

## **SCED 203 Sample Activity**

**SCED 203: Matter and Energy in Life Systems**

### **CHAPTER 7**

## **WHAT IS EVOLUTION?**

### **INTRODUCTION**

You have spent these past chapters determining common characteristics that all living things share, understanding how living things within an ecosystem interact with one another and with their environment, and (in Chapter 7) how living things pass down traits from generation to generation. We have looked at a diversity of living things, including trees, beans, flatworms, crickets, mold, onions, bacteria, and humans. Despite the vast differences between these organisms, they all share some common characteristics and interact with their environments in similar ways. Review those with your group and note the similarities below:

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Imagine that you were an ancient explorer and you visited a half-dozen cultures all across the world. You find that the Inuit, Aztec, Babylonians, Chinese, Māori and Norse all have the same musical instruments, the same songs, and the same musical notation. This would be a shock – how could these ancient cultures, a world apart, all have so much in common? Such similarity across a diversity of cultures– if it existed (which it doesn’t!)– would require an explanation.

Similarly, you might have been surprised to find in Chapter 6, when exploring inside a cell, that the yeast cell, the human cheek cell and the plant cell have nearly identical structures inside. This chapter will try to make sense of why the living things that seem so different have so much in common, and how, over time, interactions between organisms and their environment can lead to such diversity despite our commonalities.

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## FORMATIVE ASSESSMENT

***On your own:*** How do you think biologists explain this? That is, how do they account for the observation that all living things share so many characteristics?

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On the other hand, while there is great similarity between organisms, we nonetheless see a great deal of diversity (variation) – even between members of the same species. For example, there are many different breeds of dogs and two dogs of the same breed (or even two dogs from the same litter) can be quite different from one another; yet all dogs, from Chihuahuas to Great Danes are members of the same species. How do you think biologists account for this diversity?

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Group  
Discussion

Share your thoughts with your group members. See where you agree and disagree. Take some time to really listen and understand where your other group members are coming from and the reasons behind their positions. Below and on your *whiteboard* list some of the questions you still have about evolution.

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Class  
Discussion

Your instructor will now lead a whole-class discussion about the ideas from each group. Be prepared to explain your group's ideas and to write down comments from other groups that you find interesting or useful.

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## ACTIVITY 1

### ***How do populations of organisms change over time?***

#### PURPOSE

Imagine that you have a group of animals that live on an island. These animals are eating, breathing, and reproducing year after year. Will this group of animals change over time? If so, how will they change and why?

## EXPERIMENT 1

### ***How will a population of birds change over time?***

#### BACKGROUND

Pretend that you are a member of a population of birds. The birds live on an island several miles off the coast of a large continent. Long ago, there were no birds on this island. However, one winter, a big storm blew several birds from the mainland over to the island. These birds took up residence here and flourished since there were so few predators.

The birds on this island feed on rice (the seeds of a plant that lives in the wetlands on the edges of the island). The seeds of the rice plant fall into the water and the birds use their long bills to scoop the rice out of the water. The

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birds nest in cliffs a short flight away from the wetlands. Parents who are raising offspring must carry the rice from the wetlands to the cliffs where they can offer the food to their children.

Even without predators, life can be hard for the birds on this island. Unfortunately, not all offspring survive each year. Many offspring are not fed enough to survive the winter and grow up to be adults. In addition, parent birds often sacrifice their own wellbeing for the sake of their children. Most adults give all their food to their offspring with the result that the adults do not store enough food for themselves to survive the winter. Only the parent birds that collect the very most food will be able to support their offspring *and* store enough food for themselves to survive to the following spring.

All the birds on the island have long spoon-shaped bills. However, there is difference in the presence and absence of grooves in the bill and in the number and size of the grooves. These differences are the result of slight differences in the genes that are responsible for beak growth. This is similar to the way that all people have hair and a gene for hair growth yet slight differences in DNA sequence of that gene causes different individuals to have different textures and colors of hair. Offspring inherit the same beak as their parent.

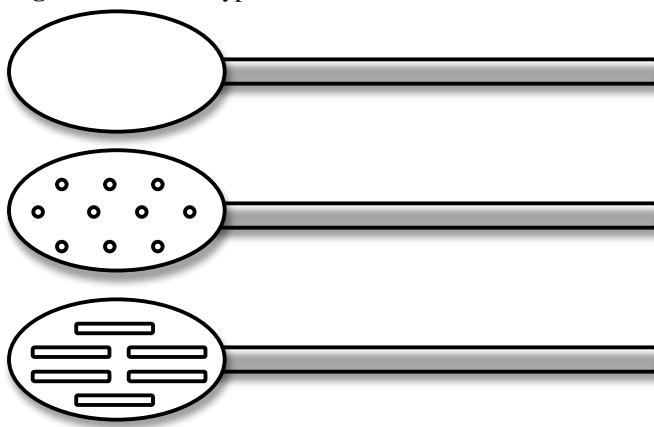
## COLLECTING & INTERPRETING EVIDENCE

### YOU WILL NEED

- large area
- rice (for food)
- one scale (for the class for weighing food)
- two large tubs (for feeding)
- one spoon (“beak”) per pair of students
- one cup (“stomach”) per pair of students

Here are sketches of the 3 beaks that are present in this population:

**Figure 7-1 – Beak types**



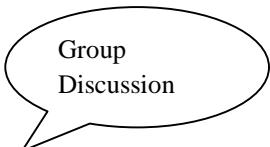
Predict which type of beak will be the most successful at surviving and raising offspring in this environment. Predict which type of beak will be the least successful. Explain the reasoning behind your choices.

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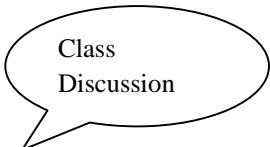
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**With your group, discuss your predictions. Write down below and on the whiteboard the group's ideas regarding which type of bird will perform best and worst in this environment and the reasons behind your predictions.**



**Your instructor will now lead a short whole-class discussion about the ideas from each group. Be prepared to explain your group's ideas and to write down comments from other groups that you find interesting or useful.**

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## **EXERCISE A**

### **STEP 1**

Divide yourselves in pairs. Within your pair, decide which person will be the parent bird and which will be that parent's offspring.

### **STEP 2**

Each parent bird will need a 'beak' (spoon) and the offspring will need a 'stomach' (cup).

### **STEP 3**

Each parent will try to get food to his/her offspring using its 'beak'. When the teacher gives the signal, the parent will start at its nest in the cliff-side, gather rice from the wetland, and bring food back to its baby as fast as possible until STOP is called. You will have about 1 minute to gather food during each 'year' (round of play).

#### **Rules of the hunt:**

- a. Food must be gathered with a 'beak' (spoon) and placed into an offspring's 'stomach' (cup). No using hands to gather or transport food at any time! The 'beak' must be grasped at the back end of the handle.
- b. Offspring must remain in their nests at the 'cliff'.
- c. The tub(s) of rice must remain at the 'wetlands'. Do not move or tilt the tubs.
- d. Do not hurt, push, elbow or injure other birds. You may however cooperate with other birds (share food, help each other gather food, etc.)

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#### STEP 4

After the **STOP signal is given**: Discard all the water from the offspring's stomach and weigh the rice. Offspring should then line up according to the weight of the food in their stomach.

- For most of the families, the parents will die that winter while the offspring will grow up to adulthood and reproduce the following spring. The parents will be 'reincarnated' as the offspring of their former chicks. (In effect, the parent in round 1 becomes the offspring in round 2 and vice versa.)
- The **three** offspring with the **most** food in their stomachs will grow up and reproduce the following spring. In addition, the parents of these offspring will have enough food to survive the winter and can have another offspring the following year.
- The **three** offspring with the **least** food in their stomachs will not survive and neither will their parents. These birds 'die' and get 'reincarnated' as the offspring of the birds that gathered the most food. New offspring inherit the same beak type as their parent.

(Please return the rice to the tub before beginning the next round of play.)

#### STEP 5

You will follow this procedure until five generations (rounds of play) have passed.

#### STEP 6

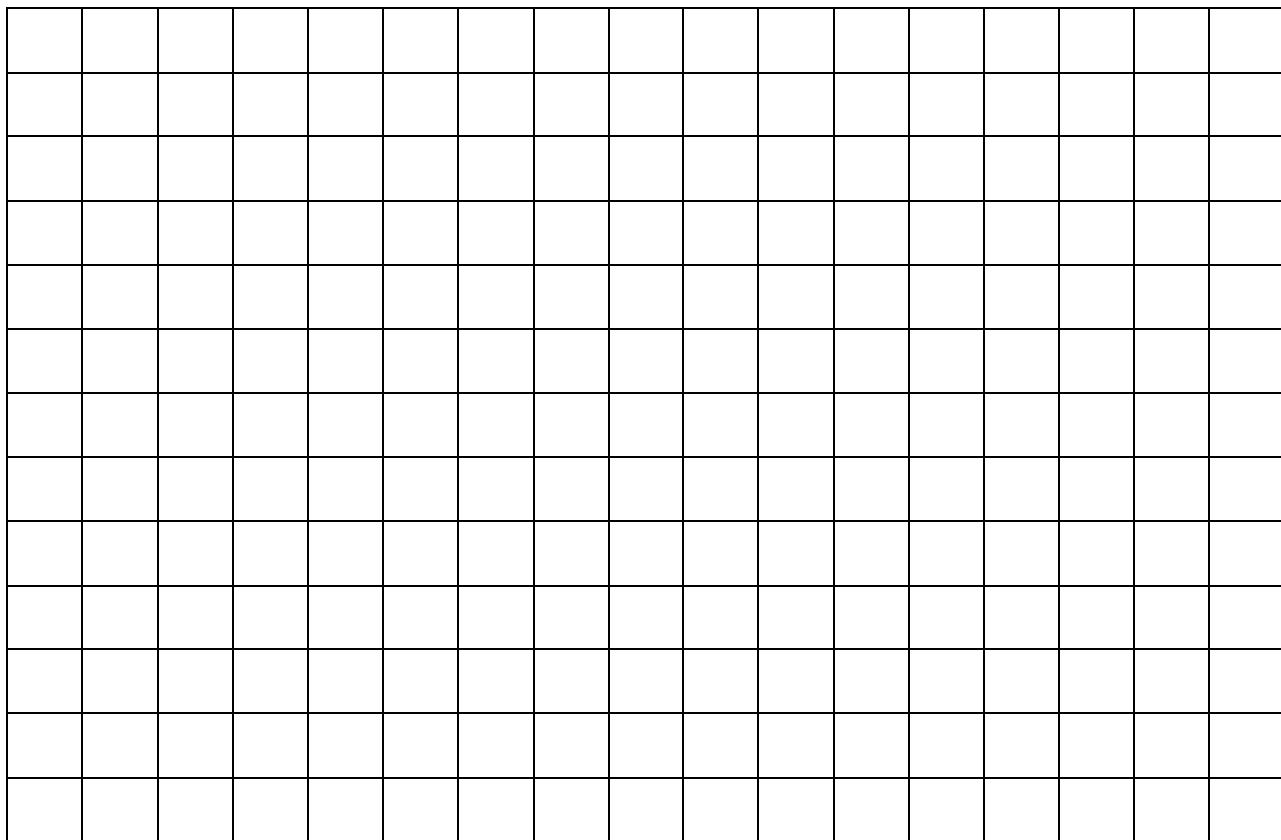
Fill in Table 7-1. In the "# + or -" column, indicate the number of birds of that variation gained or lost in that year. For instance, if the solid spoons gained a bird from the previous year, put a 1+ in that column, put a 2- if the solid spoons lost 2 birds, and put a 0 if they stayed the same. In the "# Adults of that type" column, indicate the number of adults of that type that start the next round – that is, after STEP 4, how many adults of each type are there.

**Table 7-1**

GROUP (beak shape)	GEN 0	GENERATION 1		GENERATION 2		GENERATION 3		GENERATION 4		GENERATION 5	
	# Adults of that type	# + or -	# Adults of that type								
Solid spoon											
Small holes											
Large grooves											

**STEP 7**

Graph the results in Table 7-1. In your graph, you should show how the different types of bird beaks changed over time. Plot all three beak types on the same graph (but use different colors or patterns to distinguish them from one another.) Be sure to label both the x and the y-axis.



Which beak variation was best suited to the wetlands environment in Exercise A? Which beak variation was most poorly suited to the wetlands environment. Explain why one trait did better than others.

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**Exercise B**

Oh no! Sudden changes in the climate have altered the environment so that the coastline has receded, drying up the wetlands. Fortunately, the rice still grows, however the rice no longer falls into the water. Instead, it falls onto the dry ground and must be gathered dry.

Predict which beak type will be most successful in this new environment. Predict which beak types will be the least successful. Explain your reasoning.

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#### STEPS 1-5

Follow the same rules of Exercise A until five years (rounds of play) have passed.

#### STEP 6

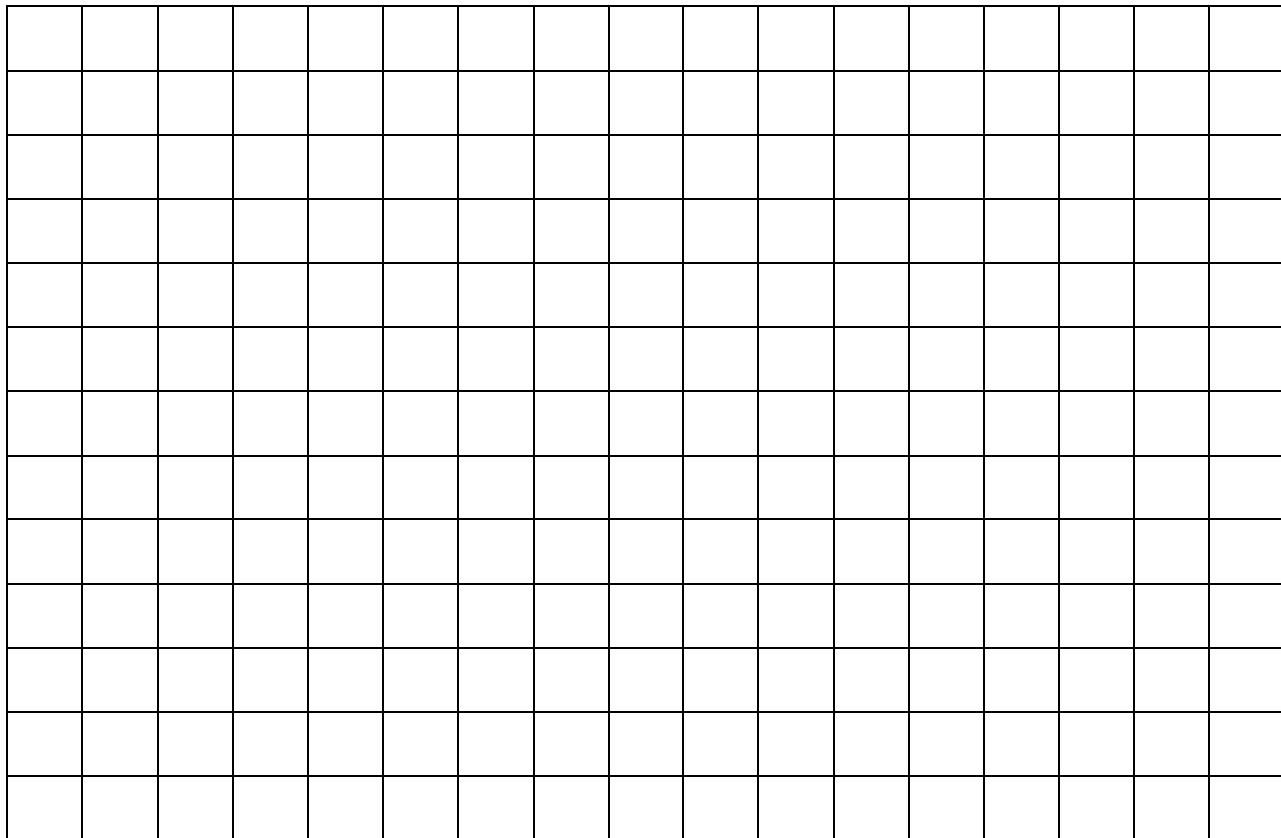
Fill in Table 7-2. For each year of play, indicate the number of adults of that type that were alive that spring. In addition, put a + in the appropriate row for each of the birds that gathered the *most* food (and the parents survived to reproduce a second year) and put a – for each of the birds that gathered the *least* food (and the offspring and their parent starved to death that winter).

Table 7-2

GROUP (beak shape)	GEN 0	GENERATION 1		GENERATION 2		GENERATION 3		GENERATION 4		GENERATION 5	
	# Adults of that type	# + or -	# Adults of that type								
Solid spoon											
Small holed											
Large grooves											

**STEP 7**

Graph the results in Table 7-2. In your graph, you should show how the different types of bird beaks changed over time. Plot all three beak types on the same graph (but use different colors or patterns to distinguish them from one another.) Be sure to label both the x and the y-axis.



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Which beak variation was best suited to the dry environment in Exercise B? Which beak variation was most poorly suited to the dry environment. Explain why one trait did better than others. Consider the differences between what happened in Exercise A (wetlands) and B (dry land).

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Imagine that the loss of the wetlands enabled some new types of plants to grow on the island, offering the birds a second food source. This new plant has very tiny, round seeds similar to a poppy seed. These tiny seeds fall onto the dry ground and can be gathered there. Birds that can take advantage of this new food source will be more successful. How will this new food source impact the population of birds over several generations? Explain your reasoning.

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Can you imagine an environment in which the birds with beaks with large grooves would out-compete the other beak variations? Describe that environment and explain why beaks with large grooves would be advantageous.

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Remember that each beak type represents a sub-set of the entire population of imaginary birds. These different beaks represent individual variations in beak types in a single species. It is important to note that even if a beak type died out during the simulation, the species as a whole survived. However, the overall genetic variation in the population was reduced. How does genetic diversity (having a lot of initial genetic variation) allow a species to better survive in a changing environment?

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In this activity, we observed changes over a total of 10 generations. Now, consider an even longer time scale. What do you think will happen to these birds over hundreds, thousands, or millions of years? What kinds of beaks and birds do you think will be on the island many, many generations from now? Explain your reasoning.

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Group  
Discussion

With your group, discuss these last two questions. Write down on the *white board* the group's ideas. Prepare to share your ideas with the class.

Class  
Discussion

Your instructor will now lead a short whole-class discussion about the ideas from each group. Be prepared to explain your group's ideas and to write down comments from other groups that you find interesting or useful.

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#### SCIENTISTS' IDEAS

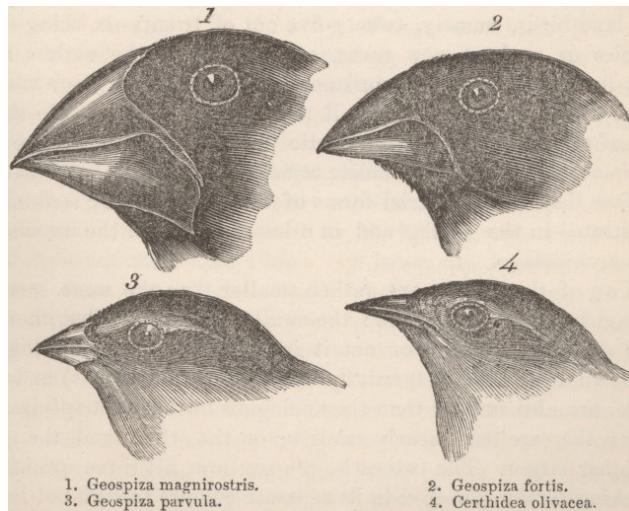
Charles Darwin (1809-1882) was a British naturalist and geologist who embarked on a five-year voyage around the world. Through the course of that journey he collected and made careful observations of the geology, plants, and animals he saw. While Darwin was in Chile, he experienced an earthquake and noticed that the coastline had been raised up by the earthquake. Mussels and clams that once grew below the high tide line where water could reach them were now left high and dry. He then observed fossilized seashells embedded in the rocks high in the Andes mountains. He came to the conclusion that perhaps a series of earthquakes over many millions of years could have raised the Andes mountains.

Soon afterwards, Darwin arrived on the Galapagos islands (a chain of volcanic islands off the coast of Ecuador). He found many interesting animals that seemed to be distant relatives of species that were seen on the mainland. Most notably, he observed and collected birds from the islands that appeared to be from very different groups: finches, blackbirds, and "gross-beaks". He noted that the beaks of these birds spanned a huge spectrum in their size from larger than the largest "gross-beak" to tiny like a warbler. However, when the specimens were carefully examined by bird experts in England, they were found to be 12 distinct species of finches, each found nowhere else in the world.

From these and other observations, Darwin came up with the idea of that perhaps these birds represented the descendants of a small group of finches blown over from the mainland. When this small starting group of birds arrived, they found a huge variety of possible food sources. Interestingly, each island in the Galapagos chain is slightly different from the others. For instance, some islands are more dry than others and the dry conditions limit the kinds of plants that grow there to ones that are more drought tolerant and had larger, tougher seeds. Other islands were wetter which allowed different kinds of plants with smaller, more tender seeds to flourish. Fortunately, there was genetic variation in the type of beak each individual bird possessed. On the dry islands with big tough seeds, birds with naturally big beaks that could crack those big, tough seeds survived better, reproduced more, and thus led to the next generation that had more big beaks.

Eventually, you could have a new species of finch with really big beaks. Conversely, on islands with more rain and small tender seeds, the little birds did better and those islands became dominated by birds with little beaks. In just the same way that a series of small earthquakes each raising the shoreline a few feet could, over a very very long time, push up the Andes mountains, small changes from one generation of birds to the next could, over a very very long time, turn a single species of finch into 12 different species.

Thus Darwin proposed two related ideas: natural selection and evolution. **Natural selection** means that the individuals with the traits that best fit their environment are the ones that are most likely to survive, reproduce, and pass on their traits to the next generation. For natural selection to occur, there has to be individual variability in a population (not everyone is the same) and this variability has to be inherited (genetic variation). In addition, there must be differential survival and reproduction (not everyone gets to survive and reproduce). Individuals with traits that are the most favorable for the conditions in which they live will leave more descendants than other individuals.



**Figure 8-2 – Darwin's finches from *The Voyage of the Beagle* (1845)**

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Over time, the population will have more and more individuals with these favorable traits. Darwin's ideas about evolution will be introduced in Activity 2.

#### SUMMARIZING QUESTIONS

Let's use our simulation to think through the process of natural selection:

1. REQUIREMENT #1: There is **variation** in a population. Different individuals have different traits. Explain and provide examples of how this was true in our simulation.

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2. Predict how the outcome of your bird experiment would have been different if there were no variations to start with. In other words, what would happen over the 10 generations if everyone started with the exact same type of beak? Explain your reasoning.

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3. REQUIREMENT #2: There is **heredity**. Traits are passed on from parent to offspring through our genes. Explain and provide examples of how this was true in our simulation.

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4. Predict how the outcome of your bird experiment would have been different if the beak types were not inherited from one generation to the next. That is, instead of a parent giving its offspring the same beak type as it had, imagine that the baby bird could choose which beak type it wanted that year or even design its own unique beak. Explain your reasoning.

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5. REQUIREMENT #3: There is **differential survival and reproduction**. Some individuals survive and reproduce more than others. Explain and provide examples of how this was true in our simulation.

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6. Predict how the outcome of your bird experiment would have been different if there were no differential survival and reproduction. That is, no offspring dies and no parent birds survive a second year. Every offspring survives to the following year and every parent bird dies over the winter.

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When all these 3 requirements are met, the end result is **natural selection** – the individuals with the traits that best fit their environment are the ones that are most likely to survive, reproduce, and pass on their traits to the next generation.

7. Explain and provide examples of how natural selection was taking place in our simulation.

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8. Clearly, the simulation we engaged in as a class resembles the real world data that Charles Darwin first observed in many ways – yet, the simulation is clearly cannot fully capture what actually happens in the real world. Describe at least 2 ways that the simulation fails to capture the complexity of natural selection in real world situations and what might happen if we could have taken those ideas into account in this Activity.

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Group  
Discussion

Class  
Discussion

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**With your group, discuss summarizing questions. Write down on the *white board* your group's ideas. Prepare to share your ideas with the class.**

**Your instructor will now lead a short whole-class discussion about the ideas from each group. Be prepared to explain your group's ideas and to write down comments from other groups that you find interesting or useful.**

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**ACTIVITY 1: HOMEWORK**

Name \_\_\_\_\_ Date \_\_\_\_\_

Consider each of the following statements. Though all are similar, they differ in significant ways:

1. The theory of evolution provides an explanation for the diversity of life on this planet.
2. The theory of evolution attempts to provide an explanation for the diversity of life on this planet.
3. I think that the theory of evolution accurately explains the diversity of life on this planet.
4. Biologists think that the theory of evolution accurately explains the diversity of life on this planet.

Do you agree with some of the statements? All of them? None of them?

Explain what someone might think if they agree with statement 2, but do not agree with statement 1.

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Explain what someone might think if they agree with statement 1, but do not agree with statement 3.

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Explain what someone might think if they agree with statement 4, but do not agree with statement 1.

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Explain what someone might think if they agree with statement 2, but do not agree with statement 4.

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Throughout this curriculum, we have begun each activity with “initial ideas” – asking you to consider your ideas about a topic and then, through experiments and engaging with scientists’ ideas, exploring how those ideas change in light of these activities. In general, many of the initial ideas students have are not consistent with biologists’ ideas, and coming to understand and believe scientists’ ideas is a matter of collecting and interpreting data, and examining how that data speaks to initial ideas.

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Evolution, however, is a unique topic. Differences between students' initial ideas and biologists' ideas often speak to a more fundamental difference that is not reconciled by examining data and engaging with scientists' ideas. Asking students to commit to an evolutionary perspective, researchers note, often "devalues the system of meaning [students] see for their lives." (Long...) Furthermore, for many students, taking on an evolutionary perspective asks them to put "the orthodox knowledge system of science in front of their commitment to inerrant faith. By this, science educators are [asking students] to change their relationship to the epistemological authority of their religious commitments."

The goal of this chapter is to deepen your understanding of core ideas in evolutionary biology. The curriculum does not ask that you agree with those ideas. That is, one goal of this chapter is for you to agree with statement 4 above:

*Biologists think that the theory of evolution explains the diversity of life on this planet.*

This is a statement of unequivocal consensus of the field of biology, and we will explore the evidence and reasoning that lead biologists to endorse this idea. By the end of the chapter, you should be able to recognize that this statement is one that is endorsed by biologists and better understand why it is that biologists agree with this.

You may find that, by engaging in this curriculum and examining how your ideas about life intersect with biologists' ideas, you come to agree with statement 3:

*I think that the theory of evolution explains the diversity of life on this planet.*

You may also find that, by engaging in this curriculum, you are further convinced that you *disagree* with this statement. Neither outcome is a goal of the curriculum; it is completely outside what we hope to teach.

For this reason, the Initial Ideas (below) explicitly asks you to consider what it is that biologists think. As in all fields, there are a vast number of biologists with a wide range of personal beliefs, but the field as a whole – represented in textbooks, journal articles, grant activity and awards – is in strong agreement regarding whether the ideas we mention below are true or false. By "biologists," then, we do not mean "everyone with a degree in biology." Instead we mean "the consensus view of the field of biology."

#### INITIAL IDEAS

Consider each of the following statements about evolution. Do you agree or disagree with that statement? Why?

- Biologists think that evolution means that a new species is formed that wasn't there before. For example, they think that giraffes developing a longer and longer neck over time is natural selection, but it is not evolution because the long-necked giraffes are still the same species as the short-necked ones.
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- Biologists think that evolution provides an accurate explanation for how life began on this planet.
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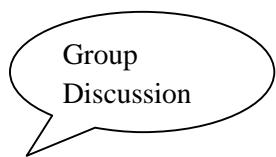
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- Biologists think that evolution provides an accurate explanation for how an organism adapts to a changing environment. For instance, I can adapt to winter by wearing warmer clothing and animals can adapt to winter by growing a warmer winter coat.
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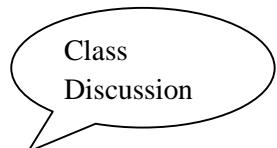
- Biologists think that evolution is a theory and not a law because it has not been fully tested. There is a great deal of debate within biology regarding whether or not evolution is an accurate theory.
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- Biologists think that natural selection is the way that evolution happens. There are no other ways for evolution to occur.
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- Biologists think that the consequence of evolution over a very long time (billions of years) is that all living things are related in a big family tree. For instance, humans and apes are closely related, and even animals and plants share a distant common ancestor.
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Before submitting homework, discuss these initial ideas with your group. Write down on the *white board* the group's ideas. Prepare to share your ideas with the class.



Your instructor will now lead a short whole-class discussion about the ideas from each group. Be prepared to explain your group's ideas and to write down comments from other groups that you find interesting or useful.

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