Artificial Selection: Evolution in Practice

Lesson Overview

In this lesson, students are presented with a hypothetical scenario in which they are asked to apply their understanding of the mechanisms driving evolutionary change. Students will engage in science practices as they propose solutions to a problem: what is the most efficient way to evolve an organism with a particular trait? This activity is meant for students already familiar with the Avida-ED software and possessing a solid understanding of fundamental evolutionary concepts; therefore, it is recommended that this exercise be used only after students have engaged in several other lessons with Avida-ED.

Big Ideas

In the *Origin of Species*, Charles Darwin provided several examples of artificial selection in which domesticated species were bred to produce particular desired traits. Although the source of selective pressure differs between artificial and natural selection (people, rather than the environment, do the selecting), the basic evolutionary mechanism is the same: variation exists in a population for a particular hereditary trait; individuals possessing the trait have a reproductive advantage (they will be selected to breed); and as a result the trait will become more prevalent in subsequent generations. Selective breeding is used widely to produce many different varieties of plants and animals for various agricultural, industrial, or commercial purposes, or sometimes unintentionally as the result of certain medical or agricultural practices (e.g., in the case of antibiotic and pesticide resistance).

Artificial selection is a powerful example of evolution in action because it can produce significant changes in a relatively short period of time. Natural selection, in contrast, is generally a much slower process and can therefore be difficult to observe. Another key difference is that artificial selection is usually intentional and the breeder has a particular goal in mind, while in natural selection the environment acts as the selective agent and there is no intended goal.

Objectives for Student Learning

Through engagement in this lesson, students will:

- Explain the mechanism of selection and how selective breeding gives rise to complex features.
- Discuss the differences and similarities between artificial and natural selection.
- Develop and test a hypothesis, using data to draw conclusions.
- Communicate results of experimental studies to a community of peers.
- Critique proposed solutions to a problem.

Students' Prior Knowledge

- A basic understanding of evolution by natural selection is required (i.e., VIST).
- Students should be very familiar with products of selective breeding such as domestic varieties of plants and animals, and phenomena such as bacterial resistance to antibiotics.
- Common misconceptions:
    - *Mutations always reduce the fitness of organisms*. In fact, mutations can be advantageous, disadvantageous or neutral.
    - *The presence of a selective agent causes advantageous mutations to occur*. In fact, mutations occur randomly and independently of selection, which then favors those that confer a competitive advantage.
    - *Because mutations are random, they cannot lead to the orderly progress that is evolution*. Mutations are indeed random; selection, however, is not – it provides the 'guide' that leads to an orderly change.
    - *Complex features (for example an eye) cannot evolve because either:*
        - *They are too complex to arise from one mutation; or*
        - *If you tried to evolve a complex feature in several intermediate steps, there would be no advantage for the intermediates (for example, a lens without a retina), so they would never evolve.*

      In fact, it is true that complex features are unlikely to evolve in one step. However, complex features do evolve because the intermediates (for example, primitive eyes rather than partial eyes) do confer some selective advantage. You can look at it like this: although you can't jump to the top of a cliff in one jump, you can get there if there is a staircase of intermediate steps and jump from one to the other.

Conceptual Connections

Biological Connections	Nature of Science Connections
Domesticated plants and animals	Science practices (inquiry)
Bacterial/viral/pest resistance	Science and society
Applied evolutionary science	Collaboration and peer review

Activity

Materials

Handout: Artificial selection: Evolution in practice

Introduction

Interactive introductory lecture: Review key ideas as necessary (see objectives).

Establish the problem: With students working in pairs, each pair to a computer, introduce the hypothetical design challenge scenario. Facilitate a class discussion to explore what students already know about the problem and what they still need to know. Read aloud the background information and the experimental design questions. Clarify any language in the questions so that the task is clearly defined, but *without providing any suggestions for how to solve the problem.*

Main Teaching Activities (120 minutes[1])

Hypothesis development and experimental design (30 minutes): Have students complete the experimental design questions in the handout, writing out their answers.

Note: Students may choose to change one or more of the organism or environmental variables in order to influence the evolution of the "oro" function in the population. Students' protocols may go in a number of directions including changing only one variable at a time, changing multiple variables, evolving the "oro" function as quickly as possible using one set of parameters and then transplanting that organism to another environment to clone it, or using only one static set of parameters for the population. Permit students to pursue any of these options; as a group, discuss the pros and cons of each.

Data collection and analysis (45 minutes): Students will collect data according to their experimental protocols, documenting the parameters for each run and recording observations. Students will create graphs to display their results and describe how their results support/refute their hypotheses.

Communicating results (45 minutes): Based on their results, students will propose protocols for evolving bacteria to degrade TCE. They will briefly present their proposals to the class, supporting with evidence from their investigations.

Conclusion

Proposal selection and discussion: Facilitate a class discussion and decide which group most effectively evolved efficient TCE-degrading bacteria. Encourage students to critique the proposed protocols and come to a consensus about what should be presented to the environmental consulting company and why. Are there any unanswered questions? Do we feel confident submitting one of these proposals? Do we need to run more experiments? This should lead to a rich discussion about the nature of scientific inquiry and the engineering design process.

[1] Students could be given more time by completing certain portions of the activity outside of class as a homework assignment.

Student Handout
Artificial Selection: Evolution in Practice

Researchers can select for resistant bacteria in order to study their genomes.

Background

Researchers use models to test hypotheses when experiments with the actual system of interest would take too long to perform, be too difficult to manage, or too expensive to conduct. For this project, you will use digital organisms to model evolving bacterial populations. In real life, bacterial populations can double as quickly as every 30 minutes. However, this is still too slow to be of practical use in answering certain questions. To overcome this problem we can use digital organisms in Avida-ED, where doubling times can be as little as one second.

Imagine that the “oro” function in Avida-ED codes for an enzyme that can degrade a substance known as trichloroethylene, or TCE. Your job in this exercise is to evolve organisms that perform “oro” (see the Design Challenge Scenario below). Beginning with the default organism (@ancestor), change any of the environmental settings and use many different environments over the course of your experiment. Your goal is to determine the best procedure for evolving a population that most effectively metabolizes the “orose” resource in an environment with only “orose.”

Assignment Tasks

Design Challenge Scenario
Your school administrators want to buy a plot of land adjacent to the school to accommodate new athletic facilities. The property includes a large warehouse that has been used for various industrial purposes over the last 50 years. During the site inspection, it was discovered that the soil and water around the warehouse are contaminated by trichloroethylene (TCE), a hazardous chemical used as a spot remover in dry cleaning and as a degreaser for metal parts.

The school board has asked your class to team up with an environmental consulting company to help clean up the TCE so that your school can move ahead with purchasing

and using the land. The environmental consulting company has informed you that current methods for TCE abatement are expensive and require the contaminated soil to be removed and disposed of in hazardous waste dumps. The company is interested in spiking the soil with bacteria that can biodegrade (break down) the TCE. Your goal is to develop a protocol for evolving a bacterial strain that can biodegrade TCE (i.e., perform the "oro" function). You must convince the company (using data to support your claims) that your protocol will lead to an efficient means of evolving TCE degrading bacteria. The company can then use your recommendations to mass produce the bacteria and clean the soil on-site instead of dumping it into a hazardous waste landfill.

Before going any further, discuss the following questions:

1. What do you know, or think you know, about this problem?

2. What things do you not know, or need to know, about this problem?

Experimental Design

Design the experiment to answer the following question: What conditions will lead to the evolution of the most efficient TCE degrading bacteria? Use the questions below to guide you through the experimental design process.

1. Write a hypothesis to answer the question, and include a justification (why do you think these conditions are ideal?).

2. What data will you need to collect in order to test your hypothesis? How many data points (number of replications, variables, etc.) do you need to be able to confidently support or reject your hypothesis?

3. Describe your experimental design. Make this a concise description of your methods (including settings, replications, data collection, etc.) that is clear enough for another group to replicate.

4. How will you organize your data as you collect it? Make a data table to fill in during the investigation.

5. How will you present the data in order to make patterns in your data clear?

Conclusion
Write a paragraph describing how your results support or refute your hypothesis.

Proposal
Propose a protocol for evolving bacteria to degrade TCE (perform “oro”) based on the results of your investigation. Prepare a brief presentation to the class explaining your proposal.

Discussion
As a class, evaluate the proposals and determine which protocol most effectively evolves efficient TCE degrading bacteria. Are there any unanswered questions? Your class may find that you have a protocol that you feel confident submitting to the environmental consulting company or you may decide that you need to run more experiments before doing so. It is important that you present data in support of your protocol in order to convince them that your protocol is likely to lead to a feasible plan for evolving TCE degrading bacteria.