Chapter 3

Teaching and Learning About Evolution

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The National Association of Biology Teachers considers evolution to be the foundation for middle school life science. In the National Science Education Standards (NSES), evolution is an essential component of the science curriculum at all grade levels. With this book as your guide, your charge is to help youth learn about evolution as the unifying theme of the life sciences. How do you guide kids' understanding? What are the potential pitfalls? This chapter covers what you need to know based on the most recent research and advice about the teaching and learning of evolution. First, I shall present the National Science Education Standards. Then I will turn to current research on some of the best ways to teach evolution. Finally, I will tell you what researchers know about how kids learn about evolution and ways to use this knowledge when you teach, whether in informal or formal settings.

All major scientific and research organizations in the United States agree that evolution is a major unifying concept in the life sciences and should be included in the K–12 science education frameworks and curricula (NSTA 2003). Why is there such consensus? Scientists use the theory of evolution because it explains, with simplicity and elegance, the similarities and diversity found in all living organisms. Whether today's youth plan to be scientists, health practitioners, teachers, engineers, politicians, or informed citizens, they must grasp the unifying role of evolutionary theory in 21st-century life science.

Teaching biological evolution can be a challenge. Our everyday intuitions about the way the world works are at odds with an evolutionary perspective. Instead of a static world inhabited by separate living kinds, evolutionary theory provides us with a dynamic world in which all living kinds are related, through a common ancestry. Evolutionary science provides a new way of thinking about the living world.

National Science Education Standards for Biological Evolution

Leading educators and scientists have come together to develop a set of national science standards aimed at improving the scientific literacy of the U.S. population. There are two major organizations involved in this effort, and although they have each tackled the standards from a different perspective, they have achieved a remarkable consensus on what students at different grade levels need to know about science. The National Research Council (NRC) developed the National Science Education

Standards, whereas the American Association for the Advancement of Science (AAAS) created the Benchmarks for Science Literacy and its more dynamic form, the *Atlas of Science Literacy.* According to these documents, an understanding of biological evolution and the nature of science should be a core component of science curricula for all students.

I shall briefly summarize the current consensus on standards for evolution content and the nature of science content for each grade level, based mostly on the NSES. The AAAS Benchmarks break down the grade levels somewhat differently (K–2, 3–5, 6–8, and 9–12), but in general the concepts expected of each age group are similar (see Table 1). The distinctive feature of the Atlas of Science Literacy is that the learning goals for a particular topic are presented on one page as a conceptual flowchart from the earlier to the later grade levels (see the AAAS flowchart for biological evolution on page 27).

Table 1: *Atlas of Science Literacy*: Learning Goals

- Scientific Inquiry: Evidence and Reasoning in Inquiry
- Scientific Inquiry: Scientific Investigations
- Scientific Inquiry: Scientific Theories
- Scientific Inquiry: Avoiding Bias in Science
- Heredity: DNA and Inherited Characteristics
- Heredity: Variation in Inherited Characteristics
- Cells: Cell Functions
- Evolution of Life: Biological Evolution
- Evolution of Life: Natural Selection

(AAAS 2001)

Evolution and the Nature of Science in the Classroom:

A grade-level comparison

Below is a summary of the relevant sections in the NSES, for each range of grade levels. A chart detailing the relationship between each of the activities in the book and the National "Life Science" Standards (Content Standard C) for Grades 5 to 8 can be found in this book on pages xvii–xix. Further information is provided in the resources section at the end of the book.

Kindergarten to fourth grade

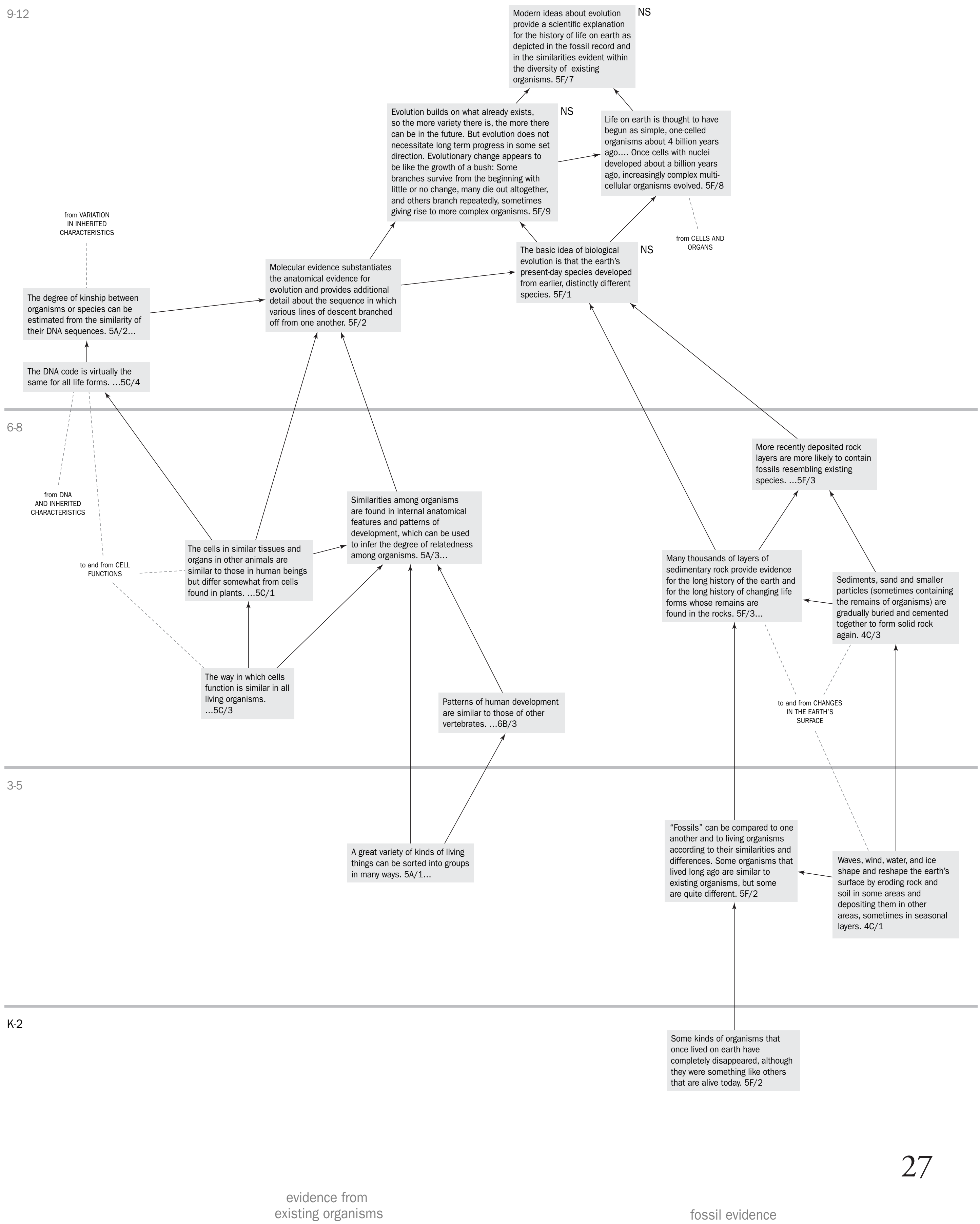
The NSES propose that children in this age-range be taught about the characteristics of different kinds of organisms (both plants and animals), their life cycles, and their ecological niches (see Table 2). In particular, they learn about the interrelationships between living things through direct experience of the living world. Young children are introduced to the nature of science as they carry out simple experiments and learn basic concepts about science as a way of thinking about the natural world. These activities are intended to be the foundational knowledge base for an understanding of the life sciences and of evolution.

Table 2: National Science Education Standards in the K–4 Classroom

Content Standard A: Science as Inquiry
Content Standard C: Life Science
Content Standard F: Changes in Environments
Content Standard G: History and Nature of Science

(NRC 1996)

Evolution of Life: Biological Evolution (AAAS 2001)



Fifth to eighth grade

For these grade levels, the NSES explicitly mention biological evolution. Children are encouraged to pay attention to the relationship between the organism and its environment, its ecosystem, and, in particular, the concepts of diversity and adaptation. They are taught about the function and structure of cells. Children also learn that how any one species moves, reproduces, and gets food is a function of its evolutionary history. The concepts of variation, inheritance, selection, and time are introduced, along with the fossil record and extinction. These concepts are also woven into a larger context—that of the study of systems—with the history of Earth and the universe portrayed as tightly coupled systems. Students' classroom activities in the fifth through eighth grades include studies of the nature and history of science. These students learn about observation, experimentation (hypothesis testing), the relationship between explanation and evidence, and modeling, particularly of theoretical and mathematical models (see Table 3).

Table 3: National Science Education Standards in the 5–8 Classroom

Content Standard A: Science as Inquiry

Content Standard C: Life Science

Content Standard D: Earth in the Solar System

Content Standard G: History and Nature of Science

(NRC 1996)

Ninth to twelfth grade

NSES for these grade levels detail the Darwinian concepts of natural selection and common descent, along with gene theory and the molecular basis of heredity. Students learn about biological classification as a hierarchy, determined by the evolutionary relationships between organisms, with species as the fundamental biological unit. Biological evolution is again woven into a larger context along with that of the origin and evolution of Earth and the universe. These students study science as a special way of knowing, based on empirical standards, logical arguments, explanation, and skepticism. They discover the principle that all scientific knowledge is subject to change in the light of new evidence (see Table 4).

Table 4: National Science Education Standards in the 9–12 Classroom

Content Standard A: Science as Inquiry

Content Standard C: Life Science

Content Standard D: The Origin and Evolution of the Earth System

Content Standard G: History and Nature of Science

(NRC 1996)

Summary

The NSES present the theory of evolution as a unifying theme for life science. Evolution integrates a life science curriculum focused on biological systems that are interrelated and constantly undergoing change. Change in one part of the system affects the other components. The origin of biological organisms is also presented as part of a broader topic, the origin of the Earth and of the universe. Importantly, science is presented as an activity that is based on evidence derived from meticulous investigations of the natural world. Over the grade levels these topics are gradually introduced, with the requirements for each level offering more depth, while building on early foundational concepts.

Teaching Science

The National Science Education Standards for teaching advocate inquiry-based activities as the best method for learning about evolution (NAS 1998; NRC 2000). The goal of the inquiry method is to have the student think and behave like a scientist. This goes beyond hands-on activities, in which a student may engage in some aspect of the scientist's behavior, such as collecting data or exploring natural phenomena. Inquiry-based learning emphasizes thinking and reasoning as well. It is known as the "minds-on" approach: Engage, Explore, Explain, Elaborate, and Evaluate (the 5E model). Students have to come up with hypotheses to explain a pattern of observations, and then conduct an experiment or a study designed to test these hypotheses. Once they have gathered the data, they have to explain the results, decide whether or not they fit with the original hypotheses, and consider alternative explanations. Finally, they have to explain their results to an audience, either in a written or an oral form. There are many data sets available that can be used to explore evolutionary hypotheses. Moreover, all of the activities in this book incorporate basic concepts of inquiry-based learning.

In contrast to the more traditional approach, the inquiry method also emphasizes collaborative learning. It is the rare scientist who works entirely alone. He or she would not be able to accomplish the work without a team. Lectures, memorization, and individual problem sets, which are the hallmarks of the traditional approach, are not absent with the inquiry method, but they clearly play a less dominant role. Overall, the inquiry method emphasizes the dynamic aspect of a scientific investigation. Science is viewed as a dynamic enterprise with current facts and theories acting as a way station to new facts and theories. Science learning experiences, in any setting, focus less on the accumulation of many superficial facts and more on the deep learning of fundamental principles.

How does inquiry-based or experiential learning play out in the everyday activities of the scientist's laboratory? Peter Medawar, a well-known evolutionary biologist, described some of the conversations in his laboratory:

- "What gave you the idea of trying...?"
- "What happens if you assume that…?"
- "Actually your results can be accounted for on a quite different hypothesis…."
- "Obviously a great deal more work has got to be done before…."

According to Medawar's own observations and those of others who have studied scientists at work, what is happening is that the scientists are "building explanatory structures, telling stories which are scrupulously tested to see if they are stories about real life" (Hoagland 1990, p. 20). These "stories" are more formally represented as hypotheses, which are then tested by collecting data to determine their truth or falsity.

The 4-H Youth Development programs share the same basic approach as that of inquiry-based learning, but with a greater emphasis on experiential learning, the hallmark of 4-H activities. Their credo is "Do-Reflect-Apply," which involves youth carrying out an activity, reflecting on the experience, then applying this experience to their own lives or that of the broader society.

The Development of Children's Concepts of Evolution

Cognitive scientists are interested in the way people reason about the world, in the absence of expert training. Recently, there has been a surge of interest in this everyday reasoning and what impact it has on the developing learner's capacity to absorb new information. Commonsense or everyday reasoning has been portrayed as a limited series of intuitive theories about the world, each one of which potentially describes a different kind of knowledge. Intuitive theories differ from scientific theories in many ways, but like scientific theories they frame the way we view the world and provide both questions and explanations (Wellman and Gelman 1998). These are the kinds of everyday explanations or hunches that most easily come to mind when we try to figure out what is going on in the world. How these intuitive theories develop over the course of a child's life and into adulthood is the focus of much recent research. I'll focus on the development of those concepts most likely to impede evolutionary thinking. Family background and the development of children's intuitive theories are the major influences on children's reasoning about evolutionary change.

How do we know about these developmental changes? Over the past 15 years or so, my colleagues and I have begun to map out the emergence of children's understanding of natural transformations, such as evolutionary change, which relate to the development of their intuitive theories of biology (Evans 2001; Rosengren, Gelman, Kalish, and McCormick 1991). In the process we have interviewed hundreds of children and their parents from different religious backgrounds. To investigate children's intuitive ideas, we ask the children unexpected questions and give them unusual tasks. This is done to make sure that they do not just give us rehearsed responses. They have to think through the issues. We also compare children's intuitions about natural transformations, such as seasonal change, with their intuitions about artificial transformations, such as making chairs or toys. These kinds of studies reveal the way children of different ages reason about different types of transformations. I shall detail what we have found and tie it in with the extensive research that science educators have carried out on older students' ideas about evolutionary change.

Four- to seven-year-olds

Over the preschool and elementary school years, children slowly abandon their idea that animals cannot change. In preschool through about second grade, most children reject the idea of almost any kind of radical biological change, from metamorphosis to adaptive variation. Thus, from the perspective of the young child's intuitive biology, living things cannot change. This age group is learning so much that is different and new, it is surely useful to have an intuitive sense that the world around them is permanent and enduring. Young children, however, do know that animals possess adaptive features such as wings for flying or fins for swimming, but they have little sense of what would happen if the environment changes. If you ask a child from this age group where the very first animals come from, you will get a variety of answers. Some are likely to respond that God made them. Other children may well reply that the very first animal came "from someplace else" or that they "came out of the ground." In other words, they appear to think that the animals were always here on Earth, but someplace else where they could not be seen. This idea may be rooted in children's everyday experiences of the world. Every spring after the snow melts or after the first spring rains, the ground seems to burst with new life.

Eight- to ten-year-olds

From about third grade to the end of fourth grade, there is a gradual shift in children's reasoning. This age group is more likely to accept some kinds of radical biological change, especially over the life cycle, such as metamorphosis. Interestingly, whatever their family background, most children in this age range endorse the idea that the very first kinds of animals were "made by someone," and often that someone is God. One reason for this belief is that unlike their younger siblings, older children are beginning to think about existential questions. This age group is more likely to know about death and understand that animal kinds are not eternal, in that they were not always here on Earth, nor will they continue to be on Earth. So, the question arises, how did different kinds of animals get here in the first place? These children appear to transfer their intuitive understanding of the human as an intentional manufacturer of new tools, and apply it to objects that have arisen naturally, such as new species.

Simultaneously, children in this age range are starting to integrate different kinds of causes into a complex causal structure. If preschool children see "Josh" knock over a glass and break it, they are perfectly capable of reasoning about the immediate cause. They can tell you who knocked over the glass and how it happened, such as "Josh didn't see the glass." But if you ask preschoolers to think a little harder about "why" Josh knocked over the glass, they have more difficulty. The older children, however, are better able to engage in a more complicated reasoning process and arrive at a more distant cause, as in the following causal chain: Josh knocked over the glass because he was in a bad mood, because he didn't get lunch, because he forgot his lunch money, and so on, until they arrive at the most distant or original cause. This sort of reasoning is necessary for understanding the origins of novel animal kinds: Why and how did something come into existence in the first place?

Ten- to twelve-year-olds

On the surface, at least, the beliefs of preadolescents are very similar to the beliefs of the adult members of their community, with the same percentage endorsing evolutionist and creationist beliefs. Children in fifth grade and older are able to reason about existential questions such as the origins and death of living things. At this point, we often see the influence of a family's system of beliefs. Children who are exposed to the evidence that animals change—from metamorphosis, to adaptive variation within species, to fossils—are most likely to accept major evolutionary changes. They will agree that one kind of animal could have originated from earlier and very different kinds of living things, although they are likely to exhibit many misconceptions about evolution. For these children who take the perspective of a naturalist, this is the beginning of a more complex understanding of the fundamental interrelationship between all living things. Conversely, children who know the least about natural history and fossils, and who go to schools that endorse Biblical literalism, are likely to endorse the idea that God created each kind of animal. But, interestingly, these beliefs seem to vary depending on the organism. Many children and their parents exhibit mixed beliefs, agreeing that butterflies and frogs evolve but that God created mammals, in particular humans.

Older youth and adults

Adolescents are often ready to assimilate basic evolutionary concepts. But their everyday intuitions continue to undermine the teaching of Darwinian theory. Most adolescents and even many adults endorse a pre-Darwinian theory of evolutionary change, which makes it difficult for them to grasp contemporary Darwinian concepts (e.g., Bishop and Anderson 1990). Perhaps the most revealing indicator of this kind of reasoning is the use of need-based or intentional explanations of evolutionary change: Animals change because they need to adapt to novel environments in order to survive. Such ideas appear to have their roots in children's and adults' understanding of the way humans fit in with or adapt to their environment. Additionally, many believe that such adaptations, acquired over the lifetime of the individual animal, can be inherited by future generations.

Education researchers have also found that science learners think of evolution as growth and improvement over time. Such ideas contribute to the rejection of the idea that living species are very likely to become extinct, which should be a core concept in major evolutionary change. Although many adults and children accept the extinction of the dinosaurs, they are less willing to generalize this understanding to include contemporary species, especially the human species (Poling and Evans 2004). Many have the idea that species continually adapt to new environments and do not really become extinct. Perhaps a more critical aspect of this problem is that the concept of extinction seems to arouse existential concerns. In practical terms, what this means is that older children and adults have difficulty contemplating the idea that humans and other species alive today might cease to exist.

Using Research on Learning to Teach Evolution

In this section, I'll show you how to identify different reasoning patterns among science learners. This will help you guide novice learners to a more informed viewpoint, and also help you assess their learning. The research described in this section is based on museum visitors' explanations of the evolutionary problems presented in this book (Evans et al. 2005).

The following reasoning patterns could serve as the basis of both your teaching and assessment tools.

- Informed Naturalistic Reasoners: People who propose Darwinian evolutionary explanations for the origin of species.
- Novice Naturalistic Reasoners: People who propose natural explanations, but who have little understanding of Darwinian evolutionary mechanisms. Many will use the pre-Darwinian concepts described earlier.
- Creationist Reasoners: People who propose supernatural explanations. In particular, they reference God's direct role in the origin of species.

- Mixed Reasoners: People who use more than one of the above reasoning patterns. This is the reasoning pattern found in most people.

By using these reasoning patterns as a diagnostic tool, you can give your science learners insights into the nature of their own reasoning. You cannot expect them to completely replace their intuitive ideas with Darwinian evolutionary concepts. But they might be able to construct dual frameworks. You will have succeeded when you and they recognize when they are shifting from informed to novice naturalistic reasoning patterns and back again. By reflecting on their own reasoning processes, they should be able to change their way of thinking about the problem.

Teachers and youth leaders can also use these reasoning patterns to assess learning. Ideally, any assessment of students' understanding should not be an endpoint in and of itself, but a further tool to help them consolidate what they have learned. Each of the activity chapters in this book has an assessment question (part four) in which the learner is asked to take on the role of a science reporter and explain a central problem in the evolution of each organism. These assessment questions provide learners with an opportunity to reflect on what they learned as they read the chapter introductions and carry out the various activities. This is a core component of inquiry-based and experiential methods. This process encourages the use of higher-order thinking skills. Students are not just memorizing facts, they are developing scientific explanations and reporting them to outsiders. They can do this individually, with the instructor evaluating each reporter's response, or as a group activity.

Informed Naturalistic Reasoners

The informed naturalistic reasoner uses evolutionary concepts and explanations rather than everyday intuitive reasoning to explain biological change. The core evolutionary concepts of variation, inheritance, selection, and time (VIST) could be used to assess children's responses to the questions at the end of each of the seven activities in this book. The VIST acronym from the University of California Museum of Paleontology website *(http://evolution.berkeley.edu)* provides a useful way of framing and remembering these concepts.

Variation

Variation refers to the differences among individuals in a population. These can be described as differences in a particular trait (feature or behavior), as a mutation, or as genetic differences. Here is an example of the kind of informed natural reasoning you might encounter about variation in Activity 5 about finch evolution (Evans et al. 2005):
The finches with the larger beaks survived I suppose. The ones who didn't died out….

Inheritance

Inheritance refers to traits (factors) that are inherited and passed from one generation to the next. Students may not use the term inheritance, but just convey the idea that some factors are passed from one generation to the next. Here is an example of informed natural reasoning about inheritance from the same activity:
Those big-beaked finches were favored by the environment. So they were able to eat, breed, and then their offspring continued to do the same….

Selection

Selection refers to the idea that organisms with traits that are adapted to the environment are more likely to survive (and pass these factors on to the next generation). A reasonable response might note the key environmental feature to which the organism is adapted. Here is an example of informed natural reasoning about selection in finches:

Well, the large-beaked birds were the only ones that survived because they could eat the seeds, and therefore they were the only ones that reproduced; and the ones with the small beaks lost out….

Time

The number of generations produced over a given time period is a clue to whether evolutionary change will occur rapidly (as in HIV) or slowly (as in whales). From one generation to the next a species may change ever so slightly, but given enough time, the result can be huge. Almost any reference to time acknowledges its crucial role.

Here is an example from the finch activity of a response that includes the four core evolutionary concepts—variation, inheritance, selection, and time (VIST):

Well, in that case I would assume that the birds evolved—well, the birds with the larger beaks were the ones better able to survive, since the larger beaks were more useful in getting the seeds. So that trait is the one that was selected for, and the birds that had the smaller beaks died out over time…. They didn't produce as many offspring.

Novice Naturalistic Reasoners

Novice naturalistic reasoners usually employ everyday reasoning, particularly intuitive ideas about biological change. We'll look at three typical kinds of everyday explanations used by science learners.

The first kind of explanation is called goal-directed or need-based change. Here is an example from the finch activity of a novice naturalistic reasoner's goal-directed response:

It's evolution. They had to—for survival, the beaks had to grow so the finch could eat. So they just adapted… their bodies adapted so that they could survive. That's not evolution, is it, it's another word. Is it development? Then their babies had those beaks.

This novice science learner is using everyday reasoning to explain how the finches could survive. She has recognized a need, which is that the finches do not have the right kinds of beaks to eat in this environment. The mechanism of change that she has identified is that the finch's beak must grow to meet the challenge. The term *development* captures an understanding that animals grow to meet an unmet future need, much in the way an individual animal develops from infancy to adulthood. The other intuitive idea expressed by this science learner is that this trait (the large beak) is acquired over the lifetime of the finch and can be passed on to future generations.

This kind of response is relatively sophisticated, but it isn't scientifically correct. What this novice science learner does not realize is that there is already a natural variation in beak size in this population and that those finches with the larger beaks are the ones that will survive. It would not take much to have her focus on the variation in the population and then figure out a Darwinian mechanism of change, such as natural selection.

The next explanation typical of novice naturalistic reasoning includes terms such as *thoughts, beliefs, wants, skills,* or *effort*. These terms are a sign that this science reasoner is using everyday intuitions about the way humans solve problems, called intentional reasoning. Here is an example from the finch activity of a novice naturalistic reasoner's intentional response:

Well, I tend to believe that a lot of animals…have capabilities of making adaptations. Like they wanted to increase the size of the beak to get the seeds so they tried to change their beaks to use in their daily life.

This kind of explanation is subtly different from the goal-directed reasoning described above. In using an intentional explanation, this science learner appears to assume that the finch can actively think about the problem and try to solve it by changing its beak, in the same way an athlete will actively train to achieve a better performance. Ask the science learner if the finch can really solve problems in the same way humans solve problems. They will probably recognize that this is unlikely. Then they can begin to think of alternative explanations for the change in beak size.

The third kind of novice naturalistic reasoning is called proximate (or immediate) cause reasoning. Recall that when asked about the origins of species, younger children would often respond as if the species were "always here on Earth, but someplace else." They did not address the most distant or original cause: Why and how did these new kinds of animals come into existence? Instead, the children described how they became visible. Interestingly, older youth and adults sometimes come up with similar immediate or proximate cause explanations to describe evolutionary change. They are most likely to do so when they are confronted with questions about the origins of organisms about which they know very little or which are not visible, such as insects, diatoms, and viruses. Here are some examples from the diatom and HIV activities of a novice naturalistic reasoner's proximate cause response:

Diatom: *Water could have been mixed throughout the whole Earth, and it could have carried new algae in different places.*

HIV: *They were there and they weren't detected.*

There are several ways to address this kind of response. First, you should help the youth realize that there is a mystery. These particular organisms did not exist before and now they do. They were not hiding elsewhere on Earth. How did they come into existence? What are the relevant clues? What has changed? With some prodding the youth should begin to realize that the change in the environment is an important clue. Then they can make the connection between environmental change and the appearance of new species.

Creationist Reasoners

Religion and evolution are perfectly compatible, with a few exceptions. One exception is Biblical Literalism, whose adherents believe that God created each kind of animal that is currently on Earth just a few thousand years ago. Such beliefs are clearly irreconcilable with evolutionary ideas. According to a 2004 Gallup Poll, about 45% accept that God created humans in this way. Most Western religions, however, do not take a literal view of the Bible. This same poll indicated that 48% of the American public consider the Bible to be divinely inspired but not to be taken literally and 38% are theistic evolutionists, believing that biological evolution occurred over millions of years, with God guiding the process. Pope John Paul, for example, viewed a belief in evolution and a belief in God as perfectly compatible. Clearly, many citizens and religious leaders find it easy to accept evolution and to believe in God. They accept that evolutionary theory has its place: It explains adaptive features and the similarities and differences among organisms in the living world, but it does not tell us how to behave. It is not a theory of morality. That is the province of family, culture, and religion.

Creationist reasoners are likely to cite God or intelligent design as directly implicated in the origin of organisms. This is an intentional mode of reasoning in which animals are created to serve God's purpose. As long as science learners describe the evolutionary concept accurately, they should be assessed appropriately, even if they also express creationist ideas. Here are two examples of a creationist reasoner's response:

I would just explain it as God being the creator with infinite wisdom, and he designed and created every organism, down to the most minute detail. . . .

I think they each were created as they are, with their own unique set of chromosomes, so I wouldn't have an answer how they would evolve.

Mixed Reasoners

Perhaps one of the more surprising findings from recent research is that many people do not consistently use a single pattern of reasoning. In fact, they are more likely to be mixed reasoners, employing two or three patterns of reasoning simultaneously. For some youth or adults this kind of reasoning may mark an unconscious transition between evolutionist and creationist reasoning or novice and informed naturalistic reasoning. In other cases, the conflict is more conscious, as it was for the parent who said, *I don't know what to believe, I just want my kid to go to heaven.* As described earlier, many youth and adults propose evolutionary explanations for the origins of most animals, with the exception of humans (and sometimes other mammals as well). Here is an example from Activity 6 on human evolution:

I don't believe that they [humans] do evolve, because I don't believe necessarily in evolution. I mean yes I believe there's a Darwinism where the stronger species survived [like in the finches], but, I'm Christian so I believe God created man and God created chimpanzees. . . .

In another kind of mixed reasoning pattern, we find creationist reasoning combined with informed naturalistic reasoning. The following response begins with creationist reasoning and concludes with a selectionist concept, as the science learner tries to explain why there are more large-beaked finches than small-beaked finches. It seems probable that the learner was unaware that she is describing an evolutionary mechanism, natural selection. This is a response from Activity 5 on finch evolution:

But like I said, I don't believe in evolution. So I don't believe that they evolved because it takes too long. There are too many failures before they evolve into something that finally works, so I just reject that view. Um, my guess would be that there probably were larger-beaked finches but there weren't as many of them and the small-beaked ones would have died out because they couldn't get the food.

You should not expect creationist reasoners to replace their belief system with Darwinian evolutionary concepts. But you can expect all of your science learners to understand evolutionary theory, so that they know how the natural world works. Many of them will be entering the kind of careers in which they will need this kind of understanding. How might they do this? By reflecting on their reasoning processes, they should be able to construct dual frameworks. You will have succeeded when you and they recognize that they are shifting from novice naturalistic or creationist reasoning patterns to informed naturalistic reasoning patterns, even if they use mixed patterns of reasoning.

Summary

Understanding how youth of different ages think and reason about evolution can lead to more effective guidance and teaching. By recognizing the nature of their thinking processes as they begin to acquire these complex and counterintuitive ideas, you can help them become better learners. The central idea is to have science learners engage in "intentional" conceptual change, in which learners are active agents in the learning process (Sinatra and Pintrich 2003). In this kind of conceptual change, learners reflect on the content of the learning process itself. Such a practice is more likely to result in lasting changes and will be an important mental tool for use in their daily lives. Teachers and youth leaders who are aware of their science learners' conceptual difficulties can use the ideas in this chapter in a variety of ways to suit the particular learning challenges that they face. These ideas represent some of the core concepts in inquiry-based and experiential learning.

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