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Darwin's Finches: Evolution and Natural Selection Lab

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This lab demonstrates how changes in environmental conditions can result in the evolution of a species. Students are introduced to the research of Peter and Rosemary Grant, which documents rapid evolutionary changes in the ground finches of Daphne Major. To illustrate natural selection and evolution in action, students will become finches, with each student representing one of four beak types. The students make hypotheses and predictions about how the different beaks will affect his/her ability to forage for food, and test those predictions by using their beaks to collect different kinds of seeds. Students graph their data to evaluate their predictions.

Keywords: evolution, natural selection, microevolution, Darwin's Finches, macroevolution, adaptive radiation

Link to Supplemental Files: http://www.ableweb.org/volumes/vol-37/orrell/supplement.html

Introduction

This lab provides students with a hands-on activity that illustrates how natural selection occurs and can result in evolutionary change in a species. To provide a framework for understanding natural selection and evolution, students are introduced to Charles Darwin's observations on the Galapagos finches, and to the research by Peter and Rosemary Grant which documented rapid evolutionary changes in the ground finches of Daphne Major. The contemporary example provided by the Grants' research shows students that evolution can in fact be observed as an ongoing process, something that many of them were not aware of previously. The finches are then used as a model for the lab exercise; the students become finches, with each student using one of four different tools (representing different beak sizes and shapes) to collect four different seed types. The students make hypotheses and predictions about how the different beak types and the seed types available will affect his/her ability to forage for food, and then test those predictions by using their "beaks" to collect seeds. At the end of the lab, students organize their data into tables and graphs, and evaluate their hypotheses and predictions. Based on the data collected, they develop their own conclusions about how changes in selection pressure can result in differences in survival, and subsequently, in the adaptation and evolution of traits in a population.

This lab requires one 2.5 hour laboratory session, and it is designed for freshmen biology majors with limited exposure to the concepts of natural selection and evolution. The lab also introduces a number of related concepts that are a bit more advanced than may be appropriate for non-majors (e.g., microevolution versus macroevolution, adaptive radiation, niche partitioning). Similarly, we expect biology majors to gain a more in-depth understanding of (and ability to apply) the scientific method, hypothesis testing, and skills associated with creating and interpreting data tables and graphs than we would expect of non-majors. We have provided a version of this lab written for non-majors which excludes the advanced concepts. The non-majors version is also appropriate for high school students.

Learning Objectives

- Define evolution and natural selection.
- Observe and describe how environmental conditions can drive natural selection.
- Explain the role of genetic variation in evolutionary change over time.
- Distinguish the processes of microevolution and macroevolution.

- Describe how natural selection has resulted in the evolution of different beak morphologies, and ultimately, in multiple species of finches in the Galapagos.
- Practice organizing, presenting, and interpreting data in tables and graphs.

Skills Acquired

Students will obtain practice in:

- Writing, testing, and evaluating simple scientific hypotheses and predictions
- Devising tables for collecting and recording data
- Creation and use of graphs to display and interpret data and to help determine whether to accept or reject their hypotheses

Student Outline

Introduction

The most basic definition for **evolution** is simply a process of change in populations or species over time. Darwin called it "descent with modification." Although the idea that species changed over time was not entirely new in Darwin's time (albeit it was an unpopular idea then), Darwin was the first person to correctly describe the process by which these changes could occur. **Natural selection** was the term he used to describe this process.

Darwin's discovery began with a five year ocean voyage around the world on the HMS *Beagle*. Often seasick, he spent as much time as possible exploring on shore. As the ship's naturalist, he collected and described many species of animals, plants, and fossils. Darwin made many notable discoveries during this trip, but none were as significant as those made on the Galapagos Islands, a cluster of volcanic islands near the equator off the coast of Ecuador. Although the Galapagos Islands were never connected to the mainland, they were populated by some plants and animals similar to those found on the mainland. Darwin also noted that each island seemed to have its own unique plant communities, as well as many unusual animals, such as huge tortoises found nowhere else in the world. But, of all the animals Darwin found, a group of finches similar to those found on the mainland particularly caught his attention. These birds have since become known as Darwin's Finches.

On the Galapagos Islands, Darwin found several types of birds with very different body sizes, bill structures, behaviors, and even feeding preferences. In fact, some birds fed on insects or fruit, quite unlike the similar mainland birds which largely fed on seeds. After returning to England, Darwin had a bird expert examine the specimens he brought back. He was surprised to find out that one group of the birds he brought back consisted of as many as 13 distinct species of finches. This realization, combined with his observations on the birds' feeding behavior and local habitats, was particularly important to his realization about how new species formed by natural selection. In his published journals from the Beagle voyage (1839), Darwin suggested that the Galapagos Islands were initially colonized by mainland species that had slowly adapted to local conditions and diversified into many new species. Darwin continued to compile data and evidence to support his theory of evolution by natural selection, but he procrastinated actual publication for so long (about 15 years) that he was nearly scooped by another British naturalist named Alfred Wallace. Wallace had made scientific expeditions to the East Indies, and in 1858 he sent Darwin a manuscript describing his ideas that were remarkably similar to Darwin's natural selection hypothesis. Later that same year, both men submitted papers to the scientific community at the same time, so both received credit for the initial discovery. However, in 1859 Darwin published his book On the Origins of Species which became an immediate best seller read by the general public as well as by scientists, and it quickly sold out at each printing.

In his book "Origins," Darwin laid out in great detail the evidence and logic supporting his theory of natural selection, which can be summarized as follows:

Facts Based on Observations of Nature:

1. Organisms in a population vary in their traits, and some of this variation is inherited. Within a species, no two individuals (except identical siblings) are exactly alike.
2. More individuals are born than survive to reproduce.
3. Individuals compete with one another for the resources that enable them to survive.

Inferences from Observations:

1. Within populations, the characteristics of some individuals make them more able to survive and reproduce in certain environmental conditions.
2. Individuals that survive and reproduce can pass on heritable beneficial traits to offspring.
3. Characteristics of populations can change over time, even resulting in new species.

Today we know that variation in traits is due in part to genetic **mutations** that provide a source of new **alleles**. If a particular allele for a trait has a selective benefit (i.e., enhances survival or reproduction) then the number of individuals with that trait will increase in the population. Conversely, a detrimental trait that decreases survival or reproduction will be selected against, and the number of individuals with that trait will decrease in the population. Hence, the expression: "evolution = change in gene frequency." This type of change that occurs on a relatively short time scale and is measured in allele frequencies is known as **microevolution**. Over longer expanses of time and a great many successive generations, mutations and selection can produce enough genetic and phenotypic change to create new species. Evolution at or above the species level is known as **macroevolution**. Evolution that occurs by small continual changes accumulating over many generations is known as **gradualism**.

Natural Selection and Darwin's Finches

The Galapagos Island Finches are an example of an evolutionary speciation process called **adaptive radiation**; one species of finch that colonized the islands about 2-3 million years ago has evolved into the 13 different species that exist today. When the finches arrived in the Galapagos, there were relatively few native bird species there to compete with, and thus many available resources and unoccupied **ecological niches**. A niche is defined as a functional role (or “job”) within an ecological community, and as such it includes all factors important for survival and reproduction. These factors include habitat and climate characteristics, food and shelter requirements, and how a species interacts with other individuals and species in the community (prey, predators, or competitors).

The finches did so well in the Galapagos Islands, that their numbers increased greatly, and thus so did competition for food and other resources. **Resource partitioning** is a process in which a population or group of organisms reduce or avoid competition with others by shifting their resource use; in effect they “partition” the available resources or habitat. This results in groups that specialize on a particular ecological niche. The different niches exert different selection pressures that drive evolution in different directions. Over time, the finches (many of which lived on separate islands and in very different habitats) became so adapted and specialized to their particular niches that they had diverged into different species. Today, there are 13 finch species adapted for different niches: some are ground-dwelling seed-eaters, a few feed on cactuses and seeds, and several species are tree-dwelling insect-eaters.

Each of the Galapagos finch species is similar in bodily proportions and coloration, but they differ from one another in beak shape. *The variation in finch beak shape reflects differences in diet.* Alteration of beak morphology is also associated with climatic fluctuations on the Galapagos. In some years the islands are parched by drought and in other years the islands are drenched by El Niño rains. Climatic fluctuations are correlated with changes in the availability of different food sources.

In 1973, Peter and Rosemary Grant from Princeton University began studying Darwin's Finches on Daphne Major, a small 100-acre island in the Galapagos chain. The Grants and their graduate students successfully banded every individual bird from two species living on the island: the large ground finch, *Geospiza magnirostris,* and the medium ground finch, *Geospiza fortis.* The birds were studied exhaustively and measurements of body and beak size were made year after year. Although there was variation in beak size in both species, *G. magnirostris* tended to have much larger, heavier beaks than *G. fortis* (see Figure 1).

Figure 1. Large beaked *G. fortis* (A), large beaked *G. magnirostris* (B), and small beaked *G. fortis* (C). (From Grant & Grant, 2006. Reprinted with permission from AAAS).

In 1977, Daphne Major experienced a drought that continued until January of 1978. The researchers found that, although birds with beaks of all sizes decreased in number during the drought, the smaller beaked birds (Figure 1) decreased the most. Birds with larger beaks tended to survive better than birds with smaller beak sizes. Thus the average beak size increased (see Figure 2). The same pattern was repeated in 1982 when there was very little rain; the small beaked birds perished in a much greater numbers than those with larger beaks. However, during wet years the small beaked birds did very well, surviving and reproducing more than the large beaked birds.

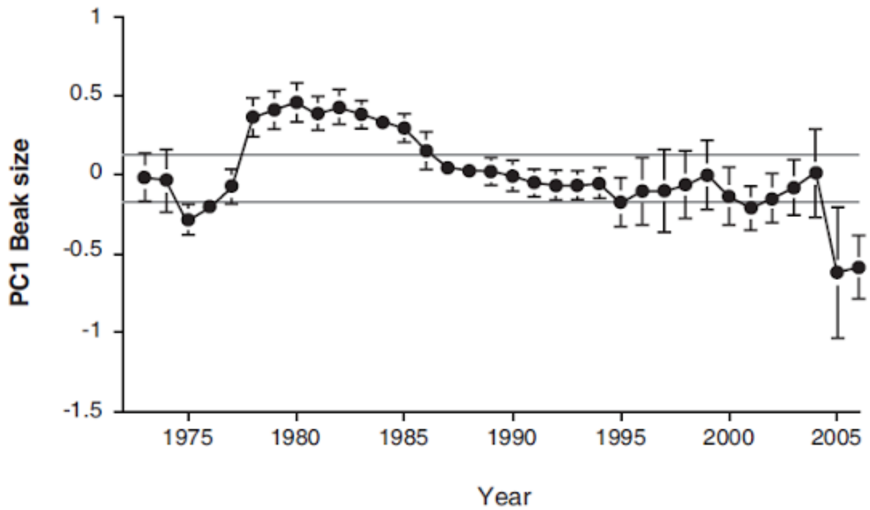

Figure 2. Change in average beak size in the medium ground finch, *G. fortis*, on Daphne Major. (From Grant & Grant, 2006. Reprinted with permission from AAAS).

The Grants' research showed that within a relatively short period of time, evolution had occurred; the average beak size in the population changed over time. What you should ask yourself at this point is WHY small beaks might be selected for during wet years and large beaks in dry years. Think about the importance of a beak to a bird: what is it used for? OBTAINING FOOD!! So, how might the amount of precipitation affect the finches' food supply? The major environmental consequence of drought is the decline in food supply. For the ground finches, this means seeds. During normal rainfall and wet seasons, an abundance of small seeds are produced by grasses and herbs. During drought, small seeds are more scarce and larger, harder-to-crack seeds predominate. You should be able to use this information to explain why the average beak size changes over time.

In this laboratory exercise, we will conduct a simple experiment to illustrate the effectiveness of different beak types on the ability to collect different kinds of seeds, and thus how natural selection might influence beak morphology. We will use four different "beak" phenotypes: pliers, beaker tongs, large forceps, and small forceps, and three kinds of seeds of different sizes including: sunflower, millet, and thistle seeds. In addition, we will examine the effects of changes in environmental conditions that can alter available food supplies (in our case changing the ratio of different seed types). Before you begin this experiment, write a hypothesis about how finch beak size affects the type or size of seeds harvested and a prediction for what you think is the most likely outcome based on your observations of the different "beaks" and seeds at your lab table (do NOT try to use the beaks at this point because that would be cheating!). Discuss this experiment with your lab group, and then write a hypothesis and a prediction that you can test in the space below. Refer to the handout "The Scientific Method and Presentation of Results" for information about writing a hypothesis and prediction.

Procedure

Before you begin the exercise, read the procedure thoroughly, and determine the best way to organize a data table. Show your data table to your lab instructor before proceeding. After your lab instructor has approved everyone's hypothesis and data table, the class will begin the experiment.

Each lab table (four students) will work as a group and complete the following steps together.

Normal Conditions

1. Count out **100 corn kernels, 100 sunflower, 100 millet, and 100 thistle seeds** into four separate cups. Mix seeds together in a fifth cup labeled **"Normal Conditions**."
2. YOU are a bird. Each student should choose one of the four "beaks" (**pliers, beaker tongs, large forceps, or curved forceps)**. Each student is to use an empty cup as their "gizzard" to hold the seeds "eaten."
3. Spread seeds from the **Normal Conditions** cup on the carpet sample at your lab table. Get in position to begin collecting seeds but do NOT test out your beak yet. Wait for instructions.
4. The lab instructor will use a timer to give all students (the birds) **one minute** to "forage" for seeds using their "beak." As you pick up seeds, put them into your cup. **Sunflower seeds must be cracked with your beak** before placing them in your cup. No shoveling/pushing seeds into the cup!
5. Count the number of each seed type "eaten" by each beak type and record in your data table. Sunflower seeds may only be counted if the outer shell was cracked (the seed can still be inside).
6. Remove cracked sunflower seeds collected and replace with an equal number of uncracked seeds, then spread all the seeds back onto the carpet (uncollected seeds stay in place on the carpet). This will restore the number of seeds to what you started with.
7. Repeat steps 4-6 three more times (total of four trials) with each student choosing a different beak type each time. If there are three students in your group, one person will do an extra one minute of collection with the unused beak for each trial.
8. Clean up the carpet and lab table by putting used seeds in the appropriate disposal bin. While the group is cleaning up, one person from each group should enter their group's data in the Google spreadsheet provided by your instructor.

Drought Conditions

9. Count out **200 corn kernels, 200 sunflower, 50 millet, and 50 thistle seeds** into four separate cups. Mix seeds together in a fifth cup labeled **'Drought Conditions.'** Select your beak type.
10. [Note: in addition to changing the proportion of seeds the instructor may choose to further simulate drought ground conditions by using a tray of sand and gravel instead of a carpet square.]
11. Spread seeds from the **Drought Conditions** cup on the carpet sample at your lab table. Repeat steps 4-7 four times (each student using a different beak each time).
12. Repeat step 8 for cleanup and data entry.

Abundance of Rain Conditions (optional depending on time)

13. Count out **50 corn kernels, 50 sunflower seeds, 125 thistle, and 125 millet seeds** into four separate cups. Mix seeds together in a fifth cup labeled **"Abundant Rain."** Select your beak type.
14. Spread seeds from the **Abundant Rain** cup on the carpet sample at your lab table. Repeat steps 4-7 four times (each student using a different beak each time).
15. Repeat step 8 for cleanup and data entry.

Analysis and Presentation of Data

1. Each student should write down the class averages (yellow boxes in the Google spreadsheet) for each seed type, beak type, and environmental condition in their own data table.
2. Use the class average data to construct a graph (or two). Refer to your handout "The Scientific Method and Presentation of Results" (Supplement 1) when completing your graph. Use colored pencils and make sure you have labeled all parts on the graph.
3. Answer post lab questions and evaluate your hypothesis.
4. Discuss questions and hypotheses as a class. Hand in your completed questions and graphs to your instructor.

Post Lab Questions

1. Which seeds were "eaten" in the highest frequency overall? Was this consistent for all beak types?
2. Which seed phenotype was most adaptive (which seed survived the best!)?
3. Which beak morphology was most adaptive (ate the most seeds)?
4. If the environment is stable and does not change for several years (no drought), what will happen to the average beak size within the population of finches?
5. Under drought conditions, which of your beak phenotypes were selected for? Which were selected against?
6. What do you think would happen if we simulated an El Niño year? Which of our beak types would be selected for under these conditions? Which would be selected against?
7. Has *microevolution* or *macroevolution* occurred in the finches observed by the Grants on Daphne Major?
8. Which beak morphologies would become the most common in the test environment over time if the climate conditions remained stable and did not change (e.g., lacked droughts or periods of abnormally high rain)? Explain.
9. What does the difference in beak morphology indicate or predict? Provide an example.
10. Did the data collected support the original hypothesis you started out with? Refer to the graph you made to show the supporting evidence. Explain what you found and concluded below. If the data did not support your hypothesis, please think about this and explain the possible reasons why it did not.

Answers to Post Lab Questions

1. Which seeds were "eaten" in the highest frequency overall? Was this consistent for all beak types?

   Answers will vary according to the results students get.

2. Which seed phenotype was most adaptive?

   Answers will vary according to the results students get, but this would be the seed that was collected least (so was most effective at not getting eaten).

3. Which beak morphology was most adaptive?

   Answers will vary according to the results students get, but this would be the seed that was collected the most.

4. If the environment is stable and does not change for several years over time (no drought), what will happen to the average beak size within the population of finches?

   If the rainfall stays the same, vegetation growth will also, so the number and size of seeds will remain constant from year to year. So the frequency of each beak type will stay roughly the same. Thus, there would be no selection for change in beak size.

5. Under drought conditions, which of your beak phenotypes were selected for? Which were selected against?

   Answers will vary according to the results students get.

6. What do you think would happen if we simulated an El Niño year? Which of our beak types would be selected for under these conditions? Which would be selected against?

   The beak that collected more small seeds (the beak that is adapted to collecting smaller seeds), or whichever phenotype that did this.

7. Has *microevolution* or *macroevolution* occurred in the finches observed by the Grants on Daphne Major? Explain.

   Microevolution; the change that took place was the increase in frequency of birds with slightly larger beaks, no new species were created.

8. Which beak morphologies would become the most common in the test environment over time if the environment climate conditions remained were stable and did not change (e.g., lacked droughts or periods of abnormally high rain)? Explain.

   Answer depends on which were most effective in the experiment (answer 3 above).

9. What does the difference (or variation) in finch beak size and morphology indicate or predict? Provide an example.

   They might have a hard time understanding what this is asking. There could be different answers that would be okay. Differences in beak morphology either within or among species indicates that selection has occurred in the past to adapt birds to different types of diets. Differences in beak morphology predict that different beak phenotypes will be best suited for collecting/feeding on a particular food type, or they predict that there are *different types of foods available in the habitat, and different groups (or species) have specialized on a particular type.*

10. Did the data collected support the original hypothesis you started out with? Refer to the graph you made to show the supporting evidence. Explain what you found and concluded below. If the data did not support your hypothesis, please think about this and explain the possible reasons why it did not.
    Answers depend on student hypotheses and their data collected.

Student Outline
Non-Major's Version of Darwin's Finches: Evolution and Natural Selection Lab

Introduction

This laboratory exercise offers historical background for the scientific theories associated with evolution**,** and demonstrates some of the principles that have been accepted as part of the scientific foundation for evolution. The most basic definition for **evolution** is simply a process of genetic change in populations or species over time. Darwin called it "descent with modification." Although the idea that species changed over time was not entirely new in Darwin's time (albeit it was an unpopular idea then), Darwin was the first person to correctly describe the process by which these changes could occur. **Natural selection** was the term he used to describe this process.

Darwin's discovery began in 1831 with start of a five year ocean voyage around the world on the HMS *Beagle*. Often seasick, he spent as much time as possible exploring on shore. As the ship's naturalist, he collected and described many species of animals and plants. Darwin made many notable discoveries during this trip, but none were as significant as those made on the **Galapagos Islands**, a cluster of volcanic islands near the equator off the coast of Ecuador. Although the Galapagos Islands were never connected to the mainland, they were populated by some plants and animals similar to those found on the mainland. Darwin also noted that each island seemed to have its own unique plant communities, as well as many unusual animals, such as huge tortoises found nowhere else in the world. A group of birds he collected that were slightly different than those found on the nearby mainland caught his attention. These birds have since become known as **Darwin's Finches**.

Darwin observed different species of finches with very different body sizes, bill structures, behaviors, and even feeding preferences. In fact, some birds fed on insects or fruit, quite unlike the mainland finches, which largely fed on seeds. Based on his observations, Darwin hypothesized that the Galapagos Islands were initially colonized by mainland species that had slowly over time adapted to local conditions and diversified into many new species. In 1858 a naturalist working in the East Indies, Alfred Wallace, sent Darwin a manuscript in which he established a hypothesis that species evolve in response to changes in their environment. Darwin had volumes of data to substantiate his and Wallace's beliefs and later that same year both men submitted papers to the scientific community at the same time, so both received credit for the initial discovery. However, in 1859 Darwin published his book On the Origins of Species which became an immediate best seller read by the general public as well as scientists, and quickly sold out at each printing.

In his book "Origins," Darwin laid out in great detail the evidence and logic supporting his theory of natural selection, which can be summarized as follows:

Facts Based on Observations of Nature

1. Organisms in a population vary in their traits, and some of this variation is inherited. Within a species, no two individuals (except identical siblings) are exactly alike.
2. More individuals are born than survive to reproduce.
3. Individuals compete with one another for the resources that enable them to survive.

Inferences from Observations

1. Within populations, the characteristics of some individuals make them more able to survive and reproduce in certain environmental conditions.
2. Individuals that survive and reproduce pass on their beneficial traits to offspring.
3. Characteristics of populations can change over time, even resulting in new species.

In short, Darwin's hypothesis (now a theory) held that changes occur in all natural populations. Today, we know these changes are in part due to gene **mutations** which occur at random in populations and contribute to variation in the genetic makeup of the individuals within a population. Changes in the environment can favor or select against a given trait and either increase or decrease its frequency in a population. Hence, the definition: "evolution = change in gene frequency." This type of change can occur in a relatively short time period and is measured in allele frequencies and is known as **microevolution**. Over longer expanses of time and a great many successive generations, variation and selection can produce enough genetic and phenotypic change to create new species. Evolution at or above the species level is known as **macroevolution**.

Natural Selection And Darwin's Finches

As you learned in the previous section, some individuals within populations leave more offspring than others because they have advantageous traits (example: size, color). Such a situation, also called natural selection, has been demonstrated in finch populations on the Galapagos Islands. The 13 species of Darwin's Finches that live on the Galapagos Islands evolved from a single common ancestor. When the finches arrived in the Galapagos, there were relatively few native bird species there to compete with, and thus there were many available resources and unoccupied **ecological niches**. A niche is defined as a functional role (or "job") within an ecological community, and as such it includes all factors important for survival and reproduction. These factors include: habitat and climate characteristics, food and shelter requirements, and how a species interacts with other individuals and species in the community (prey, predators, or competitors).

Each of the finch species is similar in body proportions and coloration, but differ from one another in beak shape. *The variation in beak shape reflects differences in diet between bird species.* Today, there are 13 finch species adapted to different niches: some are ground-dwelling seed-eaters, a few feed on cactuses and seeds, and several species are tree-dwelling insect-eaters. Alteration of beak morphology is also associated with climatic fluctuations on the Galapagos. In some years the islands are parched by drought and in other years the islands are drenched by El Nińo rains.

In 1973, Peter and Rosemary Grant, from Princeton University, began studying Darwin's Finches on Daphne Major, an islet about 100 acres large. The Grants and their graduate students successfully banded every individual bird from two species living on the island--the cactus finch, *Geospiza scandens,* and the medium ground finch, *Geospiza fortis.* The birds were studied exhaustively and measurements of body and beak size were made year after year. Although there was variation in beak size in both species, *G. magnirostris* tended to have much larger, heavier beaks than *G. fortis* **(see Figure 1).**

Figure 1. Large beaked *G. fortis* (A), large beaked *G. magnirostris* (B), and small beaked *G. fortis* (C). (From Grant & Grant, 2006. Reprinted with permission from AAAS).

In 1977, Daphne Major experienced a drought that continued until January of 1978. The researchers found that, although birds with beaks of all sizes decreased in number during the drought, the smaller beaked population was reduced the most. Birds with larger beaks tended to survive better than birds with smaller beak sizes. The same pattern was repeated in 1982: when there was very little rain, the small beaked birds perished in a much greater frequency than birds with large beaks. However, during wet years the small beaked birds did very well, surviving and reproducing more than the large beaked birds.

The researchers concluded that the predominant phenotype in the population changes over time. Large beaked birds were being selected for during periods of drought, and small beaked birds were being selected for during wet years. What you should ask yourself at this point is why small beaks might be selected for during wet years and large beaks in dry years. Think about the importance of a beak to a bird: what is it used for? OBTAINING FOOD!! So, how might the amount of precipitation affect the finches' food supply?

One major environmental consequence of drought is the decline in food supply. For the ground finch, this means seeds. During normal wet seasons, grasses and herbs produce an abundance of small seeds. During drought, the number of small seeds decrease and larger, harder to crack seeds predominate. You should be able to use this information to explain why average phenotypic beak size oscillates over time.

The beak is of obvious importance to the bird: it allows the bird to consume the appropriate food source. Since different bird species specialize on different food sources, not all birds will have the same type of beak. For example, the beak of a fish-catching bird should look different from the beak of an insect-catching bird. Therefore, beak morphologies differ between birds of the same community.

In this laboratory exercise, we will conduct a simple experiment to illustrate the effectiveness of different beak types on the ability to collect different kinds of seeds, and thus how natural selection might influence beak morphology. We will use four different "beak" phenotypes: pliers, beaker tongs, large forceps, and curved forceps, and four kinds of seeds of different sizes, including: corn kernels, sunflower, millet, and thistle seeds. In addition, we will examine the effects of changes in environmental conditions (drought, abundant rain) that can alter available food supplies (in our case changing the ratio of different seed types).

Pre-lab Questions:

1. Where are the Galapagos Islands located? Why do the Galapagos Islands provide an ideal location for the study of evolution and natural selection?
2. How does the presence of genetic variation contribute to the evolution of a species?

3. How might changes in a species' environment affect the evolution of a species?
4. What observations did the Grants make when studying the finches on the Galapagos Islands during drought years?

Lab Exercise

During today's lab you will have first-hand experience observing how the shape of a bird's beak will affect its ability to harvest seeds when environmental conditions change food availability. You will also observe how different ground conditions affect the ability of a bird to find seeds. Each member of your group will choose a different "beak" for selecting seeds. You will be able to choose from: pliers, beaker tongs, large forceps and curved forceps. Each lab group will be collecting seeds from a different "ground" simulation. The four different ground options will be soil, sand, artificial grass, and mulch. Each group will collect data using seed samples that represent three different environmental conditions: normal, drought, and an abundance of rain.

Procedure

To demonstrate the principles of natural selection, you and the other people at your lab table will prepare samples of corn kernels, sunflower seeds, thistle seeds, and millet seeds. Be prepared to discuss your group's results in class.

Normal Conditions:

1. Count out 100 of each seed (or kernel) type, and place them into separate containers.

2. Mix the seeds together in a new container. These seeds represent varied food sources available in the environment. Since the variation in seed color/size represents variation in a natural plant community, **you** will represent the predator (birds) that feeds on the seeds**.**

3. Since birds have variation in beak size/shape in natural communities, each student in a group will choose a different beak with which to capture the seeds. Pliers, beaker tongs, large forceps and curved forceps will represent the four styles of bird beaks. These are available on each lab table.

4. You and your partners will spread the seeds over the ground sample (soil, sand, artificial grass, or mulch) your group was previously provided.

5. Since birds in natural settings do not have infinite time to find food (due to natural predators), you (the bird) will be given one minute to recover all the seeds you can with your selected beak. Your lab instructor will be the time monitor. Do not begin "feeding" until the start signal is given. You must stop "feeding" when the stop signal is given.

6. Place the "eaten" seeds for each beak type back in the empty containers, sort and record the number of each type of seed (corn, sunflower seeds, thistle, and millet) recovered by your "flock" of birds for each type of beak. Record your data on a separate sheet of paper.

7. Once the seeds have been counted and recorded, your group will throw the seeds collected by the "feeding" back into the test area with the uneaten seeds, and repeat the "feeding" experiment. Once again, sort and record the number and type of seeds recovered by each beak type. Switch between people using the different types of beak in order to mimic a new population of birds coming in to feed.

8. After the "second feeding," repeat the experiment one last time.

9. Record the average number of seeds collected from the three repeated experiments in the tables below.

Drought conditions

1. Count out 75 corn kernels, 75 sunflower seeds, 25 thistle, and 30 millet seeds.

2. Repeat steps 2 through 8 above.

Abundance of Rain Conditions:

1. Count out 50 corn kernels, 50 sunflower seeds, 125 thistle, and 125 millet seeds.

2. Repeat steps 2 through 8 above.

Table 1. Example data table for number of seeds collected under drought conditions.

Seed	**Corn**			**Sunflower**			**Millet**			**Thistle**		
Trial	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Pliers												
Beaker Tongs												
Large Forceps												
Curved Forceps												

Post-Lab

1. Create a bar graph depicting the results of your experiment.
2. What seeds were "eaten" in the highest frequency during each environmental condition?
3. What seeds had the highest survival rate (did not get "eaten") during each environmental condition?
4. What beak morphology had the most successful overall feeding rate?
5. If the island environment does not change over time, what seed phenotype will become the most common?
6. If the environment experienced a drought, what seed phenotype would be at the advantage?
7. What beak morphology(s) is (are) at an advantage in the environment described in Question #6.
8. Based on the pre-lab reading and the information provided by your instructor during lab, did evolution occur in the population of finches on the Galapagos islands during the Grants' study?
9. Which beak morphology(s) would become the most common in your test environment over time if the environment remained consistent without periods of drought or an overabundance of rain?

Answers to Non-majors Pre-lab Questions

1. Where are the Galapagos Islands located? Why do the Galapagos Islands provide an ideal location for the study of evolution?

   The Galapagos Islands are located at the equator off the coast of Ecuador. The location is ideal for studying evolution because organisms originating from the mainland have been evolving in isolation from the mainland for thousands of years.

2. How does the presence of genetic variation contribute to the evolution of a species?

   Evolution requires genetic variation. A species will be unable to adapt to an environmental change unless beneficial traits/alleles already exist within the population.

3. How might changes in a species' environment affect the evolution of a species?

   The change in a species' environment will result in selection for or against certain traits/alleles.

4. What observations did the Grants make when studying the finches on the Galapagos Islands during drought years?

   The Grants observed a change in finch survival and average beak size during the drought years.

   Answers to questions 5-7 and 9 will vary depending on experiment results.

8. Has evolution occurred in the populations of Darwin's Finches on the Galapagos? Explain your answer.

   Yes, evolution has occurred because the allele frequency within the population has changed, resulting in a change in the average beak size.

Materials

Students work in groups of four. For 24 students one would need:

- About 1 lb bag of each seed type: corn, sunflower, millet, thistle
- Six needle nose pliers
- Six beaker tongs (make sure these open and close smoothly and do not bind or stick)
- Six large forceps (not tissue forceps, need flat, blunt tips)
- Six curved (needle) forceps
- 24 plastic beakers or cups for sorting and collecting seeds
- Six plastic beakers or cups for mixing seeds
- Six carpet samples with a minimum size 30 cm x 60 cm. Samples can be cut from a larger remnant. Samples should all be the same solid color and texture: a light sand/beige color works best for all seed types
- One timer or cell phone with clock/timer application
- Lab tape and sharpie marker to label seed cups
- Graph or grid paper for making a graph (we prefer students to draw graphs by hand)

Additional materials for optional variations:

- Six additional plastic cups for mixing seeds (for "Abundance of Rain" conditions)
- Six trays of ½ cm deep sand/fine gravel (if instructor is using this modification for drought conditions)
- If using the variation that calls for different substrate types (as is used in the non-major's version of the exercise), you will need 1-2 trays each of ½ cm deep soil, sand, artificial grass, and mulch (instead of carpet samples, see non-major's version of the procedure for more details)

Notes for the Instructor

Preparation for this lab is inexpensive and simple; most materials can be obtained from a local discount store (Walmart), are easily stored, and are reusable for many years (except perhaps for some seeds). Once materials are obtained, setup for the procedure takes 15-20 minutes or less. This lab can also be done outside if conditions are conducive to the activity.

This lab requires about one hour for the activity itself (reading the introduction, writing and checking hypotheses and data collection tables, then collecting and recording data). It takes about one and a half hours for students to make graphs, answer worksheet questions, evaluate hypotheses, and carry out end-of-lab discussion. If you run out of time, the graphs and/or post-lab questions can be assigned as homework. On the other hand, if you have a three-hour lab period and/or extra fast students, a good addition would be to add the "abundance of rain" condition used in the non-majors version of the lab.

During the lab exercise, the "foraging" of seeds can create a bit of havoc and mess as students become competitive, which adds to the fun. The instructor's use of a timer to coordinate the one-minute periods of seed collection keeps things running smoothly. Cleanup between rounds of foraging is done by students and relatively quick since they have to count the seeds anyway. Cleanup between lab sections and after labs are finished requires a bit of smacking of carpet squares and sweeping up seeds (to be distributed to real birds outside later). When the seed collection is done outside, there is very little cleanup.

We use a pre-made Excel file open on a lab computer for students to enter their data (the display is projected to the room) and class means are calculated automatically. Students transfer the means into their data tables and graph the means by hand. We prefer students to create tables and graphs manually to better-learn the basic skills of organizing a graph and to avoid problems with individual computers and software. The Excel file can also be opened in Google Sheets for more than one computer to add data at once. The Excel file is available online as a download from the ABLE Conference Proceedings (http://www.ableweb.org/volumes/vol-37/orrell/supplement1.htm). The Excel file also contains pre-made graphs linked to the class data entry table so graphs are created automatically as data is entered. This might be handy for a non-majors class, or for class discussion of the results, but you might want to hide the graphs so students do not see them if you want them to do the graphs themselves first.

Student Preparation for Lab

The week prior to the Finch lab, we have our students watch a 15 minute video on Peter and Rosemary Grant's research on finches in the Galapagos: http://www.hhmi.org/biointeractive/origin-species-beak-finch. It can also be done as homework outside of lab. Students complete a worksheet on the video, which the class discusses afterwards. We have provided a detailed summary of the video, a student worksheet, and a key (http://www.ableweb.org/volumes/vol-37/orrell/supplement2.htm).

In preparation for the Finch lab, students are assigned to read the handout: "The Scientific Method and Presentation of Results" to provide an understanding for writing hypotheses and making graphs and tables. Our students are assigned a pre-lab exercise on the handout (open book quiz administered in Blackboard) to be completed prior to coming to lab. The handout is provided in the supplements online (http://www.ableweb.org/volumes/vol-37/orrell/supplement3.htm) but the online quiz is not included.

Challenges

The hypotheses and predictions written by students may vary quite a bit. This is a surprisingly difficult task for some of them, so we guide those students more than others and are flexible about what we accept. Some make hypotheses/predictions about the tools and types of seeds; others make them about the birds and foraging in different conditions. We let them wrestle with it, mostly guiding them to make sure they are logical, that the wording makes sense (freshmen can have a problem with this), and that it will be something they can support/reject with the data. Many students will try to fit their prediction into an if/then format, which is okay if it works, but it is not required. We do insist on reading everyone's hypothesis before proceeding so those that need more help get it.

As part of the hypothesis/prediction segment of the lab, you may also ask students to provide appropriate alternate and/or null hypotheses. Students often do not understand the concept of alternative or null hypotheses, or why they are used. This is a good opportunity to illustrate these concepts; especially if you also go on to do chi-square tests on the data.

At the end of lab we discuss their specific predictions and the class results in the context of natural selection, i.e. "what does this mean for survival and for subsequent generations." If there is time, we go through the post-lab questions together to make sure everyone understands the main points.

Non-Majors Version of the Lab

For our non-majors students, we use a slightly different version of the lab which includes the following elements:

- Introduction is simplified (includes fewer terms).
- Addition of pre-lab questions (to match format of non-major's lab manual)
- Shorter list of post-lab questions
- Each group is given a different ground cover simulation (soil, sand, artificial grass, or mulch)
- Lab and post lab discussions include how ground cover may affect the natural selection of plant species as well as animal species

Variations and Extensions to Lab

- A variation included in the non-majors version of the lab is to vary the ground conditions (soil, sand, artificial grass, or mulch) rather than using carpet.
- When weather permits, the seed collection part of the lab may be done outside on grass-covered or dirt-covered patches of ground.
- When doing this lab indoors, one could also use a tray of sand/fine gravel for collection of seeds during the drought conditions to further simulate the sandy, dry conditions associated with the drought.
- We have also done this lab with a third environmental condition added, "Abundance of Rain" (as shown in the non-major's version), in which small seeds are more numerous than large seeds (e.g. 50 corn kernels, 50 sunflower seeds, 125 thistle, and 125 millet seeds).
- A more-advanced version of this lab could include having students design the Excel spreadsheet used to calculate means, using Excel to perform chi-square analysis, and/or having students make graphs in Excel from scratch instead of drawing them by hand.
- This lab could also be adapted to have students write a formal lab report.

Literature Cited

Darwin, Charles. 1839. Voyages of the Adventure and Beagle, Volume III Journal and remarks. 1832–1836. London, Henry Colburn.

Grant, P. R. and B. R. Grant. 2006. Evolution of character displacement in Darwin's finches. *Science,* 313: 224-226.

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