they have and how those objections are impeding their understanding of evolution. You've also consistently assured your students that you will address their objections. Of all the objections covered below, teach lessons only on the ones that are significant to your students. Don't teach lessons that create objections!

The objections presented here should help you see specific examples of this book's approach in action. Again and again, say to the students, "I'm not asking you to accept some specific aspect of evolution, but I do want you to understand the evidence for evolution and how scientists explain that evidence." By blatantly stating your expectation about understanding, but not necessarily accepting, you're reiterating to your students that you affirm their beliefs, but you're also helping them build the scientific understandings that they'll need for life in public society. Constantly reminding students of your approach is especially critical as you focus on the objections that many of them raise. In effect, you're not even asking them to abandon their objections. Instead, guide them to understand the scientific side of that objection, and leave to them their final decision about what they believe.

The tables in this section give only lesson concepts, not lesson outlines. The lesson concepts are starting points to help you create lessons. Use your finesse and understanding of the specific needs, interests, and backgrounds of your students in creating lessons effective for guiding them to examine their objections. The first two tables address lessons that may take a whole class period and are inquiry based. For these objections, the students probably need to encounter evidence directly and work through the process of inquiry to appreciate the scientific perspective pertinent to those objections. The later tables deal with objections for which a minilesson or lesson segment is more appropriate. As such, I don't advise you to use an inquiry-based approach for those minilessons in order to save time.

Objections About Deep Time

Six billion years of evolution is hard for most humans to truly fathom. That's an incredibly long span of time. Students from young-Earth traditions have the additional challenge of approaching the study of evolution from a worldview telling them the Earth is only thousands, not billions, of

years old. Where the scientific worldview talks about an amazingly long period of time required for cosmological evolution of the universe, then for geological evolution of the Earth, and then for biological evolution of life on Earth, many resistant students believe in an amazingly short period of supernatural creation of the universe, the Earth, and life on Earth. The conflict between the two worldviews is direct and deep.

Deep time is a key issue to understanding biological evolution because of the millions of years required for the evolution of species. (See the Appendix for more on deep time and radiometric dating.) Students who approach the fossil evidence with an assumption of a young Earth will encounter significant struggles in understanding how scientists explain the evidence with Darwin's theory. These students may even see very little use for evolution because they are absolutely convinced that the world is young, not old, and that the long periods of time required by evolution just didn't happen.

Don't push hard on the issue of deep time because of how fundamental young-Earth beliefs are to some resistant students' faith. Asking them to accept the scientific worldview of a very old Earth will, for many of them, cause significant conflict in their belief systems. For some, believing in an old Earth could actually cause them to be ostracized by their faith community; the stakes are high in this area. Instead, I would guide you toward helping them simply understand, but not accept, how scientists came to view the Earth as old enough to provide the time required for evolution to work and give us the life-forms we see today.

Table 6.2 provides an analysis of objections to evolution that are rooted in misunderstandings of or disbelief in deep time. It also gives the beginning points of two lessons that you could teach to deepen your students' understanding of evolution. The first lesson focuses on radiometric dating as the key scientific evidence of the ancient age of the Earth. The second lesson extends the previous lesson you taught on bird evolution and gives students more experiences with understanding how evolutionary biologists explain the fossil record. The two lessons actually could be taught together. Without the eons established by radiometric dating, evolution does not have the time required for the development of the species we see today.

Table 6.2 Lesson Concepts for Objections About Deep Time

Objection to Evolution	Target Scientific Understandings	Focus Question for Lesson	Resistant Students' Struggles	Key Message
"The Earth is a lot younger than scientists say. All of that carbon dating stuff can't be trusted because it gives the wrong dates." "The Earth is only six thousand years old, so there's not enough time for everything to have evolved."	Radiometric dating techniques are good science. Combined with the uniformitarianism inherent in the scientific worldview, radiometric dating of many different types continually uphold the ancient age of the Earth and of fossils.	What is radiometric dating and why do scientists trust it?	For some students, just examining radiometric dating with an open mind is a difficult struggle. Students who begin to accept scientific dating techniques may face doubts about their faith.	"I'm not asking you to accept that fossils prove life on Earth to be millions of years old. I want you to understand, however, that evolution explains well the data when we stick to the rule that science allows only natural explanations."
"No one has ever seen macroevolution really happen." "You just can't get complex life from simple life-forms."	*Macroevolution*, as creationists typically use the term, could never be observed by humans because it takes millions of years. The only way to observe macroevolution is to see it occurring across the fossil record, which shows a clear progression from simple to complex life-forms.	How does the fossil record support the idea of evolution of new classes of organisms?	Many resistant students see a direct conflict between their beliefs in special creation and the scientific view regarding evolution of new classes of organisms.	"I'm not asking you to accept that new classes of organisms came about by evolution, but I do want you to understand how natural explanations of the fossil record result in that conclusion."

Note how for each objection, the table gives the corresponding scientific understanding, a possible focus question for the lesson, possible resistant students' struggles, and a message you can use in guiding the student toward understanding, but not accepting, evolution. The other tables in this chapter will follow a similar format. The Target Scientific Understandings column gives you the science that contrasts with typical student objections. The Focus Question for Lesson column helps you think about how to focus the lesson away from controversy. The Resistant Students' Struggles column gives examples of possible struggles your students are facing, in case you're not sure why resistant students raise objections in this area. The Key Message column gives you an example of the kind of message that you can use to continue to reinforce with your resistant students how you don't want them to abandon their faith, but do want them to understand science.

Inquiry is probably your best approach for helping students understand deep time. As you've done throughout the unit, present students with evidence for an old Earth and guide them in seeing how scientists explain that evidence from natural causes at work. Don't simply tell them what they should believe. Several of the resources identified in the Deep Time and Radiometric Dating section of the Appendix should help you identify evidence you can use for building an effective inquiry. Hopefully all of your students, including your resistant ones, will see how natural causes provide a plausible explanation for the evidence. Be aware, though, that resistant students may be quite skeptical of those explanations because of their disbelief about deep time. Help them to understand the evidence for deep time, without requiring they accept that the Earth is old.

Objections Based on Misunderstandings of Evolution Itself

Evolution is hard to understand. It's complex and abstract, and it usually can't be directly observed. Resistant students can bring to the study of evolution a worldview having minor to major conflicts with the scientific worldview that modern life-forms evolved from single-celled organisms due only to natural causes. Without even trying, therefore, resistant students may enter your classroom with fundamental misunderstandings of the evidence for or the explanation of evolution. Table 6.3 follows the same format as the previous table and helps you think about how you might develop lessons that address four common objections to evolution that are rooted in misunderstandings of the theory itself.

To effectively structure inquiry in the first lesson, ask students to compare an older, incomplete fossil series with a current one in which some of the gaps are filled in. I was first introduced to this way of thinking during a talk by Eugenie Scott, Executive Director of the National Center for Science Education (www.ncseweb.org). She helped me see that gaps will always exist in the fossil record due to its very nature, but as paleontology progresses, many of those gaps will grow smaller and some will even be filled. Showing students how gaps in different fossils series have been filled over the past decades of science should help them better understand how science works. (See the Appendix section on whale evolution for related

Table 6.3 Lesson Concepts for Objections Based on Misunderstandings of Evolution

Objection to Evolution	Target Scientific Understandings	Focus Question for Lesson	Resistant Students' Struggles	Key Message
"There are just too many missing links for evolution to be true." "If evolution is true, then we'd have a whole lot more fossils out there showing how one species became another."	The fossil record, by its very nature, will have gaps because not all lifeforms fossilized. At the same time, scientists consistently see gaps getting smaller as more fossils are unearthed.	Why aren't evolutionary biologists worried by gaps in the fossil record?	Students may have heard a lot of information about gaps, especially if they're attuned to creationist arguments. Students may struggle with the idea that if a scientific theory is accepted, then the proof for that theory has to be absolutely solid.	"I don't expect you to believe that the fossil record proves life evolved on Earth, but I do want you to understand why the scientific community accepts evolution even with missing evidence."
"Don't scientists themselves disagree about whether evolution really happened?" "Evolution is just a theory."	Evolution is a bedrock, not tentative, belief of the scientific community. Scientists may disagree on evolutionary mechanisms, but not evolution itself.	Which do scientists debate: Did evolution occur or how did it occur?	Because resistant students typically see evolution as implausible, they focus on scientific examples that support their position. In everyday language, *theory* means something tentative. Students may think that "the theory of evolution" is just a guess by scientists.	"I don't expect you to accept that evolution is the way life came to be on the Earth, but I want you to understand that scientists accept that idea and go about their work as if evolution is a fact."

resources). Remember, though, your goal is not to get resistant students to accept that the fossil record provides conclusive proof that life evolved.

To answer the second focus question, ask students to look at statements from major scientific organizations and groups of scientists. Rather than telling students what scientists say about the bedrock nature of evolution, guide them to encounter for themselves the statements of multiple scientific groups. In this sense, you're still teaching by inquiry. You're starting with an engaging, scientific question, "Which do scientists debate: Did evolution occur or how did it occur?"; the evidence you're putting in front of students is the beliefs of practicing scientists. You're asking students to develop a general explanation of the importance of evolution in science. You're not, however, asking them to accept evolution, just understand that scientists go about their work as if evolution is an absolute fact.

Make sure as you teach this, and any of these lessons on objections, to guide students to connect back to the understandings they developed during the lesson on natural and supernatural explanations, described in Table 6.1. Help students deepen their understanding of natural explanations by seeing that science has limits; it can't displace religion. Also, help them to deepen their understanding by seeing that one of the key limits that scientists place on themselves is restricting their explanations to natural causes, even if they personally believe in the supernatural.

Objections Based on Beliefs

Religion has value. It has a long record of bringing beauty and hope to humanity, and spiritual people speak of how their faith makes them kinder, more helpful, more patient, and more focused on others. Religions have their own worldviews, however, and theistic students who adhere devoutly to their faith will experience conflict between the way their faith teaches them to look at the world and some of the tenets of the scientific worldview. Theistic students in public schools negotiate this conflict on multiple fronts, and the conflict is not simply science versus religion. In social science classes, they encounter theories of human behavior that conflict with their understanding of how people and society work. In English classes, they read literature that opposes their beliefs in subtle or even overt ways. In health classes, they may be taught sex education practices that conflict with their morality. They are growing up in the public, and they are learning to negotiate the intersections between their beliefs and the other worldviews they encounter.

In the life science and biology class, this negotiation continues as theistic students study evolution. Table 6.4 gives several objections that resistant students typically raise because of the very nature of having grown up in faith traditions. These objections don't show that students are stupid, ignorant, or obstinate. Instead, they show that students are thinking about the conflict and trying to make sense of their worlds.

The lessons you create for these objections probably won't require a whole period to teach. That's why the focus questions are labeled in the table as those for minilessons. You can address these objections in a short period of time, and you probably won't want to teach these lessons by inquiry.

Table 6.4 Lesson Concepts for Objections Based on Beliefs

Objection to Evolution	Target Scientific Understandings	Focus Question for Minilesson	Resistant Students' Struggles	Key Message
"Everything evolutionists say happened is really a result of Noah's flood."	Uniformitarianism is a key assumption of the scientific worldview.	What is uniformitarianism and how does it guide scientific explanations?	Students who have been taught that Noah's flood literally happened will struggle with science totally ignoring such a major event.	"I'm not asking you to doubt Noah's flood. Instead, I want you to understand how the principles of science cause a very different approach to the evidence scientists collect and how they explain what they find."
"There's just no way that life evolved. You can't get living stuff from nonliving stuff."	Because scientists are bound only to natural explanations, they seek to explain how life evolved from nonliving matter by natural means.	Why don't scientists use supernatural explanations?	The beauty and complexity of life on Earth has always been something that causes humans from many different religions to believe that forces bigger than just natural causes must be at work.	"I'm not asking you to stop believing in supernatural events like creation. I do want you to understand, however, why scientists don't use the supernatural when they explain the beginning of life on Earth."
"Isn't science a search for Truth?"	Science can never prove anything in an absolute sense. It can disprove things, but it can never establish truth absolutely.	Is science about a search for Truth?*	Absolute truth is part of the worldview of theistic students, beginning with their belief that the supernatural absolutely exists and impacts life on Earth. They are often truly surprised by any worldview, including that of science, that does not seek truth as its final product.	"I'm not asking you to give up your belief in absolute truth. I do want you to understand, however, that science is valuable even if it gives us tentative understandings."

*This question should be posted in written form so that students clearly see that by capitalizing the first letter, you're talking about truth in an absolute sense.

These topics can be addressed well through bursts of direct instruction inserted in other lessons, especially when the topic naturally comes up.

For the first objection, give students a brief overview of uniformitarianism, the scientific assumption that the natural processes at work today were the processes at work in the past. As you overview uniformitarianism, open up the discussion for questions from the students and listen to make sure that they really understand uniformitarianism and its implications for explaining the way events occurred as life on Earth evolved. Let students know also that you recognize that this scientific idea is in conflict with

many spiritual beliefs. Listen to their questions and guide them to understand the implications of uniformitarianism for scientists' work.

For the second objection, be ready to talk about scientists who are spiritual people themselves, but who respect the scientific requirement that they give explanations based only on natural causes. Frances Collins, who leads the Human Genome Project, is a good example. Guide students to grasp during this minilesson that many scientists are people of faith themselves, and they don't reject their supernatural beliefs as they go about the presentation and publication of their data. They simply limit themselves to natural explanations in their work. They may even talk about their beliefs across the laboratory bench or when they're out in the field, but they don't weave their spirituality into their scientific publications.

The third objection is going to be tough for any students in grades 6–10 because so many of them see the world in absolute terms. If you teach younger students, you may even decide that addressing this objection is developmentally inappropriate for your students. Begin the minilesson by asking the students the focus question. Then engage them in a discussion of the term *absolute truth* to make sure that they understand what you mean by this; ask them to list some examples of things that they believe to be absolutely true. Then, guide them to think back through the inquiries they've conducted as your students, both in the evolution unit and in other units you've taught. Direct them to see how none of the inquiries absolutely proved anything, but they did disprove certain ideas. Again, listing specific examples on the board will help. Make sure students are getting the basic idea that science isn't in the business of absolute truth, but as you've done before, continue to reassure your resistant students that you are not trying to change their belief in absolute truth itself.

Other Objections

Tables 6.5 through 6.8 give a final set of objections that really don't fit under a single theme, but I offer some guidance in addressing these as they consistently come up when resistant students learn evolution. As with the previous set of objections, I suggest that you're prepared to teach minilessons as the issues come up, especially if you could do so on a need-to-know basis.

Students in general can come to the study of evolution with the misconception that evolution is only about competition between individuals or among species, especially if the only evolution examples they've seen address competition, not cooperation. They also typically have little experience hearing scientists talk about wonder, beauty, and awe. Theistic students, in particular, may have heard or read creationist objections around this topic. In your minilesson structured after Table 6.5, remind students of examples of evolution at work to bring good things, such as the beauty of flowers and bird plumage or the cooperation that occurs in the animal kingdom. Provide them with examples of scientific ideas that focus on the beauty of the natural world, such as the work of environmental scientists who work to preserve that beauty.

Table 6.6 is one of the few sections in this book that will get anywhere close to addressing creationism directly. By now, you've clearly seen how my approach is much different from teaching that either supports or attacks creationism. These objections often find their roots in students' knowing very little about the peer-review process required for scientific publications. They think of science as something that exists in their textbook, when science can better be thought of as the understandings of the scientific community as published in peer-reviewed journals. To teach the minilesson in Table 6.6, describe in general how a scientific article gets

Table 6.5 Lesson Concept for Objections About Beauty and Wonder

Objection to Evolution	Target Scientific Understandings	Focus Question for Minilesson	Resistant Students' Struggles	Key Message
"If everything evolved because of survival of the fittest, then why do we have anything good around us? Why is the world so beautiful?"	Evolution doesn't discount beauty; beauty can be advantageous in natural selection. Evolution shows how cooperation between organisms can provide advantage. The scientific worldview recognizes the world as a wonderful, amazing place and science as often a pursuit of beauty and awe.	Does evolution say that the world should be a harsh, even terrible, place where everything is fighting for survival?	Students who have been taught creationist objections may believe that evolution focuses only on the harsh side of competition. Students may believe that good, truth, and beauty in the world come chiefly from, or only from, their religion.	"Would it surprise you if I said, 'Scientists seek out the good and the beautiful in their work'? I'm not asking you to accept that science is better than or even equal to your religion, but I do want you to understand the value that science places on helping humans to see the wonder and beauty of living on Earth."

Table 6.6 Lesson for Key Creationist Objections

Objection to Evolution	Target Scientific Understandings	Focus Question for Minilesson	Resistant Students' Struggles	Key Message
"Fossils have been found that prove that people and dinosaurs lived at the same time." "Didn't scientists make up fake fossils to prove people evolved?" "Aren't peppered moths a fake?" "The moon has just a little bit of dust, so the Earth can't be six billion years old."	Scientific evidence and explanation must go through the rigorous process of peer review before being accepted by the scientific community.	Can we trust science?	Students who have been exposed to creationist objections may believe that some or all scientists try to deceive the public. Students may have seen evidence that in their understanding contradicts evolution.	"I'm not trying to get you to disbelieve in creation, but I do want you to understand that science has layers of rules and procedures to prevent data from being faked, bad explanations from being accepted, and a few scientists from imposing their personal beliefs on the rest of the scientific community or the public."

Table 6.7 Lesson for Objections About Complexity

Objection to Evolution	Target Scientific Understandings	Focus Question for Minilesson	Resistant Students' Struggles	Key Message
"There's no way that something as complex as the eye could have just evolved. It has too many parts."	The fossil record gives clear evidence of a development in complexity, with regard both to more complex species and to more complex structures and organs required for those species to function.	How do evolutionary biologists explain the development of complex structures?	Belief in a supernatural being who creates complex life makes much more sense to some students than belief in a universe that orders itself into the complexity and beauty we see.	"I'm not asking you to accept that complex structures evolved without supernatural intervention. I do want you to understand how scientists, bound by natural explanations, explain fossil evidence."

Table 6.8 Lesson for Objections Based on the Second Law

Objection to Evolution	Target Scientific Understandings	Focus Question for Minilesson	Resistant Students' Struggles	Key Message
"The second law of thermodynamics says that evolution couldn't happen."	The Earth is not a closed system, because of the amount of energy flowing in from the Sun, and so the second law does not apply. The second law can't be used to disprove evolution because of the tremendous amount of energy in the system after the Big Bang.	Does the second law of thermodynamics disprove evolution?	The second law of thermodynamics seems tantalizingly simple and therefore an easy tool to use to disprove evolution.	"You don't have to give up your belief that the supernatural was involved in the creation of the universe and life on Earth, but I want you to clearly understand the limitations of the second law."

published, especially how the evidence and explanation in the article is carefully scrutinized for bias and error. Explain also how science, although not infallible, is inherently self-correcting; possibly give an example such as how Peking man fossils have come to be accepted as scientific evidence even though the originals are now lost to science. Question the students to make sure they're getting the basic idea of how we know scientific explanations are carefully guarded against bias, but also help resistant students understand that you're not trying to get them to give up their beliefs in special creation.

One problem with evolution for the general public is how it is counterintuitive at times. For many people, it's truly hard to believe that the amazing complexity of the world around us resulted simply from the impersonal plus time plus chance, as the Christian philosopher Francis Schaeffer has said. For resistant theistic students, the idea that complexity just happened is usually ludicrous to them because of their prior belief that supernatural forces are at work. When this objection comes up, be prepared per Table 6.7 to point the students to the fossil record, which clearly shows that complex organisms did evolve. Of course, students may quickly say, "But God made that happen." As you have done with their other objections, remind them that you don't want to change their beliefs, but that you do want them to understand how scientists develop clear explanations of the development of complex organisms using only natural explanations.

Table 6.8 addresses the very specific, but common, objection based on the second law of thermodynamics. This one always makes me chuckle a little because of how students and adults who would normally say, "Gosh, I don't know a thing about physics," can be quick to invoke this very deep and profound law of physics in casual conversations. Your minilesson should be targeted chiefly on helping students see how the second law simply does not disprove evolution. On the surface, when used simplistically, it does, but when students really understand what the second law means, they will see that evolution is allowed under it. Help your resistant students see throughout the discussion, however, that you're not trying to take away their belief in creation. You just don't want them defending their beliefs with scientific misunderstandings.

Summary

Go back and review your final focus for the unit and make sure that you've given your students the opportunity to learn all of the big ideas. Tables 2.4 and 2.5 give my final focus, and as you look at those, note how the lessons cover the big ideas of the scientific worldview, biological evolution, and natural selection. Your students will still have some final opportunities to refine their understandings as you address essential feature #5; the next chapter will guide you to allow your students to pursue their own question using project-based learning. Therefore, make a final assessment to see if you need to teach any additional lessons or minilessons to the whole class, while they're still all together, to ensure that your students understand the main concepts of evolution.

Also, do a final assessment of the engagement level of your resistant students. You've been working through weeks of lessons to engage them and to communicate to them how you value both their beliefs and an understanding of evolution. You've respectfully listened to their objections and developed lessons helping them to see scientific answers to those objections. If they're not engaged now or if they're still highly threatened by evolution, perhaps you've done all that you can. You may need to take the pressure off yourself to accomplish much more with them in the unit. You've planted a few seeds of scientific understanding that may sprout and take root later on in these students' lives.