BioEd℠

The Learning Brain

Brain Chemistry
Teacher's Guide

Neural Network Signals

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Source URLs

Page 2: Microscopic image of motor nerve endings resting on muscle tissue courtesy of Dr. Thomas Caceci, Virginia-Maryland Regional College of Veterinary Medicine, http://www.vetmed.vt.edu/education/curriculum/vm8054/labs/lab10/lab10.htm/.

Page 3: SEM image of a neural network courtesy of Paul De Koninck, Laval University, www.greenspine.ca/.

Overview

Students create an electrical circuit and investigate whether or not different dissolved substances conduct electricity.

Neural Network Signals

Neurons communicate with one another and with other cells, such as muscle cells, by sending signals along the length of a special type of output fiber known as an axon. More than a century ago, biologists discovered that these signals, also known as nerve impulses or action potentials, involved electricity. At first it was believed that electricity flowed through axons much as it travels along a wire. However, further investigation revealed that electricity does not flow passively through axons. Rather, electrical signals are actively transmitted along the length of axons.

Eventually, biologists discovered that electrical impulses are transported along the cell membranes of axons. Chemical changes along the length of the membrane cause an electrical charge to move along the length of the axon. This movement resembles a line of dominoes, in which each domino triggers the next one to fall. Once the signal reaches the end of the axon, it is passed to the next nerve cell either electrically or by a chemical messenger that crosses the synaptic cleft between nerve cells.

Movements of sodium, one of the components of salt, help generate the electrical charge that travels along the neuron membrane. Potassium, chlorine and calcium also are involved. This activity helps students observe the relationship between certain substances dissolved in water and the conduction of an electrical signal.

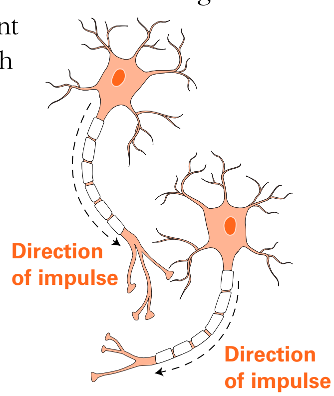
Students will build a circuit that connects a bulb to a battery. Electricity, which is the movement of electrons (negative charge), will flow from the negative terminal to the positive terminal.

Students will use their setups to investigate whether distilled water conducts electricity and compare the results to those achieved with salt water and sugar water. Students also will test the conductivity of a sports

Unit Links

Legacy of Lost Canyon
Chapters 5–6
Science box, p. 13

Brain Chemistry Explorations
"Did You Know?" p. 4
"Sending Signals," p. 7



Signals are conducted electrically in one direction along the length of a neuron's axon and passed either electrically or chemically across the synaptic cleft to the next neuron or series of neurons.

Concepts

- Nervous system messages are sent as electrical signals along the length of axons.
- Dissolved salts are important for electrical signaling in cells.

Science & Math Skills

Predicting, observing, comparing, recording observations and interpreting

Time

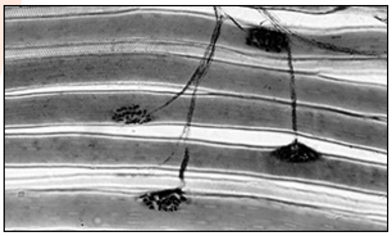
Preparation: 20 minutes
Class: 45 minutes or more

Electric Signals

- Electricity flows in one direction (negative to positive).
- Chemicals, such as salt, that dissolve into positively and negatively charged atoms (ions) in water will conduct electricity.
- Chemicals, such as sugar, that do not acquire a charge when dissolved do not conduct electricity.
- Electricity in living cells depends on positively and negatively charged atoms (ions) dissolved in water.
- Electrical signals in neurons travel very quickly—up to several hundred miles per hour.
- Nerve impulses involve the opening and closing of tiny tunnels in the cell membrane. The movement of charged atoms (such as sodium), through the tunnels creates an electrical impulse.

Neuron Firing

The photo below is of a motor neuron's nerve endings on top of skeletal muscle fibers. The dark, bumpy areas at the end of each nerve are called motor end plates (neuromuscular junctions). Each motor end plate is associated with only one muscle fiber.



Microscopic image of motor nerve endings resting on muscle tissue courtesy of Dr. Thomas Caceci, Virginia-Maryland Regional College of Veterinary Medicine.

When the neuron fires, acetylcholine (a neurotransmitter) is released into the space between the motor neuron (synaptic cleft) and that of the muscle fiber; it diffuses across the space and triggers the series of events that leads to contraction of the muscle.

The Role of Salt

In addition to its role in the nervous system, salt is important for muscle movement, digestion and the movement of fluids into and out of cells. Salt lost from the body in sweat and in urine must be replaced. Normal human blood contains about 0.9% salt.

drink. Pure water is a poor conductor of electricity. However, when salt is added, water conducts electricity very efficiently. Dissolved salt (NaCl) separates into negatively charged atoms (chloride ions, written as Cl-) and positively charged atoms (sodium ions, written as Na+). The current is carried by Cl- ions, which migrate toward a wire connected to the positive terminal of a battery.

MATERIALS

Teacher (See Setup, below)

- 60 mL of sports drink
- 8 cm black electrical tape
- Clear plastic cup, 9 oz
- Graduated cylinder (100 mL)
- Marker, black
- Measuring spoons
- String of mini-size holiday lights
- Wire cutter
- Wire stripper

Per Group of Students

- 180 mL distilled water
- 4 clear plastic cups, 9 oz
- 2 clear plastic cups, 2 oz
- 2 coffee stirrers
- 2 squares of aluminum foil, 3 cm x 3 cm each
- 1/2 teaspoon of table salt
- 1/2 teaspoon of sugar
- Battery, 9 volt
- Copper wire, 20-cm piece
- Mini-size holiday light bulb and socket, with wiring trimmed to approximately 9 cm length on each side and 3 cm of insulation stripped from each end
- Copy of "Sending the Signals" student sheet

SETUP

Purchase a set of mini-size holiday lights (or LED lights). For each group, cut a bulb/socket from the string of lights so that the socket has two 9-cm pieces of wire extending from its base. Strip 3 cm of insulation off the end of each wire to expose the copper wire inside. Also, cut a 20-cm piece of insulated copper wire (with 3 cm of insulation stripped off of each end), and provide two squares of aluminum foil (about 3 cm x 3 cm each) per group.

Label each of three 9-oz cups as "distilled water," "salt water" and "sugar water." Pour 60 mL of distilled water into each cup.

Label two 2-oz cups as "salt" and "sugar." Measure 1/2 teaspoon of salt into one cup and 1/2 teaspoon of sugar into the other cup.

If using powdered sports mix, prepare the mix according to package directions and have ready for open inquiry (see Items 10–11). Pour 60 mL of sports drink into a 9-oz cup for class discussion.

Make six copies of "Sending the Signals" sheet. Place all materials in a central location. Have students work in groups of four.

PROCEDURE

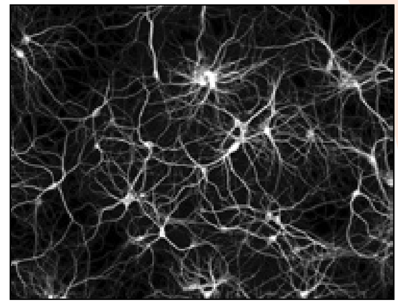
1. Remind students of the activity, "What Is a Neuron?" in which they learned about neurons. Ask, *Did you know that neurons rely on electricity to carry messages along the length of the axon? Can you think of other examples of ways that living things use electricity?* Students may offer examples such as electric eels.

2. Ask students, *Which substances in living things might be important for electrical signals in neurons?* Students may not have much prior knowledge of materials in cells. If necessary, remind students that living things consist mostly of water. In addition, a number of dissolved materials such as salts, sugars and other carbohydrates, and proteins are present in cells and other parts of living organisms.
3. Tell students that they will build an electrical circuit and use it to investigate which substances might be important for conducting electricity in cells. Have the Materials Managers from each group collect the materials.
4. Distribute copies of the student sheet. Have students follow the instructions on the sheet to build and test their circuits.
5. Ask, *Where is the source of energy for the bulb?* [battery] *Where is the electricity traveling?* [from terminal to terminal, along a wire] Point out that electricity flows in only one direction (negative to positive). Relate this to neurons by pointing out that tiny electrical impulses also travel in only one direction along the length of axons.
6. Tell students that they will use the circuit setups to conduct three tests using distilled (pure) water, a salt water solution and a sugar water solution. For each test, students will insert the foil wrapped tips of their circuits into a liquid and observe the bulb.
7. Have students create a table on the back of their student sheets or on a separate sheet of paper (see "Sample Table," right). They will need to leave enough room on their tables to record predictions, reasons for their predictions and results. Give students time to predict the outcomes of each test and justify their predictions.
8. Have students conduct each test and record the results.
9. Discuss students' outcomes: salt water conducted electricity; distilled water and sugar water did not conduct electricity. Ask, *Which of the two dissolved substances might be involved in electric signaling in neurons?* (salt)

   Note. To promote safety, make sure that students understand that tap and rain water also are good conductors of electric current. Point out that students never should use a hair dryer, radio or television near a bathtub or sink; and never should touch anything that runs on electricity with wet hands.
10. Continue by showing students the sports drink. Ask, *Why do people use these drinks?* Students may or may not know that the drinks are promoted as sources of body salts lost as sweat during exercise. Ask, *How might you be able to investigate whether the advertising claims are valid?* Challenge students to use their circuit setups to test whether the sports drink is a good source of lost salt.
11. You may want to give students time to plan and bring in other drinks or brands of sports drinks to test the next day. Students should compare their findings to the information provided on the sports drink label. Have each group present its investigation and results to the class.

Neuron Circuits

When a neuron "fires," it sends an impulse to one or more other neurons. The trigger can be a sensory signal (light, heat, sound, etc.) or it can be a signal or impulse received from other neurons.



Some neurons are coupled directly, so that an electrical signal traveling down one neuron passes directly to the next one. This type of transmission occurs very rapidly and usually is found in places in the nervous system where speed of conduction is important. Other neurons use chemical messengers, known as neurotransmitters, to send signals to other neurons. Shown above is a culture of a neuronal network.

Sample Table

	Prediction	Reason	Result
Distilled Water			
Salt Water			
Sugar Water			

Extension

Salt is an important part of the diet for humans, but it has not been plentiful at all times throughout history. Have students investigate the roles salt has played in human culture, civilization and politics.

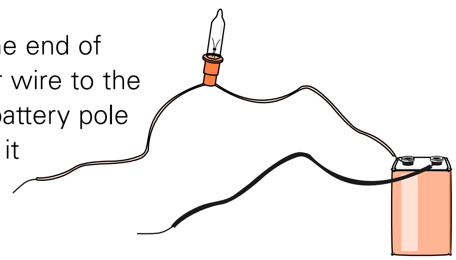
SEM image of a neural network courtesy of Paul De Koninck, Laval University.

Sending the Signals

BUILD A CIRCUIT

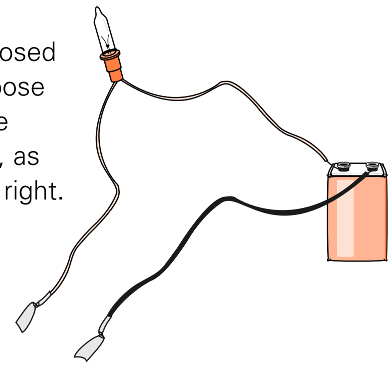
1. Wrap the exposed end of one wire from the light bulb around one pole on the battery. Tape it in place with a piece of electrical tape.

2. Attach the end of the other wire to the second battery pole and tape it in place.



3. Test the connection by briefly touching the exposed ends of the two loose wires together. (The bulb should burn brightly.)

4. Wrap the exposed ends of the loose wires with the aluminum foil, as shown to the right.



TESTING SOLUTIONS

All cells contain water, some dissolved salts and sugar. *Which substances in cells help conduct electricity?* You will investigate what happens when a tiny amount of electricity passes through distilled water, a salt-water solution, and a sugar-water solution.

1. You have three labeled cups of distilled water, a container of salt and a container of sugar. Pour the salt into the cup of water labeled "salt," and stir until the salt dissolves. Pour the sugar into the cup of water labeled "sugar," and stir until the sugar dissolves.

2. On a separate sheet of paper, or on the back of this sheet, create a chart (see sample chart, right) to record your predictions, reasons for your predictions, and test results for each liquid tested (see sample chart).

	Prediction	**Reason**	**Result**
Distilled Water			
Salt Water			
Sugar Water			

3. What do you think will happen when you put the foil-wrapped wires in the different solutions? Record your predictions and reasons.

4. Test the first solution by inserting both foil-wrapped tips below the surface of the liquid. Keep the tips apart. Record the results. Next, test each of the other two liquids and record the results.

5. Based on your observations, which substances in cells would you say helped conduct electricity? Write a paragraph describing the steps you followed, your observations and your answers to this question.