Teacher Guide

Jumpin' the Gap

Modeling the Reward Pathway

Abstract

Turn your classroom into a giant dopamine synapse! In this modeling activity, students take on the roles of vesicles, neurotransmitters, receptors, second messengers, and re-uptake transporters. Extension exercises model the ways in which drugs disrupt dopamine synapses.

Learning Objectives

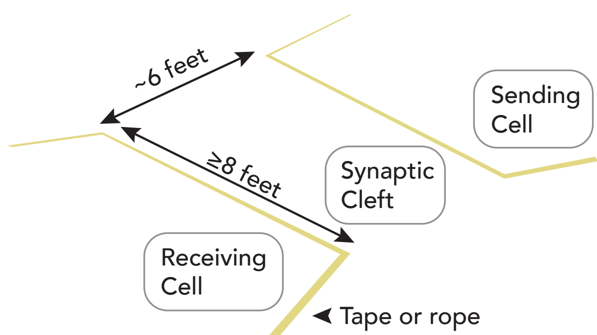
- Neurons communicate with each other at a junction called a synapse.
- Signaling between neurons requires the coordinated actions of vesicles, neurotransmitters, receptors, and second messengers.
- After relaying a signal, neurons return to homeostasis.
- (Extensions) Drugs disrupt synapses, affecting communication between neurons.

Estimated time

- Preparation: 20–30 minutes (one time only)
- Class time: 20 minutes for each scenario, add time for discussion

Materials

- 2 - 15-foot sections of rope or masking tape
- String (optional)
- Copies of cut-outs



Set-up Instructions

The included cut-outs will work for a group of 12 students (add 2 more to model the effects of drugs). Scale up or down as needed.

1. Print, laminate, and cut out the Job tags.

Optional: Punch holes in the Job tags and attach strings, so that students can hang them around their necks.

2. Place masking tape or rope on the floor of your classroom, hallway, basketball court, etc. to represent sending and receiving cell membranes. Label the sending cell, receiving cell, and synaptic cleft using (e.g., mark with tape or large pieces of paper, or write on white board above them). Arrange the membranes in an area large enough to comfortably accommodate several students moving back and forth between them.

Before you begin

3. You may wish to review the following with your students:

    a. The structure of a neuron, including cell body, nucleus, axon, synapse, and dendrites.

    b. The structure and purpose of a synapse. Project Crossing the Divide (learn.genetics.utah.edu/content/neuroscience/crossingdivide/). Explain that this activity will focus on the synapse and its role in communication between neurons, specifically in the reward pathway.

4. To show how student Jobs correlate with structures in the synapse, project Diagram A followed by Diagram B.

5. To assign student roles, hand out Job tags.

6. Position the students around the membranes according to their roles in Diagram B.

Student Actions

1. Students should prepare for an action potential:

    a. In the sending cell, each **vesicle** should find and link arms with a **dopamine neurotransmitter**. There will be some "free floating" dopamine neurotransmitters that do not have a vesicle.

    b. In the receiving cell, each **receptor** should find and stand back-to-back with a **second messenger**.

2. To represent an action potential traveling down the sending cell, say, **"Action!"**

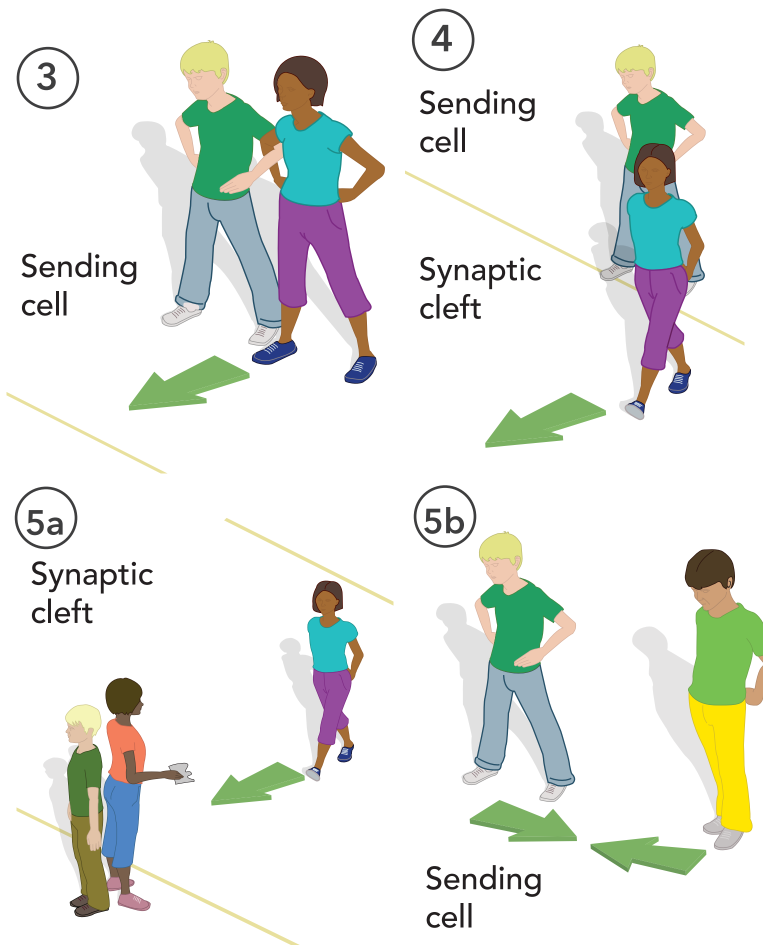
3. The **vesicles attached to dopamine neurotransmitters** move toward the synaptic cleft until they reach the membrane of the sending cell (axon terminal).

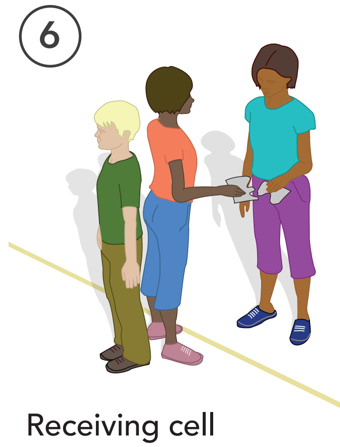
4. Upon reaching the axon terminal membrane, the **vesicles** release their **dopamine neurotransmitters** into the synaptic cleft.

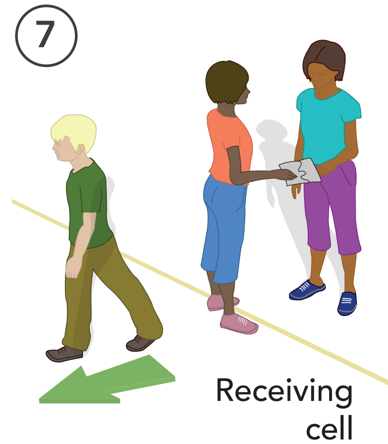
5. Simultaneously:

    a. **Dopamine neurotransmitters** in the synaptic cleft move toward the receiving cell membrane.

    b. The **vesicles** move back into the sending cell. They should find and link arms with **any available neurotransmitter**.







6. Each **dopamine neurotransmitter** in the synaptic cleft finds a **dopamine receptor**. Have them demonstrate that the shapes of their Job tags match. This represents the specificity of each receptor for a particular neurotransmitter.

7. Once a dopamine neurotransmitter finds a **dopamine receptor**, the receptor releases its **second messenger**. Upon release, the second messengers say, **"Impulse!"**

8. Once the second messengers have been released, the **dopamine neurotransmitters** move across the synaptic cleft, toward a **re-uptake transporter** on the sending cell.

9. **Re-uptake transporters** move the **dopamine neurotransmitters** into the sending cell.

10. Once inside the sending cell, **dopamine neurotransmitters** find and link arms with any available 'empty' **vesicles**.

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

Extension: Modeling the effects of cocaine and methamphetamine

Many drugs disrupt synapses, affecting communication between neurons. Cocaine and methamephetamine **activate** dopamine synapses in the **reward pathway**. This activation leads to feelings of euphoria, and it reinforces drug-taking behavior.

To review the actions of drugs on the reward pathway, visit Mouse Party (learn.genetics.utah.edu/content/addiction/mouse/)

1. Remind students that the above exercise modeled what happens after someone experiences a natural reward—things like food, drink, friendship, and romance.

2. Assign 2 students to be drug molecules (either cocaine or methamphetamine).

3. Have students work together to model how the drug affects the synapse.

   - **Cocaine** blocks re-uptake transporters on the sending cell. Large numbers of dopamine neurotransmitter molecules become trapped in the synaptic cleft, where they bind repeatedly to the dopamine receptors, overstimulating the receiving cell.

   - **Methamphetamine** is moved into the sending cell by re-uptake transporters. Methamphetamine then enters vesicles, forcing the dopamine neurotransmitters out. The re-uptake transporters start working in reverse, moving dopamine neurotransmitter out of the sending cell and into the synaptic cleft. Large numbers of dopamine neurotransmitter molecules become trapped in the synaptic cleft, where they bind repeatedly to the dopamine receptors, overstimulating the receiving cell.

4. Have students work together to model tolerance. How does the receiving cell changes to re-establish homeostasis? How does this change how the cell responds to a natural reward?

- In response to the overstimulation, the receiving cell decreases the number of dopamine receptors in its membrane. As a result, the cell's response to natural rewards is weakened.

Other drugs

Other drugs also affect the reward pathway. You may wish to refer to Mouse Party and discuss the effects of additional drugs with your students.

Note that some drugs, including opioids and alcohol, affect signaling at the reward pathway indirectly. The effects of these drugs involve additional neurons and molecules that are not included in this modeling activity.

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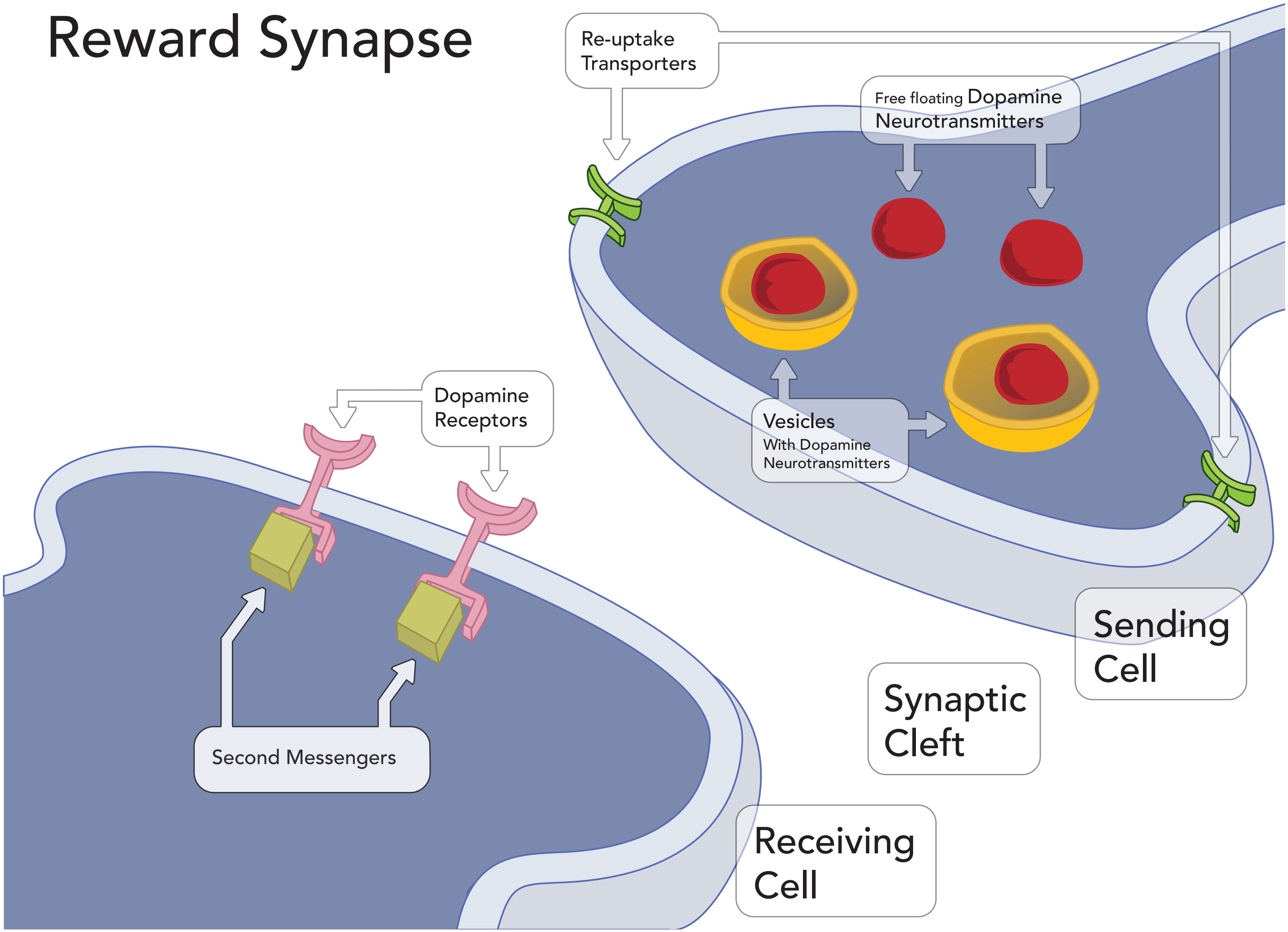
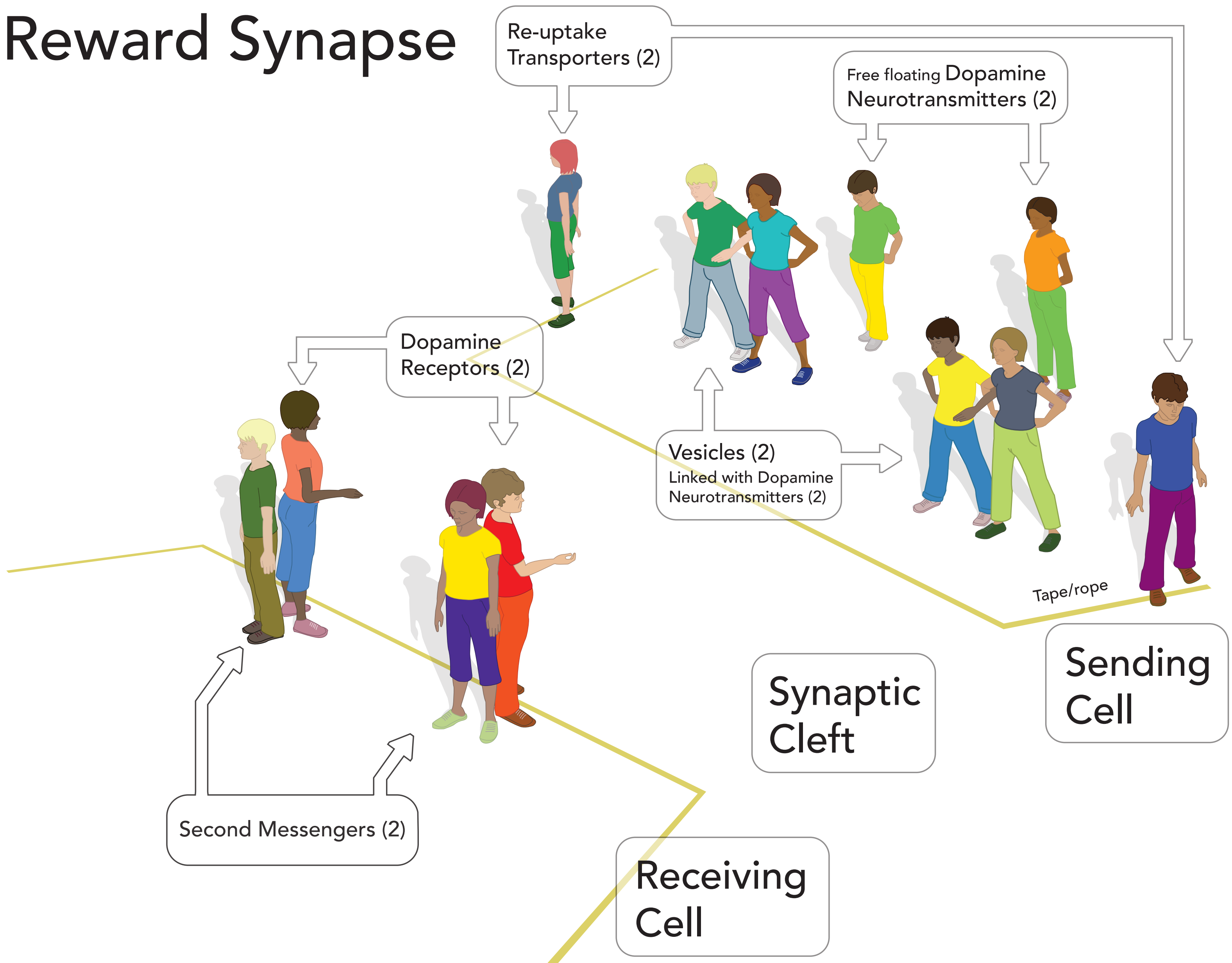
Diagram A: Synapse

Reward Synapse



Reward Synapse



Job tag cut-outs

Cut along the lines.

Vesicle **1.** Link arms with a dopamine neurotransmitter. **2.** When you hear “Action,” guide the neurotransmitter to the cell membrane. **3.** Find another dopamine neurotransmitter inside the cell; link arms with it.	**Vesicle** **1.** Link arms with a dopamine neurotransmitter. **2.** When you hear “Action,” guide the neurotransmitter to the cell membrane. **3.** Find another dopamine neurotransmitter inside the cell; link arms with it.
Second Messenger **1.** Link arms with a dopamine receptor. **2.** When it lets go, walk away from the synaptic cleft and shout, “Impulse!”	**Second Messenger** **1.** Link arms with a dopamine receptor. **2.** When it lets go, walk away from the synaptic cleft and shout, “Impulse!”
Dopamine Transporter When you find a dopamine neurotransmitter outside the cell, take its arm and gently move it into the cell.	**Dopamine Transporter** When you find a dopamine neurotransmitter outside the cell, take its arm and gently move it into the cell.
Methamphet-amine	**Methamphet-amine**
Cocaine	**Cocaine**

Job tag cut-outs

Cut along the lines.

Dopamine Neurotransmitter

1. Link arms with a vesicle, if one is available.
2. When the vesicle brings you to the cell membrane, let go and enter the synaptic cleft.
3. Find a dopamine receptor and shake its hand.
4. Find a dopamine transporter.

Dopamine Receptor

1. Link arms with a second messenger.
2. When a dopamine neurotransmitter shakes your hand, let go of the second messenger.

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