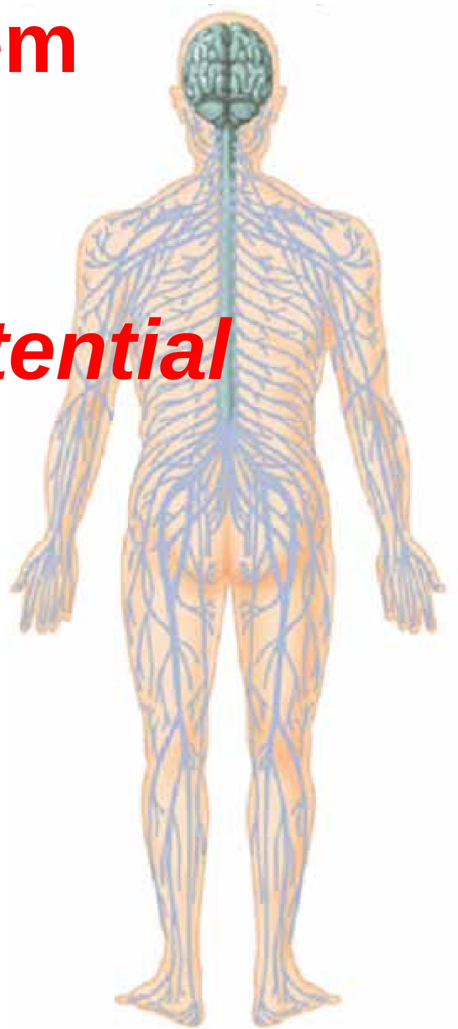
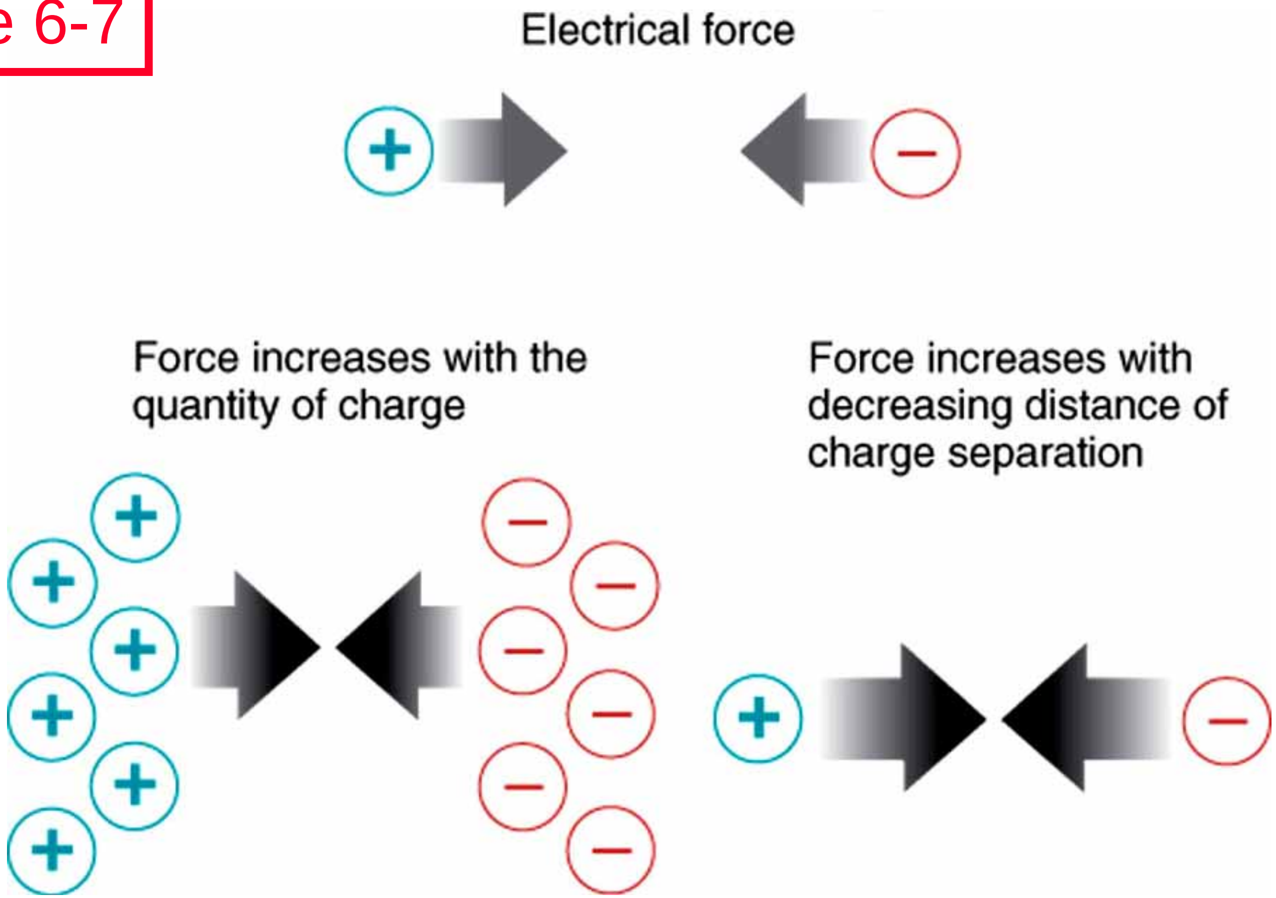
Chapter 6
Neuronal Signaling and the Structure of the Nervous System



Section B Membrane Potential

Figure 6-7

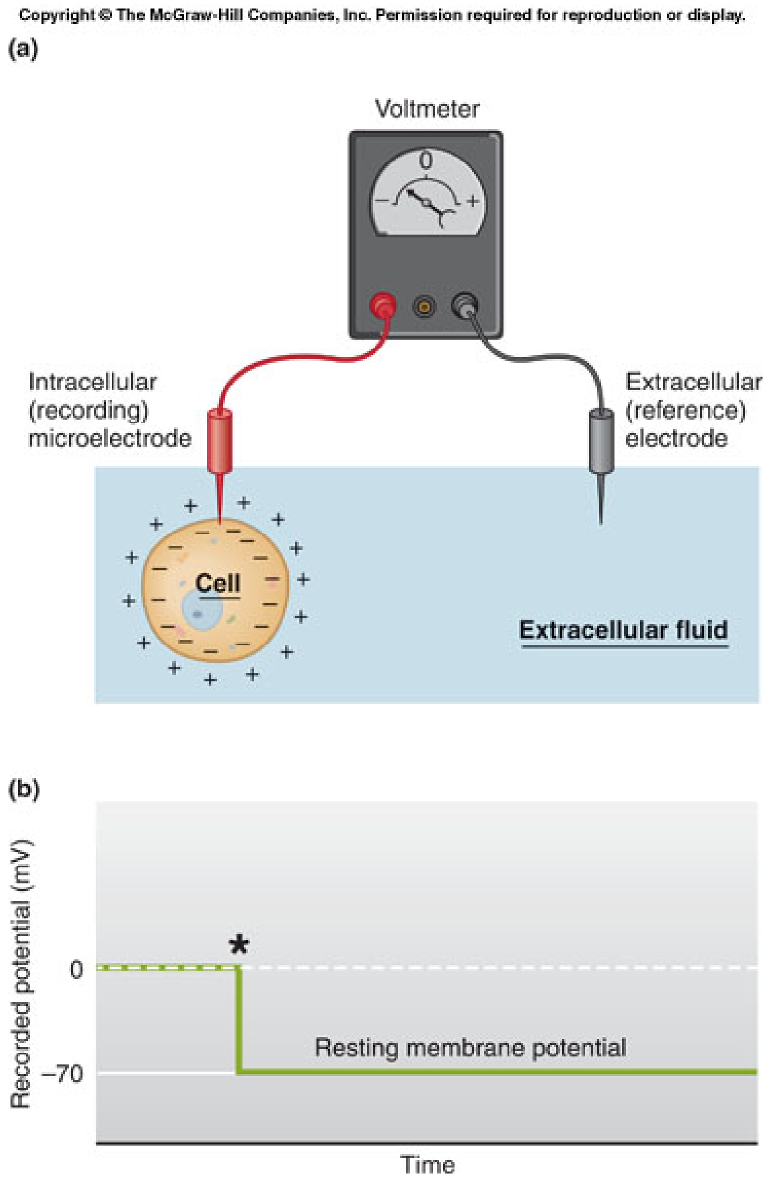


Opposite charges attract each other and will move toward each other if not separated by some barrier.

Section B Membrane Potential

- Resting membrane potential
  - Potential difference under resting conditions
- Graded potential
  - Transient change, short distance
- Action potential
  - Transient change, long distance

Figure 6-8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(a)
Voltmeter
0
–
+
Intracellular (recording) microelectrode
Extracellular (reference) electrode
Cell
Extracellular fluid
(b)
Recorded potential (mV)
0
–70
*
Resting membrane potential
Time

Figure 6-9

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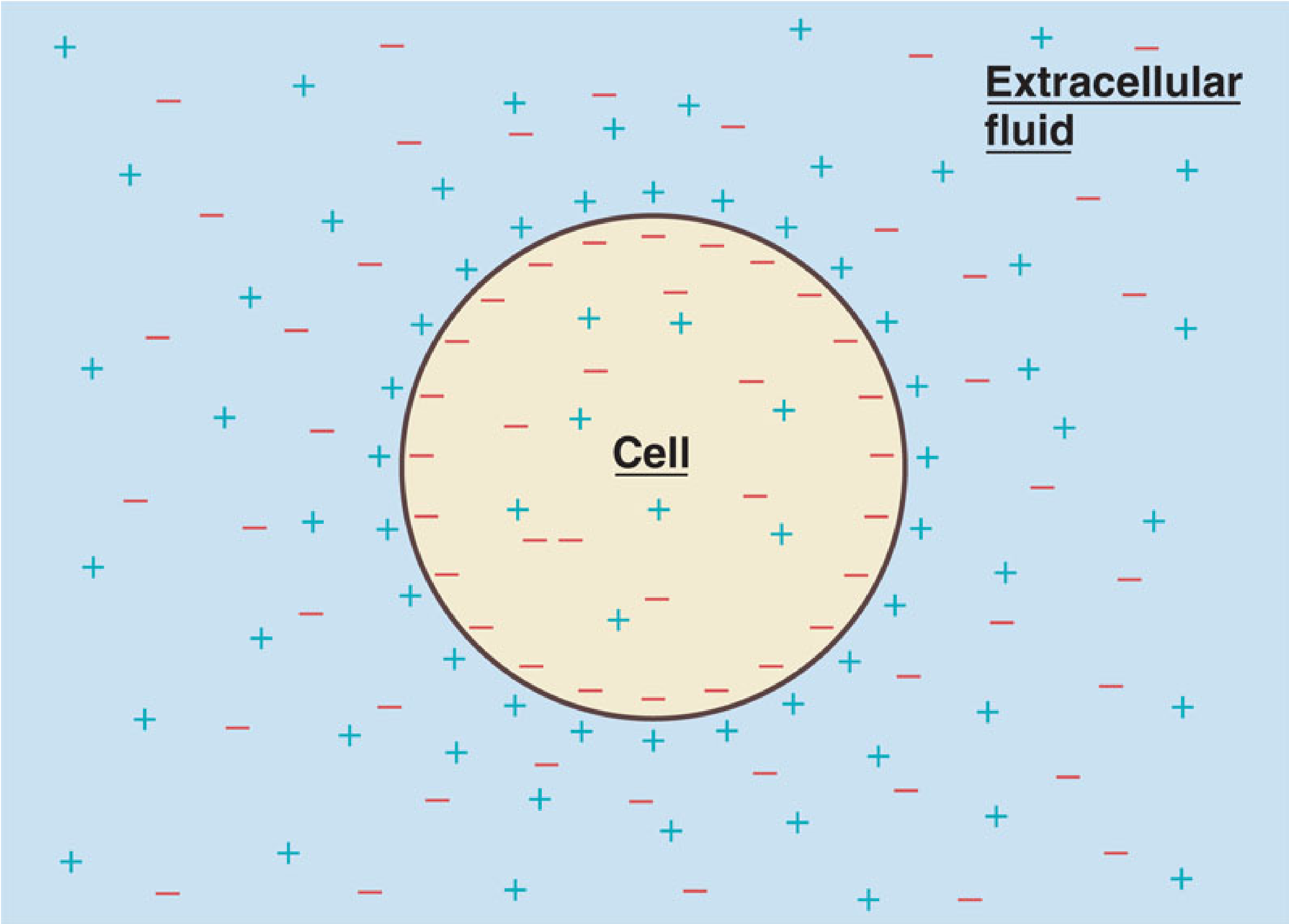

Only a very thin shell of charge difference is needed to establish a membrane potential.

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TABLE 6–2 *Distribution of Major Mobile Ions Across the Plasma Membrane of a Typical Nerve Cell*

	Concentration, mmol/L	
ION	EXTRACELLULAR	INTRACELLULAR
Na^+	150	15
Cl^-	110	7
K^+	5	150

A more accurate measure of electrical driving force can be obtained using mEq/L, which factors in ion valence. Since all the ions in this table have a valence of 1, the mEq/L is the same as the mmol/L concentration.

Begin:
K$^+$ in Compartment 2,
Na$^+$ in Compartment 1;
BUT only K$^+$ can move.

Ion movement:
K$^+$ crosses into Compartment 1;
Na$^+$ stays in Compartment 1.

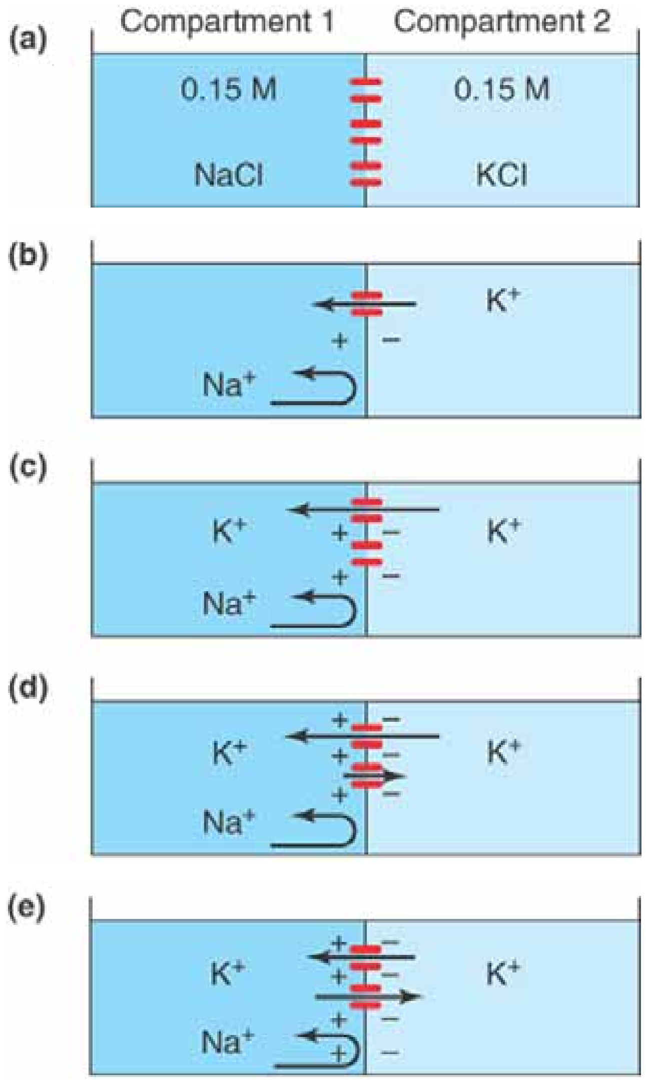
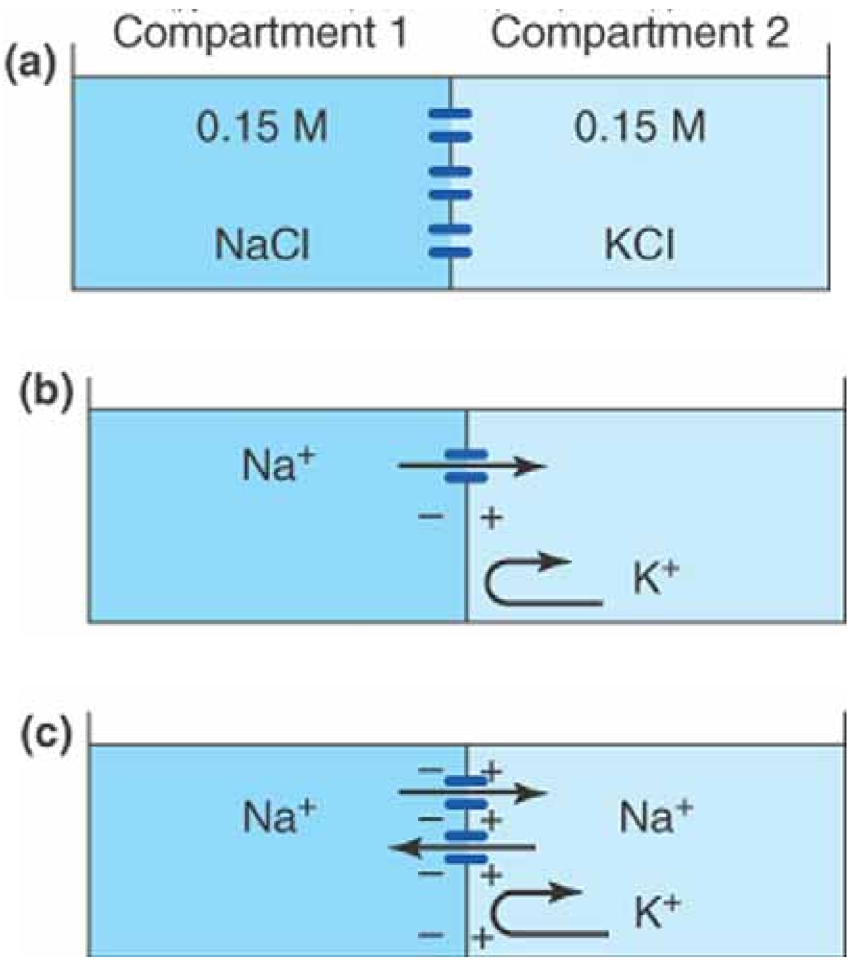


Figure 6-10

At the potassium equilibrium potential:
buildup of positive charge in Compartment 1 produces an electrical potential that exactly offsets the K$^+$ chemical concentration gradient.

Begin:

K^+ in Compartment 2,
Na^+ in Compartment 1;
BUT only Na^+ can move.

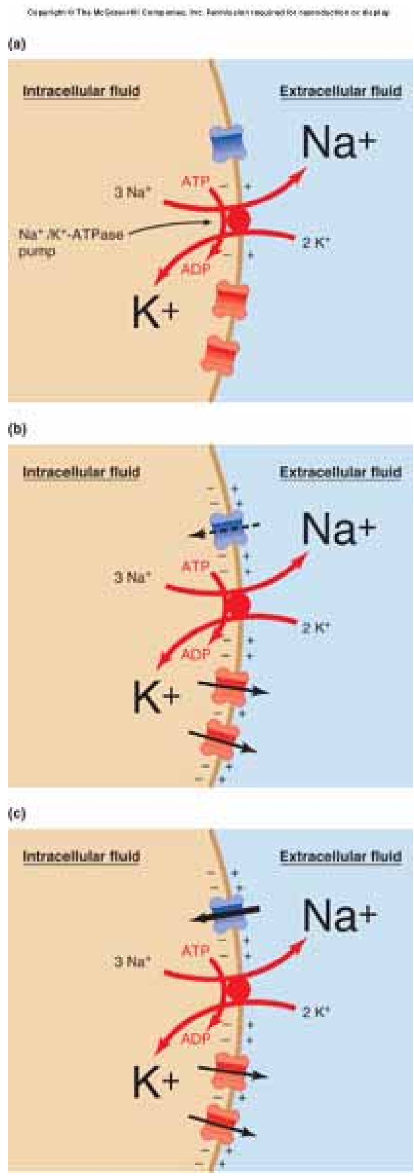


Ion movement:
Na^+ crosses into Compartment 2;
but K^+ stays in Compartment 2.

At the sodium equilibrium potential:

buildup of positive charge in Compartment 2 produces an electrical potential that exactly offsets the Na^+ chemical concentration gradient.

Figure 6-13



Establishment of resting membrane potential:

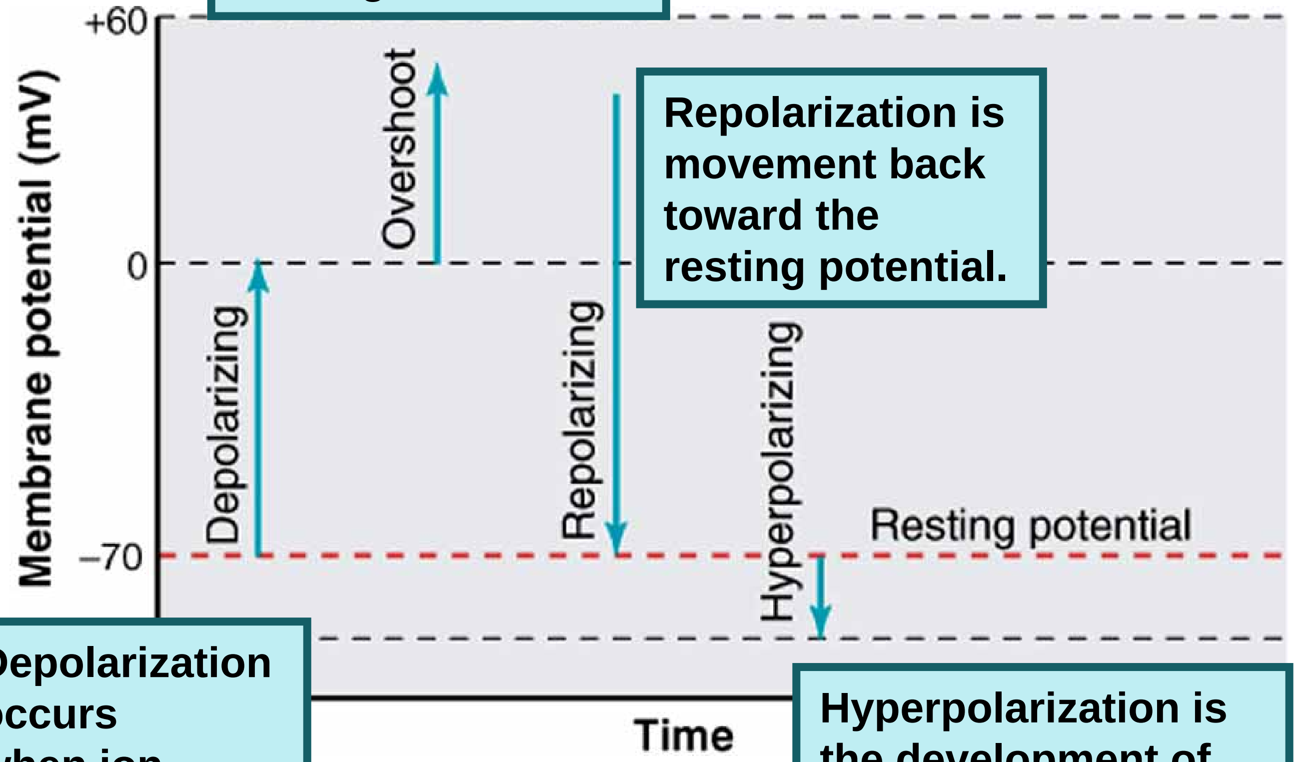
Na+/K+ pump establishes concentration gradient generating a small negative potential; pump uses up to 40% of the ATP produced by that cell!

Figure 6-14

Overshoot refers to the development of a charge reversal.

A cell is "polarized" because its interior is more negative than its exterior.

Repolarization is movement back toward the resting potential.



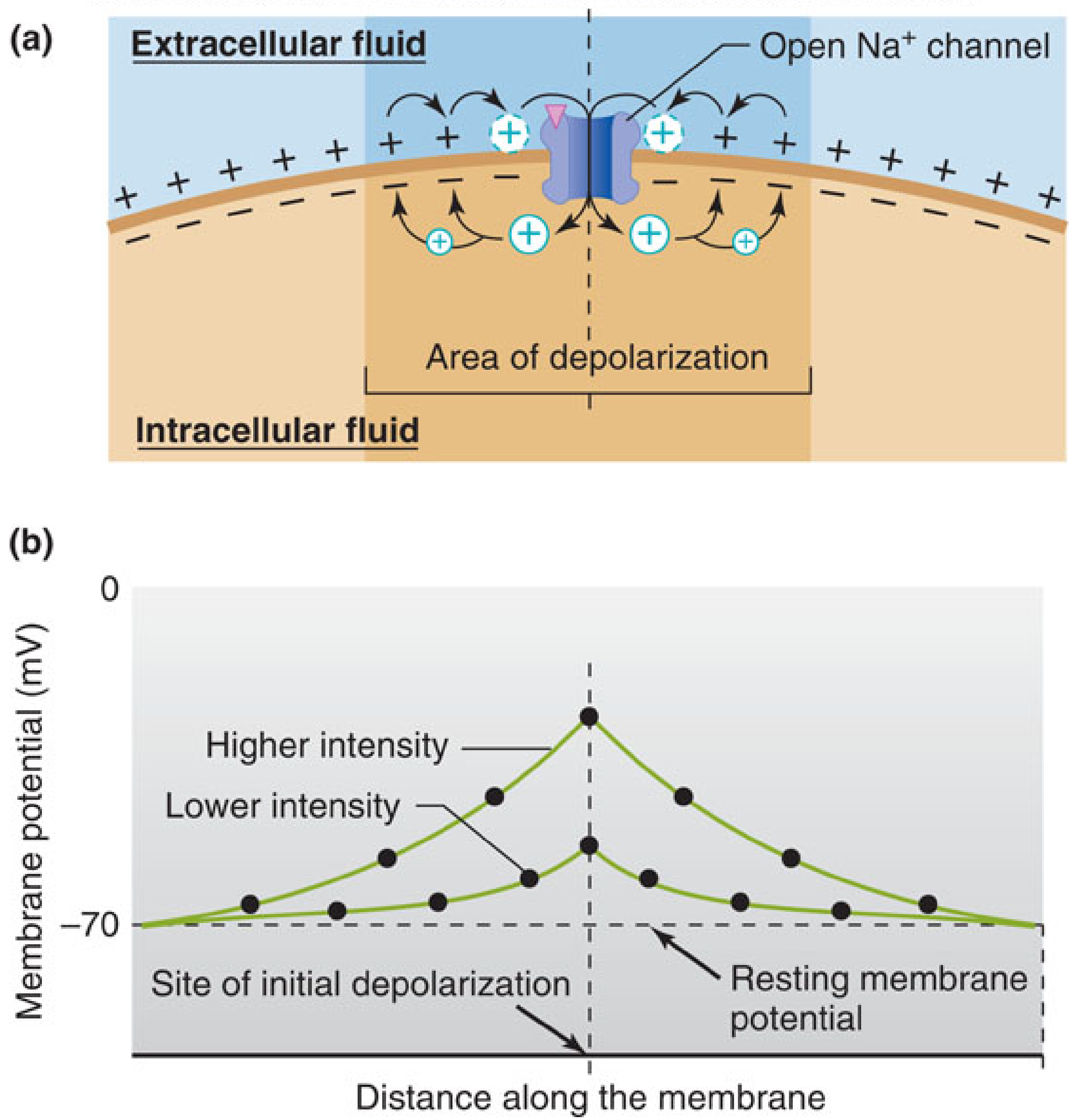
Depolarization occurs when ion movement reduces the charge imbalance.

Hyperpolarization is the development of even more negative charge inside the cell.

TABLE 6–3 A Miniglossary of Terms Describing the Membrane Potential

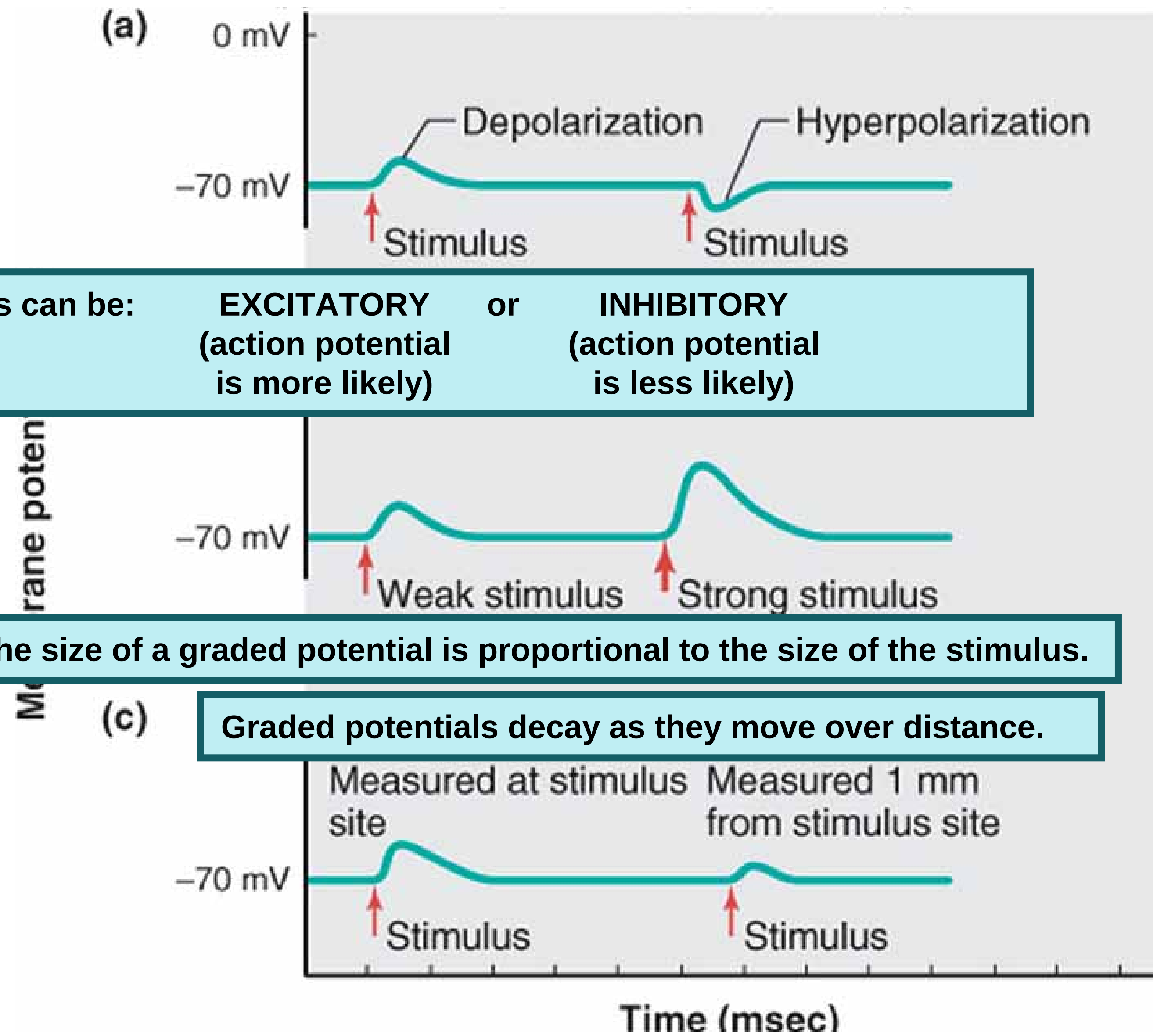
Potential = potential difference	The voltage difference between two points.
Membrane potential = transmembrane potential	The voltage difference between the inside and outside of a cell.
Equilibrium potential	The voltage difference across a membrane that produces a flux of a given ion species that is equal but opposite to the flux due to the concentration gradient of that same ion species.
Resting membrane potential = resting potential	The steady transmembrane potential of a cell that is not producing an electric signal.
Graded potential	A potential change of variable amplitude and duration that is conducted decrementally; it has no threshold or refractory period.
Action potential	A brief all-or-none depolarization of the membrane, reversing polarity in neurons; it has a threshold and refractory period and is conducted without decrement.
Synaptic potential	A graded potential change produced in the postsynaptic neuron in response to the release of a neurotransmitter by a presynaptic terminal; it may be depolarizing (an excitatory postsynaptic potential or EPSP) or hyperpolarizing (an inhibitory postsynaptic potential or IPSP).
Receptor potential	A graded potential produced at the peripheral endings of afferent neurons (or in separate receptor cells) in response to a stimulus.
Pacemaker potential	A spontaneously occurring graded potential change that occurs in certain specialized cells.
Threshold potential	The membrane potential at which an action potential is initiated.

Figure 6-15



The size of a graded potential (here, graded depolarizations) is proportionate to the intensity of the stimulus.

Figure 6-16



Graded potentials can be: **EXCITATORY** (action potential is more likely) **or** **INHIBITORY** (action potential is less likely)

The size of a graded potential is proportional to the size of the stimulus.

Graded potentials decay as they move over distance.

Figure 6-17

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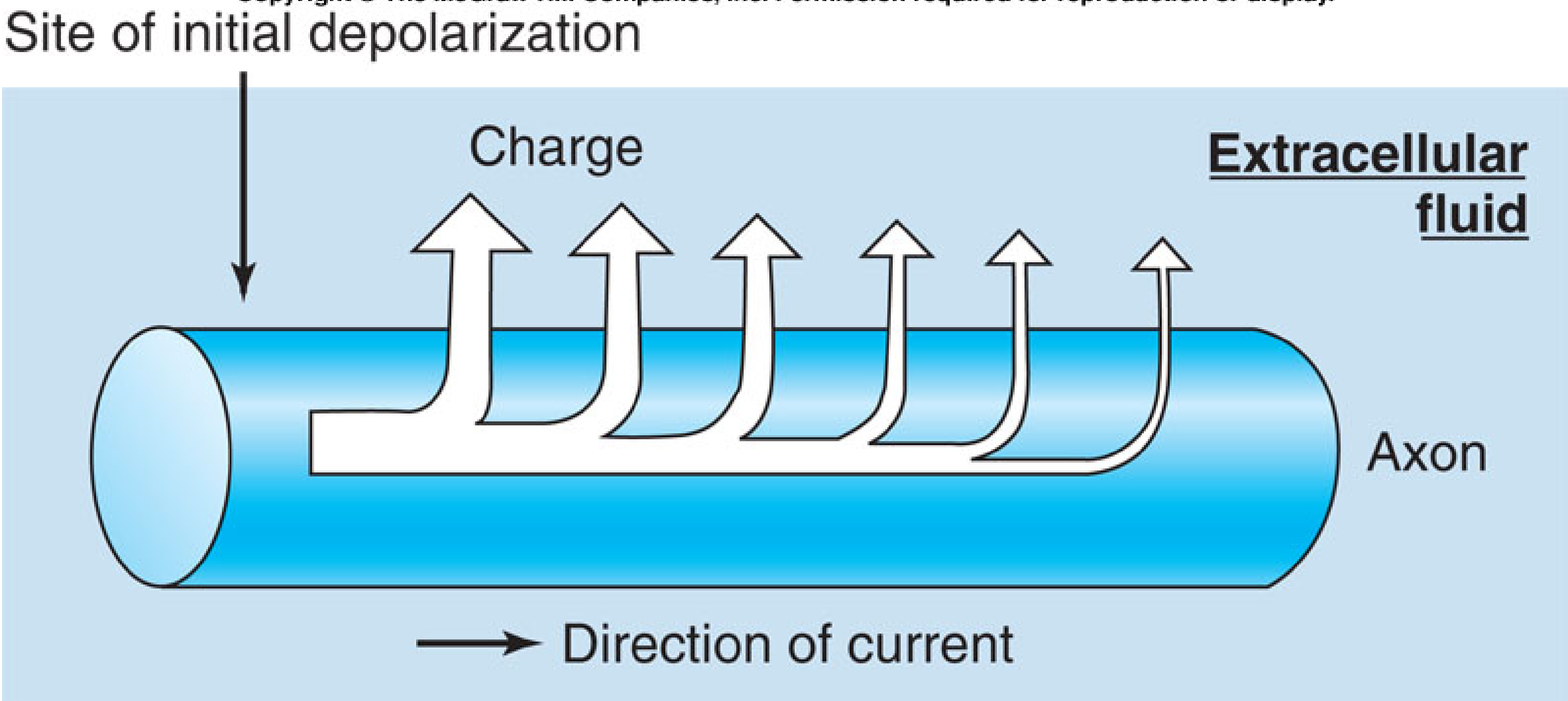
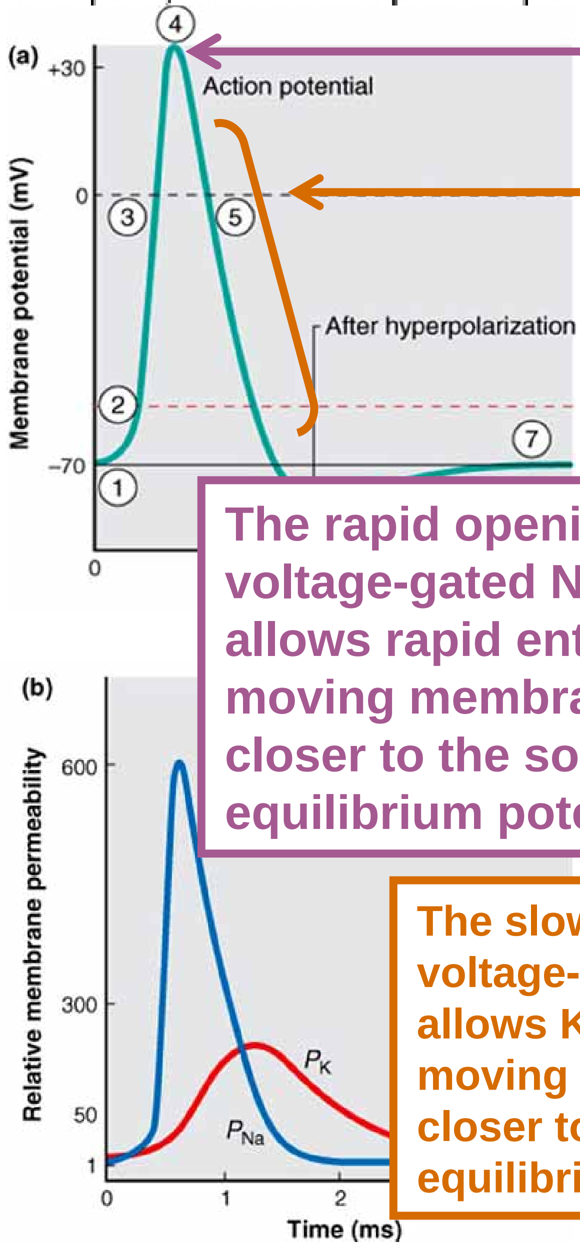


Graded potentials decay as they move over distance.

An action potential is an "all-or-none" sequence of changes in membrane potential.



The rapid opening of voltage-gated Na^+ channels allows rapid entry of Na^+, moving membrane potential closer to the sodium equilibrium potential (+60 mv)

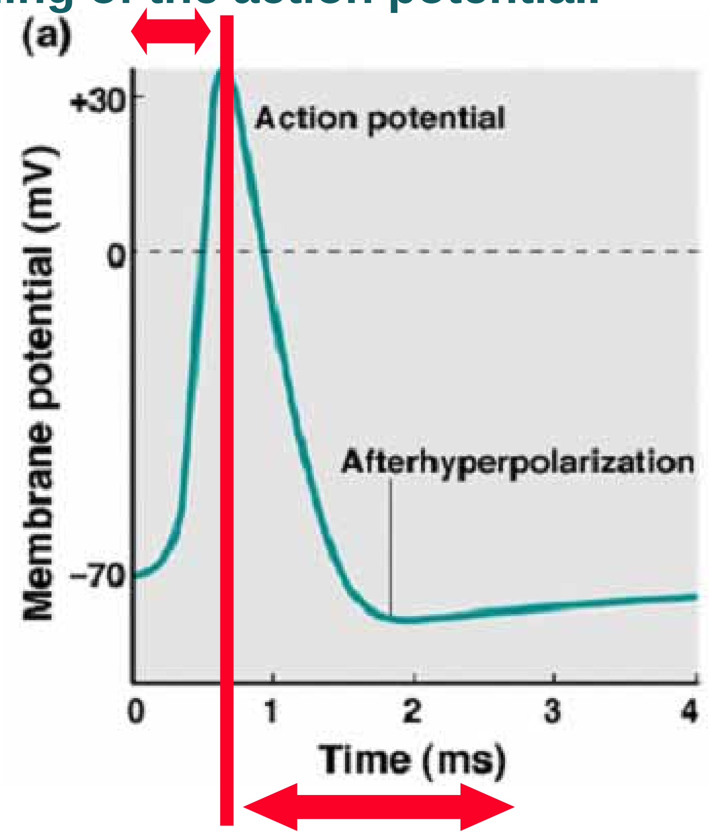
Action potentials result from an all-or-none sequence of changes in ion permeability due to the operation of voltage-gated Na^+ and K^+ channels.

The slower opening of voltage-gated K^+ channels allows K^+ exit, moving membrane potential closer to the potassium equilibrium potential (-90 mv)

Figure 6-19

Click here to play the Voltage Gated Channels and Action Potential Flash Animation

The rapid opening of voltage-gated Na^+ channels explains the rapid-depolarization phase at the beginning of the action potential.



The slower opening of voltage-gated K^+ channels explains the repolarization and after hyperpolarization phases that complete the action potential.

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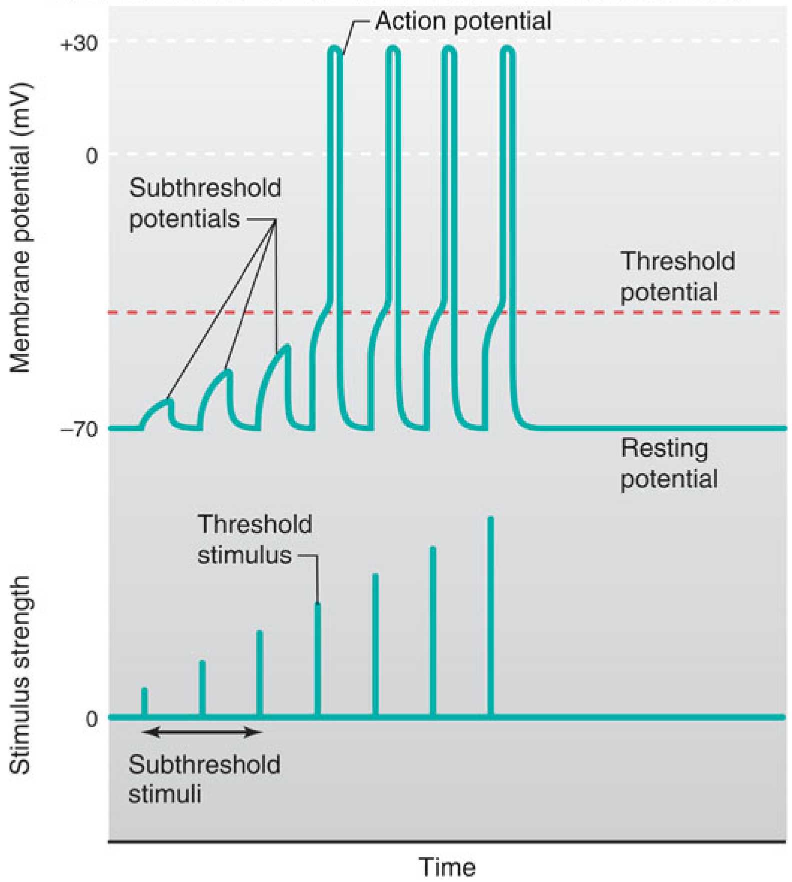
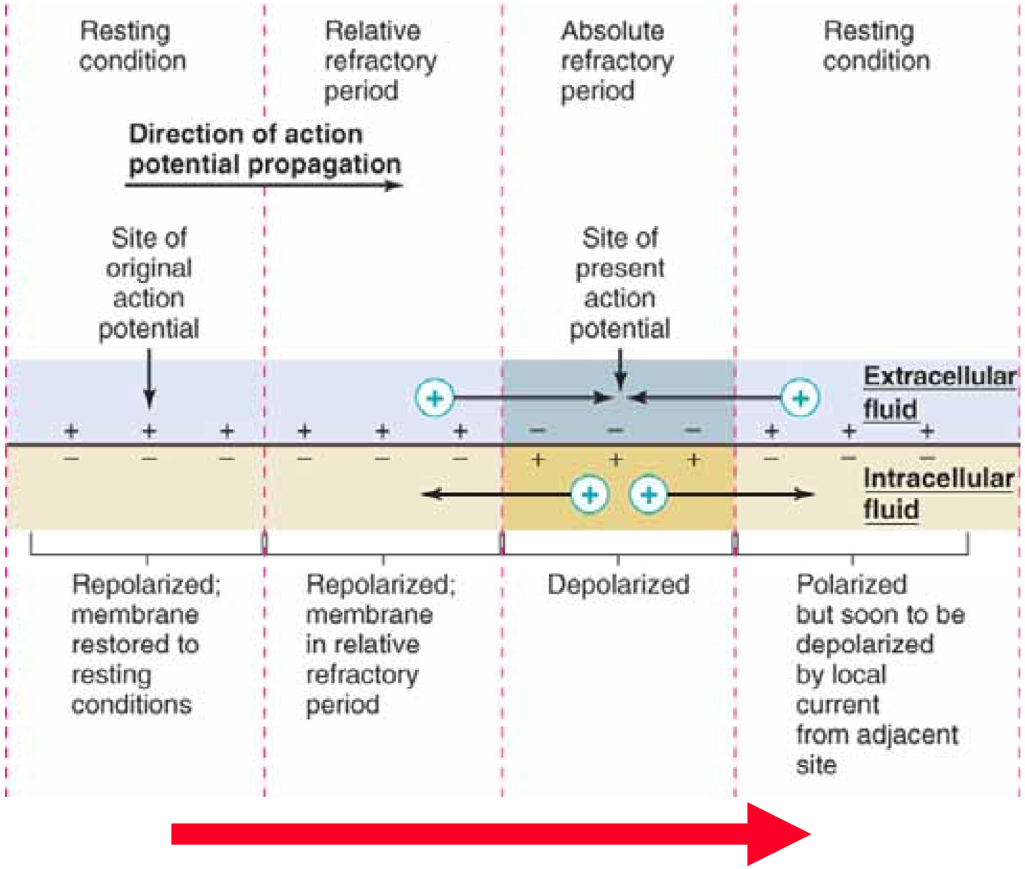


Four action potentials, each the result of a stimulus strong enough to cause deploplarization,are shown in the right half of the figure.

Figure 6-21



The propagation of the action potential from the dendritic to the axon-terminal end is typically one-way because the absolute refractory period follows along in the "wake" of the moving action potential.

Click here to play the
Action Potential Propagation
in an Unmyelinated Neuron
Flash Animation

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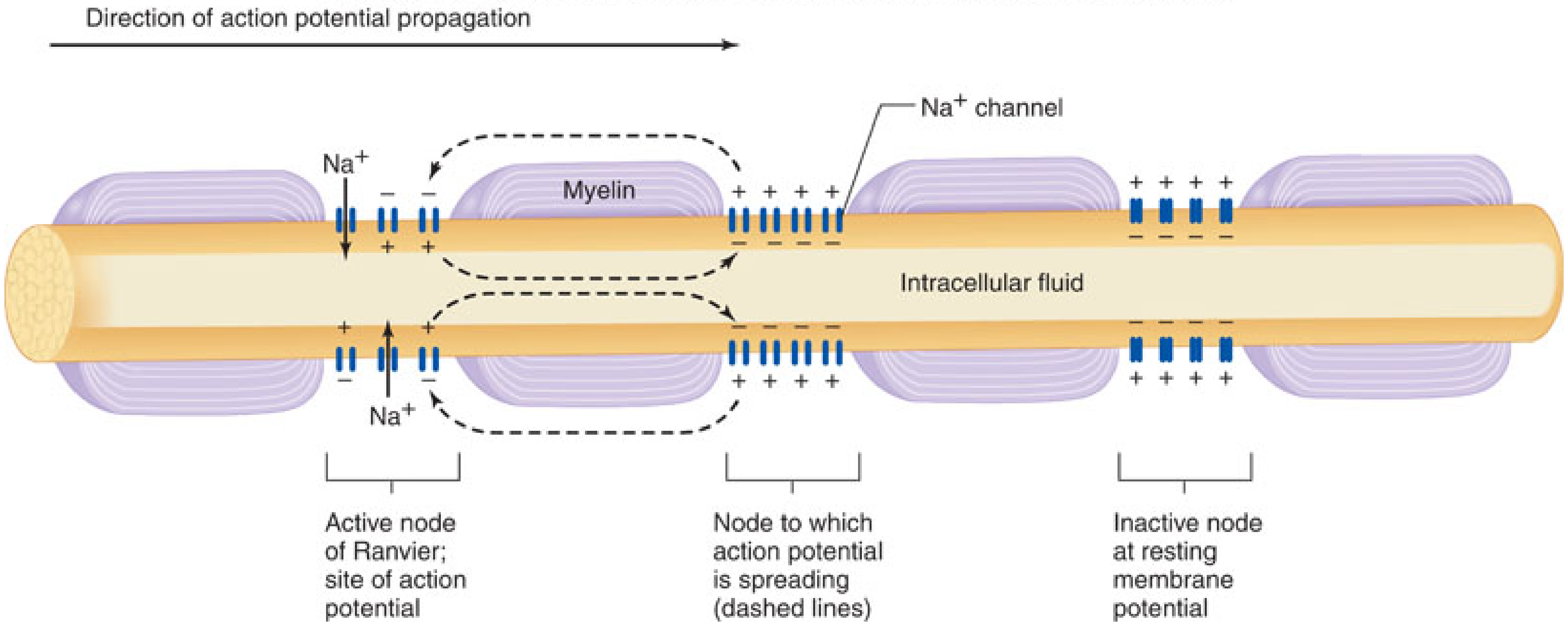

Saltatorial Conduction: Action potentials jump from one node to the next as they propagate along a myelinated axon.

Figure 6-23

Click here to play the
Action Potential Propagation
in Myelinated Neurons
Flash Animation

TABLE 6–4 *Differences between Graded Potentials and Action Potentials*

GRADED POTENTIAL	ACTION POTENTIAL
Amplitude varies with size of the initiating event.	All-or-none. Once membrane is depolarized to threshold, amplitude is independent of the size of the initiating event.
Can be summed.	Cannot be summed.
Has no threshold.	Has a threshold that is usually about 15 mV depolarized relative to the resting potential.
Has no refractory period.	Has a refractory period.
Is conducted decrementally; that is, amplitude decreases with distance.	Is conducted without decrement; the depolarization is amplified to a constant value at each point along the membrane.
Duration varies with initiating conditions.	Duration is constant for a given cell type under constant conditions.
Can be a depolarization or a hyperpolarization.	Is only a depolarization.
Initiated by environmental stimulus (receptor), by neurotransmitter (synapse), or spontaneously.	Initiated by a graded potential.
Mechanism depends on ligand-gated channels or other chemical or physical changes.	Mechanism depends on voltage-gated channels.

The End.