What can I learn from worms?

Regeneration, stem cells, and models

Lesson 2: How do planarians react to their environment?

I. Overview
In this lesson, students identify and discuss different types of behavior that are seen in both humans and planarians. After a discussion of three different taxes: chemical, mechanical, and light, students use the taxes as stimuli in order to observe responses in planarian behavior. Finally, students create their own models of how planarians sense their environment and respond to different stimuli.

Connections to the driving question
Students learn worm behaviors, make models for when the behaviors will occur and relate the behaviors to other organisms.

Connections to the previous lesson
After learning about the regenerative properties of planarians, the current lesson gives the students insights into the complex behaviors performed by such simple organisms.

II. Standards

National Science Education Standards
- Content Standard C: The Behavior of Organisms. Organisms have behavioral responses to internal changes and to external stimuli. Responses to external stimuli can result from interactions with the organism’s own species and others, as well as environmental changes; these responses either can be innate or learned. The broad patterns of behavior exhibited by animals have evolved to ensure reproductive success. Animals often live in unpredictable environments, and so their behavior must be flexible enough to deal with uncertainty and change. (9-12 C:6/2)
- Content Standard C: The Behavior of Organisms. Behavioral biology has implications for humans, as it provides links to psychology, sociology, and anthropology. (9-12 C:6/4)

Benchmarks for Science Literacy
Evolution of Life
- Natural selection leads to organisms that are well-suited for survival in particular environments. 5F/H6a

III. Learning Objectives
<table>
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<tr>
<th>Learning Objective</th>
<th>Assessment Criteria</th>
<th>Location in Lesson</th>
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<tbody>
<tr>
<td>Explain how simple organisms use their sensory systems to respond to their</td>
<td>Explanations can include:</td>
<td>Opening of lesson, models on student sheet Q. 4</td>
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<td>environments.</td>
<td>• Organisms respond to light, touch, temperature, chemicals in their environment</td>
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<td>by moving towards or away from the stimuli</td>
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<td>Describe the term ‘taxis’ and how organisms use taxes to find food and navigate</td>
<td>Descriptions can include:</td>
<td>Opening of lesson, models on student sheet Q. 4</td>
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<td>their environment.</td>
<td>• taxis is directed movement towards or away from a stimuli</td>
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<td></td>
<td>• taxis is a behavior simple organisms perform to navigate their environment for food and survival</td>
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<td>Give examples of different environmental signals, which are important to simple</td>
<td>Examples can include:</td>
<td>Opening of lesson and main part of lesson, student observations Q. 1-3</td>
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<td>organisms.</td>
<td>• light</td>
<td></td>
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<td></td>
<td>• heat</td>
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<td></td>
<td>• touch</td>
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<td></td>
<td>• chemicals / food</td>
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<td>Model how complex behaviors can arise from simple nervous systems.</td>
<td>Models can include:</td>
<td>Student sheet Q. 4, Conclusion of lesson</td>
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<td></td>
<td>• Planarian taxis (positive or negative) in response to environmental signals and</td>
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<td>explanations as to why these behaviors would exist.</td>
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**IV. Adaptations/Accommodations**

If any students have physical disabilities that limit handling of lab equipment, lab partners can be assigned to assist with the equipment.

**Safety**

Students are working with live specimens in this lesson. Students should be informed of how to work ethically with live organisms.

**V. Timeframe for lesson**

Opening of Lesson
• Discussion of chemotaxis, phototaxis, and mechanotaxis in planarians – 5-10 minutes

Main Part of the Lesson
• Activity 1: Planarian Observation – 35 minutes

Conclusion of Lesson
• Wrap up discussion – 15 minutes

VI. Advance prep and materials

Activity 1: Planarian observation

Materials:
• Small plastic tubs of Spring water with 5-10 planarians
• Small flashlights
• Clean probes for touching the planarians (round ended toothpicks are ideal)
• Frozen Bloodworms or other food source
• Spring water
• Petri plates
• Microscopes
• Petri-plates filled with frozen spring water
• Filter paper
• Student observation sheet (U2_L2_StudentSheet_PlanarianObservations.docx)

Preparation:
• Since the observation will require a feeding, it is best not to feed the planarians for approximately one week prior to this lesson in order to ensure that they are sufficiently interested in the bloodworms.
• Fill small, clean plastic tubs with spring water and add about half a dozen planarians to each. Alternatively, place a single planarian in a small Petri dish so that students can observe what happens with a single planarian.

Homework and Assessments

Materials:
• Lesson 3 Pre-Reading (U2_L3_PreReading_CoolScientistsMorgan&Randolph.docx)

VII. Resources and references

References
Teacher Background
Anyone who has seen protists or motile bacteria under a microscope knows that even the simplest forms of life can exhibit startlingly complex behaviors. Yet often these complex behaviors have very simple underpinnings. This lesson explores those behaviors in planarians and in a simulation that models some very elegant behaviors arising from very simple nervous systems. Much of this discussion arises from *Vehicles: Experiments in Synthetic Psychology* by Valentino Braitenberg.

An analogy is used to help describe how organisms move. Imagine a boat. It has a single outboard motor in the back that provides power. Connected to the throttle of this motor is a single wire, which is attached to a thermometer on the front of the boat that rests in the water (see below).

![Diagram of boat analogy](image)

Whenever the temperature increases, the thermometer sends a signal to the motor to give the engine a little more gas, and the boat speeds up. When the temperature of the water drops, the boat slows down. In this way, the boat moves more quickly when the water is warm, and more slowly when the water is cold. If the connection was reversed, the boat moved faster in response to cold water, as its behavior would flip. Using this scenario, one could say that it “avoids” cold spots and “seeks out” warm spots.

This is precisely the behavior exhibited by flagellated protists like the *Euglena* or certain bacteria like *E. Coli*. Each of these organisms has a single little flagellum that spins in response to certain signals allowing the organism to move through its environment and approach food sources, avoid light and overly hot areas, and so on.

The behavior outlined above is better known as *taxis* (tak-siz), or behavioral responses/movements to a stimulus. In this case, because the sensor detects temperature, the behavior falls under the general heading of *thermotaxis*, but it would be possible to construct different sensors for *chemotaxis* (chemicals), *phototaxis* (light), *mechanotaxis* (physical touch), or a wide variety of other behaviors.

When an organism approaches the stimulus, it is known as *positive taxis*, and when it avoids it, it is *negative taxis*. Living organisms have many types of taxes. In this lesson, students will explore the kinds of taxes exhibited by planarians.

Planarians exhibit three obvious forms of taxis that students can examine: negative phototaxis (moving away from light), positive chemotaxis (moving towards food), and negative mechanotaxis (moving away when they are touched). Through discussion and observations, students should be able to identify the “motors” that planarians use (their musculature), what the appropriate sensors are in each case (eye spots, chemoreceptors, and mechanoreceptors respectively), and describe the behavior following the stimulus.
The planarian has a simple sensory system in addition to other body systems. There are two eyespots on the head of the planarian. Although the name contains the word “eye,” the eyespots do not allow the planarian to see like a human. Instead, the eyespots contain photoreceptors that allow the planarian simply to detect light. Planarians display negative phototaxis (they will move away from bright light) and, while not controlled by a motor, the analogy described above is fairly accurate in describing how this behavior is controlled. Light is initially detected by the photoreceptors in the eyespots. This information is then transmitted to the neural ganglia, or clusters of neuron cell bodies near the head, where it is processed and activates the motor system to turn and move the planarian away from the light source. Some scientists equate the head ganglia to the brain of more complicated organisms.

Similarly, chemoreceptors in the planarians’ heads can detect certain chemicals considered ‘tastants’ or ‘odorants.’ The chemoreceptors have neuronal connections to the neural ganglia where the chemical information is processed. If the chemical/odor is food-related, the motor system in the planarian will orient the planarian so that it moves towards the food to feed. The speed of movement and the decision to go towards the food will also be influenced by the hunger state of the planarian – a hungry worm will be more likely to move or will move at a faster rate towards the food while a satiated planarian might not approach the food at all. If the chemical were a harmful substance, the planarian would turn and move away from the noxious or aversive stimulus.
VIII. Lesson Implementation

Opening of Lesson:
Begin to introduce the concepts addressed in Lesson 1 with a conversation about what students expect to see with planarians. Remind students about the model organisms reading, specifically drawing attention to the use of planarians as model organisms. Tell the students they will be given the opportunity to carefully examine what a whole planarian looks like and how it responds to a series of stimuli. Ask students:

- How do you think planarians will behave in a Petri dish without stimulation?
- How could their behavior differ in a Petri dish versus their natural environment?
- How might planarians respond to light? To touch? To the presence of food?

Ask students if they know what chemotaxis, phototaxis and mechanotaxis are.

- If the words were to be broken down, what parts of a word can be detected in these terms?
  - Chemotaxis – locomotor behavior in response to a chemical
  - Phototaxis – locomotor behavior in response to a light stimulus
  - Mechanotaxis – locomotor behavior in response to touch

Have a brief discussion about the concept of taxis and when it can be seen in different organisms. Ask students:

- What allows the different organisms to move in the different ways?

**Teacher Pedagogical Content Knowledge**
Many words used to describe animal physiology and behavior have root words in Latin and Greek. When introducing new vocabulary to students, ask them to break down the words to the root words. Doing so will help them learn meaning and aid in remembering.

Main Part of Lesson

**Activity 1: Planarian Observation**
*Students will describe what happens to the planarians for each of the taxes discussed in the introduction.*

Hand out the Student Observation Sheet. Instruct students that they should only fill out the questions on the first 2 pages and that they can be filled out in any order, depending on available materials.

Allow students to observe planarians without stimulation. Ask students:
• What do you notice about the planarians’ behavior? Are there individual differences between planarians?

**Scientific Practices: Developing and using models**

When attempting to understand complicated processes, scientists will often observe natural phenomena in a controlled setting to better provide evidence to develop models. Direct observations of intact planarians can help the students form a mental model of how taxes work. Students will make observations of all three taxes to create models of how movement happens.

*What happens when you give planarians food? (chemotaxis)*

For students to see how planarians use chemotaxis, moving towards a chemical signal, such as an odorant or tastant, students need to put some bloodworms into a petri dish containing planarians in spring water. The planarians should move towards the bloodworms and feed on them. Even without a microscope, the students will be able to see the planarians darken as they eat.

Have students make notes on the observed behavior. Questions that can be used to prompt the students to take detailed observations include:

• Do all the planarians move towards the food?
• Do they move at the same rate towards the food?
• How might you explain the differences in these behaviors?

To view the digestive tract, have the students look at the planarians under a microscope. For best viewing, it might help to slow movements by putting planarians on a Petri dish containing frozen spring water. It is important that the planarians are first placed on a piece of damp filter paper thereby separating the planarian from the ice.

*What happens when you shine a light on planarians? (phototaxis)*

In a darkened room, shine a bright, focused light onto a Petri dish containing planarians. The light should not encompass the whole dish, but be only a small “spotlight” in part of the dish. While planarians will move towards a food source, they will move away from bright light. It is important that the planarians have a darkened area to move into.

Have students make notes on the behavior. Questions that can be used to prompt the students to take detailed observations include:

• Do the planarians move towards or away from the light?
• How quickly do they move out of the light?
• Do they maintain the same speed once they’re out of the light, or do they change their rate of movement?

*What happens when you touch the planarian gently with a toothpick? (mechanotaxis)*

Have the students observe how the planarians respond to a light touch.

Have students make notes on the behavior. Questions that can be used to prompt the students to take detailed observations include:

• Do the planarians move towards or away from the touch?
• What movement is seen?
• How quickly do they move?

Have the students come back together and share what they saw for the different behaviors. Keep list of observations on board for students to refer back to after the cutting experiment (Lesson 3).

Using their observations, have the students generate model for how these behaviors might work that would explain how the organisms move using a simple sensory system. An example to show the students could be the following:

A student is hungry and the bell has just rung for lunch. The student walks down the hallway and smells the delicious pizza from the cafeteria and quickly moves there to buy pizza and enjoy it for his meal. A simple sensory model for the student might look like this:

![Diagram of sensory model](image)

**Conclusion of Lesson**

Allow students to share their model, ask students:

• What data from your observations are you using as support in your model?

Have students draw their models on the board. Ask students to compare and contrast the models that have been created.

In the models, students should include aspects of the model presented in the “Teacher Background Science Content Knowledge” section of the lesson plan.

• It is important that the models identify that when planarians sense something, a response or reaction results. This response can be either positive (moving towards) or negative (moving away) depending on the stimuli.
• There needs to be both a “sensor” and “motor” (or responder) present in the model.
• Discuss possible variations in sensors and motors, how defects in one or the other could affect behavior in response to a certain stimuli.
• Ask students about the limitations of this type of model. How does it accurately describe behavior and what does it lack?

Make certain to make connections back to the living planarians and how these models can be connected to understanding the processes in the real organism.

Questions that can be used to help guide this discussion and make connections between the simulations and the living organism include:

• What do planarians sense in the environment?
• What kind of structures would planarians need to detect stimuli (food, predators, etc.) in the environment?
• What kinds of body parts do planarians need to crawl away?

Have students make connections to taxis in other animals and think about species differences. Animals may move towards some touch and away from others.

**Teacher Content Knowledge**

It is important to avoid generalizing models generated from one species across all species. Not all species evolved to survive in the same ways, and this will affect their taxis depending on the stimuli. For example, some species prefer to move toward the light because it is where their food is normally found; other organisms may prefer the dark because their food is generally found there.

Finally, remind students of what other behavior they learned about yesterday: regeneration in planarians. Just as taxes are observable behaviors, regeneration is yet another behavior planarians perform. Explain to the students that they will be cutting their planarians and watching them over the course of several days, in order to observe what happens.

Explain that while planarians were known to be able to regenerate for many hundreds of years, it was only a little more than a century ago when scientists, such as Thomas Hunt Morgan and Harriet Randolph, began to study regeneration in these worms more rigorously by conducting cutting experiments.

• Use this discussion as an opportunity to highlight the fact that even a century ago, women like Randolph and the Polish chemist Marie Curie were pioneering critical scientific research, at a time when societal pressures kept many women out of organized science.

Students are to complete the Pre-Reading located with Lesson 3 materials (U2_L3_PreReading_CoolScientistsMorgan&Randolph.docx). In this reading, students make predictions
about how planarians might re-grow parts of their body in order to prepare the students for making hypotheses for their own cuts in Lesson 3.

Assessments
The student observation sheets can be used as an assessment. In addition, students can answer the lesson’s driving question to check for understanding of the day’s activities as a summative assessment for this lesson.