

BRAIN CHEMISTRY
TEACHER'S GUIDE

NEUROTRANSMITTERS CONTAIN CHEMICALS

WRITTEN BY

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Page 1: SEM image of a nerve ending with its neurotransmitters courtesy by Tina Carvalho, MS, (released to public domain) and courtesy of the National Institute of General Medical Sciences, NIH, <http://images.nigms.nih.gov/index.cfm?event=viewDetail&imageID=1244>.

Page 2: Microscopic image of a hippocampal neuron courtesy of Robert S. McNeil © Baylor College of Medicine. <http://www.neuralimages.org/>.

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OVERVIEW

Students play a simple card game to learn the sequence of events in the transmission of nervous system signals.

NEUROTRANSMITTERS CONTAIN CHEMICALS

Each of the billions of neurons in the nervous system communicate with one another and with other cells, such as muscle cells, through special junctions known as synapses. Some neurons share synapses with thousands of other cells. Others connect with only a few cells. As noted earlier, nervous system signals travel along the cell membranes of individual neurons, but what happens at the ends of neurons? How does a signal move across the synapse to other neurons? The answers to these questions involve highly efficient mechanisms that allow signals to be transmitted from neuron to neuron.

Nervous system signals generally travel in only one direction along a neuron. Signals are received on dendrites or on the cell body and trigger an electrical impulse that moves along the axon. Once the signal reaches the end of the axon (or axon terminal) of a neuron, it must move

through the synapse to the next neuron. At the most common type of synapse, known as a chemical synapse, the impulse triggers the release of chemical messengers, called neurotransmitters, from special pockets known as vesicles. Neurotransmitters released from the vesicles leave the cell and physically move through the narrow watery space (the synaptic cleft) between neurons. The space between neurons is about 20 nanometers (one nanometer equals 0.000,000,1 centimeters). Once on the other side of the gap, the neurotransmitters attach to special receptor molecules on a dendrite or on the cell body of the receiving neuron. The joining of the neurotransmitters to their specific receptor sites can promote the generation of a new electrical impulse (the neuron “fires”) OR the neurotransmitters can have an inhibitory effect, making it harder for the neuron to fire.

Biologists have identified more than 100 different neurotransmitters. Each has a different three-dimensional shape, which fits only a certain kind of receptor site. The relationship between a neurotransmitter and its receptor is similar to that of a key and a lock.

The story does not end, however, with the binding of the chemical messengers to receptors on the next neuron. If the messengers remained in place, no new signals could be received. Thus, mechanisms to remove the messenger from the synapse also exist.

CONCEPTS

- Nervous system signals are transmitted electrically along individual neurons.
- Neurons are separated from each other by a tiny gap.
- Chemical messengers called neurotransmitters cross the gap between neurons.
- Neurotransmitters fit into special receptor sites on receiving neurons.

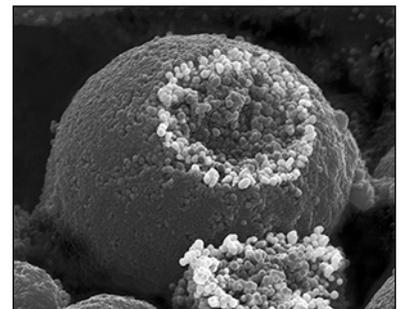
SCIENCE & MATH SKILLS

Sequencing, communicating, applying knowledge and identifying patterns

TIME

Preparation: 10 minutes

Class: 45 minutes



A scanning electron microscope image of a nerve ending (large, dark gray round object). It has been broken open to reveal vesicles containing chemicals (light gray oval shapes) used to pass messages in the nervous system.



UNIT LINKS

Legacy of Lost Canyon
Chapter 7
Science boxes, p. 22-24

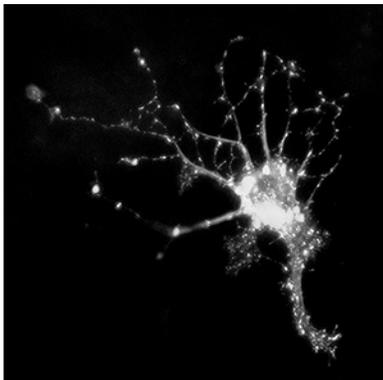
Brain Chemistry Explorations
“Chemistry Connections,”
p. 5



DEFINITION: NEUROTRANSMITTER

Researchers define a substance as a neurotransmitter when it meets the following criteria.

- The substance is synthesized in a neuron.
- The substance can be found in axon terminals of the neuron believed to release the neurotransmitter.
- The substance is released in response to an electrical signal in the cell membrane.
- When released from a neuron or applied (as a drug) onto an appropriate cell, the substance causes a biological effect.
- A mechanism exists to inactivate and/or remove the substance from the synaptic cleft.



Microscopic image of a single neuron stained to reveal specific receptors.

In some cases, neurotransmitters simply float (diffuse) away from the synapse. Other neurotransmitters are broken down or degraded by enzymes found within the synaptic cleft. Many neurotransmitters are transported, whole, back into the neuron that released them. Some drugs, such as cocaine and fluoxetine (Prozac[®]), exert their effects by interfering with the removal of neurotransmitters from the synapse.

Sometimes, neurons do not communicate through neurotransmitters. Instead, an electrical charge passes directly from neuron to neuron through what is known as an electrical synapse. This type of signaling, in which the communicating neurons are very close together, is very fast and allows many interconnected neurons to fire at the same time. Electrical synapses are less common than chemical synapses, but they are very important for the normal development and function of the nervous system.

MATERIALS

Teacher (See Setup)

- 24 sheets of 8-1/2 in. x 11 in. white card stock
- 6 bags, resealable plastic (approx. 4 in. x 6 in.)
- Document projector (or overhead projector and transparency of the “Transmitters & Receivers”

page from the activity, “What Is a Neuron?”)

Optional: Set of dominoes or small wooden blocks

Per Student

- Copy of “Locks & Keys Cards” and “Rules of Play” pages
- Pair of scissors

SETUP

Make photocopies of the “Locks & Keys Cards” page using white card stock (four per group) and photocopies of “Rules of Play” page using copy paper (one per student). Have students conduct this activity in groups of four.

PROCEDURE

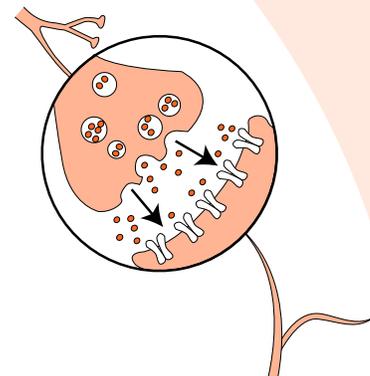
Learning About Chemical Messengers

1. Remind students of the “Neural Network Signals” activity by asking, *What happened when you tested whether salt water would conduct electricity?* Students should remember that salt dissolved in water carried the electrical current from one foil strip to the other, thus completing the circuit.
2. Tell students that rapid movements of dissolved substances like those in salt also make it possible for neurons to transmit electrical signals along the lengths of their axons. In the case of neurons, a single pulse of electricity is transmitted along the axon rather than a current.

Optional: You may want to set up a row of dominoes or small wooden blocks to demonstrate how toppling one domino will set off an impulse that topples each domino in sequence, and correlate this action to the movement of an electrical impulse along a cell membrane.



CHEMICAL COMMUNICATION



In most cases, communication across the synapse occurs chemically instead of electrically. Chemical messengers, called neurotransmitters, can either promote or inhibit the firing of receiving neurons.

GASES AS NEUROTRANSMITTERS

Scientists have discovered that some gases, such as nitric oxide, can serve as neurotransmitters. Unlike classical neurotransmitters, these molecules are made on demand and released from neurons by diffusion (the movement of dissolved substances through water or other medium).

- Project the “Transmitters & Receivers” page. Point to the top neuron and ask, *Where would signals be received on this neuron?* (dendrites or cell body). *If a signal travels along this neuron, where will it go?* (signal will travel the length of the axon).
- Point to the gap between the two neurons and ask, *What happens when the signal reaches the end of the axon? How could the message get to the next cell?* Allow students to discuss different scenarios. List their suggestions on the board. (You may want to group their suggestions into two broad categories: one representing scenarios related to electrical transmission and the other related to possible kinds of chemical transmissions.)
- Use questions to help students evaluate their list of possible ways for signals to cross the synapse from one neuron to the next. Ask, *Which of these choices would allow for rapid communication?* (electrical-type communications). *Which might allow neurons to send and receive different messages?* (systems that use different messengers, such as chemicals).
- Point out that in some cases, neurons in the human nervous system transmit messages electrically to other neurons. However, in most cases, special chemical messengers (neurotransmitters) are released and travel across the gap to the next neuron, where they attach to molecules called receptors.
- Distribute photocopies of the “Locks & Keys Cards” and “Rules of Play” pages (see Setup) to each group of students. Have students cut out the cards and arrange one set of cards in a logical sequence using the text at the bottom of each card as a guide. Discuss the sequence of events shown in the cards with the class. Point out that even though the cards depict a sequence in which a neurotransmitter promotes the firing of another neuron, neurotransmitters also can communicate a “stop” message, which makes it harder for the next neuron to fire.
- Make a list on the board of the transmission sequence in neuron communication: 1) Message Received; 2) Neuron Fires!; 3) Axon; 4) Neurotransmitters; 5) Synapse; 6) Receptor; 7) New Message; and 8) Recycle. List the sequence in order (top to bottom), but do not number the list.

Playing the Game

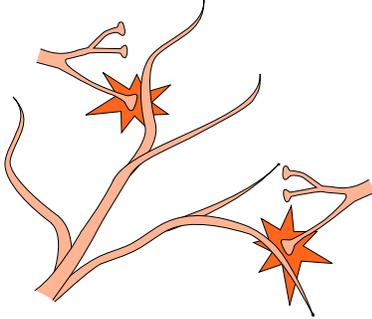
- Leave the list of steps on the board to help students as they play the game. Depending on the ages and prior knowledge of your students, you may want to erase the sequence after students have played a few rounds of “Locks & Keys.”
- Explain game rules to students, which are similar to the card game “Go Fish.”
- Have students play the game for two or more rounds, or until they are comfortable with the sequence of events depicted on the cards.
- Have students place cards in the clear plastic bags for storage.





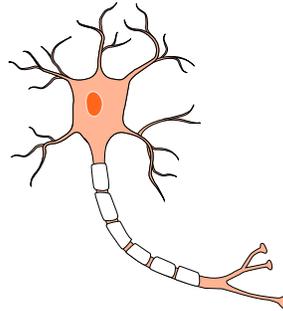
LOCKS & KEYS CARDS

MESSAGE RECEIVED



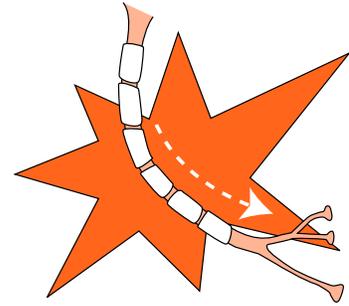
Messages are received on dendrites or on the cell body.

NEURON FIRES!



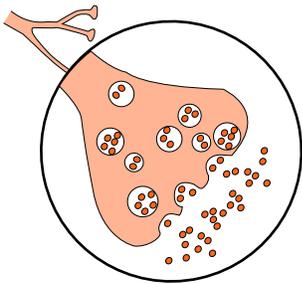
The combined messages generate an electrical impulse.

AXON



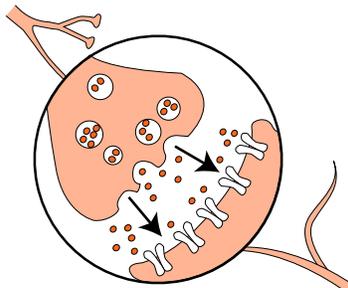
The impulse travels to the end of the axon.

NEUROTRANSMITTERS



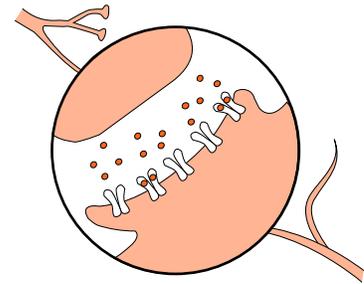
The impulse causes neurotransmitters to be released from the axon.

SYNAPSE



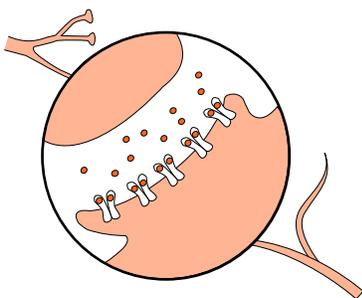
Neurotransmitters move across the gap (synaptic cleft) between neurons.

RECEPTOR



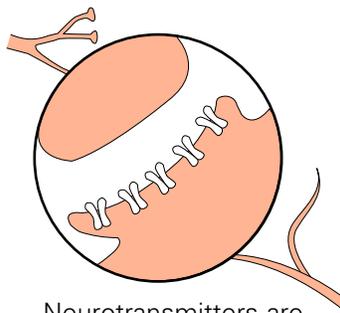
Some neurotransmitters attach to special receptors on the receiving neuron.

NEW MESSAGE



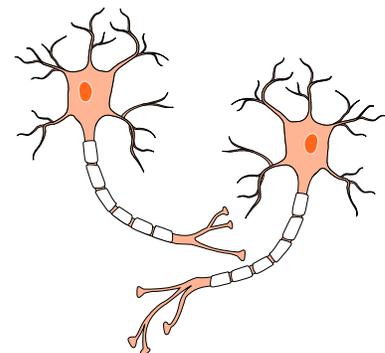
A new impulse can start in the receiving neuron.

RECYCLE



Neurotransmitters are cleared from receptor sites and the synapse.

WILD CARD



Substitute for any card.



RULES OF PLAY



- Each player is dealt five cards. The remaining cards are placed in a pile in the center of the table. Play proceeds to the left.
- Players take turns trying to obtain at least three cards in a neurotransmission sequence (run). For example:

Axon
Neurotransmitters
Synapse

- A run may contain the last and first elements of a sequence. For example:

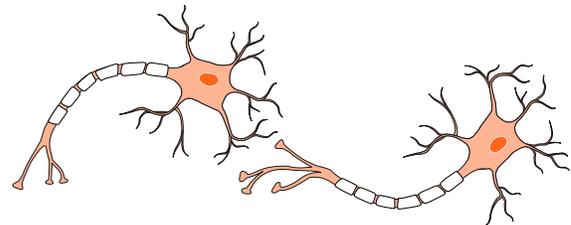
Recycle
Message Received
Neuron Fires!

- Each player begins his or her turn by asking any player for a card by name. For example, "Max, do you have any Axons?"
- If Max has one or more Axon cards, he gives all of them to the asking player, who then receives another turn to ask any player for another card. If Max does not have any Axon cards, he replies, "Locked Up!" and the asking player draws one card from the pile. Wild Cards may not be requested or given.
- If the requested card (not a Wild Card) is drawn from the pile, the asking player receives another turn. Otherwise, the player to the left begins his or her turn.

- Sets of three or more cards in sequence may be laid down at any time during a player's turn, including after a card has been drawn from the pile. Players may add cards to their existing runs, but only during their turns.

For example, if a player draws a Neuron Fires! card from the pile, he or she may add it to the run beginning with the Axon card that he or she already had laid down.

- Only one Wild Card may be included in any run (regardless of the number of cards in the run). Once a Wild Card has been used in a run, it may not be moved to another position.
- If a player has no cards in his or her hand at the end of a turn, he or she draws another card from the pile and waits until his or her next turn.
- The game proceeds until all cards have been drawn from the center pile, and no player can lay down or add to any more runs.



- **SCORING:** A player's score consists of the number of cards in the runs he or she laid down minus the number of cards still held in his or her hand.

