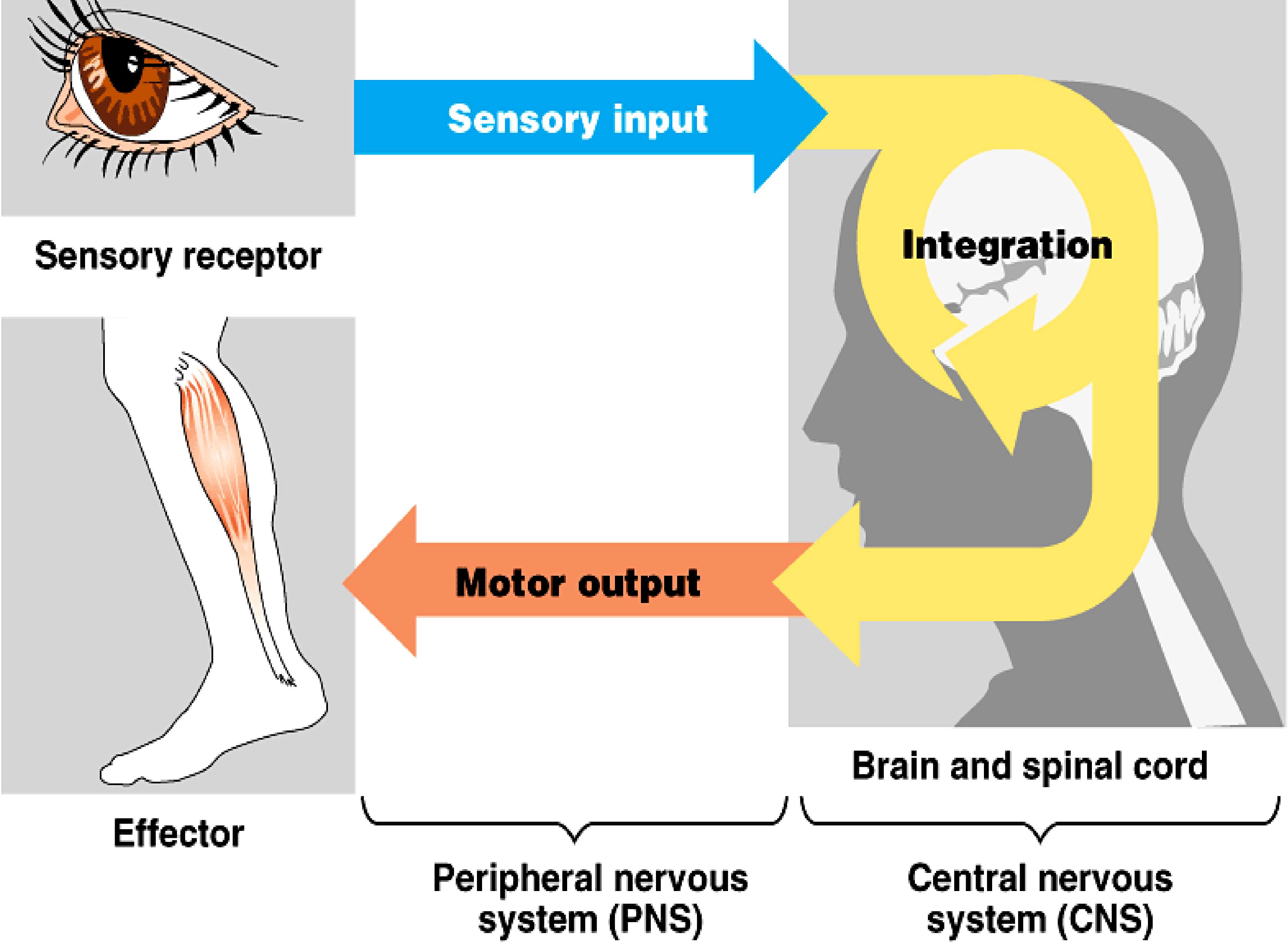
Nervous System: Part II
How A Neuron Works

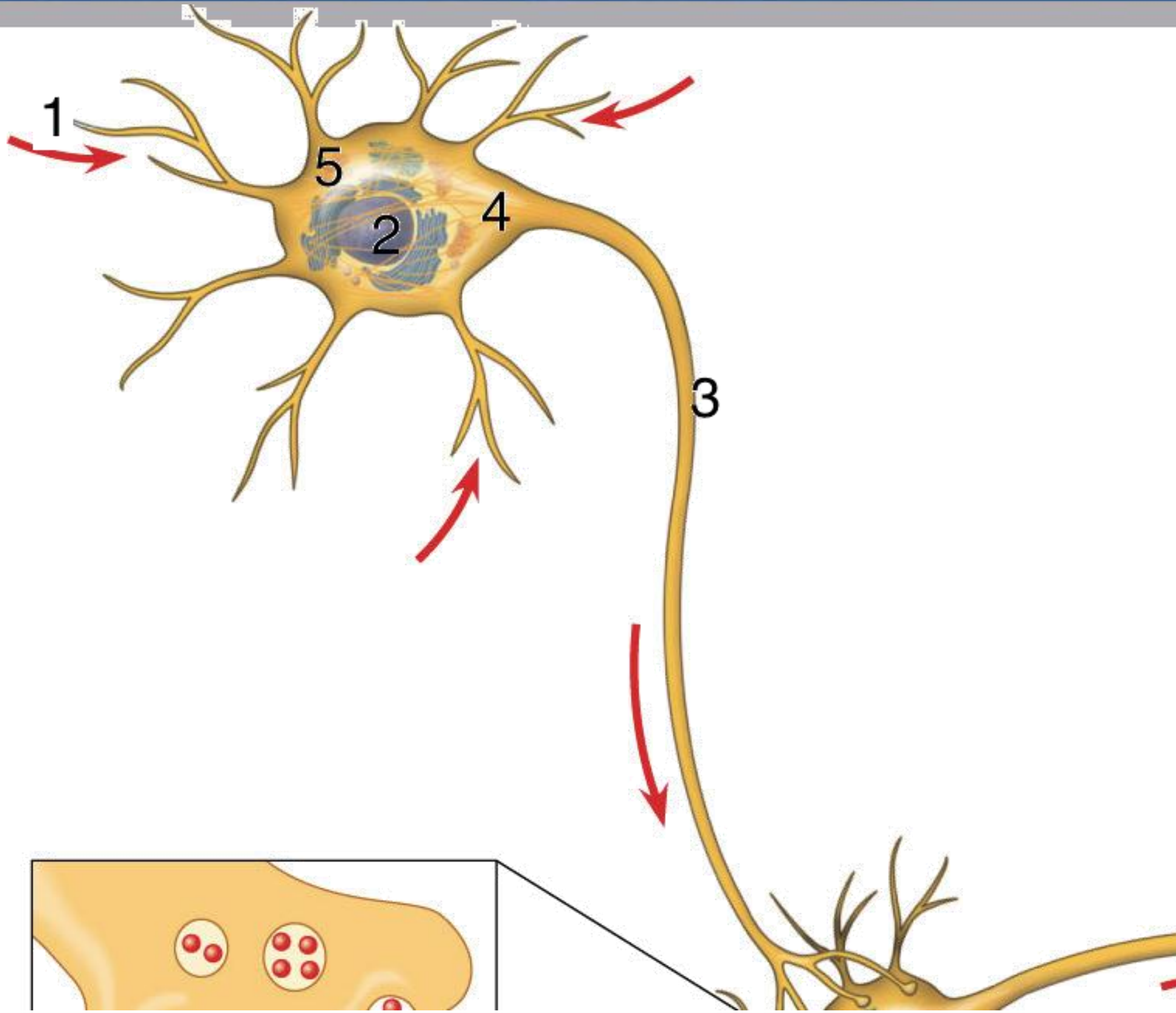
NATIONAL MATH + SCIENCE INITIATIVE

Essential Knowledge Statement 3.E.2 Continued

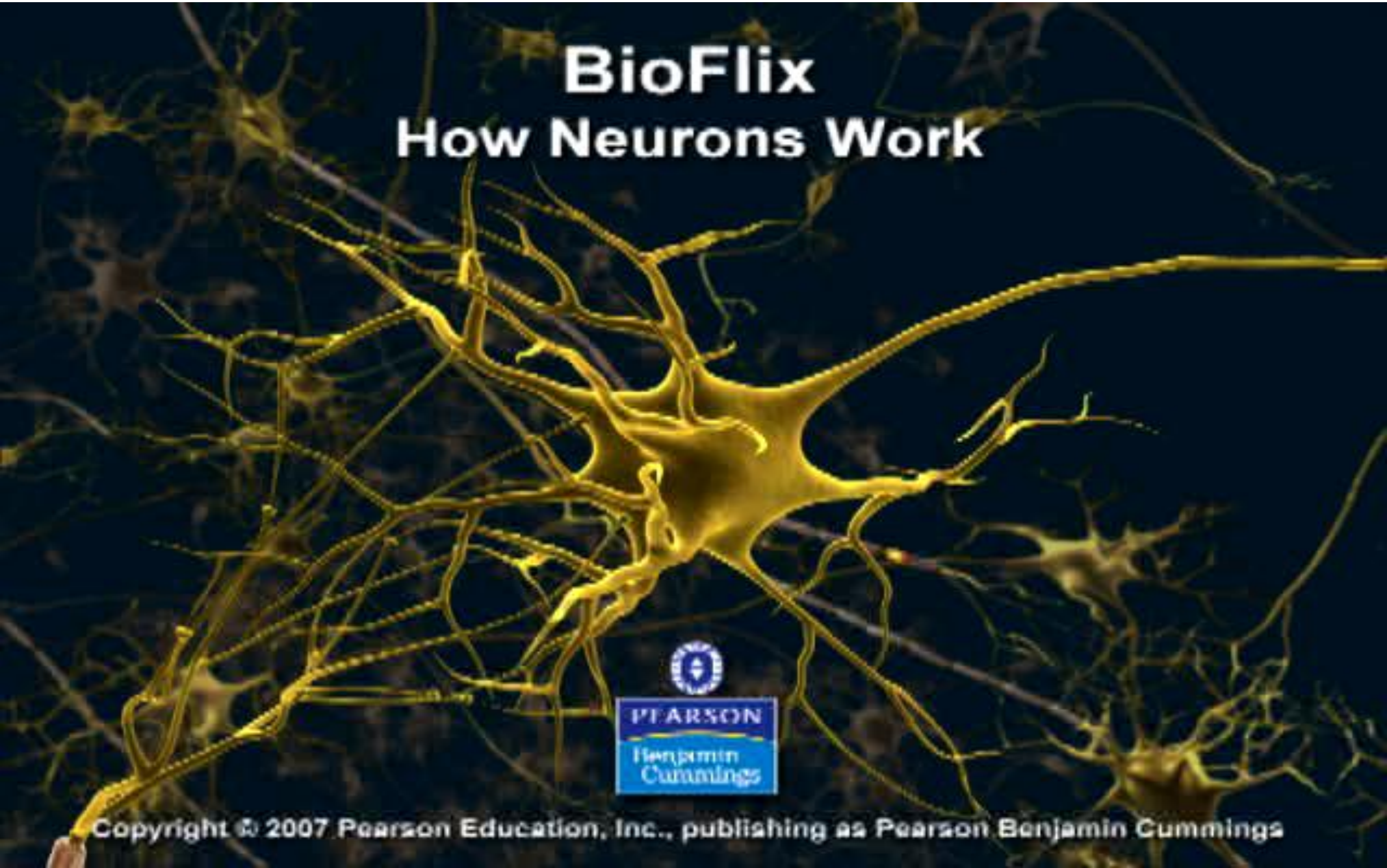
Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses


Sensory input
Sensory receptor
Integration
Motor output
Effector
Brain and spinal cord
Peripheral nervous system (PNS)
Central nervous system (CNS)

Identify the Numbered Structures

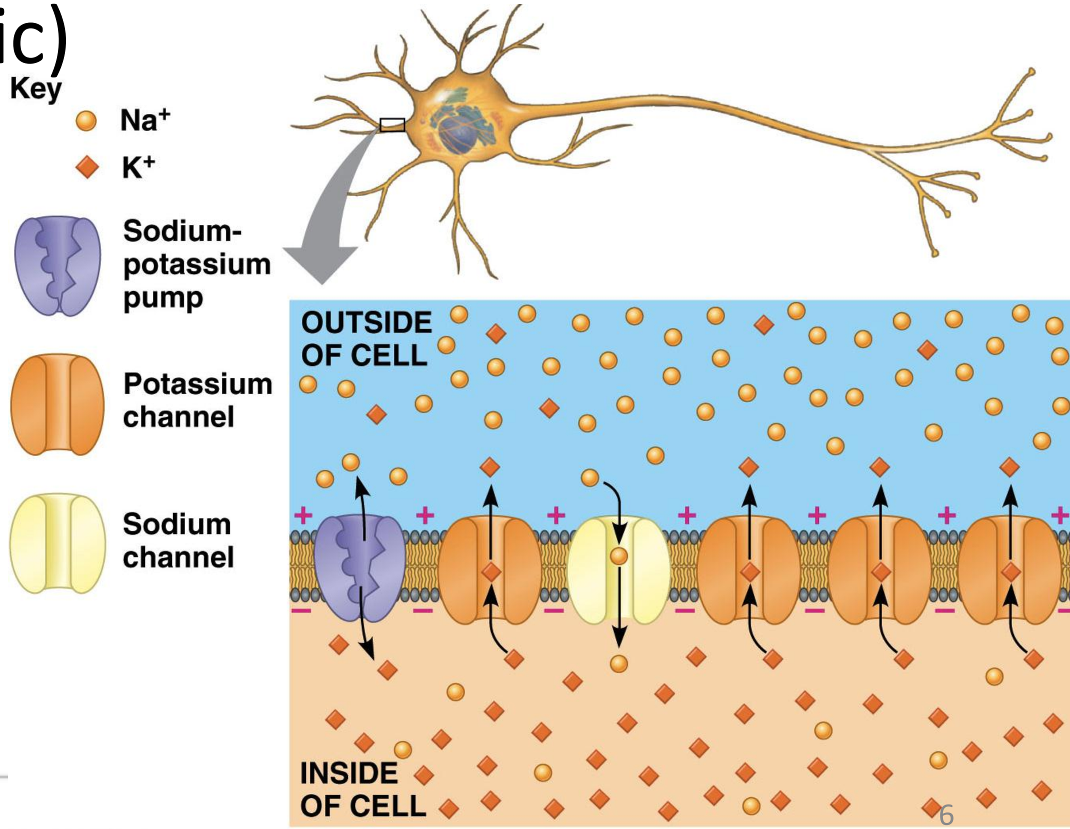


Resting Potential



Describe a Resting Potential:

- What is the charge inside the neuron at rest?
- Why is the cell negative inside and positive outside? (be specific)



Source of Charge Differences:

Table 48.1 Ion Concentrations Inside and Outside of Mammalian Neurons

Ion	Intracellular Concentration (m*M*)	Extracellular Concentration (m*M*)
Potassium (K^+)	140	5
Sodium (Na^+)	15	150
Chloride (Cl^-)	10	120
Large anions (A^-) inside cell, such as proteins	100	(not applicable)

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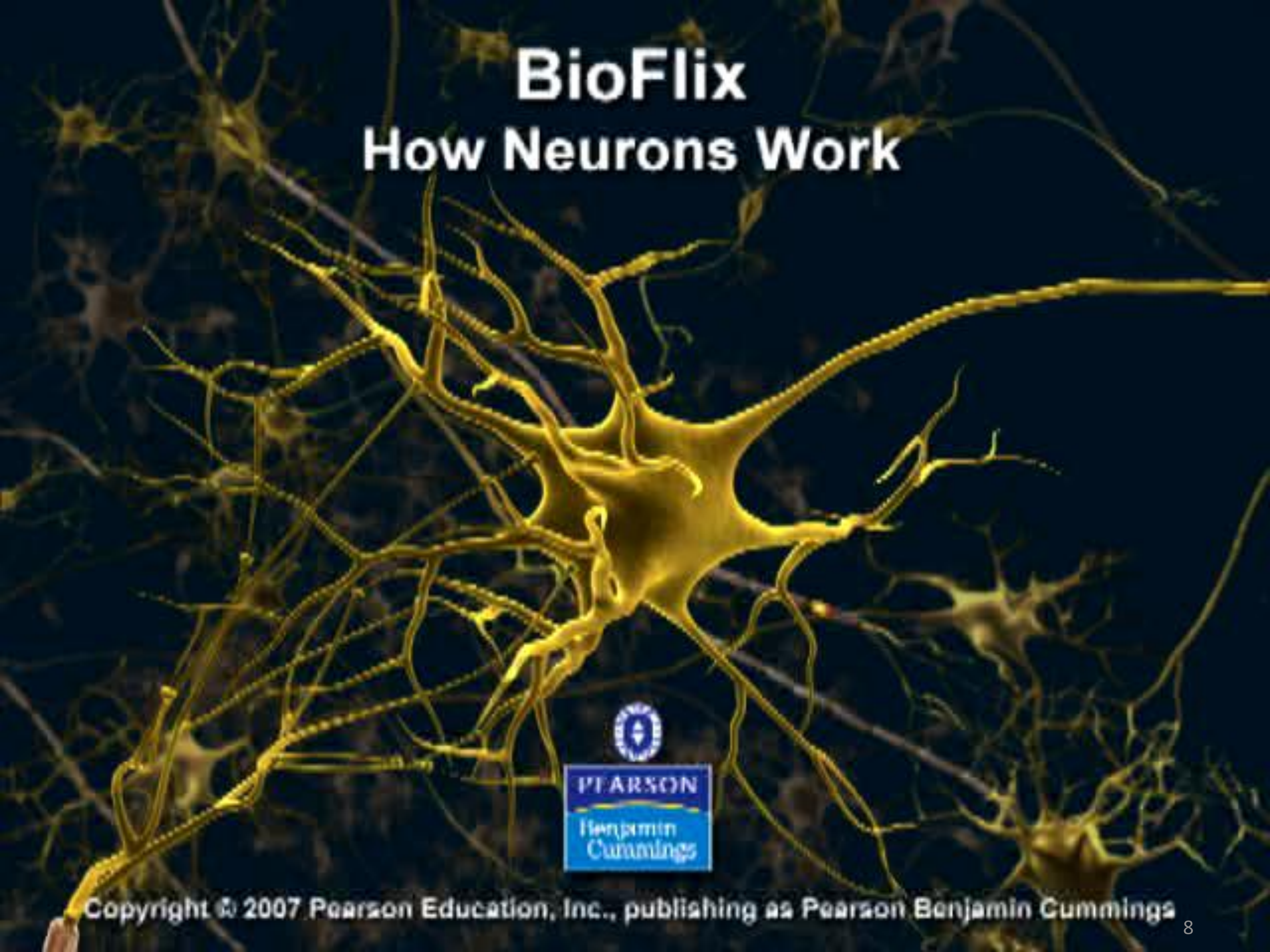
BioFlix
How Neurons Work
PEARSON
Benjamin Cummings
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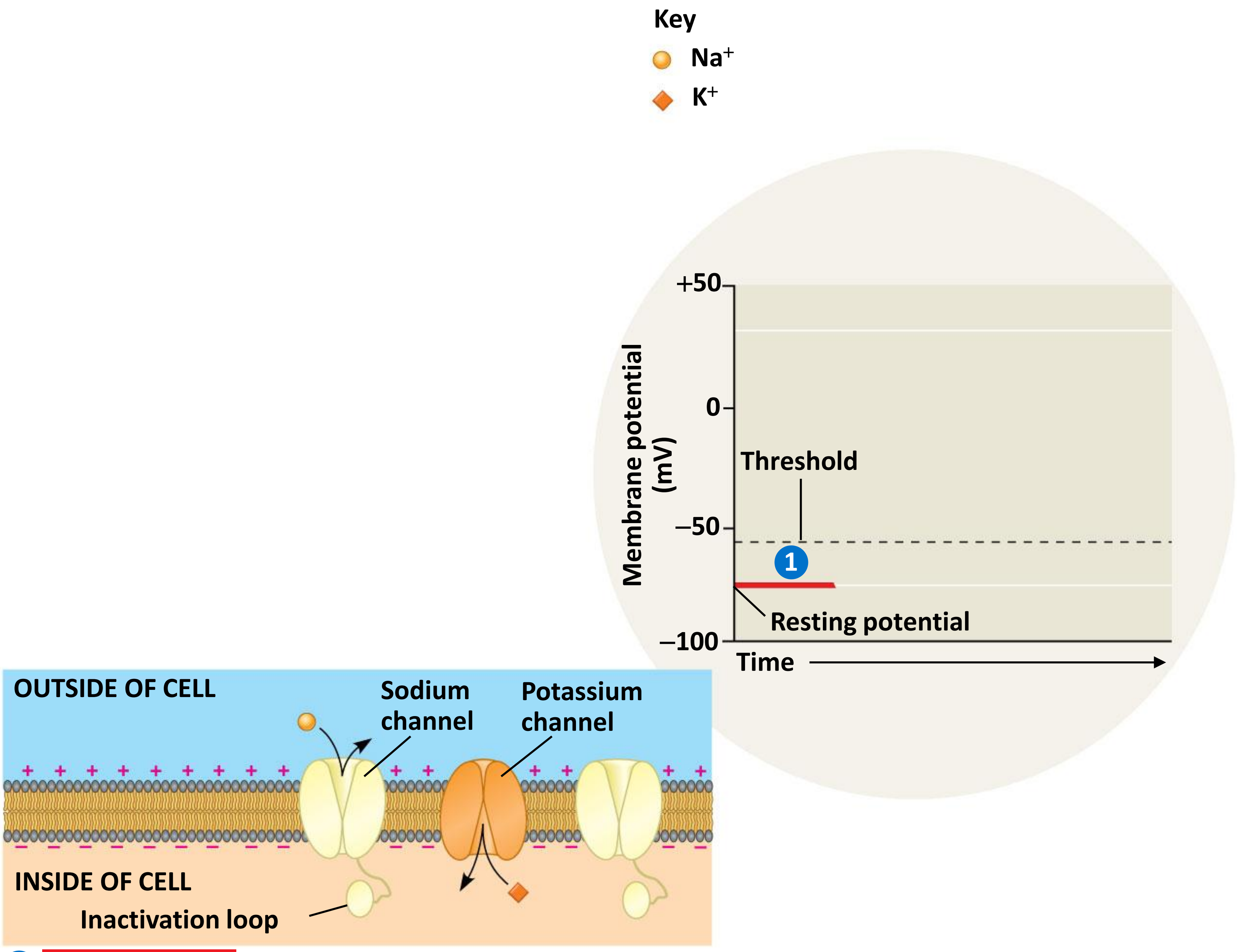
Action Potential

- Action potentials propagate impulses along neurons.
  - Membranes of neurons are polarized by the establishment of electrical potentials across the membranes.
  - In response to a stimulus, Na^+ and K^+ gated channels sequentially open and cause the membrane to become locally depolarized.
  - Na^+/K^+ pumps, powered by ATP, work to maintain membrane potential.

Label the graph of the action potential as we go through the next several slides.

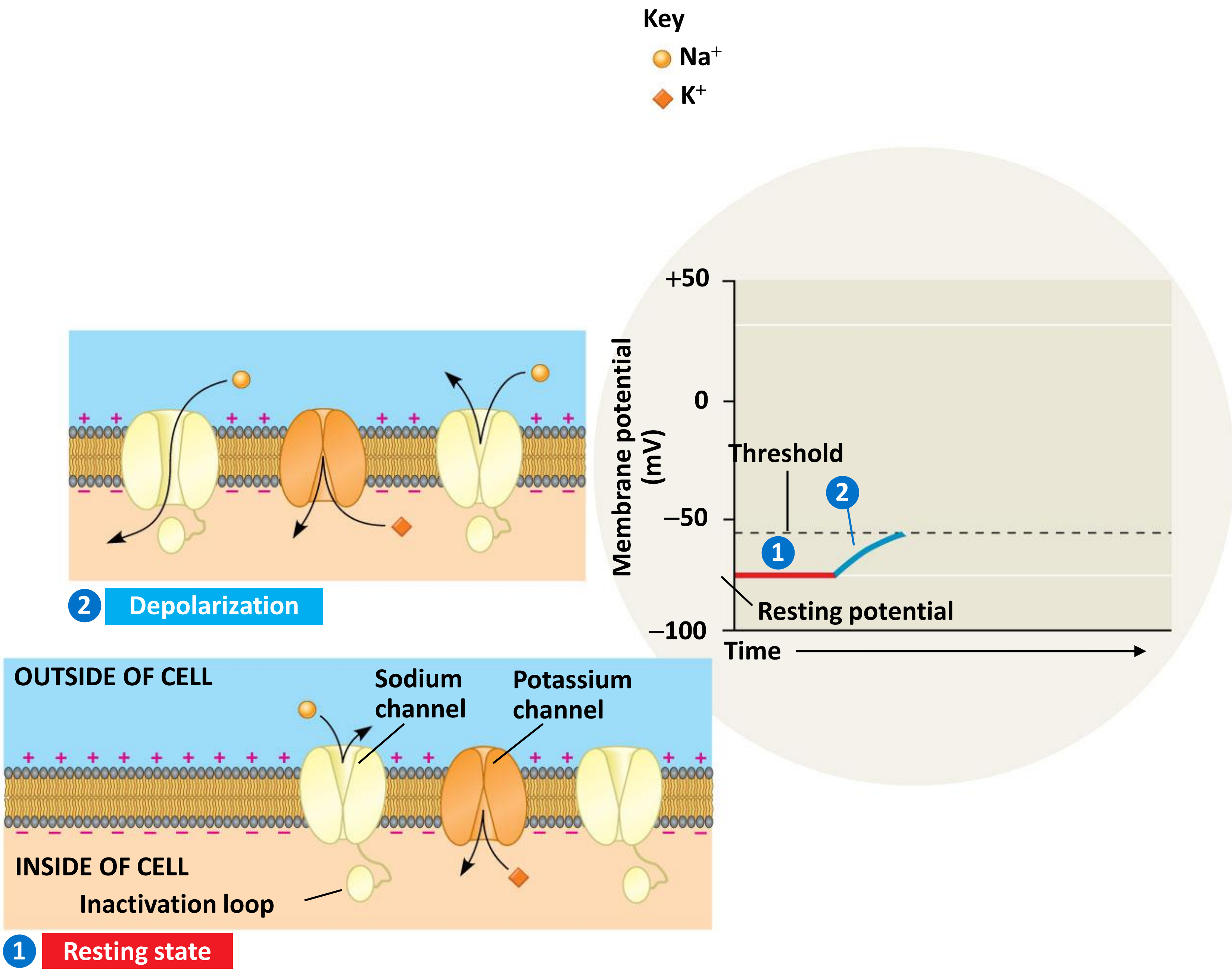
Generation of Action Potentials: *A Closer Look*

- An action potential can be considered as a series of stages
- At resting potential
    1. Most voltage-gated sodium (Na^+) channels are closed; most of the voltage-gated potassium (K^+) channels are also closed



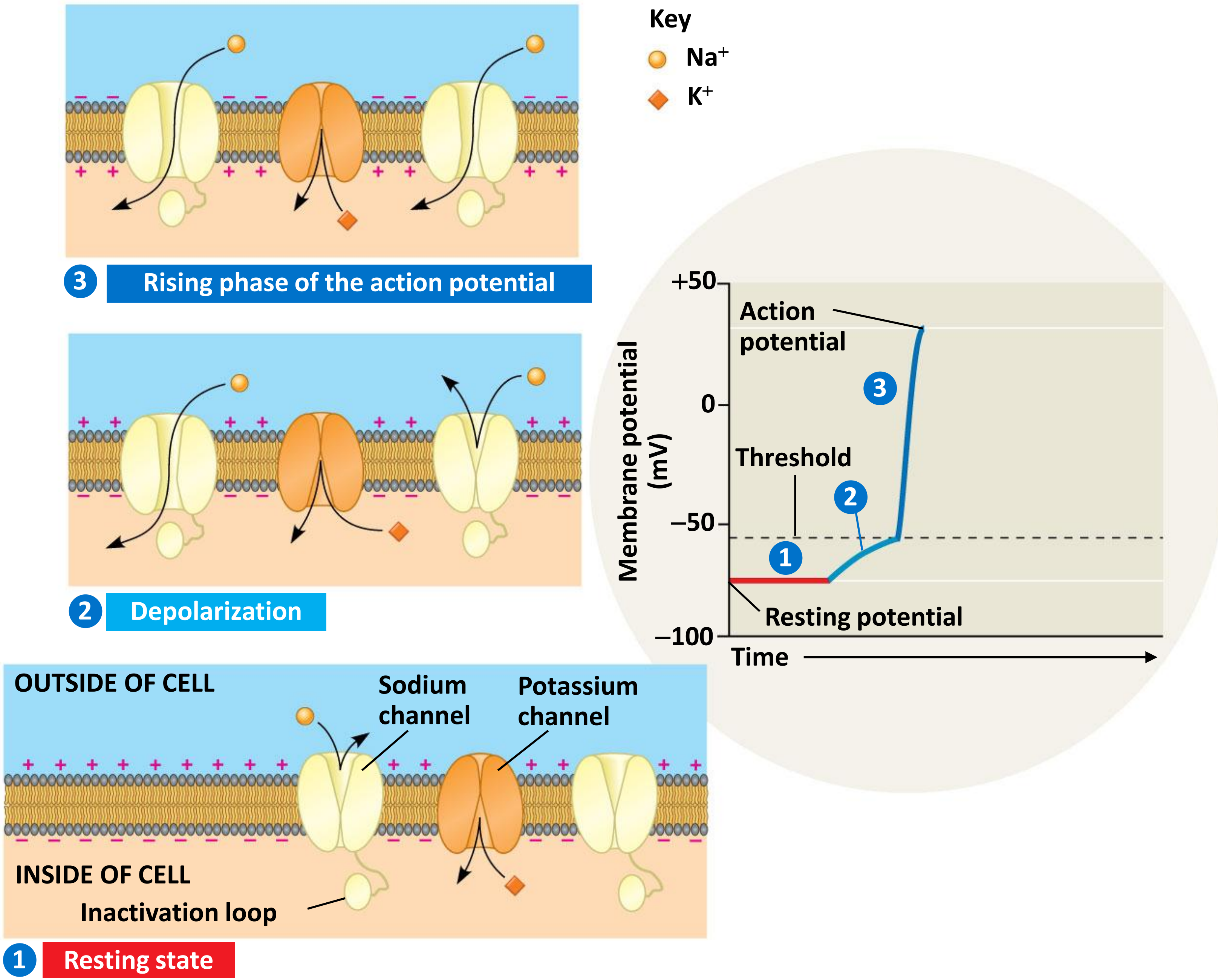
1 Resting state

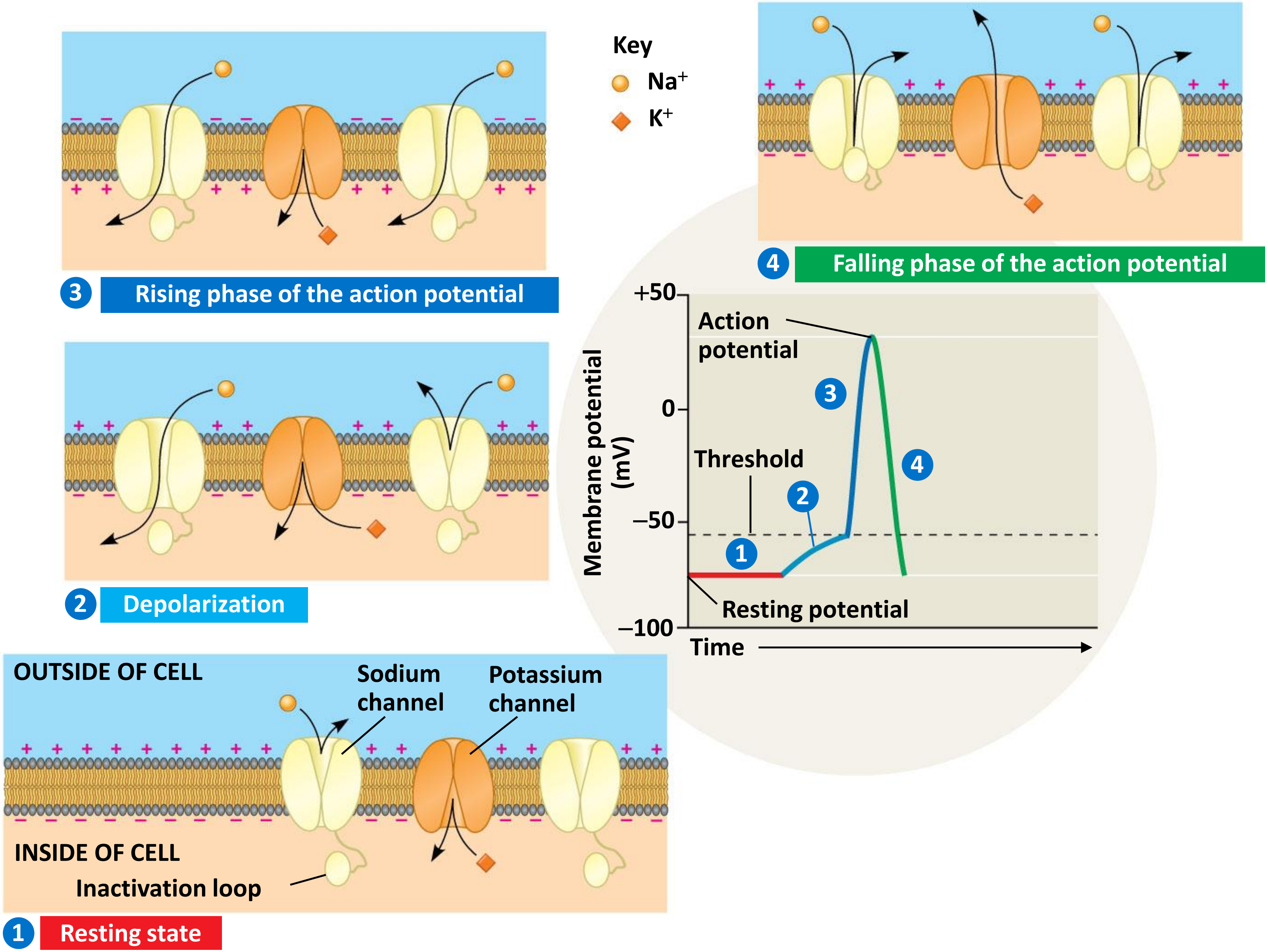
- When an action potential is generated
  2. Voltage-gated Na^+ channels open first and Na^+ flows ***into*** the cell
  3. During the *rising phase*, the threshold is crossed, and the membrane potential *increases to and past zero*


Key
Na+
K+
+50
0
−50
−100
Membrane potential (mV)
Threshold
Resting potential
Time
1
2
Depolarization
OUTSIDE OF CELL
Sodium channel
Potassium channel
INSIDE OF CELL
Inactivation loop
Resting state

- When an action potential is generated

2. Voltage-gated Na^+ channels open first and Na^+ flows ***into*** the cell
3. During the *rising phase*, the threshold is crossed, and the membrane potential *increases to and past zero*
4. During the *falling phase*, voltage-gated Na^+ channels become inactivated; voltage-gated K^+ channels open, and K^+ flows out of the cell


Key
Na+
K+
3 Rising phase of the action potential
2 Depolarization
OUTSIDE OF CELL
Sodium channel
Potassium channel
INSIDE OF CELL
Inactivation loop
1 Resting state
+50
0
−50
−100
Membrane potential (mV)
Action potential
Threshold
Resting potential
Time



Key
Na+
K+
Rising phase of the action potential
Falling phase of the action potential
Depolarization
Resting state
OUTSIDE OF CELL
INSIDE OF CELL
Sodium channel
Potassium channel
Inactivation loop
Membrane potential (mV)
+50
0
−50
−100
Action potential
Threshold
Resting potential
Time
1
2
3
4

5. During the *undershoot*, membrane permeability to K^+ is at first higher than at rest, then voltage-gated K^+ channels close and resting potential is restored

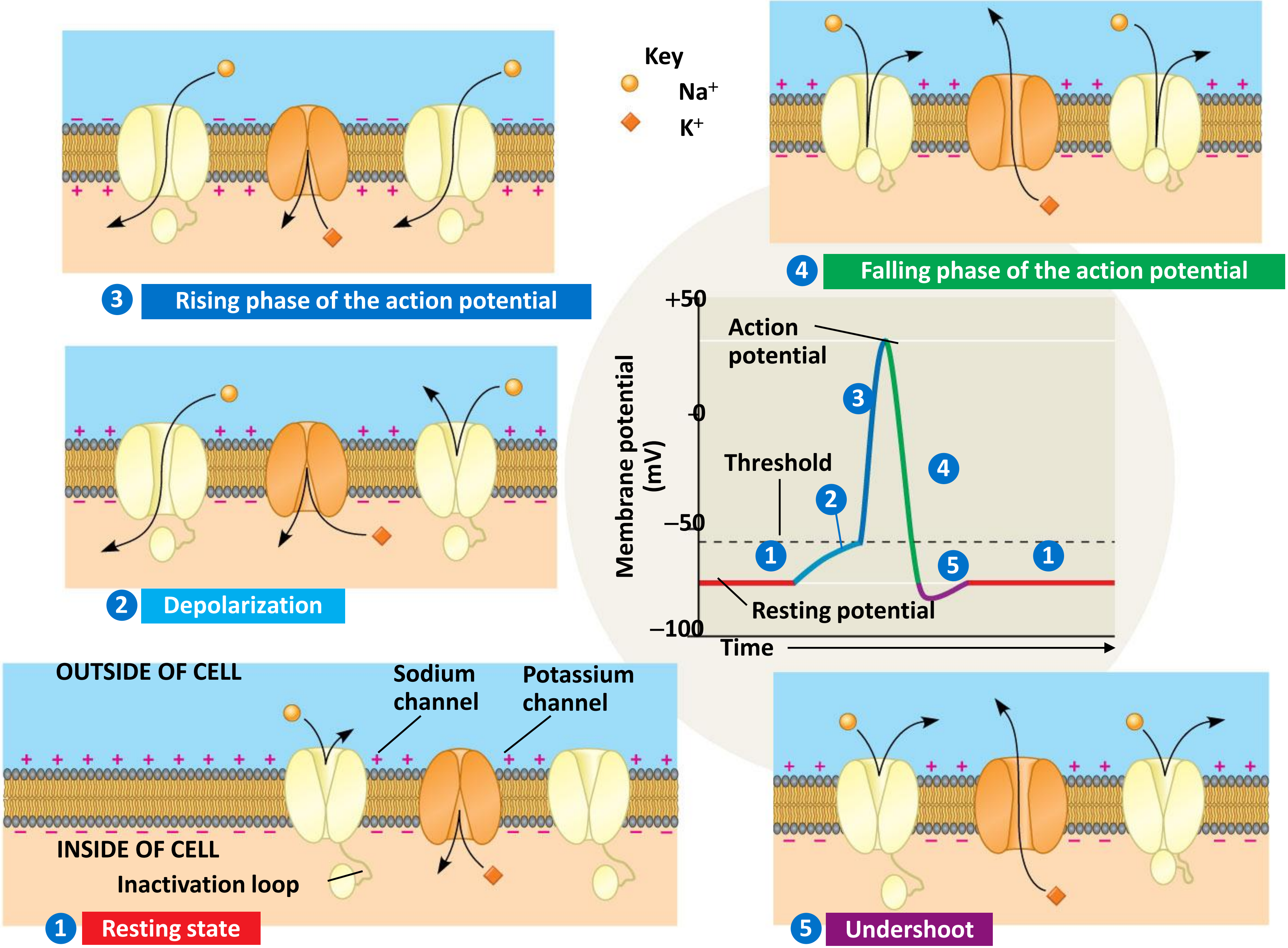
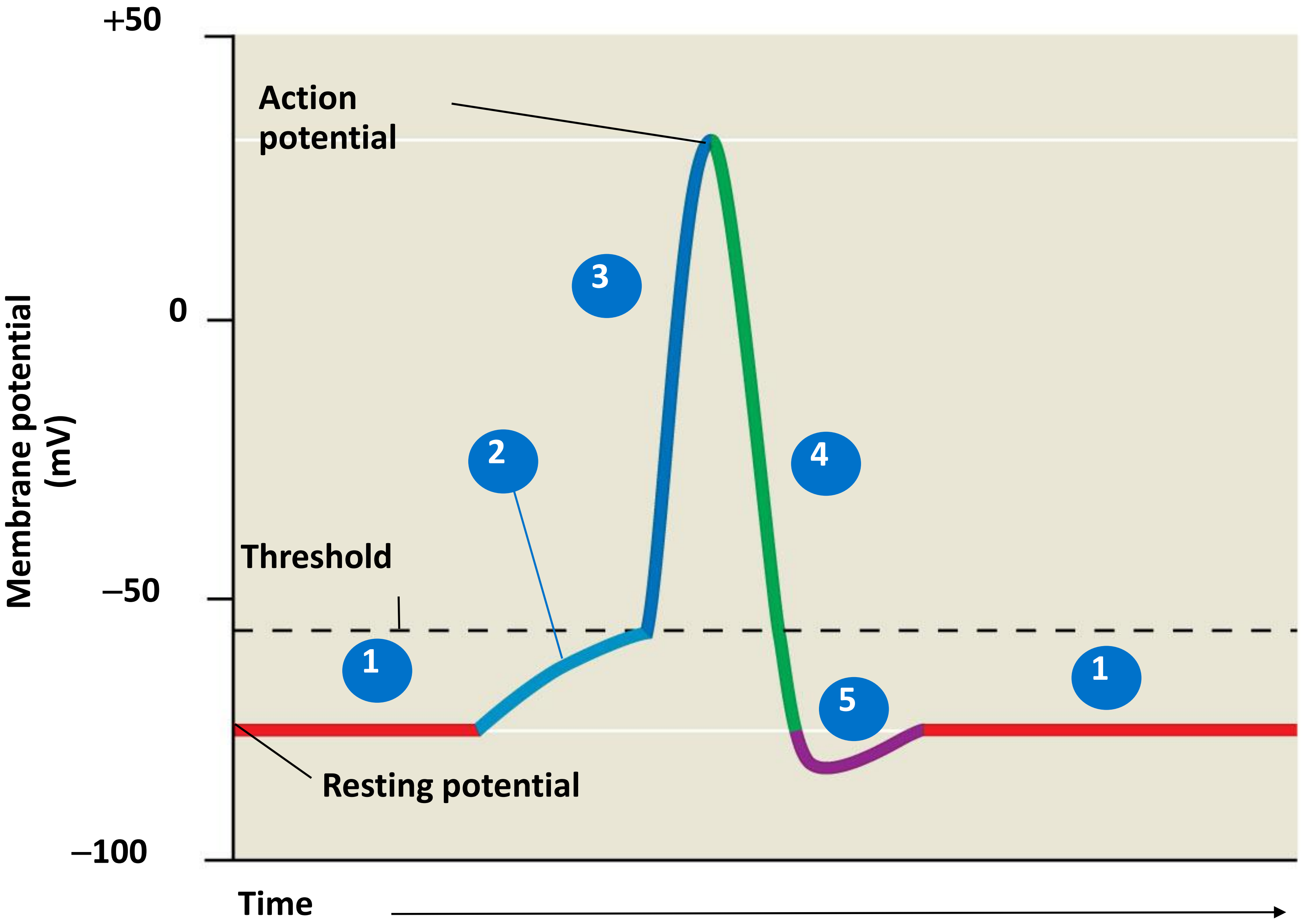
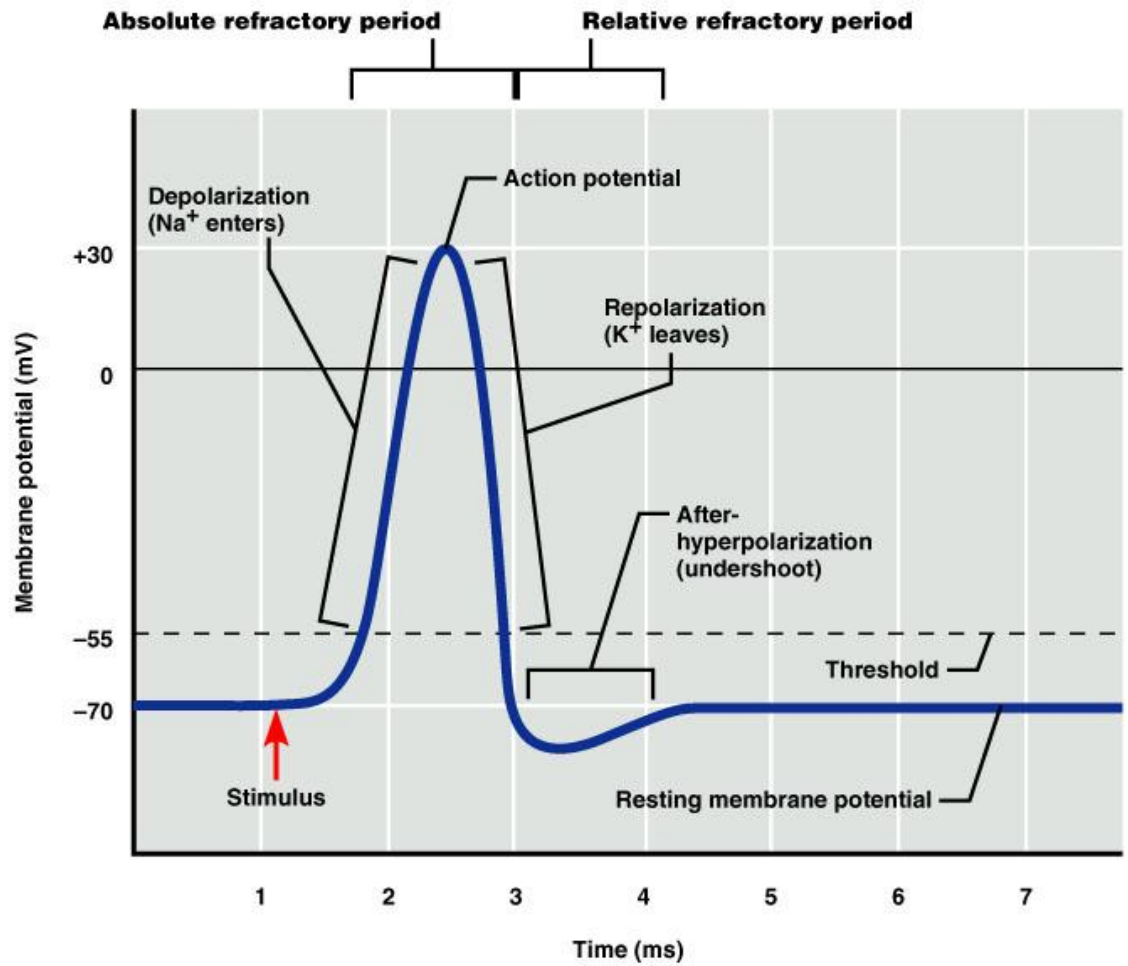

Key
Na+
K+
3 Rising phase of the action potential
4 Falling phase of the action potential
2 Depolarization
1 Resting state
5 Undershoot
OUTSIDE OF CELL
INSIDE OF CELL
Sodium channel
Potassium channel
Inactivation loop
Membrane potential (mV)
+50
0
−50
−100
Action potential
Threshold
Resting potential
Time
1
2
3
4
5
1

Figure 48.11a



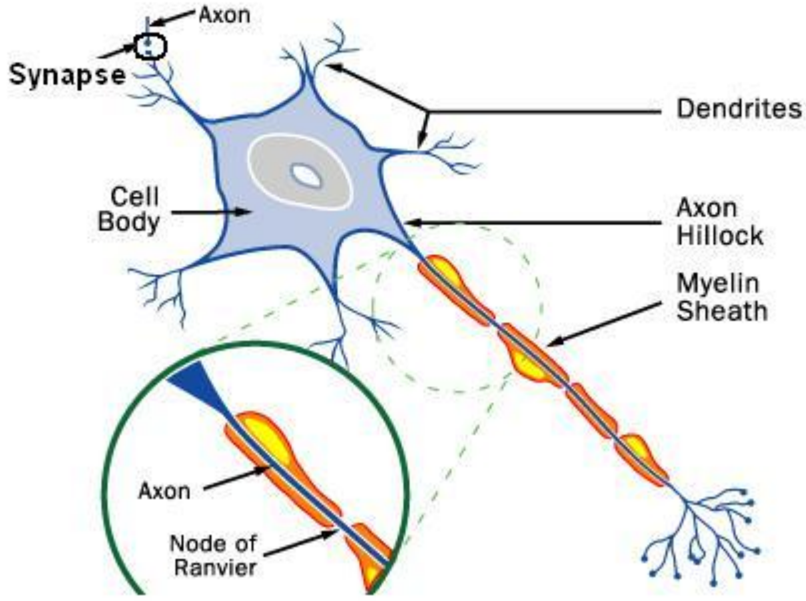
Refractory Period

- During the **refractory period** after an action potential, a second action potential cannot be initiated
- The refractory period is a result of a temporary inactivation of the Na^+ channels

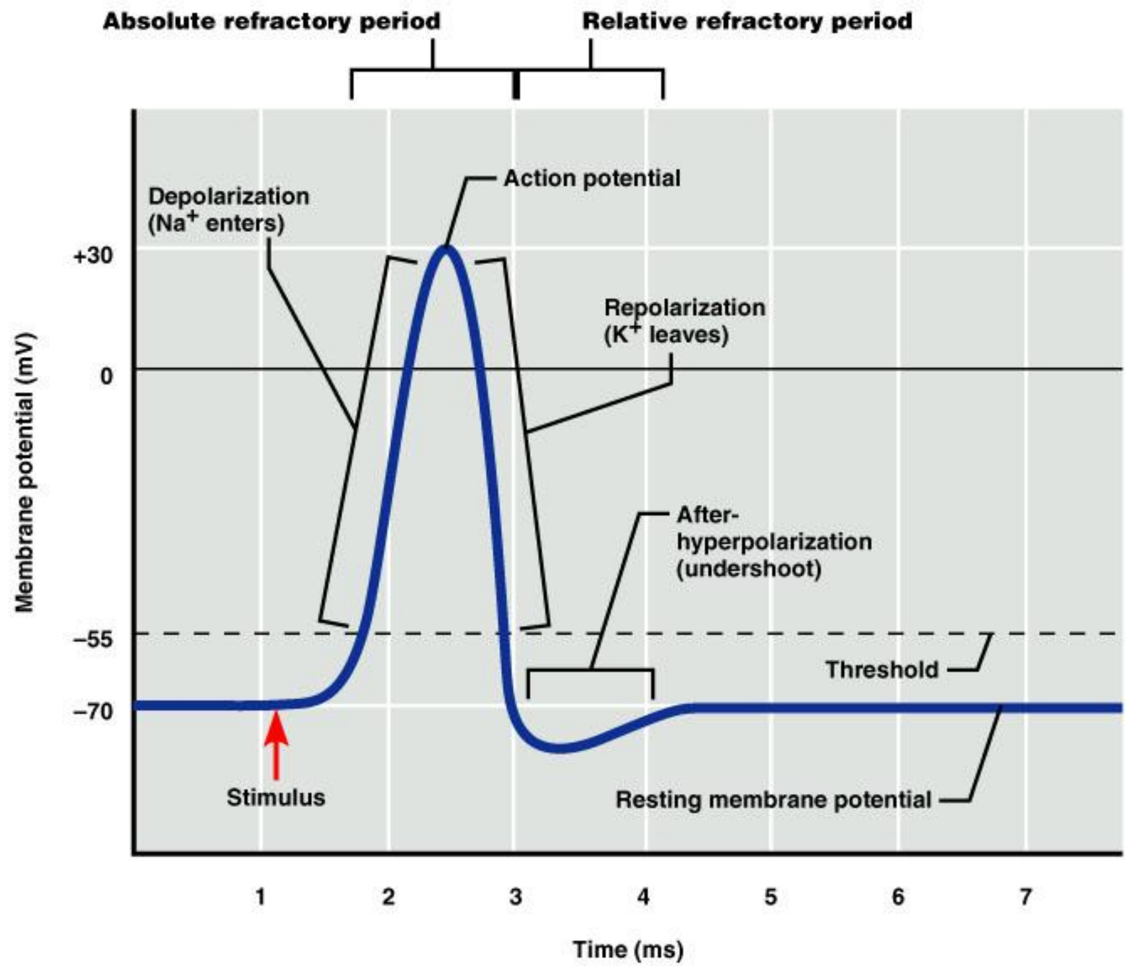


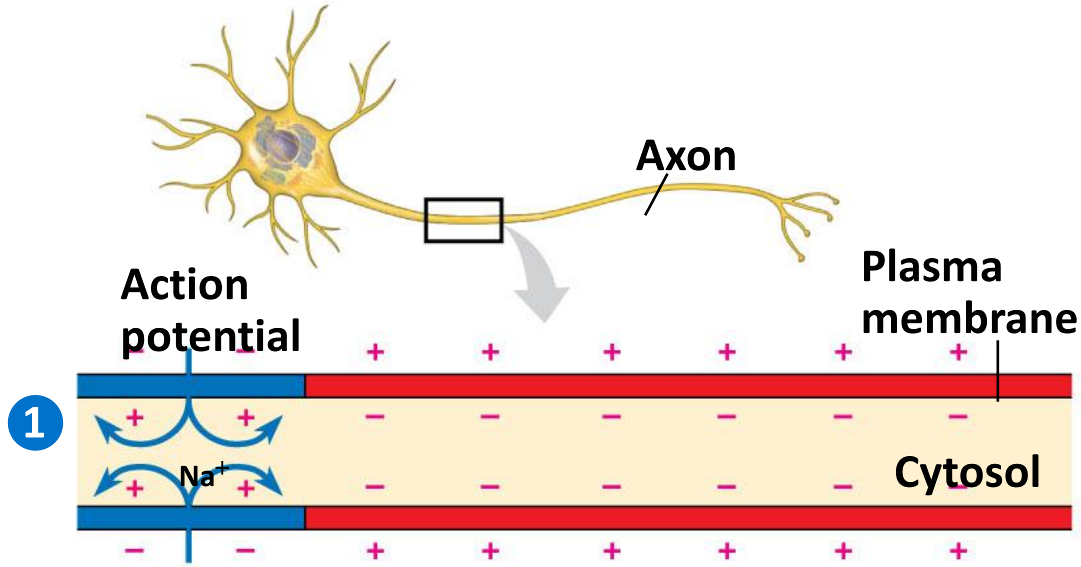
Conduction of Action Potentials

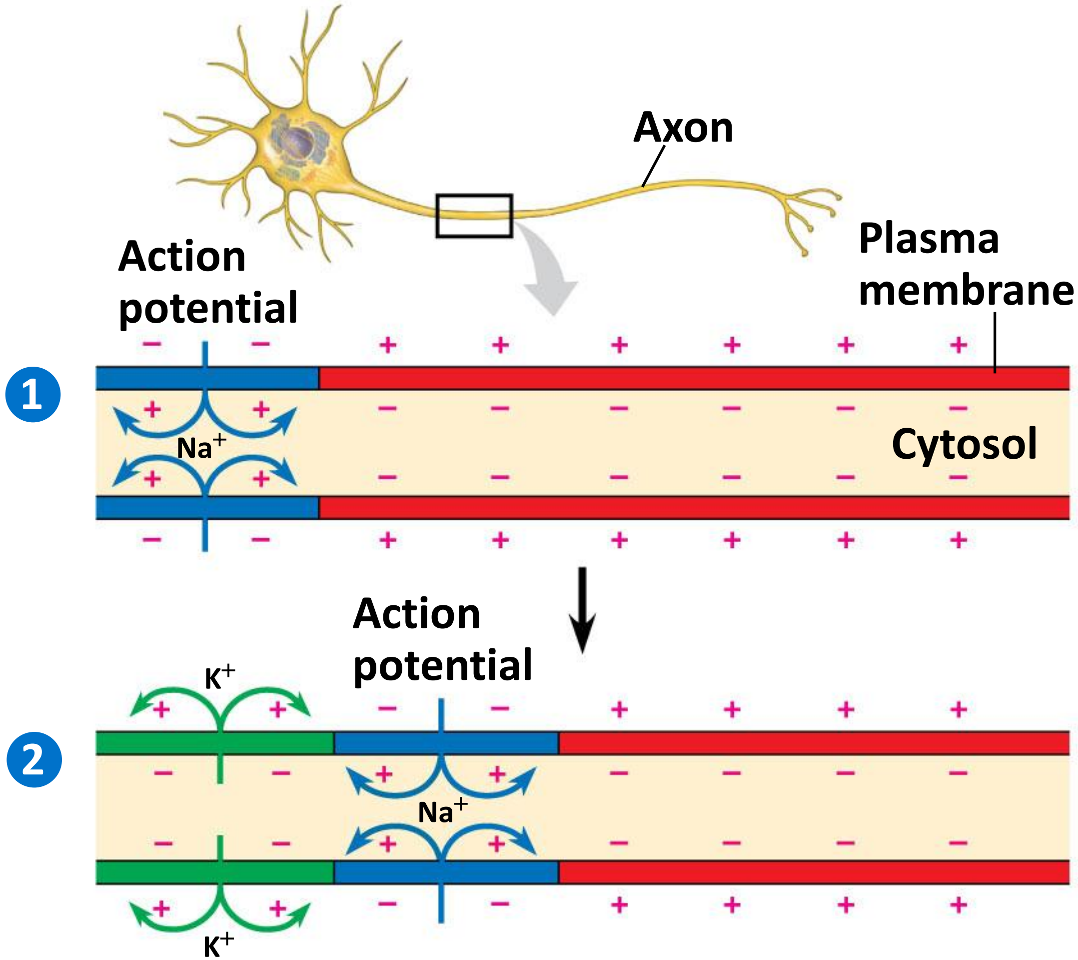
- At the site where the action potential is generated, usually the axon hillock, an electrical current depolarizes the neighboring region of the axon membrane
- Action potentials travel in only one direction: toward the synaptic terminals

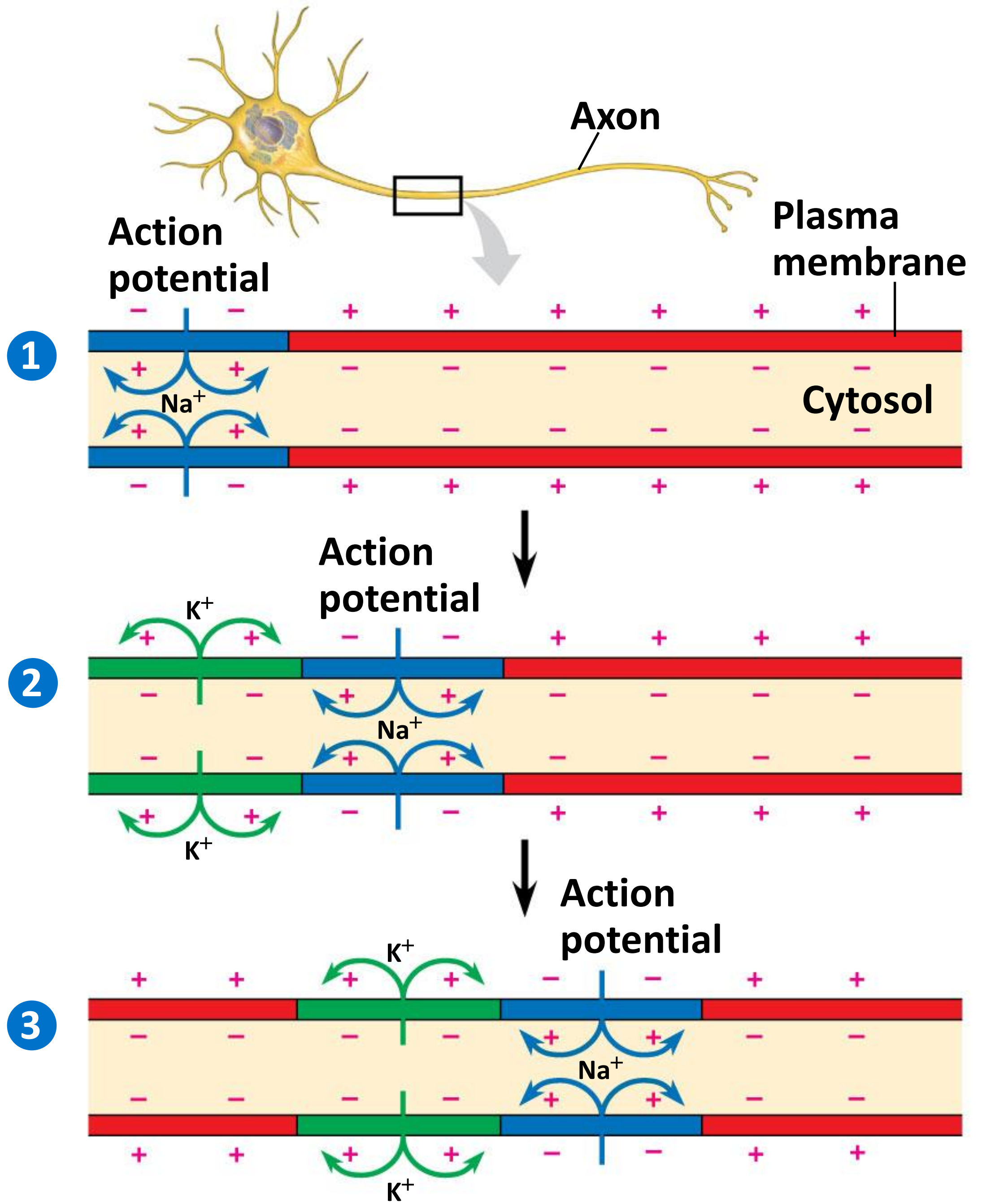


- Inactivated Na^+ channels behind the zone of depolarization prevent the action potential from traveling backwards




Axon
Action potential
Plasma membrane
1
Na+
Cytosol


Axon
Plasma membrane
Action potential
Na+
Cytosol
1
Action potential
K+
Na+
K+
2

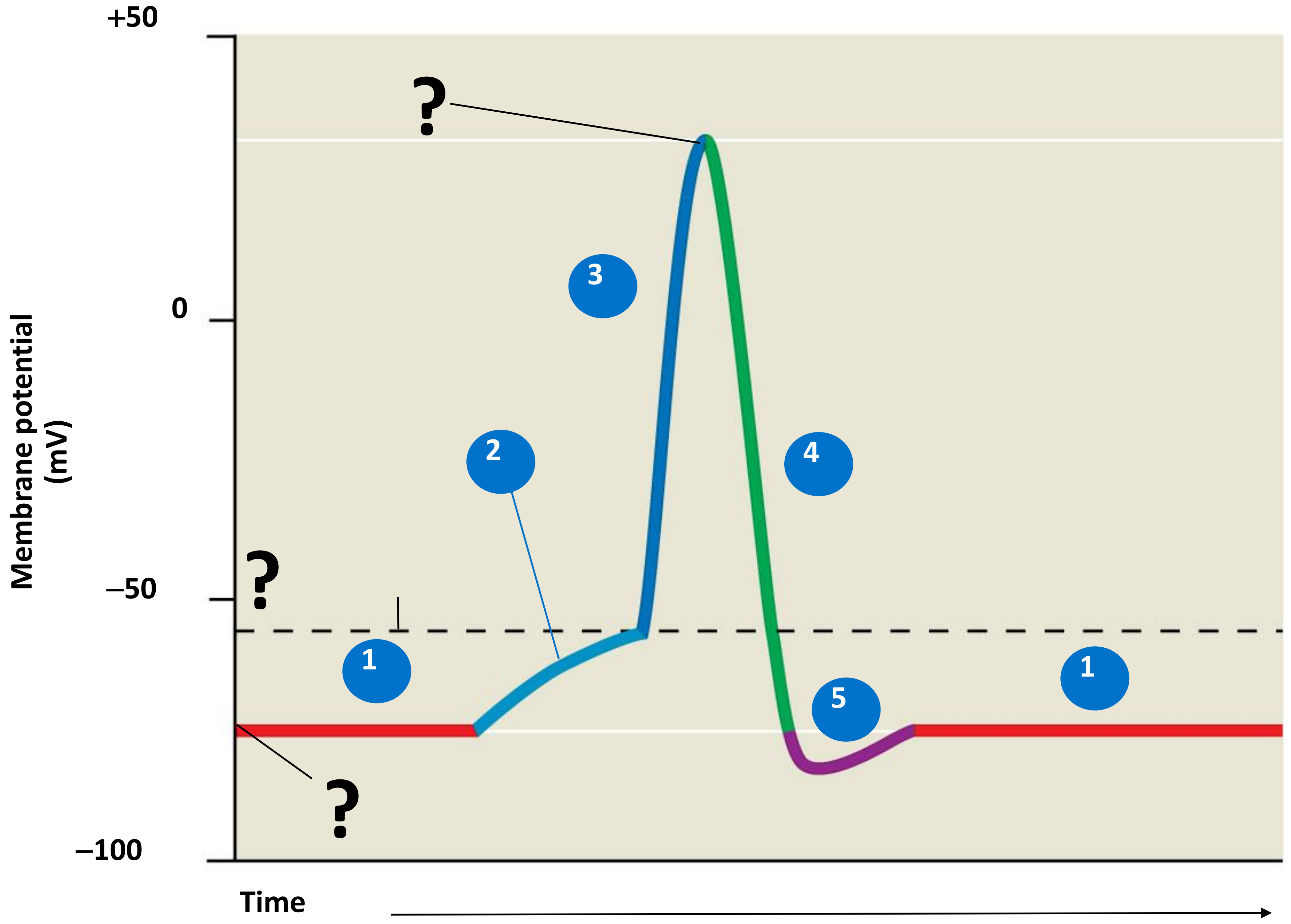

Axon
Plasma membrane
Action potential
Cytosol
Na+
K+
1
2
3

Sequence the following in order of occurrence

- Depolarization
- Resting state
- Repolarization
- Hyperpolarization

Sequenced in order of occurrence

- Resting state
- Depolarization
- Hyperpolarization
- Repolarization
- Resting state


+50
0
−50
−100
Membrane potential
(mV)
?
?
?
1
2
3
4
5
1
Time

A(n) ____ in Na^+ permeability and/or a(n) ____ in K^+ permeability across a neuron's plasma membrane could shift membrane potential from –70 mV to –80 mV.

a. increase; increase

b. increase; decrease

c. decrease; increase

d. decrease; decrease

Adding a poison that specifically disables the Na^+/K^+ pumps to a culture of neurons will cause

a. the resting membrane potential to drop to 0 mV.

b. the inside of the neuron to become more negative relative to the outside.

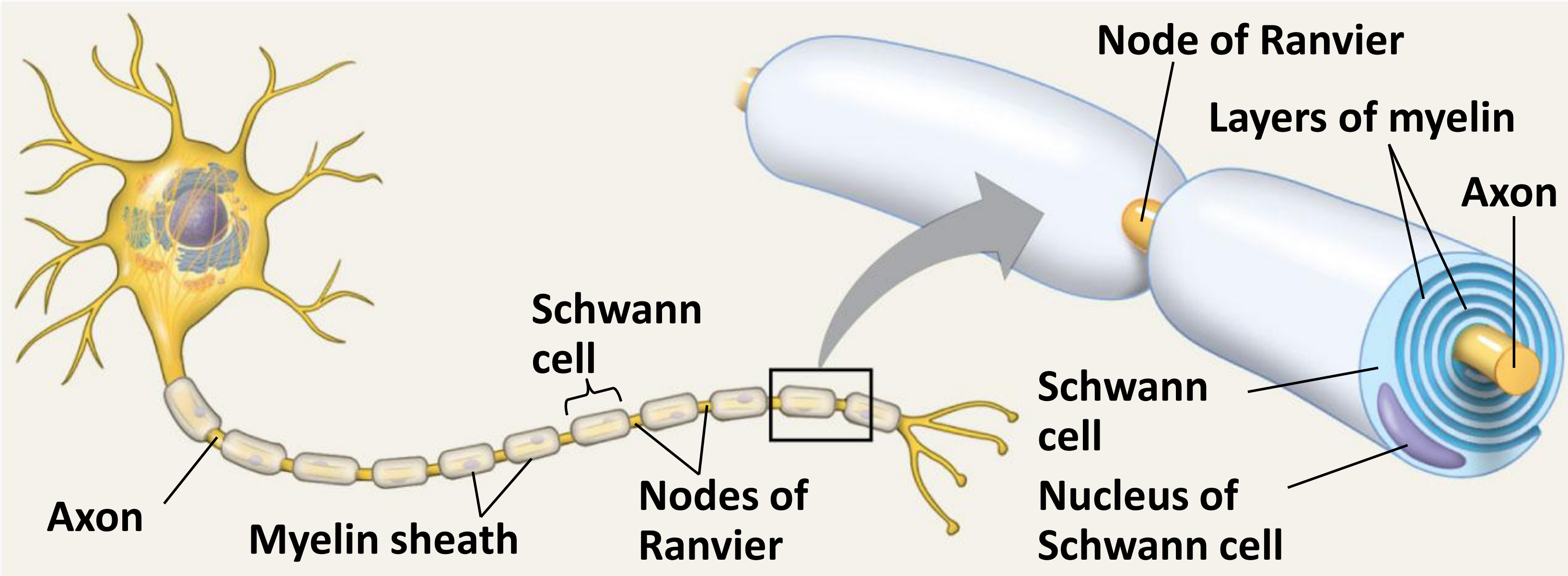
c. the inside of the neuron to become positively charged relative to the outside.

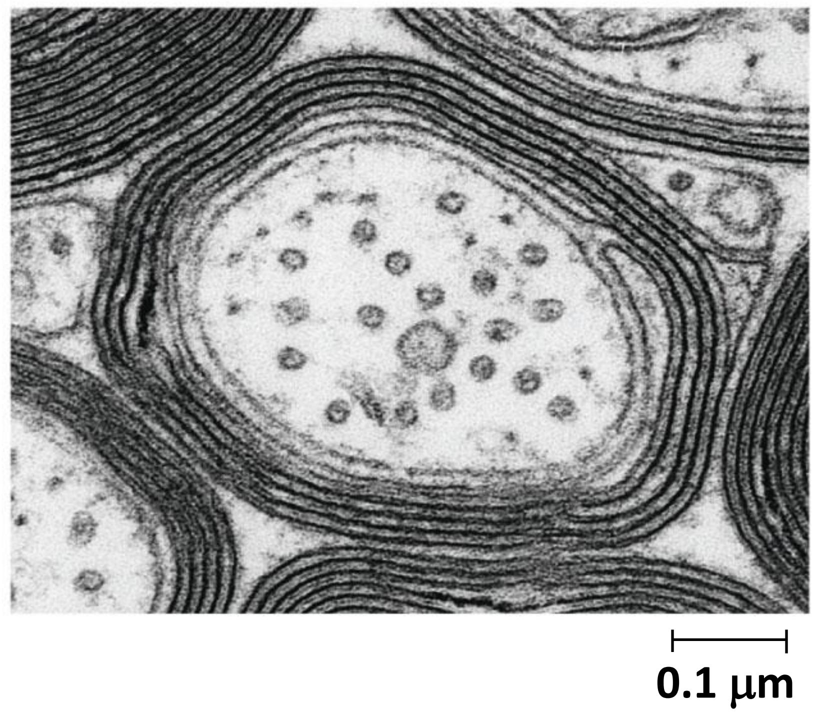
d. sodium to diffuse out of the cell and potassium to diffuse into the cell.

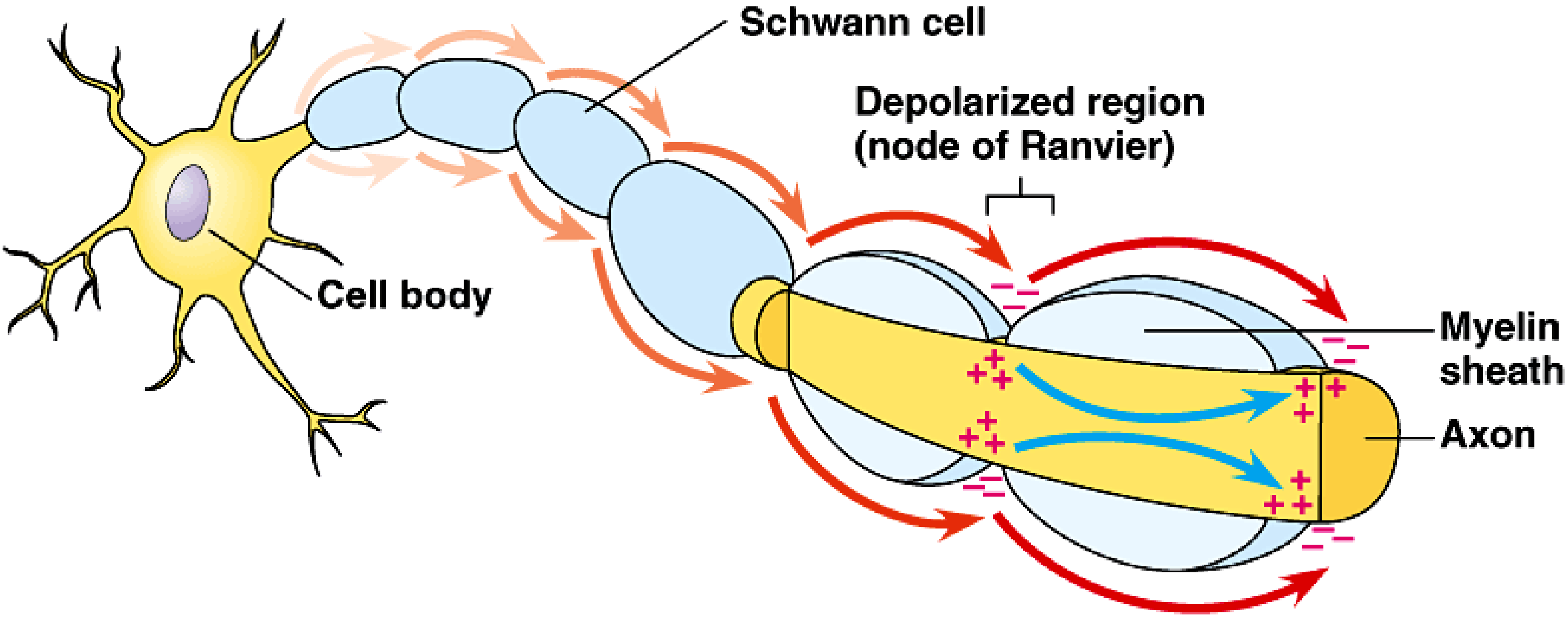
Name three specific adaptions of the neuron membrane that allow it to specialize in conduction

Evolutionary Adaptations of Axon Structure

- The speed of an action potential increases with the axon's diameter
- In vertebrates, axons are insulated by a **myelin sheath**, which causes an action potential's speed to increase
- Myelin sheaths are made by glia—**oligodendrocytes** in the CNS and **Schwann cells** in the PNS


Node of Ranvier
Layers of myelin
Axon
Schwann cell
Schwann cell
Nucleus of Schwann cell
Axon
Myelin sheath
Nodes of Ranvier


0.1 μm



Can you explain why impulses travel faster in myelinated sheaths?

Next time we will explore what happens when the impulse reaches the end of the axon.

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