Evolution and Devolution of Knowledge: A Tale of Two Biologies

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Abstract

Anthropological inquiry indicates that all human cultures classify animals and plants in similar ways. This pre-theoretical knowledge also provided common ground for competing scientific investigations. Paradoxically, despite rapid advances in biological science, our citizenry's practical knowledge of nature is diminishing. Convenient choice of American and European students as psychology's preferred study populations obscures this fact. Here we describe historical, cross-cultural and developmental research on how people ordinarily conceptualize nature (naïve or folk biology), concentrating on cognitive consequences associated with knowledge devolution. Our approach integrates three disciplinary perspectives. For cognitive science, we show that results on categorization and reasoning from "standard populations" fail to generalize to humanity at large. For developmental research, we find that the usual populations studied represent impoverished experience with nature, yielding misleading results concerning the ontogenetic relationship between folkbiology and folkpsychology. For cultural and environmental studies, we show that groups living in the same habitat can manifest strikingly distinct behaviors, cognitions and social relations relative to it. This has novel implications for environmental decision making and management, including resource dilemmas such as the commons problem.

Key words

Child Development, Commons Dilemma, Devolution, Folkbiology, Maya, Taxonomy

Introduction. As generations of students learn more about microbiology and evolution they seem to be growing less familiar with the plants and animals around them. Below is part of an interview with a university Honors student who expressed surprise that 3 and 4-year olds were asked to give examples of plants. The student was asked to generate examples herself:

I: Tell me all the kinds of trees you know.

S: Oak, pine, spruce, cherry…. (Giggle) evergreen, Christmas tree, is that a kind of tree? ……God, what's the average here? …………So what do kids say, big tree, small tree?

I: Tell me some plants.

S: I can't think of plants that aren't trees. I know a lot about angiosperms, gymnosperms, gametophytes, and sporophytes…but this is *biology*. It's not really about plants and trees.

For several years we have investigated the cognitive consequences of reduced contact with nature – what some refer to as "extinction of experience" (Nabhan & St. Antoine 1993). To get along in the world, people need to be able to understand and predict general properties and behaviors of physical objects and substances (physics), more specific properties of plants and animals (biology), and particular properties of fellow human beings (psychology). What follows highlights an ongoing research program in the domain of naïve or folk biology as it bears on loss of knowledge or devolution. We begin with aspects of folkbiology that appear to be universal as a backdrop for characterizing the consequences of diminished contact with the natural world.

Evolved Universals in Cognition and Culture. Cultural belief and activity involve a variety of cognitive and affective systems, some with separate evolutionary histories and some with no evolutionary history to speak of. Folkbiology is a domain of human thought and practice that likely has an evolutionary history (Atran 1998). In every society, people tend to think about plants and animals in special ways that are distinct from ways humans ordinarily think about other things in the world, such as stones, tools or even people.

All cultures, it appears, partition local biodiversity into taxonomies whose basic level is that of the “generic species” (Berlin et al. 1973, Atran 1990), the common man’s (folk) species (Wallace 1889:1). Generic species often correspond to scientific species (e.g., dog, apple tree); however, for a majority of perceptually salient organisms, such as vertebrates and flowering plants, a scientific genus frequently has only one locally occurring species (e.g., bear, oak).

In addition to the spontaneous division of local flora and fauna into generic species, such groups have, as Darwin (1859:43) noted, "from the remotest period in... history... been classed in groups under groups. This classification is not arbitrary like the grouping of stars in constellations." The structure of these hierarchically-organized groups, such as white oak/oak/tree or mountain robin/robin/bird, is called "folkbiological taxonomy." These nonoverlapping taxonomic structures can often be interpreted in terms of speciation (related species descended from a common ancestor by splitting off from a lineage). Biological ranks are second-order classes of groups (e.g., species, family, kingdom) whose elements are first-order groups (e.g., lion, feline, animal). Ranks are intended to represent fundamentally different levels of reality, not convenience (Atran 1990, Berlin 1992). Folkbiological ranks vary little across cultures as a function of theories or belief systems.

In our studies with Native American Menominee and various USA and Lowland Maya groups, correlations between folktaxonomies (average-link clustering of pile sorts of land mammals, reptiles, birds, tees, palms, freshwater fish) and classical evolutionary taxonomies of the local fauna and flora average $r = 0.75$ at the generic-species level and about 0.5 with higher levels included (Atran 1999, Bailenson et al. 2002, Medin et al. 2002, cf. Hunn 1975, Boster 1987). Much of the remaining variance owes to obvious perceptual biases (Itza’ Maya group swallows with swifts in one generic-species, bats with birds in the same life form) and local ecological concerns (Itza’ group poisonous coral snakes with vipers at the same intermediate family level, and trees of similar aspect with toxic sap - Sebastiana longicuspus, Metopium brownei - as distinct subkinds of the same generic species). Contrary to received notions about the history and cross-cultural basis for folkbiological classification, mere utility does not drive folktaxonomy (e.g., Itza' group Perissodactyla, such as domestic equids and wild tapir, and classify numerous unused plants) (cf. Berlin et al. 1973).

This taxonomic framework also supports indefinitely many graded inferences regarding the distribution of biologically-related properties among species, although the character of the induction (morphological, ecological, genetic) varies with experience and culture (e.g., Itza' and USA experts, like birdwatchers, do not generalize susceptibility to disease across species that occupy different ecological zones) (Lopez et al. 1997, Medin et al. 1997, Bailenson et al. 2002).

There is growing cross-cultural evidence of a commonsense assumption that each species has an underlying causal nature, or essence, uniquely responsible for the typical appearance, behavior and ecological preferences of the kind (Atran 1987). For example, in experiments in the USA, Mesoamerica and Brazil, the youngest children tested (age 4) overwhelmingly believe like adults that the identity of animals and plants follows that of their progenitors, regardless of the environment in which the progeny matures (e.g., progeny of cows raised with pigs, acorns planted with apple seeds) (Gelman & Wellman 1991, Atran et al. 2001, Sousa et al. 2002). We speculate that this notion of biological essence is universal. People in diverse cultures consider it responsible for the organism's identity as a complex entity governed by dynamic internal processes that are lawful even when hidden. This presumed essence maintains the organism's integrity even as it causes the organism to grow, change form and reproduce. For example, a tadpole and frog are considered the same animal although they look and behave differently, and live in different places. Philosophers, such as Aristotle and Locke, attempted to translate this commonsense notion of essence into metaphysical reality; however, evolutionary biologists reject the notion of essence as such. Still, biologists have traditionally interpreted conservation of identity under change as due to organisms having genotypes separate from phenotypes.

Although science does not abide metaphysical essentialism, there is growing evidence supporting the notion of psychological essentialism (Ahn et al. 2001). Even when people have no specific ideas about essences they may have an "essence placeholder" (Medin & Ortony 1989), that is, a commitment to the idea that there is an underlying nature, perhaps unknowable. This hidden, causal essence is presumably responsible for a kind's manifest properties. The fact that biological science can overturn psychological essentialism in theory construction in no way implies that psychological essentialism is dismissible from everyday thought, any more than physical science's rejection of constant intervals of space and time implies alterations in our ordinary use of absolute space and time.

There are thus strong constraints – plausibly naturally selected - on how people organize local knowledge of biological kinds. Universal appreciation of generic species may be one such functional adaptation. Pigeonholing generic species into a hierarchy of mutually exclusive taxa allows incorporation of new species and biological properties into an inductively coherent system that can be extended to any habitat, facilitating adaptation to many habitats (a hallmark of Homo sapiens) (Atran 2001). To say an evolved biological structure is naturally selected is not to say that every important aspect of its phenotypic expression is "genetically determined." Biologically poised structures "canalize" development, but do not determine it – like mountains that channel scattered rain into the same mountain-valley river basin (Waddington 1959).

In short, there is fairly strong evidence that folk biology is a constrained domain of development and that core aspects of it are either innate or universally acquired under some minimal, adequate input conditions. As a further illustration of how skeletal principles shape conceptions of nature we turn a brief review of historical developments in biology.

Historical Developments. Ancient Greek and Roman naturalists contended with only 500 or 600 local species, a number consistent with most local folkbiological ystems (Raven et al. 1971). Because biological genus and species are often extensionally equivalent in any given locale, there was no apparent basis for systematically distinguishing them. For Aristotle and Theophrastus, as for Dioscorides and Pliny, the term atomon eidos, or "species," referred to generic species (e.g., eagle, dog, oak, wheat), whereas the term megiston genos, or "genus," referred to superordinate life forms (bird, quadruped, tree, grass) (Atran 1987).

Europe's Age of Exploration introduced a multitude of new species. Joseph Tournefort (1694) originated the genus concept as the ranked class immediately superordinate to that of the species. A previously known European species now customarily served as the generic type to which foreign species were attached. This allowed the reduction of species by an order of magnitude to equivalence classes that the mind could easily manage again (this allowed a reduction from roughly 6000 known species to 600 genera).

A geometrical rate of exploration and discovery soon undermined the taxonomic priority of the genus, and attention turned to the family level, intermediate between genus and life form. The family was itself rooted in local groupings that native folk implicitly recognize but seldom name, such as felines, equids, legumes, umbellifers. The ancients called these eide anonyma or genera innominata. A local series of such groupings does not fully partition a local environment, but is instead riddled with gaps. A strategy emerged for closing the gaps: Looking to other environments to complete local gaps, naturalists sought to discern a worldwide series that would cover the lacunae in any and all environments. Linnaeus (1751) dubbed this strategy "the natural method" for completing "family fragments." A.-L. Jussieu (1789) reduced the thousands of genera proposed since Tournefort to exactly 100 families, but acknowledged this number to be based more on convenience than necessity. Jussieu's families became the standards of modern plant taxonomy. Extending the « méthode naturelle » to animals, including humans, Buffon (1774-1789) identified family plans as lineages of temporally related species. This was crucial to evolutionary thinking by Lamarck and Darwin. Although Enlightenment taxonomy kept biology tied to a readily visible world of species, genera and families, it provided a cognitively expedient morphological framework for initial exploration of the causal relations and history of species.

In fact, Darwin (1859) used all levels of folktaxonomy: from folk specifics (e.g., poodle) and varietals (toy poodle) whose variation humans had learned to manipulate, to intermediate-level families and life-form classes, such as bird. For example, he described the family affinity of Galapagos bird species to those of continental America, as "manifest in every character…. So it is with other animals, and with a large proportion of plants.... Facts such as these admit of no sort of explanation on the ordinary view of creation." The heuristic value of folk-based taxonomic strategies for scientific inquiry remains compelling (cf. Labandeira & Sepkoski 1993), despite awareness that no "true" distinctions exist between various taxonomic levels.

Devolved Knowledge and Familiarity with Nature. Despite Western science's historical take-off from the same universal principles of folkbiology found across cultures, in our globally-mobile society there is marked deterioration in commonsense understanding of the everyday living world. This impairment affects people's practical ability to interact with the environment on a sustainable basis: a person who cannot distinguish one kind of bird or tree from another cannot respond appropriately to changes in the ecological balance among these living kinds. For example, many recent immigrants to Phoenix cannot distinguish the pruned eucalyptus trees in their landscaped plots, much less surmise that the eucalyptus is not conducive to maintaining biodiversity when competition for water is scarce; and few long-standing residents of Chicago are able to identify a buckthorn, much less comprehend that a fire can selectively weed out invasive buckthorns without affecting Burr oaks and other native prairie tree species.

Lack of understanding becomes less obvious but more critical as ties with nature become less direct and more abstract. By contrast, in small-scale communities a fitter understanding may arise normally by application of universal principles given sufficient exposure to, and activity with, biological diversity.

Although folktaxonomic structure is similar in diverse cultures and historical periods, ours reveals systematically shallower knowledge than others. We examined written material in the Oxford English Dictionary for references to terms used to describe trees from the 16^{th}-20^{th} centuries (Wolff et al. 1999). After the 19^{th} century sources mentioning trees declined 45%; number of quotes fell 40%. Specificity of quotes also declined. Use of the life-form term, <u>tree</u>, only fell 26%, whereas use of generic-species terms (e.g., oak) fell 50% (Figure 1). Other life-form terms (<u>bird</u>, <u>grass</u>, etc.) also declined, but use of nonbiological superordinates (<u>furniture</u>, <u>clothes</u>, etc.) increased. Consistent with this trend, we found that, Northwestern University students mostly identify tree and bird species only at the life-form level ("tree," "bird") (Coley et al. 1999, Bailenson et al. 2002). In contrast, Itza' overwhelmingly identify plant and animal species at more specific levels. This is evidence for our culture's diminishing support for familiarity with nature.

What happens cognitively when contact with nature diminishes? To answer, we need only turn to psychology's most studied groups, undergraduates and children from schools near major universities. Generalizations from these populations about basic cognitive processes do not hold for other groups that attend to their biological surroundings (birders, fishermen, naturalists, rural children and adults, Native-American Menominee and Maya). The implications of this sampling-by-convenience strategy are considerable. Our data challenge existing models of concept development, graded category structure, category-based induction, and decision making.

Child Development. Previous work with standard populations suggests that children begin with anthropocentric conceptions of biology and must undergo fundamental conceptual change to see humans as one animal among many. To understand children's conceptions of biology as opposed to simple factual knowledge, investigators have focused on projection of novel properties (e.g., "has a green round thing called an omentum inside") from one category to others (Carey 1985). Early work showed that young children generalized from humans to animals based on similarity to humans (e.g., to dogs more than to bees), but were reluctant to generalize from animals to other animals, including humans (Figure 2a). They even preferred inferences from humans to bugs over inferences from bees to bugs. These results support the claim that children do not distinguish between naïve psychology, where humans are presumably prototypical, and naïve biology, where humans are not.

Our research undermines this claim. Human-centered reasoning patterns may reflect lack of knowledge about nonhuman living things rather than a different construal of the biological world (Atran et al. 2001, Ross et al, in press). A human-centered model may be specific to urban, industrialized cultures. We used essentially the same induction task with urban children and replicated previous results (Ross et al. in press). We also probed three culturally-distinct populations who have greater contact with plants and animals: rural Wisconsin majority-culture and Native-American (Menominee) children from a nearby reservation, and (Yukatek) Maya children from rural Mexico. Even for the youngest Yukatek (4-5-years), humans are no better as an inductive base for projecting unfamiliar biological properties than other animals (Figure 2b), and both similarity-based and ecologically-based reasoning strategies are used. Menominee children perform much like Yukatek. Rural majority-culture children also make similarity-based generalizations but are reluctant to generalize from animals to humans, justifying responses by saying "humans are not animals." Overall, the results indicate that folkbiology and folkpsychology are distinct from the start, though the perceived role of humans in the order of nature varies as a function of culture.

Urban children may generalize from humans because humans are the only animal they know much about. Rural majority-culture children are reluctant to generalize to humans because humans are seen as atypical animals. Perception of humans as atypical is a cultural construal in that Menominee and Yukatek children do not treat humans as distinct or atypical. Even within our groups experience matters. For example, Yukatek girls show less differentiated generalization from wild than from domestic animals. Analyses involved ANOVAs and t-tests on difference scores. The dependent variable for each subject was their base to target (e.g., Human to mammal) score minus their target to base (e.g., Mammal to human) score. The GENDER X AGE GROUP interaction indicates that the effect of AGE GROUP is only shown by younger girls and for wild animals (peccary), not boys or domestic animals (dog): for younger girls, AGE GROUP $F(2,50)=5.83$, $p=.005$; for younger boys, AGE GROUP $F(2,47)=.847$, $p=.44$. This is consistent with Maya girls staying at home and boys regularly venturing into the forest. What developmentalists had deemed universal now seems peculiar to our society's lack of contact with nature.

Rural majority-culture, urban majority-culture and Native-American children have three culturally-distinct conceptions of nature. Such differences may be are relevant to formal learning: "Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information" (Donovan et al. 1999). The fact that science goes from being Menominee children's best subject in their first four years to their worst subject four years later suggests that instruction is failing to capitalize on Menominee precocity and underlines this issue's significance (http:/data/dpi.state.wi.us/data/graphshell.asp, 2/26/01, Wisconsin Dept. of Public Institutions).

Categorization and Reasoning. Theories of adult cognition may be also misdirected by effects of impoverished experience with nature. A succinct summary of our studies is that biologically-knowledgeable USA adults respond more like illiterate Maya than USA college students.

One classic finding is that some category members are better examples than others and that goodness-of-example ratings are based on central tendency (Smith & Medin 1981). “Best” examples of a category are members that are similar to many other category members. However, typicality for knowledgeable adults is based on positive and negative ideals (e.g. for trees, height and weak limbs) rather than central tendency. In each case for which we have direct Itza’ ratings, the “truest” or “most representative” living kind categories are large, perceptually striking, culturally important, and ecologically prominent: for example, the jaguar (“Lord of the Forest”), the large and deadly fer-de-lance (“True Snake”) and the morphologically striking game bird, the ocellated turkey (“True Bird”)(Atran 1999). In studies with USA tree experts, bird watchers, and majority-culture and Menominee fishermen, where subjects rated typicality on a standard 7-point scale, ideals scored highest and central tendency was uncorrelated with inductive judgments about which properties are more likely to generalize from a given (generic) species to the whole (life-form) category (Lynch et al. 2000, Bailenson et al. 2002, Medin et al. 2002).

A central function of categorization is to support reasoning in the face of uncertainty. The same notion of typicality based on central-tendency plays a critical role in models of category-based induction. The prediction is that inference to a category from a typical example (robin to bird) is stronger than inference from an atypical example (turkey). These models are also used to predict diversity effects (Osherson et al. 1990). Suppose River Birch and Paper Birch trees get Disease A, and White Pine and Weeping Willow get Disease B. Which disease is more likely to affect all kinds of trees? The models would predict Disease B on grounds that White Pines and Weeping Willows are more different (diverse) than River Birch and Paper Birch.

Undergraduates show both typicality and diversity effects, seemingly paralleling scientific practice. Closer analysis shows deep underlying differences: biological experts, including systematists, often prefer alternative strategies. When experts do use diversity, it is not based on superficial similarities but on causal theories (e.g., evolution). Surface similarities may be misleading: Undergraduates generalize properties from porcupines to opossums because they appear similar, whereas biologists would not so generalize from placental mammals to marsupials (Lopez, et al. 1997). Students' superficial reliance on scientific modes of biological categorization and reasoning, such as confounding evolutionary diversity with perceptual dissimilarity, cannot make up for corresponding loss of folkbiological commonsense.

Our studies with birders, fishermen, tree experts, Menominee and Maya do not yield typicality effects and show weak or even negative diversity effects. Most often participants use causal / ecological reasoning rather than taxonomic inference. In the above example involving birch trees versus pine and willow, the modal response was the disease birches get, on grounds that birches are disease-prone and cover a wide geographical range (creating opportunities for spreading the disease to other trees) (Proffitt et al. 2000). Normatively, both ecological and taxonomic reasoning may be appropriate. Thus, the anti-cancer drug taxol was first discovered in the Pacific yew, then discovery was generalized to the European Yew; yet the best source ultimately proved to be a fungus associated with Yews (Stierle et al. 1993).

Table 1 summarizes inference strategies used by USA students, USA birders and Itza' on reasoning tasks about birds. For diversity, four pairs, each pair consisting of two pairs of birds (4 birds total) were constructed for each of the stimulus sets (USA and ITZA'). Within each diversity pair, one pair of birds was "close" in terms of mean distance between the birds in the pair across the three subject groups; the other pair was "far" in terms of mean pair distance. Within each diversity pair, close and far pairs of birds were matched for familiality (number of members in the family as the bird in question), central tendency, and frequency of sighting for USA birds (as determined by the Audobon Society), and familiality and central tendency for Guatemala birds. For USA subjects we displayed both birds in each pair and gave the following instruction:

> Assume we discovered two new enzymes (or diseases). All we know is that Enzyme A is found in these types of birds and Enzyme B is found in these types of birds. Which enzyme is more likely to be found in all types of birds?

For Itza', we discussed "very small things inside of the birds" instead of "enzymes." Subjects selected one of the birds in the pair, and provided a justification for their decision. Results indicate that people with domain-knowledge prefer content-rich strategies to abstract, similarity-based reasoning strategies of typicality and diversity.

Even taxonomic structure, which obeys universal principles, shows some knowledge effects. To set up category-based reasoning probes for bird tasks, we studied three populations: Itza', USA bird watchers, and college students (Atran 1999, Bailenson et al. 2002). Two picture sets were used: Chicago-area and Lowland Guatemala birds. Each set contained 104 species matched for evolutionary taxonomic structure. Subjects were asked to "put together the birds that go together by nature into as many different groups as you'd like." Successive compiling was repeated until the subject indicated no further grouping to be natural. Then initial sorts were restored so that subjects could "split as many of the groups as you'd like into smaller groups that go together by nature." Each subject's taxonomy was obtained by translating the groupings the subject made during the free pile, successive pile and successive subpile sorts into a taxonomic tree. From each taxonomy, we derived a pairwise bird-by-bird folk taxonomic distance matrix by calculating the distance between all possible pairs of birds in the taxonomy. Principal components analysis revealed a single factor solution across subjects within each population (ratio first to second eigenvalue > 3:1, variance accounted for by first factor > 50%). This result justified averaging across individual taxonomies to form a single aggregate taxonomy that represents each population's "cultural consensus" (Romney et al. 1986). These consensual group taxonomies were those used to set up our reasoning experiments about typicality and diversity.

We compared the average matrix from each group to an evolutionary taxonomy of the bird sets. We ran a 3X2 ANOVA with each individual's correlation with evolutionary taxonomy as the dependent measure, and subject group (novice, expert, or Itza') as one factor and bird set (USA or ITZA') as the other. Overall, scientific genera were preserved and included in higher-level groups a majority (70%) of the time, with no reliable differences among populations. By-subject mean correlations on USA birds were 0.4, 0.6, and 0.5 for novices, experts, and Itza'; respective correlations on Guatemalan birds were 0.3, 0.7, and 0.6. Effect for subject group was significant, $F(2,47) = 48.52$, $p<.05$. Itza' results are dramatic: despite no familiarity with science, systematics or USA birds, Itza' have a truer picture of the novices' world (higher correlation with scientific taxonomy) than the novices themselves (see also Lopez, et al, 1997, where it appears that USA student sorting of local mammals can largely be accounted for by the single dimension of size).

Basic Level and Inductive Privilege. Psychologists claim that correlated features in the environment combine with experience to create "basic-level" categories central to cognition. Basic-level categories like chair and fish contrast with more superordinate (furniture, animal) and more subordinate (recliner, trout) categories (Rosch et al. 1976).

Anthropologists who have studied taxonomies in small-scale cultures also argue for a single preferred level of classification, the generic-species level (Berlin et al. 1973, Bulmer 1974, Hays 1983). In these cultures, categories like oak and trout are basic, whereas for psychologists' standard populations, tree and fish are. This contrast suggests that the basic level is knowledge-dependent. There is evidence that biological experts have a more specific basic level than novices (Johnson & Mervis 1997). Note that this description takes the novice perspective as the tsandard or norm. We offer a reframing. "Experts" and people from small-scale societies have "normal" basic-level categories, corresponding to a default inference / recognition strategy that may degenerate under conditions of lack of adequate exposure.

There is reason to prefer our framing. One might expect novice, expert, and small-scale groups to privilege their respective basic levels for induction (e.g., tree for USA students, oak for experts and Maya). But our studies indicate that both industrialized and small-scale populations prefer the same folktaxonomic rank for induction. (Atran et al. 1997, Coley et al. 1997). Examining inferences from a given rank to the adjacent higher-order rank, we found a sharp decline in strength of inferences to taxa ranked higher than generic species, whereas strength of inferences to taxa ranked lower than generic species were nearly equal and similarly strong.

In these experiments, the premise category was at one of four levels: life-form (e.g., L = tree, mammal), generic-species (G = oak, dog), folk-specific (S = white oak, poodle), or varietal (V = swamp white oak, toy poodle). The conclusion category was drawn from a higher-level category, either kingdom (K = animal or plant), life-form (L), generic-species (G), or folk-specific (S). Thus, there were ten possible combinations of premise and conclusion category levels: L->K, G->K, G->L, S->K, S->L, S->G, V->K, V->L, V->G, and V->S. For example, a folk-specific-to-life form (S->L) question might be: "If all white oaks are susceptible to the called eta, are all other trees susceptible?" If a participant answered "no," then the follow-up question would be: "Are some or a few other trees susceptible, or no trees birds at all?"

We totaled the proportion of "all" responses for each kind of question (e.g., the proportion of times respondents agreed that if white oaks had a property, all oaks would have it). We counted a response of "all" as 3, "some or few" as 2, and "none" as 1. A higher score reflected more confidence in the strength of an inference. Examining inferences from a given rank to the adjacent higher-order rank (i.e., V->S, S->G, G->L, L->K), we found a sharp decline in strength of inferences to taxa ranked higher than generic species, whereas V->S and S->G inferences were nearly equal and similarly strong. For "all" responses, the overall Itza' and Michigan patterns were very similar. For example, given a premise of folk-specific (white oak, poodle) and a conclusion category of generic-species rank (oak, dog), most respondents indicated that all members of the generic species would possess a property that the folk specific has. A comparable number of respondents also indicated that a property possessed by a folk varietal (swamp white oak, toy poodle) would as likely be found with the generic species (oak, dog) as with the folk specific (white oak, poodle). In contrast, few respondents believed that properties found in a folk varietal, folk specific or generic species would be found among all members of the superordinate life-form (tree, mammal) or folk-kingdom (plant, animal) categories, or that properties found in a life form would generalize to the folk kingdom.

Nevertheless, in the combined response scores ("all" + "few") there was evidence of increased inductive strength for higher-order taxa among Americans versus Itza'. In other words, both Americans and Itza' showed the largest break between inferences to generic species versus life forms; however, only American students also showed a consistent pattern of rating inferences to life-form taxa higher than to taxa at the level of the folk kingdom: G->K vs. G->L, S->K vs. S->L, and V->K vs. V->L. For the Americans, the preferred level of perceptual identification (life form) appeared to have a secondary effect on inference, whereas for Itza' the life-form level seems to carry no inductive privilege. Although the students cannot perceptually identify most bird or tree species, they can readily form (and draw) an abstract image of BIRD or TREE. Itza' only consent to draw particular kinds of birds or trees.

In brief, only novices show a discrepancy between the level privileged in perceptual and knowledge-based measures of basicness and the level privileged in induction. There may be a universal – perhaps evolutionarily determined - underlying disposition to prefer the generic-species level as the principal source of information about the biological world and the best basis for making inductions under uncertainty (Atran 1998). Lack of knowledge about the ambient organic environment, however, may compel industrialized folk to rely on a twofold strategy for induction: one based primarily on default (naturally-selected) assumptions about the likely significance of generic species, and one based secondarily on a perceptual familiarity at the life-form level that is used to compensate for lack of experience.

Culture and Environmental Decision-Making. Differences in ecological knowledge that emerged from our categorization and reasoning studies motivated work on relations between knowledge and resource management. This research focused on interactions of mental models, cultural values and behaviors, and social networks in environmental decision-making and inter-group conflict. One case study involved three culturally-distinct groups exploiting the same habitat in Guatemala's Petén rainforest: native lowland Maya (Itza'), immigrant Maya from neighboring highlands (Q'eqchi'), and immigrant Spanish-speaking Ladinos (mixed Amerinidian and European descent). Controlling for age, income, family size and type of subsistence activity, we find that lack of knowledge correlates with unsustainable agro-forestry.

The Lowland Maya region faces environmental disaster, owing in part to open access to forest resources by non-native actors. Since 1960 massive immigration has razed more than half of Petén's forest, converting it to agriculture. Habitat destruction does not owe exclusively to population pressure because Pre-Columbian Petén once supported many more people than today.

Our studies show striking differences in folkecological models of groups exploiting the same habitat. Q'eqchi' Maya immigrants see plants as passive donors to animals, and animals having no effect on plants. Native Itza' Maya have a rich, reciprocal model of animal-plant interactions, where animals can help or hurt plants. Immigrant Ladinos display a simpler, non-reciprocal model – plants help animals but animals do not help plants. These differences in models parallel agroforestry practice. Itza' folkecological models stress reciprocity; their practices respect and preserve the forest. Q'eqchi' folkecology sees plants as resources to be exploited; their agricultural practices are correspondingly insensitive to forest survival. Ladino folkecology and agroforestry are intermediate. Our measurements of behavior patterns (plot sizes, species diversity, tree counts, canopy coverage) and consequences for soils corroborate patterns of reported behavior (as does satellite imagery) (Atran et al. 1999, 2002).

Like models of induction, abstract decision models employ a homogeneous notion of the object domain – in this case utility – where content biases and protected values simply annoy. In the area of decision making and the commons, a prevailing view is that behavior is driven by self-interest (Hardin 1968), mitigated only by institutional constraints (Berkes et al. 1989). Protected or sacred values are annoying because their "utility" may be hard to measure (Baron & Spranca 1997). Thus, analyses of commons problem may appear to be trapped somewhere between isolated individual interests which lead inevitably to commons destruction and a focus on institutions that has little need for cognitive science. Our results weaken this conception.

First we explored social structure. We asked subjects to name people "most important to your life" (social network) as well as people "to whom you would go for information about the forest" (expert network). Then we went to the people named and repeated the procedure in snow-ball fashion. Q'eqchi' form the most socially interconnected and institutionally-structured community, but are least likely to preserve the resource base (perhaps because the community is so hermetic). Consider social interconnectedness, or λ-level. The λ-level indicates the average number of links that have to be severed to disconnect a given person from all other persons in the group. Among Q'eqchi', actors named in social networks are connected at $\lambda = 4$, Ladinos at $\lambda = 2$, Itza' at $\lambda =1$. Level 5 ($\lambda = 5$) includes 90% of Q'eqchi', 21% of Ladinos and only 10% of Itza'. Q'eqchi' have lowest agreement on who the forest experts are and Itza' the highest. The two "experts" cited most by Q'eqchi' (60%) are a Washington-based NGO and a government agency.

The Itza' community is the most socially-atomized and least institutionalized, but its individuals most clearly act to maintain the common environment. For Ladinos, strong overlap between socially-connected individuals and Ladino experts provides channels of reliable but non-institutionalized ties for learning about the forest from Itza' (for Ladinos, 3 of the 4 most cited experts are also the 3 named most by Itza'). To test this learning hypothesis, we combined Itza' and Ladino responses about plant-animal relations and found a metacultural consensus (first factor scores all positive, ratio eigenvalue 1:2 = 10.4, variance accounted for = 52%). Then we regressed gender and frequency of being cited as an expert against Ladino first factor scores in the combined consensus model. The $\underline{r}^2$ on Ladino scores was .63 ($\underline{F}(2,10)=6.97$, $\underline{p}=.02$) with gender ($\underline{p}=.02$) and expertise ($\underline{p}=.008$) reliable. One subgroup of men (with one woman) averaged 5.8 expert citations, 6.0 social network citations and an average culture competence (i.e., mean of first factor scores) of .73 (vs. .75 for Itza'). Averages for the other subgroup (with one man) were respectively 0, 1.3 and .59. Male Ladino experts appear to be driving the Ladino population to a convergence of knowledge with Itza'**.**

If neither institutionalized learning nor institutional control mechanisms are exclusively responsible for commons maintenance among Itza', what is? Our evidence suggests that Itza' see forest species as a relational entities, like friends or enemies, not as objectively-defined and objectively-valuated entities, like monetary objects of a payoff matrix. Itza' consider forest spirits to be "spokesmen" for the species they protect. Consistent with this belief, Itza' rank-orderings of the importance of twenty prominent species from the viewpoint of forest spirits are significant predictors of ecological centrality (number of recognized associations of a given species with other species) and human impact (degree to which people maintain a given species population over time) (Atran et al. 2002). (Spirit preferences may represent a statistical summary of sustained human-species interactions over many generations). Ladinos and Q'eqchi' show no such relations. Multiple regressions show that male Itza' consensus on spirits (women do not usually engage forest spirits) together with the overall Itza' consensus on combined use (value of the plant for wood, shelter and cash) account for most of the variance in human impact: $\underline{r}^2 = .70$, $F(2,18) = 20.71$, $\underline{p} = .0001$, with spirits and use equally reliable predictors ($\underline{p}$'s < .01). Ladinos and Q'eqchi' state belief in forest spirits but exhibit no cultural consensus (i.e., no single factor solution) about spirit preferences, nor is belief in spirits reliably linked to forestry practice.

Finally, we asked members of several local and international NGOs with over a decade of experience in the area to rank the same trees as did Itza' and Ladinos in terms of importance to forest life. The NGOs showed marginal consensus (ratio eigenvalue1:2 = 2.73, variance = 46%). The most valued species for the NGOs were, in rank order: mahogany, tropical cedar, allspice and chicle. These are the most important trees for the extractive economy and export market. NGO preferences partially predicted consensus on preferences expressed by Ladinos ($\underline{r}^2 = .72$) and Itza' ($\underline{r}^2 = .44$). But the worst predictor of NGO rankings is male Itza' rankings of spirit preferences ($\underline{r}^2 = .06$) and Itza' ratings of ecological centrality ($\underline{r} = -.229$).

These results pertain to devolution because they show that sheer contact with nature does not suffice for development of ecological knowledge (and correlated values and practices), and that exclusive concern with economic rationality and institutional constraints do not sufficiently account for cultural differences in commons behavior. Cognitive preferences and spiritual values for which there is cultural consensus can be significant predictors.

Other studies among groups from the adjacent Chiapas rainforest in Mexico suggest that the patterns of knowledge and behavior among native Lacandon Maya versus Tzeltal and Tzotzil Maya born to families that immigrated into the area resembles that of Itza' to Q'eqchi' immigrants (Nigh 2002) The fact that these descendants of immigrants have lived all their lives in the forest indicates that mere personal exposure to the local ecology is not a deciding factor.

Our studies among Lacandon Maya also indicate inter-generational knowledge loss (Ross 2002). Formerly, Lacandones lived in dispersed settlements, moving with the agricultural cycle.

This pattern was interrupted when they were pressured to form set villages in the 1970s. Village life has resulted in the young generation losing interest in and knowledge about the rainforest. Older Lacandones show a rich model of ecological interactions, guided by intricate observations and cosmology that younger Lacandones lack. These generational differences are also reflected in agricultural practices (e.g. little crop diversity, focus on cash crops).

We think devolution can unfold in two ways: as generalized loss of knowledge and as skewing by limited goals. We suggest that, relative to native Itza', Q'eqchi' immigrants approach the forest with narrow utilitarian objectives. In parallel studies in the USA we find that majority-culture fishermen, relative to Menominee, show a corresponding influence of restricted interests (Medin et al. 2002): their answers are driven by sporting goals (catching big fish) that tend to neglect broader ecological relations involving fish life cycles. The two devolutionary paths may interact in that limited goals can, in the long run, lead to more limited knowledge. Psychology's standard populations may represent an extreme case on both counts.

Conclusion. We have provided several lines of evidence indicating that "the extinction of experience" has important cognitive and practical consequences. First, standard views of development reflect devolution rather than universal processes. Second, cognitive theories based on devolved knowledge provide misleading pictures of how people generally understand and reason about nature. Third, devolutionary processes lead to anthropocentric views of nature, neglecting cultural values and ecological variables that directly affect a society's manner and possibility of survival. Our civilization is currently in the midst of a conceptual, technological and ethical revolution with regard to biological knowledge and its uses. There is also an emerging moral consensus to leave the planet in the same or better shape than we found it (Kempton et al. 1995). But if human beings are increasingly isolated from their natural environments, how will they care for it?

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Table 1. Summary of reliable main effects found for typicality and diversity trial justifications in bird study. Subject groups are USA nonexperts (N), USA experts (E) and Itza' Maya (I). Subject type effects are listed in the first subcolumn, stimulus set effects in the second subcolumn, and indicate a difference between justifications based on USA or ITZA' stimulus set.

Justification Category	Typicality Trials		Diversity Trials	
	Subject Type	Stimulus Set	Subject Type	Stimulus Set
Typicality	N > E, I	USA > ITZA'	N > E, I	n.s.
Behavioral	I > N, E	n.s.	I > N, E	n.s.
Ecological	I > N, E	n.s.	I > N, E	n.s.
Geographical Range	E, I > N	n.s.	E, I > N	n.s.
Number	N > E, I	n.s.	n.s.	n.s.
Evolutionary Age	n.s.	n.s.	n.s.	n.s.
Diversity	_____	_____	N > I	n.s.

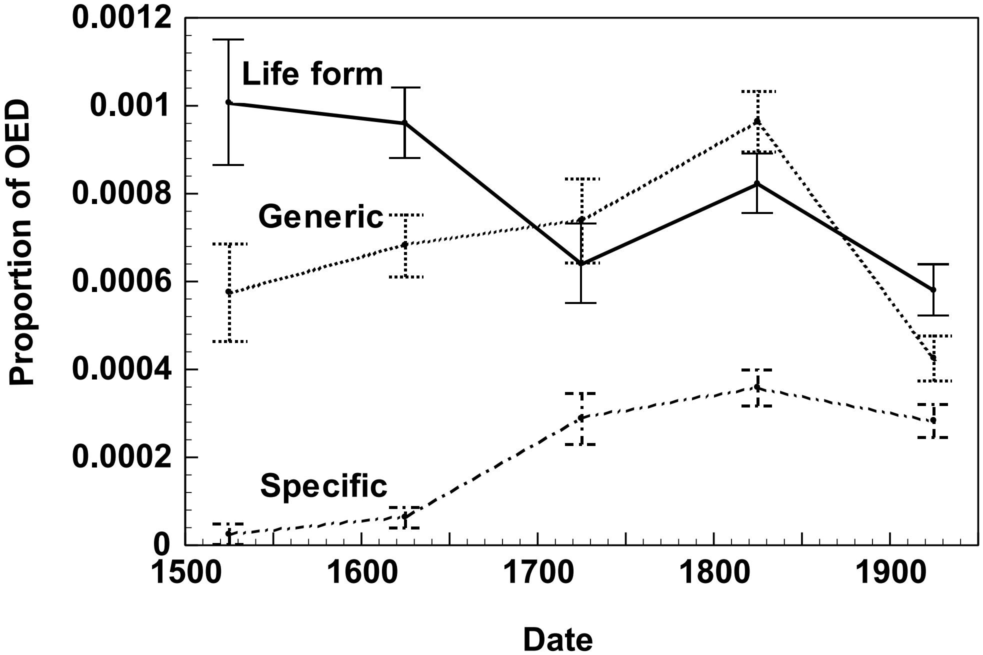

Figure 1. Proportion of quotations in the OED for different levels of specificity along with associated 95% confidence intervals (after Wolff et al. 1999). Note that before ca.1700 folk "generic" terms (e.g. "oak," "bear") referred mostly to monogeneric European species, whereas after ca. 1700 generic terms often referred to polytypic species built around a European type.

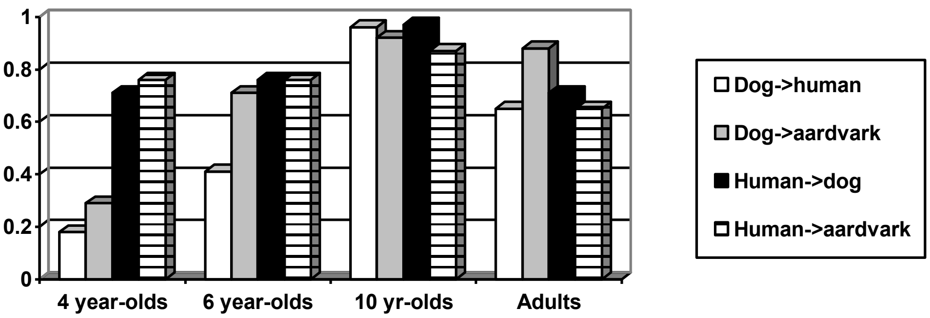

Figure 2a. Urban USA subjects' willingness to project unknown biological properties (after Carey 1985)

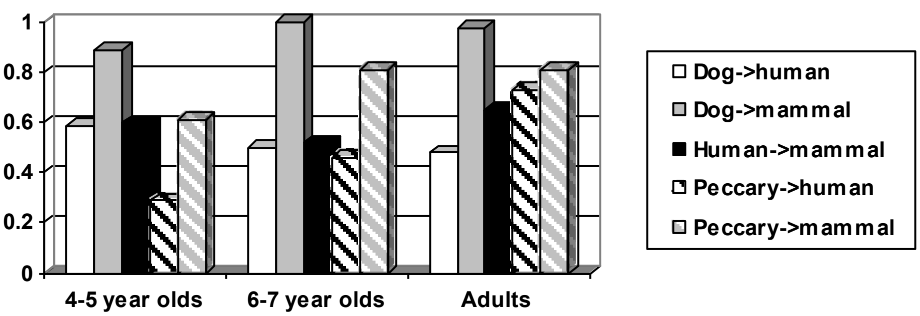

Figure 2b. Yukatek Maya subjects' willingness to project unknown biological properties (after Atran et al. 2001)