ADVANCED BIOLOGICAL SYSTEMS
Unit #1: Evolution
Instructional resource #6: Selection simulation

Instructors' notes
A modern understanding of the theory of evolution revolves around the selection of certain types within a population that over long time periods eventually leads to change of the species. This descent with modification is modeled with this activity, and leads to a subsequent lesson that has students reading about research into examples of speciation.

There are two points to make about this simulation. The first is that changes to the individual are generated through random means. Here the roll of dice and the tossing of coins are used to mimic the random appearance of mutational change. Extending this idea, only some types of changes are allowed. As seen before when we considered suboptimal forms, the process of modification must work on some pre-existing structure. The second point to make about this simulation is that reproductive success is earned by those with certain traits. Students occasionally hear the phrase "survival of the fittest" and think that the ability to survive is the fitness trait that is tested, when it is the ability to reproduce that is the true measure of fitness.

We feel that this conceptual approach to understanding selection lays a valuable foundation for students. Later, when we ask students to read primary literature into examples of natural selection where a knowledge of selection is assumed, this lesson enables a stronger focus on the science. When students understand the meaning of an outcome, the reading becomes more involved in seeing the science that allows us to proceed to the expected conclusion.

NGSS addressed in this lesson:	
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, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
HS-LS4-4	Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

Selection Simulation

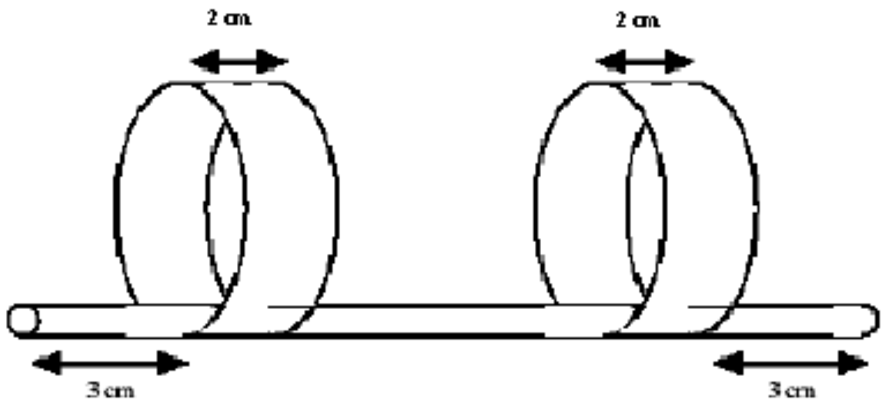
The thought breakthrough that Charles Darwin offered in his landmark treatise, *On the Origin of Species*, was that over time species change due to a process that selects for some individuals over others. He considered that species continual change as a result of variation arising within a population that inevitably leads to some individuals being more fit for the environment. Through competition, those individuals which are better adapted to the environment are likely to reproduce more effectively, and thereby make a greater contribution to the next generation. In such a way, those individuals which were more likely to survive until sexual maturity and more likely to reproduce were selected for by some natural means. Today, we call this evolutionary fitness. Over long periods of time, this slow process of selecting individuals based on fitness can generate large-scale changes to a population.

We recognize this principle in agricultural practices today as the most productive crop and animal stocks have been selected by the industry. Likewise, dog breeds were developed through a similar selection process. Of course, these processes are not natural in that the most evolutionarily fit individuals are not the one to contribute disproportionally to the next generation. Rather, we impose a selection on the population to meet some need of ours and favor the reproduction of some types. While still a selection, this is not a natural one. We call this artificial selection. We also recognize sexual selection, where a mate is chosen based on characteristics that do not otherwise increase the chosen individual's fitness. In this way, traits can become more predominant in a population that oftentimes would be considered as negative to survival. Even so, the added benefit to reproductive success must outweigh the risk to survival.

We will use a selection simulation to highlight the process. Originally published as Egyptian Origami Birds (Westerling, 1995), this simulation selects for the longest flying construction to succeed into the next generation. Over several generation, and by selecting for the best flying construction, we test to see whether a selection protocol can result in a noticeable difference in flight success. In this activity, you and a partner will produce several generations of Origami Birds and observe the effect of various traits on the flight success of your construction.

Materials:
Vellum paper, a metric ruler, a metric tape measure, masking tape, non-bending soda straws, a six-sided die, a coin, a permanent marker, and scissors.

Preparing the parent bird:
Cut two strips of thick paper, each 2 cm wide and 20 cm long. Fold one strip lengthwise into a loop with a 1 cm overlap and tape it closed. Repeat this procedure for the other strip. Tape one loop 3 cm from one end of a non-bending straw, and the other loop 3 cm from the opposite end of the same straw. Select one end of the straw to represent the head of the bird and mark that end with a permanent marker. Your parent bird should look like:



Rules of reproduction:
Your bird will asexually reproduce by laying a clutch of three eggs, each hatching into a chick. The first chick hatched has no mutations relative to flying ability. Since this chick is identical to the parent bird, you may substitute the parent bird for this chick in order to save time when testing flying ability. The other two chicks will have mutations that affect wing size or wing position. You will need to flip a coin and throw a die to determine the specific mutation each chick will express.

Coin flip:
The coin flip determines where a mutation will manifest. Heads for an anterior (front-end) wing change or tails for a posterior (back-end) wing change.

Die roll:
The die roll determines how a mutation affects a wing. The numbers one through six represent the following mutations:

1: The wing position moves 1 cm distally (toward the nearest end of the straw).
2: The wing position moves 1 cm proximally (toward the mid-point of the straw).
3: The circumference of the wing increases by 2 cm.
4: The circumference of the wing decreases by 2 cm.
5: The width of the wing increases by 1 cm.
6: The width of the wing decreases by 1 cm.

A mutation which results in a wing being positioned off the end of the straw, having a width of zero cm, or having a circumference smaller than the circumference of the straw, etc. is lethal (assume the baby bird dies in the egg). If a lethal mutation occurs, your bird will continue to lay eggs until a surviving chick hatches to take its place.

Testing the birds:
The flight distance is determined by measuring the distance from the point where the bird was thrown directly to the point where it lands. Measure from starting point to landing position, regardless of the angle relative to the throw.

Test the parent bird for flight distance by releasing it with a gentle, overhand pitch. It is important to release each bird using the same uniform technique. Test this bird twice. Add the longest flight distance onto the class Google sheet.

Test all three birds from each new generation. Test each bird twice and record only the farthest flight distance of all six trials. The most successful bird is the one that flies the farthest distance in any direction from the point of release. Add this information onto the class Google sheet.

The next generations:
The most successful bird becomes the sole parent of the next generation creating three offspring of its own. KEEP THIS BIRD with no changes; it will represent one of the three offspring in the next generation.

Allow this bird to reproduce, one like the parent (so, the one you kept) and the two others with mutations. Test all three offspring for flying ability, and determine which is the best flying bird. Repeat these procedures until five generations of birds (not including the parent) have been tested.

Data analysis and submissions:

- Create a scatterplot that shows the maximum flight distance of the best flying bird of each generation for your individual data. Treat your original parent bird as generation zero.
- Create a scatterplot that shows the mean flight distance of the best flying birds in the population (compiled class data) in each generation. This figure should include error bars that show the standard error of the mean for each data point in the scatterplot. Treat the original parent birds as generation zero.
- Run a statistical analysis on the class data to determine whether the mean flight distance at the end of the simulation was significantly greater than the mean flight distance of the parent generation. This would involve running a two sample t-test looking at a one tail P-value. Please report the test statistic, degrees of freedom, and probability for your statistical analysis. Clearly state in your caption writing whether or not the observed increase in flight distance (assuming there was an increase) was statistically significant.
- Write informative captions and properly label the axes for all figures.
- Write a one paragraph summary

Questions to consider for your summary:

- ? Did statistical analysis support that the selection process resulted in better flying birds?
- ? Are all mutations bad? Are all mutations good? Which mutations continue through the generations? Explain you reasoning.
- ? What aspects of this activity modeled the evolution of species well?
- ? What aspects of this activity did not model the evolution of species well?
- ? How might you modify this activity to include genetic drift or gene flow?
- ? What limitations did you have that an engineer might not have to worry about? How is the evolution of species unlike engineering a new species?

Westerling, Karin. 1995. Evolutionstechnik or Selection and Variation in the Egyptian Origami Bird (Avis papyrus). Activities Exchange @ accessexcellence.org. (http://www.accessexcellence.org/AE/AEC/AEF/1995/westerling_selection.php)