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Why Are Rocks Pointy? Children's Preference for Teleological Explanations of the Natural World

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Teleological explanations are based on the assumption that an object or behavior exists for a purpose. Two studies explored the tendency of adults and first-, second-, and fourth-grade elementary-school children to explain the properties of living and nonliving natural kinds in teleological terms. Consistent with the hypothesis that young children possess a promiscuous teleological tendency, Study 1 found that children were more likely than adults to broadly explain the properties of both living and nonliving natural kinds in teleological terms, although the kinds of functions that they endorsed varied with age. Study 2 was an attempt to reduce children's broad teleological bias by introducing a pretrial that described, in nonteleological terms, the physical process by which nonliving natural kinds form. In spite of this attempt, Study 2 replicated the effects of Study 1, with only fourth graders showing any shift in preference for teleological explanation.

Teleological explanations—explanations which assume that objects or events occur for a purpose—are a central aspect of adult thought. They constrain our thinking about artifacts, leading us to construe clocks and other created objects in terms of their intended function. They also play an important part in our reasoning about living things, leading us to assume that biological structures such as eyes and hearts are designed for a purpose. For most scientifically educated adults, however, teleological explanations tend to apply no further than this. A nonliving natural entity such as a river may be capable of performing any number of activities—making fields fertile, providing a habitat for fish—but these activities are not its raison d'être in any teleological sense. They are consequences of the mechanical forces that caused it to form, rather than explanations for why it formed. In other words, for most adults with a knowledge of natural mechanisms, a pointy part on an animal might exist to perform some protective function, but a pointy part on a rock is the purposeless result of a physical process such as erosion (see Keil, 1992). To a significant extent, then, Western adults' reasoning about the living and nonliving natural world is demarcated along teleological lines. But is this demarcation also true for children?

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Until late in elementary school, most American children are taught little about the mechanisms of the nonliving natural world. By preschool, they know that people make artifacts, not natural objects (Gelman, 1988; Gelman & Kremer, 1991; Keil, 1989), but their knowledge about the origins of planets, mountains, and clouds is generally limited. In the absence of such knowledge, what children often do is compensate with their understanding of intentional behavior. As a consequence, elementary-school children from both religious and nonreligious backgrounds will state that even if people do not make stars and clouds, another kind of intentional being—God—does make them (Evans, 1994, in press; see also Gelman & Kremer, 1991; Piaget, 1929). Children's assertions about the scope of intentional creation suggest an interesting relationship between their conceptions of artifacts and natural kinds. Their lack of physical knowledge also raises questions about the degree to which they might think in teleological terms about nonliving natural objects. One possibility is that even in the absence of scientific knowledge, children intuitively restrict their teleological construal of the natural world to biological properties because of the nature of domain-specific constraints on their biological reasoning. The other possibility is that in the absence of background knowledge, children apply teleological explanations more broadly because, in the course of theory formation, their intuitive reasoning about the natural world involves assumptions different from those made by scientifically educated adults.

Selective Teleology

To date, relatively little research has been conducted on the development of teleological thought; nevertheless, two schools of thought have emerged. One school of thought is referred to here as *selective teleology* (ST) because it suggests that children, like adults, limit their functional explanations to biological traits and artifacts from early in development (Keil, 1992, 1995; for a related view, see also Atran, 1995). This view originated in the context of the debate over children's understanding of biology. In response to claims by Carey and others that until elementary school, children do not have a grasp of biological causality that is independent of their "naive psychology" (Carey, 1985, 1995; Solomon, 1995), Keil (1992, 1995) proposed that young children do have an autonomous understanding of biology and that an innate sensitivity to biological function forms its core. Specifically, he suggested that from very early on, children know that biological parts such as feet and hands serve purposes for living things. Children also spontaneously recognize, or quickly learn, that the same does not apply to nonliving natural things, which do not perceptually cue functional reasoning—presumably because of their simple structure—and serve no obvious purpose. Function therefore distinguishes living and nonliving natural things that, in other respects, are similarly construed as possessing an underlying "essence" that dictates their superficial properties and true identity (Keil, 1992; see also Gelman, Coley, & Gottfried, 1994). It is obviously the case that function also applies within the artifact domain. However, Keil (1992, 1995) suggested that this does not necessarily result in children's becoming confused about the distinction between living things and artifacts because children are sensitive to different "causal homeostatic" relationships in each domain. In general, causal relations between artifact properties are directed "outward" because artifact properties exist to benefit external agents in an "other-serving" manner. In contrast, biological properties tend to interrelate in a variety of ways but with an "inward" focus: Unlike artifacts, they generally perform "self-serving" functions that physiologically benefit the organism possessing them (Keil, 1992, 1995). In sum, according to an ST account, children's selective ideas about function combine with other innate cognitive biases to play a central role in distinguishing the artifact, living, and nonliving natural kind domains from each other. They also provide the invariant basis to a naive theory of biology.

In several studies, Keil and his colleagues examined distinctions in children's functional reasoning about biological versus artifact kinds and also explored the selectivity of children's teleological ideas. In relation to the first issue, a study (reported as a "study in progress" in Keil, 1995) found that 3-year-olds identified a biological part such as a barb on a rose as self-serving but a parallel artifact part such as a barb on barbed wire as other-serving. This result supports the idea that children's reasoning about artifacts is distinguished from their reasoning about biological kinds from an early age. On a related theme, other studies suggested that by preschool, children's teleological reasoning about living things is already enriched by biology-specific assumptions about both the self-serving and physiological nature of biological function (Keil, 1995; Springer & Keil, 1989). Thus, when asked to make inheritance judgments, preschoolers were more likely to view an abnormal trait such as a "white stomach" as heritable if it had the biological functional consequence of helping an animal to stay healthy than if it had the social functional consequence of helping it stay happy (Springer & Keil, 1989, p. 644). This study, however, was criticized for not drawing a sharp distinction between biological and social functions for many of the stimulus items (see Carey, 1995, and Solomon, Johnson, Zaitchik, & Carey, 1996, for critiques).

In relation to questions about the selectivity of children's teleological intuitions, Keil (1992) explicitly examined whether children limit their teleological ideas about the natural world to biological properties: In one study, kindergarten and second-grade children were shown either an emerald or a plant and in each case were asked to choose between two explanations of the objects' green appearance. One explanation was teleological (e.g., "They are green because it helps there be more of them"), and the other explanation was physical (e.g., "They are green because tiny parts mix together to give them a green color"; Keil, 1992, p. 130). As predicted, second graders preferred functional explanations for plants and physical explanations for emeralds. Although kindergarten children had no significant preferences, trends were found in the same expected direction. Unfortunately, however, the wording of the teleological statements in this study makes these results difficult to interpret. The teleological constructions always involved verb phrases such as "p *helps* there be more q" and "it is *better for* q to have p"—expressions that people tend to use with animate objects because only living things actively respond to "help" or to conditions that have been "made better" for them. As a result, children may have applied these kinds of phrases more to biological than nonbiological natural entities because of the phrases' strong association with living things and not because of their teleological nature.

Promiscuous Teleology

An alternative to the idea that young children possess ST, is the proposal that from early on children possess *promiscuous teleology* (PT). In other words, prior to developing a more elaborate understanding of natural processes, children may differ from adults and view all kinds of entities—artifacts, living and nonliving natural objects, and their properties—as existing for a purpose.

Several factors motivate this suggestion (see Kelemen, 1999a and 1999b for a fuller discussion). First, prior to the popularization of mechanistic scientific theories such as Newtonian physics or Darwinism, historical evidence suggests that Western adults did not selectively use teleological explanations (Corey, 1993; Livingstone, 1993). People not only considered eyes and ears as beneficial artifacts designed by God but also extended this view to other kinds of natural phenomena, particularly those that had significant impacts on their lives. Thus, the earth, its water sources, climates, elements, and land formations were viewed as part of a carefully planned system designed to create a habitat for—and meet the needs of—people and other living things. Despite the protests of philosophers such as Bacon and Kant, these kinds of teleological ideas exerted a profound influence on empirical inquiry at least until the eighteenth century, when scientific advances and the Enlightenment drove the practice of science to became increasingly independent of religious theorizing. Such ideas still, of course, have a significant influence in cultures where evolutionary and other scientific explanations are not well diffused.

A second reason for suggesting that children may not use teleological explanations selectively is developmental. Research indicates that one of children's earliest developing competencies is a sensitivity to intentional behavior. By 12 months, infants construe animate objects as acting in goal-directed ways and can use this mode of construal to make predictions about a novel agent's future behavior (e.g., Csibra, Gergely, Brockbank, Bíró, & Koós, 1998; Gergely, Nádasdy, Csibra, & Bíró, 1995; Johnson, Booth, & O'Hearn, 1998). Around this time, children also show increasing awareness that agents intentionally use objects for a purpose (e.g., Abravenel & Gingold, 1985; Von Hofsten & Siddiqui, 1993; see also McCarty & Clifton, 1998). Taken together, these findings suggest an alternative to the idea that teleological intuitions about function are themselves a foundational aspect of infant cognition and raise the possibility that they derive from an early understanding of goal-directed agency and intentional object use. Specifically, children regularly see intentional agents relate to a broad variety of objects in goal-directed ways and, in the absence of reasons to think otherwise, may conclude that entities are designed for these purposes by some unspecified agent. For example, children may assume that just as cups have handles for people to drink from them, tails exist so that dogs can wag them and rivers contain water so that people can go swimming in them. Children may only begin to restrict this broad teleological view as they become more knowledgeable about the natural world and develop a more elaborate understanding of natural causation.

The proposal that young children view objects, in some sense, as quasi-artifacts does not, however, imply that children fail to discriminate between natural objects and artifacts because perceptual information (e.g., Mandler, 1992; Massey & Gelman, 1988), knowledge about human artifact origins (e.g., Gelman, 1988; Gelman & Kremer, 1991; Keil, 1989), and intuitions about natural "essence" (e.g., Gelman, 1988; Gelman et al., 1994; Keil, 1989) promote such a distinction. Furthermore, PT also does not propose that by construing objects as quasi-artifacts, children will view them as performing only artifactlike, other-serving functions: Viewing something as intentionally designed does not preclude construing it as performing a self-serving function for the system it was created to be a part of. For example, a car's fan belt is primarily designed to cool the car even if the car itself exists for an external agent to drive.

Several studies lend support to the idea that, unlike contemporary adults, young children have a promiscuous tendency to view entities of all kinds as existing for functions (Kelemen, 1996, 1997, 1999b). In one study (Kelemen, 1999b, p. 251), preschoolers and adults were asked what they thought living things, artifacts, nonliving natural objects, and their physical parts were "for" while explicitly being given the option of saying they were not "for" anything. In contrast to adults, who selectively assigned functions to biological traits, artifacts, and their parts, children responded by stating a function for almost every kind of object and part. For instance, mountain peaks were "to climb," plants were "to grow," and lions were "for walking." A further study then explored whether children really viewed these activities as teleological functions or whether they thought they were simply activities that the objects could characteristically do or be used to do. Preschoolers and adults listened to two characters discuss the teleological status of artifacts, living things, and nonliving natural kinds and decided whether, for example, a tiger is "made for something" like "walking and being seen at a zoo" or whether a tiger "isn't made for anything" and "they're just things it can do" (Kelemen, 1999b, p. 256). Consistent with PT, adults were selectively teleological, but children agreed that entities of all kinds were "made for something" and broadly assigned purposes to all kinds of entities.

These results are suggestive of promiscuous teleological thinking in young children. However, one limitation of this prior work is that children's teleological intuitions were always surveyed by asking them what objects were "for." It could therefore be argued that the developmental differences that were found arose because of a mismatch between children's and adults' understanding of this kind of teleological language. Although subsequent research on children's interpretation of questions such as "What's the *X* for?" mitigates against such a conclusion (Kelemen, 1999b), the present studies were designed to explore the scope of children's teleological construals using different kinds of teleological language, a different methodological approach, and slightly older children. Specifically, first, second, and fourth graders were selected as participants for these studies because previous work suggested that important shifts occur in children's intuitive theories between the first and fourth grades (e.g., Carey, 1985; Hatano & Inagaki, 1994).

Study 1

The present studies were designed to address two questions about children's understanding of the natural world: First, what kinds of natural properties do children and adults view as "designed for a purpose"—the properties of animals, of rocks, or of both? Second, what kinds of teleological explanations do children and adults find acceptable with different object properties?

To explore these questions, in both Study 1 and Study 2, I used a method similar to Keil's (1992) emerald and plant study described earlier. Adults and first-, second-, and fourth-grade elementary-school children were shown pictures of unfamiliar, prehistoric animals and nonbiological natural kinds. They were then asked to choose between a teleological and a physical explanation of a physical property of each kind of entity as well as of a behavioral property of each animal. In contrast to Keil's (1992) study, however, in the current study I used the neutral teleological phrasing "q had p *so that* x," phrasing that does not, in itself, imply any animacy in the object possessing the relevant property. A further manipulation in this study was that the nature of the teleological explanations was varied. In half the trials, a physical-reductionist explanation was paired with a teleological explanation that described a quasi-biological self-serving function. In other words, the properties performed functions that had a biological flavor to them in that they were easily construed as contributing to the physical well-being of the object itself. In the other half of the trials, a physical explanation was paired with a teleological explanation describing a "social" function. The social functions differed from the self-serving functions in that they focused on external agents and emphasized the social and interpersonal consequences of activities rather than any relationship to physiological goals such as self-preservation. The social teleological functions were also more artifactlike in that they described activities that were other-serving in nature. The predictions were as follows:

Both PT and ST hypotheses predict that college-educated adults will endorse teleological explanations in a highly selective way. When considering living things, adults are likely to prefer self-serving to social teleological explanations of biological properties such as long necks and animal behaviors such as neck swaying because from a commonsense biological perspective, it is more obvious that an animal might, for example, evolve an adaptation such as a long neck "so that it could grab at fish" rather than "so that it could hold up friends who are tired from swimming." This is not to deny that plausible other-serving or kin-selection accounts can be generated for biological adaptations and that for certain specific kinds of properties (e.g., breasts, udders), such other-serving explanations might be preferable. It is to hypothesize, however, that in most cases, self-serving explanations are likely to be more compelling to biological laypersons than are social accounts because they tend to evoke clear physiological consequences with direct implications for an organism's survival.[1]

In contrast to the case with animal properties, adults should reject any kind of teleological explanation of a nonliving natural kind. For a scientifically educated Western adult, the properties of nonbiological natural objects are the consequence of physical makeup and mechanical origin. Thus, rocks are pointy "because stuff builds up over time" but not "so that they won't get smashed by animals" or "so that other animals can scratch themselves."

ST predicts that children will share adults' selective teleological intuitions and avoid functional explanations of nonliving natural kinds. It also predicts that children will have sufficient sensitivity to physiological functional consequences in the biological domain that they will share adults' preference for more self-serving than social kinds of functional explanations with biological properties (Keil, 1992; Springer & Keil, 1989).

In contrast, PT predicts that first- and second-grade children will apply teleological explanations more promiscuously than will adults. It suggests that in addition to viewing biological properties in teleological terms, young children will also apply functional explanations to nonliving natural objects—a tendency that should decrease as children acquire more formal scientific knowledge. Unlike ST, PT makes no specific predictions as to younger children's relative preferences for self-serving or social teleological explanations of different kinds of entities.

Method

Participants. In Study 1, the participants were 16 adults (university undergraduates) and 48 children attending an ethnically mixed inner-city elementary school. There were 16 first-grade children (10 boys and 6 girls; mean age = 7 years 2 months; *SD* = 7 months), 16 second-grade children (10 boys and 6 girls; mean age = 8 years 3 months; *SD* = 6.4 months), and 16 fourth-grade children (10 boys and 6 girls; mean age = 10 years 4 months; *SD* = 8 months). All children were fluent English speakers. With respect to scientific literacy, the first and second graders in these studies had received no exposure to any formal curriculum in the physical sciences. A small number of the second and fourth graders had received minor exposure to a biology curriculum.

Materials. Each participant saw four pairs of realistic, hand-drawn, color pictures. Each pair consisted of an unfamiliar prehistoric animal and an unfamiliar nonliving natural object. Set 1 consisted of an aquatic reptile ("Cryptoclidus") and a pointy rock. Set 2 consisted of a large mammal ("Macreuchenia") and a still pond. Set 3 was a terrestrial bird ("Mononykus") and a grainy sand-dune. Set 4 was a small mammal ("Moeritherium") and a green stone.

Design and procedure. Participants were told that they were going to be asked some questions about pictures of things from a long time ago, that the experimenter would then suggest some possible answers, and that they should pick the answer that "made most sense" to them. Participants were also told that they could suggest their own answers. Children were interviewed individually in a quiet room with an experimenter, and they completed the task in 15–20 min. Adults completed a pencil-and-paper version of the task but received the same instructions and completed the task in 10–15 min.

During the study, participants were presented with each of the four picture sets in random order. For each picture set, participants were shown the picture of the animal and told its name (e.g., "Here is a Cryptoclidus."). They were also shown the picture of the nonliving natural object—for example, a pointy rock—and told that it was found where the animal lived. Participants were asked three questions, in random order, about the objects. Specifically, they were asked about (a) a biological property of the animal kind (e.g., "Why do you think Cryptoclidus had such long necks?"), (b) a behavioral property of the animal kind (e.g., "Why do you think Cryptoclidus' neck swayed from side to side?"), and (c) a property of the nonliving natural kind (e.g., "Why do you think the rocks were so pointy?").

As each question was asked, the relevant feature was pointed out on the picture of the animal or the natural kind. Immediately after each question, the experimenter offered two possible answers. One answer presented a physical-reductionist explanation, whereas the other answer involved a teleological explanation although its nature varied across picture sets. In two of the four picture sets, the teleological answers to all three questions described self-serving functions. In the other two picture sets, all teleological explanations involved social functions. The pairings between physical and teleological explanations were counterbalanced so that half the participants heard self-serving teleological answers with Picture Sets 1 and 2 and the other half of the participants heard social teleological explanations. As a consequence, when asked why a rock was pointy, participants in both counterbalancing sets heard the physical explanation "They were pointy because bits of stuff piled up on top of one another for a long time," but only half the participants heard this paired with the self-serving teleological explanation "They were pointy so that animals wouldn't sit on them and smash them." The other half of the participants heard the social teleological explanation "They were pointy so that animals like Cryptoclidus could scratch on them when they got itchy." After participants had indicated which of the two explanations "made most sense," they proceeded to the next question or the next picture set. The items are presented in Appendix A.

Within each counterbalancing group, half the participants received Set 1 or Set 2 first, and the other half saw Set 3 or Set 4 first. The order in which the physical versus teleological explanations were presented was randomized.

Results

To recap, both PT and ST hypotheses predict selectivity in adults' teleological intuitions. When considering living things, adults should view self-serving teleological explanations as an appropriate way to account for animal structures and behaviors but social functional explanations as less acceptable. They should reject any kind of teleological explanation with nonliving natural object properties. ST predicts the same pattern of response in

[1] A historical note: The pervasive tendency for adults to gravitate toward teleological explanations of biological properties has been of interest to biologists and philosophers for decades. This is because these kinds of explanations have the intriguing quality of accounting for the existence of traits by reference to their own effects or consequences—a form of "reverse causality" that, for some scholars, brings the explanatory validity of such accounts into serious question. Indeed, although teleological explanation remains the predominant explanatory mode within biology, some philosophers have suggested abandoning it wholesale in favor of purely physical-causal approaches (Nagel, 1961; see Sober, 1984). Regardless of its actual scientific validity, however, the tendency to adopt a teleological construal of biologically designed objects seems psychologically natural to adults and is also reinforced by formal schooling in biology. It is for this reason that PT and ST—although differing about why the initial bias exists—both predict that adults will provide teleological rather than equally appropriate physical-reductionist responses when asked, "Why does this animal have *X* biological property?" This is not to suggest that adults will never endorse a physical-causal account of a biological property. In fact, adults may do exactly that if a teleological response conflicts with their commonsense biological assumptions (hence predictions about adults' relative ambivalence to social teleological explanatons).

children of all ages. In contrast, PT predicts that younger children will endorse teleological explanations for both biological and nonbiological natural objects. Although it makes no predictions about the kinds of teleological explanations preferred with different entity types, PT does predict that children's responses will become more adultlike with age and education level.

To explore these predictions, I conducted a 4 × 3 × 2 mixed analysis of variance (ANOVA). The dependent variable was the number of times participants selected teleological explanations. The between-subjects variable was grade. The within-subject variables were property type (biological vs. behavioral vs. nonliving natural kind) and function type (self-serving vs. social). Table 1 shows the mean percentages of times that teleological explanations were endorsed for each entity type.

The analysis found main effects of grade, $F(3, 60) = 10.00, p < .01$, and function type, $F(1, 60) = 40.04, p < .01$, and a significant Grade × Property Type × Function Type interaction, $F(6, 120) = 3.07, p < .01$. The main effects occurred because children in all grades gave significantly more teleological responses than did adults (first graders, $M = 64\%$; second graders, $M = 69\%$; fourth graders, $M = 56\%$; adults, $M = 37\%$) and participants were more likely to endorse self-serving ($M = 65\%$) than social ($M = 42\%$) teleological explanations. To examine the interaction further, I performed three separate 4 (grade) × 2 (function type) mixed ANOVAs on participants' teleological responses to the biological, behavioral, and nonliving natural object properties, respectively. Post hoc tests were conducted using Fisher's least significant difference test and one-group *t* tests against chance. Main effects are reported below when theoretically relevant or when not subsumed by an interaction. One-tailed tests are reported when licensed by prediction.

The ANOVA on the biological properties found a Grade × Function Type interaction, $F(3, 60) = 4.05, p < .01$. Whereas adults and children were equally likely to endorse self-serving teleological explanations of biological parts, $F(3, 60) = 1.67, p > .05$, children at all grades were significantly more likely than adults to accept social teleological explanations, which adults actively eschewed for physical accounts, $F(3, 60) = 3.0, p < .05$. However, further examination indicated that, like adults, second and fourth graders were more ambivalent about social than self-serving teleological explanations of biological properties. Although they significantly preferred self-serving teleological accounts to physical explanations—second graders, $t(15) = 2.4$; fourth graders, $t(15) = 2.08$; $ps < .03$, one-tailed—their preference for social teleological explanations was at chance (both *t* tests, $p > .05$). Interestingly, the first graders' pattern of response differed from that of the older children. Although they endorsed both kinds of teleological explanations more than adults, first graders' preference for both kinds of functional explanation was no greater than chance (*t* tests, $p > .05$).

A similar pattern of response was found with the animal behavioral properties. Although children and adults did not differ in their preferences for self-serving accounts, children at all grades endorsed social teleological explanations more than did adults, with first graders also selecting them more than fourth graders, $F(3, 60) = 4.55, p < .05$. However, although second and fourth graders endorsed more social teleological accounts than did adults, their responses were still somewhat adultlike: Both groups of children were more ambivalent about social than self-serving teleological explanations, with second graders having chance preferences for social teleological accounts and fourth graders actively rejecting such explanations in favor of physical accounts, $t(15) = -2.4, p < .05$. First graders' responses to the animal behaviors were consistent with those of the older children. They preferred self-serving teleological explanations over physical explanations, $t(15) = 1.86, p < .04$ (one-tailed), but their preference for social teleological explanations was at chance (*t* test, $p > .05$).

The analysis of the nonliving natural objects' properties found a significant effect of grade, $F(3, 60) = 22.88, p < .01$, and a Grade × Function Type interaction, $F(3, 60) = 3.3, p < .05$. Second graders endorsed teleological explanations more than did fourth graders, and children at all grade levels endorsed them more than did adults, who consistently rejected any kind of functional explanation in favor of a physical account (first graders, $M = 71\%$; second graders, $M = 75\%$; fourth graders, $M = 57\%$; adults, $M = 11\%$). However, the kinds of teleological explanations children preferred showed interesting age and education-level trends. First graders only had a marked preference for self-serving teleological explanations, whereas second graders broadly endorsed any kind of functional explanation of rocks and stones. Fourth graders were more selective and reversed the pattern shown by first graders by only displaying a marked preference for social teleological explanations.

Because ST and PT differ most in their predictions about nonliving natural kind properties, I also conducted an individual-subject analysis to look at the consistency with which individuals

Table 1
Percentages of Trials in Which Teleological Explanations Were Endorsed in Study 1

Group	Biological properties		Behavioral properties		Nonliving natural kind properties	
	Self-serving	Social	Self-serving	Social	Self-serving	Social
First graders	53	53	69†	66	78*	63
Second graders	72*	59	81*	50	72*	78*
Fourth graders	66†	53	75*	31*	44	69*
Adults	81*	25*	72*	22*	13*	9*

Note. Mean ages of children were 7 years 2 months for first graders, 8 years 3 months for second graders, and 10 years 4 months for fourth graders. Significance levels indicate preferences differing from chance.
* $p < .05$, two-tailed. † $p < .05$, one-tailed.

within each age group endorsed teleological explanations for these property types. The results are presented in Table 2 and indicate very different patterns of response for children and adults. Whereas only 5 of 16 adults (31%) ever endorsed a teleological response at all, 13 first graders (81%) and 15 second graders (94%) endorsed a teleological explanation on two or more occasions. Twelve of 16 fourth graders (75%) endorsed a teleological choice at least twice.

Discussion

Consistent with both ST and PT, the results of Study 1 revealed that adults were selective in their application of teleological explanations and specific about the kinds of functions that they accepted. Although they viewed biological and behavioral properties as existing to serve purposes for the animals possessing them, they did not accept social teleological explanations of such properties. Importantly, in a manner that is entirely congruent with modern scientific thinking, they were resolutely nonteleological in their explanations about nonliving natural kinds such as pointy rocks.

A different pattern was evident in children at all grade levels. Consistent with ST was the finding that older children endorsed self-serving rather than social teleological explanations of the biological and behavioral properties of living things—a response pattern that was, idiosyncratically, only displayed by first graders on behavioral properties.[2] However, in a manner entirely inconsistent with ST, children at all grade levels promiscuously viewed the properties of nonliving natural objects as existing for a purpose. In other words, children in all grades, even fourth grade, preferred teleological over physical explanations of the properties of objects such as rocks and stones.

The kinds of teleological explanations children preferred did, however, undergo interesting shifts with age. Specifically, whereas first graders took the somewhat animistic view that nonliving natural object properties exist to perform functions for the entities possessing them, second graders were less discriminating. They accepted any kind of teleological explanation for nonliving natural object properties and were therefore equally inclined to accept that sand is grainy "so that it will not blow away" and "so that animals can easily bury their eggs in it." Fourth graders entirely reversed the first graders' response pattern. They were the only age group to exclusively construe nonliving natural properties in terms of their social value and usefulness to others. These differences in 7–10-year-olds' explanatory preferences may reflect reorganizations in children's understanding of biological processes, which undergo substantial change in the first decade of life (Carey, 1985). At the very least, they indicate that by fourth grade, children have a more elaborate knowledge of the kinds of explanations that are appropriate to the animate and inanimate natural worlds.

In sum, the results of this study are consistent with prior findings suggesting that young children have a promiscuous teleological tendency to believe that entities of all kinds are "made for" something. The results also indicate that by second grade, children are becoming sensitive to the kinds of teleological explanations that adults tend to emphasize when considering the biological domain. However, the surprising finding that children as late as fourth grade endorsed teleological explanations of nonliving natural kinds raises several further questions. How robust is children's generalized tendency to endorse teleological explanations at different ages and how susceptible is it to influence?

Research indicates that the context in which a task is situated sets up expectations as to how it should be approached (e.g., Resnick, 1994). Perhaps children's broad teleological responses could have been, in part, a consequence of misconstruing the study as a make-believe game rather than as a genuine inquiry into their beliefs. Although there was no evidence that this was the case from children's affect while performing the task, it was nevertheless important to explore this possibility further. To this end, in Study 2 I modified Study 1 in the following way: Prior to asking children questions about the causes of living and nonliving natural properties, I provided them with an explicit context for the task. This took the form of a short pretrial session that described in simple, nonteleological, reductionist terms the way scientists think a nonliving natural kind forms. Although the primary goal of the pretrial was to provide context rather than effect any kind of conceptual change, the pretrial nonetheless gave participants both implicit (linguistic) and explicit (content) cues as to the way physical causation applies in the nonliving natural domain. Most important, it clearly identified the study as a science task rather than as any kind of fantasy game.

In addition to this modification, the materials for Study 2 were also changed slightly. In Study 1, participants were asked questions about both the behavioral and biological properties of living things. As predicted, their patterns of answers to each of these trial types were roughly equivalent. To gain further insights into children's intuitions about the living things, in Study 2 I replaced the behavioral property trials with a second, additional, set of biological property trials. There were several reasons for making this change.

The explanation-endorsement method offers a useful way of gaining converging evidence for children's conceptual biases. This is because the processing requirements of this method are low

Table 2
Numbers of Participants Endorsing Teleological Explanations of Nonliving Natural Kind Properties in Study 1

No. of times	First grade	Second grade	Fourth grade	Adults
Never	0	0	1	11
One	3	1	3	3
Two	2	3	5	2
Three	6	7	5	0
Four	5	5	2	0

[2] The finding that first graders in Study 1 did not have a significant tendency to endorse any kind of teleological explanation with biological properties is an idiosyncratic result by both ST and PT standards. Two pieces of evidence suggest, however, that this result should be assigned to the category of anomalous findings. First, the result is entirely inconsistent with prior research indicating that young children have a robust bias to view biological properties in teleological terms (Keil, 1995; Kelemen, 1999b). Second, this effect failed to reoccur in Study 2, in which first graders presented with the same Study 1 items displayed a significant tendency to endorse both self-serving (75%) and social (84%) teleological explanations.

relative to other procedures that require children to formulate answers to open-ended questions. Nevertheless, as Carey (1995) noted in relation to research by Hatano and Inagaki (1994), the explanation-endorsement method is faced with the particular challenge of ensuring that the explanations used are equivalent in content, varying from each other on only a few dimensions of interest. In Study 1, the social teleological explanations of the biological properties differed from the self-serving teleological explanations of all object kinds on several dimensions.[3] First, whereas the self-serving functions were self-beneficial, the social functions were other-serving in nature. Second, whereas the self-serving functions emphasized activities relevant to self-preservation (e.g., self-protection and food gathering), the social teleological functions of the biological properties more frequently described activities with interpersonal implications (e.g., friendship maintenance), a factor that sometimes resulted in these explanations being as anthropomorphic as they were teleological.

In Study 2, it was therefore important to understand which particular factors had led children in Study 1 to endorse the social teleological explanations of biological properties more frequently than adults did. To this end, the social teleological explanations in the new set of Study 2 biological property trials stripped away several dimensions of difference from the self-serving explanations. The new social teleological explanations no longer made any anthropomorphic mention of friendships and emotions. As a consequence of this deemphasis, the social teleological explanations also became more similar to the self-serving explanations by focusing on activities with relevance to maintaining existence or physical well-being.[4] In general, the major distinction between the two kinds of teleological explanations was therefore whether they were self-serving or other-serving in nature. The addition of the new trials alongside the old trials in Study 2 permitted statistical comparisons to be made between the trials so that children's explanatory preferences could be better understood.

The predictions for Study 2 were the same as those for Study 1. Whereas ST would predict that children and adults should prefer self-serving teleological explanations of biological properties and physical explanations of nonliving natural kinds, PT would predict that children at all grade levels would apply teleological explanations to both living and nonliving natural kinds. However, I thought that modeling and promoting scientifically appropriate reasoning about nonliving natural objects in the pretrial might reduce the promiscuous teleological effects found in Study 1, at least for older children.

Study 2

Method

Participants. Participants were 16 first-grade children (9 boys and 7 girls; mean age = 7 years 1 month; *SD* = 4 months), 16 second-grade children (9 boys and 7 girls; mean age = 8 years 2 months; *SD* = 6 months), 16 fourth-grade children (3 boys and 13 girls; mean age = 10 years 2 months; *SD* = 7 months), and 16 adult university undergraduates. The children represented a diverse minority population attending an inner-city elementary school. All children were fluent English speakers. None of the participants in Study 2 had participated in Study 1.

Materials. The picture sets used were the same as those in Study 1. In addition, there were three small cards used in the pretrial session that showed three different kind of clouds: a big fluffy cloud, a thin wispy cloud, and a long smooth cloud. There was also a larger card with a sequence of three hand-drawn pictures depicting the stages in the formation of a cloud. Participants looked at this card during the pretrial session.

Design and procedure. Children were interviewed individually for approximately 20–25 min, and adults completed a pencil-and-paper version of the task in approximately 15–20 min. The design and procedure for Study 2 were the same as those in Study 1 apart from the addition of the pretrial session and the new biological property trials. The new trials are presented in Appendix B.

Before beginning the short pretrial session, participants were told that they were first going to look at some pictures of clouds and talk about them and that later they would see some other pictures and get to talk about those as well. Participants then engaged in a pretrial session in which the experimenter showed them drawings of three different kinds of clouds and said she would explain "how scientists think clouds form and why they think they are in the sky." The description of cloud formation was then provided in very simple nonteleological language, and a sequence of pictures depicting the explanation was shown simultaneously. The first picture depicted the sun heating up a body of water and some of the water changing into water vapor. Children were told that the heat had changed the water into "tiny bubbles that are so small you can't even see them." The second picture showed the bubbles floating upward, and children were told that as the bubbles rise they cool down and turn back into drops of water again. The children were then shown the final picture of the droplets aggregating into a cloud and were told that "scientists think that when there are lots of tiny drops in the same place, then they collect together, and when that happens they make a cloud high up in the sky." The full script of the explanation is provided in Appendix C.

At the end of the pretrial description, participants were told, "Cool! So now you know how clouds form and why they are up in the sky. They are all made up of tiny drops of water and sometimes when the water drops get really cold, then it rains. Now, here's what I want you to do. I want you to try and think like a scientist about some things." Participants were then given the same instruction as in Study 1. They were told that they were going to be asked some questions about animals that lived a long time ago and to listen to some possible answers. Participants were instructed to try and think like a real scientist and "pick the answer that makes most sense to you." They then proceeded to the main part of the study, in which they were shown each picture set and asked two questions about a biological property of the animal and one question about a nonliving natural object found in the animal's habitat. Children who did not seem to follow the pretrial did not proceed to the main part of the study. This was true of only 1 child, a second grader, who was replaced by another participant.

Results

In Study 2, a new set of biological property trials was included alongside the original Study 1 trials to see whether children's Study 1 tendency to endorse social teleological explanations more than adults did was due to the explanatory tone (i.e., anthropomorphic) rather than the other-serving teleological nature of these explanations. A preliminary 2 (trial type: old vs. new) × 2 (function type: self-serving vs. social) × 4 (grade) ANOVA comparing

[3] Only the biological property trials are at issue here because the teleological explanations of natural object properties tended to differ only on the other-serving versus self-serving dimension.

[4] Arguably, despite the increased emphasis on preserving well-being in both the self-serving and other-serving teleological explanations, the self-serving accounts still retained a more biological flavor—at least for adults. This is because adults' intuitive biological assumptions may be such that they will construe any self-serving animal property in adaptationist terms whether or not the function is explicitly attributed with survival value.

teleological answers to the old and new Study 2 biological property trials found no main effect of trial type but did find a Grade × Trial Type × Function Type interaction. Post hoc analyses indicated, however, that this effect was not carried by any particular grade responding differently to the old and new social teleological explanations—although first graders did give marginally more teleological responses to the old social teleological explanations ($M = 84\%$) than to the new nonanthropomorphic ones ($M = 66\%$), $t(15) = 1.86$, $p < .08$. Instead, further analyses indicated that the interaction was largely caused by adults and fourth graders, who had a general tendency to prefer self-serving to social teleological explanations whether they were from the new or old biological property trials. In the absence of more meaningful differences between the old and new trials, I decided to simplify further analyses by collapsing the responses to both trial types.

To quickly restate the predictions for the main analyses, in contrast to PT, ST predicts that children and adults will view the properties of nonliving natural objects as nonfunctional. ST also predicts that children and adults will construe biological properties as primarily existing to perform self-serving functions. To explore these predictions, I performed a 4 (grade) × 2 (property type: biological vs. nonliving natural kind) × 2 (function type: self-serving vs. social) mixed ANOVA comparing children's and adults' tendencies to endorse teleological explanations with the different property types. To control for the different numbers of trials for each property type, I used proportion scores in these analyses.

The analysis found main effects of grade, $F(3, 60) = 22.39$, $p < .01$, property type, $F(1, 60) = 9.24$, $p < .01$, and function type, $F(1, 60) = 12.75$, $p < .01$, with a significant Grade × Property Type × Function Type interaction, $F(3, 60) = 4.55$, $p < .01$. The effect of grade occurred because first and second graders endorsed significantly more teleological explanations than fourth graders and because children of all ages endorsed significantly more of them than adults (first graders, $M = 72\%$; second graders, $M = 69\%$; fourth graders, $M = 48\%$; adults, $M = 27\%$). The effect of property type occurred because more teleological responses were endorsed with living than nonliving natural objects (59% vs. 49%). Finally, the effect of function type occurred because self-serving teleological explanations were endorsed more than social teleological explanations (60% vs. 48%).

To understand the interaction, I conducted two separate 4 (grade) × 2 (function type) mixed ANOVAs on the frequency of participants' teleological responses to the biological and nonliving natural object trials, respectively. Table 3 presents the percentages of times that participants endorsed teleological explanations with each property type.

The analysis of the biological properties revealed a Grade × Function Type interaction, $F(3, 60) = 9.63$, $p < .01$. This occurred because participants at all grades were equally inclined to explain biological properties in self-serving teleological terms, but first and second graders were more likely to endorse social teleological explanations than were fourth graders and adults. More specifically, first graders preferred any kind of teleological explanation over a physical explanation (both t tests, $p < .05$). In contrast, whereas second graders had a significant preference for self-serving teleological explanations, their preference for social teleological accounts was at chance. Adults' and fourth graders' patterns of responses were highly similar. Both groups significantly preferred self-serving teleological explanations to physical explanations but actively rejected any kind of social teleological explanation for properties such as long necks and flat feet (both t tests, $p < .05$, one-tailed).

Table 3
Percentages of Trials in Which Teleological Explanations Were Endorsed in Study 2

	Biological properties		Nonliving natural kind properties	
Group	Self-serving	Social	Self-serving	Social
First graders	77*	75*	66†	69*
Second graders	72*	61	75*	69*
Third graders	75*	28*	41	47
Adults	67†	19*	9*	13*

Note. Mean ages of children were 7 years 1 month for first graders, 8 years 2 months for second graders, and 10 years 2 months for fourth graders. Significance levels indicate preferences differing from chance.
* $p < .05$, two-tailed. † $p < .05$, one-tailed.

With regard to the natural objects, the analysis revealed a main effect of grade, $F(3, 60) = 19.83$, $p < .01$, and no other effects. Children at all grades endorsed teleological explanations significantly more than did adults, with first and second graders also endorsing them more than fourth graders (first graders, $M = 68\%$; second graders, $M = 72\%$; fourth graders, $M = 44\%$; adults, $M = 11\%$). However, one-group t tests indicated that although first and second graders had a significant preference for teleological over physical explanations of nonliving natural object properties (both t tests, $p < .05$), fourth graders' explanatory preferences were at chance. In contrast to children at all ages, adults strongly rejected any kind of teleological explanation for the properties of rocks and sand.

Given that participants' responses to the nonliving natural kinds were highly pertinent to discriminating between PT and ST hypotheses, I also conducted an individual-participant analysis to explore the consistency of participants' teleological responses. The results are presented in Table 4. As Table 4 shows, only 4 of 16 adults (25%) ever endorsed a teleological response. In contrast, 13 of 16 first graders (81%) and 15 of 16 second graders (94%) endorsed a teleological explanation on two or more occasions. Greater conservatism was evident in the fourth graders: Only 9 of 16 fourth graders (56%) endorsed a teleological choice on two or more occasions.

Finally, in order to see whether the pretrial had any effect on children's tendency to accept physical explanations with nonliving natural kinds, I compared teleological responses to the nonliving natural kinds in Studies 1 and 2 in a 2 (study type: Study 1 vs. Study 2) × 2 (function type) × 4 (grade) ANOVA. The analysis revealed an overall effect of grade, $F(3, 120) = 41.16$, $p < .01$; fourth graders endorsed significantly more teleological responses than adults but endorsed fewer than first and second graders (first graders, $M = 69\%$; second graders, $M = 73\%$; fourth graders, $M = 50\%$; adults, $M = 11\%$). There was no effect of study type or of function type, and there were no interaction effects. In other words, there was no difference between the two studies, and the pretrial had no statistically significant impact on children's and adults'

Table 4
Numbers of Participants Endorsing Teleological Explanations of Nonliving Natural Kind Properties in Study 2

No. of times	First grade	Second grade	Fourth grade	Adults
Never	0	0	3	11
One	3	1	4	4
Two	3	3	4	0
Three	6	9	4	1
Four	4	3	1	0

tendency to endorse teleological responses with the nonliving natural objects.

Discussion

In Study 2 an attempt was made to influence children's tendency to reason in teleological terms about nonliving natural kinds by placing the task in an explicitly scientific context that provided cues about the way objects such as clouds can be physically explained. Despite this modification, no overall differences were found in participants' performance on the two tasks. As in Study 1, adults' pattern of response was to reject teleological explanations for nonliving natural objects and to restrict their teleological intuitions to self-serving functional explanations of biological properties. At all ages, children's response patterns differed from those of adults. First graders indiscriminately endorsed self-serving and social teleological explanations of both biological and nonbiological natural object properties, and although second and fourth graders inclined toward adultlike teleological intuitions about biological properties, 8- and 10-year-olds were significantly more likely than adults to endorse teleological explanations for nonliving natural objects. It should be noted, however, that in contrast to the situation in Study 1, fourth graders' teleological preference with nonliving natural objects was at chance. There was also statistical evidence, summing across Studies 1 and 2, of a developmental movement away from teleological explanations of nonliving natural kinds by fourth grade.

General Discussion

Studies 1 and 2 found that children differ from college-educated adults in preferring teleological explanations of the properties of both living and nonliving natural kinds. The findings of these studies are consistent with earlier research which indicated that prior to a formal scientific education, children promiscuously attribute functions to all kinds of living and nonliving objects, viewing them as "made for something" (Kelemen, 1996, 1999b).

The present findings also extend earlier research. They provide evidence of developmental changes in the nature of children's teleological intuitions between first and fourth grade. By fourth grade, children, like adults, actively endorse self-serving but not social teleological explanations of many biological properties. Their teleological tendency toward nonliving natural kinds also seems to undergo a shift, becoming less robust: Specifically, in contrast to first graders, who treated the properties of objects such as rocks as akin to the self-serving properties of living things, fourth graders in Study 1 tended to view such objects as existing to perform externally focused, or "social," functions. This movement away from animistic attributions to nonliving things may reflect a deepening understanding of natural processes. It may also indicate the influence of popular ecological ideas that promote the notion that objects in nature function in homeostatic support of each other. The final indication that children's tendency toward teleological explanation was reorganizing by fourth grade was the fact that 10-year-olds were the only group of children whose tendency to teleologically explain nonliving natural kinds was at chance after exposure to the Study 2 pretrial.

The degree of the child–adult differences demonstrated in both of these studies is quite striking and, of course, raises questions as to why young children promiscuously endorse teleological explanations and extend them to nonliving natural kinds. Three explanations seem possible.

The first and most cautious interpretation is that children overapplied teleological explanations because they were simply playing make-believe. In other words, children recognize that physical explanations are more appropriate when considering objects such as stones but nevertheless selected teleological explanations in the present tasks because they found them novel and therefore appropriate to something they viewed as a storytelling game.

Although such a scenario is feasible, several factors mitigate against this interpretation of the present results. First, children would have been hard-pressed to view Study 2 as a lighthearted fantasy game given its explicit science context. Yet, despite the addition of the pretrial to Study 2, the promiscuous teleological effects found in Study 1 were replicated and, in the case of first graders, strengthened. Second, there was no indication from children's general emotional affect in either study that they were engaging in make-believe. Although children enjoyed the task, they appeared to approach it seriously and in problem-solving mode.

A second possible interpretation is that these studies are revealing a systematic teleological bias but one that operates purely at the level of explanation. In other words, in the absence of knowledge, children gravitate toward teleological accounts when asked certain kinds of questions, but this explanatory bias is entirely dissociated from their everyday reasoning about objects such as rocks and stones, which—in contrast to artifacts—they construe in straightforwardly physical terms. As such, an educator's goal is to provide children with the frameworks to generate "appropriate" scientific explanations for nonliving natural things, rather than to fundamentally influence any deeper misconceptions about natural objects and the structure of the natural world.

However, although this view provides a viable account of the present results, it raises some important issues and begs as many questions as it answers: In the absence of knowledge, why is teleological explanation the default? Why not physical or mechanistic explanations, which are, in many respects, far simpler and, by Western scientific standards, more explanatory and veridical? This issue becomes even more worthy of attention when one considers that it is not just children who incline toward purpose-based accounts when potentially lacking other explanations. Adults in most cultures, particularly those in which mechanistic science is not preeminent, find intention-based or religious teleological explanations a satisfying way to account for natural objects and events (see Boyer, 1994, and Lewis, 1995, for pertinent discussion).

One explanation for the origin of a teleological explanatory bias is provided by PT. It argues that purpose-based explanations are generally compelling to people because teleological reasoning is derived from a mode of thought that, owing to our evolution as complex social animals, comes easily to us—intentional reasoning. Specifically, it seems possible that the tendency to explain objects in terms of a functional purpose develops from our bias to explain the behavior of agents by attributing mental purpose. Between 9 and 12 months, infants display a sensitivity to agents and their goal-directed behavior (Csibra et al., 1998; Gergely et al., 1995; Johnson et al., 1998). Around the same time, or shortly thereafter, they also become oriented to the way agents use objects to achieve their goals. This sensitivity to intentionality and goal-directed object use could play a powerful role in the development of children's explanatory mechanisms: During infancy, most of the inanimate objects that children encounter are human artifacts—objects such as spoons and diapers—whose presence in the environment is largely explained by the way agents intentionally use them. The early experience which suggests that objects exist in the environment for agents' purposes may, later in development, influence children's and adults' strategies when generating explanations. When compensating for a lack of an explanation, individuals may draw on their early knowledge of intentional object use and use an artifact model to generate placeholder explanations for why objects exist and have the properties that they do. This is one account of how a bias to explain objects like pointy rocks in teleological terms could exist independent of an everyday functional construal of such entities.

A final account of the present results is, however, a stronger version of the explanation given above. Perhaps the robust teleological bias displayed by children in these studies not only reflects a default explanatory strategy but also indicates a more fundamental tendency to think about both living and nonliving objects as designed for a function. In other words, it may be that for a child, a sun that is so hot that it burns or a river that is so dirty that animals cannot drink from it is just as "broken" as a refrigerator that can no longer cool things (see Schwitzgebel, 1998, for discussion on this point). In all cases, the objects are construed as being unable to perform activities that are seen as central to explaining their properties and existence.

Why would children develop this view that seems fundamentally at odds with an adult perspective? One answer is that children may make causal assumptions about the origins of natural objects that are different from those of most Western adults. Contrary to Piaget's (1929) assertion that children are "artificialists" who believe all things have a human origin, research indicates that preschool children know that it is artifacts, rather than natural objects, that are made by people (Gelman & Kremer, 1991; Keil, 1989). However, in the absence of an alternative theory for making sense of objects and events, and possessing a "drive to explain" (e.g., Gopnik & Meltzoff, 1997; Schwitzgebel, in press), children may nevertheless draw on their knowledge of intentional behavior to conclude that living and nonliving natural things have been designed for a purpose by some unspecified agent. Thus, while they may make distinctions between artifacts and living and nonliving natural kinds, they may develop the belief that the latter objects are, in some sense, artifacts that exist to perform functions in a well-ordered, intentionally created world. This belief may become increasingly obsolete as children develop more elaborated physical theories, although it may never entirely disappear as an explanatory framework because, for evolutionary reasons, people find it an intuitively satisfying default. Indeed, the tendency to reason, by default, in intention-based teleological terms may explain why people are subject to certain kinds of persistent misconceptions in their biological thinking; for example, it helps to account for children's and adults' systematic tendency to misconstrue natural selection as a goal-directed process akin to intentional design rather than as a brute mechanism acting on genetic variation in a biological population (see Brumby, 1985; Ohlsson, 1991).

Tentative support for the proposal that children's teleological assertions are related to an intention-based theory of origins is provided by several recent studies. Evans (1994, in press) presented U.S. children from both Christian fundamentalist and nonreligious backgrounds with different causal accounts for the origins of natural objects and found that irrespective of parental background, 6- to 8-year-olds were most likely to strongly endorse the view that the natural objects were "made by God." Similarly, Gelman and Kremer's (1991) study of childhood artificialism revealed that 4- to 7-year-old children, although they knew that people did not make nonliving natural objects, were nevertheless oriented toward intentional causal agency: Regardless of how their intuitions were probed in the study, a significant proportion of the children posited God, rather than any natural process, as the underlying cause of a variety of natural phenomena. This research is suggestive; however, further work is required to firmly establish whether this preference for intention-based explanation is common in children of all cultures, whether it is systematically related to teleological beliefs, and whether it is revealed in contexts besides those that ask children to provide explanations.

In summary, it remains for future studies to establish what underlies children's broad preferences for teleological explanations and to examine whether a stronger or weaker version of PT might provide the answer. Such research has implications for our understanding of children's intuitive and scientific theory formation. For example, if, consistent with PT, children's teleological ideas derive from a knowledge of intentional agency, then the suggestion by Keil (1992, 1995) and others (see Atran, 1995; Hatano & Inagaki, 1994; see also Kelemen, 1999a) that a teleological construal underlies children's first truly "biological" understanding of living things needs to be carefully evaluated. Although, as the present studies demonstrate, teleology plays an important role in children's early understanding of living things, children's tendency to view animal properties in functional terms does not necessarily entail a particularly distinctive, theoretical understanding of animals and plants as vital, physiological systems (see Carey, 1995, for further discussion). Rather, young children's broad bias to accept varying kinds of teleological explanations for living things may imply that children are driven to make structure–function mappings just as they might with intentionally designed artifacts. Thus, while the present findings do not resolve whether young children have an autonomous way of thinking about living things, they do suggest that teleological intuitions are not sufficient to demarcate the causal-explanatory system for biology or to insert biological content into children's reasoning about living things.

More positively, however, the current studies empirically demonstrate that a phenomenon that seems profoundly human and fundamental to adults' cognitive structure is pervasive from an early age. As Richard Dawkins (1995, p. 96) observed, "We humans have purpose on the brain. We find it hard to look at anything without wondering what it is 'for,' what the motive for it is, or the purpose behind it." Questions concerning the origin of the teleological bias and its influence on developing cognition are important issues meriting further investigation.

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Appendix A

Study 1 Stimuli

Cryptoclidus (Aquatic Reptile)

Biological property. "Cryptoclidus had these long necks. Why do you think they had such long necks?"

Physical: "They had long necks because the stuff inside got all stretched out and curved."

Self-serving: "They had long necks so that they could grab at fish and feed on them."

Social: "They had long necks so that they could hold up their friends when they got tired swimming."

Behavioral property. "When Cryptoclidus moved, their necks swayed from side to side. Why do you think their necks swayed?"

Physical: "Their necks swayed because of the way the bones fit together on their bodies."

Self-serving: "Their necks swayed so that they could move quickly through the water."

Social: "Their necks swayed so that they could soothe their children to sleep."

Natural kind property. "All around where Cryptoclidus lived, there were these pointy kinds of rocks. Why do you think the rocks were so pointy?"

Physical: "They were pointy because little bits of stuff piled up on top of one another over a long time."

Self-serving: "They were pointy so that animals wouldn't sit on them and smash them."

Social: "They were pointy so that animals like Cryptoclidus could scratch on them when they got itchy."

Macreuchenia (Large Terrestrial Mammal)

Biological property. "Macreuchenia had these big snouts. Why do you think they had such big snouts?"

Physical: "They had big snouts because their face muscles and bones pulled down and got longer."

Self-serving: "They had big snouts so that they could pull down leaves from trees and eat them."

Social: "They had big snouts so that they could stroke their babies and make them feel loved."

Behavioral property. "When Macreuchenia walked around, they often knocked into trees. Why do you think they knocked into trees?"

Physical: "They knocked into trees because they were large and moved awkwardly—with difficulty."

Self-serving: "They knocked into trees so that they could get ripe fruit to fall down."

Social: "They knocked into trees so that their friends would hear and find them if they needed them."

Natural kind property. "All around where Macreuchenia lived, there were these very still kinds of ponds—ponds that never had waves. Why do you think the ponds were so still?"

Physical: "They were still because no moving water ever ran into them."

Self-serving: "They were still so that they would never spill and lose all their water."

Social: "They were still so that animals like Macreuchenia could cool off in them without being washed away."

Mononykus (Terrestrial Bird)

Biological property. "Mononykus had these long tails. Why do you think they had such long tails?"

Physical: "They had long tails because their feathers were big and stuck out from behind their body."

Self-serving: "They had long tails so that they could keep balance while they ran."

Social: "They had long tails so that their behinds were covered and other animals could look without getting embarrassed."

Behavioral property. "When Mononykus lay down, their feathers puffed out from their bodies. Why do you think their feathers puffed out?"

Physical: "Their feathers puffed out because of the way their bodies changed position when they weren't standing up."

Self-serving: "Their feathers puffed out so that they could stay warm while they were not moving."

Social: "Their feathers puffed out so that their friends would know they were asleep and would get mad at them if they were woken up."

Natural kind property. "All around where Mononykus lived, there was this grainy (rough) kind of sand. Why do you think the sand was so grainy?"

Physical: "It was grainy because bits of shells got broken and mixed up making it that way."

Self-serving: "It was grainy so that it wouldn't get blown away and scattered by the wind."

Social: "It was grainy so that animals like Mononykus could easily bury their eggs in it."

Moeritherium (Squat Mammal)

Biological property. "Moeritherium had these flat feet. Why do you think they had such flat feet?"

Physical: "They had flat feet because their toe bones got shortened and all smoothed out."

Self-serving: "They had flat feet so that they could stand on wet ground without slipping."

Social: "They had flat feet so that they could have fun playing and kicking mud on each other."

Behavioral property. "When Moeritherium searched about on the ground, their ears flapped from side to side. Why do you think their ears flapped from side to side?"

Physical: "Their ears flapped because of the way they joined to the sides of their heads."

Self-serving: "Their ears flapped so that they could keep flies from landing on them."

Social: "Their ears flapped so that they could show their friends where to find tasty food."

Natural kind property. "All around where Moeritherium lived, there were these green kinds of stones. Why do you think the stones were so green?"

Physical: "They were green because lots of colored stuff mixed together to make them that way."

Self-serving: "They were green so that they couldn't be seen in the grass and no-one would pick them up and take them."

Social: "They were green so that animals like Moeritherium could live in a nice place with pretty things around them."

Appendix B

Study 2 New Biological Property Trials

Cryptoclidus (Aquatic Reptile)

"Cryptoclidus had smooth skin. Why do you think they had such smooth skin?"

Physical: "They had smooth skin because it got stretched out tight across their bones."

Self-serving: "They had smooth skin so that they could move easily through the water."

Social: "They had smooth skin so that other animals could swim alongside without getting cut."

Macreuchenia (Large Terrestrial Mammal)

"Macreuchenia had a big body. Why do you think they had such big bodies?"

Physical: "They had big bodies because of the way all their fat deposits collected around their muscles."

Self-serving: "They had big bodies so that they could push a path through all the trees in the forest."

Social: "They had big bodies so that smaller animals could shelter underneath them from the rain."

Mononykus (Terrestrial Bird)

"Mononykus had soft feathers on their bodies. Why do you think they had such soft feathers?"

Physical: "They had soft feathers because furry stuff got built up all over them and pressed together in a certain way."

Self-serving: "They had soft feathers so that they could look like leaves on trees and stay hidden."

Social: "They had soft feathers so that other tiny animals could crawl under them and stay warm and protected."

Moeritherium (Squat Mammal)

"Moeritherium had a wide back. Why do you think they had such wide backs?"

Physical: "They had wide backs because they had large bones that got joined together in a particular way."

Self-serving: "They had wide backs so that their bodies would be strong and firm."

Social: "They had wide backs so that birds and other animals could ride around on top off them."

Appendix C

Study 2 Cloud Formation Description

"Today we're going to do a couple of fun things. First we're going to look at some pictures of clouds together and talk about them. After that we're going to look at some other pictures and talk about those as well.

"But first of all, look at these! Now . . . There are all kinds of clouds. See . . . there are big fluffy ones like this, thin wispy ones like this, and long smooth ones like this. I am going to tell you how scientists think clouds form and why they think they are in the sky . . . OK?

"Here's what scientists say. Although they may not look like it, actually clouds are made up of lots and lots of cold drops of water. Here's what happens:

[Picture 1] "When the sun shines, it can get quite hot, can't it? Well . . . when the sun shines on water—like an ocean or a lake—then the water warms up, and once water gets warmed up to a certain point, it changes. It turns into tiny warm watery bubbles. These bubbles are *so* small you can't even see them—that's how small they are.

[Picture 2] "What happens then is that these tiny bubbles float up through the air. They go higher and higher and higher. As the bubbles get higher in the sky they start to cool down—in fact they get so cold, they change back into drops of water again.

"Now, here's the last part in how clouds form:

[Picture 3] "Scientists say that when there are lots of tiny drops all in the same place then they collect together. When that happens they make a cloud high up in the sky.

"If the cloud is full of tiny drops of water that are very cold then what happens is that the drops fall to the ground as rain. That's how scientists explain rain."

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