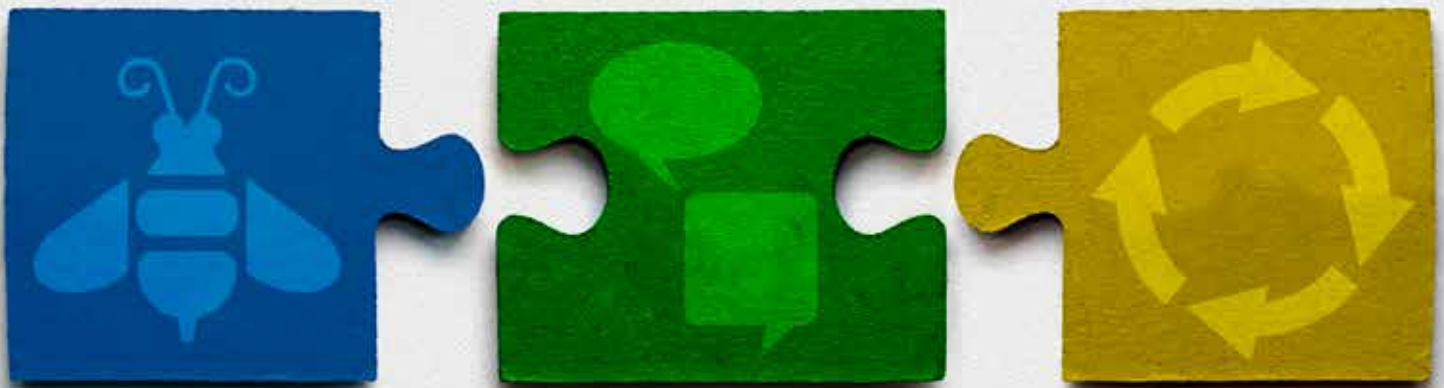


# Argument-Driven Inquiry in LIFE SCIENCE

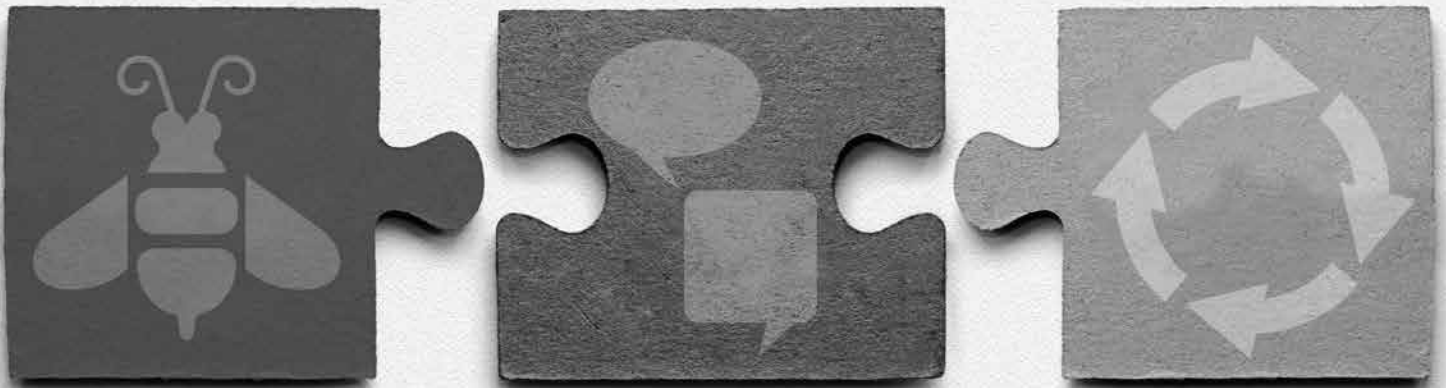


LAB INVESTIGATIONS  
for GRADES 6–8

Patrick J. Enderle, Ruth Bickel, Leanne Gleim,  
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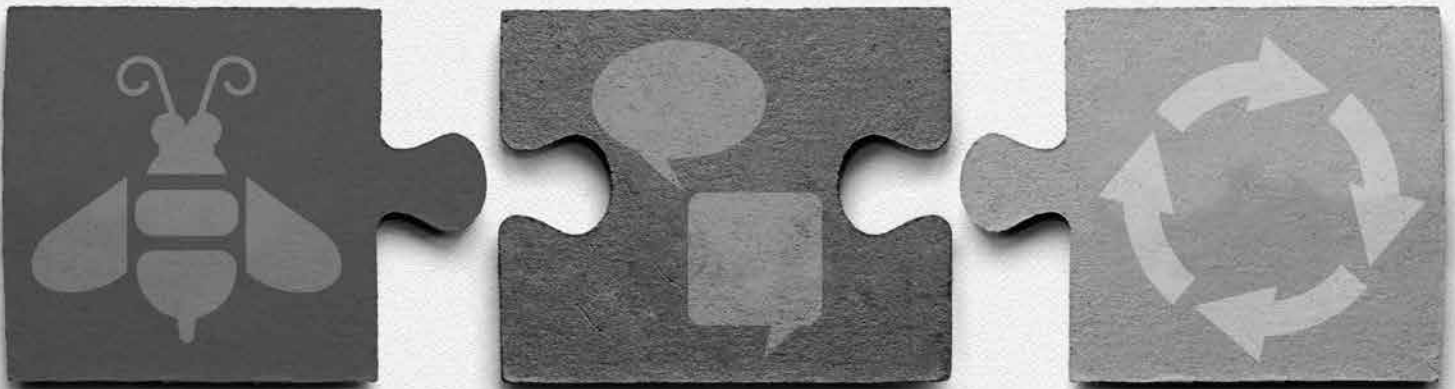
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# PREFACE

There is a push to change the way science is taught in the United States, called for by a different idea of what it means to know, understand, and be able to do in science. As described in *A Framework for K–12 Science Education* (National Research Council [NRC] 2012) and the *Next Generation Science Standards* (NGSS Lead States 2013), science education should be structured to emphasize ideas *and* practices to

ensure that by the end of 12th grade, *all* students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (p. 1)

Instead of teaching with the goal of helping students learn facts and concepts, science teachers are now charged with helping their students become *proficient* in science by the time they graduate from high school. To allow for this proficiency, the NRC (2012) suggests that students need to understand four core ideas in the life sciences,<sup>1</sup> be aware of seven crosscutting concepts that span across the various disciplines of science, and learn how to participate in eight fundamental scientific practices in order to be considered proficient in science. These important practices, crosscutting concepts, and core ideas are summarized in Figure 1 (p. xii).

As described by the NRC (2012), new instructional approaches are needed to assist students in developing these proficiencies. This book provides 20 lab activities designed using an innovative approach to lab instruction called argument-driven inquiry (ADI). This approach and the labs based on it are aligned with the content, crosscutting concepts, and scientific practices outlined in Figure 1. Because the ADI model calls for students to give presentations to their peers, respond to questions, and then write, evaluate, and revise reports as part of each lab, the lab activities described in this book will also enable students to develop the disciplinary-based literacy skills outlined in the *Common Core State Standards* for English language arts (NGAC and CCSSO 2010). Use of these labs, as a result, can help teachers align their instruction with current recommendations for making life science more meaningful for students and more effective for teachers.

---

<sup>1</sup> Throughout this book, we use the term *life sciences* when referring to the core ideas of the *Framework* (in this context the term refers to a broad collection of scientific fields), but we use the term *life science* when referring to courses at the middle school level (as in the title of the book).

## FIGURE 1

The three dimensions of the framework for the NGSS

<p><b>Scientific Practices</b></p> <ol style="list-style-type: none"> <li>1. Asking questions and defining problems</li> <li>2. Developing and using models</li> <li>3. Planning and carrying out investigations</li> <li>4. Analyzing and interpreting data</li> <li>5. Using mathematics and computational thinking</li> <li>6. Constructing explanations and designing solutions</li> <li>7. Engaging in argument from evidence</li> <li>8. Obtaining, evaluating, and communicating information</li> </ol>	<p><b>Crosscutting Concepts</b></p> <ol style="list-style-type: none"> <li>1. Patterns</li> <li>2. Cause and effect: Mechanism and explanation</li> <li>3. Scale, proportion, and quantity</li> <li>4. Systems and system models</li> <li>5. Energy and matter: Flows, cycles, and conservation</li> <li>6. Structure and function</li> <li>7. Stability and change</li> </ol>
<p><b>Life Sciences Core Ideas</b></p> <ul style="list-style-type: none"> <li>• LS1: From molecules to organisms: Structures and processes</li> <li>• LS2: Ecosystems: Interactions, energy, and dynamics</li> <li>• LS3: Heredity: Inheritance and variation of traits</li> <li>• LS4: Biological evolution: Unity and diversity</li> </ul>	

Source: Adapted from NRC 2012, p. 3.

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## ABOUT THE AUTHORS

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# INTRODUCTION

## The Importance of Helping Students Become Proficient in Science

The new aim of science education in the United States is for all students to become proficient in science by the time they finish high school. It is essential to recognize that science proficiency involves more than an understanding of important concepts, it also involves being able to *do* science. *Science proficiency*, as defined by Duschl, Schweingruber, and Shouse (2007), consists of four interrelated aspects. First, it requires an individual to know important scientific explanations about the natural world, to be able to use these explanations to solve problems, and to be able to understand new explanations when they are introduced to the individual. Second, it requires an individual to be able to generate and evaluate scientific explanations and scientific arguments. Third, it requires an individual to understand the nature of scientific knowledge and how scientific knowledge develops over time. Finally, and perhaps most important, an individual who is proficient in science should be able to participate in scientific practices (such as designing and carrying out investigations and arguing from evidence) and communicate in a manner that is consistent with the norms of the scientific community.

In the past decade, however, the importance of learning how to participate in scientific practices has not been acknowledged in the standards of many states. Many states have also attempted to make their science standards “more rigorous” by adding more content to them or lowering the grade level at which content is introduced rather than by emphasizing depth of understanding of core ideas and crosscutting concepts, as described by the National Research Council (NRC) in *A Framework for K–12 Science Education* (NRC 2012). The result of the increased number of science standards and the pressure to “cover” them to prepare students for high-stakes tests that target facts and definitions is that teachers have “alter[ed] their methods of instruction to conform to the assessment” (Owens 2009, p. 50). The unintended consequences of this change has been a focus on content (learning “facts”) rather than on developing scientific habits of mind or participating in the practices of science. Teachers must move through the curriculum quickly before the administration of the tests, forcing them to cover many topics in a shallow fashion rather than to delve into them deeply to foster understanding.

Despite this high-stakes accountability for science learning, students do not seem to be gaining proficiency in science. According to *The Nation’s Report Card: Science 2009* (National Center for Education Statistics 2011), only 21% of all 12th-grade students who took the National Assessment of Educational Progress in science scored at the proficient level. The performance of U.S. students on international assessments is even bleaker, as indicated by their scores on the science portion of the Programme for International Student Assessment (PISA). PISA is an international study that was launched by the Organisation for Economic Co-operation and Development (OECD)

in 1997, with the goal of assessing education systems worldwide; more than 70 countries have participated in the study. The test is designed to assess reading, math, and science achievement and is given every three years. The mean score for students in the United States on the science portion of the PISA in 2012 is below the international mean (500), and there has been no significant change in the U.S. mean score since 2000; in fact, the U.S. mean score in 2012 is slightly less than it was in 2000 (OECD 2012; see Table 1). Students in countries such as China, Korea, Japan, and Finland score significantly higher than students in the United States. These results suggest that U.S. students are not becoming proficient in science, even though teachers are covering a great deal of material and being held accountable for it.

**TABLE 1**  
**PISA scientific literacy performance for U.S. students**

Year	U.S. mean score*	U.S. rank/Number of countries assessed	Top three performers
2000	499	14/27	Korea (552) Japan (550) Finland (538)
2003	491	22/41	Finland (548) Japan (548) Hong Kong–China (539)
2006	489	29/57	Finland (563) Hong Kong–China (542) Canada (534)
2009	499	15/43	Japan (552) Korea (550) Hong Kong–China (541)
2012	497	36/65	Shanghai–China (580) Hong Kong–China (555) Singapore (551)

\*The mean score of the PISA is 500 across all years.  
 Source: OECD 2012.

Additional evidence of the consequences of emphasizing breadth over depth comes from empirical research in science education supporting the notion that broad, shallow coverage neglects the practices of science and hinders the development of science proficiency (Duschl, Schweingruber, and Shouse 2007; NRC 2005, 2008). As noted in the *Framework* (NRC 2012),

K–12 science education in the United States fails to [promote the development of science proficiency], in part because it is not organized systematically across multiple years of school, emphasizes discrete facts with a focus on breadth over depth, and does not provide students with engaging opportunities to experience how science is actually done. (p. 1)

Based on their review of the available literature, the NRC recommends that science teachers delve more deeply into core ideas to help their students develop improved understanding and retention of science content. The NRC also calls for students to be given more experience participating in the practices of science, with the goal of enabling students to better engage in public discussions about scientific issues related to their everyday lives, to be consumers of scientific information, and to have the skills and abilities needed to enter science or science-related careers. We think the school science laboratory is the perfect place to focus on core ideas and engage students in the practices of science and, as a result, help them develop the knowledge and abilities needed to be proficient in science.

## How School Science Laboratories Can Help Foster the Development of Science Proficiency

Investigators have shown that lab activities have a standard format in U.S. secondary-school classrooms (Hofstein and Lunetta 2004; NRC 2005). (We use the NRC’s definition of a school science lab activity, which is “an opportunity for students to interact directly with the material world using the tools, data collection techniques, models, and theories of science” [NRC 2005, p. 3].) This format begins with the teacher introducing students to a concept through direct instruction, usually a lecture and/or reading. Next, students complete a confirmatory laboratory activity, usually following a “cookbook recipe” in which the teacher provides a step-by-step procedure to follow and a data table to fill out. Finally, students are asked to answer a set of focused analysis questions to ensure that the lab has illustrated, confirmed, or otherwise verified the targeted concept(s). This type of approach does little to promote science proficiency because it often fails to help students think critically about the concepts, engage in important scientific practices (such as designing an investigation, constructing explanations, or arguing from evidence), or develop scientific

habits of mind (Duschl, Schweingruber, and Shouse 2007; NRC 2005). Further, this approach does not perceptibly improve communication skills.

Changing the focus of lab instruction can help address these challenges. To implement such a change, teachers will have to emphasize “how we know” in the life sciences (i.e., how new knowledge is generated and validated) equally with “what we know” about life on Earth (i.e., the theories, laws, and unifying concepts). Because it is an essential practice of science, the NRC calls for *argumentation* (defined as proposing, supporting, and evaluating claims on the basis of reason) to play a more central role in the teaching and learning of science. The NRC (2012) provides a good description of the role argumentation plays in science:

Scientists and engineers use evidence-based argumentation to make the case for their ideas, whether involving new theories or designs, novel ways of collecting data, or interpretations of evidence. They and their peers then attempt to identify weaknesses and limitations in the argument, with the ultimate goal of refining and improving the explanation or design. (p. 46)

This means that the focus of teaching will have to shift more to scientific abilities and habits of mind so that students can learn to construct and support scientific knowledge claims through argument (NRC 2012). Students will also have to learn to evaluate the claims or arguments made by others.

A part of this change in instructional focus will need to be a change in the nature of lab activities (NRC 2102). Students will need to have more experiences engaging in scientific practices so that lab activities can become more authentic. This is a major shift away from labs driven by prescribed worksheets and data tables to be completed. These activities will have to be thoughtfully constructed so as to be educative and help students develop the required knowledge, skills, abilities, and habits of mind. This type of instruction will require that students receive feedback and learn from their mistakes; hence, teachers will need to develop more strategies to help students learn from their mistakes.

The argument-driven inquiry (ADI) instructional model (Sampson and Gleim 2009; Sampson, Grooms, and Walker 2009, 2011) was designed as a way to make lab activities more authentic and educative for students and thus help teachers promote and support the development of science proficiency. This instructional model reflects research about how people learn science (NRC 1999) and is also based on what is known about how to engage students in argumentation and other important scientific practices (Berland and Reiser 2009; Erduran and Jimenez-Aleixandre 2008; McNeill and Krajcik 2008; Osborne, Erduran, and Simon 2004; Sampson and Clark 2008).

## Organization of This Book

The remainder of this book is divided into six sections. Section 1 begins with two chapters describing the ADI instructional model and the development and components of the ADI lab investigations. Sections 2–5 contain the lab investigations, including notes for the teacher, student handouts, and checkout questions. Section 6 contains four appendixes with standards alignment matrixes, timeline and proposal options for the investigations, and a form for assessing the investigation reports.

## Safety Practices in the Science Laboratory

It is important for science teachers to make hands-on and inquiry-based lab activities as safe as possible for students. Teachers therefore need to have proper engineering controls (e.g., fume hoods, ventilation, fire extinguisher, eye wash/shower), standard operating safety procedures (e.g., chemical hygiene plan, board of education/school safety policies), and appropriate personal protective equipment (sanitized indirectly vented chemical-splash goggles, gloves, aprons, etc.) in the classroom, laboratory, or field during all hands-on activities. Teachers also need to adopt legal safety standards and enforce them inside the classroom. Finally, teachers must review and comply with all safety polices and chemical storage and disposal protocols that have been established by their school district or school.

Throughout this book, safety precautions are provided for each investigation. Teachers should follow these safety precautions to provide a safer learning experience for students. The safety precautions associated with each activity are based, in part, on the use of the recommended materials and instructions, legal safety compliance standards, and current better professional safety practices. Selection of alternative materials or procedures for these activities may jeopardize the level of safety and therefore is at the user's own risk. We also recommend that students, before working in the laboratory for the first time, review the National Science Teacher Association's safety acknowledgment form in the document *Safety in the Science Classroom, Laboratory, or Field Sites* under the direction of the teacher. This document is available online at [www.nsta.org/docs/SafetyInTheScienceClassroomLabAndField.pdf](http://www.nsta.org/docs/SafetyInTheScienceClassroomLabAndField.pdf). The students and their parents or guardians should then sign this document to acknowledge that they understand the safety procedures that must be followed during a lab activity. Additional safety compliance resources can be found on the NSTA safety portal at [www.nsta.org/safety](http://www.nsta.org/safety).

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# LAB 18

## ***Teacher Notes***

### **Lab 18. Environmental Change and Evolution: Which Mechanism of Microevolution Caused the Beak of the Medium Ground Finch Population on Daphne Major to Increase in Size From 1976 to 1978?**

#### **Purpose**

The purpose of this lab is for students to *apply* what they know about migration, genetic drift, and natural selection to explain the evolution of beak size in a population of birds. Specifically, this investigation gives students an opportunity to use an existing data set to test three different potential explanations for a case of microevolution. Through this activity, students will have an opportunity to learn how scientists use system models to understand natural phenomena and to learn about the connection between structure and function in living things. Students will also have the opportunity to reflect on the difference between theories and laws in science and on the various methods that scientists can use during an investigation.

#### **The Content**

*Microevolution* is a change in gene frequency in a population over time. A population is a group of organisms that share a common gene pool, and a population of animals is a group of individuals that live in the same area and are able to mate and produce fertile offspring. Figure 18.1 provides an illustration of microevolution in a population of mosquitoes. In this example, a gene for pesticide resistance becomes more common in the mosquito population over time.

There are four basic mechanisms of microevolution: *mutation*, *migration*, *natural selection*, and *genetic drift*. Any one these four mechanisms can affect the frequency of a gene in a population. These four mechanisms can also work in combination.

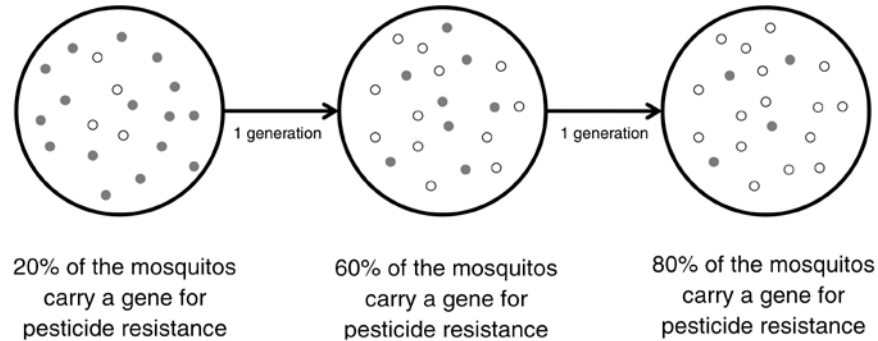
The first mechanism of microevolution is a genetic mutation. A mutation during the DNA replication process can result in an individual being born with a new version of a gene. The individual with the new gene can then have offspring with the same gene. The new gene could then become more common in a population over time. Figure 18.2 provides an illustration of how a genetic mutation can lead to change in the frequency of a gene for pesticide resistance within a population of mosquitoes over time. It is important to note, however, that mutations are rare and only happen in individuals. Genetic mutations therefore cannot result in a big change in the frequency of a gene within a population in only one or two generations.



Which Mechanism of Microevolution Caused the Beak of the Medium Ground Finch Population on Daphne Major to Increase in Size From 1976 to 1978?

**FIGURE 18.1**

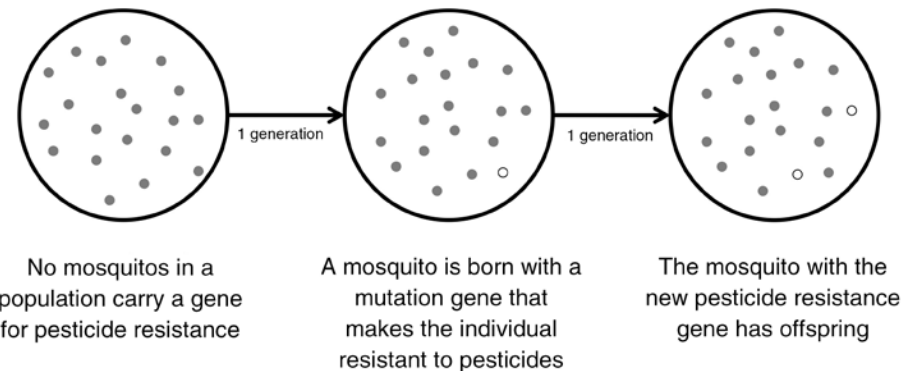
**Microevolution in a population of mosquitoes**



Note: The white dots within each circle represent the gene for pesticide resistance.

**FIGURE 18.2**

**Microevolution in a population of mosquitoes due to a genetic mutation**



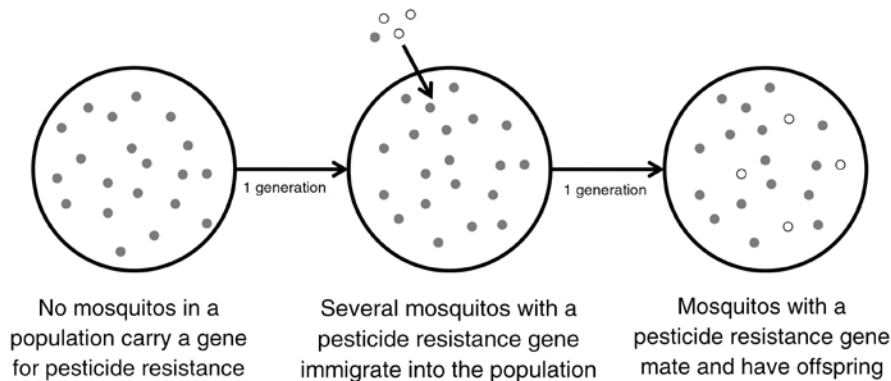
Note: The white dots within each circle represent the gene for pesticide resistance.

The second mechanism of microevolution is migration, which is also known as *gene flow*. Individuals can either join a population (immigration) or leave a population (emigration). A specific version of gene will become less common within a population when several individuals with that gene leave the population, and a specific version of a gene will become more common within a population when several individuals with that gene join the population. The migration of a large number of individuals into or out of a population can therefore result in a dramatic shift in the frequency of a gene within a population in a relatively short period of time. Figure 18.3 (p. 298) provides an illustration of how migration or gene flow can change the frequency of a gene for pesticide resistance in a population of mosquitoes over time.

# LAB 18

**FIGURE 18.3**

**Microevolution in a population of mosquitoes due to migration (gene flow)**



*Note:* The white dots within each circle represent the gene for pesticide resistance.

Natural selection is the third mechanism of microevolution. Natural selection occurs when

- there is variation in a trait among the individuals that make up a population,
- the trait is determined by one or more genes,
- the trait affects survival and/or ability to reproduce, and
- individuals who reproduce pass on their genes to the next generation.

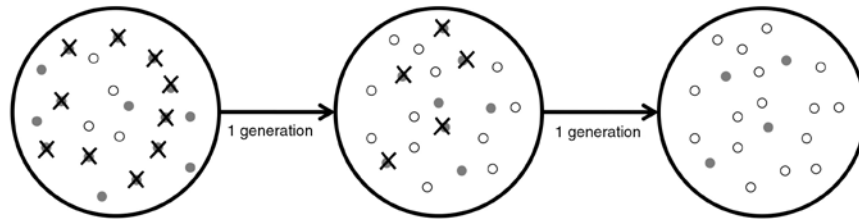
The frequency of a gene in any given generation, as a result, reflects the traits and genes of the individuals that were able to survive long enough to reproduce in the previous generation. Over time, genes that determine traits that are associated with an increased chance of survival and successful reproduction will become more common in a population, and the genes that determine traits that decrease an individual's chance of survival or reproduction will become less common. Figure 18.4 provides an illustration of how natural selection can change the frequency of the gene for pesticide resistance in a population of mosquitoes over time.

The fourth mechanism of microevolution is genetic drift. In any generation, some individuals may, just by chance, survive longer or leave behind more offspring than other individuals. The frequency of a gene in the next generation will therefore reflect the genes and traits of these lucky individuals rather than individuals with traits that are advantageous in terms of survival or reproduction. This process causes the frequency of genes in a population to change (or drift) over time. Genetic drift tends to act faster and has more drastic results in smaller populations. It also tends to decrease genetic variation in populations.

Which Mechanism of Microevolution Caused the Beak of the Medium Ground Finch Population on Daphne Major to Increase in Size From 1976 to 1978?

## FIGURE 184

Microevolution in a population of mosquitoes due to natural selection



Some mosquitos in a population carry a gene for pesticide resistance and some do not. Individuals with the pesticide resistance are more likely to survive and reproduce because people spray with pesticides. The gene for pesticide resistance becomes more common in the population of each generation.

*Note:* The white dots within each circle represent the gene for pesticide resistance, and the Xs represent individual mosquitoes that do not survive.

In this lab, the students study a specific bird population, the medium ground finch (*Geospiza fortis*), that lives in the Galápagos Islands, an archipelago of volcanic islands in the Pacific Ocean. The major factor that affects the survival of these birds is the availability of food. The medium ground finch has a small beak and prefers to eat small seeds with soft shells. In 1977, the islands received very little rain. The plants on the island withered and stopped producing seeds. The medium ground finches quickly depleted the supply of small seeds with soft shells. There were, however, still large seeds with hard shells on the island. The finches with larger beaks were able to crack open and eat the larger seeds, but the smaller-beaked birds were not. The smaller-beaked birds therefore died of starvation and the larger-beaked birds survived the drought and reproduced. The average beak size in the next generation of these finches, as a result, was about 1 mm larger than the previous generation.

### Timeline

The instructional time needed to implement this lab investigation is 130–200 minutes. Appendix 2 (p. 355) provides options for implementing this lab investigation over several class periods. Option C (200 minutes) should be used if students are unfamiliar with scientific writing, because this option provides extra instructional time for scaffolding the writing process. You can scaffold the writing process by modeling, providing examples, and providing hints as students write each section of the report. Option D (130 minutes) should be used if students are familiar with scientific writing and have the skills needed to write an investigation report on their own. In option D, students complete stage 6 (writing the investigation report) and stage 8 (revising the investigation report) as homework.

# LAB 18

## Materials and Preparation

The materials needed to implement this investigation are listed in Table 18.1. The *Finch Data.xls* file is available at [www.nsta.org/publications/press/extras/adi-lifescience.aspx](http://www.nsta.org/publications/press/extras/adi-lifescience.aspx). You should download the file and explore it before beginning the lab investigation. Since this is an “application” lab, students should be familiar with the mechanisms of microevolution before the lab.

The data found in the Finch Data Excel files are based on the published work of Peter R. Grant, B. Rosemary Grant, and their colleagues who have studied the Medium Ground Finches on Daphne Major for the past four decades. The actual data are drawn from the following sources: Boag and Grant 1981, 1984; Grant 1989; Grant and Grant 1980, 2002. The individual bird characteristics, amount of rainfall, and seed type abundance data provide a simplified data set, consistent in all respects with the published data but with fewer data points, to make these data more accessible to students.

**TABLE 18.1**

### Materials list

Item	Quantity
Computer with a spreadsheet application such as Microsoft Excel or Apple Numbers	At least 1 per group
Finch Data Excel file	At least 1 per group
Investigation Proposal B (optional)*	1 per group
Whiteboard, 2' × 3'†	1 per group
Lab Handout	1 per student
Peer-review guide	1 per student
Checkout Questions	1 per student

\* We highly recommend that students fill out an investigation proposal for this lab.

† Students can also use computer and presentation software such as Microsoft PowerPoint or Apple Keynote to create their arguments.

## Safety Precautions

Follow all normal lab safety rules.

## Topics for the Explicit and Reflective Discussion

### *Concepts That Can Be Used to Justify the Evidence*

To provide an adequate justification of their evidence, students must explain why they included the evidence in their arguments and make the assumptions underlying their

### *Which Mechanism of Microevolution Caused the Beak of the Medium Ground Finch Population on Daphne Major to Increase in Size From 1976 to 1978?*

analysis and interpretation of the data explicit. In this investigation, students can use the following concepts to help justify their evidence:

- Population dynamics
- Inheritance of traits
- Microevolution
- Mutation
- Migration
- Natural selection
- Genetic drift

We recommend that you review these concepts during the explicit and reflective discussion to help students make this connection.

#### ***How to Design Better Investigations***

It is important for students to reflect on the strengths and weaknesses of the investigation they designed during the explicit and reflective discussion. Students should therefore be encouraged to discuss ways to eliminate potential flaws, measurement errors, or sources of bias in their investigations. To help students be more reflective about the design of their investigation, you can ask the following questions:

- What were some of the strengths of your investigation? What made it scientific?
- What were some of the weaknesses of your investigation? What made it less scientific?
- If you were to do this investigation again, what would you do to address the weaknesses in your investigation? What could you do to make it more scientific?

#### ***Crosscutting Concepts***

This investigation is aligned with two crosscutting concepts found in *A Framework for K–12 Science Education*, and you should review these concepts during the explicit and reflective discussion.

- *Systems and system models*: Scientists often need to define the system they are studying (e.g., the components of a habitat) and then use a model to understand it. Models can be physical, conceptual, or mathematical.
- *Structure and function*: In nature, the way a living thing is shaped or structured determines how it functions and places limits on what it can and cannot do. In this investigation, for example, beak shape affected a bird's ability to eat.

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## *The Nature of Science and the Nature of Scientific Inquiry*

This investigation is aligned with two important concepts related to the *nature of science* (NOS) and the *nature of scientific inquiry* (NOSI), and you should review these concepts during the explicit and reflective discussion.

- *The difference between laws and theories in science:* A scientific law describes the behavior of a natural phenomenon or a generalized relationship under certain conditions; a scientific theory is a well-substantiated explanation of some aspect of the natural world. Theories do not become laws even with additional evidence; they explain laws. However, not all scientific laws have an accompanying explanatory theory. It is also important for students to understand that scientists do not discover laws or theories; the scientific community develops them over time.
- *Methods used in scientific investigations:* Examples of methods include experiments, systematic observations of a phenomenon, literature reviews, and analysis of existing data sets; the choice of method depends on the objectives of the research. There is no universal step-by-step scientific method that all scientists follow; rather, different scientific disciplines (e.g., biology vs. physics) and fields within a discipline (e.g., ecology vs. molecular biology) use different types of methods, use different core theories, and rely on different standards to develop scientific knowledge. In this investigation, for example, students use a large data set; they do not conduct a field study.

## **Hints for Implementing the Lab**

- Show students how to use the spreadsheet application as part of the tool talk. At a minimum, students will need to know how to use formulas, make new sheets, and create charts.
- The students should be encouraged to think of ways to use the available data to test the three potential explanations for the evolutionary change in beak size. We recommend that students fill out Investigation Proposal B at the beginning of the lab to help them generate predictions based on each explanation.
- Encourage students to make a copy of the Finch Data Excel file using the “Save as” feature before they start analyzing the data.
- Students can cut and paste the data into new sheets to facilitate analysis.
- A group of three students per computer tends to work well.
- Have students create charts in the spreadsheet application for the argumentation sessions and investigation reports.
- Students may not be able to refute one or more alternative explanations due to limitations in the data set. Be sure to remind students to acknowledge the limitations in the data and then encourage them to think about what other data they would need to determine which explanation is the most valid or acceptable.

*Which Mechanism of Microevolution Caused the Beak of the Medium Ground Finch Population on Daphne Major to Increase in Size From 1976 to 1978?*

### Topic Connections

Table 18.2 provides an overview of the scientific practices, crosscutting concepts, disciplinary core ideas, and support ideas at the heart of this lab investigation. In addition, it lists NOS and NOSI concepts for the explicit and reflective discussion. Finally, it lists literacy and mathematics skills (*CCSS ELA* and *CCSS Mathematics*) that are addressed during the investigation.

**TABLE 18.2**

**Lab 18 alignment with standards**

<b>Scientific practices</b>	<ul style="list-style-type: none"> <li>• Asking questions and defining problems</li> <li>• Developing and using models</li> <li>• Planning and carrying out investigations</li> <li>• Analyzing and interpreting data</li> <li>• Using mathematics and computational thinking</li> <li>• Constructing explanations</li> <li>• Engaging in argument from evidence</li> <li>• Obtaining, evaluating, and communicating information</li> </ul>
<b>Crosscutting concepts</b>	<ul style="list-style-type: none"> <li>• Systems and system models</li> <li>• Structure and function</li> </ul>
<b>Core ideas</b>	<ul style="list-style-type: none"> <li>• LS2: Ecosystems: Interactions, energy, and dynamics</li> <li>• LS3: Heredity: Inheritance and variation of traits</li> <li>• LS4: Biological evolution: Unity and diversity</li> </ul>
<b>Supporting ideas</b>	<ul style="list-style-type: none"> <li>• Population dynamics</li> <li>• Inheritance of traits</li> <li>• Microevolution</li> <li>• Mutation</li> <li>• Migration</li> <li>• Natural selection</li> <li>• Genetic drift</li> </ul>
<b>NOS and NOSI concepts</b>	<ul style="list-style-type: none"> <li>• Scientific laws and theories</li> <li>• Methods used in scientific investigations</li> </ul>
<b>Literacy connections (CCSS ELA)</b>	<ul style="list-style-type: none"> <li>• <i>Reading</i>: Key ideas and details, craft and structure, integration of knowledge and ideas</li> <li>• <i>Writing</i>: Text types and purposes, production and distribution of writing, research to build and present knowledge, range of writing</li> <li>• <i>Speaking and listening</i>: Comprehension and collaboration, presentation of knowledge and ideas</li> </ul>
<b>Mathematics connections (CCSS Mathematics)</b>	<ul style="list-style-type: none"> <li>• Make sense of problems and persevere in solving them</li> <li>• Reason abstractly and quantitatively</li> <li>• Construct viable arguments and critique the reasoning of others</li> <li>• Model with mathematics</li> <li>• Use appropriate tools strategically</li> <li>• Look for and express regularity in repeated reasoning</li> </ul>

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## Lab Handout

# Lab 18. Environmental Change and Evolution: Which Mechanism of Microevolution Caused the Beak of the Medium Ground Finch Population on Daphne Major to Increase in Size From 1976 to 1978?

## Introduction

Bacteria have developed resistance to antibiotics over time. A pesticide that was once highly effective at killing mosquitoes no longer works. House sparrows that live in the northern United States and Canada are larger-bodied than the ones that live in the southern United States and Mexico. These cases are all examples of *microevolution*, or evolutionary change on a small scale. Microevolution occurs within a population. A population is a group of organisms that live in the same area and mate with each other. Biologists define microevolution as a change in the frequency of one or more genes within a population over time. As specific genes within a population become more or less common over time, the traits that are associated with those genes will also change. There are four basic mechanisms that drive microevolution.

The first mechanism of microevolution is a genetic *mutation*. A mutation in a gene can result in an individual having a new version of a trait. The individual with the new gene can then have offspring with the same gene. The new gene could then become more common in a population over time. However, since mutations are rare and only happen in individuals, this process alone cannot result in a big change in the frequency of a gene within a population in only one or two generations.

The second mechanism of microevolution is the process of *migration*. Individuals can either join a population (immigration) or leave a population (emigration). A specific version of a gene will become less common within a population when several individuals with that gene leave the population, and a specific version of a gene will become more common within a population when several individuals with that gene join the population. The migration of a large number of individuals into or out of a population can therefore result in a dramatic shift in the frequency of a gene within a population in a relatively short period of time.

The third mechanism of microevolution is *natural selection*, which occurs when (a) there is variation in a trait among the individuals that make up a population, (b) the trait is determined by one or more genes, (c) the trait affects survival and/or ability to

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reproduce, and (d) individuals who reproduce pass on their genes to the next generation. The frequency of a gene in any given generation, as a result, reflects the traits and genes of the individuals that were able to survive long enough to reproduce in the previous generation. Over time, genes that determine traits that are associated with an increased chance of survival and successful reproduction will become more common in a population, and genes that determine traits that decrease an individual's chance of survival or reproduction will become less common.

**FIGURE L18.1**

The Galápagos archipelago



The fourth, and final, mechanism of microevolution is *genetic drift*. In any generation, some individuals may, just by chance, survive longer or leave behind more offspring than other individuals. The frequency of a gene in the next generation will therefore reflect the genes and traits of these lucky individuals rather than individuals with traits that are advantageous in terms of survival or reproduction.

It is often difficult to determine which of these four mechanisms is responsible for an evolutionary change within a population. To illustrate this point, you will be studying a population of birds called the medium ground finch (*Geospiza fortis*) that lives in the Galápagos Islands, an archipelago made up of a small group of islands located 600 miles off the coast of mainland Ecuador in South America (see Figure L18.1). There is a small island in the Galápagos called Daphne Major (see Figure L18.2).

**FIGURE L18.2**

Daphne Major



Biologists Peter and Rosemary Grant have been studying the medium ground finch population on Daphne Major since 1974. They travel to Daphne Major every summer to study these birds. They capture, tag, and measure the physical characteristics of every bird on the island. They also keep track of the ones that die. Finally, and most importantly, they keep track of when a bird breeds, how many offspring it produces, and how many of those offspring survive long enough to breed.

In the summer of 1976, there were 751 finches on Daphne Major when the Grants left the island. The 1976 medium ground finch population had an average beak depth of 9.65 mm and an average beak length of 10.71 mm. In 1977 a severe drought began, and only 20 mm of rain fell on the island over the entire year. Much of the plant life on the island withered and died. The medium ground finches on Daphne Major, as a result, struggled to find food, and the population quickly decreased in size. By the end of 1978, there were only 90 finches left on the island. When the Grants returned to Daphne Major in 1978 to study the

### *Which Mechanism of Microevolution Caused the Beak of the Medium Ground Finch Population on Daphne Major to Increase in Size From 1976 to 1978?*

characteristics of the finch population, they made an unexpected discovery. They found that the average size of the beak for the medium ground finch on this island had increased. The 1978 population of the medium ground finch population on Daphne Major had an average beak depth of 10.55 mm and an average beak length of 11.61 mm, which was almost a full mm thicker and longer than the 1976 population. The beak of the medium ground finch population had clearly evolved in only two years.

The dramatic increase in the size of the medium ground finch beak was a clear example of microevolution. The Grants therefore wanted to determine which mechanism of microevolution caused the dramatic change in beak size. After they had analyzed the data that they had collected from 1976 to 1978, the Grants proposed that natural selection was the mechanism that caused the beak of the medium ground finch to increase in size. Some scientists, however, thought that this explanation was unacceptable because the change in the trait happened in only two years, and they viewed natural selection as a slow and gradual process. These scientists suggested that a better explanation for the increase in beak size was migration or genetic drift. In this investigation, you will use the data that the Grants collected on Daphne Major to determine which of these three explanations is the most valid or acceptable.

### **Your Task**

Use the Grant's finch data set and what you know about migration, natural selection, and genetic drift to determine which of these three mechanisms of microevolution caused the average size of the medium ground finch beak to increase from 1976 to 1978.

The guiding question of this investigation is, **Which mechanism of microevolution caused the beak of the medium ground finch population on Daphne Major to increase in size from 1976 to 1978?**

### **Materials**

You will use an Excel file called Finch Data during this investigation.

### **Safety Precautions**

Follow all normal lab safety rules.

**Investigation Proposal Required?**    Yes       No

### **Getting Started**

You will need to examine the characteristics of the medium ground finch on Daphne Major before and after the drought of 1977 in order to answer the guiding question for this investigation. Luckily, we know a lot about the physical characteristics of all the medium ground finches found on Daphne Major.

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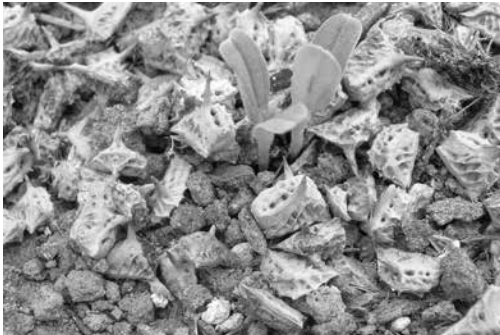
**FIGURE L18.3** \_\_\_\_\_  
A medium ground finch



The medium ground finch is a small brown bird (see Figure L18.3). Their brown color helps them blend into their surroundings and avoid the owls that live on the island. (Owls eat small birds.) As with any species, no two medium ground finches are exactly alike. Medium ground finches weigh between 12 and 17 grams and have wings that range in size from 60 mm to 70 mm. These birds also have small beaks. The beak of a medium ground finch ranges in size from 8 mm to 13 mm. The medium ground finch eats seeds (which they must crack open before eating) and the occasional insect.

You may also need to examine the characteristics of the plant life found on Daphne Major before, during, and after the drought of 1977. There are two species of seed-producing plants on Daphne Major: *Tribulus terrestris* (puncturevine) and *Portulaca oleracea* (purslane). The *Tribulus* plants produce large, hard seeds (Figure L18.4) and the *Portulaca* plants produce small, soft seeds (Figure L18.5). Medium ground finches tend to eat seeds from the *Portulaca* plants because they are soft and easy to get.

**FIGURE L18.4** \_\_\_\_\_  
Seeds produced by the *Tribulus* plant



**FIGURE L18.5** \_\_\_\_\_  
Seeds produced by the *Portulaca* plant



You will be given the observations and measurements collected by the Grants. These data have been entered into an Excel spreadsheet. The spreadsheet will make it easier for you to analyze all the available data. To answer the guiding question for this investigation, however, you must determine what type of data you will need to examine and how you will analyze it. To determine *what data you will need to examine and how you will analyze these data*, think about the following questions:

### *Which Mechanism of Microevolution Caused the Beak of the Medium Ground Finch Population on Daphne Major to Increase in Size From 1976 to 1978?*

- What would you expect to see if the change in beak size in the 1976 and 1978 populations of the medium ground finch was caused by migration? Natural selection? Genetic drift?
- What types of comparisons will you need to make between the two populations to test each of the three explanations?
- Are there trends or relationships that you will need to look for in the data?
- Are there other factors that may help you test each explanation?

### **Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry**

As you work through your investigation, be sure to think about

- the important role that conceptual models play in science,
- the relationship between structure and function in nature,
- the different types of methods that scientists use to answer questions, and
- the difference between laws and theories in science.

### **Initial Argument**

Once your group has finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a claim, evidence to support your claim, and a justification of the evidence. The claim is your group's answer to the guiding question. The evidence is an analysis and interpretation of your data. Finally, the justification of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L18.6.

### **Argumentation Session**

The argumentation session allows all of the groups to share their arguments. One member of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations one at a time to listen to and critique the arguments developed by their classmates. This is similar to how scientists present their arguments to other scientists at conferences. If you are responsible for critiquing your classmates' arguments, your goal is to look for mistakes so these mistakes can be fixed and they can make their argument better. The argumentation session is also a good time to think about ways you can

**FIGURE L18.6** \_\_\_\_\_  
**Argument presentation on a whiteboard**

The Guiding Question:	
Our Claim:	
Our Evidence:	Our Justification of the Evidence:

# LAB 18

make your initial argument better. Scientists must share and critique arguments like this to develop new ideas.

To critique an argument, you might need more information than what is included on the whiteboard. You will therefore need to ask the presenter lots of questions. Here are some good questions to ask:

- What did your group do to analyze the data? Why did your group decide to analyze it that way?
- What other ways of analyzing and interpreting the data did your group talk about?
- Why did your group decide to present your evidence in that way?
- Why did your group abandon the other explanations?
- How sure are you that your group's claim is accurate? What could you do to be more certain?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

## Report

Once you have completed your research, you will need to prepare an investigation report that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. The report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!

### **Checkout Questions**

## **Lab 18. Environmental Change and Evolution: Which Mechanism of Microevolution Caused the Beak of the Medium Ground Finch Population on Daphne Major to Increase in Size From 1976 to 1978?**

Use the following information to answer questions 1–3.

The beach mouse (*Peromyscus polionotus*), shown in the figure below, is a small rodent found in the southeastern United States. It lives primarily in old fields and on white sand beaches. The fur of the beach mouse ranges from dark brown to very light brown. The darkest-color mice tend to live inland, and the lighter-color mice tend to live on light sand beaches.



**A dark brown beach mouse**

Some scientists think the trend in the coloration of the beach mouse is due to natural selection, and others think it is due to genetic drift.

1. Describe the process of natural selection, and explain how this process could result in darker-color mice living inland and lighter-color mice living on light sand beaches.

# LAB 18

2. Describe the process of genetic drift and explain how this process could result in darker-color mice living inland and lighter-color mice living on light sand beaches.
  
3. Describe a test that you could conduct to determine if pattern in mouse coloration is due to natural selection or genetic drift.
  
4. Scientists often use existing models or develop a new model to help understand a system. Explain why models are useful in science, using an example from your investigation about environmental change and evolution.



*Which Mechanism of Microevolution Caused the Beak of the Medium Ground Finch Population on Daphne Major to Increase in Size From 1976 to 1978?*

5. The structures that make up an organism's body are not related to the functions they perform.
- I agree with this statement.
  - I disagree with this statement.

Explain your answer, using an example from your investigation about environmental change and evolution.

6. A scientific law describes the behavior of a natural phenomenon, and a scientific theory is a well-substantiated explanation of some aspect of the natural world.
- I agree with this statement.
  - I disagree with this statement.

Explain your answer, using an example from your investigation about environmental change and evolution.

7. There is no universal step-by-step scientific method that all scientists follow; rather, the choice of method depends on the objectives of the research. Explain why scientists need to use different types of methods to answer different types of questions, using an example from your investigation about environmental change and evolution.

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# Argument-Driven Inquiry

in

## LIFE SCIENCE



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