Teacher Notes for "What is natural selection?"[1]

This minds-on, analysis and discussion activity introduces students to the process of natural selection, including key concepts and vocabulary. In addition, students analyze several examples to learn about the conditions that are needed for natural selection to occur. (This activity is an expanded version of the first section of the hands-on activity "Evolution by Natural Selection" (https://serendipstudio.org/sci_edu/waldron/#evolution).)

Learning Goals

In accord with the Next Generation Science Standards[2] and A Framework for K-12 Science Education[3]:

- Students will gain understanding of the Disciplinary Core Idea:
  - LS4.C Adaptation. "Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. Adaptation also means that the distribution of traits in a population can change when conditions change."
- Students will engage in the Scientific Practice:
  - Constructing Explanations and Designing Solutions: "Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects."
- This activity provides the opportunity to discuss the Crosscutting Concepts:
  - Cause and effect: Mechanism and explanation – "In grades 9-12, students… suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system."
  - Stability and Change – "Students understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems …"

This activity helps to prepare students for the Performance Expectation[4]:

- HS-LS4-4, "Construct an explanation based on evidence for how natural selection leads to adaptation of populations."

Additional Content Learning Goals

- Fitness is the ability to survive and reproduce.
- A characteristic which is influenced by genes and can be inherited by a parent's offspring is called a heritable trait.

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[1] by Dr. Ingrid Waldron, Department of Biology, University of Pennsylvania, © 2022. These Teacher Notes and the Student Handout for this activity are available at https://serendipstudio.org/exchange/bioactivities/NaturalSelectionIntro.

[2] http://www.nextgenscience.org/sites/default/files/HS%20LS%20topics%20combined%206.13.13.pdf

[3] http://www.nap.edu/catalog.php?record_id=13165

[4] This activity is designed for high school students, but it can be modified to help middle school students prepare for the Performance Expectations, 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."

- A heritable trait that increases fitness is an adaptation. An adaptation tends to become more common in a population. Because the adaptation increases fitness, individuals with this trait generally produce more offspring. Because the trait is heritable, offspring generally have the same trait as their parents. Therefore, the adaptation tends to become more common in the population. This process is called natural selection.
- Evolution by natural selection only occurs if there is variation in a heritable trait which contributes to differences in fitness.
- Which characteristics are adaptations depends on which type of environment the population is in. The same population will evolve differently in different environments.

This activity counteracts several common misconceptions about evolution.[5]
- Individual organisms can evolve during a single lifespan.
- The "needs" of organisms account for the changes in populations over time (goal-directed or teleological interpretation).
- The fittest organisms in a population are those that are strongest, fastest, and/or largest.

Instructional Suggestions and Background Biology
To maximize student learning, I recommend that you have your students complete groups of related analysis and discussion questions individually or in pairs and then have a class discussion for each group of related questions. In their responses to these questions, students are likely to include some of the misconceptions listed above. When these misconceptions come up in the whole class discussions, thoughtful questions often can elicit more accurate interpretations from your students.

If your students are learning online, I recommend that they use the Google Doc version of the Student Handout available at https://serendipstudio.org/exchange/bioactivities/NaturalSelectionIntro. You may want to revise the GoogleDoc or Word document to prepare a version of the Student Handout that will be more suitable for your students; if you do this, please check the format by viewing the PDF.

A **key** for this activity is available upon request to Ingrid Waldron (iwaldron@upenn.edu). The following paragraphs provide additional instructional suggestions and biological information – some for inclusion in your class discussions and some to provide you with relevant background that may be useful for your understanding and/or for responding to student questions.

Discussion of question 1 provides the opportunity for you to learn about what your students already know about the guiding question, "What is natural selection?" After you have discussed student answers to questions 2-3, it may be helpful to explain that the figure shows a simple example of natural selection.

The Student Handout defines fitness as the ability to survive and reproduce. A more general definition for fitness is "the extent to which an individual contributes genes to future generations…" (from Evolutionary Analysis by Freeman and Herron).

Page 2 of the Student Handout provides a more detailed analysis of the example discussed in questions 2-3. The chart on the top of page 2 of the Student Handout suggests that mice form pair bonds. Most mice are promiscuous, but *Peromyscus polionotus* are monogamous

[5] Most of these misconceptions are excerpted from Misconceptions about evolution, available at http://evolution.berkeley.edu/evolibrary/misconceptions_teacherfaq.php

(https://animaldiversity.org/accounts/Peromyscus_polionotus/).[6] The chart further suggests that each color mouse only mates with another mouse of the same color and all of their offspring have the same fur color. A more realistic scenario would necessitate discussing the complex genetics of inheritance of fur color. To keep the focus on natural selection, I have chosen to make the simplifying assumptions mentioned.

Students should understand that, in discussing natural selection, we use the word "adaptation" to refer to a heritable trait that increases survival and reproduction. This differs from the common usage of adapting to the environment which refers to changes in an organism's characteristics during its lifetime. To help your students understand this distinction, you may want to use the analysis and discussion activity "Evolution and Adaptations" (http://serendipstudio.org/exchange/bioactivities/evoadapt)

When you discuss questions 9-10, you may want to emphasize that organisms are not evolving to some pre-ordained "perfection" but are evolving to greater fitness in a given environment. You may want to use the example that polar bears are adapted to the snowy Arctic environment, whereas bears with brown or black fur are found in lower latitudes.

Question 12 introduces the important point that differences in fecundity (independent of differences in longevity) may also be favored by natural selection. For any organism, there will be trade-offs between various favorable characteristics, including fecundity and longevity.[7] For organisms that live in transient environments, natural selection tends to favor breeding early, rather than investing in longevity.

In the Student Handout, evolution is defined as a change over time in the inherited characteristics of a population. (A population is a group of individuals of the same species living in the same geographic area at the same time.) Biologists often use other related definitions of evolution, e.g., a change in the genetic composition of a population over time (especially a change in allele frequencies) or a change in the inherited characteristics of species over generations. Other definitions of evolution are less closely related, e.g., the process by which new species develop from existing species or descent with modification.

Questions 14-17 will help students to understand the necessary conditions for natural selection by considering what would happen if any of these conditions is not met. In question 13a, students are asked whether natural selection could occur if only gray mice migrated onto the white sand desert. The simple answer is that without any variation there would be no opportunity for natural selection. However, more sophisticated students may point out that natural selection could occur if a mutation for white fur occurred in the population.

One limitation of this activity is that most of the examples relate to camouflage. Question 18 provides the opportunity for you to discuss with your students the great variety of adaptations that have resulted from natural selection, including anatomical, physiological, molecular and behavioral adaptations. Plant defenses against herbivores include thorns or spines and chemical defenses (https://www.nature.com/scitable/knowledge/library/plant-resistance-against-herbivory-

[6] These monogamous mice even use "angry" vs. "friendly" vocalizations when a pair is reunited after a separation with vs. without contact with other mice (https://www.nationalgeographic.com/animals/article/california-mice-monogamous-vocalize-after-infidelity).

[7] If you include this question, it may be advisable to discuss with your students the fact that humans have been so successful at reproducing that we are degrading our environment (e.g., by climate change). In this context, there will be multiple advantages if humans decrease their fertility in order to limit population size.

96675700/). Examples of human adaptations include our big brains, opposable thumbs, sickle-cell trait in human populations where malaria has been common, and the ability to digest lactose among herders and their descendants (http://serendipstudio.org/exchange/bioactivities/evolrec). Examples of natural selection in action include the trends in some bacteria toward antibiotic resistance (https://sitn.hms.harvard.edu/flash/2011/issue103/) and the trends in some species toward insecticide and fungicide resistance (https://www.canr.msu.edu/grapes/integrated_pest_management/how-pesticide-resistance-develops).

Follow-up Activities

"Evolution of Fur Color in Mice – Mutation, Environment and Natural Selection" (http://serendipstudio.org/exchange/bioactivities/NaturalSelectionMice)
This analysis and discussion activity reinforces student understanding of natural selection. Students view a brief video that presents research findings concerning the roles of mutation and natural selection in the evolution of fur color in rock pocket mice. Questions in the video and in the Student Handout guide students to a deeper understanding of natural selection, including how natural selection varies depending on the environment, how convergent evolution occurs, and how analysis at multiple levels from the molecular to the ecological contributes to a better understanding of evolution by natural selection. This activity is aligned with the Next Generation Science Standards (NGSS).

"Natural Selection and the Peppered Moth" (https://serendipstudio.org/exchange/bioactivities/NaturalSelectionMoth)
In this minds-on analysis and discussion activity, students interpret evidence concerning natural selection in the peppered moth and answer questions to consolidate a scientifically accurate understanding of the process of natural selection. The evidence presented includes (1) the results of experiments that evaluated predation by birds on different color forms of the peppered moth in different environments, (2) the genetic basis for the different color forms, and (3) trends in both the environment and the color forms of the peppered moth in industrialized and rural regions in England and the US. This activity is aligned with the Next Generation Science Standards (NGSS).

"Resources for Teaching and Learning about Evolution" (http://serendipstudio.org/exchange/bioactivities/evolrec)
These Teacher Notes provide (1) suggestions for teaching evolution to students with religious concerns, (2) a review of major concepts and common misconceptions concerning natural selection and recommended learning activities, (3) recommended activities for students to analyze and understand the evidence for evolution, and (4) recommended general resources for teaching about evolution.