COLUMBIA | Zuckerman Institute

BRAIN STEM | Bringing Neuroscience to the Classroom

Nature vs. Nurture: How Genes and Environment Shape Vocal Learning in Songbirds

Supported by: ΙΣΝ SNF ΙΔΡΥΜΑ ΣΤΑΥΡΟΣ ΝΙΑΡΧΟΣ STAVROS NIARCHOS FOUNDATION

Nature vs. Nurture: How Genes and Environment Shape Vocal Learning in Songbirds

Students design and conduct virtual experiments using real data from scientists as evidence to assess how genes and environment influence vocal learning in songbirds.

Suggested duration

- 1 x 45 min class period

Essential question

- In what ways do genes and environment affect song learning in finches?

Objectives

All students will...

- Make and defend a claim that answers the following question: "In what ways do genes and environment affect song learning in finches?"
- Design virtual experiments and use real data from scientists as evidence for their claims.

Materials

- Projector (if teaching in person)
- Computer with internet access
- Virtual experiment website https://sites.google.com/view/finch-experiment/
- Nature vs. Nurture slidedeck
- Student Worksheet (Level 1)
- Student worksheet (Level 2)
- "Curious Minds: How Do Birds Change Their Tune?"
  Research by Jordan Moore, Ph.D., & Sarah M. N. Woolley, Ph.D.
  https://www.youtube.com/watch?v=tSIerr0F5Ww

Based on

The Stavros Niarchos Brain Insight Lecture

- “Singing in the Brain”
  By Sarah M. N. Woolley, Ph.D.
  https://www.youtube.com/watch?v=2eAFVdXcTBE

Remote learning tips

- This lesson can be done as a teacher-led exercise in person or virtually. It can also be as a student-paced exercise asynchronously.
- The slidedeck for this lesson is integrated with Pear Deck, which is used for small formative assessments along the way. The assessments can also be done verbally or using typing via chat (e.g. on zoom) without Pear Deck.

Instructional Activities

1. Opening: Genetics vs. Environment Continuum | 5min

Use Nature vs. Nurture slides 2-7

This Opening Activity can be done as a kinesthetic activity in-person, or using Pear Deck virtually.

In-Person:

- Place signs or write “Genes- Nature” on one side of the room and “Environment- Nurture’’ on opposite sides of the room to create a spectrum.
- Ask students to orient themselves along the spectrum to indicate what they think influences different traits.
- After they have oriented themselves, ask for volunteers or call on students to justify their placement.

Virtually:

- Students can use Pear Deck or typing via chat to indicate where they would place each of the traits on the continuum from 100% genetic to 100% environmental and to justify their position.
- They can do this by indicating which letter would be closest to the spot on the continuum.
- Note: if you have the paid version of Pear Deck, you can change the slide to use a draggable so they can drag an icon to a spot on the continuum.

Important: *Whether in-person or virtually, discrepancies in student responses can lead to interesting discussion. The takeaway is that most traits involve both genetics and environment in some way.*

2. Background Information: Neuroscience of Vocal Learning in Songbirds | 15min

Use Student Worksheet: Part 1 (either level)

Show students slides 9-25

- This can be done as a teacher-led exercise in person or virtually. It can also be done as a student-paced exercise asynchronously.
- Pear Deck questions are included as small formative assessments along the way. These can also be done verbally if you do not use Pear Deck

Key points to stress in preparation for experiment:

- Vocal learning is a complicated trait that has been identified in 8 different types of animals.
- Finches are songbirds that have the trait of vocal learning and are used as a model to study how humans learn language. Different finches have distinct and different songs that males use to attract females.

Show students the video "Curious Minds: How Do Birds Change Their Tune?"

- Finches and humans have unique brain circuitry that connects the listening areas of the brain to the motor (movement) areas that control the voice. This unique circuit is associated with the activation of 50-70 genes that are shared by birds and humans. It also grants vocal learners a feedback loop to listen, practice, and learn songs/language based on their environments.
- Genetics create the circuit, and the environment shapes the circuit (neuroplasticity) as the finches learn songs from a tutor.
- Neuron activity in the brain is much higher when a finch listens to a song from its own species.

3. Virtual Experiment | 15min

Show students slides 26-28

Use Student Worksheet: Parts 2 & 3 (either level)

Use website
https://sites.google.com/view/finch-experiment/

Students can work in groups or individually (live or asynchronously) to develop an experiment like those done by Dr. Moore & Dr. Woolley.

- They need to pick a species of finch to use as their experimental and control finches.
- They need to pick a different species to be a tutor or select no tutor for their experimental finch.
- After recording their choices on the student worksheet and making predictions, they can use the website to enter their choices and view/ listen to the data that were generated from that combination of variables.
- They can record their observations and conclusions on the student worksheet.

There are many possible combinations, but in general:

- Control birds will learn the songs of their own species and will show high activity in the neurons of the secondary and deep listening areas of the brain when they hear their own song.
- Experimental birds that are cross-fostered by another species will learn the song of the tutor species and will show high neuron activity when they hear the tutor species song.
- Experimental birds that are raised as isolates without a tutor will not learn a coherent song but will sing randomly. They will not show high neuron activity to any songs.

4. Assessment | 10min

Use Student Worksheet: Part 4 (Level 1)

- The claim has been provided based on the results from the virtual experiments.
- Students will use 3 pieces of evidence from their experimental data and/or the background material and provide reasonings to support the claim.

For advanced students:

Use Student Worksheet: Part 4 (Level 2)

- Each student will generate their own claim based on the results from their virtual experiments.
- Students will use 3 pieces of evidence from their experimental data and/or the background material and provide reasonings to support their claim.

Important: *A potential misconception is that students may think that traits are determined by either genetics or environment, when in reality they are the result of interplay between the two.*

Standards

NEXT GENERATION SCIENCE STANDARDS (NGSS)	Disciplinary Core Ideas: LS3.B: Variation of Traits ▪ Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-2, HS-LS3-3) Science and Engineering Practices: Engaging in Argument from Evidence ▪ Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. ▪ Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2) Crosscutting Concepts: Cause and Effect ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS3-1, HS-LS3-2)
CONTENT SPECIFIC CURRICULUM STANDARDS	Major Understandings 2.1a Genes are inherited, but their expression can be modified by interactions with the environment.
COMMON CORE STANDARDS	RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-LS3-1) WHST.9-12.1 Write arguments focused on discipline-specific content. (HS-LS3-2)

Vocabulary

Control treatment	Treatment for a group not exposed changes in the independent variable to establish a baseline for comparison with the experimental treatment
Electrode	A conductive device, typically a small disc, needle, or tube, that measures electrical signals from the brain or neurons
Environment	The total of all living and nonliving things in nature that affect an individual's survival and development
Experimental Treatment	Treatment for a group exposed to changes in the independent variable being tested
Gene	A unit of heredity passed from a parent to the offspring and determines some characteristic of the offspring
Isolate	A bird that grew up without learning song from adult male tutors
Model organism	Non-human species used in the laboratory to help scientists understand biological processes
Neuron	A specialized cell that is electrically excitable and able to communicate with other cells through connections called synapses; the building block of nervous system, including the brain
Neuroplasticity	The ability of the brain to form and reorganize synaptic connections, especially in reponse to learning, experience, or after injury
Spectrogram	A visual representation of the spectrum of sound frequencies recorded over time
Synapse	A structure that permits a neuron (or nerve cell) to pass an electrical or chemical signal to another neuron or other cell

Vocabulary

Trait	A specific characteristic of an organism determined by genetic factors, environmental factors, or more commonly by interactions between both factors
Tutor	An adult male bird that sings a song, which is eventually learned by young male songbirds
Vocal learning	The ability to modify sounds, acquire new sounds through imitation, and produce vocalizations

Sources

The Stavros Niarchos Brain Insight Lecture, “Singing in the Brain” by Sarah M. N. Woolley, Ph.D.
https://www.youtube.com/watch?v=2eAFVdXcTBE

Acknowledgements

Co-created by:

Erik Shold

Brittany Klimowicz

Edited by:

Diana Li

With input from:

Andrew Anderson

Francesca DiPietro

Stephen Gallagher

Nicole Holmes

Vincent Joralemon

Vanessa Keen

Laura Klancer

Bonnie Lestz

Heather Lochridge

Preeti Natarajan

Suzette Nelson

Deborah Reich

Bradley Scalise

Tamanna Shahid

Theresa Stanley

Meng-Ping Tu

Zora Tucker

Joshua Wickline