EVOLUTION IN ACTION: GRAPHING AND STATISTICS

INTRODUCTION

Relatively few researchers have been able to witness evolutionary change in their lifetimes; among them are Peter and Rosemary Grant. The short film *The Beak of the Finch* focuses on the Grants' 40-year study of the finches of the Galápagos Islands. In 1973, the Grants began observing and studying finches on several islands in the Galápagos archipelago. They wanted to understand how species change over time and, in particular, how changes in the environment can influence a species' physical characteristics.

As part of their work, the Grants intensively studied the population of medium ground finches (*Geospiza fortis*) on the island of Daphne Major. Every year, the Grants measured the wing length, body mass, and beak size of hundreds of individual medium ground finches. They focused on these characteristics because they vary widely among individual birds within the same species –for example, some birds in a population will be larger than other birds or have bigger beaks, even though they all belong to the same species. It is normal for heritable traits to vary among individuals in a population because no two individuals, except for twins, are genetically identical. In some cases, individuals with one form of a trait, such as a larger beak, will have a survival advantage over individuals with a different form of the trait, such as a smaller beak. Those advantageous traits may make it more likely for some individuals to survive and produce more offspring, and therefore are more likely to be passed on to the next generation. This process is what Charles Darwin called natural selection.

The medium ground finch (*Geospiza fortis*). The medium ground finch is one of the finch species that lives on the island of Daphne Major. (Photo courtesy of John van de Graaff.)

In the film *The Beak of the Finch* the Grants described the findings from their research: When the weather changed drastically on the island of Daphne Major, individuals with a particular beak size were more likely to survive. In this activity, you will analyze some of the actual measurements that Peter and Rosemary Grant collected. You will interpret their data and suggest hypotheses to explain their observations. In addition, you will use their data to construct graphs and learn why it was important for the Grants to collect data on so many birds. Finally, you will propose how and why some characteristics are more likely than others to change from one generation to the next under specific environmental conditions.

The Origin of Species
The Beak of the Finch

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STUDENT HANDOUT
BASIC ACTIVITY

MATERIALS

- Scientific calculator or a computer with a spreadsheet program like Excel or Google spreadsheet
- Colored pencils for graphing if not using a computer
- Ruler for graphing if not using a computer
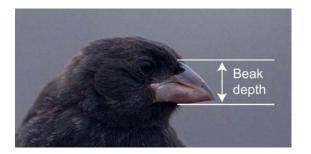
PROCEDURE

Part A: Introducing the Data Set

Every year for 40 years, Peter and Rosemary Grant carefully measured the physical characteristics of hundreds of individual medium ground finches living on the island of Daphne Major. In an accompanying Excel spreadsheet, the Grants have provided the measurements they took in a sample of 100 birds born between 1973 and 1976.

For this part of the activity, you should familiarize yourself with the dataset, as instructed by your teacher.

Note that the sample provided by the Grants includes 50 ground finches that lived until 1977. That year, an 18-month-long drought began that resulted in the death of more than 80% of the medium ground finches on the island. The other 50 finches in the dataset survived the drought and lived to 1978 and beyond.

Part B: Analyzing Graphical Data

Although you may have been able to see some differences between the two groups of birds by looking at the data in the spreadsheet, one way to more clearly visualize such differences is to graph the data. Figure 1 shows two graphs of beak depth measurement for the 50 medium ground finches that died in 1977 and did not survive the drought (nonsurvivors) and the 50 medium ground finches that lived beyond 1977 and survived the drought (survivors).
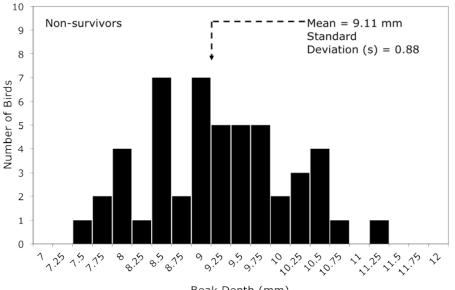

What is beak depth? The Grants took many measurements of the finches' beaks: length, width, and depth. The image on the left shows how beak depth is measured.

Each graph includes average (mean) beak depth and standard deviation (s) for that group of birds.

Standard deviation quantifies the amount of variation in a set of measurements. Simply put, it is a measure of how spread out the numbers are. **The larger the standard deviation, the more the data points are spread out for a measured characteristic, such as beak depth, in a population**. In the two graphs in Figure 1, the standard deviations are 0.88 and 0.84, meaning that most birds in the first sample have beak depths that are plus or minus 0.88 mm of the mean of 9.11 mm and most birds in the second sample have beak depths that are plus or minus 0.84 mm of the mean of 9.67 mm.

Study the information provided in the graphs and then answer questions 1–4. To answer some of the questions, you will need to recall from the film what major change occurred on the island as the drought progressed.

Beak Depths of 50 Medium Ground Finches That Did Not Survive the Drought

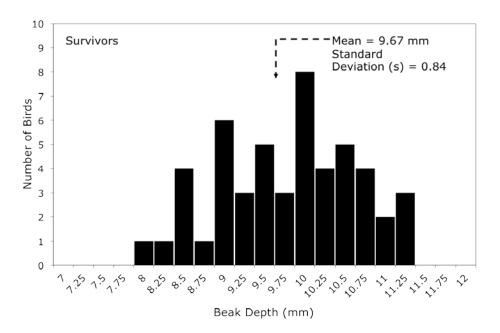**Beak Depths of 50 Medium Ground Finches That Survived the Drought**

Figure 1. The two graphs above show the beak depths, measured in mm, of 100 medium ground finches from Daphne Major. Fifty birds did not survive the drought of 1977 (top graph). The other 50 birds survived the drought and were still alive in 1978 (bottom graph).

1. a. What observations can you make about the overall shape of each graph? (Imagine that you are drawing a line that connects the tops of the horizontal bars.)

    b. What do the shapes of the two graphs indicate about the distribution of beak depth measurements in these two groups of medium ground finches?

2. Compare the distribution of beak depths between survivors and nonsurvivors. In your answer, include the shape of the distributions, the range of the data, and the most common measurements.

3. Based on what you saw in the film, think about how changes in the environment may have affected which birds survived the drought. Propose a hypothesis to explain differences in the distribution of beak depths between survivors and nonsurvivors.

4. Let's look in more detail at the mean beak depths in the two groups of birds to understand the meaning of standard deviation.
    a. How do the mean beak depths and standard deviations of the mean beak depths compare?

    b. If the standard deviation of the two samples were to be vastly different, what would you conclude about the two groups?

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Part C: Examining the Importance of Sample Size

The Grants measured beak depths of hundreds of birds every year, and this extraordinary effort was critical to their discoveries. But why was it important for the Grants to collect data on so many birds? **What if the Grants had collected data from far fewer birds?** Instead of hundreds of birds, assume that they only collected data from either 5 or 15 birds each year. Table 1 below shows data from samples of 5 and 15 birds randomly selected from the Grants' complete set of measurements from nonsurvivors and survivors. **Answer questions 5–9**.

Table 1. Beak Depths in Two Samples of Finches That Did Not Survive the Drought and Two Samples That Did Survive

Nonsurvivors				Survivors			
5-bird sample		15-bird sample		5-bird sample		15-bird sample	
Bird ID #	Beak Depth (mm)	Bird ID #	Beak Depth (mm)	Bird ID #	Beak Depth (mm)	Bird ID #	Beak Depth (mm)
12	7.52	283	11.20	943	9.10	316	9.85
347	9.31	288	9.10	1643	8.80	623	8.80
413	8.20	294	10.50	1884	9.15	673	10.10
522	8.39	315	8.80	2244	11.01	678	9.70
609	10.50	321	8.48	8191	10.86	891	8.00
		352	7.70			1019	11.21
		413	8.20			1477	10.10
		468	9.02			1528	8.55
		503	9.10			1797	9.31
		507	8.85			1850	10.40
		561	10.20			1884	9.15
		610	9.00			2242	9.45
		619	9.25			2378	9.86
		621	7.60			2249	10.68
		676	9.70			2939	8.31
Mean		Mean		Mean		Mean	
s		s		s		s	

5. For each sample, calculate the mean beak depth and standard deviation (s) for those samples and add those numbers to Table 1.

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To calculate standard deviation, use the following formula and steps:

$$s = \sqrt{\frac{\sum (x_i - \overline{x})^2}{(n-1)}}$$

- Calculate the mean ($\overline{x}$) of the data set.
- For each measurement (x_i) in the set of data, determine the difference between that measurement and the mean ($\overline{x}$) of the entire set. ($x_i - \overline{x}$).
- Square each result ($x_i - \overline{x}$)^2.
- Add up (sum, Σ) all of the squared differences. $\Sigma(x_i - \overline{x})^2$.
- Divide by sample size minus 1 ($n - 1$)
- Take the square root and **round your answer to the second decimal place**.

6. Record the means and standard deviations for each sample of survivors and nonsurvivors from Figure 1 in Part B (50 birds) and Table 1 in Part C (5 and 15 birds) in Table 2 below.

Table 2. Mean Beak Depths for 50-, 15-, and 5-Finch Samples of Birds That Survived and Did Not Survive the Drought

	Mean			Standard deviation		
	50-finch sample	15-finch sample	5-finch sample	50-finch sample	15-finch sample	5-finch sample
Survivors						
Nonsurvivors						

7. Compare the means and standard deviations for each sample size (5 birds, 15 birds, and 50 birds) within each group of survivors and nonsurvivors.

   a. Are the means in smaller samples different from the means in larger samples? Explain why you think that is.

   b. Are the standard deviations in smaller samples different from standard deviations in larger samples? Explain why you think that is.

8. Which results (i.e., from 5, 15, or 50 birds) do you think are closer to the means and standard deviations of the entire population of medium ground finches on the whole island? Explain your answer.

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9. What is one advantage and one disadvantage of calculating the mean from a *sample* of a population rather than the *entire* population?
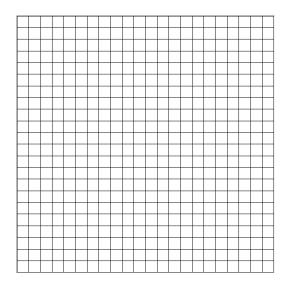
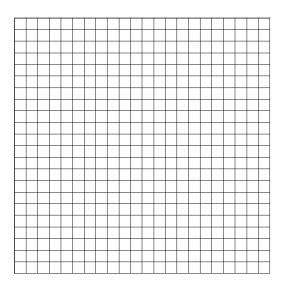**Part D: Adaptive Traits and Constructing Graphs**

In addition to beak depth, Peter and Rosemary Grant collected dozens of other measurements, for example wing length and body mass. Table 2 below summarizes the mean and standard deviation of body mass and wing length for 50 birds that did not survive the drought and 50 birds that survived the drought.

Table 3. Body Mass and Wing Length Measurements of Nonsurvivors and Survivors

	Body Mass		Wing Length	
	Nonsurvivors	**Survivors**	**Nonsurvivors**	**Survivors**
Mean	15.70 g	17.00 g	67.8 mm	69.3 mm
s	1.36	1.77	2.28	2.33

10. To compare a single value for two different populations, a bar graph is often a good choice. In the space below, construct two bar graphs showing the mean values for wing length for the two groups of birds on one graph and mean values for body mass for the two groups of birds on the other. Title your two graphs and label your axes.

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11. Based on the graphs you have drawn how does wing length compare between survivors and nonsurvivors? What about body mass?

12. What do the results illustrated by your graphs indicate about the effects of the drought on birds with particular wing lengths and body masses?

13. The Grants say in the film that a key trait that made the difference in survival for the birds during the drought was beak depth. Is that conclusion consistent with the data presented in this activity (including Part B)?

14. Explain why the Grants concluded that beak depth may have played a more important role in survival during the drought than wing length or body mass. Correctly use the terms **natural selection**, **adaptation**, and **fitness** in your answer.

15. Explain the role of variation in important traits (like beak depth) in a population for the survival of a species.