Lesson Summary: Neurons transfer information by releasing neurotransmitters across the synapse or space between neurons. Students model the chemical communication between pre-synaptic and post-synaptic neurons by transferring cotton-ball neurotransmitters between human neurons.

Grade Level 5-8
Lesson Length **1 class period**

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Standards Alignment

Next Generation Science Standards

- MS-LS1-1. Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.
- MS-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.
- MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.
- MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories
- **Framework for K-12 Science Education**: Science & Engineering Practices 1,2,3,5,6

National Science Standards – Project 2061: Atlas of Science Literacy reference

a) Cells: Cell functions – basic needs and basic functions (p. 73, Atlas Vol. 1)

Research on student learning: "Preliminary research indicates that it may be easier for students to understand that the cell is the basic unit of structure (which they can observe) than that the cell is the basic unit of function (which has to be inferred from experiments)." (p.72, Atlas Vol. 1)

b) Models – uses of models and limitations of models (p.93, Atlas Vol. 2)

Research on student learning: "Prior to instruction, or after traditional instruction, many middle- and high-school students continue to focus on perceptual rather than functional similarities between models and their referents, and think of models predominantly as small copies of real objects. Consequently, students often interpret models they encounter in school science too literally and unshared attributes between models and their referents are a cause of misunderstanding. Some middle- and high-school students view visual representations such as maps or diagrams as models, but only a few students view representations of ideas or abstract entities as models." (p.92, Atlas Vol. 2)

Objectives—Students will be able to

- model, draw, and describe the movement of a message along a chain of neurons. To be included:
  - o label dendrite, cell body, and axon of each neuron.
  - o show that the space between neurons is called the synapse. Neurons do not touch each other or the muscle.
  - o describe how the action potential (an electrical signal) moves down the axon from cell body to axon terminal.
  - o describe how neurotransmitters move from axon terminal to dendrite of next neuron or to the neuromuscular junction of the muscle.
- identify ways that the movement of a message can be sped up, slowed down, or stopped.

Assessment Options

- Grade drawing that depicts the communication between two neurons and a muscle.
- Assign points for effective participation in the modeling of neuron communication.
- Ask students to draw and label a picture - or write a paragraph - that explains how the passing of a message between neurons can be sped up, slowed down, or stopped.
- Direct students to develop a comic strip or picture book that illustrates the communication between neurons.

Teacher Notes—See Science Standard Alignment Matrixes

Terms—important vocabulary that strengthens the lesson. Select terms according to the needs and abilities of your students.

- action potential – an electrical charge that travels away from the cell body along the axon, to the axon terminal where it triggers or inhibits the release of neurotransmitters
- axon – the part of a neuron that **sends the signal** away from the cell body and towards target cells/neurons
- axon terminal – end part of an axon that makes a synaptic contact with another cell; the point where neurotransmitters are released
- cell body – the part of the neuron that decides whether or not to send a signal along the axon
- dendrite – the part of a neuron that **receives the signal** from other neurons.
- excitatory neuron – a neuron whose neurotransmitter stimulates another neuron, increasing the probability that the target neuron will fire an action potential
- inhibitory neuron – a neuron whose neurotransmitter inhibits another neuron, decreasing the probability that the target neuron will fire an action potential
- neuromuscular junction – the special synapse onto a muscle
- neuron – nerve cell that is specialized for sending information; characterized by long fibrous projections called axons, and shorter, branch-like projections called dendrites
- neurotransmitter– a chemical released by neurons at a synapse to send a signal to nearby dendrites of neighboring neurons; bind to special receptor molecules on dendrites to generate the signal
- post-synaptic neuron – the neuron whose dendrite receives the neurotransmitter
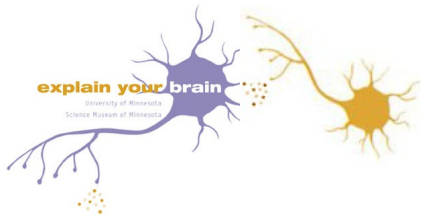
- pre-synaptic neuron – the neuron releasing the neurotransmitter
- receptors – special molecules on dendrites that taste each specific neurotransmitter. both neurotransmitter and receptor have to fit together like a lock and key
- synapse – a gap between two neurons forming the site of information transfer from one neuron to another; place where neurotransmitters are released from pre-synaptic axon terminals and bind to receptors on post-synaptic dendrites
- threshold – the minimum amount of input needed by a neuron cell body to cause it to fire an action potential

Materials (for each group of students)

- white cotton balls
- colored cotton balls (optional)
- non-latex gloves (optional)
- 2-4 stopwatches (optional)

Procedures

Engage — Neuronal Communication

Use a student model to demonstrate how neurons pass messages between each other and to review the parts of a neuron.

1. Line up three students at the front of the classroom to represent two neurons and a muscle.
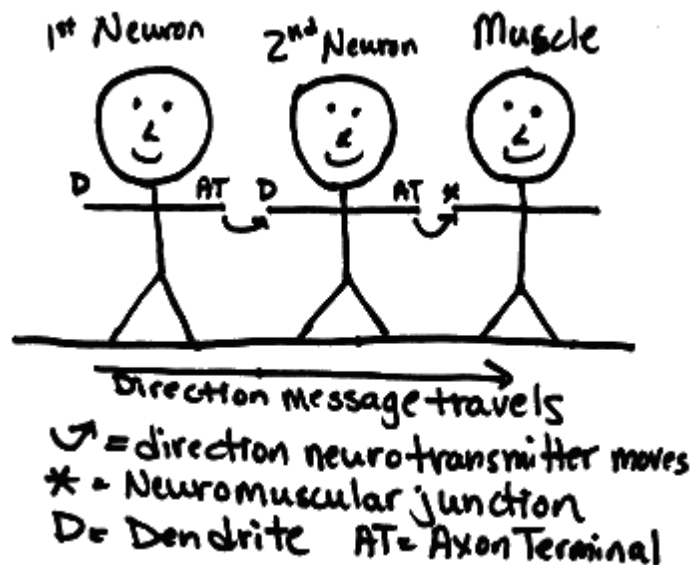
2. Put five white cotton balls in the right hands (axon terminals) of the two student neurons.

   - Tell the class to decide which of each students' hands are dendrites, which are axons. Ask them describe the functions of axons and dendrites.

   - Ask the class what they think the cotton ball could represent (neurotransmitter).

3. Explain that neurotransmitters are released by the axon terminal, where they move across the synapse and attach to receptors on the dendrites of an adjacent neuron (to send a message or information).

   - Ask students to demonstrate the communication between neurons.

   - When receiving a sensory input (tap from the teacher), the 1st student needs to send a message to the 2nd student by releasing neurotransmitters (cotton balls) from the axon terminal into the synapse.

   - The dendrites of the 2nd student receive the neurotransmitters and release neurotransmitters from the axon terminal.

   - When the 3rd student in the chain (representing a muscle) receives the neurotransmitters at the neuromuscular junction, the student flexes muscles to show the message was received.

   After touching a dendrite, neurotransmitters can drop to the floor and later be recycled by being picked up by the axon terminal. This is similar to how neurotransmitters are recycled in the nervous system. Dendrites do NOT pick up neurotransmitters (or transfer them back to their Axon Terminal hand). Within a single neuron, only electrical signals go from the dendrite to the cell body to the axon terminal.

   If anyone drops a cotton ball, ask whether or not the students think this actually happens in the brain. Some neurotransmitters actually do not reach their targets, so it does happen.

4. Explain that within a signal neuron, the neurotransmitter attaches to the receptors on the dendrites, generating an electrical signal that is sent to the cell body. The cell body decides when enough input signals are received, and then produces a large electrical signal, called an action potential, that moves down the axon to the axon terminal where neurotransmitters are then released.

   - Ask students how the student neurons could show an action potential.

   - Now repeat the demonstration; incorporate acting out the action potential.

   - Again, ask the class if the student neurons correctly illustrated the entire process.

   - Ask students to draw and label the parts of a neuron, including the functions.

Explore — Neuronal Communication

1. Give each student one pair of gloves to decorate, one as dendrite and one as axon. They can label one hand **D** and the other **AT**.

2. Divide students into groups and provide them with cotton balls. Groups can have different number of students.

   - Instruct each group to arrange themselves for neuronal communication, similar to the previous student model.

   - Teacher can verbally start all groups at once. Either the teacher or group could time each trial. Several rounds may be necessary.

- Keep track of the total time per group for each trial. Have students calculate the time needed per synapse for each trial.

3. After the group demonstration, promote discussions among the students. These discussions may include, but are not limited to, talking about their performance and evaluating how well they modeled neuronal communication.

Develop Questions

Brainstorm additional actions dependent upon neuronal communication — ex: blinking, speaking, calculating an answer, release of a hormone, etc.

Explore and Explain — Changing Neuronal Communication

Speed It Up

Challenge the groups to figure out how to speed up sending the message from the first to the last person while still using the same number of people and modeling the sequence of events (as they did in **Engage** — **Neuronal Communication** Step #3).

1. Give the group a few minutes to get organized.

2. Let students time their performance (optional).

3. Ask students to share what changes they made to the process.

4. Discuss differences in how students modeled neuron communication.

Stop It Cold (Can be skipped if doing **Expand – Neuronal Communication**)

Ask students to develop two ways to prevent the signal from going through.

1. Give students a few minutes to get organized.

2. Have them demonstrate their strategies.

3. Ask students to share what changes they made to the process.

4. Discuss differences in how students modeled this change in neuron communication.

Slow It Down (Can be skipped if doing **Expand – Neuronal Communication**)

Ask students to devise a way to slow down movement of the signal. Explain to the students that once the signal moves from the cell body to the axon, the electrical message has to go on until it reaches the axon terminal.

1. Give students a few minutes to get organized.

2. Have them demonstrate their strategies.

3. Ask students to share what changes they made to the process.

4. Discuss differences in how students modeled this change in neuron communication.

Expand – Neuronal Communication

Circuit Frenzy

Challenge the groups to get the most messages passed in one minute.

1. Tell the initial neuron that it may fire an action potential as many times as it wishes, but that after each tap, it must wait until the cotton balls are recycled back into the axon terminal before tapping again.

2. Tell the neurons that they need to illustrate neurotransmitter re-uptake by picking up cotton balls that are dropped.

3. Ask the initial neuron to keep track of the number of times it fired an action potential in the one-minute period.

4. Ask the muscle to keep track of the number of times it flexed in the one-minute period.

5. Approach at least one person in each group and tell that person that s/he may not pass a message on until 2 (or 3 or 4) incoming messages have been received.

6. Afterwards, let the muscle tell how many times it contracted and the initial neuron tell how many times it tapped. Ask the class to explain why the number of muscle flexes does not match the number of taps.

Once the class understands that some of the students only pass a message for every 2, 3, or 4 incoming messages, introduce the idea of threshold – that a cell body must add up all incoming messages and when a certain amount are received (a threshold) then an action potential can be sent down its axon.

Excitement and Inhibition

1. Randomly replace one student's white cotton ball with a colored cotton ball in each group.

2. Tell the students that if a COLORED cotton ball touches their dendrites, they may NOT pass on the message. (*The last neuron in the chain must always be excitatory and use white balls because mammalian muscles cannot bind with inhibitory neurotransmitters*.)

3. Assemble students back into their teams and instruct them to transmit a message along their circuit.

4. Discuss what happened after the activity. Ask students:

   - What happened to the signal downstream of the colored cotton ball?

   - Why would a neuron want to send a message to stop further signaling?

   - What would happen if the colored cotton ball just subtracted a unit of one from the cell body's count of inputs received as it tries to reach threshold?

   - How would you slow down message transfer in a neuronal circuit?

5. Introduce the concept of excitatory and inhibitory neurons. Discuss the possibility that a neuron receives multiple inputs and sends multiple outputs.
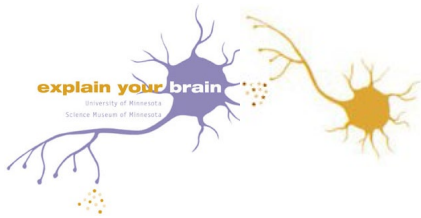
Complicated Circuitry

1. Ask students to arrange themselves in circuits with internal branches or a loop along the straight pathway and transmit a message.

2. Run the circuit again giving the white cotton balls a value of +1 and colored cotton balls a value of –1.

3. Tell each group to keep track of the number of times the initial neuron fires and the number of times the muscle contracts in a minute.

4. Discuss how the circuit shape affected how well the message was sent. Reliability, consideration of all inputs, and limits to speed are the most important issues.

   - What happens to the rate of muscle contraction?

   - What happens to the rate of muscle contraction if the loop contains an inhibitory neuron?

   - Does the position of the inhibitory neuron affect the rate of muscle contraction?

   - What happens if there are branches of unequal numbers of neurons?

   - What happens if the loop reattaches at different places? Try both downstream and upstream of the branch point.

   - What happens if there are multiple initial neurons?