

Jumpin' the Gap

Abstract

Turn your classroom into a giant synapse as students act out communication at the neural level by behaving as pre-synaptic vesicles, neurotransmitters, post-synaptic receptors, secondary messengers and re-uptake transporters. Neurotransmitters and receptors interact via “lock-and key” puzzle pieces (included).

Logistics

Time Required

- ▶ **Class Time:**
40 – 50 minutes
- ▶ **Prep Time:**
30 – 40 minutes

Materials

- (2) 15-foot sections of rope or masking tape
- Classroom set of Job Assignment Tags (included)
- String for Job Assignment Tags
- Neurotransmitter/Receptor complex puzzle pieces (included)
- CD or tape player, music

Prior Knowledge Needed

Basic neuron structure, neurons communicate using action potentials and chemicals called neurotransmitters

Appropriate For:

Primary Intermediate Secondary College

Learning Objectives

- ▶ Nerve cells communicate with each other at a junction called a synapse.
- ▶ When stimulated by an action potential, a neuron releases neurotransmitters into the synapse.
- ▶ Receptors on the outside of the receiving cell (post synaptic cell) fit synaptic neurotransmitters similar to a “lock and key”.
- ▶ Once neurotransmitters “lock” into the appropriate receptor, a secondary messenger is released in the receiving cell.
- ▶ After neurotransmitters have done their job, they are released from the receptors and sent back through the cell through re-uptake transmitters.
- ▶ In the sending cell, neurotransmitters are packaged in vesicles.

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Classroom Implementation

Teacher Action

1. Place masking tape or rope on the floor of your classroom, hallway, basketball court etc... to represent pre- and post- synaptic membranes. The membranes need to be arranged in an area large enough for several of your students to move back and forth from one side to the other comfortably.

2. Review the structure of a neuron, including: cell body, nucleus, axon, synapse and dendrites. Focus student's attention on the terminal end of the axon and the synapse. Show Overhead A. Explain that this activity will focus on this area and it's role in communication between neurons.

3. Place Overhead B on top of Overhead A to show how student roles correlate with structures in the synapse. Assign students their roles and give the students the appropriate Job Assignment tag prepared from the Teacher Resource Pages 5-6.

4. Position the students around the membranes you've created on the floor accordingly. Give the students who are dopamine neurotransmitters a dopamine neurotransmitter puzzle half (Teacher Resource Pages 2-3).

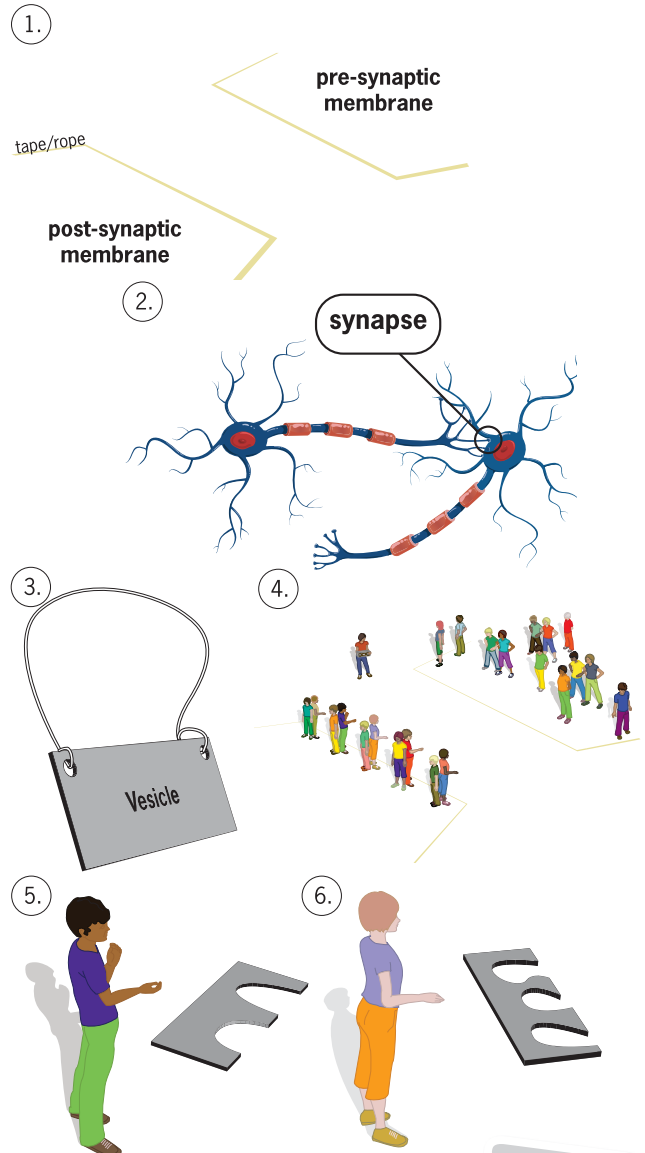
5. Give students who are dopamine receptors a dopamine receptor puzzle half (Teacher Resource Page 1).

6. The two students who are serotonin receptors should also be given a serotonin receptor puzzle half (Teacher Resource Page 4). There will be no complementary puzzle half for these.

Preparation

For a group of 23

- ▶ Print Job Assignment tags, cut out, attach string to hang around the neck (Teacher Resource Pages 5-6)
- ▶ Print Neurotransmitter and Receptor puzzle halves (Teacher Resource Pages 1-4), cut out and laminate.



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Student Action

1. The vesicles (standing in the axon terminal) must link arms with the dopamine neurotransmitters in preparation for an action potential. There will be some "free floating" dopamine neurotransmitters that do not have a vesicle.

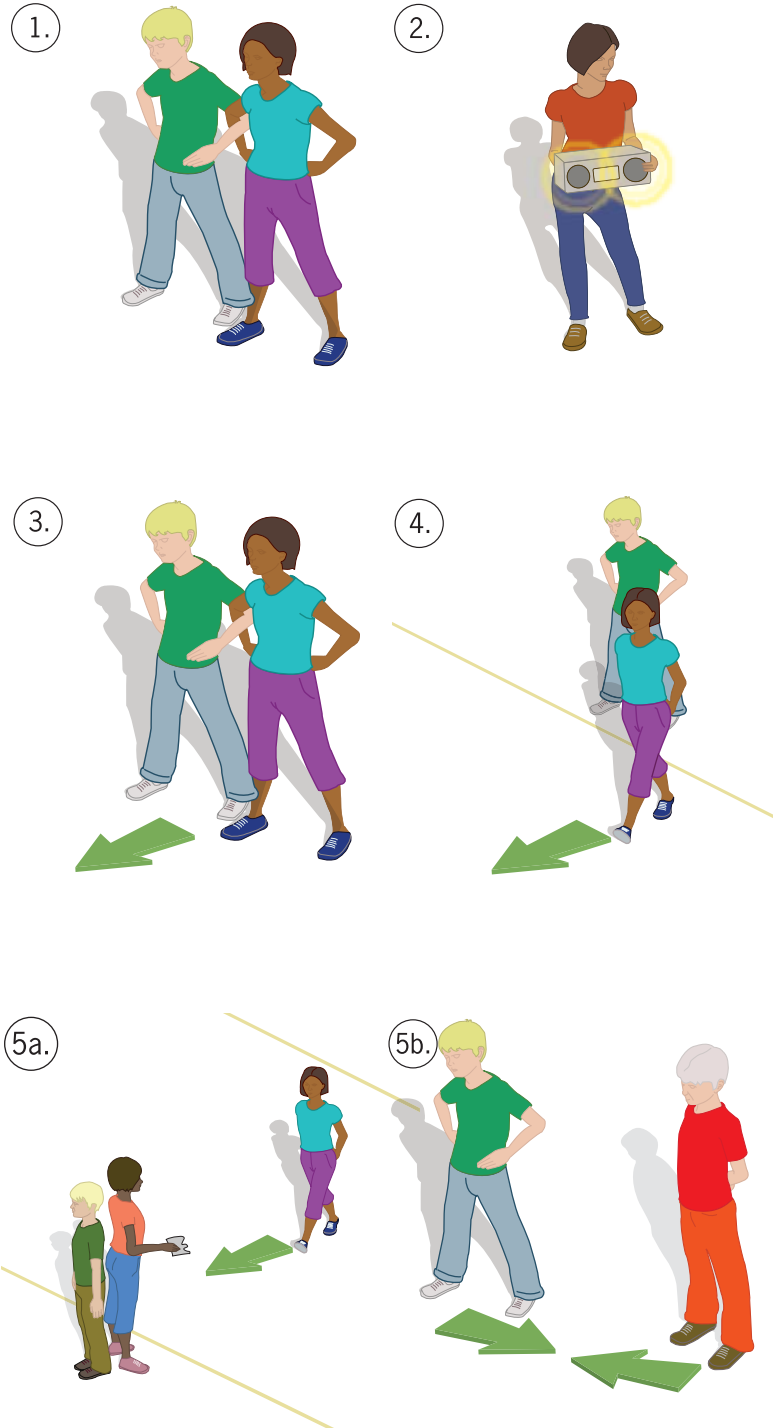
2. Next, the DJ turns on music for a brief, startling period of time to simulate the action potential traveling down the neuron.

3. Upon the start of the music, the vesicles attached to dopamine neurotransmitters move toward the synapse and come into contact with the pre-synaptic membrane.

4. Once the vesicles reach the axon terminal membrane, they release their dopamines into the synapse.

5a. The neurotransmitters that were released into the synapse move across the synaptic cleft to the dopamine receptors on the post-synaptic membrane.

5b. The vesicles remove themselves from the membrane and float back into the axon terminal to refill with any available neurotransmitters. Vesicles and neurotransmitters should hook elbows in preparation for another action potential to signal their movement.



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Student Action

6. The dopamine neurotransmitters find the receptor with which their puzzle piece matches, indicating the specificity of receptors for a particular neurotransmitter.

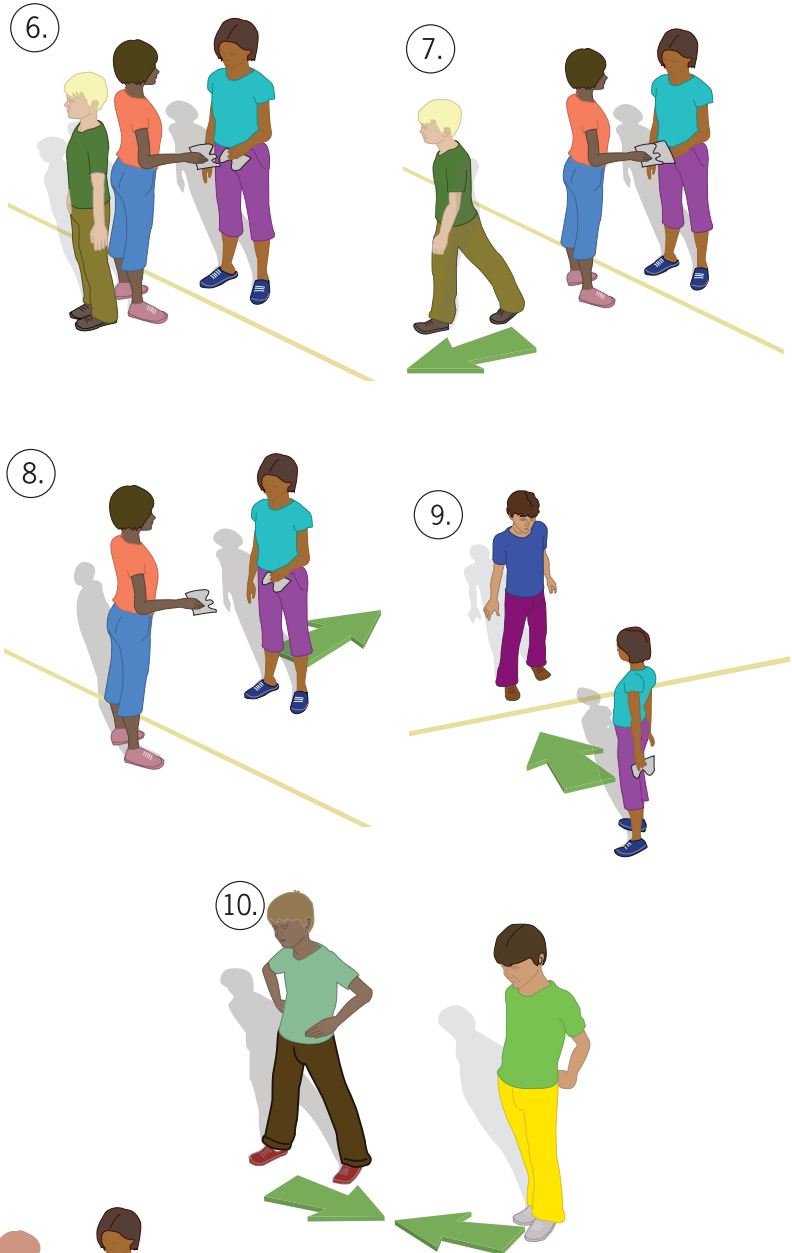
7. Once the dopamine neurotransmitters match with their receptors, the second messengers (attached to the dopamine receptors) should let go and continue to carry the message down the post-synaptic membrane. The second messengers attached to the serotonin receptors should not be released but should remain attached to their receptors.

8. Once the second messengers have been released from the dopamine receptors: the connection between the dopamine neurotransmitters and the dopamine receptors is broken, and the dopamine neurotransmitters are released into the synapse to diffuse back toward the pre-synaptic membrane.

9. Free-floating neurotransmitters are pulled back in to the pre-synaptic axon terminal by uptake transporters.

10. Available 'empty' vesicles will again link arms with available neurotransmitters.

Repeat steps 1-10 at a faster pace with decreasing direction until the process runs smoothly.



Teacher Hint: the puzzle halves for the serotonin receptors will not match those of the dopamine neurotransmitters. Have students try to match to demonstrate this.

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Teacher Action

Explain that neurons communicate in this way using a wide variety of neurotransmitters. The neurotransmitter differs with the type of message being sent. Dopamine neurotransmitters are responsible for communicating pleasure and reward. The process just witnessed happens any time you do something that makes you feel good like winning a basketball game, or eating your favorite food and is part of the reward pathway in the brain.

Option 1: Have students trade participant roles when they rerun the activity so they understand all parts of the sequence.

Option 2: Once the students are comfortable with the sequence above, have them write or illustrate the sequence in a journal.

Assessment Suggestion: Ask students to recall what they have learned by filling out the Jumpin' The Gap worksheet (page S-1)

Adaptations:

Modify the student roles to illustrate the effect of drugs on the synapse in the following ways:

- **Cocaine:** Instruct some students to be cocaine. Cocaine blocks the uptake transporters. As a result, dopamine becomes trapped in the synaptic cleft and binds repeatedly to the dopamine receptors. This overstimulation results in the euphoria commonly reported by cocaine abusers.
- **Methamphetamine:** Instruct some students to be methamphetamine. Because methamphetamine mimics dopamine, it is taken into the pre-synaptic cell by the uptake transporters. Methamphetamine then enters the vesicles, forcing the dopamine neurotransmitters out. The excess dopamine in the cell causes the uptake transporters to start working in reverse, actively pumping dopamine out of the cell and into the synaptic cleft. The excess dopamine becomes trapped and binds repeatedly to the dopamine receptors. This overstimulation results in the euphoria commonly reported by methamphetamine abusers.
- **Ecstasy:** Instruct some students to be ecstasy. For this simulation you will need to use serotonin at the synapse rather than dopamine. Switch your dopamine neurotransmitter students to serotonin neurotransmitters. Ecstasy mimics serotonin and is taken into the pre-synaptic cell by the uptake transporters. This interaction with ecstasy alters the transporter. The transporter becomes temporarily 'confused' and starts to do its job in reverse. The transporter starts transporting serotonin out of the cell. The excess serotonin becomes trapped in the synaptic cleft. As a result, it binds repeatedly to the serotonin receptors. This overstimulation results in the euphoria commonly reported by ecstasy abusers.

Extensions

- To review the parts of a neuron visit Make a Mad, Mad Neuron in The New Science of Addiction: Genetics and the Brain module on our website.
- To review neural communication at the synaptic level prior to or after completing this activity, visit the animated slideshow Crossing the Divide: How Neurons Talk to Each Other, in The New Science of Addiction: Genetics and the Brain module on our website.

Jumpin' the Gap

Standards

A. U.S. National Science Education Standards:

Grades 5-8

Content Standard C: Life Science

- Structure and Function In Living Systems
 - » Specialized cells perform specialized functions in multicellular organisms.

Grades 9-12

Content Standard C: Life Science

- The Cell
 - » Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane that separates it from the outside world. Inside the cell is a concentrated mixture of thousands of different molecules which form a variety of specialized structures that carry out such cell functions as energy production, transport of molecules, waste disposal, synthesis of new molecules, and the storage of genetic material.
- The Behavior of Organisms
 - » Multicellular animals have nervous systems that generate behavior. Nervous systems are formed from specialized cells that conduct signals rapidly through the long cell extensions that make up nerves. The nerve cells communicate with each other by secreting specific excitatory and inhibitory molecules. In sense organs, specialized cells detect light, sound, and specific chemicals and enable animals to monitor what is going on in the world around them.

B. AAAS Benchmarks for Science Literacy:

Grades 9-12

The Living Environment

- Cells
 - » Within every cell are specialized parts for the transport of materials, energy transfer, protein building, waste disposal, information feedback, and even movement. In addition, most cells in multicellular organisms perform some special functions that others do not.
- The Human Organism
 - Basic Functions
 - » The nervous system works by electrochemical signals in the nerves and from one nerve to the next. The hormonal system exerts its influences by chemicals that circulate in the blood. These two systems also affect each other in coordinating body systems.
 - » Communication between cells is required to coordinate their diverse activities. Along nerve cells, electrical impulses carry information much more rapidly than is possible by diffusion or blood flow.

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Credits

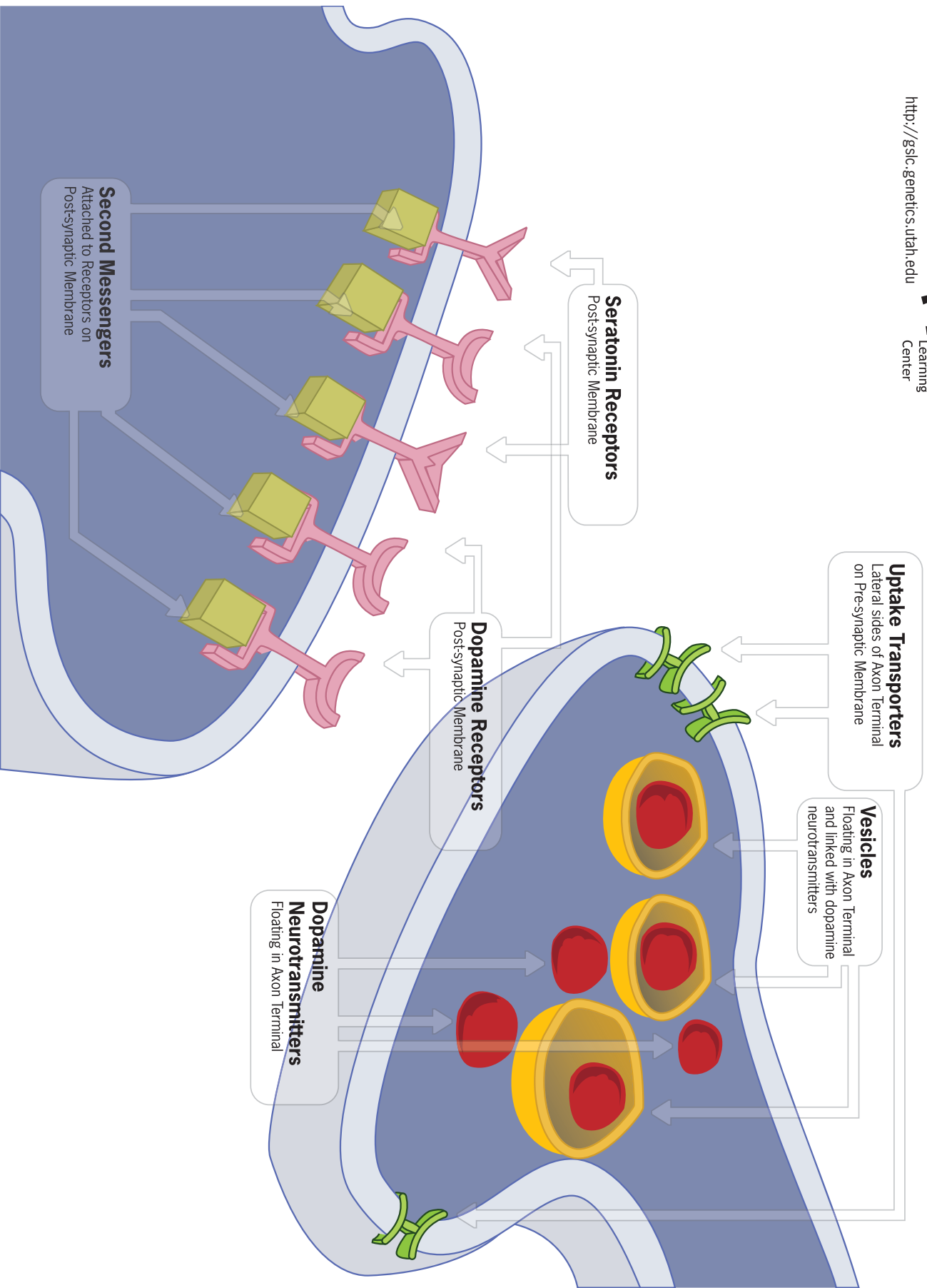
Activity created by: Carrie Hartman, Murray High School, Murray, Utah
Molly Malone, Genetic Science Learning Center
Brendan Nicholson, Genetic Science Learning Center (illustrations)

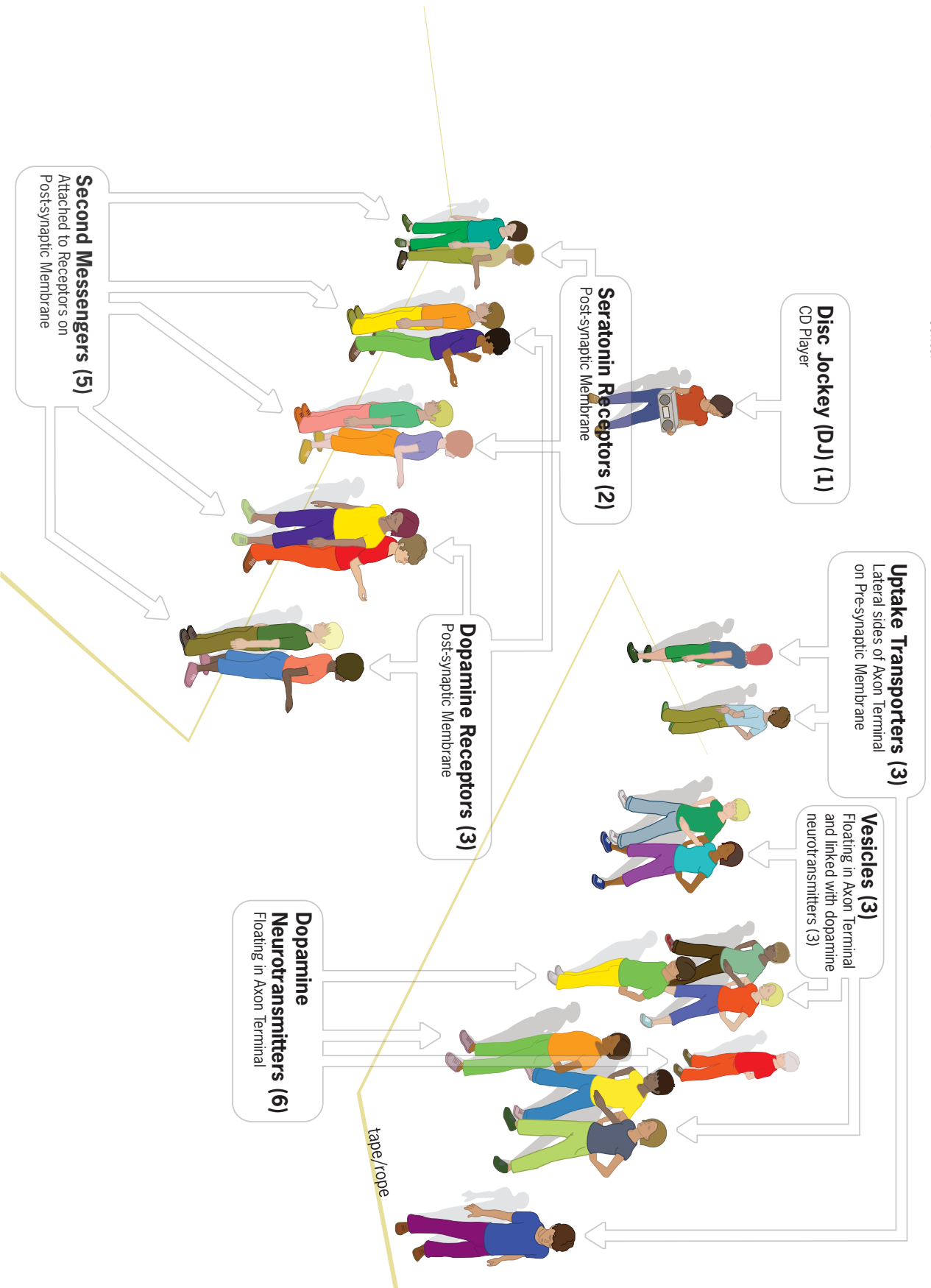
Funding

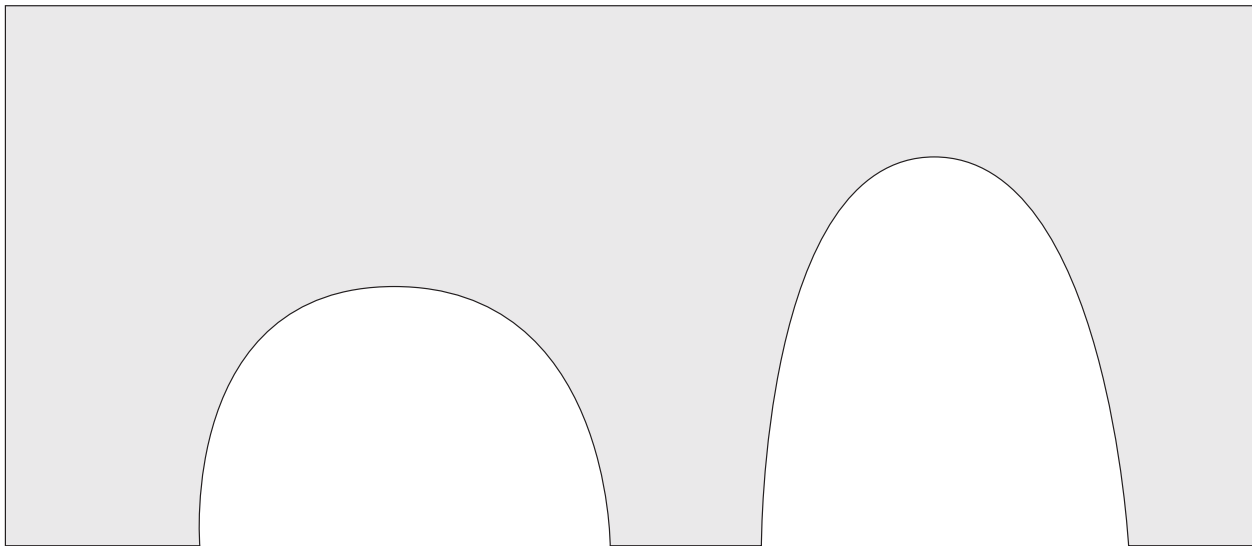
Funding for this module was provided by a Science Education Drug Abuse Partnership Award (SEDAPA) from the National Institute on Drug Abuse, a component of the National Institutes of Health, Department of Health and Human Services.



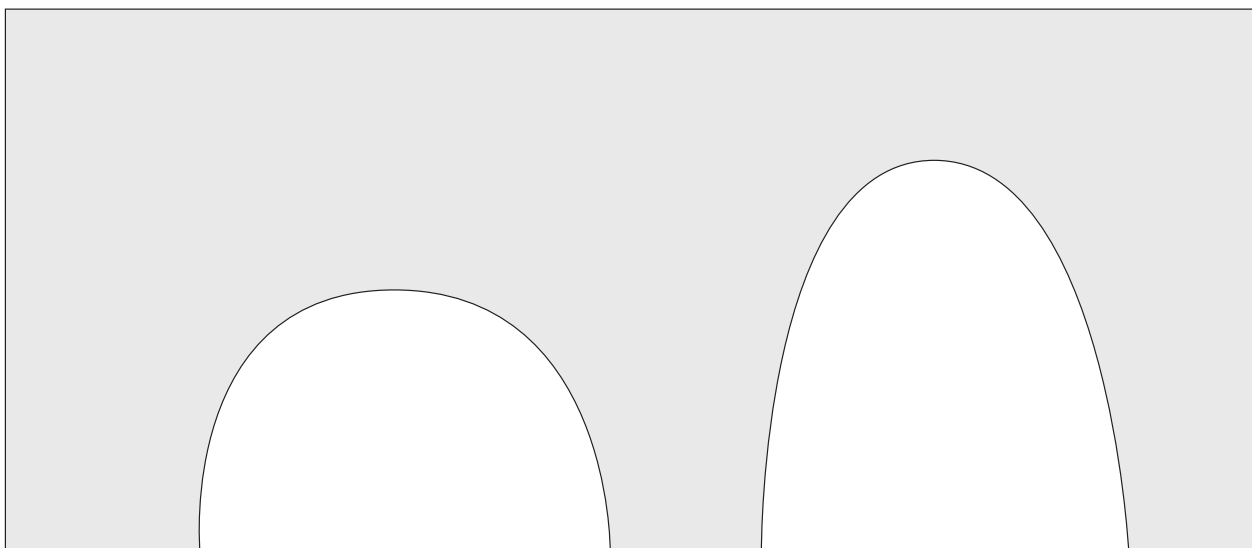
OVERHEAD A: Synapse between two neurons.



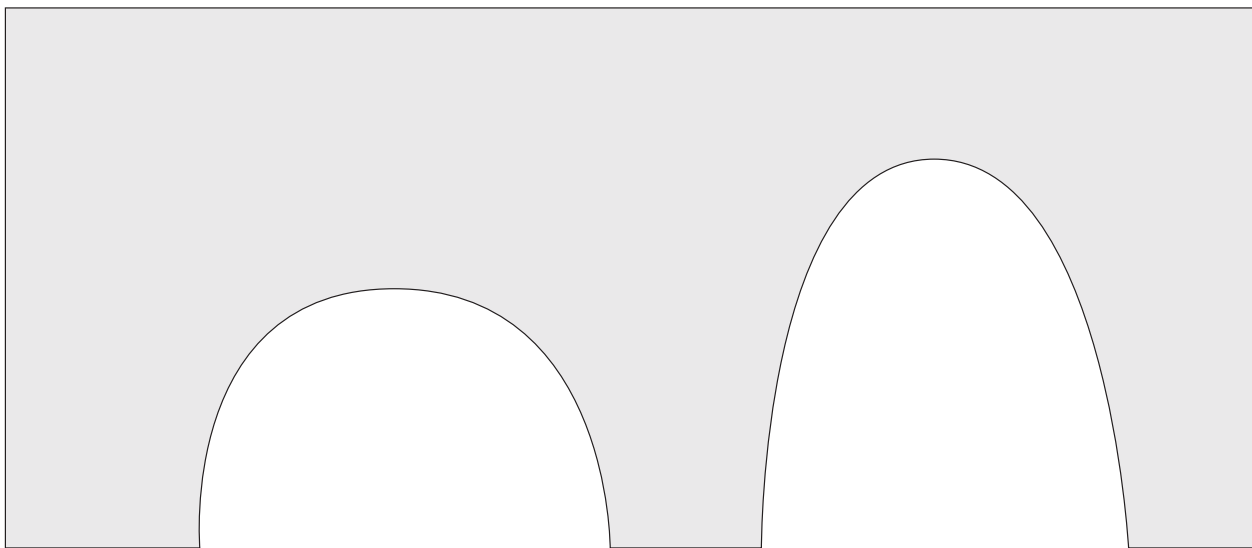




↑ Dopamine Receptor Piece



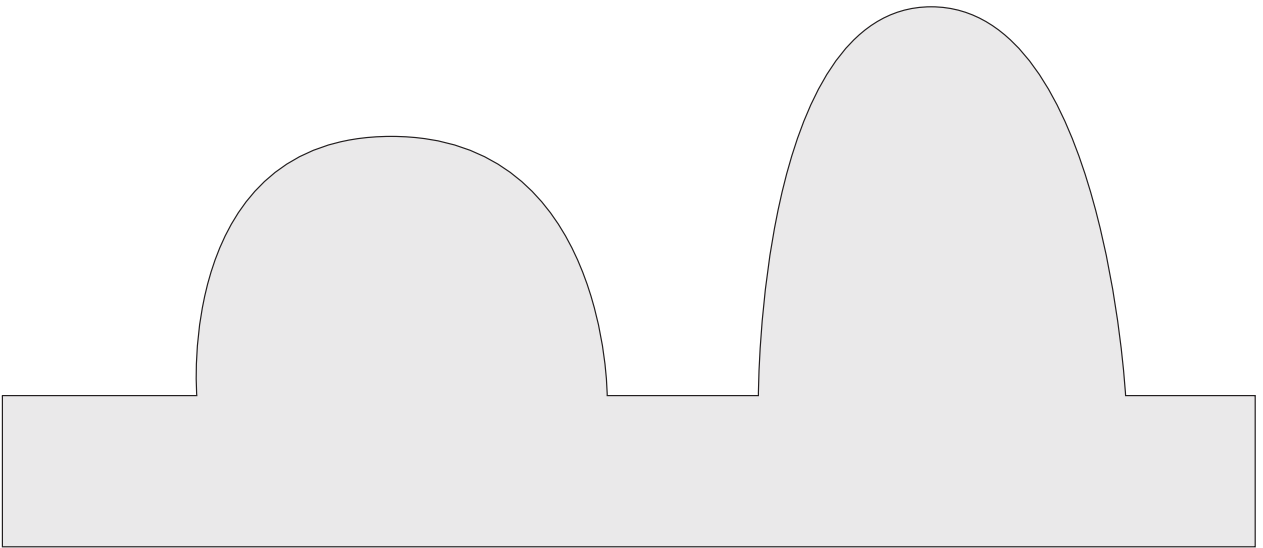
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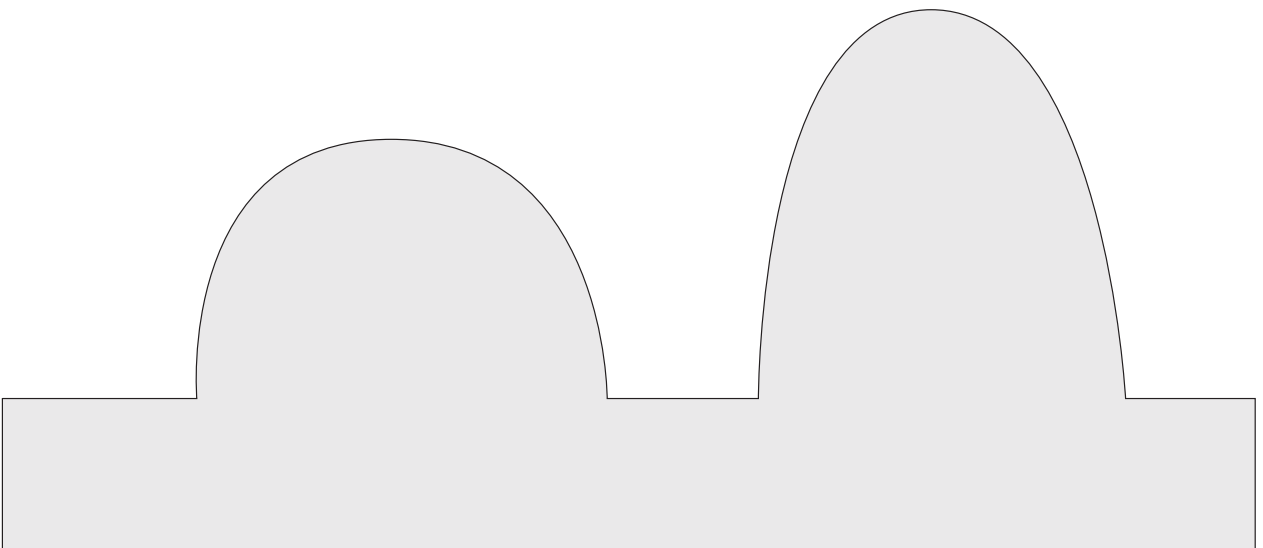
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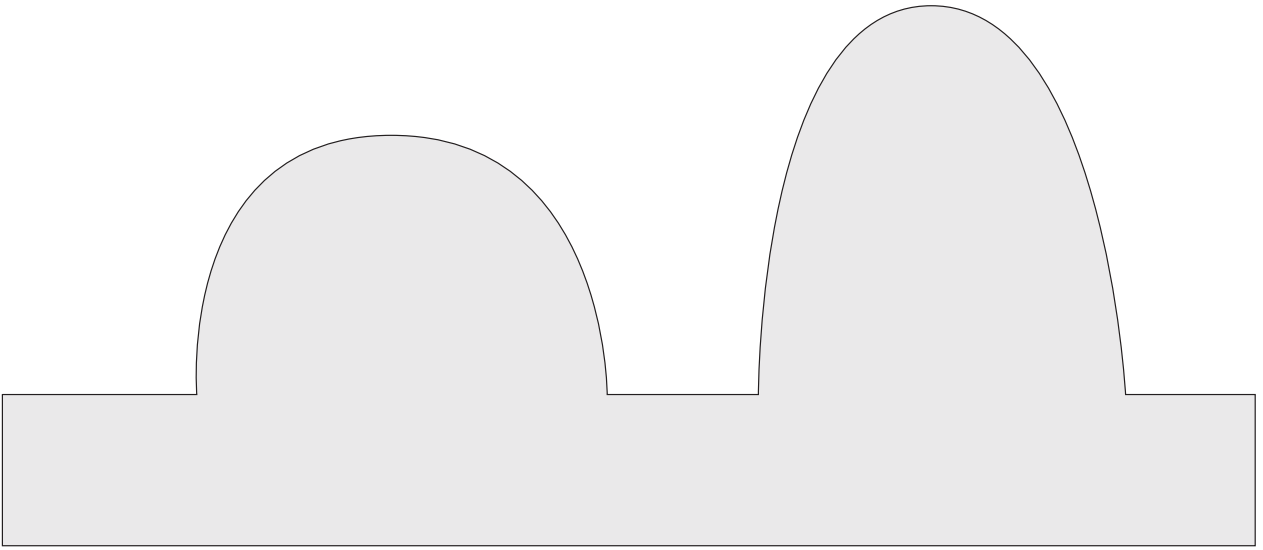
↑ Dopamine Neurotransmitter Piece



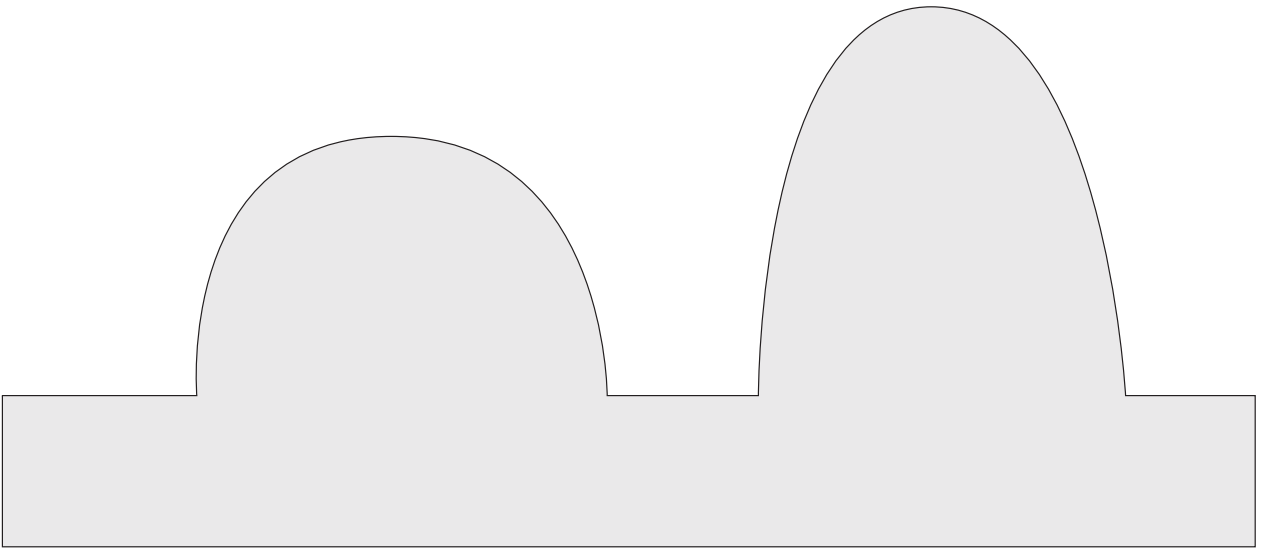
↑ Dopamine Neurotransmitter Piece



↑ Dopamine Neurotransmitter Piece



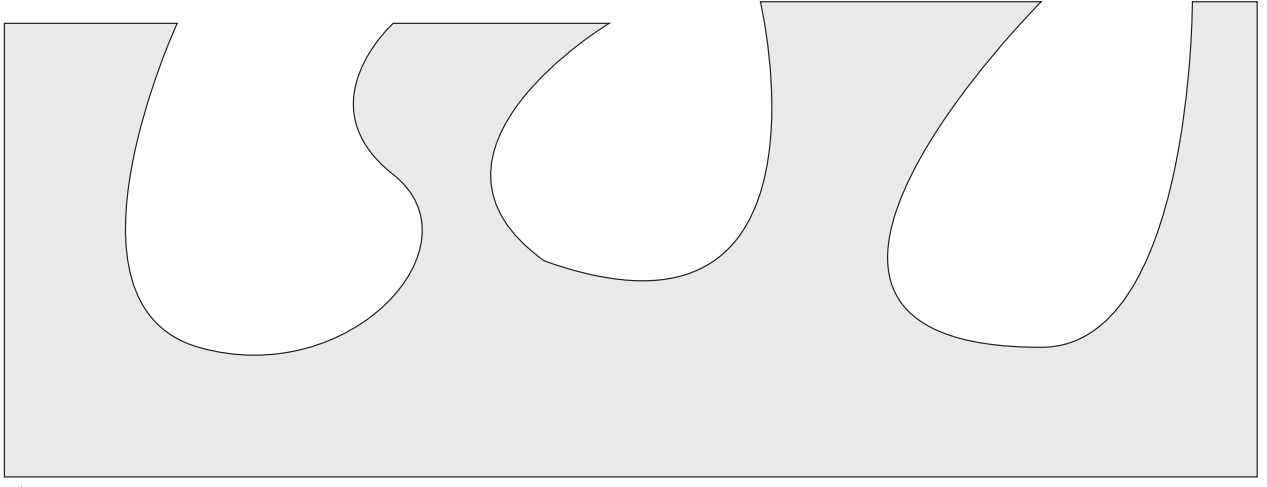
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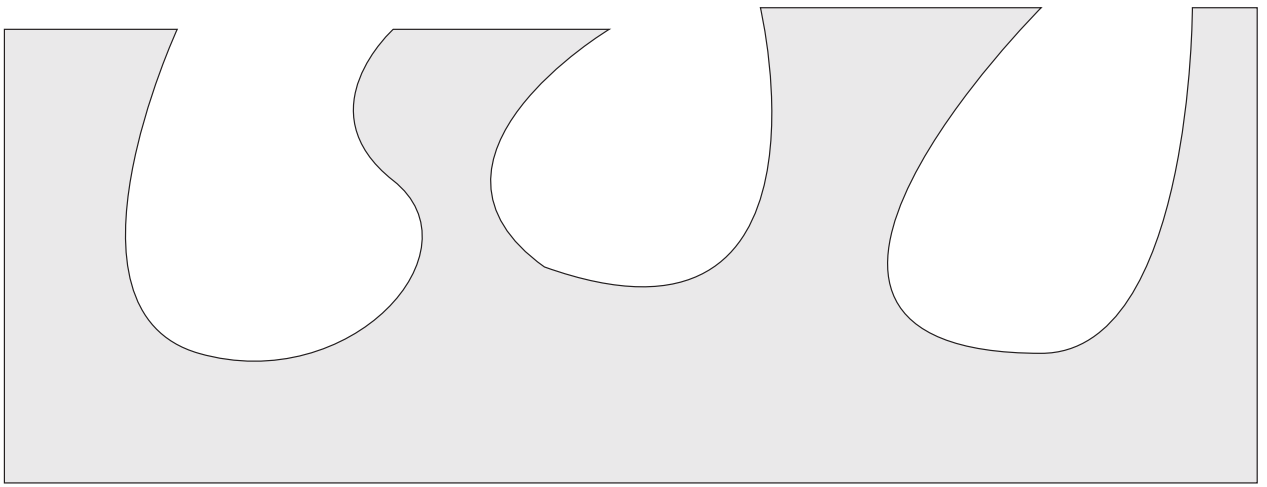
↑ Dopamine Neurotransmitter Piece



↑ Dopamine Neurotransmitter Piece



↑ Serotonin Receptor Piece



↑ Serotonin Receptor Piece

cut along lines and punch out holes

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TEACHER RESOURCE PAGE 5: **Job Assignment Tags**

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TEACHER RESOURCE PAGE 6: **Job Assignment Tags**

Name _____

Date _____

Jumpin' The Gap: Worksheet

Instructions: Please answer the following questions following the *Jumpin' The Gap* activity

1. What structure is responsible for "recycling" neurotransmitters back into the axon terminal once they have done their job?

2. How do the vesicles "know" when to move to the membrane to dump their contents into the synapse?

3. How does the message continue past the post-synaptic membrane?

4. Diagram, label and describe the action of dopamine while communicating a pleasure or reward message across the synapse.