MEETS BIOLOGY ENGINEERING AT THE UNIVERSITY OF CINCINNATI

Kinesis & Taxis Lesson Overview

Title	Kinesis & Taxis
Grade Level Target / Range	10-12
Subject Area(s)	biology, engineering, computer science
Time Required	1-1.5 hours
Group Size	2 per group
Materials Needed	Spinner A coin Playing pawn (blue arrows – see grid sheet #1 for the pawns to be used) Student Worksheets: ● Rules for Experiments ● Kinesis ● Kinesis / Taxis with a Single Sensor ● Taxis with Two Sensors ● Kinesis Taxis Grids (digital copy for each group) ● Kinesis Taxis Data Sheets (print copies for each group)
Assessments	Kinesis & Taxis Student Questions
Expendable Cost Per Group	*Prices are Estimates as of April, 2022* Spinners (pack of 12) - $9
Key Words	sensory biology, engineering, algorithmic thinking
National Educational Standards	Next Generation Science Standards (NGSS) International Society for Technology in Education (ISTE)
State Specific Educational Standards	Indiana Science Standards Ohio Science Standards West Virginia Science Standards

Introduction

This lab explores two mechanisms of orientation, **kinesis** and **taxis**, two fundamentally different ways organisms use sensory systems to reach an attractive stimulus source (or flee a repellant source). Students will test the relative efficiency of these mechanisms by simulating the movement of organisms as they operate according to the rules of each system (and variations thereon).

This unit was created collaboratively with faculty from the University of Cincinnati College of Arts and Sciences, College of Engineering, and School of Education. Combining biology with engineering activities provides students with a unique opportunity to understand the parallels between animal and robot behavior and sensory/sensor function and addresses broad Next Generation Science Standards (NGSS Lead States, 2013) and International Society for Technology in Education Standards (International Society for Technology in Education, 2022).

Investigating / Essential Questions

- How can I use simulated biological data to test hypotheses?
- What are possible sensory stimuli that may be used to identify and guide animal movement to/from its source?

Learning Objectives

1. Describe and illustrate the animal orientation mechanisms of kinesis and taxis and their differences.
2. Provide examples of the locomotory behaviors different organisms use to move in their environment
3. Test hypotheses in animal orientation.
4. Explain the advantages/disadvantages of single vs multi-sensor models as well as the importance of sensor spatial separation.
5. Provide examples of biological principles embodied in robots.
6. Provide examples of how robots are used to test hypotheses about animal behavior.

Prerequisite Student Knowledge

Students should be comfortable tracking and organizing data, testing and reasoning about hypotheses, and have an understanding of the terms “stimulus” and “response”.

Instructional Summary

In this lesson, students will test three different hypotheses using simulated data. In the first activity, students explore kinesis under three different experimental conditions. In the second, they will explore kinesis/taxis with a single sensor. Finally, in the third activity, students will examine kinesis/taxis with two sensors. Students will be asked to support or reject a hypothesis based on their findings in each activity.

Instructional Plan

1.1 Introduction and Motivation

Show the video clip of a pill bug experiment. Have students make observations and then write down what the students noticed and wondered. Ask students to identify the questions that are testable. Highlight them as they are discussed. Also highlight the words that students use to describe the movement of the pill bugs (random, faster, slower, etc.) to introduce some new vocabulary. Tell students that they will be exploring an organism's movement towards an attractive source through somewhat of a game. They will need to determine if the data produced defends the given hypothesis.

1.2 Procedure

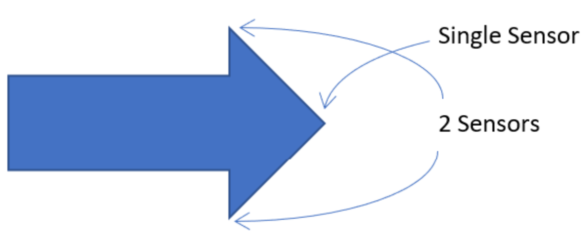
1.2.1 Definitions & Rules

1. Kinesis: un-directed movement consisting of rotational 'tumbles' and linear 'runs', in which the speed (or distance) of runs, or the frequency of tumbles, depend on the intensity of stimulus.
2. Taxis: directed movement either toward or away from the source of stimulation

In this activity, the student will simulate an organism's movement toward an attractive source using (a) kinesis, (b) taxis - with a single sensor, and (c) taxis –with two sensors

The following rules and definitions apply to all activities unless noted. These are available on a separate sheet for student use.

1. At the beginning of each activity, place your pawn in the middle of the printed grid on the circle labeled Start.
2. Tumbles are always followed by runs.
3. Unless otherwise noted, runs are defined as moving the pawn 2 'arrow lengths' directly forward. **IMPORTANT: the grid is NOT for discrete pawn placement, the pawn moves in pawn arrow lengths and lies across the grid in whichever place and orientation it wants!** The grid only indicates local stimulus intensity.
4. Tumbles are changes in direction, or turns, determined by spinning your spinner to indicate the direction of your next run.
5. The stimulus source is denoted by a smiley face(s).
6. If the pawn runs off the edge of the grid, the pawn is returned to the edge square at which it left the grid. The pawn performs a tumble again.
7. If the pawn reaches the stimulus source or runs off the stimulus edge the activity ends.



Example of the 'pawn' to be used on the grid sheets (see sheet #1 for actual pawns – use them <u>as</u> <u>is</u>! Do not change size or shape!).

1.2.2 Kinesis

This first set of exercises demonstrate the nature of motion by kinesis under three different experimental conditions, Part I: without intensity-dependent behavior; Part II: with intensity-dependent behavior, i.e., run length will depend on stimulus intensity, moving faster with approach (this is ORTHOKINESIS); Part III with intensity dependent behavior, moving slower with approach.

Given the following hypothesis, students will determine whether their own data supports it or not. Students can use the directions on the Kinesis worksheet to guide their work.

Hypothesis: Adding intensity-dependent behavior (orthokinesis), in the form of increased distance moved per (randomly directed) run, will lead to an increased likelihood the pawn will successfully reach the stimulus source (i.e., the pawn will reach the stimulus source more during Part II than Part I).

1.2.3 Kinesis / Taxis with a Single Sensor

This exercise demonstrates organismal movement with the addition of a single sensor, which by definition is non-directional, but by adding memory might be used to gain directionality. The movement consists of runs in which direction information is available through successive stimulus measurements, and modifies run direction.

Ask: Is this a form of KLINOKINESIS or KLINOTAXIS?

Students will determine whether their own data support the hypothesis below. Use the Kinesis Taxis with a Single Sensor student worksheet as a guide.

Hypothesis: The presence of a single sensor that measures successive stimulus intensities will lead to source localization.

1.2.4 Taxis with Two Sensors

This exercise demonstrates taxis when there is bilateral comparison of two sensors and movement is directed. Many animals compare two sensors' simultaneous output to detect attractant and repellent stimulus direction in their environment and respond appropriately. Here turns, not runs, are modified by direction. This is TROPOTAXIS.

The sensors are the lateral points of the arrowheads. This must be emphasized. Students will again determine whether their own data support the hypothesis below. Use the Taxis with Two Sensors student worksheet as a guide.

Hypothesis: The presence of two sensors will lead to increased stimulus localization over one sensor. The distance between the sensors (wide or narrow) will be correlated with the ability to localize the stimulus (success rate, speed).

Extensions

Assessments

Kinesis & Taxis Student Questions

Have students turn in the data sheets along with their questions. You can collate and graphically summarize all class data to discuss during a future class.

Supporting Activity Information / Background

[Primer for teacher to read]

[Paul Andersen - Animal Behavior]

National Educational Standards

NGSS	**Performance Expectations:** *HS-LS1-3.* ~~Plan and~~ conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity ~~and populations~~ in ecosystems ~~of different scales~~. *HS-LS4-3.* Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. *HS-LS4-5*. Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. **Disciplinary Core Ideas:** *LS1.A: Structure and Function* ● Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. **Crosscutting Concepts:** *Stability and Change* Feedback (negative or positive) can stabilize or destabilize a system. *Systems and System Models* Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. **Science and Engineering Practices:** ● Developing and Using Models ● ~~Planning and~~ Carrying out Investigations ● Analyzing and Interpreting Data ● Using Mathematics and Computational Thinking

	● Constructing Explanations ~~and Designing Solutions~~ ● Engaging in Argument from Evidence ● Obtaining, Evaluating, and Communicating Information
ISTE Standards	1.5 Computational Thinker b. Students collect data or identify relevant data sets, use digital tools to analyze them, and represent data in various ways to facilitate problem-solving and decision-making. c. Students break problems into component parts, extract key information, and develop descriptive models to understand complex systems or facilitate problem-solving. 1.7 Global Collaborator c. Students contribute constructively to project teams, assuming various roles and responsibilities to work effectively toward a common goal.

State Specific Educational Standards

<table>
<tr><td>Ohio Science Standards</td><td>AP.LO.3 Homeostasis
B.E.1 Mechanisms
B.E.2: Speciation

Cognitive Demands for Science
Demonstrating Science Knowledge
Requires student to use scientific practices and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather and organize data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments.
Interpreting and Communicating Science Concepts
Requires students to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experiences using grade-appropriate scientific terminology, technological knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios, real-world data and valid scientific information.
Recalling Accurate Science
Requires students to provide accurate statements about scientifically valid facts, concepts and relationships. Recall only requires students to provide a rote response, declarative knowledge or perform routine mathematical tasks. This cognitive demand refers to students' knowledge of science fact, information, concepts, tools, procedures (being able to describe how) and basic principles.</td></tr>
<tr><td>Indiana Science Standards</td><td>AP.1.3 Homeostasis
B.5.3 Apply concepts of statistics and probability to support a claim that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.
B.5.4 Evaluate evidence to explain the role of natural selection as an evolutionary mechanism that leads to the adaptation of species, and to support claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and/or (3) the extinction of other species.</td></tr>
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	Science and Engineering Process Standards (SEPS) SEPS.2 Developing and using models and tools SEPS.3 ~~Constructing and~~ performing investigations SEPS.4 Analyzing and interpreting data SEPS.5 Using mathematics and computational thinking SEPS.6 Constructing explanations (for science) ~~and designing solutions (for engineering)~~ SEPS.7 Engaging in argument from evidence SEPS.8 Obtaining, evaluating, and communicating information
West Virginia Science Standards	S.10.LS.3 ~~Plan and~~ conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. S.10.LS.11 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity ~~and populations~~ in ecosystems ~~of different scales~~. S.10.LS.22 Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking in this trait. S.10.LS.24 Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increase in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

References

Fraenkel, G.S. and D.L. Gunn. (1961). *The Orientation of Animals – Kineses, Taxes and Compass Reactions*. Dover Publications, Inc. New York, New York.

Indiana Department of Education. (2017). *Indiana Academics for Science. Science: Anatomy & Physiology.* *https://www.in.gov/doe/students/indiana-academic-standards/science-and-computer-science-2016-2010/*

International Society for Technology in Education. (2022). *ISTE Standards: Students.* https://www.iste.org/standards/iste-standards-for-students

jenna1235. (n.d.). *Pillbug Project 1*. YouTube. Retrieved June 22, 2022, from https://www.youtube.com/watch?v=IUjkRKEqKaE&t=760s

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

Ohio Department of Education. (2018-19). *Ohio's Learning Standards and Model Curriculum Science.* https://education.ohio.gov/Topics/Learning-in-Ohio/Science/Ohios-Learning-Standards-and-MC

West Virginia Department of Education. (2015). *Policy 2520.3C: Next Generation Content Standards and Objectives for Science in West Virginia Schools.* *https://wvde.us/middle-secondary-learning/science/standards-and-guidance/*

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