Experimental Evolution Project with Evolving Digital Organisms

Lesson Overview

In this exercise, students have the opportunity to pursue a question of their choosing. They will generate a hypothesis to answer their question and develop an experimental protocol for testing it in Avida-ED. They will then conduct their experiment(s), collect and analyze data, and decide how to appropriately represent and explain the patterns that they find. The lesson concludes with the students writing a short research paper to communicate their findings.

Big Ideas

Scientists learn about the natural world by observing and developing explanations for physical phenomena. Scientific explanations are based on evidence derived ultimately from observation—both directly and inferred from patterns. Scientific progress is marked by an accumulation of evidence via a cycle of asking questions, hypothesizing, making predictions, testing and evaluating hypotheses, and communicating findings.

Evolutionary biology serves as an excellent example of how science is done. Patterns revealing how life on Earth has changed over time abound from evidence in the fossil record, DNA, behavior, ecology, and even research on genetic algorithms. Evidence from each of these areas of research has contributed to evolutionary theory, which forms the basis for our understanding of all biology.

Objectives for Student Learning

Through engagement in this lesson, students will:

- Authentically engage in the practices of science, including generating questions, developing hypotheses and predictions, designing experimental protocols to test hypotheses, and effectively communicating findings to peers.
- Explain why evolutionary biology is an exemplar of how science is done.

Students' Prior Knowledge

This exercise takes students through all stages of the scientific process and is intended to be largely independent. Therefore, it is important that students are familiar with fundamental evolutionary concepts, science practices, and the Avida-ED software before engaging in this activity.

Conceptual Connections

Biological Connections	Nature of Science Connections
Students may choose to test hypotheses regarding biological phenomena using a digital model.	Scientific habits of mind (e.g., evidentiary basis of scientific claims; observation vs. inference) Practices of science

Activity

Materials

- Handout: Experimental Evolution Project with Evolving Digital Organisms

Introduction

Introduce the project: Explain to students that they will be synthesizing and applying the concepts that they have learned by designing and conducting a study with Avida-ED to address an evolutionary question of their choosing. Be sure to stress that the questions must be testable in Avida-ED, and the scope of the study must be limited to what can be completed within the allotted timeframe.
Note: If students are having difficulty generating a suitable question, you may choose to refer to the list of potential study ideas included below. This list is intended for inspiration only; you will need to decide whether a project is appropriate given your particular objectives and your assessment of each student's level of preparedness.

Main Teaching Activities (Estimated class time: -- minutes)

Much of the student work for this project is independent and will occur outside of class, ideally over the course of several weeks. Some class time can be spent periodically updating peers as to the progress of the project and in reporting outcomes.

Conclusion

Discussion of Science Practices: After students have completed their projects, guide them in a whole-class discussion of the process they went through in conducting their studies. How did they generate their research questions? How did they decide on an experimental protocol? Did they refer to the primary literature, and if so, to what degree was this helpful? Did all students go through precisely the same process? If not, what sorts of differences were there? What sorts of challenges did students face? What other questions emerged as a result of the project? How might students approach the same question differently if they were to repeat the project?

Variations and Supplemental Activities

- Supplemental activity: Mini-conference. In addition to the papers students will write, the instructor may choose to have students practice presenting their research either with timed oral presentations or as a poster session. The mini-conference can be advertised and the public invited to attend. This experience will be especially valuable if the students have the opportunity to explain their work to individuals not taking the course and not specializing in the sciences.

Potential project ideas

Effects of changing parameters: Make predictions about how different experimental parameters (e.g., mutation rate, resource availability, dish size, etc.) will affect population dynamics.

Artificial selection experiments: Propose a protocol for evolving organisms with a particular phenotype (function or set of functions).

Exploring descent with modification (building phylogenies): Starting with a single ancestor, create different lineages of organisms and use these to construct a tree showing how they are related. Use various established techniques for estimating degree of relatedness to determine how well they match the known relationships.

Random mutation vs. non-random selection: If mutations are random, how can evolution lead to complexity? Can particular outcomes be predicted given certain environmental conditions?

Relationships between genotype/phenotype/environment: Explore how variation at the level of the genome affects phenotypic variation, or the role played by the environment in shaping population diversity.

Why is evolution good science?: What makes evolutionary biology such a great example of science done well?

“Everything is adaptive”: Test the claim that observable traits always contribute to an organism’s fitness.

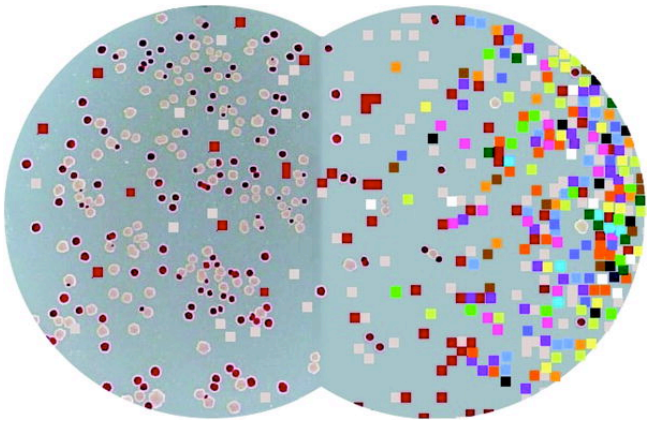
“Survival of the fittest”: Determine whether this well-known phrase is an accurate description of how evolution works.

Evolved vs. engineered organisms: Compete organisms that have evolved to use particular functions against those that have been engineered. Which is better?

Studying biological systems with digital models: Use Avida-ED to test/confirm patterns in biological systems (e.g., Luria-Delbrück; coat color in rock pocket mice; *E. coli* evolving to metabolize citrate; effects of radiation on indicator species – individuals & populations, etc.).

Student Handout

Experimental Evolution Project with Evolving Digital Organisms



Two model systems: *E. coli* & digital organisms.

Background

Some evolutionary biologists, such as Richard Lenski at Michigan State University, conduct experiments using microorganisms like *E. coli* to answer questions about evolution. Bacteria are useful model organisms because they replicate quickly and their small size means that they don't take up much space in the laboratory. Lenski's work with *E. coli* has helped shed light on aspects of the evolutionary process and, having spanned 25 years and over 60,000 bacterial generations, is the longest-running investigation of its kind.

As far as biological organisms go, *E. coli* replicates—and evolves—at an incredible rate. Even so, it is still too slow to be of practical use in addressing certain questions about evolution. To pursue such questions scientists sometimes use digital organisms that model biological systems. Avida is just such a model system, used by researchers to study evolutionary processes and find solutions to engineering problems.

In this exercise you have the unique opportunity to pursue an evolutionary question of your choosing using evolving digital organisms in Avida-ED. It is up to you to generate, develop, and test a hypothesis to answer your question and report your findings in the style of a scientific publication.

Assignment Tasks

Hypothesize: Propose a hypothesis to an evolutionary question that can be tested using Avida-ED.

Predict: Indicate what outcomes you would expect in the event that your hypothesis is true.

Design an experiment: Develop an experimental protocol that you will follow to test your hypothesis. You should consider relevant variables, what data to collect, and how many replications you will need.

Conduct your experiment: Follow your protocol and record the appropriate data.

Analyze your data: Summarize your data and perform appropriate statistical tests. Decide how best to represent your data and create appropriate tables and/or graphs.

Report your findings: Write up your experiment as a standard scientific paper. Your report should include (i) introductory background information and a statement of your hypothesis, (ii) methods, (iii) results, and (iv) conclusions and discussion. The complete report should be no more than 5 pages long.