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# K-12 Partnership Lesson Plan

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# *Don’t Shell Yourself Short*

# *Natural selection on mussel shell thickness*

## Overview

Students explore the effects of natural selection on populations with or without trait variation. Students play a game with nuts simulating crab-mussel interactions, gather data from the game, analyze it by making figures, and draw conclusions about how an introduced predator could cause quick evolutionary change in only a few generations of the prey species. Students answer questions about the three requirements for evolution by natural selection and discuss other examples of rapid evolution.

**Objectives**

At the conclusion of the lesson, students will be able to:

* List the three requirements for evolution by natural selection
  + Phenotypic variation in a trait
  + Relationship between that trait and fitness
  + The trait must be heritable
* Determine whether evolution happened in a given situation

**Length of Lesson**

Two hour long class periods (one to play the game and collect data, one to plot data and discuss)

**Grade Levels**

This lesson is targeted for grades 9-12, but can be simplified for grades 5-8

**Standards covered (NGSS)**

Disciplinary Core Ideas:

*Middle School*

* **MS-LS2-4**: construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations
* **MS-LS1-4**: use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
* **MS-LS4-4**: construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals’ probability of surviving and reproducing in a specific environment.
* **MS-LS4-6**: use mathematical representations to support explanations for how natural selection may lead to increases and decreases of specific traits in populations over time.

*High School*

* **HS-LS4-2:** construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
* **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-LS4-4**: construct an explanation based on evidence for how natural selection leads to adaptation of population.

Cross Cutting Concepts:

* Patterns
* Cause and effect
* Structure and function
* Stability and change of systems

Science and Engineering Practices

* Developing and using models
* Planning and carrying out investigations
* Analyzing and interpreting data
* Engaging in argument from evidence

***Previous Michigan Standards Met:***

* **B5.1A**: summarize the major concepts of natural selection (differential survival and reproduction of chance inherited variants, depending on environmental conditions)
* **B5.1B**: describe how natural selection provides a mechanism for evolution
* **B5.1d**: explain how a new species or variety originates through the evolutionary process of natural selection
* **B5**.**1e**: explain how natural selection leads to organisms that are well suited for the environment
* **B5**.**3A**: explain how natural selection acts on individuals, but it is populations that evolve. Relate genetic mutations and genetic variety produced by sexual reproduction to diversity within a given population
* **L.EV.M.1**: species adaptation and survival- species with certain traits are more likely than others to survive and have offspring in particular environments. When an environment changes, the advantage or disadvantage of the species’ characteristics can change. Extinction of a species occurs when the environment changes and the characteristics of a species are insufficient to allow survival
* **L.EV.05.12**: describe the physical characteristics (traits) of organisms that help them survive in their environment
* **L**.**EC.06.23**: predict how changes in one population might affect other populations based up on their relationships in the food web
* **L**.**HE.07.21**: compare how characteristics of living things are passed on through generations, both asexually and sexually

**Materials**

* Peanuts and almost (in the shell)
* Student worksheet
* Powerpoint
* Excel file to generate figures

**Background**

*Phenotype*: Observable traits that result from a combination of genes and environment (G x E)

*Genotype*: Genetic makeup of an organism

*Heritability*: The passing of traits from parent to offspring

*Fitness*: Survival and reproduction

Asian shore crabs (*Hemigrapsus sanguineus*) are native to the western Pacific Ocean, but since the late 1980s they have been spreading throughout the northern Atlantic coast of the United States. Crabs are tiny (about the size of a penny), but populations are growing very quickly. They are generalist predators (eat lots of different prey). Blue mussels (*Mytilus edulis*) in the northeast US are becoming more resistant to predation by crabs. How is this happening?

Within populations of this single species of mussel, some individual mussels have thicker shells than others, so there is phenotypic variation in the trait. This trait (shell thickness) is heritable, meaning that thick-shelled crabs have thick-shelled offspring and thin-shelled crabs have thin-shelled offspring. Crabs are exerting selection pressure on this trait, creating a relationship between the trait and fitness (mussels’ ability to survive and reproduce) by eating only the thin-shelled mussels. The three requirements for evolution (heritable trait, phenotypic variation in the trait, relationship between trait and fitness) are met, so the mussel population is able to evolve in response to predation by the crabs.

Evolution is a change in the mean (average) trait value in a population over time. Evolution does not happen to an individual; it happens to a population. It cannot happen in less than a single generation, because traits must be passed on to the offspring. Evolution can happen rapidly; “rapid evolution” happens in tens or hundreds of years (relative to the life span of the organism), instead of thousands of years or longer.

There are many different examples of rapid evolution, with the most famous being the peppered moth in England during the Industrial Revolution. The moth was originally light colored with dark speckles, but after the heavy coal burning dirtied the buildings and trees, populations of the moths shifted to being dark colored with light speckles. Other examples include the percent white in the tails of dark-eyed juncos (birds) in a new coastal habitat, beak length of a population of soapberry bugs living on introduced trees, and the growth rate of pink salmon due to the size of gill nets used by fisheries. Details of these examples are given in the PowerPoint presentation.

### Activities of the session

1. Pass out the student worksheet **(included)**.
2. Present the introduction in the PowerPoint **(included)**, having student volunteers present definitions of the four terms. This should allow you to find out their misconceptions.
3. Explain the mussel/crab situation, as described above and briefly in the PowerPoint.
4. Divide the students into four groups. Each group has one population of blue mussels.
   1. Two groups will be “Variation populations”: each person in the group gets 9 peanuts in the shell and 1 almond in the shell. Everybody in the group dumps their nuts into a pile in the middle of the table. This pile is that group’s population.
   2. Two groups will be “No variation population”: each person in the group gets 10 peanuts in the shell. Everybody in the group dumps their nuts into a pile in the middle of the table. This pile is that group’s population.
5. Data collection: The students should fill out the table in the worksheet for their population.
6. Selection, generation 1: Everybody removes one nut, shells and eats it, and goes back for more nuts, one at a time. If you can’t shell the nut, return it to the table and take another. Selection continues for 60 seconds.
7. Reproduction, generation 1: Count the number of each type of nut left\* and add more nuts to double the number of each type. (Example: 50 peanuts are left and 20 almonds are left. After reproduction, you will have 100 peanuts and 40 almonds.) \*Before adding more nuts, divide the number of remaining peanuts by the number of peanuts before the selection round. This will be the proportion of nuts reproducing (average fitness of soft-shelled mussels). Do the same for the almonds (hard-shelled mussels).
8. Repeat Selection and Reproduction for generations 2 and 3, filling out the data table **after Reproduction** for each generation.
9. Compile all the groups’ data, filling out the table in the student worksheet.
10. Make figures by having each group read their data aloud for each generation, filling in the table in the Excel worksheet. Line graphs should appear; have the students make line graphs by plotting variation groups with solid lines and no variation groups with dashed lines.
11. Discuss your results and fill out questions in student worksheet. Depending on your class, you might decide to have students answer some questions in their groups and others with the class as a whole.
12. Final results can vary. Some groups might have a population explosion because the “crabs” could not keep up with the “mussel” reproduction (weak selection pressure). Some groups might deplete all of the soft-shelled “mussels”, leaving only hard-shelled “mussels” (strong selection pressure). Some might eat enough soft-shells to keep the “mussel” population stable (moderate/strong selection). The different results provide an opportunity to discuss differences in the “crab” populations that lead to different “mussel” population results.
13. Collect the student worksheets and use them to assess student learning.

**Resources**

* A Powerpoint, student worksheet, and excel file to aid in graphing the results are listed on the “Don’t Shell Yourself Short” lesson page on the KBS GK-12 website.

**Extensions and Modifications**

The lesson can be used as is for grades 9-12. We recommend removing graphs and discussion questions that relate only to population number for grades 5-8 as they may cause confusion. Population number is included in the discussion as an additional effect of crabs on mussels, but it does not directly affect the evolution of the mussel population.

**Assessment**

Student worksheet includes reflection questions.