BEAKS AS TOOLS: SELECTIVE ADVANTAGE IN CHANGING ENVIRONMENTS

INTRODUCTION

Peter and Rosemary Grant's pioneering work on the Galápagos Island finches has given us a unique insight into how species evolve over generations. The film *The Origin of Species: The Beak of the Finch* illustrates that some traits may enable an animal to find food or attract mates better than other individuals can. If beneficial traits like these have a genetic basis and can be passed on to future generations, we refer to them as *adaptations*, which are selected for by the environment through a process called *natural selection*. Beneficial traits increase an individual's fitness by allowing it to survive and ultimately produce more offspring than individuals without the traits. This can lead to evolution if, over time, these traits (and their associated genetic variants, or alleles) become more common in the population while unfavorable traits slowly disappear.

One crucial insight into how adaptation occurs came from the medium ground finch (*Geospiza fortis*). With its short, blunt beak, the medium ground finch is perfectly adapted to picking up seeds from the ground, although beak size varies slightly within medium ground finch populations. When food was plentiful and included different seed sizes, all ground finches were able to find food. However, when drought struck the small island of Daphne Major in 1977, the vegetation and the available seeds changed considerably, so that the finches now had to compete for food. When the smaller seeds disappeared, the finches had to turn to the much larger, spiny seeds that were hard to crack open. The smaller medium ground finches with slightly smaller beaks ran out of food. But finches that had slightly larger beaks could still forage on the much bigger, spiny seeds, which gave them a survival advantage.

Five years later, unusually long-lasting rainfalls allowed vines to overrun the island and again changed the vegetation drastically. The dominant slow-growing plants that produced large, tough seeds were replaced by fast-growing plants with smaller, softer seeds such as grasses and vines. When drought struck again two years later and birds had to compete for food, *larger* seeds were scarce. The birds with larger beaks now had difficulty picking up the more abundant small seeds produced by the vines and grasses. Therefore, selection swung in the opposite direction; more finches with smaller beaks survived, and their offspring inherited smaller beaks. Although the beak size difference itself was small, it made the difference between life and death during both droughts.

Darwin's finches.
Galápagos finches are adapted to living in habitats with strikingly different food sources, such as the cactus finch on the left and the medium ground finch on the right. Changes in beak shapes over time have enabled each finch species to find and manipulate the food that is most common in their habitat. (Photos courtesy of John Van de Graaff.)

This activity will demonstrate why a slight difference in beak size can significantly impact a bird's ability to survive. You will act as the finches and fight for survival by "eating" as many seeds as possible within the allotted time. You will use two different types of tools to represent different beak types to see which is best adapted to collect and "eat" food under different conditions. The activity exaggerates the differences in beak size to illustrate that a beak is like any other tool: You need the right tool for the right job.

MATERIALS

Each group will use the following:

- 1 box
- Two types of tools: regular tweezers and pliers (your "beaks")
- Substrate (astroturf)
- Two types of seeds (rice, beans)
- 4 paper cups for seed collection (2 for each tool)
- Timer
- Tablespoons and measuring cups (shared with other groups)

PROCEDURE AND DATA COLLECTION

Form groups of three to five students. At any one time, two group members will act as finches, each equipped with a different tool, while the others will be observers.

Finches will try to collect as many seeds as possible with their tool under three different food conditions. There will be small and large seeds, but to feed on a large seed with a tough shell, large seeds have to be cracked open to get to the nutritious insides. **So whenever a large seed is collected, crush it or it won't count!**

Observers add the food to the environment, oversee and time the foraging trials, and count the "eaten" seeds. Observers also have to make sure that large seeds, if present, are crushed and counted correctly.

Foraging Practice and Preparation of Box Environment

1. Take a few seeds of each type and try to pick them up with each tool. Try to also *crush* the large seeds.
2. Set up your box environment by putting the astroturf on the bottom of your box.
3. Make careful **observations** of your tools (or "beaks"), the box environment, and the seeds. Write down your observations:

   *Beaks:*_____

   _____

   Environment (Hint: Consider the substrate and how it will affect access to seeds): _____

   _____

   _____

   *Seeds:*_____

   _____

4. Based on your observations, make a **prediction** about each beak's ability to pick up enough food in your environment under the three different food conditions listed below.

   Plenty of both small and large seeds:

   _____

   _____

Only a few small seeds (HINT: Small seeds can fall into small, less accessible spaces within the astroturf):

Only a few large seeds (remember that they have to be crushed):

Foraging Experiment

5. To test your predictions, you will now run a **foraging experiment** under food conditions that simulate the conditions *before* and *during* the two major droughts that were described in the movie. The conditions are:
    A. ***Land of Plenty:*** lots of large and small seeds are available (simulates food availability *before* the droughts)
    B. ***Drought 1:*** only large seeds are available and birds have to compete for food (simulates food availability during the first drought in 1977)
    C. ***Drought 2:*** only small seeds are available and birds have to compete for food (simulates food availability during the second drought years later)

    To run the experiment, follow the steps below.

Condition A: Land of Plenty

6. Appoint two members of your group to be finches and the remaining member(s) to be the observer(s). Each finch chooses one of the two tools to be used as a beak and takes two of the four cups.
7. The observer(s) sprinkle(s) 2/3 cup of large seeds (beans) and 3 tbsp. of small seeds (rice) into the box.
8. Run your **first trial** of **30 seconds**. Read through steps a) and b) before you start:
    a) The observer(s) start the trial.
    b) Finches pick up as many seeds as possible and place them in their cups. Small and large seeds go in separate cups. Large seeds have to be crushed! Observers count each large seed as they are crushed. Small seeds can be counted at the end of the trial.
    c) After 30 seconds, observers end the trial and count the small seeds collected by each finch.
    d) For each beak type, enter the total number of collected seeds (no matter what size) in the table under "Land of Plenty" and "Trial 1."
    e) Empty the cups. Do not replenish the seed supply in your environment.
    f) Repeat **steps a)-e) three more times** to run a total of **four trials** and enter your numbers under Trials 2, 3, and 4. Let someone else be the observer each time. When it's your second time to be a finch, use a different tool.
    g) After the fourth trial, add up the total seed counts for each beak in your table.
    h) **Remove all seeds** from your environment and move on to the next condition.

Condition B: Drought 1

9. The observers sprinkle 1/3 cup of large seeds (beans) into the box.
10. Run your **first trial** of **30 seconds**. Read through steps a) and b) before you start:
    a) The observer(s) start the trial.
    b) Finches pick up and crush as many large seeds as possible. Place the crushed remains in a cup. Observers have to keep count as each large seed is crushed.
    c) After 30 seconds, observers end the trial.
    d) For each beak type, enter the total number of collected seeds in the table under "Drought 1" and "Trial 1."
    e) Proceed as in Condition A, steps e)-h).

Condition C: Drought 2

11. The observer(s) sprinkle(s) 1.5 tbsp. of small seeds into the box.
12. Run your **first trial** of **30 seconds**. Read through steps a) and b) before you start:
    a) The observer(s) start the trial.
    b) Finches pick up as many small seeds as possible and place them in their own cup.
    c) After 30 seconds, observers end the trial and count the small seeds in each cup.
    d) For each beak type, enter the total number of collected seeds in the table under "Drought 2" and "Trial 1."
    e) Proceed as in Condition A, steps e)-g).

GROUP RESULTS	FOOD CONDITION					
	LAND OF PLENTY		DROUGHT 1		DROUGHT 2	
	"BEAK" TYPE		"BEAK" TYPE		"BEAK" TYPE	
TRIAL	S	L	S	L	S	L
1						
2						
3						
4						
TOTAL						

S = small beak (tweezers); **L** = large beak (pliers)

Use the table below and (if applicable) the provided Excel spreadsheet to enter the class results.

CLASS RESULTS	FOOD CONDITION					
	LAND OF PLENTY		DROUGHT 1		DROUGHT 2	
GROUP TOTALS	"BEAK" TYPE		"BEAK" TYPE		"BEAK" TYPE	
	S	L	S	L	S	L
Group 1						
Group 2						
Group 3						
Group 4						
Group 5						
Group 6						
Group 7						
Group 8						
Group 9						
Group 10						
TOTAL						
MEAN						

After the Experiment

13. The teacher will either collect each group's results in the Excel spreadsheet provided or write them on the board. In either case, copy all group results into your "Class" table above.
14. Enter the class mean (average) in the table under each condition and beak type. You will have to calculate the mean yourself if you are not using the spreadsheet.
15. Calculate whether the finches were able to survive the two simulated drought conditions: The **total number of seeds** each finch collected during Condition A (Land of Plenty) are the free-feeding amounts that it would eat to be fully satiated. For a bird to survive, it needs to obtain at least on average 80% of its free-feeding amount. Follow these steps:

    a) Food limit for small-beaked finches: Use the class mean for beak type "S" under Condition A (Land of Plenty) and calculate the 80% limit.

b) Food limit for large-beaked finches: Use the class mean for beak type "L" under Condition A (Land of Plenty) and calculate the 80% limit.
c) Compare each finch's food limit with the average (mean) amounts it obtained in Conditions B and C (Droughts 1 and 2). If the average is greater than or equal to the limit, the finch survived; if it's less than the limit, the finch died. Mark those that died with a cross.

16. Answer the questions below.

QUESTIONS

1. Carefully review the class results.
   a) Compare the means in your class table. Which beak collected the largest average number of all seeds? Identify one for each food condition.

      Land of Plenty: _____

      Drought 1: _____

      Drought 2: _____

   b) Which beak collected the smallest average number of seeds? Identify one for each food condition.

      Land of Plenty: _____

      Drought 1: _____

      Drought 2: _____

   c) Which beak collected most of the large seeds in Drought 1 and most of the small seeds in Drought 2?

      Large seeds: _____

      Small seeds: _____

   d) Did either of the two beak types consistently collect more seeds than the other under all conditions? If so, which one?

      _____

      _____

   e) Did any of the finches collect less food than its 80% limit during Drought 1 or 2 and starve to death as a consequence? List the ones that died during each drought.

      Drought 1: _____

      Drought 2: _____

2. Was there any difference in the two beaks' ability to pick up **small** seeds? If so, what features made one beak more successful than the other?

   _____

   _____

3. Was there any difference in the ability of the two beaks to pick up *and* crush **large** seeds? If so, what features made one beak more successful than the other?

4. Did your results support your predictions? Explain your answer.

5. Consider the physical characteristics of the substrate (the astroturf) in your model environment and the effort it took to collect large and small seeds under any of the food conditions.

   a) What characteristics made seeds less accessible, and which seeds were most affected?

   b) Would you say that the astroturf made it hard for some finches to find enough food to survive? If so, which finch had the greatest trouble? You may go back to Question 1e) and 2 to help with your answer.

6. Based on your results, what (if anything) can you conclude about each bird's ability to collect food and survive in your model environment under the three different conditions? Propose an answer for each condition separately and incorporate the effect of your substrate on food availability.

7. If you saw a difference between a bird's ability to obtain food based on beak shape, explain how this leads to evolution over time. (Remember that the different beak types you tested in your experiment represent birds of the same medium ground finch species. They merely show variations in beak size.)

_____

_____

_____

8. This activity simulates a variety of concepts that play an important role in the process of evolution. Name a specific example from this activity simulating each concept below:

   - Variation:

     _____

   - Adaptation (i.e., a beneficial trait that is heritable):

     _____

     _____

   - Selective pressure or selecting agent (i.e., what selected for one beak type versus the other?):

     _____

     _____

   - Fitness (i.e., increased likelihood to survive and reproduce):

     _____

     _____

AUTHOR

Written by Jason Crean, MA, MS, Lyons Township High School, La Grange, Illinois
Edited by Sandra Blumenrath, PhD and Laura Bonetta, PhD, HHMI, and Ann Brokaw, Rocky River High School, Ohio; copyedited by Linda Felaco
Scientific review by Jonathan Losos, PhD