Pom-Pom Potential

Abstract

Students take on the role of membrane proteins, moving pom-poms to simulate the movement of sodium and potassium ions during an action potential. This whole-classroom, kinesthetic, color-coded simulation helps students visualize how an action potential travels down a neuron.

Learning Objective

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

Estimated time

- 45 minutes

Materials

- About 600 green pom-poms and 300 blue pom-poms
- 1 large bag of small candies, such as M&M's®, Skittles®, or jelly beans (optional)
- 4 lengths of masking tape or rope (optional)

Set-up

1. Lay out lengths of rope or masking tape in the classroom or hallway to represent two parallel cell membranes (see image, right). You may wish to label the inside and outside of the cell.

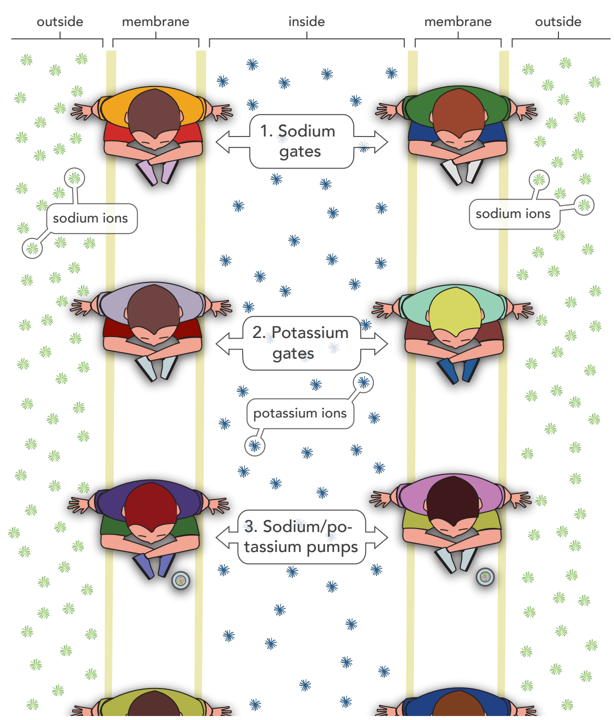
2. Show your students diagram A, which shows the key components along the axon of a neuron. Then show diagram B, to show how their roles correspond to these components.

3. Arrange students into two lines along the "membranes," spaced a reasonable distance apart, sitting cross-legged on the floor.

4. Scatter 300 blue pom-poms in the area between the lines of students. Scatter 600 green pom-poms: 300 outside each line of students.

5. Starting at one end of the line, have students count off numbers 1–3. Assign roles as follows:

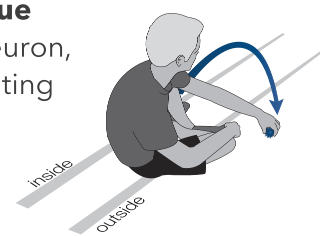
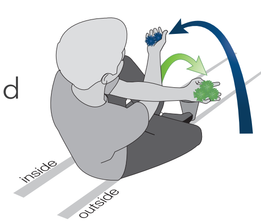
- Students who count 1 – sodium gates
- 2 – potassium gates
- 3 – sodium-potassium pumps



6. Give about 12 small candies to each student representing sodium-potassium pumps. They should not to eat any yet!

7. Review the key parts of the simulation:
   - Green pom-poms represent sodium ions, which are positively charged.
   - Blue pom-poms represent potassium ions, which also have a positive charge.
   - Notice there are a lot more pom-poms outside the neuron than inside. This imbalance of positive ions gives the inside of the resting neuron a less positive (or more negative) charge.

Simulation instructions

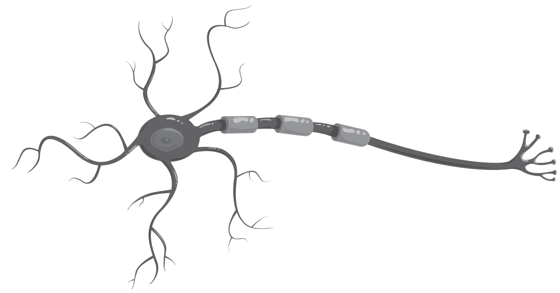
Step	What happens in a neuron	Student actions for the simulation
1	The neuron receives an activating signal, causing the closest sodium gates to open. Sodium ions move through the gate along their concentration gradient: from high concentration (outside) to low (inside).	The first **sodium gate** in each row transfers **30 green pom-poms** from outside the neuron to the inside, one at a time, while counting out loud.  Tip: *It helps if the students place the pom poms slightly ahead of them.*
2	The movement of positive ions changes the charge balance across the membrane. Once the charge difference reaches a threshold, nearby potassium gates open. Potassium ions move through the gate from high concentration (inside) to low (outside).	The nearest **potassium gate** in each row transfers **30 blue pom-poms** out of the neuron, one at a time, while counting out loud. 
3	At the same time, the change in charge activates nearby sodium gates. Sodium ions move through the gate as in step 1, and the process continues down the membrane.	Repeat the actions of the gates in steps 1 & 2 in turn with the remaining sets of students along the rows. This simulates how an action potential travels down a membrane.
4	Meanwhile, to prepare the membrane for another action potential, the sodium-potassium pumps begin moving ions to restore what's called the resting state. The pump moves 3 sodium ions from inside the neuron to the outside, and 2 potassium ions from the outside to the inside. Since the pump moves ions against their concentration gradient, this step requires energy (a molecule of ATP with each turn of the pump).	*As pom-poms become available in a 3:2 ratio:* The **sodium-potassium pumps** should collect **3 green pom-poms** from inside the neuron in one hand, and **2 blue pom-poms** from outside in the other. As they eat a piece of candy (to represent ATP), they should move the pom-poms to the opposite sides of the membrane.  * Repeat as needed to maintain the resting state.

Discussion points

1. Students may notice that the sodium-potassium pumps takes longer to move pom-poms than the sodium and potassium gates, so the pumps end up falling behind. This is true in neurons too.

    - After an action potential, the time it takes for the pump to return the membrane to its resting state is called the refractory period. During this brief period of time, a neuron cannot transmit another signal.

    - The refractory period keeps an action potential moving along the axon in the same direction; it cannot reverse course.



An action potential can travel the length of a neuron in just 1-2 milliseconds (one-thousandths of a second)!

2. It takes a lot of energy to keep messages zipping around the brain and body! Each neuron has many sodium-potassium pumps, and each one uses a lot of ATP. In fact, about 30% of the ATP the body makes every day goes to powering sodium-potassium pumps.

3. Students may notice that because the sodium-potassium pump transfers pom-poms in a 3:2 ratio, some extra blue potassium ions are left outside the cell. The same thing is true about a neuron at rest—but it does not cause a problem. The number of ions in and around a neuron is vast. To carry an action potential, a neuron needs to maintain the proper ion balance only in the area very close to the membrane.

To learn more about the sodium-potassium pump, visit https://pdb101.rcsb.org/motm/118

Funding: Original funding for this activity 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.

Funding for updates was provided by the Utah State Board of Education.

The contents provided here are solely the responsibility of the authors and do not necessarily represent the official views of the funders.

Diagram A: Axon anatomy

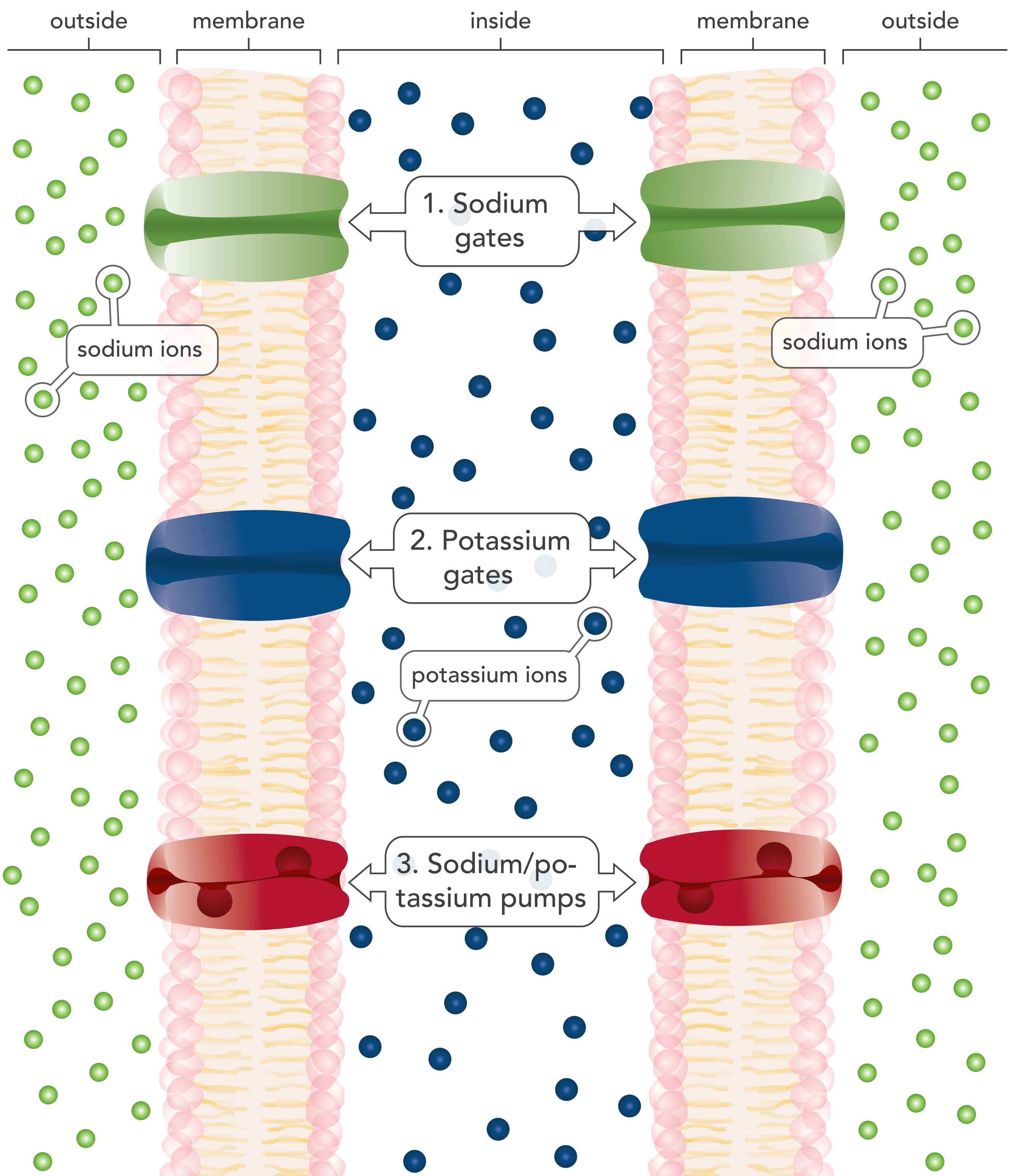


Diagram B: Set-up