Teacher Guide

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GENETIC SCIENCE LEARNING CENTER

Jumpin' the Gap

Modeling the Pain Pathway

Abstract

Turn your classroom into a giant pain pathway synapse! In this modeling activity, students take on the roles of neurotransmitters, receptors, and native opioids. Then they model the ways in which opioid drugs and other molecules affect the synapse.

Learning Objectives

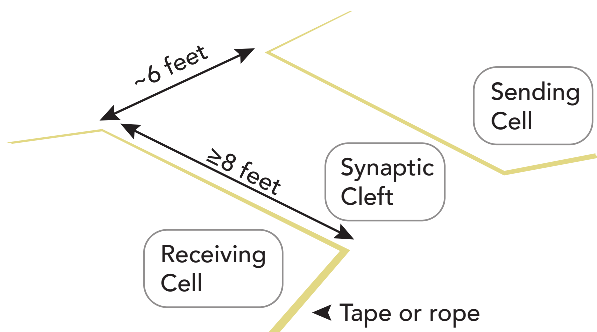
- Neurons communicate with each other at a junction called a synapse.
- Signaling between neurons requires the coordinated actions of vesicles, neurotransmitters, receptors, and second messengers.
- After relaying a signal, neurons return to homeostasis.
- Drugs disrupt synapses, affecting communication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



Set-up Instructions

The included cut-outs will work for a group of 12 students (plus 4 more for the extensions). 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 a synapse and its role in communication between neurons–specifically in a pain 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: Pain signal

For this demo, the native opioids and the opioid receptors do not carry out any actions.

1. Students should prepare for an action potential.

    a. In the sending cell, each **vesicle** should find and link arms with a **pain neurotransmitter**.

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

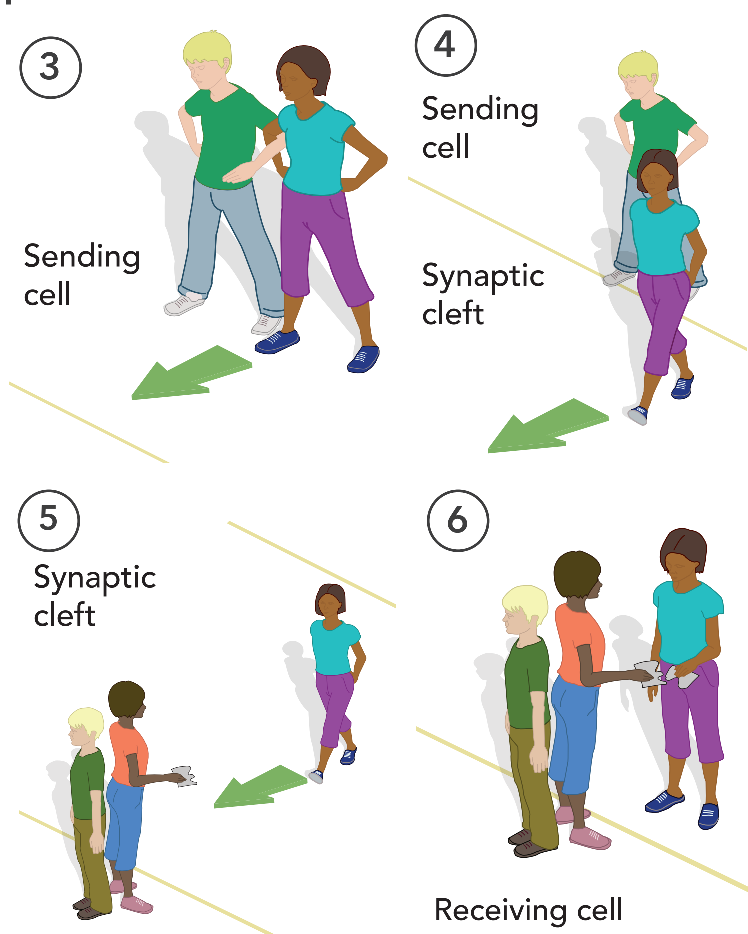
2. A painful event activates the sending cell. To represent an action potential traveling down the sending cell, say, **"Pain signal!"**

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

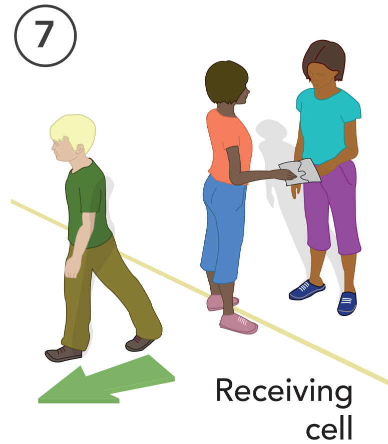
4. Upon reaching the membrane, the **vesicles** release their **pain neurotransmitters** into the synaptic cleft.

5. **Pain neurotransmitters** move toward the receiving cell membrane.

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



7. Activated **pain receptors** release their **second messengers**. Upon release, the second messengers say, **"Pain signal!"**



Everyone should return to their starting positions. Repeat steps 1–7 at a faster pace and with decreasing direction, until the process runs smoothly.

Student Actions: Native opioids block pain signaling

1. Students should prepare for an action potential as in the Pain signal demo, above.

2. **Native opioids** move to **opioid receptors** on both the sending and receiving cells. Have them demonstrate that the shapes of their Job tags match.

3. Simultaneously:

    a. The **opioid receptor in the sending cell** holds onto a **vesicle**, preventing it from moving.

    b. The **opioid receptor in the receiving cell** holds onto a **second messenger**, preventing it from moving.

4. A painful event activates the sending cell. To represent an action potential traveling down the sending cell, say, **"Pain signal!"**

5. The **vesicle and attached pain neurotransmitter** that are not being held back move toward the synaptic cleft until they reach the membrane of the sending cell (axon terminal).

6. Upon reaching the membrane, the **vesicle** releases the **pain neurotransmitter** into the synaptic cleft.

7. **Pain neurotransmitters** move toward the receiving cell membrane.

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

9. Once the pain neurotransmitter finds a **pain receptor**, the receptor releases its **second messenger**—*but only if it is not being held back*. Upon release, the second messenger says, **"Pain signal!"**

Repeat as needed until the process runs smoothly.

Discuss: How did the native opioid affect the transmission of the pain signal?

Extensions

Opioid drugs disrupt pain synapses, blocking the transmission of pain signals. (To review the short and long-term effects of opioids on pain pathways, visit Opioids and Tolerance.)

1. Remind students that the above exercise modeled the effects of the body's native opioid mole-

cules on the synapse.

2. Assign 2 students to be opioid drug molecules (these can be prescription painkillers or illegal drugs such as heroin).

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

    - Like the body's native opioids, **opioid drugs** block pain signals. But opioid drugs act across much larger distances and for much longer periods of time. While native opioids are cleared quickly from the synapse, opioid drugs are left to bind again and again.

4. Have students work together to model opioid tolerance. How do the sending and receiving cell change to re-establish homeostasis? How does these changes affect the cells' response to pain signals?

    - Continual activation of opioid receptors causes them to be sensitized. Opioids have less of an effect over time, and the neurons transmit pain signals more effectively. At the same time, native opioids have a decreased effect.

5. Now imagine that this synapse is in the brain pathway that controls breathing. Opioid drugs have a similar effect the pain and breathing pathways: they decrease signaling between neurons.

    a. Have students work together to model an opioid overdose.

        - Opioid drugs decrease signaling, thereby decreasing or even stopping breathing.

    b. Have students work together to model the action of **naloxone**, a drug that reverses opioid overdoses.

        - Naloxone binds to opioid receptors, but it does not activate them. Naloxone binds to the receptor tightly, displacing opioid drugs and blocking them from attaching.

Notes

This activity uses a generic "pain neurotransmitter" that activates a generic "pain receptor." In reality, pain signaling involves multiple types of neurotransmitters and receptors—sometimes within the same cell.

The neurons that transmit the fast-moving, short-acting signals associated with acute pain mostly use the neurotransmitter glutamate. Those that transmit the slow-moving, long-acting pain signals more often associated with chronic pain mostly use the neurotransmitter substance P.

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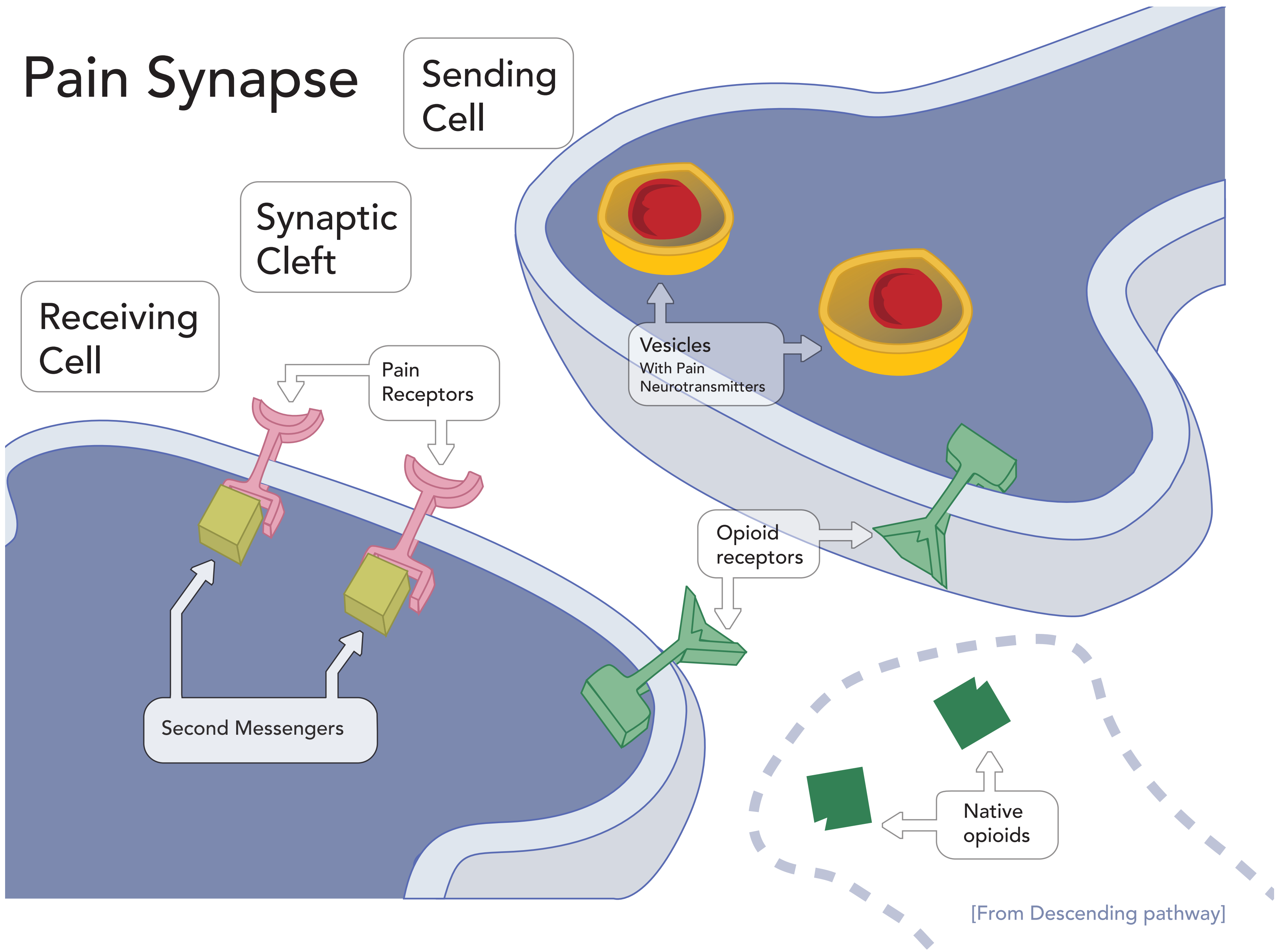
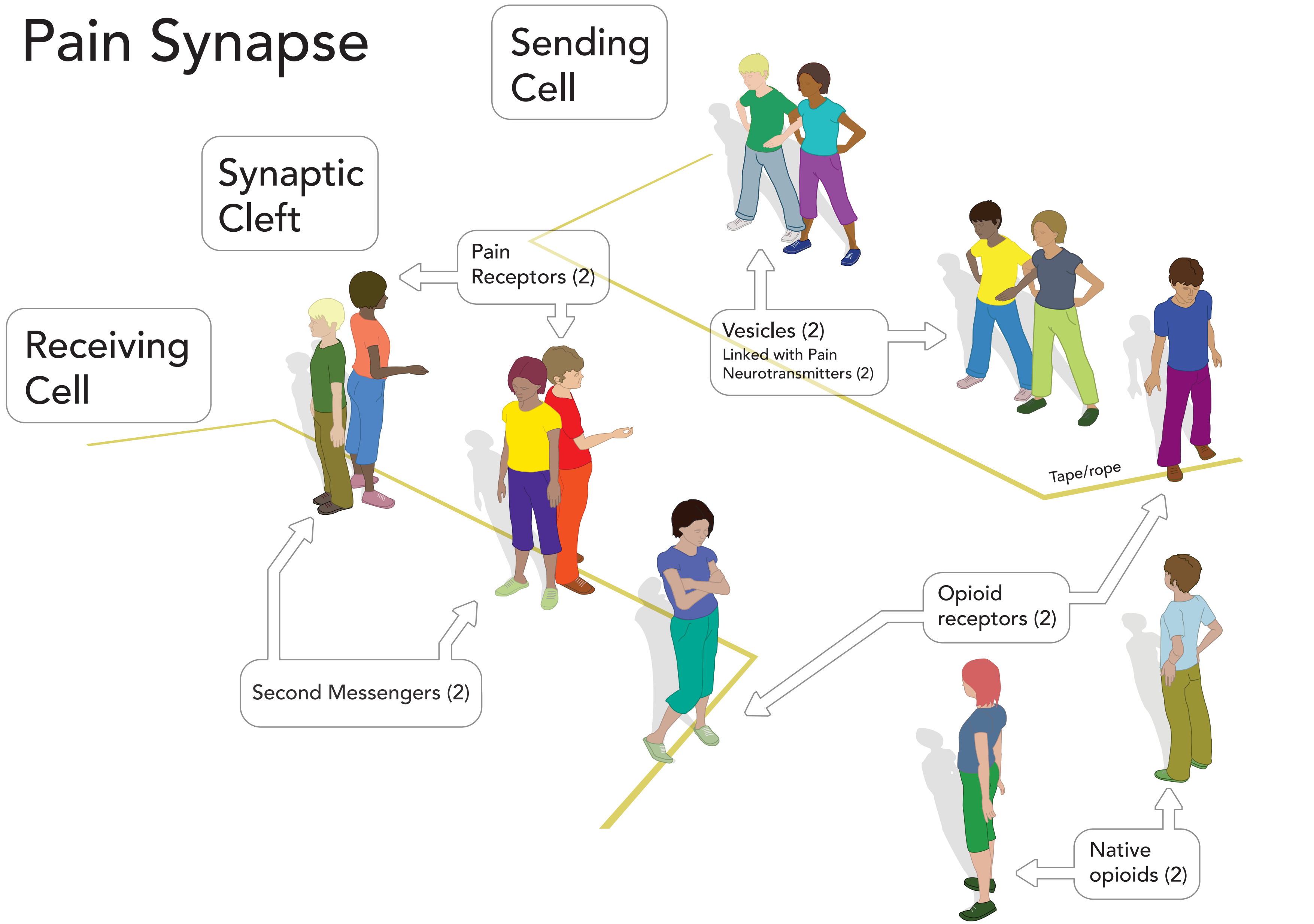
Diagram A: Synapse



Pain Synapse



Job tag cut-outs

Cut along the lines.

Vesicle

1. Link arms with a pain neurotransmitter.
2. When you hear "Pain signal," guide the neurotransmitter to the cell membrane.

Vesicle

1. Link arms with a pain neurotransmitter.
2. When you hear "Pain signal," guide the neurotransmitter to the cell membrane.

Second Messenger

1. Link arms with a pain receptor.
2. When it lets go, walk away from the synaptic cleft and shout, "Pain signal!"

Second Messenger

1. Link arms with a pain receptor.
2. When it lets go, walk away from the synaptic cleft and shout, "Pain signal!"

Naloxone

Naloxone

Pain Neurotransmitter

1. Link arms with a vesicle.
2. When the vesicle brings you to the cell membrane, let go and enter the synaptic cleft.
3. Find a pain receptor and shake its hand.

Pain Neurotransmitter

1. Link arms with a vesicle.
2. When the vesicle brings you to the cell membrane, let go and enter the synaptic cleft.
3. Find a pain receptor and shake its hand.

Pain Receptor

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

Pain Receptor

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

Job tag cut-outs

Cut along the lines.

Opioid Receptor
(sending cell)

After an opioid shakes your hand, block a vesicle from reaching the membrane.

Native Opioid

Find an opioid receptor and shake its hand.

Opioid Drug

Opioid Receptor
(receiving cell)

After an opioid shakes your hand, hold a second messenger attached to its pain receptor.

Native Opioid

Find an opioid receptor and shake its hand.

Opioid Drug