Knowledge-based Learning Outcomes

Upon completion of *Action Potentials Extended*, students should be able to:

1. Describe action potentials as electric pulses that rapidly convey information within neurons, while neurotransmitters are chemical signals for communication between neurons.
2. Describe how information can be relayed in the rate and timing of action potentials.
3. Describe how blocking action potentials with anesthetics can prevent the perception of pain.
4. Explain basic electric properties of the neuron: Describe membrane potential, and that most neurons are around -65 mV at rest, state the relative amounts of Na^+ and K^+ inside and outside a neuron at rest, and how ions can only cross the cell membrane by moving through specific ion channels.
5. Explain how the opening of Na^+ and K^+ channels result in membrane potential changes, which produce the action potential.
6. Explain how action potentials are an all-or-nothing event, and why a weak stimulus might not trigger an action potential.
7. Distinguish between threshold stimulus and threshold potential.
8. Explain how a change in membrane potential triggers the opening of voltage-gated Na^+ and K^+ ion channels, and describe differences between these two channels (i.e., inactivation, which opens first, etc.).
9. Explain how the propagation of action potentials differs in myelinated and unmyelinated neurons.
10. Describe how electrical forces and diffusion affect ion movement.
11. Define hyperpolarization and depolarization, and describe what causes hyperpolarization and depolarization during an action potential.
12. Define transduction, describe how transduction channels are different from voltage-gated Na^+ and K^+ channels that generate the action potential, and explain why transduction alone is insufficient to relay information through the whole neuron.
13. Describe equilibrium potential as the membrane potential at which electrical forces are opposed and balanced by diffusion, resulting in no net movement of ions into or out of the cell.
14. Describe resting membrane potential and how Na^+ and K^+ conductance affects membrane potential.
15. Explain how ion pumps maintain Na^+ and K^+ concentrations inside and outside the cell membrane and why they require the input of energy.

Skills-based Learning Outcomes

Upon completion of *Action Potentials Extended*, students should be able to:

1. Predict the net direction of ionic movement when Na^+ or K^+ channels are open, given relative ionic concentrations inside and outside of the cell.
2. Identify which part of the action potential is disrupted, given a neuron's response to various toxins, drugs, or diseases.
3. Diagram a neuron, labeling the soma, axon, axon terminal, and dendrites, and annotate their functions.
4. Diagram the flow of ions, into or out of a neuron, that would result in hyperpolarization or depolarization.
5. Draw an action potential on a plot with time on the x-axis and V_m on the y-axis, and annotate the opening, inactivation, and closing of voltage-gated Na^+ and K^+ ion channels.
6. Predict the effect on an action potential, given a perturbation to the Na^+ or K^+ channels. If the perturbation is to a sensory neuron, predict how perception might be affected.
7. Predict the direction ions will move (into/out of the cell), given membrane potential and relative Na^+ and K^+ concentrations.
8. Predict how V_m will change as Na^+ and K^+ conductance changes.

9. Predict how changing the Na^+ and K^+ concentrations inside/outside of the cell will affect membrane potential when Na^+ or K^+ channels are opened.