Contents

ACKNOWLEDGMENTS  ix
INTRODUCTION  xi

CHAPTER ONE: FRAMING THE ISSUES  1

*The Approach:* Guiding student learning in a nonthreatening manner to help students understand without necessarily accepting evolution

*Evolution Is Essential:* Helping students recognize that evolution is one of the most powerful ideas in science, and that they need to understand it to make sense of practical issues in everyday living

*Religion Is Valuable:* Teaching not to undermine students’ beliefs, but to make sure they are understanding this key concept

*Teaching via Inquiry:* Engaging students through an inquiry-based model that allows them to ask questions and to reason answers on their own

Summary

CHAPTER TWO: DECIDING THE FOCUS OF YOUR UNIT  12

*The Big Ideas and the Central Concepts:* Deciding the focus of your unit so that students remember the big ideas

*The Essential Question:* Choosing an inspiring question leading to conversation, exploration, and application

Summary
CHAPTER THREE: ENGAGING STUDENTS IN STUDYING EVOLUTION  ■  27

*Understanding* Engagement in Inquiry: Engaging students effectively in the study of evolution by tying it to scientific questions they already have about life or the world around them

*Understanding* Religious Conflicts: The three positions of scientism, deism, and theism, and how those positions can help you understand your students and conflicts that may arise in your classroom

*Selecting an Engaging Experience*: Ways to engage your students through real-life applications (for mixed classrooms) and through understanding their concerns (for classrooms with mostly resistant students)

*Discussing the Experience*: Guiding your students through discussions of experiences and concerns they have

*Introducing the Unit Essential Question*: Solidifying students’ focus on the actual science involved

*Dealing with Objections*: Building a list of objections while laying a foundation for effectively examining them throughout the unit on evolution

Summary

CHAPTER FOUR: GUIDING STUDENTS TO EXAMINE THE EVIDENCE FOR EVOLUTION  ■  44

*Selecting the Evidence for Students to Examine*: Choosing resources for guided inquiry

*Guiding Students to Examine the Evidence for Natural Selection*: An inquiry-based lesson you can use for introducing your students to evidence for natural selection

*Accommodating Resistant Students During Inquiry*: Establishing an intellectually safe environment for resistant students and acknowledging their objections without losing focus on the lesson

*Guiding Students to Examine the Evidence for Evolution*: Continuing the plan of starting with evidence, not explanations, for introducing students to evidence for evolution itself

Summary
CHAPTER FIVE: GUIDING STUDENTS TO EXAMINE EVOLUTION ITSELF

Natural and Supernatural Explanations: Helping your students understand the difference between natural and supernatural explanations and how the scientific worldview does not allow supernatural explanations.

The Lessons: Three sample lessons that focus on explanations of evidence and help students better understand the theory of evolution itself.

Explaining Whale Evolution: Extending the lesson on evidence of whale evolution to an understanding of the logic of scientists’ arguments for whales’ evolving from terrestrial mammals.

Explaining Antiviral Resistance: Focusing students on their understanding of the theory of evolution itself within the context of a lesson on antibiotic-resistant HIV strains.

Explaining Bird Evolution: A variety of instructional methods to keep students focused on developing a general understanding of evolution.

Summary

CHAPTER SIX: DEEPENING STUDENTS’ UNDERSTANDING AND ADDRESSING OBJECTIONS

Scientific Worldview: Guiding students, through inquiry, to understand the nature of scientific explanations.

Objections to Evolution: Addressing students’ objections by helping them build the scientific understandings they’ll need.

Objections About Deep Time: Ways to develop lessons addressing students’ objections rooted in young-Earth views.

Objections Based on Misunderstandings of Evolution Itself: Ways to develop lessons addressing objections grounded in misconceptions about the theory itself.

Objections Based on Beliefs: Minilessons for addressing religious objections to evolution.

Other Objections: Minilessons for addressing other objections to evolution.

Summary
CHAPTER SEVEN: USING PROJECT-BASED LEARNING TO SOLIDIFY STUDENT UNDERSTANDING

Possible Projects: Examples of projects that can be used to help students solidify their understanding of evolution

For All Students: Projects that benefit a wide range of students and their beliefs

For Theistic Students: Projects that benefit theistic students specifically

Guiding the Projects: Tips on guiding project-based learning effectively

Alternatives to Project-Based Learning: Other ways to help students end their study of evolution, connecting it with their interests and values

Ending the Unit: Final reflections on the unit

CHAPTER EIGHT: WRAPPING UP

Looking Back: A summary of key points from the book

“What Do You Believe?” Addressing students’ questions about your own beliefs

Looking Ahead: Using this approach as a springboard and the hope of opening doors for all students

APPENDIX: HELP! I’M A BIOLOGY TEACHER, AND I DON’T THINK I UNDERSTAND EVOLUTION MYSELF!

Whale Evolution: Understanding the evolution of whales as a specific case of the evolution of new species

Deep Time and Radiometric Dating: Understanding the evidence for the long periods of time necessary for the evolution of modern life on Earth

Human Evolution: Understanding the evidence for the often-contentious issue of human evolution in case students ask questions on this topic

Summary

DISCUSSION QUESTIONS FOR STUDY GROUPS

REFERENCES
Guiding Students to Examine Evolution Itself

You’ve guided your students through lessons focused on the first two essential features of inquiry. You’ve invested in lessons that engage their interest (essential feature #1), rather than just telling them that they must learn evolution. Your resistant theistic students realize that you want to involve them as much as they are able in studying evolution without threatening their faith. You’ve also guided students through lessons in which they’ve looked at the evidence for evolution (essential feature #2), and they understand that all of the ideas about evolution must grow out of actual data. Your resistant students realize that although you respect alternative views of origins that they may have, you require them to encounter the plethora of evidence for evolution.

Now, you’re ready to focus your students on evolutionary theory itself. They’re ready to move to the essential feature #3 of inquiry:

Learners formulate explanations from evidence to address scientifically oriented questions. Although similar to the previous feature, this aspect of inquiry emphasizes the path from evidence to explanation rather than the criteria for and characteristics of the evidence. Scientific explanations are based on reason. They provide causes for effects and establish relationships based on evidence and logical argument. They must be consistent with experimental and observational evidence about nature. . . .

Explanations are ways to learn about what is unfamiliar by relating what is observed to what is already known. So, explanations go beyond
current knowledge and propose some new understanding. For science, this means building upon the existing knowledge base. For students, this means building new ideas upon their current understandings. In both cases, the result is proposed new knowledge. (National Research Council 2000, 26-27)

The lessons you create in this part of the unit should guide students toward a basic level of understanding of evolution. Refined understanding comes later, as students continue to sharpen their understanding in the lessons focusing on essential feature #4, as discussed in Chapter 6.

Three sample lessons are given in this chapter, and they move broadly across the territory of evolution. The first focuses on whale evolution as a clear example of the evolution of a new species. The second focuses on the evolution of antiviral-resistant HIV as an example of evolution at work around us now. The third focuses on bird evolution as a historical example of the evolution of a whole new class of organisms. The three lessons are purposefully designed to paint evolution on a big-picture level so that students can focus their attention on understanding the theory itself, including recognizing misunderstandings they have about evolution.

As you prepare to teach these lessons, check your students’ level of engagement. Now is a good time to reconnect with the essential question of the unit. Assess whether students are developing their own answer to “Why can’t we just skip evolution?” especially if as a class they’re losing interest or if the frustration of your resistant students is mounting. Consider taking ten to fifteen minutes at the start of class to refocus the students on the essential question and listen to their thoughts now that they’ve had several lessons on evolution. Do they have new insight on the essential question? Are they seeing any new practical applications to the study of evolution? Is the safe environment you’re creating helping some to realize that evolution isn’t quite so scary as they thought it would be? For a quality discussion, have the students review their initial thoughts on the essential questions that they recorded in their notebooks, brainstorm new answers in their small groups, report their new thoughts in large group, and then complete a new reflection on the essential question in their notebooks.
Natural and Supernatural Explanations

You’ve worked hard to engage your resistant students in an intellectually safe environment. Hopefully, they realize both the value you place on their beliefs and the sense of the importance you place on their understanding of evolution. They may even be a little confused, hearing what they think to be mixed signals from you. In the lessons focusing on essential feature #3, you guide students to clarify their understanding as you help them distinguish natural from supernatural explanations.

Your resistant theistic students are probably experiencing a world of tensions. Their families have chosen for them to receive education in the public setting, but they also emphasize the importance of faith. These students are not in a religious school where all of the content can be aligned with their faith. They’re not from families where religion plays little or no importance. They’re trying to make sense of their beliefs in a public environment. Now, as they study evolution, those tensions are stretched as tightly as they probably ever will be during your students’ educations.

These students face a conflict between two different worldviews as they consider the origin of life on Earth. The scientific worldview focuses on answering the question “How?” by means of natural explanations of scientific evidence. The scientific worldview can’t disprove religion or God, but it won’t allow supernatural explanations. Theistic worldviews answer the question “Who?” by means of faith and revelation. Theistic students are asked by their faith to believe what they can’t prove, and a dependence on the logic of natural explanations goes against the call they hear to believe in what they can’t see. No wonder evolution can be so upsetting to some people! Proof, evidence, and natural forces—core values of science—are antithetical to living by faith.

You can’t resolve these tensions for your students, so please don’t try. It’s not our place as science teachers to impact students’ religious beliefs, even if we’re being “helpful.” That’s something that we must leave to their families and their spiritual leaders.

We can, though, use the study of evolution to help students deepen their understanding of the nature of science itself. How do scientists make
conclusions? Upon what criteria are those conclusions made? How far can science go? Does it have limits? A study of evolution can sharpen students’ understanding of science itself, and the lessons in this chapter broaden the focus of study from evolution to the bigger issues of the scientific worldview. You’ll begin to distinguish natural and supernatural explanations over the next several lessons.

Natural explanations are those typical of science, focusing on the work of natural forces from the physical world around us. Natural explanations can be as simple as the weathering effect on rocks of wind and water or as complex as plate tectonics providing a mechanism of continental drift. Natural selection is a natural explanation of how advantaged offspring dominate the gene pool. Evolution is a natural explanation of how the effects of natural selection over millions of years have resulted in the spectacular diversity of life on Earth.

Supernatural explanations, on the other hand, are those offered by religions, which explain the creation of the world and the origin of life by the action of supernatural forces. As your theistic students look back into the Earth’s history, they find deep meaning in the interplay of supernatural forces with the natural world. These students also believe that supernatural forces are at work right now, shaping their daily lives.

In the lessons ahead, simply begin raising the difference between natural and supernatural explanations, saving in-depth discussion for the lessons outlined in the next chapter. Help your resistant theistic students look back and forth between the two worldviews. You can’t and shouldn’t dictate how they resolve the differences between the two in their own thinking. That’s a personal decision that they must make with the guidance of their families and spiritual mentors. As students in a public school, however, they should learn to distinguish worldviews different from their faith. In English classes, they are exposed to literature with views different from their own. In history, they see multiple perspectives provided by different historical documents. In science, they should learn how science explains evidence from the natural world with natural explanations. Specific to evolution, they should understand what the theory says, but they don’t necessarily have to accept it.
The Lessons

Three sample lessons are presented in this chapter. All three focus on explanations of evidence, the third essential feature of inquiry, and each is designed to help students better understand the theory of evolution itself. Each lesson begins with the question “What does the theory of evolution say?” Repeating the question is purposeful. Keep emphasizing your goal that students have a strong understanding of what evolution does and does not cover. Make sure that they don’t have misconceptions about the theory. This is important for your resistant students, especially if they come to class with objections based on creationism. Many of those objections are actually based on a misunderstanding of evolution, and you don’t want them to continue tilting at false windmills.

The three sample lessons move broadly between evolution and natural selection, addressing different species. The broad movement is also purposeful. To develop student understanding of the big idea of evolution, don’t dive too deeply into the details. Instead, guide students to encounter widely varying evidence from the natural world so that they can see how evolution offers a natural explanation for that data.

The lessons are sequenced so that you can progressively lay the foundation for the separation of natural and supernatural explanations. In the first lesson, continue to focus on establishing an intellectually safe environment, intervening with your resistant students only if you feel that you must to keep them engaged. In the second lesson, point out the difference in natural and supernatural explanations, but without commenting on it. In the third lesson, gently challenge students’ understanding, but only to make sure that they see how natural explanations work. The distinctions you make in these lessons between natural and supernatural explanations lay the foundation for the first lesson presented in Chapter 6, a lesson specifically on the nature of science and the crucial role of natural explanations.
Explaining Whale Evolution

The first lesson extends the previous one on whale evolution, and it uses the same set of resources. Students apply their previous look at the evidence for whale evolution to an understanding of the logic of the argument that scientists use in explaining how whales evolved from terrestrial mammals. As you look at the lesson plan (Table 5.1), note how it begins and ends with the question “What does the theory of evolution say?” The students use the specific example of whale evolution to look at the theory of evolution in general. The lesson moves the students more quickly through the first two essential features than previous lessons and slows down to focus on explanation, which is essential feature #3.

Guiding this lesson successfully requires having a firm grasp on the content yourself. Before teaching the lesson, go back to the evidence for whale evolution and make sure you fully understand the key points involved in the overall argument scientists use when they present whale evolution as one of the best known examples of a new species. Keep the argument clearly in your mind while students work in their small groups; this allows you to coach them and answer any questions they raise. A clear understanding is absolutely essential during the large-group discussion, where you function as facilitator. Don’t be shy at that point in the lesson about pointing out errors or bringing up missing information. If you don’t, students may exit the lesson with misconceptions based on the partial understanding their peers reported. You’re the content expert, and students need you to step firmly into that role at this point so that they can refine their understanding to match that of established science.

For resistant theistic students, the lesson will challenge them to keep their focus on the natural explanations provided by science. Encourage these students to hold off on their objections just a little more because you want them first to understand how science explains the evidence using natural forces, but remind them that you don’t expect them to accept that whales evolved, either now or anytime later in the unit. You expect them to understand the explanations offered by the scientific worldview, but not necessarily accept those explanations as part of their own personal worldview.
Explaining Antiviral Resistance

The second lesson begins and ends, as did the first, by focusing students on their understanding of the theory of evolution itself. It takes a different tack, though, by asking students to pose questions they have about the theory. The students as a class generate a list of questions that they have, and they return to those questions at the end of the lesson to see how many answers they have developed.

The lesson content focuses on how viruses evolve to become antiviral resistant, using HIV as an example. It also asks students to develop a basic sense of how HIV itself evolved from SIV (simian immunodeficiency virus). Before teaching the lesson, identify or create a resource for your students to use to understand the evidence for HIV evolution. Following are some guidelines for developing the resource, including websites you can tap. You may decide from the start, however, not to address the issue of the evolution of HIV from SIV due to the complexity it adds to the lesson.

Guidelines for Developing a Resource for the HIV Inquiry

- As always with inquiry, the resource needs to give students actual evidence to consider, not an explanation. They will develop explanations based on this evidence.
- A good source of evidence is the homepage of scientists working on the leading edge of that field. These sites often include scientific papers the authors have written that are filled with evidence you can present to your students. Although the papers are usually too technical for secondary students, you can pull graphs, charts, and data tables for your students to consider. For HIV, Dr. Brendan Larder is a leading researcher, and I found information on him at the website of the HIV Resistance Response Database Initiative (Google keywords: RDI Larder).

\footnote{www.hivrdi.org/brendan.htm.}
The Scientific Publications tab\(^2\) of that website gives many research papers. In particular, consider the posters listed there, because scientific posters are designed to digest the research quickly.

In Dr. Larder’s research, I found an extensive resource on antiviral resistance at the HIV Database’s page on HIV Database Review Articles\(^3\) (Google keywords: HIV database review), entitled “Mutations in Retroviral Genes Associated with Drug Resistance.” Because it appears multiple times on the site, be sure to start with the most current version of the article. It will give you table after table listing the evidence for antiviral resistance in HIV, including in many cases the actual codon change occurring. You’ll probably only present a few of these tables to the students; they won’t need to spend time looking at a lot of the data to get the point that mutations in HIV cause them to react differently to medications.

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\(^{2}\)www.hivrdi.org/scientific_publications.htm.

\(^{3}\)www.hiv.lanl.gov/content/sequence/HIV/REVIEWS/reviews.html.
Consider how much to scaffold the students’ work with the evidence for antiviral resistance. High school students who are adept at looking at data could probably plunge right into the tables. Middle school...
students and students unfamiliar with inquiry may need from you a set of step-by-step instructions guiding them in making sense of the data.

- Consider your students’ prior knowledge about DNA and mutations. You may need to give students an overview of DNA codons and how they dictate cellular function, but keep this brief. Don’t feel that you have to teach a three-day miniunit on DNA for students to get the point of the data.

- Web pages with scientific references can also be good sources of evidence. I found a page \(^4\) entitled “The Origin of AIDS and HIV and the First Cases of AIDS” (Google keywords: origin HIV avert) at the Avert.org website. The advocacy stance of the Avert organization may make it a resource that you wouldn’t direct your students to, but the HIV origins page lists several scientific papers that you could scan for evidence.

- The most helpful resource I found on HIV evolution was the 1999 article from *Nature* authored by Gao et al., listed as the first reference on the above Avert.org Web page. The figures in that article provide phylogenetic trees detailing how mutations in the SIV virus caused changes that allowed it to jump species and infect humans in the new form of HIV. The data in the article are technical; you’ll need to scaffold for your students. Remember, it’s still inquiry if you give them steps to follow in understanding the evidence.

Because HIV is sexually transmitted, you may decide that you need to use a different virus so that you don’t create so much classroom controversy that the students miss the point of the lesson. Taking on evolution and HIV may just be too much for some students! Middle schoolers in general may not be able to handle a discussion of HIV. Some students come from homes and faiths that may make discussing a sexually transmitted disease truly uncomfortable because of the conflict in moral values that they may project on the discussion. Consider influenza as an alternative if you think that HIV is too much of a hot button for your students.

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As you review the lesson outline presented in Table 5.2, note that some students might object, saying that what you’re referring to as the evolution of HIV resistance is nothing more than natural selection. They are correct that this is an example of natural selection. As antivirals are applied to a virus population, all of the individuals without resistance are selected out, leaving only the few with advantageous genetic differences enabling them to survive. They are incorrect, though, in thinking that natural selection doesn’t imply evolution. Many students view natural selection as something fundamentally different than evolution; they do not see evolution over eons as the sum of natural selection acting day by day. If students raise this point, accept their point without much comment, other than something simple like, “Oh, you see natural selection and evolution as different explanations.” Keep in mind the foundational nature of these current lessons; you’ll have other opportunities in future lessons to return to this point. Keep the focus on laying down the evidentiary basis they need for understanding evolution.

This lesson provides you with the opportunity to assess the comfort level of resistant students now that the unit is well under way. You’ve worked hard to develop a classroom climate of intellectual safety, but resistant students may still be aloof or antagonistic. Perhaps they’re engaging as much as they are able and you’re seeing realistic expectations for how comfortable they’ll ever be during the unit. Continue asking them to understand, but not necessarily accept, evolution, whether doing so is ever comfortable for them.

**Explaining Bird Evolution**

This lesson begins again with the question “What does the theory of evolution say?” to keep the students focused on developing a general understanding of the theory, but provides a different approach to beginning and ending the lesson, mainly as a way of maintaining the students’ interest through a variety of instruction. It focuses on having the students examine the broad sweep of scientific evidence showing how modern birds evolved from dinosaurs. The point of the lesson is that students see how scientists
construct an argument for the evolution of a whole new class of organism, in this case birds evolving from dinosaurs, based on fossil evidence.

You’ll need to develop the actual inquiry you want your students to complete. Following is a set of guidelines to help you develop your inquiry.

**Guidelines for Developing the Inquiry on Bird Evolution**

- Consider how directive you want to be with the instructions that you create for your students. If you teach younger middle school students or students inexperienced with inquiry, create a set of explicit, step-by-step instructions for them to follow. If your students are older or if they have had enough inquiry experience so that they can direct

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### Table 5.2  Lesson Outline for Explaining Antiviral-Resistant HIV

**What Does the Theory of Evolution Say?**

*(Learners Engage in a Scientific Question)*

<table>
<thead>
<tr>
<th>Lesson Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Ask the students to ponder silently the question “What does the theory of evolution say?”</td>
</tr>
<tr>
<td>■ Ask them to think about questions they have about the theory of evolution. Emphasize again that for now, you want them to focus on what the theory says, not so much on objections they may or may not have with the theory.</td>
</tr>
<tr>
<td>■ Guide a large-group discussion in which students brainstorm questions about the theory; post their questions to the board.</td>
</tr>
<tr>
<td>■ Ask them to write in their notebooks one to three questions about evolution that they find most important or interesting, using either questions posted to the board or ones they’ve thought of on their own. As they write, move around the room to get a sense of the questions noted as important by many of your students.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accommodations for Resistant Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Monitor the participation of resistant students. Gauge how comfortable they appear to feel about stating their questions. Draw their questions out if you think you can do so without starting controversy. Help them understand that you truly welcome their honest questions.</td>
</tr>
<tr>
<td>■ Assess the level of intellectual safety your resistant theistic students feel about asking difficult questions. Be realistic with yourself, though. Recognize that students may feel a level of peer pressure from students of their faith that nothing you do can alleviate.</td>
</tr>
<tr>
<td>■ As you monitor all students’ written responses, make special note of any patterns that you see in the questions that your resistant students list as most important to them.</td>
</tr>
</tbody>
</table>

**Examining Antiviral Resistance**

*(Learners Give Priority to Evidence)*

| ■ Introduce the inquiry and the resource you’ve chosen to guide students in understanding antiviral resistance. Clarify that they are looking at actual evidence, even though this evidence is at the level of changes within a large population, not changes to specific individuals. |
| ■ Direct them to consider two questions as they look at the evidence: How does HIV become resistant to an antiviral? What is the origin of HIV? Give them specific instructions on how to work as a group to examine the resource and to record the evidence they encounter. |
| ■ Remind them to look now for evidence and that explanations come later. |

| ■ Monitor the engagement of resistant students. If they raise objections because they sense the evolutionary implication of the lesson, encourage them for now to stick with just getting a good understanding of the evidence itself. |

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themselves in pursuing answers to a question, you may simply give them oral instructions about the type of work to do and then ask them to work with their group to plan their inquiry before they start.

Focus the students on actual scientific evidence for the evolution of birds, maintaining the focus on evidence that you’ve kept throughout the unit. Direct them especially to sources that give fossil evidence that students can consider.

Table 5.2  Continued

Answering the Focus Question
(Learners Develop Explanations Based on Evidence)

Lesson Segments
- Direct the students to the focus question “How can evolution explain the evidence for antiviral resistance?” Ask them to ponder the question silently.
- Direct the students to work with their group for five to ten minutes to prepare their speaker to report the group’s answer to the focus question.
- As the students work, monitor their progress to make sure they stay on task and productive. Answer questions that the group has, especially those communicated through the group’s speaker or facilitator.

Accommodations for Resistant Students
- If students begin discussing alternative explanations for the data, remind the groups that the task for now is to focus on the explanation provided by evolution. Tell them, though, that they’re welcome to make notes of their alternative explanations for use in later discussions.

Group Presentations of Answers to the Focus Question
(Learners Evaluate Their Explanations)

- Designate one group’s speaker to go first and present the explanation developed by the group.
- After the first speaker finishes, address the rest of the speakers and say, “I’m curious to know whether your group’s explanation builds on or differs from what you heard. Who would like to speak next?” Make sure that the speakers realize that you don’t want them simply to restate an explanation that has already been presented.
- Continue calling on speakers until all important points of the groups’ explanation have been presented, assessing the students’ understanding as they present.
- Briefly add any key points that you feel the students are missing without undermining the work that they did in their groups.

Small-Group and Individual Metacognition
(Learners Communicate and Justify Their Explanations)

- Ask the students to silently review the posted list of questions they raised about evolution at the beginning of the lesson. Ask, “Which of your questions about evolution did this lesson help you begin to answer?”
- Lead a large-group discussion about how students are refining their understanding of evolution itself. Mark on the posted list questions that appear to be answered and those that still remain.

Assess how well your students are building their understanding of the basics of evolutionary theory based on classroom interactions. How comfortable are they discussing their ideas with peers? Are they willing to say the word evolution as they talk? How many appear to be beginning to accept the division you’re proposing between natural and supernatural explanations?
Consider the Tree of Life\textsuperscript{5} Web project (Google keywords: tree of life evolution) as the main source for the students’ work. Using the “Containing group” link on each page, students can work backward from Neornithes (modern birds) along evolutionary pathway to Dinosauria. The Tree of Life Web interface takes a little playing with to get used to. Explore it so you get used to how it functions, and tell your students to do the same before they plunge into the actual evidence.

Consider having the students do their work using live Web access if at all possible. If your school has a computer lab, reserve it well in advance. As I worked on understanding the relationship between modern birds and dinosaurs, I found myself clicking up and down the phylogenetic tree again and again, trying to put the relationships together in my mind. Working online was helpful in that process.

If you can’t get computer access for your students, then consider other options. You could print key pages from the Tree of Life website and present the copies to students in random order; having to reconstruct the proper sequence will help them understand the path of bird evolution. If you have a teachers’ presentation station with live Internet access, consider a large-group discussion in which students ask questions of the site and you click the links as they try to build their understanding of how birds evolved.

Consider how you want your students to represent the understanding they’re building as they examine the evidence. Is simply taking notes enough? Do you want your high school students to create a phylogenetic tree from scratch? Do you want your middle school students to finish a phylogenetic tree that you partially completed?

Consider how to direct students to ground the explanation that they build in actual evidence. Perhaps require them to include a brief description of the key fossil evidence and age for five to ten actual species that illustrate the development of modern birds from dinosaurs. The Tree of Life pages often provide an “Information on the Internet” section that students could tap as they research specific species.

\textsuperscript{5}www.tolweb.org.
Consider how directive you want to be regarding the key relationships you want students to see as they work. An example of one such relationship would be how modifications to the wrist joint in *Maniraptora* allowed for the evolution of bird wings.\(^6\) Based on your students’ maturity, skills for inquiry, and engagement in the topic, you may decide to see if they pick up on this relationship themselves, knowing that if they miss it you can bring it out during large-group discussion later. Or, you may decide to create an explicit instruction step asking them to look at key relationships, such as wrist modifications in *Maniraptora*, that influenced bird evolution.

The lesson outline in Table 5.3 is structured similarly to previous lessons: Student work in groups to examine evidence for bird evolution and to develop their understanding of the scientific explanation of that evidence. They then provide via the group’s speaker the initial points for a large-group discussion in which you guide all of the students to develop their understanding of how scientists explain the data. Note, though, that this lesson doesn’t use a formal focus question. As students become more comfortable with inquiry, I prefer to shift large-group discussions to ones that are more open-ended. I want my students to own the discussions more and more, and I find that tight scaffolding can get in the way of that ownership once the students become accustomed to the basics of productive large-group discussions. If your students aren’t ready for this amount of freedom, however, feel free to adjust the lesson by developing and posting a focus question to guide their small- and large-group work.

The content of this lesson is ripe for objections, and even nonresistant students may join in the dissent. The evolution of birds from dinosaurs requires interpretation of fossil evidence representing millions of years of change, and the scientific explanation seems to defy common sense. We look around us and never see one species turning into another, much less becoming a whole new class of organism, and yet this is exactly the scientific conclusion when the time span expands to millions of years. This difficulty

\(^6\)See [www.ucmp.berkeley.edu/diapsids/saurischia/maniraptora.html](http://www.ucmp.berkeley.edu/diapsids/saurischia/maniraptora.html) for more information.
Table 5.3 Lesson Outline for Explaining Bird Evolution

<table>
<thead>
<tr>
<th>Lesson Segments</th>
<th>Accommodations for Resistant Students</th>
</tr>
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<tbody>
<tr>
<td>- Ask the students to ponder silently the question “What does the theory of evolution say?” and how their answers to the question are shifting.</td>
<td>- Monitor the engagement of your resistant students. How do they respond to your raising a common objection that they probably have heard often? Do they sense that you’re trying to set a trap for them or that you’re maintaining an intellectually safe environment?</td>
</tr>
<tr>
<td>- Tell them that in this lesson you’re going to use one of the objections people often raise to evolution as a way to further delineate what the theory actually says.</td>
<td></td>
</tr>
<tr>
<td>- Describe briefly the common objection that evolution can’t be accurate because we don’t see the evolution of new species occurring around us right now. Use several specific examples of the objection, such as monkeys becoming humans. Ask, “Does the theory of evolution say that we should see that kind of evolution occurring around us?”</td>
<td></td>
</tr>
<tr>
<td>- Listen to several students’ responses to see how effective the objection is for engaging the students in the lesson.</td>
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Examining the Evidence for Bird Evolution

(Learners Give Priority to Evidence)

- Direct the students in starting the bird inquiry that you’ve developed.

Explaining Bird Evolution: Small-Group Discussion

(Learners Develop Explanations Based on Evidence)

- When the groups have had sufficient time to examine the evidence, direct them to prepare their speakers to report why birds have survived and dinosaurs have not.

- Expect objections here, especially ones along the lines of “That’s just crazy. Who would believe that dinosaurs become birds?” If you’ve created an intellectually safe environment, students may be even more apt to express objections, but the objections should be less an attack and more an expression of their current understandings.

Explaining Bird Evolution: Large-Group Discussion

(Learners Evaluate Their Explanations)

- Call the students back together. Ask several speakers to report their group’s understanding.

- After each group presents, ask the whole class for questions, comments, or concerns that they want to address. Redirect the conversation as often as needed back to the focus on natural explanations of evidence for the evolution of birds.

- Provide any expert feedback, based on your assessment of how well the students are building an understanding of the basic ideas of the evolution of new kinds of life.

- Use expressed objections as another opportunity to distinguish natural from supernatural explanations. Consider responding to objections with something similar to “I hear your concern, but I want to challenge you a little. How would you explain this evidence if you couldn’t use the supernatural in your explanation? That’s the challenge scientists face, even if they personally believe in the supernatural.”

Small-Group and Individual Metacognition

(Learners Communicate and Justify Their Explanations)

- Ask the students, “So, what does the theory of evolution say?” Remind them how this question led off the last three lessons. Ask them to ponder silently how their understanding has changed.

- Ask the groups to work together for ten minutes to develop a two- to three-sentence statement of what the theory says, using their own words.

- Ask the speakers to read their statements for the whole class. Ask the other students to simply listen without commenting. Assess the students’ understanding based on their responses, noting any refinements you’ll want to target in future lessons.

- As you monitor the group work, note the engagement and understanding of your resistant theistic students. How well do they understand what evolution says? Do they realize that you expect their understanding, but not acceptance, of the theory? What are they concerned about now? Note any adjustment you’ll want to make in future lessons to continue to support their learning.
is why I suggest that you allow students to openly express their objections in this lesson. The questions and concerns students raise now continue to provide a segue to the lesson you will teach next on natural and supernatural explanations. You’ll use their objections to further illustrate how scientists bind themselves to the use of only natural explanations as they go about their work.

Summary

As you move forward from these three lessons, consider how well your students understand the basics of evolution for explaining evidence from the natural world about how organisms adapt in the short and long term. Review the target benchmarks appropriate to your level in Tables 2.2 and 2.3. If most students have a basic understanding, then you’re ready to move forward to the lessons on essential feature #4, as discussed in Chapter 6, where students will build finesse with understanding evolution and using it to explain data. If your students still struggle with the basics of evolution, consider teaching one or two more lessons about evolution itself.

Also, consider any direct support your resistant students may need, especially if you still struggle to engage them in the study or if their objections significantly hinder their understanding. Individual or small-group conferences with resistant students may be just what some of them need now, especially if you simply listen to their concerns or confusions. Knowing that you are willing to listen goes a long way toward diffusing tension with students. If you have any students taking a leadership role in objecting to evolution, consider especially a one-on-one conference with those students. Craft a true dialogue by first listening to their concerns, as you do with any struggling student, but then ask them to listen to your goal of wanting all your students, including the other resistant students, to be able to function in the real world, which requires an understanding of evolution. Challenge them to lead well, and you may even have to direct them to tone down their dissent if you feel that it is harming other students.
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