YOUR BRAIN
NEUROSCIENCE AND SOCIETY

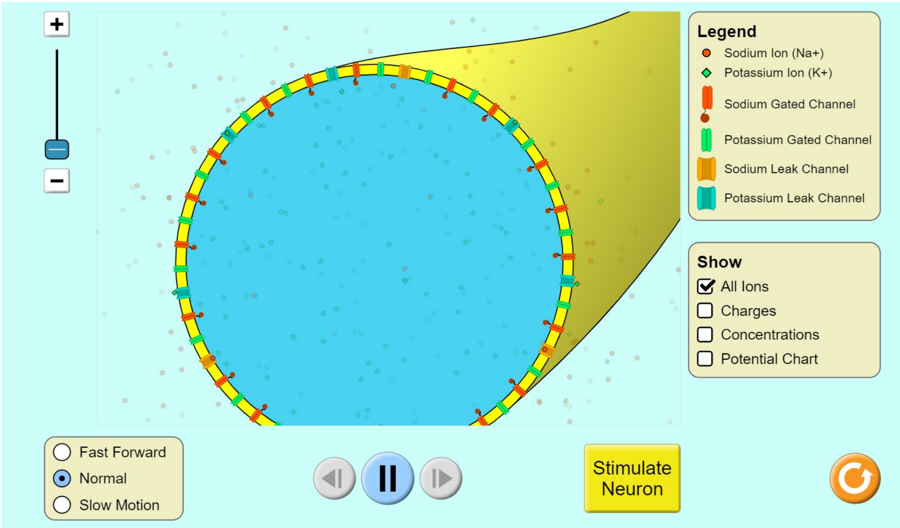
EXPLORE AN ACTION POTENTIAL

Teacher Guide

Introduction:

In this activity, you will be exploring a virtual simulation of how a neuron transmits an electrical signal from one end of the cell to the other. Below is an image of what the simulation looks like—a cross-section slice of an axon (yellow).

Go to the PHeT Sim developed by the University of Colorado and follow the steps below: https://phet.colorado.edu/sims/html/neuron/latest/neuron_all.html



Part 1: **Observe the axon in its resting state.**

1. Click the options in the lower right menu to show “Charges”. Uncheck all other options.

2. Observe and answer the following questions:
   a. Where do you see positive and negative symbols to indicate electrical charge?
   b. What keeps them separated?
   The size of the symbol corresponds to the strength of the charge. The electrical charge symbols get smaller (weaker), briefly reverse (negative outside, positive inside), then go back to normal.

Key takeaway: The separation of charges stores energy as electrical potential.

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Part 2: **Observe the stimulus.**

1. Zoom into a section of the membrane by moving the slider at top left halfway up.

2. Click the option in the bottom left menu for "Slow Motion."

3. Click "Stimulate Neuron" and observe what happens to the charge symbols as the purple stimulus arrives.

4. Answer the questions below:
   a. What happens to the charge symbols as the purple stimulus arrives?
   b. What do you think the size of the charge symbols represents?
   The size of the symbol corresponds to the strength of the charge. The electrical charge symbols get smaller (weaker), briefly reverse (negative outside, positive inside), then go back to normal.

Part 3: **Observe the ions and ion channels.**

1. To take a closer look at the elements of the action potential click the orange reset button in the lower right corner.

2. Now only the "All Ions" option should be checked in the Show menu.

3. Zoom in a bit to see the ions more easily.

4. Answer the questions below:
   a. Notice the sodium ions (red circles) and the potassium ions (green diamonds). Which ones are on which side of the membrane?
   b. Find the orange and blue leak channels. What's going on with them?
   c. Now find the red and green gated channels. What's happening there?
   d. Do you see more gated channels or leak channels in the membrane? (You may need to zoom out to see.) Why do you think that might be important?

   a. There are more sodium ions outside and more potassium ions inside the membrane (you can zoom in a bit to make it easier to see). This separation is what creates the electrical potential.

   b. Leak channels are always open, so ions go back and forth to maintain the cell's resting electrical potential.

   c. Gated channels are closed in the resting state to keep most of the sodium and potassium ions separated.

   d. More gated channels help to maintain the proper concentration of ions on each side of the membrane.

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Part 4: Watch the action potential in motion.

1. Zoom in about halfway, making sure all 4 types of channels are visible in the zoomed in view.
2. Select "Slow Motion."
3. Focus on each of the following elements, one at a time, and click "Stimulate Neuron."
4. Answer the questions below:
   a. What happens to each element during the action potential?
      i. Orange leak channels:
      ii. Blue leak channels:
      iii. Red gated channels:
      iv. Green gated channels:

Orange leak channels - red ions flow into the cell, but no sudden rush

Blue leak channels - green ions flow out of the cell, but no sudden rush

Red gated channels - channel opens, red ions rush in, channel closes

Green gated channels - channel opens, green ions rush out, channel closes

Key takeaway: The flow of ions through the gated channels causes the change in electrical potential we saw with the charge symbols earlier.

Part 5: (Optional) Continue playing around with the simulation.

1. Click the options to show the ion concentrations and the potential chart to demonstrate when the axon has returned to a resting state and another action potential can be stimulated.
2. Note that it is not possible to stimulate the neuron again immediately.
   a. Why do you think that is important?
   The electrical potential needs to recharge to ensure that the action potential can fire at full strength and the signal is not lost or weakened.

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