Signal Across a Gap

Trace how an electrical signal becomes a chemical message and back again.

HS-AP5-4 "Identify and model how action potentials are generated, via neurotransmitters, the ions and channel protein involved, and the basic structural and functional aspects which allow for synaptic connection."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline each change in ion movement that helps a signal start, travel, or trigger neurotransmitter release, circle the structures or channel proteins involved, and number the underlined changes in signal order.

From Starting Signal to Synapse

1. When a runner hears the starting signal, one neuron can pass information to another across a tiny gap called a synaptic cleft. The sending neuron's axon ends in a terminal that faces a receiving neuron's dendrite. Neurotransmitters released from the terminal cross the cleft and bind to receptor proteins on the dendrite. Some receptors are ion channels that open when a neurotransmitter binds. If enough positive ions, often Na^+, enter, the receiving neuron's membrane becomes less negative. Many small inputs can add together. An action potential begins only if the membrane reaches a threshold near the start of the axon.

2. At rest, a neuron's membrane has unequal ion concentrations on its two sides, maintained partly by the sodium-potassium pump and leak channels. At threshold, voltage-gated Na^+ channels open near the start of the axon. Na^+ rushes in, making that patch of membrane more positive. This change triggers nearby voltage-gated Na^+ channels to open, so the action potential travels along the axon. Voltage-gated K^+ channels then open, and K^+ leaves the cell, bringing the membrane back toward its resting voltage. The moving signal is a brief change in membrane voltage, not a stream of neurotransmitter flowing down the axon.

3. When the action potential reaches the axon terminal, its voltage change opens voltage-gated Ca^{2+} channels. Ca^{2+} enters the terminal and helps membrane-bound sacs called vesicles fuse with the terminal membrane. The vesicles release neurotransmitter into the synaptic cleft. Neurotransmitter diffuses across the gap, so the two neurons need not touch. Receptors on the receiving dendrite respond only to molecules that fit them, linking the chemical message to a new electrical change. Whether that change starts another action potential depends on the receiving neuron's combined inputs reaching threshold. Without enough input, a signal may stop at this connection.

2 ANSWER WITH EVIDENCE

Use the passage

1. How do the positions of the axon terminal, synaptic cleft, and dendrite allow one neuron to affect another without the cells touching?

2. How can inputs at the dendrite lead to an action potential that travels down the axon? Name the ion and channel involved.

3. After Na^+ enters during an action potential, how do voltage-gated K^+ channels change the membrane voltage?

4. Trace how an action potential arriving at the axon terminal leads to neurotransmitter entering the synaptic cleft. Include the ion, channel, and vesicles.

3 YOUR TURN

Your own words

A mutation changes a receiving neuron's receptor so the usual neurotransmitter cannot bind. In four to five sentences, explain what happens when a signal reaches the sending neuron's terminal and whether a new action potential forms in the receiving neuron, assuming this is its only input. Name two ions and at least three structures or channel proteins.

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PART 1 · READ AND MARK

Underline each change in ion movement that helps a signal start, travel, or trigger neurotransmitter release, circle the structures or channel proteins involved, and number the underlined changes in signal order. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	How do the positions of the axon terminal, synaptic cleft, and dendrite allow one neuron to affect another without the cells touching?	**The axon terminal faces the receiving dendrite across the cleft. Neurotransmitter released from the terminal crosses the gap and binds to receptors on the dendrite.**
2	How can inputs at the dendrite lead to an action potential that travels down the axon? Name the ion and channel involved.	**Inputs can add together until the membrane reaches threshold near the start of the axon. Voltage-gated Na^+ channels open, and Na^+ enters; the voltage change opens nearby channels, carrying the action potential along the axon.**
3	After Na^+ enters during an action potential, how do voltage-gated K^+ channels change the membrane voltage?	**The K^+ channels open, allowing K^+ to leave the cell. The membrane moves back toward its resting voltage.**
4	Trace how an action potential arriving at the axon terminal leads to neurotransmitter entering the synaptic cleft. Include the ion, channel, and vesicles.	**The voltage change opens voltage-gated Ca^{2+} channels. Ca^{2+} enters and helps vesicles fuse with the terminal membrane, releasing neurotransmitter into the cleft.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

The arriving action potential opens voltage-gated Ca^{2+} channels in the sending neuron's axon terminal. Ca^{2+} enters, helping vesicles release neurotransmitter into the synaptic cleft. The neurotransmitter cannot bind to the changed receptors on the receiving dendrite, so those receptor channels do not open to let Na^+ enter. With no other input, the receiving neuron does not reach threshold, and its voltage-gated Na^+ channels do not start a new action potential.

Accept descriptions that correctly connect threshold to voltage-gated Na^+ channels, repolarization to K^+ leaving, and terminal release to Ca^{2+} entering. For Part 3, the key distinction is that release can occur in the sending neuron even though the changed receptor prevents this input from starting an action potential in the receiving neuron.