



# SCIENTIFIC ARGUMENTATION IN BIOLOGY

**30** CLASSROOM  
ACTIVITIES

VICTOR SAMPSON  
SHARON SCHLEIGH

**NSTA**press  
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# Preface

## What Is Scientific Argumentation?

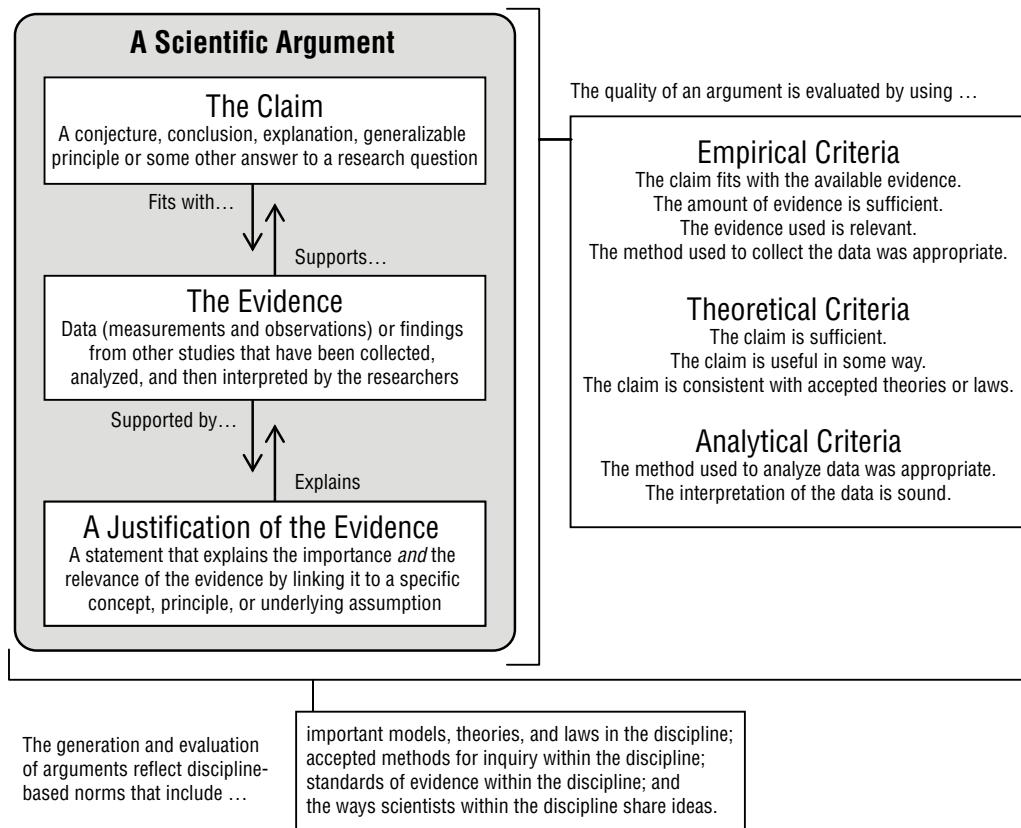
Scientific argumentation is an important practice in science. We define scientific argumentation as an attempt to validate or refute a claim on the basis of reasons in a manner that reflects the values of the scientific community (Norris, Phillips, and Osborne 2007). A claim, in this context, is not simply an opinion or an idea; rather, it is a conjecture, explanation, or other conclusion that provides a sufficient answer to a research question. The term *reasons* is used to describe the support someone offers for a conclusion. The term *evidence* is often used to describe the reasons used by scientists, especially when the support is based on data gathered through an investigation. Yet reasons do not have to be based on measurements or observations to be viewed as scientific. Charles Darwin, for example, provided numerous reasons in *The Origin of Species* to support his claims that all life on Earth shares a common ancestor, biological evolution is simply descent with modification, and the primary mechanism that drives biological evolution is natural selection. Some of the reasons that Darwin used were theoretical in nature, such as appealing to population theory from Malthus and the

ideas of uniformitarianism advocated by Lyell, while others were more empirical in nature, such as the appeals he made to the data that he gathered during his voyage to Central and South America. What made “Darwin’s one long argument” (Mayr 1964, p. 459) so convincing and persuasive to others, however, was the way he was able to coordinate theory and evidence in order to validate his claims.

It is also important for teachers and students to understand how an argument (i.e., a written or spoken claim and support provided for it) in science is different than an argument that is used in everyday contexts or in other disciplines such as history, religion, or even politics. In order to make these differences explicit, we use the framework illustrated in Figure 1 (p. x).

In this framework, a claim is a conjecture, conclusion, explanation, or a descriptive statement that answers a research question. The evidence component of the argument refers to measurements, observations, or even findings from other studies that have been collected, analyzed, and then interpreted by the researchers. Biologists, for example, will often examine the data they collect in order to determine if there is (a) a trend over time, (b) a difference between groups or objects, or

**Figure 1. A Framework That Can Be Used to Illustrate the Components of a Scientific Argument and Some Criteria That Can and Should Be Used to Evaluate the Merits of a Scientific Argument**



(c) a relationship between variables, and then they interpret their analysis in light of their research question, the nature of their study, and the available literature. Finally, the justification of the evidence component of the argument is a statement or two that explains the importance and the relevance of the evidence by

linking it to a specific principle, concept, or underlying assumption.

It is also important for students to understand that some forms of evidence and some types of reasons are better than others in science. An important component of scientific argumentation involves the evaluation of the acceptability and

sufficiency of the evidence or reasons that are used to support or challenge a claim. Therefore, in addition to the structural components of an argument, the framework in Figure 1 also highlights several empirical and theoretical criteria that students can and should use to evaluate the quality or merits of an argument in science. Empirical criteria include (a) how well the claim fits with all available evidence, (b) the sufficiency of the evidence included in the argument, (c) the quality of the evidence (i.e., validity and reliability), and (d) the predictive power of the claim. Theoretical criteria, on the other hand, refer to standards that are important in science but are not empirical in nature. These include criteria such as (a) the sufficiency of the claim (i.e., it includes everything it needs to), (b) the usefulness of the claim (e.g., it allows us to engage in new inquiries or understand a phenomenon), and (c) how consistent the claim and the reasoning is with other accepted theories, laws, or models. What counts as quality within these different categories, however, varies from discipline to discipline (e.g., physics, biology, geology) and within the fields that are found with a discipline (e.g., cell biology, evolutionary biology, genetics) due to differences in the types of phenomena investigated, what counts as an accepted mode of inquiry (e.g., experimentation vs. fieldwork), and the theory-laden nature of scientific inquiry. It is therefore important to keep in mind that the nature of scientific arguments and what counts as quality in science is discipline- and field-dependent.

## **Why Integrate Argumentation Into the Teaching and Learning of Biology?**

A major aim of science education in the United States is for all students to become proficient in science by the time they finish high school. Science proficiency consists of four interrelated aspects (Duschl, Schweingruber, and Shouse 2007). 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. Second, it requires an individual to be able to generate and evaluate scientific explanations and scientific arguments. Third, individuals need to understand the nature of scientific knowledge and how scientific knowledge develops over time. Finally, and perhaps most importantly, individuals that are proficient in science should be able to understand the language of science and be able to participate in scientific practices (such as inquiry and argumentation). Empirical research, however, indicates that many students do not develop this knowledge or these abilities while in school (Duschl, Schweingruber, and Shouse 2007; NRC 2005, 2008).

One way to address this problem is to engage students in scientific argumentation as part of the teaching and learning of biology (Driver, Newton, and Osborne 2000; Duschl 2008; Duschl and Osborne

## PREFACE

2002). In order to help students develop science proficiency by engaging them in scientific argumentation, however, the focus and nature of instruction inside biology classrooms will need to change from time to time. This change in focus, in part, will require teachers to place more emphasis on “how we know” in biology (i.e., how new knowledge is generated and validated) in addition to “what we know” about life on Earth (i.e., the theories, laws, and unifying concepts). Science teachers will also need to focus more on the abilities and habits of mind that students need to have in order to construct and support scientific knowledge claims through argument and to evaluate the claims or arguments developed by others.

In order to accomplish this goal, science teachers will need to design lessons that give students an opportunity to learn how to generate explanations from data, identify and judge the relevance or sufficiency of evidence, articulate and support an explanation in an argument, respond to questions or counterarguments, and revise a claim (or argument) based on the feedback they receive or in light of new evidence. Science teachers will also need to find a way to help students learn, adopt, and use the same criteria that biologists use to determine what counts as warranted scientific knowledge in a particular field of biology. This task, however, can be difficult for teachers to accomplish given the constraints of a science classroom without the development of new instructional strategies or techniques (Price Schleigh, Bosse, and Lee 2011). We have

therefore used the available literature on argumentation in science education (e.g., Berland and Reiser 2009; Clark, Schleigh, and Menekse 2008; McNeill and Krajcik 2008a; Osborne, Erduran, and Simon 2004; Sampson and Clark 2008; Sandoval and Reiser 2004) to develop two different instructional models that teachers can use to promote and support student engagement in scientific argumentation in the biology classroom. We have also designed several stand-alone writing activities that teachers can use to help students learn how to write extended arguments that consist of multiple lines of reasoning that will help solidify their understanding of important biology content as part of the process.

All of these activities are designed so they can be used at different points during a biology course and in a variety of grade levels to help students learn how to generate a convincing scientific argument and to evaluate the validity or acceptability of an explanation or argument in science. In fact, we have used these activities included in this book to engage learners in scientific argumentation in middle school classrooms, high school classrooms, and in science teacher education programs. The activities in this book can also be used to help students understand the practices, crosscutting concepts, and core ideas found in *A Framework for K–12 Science Education* (NRC 2012) and develop the literacy in science skills outlined in the *Common Core State Standards for English Language Arts and Literacy* (NGA and CCSSO 2010).

## Development of the Activities

The integration of scientific argumentation into the teaching and learning of biology can be difficult for both the teachers and students. In fact, teachers often ask for specific instructional strategies and engaging activities based on these instructional activities that would allow students to learn how to engage in scientific argumentation as part of the inquiry process (see Sampson and Blanchard, forthcoming). We have also received many requests to help teachers develop the skills in facilitating this kind of activity inside the classroom. We have designed this book to satisfy these requests. This book's instructional strategies and the activities based on these strategies are grounded in not only current research on argumentation in science education (Berland and McNeill 2010; Clark et al. 2008; Driver, Newton, and Osborne 2000; Erduran and Jimenez-Aleixandre 2008; Jimenez-Aleixandre, Rodriguez, and Duschl 2000; McNeill and Krajcik 2008b; McNeill et al. 2006; Osborne, Erduran, and Simon 2004; Sampson and Blanchard, forthcoming; Sampson and Clark 2008, 2009; Sampson, Grooms, and Walker 2011) but also our experiences inside the classroom. Each activity has been field-tested in at least one middle school or high school (see Appendix A, p. 367, for a list of field test sites and teachers). The classrooms we used to test the activities were diverse and represented a wide range of student achievement levels (honors, general, advanced, and so on).

We used teacher comments and suggestions to refine the activities and to provide the guidance teachers need to implement the activities as Teacher Notes.

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# Introduction

**M**any science educators view inquiry as a key component of any effort to help students develop science proficiency (Duschl, Schweingruber, and Shouse 2007; NRC 2008, 2012). Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry refers to the understanding of how scientists study the natural world as well as the activities that students engage in when they attempt to develop knowledge and understanding of scientific ideas (NRC 1999). Students who learn science through inquiry are able to participate in many of the same activities and thinking processes as scientists do when they are seeking to expand our understanding of the natural world (NRC 2000). Yet educators seeking to engage students in inquiry inside the classroom do not always emphasize many of the activities and thinking processes used by scientists to generate and evaluate scientific knowledge.

Within the context of schools, scientific inquiry is often conceptualized as a straightforward process of “asking a question, devising a means to collect data to answer the question, interpreting

this data, and then drawing a conclusion” (Sandoval and Reiser 2004, p. 345). Instruction, therefore, tends to focus on helping students master specific *skills* that are important to this process. Examples of such skills are formulating good research questions, designing controlled experiments, making careful observations, and organizing or graphing data. Although these types of skills are an important part of the inquiry process, they are often overemphasized at the expense of other important practices in inquiry such as proposing and testing alternatives, judging the quality or reliability of evidence, evaluating the potential viability of scientific claims, and constructing scientific arguments. As a result, typical science classrooms tend to place too much emphasis on individual exploration and the importance of experimentation in the inquiry process, which can cause students to develop an inaccurate understanding of how scientists study the natural world and how new knowledge is generated, justified, and evaluated by scientists (Duschl and Osborne 2002; Lederman and Abd-El-Khalick 1998; Osborne 2002; Sandoval 2005).

In light of this issue, *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* highlights a



set of practices—such as asking questions, developing and using models, analyzing data, and communicating information—that students need to learn in order to be able to engage in inquiry (NRC 2012). The *Framework* also calls for explanation and argument to play a more central role in the teaching and learning of science. The *Framework* views explanation and argument as both the goal of an inquiry and the means to get there; that is, students construct explanations and supporting arguments in order to understand the phenomenon under investigation, and they also use explanation and argument as a guide to engage in the inquiry process (Bell and Linn 2000; Goldman et al. 2002; Sandoval and Reiser 2004). The National Research Council (NRC) made argumentation a foundation of the new framework because:

All ideas in science are evaluated against alternative explanations and compared with evidence; acceptance of an explanation is ultimately an assessment of what data are reliable and relevant and a decision about which explanation is the most satisfactory. Thus knowing why the wrong answer is wrong can help secure a deeper and stronger understanding of why the right answer is right. Engaging in argumentation from evidence about an explanation supports students' understanding of the reasons and empirical evidence for that explanation, demonstrating

that science is a body of knowledge rooted in evidence. (2012, p. 44)

In order to make engaging in argument from evidence an important practice *within* a science classroom, teachers need to help students develop the abilities and habits of mind needed to generate explanations and evaluate the conclusions or claims put forth by others. Teachers, therefore, need to give students opportunities to learn how to articulate a claim, support it with evidence, respond to critiques, and revise a claim based on feedback or new evidence. This type of focus supports learning by establishing a context for students that allows them to contrast varied forms of evidence, link evidence to methods, explore the criteria for selecting evidence, and reflect on the nature of scientific investigation (Abell, Anderson, and Chezem 2000). Driver et al. (1994) argue that these types of goals are not additional extraneous aspects of science but instead represent an essential element of science education. Jimenez-Aleixandre et al. emphasize the same idea:

Argumentation is particularly relevant in science education since a goal of scientific inquiry is the generation and justification of knowledge claims, beliefs and actions taken to understand nature. Commitments to theory, methods, and aims are the outcome of critical evaluation and debates among communities of scientists. (2000, p. 758)

Current research in science education also supports calls to integrate argumentation in the teaching and learning. First, several studies have demonstrated that students who engage in argumentation as part of an inquiry often change or refine their image of science (Bell and Linn 2000; Price Schleigh, Bosse, and Lee 2011) or enhance their understanding of the nature of scientific knowledge (Yerrick 2000), because learners are able to experience the nature of science firsthand (Driver et al. 1994; Duschl 2000). Second, several studies have shown that students can learn to develop a better understanding of important content knowledge by engaging in argumentation (Bell and Linn 2000; Zohar and Nemet 2002). Third, current research indicates that argumentation encourages learners to develop different ways of thinking, because they have more opportunities to engage in the reasoning and discursive practices of scientists (Brown and Palincsar 1989; Kuhn 1993; Sandoval and Millwood 2005). Finally, research has demonstrated that opportunities to engage in argumentation as part of the inquiry process can improve students' investigative competencies (Sandoval and Reiser 2004; Tabak et al. 1996). Taken together, these studies provide strong support for efforts to integrate argumentation into science education.

There are a number of strategies or approaches that biology teachers can use to integrate argumentation into the teaching and learning of biology. One approach, which is frequently described in the science education literature, involves

engaging students in the production and evaluation of scientific arguments. This approach frames the goal of inquiry as the construction of a good argument that provides and justifies a conclusion, explanation, or some other answer to a research question. Students develop one or more ways to investigate the phenomenon, make sense of the data they gather, and produce an argument that makes clear their understanding. The quality of these arguments then becomes the focal point of discussion in the classroom as students evaluate and critique methods, explanations, evidence, and reasoning (Erduran and Jimenez-Aleixandre 2008; Sandoval and Reiser 2004).

Another common framework for promoting and supporting scientific argumentation in classrooms has focused on designing activities or tasks that require students to examine and evaluate alternative theoretical interpretations of a particular phenomenon (Erduran and Jimenez-Aleixandre 2008; Monk and Osborne 1997; Osborne, Erduran, and Simon 2004). This type of approach provides opportunities for students to examine competing explanations, evaluate the evidence that does or does not support each perspective, and construct arguments justifying the case for one explanation or another.

Finally, teachers can also engage students in argumentation by requiring them to write a refutational essay. A refutational essay—which is designed to give students an opportunity to not only write

to learn but also learn how to write at the same time— requires students to explain why a common misconception is inaccurate and then explain why a scientific view is more valid or acceptable from a scientific perspective.

The activities included in this book were designed based on this literature. The first 10 activities were designed using an instructional model called Generate an Argument (Sampson and Grooms 2010). This model requires students to develop a claim that answers a research question based on a supplied data set. The second set of 10 activities were designed using the Evaluate Alternatives instructional model (Sampson and Grooms 2009). This model requires students to collect data in order to test the merits of two or three alternative explanations. The remaining 10 activities are refutational writing activities. These activities are designed to give students an opportunity to write to learn and learn to write at the same time. In the sections that follow, we will describe how each of the models or techniques work.

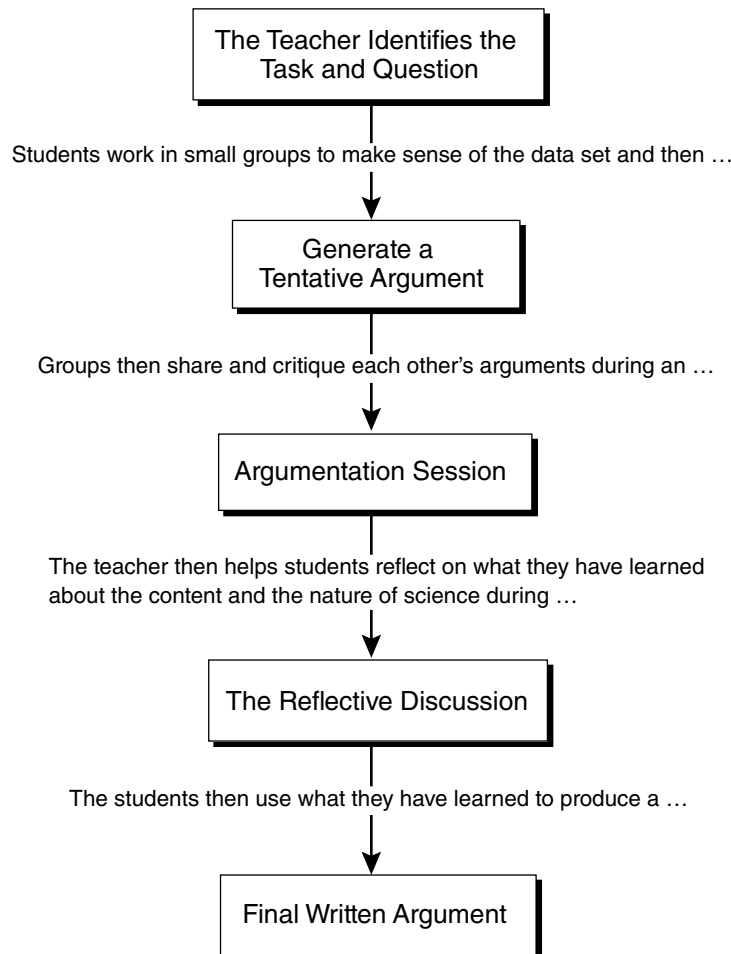
### **Generate an Argument Instructional Model**

This instructional model is designed to provide an opportunity for small groups of students to develop a claim that answers a research question based on an available data set. As part of this process, groups create a tentative argument that provides this claim and the evidence that supports it, using a medium that can be viewed by others. Each group then has an

opportunity to share their ideas during an argumentation session. These sessions are designed to create a need for students to discuss the validity or acceptability of the various arguments based on the available information. Based on the outcomes of these discussions, students refine their claims in order to better explain or describe the phenomenon under investigation. Each student is required to write and submit a final argument to his or her teacher for the purpose of assessment. To conclude the activity, the teacher leads a whole-class reflective discussion and encourages students to consider what they learned about the content and the nature of science. This model consists of five stages (see Figure 2).

### **Stage 1: The Identification of a Problem and the Research Question**

The teacher initiates the activity by identifying a problem to investigate and a research question for the students to answer. The goal of the teacher at this stage is to capture the students' interest and provide them with a reason to engage in the activity. To do this, the teachers should make photocopies of the activity and distribute to each student in the class. The pages include a brief introduction to a puzzling phenomenon or a discrepant event and a research question to answer. The pages also include information about the nature of the artifact they will need to produce (i.e., an argument), the data set they will use to develop these artifacts, and some criteria that will be

**Figure 2. Stages of the Generate an Argument Instructional Model**

used to judge argument quality (e.g., the sufficiency of the explanation, the quality of the evidence, and so on). The classroom teacher should have a different student read each section of the activity aloud and then pause after each section to clarify expectations, answer questions, or provide additional information as needed. Once all the students understand the goal of the activity, the teacher should divide

the students into small groups (we recommend three students per group), and move on to the second stage of the model.

### **Stage 2: The Generation of a Tentative Argument**

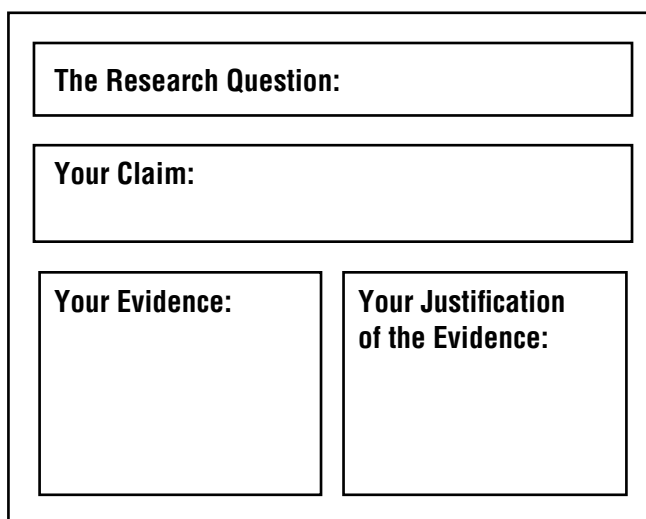
The next stage of the instructional model calls for students to use the raw data that is supplied during the first stage of the model to develop an answer to

the research question. To do this, each group of students need to be encouraged to first make sense of the provided measurements (e.g., size, temperature) or observations (e.g., appearance, location, behavior) by looking for trends over time, difference between groups, or relationships between variables. Once the groups have examined and analyzed the data, they are instructed to create a tentative argument that consists of (1) their answer to the research question, (2) their evidence (the data that has been analyzed and interpreted), and (3) a rationale (i.e., a statement that explains why the evidence they decided to use is important or relevant) on a medium that can be easily viewed by their classmates (see Figure 3). We recommend using a 2 ft. × 3 ft.

whiteboard, such as the example shown in Figure 4, a large piece of butcher paper, or a digital display on a group computer.

The intention of this stage is to provide students with an opportunity to make sense of what they are seeing or doing. As students work together to create a tentative argument, they must talk with each other and determine how to analyze the data and how to best interpret the trends, difference, or relationships that they uncover. They must also decide if the evidence (i.e., data that have been analyzed and interpreted) they decide to include in their argument is relevant, sufficient, and convincing enough to support their claim. This, in turn, enables students to evaluate competing ideas and weed out any claim that is inaccurate,

**Figure 3. The Components of an Argument for Stage 2 of the Generate an Argument Instructional Model**



**Figure 4. An Example of an Argument Created by High School Students**

Question: Which of these Patients could have Cancer?  
 Claim: Slide two is an example of a cancer patient.

Evidence

Cell Type	Total Cell	Cell's in Mitosis	% of Cells in Mitosis
Onion	376	34	9%
Parascarium	36	4	11%
Pat. 1	432	56	12%
Pat. 2	331	69	20%

Justification:

1. Most cells spend their time in interphase
2. If that is the case, we can infer that only a small % of healthy cells are in mitosis
3. After evaluating 2 different normal samples of healthy cells, we saw a 9% & 11% concentration of cells in mitosis.
4. Patient 1 had a 12% mitosis rate consistent w/ healthy cells, Patient 2 had double of the % of mitosis rate.
5. Therefore, since we know cancer cells are the result of unchecked mitosis, then Patient 2 would be the most probable candidate for cancer.

contains contradictions, or does not fit with all the available data.

This stage is also designed to focus students' attention on the importance of argument in science. In other words, students need to understand that scientists must be able to support a conclusion, explanation, or an answer to a research question with appropriate evidence and then justify their use or choice of evidence with an adequate rationale. It also helps students develop new standards for what counts as high-quality evidence and a sufficient or adequate rationale (i.e., statements that explains why the evidence is important or relevant to the task at hand).

This stage of the model can be challenging for students because they are rarely asked to make sense of a phenom-

enon based on raw data. We therefore recommend that the classroom teacher circulate from group to group in order to act as a resource person for the students. It is the goal of the teacher at this stage of the model to ensure that students think about what they are doing and why. For example, teachers should ask students probing questions to help them remember the goal of the activity (e.g., *What are you trying to figure out?*), to encourage them to think about whether or not the data are relevant (e.g., *Why is that characteristic important?*), or to help them to remember to use rigorous criteria to evaluate the merits of an idea (e.g., *Does that fit with all the data or what we know about the solar system?*). It is also important to remember that students will struggle with this type of practical work at the beginning of the

year and will often rely on inappropriate criteria such as plausibility (e.g., “That sounds good to me”) or personal experience (e.g., “But that is what I saw on TV once”) as they attempt to make sense of the content. However, over time and with enough practice students will improve their skills. This is an important principle underlying this instructional model.

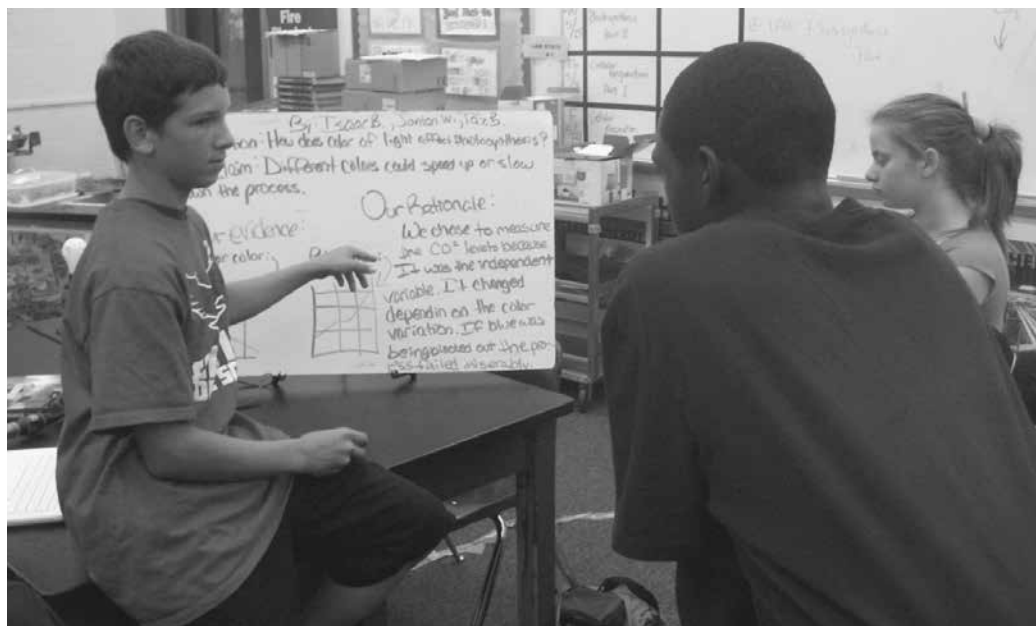
### Stage 3: The Argumentation Session

The third stage in the Generate an Argument instructional model is called the argumentation session. In this stage, students are given an opportunity to share, evaluate, and revise the products or process of their investigations with their classmates (see Figure 5). This stage is included in the model because research indicates that students learn more about

the content and how to engage in better critical thinking when they are exposed to the ideas of others, respond to the questions and challenges of other students, articulate more substantial warrants for their views, and evaluate the merits of competing ideas (NRC 2008). It also provides an opportunity for students to learn how to distinguish between ideas using rigorous scientific criteria and to develop more scientific habits of mind (such as treating ideas with initial skepticism, insisting the reasoning and assumptions are made explicit, and insisting that claims are supported by valid reasons).

It is important to note, however, that supporting and promoting this type of interaction among students inside the classroom is often difficult because this type of discussion is foreign to most stu-

**Figure 5. The Argumentation Session**



dents. This is one reason why students are required to generate their arguments on a medium that can be seen by others. This helps students to focus their attention on evaluating evidence and reasoning rather than attacking the source of the ideas. We also recommend that teachers use a round-robin format rather than a whole-class presentation format. In the round-robin format, one member of the group stays at the workstation to share the group's ideas while the other group members will go to different groups one at a time in order to listen to and critique the explanations developed by their classmates. (See Figures 6 below and 7 [p. xxiv]. In Figure 7, students A1, B1, and C1 stay at their table while other students move from table to table in sequence to listen to and evaluate the arguments of the other groups.) This type of format ensures that all ideas are heard and more students are actively involved in the process.

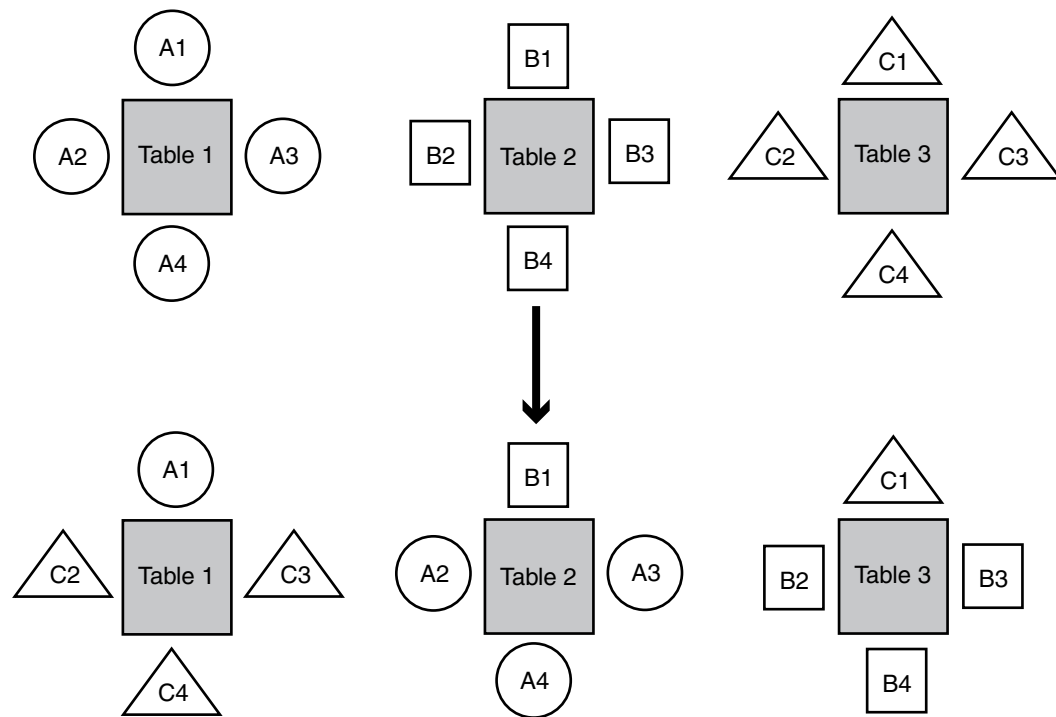
It is also important for the classroom teacher to be involved in the discus-

sion during the argumentation session. The teacher should move from group to group not only to keep students on task but also to model good scientific argumentation. The teacher can ask the presenter questions such as *How did you analyze the available data?* or *Was there any data that did not fit with your claim?* to encourage students to use empirical criteria to evaluate the quality of the arguments. The teacher can also ask the presenter to explain how the claim fits with the theories, laws, or models of science or to explain why the evidence is important. In addition, the teacher can also ask the students who are listening to the presentation questions such as *Do you think their analysis is accurate?* or *Do you think their reasoning is appropriate?* or even *Do you think their interpretation is correct?* in order to remind them to use analytical criteria during the discussions. Overall, the goal of the teacher at this stage of the lesson is to encourage students to think about how they know

**Figure 6. A Round-Robin Argumentation Session**





**Figure 7. Example of a Round-Robin Argumentation Session**

what they know and why some claims are more valid or acceptable in science. It is not the time to tell the students if they are right or wrong.

#### Stage 4: A Reflective Discussion

The next stage in this instructional model is for the original groups to reconvene and discuss what they learned by interacting with individuals from the other groups. They should then modify their tentative argument as needed or conduct an additional analysis of the data. After the teacher gives the students a chance to debrief with their group, the teacher should lead a whole-class discussion. The teacher should encourage the students

to explain what they learned about the phenomenon under investigation. This enables the classroom teacher to ensure the class reaches a scientifically acceptable conclusion and thinks about ways to improve the nature of their arguments in the future. The teacher can also discuss any issues that were a common challenge for the groups during the second and third stage of the activity.

#### Stage 5: The Production of a Final Written Argument

In the final stage of the model, each student is required to make sense of his or her experience by producing a final argument in writing. This component is included in

the instructional model because writing is an important part of doing science. Scientists must be able to read and understand the writing of others as well as evaluate its worth. They also must be able to share the results of their own research through writing. In addition, writing helps students learn how to articulate their thinking in a clear and concise manner; it encourages metacognition and improves student understanding of the content (Wallace, Hand, and Prain 2004). Finally, and perhaps most importantly, writing makes each student's thinking visible to the teacher (which facilitates assessment) and enables the teacher to provide students with the educative feedback they need to improve.

In order to help students learn how to write a persuasive and convincing scientific argument, we use the prompt provided in Figure 8. This prompt is

designed to encourage students to think about what they know, how they know it, and why they accept it over alternatives. It is also designed to encourage students to think about the organization, sentence fluency, word choice, and writing conventions. Teachers can make a photocopy of the prompt for each student and have the student write his or her argument under the prompt. To reduce photocopies and paper usage, the teacher can also project the prompt on a screen by using a document camera, an overhead projector, or a computer for all students in the class to see and have students write their argument on their own piece of paper. In addition, teachers can have students write their arguments using a word processing application (or in another digital medium such as a wiki). A rubric for scoring these arguments is provided in Appendix B (p. 366). This rubric includes criteria that

**Figure 8. Writing Prompt for the Generate an Argument Instruction Model**

In the space below, write an argument in order to persuade another biologist that your claim is valid and acceptable. As you write your argument, remember to do the following:

- State the claim you are trying to support
- Include genuine evidence (data + analysis + interpretation)
- Provide a justification of your evidence that explains why the evidence is relevant and why it provides adequate support for the claim
- Organize your argument in a way that enhances readability
- Use a broad range of words including vocabulary that we have learned
- Correct grammar, punctuation, and spelling errors

target many of the components of a quality argument in science outlined on the previous page as well as the quality of the students' writing (e.g., organization, word choice, and conventions).

### **Evaluate Alternatives Instructional Model**

The Evaluate Alternatives instructional model is similar in many ways to the Generate an Argument model. This model, however, places more emphasis on the evaluation of alternative explanations and the importance of designing an informative investigation that can be used to test the merits of an explanation. To do this, students are placed into groups and then introduced to a phenomenon that needs to be explored, a research question, and two or three alternative explanations that provide an answer to the research question. The groups of students are then directed to design and carry out an investigation that will allow them to gather the data needed to either support or challenge the validity or acceptability of an explanation. Students are also provided with information about relevant scientific theories, laws, or models so they can use this information to provide a rationale for their evidence (i.e., data that has been collected, analyzed, and interpreted by the students). Once the groups of students gather the data they need, they create a tentative argument for the explanation that they consider most valid or acceptable and one or more counterarguments that challenge the other explanations. Each group then shares their ideas during

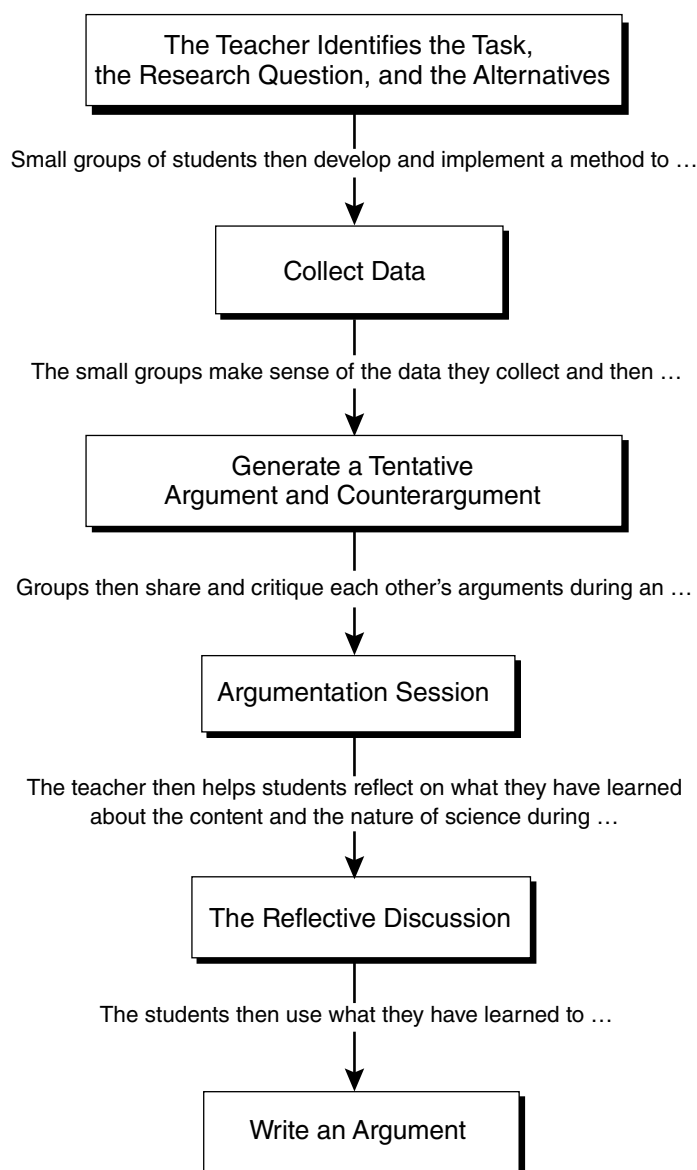
an argumentation session. After the critical discussions are finished, the students are given a chance to meet with their original groups to refine their arguments in an effort to better support or challenge the various explanations. To conclude the activity, each student is required to write and submit a final argument in support of one of the explanations *and* a counterargument that challenges the validity of the other two explanations.

This instructional model, like the Generate an Argument model, is also designed to help students develop a deeper understanding of (1) the content, (2) the empirical and theoretical grounding for that content, and (3) what counts as warranted knowledge in science, by providing students with an opportunity to discuss what they know, how they know it, and why they should accept the knowledge as the most valid or acceptable explanation. It will also give students an opportunity to improve their verbal communication and writing skills, their understanding of argumentation in science, and their critical-thinking skills, or scientific habits of mind. An activity designed using this model consists of six stages (see Figure 9).

#### **Stage 1: Introduce the Phenomenon to Investigate, the Research Question, and the Alternative Explanations**

The teacher, as noted earlier, initiates the activity by introducing a puzzling phenomenon to investigate. This stage of the model is designed to capture the

**Figure 9. Stages of the Evaluate Alternatives Instructional Model**



students' attention, or spark their curiosity, and to give them a reason to engage in scientific argumentation. To do this, the teacher should make a photocopy of the activity pages for each student (or the teacher can project the activity on a screen using a document camera, an overhead projector, or a computer). The activity pages provide students with information about the phenomenon under investigation, a research question to answer, and two or more alternative explanations to evaluate. The teacher should use the information provided to create a need for the students to make sense of the underlying cause of the phenomenon. Once the students have read the information and the teacher has answered any of their questions about the goal of the activity or the materials available for them to use, the teacher can then break the students into small groups (we suggest groups of three) and begin Stage 2 of the lesson.

### **Stage 2: The Generation of Data**

Each group must design and carry out an investigation that they can use to determine which alternative explanation provided on the activity pages is the most valid or acceptable. This stage provides students with an opportunity to learn how to design informative investigation and collect high-quality data. However, this type of practical work can be challenging for students because the strategies they use to generate data or to test ideas are often guided by a confirmation bias (i.e., the tendency to seek out data that support an existing belief while

ignoring or distorting everything else). This type of thinking will often prevent students from designing an investigation that tests the merits of each potential explanation in a systematic manner. Therefore, it is important for the teacher to circulate from group to group and act as a resource. It is also the goal of the teacher to ensure that students think about what they are doing and why. For example, teachers should ask students probing questions to help them remember the goal of the activity (e.g., *What are you trying to do?*) and to encourage them to think about what type of data they will need to collect (e.g., *What will you try to measure or observe?*). The teacher can also ask a probing question in order to remind the students of the importance of using a rigorous method (e.g., *If you don't include a comparison group how will you know that it changed? Do you think a single trial is enough?*) and to get them to think about how they will analyze their data once they have it collected (e.g., *How will you show that there is a difference between the two groups?*). Lastly, it is important for teachers to remember that students will struggle with this type of practical work when this instructional model is first implemented, but over time students will get better at designing investigations.

### **Stage 3: The Generation of Tentative Arguments and Counterarguments**

Next, the students should be directed to create a tentative argument on a medium that can be easily seen by others (see Figure 10). This argument should include

a claim that is supported by evidence and rationales. We also suggest that students develop a challenge for at least one of the alternative explanations on the same whiteboard. We recommend that teachers require students to construct their arguments and challenge using the template provided in Figure 11, which can also be found on each of the activity pages. This will help students understand and adopt new standards for what counts as warranted knowledge in science.

As in the other instructional model, we recommend that the classroom teacher circulate from group to group in order to act as a resource. The main goal of the teacher at this point is to help students think about what makes an argument persuasive or convincing in science (i.e., claims need to be supported by sufficient evidence and an adequate rationale). To do this, teachers should ask students probing questions to help them think about what counts as evidence and to encourage them to articulate the reasons behind their decision to collect a particular type of data or to complete a specific type of analysis. Teachers should also encourage students to include relevant theories and laws in their argument or counterargument in order to support the claims they are attempting to make.

#### Stage 4: An Argumentation Session

The fourth stage in the Evaluate Alternatives instructional model is an argumentation session. As in the Generate an Argument model, students are given an opportunity to share and critique

**Figure 10. Students Develop Tentative Arguments and Counterarguments on a Whiteboard**



**Figure 11. The Components of an Argument and Challenge**

<b>The Research Question:</b>	
<b>Your Claim:</b>	<b>An Alternative Claim:</b>
<b>Your Evidence:</b>	<b>Your Challenge to the Alternative Claim:</b>
<b>Your Justification of the Evidence:</b>	

the various arguments in a small group format. We once again recommend that teachers use the round-robin structure so more students have an opportunity to determine if the data gathered by other groups is relevant, sufficient, and convincing enough to support one explanation over another.

### **Stage 5: The Reflective Discussion**

The next stage in this instructional model is for the original groups to reconvene and discuss what they learned by interacting with individuals from the other groups. Based on the discussion, they should then modify their tentative argument or collect and analyze additional data as needed. After the teacher gives the students a chance to debrief with their group, the teacher should lead a whole-class discussion. The teacher should, as in the Generate an Argument instructional model, encourage the students to explain what they learned about the phenomenon under investigation and to think about ways to improve the nature of their arguments in the future. The teacher should also pose questions to discuss ways to improve future investigations (e.g., *Why is it important to include a control? Why is it important that we conduct multiple trials?*).

### **Stage 6: The Production of a Final Written Argument**

In the last stage of the lesson, each student is required to produce a written argument in support of one of the explanations that also includes a challenge to an alternative explanation. The prompt

provided in Figure 11 is included as part of the activity pages for each Evaluate Alternatives activity. This prompt is designed to encourage students to think about what they know, how they know it, and why one explanation is more valid or acceptable than the alternatives. It is also designed to encourage students to think about sentence fluency, word choice, and writing conventions. Perhaps more importantly, the writing prompt provides a summative assessment of student learning. Teachers can use the arguments and counterargument that students write to determine how well each student understands the content and how well he or she can provide evidence to support or challenge an explanation. A rubric for scoring the students' arguments is provided in Appendix C (p. 367).

### **Refutational Writing Activities**

This book, as discussed earlier, also includes several refutational writing activities (see Dlugokienski and Sampson 2008) that can be integrated into a unit. A refutational text introduces a common concept or idea; refutes it; offers an alternative concept, idea, or theory; and then attempts to show that this alternative way of thinking is more valid or acceptable (Guzzetti et al. 1997). An example of a refutation of the misconception that hypotheses become theories that in turn become laws can be seen in the following excerpt from a chapter written by William McComas, "The principal elements of the nature of science: Dispelling the myths of

**Figure 11. The Evaluate Alternatives Writing Prompt**

In the space below, write a one- to three-paragraph argument to support the explanation that you think is the most valid or acceptable. Your argument must also include a challenge to one of the alternative explanations.

As you write your argument, remember to do the following:

- State the explanation you are trying to support
- Include genuine evidence (data + analysis + interpretation)
- Explain why the evidence is important and relevant
- State the explanation you are trying to refute
- Explain why the alternative explanation is invalid or unacceptable
- Organize your argument in a way that enhances readability
- Use a broad range of words including vocabulary that we have learned
- Correct grammar, punctuation, and spelling errors

science.” The key sentence that identifies this passage as refutational in nature is in *italics*.

[There is a] general belief that with increased evidence there is a developmental sequence through which scientific ideas pass on their way to final acceptance as mature laws. The implication is that hypotheses and theories are less secure than laws. A former U.S. president expressed his misunderstanding of science by saying that he was not troubled by the idea of evolution because it was, in his words, “just a theory.” The president’s misstatement is the essence of this myth; an idea is not worthy of consideration until “law-ness” has been bestowed

upon it. *Theories and laws are very different kinds of knowledge, but the misconception portrays them as different forms of the same knowledge construct.* Of course there is a relationship between laws and theories, but it is not the case that one simply becomes the other—no matter how much empirical evidence is amassed. Laws are generalizations, principles, or patterns in nature and theories are the explanations of those generalizations. (Lederman and Abd-El-Khalick 1998, p. 56)

A text that is refutational in nature, such as the example provided, is one of three kinds of persuasive arguments that are often found in scientific writing (Hynd



2003). A one-sided persuasive argument only presents the concept, idea, or theory the author prefers a reader to adopt. Two-sided arguments can be nonrefutational or refutational. A two-sided, nonrefutational argument presents both sides of an issue but makes one side seem stronger by presenting more evidence, explaining it more logically, or in some other way making the argument more compelling yet without explicitly stating that the author prefers it. A refutational argument, in contrast, is more explicit than a nonrefutational argument about which is the preferred side.

Most textbooks and science trade books are written in an expository and authoritative style, and as a result usually do not include arguments. When they do, they often use one-sided arguments rather than refutational two-sided arguments. Thus, students are likely to be unfamiliar with this type of writing and will need explicit instruction, a great deal of practice, and good feedback in order to learn how to write in this manner. Science teachers, however, can help students learn to write a high-quality essay that is refutational in nature (and develop a better understanding of the content as part of the process) by using the refutational writing activities included in this book. These writing activities require students to produce an extended essay that refutes a common misconception related to an important biological concept (e.g., species do not evolve over time, or all bacteria cause disease) or to the nature of science (e.g., there is one scientific method, or theories turn into laws).

Each refutational writing prompt begins with a particular misconception to refute. It then outlines all the information a student will need such as the topic, the audience, the purpose, the form of the text, and reminders (Turner and Broemel 2006). The reminders are designed to focus the writer's attention on important components of a quality refutational text that novices often forget or overlook in their writing. The prompt then concludes with information about the steps of the writing process that the student should follow (e.g., conducting research, creating an outline, producing a rough draft, editing, and publication). It also provides a space for the teacher to assign a due date for each step of the process. A rubric for scoring the argument is provided in Appendix D (p. 368).

We recommend that teachers treat these writing activities as opportunities for students to conduct literature reviews as part of the writing process. We also suggest that the essays are at least 100 words long, that students type their initial and final draft, and include properly formatted in-text citations. Students need to write to learn but also need to learn how to write in the context of science. The refutational writing activities provide students with an opportunity to do both inside the biology classroom.

### **The Activities in This Book**

This book includes 30 activities. These activities have been organized into three sections based on type. Ten of the activi-

ties are designed around the Generate an Argument model, and 10 are designed using the Evaluate Alternatives model. The remaining 10 activities are refutational writing activities. The investigations in many of these activities require safety considerations. Certain activities contain safety notes as needed, but before any activity, teachers should review NSTA's "Safety in the Science Classroom," which can be found at <http://www.nsta.org/pdfs/SafetyInTheScienceClassroom.pdf>.

Teachers can use these activities to integrate more scientific argumentation into the teaching and learning of biology. When teachers use several of these activities over the course of an academic year (e.g., two or three per semester), students will not only have an opportunity to learn important content (i.e., learn from scientific argumentation), but they will also learn more about scientific argumentation (i.e., what counts as evidence, how to support claims, how to evaluate scientific argument) in Biology. These activities can also be used to improve students' communication and critical-thinking skills.

## **How to Use the Activities**

The activities in this book are not designed to replace an existing curriculum but to supplement what teachers are already doing in the classroom. The teacher notes for each activity will suggest content that should be covered before, during, and after the activities in order to best foster student learning. The teacher notes also highlight the aspects

of *A Framework for K–12 Science Education* that are aligned with each activity and the particular Common Core State Standards for English Language Arts and Literacy that the activity addresses. Lastly, the teacher notes also provide some suggestions for how to implement the activity in a particular context. It is suggested that teachers review the Curricular and Instructional Considerations section of each activity's teacher notes to best determine how the activity might supplement an existing curriculum. While we believe that the purpose of the activity is to help students understand important content and practices in science, teachers often need guidance about when to implement an activity and what to do before, during, and after a lesson. Reviewing this section will help teachers make these types of decisions.

The activities are flexible in that they can be used to at different points in the curriculum. A teacher can use these activities as a way to introduce students to new content or as a way to give students an opportunity to apply a theory, law, or unifying concept to a novel situation. Teachers can even use these activities as a way to allow students to demonstrate what they have learned after an instructional unit. To support student learning, we provide research related to misconceptions and suggestions to address the misconceptions.

In the Recommendations for Implementing the Activity section, we provide information about what teachers should look for while teaching and strategies

that teachers can use to execute the activity. We also provide information about how much instructional time the activity takes to complete and ways a teacher can break the activity over several days of instruction. Appendix E (p. 369) provides two options for implementing the Generate an Argument Activities, and Appendix F (p. 370) provides two options for implementing the refutational writing activities. These tricks of the trade come from both the feedback we received from the pilot teachers and our personal experiences with this type of instruction.

The development of a discourse community through the organization of group structures and interactions also plays an important role in promoting student engagement in scientific argumentation and the negotiation of meaning on both the group and individual level. While the activities that are based on the Generate an Argument and the Evaluate Alternatives instructional models provide opportunities for small-group and whole-class discussions, teachers must encourage all students to become active participants in the community. It is also important that interactions, whether in large or small groups, include opportunities for students to make their ideas explicit through oral, graphical, and written communication forms, in order to promote learning for both the student and the audience (Black et al. 2003). Although the activities could be implemented to take advantage of a wide variety of group interactions, our models rely on small-group interactions that lead

into large-group interactions and then lead back to the individual. Some develop argumentation skills more quickly by starting in small groups in which they can feel comfortable and safe in sharing their ideas and expressing disagreement with others. Teachers, however, need to be aware of the types of interactions that are taking place within each group and how individual member's skills are developing (or not developing) over time. We also recommend that teachers group students who have different ideas and varying skills in scientific processes and critical thinking. Heterogeneous groups will lead to better argumentation and more learning.

### **The Role of the Teacher During the Activities**

The goal of the teacher during these activities is to support the groups as they work and encourage students to negotiate meaning with one another. Teachers should, therefore, encourage students to critique one another's ideas about how they design and conduct their investigations, analyze data, and develop conclusions. Teachers need to guide or coach but should not explain or correct. The more independence students have to make decisions, the more ownership, responsibility, and accountability they gain when creating their conclusions and arguments. Students become more engaged, more motivated, more interested, and more invested, and learn more as a result. Teachers, however, need to ensure that throughout each activity students

are using criteria valued in science to critique and evaluate ideas. Teachers also need to assist students as they attempt to negotiate meaning during the activities. Collaborative intra- and intergroup discussions provide ample opportunity for socially constructing concepts or ideas by making claims (i.e., drawing inferences) and then supporting them with evidence based on the supplied data or data they collected during their investigations. The social construction and evaluation of claims requires students to use their own ideas but also interact with the ideas of the entire class.

In order to promote and support learning during these activities, teachers need to engage in certain behaviors and avoid others. Tables 1 and 2 (pp. xxxvi–xxxvii), therefore, provide examples of teacher behaviors that are consistent and inconsistent with each stage of the Generate an Argument instructional model and the Evaluate Alternatives instructional model. These recommendations, however, are not an exhaustive list; they are intended to illustrate what we think teachers should do and not do during these activities in order to make them as effective as possible.

## **Assessments**

We have provided a section dedicated to supporting the teacher in considering how to assess student learning. Knowing what students know and how their ideas may have changed is fundamental in being an effective teacher. This requires assessments that are both valid and reli-

able and are implemented at the right moment during instruction. Because each of the activities in this book requires students to share their ideas and content knowledge, the activities can serve as assessments as well as instructional tools. In the Assessments section, we provide suggestions on how each activity, as an assessment tool, may best serve the curriculum based on the purpose; however, the activities can easily be used at any time within the curriculum to serve many purposes of assessment or learning events. We suggest that the purpose of the activity and the action of the students be considered in determining when to use each activity and for what role in the assessment.

We also provide suggested rubrics to facilitate reliability during the teacher's evaluation of student work. In addition, we include student samples from our test classrooms to illustrate not only the kinds of work teachers might anticipate but also the way that the rubrics can be used to assess. It should be noted that these samples, although identified as high, medium, and low quality, are collected from different classrooms, different students, and different points within the curriculum and therefore do not serve as examples of learning progression.

The student samples from these activities can serve as assessments for different points within the curriculum depending on the point of implementation, the follow-up, and emphasis of the teacher. For diagnostic assessment, for example, a teacher might use one of

**Table 1. Generate an Argument Instructional Model Teacher Behaviors**

Stage	What the teacher does that is ...	
	Consistent with the Generate an Argument instructional model	Inconsistent with the Generate an Argument instructional model
1. The Identification of the Problem and the Research Question	<ul style="list-style-type: none"> <li>• Sparks the students' curiosity</li> <li>• Creates a need for the students to develop arguments</li> <li>• Organizes the students into collaborative groups</li> <li>• Supplies the students with the materials they will need</li> <li>• Provides the students with hints</li> </ul>	<ul style="list-style-type: none"> <li>• Provides students with possible answers to the research question</li> <li>• Allows students to organize into groups of existing consensus</li> <li>• Tells students that there is one correct answer</li> </ul>
2. The Generation of a Tentative Argument	<ul style="list-style-type: none"> <li>• Reminds students of the research questions and what counts as appropriate evidence in science</li> <li>• Requires students to generate an argument that provides and supports a claim with genuine evidence</li> <li>• Suggests that a model, diagram, or representation is created</li> <li>• Asks students what opposing ideas or rebuttals they might anticipate</li> <li>• Provides related theories and reference materials as tools</li> </ul>	<ul style="list-style-type: none"> <li>• Requires only one student to be prepared to discuss the argument</li> <li>• Moves to groups to check on progress without asking students questions about why they are doing what they are doing</li> <li>• Does not interact with students (uses the time to catch up on other responsibilities)</li> <li>• Does not expect students to address validity or reliability of data collection</li> <li>• Tells students which theories are best to support their ideas</li> </ul>
3. Argumentation Session	<ul style="list-style-type: none"> <li>• Reminds students of appropriate and safe behaviors in the learning community</li> <li>• Encourages students to ask peers the questions that the teacher asked in the previous stage</li> <li>• Keeps the discussion focused on the evidence and data</li> <li>• Encourages students to use appropriate criteria for determining what does and does not count</li> </ul>	<ul style="list-style-type: none"> <li>• Tells students when a good point was posed</li> <li>• Allows students to negatively respond to others</li> <li>• Asks questions about students' claims before other students can ask</li> <li>• Allows students to be satisfied with ideas that are not supported by evidence</li> <li>• Allows students to use inappropriate criteria for determining what does and does not count</li> </ul>
4. Reflective Discussion	<ul style="list-style-type: none"> <li>• Encourages students to discuss what they learned about the content and how they know what they know</li> <li>• Encourages students to discuss what they learned about the nature of science</li> <li>• Encourages students to discuss ways in which they could be more productive in the future</li> </ul>	<ul style="list-style-type: none"> <li>• Provides a lecture on the content</li> <li>• Provides a lecture about the nature of science</li> <li>• Tells students what they should have learned or identifies what they should have figured out</li> </ul>
5. The Production of a Final Written Argument	<ul style="list-style-type: none"> <li>• Provides an authentic purpose for the writing of the final argument</li> <li>• Reminds students about the audience, topic, and purpose</li> <li>• Provides a rubric in advance</li> </ul>	<ul style="list-style-type: none"> <li>• Places emphasis on spelling and grammar</li> <li>• Moves on to the next activity or topic without providing feedback</li> </ul>

**Table 2. Evaluate Alternatives Instructional Model Teacher Behaviors**

Stage	What the teacher does that is ...	
	Consistent with the Evaluate Alternatives instructional model	Inconsistent with the Evaluate Alternatives instructional model
1. Introduce the Phenomenon to Investigate, the Research Question and the Alternative Explanations	<ul style="list-style-type: none"> <li>• Sparks the students' curiosity</li> <li>• Creates a need for the students to develop arguments</li> <li>• Organizes the students into collaborative groups</li> <li>• Provides the students with hints</li> </ul>	<ul style="list-style-type: none"> <li>• Provides students with a specific explanation</li> <li>• Allows students to organize into groups of existing consensus</li> <li>• Tells students that there is one correct answer or a grade connected to an answer</li> </ul>
2. The Generation of Data	<ul style="list-style-type: none"> <li>• Supplies the students with the materials they will need</li> <li>• Asks students what relationships or patterns they see in the data</li> <li>• Asks students questions about how they plan to interpret the data</li> <li>• Asks students if everyone in the group has shared ideas about the data</li> <li>• Provides suggestions about use of tools or methods of data collection</li> </ul>	<ul style="list-style-type: none"> <li>• Tells students what they should have noticed in the data</li> <li>• Provides a step-by-step procedure to conduct an experiment or collect data</li> <li>• Requires only one student to make meaning of the data</li> <li>• Limits the resources students identify as means of data collection or sense making</li> </ul>
3. The Generation of Tentative Arguments and Counterarguments	<ul style="list-style-type: none"> <li>• Reminds students of the research questions and what counts as appropriate evidence in science</li> <li>• Requires students to generate an argument that provides and supports a claim with genuine evidence</li> <li>• Suggests that a model, diagram, or representation is created</li> <li>• Asks students what opposing ideas or rebuttals they might anticipate</li> <li>• Provides related theories and reference materials as tools</li> </ul>	<ul style="list-style-type: none"> <li>• Requires only one student to be prepared to discuss the argument</li> <li>• Moves to groups to check on progress without asking students questions about why they are doing what they are doing</li> <li>• Does not expect students to address validity or reliability of data collection</li> <li>• Tells students which theories are best to support their ideas</li> </ul>
4. An Argumentation Session	<ul style="list-style-type: none"> <li>• Reminds students of appropriate and safe behaviors in the learning community</li> <li>• Encourages students to ask their peers the questions that the teacher asked in the previous stage</li> <li>• Keeps the discussion focused on the evidence and data</li> <li>• Encourages students to use appropriate criteria for determining what does and does not count</li> </ul>	<ul style="list-style-type: none"> <li>• Tells students when a good point was posed</li> <li>• Allows students to negatively respond to others</li> <li>• Asks questions about students' claims before other students can ask</li> <li>• Allows students to be satisfied with ideas that are not supported by evidence</li> <li>• Allows students to use inappropriate criteria for determining what does and does not count</li> </ul>
5. The Reflective Discussion	<ul style="list-style-type: none"> <li>• Encourages students to discuss what they learned about the content and how they know what they know</li> <li>• Encourages students to discuss what they learned about the nature of science</li> <li>• Encourages students to discuss ways they could to improve their investigation in the future</li> </ul>	<ul style="list-style-type: none"> <li>• Provides a lecture on the content</li> <li>• Provides a lecture about the nature of science</li> <li>• Tells students what they should have learned or what they should have figured out</li> </ul>
6. The Production of Final Written Argument	<ul style="list-style-type: none"> <li>• Requires students to complete both writing prompts</li> <li>• Reminds students about the structure of an argument and the audience, topic, and purpose of the writing task</li> <li>• Provides the rubric in advance</li> </ul>	<ul style="list-style-type: none"> <li>• Does not include expectations for refutation or inclusion of misconceptions</li> <li>• Moves on to the next activity or topic without providing feedback</li> </ul>

the activities before engaging students in the instructional content to find out what the students know, to help students think about what they already know, to initiate students' exploration, and to challenge ideas that may be supported by misconceptions. For formative assessment, a teacher might use one of the activities in the middle of a unit to help identify how well students understand the information and how well they can apply it to a real-world event. This would allow the teacher to then decide if more instruction is needed. For summative assessment, an activity could be used at the end of a unit to determine if the students have a deep understanding of the content and practices of science. In this case, the teacher would look to see if the students are using content and vocabulary introduced during the unit and if they are able to design an investigation, analyze data, or craft a high-quality scientific argument.

### **Teacher Notes**

An effective science teacher must consider when to implement a specific activity, how to use an instructional activity most effectively in terms of promoting and supporting student learning, and the desired outcomes for student learning. To help teachers make instructional decisions about when and how to use the activities in a science classroom, each of the activities includes a section with suggestions on how to identify placement in the curriculum related to assessments, to link ideas addressed within the activities to stan-

dards, to uncover common misconceptions and discover prior knowledge. The sections also include additional resources that will support both the teacher and the student during the activity.

### **Purpose**

This section of the teacher notes describes the value of the activity in terms of both conceptual and the nature of science skills development, and its relevance to the student. Identifying which concepts are covered and what skills are being addressed will help the teacher make decisions about the strategies for introducing and scaffolding the activity and the model.

### **The Content and Related Concepts**

This section of the teacher notes will provide background information to support content knowledge that the teacher will need to best address students' questions during the data collection and the discussions. Key terms, current theories, and descriptions of data provided in the activities will support the teacher in identifying standards connections and creating assessments. The standards that are addressed for each activity are also described in this section.

### **Curricular and Instructional Considerations**

The activities in this book have been designed for both middle and high school, grades 6–12. To be able to implement these activities at these grades, teachers should have some ideas not only about

what students at each grade level may have learned related to the content and concepts of the activities but also about common misconceptions that may have been developed through previous experiences. This information should be used to make decisions about when to implement the activities, what content should be covered before implementing the activities, and whether to return to the same activity later to identify how students' ideas may or may not have changed as a result of completing an activity.

### Recommendations for Implementing the Activity

This section provides suggestions about how to implement the activity to focus on the main concepts and suggestions to address misconceptions. The suggestions are sometimes age-specific and sometimes content-specific. This section also includes practical information about the time needed to implement the activity and possible ways to break up the activity over multiple days.

### Assessment

To help the teacher develop criteria for identifying student content knowledge and learning development in argumentation and the nature of science, this section provides student samples and a scored rubric with grading suggestions. For a more in-depth look at the student products for assessments at a low, medium, and high level, teachers should review the material in the Assessments chapter.

### Framework Matrices

The *Framework* matrices indicate how well an activity is aligned with the practices, crosscutting concepts, and core ideas in *A Framework for K–12 Science Education* (NRC 2012). The matrices also provide information about how well an activity is aligned with the Literacy in Science components of the *Common Core State Standards for English Language Arts and Literacy* (NGA and CCSSO 2010). This information provides a quick reference for teachers interested in a specific topic.

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# GENERATE AN ARGUMENT

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SECTION 1: GENERATE AN ARGUMENT

# FRAMEWORK MATRIX

	Activities									
	Classifying Birds in the United States	Color Variation in Venezuelan Guppies	Desert Snakes	Fruit Fly Traits	DNA Family Relationship Analysis	Evolutionary Relationships in Mammals	Decline in Saltwater Fish Populations	History of Life on Earth	Surviving Winter in the Dust Bowl	Characteristics of Viruses
<i>A Framework for K–12 Science Education</i>										
<b>1. Scientific Practices</b>										
Asking questions										
Developing and using models			■	■	■	■				
Planning and carrying out investigations										
Using mathematics and computational thinking		□	■	■		□	□	■	■	
Constructing explanations	■	■	■	■	■	■	■	■	■	■
Engaging in argument from evidence	■	■	■	■	■	■	■	■	■	■
Obtaining, evaluating, and communicating information	■	■	■	■	■	■	■	■	■	■
<b>2. Crosscutting Concepts</b>										
Patterns		■	■	■	■	■		■		■
Cause and effect: Mechanism and explanation	■	■	■	■	■	■	■	■	■	
Scale, proportion, and quantity		■		□				■		
Systems and system models									■	
Energy and matter: Flows, cycles and conservation							□		■	
Structure and function	■	□	■	■		■	■			
Stability and change		□		□				■	■	■

■ = Strong alignment    □ = Weak alignment

## SECTION 1: GENERATE AN ARGUMENT

	Activities									
<i>A Framework for K–12 Science Education</i>	Classifying Birds in the United States	Color Variation in Venezuelan Guppies	Desert Snakes	Fruit Fly Traits	DNA Family Relationship Analysis	Evolutionary Relationships in Mammals	Decline in Saltwater Fish Populations	History of Life on Earth	Surviving Winter in the Dust Bowl	Characteristics of Viruses
<b>3. Life Sciences Core Ideas</b>										
From molecules to organisms: Structures and processes					■	■		■	■	■
Ecosystems: Interactions, energy, and dynamics		□	□				■		■	
Heredity: Inheritance and variation in traits	■	■	■	■	■					
Biological evolution: Unity and diversity	■	■	■	□	□	■		■		
<b>Common Core State Standards for English Language Arts and Literacy: Literacy in the Disciplines</b>										
<b>1. Writing</b>										
Text types and purposes	■	■	■	■	■	■	■	■	■	■
Production and distribution of writing	■	■	■	■	■	■	■	■	■	■
Research to build and present knowledge	■	■	■	■	■	■	■	■	■	■
Range of writing	■	■	■	■	■	■	■	■	■	■
<b>2. Speaking and Listening</b>										
Comprehension and collaboration	■	■	■	■	■	■	■	■	■	■
Presentation of knowledge and ideas	■	■	■	■	■	■	■	■	■	■

■ = Strong alignment    □ = Weak alignment



# CLASSIFYING BIRDS IN THE UNITED STATES (SPECIES CONCEPT) 1

**M**odern biological classification schemes generally contain a number of categories, each representing a group of organisms with a particular degree, or level, of relatedness to one another. Organisms that have the greatest number of shared characteristics are grouped together in the category of species. However, as important as the concept of a species is, the category itself is sometimes hard to define in practice. The following task is an example of this problem.

Figures 1.1–1.10 show 10 different birds that were recently observed in different parts of the United States.



**Figure 1.1.**  
**Bird A**



**Figure 1.2.**  
**Bird B**



**Figure 1.3.**  
**Bird C**



**Figure 1.4.**  
**Bird D**



**Figure 1.5.**  
**Bird E**



**Figure 1.6.**  
**Bird F**



**Figure 1.7.**  
**Bird G**



**Figure 1.8.**  
**Bird H**



**Figure 1.9.**  
**Bird I**



**Figure 1.10.**  
**Bird J**

All of these birds have very similar body shapes and coloration, but each one has a unique set of physical characteristics that can be used to distinguish it from the others (see Table 1.1, p. 7). As a result, some people think that these 10 birds represent 10 different species, while others think that these 10 birds represent one species consisting of many different varieties.

This has made many people wonder: **How many species do these 10 different birds represent?**

With your group, develop a claim that best answers this question. Once your group has developed your claim, prepare a whiteboard that you can use to share and justify your ideas. Your whiteboard should include all the information shown in the diagram on Figure 1.11(p. 6).



## SECTION 1: GENERATE AN ARGUMENT

### 1 CLASSIFYING BIRDS IN THE UNITED STATES

To share your work with others, we will be using a round-robin format. This means that one member of the group will stay at your workstation to share your groups' ideas while the other group members will go to the other groups one at a time in order to listen to and critique the arguments developed by your classmates.

To share your work with others, we will be using a round-robin format. This means that one member of the group will stay at your workstation to share your group's ideas while the other group members go to the other groups one at a time in order to listen to and critique the arguments developed by

your classmates. Remember, as you critique the work of others, you need to decide if their conclusions are valid or acceptable based on the quality of their claim and how well they are able to support their ideas. In other words, you need to determine if their argument is convincing or not. One way to determine if their argument is convincing is to ask them some of the following questions:

- How did you analyze or interpret your data? Why did you decide to do it that way?
- How do you know that your analysis of the data is free from errors?
- Why does your evidence support your claim?
- Why did you decide to use that evidence? Why is your evidence important?
- How does your rationale fit with accepted scientific ideas?
- What are some of the other claims your group discussed before agreeing on your claim, and why did you reject them?




**Figure 1.11. Components of the Whiteboard**

<b>The Research Question:</b>	
<b>Your Claim:</b>	
<b>Your Evidence:</b>	<b>Your Justification of the Evidence:</b>

## SECTION 1: GENERATE AN ARGUMENT

### CLASSIFYING BIRDS IN THE UNITED STATES 1

**Table 1.1. Information About the 10 Birds**




Bird	Appearance	Characteristics
<b>A</b>		<p><b>Habitat:</b> Deciduous woodlands and shade trees</p> <p><b>Range:</b> Washington, Oregon, California, Indiana, Nevada, Utah, Arizona, New Mexico, Texas, Montana, Wyoming, North Dakota, and South Dakota; Winters in tropics</p> <p><b>Gender:</b> Male</p> <p><b>Length:</b> 18–22 cm</p> <p><b>Diet:</b> Insectivorous but will eat fruit when available</p> <p><b>Song:</b> Clear and flutelike whistle; single or double notes in short, distinct phrases with much individual variation; also a rapid chatter</p> <p><b>Clutch Size:</b> Four to six grayish eggs</p> <p><b>Interactions:</b> Will not mate with Birds A, C, D, E, F, G, H, I, or J</p> <p><b>Behavior:</b> Creates a well-woven pendant bag nest that is made of plant fibers, bark, and string and is suspended from the tip of a branch</p>
<b>B</b>		<p><b>Habitat:</b> Deciduous woodlands and shade trees</p> <p><b>Range:</b> Washington, Oregon, California, Indiana, Nevada, Utah, Arizona, New Mexico, Texas, Montana, Wyoming, North Dakota, and South Dakota; Winters in tropics</p> <p><b>Gender:</b> Female</p> <p><b>Length:</b> 16–20 cm</p> <p><b>Diet:</b> Insectivorous but will eat fruit when available</p> <p><b>Song:</b> None</p> <p><b>Clutch Size:</b> Four to six grayish eggs</p> <p><b>Interactions:</b> Will not mate with Birds B, C, D, E, F, G, H, I, or J</p> <p><b>Behavior:</b> Lays eggs in a well-woven pendant bag of plant fibers, bark, and string and is suspended from the tip of a branch</p>
<b>C</b>		<p><b>Habitat:</b> Deciduous woodlands and shade trees</p> <p><b>Range:</b> North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Montana, Arizona, Texas, Louisiana, and Virginia; Winters in Florida and the southern Atlantic coast</p> <p><b>Gender:</b> Male</p> <p><b>Length:</b> 18–22 cm</p> <p><b>Diet:</b> Insectivorous but will eat fruit when available</p> <p><b>Song:</b> Clear and flutelike whistled single or double notes in short, distinct phrases with much individual variation</p> <p><b>Clutch Size:</b> Four to six grayish eggs</p> <p><b>Interactions:</b> Will not mate with Birds A, B, C, D, E, G, H, I, or J</p> <p><b>Behavior:</b> Creates a well-woven pendant bag nest that is made of plant fibers, bark, and string and is suspended from the tip of a branch</p>

*(continued)*

## SECTION 1: GENERATE AN ARGUMENT

### 1 CLASSIFYING BIRDS IN THE UNITED STATES

**Table 1.1. Information About the 10 Birds** (continued)




Bird	Appearance	Characteristics
D		<p><b>Habitat:</b> Tree plantations, city parks, and suburban areas with palm or eucalyptus trees and shrubbery</p> <p><b>Range:</b> California, Nevada, Arizona, New Mexico, and Texas</p> <p><b>Gender:</b> Male</p> <p><b>Length:</b> 18–20 cm</p> <p><b>Diet:</b> Insectivorous but will eat fruit when available</p> <p><b>Song:</b> Series of whistles, chatters, and warbles</p> <p><b>Clutch Size:</b> Three to five white eggs with dark brown and purple splotches</p> <p><b>Interactions:</b> Will not mate with Birds A, B, C, D, E, F, G, H, or I</p> <p><b>Behavior:</b> Makes a basket nest of plant fibers with the entrance at the top, hanging from palm fronds or the branches of eucalyptus trees</p>
E		<p><b>Habitat:</b> Forest and scattered groves of trees that are near water</p> <p><b>Range:</b> Texas</p> <p><b>Gender:</b> Male</p> <p><b>Length:</b> 23–25 cm</p> <p><b>Diet:</b> Insectivorous but will eat fruit when available</p> <p><b>Song:</b> Series of loud whistles and harsh chatters</p> <p><b>Clutch Size:</b> Two to four white eggs with purple streaks</p> <p><b>Interactions:</b> Will not mate with A, B, C, D, E, F, G, H, I, or J</p> <p><b>Behavior:</b> Creates a cylindrical or bag-shaped nest up 60 cm long, woven of tough fibers and suspended from a branch</p>
F		<p><b>Habitat:</b> Deciduous woodlands and shade trees</p> <p><b>Range:</b> North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Montana, Arizona, Texas, Louisiana, and Virginia; Winters in Florida and the southern Atlantic coast.</p> <p><b>Gender:</b> Female</p> <p><b>Length:</b> 17–21 cm</p> <p><b>Diet:</b> Insectivorous but will eat fruit when available</p> <p><b>Song:</b> None</p> <p><b>Clutch Size:</b> Four to six grayish eggs</p> <p><b>Interactions:</b> Will not mate with Birds A, B, C, D, E, F, G, H, I, or J</p> <p><b>Behavior:</b> Lays eggs in a well-woven pendant bag nest that is made of plant fibers, bark, and string and is suspended from the tip of a branch</p>

(continued)

## SECTION 1: GENERATE AN ARGUMENT

### CLASSIFYING BIRDS IN THE UNITED STATES 1

**Table 1.1. Information About the 10 Birds** (continued)


Bird	Appearance	Characteristics
<b>G</b>		<p><b>Habitat:</b> Woodlands in semidesert areas, yucca trees or palms in deserts, and sycamores or cottonwoods in canyons</p> <p><b>Range:</b> California, Nevada, Utah, Arizona, New Mexico, and Texas</p> <p><b>Gender:</b> Male</p> <p><b>Length:</b> 19–21 cm</p> <p><b>Diet:</b> Insectivorous but will eat fruit when available</p> <p><b>Song:</b> A series of rising and falling flutelike notes</p> <p><b>Clutch Size:</b> Three to five bluish white eggs</p> <p><b>Interactions:</b> Will not mate with Birds A, B, C, D, E, F, G, H, or J</p> <p><b>Behavior:</b> Builds a grassy hanging pouch nest in dry yucca fronds, pines, or live oaks</p>
<b>H</b>		<p><b>Habitat:</b> Open country with scattered trees, orchards, or gardens</p> <p><b>Range:</b> Florida</p> <p><b>Gender:</b> Male</p> <p><b>Length:</b> 20 cm</p> <p><b>Diet:</b> Insectivorous but will eat fruit when available</p> <p><b>Song:</b> Loud, varied, and continuous</p> <p><b>Clutch Size:</b> Four whitish eggs with black streaks</p> <p><b>Interactions:</b> Will not mate with Birds A, B, C, D, E, F, G, H, I, or J</p> <p><b>Behavior:</b> Builds a woven basket nest of palm fibers or other vegetable matter</p>
<b>I</b>		<p><b>Habitat:</b> Woodlands in semidesert areas, yucca trees or palms in deserts, and sycamores or cottonwoods in canyons</p> <p><b>Range:</b> California, Nevada, Utah, Arizona, New Mexico, and Texas</p> <p><b>Gender:</b> Female</p> <p><b>Length:</b> 18–20 cm</p> <p><b>Diet:</b> Insectivorous but will eat fruit when available</p> <p><b>Song:</b> None</p> <p><b>Clutch Size:</b> Three to five bluish white eggs</p> <p><b>Interactions:</b> Will not mate with Birds A, B, C, D, E, F, H, I, or J</p> <p><b>Behavior:</b> Lays eggs in a grassy hanging pouch nest in dry yucca fronds, pines, or live oaks</p>

(continued)

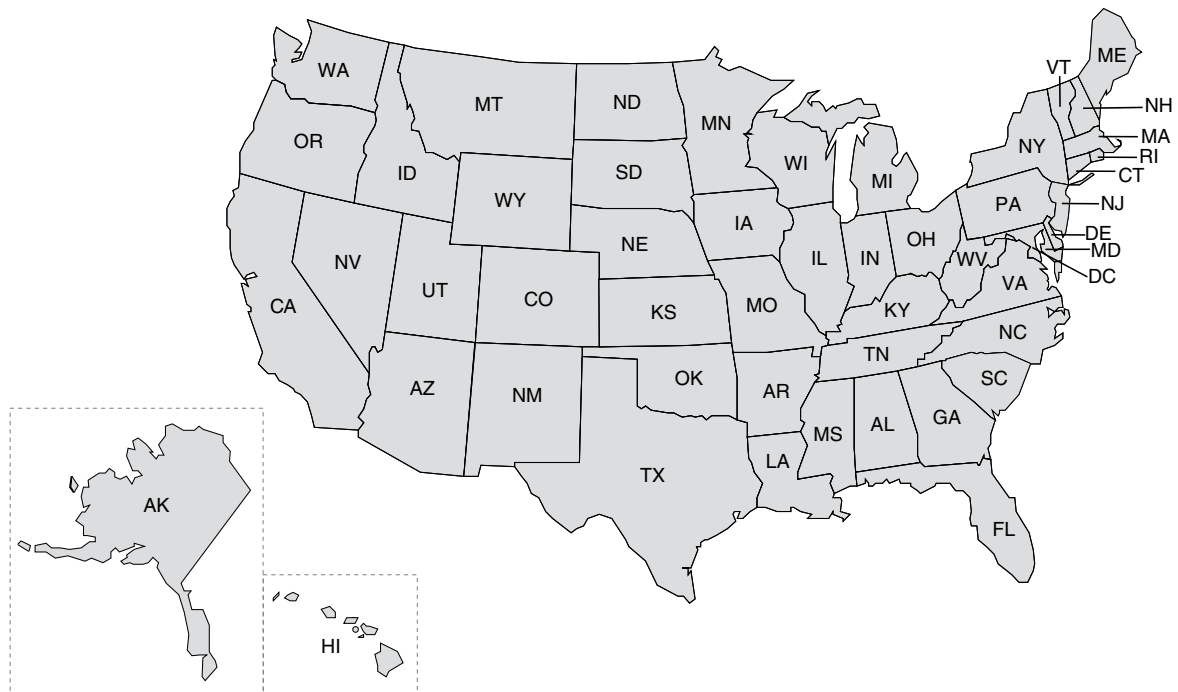
## SECTION 1: GENERATE AN ARGUMENT

### 1 CLASSIFYING BIRDS IN THE UNITED STATES

**Table 1.1. Information About the 10 Birds** (continued)

Bird	Appearance	Characteristics
J		<p><b>Habitat:</b> Tree plantations, city parks, and suburban areas with palm or eucalyptus trees and shrubbery</p> <p><b>Range:</b> California, Nevada, Arizona, New Mexico, and Texas</p> <p><b>Gender:</b> Female</p> <p><b>Length:</b> 18–20 cm</p> <p><b>Diet:</b> Insectivorous but will eat fruit when available</p> <p><b>Song:</b> None</p> <p><b>Clutch Size:</b> Three to five white eggs with dark brown and purple splotches</p> <p><b>Interactions:</b> Will not mate with A, B, C, E, F, G, H, I, or J</p> <p><b>Behavior:</b> Lays eggs in a basket nest of plant fibers with the entrance at the top, hanging from palm fronds or eucalyptus tree branches</p>

**Figure 1.12. A Map of the United States of America**



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

## CLASSIFYING BIRDS IN THE UNITED STATES: **What Is Your Argument?**

In the space below, write an argument in order to persuade another biologist that your claim is valid and acceptable. As you write your argument, remember to do the following:

- State the claim you are trying to support
- Include genuine evidence (data + analysis + interpretation)
- Provide a justification of your evidence that explains why the evidence is relevant and why it provides adequate support for the claim
- Organize your argument in a way that enhances readability
- Use a broad range of words including vocabulary that we have learned
- Correct grammar, punctuation, and spelling errors

# 1 CLASSIFYING BIRDS IN THE UNITED STATES

## TEACHER NOTES

### Purpose

The purpose of this activity is to help students understand (1) what counts as a species in the field of biology, (2) some of the various definitions for species that can be used by biologists, and (3) the challenges associated with biological classification. This activity also helps students learn how to engage in practices such as constructing explanations, arguing from evidence, and communicating information. This activity is also designed to give students an opportunity to learn how to write in science and develop their speaking and listening skills, which are important goals for literacy in science (see Standards Addressed in This Activity for a complete list of the practices, crosscutting concepts, core ideas, and literacy skills that are well-aligned with this activity).

### The Content and Related Concepts

A species can be defined as “a population or group of populations whose members have the potential to interbreed with one another in nature to produce viable, fertile offspring, but who cannot produce viable, fertile offspring with members of other species” (Campbell and Reece 2002, p. 465). This definition is known as the *biological species concept*. The basic principle underlying the biological species concept is simple: A species is a group of individuals that can exchange genetic information and

is reproductively isolated from other groups of living things. A group of individuals can therefore be classified as a species when there are one or more factors that will prevent them from interbreeding with individuals from another group. These factors block genetic mixing and lead to reproductive isolation. These factors usually fall into one of two categories: Prezygotic barriers and postzygotic barriers. Prezygotic barriers hinder individuals from mating or prevent the fertilization of an egg if two individuals attempt to mate. Examples of prezygotic barriers include geographic isolation (i.e., individuals live in different regions), habitat isolation (i.e., individuals live in different habitats within the same region), temporal isolation (i.e., some organisms are only active during specific times of day or breed during specific seasons), mechanical isolation (i.e., anatomical differences that prevent copulation), and gametic isolation (i.e., egg and sperm fail to fuse to form a zygote). Postzygotic barriers, on the other hand, are factors that prevent a zygote from developing into a viable and fertile adult once sperm and egg fuse. The two most common postzygotic barriers are reduced hybrid viability (i.e., the zygote fails to develop) and reduced hybrid fertility (i.e., the offspring is sterile).

In nature, however, the biological species concept does not always work well. A bacterium, for example, reproduces by copying its

**Table 1.2. Classification of the 10 Birds**

Rank	Name
Kingdom	Animalia
Phylum	Chordata
Class	Aves
Order	Passeriformes
Family	Icteridae
Genus	<i>Icterus</i>

genetic material and then splitting (which is called binary fission). Therefore, defining a species as a group of interbreeding individuals only works with organisms that do not use an asexual form of reproduction. Most plants (and some animals) that use sexual reproduction can also self-fertilize, which makes it difficult to determine the boundaries of a species. Biologists are also unable to check for the ability to interbreed in extinct forms of organisms found in the fossil record. The biological species concept therefore has limitations. In order to address some of these limitations, many other species concepts have been proposed by scientists, such as the ecological species concept (which means a species is defined by its ecological niche or its role in a biological community), the morphological species concept (which means a species is defined using a unique set of shared structural features), and the genealogical species concept (which means a species is a set of organisms with a unique genetic history). The species concept that a scientist chooses to use will often reflect his or her research focus. Scientists, however, are expected to decide on a

species concept, provide a rationale for doing so, and then use it consistently. Yet, scientists tend to use the biological species concept for most purposes and for communication with the general public.

All 10 birds in this activity are members of the same genus *Icterus*, or orioles (see Table 1.2 for more information about the way these birds are classified by biologists). When the biological species concept is used, the 10 birds represent six different species. Table 1.3 (p. 14) provides the species name for each bird. One of the most challenging aspects of classifying the birds is the fact that the female and male birds from the same species do not always have the same coloration. This is an example of sexual dimorphism or in this specific case, sexual dichromatism (different coloration). Sexual dichromatism in male and female birds results from sexual selection. The females tend to be most attracted to the brightest or flashiest males. Therefore, the brightest males tend to reproduce more than the dull males. The bright coloration, as a result, becomes more common in the population over time. The frequent occurrence of sexual dimor-



## SECTION 1: GENERATE AN ARGUMENT

### 1 CLASSIFYING BIRDS IN THE UNITED STATES TEACHER NOTES

**Table 1.3. Names of the 10 Birds**

Bird	Gender	Scientific Name	Common Name
A	Male	<i>Icterus bullockii</i>	Bullock's oriole
B	Female	<i>Icterus bullockii</i>	Bullock's oriole
C	Male	<i>Icterus galbula</i>	Baltimore oriole
D	Male	<i>Icterus cucullatus</i>	Hooded oriole
E	Male	<i>Icterus gularis</i>	Altamira oriole
F	Female	<i>Icterus galbula</i>	Baltimore oriole
G	Male	<i>Icterus parisorum</i>	Scott's oriole
H	Male	<i>Icterus pectoralis</i>	Spot-breasted oriole
I	Female	<i>Icterus parisorum</i>	Scott's oriole
J	Female	<i>Icterus cucullatus</i>	Hooded oriole

phism and sexual dichromatism in nature is one reason why biologists cannot simply rely on appearance when attempting to define the boundaries of a species.

It is also important to note that the Bullock's oriole and the Baltimore oriole were once combined into a single species, called the northern oriole. This reclassification occurred after humans began planting trees on the Great Plains, which allowed the two different types of birds to extend their ranges and intermingle. At this point, the two types of birds began to interbreed, so the birds were combined into a single species. Now, it seems that in some places in the Central Plain, the birds are choosing mates of their own type (due to a behavioral prezygotic barrier). The birds are therefore considered two separate species again. This situation is an interesting example of how the

biological species concept can be difficult to use in practice.

### **Curriculum and Instructional Considerations**

This activity can be used at several different points in a traditional biology curriculum. It can be used as part of a unit on classification, ecology, or evolution. It also may be used to either introduce students to the biological species concept or to give students a chance to apply their understanding of this concept in an unfamiliar context. If a teacher decides to use this activity as an introduction to the biological species concept, students do not need any additional information beyond what is supplied as part of the student pages in order to complete the activity. The teacher, however, will need to ask guiding questions, such as *Can*

**Table 1.4. Materials Needed to Implement the Activity in a Classroom of 28 Students**

Material	Amount Needed With ...	
	Groups of 3	Groups of 4
Whiteboards (or chart paper) <sup>+</sup>	10	7
Whiteboard markers (or permanent if using chart paper) <sup>+</sup>	20	14
Copy of Student Pages (pp. 5–10) <sup>*</sup>	28	28
Copy of Student Page (p. 11) <sup>*</sup>	10	7
Copy of Appendix B (p. 366) <sup>*</sup>	28	28

<sup>+</sup> Teachers can also have students prepare their arguments in a digital medium (such as PowerPoint or Keynote).

<sup>\*</sup> Teachers can also project these materials onto a screen in order to cut down on paper use.

*organisms look different and still be part of the same species?* and *What type of criteria should you use to determine if something is part of the same species?* as students attempt to make sense of the data and develop their tentative argument. The teacher will also need to explicitly discuss the concept and provide a working definition for the students as part of the reflective discussion stage of the lesson if the students are expected to develop a nuanced understanding of this important biological principle. On the other hand, if the activity is used as a way to allow students to apply their understanding of the biological species concept to an unfamiliar situation, then it will be important for the teacher to teach students about the concept before attempting to use this activity. The focus of the explicit discussion should then be on an aspect of nature of science or the nature of scientific inquiry. For example, a teacher could discuss how scientists use theories and laws to help make sense of their observations or the

difference between data and evidence using what the students did during this activity as an illustrative example.

## Recommendations for Implementing the Activity

This activity takes approximately 100 minutes of instructional time to complete, but the amount of time devoted to each activity varies depending on how a teacher decides to spend time in class. See Appendix E for more information about how to implement this activity.

Table 1.4 provides information about the type and amount of materials needed to implement this activity in a classroom with 28 students with groups of four and groups of three.

## Assessment

The rubric provided in Appendix B can be used to assess the arguments crafted by each student at the end of the activity. To illustrate how

## SECTION 1: GENERATE AN ARGUMENT

### 1 CLASSIFYING BIRDS IN THE UNITED STATES TEACHER NOTES

the rubric can be used to score an argument, consider the following example. This sample, which was written by an eighth-grade student, is an example of an argument that is weak in terms of content but adequate in terms of writing mechanics.

The claim I'm supporting is that there is seven different species of bird. To prove this claim I compared which birds mate together. **Most of the birds live in woodlands and shaded tree areas. All the birds ate the same food. All the females laid eggs in a nest. Also, all the male birds create the nest. Male birds sing songs (whistles) to attract females. The information from the packet tells what birds don't interact with each other. Most of the birds range in Texas.** This is all the evidence that supports the claim that I'm supporting and trying to prove that there seven different kinds of birds.

The content of the example argument is weak for several reasons. The student's claim (underlined) is sufficient (1/1) but inaccurate (0/1). The student does not use genuine evidence, (in bold); she does not use the supplied data (0/1) to make comparisons between the various types of birds (0/1) and does not provide an interpretation of such a comparison (0/1). Instead, she uses the supplied information to show how all the different varieties of bird are similar (which would be evidence for all the birds belonging to the same species). The student also does not include a sufficient

justification of the evidence in her argument because she does not explain why the evidence is important by linking it to a specific principle, concept, or underlying assumption (0/2). The author also uses rhetorical references (e.g., "to prove this claim" and "I'm supporting and trying to prove") that misrepresent the nature of science (0/1), although her use of scientific terminology is acceptable (1/1). The organization of the argument overall is good because the arrangement of the sentences does not distract from the development of the main idea (1/1). Finally, although there are a few grammatical errors in this student's argument (0/1), she does use appropriate spelling, punctuation, and capitalization (1/1). The overall score for the sample argument, therefore, is 4 out the 12 points possible.

### Standards Addressed in This Activity

This activity can be used to address the following dimensions outlined in *A Framework for K–12 Science Education* (NRC 2012):

#### Scientific Practices

- Constructing explanations
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

#### Crosscutting Concepts

- Cause and effect: Mechanism and explanation
- Structure and function

### Life Sciences Core Ideas

- Heredity: Inheritance and variation of traits
- Biological evolution: Unity and diversity

This activity can be used to address the following standards for literacy in science from the *Common Core State Standards for English Language Arts and Literacy* (NGA and CCSSO 2010):

### Writing

- Text types and purposes
- Production and distribution of writing
- Research to build and present knowledge
- Range of writing

### Speaking and Listening

- Comprehension and collaboration
- Presentation of knowledge and ideas

### References

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