Teacher Guide

Neuropathfinding: Kinesthetic Model

Lesson Summary: Students will model the migration of neurons to understand that nerves are not born in place or connected. Once they have moved to their correct location, they need to then make connections.

Grade Level 5-12

Lesson Length 1-2 class periods

Standards Alignment

Next Generation Science Standards – Alignment Matrix

- 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.
- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
- 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.
- HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.
- **Framework for K-12 Science Education**: Science & Engineering Practices 2,3,6,7,8

Minnesota Science Standards – Alignment Matrix brainu.org/resources/MNSTDS

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

- use a kinesthetic activity to model neuron pathfinding to their appropriate targets.
- discuss the concepts of “sprouting” and “pruning” in the CNS.

Assessment Options

- Ask students to generate rules of pathfinding.
- Encourage students to describe an example of a situation when “sprouting” and/or “pruning” might occur in their own brain.

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

- chemotaxis – using chemicals (chemo) to help a growth cone move towards (taxis) the correct neuron to attach to
- growth cone – the tip of a growing axon that senses and uses chemical signals to find its targets
- pathfinding – the process of the axons finding the right neuron to connect to
- pioneer – end part of an axon that makes a synaptic contact with another cell; the point where neurotransmitters are released
- pruning – the process of neuron axonal shortening/reducing in number in response to growth signals
- sprouting – the process of neuron axonal lengthening/increasing in number in response to growth signals

Materials (for each group of students)

- 8 balls of string / yarn (4 balls ea of 2 different colors; optional: mark every meter or yard)
- 24 film canisters or other small containers with lids (8 canisters should be different color than remaining canisters or marked for identification on the bottom)
- 24 cotton balls
- 2 different target scents (clear food flavoring or essential oils, suggest mint and lemon)
- 8 writing surfaces (ie: clipboards, cardboard squares, or books)
- 1 transparency copy of room map
- overhead projector and screen
- 16 pieces of paper numbered 1-16
- 16 blank transparencies
- 8 transparency markers
- 8 copies of room map
- 1 shoe box (optional)

Preparation - General

- Place the numbers 1-16 around the classroom creating a maze of designations for the scents.
- Make 8 copies of a room map. Clearly mark the copies to indicate the location of each potential “chemical target” (write a number where a scent container will be placed). See the Sample Room Map. Attach one map to each clipboard with two transparencies and a marker. Place a small “X” in the bottom right-hand corner of each transparency.
- Make an overhead transparency of the room map.

Preparation - Scents

- Place a cotton ball inside each container.
- Choose two scents to be used for the pathfinding neurons (target scents).
- Select 8 canisters to be identified as target scents. Divide the eight canisters designated for target scents into two groups of 4. Place one to two drops of the first target (ie. mint) scent into one group of 4 canisters. Place a drop or two of the second target scent (ie. lemon) into the second set of 4 canisters. Mark or code the bottom of each canister so students are unaware of the coding system.
- Of the remaining 16 canisters, 2 will be used as matches for the target scents and 14 will be used as distractors. Prepare two canisters as above so one has a target scent (mint) and another has the second target scent (lemon). Set these canisters aside. Put cotton balls with no scent in the remaining 14 canisters.
- Place a canister at each of the 16 designated positions in the classroom. When finished, there will be:
    - 4 canisters of target scent #1 (ex. mint) for growth cones
    - 1 canister of target scent #1 (ex. mint) for one scent station
    - 4 canisters of target scent #2 (ex. lemon) for growth cones
    - 1 canister of target scent #2 (ex. lemon) for another scent station
    - 14 canisters with NO SCENT for remaining scent stations

Engage — Discussion of the parts of a neuron and what occurs during brain development

Discuss with and/or ask students:

1. the parts of the neuron (cell body, dendrites, axon).
2. how the number of cells in an embryo compares to the number in a baby (LOTS more in the baby).
3. formation of the neural plate and neural tube.
4. how all the neuron cells from the brain and spinal cord know which other neurons to connect to. (Answers will probably include genes, maybe signals.)
5. what sort of signals they think cells might send out (chemical, electrical, etc).
6. that in this case we are representing chemical signals with smells.

Explore — Setup

Students will play neurons trying to find their appropriate targets in a developing brain. There are three student roles: Pathfinding Growth Cones/Axons [8 students], Cell Bodies [8 students], and Chemical Targets [remaining students].

1. Choose 8 students to play the part of *growth cones/axons* of pathfinding neurons. Growth cones will move throughout the room attempting to find their target scents.

2. Choose 8 students to play the *cell bodies* of the growth cone axons. The cell body will be responsible for documenting, on the transparency, the path that the growth cone takes on its journey to find its target.
3. Assign each growth cone a cell body partner whose arms and legs are dendrites.
4. Give each growth cone a roll of yarn and a canister with a target scent.
5. Give each cell body a transparency sheet, a transparency marker, a map of the room, and a writing surface. Each transparency should have an "X" in the bottom right-hand corner.
6. Remaining students play the role of *chemical target* cell areas. Their job is to sit at one of the designated scent stations and to present the scents to the wandering growth cones.
7. After each visit by a growth cone, the chemical target cell should re-cover the scent.

Explore — Getting Started

1. Give a canister to each chemical target student. Remind them:
   a. NOT to open the canister and
   b. when allowed to open the canister, to keep the scent a **secret**.
2. Tell students that each growth cone must check each chemical target student's scent to see if it is the growth cone student's target scent.
   a. If it is the target scent, the growth cone/axon should remain standing next to target student.
   b. If it is not the target scent, the growth cone should move on to another target.
3. Tell cell body students that they must record the growth cone paths on their transparencies.
4. Remind the students that the brain does not communicate with spoken language. The only communication that should be going on is with the scents.
5. You'll start the activity by saying "Growth cones, find your targets!" and starting the timer. You will stop timing when all cones have found their correct targets.

Do it!

1. Ask students to move to their starting positions: Growth cones/axons and cell bodies stand at one end of the classroom; chemical targets sit or stand at a scent station.
2. Give the command "Growth cones, find your targets" and start timing.
3. Stop timing when all axons have stopped at the correct receiving neurons.

   Alternative ending: call time when there is still a cone not at the proper place and cut its string.

Explain — Discuss findings / Develop questions

1. Collect transparencies from the cell bodies. Stack the transparencies for each group into separate piles. (Use the "X" in the bottom right-hand corner to orient the transparencies.)
   a. Place each group in turn on the overhead.
   b. Inform the students that there were only two target scents.

c. Discuss the efficiency with which the growth cones/axons found their matching scents.

d. Lead the students in a discussion to find a more efficient, organized way for growth cones to find their target scent, using fewer proteins and less energy.

2. Encourage students to create a plan of action to re-create the model more efficiently. Guide them to the idea of having the one growth cone in their group "pioneer" and find the correct receiving neuron, then let the other cones know the path is made by jiggling his/her axon (hand or foot). Then all like growth cones may simply follow the path.

Explore

1. Ask students to return to their starting places.
2. Redistribute scent station canisters around the room. Take care not to place the two scent station canisters which hold the target scents at spots near the front.

Get set - Go!

1. Give the command "Growth cones, find your targets."
2. Start timing.
3. Stop timing when all cones have stopped at the correct targets.
4. Ask students to "spool back" to their cell bodies as they did above but with **Round 2** in the upper left.

Expand activity

1. Collect transparencies from the cell bodies. Stack the transparencies for each group into separate piles. (Use the "X" in the bottom right-hand corner to orient the transparencies.)

   a. Place each group in turn on the overhead.

   b. Discuss how the paths compared to the first trial. Was this strategy successful at reducing time and energy spent?

2. Which process do they think better models how neurons find their connections? (Second one – much more efficient in terms of energy and resource use.)
3. Do students think neurons could connect to anything else this way? (Yes- other neurons in body and brain.)
4. How many axons do they think can connect to each neuron? (Up to 10,000 axons can connect to a single other neuron.)
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. What do they think happens to the other neurons that no neurons connected to? (They wind up either with other axons coming to connect or they are "pruned" – ie: die.)
7. As review, where is this happening in our example? Where else must it happen? (All other brain and spinal cord connections – similar process to connect to other tissue.) WHEN is it

happening? (Second and third trimester of the pregnancy – AFTER neurons have migrated to their locations and have started growing dendrites and axons.)

8. What do you think if neurons take too long to grow to their targets? They might get pruned away!

Closure

1. Review the vocabulary and identify which part of the activity was represented by each term.
2. Based on the kinesthetic model, ask students to attempt to generate the rules of pathfinding.
   a. Growth cones/axons use chemical signals to find the target neurons or muscle fibers to attach to.
   b. Like/similar axons group together.
   c. One growth cone/axon becomes the pioneer that blazes the trail for other similar axons to follow.
3. Describe an example of a situation when “sprouting” and/or “pruning” might occur in their own brain.