Epistemology and Science Education

Understanding the Evolution vs. Intelligent Design Controversy

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Routledge
Taylor & Francis Group
NEW YORK AND LONDON

Chapter 6

Engaging Multiple Epistemologies

Implications for Science Education

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Introduction

> It might seem contradictory to believe that humans were created in their present form at one time within the past 10,000 years and at the same time believe that humans developed over millions of years from less advanced forms of life. But, based on an analysis of the two side-by-side questions asked this month about evolution and creationism, it appears that a substantial number of Americans hold these conflicting views.
>
> (Gallup, June 11, 2007, p. 4)

In a 2007 Gallup poll, 24% of Americans endorsed beliefs in both evolution and creationism, with another 41% believing that creationism is true and evolution is false. Of the rest, 28% believe that evolution is true and creationism is false (June 11, 2007). This result echoes earlier findings among parents and their adolescent children in the Midwest, with about a third of the sample endorsing both creationist and evolutionist views (Evans, 1994/95, 2000a, 2000b, 2001). Our focus in this chapter is on this phenomenon. What are the conceptual processes that underlie the endorsement of seemingly mutually inconsistent epistemologies? To address this issue we draw upon research in three related areas—beliefs about illness, death, and origins—and link these findings to recent work on the development of intuitive theories of biology and psychology. Although evolution is typically treated as if it were distinctly different from other areas of biological reasoning, we highlight similarities in the reasoning of children and adults across these three areas. In this process, we examine the different ways in which individuals engage multiple epistemologies and the circumstances that foster such an engagement. We conclude by drawing out the implications of this line of research for informal and formal science education.

Most of the media focus on the evolution–creationist controversy tends to report it as a clash of belief systems, an either/or debate, with notable atheists, such as Dawkins, taking up one side of the debate and notable creationists, exemplified by the biblical literalists, taking the opposing view (Scott, 2005).

Similarly, the focus of most Gallup polls conducted over the last 20 years (in the United States) has been on evolution and creationism as competing beliefs, particularly with respect to the origin of humans (Gallup, 2007). The pattern of results has remained relatively unchanged over that time period. Dawkins' position, that humans evolved without the help of a supernatural being, is regularly endorsed by about 13% of the sample, with the biblical version of human origins endorsed by 46%. Yet, typically, a substantial portion of these samples (about 36%) accepted evolution, while also acknowledging a role for God. How is it possible to endorse such seemingly incompatible belief systems? Without more detailed analyses it is difficult to know exactly how these beliefs were reconciled, but one strong possibility is that they endorsed theistic evolution, the belief that God is a supernatural agent who set up the naturalistic conditions under which evolution occurred (Evans, 1994/95, 2001, 2008; Scott, 2005). In this scenario, variations of which are endorsed by theologians from most non-fundamentalist Western religions (Ruse, 2005), God is the final or ultimate cause, with evolutionary causes at a more proximal point on the causal chain. This contrasts with the view of biblical literalists who believe that God was directly involved in the creation of humans and other species (Scott, 2005). The latter version, with God as the proximate cause, is the definition of creationism that we use in this chapter.

Furthermore, theologians who endorse religious and evolutionary explanations for the origins of species are not alone; many contemporary scientists also reconcile these belief systems in similar ways. Gould, the evolutionary biologist, described them as "nonoverlapping magisteria" (Gould, 1997), each of which plays a crucial role in human affairs. For geneticist Frances Collins, God "exists outside of space and time" (Biema, 2006). In these types of epistemological blends, most notably championed by evolutionary biologist Ken Miller (1999), a devout Catholic, religion and science are viewed as complementary, not competing views of the world. This analysis suggests that there are a range of complementary rather than competing belief systems about science and religion (see www.templeton.org/belief, for some intriguing examples).

These different ways of engaging multiple epistemologies appear to be relatively common among scientific, philosophical, and religious leaders who have been forced to confront the apparent contradictions, but this mode of reasoning has yet to be investigated in much detail in the lay public. The traditional analysis suggests that these different worldviews can be viewed as competitive *ways of knowing*, with science and religion in a battle for the *truth*, or as complementary but distinct epistemological stances. Our investigations of the beliefs of lay adults and children suggest, however, that there are additional models that could bind these beliefs in coherent explanatory frameworks. In our analyses we recognize two broad sources of belief (Sperber, 1996), the first derived directly from the sociocultural context, via the media and cultural institutions, and the second, intuitive beliefs, which

are largely untutored and derived from our everyday reasoning (Atran & Sperber, 1991). We begin by reviewing some work on intuitive beliefs about the natural world, which, we claim, underlie the culturally endorsed epistemological stances. Moreover, from this work on an intuitive epistemology it would appear that epistemological blends and shifts between epistemological stances are commonplace and part and parcel of the causal flexibility that characterizes human thought (Gutheil, Vera, & Keil, 1998; Poling & Evans, 2002).

Intuitive Theories

Over the course of a day children and adults use a wide variety of explanatory models to reason about the outcome of various events, such as the disappearance of a cookie in a cookie jar, the shattering of a drinking glass on a ceramic tile, or the lack of movement in a robin lying on the front walk. In many instances a single explanation adequately captures the causal structure of the event. Because of his past habits and love of cookies it is surmised that Dad raided the cookie jar, that the drinking glass broke because it fell to the floor and glass is more fragile than tile, and the robin is not moving because it has died. In these situations explanations from the realms of three different foundational theories, those of intuitive psychology (theory of mind), intuitive physics (or mechanics), and intuitive biology, adequately capture plausible and likely causes of the three events (Wellman & Gelman, 1998). Although it would be possible to talk about each of these events using other types of explanations, such as magic or the will of God, these do not seem as straightforward as those provided by intuitive psychology, physics, and biology.

In their everyday lives children and adults shift between these different forms of causal understanding (Schult & Wellman, 1997), though at times causal explanations from one of these domains pop up in one of the other domains. For example, an individual might say that his car "was hurt" in an accident as if the car was a biological organism that could be injured and perhaps "heal." Or another individual might say her car "doesn't want to start" as if the car has a mind of its own that determines whether it starts or not. In other instances individuals may take widely divergent worldviews, perhaps religious and scientific ones, and combine them to create a coherent model of the world. Still others might be quite happy to compartmentalize these different worldviews to describe different phenomena or use these different perspectives in distinctly different contexts. One of the goals of this chapter is to examine those circumstances when children and adults maintain a sharp boundary between different types of explanations, when individuals allow seemingly contradictory explanations to co-exist, and when individuals blend these contradictory explanations into a relatively coherent framework.

In the next sections, we explore how children and adults navigate between different causal explanations for biological phenomena. Although multiple

forms of explanation can be used to explain a variety of psychological and physical phenomena, we focus here on biology because of the central problem of understanding how children and adults reason about evolutionary processes. First, we provide evidence, using examples from our own research, that individuals, from both Western and non-Western samples, combine or shift between natural and supernatural explanations to explain phenomena that address fundamental existential questions: *illness*, *death*, and *origins*. In the process we comment on several factors that serve to trigger these novel alignments. Finally, we shall argue, again using research data, that although different individuals approach evolutionary reasoning from very different perspectives, by and large their explanations fall into characteristic patterns.

Using Multiple Epistemologies to Reason about Biological Phenomena

The issue of how children and adults coordinate natural and supernatural belief systems regarding biological phenomena is a broad one that, we propose, is of universal concern. On the one hand, there is no society we are aware of that wholly excludes supernatural beliefs. Even within highly educated, industrialized modern communities, at least some individuals endorse supernatural beliefs, ranging from God to ghosts to astrology (Evans, 2000b; Zusne & Jones, 1989). On the other hand, there is no society we are aware of that wholly excludes natural beliefs. Even within highly traditional, non-industrialized communities, at least some individuals endorse folk-biological beliefs (e.g., regarding inheritance, Astuti, Solomon, & Carey, 2004, and death, Astuti & Harris, 2008). Thus, access to natural and supernatural explanatory frameworks is a universal psychological experience, and coordinating these different belief systems is a general cognitive problem. People in all societies are faced with the task of conceptualizing potentially contradictory belief systems about biological phenomena.

One approach to investigating the relationship between different epistemologies is to focus on content areas in which both natural and supernatural explanations are prevalent (Evans, 2001). Although there are potentially a number of different content areas that are particularly apt to draw on divergent explanatory systems, focusing on individuals' understanding of the illness, death, and the origins of species are specific areas where the prevalence of multiple explanations may be quite common. These concepts also share a number of properties that may enhance the likelihood of drawing on different types of explanation. First, a central aspect of these phenomena is that they often involve unobservable causes such as microorganisms and genes. Second, each of these content areas is associated with strong emotions. For illness and death these emotions arise from the loss or potential loss of loved ones. For the concept of origins, the emotions surround the belief that humans are somehow special and different from other organisms (Evans, 2001) or that acceptance of evolution is

associated with a range of negative outcomes (e.g., Evans, 2008; Brem, Ranney, & Schindel, 2003). These emotions, whether due to existential crises about humans' role in the universe or due to the loss or potential loss of loved ones, may serve to elicit those intuitive explanations most intimately concerned with human affairs, namely an intuitive psychology. Finally, both illness and death are associated with particular rituals that are embedded in specific cultural contexts and practices that predate our current scientific understanding of these concepts and which continue to co-exist alongside our scientific knowledge. In the case of origins, different cultures clearly treat the status of humans as elevated compared to other species, and an evolutionary account of origins calls this cultural understanding into question.

A Taxonomy of Cultural and Intuitive Beliefs

Before delving into the studies, we first outline a proposal for a taxonomy of beliefs, which is portrayed in a simplified graphic (see Table 6.1) that is

Table 6.1 A Proposed Taxonomy of Cultural and Intuitive Beliefs: Explaining Origins, Death, and Disease

	Cultural beliefs		*Intuitive beliefs*	
	Science	*Supernatural*	*Intuitive biology*	*Intuitive psychology*
Cultural beliefs	*Quadrant A*		*Quadrant C*	
Science	Competing cultural models i. Science dominant ii. Supernatural dominant		Synthetic blends Fusion of intuitive and cultural beliefs, with intuitive beliefs dominating	
Supernatural	Co-existence cultural models i. Causal chain ii. Target dependent iii. Parallel iv. Juxtaposition			
Intuitive beliefs	*Quadrant B*		*Quadrant D*	
Intuitive biology	Overlay models Cultural model overlay, intuitive model underlay (or foundation)		Competing intuitive models i. Intuitive psychology dominant ii. Intuitive biology dominant	
Intuitive psychology			Co-existence intuitive models i. Causal chain ii. Target dependent iii. Parallel iv. Juxtaposition	

divided into four quadrants, each of which represents a different combination of cultural and intuitive beliefs. This graphic will be used to frame the specific models presented in each quadrant. To make the problem of creating such a taxonomy tractable, we have reduced the problem space by focusing on scientific and supernatural perspectives, construed broadly, for cultural beliefs, and only on intuitive biology and psychology for intuitive beliefs.

We start with the cultural models, found in Quadrant A of Table 6.1: these characterize the different ways in which individuals might represent both scientific and supernatural beliefs. The model most often cited in the media is a competitive one in which one mode dominates and the other is dismissed, though its presence is acknowledged. A key example here is Dawkins' championing of evolutionary explanations and his contention that supernatural explanations are childish (Dawkins, 1995). Reconciliations of these two extremes are presented in a variety of *co-existence* models. In a *causal chain*, described earlier, a supernatural cause might precede the scientific cause, as in theistic evolution. Yet another possibility is the *target-dependent* model, in which one form of reasoning is reserved for a particular entity or domain, and other forms of reasoning for other entities or domains. For example, some individuals treat humans, but not other animals, as created by God (Evans, 2001). This type of reasoning also captures Gould's (1997) concept of non-overlapping magisteria, where religion and science occupy separate realms, the one supernatural and the other natural, and are used to explain different phenomena, such as the meaning of life versus what constitutes life. Collins' belief that God exists outside time and space may also fit here (Biema, 2006). A third co-existence model is one where individuals hold two very different types of beliefs that are used to explain the same or highly similar phenomena. One example of this model is provided by Subbotsky (2000, 2001) who has shown that both children and adults provided the right context will deny the existence of magic, a form of supernatural reasoning, but will behaviorally exhibit evidence of credulity toward magic for the same seemingly impossible event. We refer to this form of co-existence reasoning as a *parallel reasoning* model in which two different epistemological beliefs are used by the same individual to explain the same or similar outcome. A final form of the co-existence model has been labeled as *juxtaposition reasoning* (Legare & Gelman, 2008; Piaget, 1928). In this model two different forms of reasoning may be used, but not necessarily in any systematic or well-integrated manner.

For intuitive beliefs, found in Quadrant D, the competitive and co-existence models are now used to refer to an intuitive biology and intuitive psychology. As described earlier, the latter provide natural, everyday or commonsense explanations for natural phenomena, from human behavior to growth and development, to evolutionary change. Given the emphasis of this chapter on biological phenomena, we do not directly address claims that an intuitive psychology might also yield religious beliefs (Boyer, 1993; Evans & Wellman, 2006; but see Atran, 2002). Characterizing the ways in which intui-

tive and cultural beliefs might blend is more difficult. For the moment we acknowledge two broad types, one in which cultural beliefs *overlay* a foundation of intuitive beliefs (Table 6.1, Quadrant B), with cultural beliefs dominating, and the other in which cultural and intuitive beliefs may fuse, in *synthetic blends*, with intuitive beliefs dominating (Table 6.1, Quadrant C). These differ from co-existence models, in that the latter refer to combinations of cultural beliefs (Quadrant A) or of intuitive beliefs (Quadrant D), but not cultural–intuitive blends.

In the next section, we discuss relevant research pertaining to understanding of illness, proceed to talk about death, and then continue with a discussion of research examining explanations of origins. These examples demonstrate how this taxonomy can be applied to different problems in different contexts. We use these examples to suggest that reasoning about evolution is in many ways similar to reasoning about certain other types of biological phenomena that involve existential issues.

Using Multiple Epistemologies to Reason about Illness

Most diseases are caused by an amalgamation of several factors (Thagard, 1998). Anthropological evidence from both industrialized and developing countries indicates that illness is not always interpreted exclusively in biological terms (Green, 1999). Instead, a combination of biological, social, and supernatural explanations are available to explain the process of illness transmission (Brandt & Rozin, 1997; Shweder, Much, Mahapatra, & Park, 1997). For humans, the transfer of illness typically involves a human vector and can therefore be interpreted as interpersonal as well as biological (Nemeroff & Rozin, 2000). Due to the awareness of malicious human action in promoting suffering, especially in contexts of oppression and inequality, people often assume human causes of illness. Among deeply impoverished groups, those who improve their socioeconomic status are subject to witchcraft accusations. In many regions of sub-Saharan Africa and the Caribbean, anthropological reports suggest that supernatural explanations in terms of witchcraft, as well as biological explanations, are both used as explanatory frameworks for illness (Ashforth, 2005; Farmer, 1999).

Co-existence of Beliefs: Biological and Witchcraft Attributions of Illness in South Africa

The co-existence of natural and supernatural belief systems can be investigated most clearly in cultural settings where both these belief systems are prevalent. The AIDS crisis in South Africa provides such a context. In South Africa, multiple approaches to illness are available, including traditional folk medicine, faith healing, and modern biomedical services (Schlebusch & Ruggieri, 1996).

Perhaps the most prominent supernatural explanation for AIDS in South Africa is that of witchcraft, or the practices of persons with malicious intent to cause harm through the use of harmful substances and invisible supernatural forces (Ashforth, 2005). Witchcraft is often associated with *muthi* (*sejeso* in Sesotho), or the malicious manipulation of herbs and other substances, and is believed to cause a wide variety of misfortunes ranging from unemployment and interpersonal discord to illness and death. The civilizing agenda of both the colonial and apartheid regimes viewed any beliefs and practices associated with witchcraft as irrational and primitive. This perspective clearly is one of competing epistemologies with an attempt of the established regimes to drive out the competing epistemology. Education based on Western science and Christianity was viewed as a necessary prerequisite for ameliorating and replacing such beliefs. However, traditional health practices do not necessarily disappear with modernization or education (Ashforth, 2005; Niehaus, 2001). In South Africa, a country of 47 million people, there are nearly 500,000 traditional health practitioners, healers, and prophets working outside the formal biomedical system and 25,000 medical doctors. This is equivalent to one traditional healer for every 80 people in contrast to one medical doctor for every 1,600 people. Notably, the medical doctor to patient ratio in the United States is 1:375. Traditional healers serve to interpret and counteract perceived cases of witchcraft, and provide indirect evidence that millions of South Africans attribute misfortunes to witchcraft (Ashforth, 2001, 2005; Niehaus, 2001).

How do intuitive biological (including scientific) explanatory systems coexist with non-scientific, supernatural explanatory frameworks? There are several broad possibilities. One is that the natural and supernatural realms remain distinct, alternative views of the world recruited to explain distinct phenomena, contexts, and events as in the target-dependent model described earlier. For example, regarding illness, natural explanations may be used to explain transient illnesses such as colds, and supernatural explanations may be used to explain severe illnesses such as AIDS. A second possibility is that natural and supernatural frameworks are used jointly in a blended or synthetic fashion to explain the same phenomena. On this latter possibility, the integration of the frameworks might be quite loose (a person may appeal to both natural and supernatural explanations, but without consideration of how they would interact) as in the juxtaposition model, or instead may combine precisely (a person may treat natural causes as proximate, but supernatural causes as ultimate: e.g., contaminated blood causes illness, but bewitchment causes a person to come into contact with the contaminated blood), as in the causal chain model.

However, given the seemingly contradictory nature of natural and supernatural explanatory frameworks, it is also feasible that they compete. A major implication of the competition model is that the acquisition of a biological explanation could gradually supplant a supernatural explanation, which exists only in the absence of an accurate and coherent biological explanation. Thus, supernatural explanations for illness might exist as a "placeholder" for biolog-

ical information, which, once acquired, replaces supernatural explanations (Mitchell, 1965).

Legare and Gelman (2008) examined the co-existence of natural and supernatural explanations for illness and disease transmission from a developmental perspective. The participants (5-, 7-, 11-, and 15-year-olds and adults; $N = 366$) were drawn from two Sesotho-speaking, South African communities, where Western biomedical and traditional healing frameworks are both available. In Studies 1 and 2, participants were given the opportunity to endorse or reject a variety of biological and supernatural explanations for AIDS. Results indicated that although biological explanations for illness were endorsed at high levels in that participants of all age groups endorsed biological explanations for at least one vignette, witchcraft was also often endorsed. Bewitchment explanations for at least one vignette were endorsed by 47% of 5-year-olds, 59% of 7-year-olds, 47% of 11-year-olds, 34% of 15-year-olds, and 100% of adults. Importantly, bewitchment explanations were not the result of ignorance of biological causes. Thus, they existed alongside, and were not replaced by biological explanations.

Studies 1 and 2 also showed that while endorsement of witchcraft explanations for AIDS was high among adults, it was significantly lower among adolescents. Hence, there were considerably fewer co-existence responses among adolescents. One plausible explanation for this difference between adolescents and adults is that adolescents in school have had more exposure to educational programs concerning the biological causes of AIDS and these have been successful in reducing their belief in explanations based on witchcraft. This would be an important result for both theoretical and practical reasons. First, from a theoretical point of view it provides evidence that natural and supernatural frameworks do not always co-exist. They can be brought into conflict with one another. More specifically, it implies that adolescents who receive information about the viral basis of AIDS are subsequently less prone to endorse explanations based on witchcraft. Second, from a practical point of view, it suggests that adolescents who have a more thorough medical understanding of AIDS will be more likely to have a realistic and accurate appreciation of what constitutes risky behavior as well as the preventive steps that can be taken.

This study also indicated several ways that individuals reconcile and reason about seemingly incompatible belief systems. In Study 3, adolescent and adult participants provided explanations for vignettes that provided a substantial amount of contextual information about characters who had been afflicted by AIDS. There were four conditions that varied in the kind of explanatory system that was primed: biological only, bewitchment only, both biological and bewitchment, and neither. Results indicated that although biological explanations are the default explanatory system for interpreting AIDS, when attention is drawn to socially risky behavior believed to put one at risk for witchcraft attacks (lack of generosity or jealousy), participants give primarily witchcraft explanations for AIDS. Additionally, the data from this study provided evidence that biological and bewitchment explanations can co-exist

in at least three distinct ways in this cultural context: juxtaposition reasoning, parallel reasoning, and causal chain reasoning (see Table 6.1). Each reasoning type is a different solution to the problem of how to combine biological and bewitchment belief systems to explain illness.

Juxtaposition reasoning accommodates multiple belief systems, though not in a clearly integrated manner (i.e., it is not clear what role each domain plays). An example of juxtaposition reasoning was provided by one informant who suggested that AIDS was caused by "Witchcraft, which is mixed with evil spirits, and having unprotected sex." Parallel reasoning provides the greatest separation between biology and witchcraft. More specifically, the same illness is believed to have either natural or supernatural origins that are entirely non-interactive. Adults using parallel reasoning maintain that although AIDS has a biological explanation, witchcraft can cause an equally deadly disease that mimics AIDS. For example, "Witchcraft can cause a disease that looks like AIDS" or "To medical doctors it seems like AIDS but it is not. The spell was supposed to look like AIDS." The notion of "supernatural AIDS" is arguably a reaction to the information people receive from AIDS education programs indicating explicitly that witchcraft does not cause AIDS, while nonetheless maintaining witchcraft as an explanatory system for illness and misfortune generally (Niehaus, 2001). Causal chain reasoning appears to be the most coherent co-existence reasoning pattern because it takes into account which aspects of the causal chain should be attributed to each explanation type. This kind of reasoning addresses the "how" versus "why" distinction in causal explanations. Most typically, the proximate cause is identified as unprotected sex, whereas the final cause is believed to be witchcraft. For example, witches are believed to be capable of distorting your sense of good judgment or putting an AIDS-infected person in your path. This series of studies provides strong evidence for the co-existence model of natural and supernatural explanatory frameworks.

Returning to the overview of different ways of combining biological and supernatural explanations (see Table 6.1), in this discussion of AIDS transmission the focus has been on culturally derived beliefs (see Table 6.1, Quadrant A). Witchcraft and biological or natural explanations of AIDS are both embedded in cultural models sanctioned by the purveyors of folk medicine and biomedical services. Participants in these studies endorsed competing and co-existence models of AIDS transmission, combining the latter forms of explanation in diverse ways. Likewise, in the following discussion of beliefs about death, the role of cultural beliefs is examined in detail, but this time in a Western context with children from different ethnic backgrounds.

Using Multiple Epistemologies to Reason about Death

Like illness, death can be explained using a variety of different types of explanations. We can discuss death in terms of the cessation of biological processes

or in the case of humans and some other higher organisms we can discuss death in terms of the cessation of psychological processes. This is another example of target-dependent reasoning, but in this case it involves foundational theories of biology and psychology. We can also think of death in terms of a third intuitive theory, physics or mechanics, when we refer to the physical body that is left after death and the space that it occupies. But these forms of explanation seem distant, far removed from the emotionally laden situation that arises when an individual experiences the death of a loved one. This may be one reason why explanations based on intuitive biology or other foundational theories often give way to religious and spiritual explanations of death.

New research has investigated children's understanding of death in the context of the larger cultural discourse around death (Gutiérrez, Vasquez, Anderson, Rosengren, & Miller, 2007; Rosengren, Gutiérrez, & Miller, 2009). In the United States, death is rarely discussed openly with children, rather it is something that is generally avoided, with parents routinely shielding their children from images and experiences related to death (Aries, 1974). In contrast, in Mexico, death is celebrated, viewed as part of the fabric of everyday life, with children participating as partners in rituals and traditions surrounding death, such as the Day of the Dead celebration (Lomnitz, 2005). In Mexican culture images of death that would be viewed as macabre in the United States are common in the lives of children. How do children in these neighboring, but very different, cultures experience death and come to understand it?

Traditionally, based on Piaget's research and theory (Piaget, 1929), children were thought not to have a very sophisticated or biological understanding of death until as late as 9 or 10. Piaget clearly assumed a competitive model with respect to different epistemologies, believing that scientific reasoning eventually won over earlier forms of reasoning that were pre-causal and non-scientific. This view, still relatively widely held by practitioners working with children, suggests that the strong emotions surrounding death make it particularly difficult for children to understand the finality of death. Researchers such as Speece and Brent (1984) have identified a number of additional subconcepts that children appear to have some difficulty grasping, including causality (death is brought about by particular causes), universality (all living things eventually die), and irreversibility (once a living thing dies it cannot come back to life). More recent work suggests that children understand important aspects of these subconcepts by as young as four years of age and potentially earlier, especially if death is discussed with respect to entities such as plants that are far removed from humans (Nguyen & Gelman, 2002), or the focus is on animals rather than humans, or if the questions focus on the cessation of biological rather than psychological behaviors (Harris & Giménez, 2005; Poling & Evans, 2004b). This more current work has tended to suggest that children have a fairly accurate understanding of death from a biological perspective by a relatively young age (four to six years) (Slaughter & Lyons, 2003).

The relatively sophisticated understanding of death, reported by cognitive developmental researchers, contrasts sharply with reports from parents that their children have substantial misconceptions about death (Nguyen & Rosengren, 2004). This research suggests that parents believe their children to have particular difficulty with the concepts of the finality and irreversibility of death. In their analysis of children's understanding of death, Nguyen and Rosengren (2004) suggest that these misconceptions should perhaps be construed as "alternative conceptions" that combine biological conceptions of death with those based on religious or spiritual explanations. Research by Harris and Giménez (2005) has also found that children often endorse both biological and religious conceptions of death. In their research they found these forms of reasoning vary by context (secular versus religious) and age, with older children exhibiting more evidence for the co-existence of these two different types of beliefs. It is likely that in both of these research studies instances of causal chain or juxtaposition reasoning were present.

Rosengren and colleagues have been investigating children's reasoning about death more directly in interviews with children and their parents (Rosengren et al., 2009). These researchers have also investigated how death is presented in books commonly read to children. What this research has revealed, as Aries originally suggested (1974), is that children in the United States are often shielded from death and death-related experiences by parents and the larger culture. For example, in an analysis of 100 common books read to young children, only three had any mention of death (Gutiérrez, 2006).

When children are exposed to death, a wide range of explanations of death seem to be provided to them. These explanations often involve a single causal model that may be purely natural or scientific (e.g., when you die, your body stops working), or purely religious (e.g., when you die you go to heaven). Other explanations provided by parents or in books adopt a co-existence model of death that resembles the causal chain reasoning discussed earlier (e.g., when you die your body stops working, but your soul goes to heaven). In an analysis of parents' comments to children's questions, as well as an in-depth study of literature especially designed for children who have lost a loved one, these researchers have found that divergent forms of explanation are commonly provided in the same book or parental response to children's questions. Thus, many children appear to be exposed to multiple forms of explanation for death throughout childhood. This exposure to multiple forms of explanation is likely the case for other aspects of biological reasoning such as illness and origins.

How do children interpret this seemingly contradictory information? To answer this question Rosengren et al. (2009) have been coding three- to five-year-old children's responses to an in-depth interview about biological processes. The interview focuses on children's understanding of life processes (e.g., growth, illness, what makes something alive?) and children's understanding of death. These researchers explicitly investigated children's under-

standing of the subconcepts of death (finality, universality, causality, and irreversibility) as well as children's understanding of the continuity of life processes following death. What they have been finding is that children's understanding of these concepts varies as a function of age, religiosity of the family of origin, and cultural background. Specifically, younger children, those from more highly religious families, and those from Mexican-American families tend to treat many life processes as continuing after death. In Mexican-American families this effect remains significant even after controlling for religiosity, suggesting an effect of culture above and beyond any effect of religion. In some ways it may not be that surprising that in religions and cultures that support afterlife beliefs, children think that more life processes continue after death, but this finding contrasts sharply with traditional cognitive developmental accounts of children's understanding of death.

Our analysis of individual children suggests that about half of the white middle-class children adopt a dominant biological approach to explaining life and death. Only a small number of children in this sample appeared to adopt a dominant religious approach to death, mentioning God or some sort of religious entity throughout the interview. The remaining children provided some form of co-existence reasoning, in some cases using juxtaposition reasoning and others target-dependent reasoning. Children in this later group used primarily biological explanations for death, unless explicitly asked questions that probed about the afterlife or spirituality, in which case the children provided a religious explanation. A final group of children appear to combine explanations into a more integrated or blended approach that incorporates both everyday views of biology with religious or spiritual ones. For example, one child talked about how her mother who had recently died was tired. Further questioning revealed that the child thought that her mother was standing all day long on a cloud in heaven, and that this must be physically tiring. In this case, an intuitive biology is merged with the cultural notion of heaven into a synthetic blend (see Table 6.1, Quadrant C).

Thus, as early as ages three to five years, children are beginning to use multiple epistemologies, sometimes in competition, sometimes to complement one another, and in other cases synthesizing them into a single, coherent explanatory system. Future research should explore the source of these individual differences. While it is likely that some are due to how parents socialize children, it is also likely that certain child characteristics influence whether a child adopts a single consistent model, a co-existence model, or attempts to unify seemingly contradictory ideas into a blended model.

Regardless of cultural context, the research summarized to date indicates that the endorsement of apparently competing epistemologies is commonplace in both Western and non-Western contexts. So far, the major emphasis has been placed on culturally derived sources of belief, which suggests that religious and scientific ideas may replace intuitive beliefs about death or illness, or provide a cultural overlay (see Table 6.1, Quadrant B). In addition

to the co-existence models already described for AIDS transmission, this analysis of death concepts reveals a *target-dependent* model, with the soul treated differently than the body. These target-dependent models can operate at the entity level (human versus animals) and at the domain level (intuitive biology versus intuitive psychology). The following analysis of beliefs about the origin of species builds on these co-existence models and extends the discussion to include intuitive beliefs.

Using Multiple Epistemologies to Reason about the Origin of Species

Cultural Models: Supernatural and Scientific

As many as 30% of the U.S. population, from a range of religious backgrounds, endorse a literal interpretation of the Bible in which God plays a direct role in the origins of species (Doyle, 2003), the core creationist viewpoint presented in this chapter. Creation science and intelligent design provide the most coherent contemporary models of this viewpoint, at least in the United States. Although supernatural beliefs about the origins of living kinds prevail in most cultures (Campbell, 1972), predating evolutionary ideas (Mayr, 1982), these models emerged relatively recently, in the late 20th century (Evans, 2001; Morris & Parker, 1982; Numbers, 1992). Unlike creation scientists, who adhere closely to the biblical description of origins, intelligent design theorists accept current views of the age of the Earth. Both creation scientists and intelligent design theorists, however, deny naturalistic explanations for the origins of species (Scott, 2005). This point was made most forcefully by Judge John Jones III in the recent Dover trial. He concluded that intelligent design could not be taught in the science classroom because it was, at base, a non-materialistic, supernatural perspective (Mervis, 2006). The creationist viewpoint contrasts markedly with a post-Darwinian evolutionary perspective in which all living beings share a (tangled) common ancestry of natural origins (Doolittle, 2000).

In the Introduction, we briefly reviewed some of the ways in which theologians from non-fundamentalist religions and some evolutionary biologists reconcile supernatural and scientific explanations of the origin of species, in various co-existence models (see Table 6.1). Next, we provide evidence that such blends are also endorsed by members of the public. Finally, we shall use these models as a starting point for a consideration of the ways in which culturally derived and intuitive models might be combined.

Co-existence Models of Evolutionary and Creationist Origins

An interesting example of a target-dependent co-existence model is the provision, by creationists, of different explanations for micro- and macro-

evolution. Darwinian evolution consists, essentially, of two related processes, micro-evolutionary or small-scale evolution and macro-evolutionary or large-scale evolution. The former refers to changes in gene frequencies within a population, whereas the latter refers to large-scale changes that result in ancestor and descendent species of markedly different phenotypes, the origin of new species (Futuyma, 1998). While creationists may accept that micro-evolution is a biological process, they routinely reject the idea that macro-evolution is also a biological process, as in the following example:

> The evolution of HIV is not disputed by creationists. The only complaint that creationists have … is the confusing use of the term evolution to describe both variation within a species and the origin of new kinds of life.
>
> (Jones, 2005)

The rationale offered to justify this model is that variation within a population (a micro-evolutionary process) is not only observable, but is also consistent with the claim that God built diversity into the DNA of each living kind (Evans, 2008; Greenspan, 2002; Morris & Parker, 1982). Macro-evolutionary processes require, however, not only acceptance of a timescale that is inconsistent with biblical accounts, but also acceptance of transitional forms (some of which are inferred rather than observed), and, most critically, acceptance of the idea that new forms of life may emerge from earlier forms (Evans, 2008). According to creationists, each living kind has a unique essence (DNA) bestowed by the direct hand of God, thus it cannot have descended from or be the ancestor of a different living kind (Whitcomb, 1988).

There are several examples of this kind of reasoning among members of the public. According to one natural history museum visitor, God built diversity into the DNA of the original wolf-dog pair that made it onto Noah's Ark (Evans, 2008):

> Ok, I believe … um …, God created a pair, a male and female of everything with the ability to diversify. So I guess what I meant at the time of the flood, […] they had the genetic background to be able to diversify into all of the, like for instance, dogs, and all the different kinds that we have. And so … um …. does that help? Just a creationistic view.
>
> (Evans et al., 2009)

In this kind of argument, the variation originally locked into the DNA of one pair of canine ancestors is now manifest in diverse dogs, from dingoes to dachshunds, which are adapted to life in different parts of the world. Thus, dachshunds and dingoes comprise one living kind that share a common essence, bestowed by God. This appears to be an example of a target-dependent model with supernatural and scientific explanations of macro- and

micro-evolution, respectively. God placed each living kind on Earth and local adaptations resulted in the variation observed in canines across the world. If these two processes were clearly linked in the mind of this individual, then this would be considered a causal chain model rather than a target-dependent one.

A second example of a target-dependent co-existence model is the differential treatment of the human versus other animals. This model is widespread (Evans, 2000b, 2001). In a recent interview study, 30 adult natural history museum visitors were asked to explain evolutionary problems about seven different species (they were not told these were evolutionary problems). When the human was the target, 28% of them included creationist explanations. Only 6% were consistently creationist for the other species, which ranged in size from a diatom to a whale (Diamond & Evans, 2007). In a more in-depth study of this type of pattern, 115 6–12-year-olds, and their parents, from both biblical literalist and theistic evolutionist families (defined by parental belief system) were asked about the origins of humans, non-human mammals (e.g., deer), and animals that undergo metamorphosis, such as frogs and butterflies. All age groups were more likely to accept (pre-Darwinian) macro-evolutionary explanations (it came from a different kind of animal) for animals that were taxonomically distant from the human, and least likely to accept evolutionary explanations for the human (Evans, 2008; Evans, Rosengren, Szymanowksi, Smith, & Johnson, 2005). This kind of nuanced investigation is rare in national polls, where the human is the most typical target of surveys.

Why is the human treated so differently? One possible explanation is the children do not realize that the human is an animal (Carey, 1985). This possibility was investigated in the same study by asking children which of the above species were animals (Evans et al., 2005). There was an effect both of age and of community of origin. Overall, younger children were less likely to agree that the human was an animal (all agreed that the other species were animals). Additionally, children from biblical literalist families, regardless of age, were less likely than children from theistic evolutionist families to agree that the human was an animal. Further, children's acceptance of the human as an animal predicted their acceptance of evolutionary origins, independently of other relevant factors (Evans, 2008).

Overlay Models: Cultural and Intuitive Beliefs

In addition to revealing the ways that members of the lay public combine religion and science into relatively coherent target-dependent co-existence models, these two examples also reveal something of the underlying intuitive belief systems that constrain an understanding of evolution. A crucial element of an intuitive biology is the belief in the relative immutability of species, called essentialism (Gelman, 2003). This intuition is magnified in a cultural

context, in that creationists will not accept the idea of common ancestry because it violates the essentialist principle that each living kind has a unique unchanging essence. Biblical literalism explicitly supports this viewpoint (Evans, 2000b, 2001). On the other hand, in the second example, we see that this intuitive essentialism can be modified by exposure to evidence of within-species change, provided the cultural context supports this position (Evans, 2008). These researchers predicted that pre-Darwinian evolutionary explanations of the origin of species were more likely to be accepted for species that underwent metamorphosis, because such dramatic biological change might modify essentialist beliefs in the continuity and stability of species; this turned out to be the case (Evans et al., 2005; Rosengren, Gelman, Kalish, & McCormick, 1991). The human, on the other hand, elicits an intuitive psychology, which arouses emotions and is accompanied by a natural resistance to the idea that humans are subject to the same biological processes that constrain the rest of the animal world: Humans are privileged (Evans, 2001; Poling & Evans, 2004b). Both of these examples imply that evolutionary and creationist ideas, initially at least, are superimposed on a foundation of intuitive beliefs, which both constrain and potentially make possible these cultural forms (see Table 6.1, Quadrant B).

These observations suggest that there are many ways in which intuitive beliefs constrain the expression of evolutionary ideas. On the face of it, evolutionary ideas are strongly counterintuitive, in that they require that we abandon or modify essentialist ideas in the stability of species and that we treat the human as another kind of animal (Evans, 2008). How are these strong intuitions overcome? One possible route is explored by examining the nature of synthetic blends and their potential role as transitional concepts from purely intuitive to purely cultural concepts.

Synthetic Blends and Intuitive Beliefs

In synthetic blends (Table 6.1, Quadrant C), intuitive or everyday beliefs are fused with culturally available ideas from science and religion (Poling & Evans, 2004a; Vosniadou, Vamvakoussi, & Skopeliti, 2008). An overarching goal of this section is to characterize the different ways in which these intuitive and cultural beliefs are combined, and to identify those transitional forms that might serve to bridge the gap between intuitive and scientific beliefs.

In one study, open-ended interviews about evolution were carried out with a sample of 32 adult natural history museum visitors. This study provided a window into the thinking of members of the general public who are both interested in natural history and are more likely to have completed college than the public at large (Evans et al., 2009). This group was less likely than other members of the lay public to endorse creationist ideas. Moreover, by and large their creationist ideas were confined to the human. In addition to the human, the visitors were presented with scenarios describing evolutionary

change in six other organisms, from HIV to whales, and asked to explain what had happened. Importantly, they were told only that they would be asked about "some new scientific discoveries about living things" (the term evolution was not mentioned) as this allowed an assessment of whether the visitors would spontaneously recognize these as evolutionary problems. Responses were coded as multiple themes under (Darwinian) evolutionary, intuitive, or creationist reasoning patterns.

Surprisingly, not one visitor consistently used evolutionary reasoning across all seven organisms. Overall, visitors endorsed a synthetic blend with 72% combining evolutionary and intuitive themes from those two reasoning patterns, and another 28% also including creationist reasoning. The whale, finch, and human were more likely to elicit Darwinian evolutionary themes, whereas the HIV and the fly, ant, and diatom were more likely to elicit intuitive themes. Only 34% of the visitors used evolutionary reasoning in the majority of their responses; for over half of the visitors, intuitive reasoning was the dominant pattern.

The key to understanding conceptual change is to make sense of the nature of these synthetic blends and, in particular, the nature of visitors' intuitive beliefs. To this end, a detailed analysis of visitors' concepts ensued (Evans et al., 2009). We shall comment on two key themes in this chapter. Consistent with other research (see Evans, 2008 for a summary), the study revealed that visitors' intuitive concepts of biological change included need-based (or goal-directed) reasoning, with the change described as directed toward the goal of enabling the organism to adapt to a changed environment. This is one of a family of *teleological* themes found in folk-biologies the world over and, along with essentialism, this kind of reasoning characterizes an intuitive biology (Medin & Atran, 2004). In the study of museum visitors, just described, need-based reasoning from an intuitive biology was distinguished from the desire-based, intentional or mental-state reasoning characterizing an intuitive psychology (Evans et al., 2009).

Although both an intuitive psychology and an intuitive biology involve purpose or goals, a core feature of teleological reasoning, the underlying reason differs. This is illustrated using examples from the Galapagos finch problem (Evans et al., 2009). In an intuitive biology the underlying goal is one of survival: of necessity the organism needs to change in order to survive in a particular environment. This is accomplished through physiological means. In the following synthetic blend, this visitor clearly recognized that the finch problem was one of evolutionary change. However, the visitor provided a non-Darwinian mechanism, derived from an intuitive biology, to explain the change: "evolution for survival … well, in order to survive, their body parts had to adjust to certain things … so the beak grew longer in order to deal with the tougher seeds." In the next example a mental state is invoked, indicating that the change comes about through intentional means, from an intuitive psychology: "in order to eat the seeds" the finch "had to try to work harder,

probably, to develop their beaks." By distinguishing between these two intuitive modes, Evans et al. (2009) were able to get a better handle on the nature of these concepts and their relationship with the other themes. Whereas need-based reasoning was prevalent, elicited in more than 44% of the responses, fewer than 20% of the responses involved intentional reasoning. The pattern of endorsement of these two themes was examined in greater detail in a follow-up study that included children as well as adults.

Thirty adults and 34 11–18-year-olds visited an exhibition on contemporary evolution research with the same seven organisms. As they were recruited for this study, it was not possible to disguise the fact that the exhibition was on evolution (Spiegel et al., 2009). In the questionnaire, eight closed-ended explanations, derived from major themes found in the first study, were attached to each of the seven original scenarios. For each scenario, visitors could express their degree of agreement with each explanation.

Following the visit to the evolution exhibition, and regardless of age, demographic characteristics, and interest in the organism, there was a significant increased agreement with all three evolutionary explanations, across all organisms. However, agreement with the goal-directed explanation (needed to change) also increased. At the same time there was significant decrease in visitors' agreement with the intentional explanation (wanted to change). Children were less likely to endorse evolutionary explanations and more likely to endorse intentional explanations than adults. Visitors for whom evolution was compatible with their religion were more likely to endorse evolutionary and goal-directed reasoning. Visitors for whom evolution was incompatible with their religion were less likely to endorse evolution, and more likely to endorse creationism (created that way). Although there was no wholesale conversion to an evolutionary explanation, visitors did increase their endorsement of evolutionary explanations, while decreasing intentional and creationist explanations. Importantly, need-based reasoning appeared to act as a bridge between intuitive and evolutionary explanations (Spiegel et al., 2009)

In the first study, need-based reasoning was negatively correlated with the micro-evolutionary theme of natural selection, but uncorrelated with the macro-evolutionary theme, common descent (Evans et al., 2009). Further investigation of this pattern of findings suggested that while many visitors accepted the idea of evolution, as indicated by their endorsement of common descent, only some of them grasped the Darwinian mechanism of natural selection; instead, they provided a need-based mechanism of change. The synthetic blend of common descent and need-based reasoning was found in the second study, as well (Spiegel et al., 2009). On the other hand, for visitors who understood natural selection, which is best tested in an open-ended format, need-based explanations of evolutionary change were no longer used, hence the negative correlation between these two themes. Moreover, this pattern sheds light on one of the co-existence models described earlier. In the lay public's mind the acceptance or rejection of evolution seems to refer to the

macro-evolutionary principle, common descent, but not to natural selection. It appears that members of the public can accept, or, if they are creationist, reject, macro-evolutionary concepts, while misunderstanding (or even understanding) the Darwinian mechanism of evolutionary change (Evans, 2008). In terms of public understanding, the two evolutionary principles are somewhat orthogonal, even though for the evolutionary biologist they are seamlessly connected.

What about intentional reasoning? There was nothing in the exhibition to suggest that such reasoning was incorrect. Yet, older visitors, in particular, were less likely to endorse this theme after the gallery visit. The exhibition appears to have had the effect of fine-tuning visitors' explanatory repertoire, helping them to discriminate between survival or need-based reasoning and intentional or mental-state reasoning. Once they have realized that the organism's survival depends on a particular change, and that this change cannot come about through conscious effort, then they may be ready to grasp the principle of natural selection.

Children, however, were less influenced by the exhibition, even though children as young as five years are capable of distinguishing between those themes, reasoning, for example, that animals breath because they *need to* not because they *want to* (Poling & Evans, 2002). Past research has shown that children are more susceptible to intentional themes, in part because their grasp of an intuitive psychology is undergoing rapid change over the preschool through elementary school years (Evans, 2008). Moreover, they are more likely to explain biological change in intentional terms, particularly if they have been raised in communities that support such interpretations and if they are questioned about macro-evolutionary themes (e.g., where did the very first X come from?), rather than within-population change (Evans, 2000a, 2001, 2008).

These findings suggest that anthropomorphizing nature in an exhibition or in school curricula should have a particularly deleterious effect on children's scientific reasoning, even if it makes the topic more attractive. This hypothesis was tested in a recent study with an experimental manipulation of the language used to tell children stories about evolutionary change in birds (Legare, Evans, & Lane, 2009). One story used need-based language, another intentional language, and the third, natural selection. The outcome variable was children's endorsement of need, intention, and natural selection themes and their use of such language when asked to repeat the story back to the experimenter. There was a main effect of story type with the intentional story eliciting intentional themes, particularly in younger children. Need-based and natural selection stories were equally likely to elicit need-based and natural selection reasoning at all ages. This finding provides further converging evidence that need-based reasoning may be a crucial intermediary concept, easing the transition from intuitive to evolutionary reasoning.

Synthetic Blends: Bridging the Transition from Intuitive to Cultural Explanations

Across the three domains of illness, death, and origins, we have peeled back the cultural layers to expose their intuitive foundations, and, in effect, revealed the process of conceptual change, in reverse. Table 6.1 provides a developmental model. At an early point in development, children have at hand a repertoire of intuitive beliefs that makes their world comprehensible. These concepts give stability, coherence, and purpose to what would otherwise be a bewildering and incomprehensible environment. These intuitive concepts (Quadrant D, Table 6.1) persist into adulthood where they play the same role in adult reasoning, when adults are confronted with unfamiliar problems. As children (and adults) assimilate cultural concepts, from God to atoms to evolution, they construct synthetic blends (Quadrant C, Table 6.1), fusing newly acquired ideas to familiar intuitions, which makes the cultural concepts more tractable. Gradually, these cultural concepts appear to become detached from their intuitive base (Quadrants B–A, Table 6.1), at least in experts (though this is debatable). The studies with museum visitors indicate, however, that, without consistent reinforcement, synthetic blends are normative and represent the understanding that most lay adults will have of evolution and, probably, of most complex scientific topics. Even experts revert to such synthetic blends when talking to students or writing for the general public (Evans, 2008). Evolutionary theory is particularly problematic, because it is highly counterintuitive, denying even the appearance of stability and purpose to the natural world. Not surprisingly, then, it has an effective cultural competitor. Co-existence models of religion and evolutionary science provide a solution to this problem, at least for many theologians and scientists.

Some Unanswered Questions

This series of studies demonstrate that children from diverse cultural contexts come into the classroom with a range of approaches that involve combinations of very different explanatory models (see Table 6.1). While this is true of illness and death we also see this with respect to understanding the origins of living kinds. In our view, one of the real dangers of introducing creationism or intelligent design alongside evolution in the classroom is that it is likely to induce some children to create models that contradict the actual science. On the other hand, as described earlier, leading theologians and scientists have combined religious and scientific epistemologies in ways that leave evolutionary theory intact. Is this the way to approach this issue in the classroom? This would seem to be beyond the scope of the science classroom, but such discussions might well have a role in the broader curriculum.

Why do some children and adults adopt a single explanatory approach when confronted with competing epistemologies? Why do other children and

adults treat different epistemologies as complementary rather than competing worldviews? Why do still other individuals blend different intuitive and cultural epistemologies into a single synthetic approach? Our research has begun to answer these questions and suggests that age and experience coupled with language and contextual influences operate at a relatively global level to influence the normative reasoning patterns within particular groups or cultures. That is, when children and adults live within a culture where multiple epistemologies are common, they are more willing to embrace what often seem to be contradictory explanations to reason about illness, death, and the origin of species. We have reported evidence in support of this from research conducted examining explanations for AIDS in South Africa, research on death in children in the United States and Mexico, and from children in the United States from religious and non-religious backgrounds with respect to both death and the origin of living things. While this research suggests that age and context influence the overall use of different epistemologies, and whether they compete, complement, or are combined, we still do not have a complete understanding of why certain individuals adopt one explanatory model over another, choose to treat them in a complementary fashion, or blend them into a single, relatively coherent model. Here we provide some ideas of what might influence an individual to adopt one or the other of these approaches.

Adoption of a blended approach may differ from adopting a single epistemology, or using complementary ones. Co-existence cultural models may require more cognitive effort to bring together views that seem on the face of it to be in direct competition or even incompatible. For adults, we suggest that some sort of conflict triggers the effort to create a coherent, integrated model of different epistemologies. This kind of conflict has often been reported by individuals with strong Christian fundamentalist beliefs who are brought into direct contact with scientific evidence that directly contradicts those views (Numbers, 1992; Poling & Evans, 2004b). Peter Woo, a biochemist, who now shares Collins' co-existence beliefs, described this conflict as he entered university where "my Christian faith was seriously challenged and replaced by tormenting, depressing doubt." Eventually, he achieved a reconciliation of his faith and the scientific evidence with the realization that "the nature and the existence of God are beyond the scope of science and human intellect" (Woo, 2004).

A conflict may also trigger this pattern in young children. For example, the death of a loved one may force children to combine different explanations experienced at home, school, and church to reach a single, blended, explanation that provides meaning to a traumatic event. These might be co-existence cultural models or synthetic blends of intuitive and cultural beliefs. But even in these cases, which epistemologies will enter into the mix is clearly dependent upon those the individual is exposed to in their family of origin and broader culture.

In many cases, however, this might not be a conscious process. As described earlier, as students struggle to grasp unfamiliar scientific concepts,

they are likely to assimilate them to familiar intuitive concepts that, at least, offer one coherent model. Students may not be aware that their understanding of the science is rooted in their intuitive epistemologies. Moreover, these synthetic blends might be helpful or a hindrance. At least for evolution, the research reported here suggests that as students fine-tune their explanatory repertoire, the jettisoning of intentional concepts, while retaining need-based concepts, might provide a bridge to a more scientific understanding. The core question here is whether making students aware of this unconscious process would help them achieve a more coherent scientific model.

Implications for Informal and Formal Evolution Education

We have chosen to discuss three different areas of biological understanding—illness, death, and origins—to highlight the similarities across these different areas. That is, each involves learning about unseen processes that have important outcomes and may exact an emotional cost. Each is often learned in the context of competing explanatory models. Each also involves the acquisition of intuitive knowledge prior to onset of formal schooling. Thus, there appear to be some general issues and processes that cut across these three areas of knowledge. In this sense, teaching about evolution should perhaps be done in a manner that is similar to the teaching of other biological concepts, though teachers should be attentive to those issues that are most likely to elicit existential concerns.

What are the implications for science educators? First, educators clearly face a difficult task. Children will enter their classrooms with very different ways of handling information. Some will approach the information from a single unified causal model. But for others the model may not be scientific at all, as they embrace strong religious or supernatural beliefs. In many situations, the parents themselves may resolve the educational quandary by simply removing the child from public education and enrolling them in a school that complements their beliefs. Other children likely enter the classroom with explanatory models that co-exist, using one in a particular context and the other one in a different context. In traditional classrooms the context may provide ample support to enable a consistent scientific model to expand and flourish, so children who enter with this mix of explanations may not present much of a problem.

The evidence presented in this chapter indicates, however, that two of the co-existence models present a unique challenge to evolution educators. If the classroom instruction or exhibition focuses on non-human animals and micro-evolutionary processes, students are likely to be comfortable with the information in that it does not appear to elicit existential fears. However, once macro-evolutionary themes are introduced, especially those involving the human, then these conflicts are more likely to arise. As several researchers

have noted, the absence of macro-evolution from the typical classroom results in students with little understanding of the links between these two processes (e.g., Catley, 2006). Ironically, the reverse pattern is likely to be found in natural history museums, which house the evidence for macro-evolution (Diamond & Scotchmoor, 2006). One feasible solution is to focus on non-human animals, but link micro- and macro-evolutionary processes from the earliest years. Dinosaurs are often incorporated into the typical second-grade curriculum, but children have little sense of their evolutionary history, even if they can classify them with ease (Evans, 2000a). By linking the evolutionary history of dinosaurs to that of modern birds, macro-evolution is introduced in a way that maps onto children's fascination with dinosaurs. Similarly, the middle-school curriculum includes health. Why not link this to evolutionary explanations of why people get sick (Nesse & Williams, 1996)? In sum, evolutionary reasoning should be introduced early and tied to compelling topics, throughout the curriculum.

Educators should also work to harness children's and adults' intuitive beliefs about the world (Carey, 2000). This involves reinforcing those beliefs that conform to scientific understanding, and directly confronting ones, such as the essentialist view of species, that conflict with known science. Children who adopt a blended or synthetic form of explanation may present a very difficult challenge for teachers, depending on the nature of the blending. Also, if we are correct in thinking that some of these synthetic models arise out of cognitive or emotional conflict they may be more strongly held and more difficult to challenge. On the other hand, some synthetic blends, such as the use of need-based reasoning to explain evolutionary change, appear to be crucial bridges to an evolutionary understanding. Students' acceptance of the idea of common ancestry, even if accompanied by need-based reasoning, is a significant step toward a full grasp of evolutionary theory. These small steps should not be seen as failures of instruction but as small victories. In either of these cases, identifying students' reasoning patterns is a crucial first step. This could then be followed by a process of intentional conceptual change (see Sinatra & Pintrich, 2003), in which students are made aware of their own thinking processes and of their use of language when explaining scientific processes.

As we have shown, children and adults alike are adept at shifting between explanatory modes. This causal flexibility facilitates different ways of handling what are often viewed as incompatible and conflicting worldviews and integrating these with intuitive beliefs. It is not simply that they hold alternative concepts, but these conceptions are rooted in different ways of understanding how things in the world work. It is not enough to classify these as misconceptions; it is also necessary to understand the underlying explanatory systems that support these systems of belief.

Acknowledgments

The material on evolution is based, in part, upon studies supported by the National Science Foundation with grants to: Evans (PI) & Rosengren (#0411406), Diamond (PI), University of Nebraska State Museum of Natural History (#0229294), and to Weiss (PI), New York Hall of Science, & Evans (#0540152).

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