Look Who's Coming for Dinner: Selection by Predation

hhmi | BioInteractive

Activity
Educator Materials

OVERVIEW

In this activity, students formulate a hypothesis and collect and analyze real research data about how quickly natural selection can act on specific traits in a population as a result of predation. The activity uses measurements from a year-long field study that introduced a large predator to small islands inhabited by anole lizards (*Anolis sagrei*). It emphasizes that strong selective pressure can have measurable effects on trait variations in a population within a short time.

After watching the short film *The Origin of Species: Lizards in an Evolutionary Tree*, students work through the four parts of the activity:

- **Part 1** introduces the field study and asks students to formulate a hypothesis.
- **Part 2** states the hypothesis formulated by the scientists and how they tested it.
- **Part 3** asks students to collect data, perform simple calculations, and answer questions, which include calculating and interpreting simple descriptive statistics and plotting line graphs.
- **Part 4** prompts students to watch a video clip on additional findings and answer discussion questions.

Additional information related to pedagogy and implementation can be found on this resource's webpage, including suggested audience, estimated time, and curriculum connections.

KEY CONCEPTS

- Many traits vary among individuals in a population. Depending on environmental conditions, including the presence of predators, shelter availability, and competition for food, individuals with one form of a trait may have a survival advantage over individuals with other forms of the trait.
- Natural selection acts on variations in traits. It is a process by which some individuals are more likely to survive and/or reproduce than others.
- Predation can pose strong selective pressure on populations. Individuals with traits that enhance their ability to evade predators are more likely to survive and reproduce than individuals without those traits.
- Evolution by natural selection occurs if, over generations, certain traits (and their associated alleles) become more common in the population, and unfavorable traits become less common or disappear.
- Evolutionary processes can be tested empirically by conducting experiments with living species.
- Graphing data helps identify patterns and trends in data sets.

STUDENT LEARNING TARGETS

- Make predictions based on observations.
- Organize and analyze data by interpreting graphs and performing simple calculations.
- Draw conclusions about advantageous traits that are crucial to survival under certain selective pressures.

PRIOR KNOWLEDGE

Students should be familiar with:

- basic evolutionary theory, including concepts such as adaptation, fitness, and natural selection
- constructing graphs, as well as with organizing and analyzing data using simple descriptive statistics
- making and justifying claims using experimental evidence and scientific reasoning

MATERIALS

- ruler for graphing
- colored pens or pencils (recommended for graphing, but not required)
- at least one or two basic calculators

BACKGROUND

The activity illustrates the role of predation as an agent of natural selection and emphasizes that strong selective pressures can change a population by favoring the survival of individuals with certain trait variations over others. It also shows that the direction of selective pressure can change rapidly depending on the environment.

This activity is based on a study by Losos et al. (2006). For the activity, Losos and colleagues provided survival and habitat use measurements recorded before and after the introduction of a predator. Original data sets were modified slightly for the purpose of the activity. All sample measurements came from *A. sagrei* populations living on the small Bahamian islands near Abaco.

TEACHING TIPS

- Suggestions for organizing the parts of the activity are given below and in Figure 1:
  - Students can watch the film *The Origin of Species: Lizards in an Evolutionary Tree* and complete **Part 1** of the "Student Handout" as homework in advance.
  - **Parts 2 and 3** should be completed in class. It is recommended to include a brief class discussion (about 10 minutes) of the answers to Questions 2–10 in Part 3.
    - The beginning of Part 2 reveals the hypothesis that students have to formulate in Part 1. It may therefore be best if students get Part 1 separately before receiving the rest of the parts.
  - In **Part 4**, some of the questions may take longer to answer than others. Select only a few of the questions, or assign them as follow-up homework, if class time is limited. If any of the questions are assigned as homework, the answers can be discussed in the next class period.
    - The *Selection by Predation* video, which students are instructed to watch before Question 12, gives away the answer to Question 11. Students should complete Question 11 *before* watching the video and Questions 12–14 after.
- Emphasize to students that this activity does *not* show how speciation occurs. Speciation can be a difficult concept for students to fully comprehend, so it may be helpful to show the short animation *Reproductive Isolation and Speciation in Lizards*, which summarizes the basic principles of how new species arise. This animation could be assigned as homework together with a short discussion on why the experiment in this activity only shows natural selection, not the evolution of new species.
- Make sure that students understand the difference between the changes in hindlimb length discussed in the film *The Origin of Species: Lizards in an Evolutionary Tree* and in this activity. In the film, changes in hindlimb length are adaptations characteristic of *different anole species*. This activity examines the effect of natural selection on hindlimb length in a *single population of anoles*. (The anole species in this activity is a trunk-ground anole adapted to living on the ground. Trunk-ground anoles have longer hindlimbs compared to other anole species, but individuals' hindlimb lengths vary within the species.)

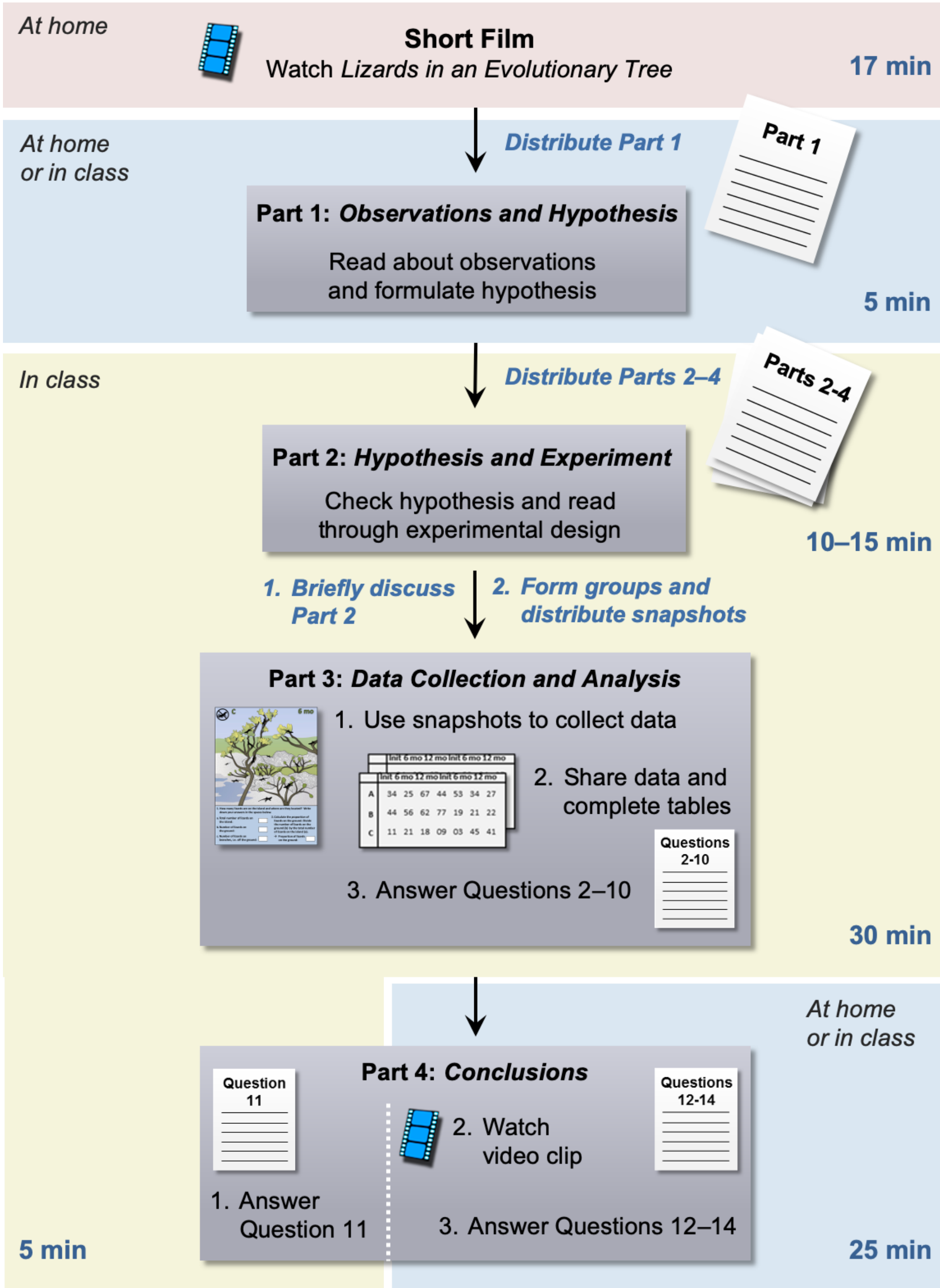
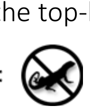


Figure 1. Activity overview, including suggestions for organizing class time and estimated time requirements.

- This activity uses two sets of cards, which can be downloaded as PDFs from the activity's webpage. The cards can be printed in either color or black-and-white. Make one-sided printouts of the cards, then cut them apart before distributing them to students.
  - The **"Island Snapshots Cards"** PDF contains 24 snapshots (two on each page), which show how many anole lizards were living on each island, and where, over time.
    - There are 24 island snapshots total (8 islands x 3 time points per island). The three time points are for the start of the experiment, after 6 months, and after 12 months. The eight islands consist of four experimental islands and four control islands, each labeled with a letter (control: A–D, experimental: E–H) and an icon (representing the large lizard predator) in the top-left corner of the snapshot.

Experimental island:  Control island: 

   - To reuse the snapshots, laminate them and use dry-erase pens, or have students record the data in their notebook or on the "Anole Assignment" cards.
  - The **"Anole Assignment Cards"** PDF contains 24 cards (12 on each page), where students can record the number of anoles and the proportion on the ground in each of the 24 island snapshots.
- You may wish to have students work in groups of two to four and have each group look at a subset of the island snapshots.
  - **Table 1** below illustrates two possible ways to split up the snapshots among groups. A group could get all the snapshots for a particular island over time (i.e., all the "A" snapshots) or all the same time points for different islands (i.e., all the "6-month" snapshots). You could also use the "Anole Assignment" cards to assign snapshots to groups.
  - After each group finishes analyzing their snapshots, they should share their data with the class so that everyone can complete Tables 1 and 2 of the "Student Handout." Consider projecting the tables on a screen or drawing them on the board for students to add their data.

CONTROL			EXPERIMENTAL		
Start	6 months	12 months	Start	6 months	12 months
A	A	A	E	E	E
B	B	B	F	F	F
C	C	C	G	G	G
D	D	D	H	H	H

Table 1. Two ways to distribute island snapshots among student groups. Each shaded rectangle represents one group. The "horizontal rectangle" scheme has eight groups that each look at snapshots of a particular island at three different time points. The "vertical rectangle" scheme has six groups that each look at either all control (A–D) or all experimental (E–H) islands at a particular time point.

- Before students begin working with the island snapshots, you may want to go over a sample snapshot with them. Explain the symbols, labels, and graphics as shown in **Figure 2**. Some anoles will be hard to see, but you can explain to your students that this is similar to what scientists experience out in the field.

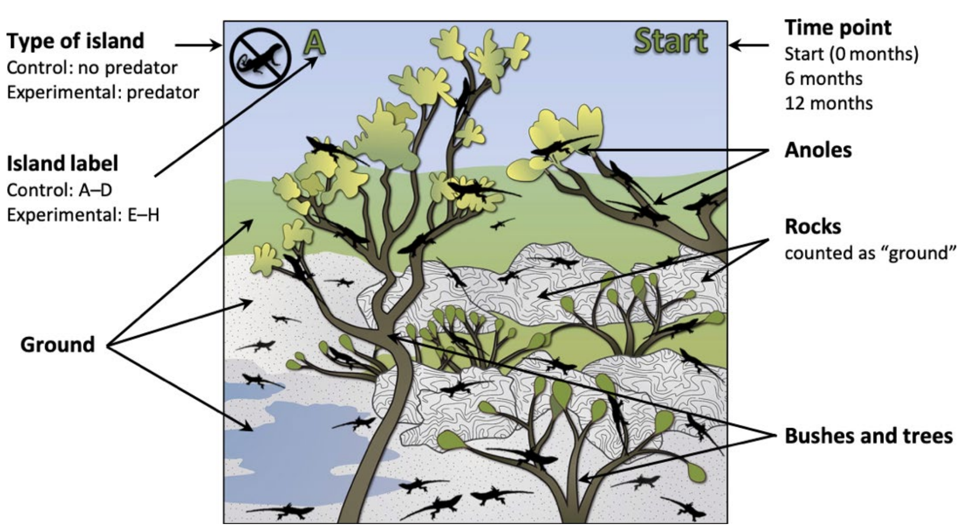


Figure 2. Explanation of symbols, labels, and graphics used on an island snapshot card.

- Students may wonder why, initially, about half of the anoles were found on the ground on all the islands. You may want to explain that the anoles usually spend time on the ground when active, i.e., searching for prey and mates. When the anoles are resting, they typically move to trunks or branches close to the ground.
- Make sure students understand that the snapshots include only the anoles that were marked at the *start* of the experiment, not offspring that were born into the population later. So even though the snapshots show the numbers of anoles decreasing on all the islands (including control islands) over time, this just means that members of the initial population are dying out, not that the entire population will eventually go extinct.
- Students may note that the initial numbers of anoles on each island are not the same, which makes direct comparisons difficult. You may want to explain that unequal sample sizes are common in experiments involving real populations, and one way to make comparisons easier is to calculate ratios or relative values. In Question 6 of Part 3, for example, students are asked to calculate the proportion of anoles that survived (survival rate). These calculations control for the initial, unequal sample sizes by dividing the numbers by the mean number of anoles present at the start of the experiment.
- Consider assigning the scientific paper that this activity was based on (Losos et al. 2006) as additional reading, if it is suitable for your students.
- Consider using this activity with complementary BioInteractive resources, such as the following:
    - Using the *Lizard Evolution Virtual Lab* prior to this activity can help students see how anole traits are measured. In particular, in Module 3 of the virtual lab, students measure hindlimb length for a different experiment that looked at the change in hindlimb length over generations.
    - The short film *The Origin of Species: The Beak of the Finch* provides an additional example of the effect of natural selection on a trait. It features biologists Peter and Rosemary Grant, who documented the evolution of the famous Galápagos finches by tracking changes in body traits directly tied to survival, such as beak length before and after two major droughts. They observed similar consequences in a very short time: populations decreased in size and the average beak size of survivors was different than the average beak size in the initial population. In contrast to Losos and his colleagues, however, the Grants were also able to look at future generations and observe evolution.

ANSWER KEY

PART 1: Observations and Hypothesis

1. Based on these initial observations, formulate a hypothesis about how the predatory lizard *L. carinatus* affects where *A. sagrei* anoles live. Explain your reasoning.

   One hypothesis is that the presence of the curly-tailed lizard L. carinatus *causes* A. sagrei *to live higher above the ground. This is supported by the observation that* A. sagrei *spends most of its time higher up (in the bushes and trees) on islands with* L. carinatus*.*

PART 2: Hypothesis and Experiment

Part 2 states the hypothesis formulated by Losos and colleagues and describes the experiment they designed to test their hypothesis. Students are provided with the background needed to understand the data they will collect and analyze in Part 3.

PART 3: Data Collection and Analysis

Table 1. Total numbers of *A. sagrei* anoles from the initial populations, not including offspring.

NUMBER OF SURVIVORS	CONTROL ISLANDS			EXPERIMENTAL ISLANDS			
Island	Start	6 Months	12 Months	Island	Start	6 Months	12 Months
A	*34*	*31*	*27*	E	*33*	*13*	*10*
B	*30*	*24*	*20*	F	*50*	*8*	*4*
C	*19*	*13*	*9*	G	*43*	*7*	*5*
D	*33*	*7*	*4*	H	*50*	*16*	*3*
Mean	*29*	*18.75*	*15*	*Mean*	*44*	*11*	*5.5*

Table 2. Proportions of *A. sagrei* anoles found on the ground.

PROPORTION ON GROUND	CONTROL ISLANDS			EXPERIMENTAL ISLANDS			
Island	Start	6 Months	12 Months	Island	Start	6 Months	12 Months
A	*0.59*	*0.32*	*0.56*	E	*0.49*	*0.08*	*0.10*
B	*0.40*	*0.33*	*0.35*	F	*0.48*	*0.13*	*0*
C	*0.42*	*0.38*	*0.44*	G	*0.58*	*0.14*	*0.20*
D	*0.61*	*0.57*	*0.50*	H	*0.46*	*0.13*	*0*
Mean	*0.51*	*0.40*	*0.46*	*Mean*	*0.50*	*0.12*	*0.08*

2. Compare the mean *numbers* of anole survivors, as shown in the last row of **Table 1**. Do you see any difference in the results for the control and experimental islands over time? Explain your answer.
   In general, the mean numbers of anoles on experimental islands declined much more rapidly than on control islands. (One exception is the sharp decline in anoles on Island D, which is a control island. Consider using this as an opportunity to discuss the importance of repeating an experiment. What would have happened if the scientists had used only one experimental island, and that experimental island had been Island D?)

3. Use the data in Table 1 to calculate the survival rates on the control and experimental islands after 6 and 12 months. Record your results in the table below.

Survival Rate	Equation	Control Islands	Experimental Islands
After 6 months	$\frac{\text{mean \# after 6 months}}{\text{mean \# at the start}}$	***0.65 (65%)***	***0.25 (25%)***
After 12 months	$\frac{\text{mean \# after 12 months}}{\text{mean \# at the start}}$	***0.52 (52%)***	***0.13 (13%)***

4. Based on your calculations, were the anoles more likely to survive on the control or experimental islands? How would you explain this difference?

   The control islands had higher survival rates after both 6 and 12 months. That means the anoles were more likely to survive on the control islands than on experimental islands, probably because the control islands didn't have the predator L. carinatus*.*

5. What additional factors could cause the anoles to die, even on control islands?

   The anoles could be dying from old age, disease, competition, etc. They could also be killed by other predators on the islands, such as birds.

6. Compare the mean *proportions* of survivors on the ground, as shown in the last row of **Table 2**. Do you see any difference in the results for the control and experimental islands over time? Explain your answer.

   After both 6 and 12 months, the proportion of survivors on the ground was smaller for the experimental islands than for the control islands, meaning that anoles were found on the ground less often on the experimental islands. This could be because the predator L. carinatus*, which was on the experimental islands only, hunts for anoles on the ground. So anoles on the ground were more likely to be eaten on the experimental islands.*

7. Follow the steps below to construct a line graph for the data in **Table 2**. This graph should show the mean proportion of anoles on the ground over time, for both the control islands and the experimental islands. *Student answers may vary. Example answers are shown below.*

   a. Remember that the experiment investigated how the proportion of anoles on the ground changed over time in response to a predator. What is the **independent variable** for the experiment?
   Time

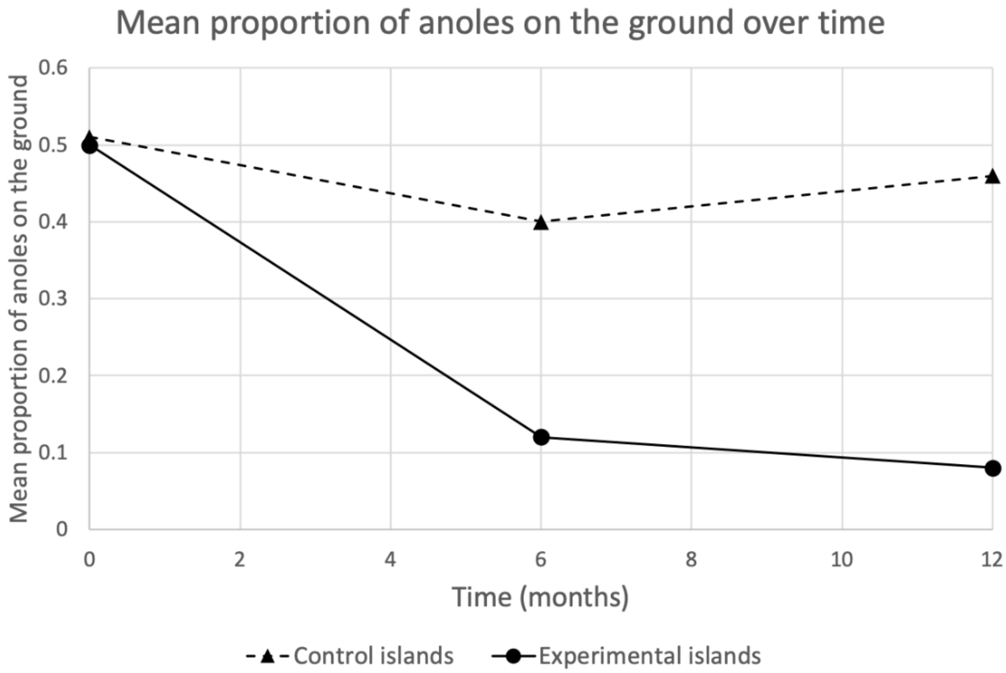
   b. What is the **dependent variable** for the experiment?
   The proportion of anoles on the ground

   c. What will be your label for the ***x*-axis**? Make sure to include units.
   Time (months)

   d. What will be your label for the ***y*-axis**?
   Mean proportion of anoles on the ground

   e. What will be your title for the graph?
   Mean proportion of anoles on the ground over time

   f. Create your graph in the space below, making sure to add the axes labels and title you described. On your graph, plot the mean proportions for the control islands and connect the data points with lines. Do the same for the experimental islands, but with a different line color or style. Add a **legend** that distinguishes between the data for the control and experimental islands.



8. Describe any trends or patterns you see in your graph. Make sure to compare the control and experimental islands.

   On the experimental islands, the mean proportion of anoles found on the ground decreased a lot after 6 months and even more after 12 months. On the control islands, the mean proportion of anoles on the ground stayed nearly the same over all 12 months, with just a small fluctuation.

9. Do these data support the hypothesis you formulated in Part 1? Explain your answer.

   Student answers will vary depending on their initial hypothesis. If their hypothesis was similar to the scientists' (i.e., that the presence of L. carinatus *would cause the anoles to live mostly above the ground), then the data do support the hypothesis. This is because the data show a higher proportion of anoles above the ground over time on the experimental islands, where* L. carinatus *is present. The proportion of anoles found on the ground on control islands without* L. carinatus*, on the other hand, changed relatively little over time.*

10. Use the data you collected in Tables 1 and 2 to complete the following statement, filling in each blank with one of the following words: "bigger," "smaller," or "similar."

    Compared to the control islands, on the experimental islands, a ***smaller*** number of anoles from the initial populations survived, and a ***smaller*** proportion of survivors were found primarily on the ground.

PART 4: Conclusions

11. Based on your findings in Part 3, would you predict a difference in the *average hindlimb length of surviving anoles* on experimental islands compared to those on control islands? List your predictions for each time point below and explain your reasoning. (*Hint:* Think about the connection between hindlimb length and habitat use described in the film [*The Origin of Species: Lizards in an Evolutionary Tree*].)

    Student answers may vary. The film suggests that long legs are advantageous when running on the ground, whereas short legs are better suited for climbing twigs in small trees and bushes. Part 1 of the "Student Handout" also mentions that A. sagrei *anoles are generally long-legged lizards, but there is slight variation in leg length within populations that natural selection can act on.*

    Start of experiment: ***Students will likely predict that the average hindlimb length was about the same on*** *both control and experimental islands, since the islands were all similar before the predator was introduced.*

After 6 and 12 months: *Students may predict that the average hindlimb length of survivors decreased over time as more anoles started living above the ground on bushes/trees, selecting for those with slightly shorter legs. Other students may predict that both short and long legs were advantageous throughout the course of the experiment and that the average hindlimb length didn't change. None of these answers is incorrect. In fact, Losos and colleagues also did not predict precisely what the study showed.*

12. After listing your predictions, watch the short video ***Selection by Predation***, in which Losos describes what he and his colleagues discovered from their experiment. Use this video to answer the following questions.

    a. What did Losos and his colleagues discover about the average hindlimb length of survivors after 6 months and after 12 months?

       After 6 months, the average hindlimb length of the survivors was longer than that of the population at the start. After 12 months, the average hindlimb length of the remaining survivors had decreased from what it was at 6 months.

    b. According to the video, why did the average hindlimb length change in this way?

       When the predator, the curly-tailed lizard L. carinatus*, was first introduced to the experimental islands, the anoles had to run away to escape. Longer-legged anoles were able to run more quickly, and shorter-legged anoles were more likely to be killed by the predator. So, after 6 months, the average hindlimb length of the survivors was greater than that of the population at the start.*

       Over time, the survivors started living mostly in bushes to avoid L. carinatus*. Shorter-legged anoles were better at climbing the branches of the bushes, so they were more likely to survive than longer-legged anoles were. So, after 12 months, the average hindlimb length of the remaining survivors had decreased from what it was at 6 months.*

    c. Were these findings different from what you expected? Explain your answer.
       Student answers will vary. They may be confused about why the longer-legged anoles didn't stay on the ground if they had been fast enough to escape the predator during the first six months (i.e., why they started living in bushes and small trees). If so, explain to students that living on the ground was dangerous, even for fast anoles, so it became advantageous to find other ways to escape, like climbing bushes and small trees.

13. Determine whether the predation experiment supports each of the following claims for the trait *of hindlimb length*. For each supported claim, list the evidence from the experiment that supports it. If a claim was not supported by the experiment, explain why not and what additional evidence would be needed to support the claim.

    a. There was variation in the trait among individual anoles in the population.

       Yes, this claim can be supported by this experiment. The scientists measured the hindlimb lengths of individual anoles, so they could see that the lengths varied within the population.

    b. Variation in the trait was heritable.

       No, this claim is not supported by this experiment, because the scientists only looked at one generation. Additional evidence to support this claim could include measuring the hindlimb lengths of offspring and comparing them to those of the parents, or investigating whether certain genes are involved in this trait.

    c. Some anoles had a fitness advantage over other anoles.

       No, this claim is not supported by this experiment, again because the scientists only looked at one generation. If we don't know how many offspring the anoles produced, we can't determine their fitness. To measure fitness, the scientists could count the number of offspring each surviving anole produced. (Students might assume that the survivors would ultimately produce more offspring because they were *more numerous, but the experiment didn't directly confirm this. Emphasize that the experiment only showed differential survival, which is only one component of fitness.)*

d. Natural selection favored certain trait variations.

Yes, this claim can be supported by this experiment. The first six months of the experiment showed that natural selection favored longer legs, since anoles with longer legs were more likely to escape the predator. The next six months of the experiment showed that natural selection favored shorter legs, since anoles with shorter legs were better at climbing bushes.

e. Beneficial trait variations were passed on to future generations, and the population evolved as anoles with traits better adapted to living on trees became more common.

No, this claim is not supported by this experiment, again because the scientists only looked at one generation. They would need to measure hindlimb length over multiple generations to determine whether evolution had occurred.

14. If the scientists had been able to continue their experiment and measure the anoles on these islands over many generations, what do you predict they would have found? How might the populations have changed over many generations?

Student answers may vary. They may predict that the average hindlimb length of a population would have become shorter over multiple generations (assuming that environmental conditions stayed mostly the same, that hindlimb length is a heritable trait, that there are not limiting biological constraints on hindlimb length, etc.). This prediction would be consistent with what Losos and colleagues have found in other experiments, such as the one shown in the film The Origin of Species: Lizards in an Evolutionary Tree*.*

REFERENCE

Losos, Jonathan B., Thomas W. Schoener, R. Brian Langerhans, and David A. Spiller. "Rapid temporal reversal in predator-driven natural selection." *Science* 314, 5802 (2006): 1111. https://doi.org/10.1126/science.1133584.

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Figure 1 in the "Student Handout" adapted from MapMaker Interactive maps, National Geographic Society