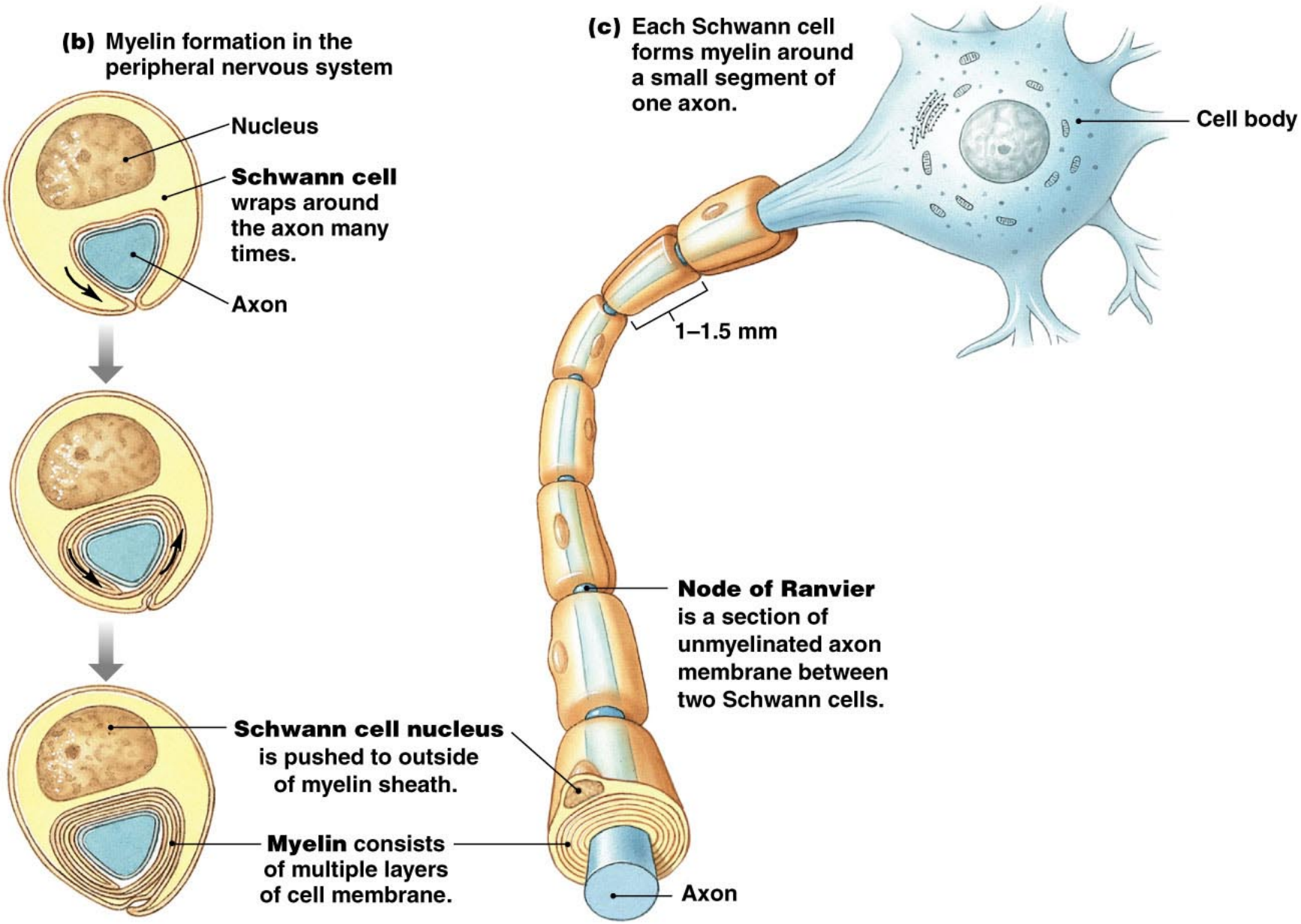


Figure 8-6, b–c

TABLE 8-2 Ion Concentrations and Equilibrium Potentials

ION	EXTRACELLULAR FLUID (mM)	INTRACELLULAR FLUID (mM)	E_{ion} AT 37° C
K^+	5 mM (normal range: 3.5–5)	150 mM	−90 mV
Na^+	145 mM (normal range: 135–145)	15 mM	+60 mV
Cl^-	108 mM (normal range: 100–108)	10 mM (range: 5–15)	−63 mV
Ca^{2+}	1 mM	0.0001 mM	see Concept Check question 6

Graded Potential

and

Action Potential

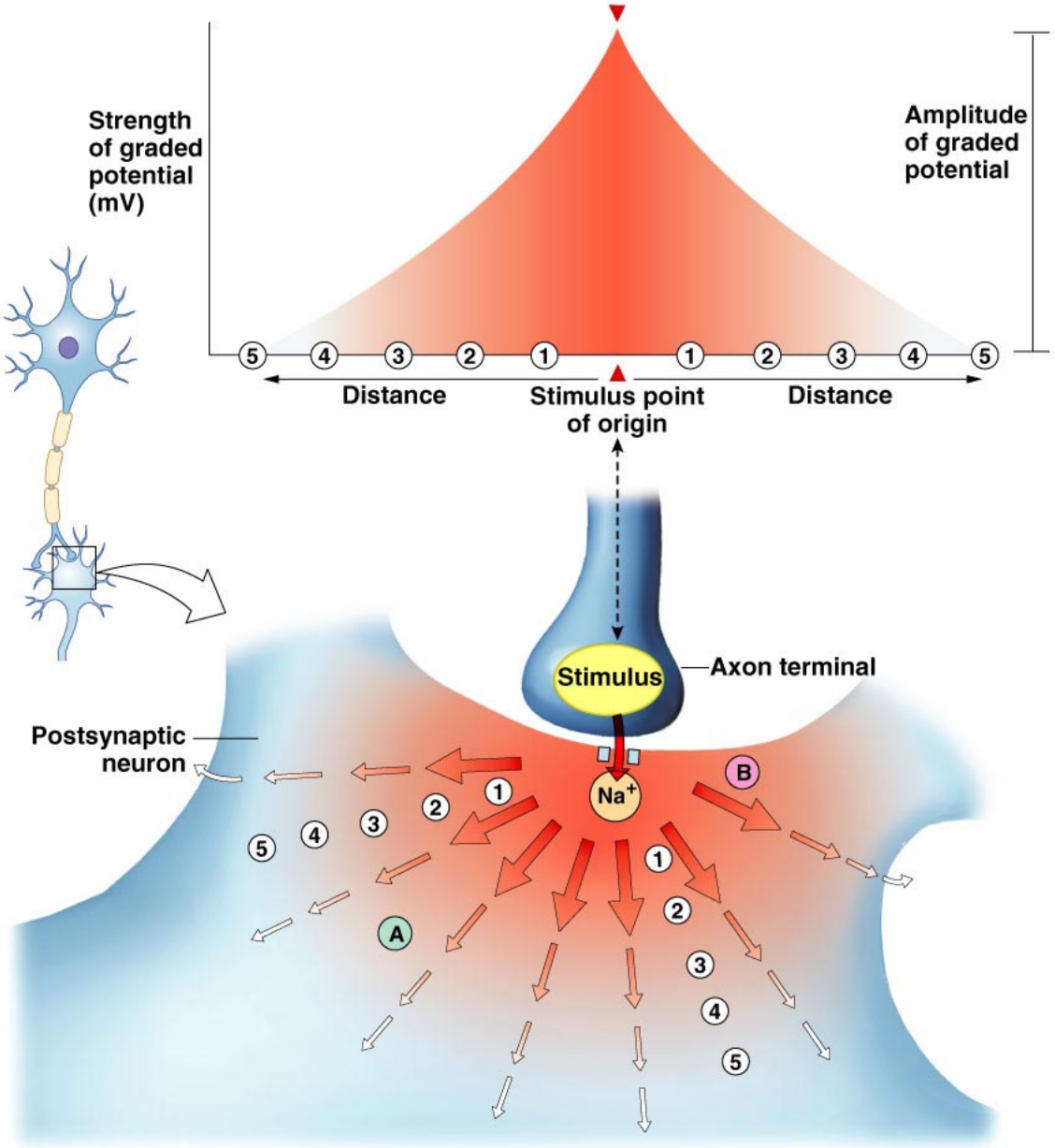


Figure 8-7

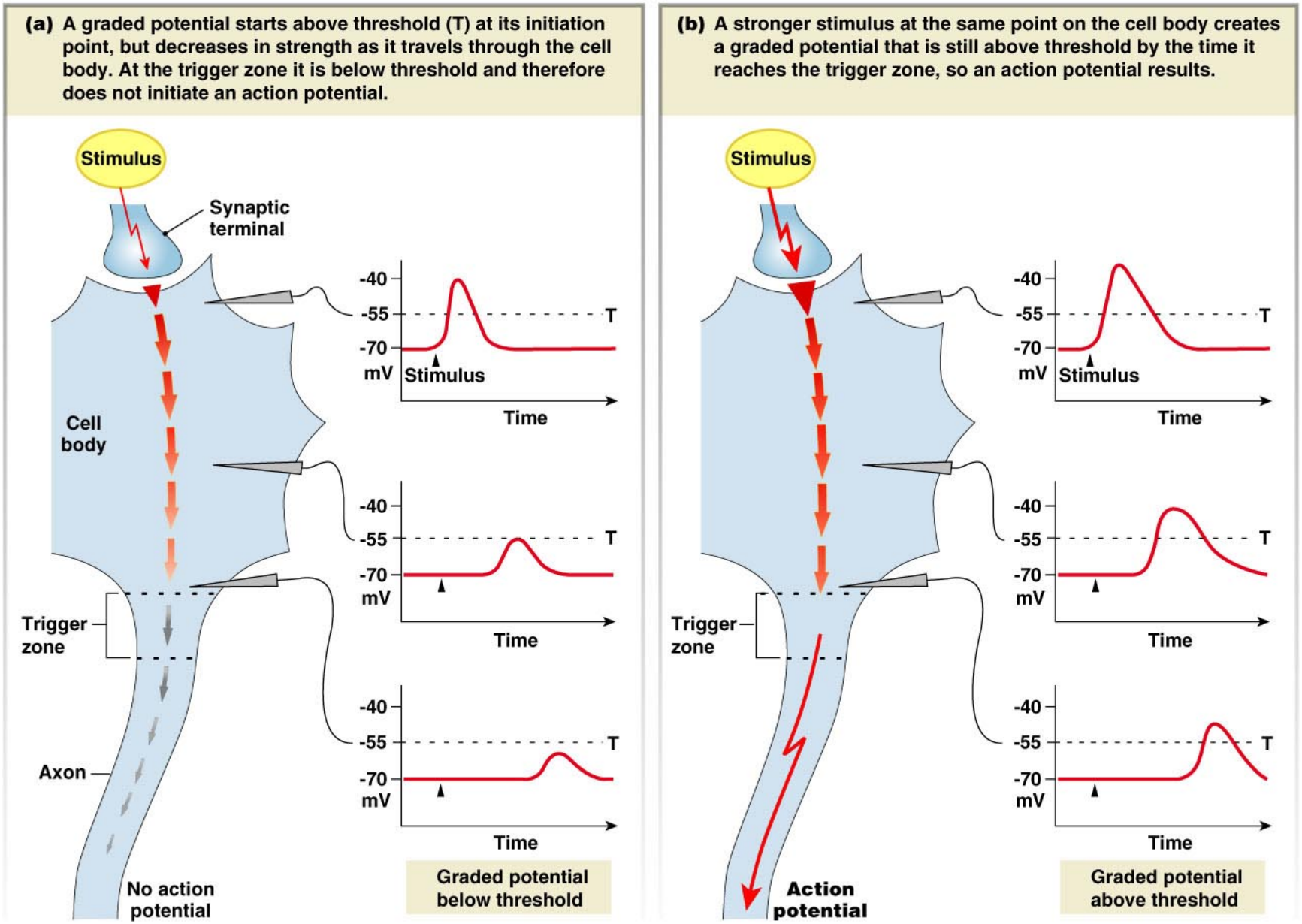
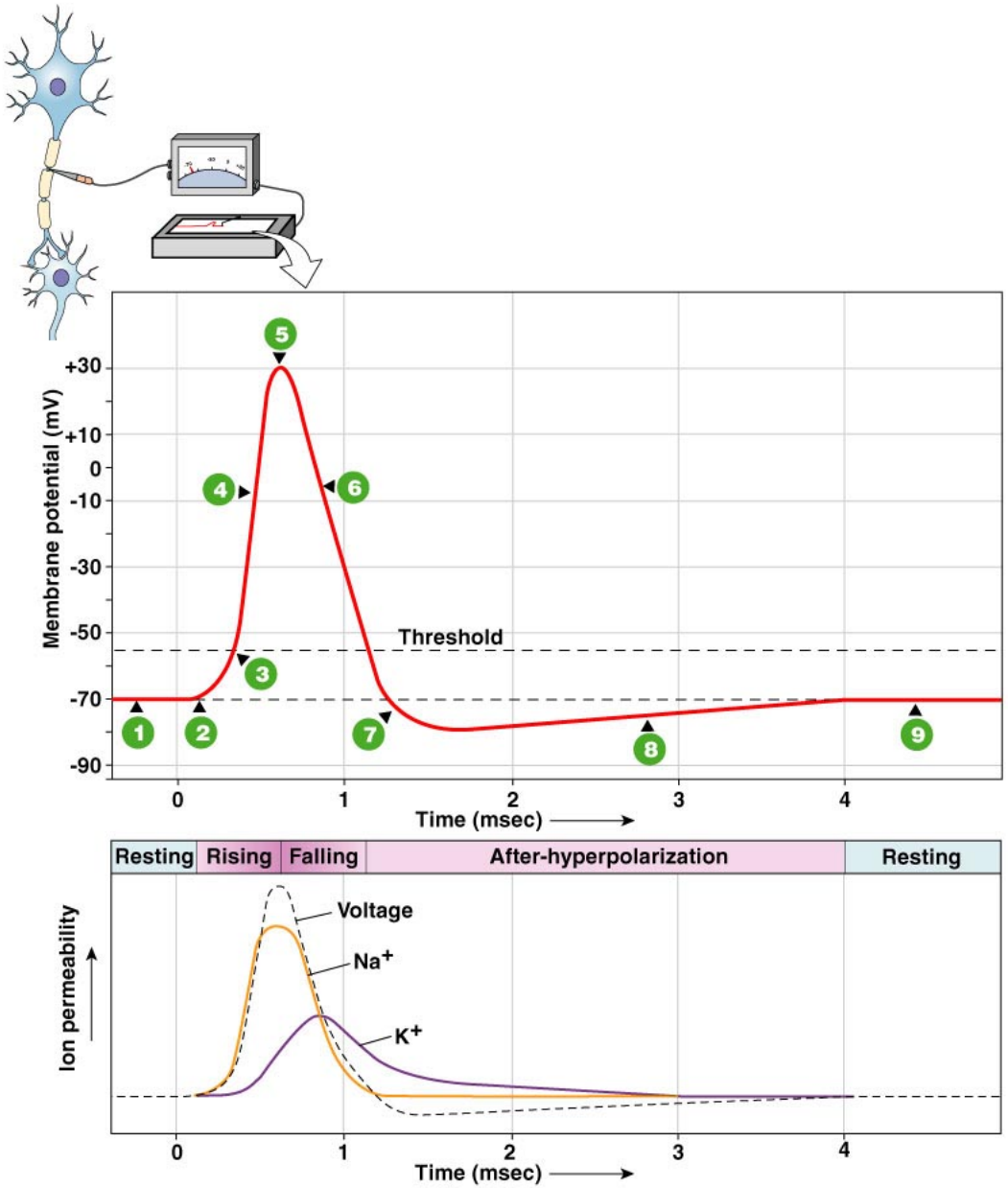


Figure 8-8 - Overview



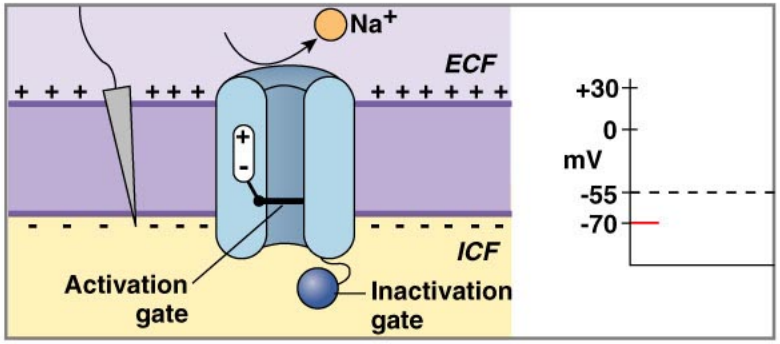
1. Resting membrane potential
2. Depolarizing stimulus
3. Membrane depolarizes to threshold. Voltage-gated Na^+ channels open and Na^+ enters cell. Voltage-gated K^+ channels begin to open slowly.
4. Rapid Na^+ entry depolarizes cell.
5. Na^+ channels close and slower K^+ channels open.
6. K^+ moves from cell to extracellular fluid.
7. K^+ channels remain open and additional K^+ leaves cell, hyperpolarizing it.
8. Voltage-gated K^+ channels close, less K^+ leaks out of the cell.
9. Cell returns to resting ion permeability and resting membrane potential.

Figure 8-9 - Overview

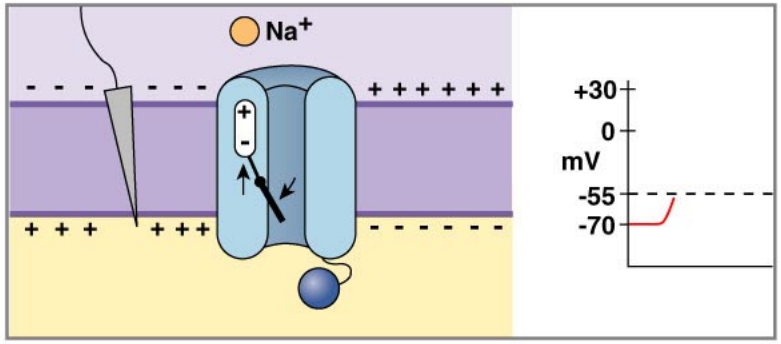
TABLE 8-3 Comparison of Graded Potential and Action Potential in Neurons

	GRADED POTENTIAL	ACTION POTENTIAL
Type of signal	Input signal	Conduction signal
Where occurs	Usually dendrites and cell body	Trigger zone through axon
Types of gated ion channels involved	Mechanically, chemically, or voltage-gated channels	Voltage-gated channels
Ions involved	Usually Na^+, Cl^-, Ca^{2+}	Na^+ and K^+
Type of signal	Depolarizing (e.g., Na^+) or hyperpolarizing (e.g., Cl^-)	Depolarizing
Strength of signal	Depends on initial stimulus; can be summed	Is always the same; (all-or-none phenomenon); cannot be summed
What initiates the signal	Entry of ions through channels	Above-threshold graded potential at the trigger zone
Unique characteristics	No minimum level required to initiate	Threshold stimulus required to initiate
	Two signals coming close together in time will sum	Refractory period: two signals too close together in time cannot sum
	Initial stimulus strength is indicated by frequency of a series of action potentials	

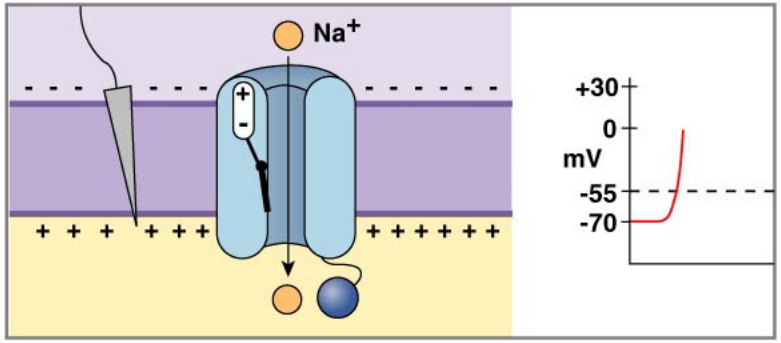
(a) At the resting membrane potential, the activation gate closes the channel.



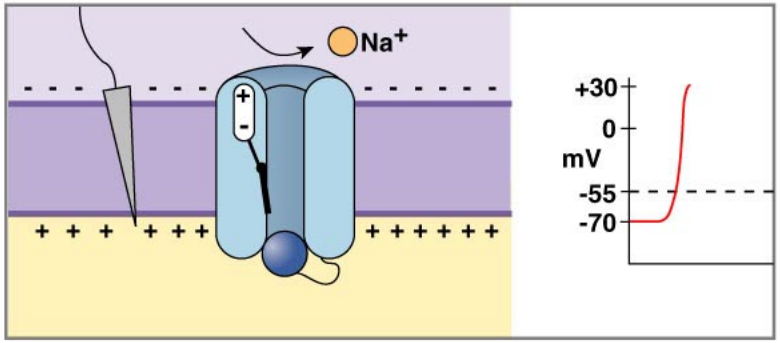
(b) Depolarizing stimulus arrives at the channel.



(c) With activation gate open, Na^+ enters the cell.



(d) Inactivation gate closes and Na^+ entry stops.



(e) During repolarization caused by K^+ leaving the cell, the two gates reset to their original positions.

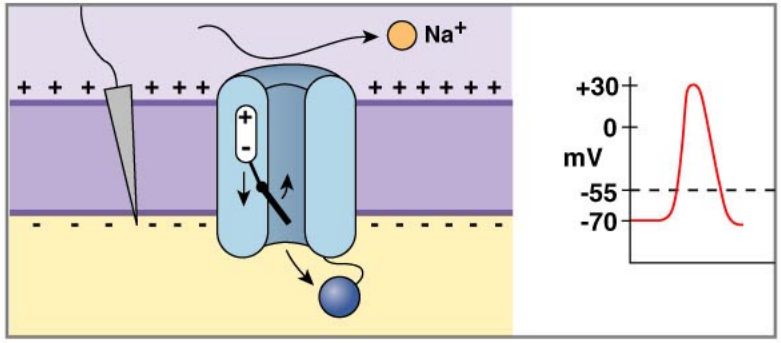


Figure 8-10 - Overview

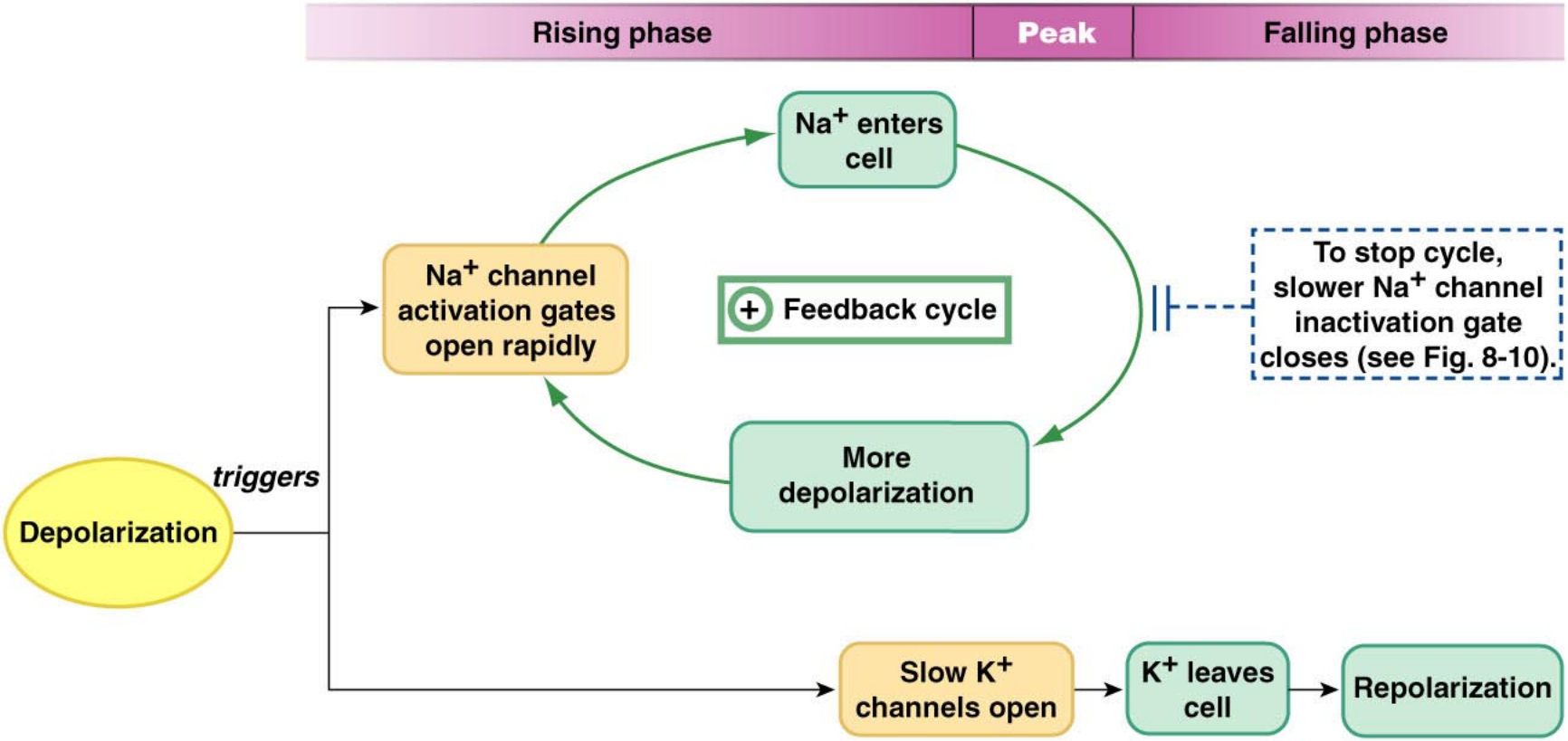
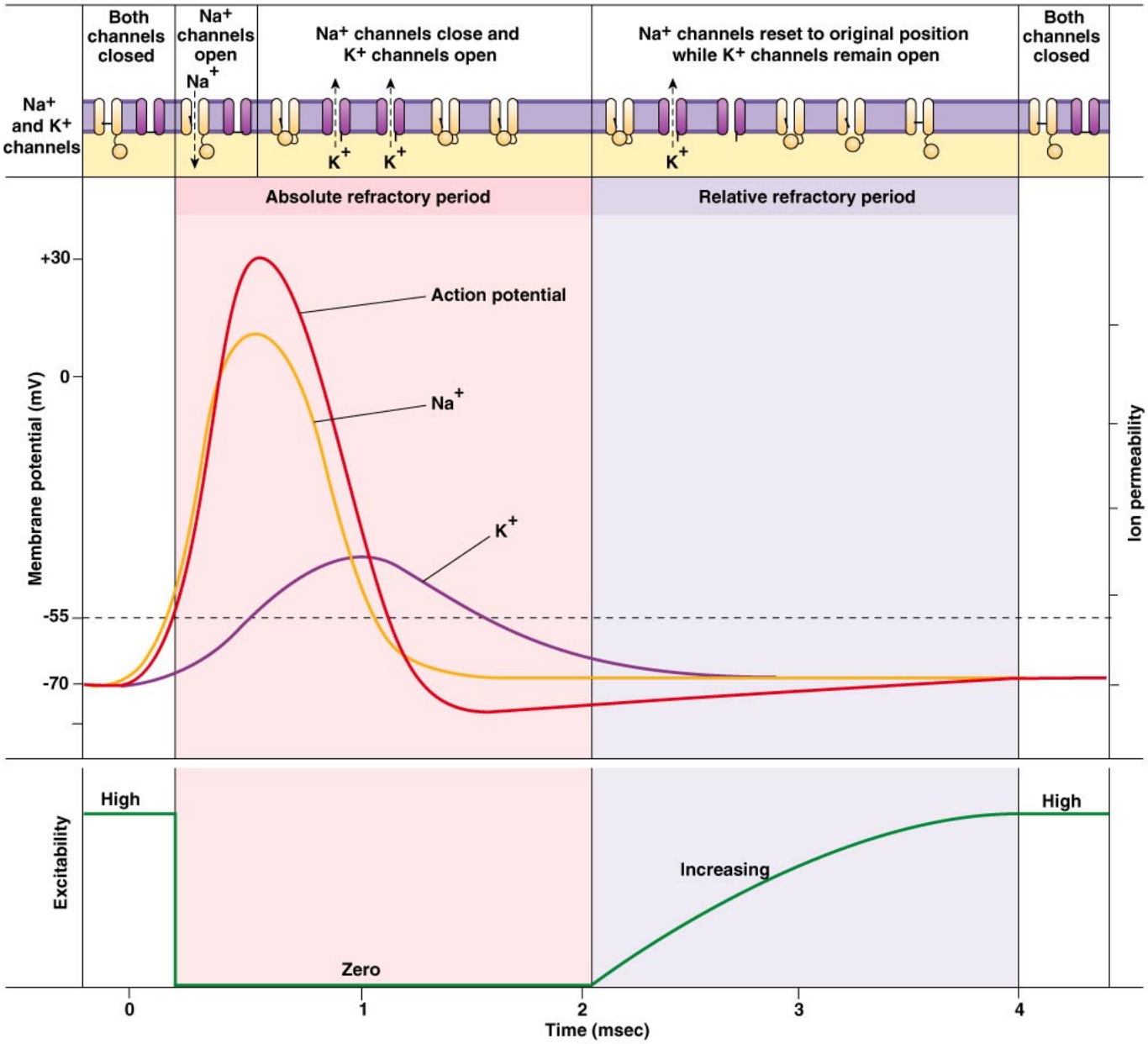


Figure 8-11



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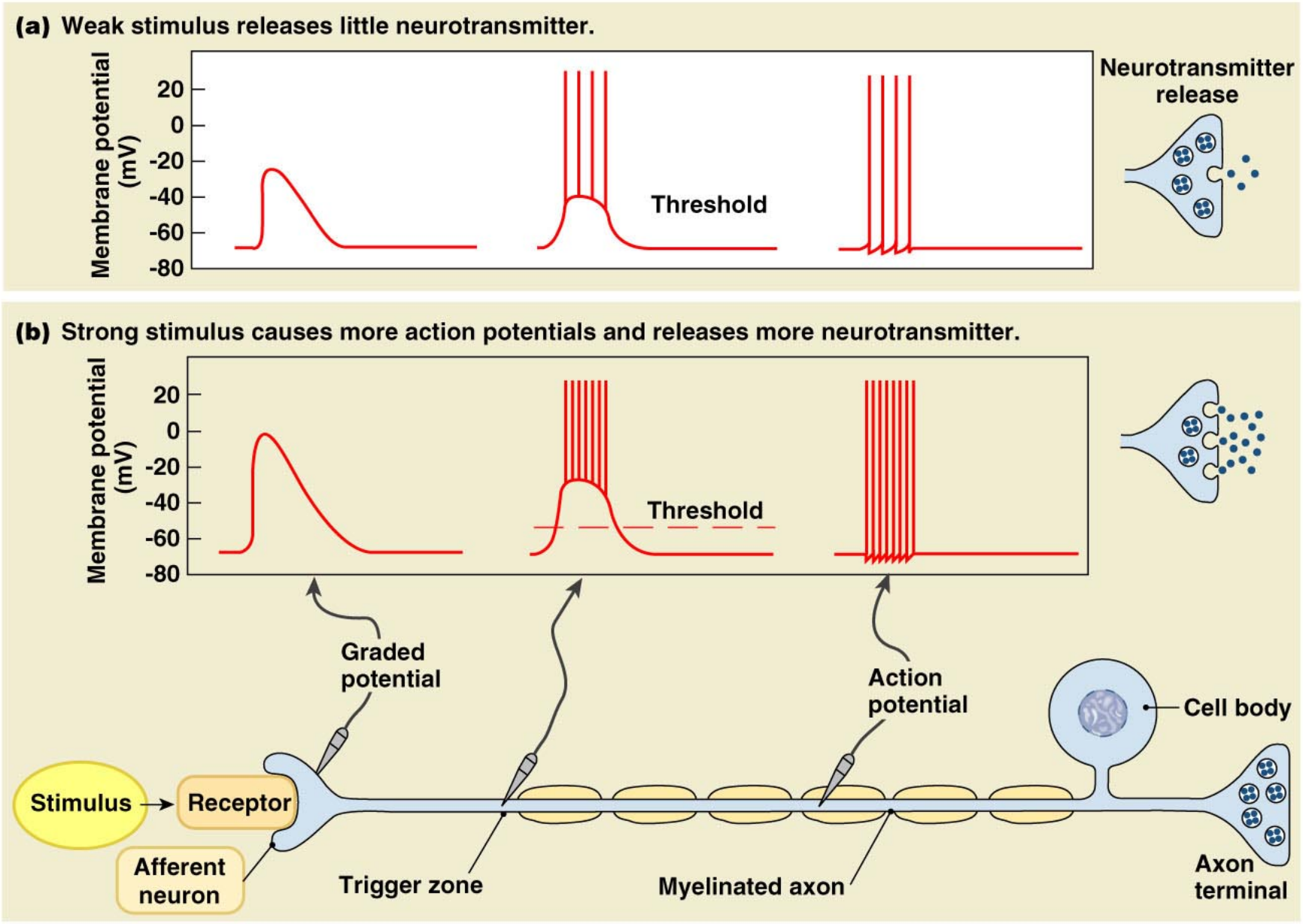

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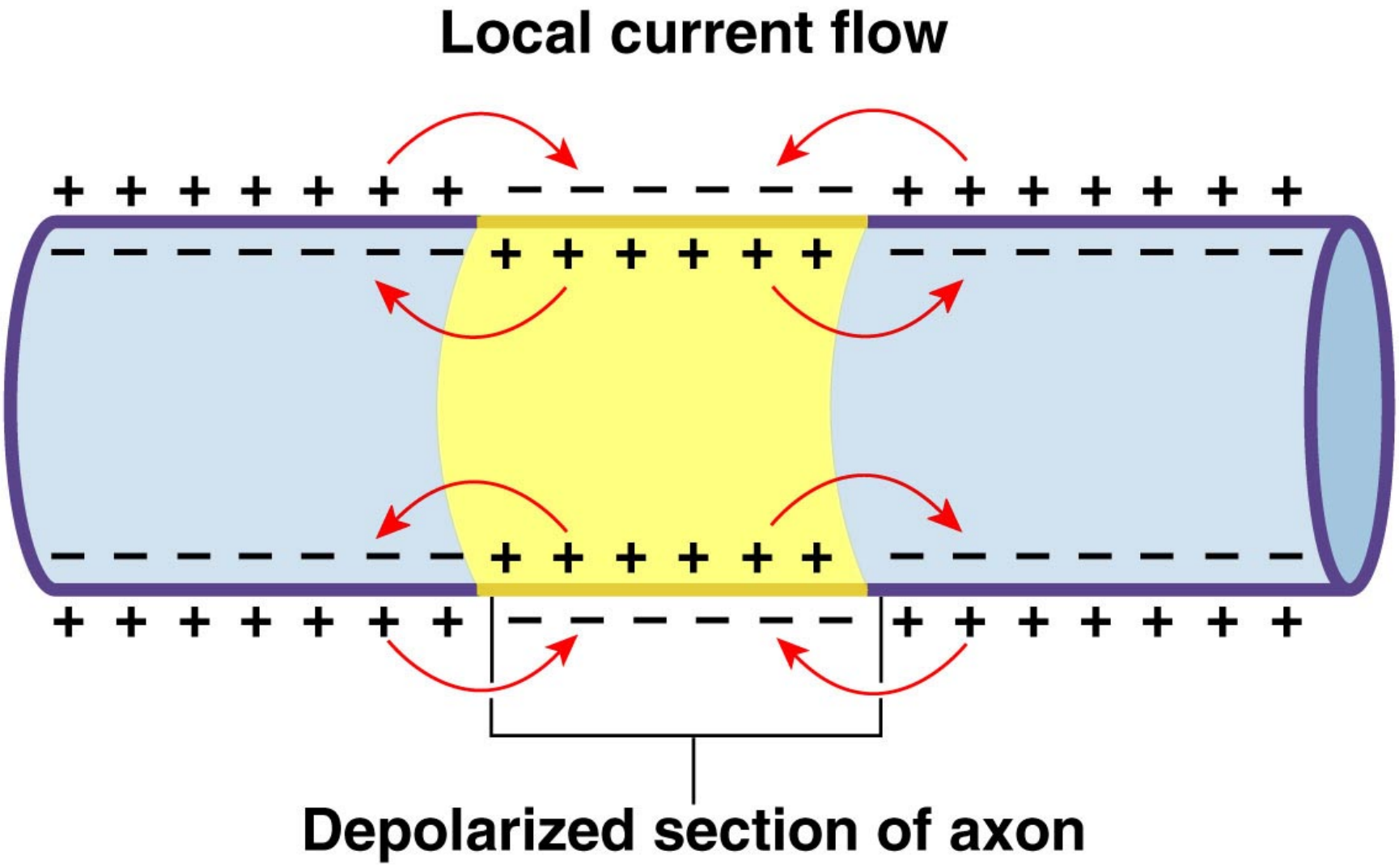

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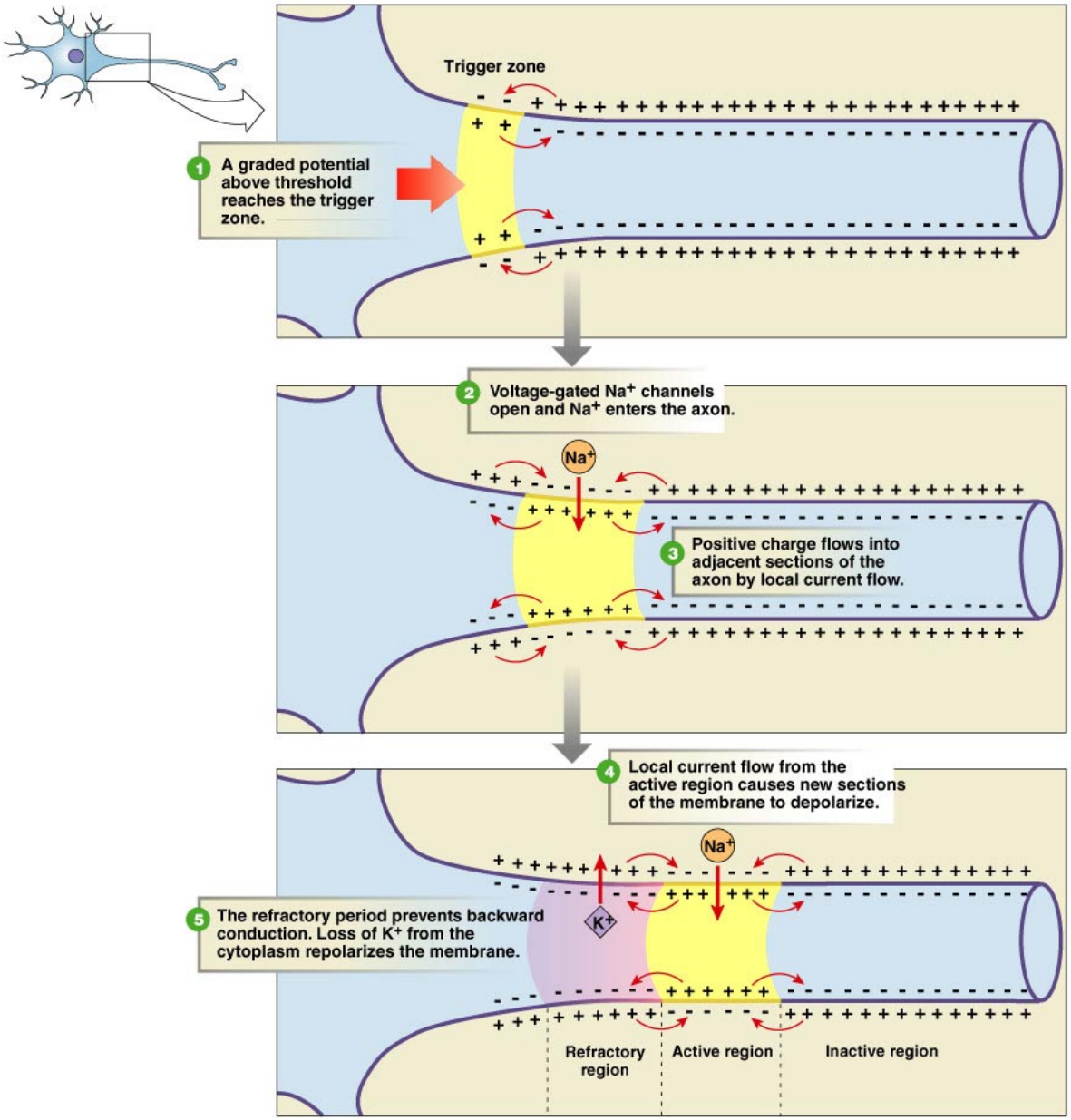

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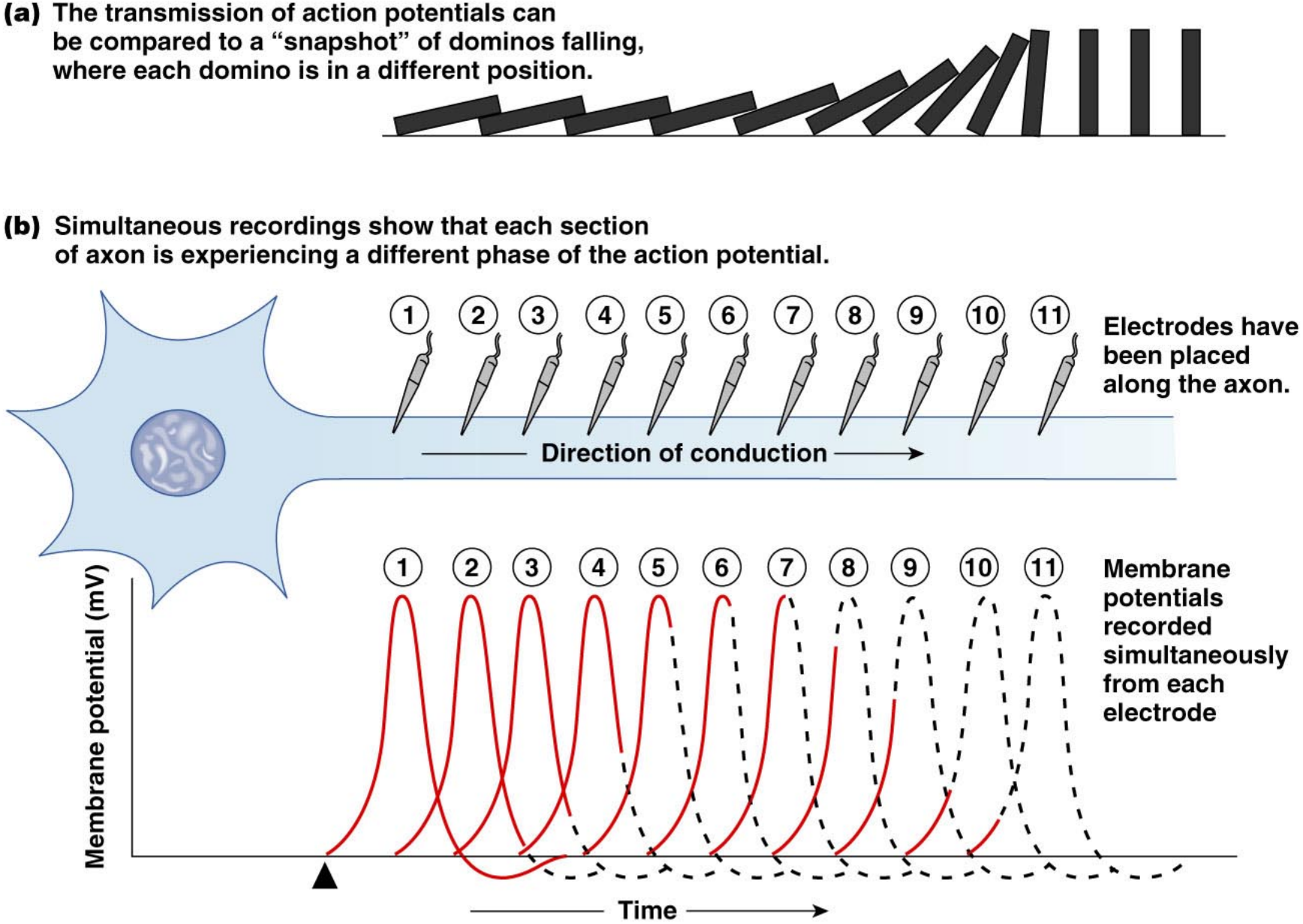

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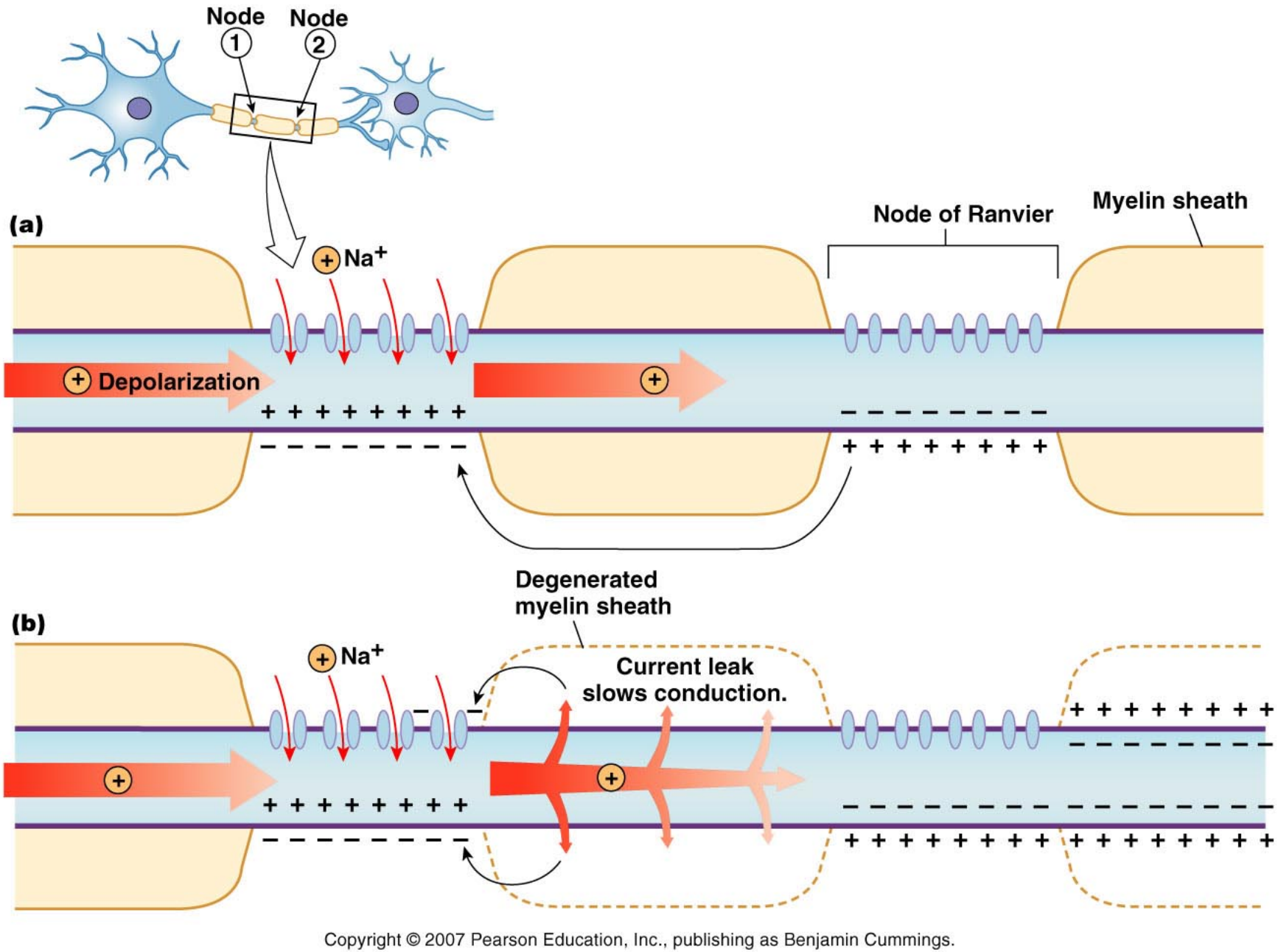

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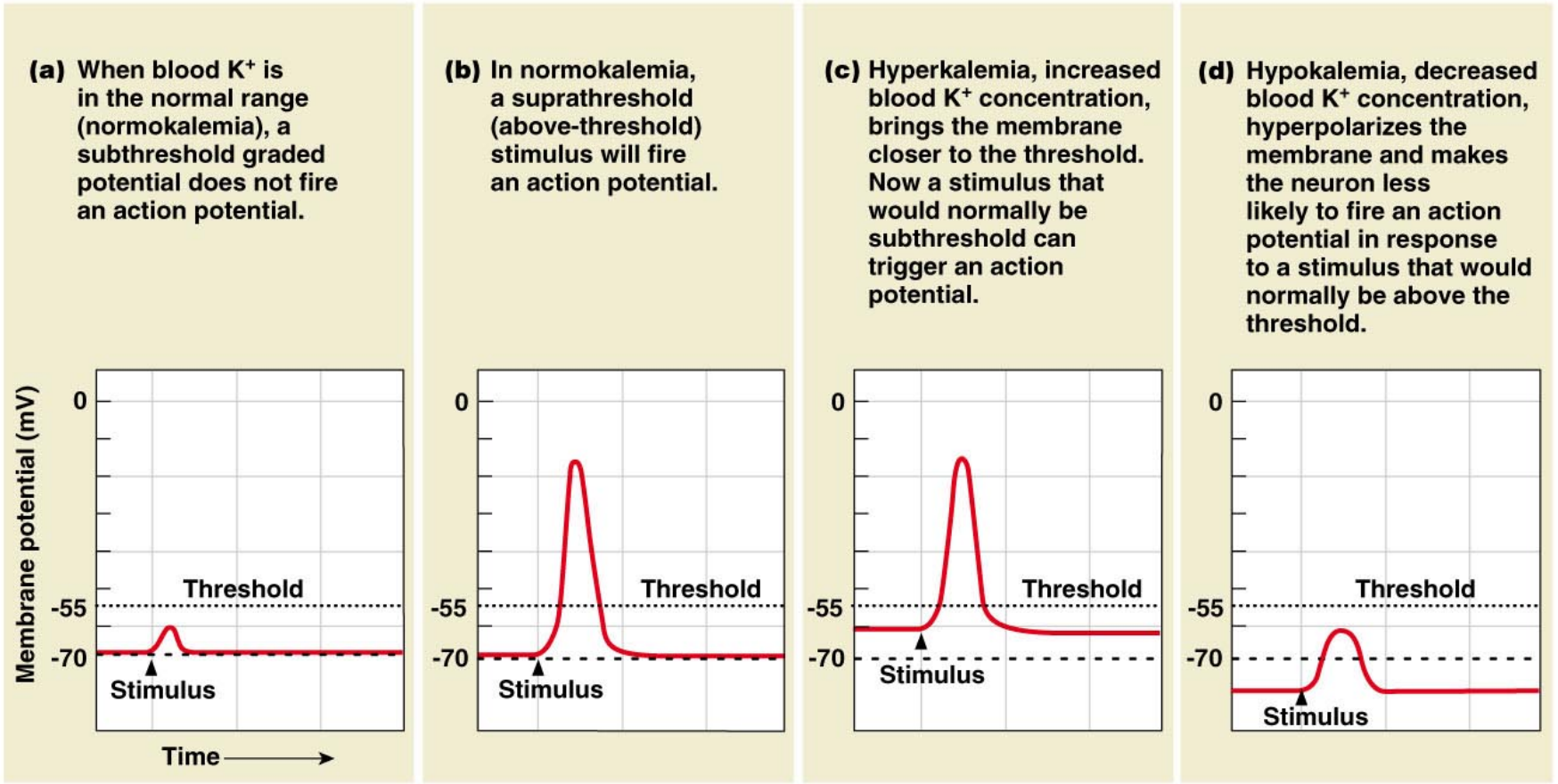

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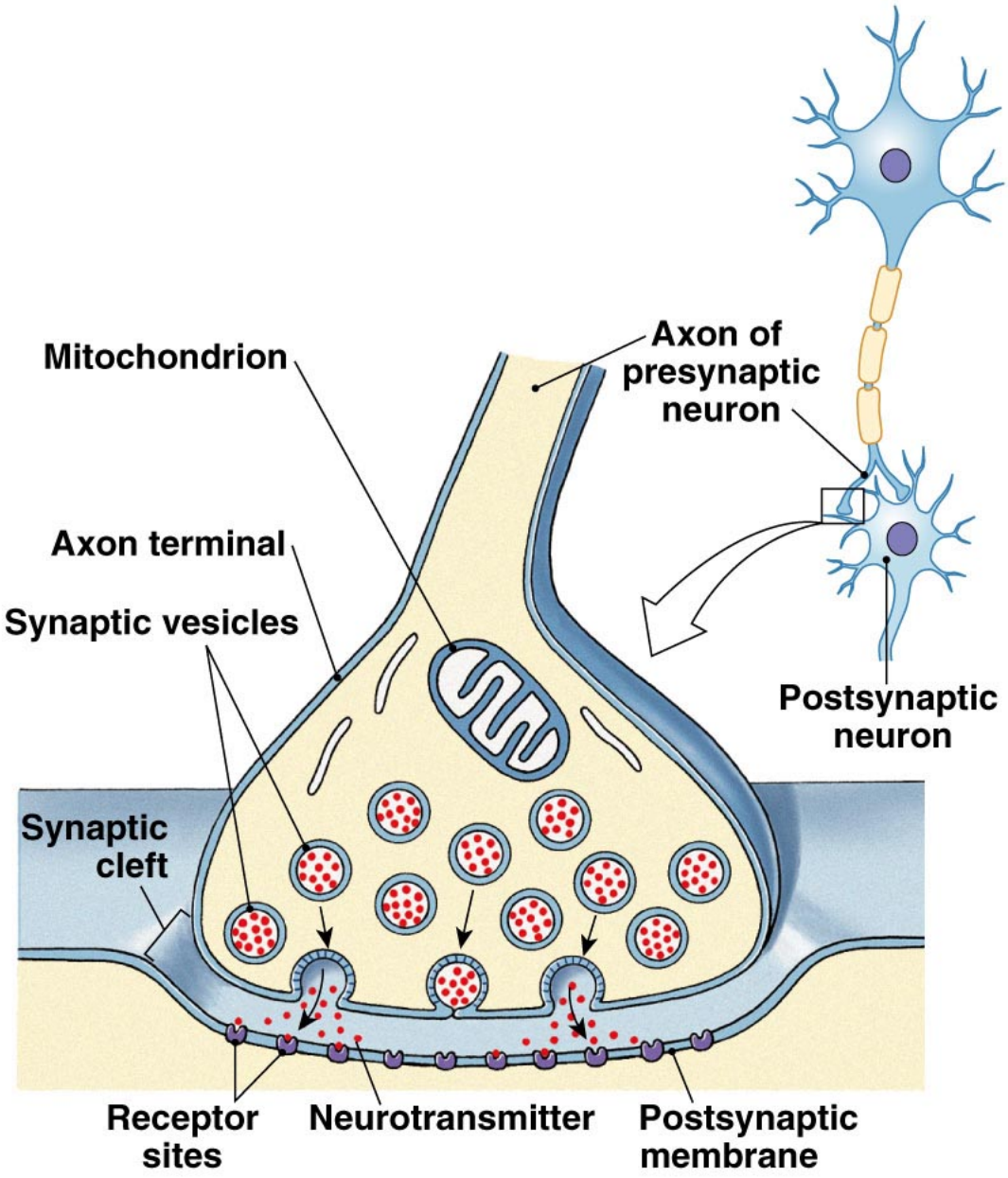

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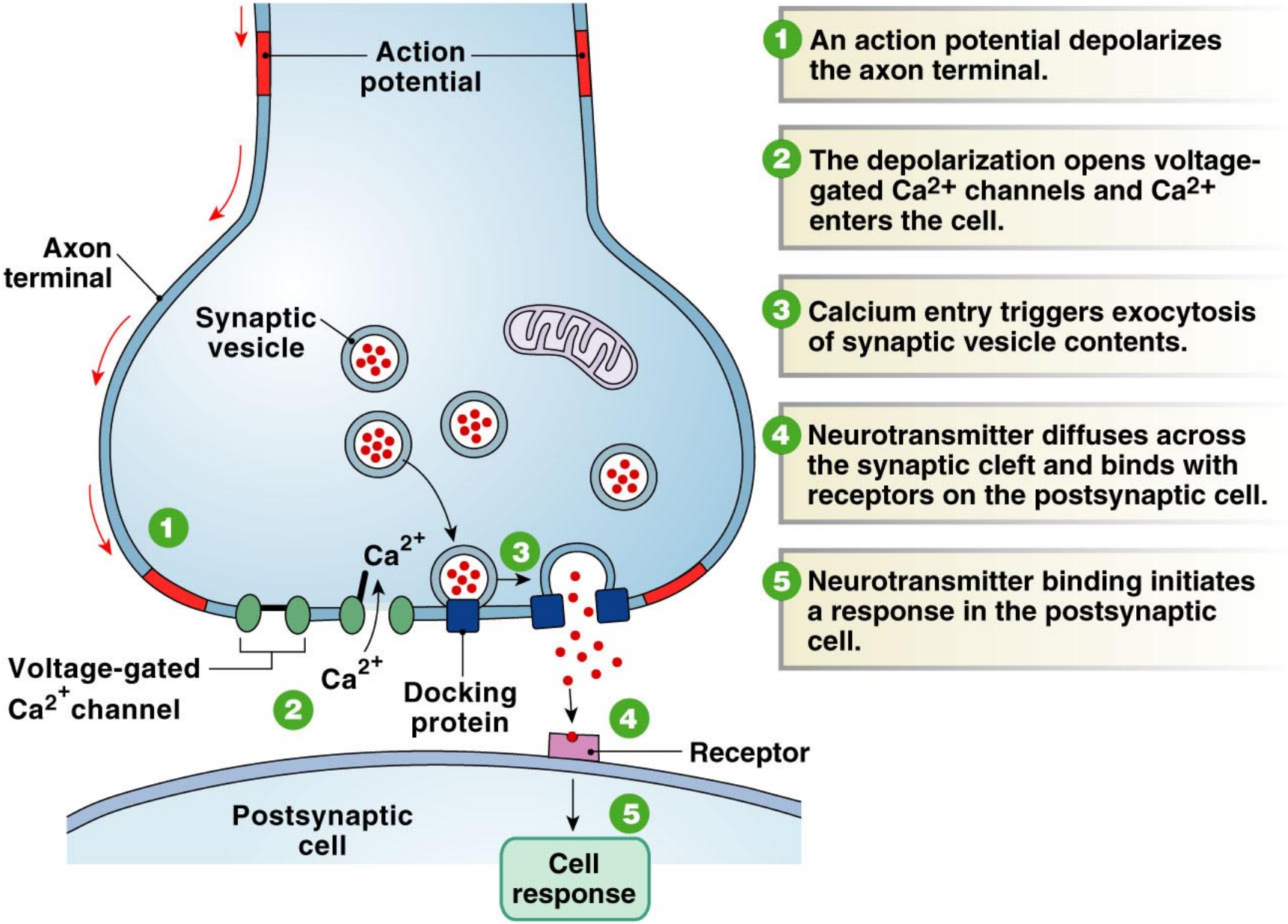


Figure 8-21 - Overview

TABLE 8-4 Major Neurocrines

CHEMICAL	RECEPTOR	TYPE	RECEPTOR LOCATION	KEY AGONISTS, ANTAGONISTS, AND POTENTIATORS*
Acetylcholine (ACh)	Cholinergic			
	Nicotinic	ICR** (Na^+, K^+)	Skeletal muscles, autonomic neurons, CNS	Nicotine: agonist; curare, α-bungarotoxin: antagonists
	Muscarinic	GPCR	Smooth and cardiac muscle, endocrine and exocrine glands, CNS	Muscarine: agonist; atropine: antagonist
Amines				
Norepinephrine (NE)	Adrenergic (α, β)	GPCR	Smooth and cardiac muscle, endocrine and exocrine glands, CNS	α: Prazosin (Minipress); β: propranolol
Dopamine (DA)	Dopamine (D)	GPCR	CNS	Antipsychotic drugs: antagonists; bromocriptine: agonist
Serotonin (5-hydroxytryptamine, 5-HT)	Serotonergic (5-HT)	ICR (Na^+, K^+) GPCR	CNS	Sumatriptan: agonist LSD: antagonist
Histamine	Histamine (H)	GPCR	CNS	Ranitidine (Zantac®) and cimetidine (Tagamet®): antagonists

*This list does not include many chemicals that are used as agonists and antagonists in physiological research. To review potentiation, see p. 000.

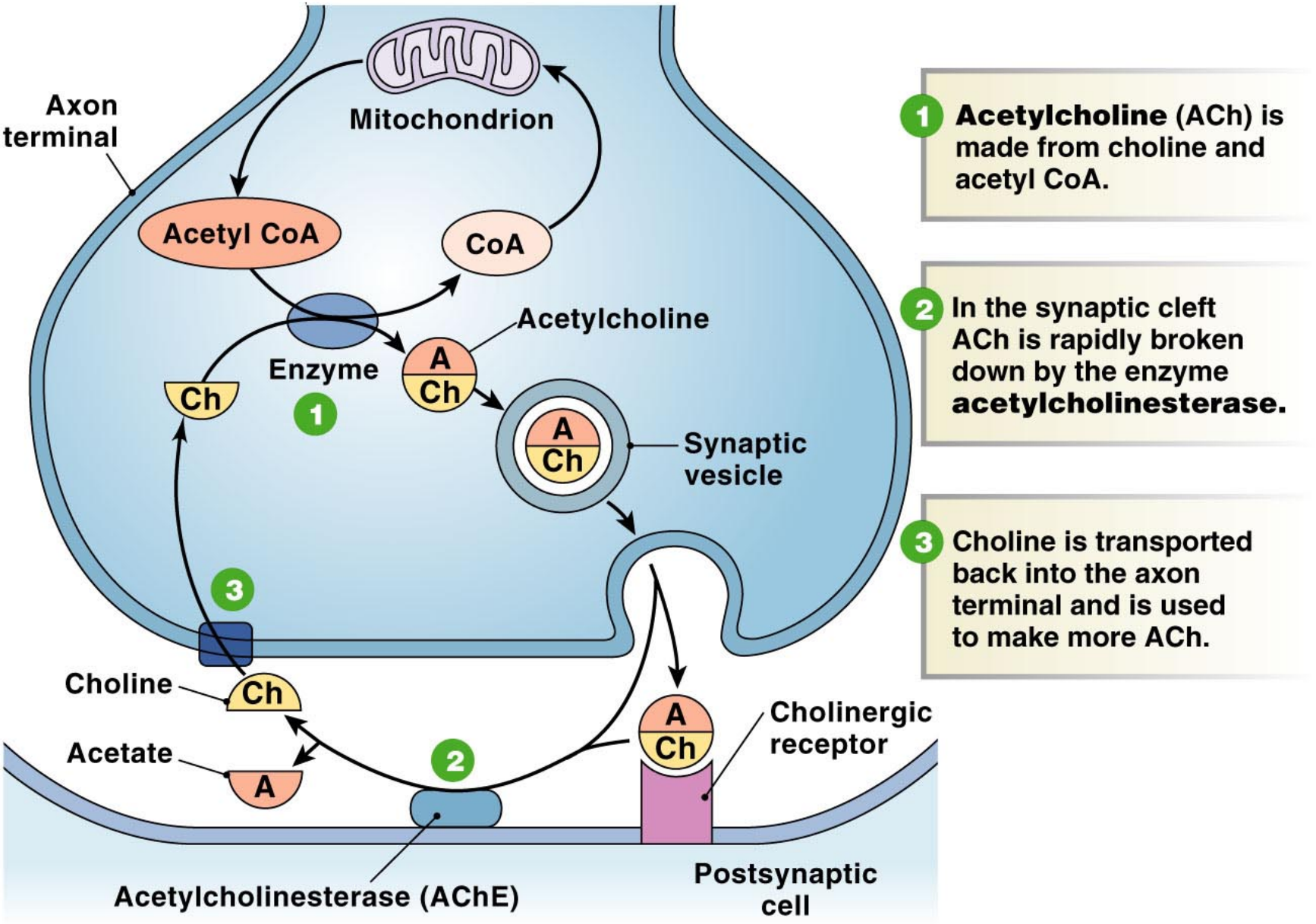
**ICR = ion channel-receptor; GPCR = G protein-coupled receptor; AMPA = α-amino-3-hydroxy-5-methyl-4 isoxazole proprionic acid; NMDA = N-methyl-D-aspartate; LSD = lysergic acid diethylamine; N/A = not applicable.

TABLE 8-4 Major Neurocrines

CHEMICAL	RECEPTOR	TYPE	RECEPTOR LOCATION	KEY AGONISTS, ANTAGONISTS, AND POTENTIATORS*
Amino acids				
Glutamate	Glutaminergic ionotropic			
	AMPA	ICR (Na^+, K^+)	CNS	
	NMDA	ICR (Na^+, K^+, Ca^{2+})	CNS	
	Glutaminergic metabotropic	GPCR	CNS	Glycine: potentiator
GABA (γ-aminobutyric acid)	GABA ($GABA_A$, $GABA_B$)	ICR (Cl^-) GPCR	CNS	Picrotoxin: antagonist; alcohol, barbiturates: potentiators
Glycine	Glycine	ICR (Cl^-)	CNS	Strychnine: antagonist
Purines				
Adenosine	Purine (P)	GPCR	CNS	
Gases				
Nitric Oxide (NO)	None	N/A	N/A	

*This list does not include many chemicals that are used as agonists and antagonists in physiological research. To review potentiation, see p. 000.

**ICR = ion channel-receptor; GPCR = G protein-coupled receptor; AMPA = α-amino-3-hydroxy-5-methyl-4 isoxazole proprionic acid; NMDA = N-methyl-D-aspartate; LSD = lysergic acid diethylamine; N/A = not applicable.



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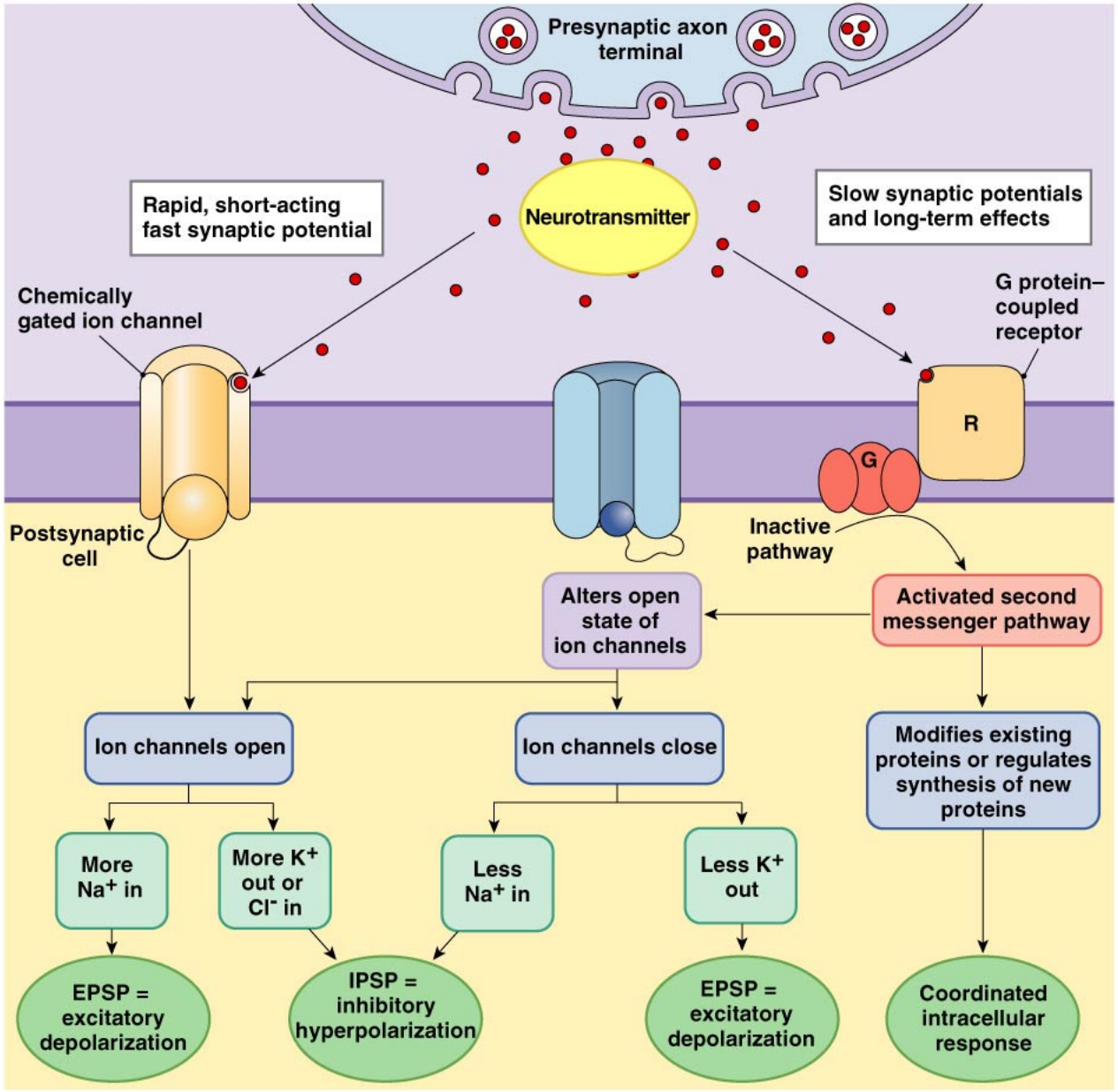

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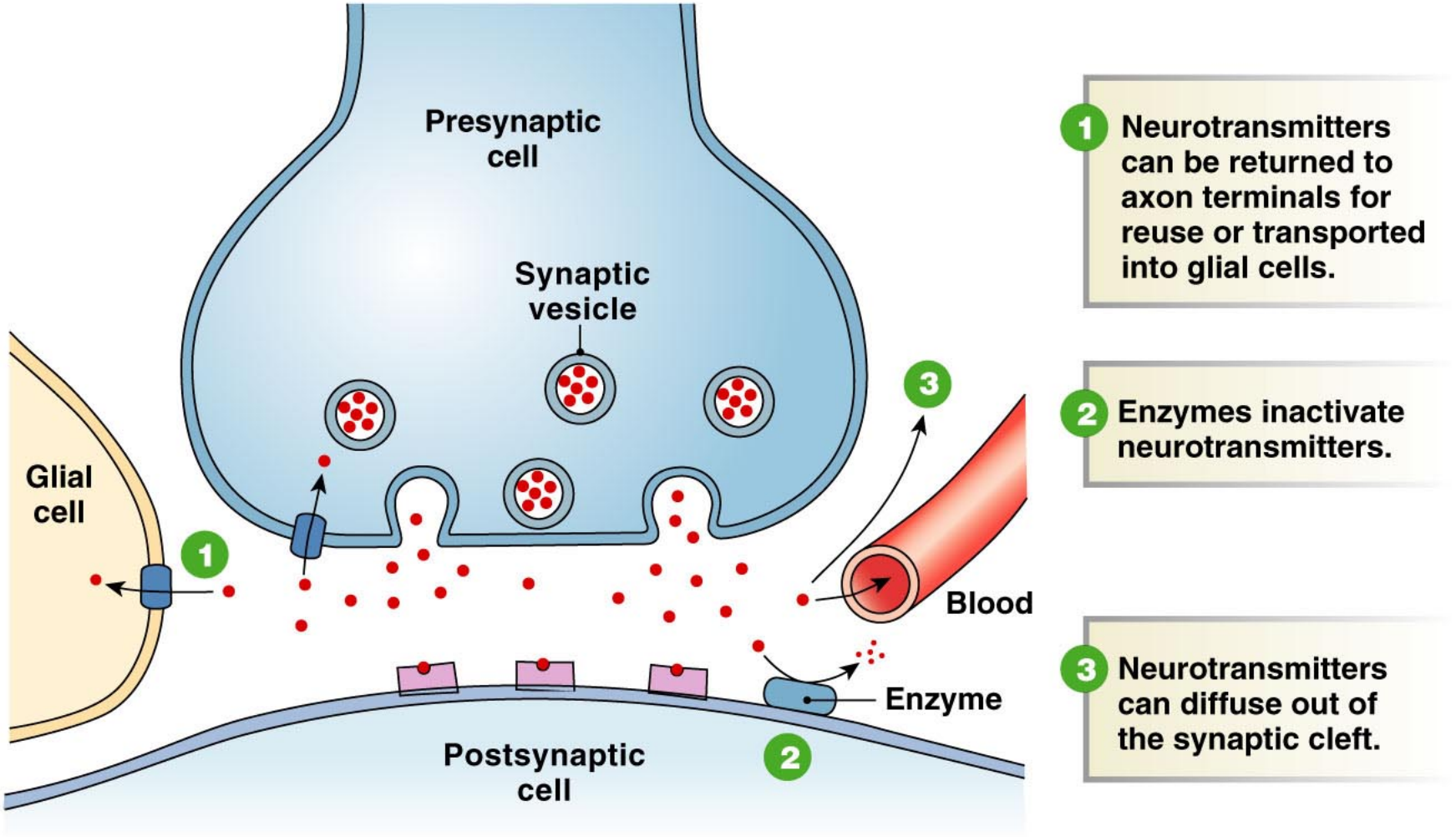

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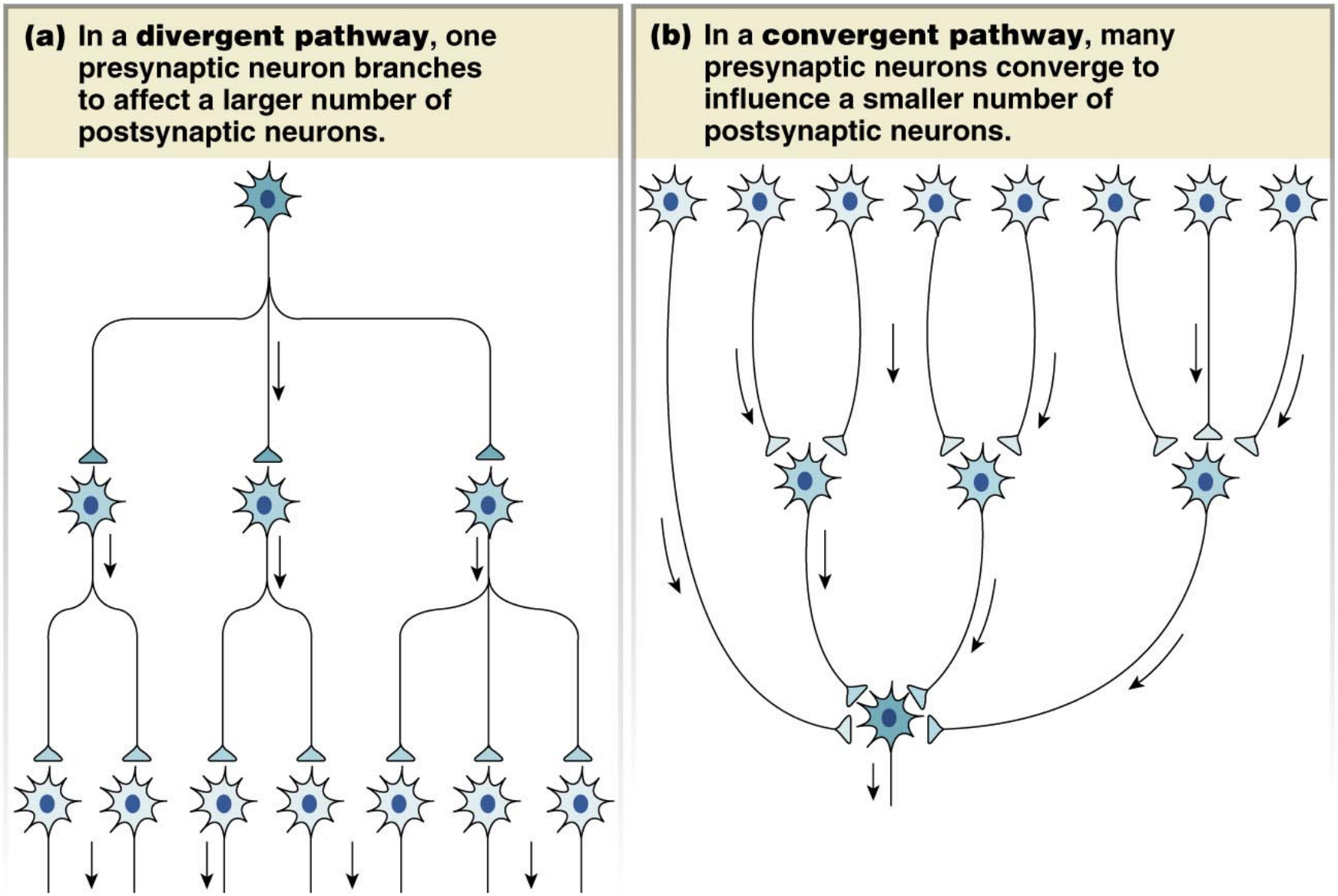

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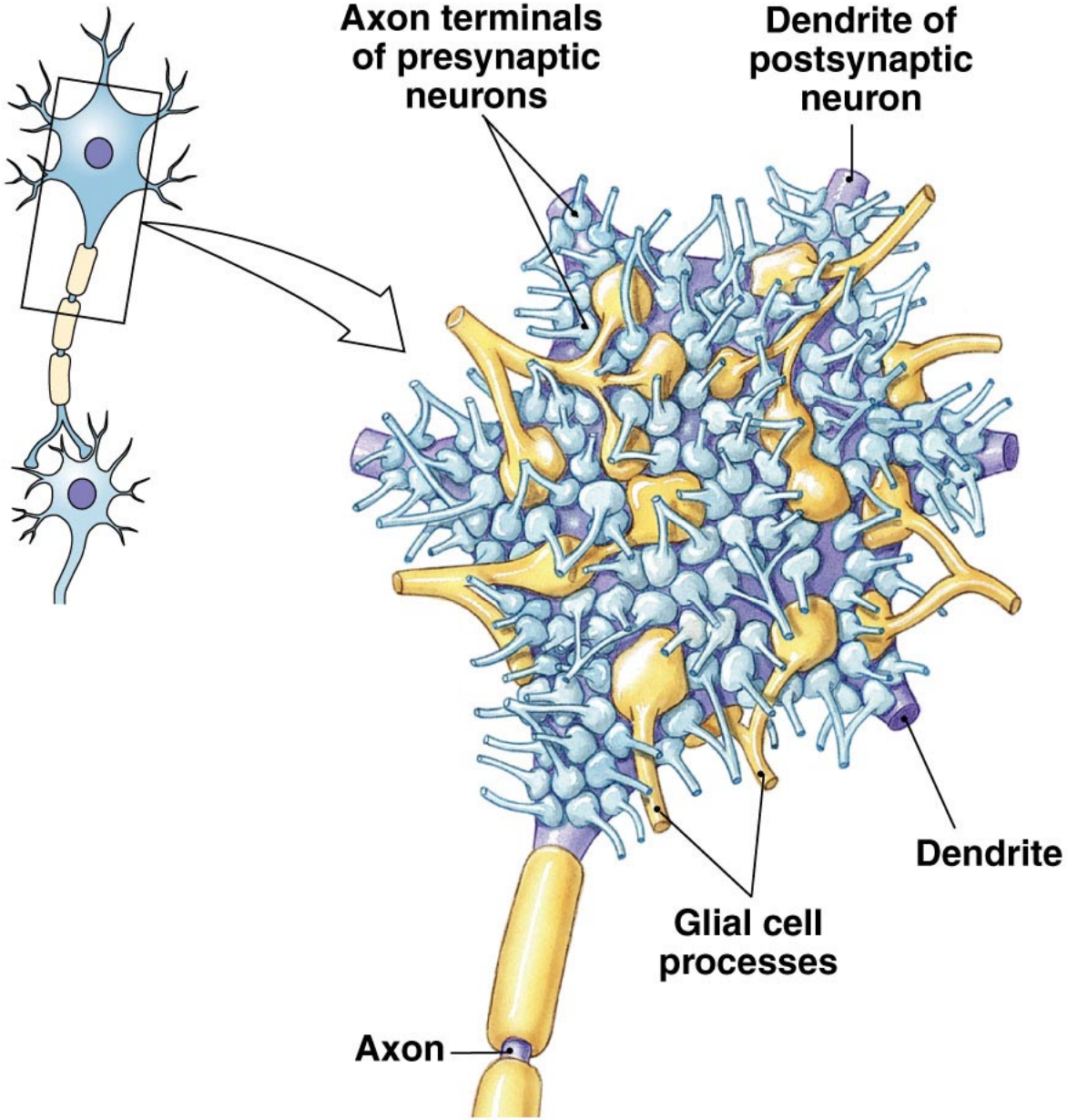

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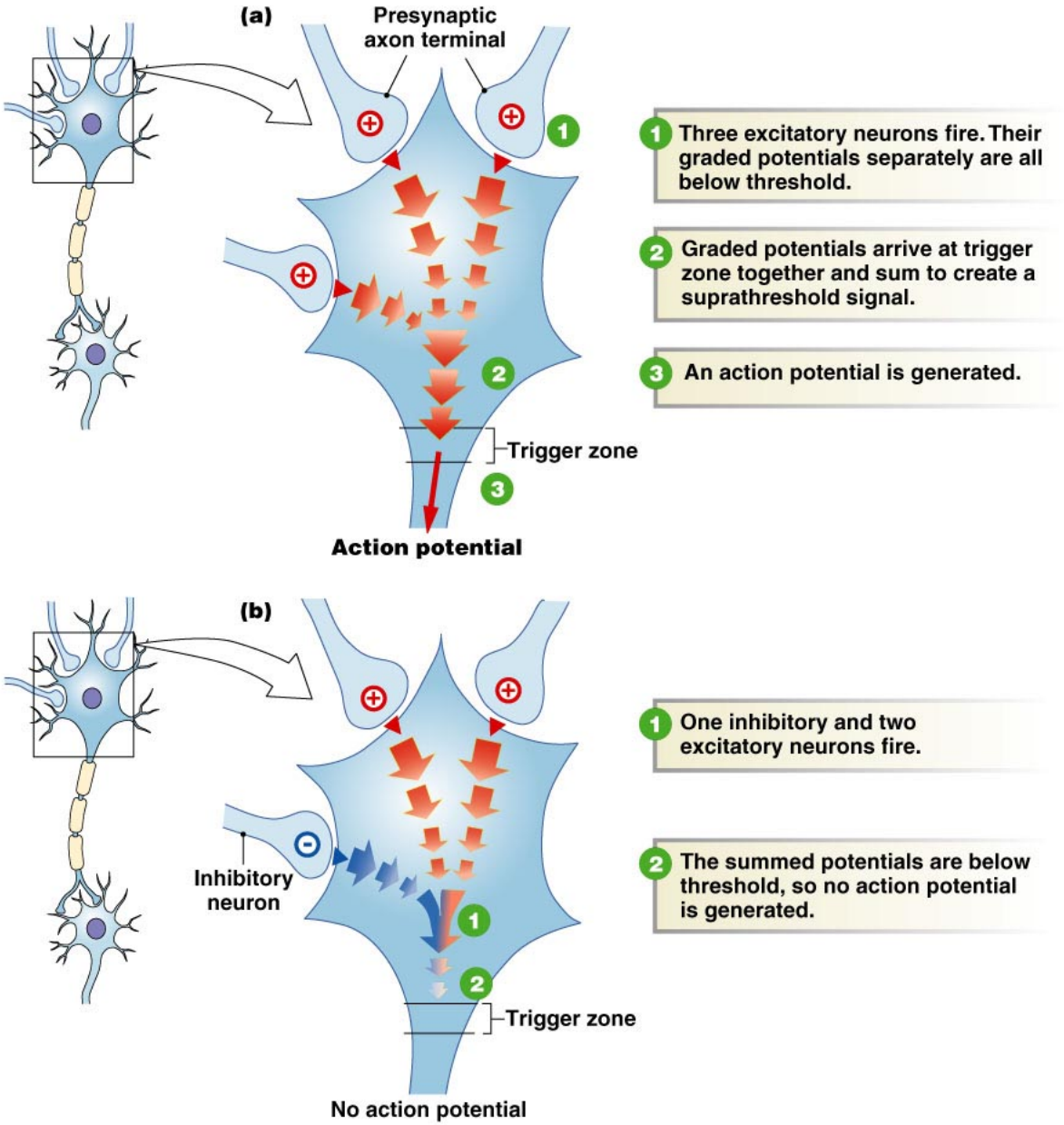

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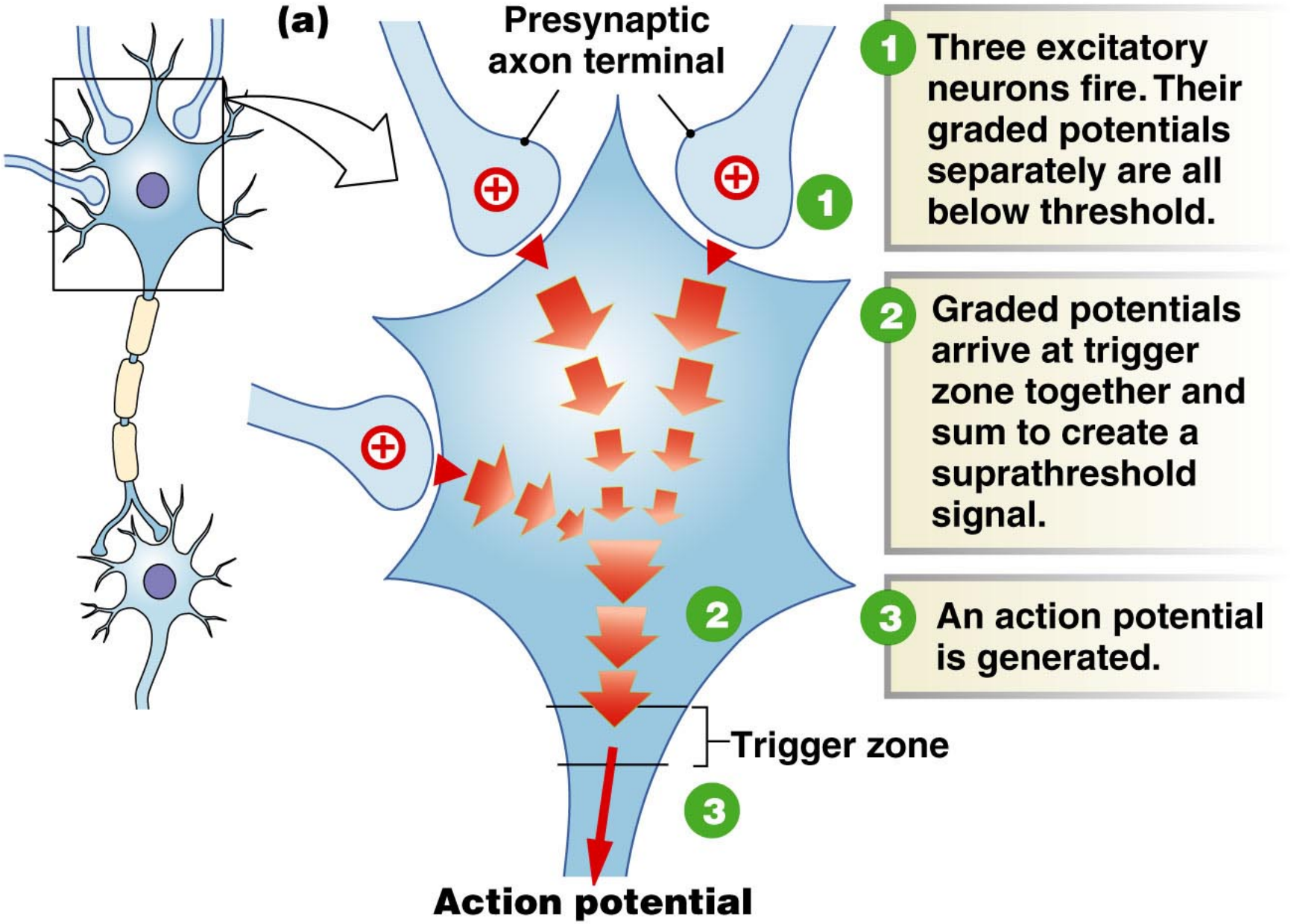


Figure 8-27a - Overview

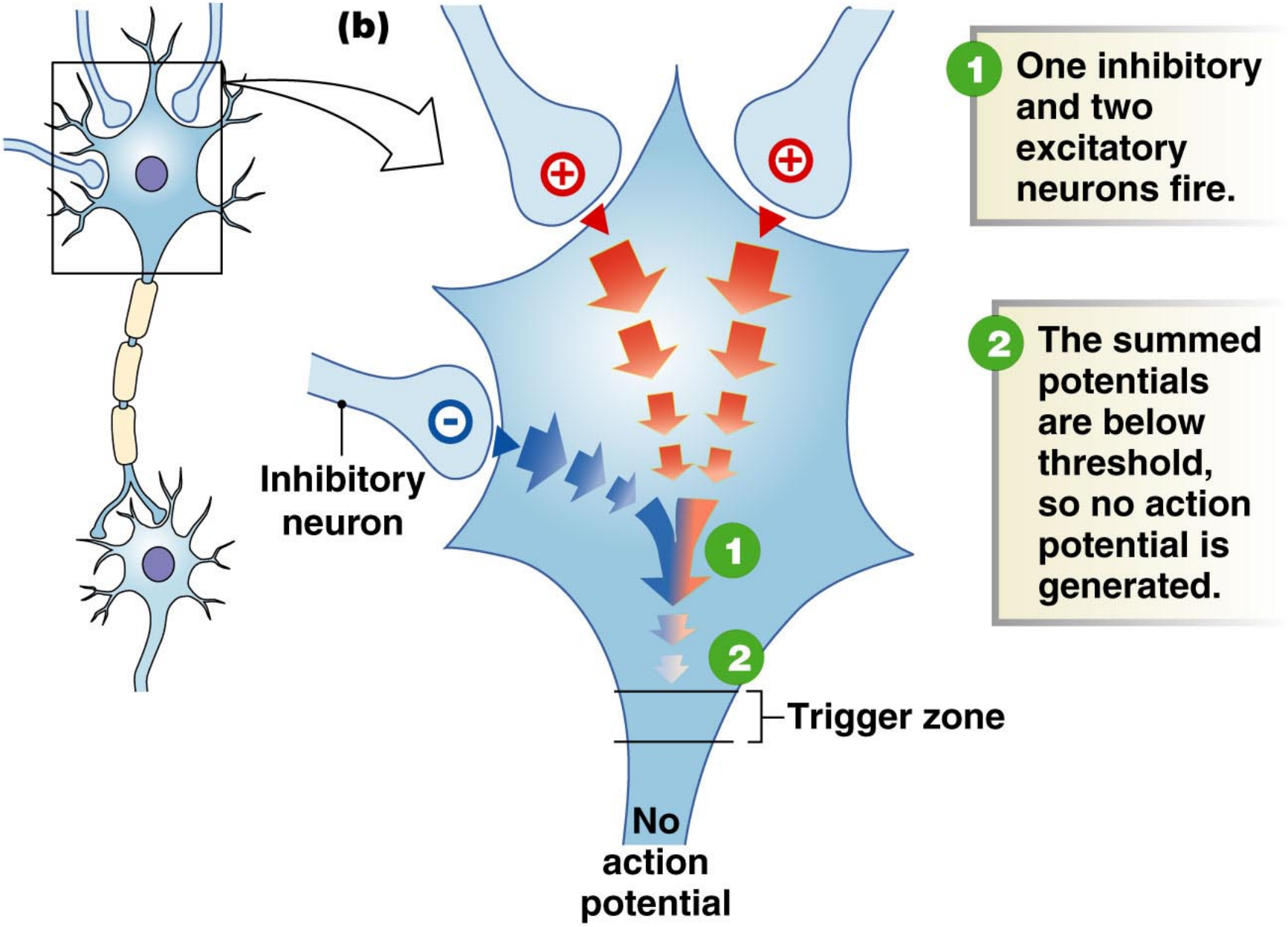
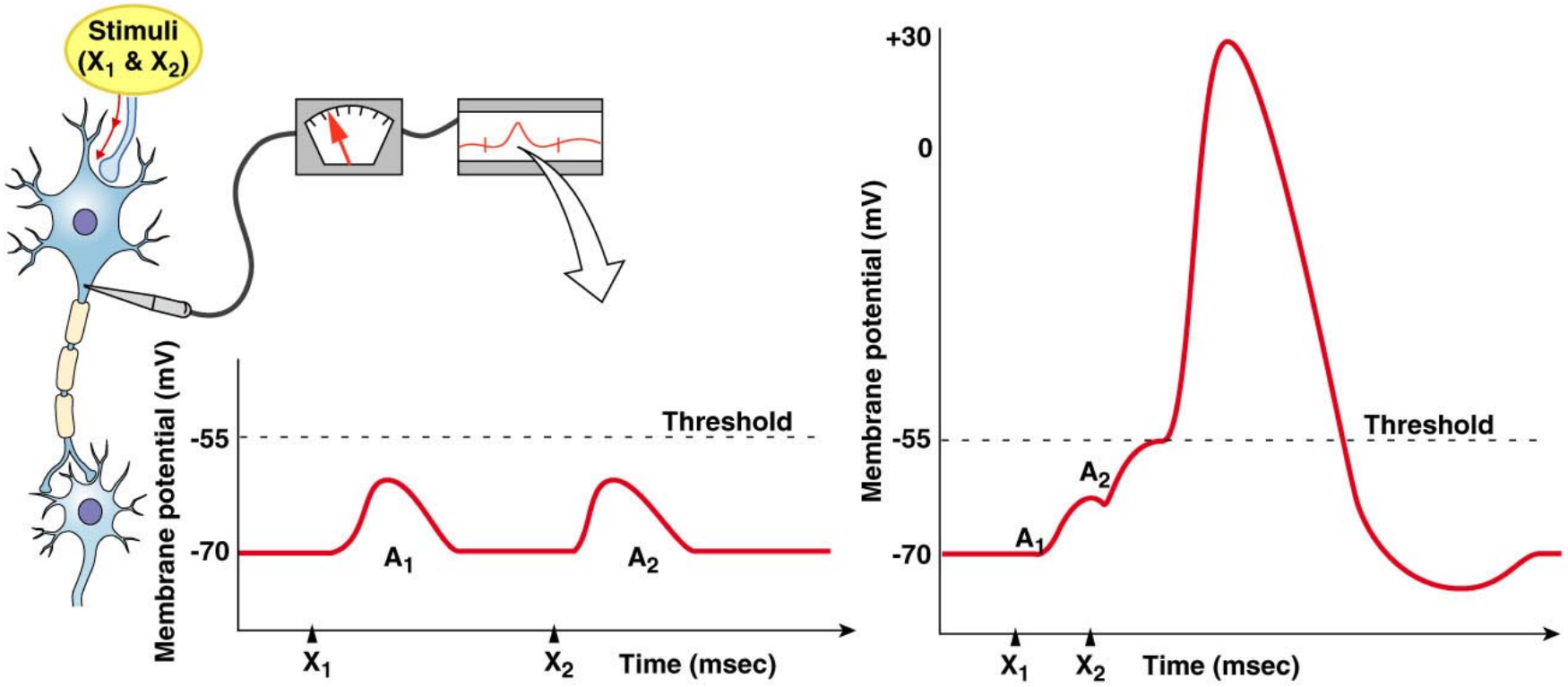
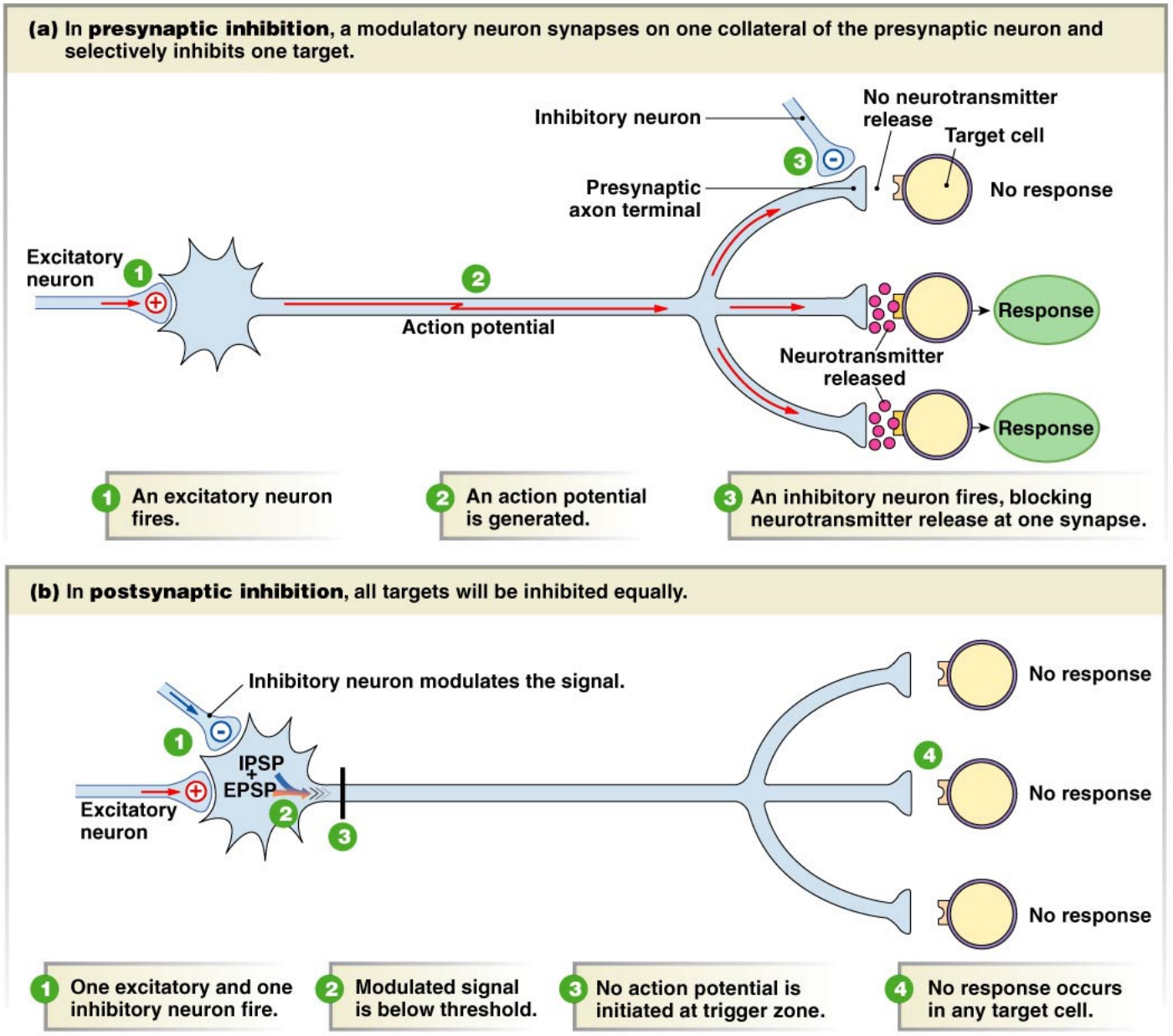


Figure 8-27b - Overview



(a) No summation. Two graded potentials will not cause an action potential if they are far apart in time.

(b) Summation causing action potential. If two subthreshold potentials arrive at the trigger zone within a short period of time, they may sum and create an action potential.



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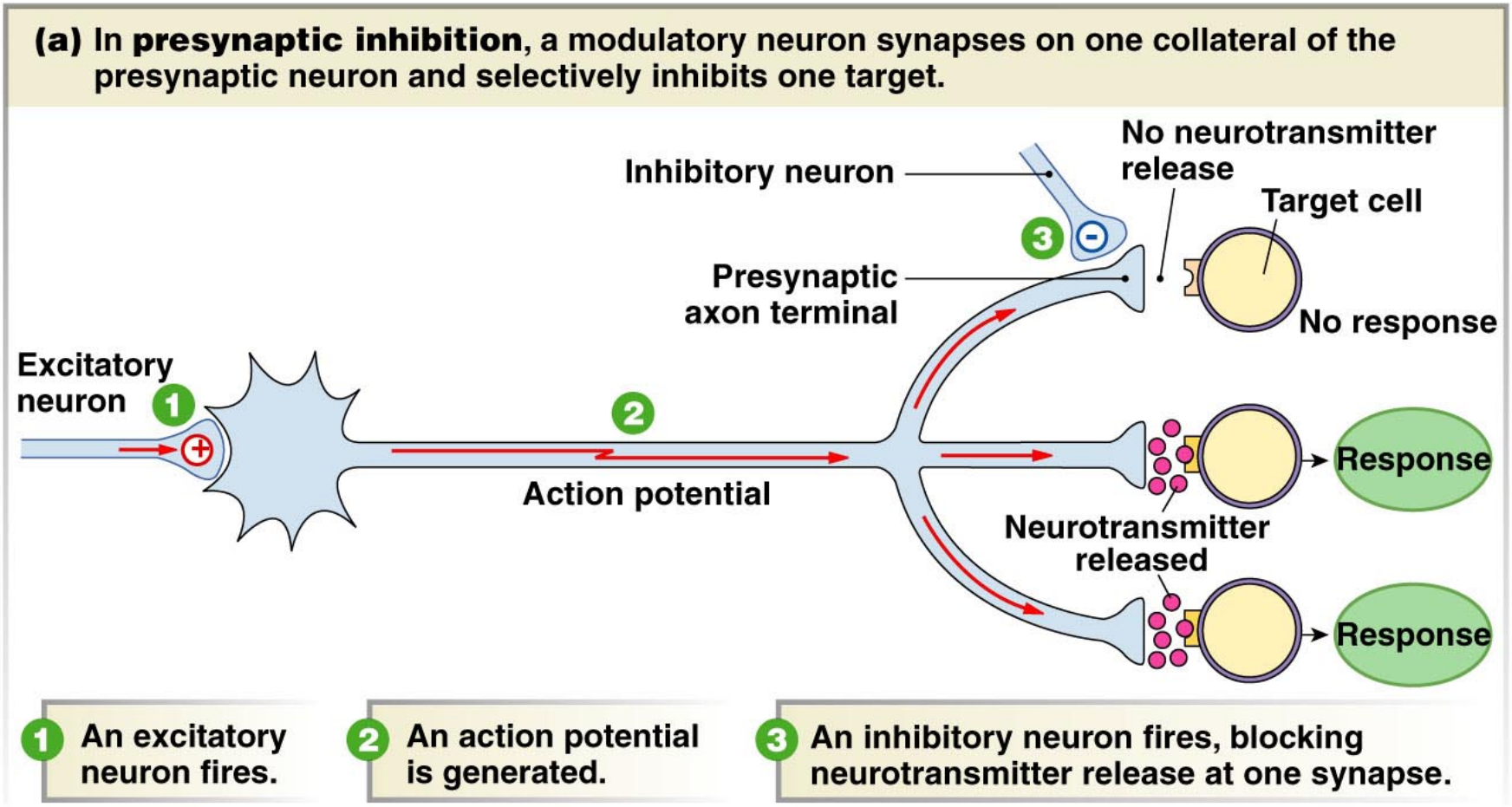

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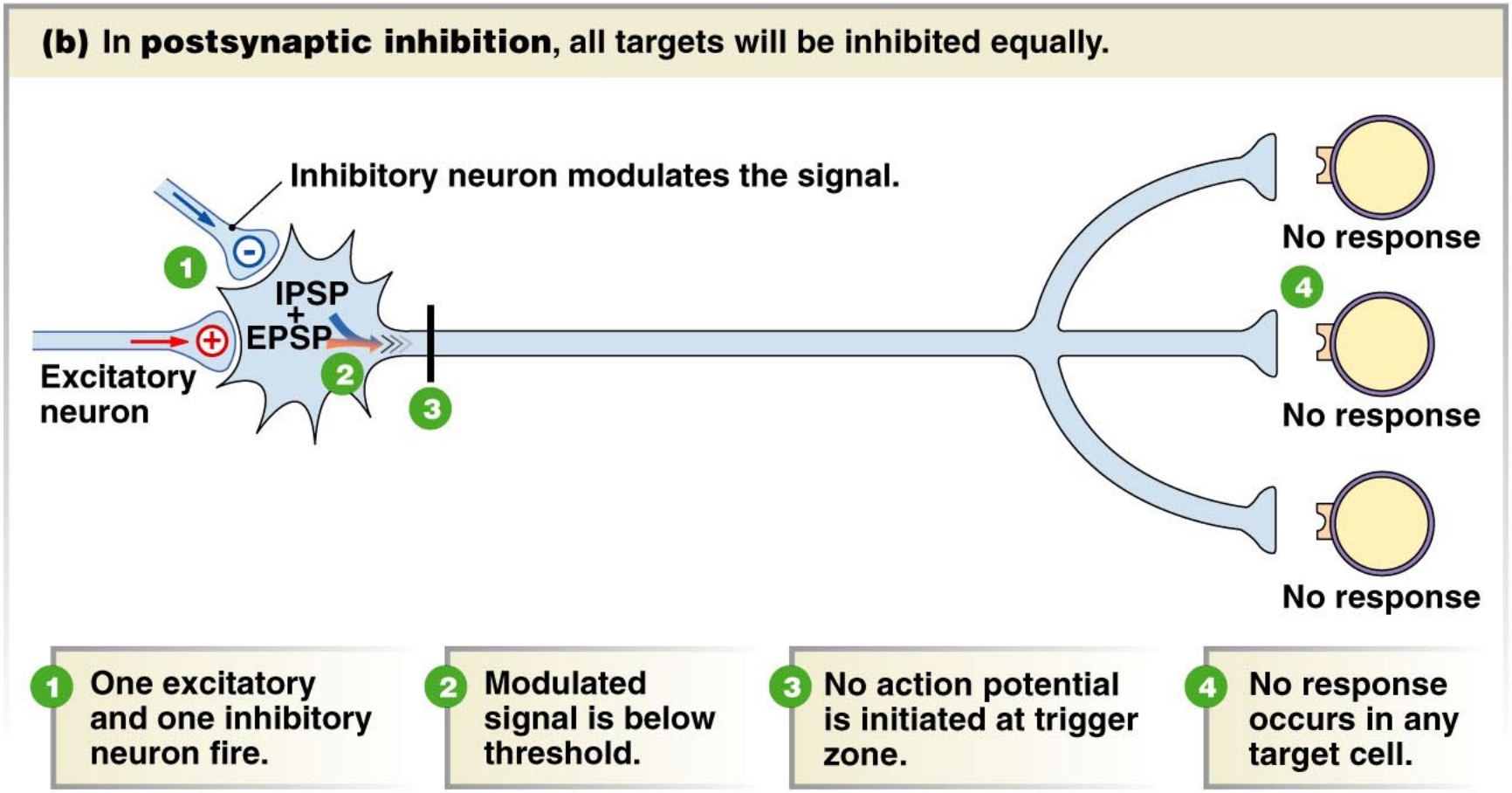
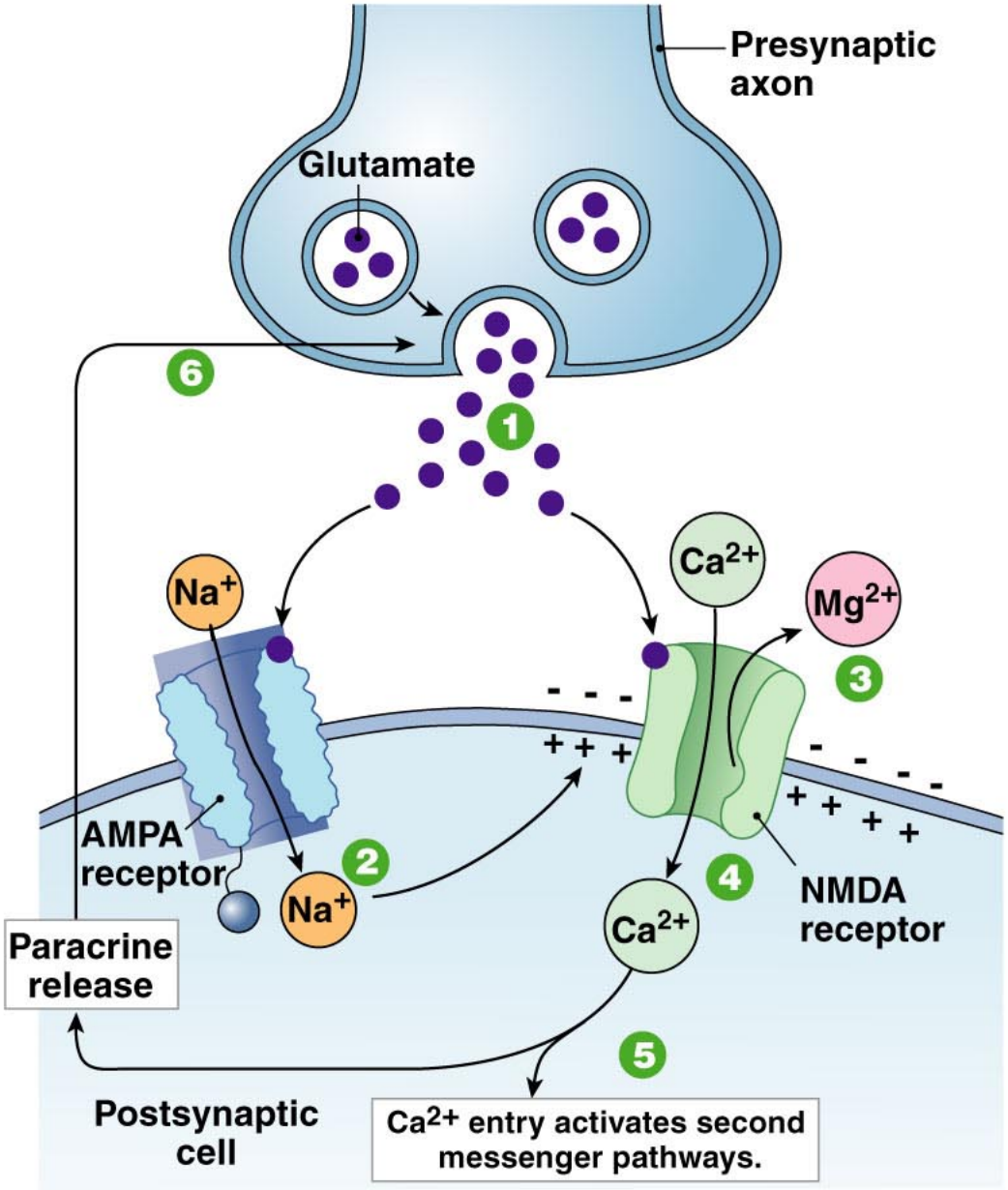


Figure 8-29b - Overview



1. Glutamate is released.
2. Net Na^+ entry depolarizes the postsynaptic cell.
3. Depolarization ejects Mg^{2+} and opens channel.
4. Ca^{2+} enters cytoplasm.
5. Cell becomes more sensitive to glutamate.
6. Paracrine from postsynaptic cell enhances glutamate release.

Figure 8-30 - Overview

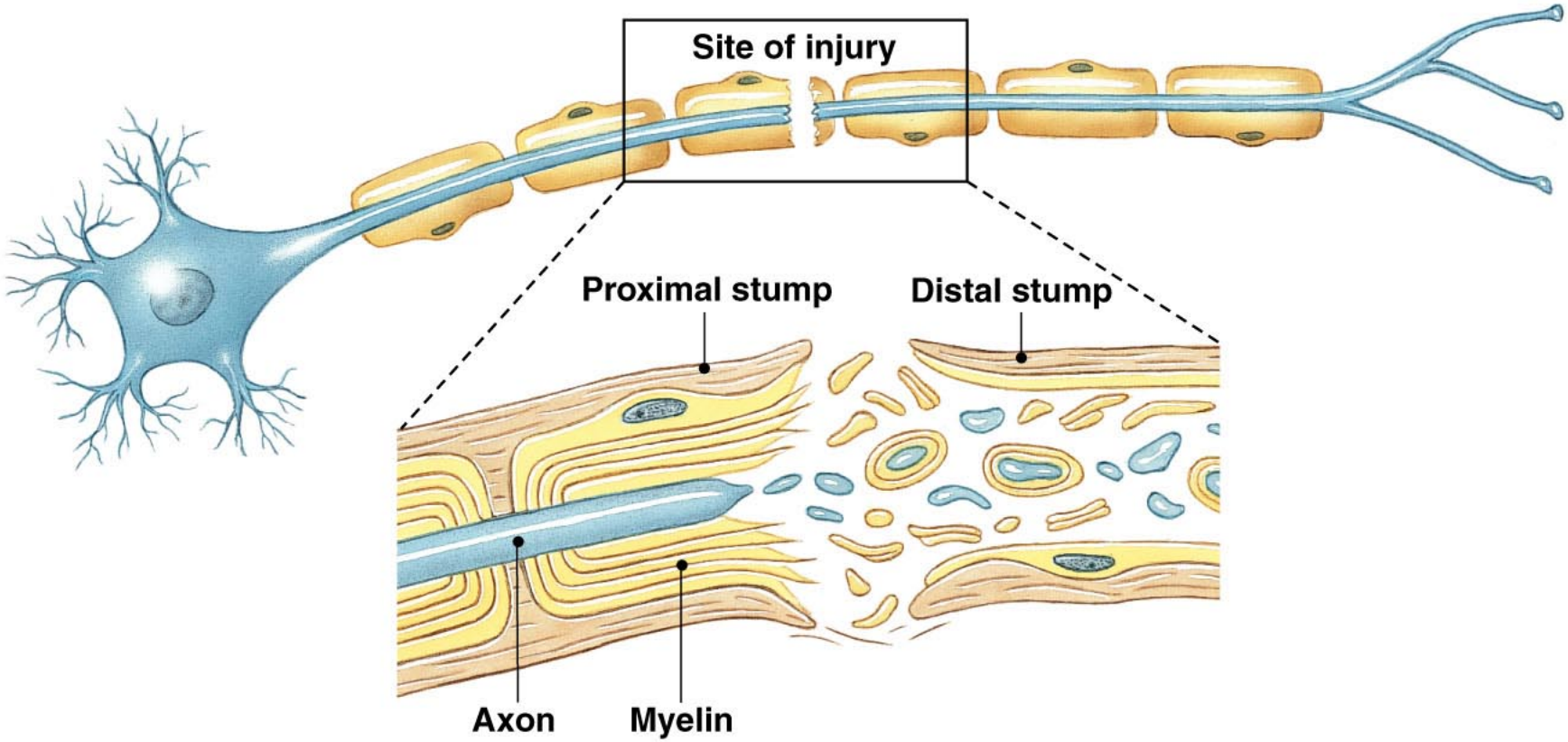


Figure 8-32