

Pom-Pom Potential

Abstract

Students move pom-pom “ions” across a membrane to simulate how an action potential is propagated along an axon. Done as a whole-class, this kinesthetic, color-coded simulation helps students visualize how an action potential travels down a neuron.

Learning Objectives

- ▶ An action potential is an electrical signal that is generated by the movement of ions across the membrane of a neuron.

Logistics

Time Required

- ▶ **Class Time:**
45 minutes
- ▶ **Prep Time:**
15 minutes

Materials

600 green pom-poms
300 blue pom-poms
1 large bag of small candies (M&M's®, Skittles® jelly beans)
2 color overheads (copymasters provided)

Prior Knowledge Needed

Neuron, axon, membrane structure, carrier proteins, ions

Appropriate For:

Primary Intermediate Secondary College

Special Features You'll Find Inside

- ▶ Colorful overhead masters to show your students how their simulation relates to a real action potential.
- ▶ Descriptive illustrations walk you through each part of the simulation procedure from start to finish.

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Classroom Implementation

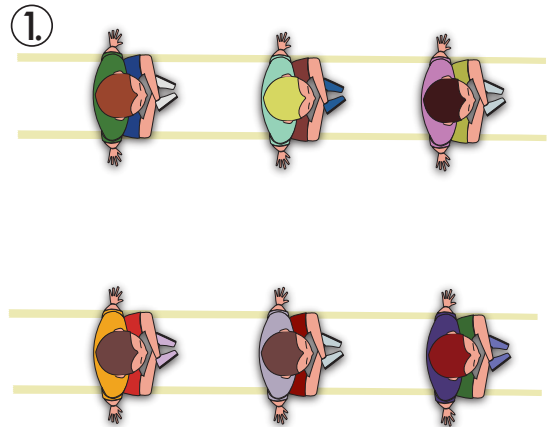
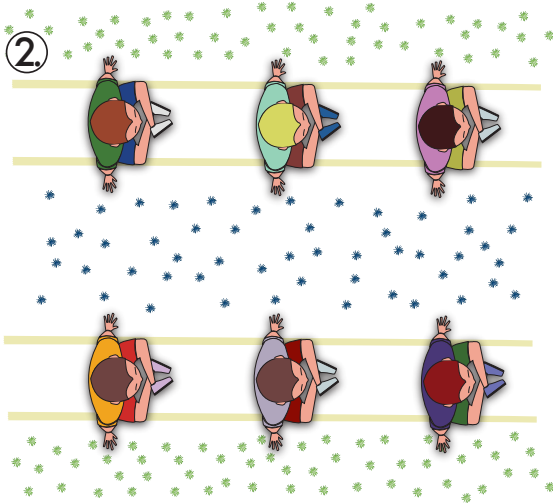
Describe the simulation prior to setting up:

Print out color transparencies using the overhead masters at the end of this guide. First, show your students the overhead of the Axon of a Neuron. Then place the Simulation Set-Up overhead on top of the first overhead. Explain to your students how they will be playing the role of these proteins in the simulation.

Set up an "axon" in your classroom or hallway:

Teacher Action 1

Ask the students to form two lines down the classroom or hallway, spaced a reasonable distance apart, sitting cross-legged on the floor. (Phospholipid bilayers or membranes that form the axon of a single cell)

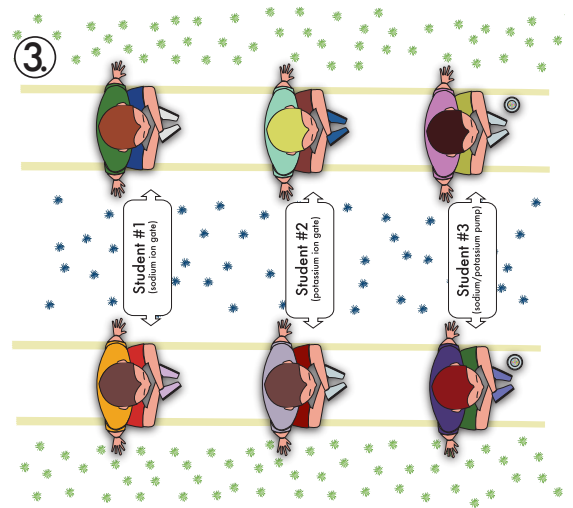


Teacher Action 2

Place roughly 300 blue pom-poms on the floor in the area between the students. (Potassium ions inside the cell) Place roughly 300 green pom-poms outside both rows of students (600 green pom-poms total). (Sodium ions outside the cell)

Teacher Action 3

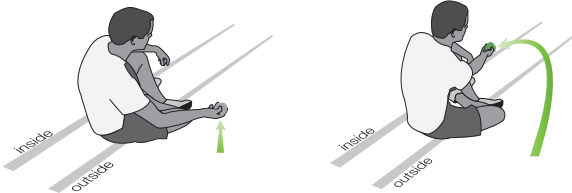
- Starting at one end of the line, have each student count off numbers 1-3.
- Assign those students that are #1 to be sodium ion gates.
- Assign those students that are #2 to be potassium ion gates.
- Assign those students that are #3 to be sodium/potassium pumps.
- Hand out roughly 12 small candies to each of the students that represent sodium/potassium pumps. Instruct them not to eat any yet.



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Describe the simulation procedure using the script below:

- Each row of students represents the phospholipid bilayer or membrane of the nerve cell with embedded sodium and potassium ion gates and sodium/potassium pumps.
- The green pom-poms represent sodium ions that are positively charged.
- The blue pom-poms represent potassium ions which also have a positive charge.
- Notice that there are a lot more pom-poms outside the neuron than there are inside. This imbalance of positive ions is what gives the inside of the resting neuron a less positive (or more negative) charge.
- When a neuron is stimulated at one end, it causes the sodium gate at that end to open and sodium ions move from where they are highly concentrated outside the neuron into the neuron where they are less concentrated.

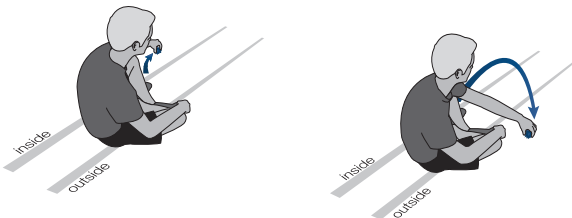


Student Action

Have the first “sodium gate” (the first student) in each row simulate this action by transferring 30 green pom-poms from the outside of the neuron to the inside of the neuron one at a time while counting out loud. It helps if the student places the pom poms slightly ahead of them.

- With the addition of new positive ions to the inside of the nerve, this end of the nerve is now very positively charged compared to the rest of the inside of the nerve. The outside has thus become more negative because of the loss of positive ions.
- This causes the potassium gate to open and potassium ions move from inside the neuron out of the neuron to where they are less concentrated.

Note: Potassium gates open once a “threshold” of positive ions is reached inside the neuron (for this activity it is 30 green pom-poms moved by one student or sodium gate).

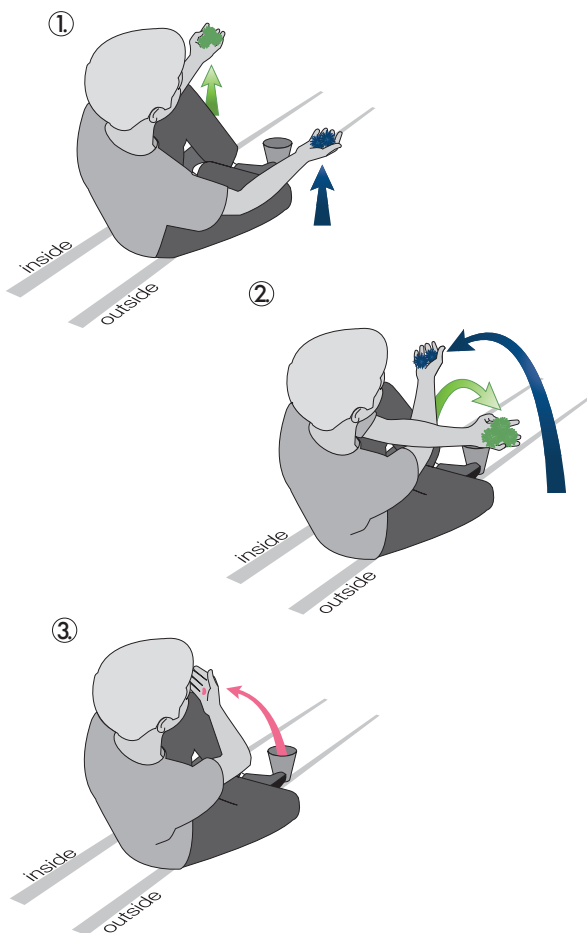


Student Action

Have the second student (they are potassium gates) in each row simulate this action by transferring 30 blue pom-poms out of the neuron one at a time while counting out loud. It helps if the student places the pom poms slightly ahead of them.

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- At this point, the amount of charge on each side of the membrane is restored to its original condition but what is different from the way the nerve started? **Answer:** The sodium and potassium ions are on the wrong side of the membrane.
- In an effort to restore everything to its proper order, the sodium/potassium pump will take three sodium ions (green) on the inside of the nerve and move them out while taking two potassium ions (blue) on the outside and moving them back in. Since the pump is moving ions (pom-poms) against their concentration gradients, energy is required in the form of ATP.



- Normally the next sodium channel in line is stimulated by the change in charge and opens right as the sodium/potassium pump before it begins its work. However, let's start the whole thing again from the beginning.

Student Action

Have the third student in each row (the sodium/potassium pumps) simulate this action by following these steps:

- Collect three sodium pom-poms inside the nerve with one hand and two potassium ions outside the nerve with the other hand.
- Cross your arms over each other and drop the pom-poms back onto their original sides of the membrane.
- Because this requires energy, eat a piece of candy (ATP) completely before transferring any more pom-poms.

Repeat the steps above until you cannot make another transfer. The transfer **MUST** be made in a 3:2 ratio! If not enough green pom-poms are available, you must wait.

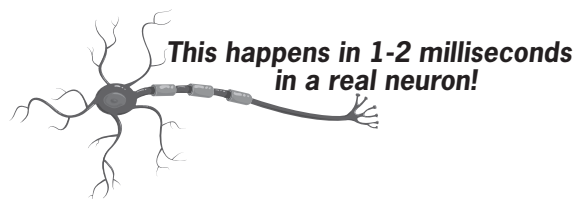
Note: Instruct the sodium/potassium pump students that at any time in the simulation if they can grab three green sodium pom-poms on the inside AND two blue potassium pom-poms on the outside in the region where they are sitting then they must perform their action and eat a piece of candy.

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Simulate an electrical signal traveling down the axon:

Repeat the steps above (annotated version below) WITHOUT pausing to explain what is happening at each step. Continue down the length of the “neuron” from one end to the other.

- The neuron is stimulated at one end.
- The sodium gates at that end open and transfer 30 sodium ions inside the neuron one at a time. Students count out loud.
- As soon as the sodium gates transfer their 30th pom-pom, TWO things happen at the same time:
 - » the next potassium gate begins to transfer blue potassium ion pom-poms out of the nerve, counting out loud to 30.
 - » stimulated by the change in charge next to it, the next sodium ion gate in line begins to transfer sodium ions across the membrane, counting out loud to 30.
- The sodium/potassium pumps begin transferring 3 sodium ions and 2 potassium ions whenever they can from their immediate area eating a piece of candy between each transfer.
- To help students visualize the electrical signal, the instructor should walk down the length of the neuron tracking the general area that has the most positive charge as the pom-pom transfer progresses.
- Repeat the steps above until the positive charge (action potential) has traveled the length of the axon or neuron.



Discuss with your class these additional observations:

- Some students should make the observation that the sodium/potassium pump takes a lot longer to transfer their pom-poms than the sodium and potassium gates and end up falling behind. This is true in the neuron also. There is a brief period of time (called the refractory period) in which a nerve cannot transmit another signal because it is still waiting for the sodium/potassium pumps to restore the ions to their original positions.
- Students should also note that with the sodium/potassium pump transferring pom-poms in a 3:2 ratio, there are always some extra blue potassium ions left on the outside that cannot seem to be brought back into the neuron. The same thing is true about the nerve at rest. However, since there are so many ions inside and outside of the neuron, they are often leaking in or out. As this happens, the sodium/potassium pumps will quickly correct the problem.
- You may want to remind students that this whole process is driven by the need to maintain homeostasis in relation to charge inside and outside the membrane.

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Standards

A. U.S. National Science Education Standards:

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

- » Nervous systems are formed from specialized cells that conduct signals rapidly through the long cell extensions that make up nerves.

B. AAAS Benchmarks for Science Literacy:

Grades 9-12

The Living Environment

• Cells

- » Every cell is covered by a membrane that controls what can enter and leave the cell.
- » 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

- » 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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