Cognitive Development 18 (2003) 25–47

COGNITIVE DEVELOPMENT

Cultural and experiential differences in the development of folkbiological induction

Norbert Ross [a,*], Douglas Medin [a], John D. Coley [b], Scott Atran [c]

[a] *Psychology Department, Northwestern University, 2029 Sheridan Road, Evanston, IL 60208, USA*
[b] *Northeastern University, Boston, MA, USA*
[c] *CNRS, 75794 Paris Cedex 16, France*

Received 1 March 2002; received in revised form 1 August 2002; accepted 1 September 2002

Abstract

Carey's (1985) book on conceptual change and the accompanying argument that children's biology initially is organized in terms of naïve psychology has sparked a great detail of research and debate. This body of research on children's biology has, however, been almost exclusively been based on urban, majority culture children in the US or in other industrialized nations. The development of folkbiological knowledge may depend on cultural and experiential background. If this is the case, then urban majority culture children may prove to be the exception rather than the rule, because plants and animals do not play a significant role in their everyday life. Urban majority culture children, rural majority culture children, and rural Native American (Menominee) children were given a property projection task based on Carey's original paradigm. Each group produced a unique profile of development. Only urban children showed evidence for early anthropocentrism, suggesting that the co-mingling of psychology and biology may be a product of an impoverished experience with nature. In comparison to urban majority culture children even the youngest rural children generalized in terms of biological affinity. In addition, all ages of Native American children and the older rural majority culture children (unlike urban children) gave clear evidence of ecological reasoning. These results show that both culture and expertise (exposure to nature) play a role in the development of folkbiological thought.

* Corresponding author. Tel.: +1-847-467-2421; fax: +1-847-491-7859.
E-mail address: n-ross@northwestern.edu (N. Ross).

0885-2014/02/$ – see front matter
PII: S0885-2014(02)00142-9

1. Introduction

Current views of cognition portray concepts as being embedded in theory-like explanatory frameworks (Carey, 1985, 1995; Keil, 1989; Medin, Lynch, & Solomon, 2000; Murphy & Medin, 1985). These framework theories differ in different domains of experience; a framework theory for understanding and predicting the behavior of physical objects necessarily differs from one, which allows us to predict the behavior of sentient beings. Correspondingly, theorists have begun to conceive of conceptual development as a domain-specific process, and have investigated development in core domains such as naïve physics and naïve psychology (Gelman & Hirschfeld, 1999; Wellman & Gelman, 1992; Wellman & Inagaki, 1997). However, recent research with adults indicates that framework theories, as well as domain-specific knowledge and reasoning strategies, differ across adult populations varying in expertise and cultural background (see Medin, Ross, Atran, Burnett, & Blok, 2002 for an overview). Most of these advances have been reported within the domain of folkbiology, encompassing how people understand, categorize and reason about plants and animals (Medin & Atran, 1999).

A good deal of research has been conducted in the last 15 years on the acquisition of folkbiology, both because of the intrinsic importance of the domain and as a test case for more general ideas about conceptual development. However, most of this research has ignored potentially important differences with respect to the experiential base and the cultural background of the children. Studies have focused on urban majority culture children in either the US or other industrialized cultures. Given the findings with adults on the role of culture and experience (see for example López, Atran, Coley, Medin, & Smith, 1997; Medin, Lynch, Coley, & Atran, 1997) the focus on such a restricted participant pool seems surprising.

An influential idea to emerge from this body of work is that children's understanding of the biological world undergoes a profound shift between ages 4 and 10. Carey (1985, 1995) argues that children's early understanding of plants and animals is anthropocentric. That is, children's understanding of other living things is largely in reference to, or by analogy to, human beings. As a consequence, prototypicality of humans is central to children's conceptions of the biological world.

One source of evidence that young children possess an anthropocentric folkbiology comes from a property projection task where children are taught a new fact about a given biological kind (e.g., a dog "has an omentum") and asked whether other kinds (a bird, a fish, a plant) share that property. The rationale is that projection of a novel internal property is an index of the biological affinity between base and target species (Carey, 1985). By examining patterns of projection, and comparing those patterns to predictions derived from competing conceptual schemes, we may be able to diagnose which theories children are using to understand the world around them. Carey (1985) used this task to explore how children's projections from one basic-level animal category to other categories differed based on the similarity of the base and target categories.

The task relies on two related ideas: first, inductive inferences from prototypical members of a category are perceived as stronger than inferences from less central, typical members of that category (Osherson, Smith, Wilkie, & Shafir, 1990; Rips, 1975). Second, inductive inferences are guided by the similarity between the base and target items. Within this paradigm an anthropocentric folkbiology makes two straightforward predictions: first, if humans are central, prototypical exemplars of living things, then on average projections from humans should be stronger than projections from other living things. Second, an anthropocentric folkbiology should lead to asymmetries in projection. For example, inferences from human to dog should be stronger than from dog to human (see Osherson et al., 1990 for a formal model that predicts asymmetries of inferences between typical and atypical category members).

The 4- and 6-year-olds studied by Carey (1985) generalized as would be predicted by an anthropocentric view. Four-year-olds readily generalized from humans as a base but showed little generalization from dogs and almost none from bees as a base. For 6-year-olds, humans were still somewhat privileged, as children were more likely to project from humans to other animals (69%) than from dogs to other animals (54%). Furthermore, asymmetries were evident in comparing human $\geq$ dog (76%) to dog $\geq$ human (41%), and human $\geq$ bee (59%) to bee $\geq$ human (12%). For 10-year-olds and adults, humans are no longer uniquely central, though some effects suggestive of anthropocentrism are still evident in the 10-year-old responses.

Carey interpreted these results as supporting a comparison-to-exemplar model of biological reasoning in which the folkbiological gold standard is people. Carey (1985) argues that, "The prototypicality of people plays a much larger role in determining 4-year-olds' projection of having a spleen than does similarity among animals" (p. 128). Thus, according to Carey, early folkbiology is essentially anthropocentric (see also Johnson & Carey, 1998). More generally, Carey interprets this pattern of reasoning, along with other evidence, as demonstrating that young children possess a qualitatively different understanding of biological phenomena, incommensurate with that of adults. As a consequence, pervasive conceptual change is necessary for children to acquire the adult model in which humans are seen as one animal among many (e.g., Carey, 1999).

Carey's original findings stimulated a great deal of research on children's biology. Much of this debate has centered on the question of whether children's biology is distinct from children's psychology. By now there are a number of studies that suggest that urban children have distinct notions of biology (e.g., Coley, 1995; Gelman & Wellman, 1991; Hatano & Inagaki, 1994, 1999; Hickling & Gelman, 1995; Keil, 1989, 1995 but see also Au & Romo, 1999; Johnson & Carey, 1998; Solomon, Johnson, Zaitchik, & Carey, 1996) and that contextual factors may affect the likelihood of children using a biological framework for explanation (Gutheil, Vera, & Keil, 1998). Although our study bears on the separation of folkbiology from folkpsychology, our focus is on the role of cultural and experiential factors in children's inductive reasoning, especially with respect to anthropocentrism.

In some respects the claim that for young children humans are prototypical living things represents a puzzle if not a paradox. Most human cultures draw a sharp distinction between human beings and other animals and one might expect people to be very atypical animals. Johnson, Mervis, and Boster (1992) found just that (see also Anglin, 1970). In their study (based on a triad similarity comparison) children and adults showed converging patterns of similarity relationships among mammals. However, adults considered humans more like other mammals than children did. Indeed, when presented with human–nonhuman–nonhuman triads, children almost never paired a human with another animal. This suggests that children see humans as much more distinctive and peripheral mammals than adults do.

So why the apparent difference between the Johnson et al. findings and the Carey results? In the present study we evaluate the idea that the amount and intimacy of children's contact with plants and animals as well as their cultural background has a critical influence on the development of folkbiological reasoning. Both dimensions are important in explaining adult reasoning patterns (Atran et al., 1999; López et al., 1997) and both may be relevant to children's reasoning as well. Furthermore, there is evidence that industrialization and urbanization has led to biological kinds being less psychologically salient than they were a few centuries ago (Wolff, Medin, & Pankratz, 1999). The extent of this "devolution" or loss of contact with nature may vary as a function of culture and setting (Ross, 2002a, 2002b). For example, plants and animals may be less salient to urban folk than they are for rural folk (e.g., compare Stross, 1973 with Dougherty, 1978). Obviously, urban children visit zoos, watch animals and plants on television, own pets, observe squirrels, robins and pigeons in parks and walk past trees on a daily basis. However, these sorts of experiences may not be especially "intimate." The most specific level that Northwestern University undergraduates can name trees, on average, is just "tree" (Coley, Medin, Proffitt, Lynch, & Atran, 1999).

In rural Wisconsin, home to two of our study populations, children are introduced to hunting and fishing at an early age. Parents may call the attention to the fact that deer prefer the acorns of white oaks to those of other oaks or note that beavers love poplars. Even owning pets might be associated with different meanings in urban and rural contexts. In an urban setting dogs are often treated as family-members and live in the home. In contrast, in our Wisconsin study area the value of a dog is often judged by its abilities as a hunting dog and most dogs do not live in the home. These differences in treatment and respect may affect how children reason about living kinds in relation to human beings. If these considerations are correct, the anthropocentrism displayed by the young children in Carey's (1985) study may not be caused by the fact that humans represent the prototypical animal, but, instead, may be attributable to humans being the only animal about which they have extensive knowledge.

If anthropocentrism is indeed a consequence of the knowledge devolution among urban children, then we should find clear differences among children of different cultural and experiential backgrounds. In our study we examine the degree to which children with different cultural beliefs and a rural versus an urban background reflect anthropocentric folkbiological reasoning.

The degree to which a shift from an anthropocentric to a biocentric folkbiology is a universal aspect of conceptual development has not been addressed by previous research. To do so requires looking at conceptual development among children that differ in relevant ways from Carey's population (Coley, 2000). It is important to examine the generality of this anthropocentric pattern of reasoning, on at least two grounds. First, as we have just noted, anthropocentric folkbiology may reflect a lack of close experience with the biological world. More precisely, urban children may be relative folkbiological novices. Indeed, there is evidence suggesting that knowledge has an impact on young children's reliance on humans as a base for reasoning. Inagaki and Hatano (1987, 1991) find that humans serve as a privileged base for property projection, but that this process is constrained by knowledge. For example, properties are not projected from humans to nonhuman organisms when such an inference would contradict children's knowledge of the nonhuman in question. This account differs from other models of analogy in that (1) rather than searching for most appropriate analogical base, a decision is made on whether humans are appropriate or not, and (2) object-specific knowledge is used, not to choose an appropriate analogical base, but rather to (a) judge the feasibility of the already-predicted behavior, and (b) compute the organism's similarity to humans. Moreover, this account differs from Carey's in that humans constitute a privileged analogical base because of children's relatively rich knowledge about humans, not because of the centrality of humans in children's biological theories.

Furthermore, Inagaki (1990) presented evidence that knowledge influences children's use of biological analogy. In her study all children were asked questions about observable and nonobservable properties of goldfish, asked to reason about goldfish in novel situations, and asked to reason about a novel aquatic animal (a frog) in similar situations. Children who were actively raising goldfish possessed more knowledge about both observable and unobservable attributes of goldfish. They were also more likely to make reasonable predictions about the behavior of goldfish in novel situations. Most importantly, while both groups tended to analogize from humans to frogs when answering questions about frogs, the goldfish raisers were more likely to analogize from goldfish to frogs when answering the same questions. This suggests that knowledge of goldfish enabled children who were actively raising goldfish to employ goldfish as an analogical base in a way that children who were not goldfish raisers could not.

Similar differences in knowledge and associated reasoning patterns are documented in another study of our research team. Atran et al. (2001) found that among Yukatek Maya (southern Mexico) young girls showed less differentiation than boys when the peccary was the base for induction, a pattern consistent with an effect of experience or familiarity. Boys go with their fathers into the forest at an early age and, therefore, are much more familiar with the peccary than are girls. In general, for this rural population even the youngest children tested (4–5-year-olds) showed no evidence of anthropocentrism; they generalized readily from both humans and other animals as a function of biological relatedness. Note that the experiential differences documented in both Atran et al. (2001) and Inagaki (1990) undermine arguments about urban children being heavily exposed to and knowledgeable about animals (bugs, squirrels, etc.).

In this study, we take the issue a step further by examining how differences in experience and/or culture might lead to differences in reasoning about plants and animals. Following Carey, we teach children novel properties about humans, wolves, bees, goldenrod, and water, and then see whether they are willing to project these new properties to an array of animals, plants, and nonliving objects. Of central importance is the question of comparative development: how do experience and cultural beliefs about nature affect inferences in the biological domain?

To address this question we examine children from three distinct populations: Native American children from the Menominee Indian Tribe of Wisconsin, rural majority culture children from the neighboring town of Shawano, Wisconsin, and Urban children from East Boston, MA. For a number of reasons, the Menominee population is of particular interest for this study. First, traditional folkbiological knowledge may be especially salient to the Menominee. Unlike most woodland tribes, the Menominee reservation occupies (a small fraction of) their traditional range; hence, traditional knowledge of local plant and animal species is still current and pertinent. Menominee harvest a wide array of forest products (such as timber, firewood, ginseng, wild berries, roots, and mushrooms) and children participate from an early age on in these activities. Hunting and fishing is common for children of both sexes and one can frequently observe groups of children (of different ages) pursuing these activities along the rivers and lakes of the reservation. Although this does not preclude them from owning pets and watching television (which they also do), it casts their relation with the environment in a different perspective. The Menominee tribe is well known for its record of sustainable forestry (Hall & Pecore, 1995). In part, this seems to reflect a consensual folkecological model (see Medin et al., 2002) that stresses the importance of living kinds interacting in the local environment, including interacting with humans.

The nearby majority culture town of Shawano provides a useful comparison population. Children in Shawano grow up in a very similar physical environment, also are introduced to fishing and hunting at an early age and also have a great deal of first hand experience with the natural world. However, with respect to the predominant adult models (the potential end product of the developmental process) we still find clear cultural differences. Ecological relations are much more salient and important for Menominee fishermen than for majority culture fishermen (Medin et al., 2002).

Examining these populations allows us to examine the pervasiveness of anthropocentric origins of folkbiology, and to begin to “triangulate” with respect to possible causes of conceptual differences (Bailenson, Shum, Atran, Medin, & Coley, 2002; Medin et al., 2002). To the degree that the two Wisconsin populations are similar, experience is implicated in shaping folkbiological beliefs. To the degree that the rural majority culture children resemble the urban children rather than the Menominee children, a role of cultural beliefs, practices and goals about nature may be implicated. Distinct patterns among the three populations might suggest a combination of these factors in shaping conceptual development, whereas commonalties among all the groups would suggest candidates for universals in development. Obviously, whatever the results are (other than universals), much work remains to be done to understand the causes of these differences. How are distinct cultural models learned and transmitted? What are the channels of learning, and what kind of experience has what kind of effects? To tackle these issues is beyond the scope of this paper. To address them we need first a clear understanding of the differences and commonalties in children's development of folkbiology. This issue is the main focus of what follows.

Our study differed from Carey's in that we included two additional types of inductive bases, goldenrod and water. We added goldenrod so that we could examine generalization both from animals to plants and from plants to animals. We had reason to believe that Menominee children would have a broad view of living kinds that includes not only plants but also natural entities such as rocks. In traditional Menominee culture all natural entities like rocks and water are alive (in related work in progress we are systematically examining cultural differences in children's conception of alive by a series of detailed probes). Our original motivation for including water as a base was to see if ecological relations might play some role in children's inductions. Previously we had found that adults knowledgeable about biology often rely on ecological reasoning strategies (López et al., 1997, Proffitt, Coley, & Medin, 2000) and we were interested in whether and when such strategies might appear in children's reasoning. As it turned out, however, when water is a base children use a wide variety of strategies and it is difficult to draw any clear conclusions. To reduce the complexity of an already complex design, we do not present the results for water as a base in this paper. Nonetheless, we were able to educe evidence for ecological reasoning from other bases.

2. Method

2.1. Participants

A total of 242 children from three distinct populations participated in the study. Native American children attended Keshena Elementary in Keshena, WI, a recently built school located on the Menominee Reservation. Rural children attended Lincoln Elementary School in neighboring Shawano, WI. Urban children attended the Guild School located in an urban area of East Boston, MA.

Participants in each locale were divided into three age groups: Kindergartners and first-graders ("young"), second- and third-graders ("middle"), and fourth-graders ("old"). Details on mean ages and ranges for each population are presented

Table 1
Mean ages and age range for the individual groups

Group	Age group	Count	Mean age	Age range
Urban majority	6-year-olds	14	6-0	5-4 – 6-8
	8-year-olds	16	8-0	7-3 – 9-10
	10-year-olds	26	10-0	9-0 – 11-2
Rural majority	6-year-olds	29	6-6	6-0 – 6-10
	8-year-olds	50	8-1	7-7 – 8-6
	10-year-olds	30	9-8	9-8 – 10-9
Rural Menominee	6-year-olds	24	6-03	5-06 – 7-06
	8-year-olds	32	8-07	7-08 – 9-05
	10-year-olds	21	10-03	9-08 – 11-00

in Table 1. All children were monolingual English speakers (though Menominee children typically know Menominee terms for clan animals), and were interviewed individually by research assistants from their community.

2.2. Materials

Detailed color drawings of five different inferential bases (human, wolf, bee, goldenrod, water) and 16 target objects (human, bear, raccoon, eagle, bluejay, turtle, gartersnake, sturgeon, trout, fly, worm, maple, milkweed, rock, pencil, bicycle) were used to present the questions. Categories were chosen to cover a large range of plants, animals, and nonliving objects. Bases were chosen to correspond to Carey's items (human, dog and bee), as well as to examine the extent to which children were willing to project properties of plants (from goldenrod). Target objects fell into higher order classes (nonhuman mammals, birds, reptiles, fish, invertebrates, plants, nonliving natural objects, and human-made artifacts).

2.3. Design

Children were asked about projecting unfamiliar properties from all five bases to all 16 targets. Properties were the names of substances (*sacra*, *andro*, *estro*, *hema*, and *gluco*) said to be found inside the base. A different property was used with each base, and bases and targets were presented in a random order for each child. Most children took more than one session to finish the task.

2.4. Procedure

Children who had received parental permission were interviewed individually at their school. Each child was first given two warm-up tasks. In the first, they were asked to name all the plants and animals that they knew. In the second, they were shown a shape and asked two questions about it. For instance, they might be shown a red triangle and asked, “Is this red? Is it a square?” The object was to get the child to answer both “yes” and “no” in the experimental context and to minimize response biases.

Children were then shown a picture of one of the bases and asked to name it. If they named it correctly, they were given positive feedback. If not, they were gently corrected. Next, they were taught a new property about the base. For example, the experimenter might show the wolf picture, and say, “Now, there’s this stuff called andro. Andro is found inside some kinds of things. One kind of thing that has andro inside is wolves. Now, I’m going to show you some pictures of other kinds of things, and I want you to tell me if you think they have andro inside like wolves do, OK?” Children were then shown each target individually, asked to name them (the first time through, with feedback given as above), and then asked whether they “have andro inside, like the [base].” Questions were asked generically, about the kinds in question (“Do trout have andro inside, like wolves do?”) rather than about the individuals pictured (“Does this trout have andro inside, like this wolf does?”).

Responses were scored 1 for “yes” (making the projection from base to target) and 0 for “no” (declining to make the projection). Like Carey, we took property projection as a measure of perceived biological affinity. The fact that we found that associations may be made on the basis of either taxonomic similarity or ecological relatedness poses something of an interpretative challenge.

3. Results

Each of the three study populations produced a unique profile. (Mean projections by base, target and age for the three groups presented in Tables 2–4.) Although there were a number of similarities, the clear differences undermine the idea that anthropocentrism is a universal feature of folkbiological development. Below we detail these results organized to address three questions: the extent to which biological similarity guided projections, evidence for anthropocentric reasoning, and evidence for causal/ecological reasoning.

3.1. Within-group differences

We conducted factor analyses for each age group for each population to see if we could find distinct patterns of responding within a group. The rationale for this analysis is to test if one underlying model (factor) explains a large amount of the variance. If this is the case, we can readily assume a general consensus among the participants (see Romney, Weller, & Batchelder, 1986 for the original model and Atran et al., 1999 for its application as a tool to explore existing consensus). In almost every case a single factor solution gave a good account of the data and there were no obvious subgroups. For the young urban children there was no clear consensus and the second factor accounted for 12% of the variance. When we

Table 2
Summary responses of urban majority culture children

	Human	Bear	Raccoon	Eagle	Bluejay	Turtle	Gartersnake	Sturgeon	Trout	Fly	Worm	Maple	Milkweed	Rock	Pencil	Bicycle
Young																
Hum	.93	.50	.43	.57	.64	.57	.57	.36	.43	.29	.43	.43	.43	.36	.50	.43
Wolf	.21	.43	.43	.43	.50	.57	.64	.64	.36	.57	.36	.50	.43	.07	.21	.36
Bee	.50	.43	.50	.43	.29	.43	.43	.71	.64	.50	.43	.43	.57	.21	.43	.36
Goldenrod	.50	.50	.50	.43	.50	.50	.50	.43	.43	.57	.43	.64	.93	.50	.50	.36
Water	.57	.64	.50	.50	.57	.86	.57	.86	.86	.43	.57	.57	.57	.36	.36	.36
Middle																
Human	1.00	.67	.73	.67	.73	.73	.53	.47	.40	.47	.47	.47	.53	.20	.13	.07
Wolf	.33	.93	1.00	.69	.69	.69	.63	.63	.56	.50	.56	.38	.25	.13	.06	–
Bee	.31	.50	.50	.75	.56	.56	.63	.44	.44	1.00	.38	.25	.56	.06	.06	–
Goldenrod	.13	.44	.19	.38	.31	.50	.38	.31	.13	.31	.19	.81	.75	.19	.13	–
Water	.63	.25	.13	.38	.25	.80	.50	.81	.88	.13	.27	.50	.63	.13	–	.06
Old																
Human	1.00	.81	.65	.73	.77	.62	.65	.46	.62	.35	.20	.31	.23	.12	.12	–
Wolf	.35	.92	.88	.85	.69	.62	.46	.31	.38	.38	.38	.19	.04	–	–	–
Bee	.08	.62	.50	.77	.73	.46	.73	.54	.35	.96	.46	.38	.50	.08	.08	.04
Goldenrod	.12	.38	.38	.27	.38	.19	.58	.27	.35	.62	.38	.88	.96	.35	.15	–
Water	.58	.50	.35	.46	.50	.81	.46	.96	.92	.31	.42	.69	.77	.46	–	.12

Rows represent the average projection for each base according to the three age groups.

Table 3
Summary responses of rural majority culture children

	Human	Bear	Raccoon	Eagle	Bluejay	Turtle	Gartersnake	Sturgeon	Trout	Fly	Worm	Maple	Milkweed	Rock	Pencil	Bicycle
Young																
Hum	.96	.57	.46	.36	.46	.29	.25	.29	.32	.07	.29	.25	.07	.04	.04	.14
Wolf	.24	.76	.75	.45	.41	.31	.31	.28	.28	.38	.41	.17	.10	.14	.03	–
Bee	.28	.45	.31	.48	.45	.31	.34	.31	.28	.90	.24	.28	.24	.07	.03	.07
Goldenrod	.10	.24	.24	.21	.21	.14	.28	.17	.17	.24	.24	.59	.83	.10	–	.03
Water	.52	.48	.31	.31	.34	.66	.24	.66	.66	.21	.24	.17	.31	.17	.07	–
Middle																
Hum	.98	.60	.55	.40	.40	.34	.36	.34	.32	.34	.24	.14	.20	.02	.04	.02
Wolf	.16	.84	.73	.58	.52	.30	.44	.32	.28	.28	.26	.10	.18	.02	.02	–
Bee	.20	.28	.22	.36	.32	.16	.28	.14	.16	.86	.32	.22	.38	.02	.02	.02
Goldenrod	.12	.28	.22	.12	.24	.22	.40	.12	.20	.34	.34	.68	.90	.08	.06	.02
Water	.54	.50	.43	.35	.45	.67	.45	.86	.76	.22	.36	.56	.53	.29	.10	.02
Old																
Hum	1.00	.77	.83	.70	.73	.63	.53	.60	.63	.63	.40	.30	.30	.03	–	.03
Wolf	.47	.93	.90	.73	.60	.60	.53	.40	.37	.47	.24	.30	.13	.07	.03	.03
Bee	.53	.73	.40	.53	.70	.27	.50	.23	.20	.93	.33	.50	.67	–	.13	.07
Goldenrod	.30	.53	.30	.23	.41	.47	.57	.37	.30	.33	.40	.73	.90	.13	.27	.07
Water	.93	.96	.86	.75	.68	.93	.61	.89	.89	.41	.54	.79	.69	.24	.25	.07

Rows represent the average projection for each base according to the three age groups.

Table 4
Summary responses of Menominee children

	Human	Bear	Raccoon	Eagle	Bluejay	Turtle	Gartersnake	Sturgeon	Trout	Fly	Worm	Maple	Milkweed	Rock	Pencil	Bicycle
Young																
Hum	.87	.58	.58	.67	.54	.63	.54	.63	.63	.46	.46	.38	.21	.13	.04	.04
Wolf	.42	.75	.75	.71	.58	.74	.63	.50	.57	.57	.57	.46	.50	.21	.04	0
Bee	.63	.58	.54	.75	.79	.63	.71	.58	.58	.79	.46	.46	.46	.17	.08	.04
Goldenrod	.42	.46	.54	.46	.54	.42	.48	.33	.33	.29	.46	.75	.88	.21	.04	.08
Water	.46	.50	.29	.42	.33	.52	.42	.58	.67	.38	.54	.50	.63	.33	.17	.17
Middle																
Hum	.96	.71	.66	.63	.74	.74	.41	.55	.65	.55	.47	.16	.28	.10	.13	.03
Wolf	.47	.84	.81	.78	.72	.69	.66	.69	.56	.56	.47	.31	.35	.19	.13	.09
Bee	.35	.66	.45	.56	.63	.45	.53	.45	.32	.68	.44	.35	.45	.13	.16	.10
Goldenrod	.41	.44	.39	.31	.48	.48	.45	.39	.38	.41	.47	.81	1.00	.28	.19	.16
Water	.59	.44	.38	.53	.50	.68	.47	.81	.88	.34	.44	.59	.63	.38	.19	.13
Old																
Hum	.81	.81	.62	.62	.57	.57	.48	.52	.62	.48	.43	.29	.38	.24	0	.05
Wolf	.52	.95	.81	.67	.62	.48	.43	.48	.62	.52	.33	.19	.29	.05	.05	0
Bee	.38	.62	.52	.48	.57	.29	.52	.43	.43	.81	.43	.33	.52	.14	.14	.10
Goldenrod	.38	.43	.48	.33	.43	.43	.52	.33	.38	.43	.24	.76	.86	.24	.14	.05
Water	.67	.76	.57	.67	.48	.71	.33	.81	.81	.48	.38	.76	.76	.24	.05	0

Rows represent the average projection for each base according to the three age groups.

separated young urban children based on their second factor scores, the most salient difference was that one group tended to say yes to most of the projections and the other group tended to say no to them. Both subgroups had broad, undifferentiated generalizations. Overall, there were no salient within-group clusters and the group patterns are not artifacts of averaging over distinct sub-profiles.

3.2. Biological similarity as a guide to projections

If children have a clear notion of biological affinity, the likelihood of projection should be predicted by biological similarity between base and target. We addressed this question in several ways. First, we conducted trend analyses to ascertain whether projections of properties from *human* and *wolf* showed a linear decrease in likelihood to bases in the following order: *mammals*, *birds*, *reptiles and fish*, *invertebrates*, and *plants*. A reliable linear trend would indicate projections based on biological similarity. *R*-squared values for the regressions, by age group and population, are presented in Table 5. Second, in order to further detail the shape of these linear trends, we combined our targets into higher order categories: (1) *higher animals* (nonhuman mammals, birds, and reptiles), (2) *lower animals* (fish and invertebrates), (3) *plants*, and (4) *inanimates*. We then conducted separate 3 (age group) × 4 (target group) ANOVAs for each population exploring projections from *human* and *wolf* as a function of the phylogenic distance from these bases to the targets. Projections based on biological similarity should show decreasing strength with phylogenetic distance from the bases; moreover, differences in projection to each base group may also be informative. Third, biological similarity predicts that projections from *goldenrod* should be relatively high to plants, and higher to animals than to inanimates. Moreover, this pattern of projections from

Table 5
R–squared values for linear trend analyses of projections from *human* and *wolf*

Group	From human	From wolf
Boston		
Young	No trend	No trend
Middle	.47*	.90**
Old	.77**	.87**
Shawano		
Young	.74**	.74**
Middle	.90**	.89**
Old	.86**	.85**
Menominee		
Young	.54**	.64**
Middle	.65**	.91**
Old	.81**	.87**

Note: (*) $P < .05$, (**) $P < .001$.

goldenrod can also be taken as evidence for some unified concept of *living thing* subsuming plants and animals. We therefore examined projections from *goldenrod* using the same analysis strategy.

3.3. Urban children

Patterns of projection for young urban children differed from middle and older children in several ways. First, trend analyses show no decreasing projections from *human* or *wolf* as a function of phylogenic distance (see Table 5). Young urban children show evidence of biological similarity only at a very gross level. Projections from *human* did not differ by target; young urban children were no more likely to project properties from *human* to *bear* than from *human* to *rock*. However, projections from *wolf* to other animals and plants were higher than to inanimates ($F(3, 39) = 4.78$, M.S.E. $= .053$, $P = .0062$). Also, projections from goldenrod to plants were higher than to other target categories ($F(3, 39) = 5.15$, M.S.E. $= .069$, $P = .0043$), although this seems to be due to local similarity rather than any sense of *living thing* as a coherent concept; projections from plants to animals didn't differ from projections from plants to inanimates.

In contrast, middle and older urban children both showed reliable linear trends; projections decreased with decreasing biological similarity between base and target (see Table 5). Moreover, projections from *human* to higher animals were stronger than projections to lower animals and plants, all of which were stronger than projections to inanimates ($F(3, 117) = 26.41$, M.S.E. $= .083$, $P < .0001$). Projections from *wolf* to higher animals were stronger than projections to lower animals which were stronger than projections to plants, which were stronger than projections to inanimates ($F(3, 120) = 78.06$, M.S.E. $= .049$, $P < .0001$). Projections from *goldenrod* to plants were higher than to animals, which in turn were higher than to inanimates ($F(3, 120) = 58.56$, M.S.E. $= .063$, $P < .0001$) suggesting both biological similarity and some idea of affinity between plants and animals. Thus, projection patterns for middle and older urban children reflect a much more refined sense of biological similarity than for younger children.

3.4. Rural children

Unlike urban children, Shawano children's projections showed linear decreases with decreasing biological similarity at all ages (Table 5). Projections from *human* to higher animals were stronger than projections to lower animals which were stronger than projections to plants, which were stronger than projections to inanimates ($F(3, 144) = 29.16$, M.S.E. $= .074$, $P < .0001$). Likewise, projections from *wolf* decreased significantly to each increasingly distant target group ($F(3, 147) = 59.88$, M.S.E. $= .057$, $P < .0001$). Finally, like the two older urban groups, projections from *goldenrod* to plants were higher than to animals, which in turn were higher than to inanimates ($F(3, 147) = 79.10$, M.S.E. $= .052$,

$P < .0001$) indicating both biological similarity and some idea of affinity between plants and animals. The only age difference in responses was that older children were more likely to project from *goldenrod* than were middle or younger children ($F(2, 147) = 4.45$, M.S.E. $= .148$, $P = .0167$). Thus, there is clear evidence of projections based on biological similarity at all ages in the rural majority culture population.

3.5. Menominee children

As with the rural majority culture children, reliable linear trends for Menominee children of all ages show clear conceptions of biological affinity in their projections from *human* and *wolf* (Table 5). Projections from *human* to higher and lower animals were stronger than projections to plants, which were stronger than projections to inanimates ($F(3, 153) = 51.09$, M.S.E. $= .068$, $P < .0001$). Interestingly, unlike the two majority culture groups, Menominee children did not differentially attribute properties from humans to higher versus lower animals. This might reflect a different sense of the place of humans in the biological world. Like rural children, Menominee projections from *wolf* decreased significantly to each increasingly distant target group ($F(3, 153) = 43.08$, M.S.E. $= .085$, $P < .0001$). Finally, like the older urban children and all rural groups, Menominee projections from *goldenrod* to plants were higher than to animals, which in turn were higher than to inanimates ($F(3, 153) = 50.20$, M.S.E. $= .068, P < .0001$). The only age difference in responses was that older children were more likely to project from *human* than were middle or younger children ($F(2, 153) = 5.03$, M.S.E. $= .165$, $P = .0101$). Thus, there is clear evidence of projections based on a refined sense of biological similarity at all ages among Menominee children.

Another notable trend, most evident in the children's justifications, is that Menominee children often made inferences in terms of ecological relations. All age groups showed a propensity for generalizing from bees to bears and they often mentioned that a bee might sting a bear or that a bear would eat honey. These sorts of justifications only appeared in older rural majority culture children and not at all with the urban children.

3.6. Summary

Biological similarity guided the projections of middle and older urban children, and of all age groups of rural and Menominee children. Likewise, stronger projections from *goldenrod* to animals versus inanimates suggests some unified concept of living thing in all of these groups. Young urban children showed evidence of biological similarity only at a very gross level; indeed, examination of Table 2 suggests a largely indiscriminate pattern of projection for this group. In contrast, young rural and Menominee children show clear evidence of a differentiated sense of biological similarity. Finally, Menominee children were just as likely to project properties from human to lower animals as to higher animals, which may reflect a greater perceived intimacy between humans and nonhuman animals.

3.7. Anthropocentrism

An anthropocentric folkbiology predicts that, on average, projections from humans — the central exemplar of *living thing* — should be stronger than projections from other living things. To examine this, we compare average projections from *human*, *wolf*, *bee*, and *goldenrod* to all targets. Furthermore, according to Carey, children's anthropocentric folkbiology leads to asymmetries in projection favoring humans. To measure asymmetries in projection, for each child the average of projections from *human* to mammal, insect, and plant targets was calculated, as was the average of projections from *wolf*, *bee*, and *goldenrod* to *human*. If asymmetries exist, then average projections from *human* to specific targets should be higher than average projections from related bases to human targets. Our three populations showed clear differences in the presence and developmental course of anthropocentric reasoning.

3.8. Urban children

The urban sample showed mixed evidence of anthropocentric reasoning. Each age group showed a different pattern of overall projections from the four living bases, although contrary to the anthropocentric prediction, humans did not emerge as privileged. For younger children, there were no differences between average projections ($F(3, 39) = 1.18$, M.S.E. $= .034$, $P = .330$). Remember, however, that their projections were broad and indiscriminate. For the middle age group, projections from *human*, *wolf*, and *bee* did not differ from each other, but all were stronger than projections from *goldenrod* ($F(3, 42) = 8.46$, M.S.E. $= .013$, $P = .0002$). For older children, projections from *human* were only marginally stronger than projections from *goldenrod*; projections from *wolf* and *bee* differed from neither ($F(3, 75) = 2.58$, M.S.E. $= .013$, $P = .059$).

In contrast, both the middle and older urban children show clear asymmetries in their projections. To test for asymmetries, mean projections from *wolf*, *bee*, and *goldenrod* to human were subtracted from mean projections from *human* to mammals, insects, and plants. Higher values represent stronger anthropocentric asymmetries in projection. One-tailed *t*-tests were used to compare these difference scores to zero for each age group. Although young urban children showed no asymmetries, middle ($M = .289$, $t(14) = 5.77$, $P < .0001$) and older ($M = .250$, $t(25) = 4.02$, $P = .0002$) urban children clearly favored projections from humans over projections to humans. The lack of asymmetries in the youngest urban group may be a byproduct of their relative lack of systematic projections over these stimuli; we return to this point in Section 4. Results for the older groups are consistent with Carey's predictions about anthropocentric folkbiology. It is interesting to note, however, that in our urban population there was no reduction in asymmetries over time; the pattern was as strongly evident among fourth graders as among second graders.

3.9. Rural children

The rural, majority culture sample also showed mixed evidence of anthropocentric reasoning. Age groups did not differ in overall patterns of projections from the four living bases; no differences between average projections emerged ($F(3, 144) = .25$, M.S.E. $= .023$, $P = .8596$). Some anthropocentric asymmetries were evident, although the differences were smaller than for the urban children, and asymmetries weakened and disappeared among older rural children. Specifically, young rural children showed reliable asymmetries ($M = .167$, $t(15) = 1.91$, $P = .0379$), middle children showed marginal asymmetries ($M = .136$, $t(21) = 1.71$, $P = .0506$) and older rural children showed no asymmetries at all. Like the urban children, rural children show some evidence of anthropocentric reasoning, but in striking contrast to urban children, anthropocentrism declines over time.

3.10. Menominee children

Menominee children showed virtually no evidence of anthropocentric reasoning. Like the urban, majority culture group, all age groups projected equally from the four living bases ($F(3, 153) = .79$, M.S.E. $= .041$, $P = .5001$). Unlike the other groups, Menominee young and middle age groups showed no anthropocentric asymmetries. Interestingly, older Menominee children did show reliable anthropocentric asymmetries ($M = .238$, $t(13) = 2.74$, $P = .0084$). This, however, is the only evidence of anthropocentric reasoning to emerge from Menominee children.

3.11. Summary

The three populations show distinct developmental trajectories with regards to anthropocentric reasoning. For the urban population, anthropocentric reasoning seems to accompany increasingly organized folk biological projections, and remains strong in 10-year-olds. For the rural population, anthropocentric reasoning is present early on, but is waning in 8-year-olds and disappears altogether in older children. For Menominee children, there is almost no evidence of anthropocentric reasoning at all.

3.12. Ecological reasoning

By ecological reasoning we refer to cases in which the inductive reasoning of the children is not based on biological similarity but on a relation the two species entertain. An example for the former would be that A and B share a property because they are both mammals. An example for the latter would be that A (bees) and B (bears) share a property because bears eat honey or bees sting bears. Obviously, the two reasoning strategies are distinct and one might argue that ecological reasoning has to be grounded in more specific knowledge. Our stimuli were not designed to measure ecological reasoning. However, other results (e.g., López et al., 1997; Medin et al., 2002; Proffitt et al., 2000) give us reason to ask whether culture and/or experience may heighten the salience of causal/ecological relations as a basis for inductive projection, especially in rural and Native American children.

We have already mentioned that the Menominee children tended to give ecological justifications for inferences from bees to bears. We also find some evidence that the rural majority culture children show ecological reasoning in the projection task. In particular, human interaction with fish and the ecological role of bees seem to be salient knowledge for both of our older rural samples. Consider, for example, projections from bees to humans, bee to bears and from bee to plants. Between the middle and old group of rural majority culture children, the proportions increase from .20, .28 and .30, respectively to .53, .73 and .58. The corresponding proportions for the urban middle and old groups of children go from .31, .50 and .40 to .08, .62, and .44. A three (item) by two (age) by two (location) ANOVA revealed a reliable interaction of age and location ($F = 15.5$, M.S.E. $= 2.8$, $df = 1, 354$, $P = .000$). A common justification for the rural children is that bees might sting or that bears eat honey. Projections from goldenrod to animals also demonstrate a clear increase not seen in urban children. In brief, rural majority culture children not only make inductions based on biological affinity from an early age; but older children also show ecological sensitivity not present in urban children. As noted before, we find the same sensitivity to ecological factors among even younger Menominee children tested.

4. General discussion

The background for this study was the question of whether an anthropocentric folkbiology would inform reasoning as had been found in previous work with urban populations (e.g., Carey, 1985). However, against the backdrop of studies with adults (Bailenson et al., 2002; López et al., 1997; Medin et al., 2002) and Yukatek Maya children (Atran et al., 2001), we expected to find both cultural and experiential differences in the development of folkbiological knowledge. Testing urban majority culture children, rural majority culture children, and rural Native American (Menominee) children, we observed three distinct developmental trajectories.

Urban majority-culture children show a clear development from largely undifferentiated projections to similarity-based patterns of projection. For the two groups of older children we find clear asymmetries in their projections (with stronger projections from humans than to humans). However, humans do not emerge as privileged or prototypical animals, nor are they seen as one animal among many. Instead, it appears that humans are seen as atypical animals and justifications for not generalizing from some animal to humans tend to appeal to the claim that humans are not animals (see also Johnson et al., 1992 who report related findings).

Rural majority-culture children exhibited a clear pattern for reasoning in terms of biological affinity even at the youngest age tested. Asymmetries between humans and other animals found among the youngest children tend to disappear with development. Furthermore, rural majority children show a developing sensitivity to ecological relations not observed among urban children.

Menominee children provide yet a third profile. The youngest children show broad, similarity-based projection from the four living bases, and exhibit signs of clear ecological reasoning. These trends did not appear to change much with age and none of the age groups showed asymmetries in their projections between humans and other animals.

In a sense we expected this precocious ecological responding among Menominee children given the adult data cited earlier (Medin et al., 2002) suggesting that Menominee fishing experts pay much more attention to ecological relations than do their majority culture counterparts. Although we expect that this cultural difference in "habits of the mind" is passed on to children, we are only now beginning to explore the social channels and cognitive mechanisms of cultural transmission (Atran et al., 2002; Medin et al., 2002).

These findings undermine the universality of Carey's claim of an anthropocentric development of folkbiological thought. Evidence seems to point at anthropocentrism as being largely an effect of the lack of relevant knowledge about the environment. Hence, with an increase of knowledge of biological affinity and ecological relations, anthropocentrism disappears. The only exceptions are urban children. The lack of knowledge among the younger children of this group seems to inhibit any kind of patterned reasoning about plants and animals. It is logically possible that our rural populations (both Menominee and majority culture) are simply advanced in their development and passed through the anthropocentric stage at an earlier age compared to their urban counterparts. However, there is no empirical support for such an assumption. Even 4–5-year-old Yukatec Maya children in Mexico fail to show evidence for an anthropocentric folkbiology (see Atran et al., 2001). Furthermore, later aspects of the developmental trajectories (both within our data and looking at adults) do not coincide across the three groups. This means that there is no compelling reason to entertain the idea of parallel developmental processes.

It is important to note that it appears to be the lack of knowledge among young urban children that drives their anthropocentric understanding of folkbiology. Given that we do not find any evidence among children with greater knowledge of the natural environment, the data seem to reflect the fact that urban children use a readily accessible cognitive heuristic that compensates for the lack of sustained contact and interaction with local biodiversity. This readily accessible crutch can be discarded once a certain level of biological awareness and competence has been achieved, leading to the conceptual shift described by Susan Carey. This interpretation is bolstered by two findings. First, it has been documented that western societies since the industrial revolution have indeed steadily lost intimacy and knowledge with respect to local biota (Wolff et al., 1999). Second, studies with Maya children in Yucatan, Mexico, showed gender effects caused by differences in expertise (Atran et al., 2001).

The data suggest two future avenues for further work. First, we plan to look at exotic species, like those found in zoos, in order to test the role of familiarity with the species. On some grounds one might expect that urban children would fare better as they may be more familiar with exotic species than native animals. Rural children have much less experience with exotic species but, based on Inagaki's (1990) findings on children's ability to use their knowledge about certain species to reason about others, we do not expect different results in rural children. Second, it remains somewhat unclear why Menominee and rural majority culture children differ from one another. Here we will have to isolate these differences and look at the cultural contexts of learning about biology in order to understand the emergence of these different patterns.

Finally, it is of considerable practical interest to understand whether and how these group differences carry over to and influence learning in the classroom. It is interesting to consider how one might take advantage of the relative precocity of the rural children (especially the Menominee children), or how one might remedy the relatively impoverished experience of the urban children.

5. Conclusion

In this paper we have analyzed the development of folkbiological induction in children of three distinct cultural groups. Our findings suggest different underlying construals of the biological world among our three populations. The differences between urban and rural majority-culture children seem to reflect differences in both the cultural support for an interest in nature and for direct experience with nature. Both groups of majority-culture children may share anthropocentric cultural beliefs, but the richer experience of rural children seems to support more biocentric thought earlier than is seen among urban children.

One way to capture the difference between the two rural groups is to argue that Menominee children's patterns of folkbiological reasoning reflect a framework where ecological reasoning, the relations between species — including humans — is very salient. Some evidence for such a view comes from studies with Menominee and majority culture fish experts (Medin et al., 2002). Majority culture experts show a clear influence of goal orientation in the ways they perceive local fish while Menominee experts pay more attention to ecological features. Goal orientation, however, is another way to put human beings in the center of the perspective — as different from animals.

Both culture and experience play an important role in the development of folkbiological knowledge. We think that analyzing cognitive development in terms of domain-specificity is a very fruitful strategy. Nonetheless, given our results, it seems hazardous to develop universal generalizations on the basis of data from children from populations where both cultural support for, and direct experience with, nature is generally impoverished.

The novel empirical implication in this regard is that relative expertise and interaction, rather than mere exposure and observation, with respect to natural biodiversity may be the default condition for most human groups (and perhaps for ancestral humanity). From a theoretical perspective, then, the chief interest (other than mere convenience) in studying "standard groups," such as urbanized children in and around major western research institutions, may not be to establish a baseline for generalizations about folkbiological knowledge, but to explore the cognitive consequences of limited input and devolutionary cultural processes on theory building in an impoverished environment.

Acknowledgments

The authors thank the children, parents and staff of the Guild School of Boston, the Lincoln Elementary School in Shawano, Wisconsin and the Keshena Elementary School on the Menominee Reservation. We also would like to thank Bernadette Bear, Connie Rasmussen, Bill Waukau, Brian White, Lisa James, Robin Pitt, Kay Frederick, Anna Corinne Freeman and Christopher Lawson for their contribution to this project. Sandra Waxman provided constructive comments and suggestions throughout this project. We also thank Irene Pywasit for her advice and we dedicate this article to her memory. This research was supported by NIH grants MH55079 and RO1HD41653-01 and NSF grants 9983260 and BCS-0132469.

References

Anglin, J. (1970). *The growth of word meaning*. Cambridge, MA: MIT Press.

Atran, S., Medin, D., Ross, N., Lynch, E., Coley, J., Ucan Ek', E., & Vapnarsky, V. (1999). Folkecology and commons management in the Maya Lowlands. *Proceedings of the National Academy of Science, 96*, 7598–7603.

Atran, S., Medin, D. L., Lynch, E., Vapnarsky, V., Ucan Ek', E., & Sousa, P. (2001). Folkbiology doesn't come from folkpsychology: Evidence from Yukatek Maya in cross-cultural perspective. *Journal of Cognition and Culture, 1*, 3–43.

Atran, S., Medin, D., Ross, N., Lynch, E., Vapnarsky, V., Ucan Ek', E., Coley, J., Timura, C., & Baran, M. (2002). Folk ecology, cultural epidemiology, and the spirit of the commons. A garden experiment in the Maya Lowlands, 1991–2001. *Current Anthropology, 43*(3), 1–23.

Au, T. K., & Romo, L. F. (1999). Mechanical causality in children's "folkbiology." In D. L. Medin & S. Atran (Eds.), *Folkbiology*. Cambridge, MA: MIT Press.

Bailenson, J., Shum, M., Atran, S., Medin, D., & Coley, J. (2002). A bird's eye view: Triangulating biological categorization and reasoning within and across cultures and expertise levels. *Cognition, 84*, 1–53.

Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.
Carey, S. (1995). On the origin of causal understanding. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal cognition: A multidisciplinary debate*. New York: Oxford University Press.
Carey, S. (1999). Sources of conceptual change. In E. Scholnick, K. Nelson, S. Gelman, & P. Miller (Eds.), *Conceptual development: Piaget's legacy*. Mahwah, NJ: Erlbaum.
Coley, J. (1995). Emerging differentiation of folkbiology and folkpsychology: Attributions of biological and psychological properties to living things. *Child Development*, *66*, 1856–1874.
Coley, J. (2000). On the importance of comparative research: The case of folkbiology. *Child Development Special Issue*, *71*(1), 82–90.
Coley, J. D., Medin, D. L., Proffitt, J. B, Lynch, E. B., & Atran, S. (1999). Inductive reasoning in folkbiological thought. In D. L. Medin & S. Atran (Eds.), *Folkbiology*. Cambridge, MA: MIT Press.
Dougherty, J. W. (1978). Salience and relativity in classification. *American Ethnologist*, *5*, 66–80.
Gelman, S., & Hirschfeld, L. (1999). How biological is essentialism. In D. Medin & S. Atran (Eds.), *Folkbiology*. Cambridge, MA: MIT Press.
Gelman, S., & Wellman, H. M. (1991). Insides and essences: Early understandings of the nonobvious. *Cognition*, *38*, 213–244.
Gutheil, G., Vera, A., & Keil, F. (1998). Do houseflies think? Patterns of induction and biological beliefs in development. *Cognition*, *66*, 33–49.
Hall, K., & Pecore, M. (1995). *Case study: Menominee tribal enterprises*. Madison, WI: Institute for Environmental Studies and the Land Tenure Center, University of Wisconsin-Madison.
Hatano, G., & Inagaki, K. (1994). Young children's naive theory of biology. *Cognition*, *50*, 171–188.
Hatano, G., & Inagaki, K. (1999). A developmental perspective on informal biology. In D. L. Medin & S. Atran (Eds.), *Folkbiology*. Cambridge, MA: MIT Press.
Hickling, A. K., & Gelman, S. A. (1995). How does your garden grow? Early conceptualization of seeds and their place in the plant growth cycle. *Child Development*, *66*, 856–876.
Inagaki, K. (1990). The effects of raising animals on children's biological knowledge. *British Journal of Developmental Psychology*, *8*, 119–129.
Inagaki, K., & Hatano, G. (1987). Young children's spontaneous personification as analogy. *Child Development*, *58*, 1013–1020.
Inagaki, K., & Hatano, G. (1991). Constrained person analogy in young children's biological inference. *Cognitive Development*, *6*, 219–231.
Johnson, S., & Carey, S. (1998). Knowledge enrichment and conceptual change in folkbiology: Evidence from people with Williams Syndrome. *Cognitive Psychology*, *37*, 156–200.
Johnson, K. E., Mervis, C. B., & Boster, J. S. (1992). Developmental changes within the structure of the mammal domain. *Developmental Psychology*, *28*, 74–83.
Keil, F. C. (1989). *Concepts, kinds, and cognitive development*. Cambridge, MA: MIT Press.
López, A., Atran, S., Coley, J. D., Medin, D. L., & Smith, E. (1997). The tree of life: Universal and cultural features of folkbiological taxonomies and inductions. *Cognitive Psychology*, *32*, 251–295.
Medin, D., & Atran, S. (1999). Introduction. *Folkbiology*. Cambridge, MA: MIT Press.
Medin, D. L., Lynch, E., Coley, J., & Atran, S. (1997). Categorization and reasoning among expert populations: Do all roads lead to Rome? *Cognitive Psychology*, *32*, 49–96.
Medin, D., Lynch, E., & Solomon, K. (2000). Are there kinds of concepts. *Annual Review of Psychology*, *51*, 121–147.
Medin, D., Ross, N., Atran, S., Burnett, R., Blok, S. (2002). Categorization and reasoning in relation to culture and expertise. *The psychology of learning and motivation* (Vol. 41, pp. 1–41). New York: Academic Press.
Murphy, G. L., & Medin, D. L. (1985). The role of theories in conceptual coherence. *Psychological Review*, *92*, 289–316.
Proffitt, J., Coley, J., & Medin, D. (2000). Expertise and category-based induction. *Journal of Experimental Psychology: Learning. Memory and Cognition*, *25*, 811–828.
Osherson, D. N., Smith, E. E., Wilkie, O., López, A., & Shafir, E. (1990). Category-based induction. *Psychological Review*, *97*, 185–200.

Rips, L. (1975). Inductive judgments about natural categories. *Journal of Verbal Learning and Verbal Behavior*, *14*, 665–681.

Romney, A. K., Weller, S., & Batchelder, W. (1986). Culture as consensus: A theory of culture and informant accuracy. *American Anthropologist*, *88*, 313–338.

Ross, N. (2002a). Lacandon Maya intergenerational change and the erosion of folkbiological knowledge. In J. R. Stepp, F. S. Wyndham, & R. K. Zarger (Eds.), *Ethnobiology and biocultural diversity* (pp. 585–592). Athens: University of Georgia Press.

Ross, N. (2002b). Cognitive aspects of intergenerational change: Mental models, cultural change and environmental behavior among the Lacandon Maya of Southern Mexico. *Human Organization*, *61*(2), 125–138.

Solomon, G. E. A., Johnson, S. C., Zaitchik, D., & Carey, S. (1996). Like father, like son: Young children's understanding of how and why offspring resemble their parents. *Child Development*, *67*, 151–171.

Stross, B. (1973). Acquisition of botanical terminology by Tzeltal Children. In M. S. Edmonson (Ed.), *Meaning in Mayan languages*. The Hague: Mouton and Co.

Wellman, H. M., & Gelman, S. A. (1992). Cognitive development: Foundational theories of core domains. *Annual Review of Psychology*, *43*, 337–375.

Wellman, H. M., & Inagaki, K. (Eds.). (1997). The emergence of core domains of thought: Children's reasoning about physical, psychological and biological phenomenon. *New Direction for Child Development*. San Francisco: Jossey-Bass Publishers.

Wolff, P., Medin, D., & Pankratz, C. (1999). Evolution and devolution of folkbiological knowledge. *Cognition*, *73*, 177–204.