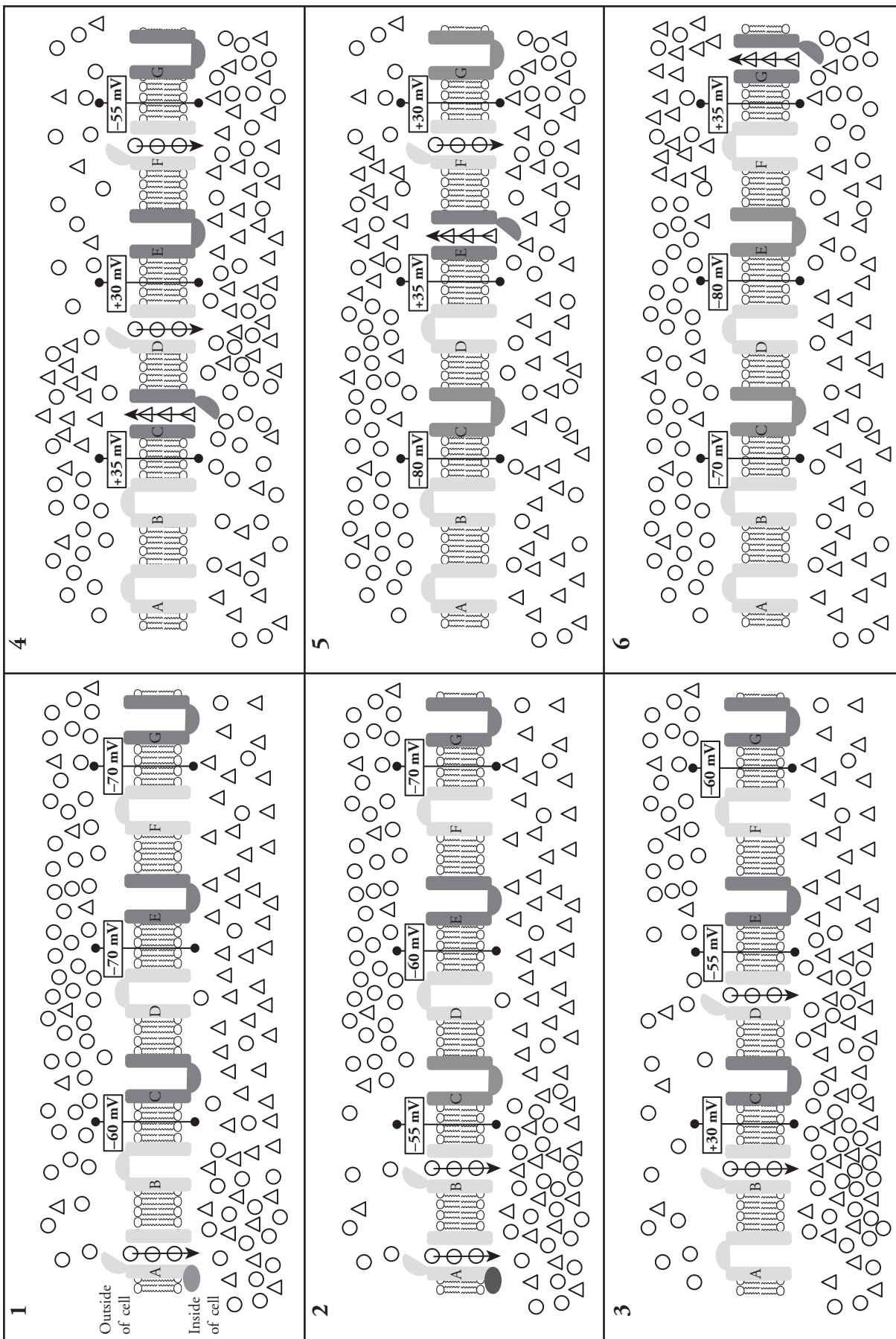# Neuron Function

How does a signal travel across and between neurons?

Why?

Just as the coaxial cables that run down your street or through your house carry television and internet signals, the job of a neuron is to move an electrical signal from one place to another in order to send sensory messages throughout the body. In a previous activity you saw how a membrane potential is formed both at rest and during an inflow of ions. In this activity you will explore how changes in membrane potentials can propagate a signal down the axon of a neuron.

1. Which of the gated embedded proteins in Model 1 allow sodium ions ($\bigcirc$) through the membrane?

2. Which of the gated embedded proteins in Model 1 allow potassium ions ($\triangle$) through the membrane?

3. The neuron illustrated in Model 1 has received a signal from either a sensory cell (taste bud, skin cell, retinal cell, etc.) or from another neuron. What evidence do you find in diagram 1 of the model that indicates a signal has been received?

4. In diagram 2 of Model 1, gated embedded protein B has opened. Was this opening triggered by the arrival of a signal ligand? If no, propose an alternate stimulus that might have triggered the gate to open.

5. Consider Model 1.

   a. When a signal moves down the axon of the neuron, which direction do sodium ions move through the voltage-gated embedded proteins?

   b. What does the movement of sodium ions across the membrane do to the membrane potential near the open embedded protein?

6. Consider Model 1.

   a. When a signal moves through the axon of the neuron, which direction do potassium ions move through the voltage-gated embedded proteins?

   b. What does the movement of potassium ions across the membrane do to the membrane potential near the open embedded protein?

Model 1 – An Action Potential

1

Outside of cell

Inside of cell

−60 mV −70 mV −70 mV

A B C D E F G

2

−55 mV −60 mV −70 mV

A B C D E F G

3

+30 mV −55 mV −60 mV

A B C D E F G

4

+35 mV +30 mV −55 mV

A B C D E F G

5

−80 mV +35 mV +30 mV

A B C D E F G

6

−70 mV −80 mV +35 mV

A B C D E F G

Read This!

When a neuron is resting, the cell membrane is said to be **polarized**. The degree of polarization is measured by the cell membrane potential. The gated embedded proteins in the axon of a neuron are triggered to open by changes in electrical potential across the membrane. The voltage at which they open is called the **threshold potential**.

7. Refer to Model 1.

   a. What is the threshold potential that causes the sodium ion gates to open?

   b. At what potential are the potassium ion gates fully open?

   c. At what potential are the sodium ion gates closed?

   d. At what potential are the potassium ion gates closed?

8. A nerve impulse is said to "move along" the length of the cell. In one or more complete sentences, describe how the electrical signal in the neuron moves. Discuss this with your group members before writing an answer.

9. Consider the diagrams in Model 1.

   a. When the gated embedded proteins (either sodium or potassium) close, do the sodium and potassium ions remain on the side of the membrane that they are on, or do they move back to their original position?

   b. Propose a mechanism that the cell might use to accomplish the change you described in part *a.*

   c. Could another signal be sent down the length of the neuron cell if the sodium ions and potassium ions were not returned to their original position? Explain.

Read This!

When the action potential is in progress the cell membrane is **depolarized**—the potential difference between the two sides of the membrane is decreased. After a sodium ion gate has been opened and closed, it is in a **refractory period** where the membrane potential in the immediate vicinity is very low and the embedded protein cannot be opened again. This is called **hyperpolarization** and **repolarization**.

10. Consider the parts of the word "hyperpolarization" and write a definition of this state of the neuron.

11. According to Model 1, what is the membrane potential near sodium ion gates during the refractory period?

12. Nerve impulses always move in one direction. Explain how the refractory period for a voltage-gated embedded protein is necessary to make this possible.

13. The graph below shows the voltages near embedded protein B of Model 1 versus time. Identify the points on the graph where each of the diagrams (1–6) in Model 1 occurred.
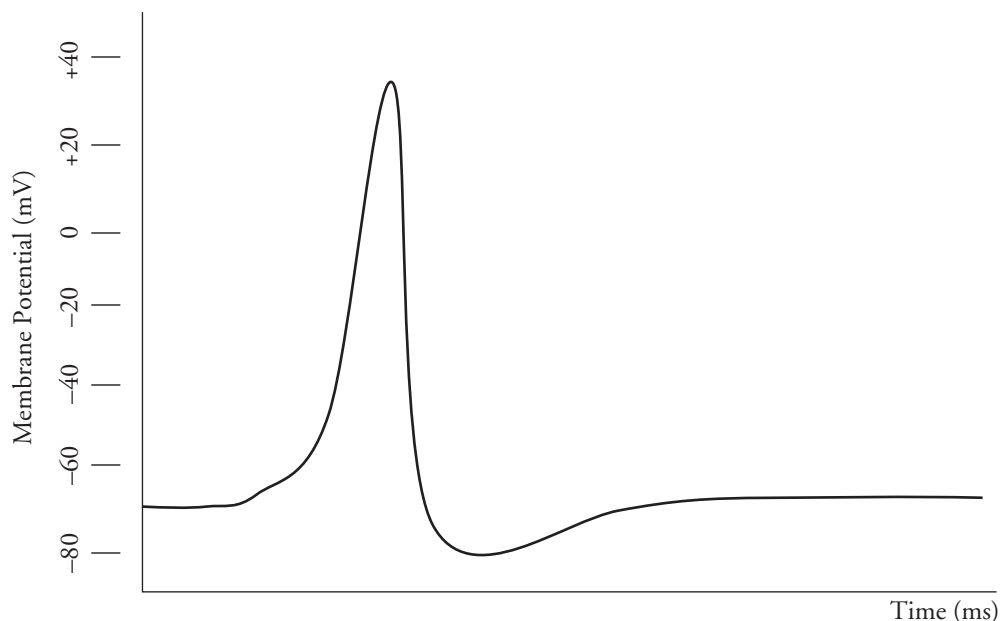
14. Which diagrams in Model 1 represent the following states for embedded protein B?

    a. Polarization   _____
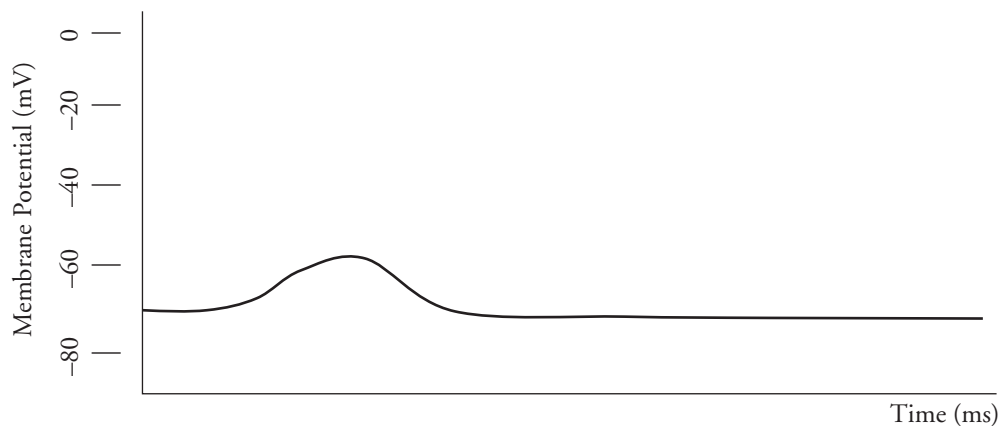
    b. Depolarization   _____

    c. Hyperpolarization   _____

15. Consider the membrane potentials near voltage-gated protein D in Model 1. Sketch the membrane potential curve for gate D on the graph in Question 13 using a dotted line.

16. Examine the graph of a membrane potential below. Did the sodium ion gate in this section of the membrane open? Justify your reasoning.


17. Not every signal that a neuron receives is acted upon and transmitted to the next nerve cell. In some cases the signal is too weak to make the membrane potential reach the threshold potential. What advantage does the organism have when there is a minimum signal required that may have influenced the evolution of this mechanism?

STOP

Extension Questions

18. One student described the diagrams in Model 1 by saying "As more gates open the concentration of sodium inside the cell increases and this causes even more gates to open." Is this an example of a positive or negative feedback loop? Justify your reasoning.

19. Consider the following analogy to the function of a neuron. Use the numbers in the statements of the analogy and indicate the segments of the membrane potential graph that match.
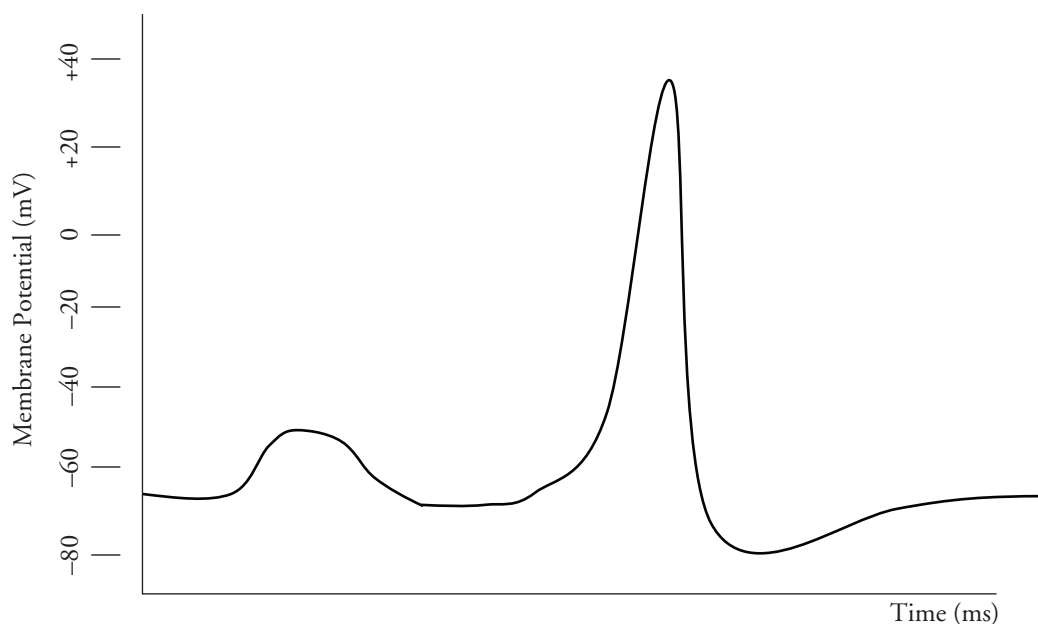
1. Hanging out after school.

2. Your cell phone rings. It's your mother. You don't answer. She leaves a message.

3. Your cell phone rings. It's your best friend. You pick up.

4. Your friend invites you to go on vacation with his/her family.

5. You hang up. You don't feel like talking to anyone right now.

20. For a neuron to function, an input of free energy from ATP is required to set up the sodium and potassium ion concentration gradients such that a signal can be propagated down the axon of a neuron without the necessity of ATP. The system could have worked the opposite way. The neuron could have used ATP to move ions across when a signal was being propagated and then allow natural diffusion to return the ions to their respective sides of the membrane. What advantage does the organism have using ATP up front?