EVOLUTION AND DEVOLUTION OF KNOWLEDGE: A TALE OF TWO BIOLOGIES

Scott Atran, Douglas Medin & Norbert Ross
CNRS-Institut Jean Nicod, Northwestern University & Vanderbilt University

Anthropological enquiry suggests that all societies classify animals and plants in similar ways. Paradoxically, in the same cultures that have seen large advances in biological science, practical knowledge of nature has dramatically diminished. Here we describe historical, cross-cultural, and developmental research on the ways in which people ordinarily conceptualize organic nature (folk biology), concentrating on cognitive consequences associated with knowledge devolution. We show that the results of psychological studies of categorization and reasoning from 'standard populations' fail to generalize to humanity at large. The populations most commonly used in studies by psychologists (Euro-American college and university students) have impoverished experience of nature, and this generates misleading results about knowledge acquisition and the ontogenetic relationship between folk biology and folk psychology. We also show that groups living in the same habitat can manifest strikingly distinct behaviours, cognitions, and social relations relative to it. This has novel implications for environmental decision making and management, including commons problems.

As generations of college students learn more about microbiology and evolution, they seem to be growing less and less familiar with the plants and animals around them. Provided below is part of an interview with an Honours student at a major American research university. The student expressed surprise at being told that we had previously undertaken a study in which children as young as 3 and 4 years old had been asked to give examples of plants which they could name. We then asked the student to generate examples herself:

Interviewer: Tell me all the kinds of trees you know.
Student: 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?
Interviewer: Tell me some plants.
Student: 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 been investigating 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 behaviours of

J. Roy. anthrop. Inst. (N.S.) **10**, 395-420

physical objects and substances (physics), more specific properties of plants and animals (biology), and particular properties of fellow human beings (psychology). This article builds on the findings of research exploring the logic and conceptual frameworks underlying different schemes of folk biology, a term which we use to refer to how people ordinarily categorize and infer relationships about local biodiversity. Our particular concern is with the ways in which these different types of folk biology relate to the loss or degradation of people's knowledge of the natural world.

Our choice and interpretation of methods and models is informed by over a decade of intensive ethnographic, ethnolinguistic, and ethnobiological fieldwork involving an international team of anthropologists, psychologists, linguists, and biologists. A further goal of this article is to show anthropologists how experimental methods and quantitative models can be applied to issues of environmental cognition and management that are central to cultural survival. Without quantifiable replicability, there can be little if any dialogue with either the wider scientific community or with governments and non-governmental organizations (NGOs). The danger here is that anthropological information can become marginalized, rather than fulfilling its potential to enrich and inform debate on environmental issues. Yet another of our aims is to show psychologists that replicable cross-cultural analyses involving small-scale societies are not only possible but necessary in any attempt to establish what is and what is not universal in human cognition. This is especially important for education programmes throughout the world.

Evolved universals in cognition and culture

The term folk biology refers to the ways in which humans classify and reason about the organic world. Ethnobiology is the anthropological study of folk biology; one of the key concerns of ethnobiologists is folk taxonomy, a term referring to the hierarchical structure, organic content, and cultural function of folk-biological classifications that ethnobiologists appear to find in every society around the world. Naive biology is a term denoting the psychological study of folk biology in industrialized societies; those engaged in this area of research are often principally concerned with category-based induction, a term referring to the ways in which children and adults learn about, and reason from, biological categories.[1]

We begin with aspects of folk biology that appear to be universal; this will provide the essential context for our attempt to analyse the consequences of diminished contact with nature in the naive biologies of industrialized societies. 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. Folk biology is a domain of human thought and practice that probably has its origins in processes of human evolutionary development engaged specifically with the task of accommodating to the biological environment (Atran 1998). In every society, people tend to think about plants and animals in special ways that are distinct from the ways in which they ordinarily think about other things in the world, such as stones, tools or even people.

Over a century of ethnobiological research has shown that even within a single culture there may be several different sorts of 'special-purpose' folk-biological classifications, which are organized by particular interests for particular uses (for example, beneficial/noxious, domestic/wild, edible/inedible). Beginning with the pioneering work of Berlin and colleagues (Berlin, Breedlove & Raven 1973), a growing body of ethnobiological evidence has demonstrated that societies everywhere also employ 'general-purpose' taxonomy which supports the widest possible range of inductions about living kinds that are relevant to everyday life (Atran 1998). This 'default' taxonomy, which serves as an inductive compendium of biological information, is composed of a fairly stable hierarchy of inclusive groups of organisms, or taxa. At each level, the taxa, which are mutually exclusive, partition the locally perceived biota in a virtually exhaustive manner. Lay taxonomy is composed of a small number of absolutely distinct hierarchical levels, or ranks (Berlin 1992): the levels of folk kingdom (for example, animal, plant), life form (for example, bug, fish, bird, mammal, tree, herb/grass, bush), generic species (gnat, shark, robin, dog, oak, clover, holly) folk specific (poodle, white oak), and folk varietal (toy poodle, spotted white oak). Ranking is a cognitive mapping that projects living-kind categories onto a structure of absolute levels, that is, fundamentally different levels of reality. Taxa of the same rank tend to display similar linguistic, biological, and psychological characteristics. Ranks, not taxa, are apparently universal.

In all cultures, it appears, people partition local biodiversity into taxonomies whose primary level of organization is that of the 'generic species' (Atran 1990; Berlin, Breedlove & Raven 1973; Brown 1984; Hays 1983; Hunn 1977), the common man's (folk) species (Wallace 1889: 1). Generic species comprise the overwhelming majority of taxa in any folk-biological system. Generic species are also typically the categories most easily recognized, most commonly named, and perhaps most easily learned by children (Stross 1973). Ethnobiologists who otherwise differ in their views of folk taxonomy tend to agree that one level best captures discontinuities in nature and provides the fundamental constituents in all systems of folk-biological categorization, reasoning, and use (Bulmer 1974; Descola 1996; Ellen 1999; Hunn 1982; Morris 1996).

Generic species often correspond to scientific species (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 (bear, oak). For less perceptible organisms, whose morphologies and ecological proclivities are distant from humans (insects, bryophytes), violations of scientific taxonomy tend to be more pronounced, with a single generic species sometimes encompassing biological families, orders, and occasionally whole phyla. Still, in this respect as in others, folk-biological taxonomies resemble one another, including the folk-biological system that initially gave rise to scientific systematics.

In addition to the spontaneous division of local biota 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 a non-overlapping folk taxonomy that 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 (for example, species, family, kingdom) whose elements are first-order groups (lion, feline, animal). Folk-biological ranks show little variation across cultures as a function of theories or belief systems (Malt 1995).

We studied the following populations:

Itza' Maya. A good deal of our work concerns Native Itza' Maya in the municipality of San José in Guatemala's Department of El Petén. Men are primarily occupied with practising agriculture and horticulture, hunting game and fish, and extracting timber and non-timber forest products for sale. Women mainly attend to household gardening and maintenance. The climate is semi-tropical, with quasi-rainforest predominating (tropical dry forest/subtropical humid forest).

Yukatek Maya. We have also worked with children and adults from Yukatek-speaking rural villages in southcentral Quintana Roo, Mexico. Like the Itza', they practise agriculture, hunting, and extracting forest products, though their forests are more degraded than those of the Itza'. Yukatek were chosen because of their close linguistic and cultural connection with the Itza', and because there are thousands of Yukatek-speaking children, but no longer children who speak Itza' as a first language.

Native American Menominee. The Menominee ('Wild Rice People') are the oldest continuous residents of Wisconsin. There are between four and five thousand Menominee living on tribal lands in and around three small communities. Over 60 per cent of Menominee adults have at least a secondary school education and 15 per cent have received some higher education. As in the past, the reservation is heavily forested. Hunting and fishing are important activities for most adult males and for many females. We also studied children. This European-American group included both urban and rural children and rural adults. The rural participants were from a county in Wisconsin adjacent to the Menominee Reservation.

Majority-culture USA undergraduates. This group consists of students taking an introductory psychology course at major research universities in the Midwest. They may differ from students in smaller, more locally focused colleges and universities in showing a greater willingness to travel away from home to pursue a university education.

USA biology 'experts'. This category includes diverse groups with distinct kinds of expertise: bird-watchers, maintenance workers in parks, landscape architects, and professional taxonomists. Typically, they had at least twenty years experience in their occupation or avocation.

When people are asked to sort biological kinds into groups, they show strong agreement, both within and across cultures, that also corresponds fairly well with scientific taxonomy. We asked people in three broadly contrasting cultural and social settings (Native American Menominee, majority-culture USA, Lowland Itza', and Yukatek Maya), as well as different sets of people within the same society, to sort pictures or specimens of animals or plants using the instruction: 'please put together these [pictures or specimens of plants or animals are shown] that go together by nature into as many different groups as you'd like'.[2] Successive compiling was repeated until an informant indicated no further grouping to be natural. Then initial sorts were restored so that informants could 'split as many of the groups as you'd like into smaller groups that go together by nature'. Each informant's taxonomy was obtained by translating the groupings made during the free pile, successive pile, and successive sub-pile sorts into a taxonomic tree. Pile sorts resulted in individual distance matrices representing the informant's taxonomic ordering of species. We then used Principal Component Analysis, which allows the description of shape variability using a restricted number of parameters. These parameters (or modes) can be used to quantify the difference between any number of shapes (in this case, any number of individual taxonomies) through the computation of a modal distance. A statistical test can then be applied to this set of measurements in order to detect significant differences or consensus among subjects. Once consensus between informants was established, the distance matrices of all individuals were combined by averaging across the entries. On this basis we were able to generate a modal distance matrix, representing the cultural consensus. It was this average link (distance) matrix that was compared to scientific taxonomies.[3]

In our studies with Native American Menominee and various United States and Lowland Maya adults, correlations between folk taxonomies (average-link clustering of pile sorts of mammals, birds, reptiles, trees, 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, Shum, Atran, Medin & Coley 2002; Medin, Ross, Atran, Burnett & Blok 2002; cf. Boster 1987; Hunn 1975). Much of the remaining variance can be attributed to the fact that most schemes of folk biology give particular emphasis to size (Hunn 1999). Another factor here was probably to do with certain perceptual biases (Itza' Maya group swallows and swifts under the same generic-species term, *ix-kusam*, and group bats with birds under the same life-form term, *chiich'*) and local ecological concerns (Itza' group poisonous coral snakes with vipers at the same intermediate family level, and trees with toxic sap and similar aspect – *Sebastiana longicuspus*, *Metopium brownei* – as distinct sub-kinds of one generic species). Contrary to received notions about the history and cross-cultural basis for folk-biological classification, mere utility does not drive general-purpose folk taxonomy (for example, Itza' group Perissodactyla, such as domestic equids and wild tapir, and classify numerous unused plants) (Atran 1990; Berlin, Breedlove & Raven 1973).

This taxonomic framework also supports indefinitely many graded inferences regarding the distribution of biologically related properties among species. On finding out that red oaks are susceptible to some new disease, informants are likely to infer that other oaks may also be susceptible to this disease. The detailed character of the induction (morphological, ecological, genetic) varies with experience and culture (for example, Itza' and United States experts, like birders, do not generalize susceptibility to disease across kinds that occupy different ecological zones) (Bailenson, Shum, Atran, Medin & Coley 2002; López, Atran, Coley, Medin & Smith 1997; Medin, Lynch, Coley & Atran 1997).

There is also growing cross-cultural evidence of a common-sense assumption that each species has an underlying causal nature, or essence, that is uniquely responsible for the typical appearance, behaviour, and ecological preferences of the kind. On evolutionary grounds one would expect that innate potential is vested at the generic species level: for the most part, generic species are genetically, geographically and reproductively isolated (Mayr [1982] calls these 'nondimensional species'). Hence, we would expect presumptions of essence to be at the generic-species level, where innate potential actually resides.

In experiments in the United States, Mesoamerica, and Brazil, the youngest children tested (aged 4 years) believe overwhelmingly, as do adults, that the identity of animals and plants follows that of their progenitors, regardless of the environment in which the progeny matures (for example, progeny of cows raised with pigs, acorns planted with apple seeds) (Atran *et al.* 2001; Gelman & Wellman 1991; Sousa, Atran & Medin 2002). Even in cultures where adult discourse is anti-essentialist, both children and adults appear to essentialize animals (Astuti 2002). This notion of biological essence may be universal. People in diverse cultures consider this biological essence to be responsible for the organism's identity as a complex entity governed by dynamic internal processes that function as invariable structuring principles even if their operation is not immediately visible to observers. This presumed essence maintains the organism's integrity even as it causes the organism to grow, change form, and reproduce: a tadpole and frog are considered to be the same animal although they look and behave differently and live in different places. Beginning with Aristotle and continuing through to Locke and many of his successors, Western philosophers have long sought to translate this common-sense notion of essence into metaphysical reality. In contrast, evolutionary biologists reject the very notion of essence. Yet their traditional explanation for the fact that certain characteristics persist in the face of change has focused on the distinction between an organism's genotypes as opposed to its phenotypes.

Although science rejects metaphysical essentialism, there is growing evidence pointing to 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 such a thing as an underlying nature, though perhaps an unknowable one. This hidden, causal essence is presumably responsible for the manifest properties of any given kind. The fact that biological science can overturn psychological essentialism in the construction of theoretical explanation in no way implies that psychological essentialism is dismissible from everyday thought, any more than physical scientists' rejection of constant intervals of space and time stops us from using notions of absolute space and time as everyday points of reference.

There are thus strong constraints – possibly arising from the process of natural selection – on the ways in which people organize local knowledge of biological kinds. Universal appreciation of generic species may be one such functional adaptation. Pigeon-holing 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). In short, there is fairly strong evidence that folk biology is a constrained domain of development and that its core aspects are either innate or universally acquired under some minimal but adequate input conditions.

Historical developments

To throw further light on the ways in which skeletal principles shape conceptions of nature we turn to a brief review of historical developments in biology. Understanding how scientific concepts in industrialized societies developed out of folk understanding is important for several reasons. First, it helps to show where and how scientific understanding both converges with and diverges from folk understanding. Science education programmes are often based on intuitive and anecdotal appreciation of these relationships, rather than on careful scrutiny of the historical record. Secondly, the historical record can inform our knowledge of the conceptual difficulties and possibilities for children and ordinary people in comprehending scientific concepts. This has obvious implications not only for science education but, more generally, for public policy with regard to science. Thirdly, tracking developments in understanding within industrialized societies can help peoples from other cultural backgrounds to overcome or profit from these lessons. In developing countries, nearly all governments endeavour to impose 'modernized' science education programmes on their citizens, although there is often little attempt to explore compatibilities and incompatibilities between 'our' science and other peoples' awareness of nature.

Ancient Greek and Roman naturalists had knowledge of only five or six hundred local species, a number consistent with most local folk-biological systems (Raven, Berlin & Breedlove 1971). Because biological genus and species are often extensionally equivalent in any given locale, ancient naturalists had no apparent basis on which to make systematic distinctions between them. For Aristotle and Theophrastus, as for Dioscorides and Pliny, the term *atomon eidos*, or 'species', referred to generic species (eagle, dog, oak, wheat), whereas *megiston genos*, or 'genus', referred to superordinate life forms (bird, quadruped, tree, grass) (Atran 1990).

During the so-called Age of Exploration in the sixteenth and seventeenth centuries Western explorer-navigators introduced a great many new species to Europe. The French naturalist Tournefort (1694) was the first to use the term genus to identify 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. The result was that the classification of plants could now be achieved with reference to a mere 600 genera, rather than something in the neighbourhood of 6,000 known species. This process thus produced a set of equivalence classes on a scale that could be much more readily coped with by the human mind.

A geometrical rate of exploration and discovery soon undermined the taxonomic priority of the genus, and attention turned to the family level, which lies at an intermediate point between the genus and the life form. The family was itself rooted in local groupings that many native peoples implicitly recognize but seldom name, such as felines, equids, legumes, and umbellifers (Atran

1983). 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 world-wide 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 that had been proposed since Tournefort's time to exactly 100 families, but acknowledged this number to be based more on convenience than necessity. Jussieu's families became the standard categories of modern plant taxonomy. Extending the *méthode naturelle* to animals, including humans, Buffon (1774-89) identified family plans as lineages of temporally related species. This was crucial to the evolutionary thinking of both 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.

Darwin (1859) used all levels of folk taxonomy: from folk specifics (for example, 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 enquiry remains compelling (cf. Labandeira & Sepkoski 1993), despite awareness that no 'true' distinctions exist between various taxonomic levels. In short, although modern evolutionary theory has discarded folk-biological notions of essence and of fixed, enduring species, these folk concepts and associated ranked taxonomies have provided the scaffolding that has made these advances possible.

Devolved knowledge and familiarity with nature

Despite Western science's historical origins in universal principles of folk biology that are found in many different cultures, among people in globally mobile, technologically orientated societies there is marked deterioration in common-sense understanding of the everyday living world (Atran 1998; Coley, Medin, Proffitt, Lynch & Atran 1999; López, Atran, Coley, Medin & Smith 1997; Nabhan & St Antoine 1993; Ross, Medin, Coley & Atran 2003). This impairment affects people's practical ability to interact sustainably with the environment: 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. Many recent immigrants to Phoenix, Arizona, cannot distinguish the pruned eucalyptus trees in their landscaped plots, much less surmise that the eucalyptus is not conducive to maintaining biodiversity in the face of competition for scarce water; and few residents of Chicago are able to identify a buckthorn, much less comprehend that fires 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 folk-taxonomic structure is similar in diverse cultures and historical periods, technological advances appear to be accompanied by shallower knowledge of biology. In one line of research, we examined written material in the *Oxford English Dictionary* (*OED*) for references to terms used to describe trees from the sixteenth to the twentieth centuries (Wolff, Medin & Pankratz 1999). The *Oxford English Dictionary* is available on-line and provides dated quotations illustrating word-use; its sources are books and journals (we excluded sources that were not from England). We looked only at incidental references to trees (in other words, when some other word was being illustrated). From the twentieth century, the number of sources mentioning trees declined by 45 per cent; the number of quotations fell by 40 per cent. The specificity of quotes also declined. Use of the life-form term, tree, fell only by 26 per cent, whereas use of generic-species terms (for example, oak) fell by 50 per cent (see Figure 1). This pattern held, regardless of whether the tree in the quotation was the topic of the sentence in question or was incidental to it. Other life-form terms (bird, grass, etc.) also declined, but use of non-biological superordinates (furniture, clothes, etc.) increased.

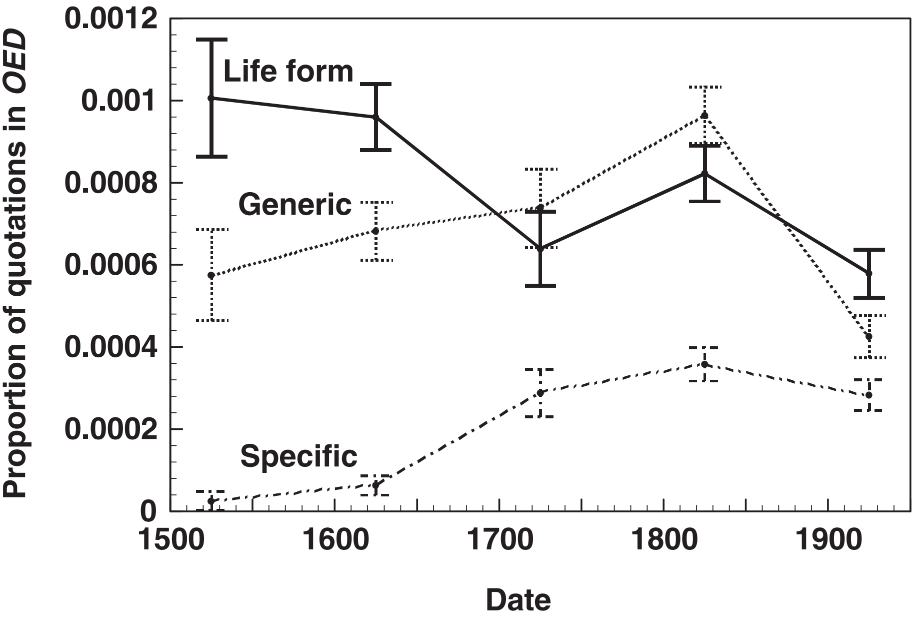

FIGURE 1. Proportion of quotations in the *Oxford English Dictionary* for different levels of specificity along with associated 95 per cent confidence intervals (after Wolff, Medin & Pankratz 1999). Note that before *c.*1700 'generic' (that is, generic-species) terms (such as 'oak', 'bear') referred mostly to monogeneric European species, whereas after *c.*1700 generic terms often referred to polytypic species built around a European type.

Consistent with this devolutionary pattern, we found that American students from Northwestern University tend to identify tree and bird species only at the life-form level ('tree', 'bird') (Bailenson, Shum, Atran, Medin & Coley 2002; Coley, Medin, Proffitt, Lynch & Atran 1999). In contrast, Itza' Maya overwhelmingly identify plant and animal species at more specific levels. This evidence associates technologically orientated cultures with diminishing interaction and familiarity with nature. Even among indigenous groups, however, hitherto close and intricate relationships with nature may be undergoing degradation. For example, a recent study among Tzotzil Maya in the Highlands of Chiapas reveals that tree species are much more salient for women than for men; this appears to be an effect of ongoing cultural changes that lead men, but not women, away from intimate contact with nature.[4]

What happens cognitively when contact with nature diminishes? To answer, we need only turn to psychology's most studied groups, American undergraduates, and children from schools near major universities in industrialized countries. 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 cross-cultural data challenge existing psychological models of graded category structure, category-based induction, conceptual development, and decision-making.

Categorization and reasoning

One very important function of categories in human thought is to support inductive reasoning, which makes generalizations about the world possible. If one learns that ducks are susceptible to the West Nile virus, one might well entertain the idea that geese are also susceptible to it. Psychological models for the ways in which people generate inductive inferences across categories – or 'category-based reasoning' – have focused on the notion of similarity. It seems intuitively compelling that the more properties or features two categories share, the more likely it will be that some novel property discovered to be true of one (for example, susceptibility to some virus) will also be true of the other. A succinct summary of our studies is that in experiments comparing biologically knowledgeable American adults, illiterate Maya, and United States college students, the students are the 'odd group out'. Generalizations about basic categorization and reasoning have been based on a group that is far from representative of the world at large.

One classic finding in cognitive psychology 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 (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 involving tree experts, bird-watchers, and majority-culture and Menominee fishermen, where subjects rated typicality on a standard seven-point scale, ideals scored highest and central tendency was uncorrelated with ratings (Lynch, Coley & Medin 2000; Medin, Ross, Atran, Burnett & Blok 2002).

A key function of categorization is to support reasoning in the face of uncertainty. By studying category-based inductive inferences we can see how taxonomic and ecological knowledge is put into practice to generate expectations. 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, Smith, Wilkie, López & Shafir 1990). Suppose river birch and paper birch trees contract disease A, and white pine and weeping willow contract 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 are 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 (for example, evolution). Surface similarities can mislead: undergraduates generalize properties from porcupines to opossums because they appear similar, whereas biologists would not generalize from placental mammals to marsupials (López, Atran, Coley, Medin & Smith 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 folk-biological common sense.

Studies with birders, fishermen, tree experts, Menominee, and Maya do not yield typicality effects and show weak or even negative diversity effects. Participants most commonly use causal or ecological reasoning rather than taxonomic inference. In the example given above, the modal response was the disease contracted by birches, on the grounds that birches are disease-prone and cover a wide geographical range (creating opportunities for spreading disease to other trees) (Proffitt, Coley & Medin 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, Strobel & Stierle 1993).

Even taxonomic structure, which obeys universal principles, shows some knowledge effects. To set up category-based reasoning probes for bird tasks, we studied Itza', and United States bird-watchers and college students (Atran 1999; Bailenson, Shum, Atran, Medin & Coley 2002). Two picture sets were used: Chicago-area and Lowland Guatemala birds. Each set contained 104 species matched for evolutionary taxonomic structure. We asked informants to sort the birds; then we translated the groupings made during the sorting procedure into a taxonomic tree (as described earlier). 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 per cent). This result justified averaging across individual taxonomies to form a single aggregate taxonomy representing each population's 'cultural consensus' (Romney *et al.* 1986).[5] These consensual group taxonomies were those used to set up our reasoning experiments about typicality and diversity.

We compared each group's average matrix to an evolutionary taxonomy of the bird sets. Overall, scientific genera were preserved and included in higher-level groups 70 per cent of the time, with no reliable differences among populations. By-subject mean correlations on United States 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.[6] Itza' results are dramatic: despite no familiarity with science, systematics, or United States birds, Itza' have a truer picture of the novices' world (higher correlation with scientific taxonomy) than novices themselves (in López, Atran, Coley, Medin & Smith 1997, student sorting of mammals is largely attributable to 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, Mervis, Grey, Johnson & Boyes-Braem 1976). Anthropologists who have studied taxonomies in small-scale cultures also argue for a single preferred level of classification, the generic-species level (Atran 1990; Berlin, Breedlove & Raven 1973; Bulmer 1974). In these cultures, categories like oak and trout are basic, whereas for psychologists' standard populations, it is tree and fish that are basic. This contrast suggests that the basic level is knowledge-dependent. There is evidence that biological experts have a more specific basic level than novices, but this describes results from a novice perspective (Dougherty 1978; Johnson & Mervis 1997; Tanaka & Taylor 1991). We thus propose a reframing. 'Experts' and people from small-scale societies have 'normal' basic-level categories, corresponding to a default inference/recognition strategy whose recognition component degenerates with lack of exposure, but whose inference component remains intact.

There is reason to prefer our framing. One might expect novice, expert, and small-scale groups to privilege their respective basic levels for induction (for example, tree for USA students, oak for experts and Maya). But our studies indicate that both industrialized and small-scale populations prefer the same folk taxonomic rank for induction (Atran, Estin, Coley & Medin 1997; Coley, Medin & Atran 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 premiss category was at one of four levels: life form (for example, 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).

There were ten possible combinations of premiss 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 disease 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 *none* at all?'

Examining inferences from a given rank to the adjacent higher-order rank (that is, 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, overall Itza' and Michigan patterns were very similar. For example, given a premiss 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. Respondents also tended to think that a property possessed by a folk varietal (swamp white oak, toy poodle) would be as likely to be shared 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 life-form (tree, mammal) or folk-kingdom (plant, animal) categories, or that properties found in a life form would generalize to the folk kingdom (Figure 2).

Nevertheless, in combined response scores ('all' + 'few') there was evidence of increased inductive strength for higher-order taxa among Americans versus Itza'. Although both Americans and Itza' showed the largest break between inferences to generic species versus life forms, only Americans also showed a consistent pattern of rating inferences to life-form taxa higher than to taxa at the folk-kingdom level. For the Americans, the preferred level of perceptual identification (life form) had a secondary effect on inference; for Itza' the life-form level carried 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' will draw only particular kinds of birds or trees.

In sum, only the Americans show a discrepancy between the level that is found to be preferred in perceptual and knowledge-based measures of basic level versus the level that is found to be preferred in induction. There may be a universal underlying disposition to prefer the generic-species level as the principal source of information about nature and the best basis for making inductions under uncertainty (Atran 1998).[7] Lack of knowledge about the ambient organic environment, however, may compel people in industrialized societies to rely on a twofold strategy for induction: the first being one that is based primarily on default (naturally selected) assumptions about the likely

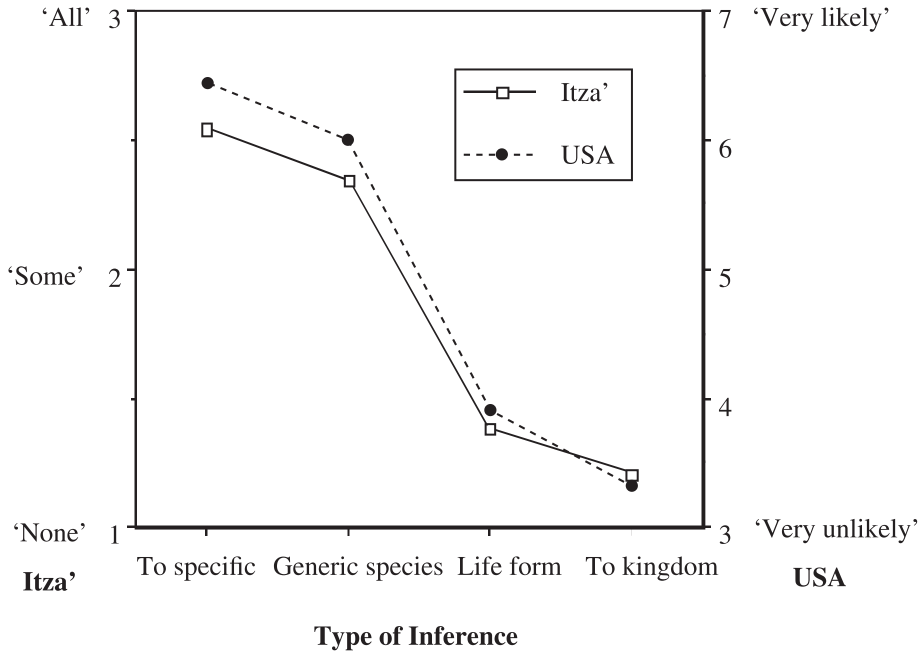

FIGURE 2. Inductive inferences for Itza' Maya and United States students compared (after Coley, Medin & Atran 1997).

significance of generic species, and the second a strategy based on perceptual familiarity at the life-form level that compensates for lack of experience. It is possible that there is an evolutionary advantage in having both domain-general perceptual heuristics and domain-specific learning mechanisms. The first allows for flexible adaptation to the variable conditions of experience, and the second, which tends towards more lasting and inflexible forms of awareness, may serve to foster awareness of the more permanent aspects of the natural world, especially those that are causally recurrent and therefore central to the emergence of human life and cognition.

Concept development

We suggested above that folk biology, folk psychology, and folk physics are distinct domains to which innate skeletal principles may be associated (Atran 2001). In developmental, cognitive and evolutionary psychology, there is considerable research exploring the scope and limits of such 'domain-specific' or 'modular' conceptual systems (Hirschfeld & Gelman 1994; Pinker 1997; Sperber, Premack & Premack 1995). Carey (1985) has questioned the assumption that folk (or 'naive') biology is originally distinct from folk psychology: children's biology is initially conflated with, and grows out of, naive psychology. In her view, children begin with anthropocentric conceptions of biology and must undergo fundamental conceptual change to see humans as one animal among many. Her striking findings increasingly inform educational programmes for science teaching in the United States and elsewhere.

To understand children's conceptions of biology as opposed to their simple factual knowledge, Carey focused on projection of novel properties (for example, 'has a green round thing called an omentum inside') from one category to others. Patterns of generalization provide suggestive evidence concerning the ways in which children conceptualize humans and other kinds of living things. Early work by Carey showed that young children generalized from humans to animals based on similarity to humans (for example, to dogs more than to bees), but were reluctant to generalize from animals to other animals, including humans (see Figure 3*a*). Young children even preferred inferences from humans to insects over inferences from bees to insects.

These results suggest that children do not distinguish between naive psychology, where humans are presumably prototypical, and naive biology, where humans are not. If true, then educational policies aimed at improving teaching and learning of biology should focus on disentangling folk-psychological concepts (for example, a tree wants water because it is thirsty) from biological concepts as such (a tree needs water to live and grow), and doing so at the appropriate age or stage in conceptual development. Because educational programmes in industrialized countries almost invariably become models for those of the developing world, the implications of these findings are not merely academic.

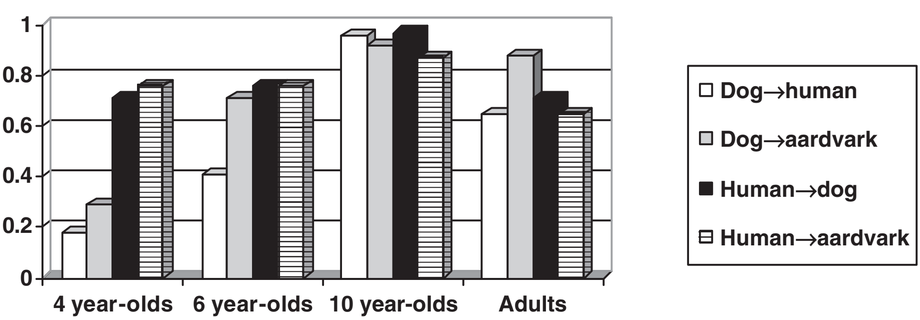

FIGURE 3*a*. Urban United States subjects' willingness to project unknown biological properties (after Carey 1985).

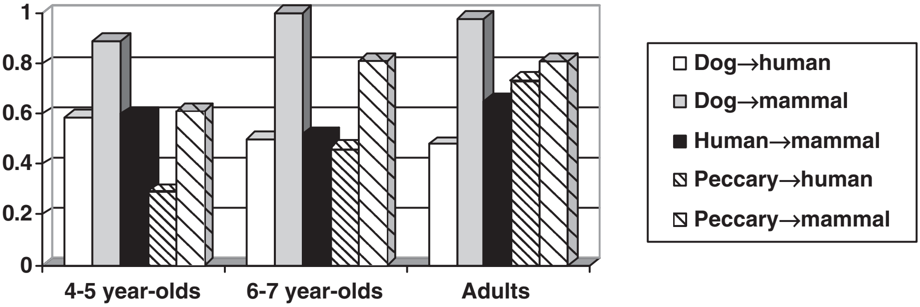

FIGURE 3*b*. Yukatek Maya subjects' willingness to project unknown biological properties (after Atran *et al.* 2001).

More recent research has undermined Carey's strong claim (Gutheil, Vera & Keil 1998; Inagaki & Hatano 2002), and our cross-cultural work suggests that her observations do not generalize to non-standard populations (she used American urban, middle-class children). Human-centred reasoning patterns may reflect industrialized cultures' lack of knowledge about non-human living things rather than a different construal of nature (Atran, Medin, Lynch, Vapnarsky, Ucan Ek' & Sousa 2001; Ross, Medin, Coley & Atran 2003). We performed essentially the same induction exercise with urban children, partially replicating Carey's results (Ross, Medin, Coley & Atran 2003). 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 (aged 4 to 5 years), humans are no better as an inductive base for projecting unfamiliar biological properties than other animals (see Figure 3*b*), 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, results indicate that folk biology and folk psychology are distinct for children as young as 4 years old, provided that they have not had impoverished contact with nature (though the perceived role of humans in the order of nature varies culturally). Because current experimental tasks based on property projection have not been successfully administered to children under 4 years old, we cannot claim from these results that folk biology and folk psychology are innately distinct domains of human cognition. Nevertheless, other sorts of experiments (for example, sorting tasks: Mandler, Bauer & McDonough 1991) and considerations (for example, plausible evolutionary scenarios: Atran 2003) suggest that folk biology and folk psychology emerged somewhat independently for performing different tasks (understanding species relationships versus understanding human beliefs, desires, and goals), and that their conceptual entanglement in urbanized children is a particular rather than a universal cultural and historical development.

Urban children may generalize from humans because humans are the only animal of which they have much knowledge. 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 these groups experience matters. Thus Yukatek girls show less differentiated generalization from wild animals as compared to domestic ones.[8] This is consistent with the fact that Maya girls typically remain at home while boys regularly venture into the forest. What developmentalists had deemed to be universal now seems peculiar to lack of contact with nature which is characteristic of Western industrialized societies.

Rural majority-culture, urban majority-culture, and Native-American children have three culturally distinct conceptions of nature. Such differences may be 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, Bransford & Pellegrino 1999). The fact that Menominee children do better in science than in any other subject in their first four years of school but then find science to be their worst subject four years later suggests that instruction is failing to capitalize on Menominee precocity and underlines the significance of this issue (http:/data/dpi.state.wi.us/data/graphshell.asp, 2/26/01, Wisconsin Dept. of Public Institutions).

Culture and environmental decision-making

Differences in ecological knowledge that emerged from our categorization and reasoning studies led us to undertake research between knowledge and resource management. There are precedents for our approach (e.g. Ellen 1999; Posey 1983), but to our knowledge there have been few if any attempts to explore the role of cultural orientation in deforestation and land-use in statistically identifiable and verifiable ways. This research focused on the interactions between social networks and mental models, cultural values and behaviours in environmental decision-making and inter-group conflict. One case study involved three culturally distinct groups exploiting the same habitat in the Petén rainforest of Guatemala: Native Lowland Maya (Itza'), immigrant Maya from neighbouring highlands (Q'eqchi'), and immigrant Spanish-speaking Ladinos (mixed Amerindian 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 is currently threatened with environmental disaster, largely as a result of the opening of its forest areas to non-Native in-comers. Since the 1960s these settlers have been engaged in a massive programme of agricultural expansion, and this influx has led to the destruction of over half of the Petén region's forests. Habitat destruction is not merely the result of population pressure, since Pre-Columbian Petén once supported many more people than today.

Our studies show striking differences in folk-ecological models held by the different groups who are all currently exploiting this habitat. Q'eqchi' Maya immigrants see plants as passive donors to animals, and animals as having no effect on plants. Native Itza' Maya have a rich, reciprocal model of animal-plant interactions, in which animals can either 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 agro-forestry practice. Itza' folk ecological models stress reciprocity; their practices respect and preserve the forest. Q'eqchi' folk ecology sees plants as resources to be exploited; their agricultural practices are correspondingly insensitive to forest survival. Ladino folk ecology and agro-forestry are intermediate. Our measurements of behaviour patterns (plot sizes, species diversity, tree counts, canopy coverage) and consequences for soils corroborate patterns of reported behaviour (as does satellite imagery) (Atran *et al.* 1999; 2002).

Itza' reported that classes of animals differentially affected classes of plants; Ladinos reported more universal effects. Plant kinds were collapsed into four categories (Fruit, Grass/Herb, Palm, and Other), as were animal categories (Arboreal, Bird, Rummager, and Predator). Figure 4 shows their interaction

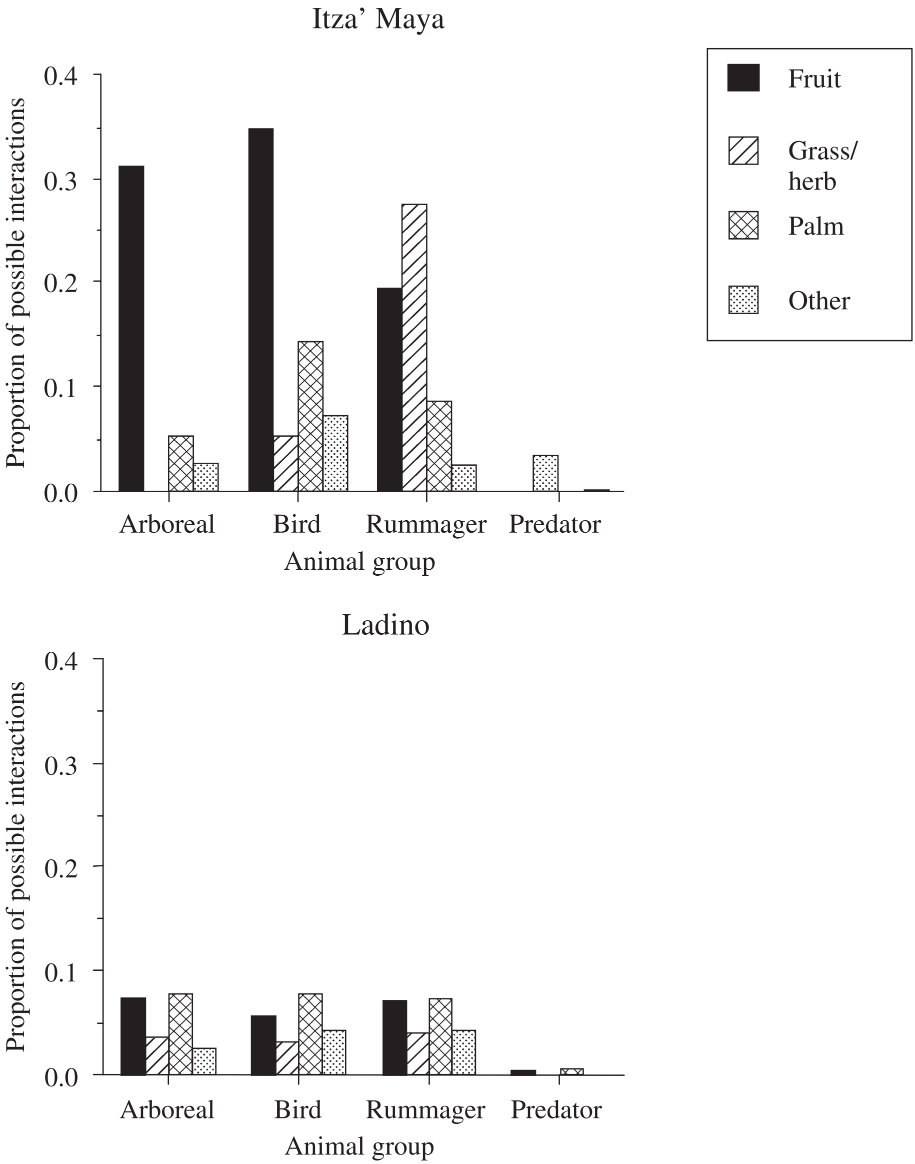

FIGURE 4. Frequency of specific types of animal-plant relations reported by Itza' and Ladinos (after Atran *et al.* 2002).

and indicates that: (1) arboreals were much more likely to interact with fruit trees than with other plant groups, (2) birds were also most likely to interact with fruit trees, but also had moderate levels of interactions with palms, (3) rummagers interacted primarily with grasses/herbs, and to a lesser extent with fruit trees, (4) predators showed few if any interactions with plants. The absolute level of interactions is much lower for Ladinos, who report that all animal groups (save predators) interact with all plant groups in roughly similar ways. Animals that were most likely to affect plants were rummagers, birds, and arboreals; plants most likely to be affected were fruit trees and 'other' plants. Unlike Itza', Ladinos do not report animal groups as affecting plant groups in different ways.

Qualitatively, although both groups acknowledge animals having a large impact on fruit trees, Itza' differ from Ladinos in understanding these relations. Ladinos infer that animals harm plants by eating fruit. Itza' have a subtler view, based on properties of the seed and on how the animal chews and digests. If the seed is soft and the animal crunches through the casing, the interaction is harmful because the animal will likely destroy the seed; but if the seed is hard and digestion rapid, the interaction can be helpful if the seed passes through the animal's body, since the animal assists seed dispersal and fertilization.

The picture thus far suggests common models with distinct variations for each group. On plants helping animals, Itza' and Ladinos have similar models with over 80 per cent overlap on pairwise interactions. The Q'eqchi' model is much less elaborated, being a proper subset with less than one-sixth of the relations reported by the other groups. Examining the ways in which animals are reported to affect plants further reveals the paucity of the Q'eqchi' folk ecological model. Q'eqchi' reach a non-zero consensus on only 10 out of 812 possible relations. These findings suggest a complex Itza' folk-ecological model of the forest, wherein different animals affect different plants, and relations among plants and animals are reciprocal. Ladinos also possess a relatively elaborate model, but relations are more unidirectional and less specific. Q'eqchi' acknowledge a greatly reduced role for plants, and almost no role for animals.

It is important to recognize that these apparently simple models of species relationships, where information from each informant is reduced to a plant × animal matrix whose cells consist only of '1' (help), '−1' (hurt) or '0' (no perceived relationship), are informed by long-term fieldwork and participation in informants' cultural life. Each cell is a digest of information that can represent hours of interviews. That information is not lost (it imbues several linguistic, ethnographic, and ethnobiological articles and monographs [e.g. Lois 1998; Atran, Lois & Ucan Ele' 2004]); it is merely condensed for statistical and analytic purposes so as to yield replicable generalizations supported by participant observation.

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 do not neatly fit into standard accounts, and so tend to be ignored by researchers or treated in an *ad hoc* fashion (for a review, see Markman & Medin 2002). On the issue of decision-making and the commons one highly influential view is that human behaviour is driven by self-interest (Hardin 1968) mitigated only by institutional constraints (Berkes, Feeny, McCay & Acheson 1989). Protected or sacred values are annoying because their 'utility' may be hard to measure (Baron & Spranca 1997). Thus analyses of commons problems 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 challenge such assumptions.

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 snowball 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). This standard sociological technique for exploring social networks was informed by long-term anthropological fieldwork on social organization, without which correct interpretation of the quantitative data would not be possible.

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 per cent of Q'eqchi', 21 per cent of Ladinos, and only 10 per cent of Itza'. Q'eqchi' have lowest agreement as to who the forest experts are and Itza' the highest. The two 'experts' cited most by Q'eqchi' (60 per cent) were a Washington-based NGO and a government agency.

The Itza' community is the most socially atomized and least institutionalized, but its individuals are the most inclined to act in ways which tend towards maintenance of the common environment. For Ladinos, a 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, three of the four most cited experts are also the three named most by Itza). 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.[9] Results suggest that male Ladino experts are 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 does explain it? Our evidence suggests that Itza' see forest species as relational entities, like friends or enemies, not as objectively defined and objectively evaluated entities, like monetary objects of a pay-off 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). For Itza', spirit preferences may represent a statistical summary of sustained human-species interactions over many generations. Ladinos and Q'eqchi' show no such relations. Regression analyses 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, that is,[10] these two factors predict which tree species Itza' do and do not protect. Ladinos and Q'eqchi' both say that they believe in forest spirits but exhibit no cultural consensus (that is, 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 in terms of importance to forest life as we had asked Itza' and Ladinos to rank. The NGOs showed marginal consensus (ratio eigenvalue 1 : 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 predicted consensus on preferences expressed by Ladinos ($r^2 = 0.72$) and partially so for Itza' ($r^2 = 0.44$). The worst predictor of NGO rankings is male Itza' rankings of spirit preferences and Itza' ratings of ecological centrality.

These results pertain to devolution, in the sense of degradation of knowledge, 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 does not sufficiently account for cultural differences in commons behaviour. In addition, they show that understandings of nature and not abstract calculations of economic utility are organizing factors in environmental decision-making. 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 behaviour 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 intergenerational knowledge loss (Ross 2002). Formerly, Lacandones lived in dispersed settlements, moving with the agricultural cycle. Their way of life changed dramatically in the 1970s when the regional state authorities induced them to settle in fixed village sites and take up a sedentary life of cultivation and wage labour. For the younger generation, village life has led to a loss of interest in and knowledge about the rainforest. Older Lacandones still conceive of the natural world in terms of a richly textured model of ecological interactions. In this they are guided by cosmological knowledge and an ability to make minute observations; for younger Lacandones these capacities are severely degraded. These generational differences are also reflected in agricultural practices (for example, little crop diversity and a focus on cash crops).

Devolution may 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 United States we have found that majority-culture fishermen, relative to Menominee, show a corresponding influence of restricted interests (Medin, Ross, Atran, Burnett & Blok 2002): their answers are driven by sporting goals (catching big fish) which 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. In both senses, the populations most commonly used as subjects in psychologists' studies may represent an extreme case.

Conclusion

This article has explored several lines of evidence suggesting that 'the extinction of experience' has important cognitive and practical consequences. First, cognitive theories based on devolved knowledge provide misleading pictures of how people generally understand and reason about nature. Secondly, standard views of development reflect devolution rather than universal processes. Thirdly, 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. Industrial and post-industrial societies are currently in the midst of a conceptual, technological, and ethical revolution with regard to biological knowledge and its uses. Many people now share a growing moral consensus about the need for human beings to try to improve the world's physical environment through the course of any given lifetime, or at the very least to find ways to avoid doing damage to their habitat as they live their lives (Kempton, Boster & Hartley 1995). But if people are becoming increasingly isolated from their environments, it is hard to imagine how they can possibly achieve these goals.

NOTES

Research was supported by the National Science Foundation (USA), National Institutes of Health (USA), Russell Sage Foundation (USA), and the Centre National de la Recherche Scientifique (France). An earlier version was presented at the British Academy, London, June 2002.

[1] The study of folk biology roughly divides into adherents of 'cultural universals' versus 'cultural relativism' (debated also as 'intellectualism' versus 'utilitarianism': Brown [1995]). Universalists highlight folk-taxonomic principles that are only marginally influenced by people's needs and the uses to which taxonomies are put (Berlin [1992]). Relativists emphasize those structures and contents of folk-biological categories that are fashioned by cultural interest, experience, and use (Ellen [1999]). Universalists grant that within a culture there may be different 'special-purpose classifications'. Nevertheless, universalists maintain that there is only one cross-culturally universal kind of 'general-purpose taxonomy', which supports the widest possible range of inductions (Hays [1983]). Relativists note that even in seemingly general-purpose taxonomies, categories can reflect 'special-purpose' distinctions of cultural practice and expertise (Posey [1981]). Still, relativists usually acknowledge that people seem spontaneously to classify plants and animals into primary categories that roughly correspond to what field biologists call 'non-dimensional species' (populations of organisms that appear to be reproductively isolated from one another and which also appear to occupy distinct ecological niches, at least when observed over just a few generations: Mayr [1982]).

[2] Although one may find broad cross-cultural agreement in biological categorization it is important to recognize that different elicitation procedures may yield different patterns of taxonomic or ecological sorting. Thus, in pre-tests with Itza', we asked the people we worked with to sort things most 'similar' (*b'ay*) or 'alike' (*je-b'ix*) so as to replicate as closely as possible instructions given to our American subjects (for example, Boster and Johnson [1989]). Initial results were discouraging: consensus among participants was low, and informants often appeared to justify their sortings by what seemed to us to be often idiosyncratic and conflicting notions of use (for example, horses and cows are more similar to one another than to tapirs because tapirs do not carry loads; tapirs and cows are more similar to one another than to horses because horses are not eaten at festivals). But the ethnohistorical evidence indicates that the expression of a deeper taxonomic reasoning endures over time (Trager [1939]). Thus it has been established that in the sixteenth century, following the Spanish Conquest, Itza' taxonomically assimilated the horse (a perissodactyl, and an animal previously unknown in South America) by identifying it as a kind of tapir (the only native perissodactyl) (Landa 1985 [1566]). Itza' still attach the same name to the horse (*tzimin*) and tapir (*tzimin~che'* = forest *tzimin*),

although they are maximally distant by functional criteria: the former is terrestrial, domestic, and inedible; the latter is aquatic, wild, and edible. Interviews reveal that Itza' consider the tapir and horse to be 'companions by nature' (*et'~ok*, 'go together'). This proved the key to asking Itza' to sort items that 'go together by nature', which yielded taxonomies resembling those found in cultures the world over (López, Atran, Coley, Medin & Smith 1997). By contrast, there was no significant difference in the performance of American students asked to sort items that 'go together by nature' or as being 'most similar'.

[3] The aim of cluster analysis is to provide a succinct visual summary of similarity relationships. Items that are similar to each other will tend to be placed in the same, low-level cluster, and items different from each other will tend to be placed in different clusters. The clustering algorithm attempts to capture the overall pattern of similarity relationships across all pairs by a simplest hierarchical clustering scheme. A number of algorithms exist that vary in the relative importance assigned to differences versus similarities and the average link cluster method represents a good compromise between the two focuses.

[4] In a free-listing task carried out in Zincantan, women generate more species ($M = 9.7$) than men ($M = 8.5$; $F = 7.99$, $p = 0.005$). Men (particularly young men) are more likely ($M = 0.16$) than women ($M = 0.10$) to report important species in Spanish rather than Tzotzil ($F = 13.3$, $p = 0.000$).

[5] The 'Cultural Consensus Model' assumes that widely shared information is reflected by a high concordance among individuals. When there is consensus, individuals may differ in their knowledge or 'cultural competence'. Estimation of individual competencies is derived from the pattern of inter-informant agreement on the first factor of a principal component analysis (essentially factor analysis). A cultural consensus is found if the data overall conform to a single factor solution (the first latent root is much larger than all other latent roots) and individual competence scores on the first factor are strongly positive. The model can be used to explore agreement patterns both within and across populations, the latter describing potential 'meta-cultural' models. This promotes exploration of pathways of information exchange within and between cultural groups, illuminating processes of cultural formation, transformation and evolution.

[6] Effect for subject group was significant, $F(2, 47) = 48.52$, $p < 0.05$.

[7] Language may be important in targeting privileged kinds by using short, easy to remember names (generally a single, unanalysable lexical constituent) to trigger biological expectations in the absence of actual experience or knowledge of those kinds. Language, however, can only signal that such an expectation is appropriate for a given lexical item; it cannot determine the nature of that expectation (as a 'deep' causal nexus of biological properties and relationships).

[8] Analyses involved ANOVAs and *t*-tests on difference scores. The dependent variable for each subject was their base to target (for example, Human to mammal) score minus their target to base (for example, Mammal to human) score. The gender × 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 $F(2, 50) = 5.83$, $p = 0.005$; for younger boys, age group $F(2, 47) = 0.847$, $p = 0.44$.

[9] The r^2 on Ladino scores was 0.63 ($F(2,10) = 6.97$, $p = 0.02$) with gender ($p = 0.02$) and expertise ($p = 0.008$) reliable. One sub-group 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 0.73 (versus 0.75 for Itza'). Averages for the other sub-group (with one man) were respectively 0, 1.3, and 0.59.

[10] $r^2 = 0.70$, $F(2, 18) = 20.71$, $p = 0.0001$, with spirits and use equally reliable predictors (p's < 0.01).

REFERENCES

Ahn, W. *et al.* 2001. Why essences are essential in the psychology of concepts. *Cognition* **82**, 59-69.

Astuti, R. 2002. A cognitive and anthropological study of animal and human categorization among the Vezo of Madagascar. Paper presented to the Department of Anthropology Colloquium Series, University of Toronto, 14 Feb. TS.

Atran, S. 1983. Covert fragmenta and the origins of the botanical family. *Man* **18**, 51-71.

——— 1990. *Cognitive foundations of natural history*. Cambridge: University Press.

——— 1998. Folkbiology and the anthropology of science. *Behavioral and Brain Sciences* **21**, 547-609.

——— 1999. Itzaj Maya folkbiological taxonomy. In *Folkbiology* (eds) D. Medin & S. Atran, 119-203. Cambridge, Mass.: MIT.

——— 2001. The case for modularity. *Evolution and Cognition* **7**, 46-55.

——— 2003. Modest adaptationism. *Behavioral and Brain Sciences* **25**, 504-6.

——— P. Estin, J. Coley & D. Medin 1997. Generic species and basic levels. *Journal of Ethnobiology* **17**, 22-45.

——— X. Lois & E. Ucan Ek' 2004. *Plants of the Petén Itza' Maya*. Ann Arbor: University of Michigan.

——— *et al.* 1999. Folkecology and commons management in the Maya Lowlands. *Proceedings of the National Academy of Sciences* **96**, 7598-603.

——— *et al.* 2001. Folkbiology doesn't come from folkpsychology. *Journal of Cognition and Culture* **1**, 3-42.

——— *et al.* 2002. Folkecology, cultural epidemiology, and the spirit of the commons: A garden experiment in the Maya Lowlands (1991-2001). *Current Anthropology* **43**, 421-50.

Bailenson, J., M. Shum, S. Atran, D. Medin & J. Coley 2002. A bird's eye view. *Cognition* **83**, 1-53.

Baron, J. & M. Spranca 1997. Protected values. *Organizational Behavior and Human Performance* **70**, 1-16.

Bartlett, H. 1936. *Botany of the Maya area*. Washington: Carnegie Institution.

Berkes, F., D. Feeny, B. McCay & J. Acheson 1989. The benefit of the commons. *Nature* **340**, 91-3.

Berlin, B. 1992. *Ethnobiological classification*. Princeton, NJ: Princeton University Press.

——— D. Breedlove & P. Raven 1973. General principles of classification and nomenclature in folk biology. *American Anthropologist* **74**, 214-42.

Boster, J. 1987. Agreement among biological classification systems is not dependent on cultural transmission. *American Anthropologist* **89**, 914-20.

——— & J. Johnson 1989. Form or function: A comparison of expert and novice judgments of similarity among fish. *American Anthropologist* **91**, 866-89.

Brown, C. 1984. *Language and living things*. New Brunswick, NJ: Rutgers University Press.

——— 1995. Lexical acculturation and ethnobiology: Utilitarianism and intellectualism. *Journal of Linguistic Anthropology* **5**, 51-64.

Buffon, G. 1774-89. *Histoire générale et particulière: supplément*. Paris: Imprimerie Royale.

Bulmer, R. 1974. Folk biology in Highland New Guinea. *Social Science Information* **13**, 19-28.

Carey, S. 1985. *Conceptual change in childhood*. Cambridge, Mass.: MIT.

Coley, J., D. Medin & S. Atran 1997. Does rank have its privilege? *Cognition* **63**, 73-112.

———, ———, J. Proffitt, E. Lynch & S. Atran 1999. Inductive reasoning in folk-biological thought. In *Folkbiology* (eds) D. Medin & S. Atran, 205-32. Cambridge, Mass.: MIT.

Darwin, C. 1859. *On the origins of species*. London: Murray.

Descola, P. 1996. Constructing natures. In *Nature and society* (eds) P. Descola & G. Pálson, 82-102. London: Routledge.

Diamond, J. & K. Bishop 1999. Ethno-ornithology of the Ketengban people. In *Folkbiology* (eds) D. Medin & S. Atran, 17-46. Cambridge, Mass.: MIT.

Donovan, M., J. Bransford & J. Pellegrino 1999. *How people learn*. Washington: National Academies Press.

Dougherty, J. 1978. Salience and relativity in classification. *American Ethnologist* **5**, 66-80.

Ellen, R. 1999. Models of subsidence and ethnobiological knowledge. In *Folkbiology* (eds) D. Medin & S. Atran, 91-118. Cambridge, Mass.: MIT.

Gelman, S. & H. Wellman 1991. Insides and essences. *Cognition* **38**, 213-44.

Gutheil, G., A. Vera & F. Keil 1998. Do houseflies think? *Cognition* **66**, 33-49.

Hardin, G. 1968. The tragedy of the commons. *Science* **162**, 1243-8.

Hays, T. 1983. Ndumba folk biology. *American Anthropologist* **85**, 592-611.

Hirschfeld, L. & S. Gelman (eds) 1994. *Mapping the mind*. New York: Cambridge University Press.

Hunn, E. 1975. A measure of the degree of correspondence of folk to scientific biological classification. *American Ethnologist* **2**, 309-27.

——— 1977. *Tzeltal folk zoology: the classification of discontinuities in nature*. New York: Academic Press.

——— 1982. The utilitarian factor in folk biological classification. *American Anthropologist* **84**, 830-47.

——— 1999. Size as limiting the recognition of biodiversity in folkbiological classifications: one of four factors governing the cultural recognition of biological taxa. In *Folkbiology* (eds) D.L. Medin & S. Atran, 47-69. Cambridge, Mass.: MIT Press.

Inagaki, K. & G. Hatano 2002. *Young children's thinking about the biological world*. New York: Psychology Press.

Johnson, K. & C. Mervis 1997. Effects of varying levels of expertise on the basic level of categorization. *Journal of Experimental Psychology: General* **126**, 248-77.

Jussieu, A.L. 1789. *Genera plantarum*. Paris: Herissant.

Kempton, W., J. Boster & J. Hartley 1995. *Environmental values in American culture*. Cambridge, Mass.: MIT.

Labandeira, C. & J. Sepkoski 1993. Insect diversity in the fossil record. *Science* **261**, 310-15.

Landa, Diego de 1985 [1566]. *Relación de la cosas de Yucatán*. (Crónicas de America **7)**. Madrid: Historia 16.

Linnaeus, C. 1751. *Philosophia botanica*. Stockholm: G. Kiesewetter.

Lois, X. 1998. Gender markers as 'rigid determiners' of the Itzaj Maya world. *International Journal of American Linguistics* **64**, 224-82.

López, A., S. Atran, J. Coley, D. Medin & E. Smith 1997. The tree of life: universals of folk-biological taxonomies and inductions. *Cognitive Psychology* **32**, 251-95.

Lynch, E., J. Coley & D. Medin 2000. Tall is typical. *Memory and Cognition* **28**, 41-50.

Malt, B. (1995). Category coherence in cross-cultural perspective. *Cognitive Psychology* **29**, 85-148.

Mandler, J., P. Bauer & L. McDonough 1991. Separating the sheep from the goats: differentiating global categories. *Cognitive Psychology* **23**, 263-98.

Markman, A.B. & D. Medin 2002. Decision making: In *Stevens handbook of experimental psychology*, vol. 2: *Memory and cognitive processes* (ed.) D. Medin, 413-66. (Third edition). New York: John Wiley & Sons.

Mayr, E. 1982. *The growth of biological thought*. Cambridge, Mass.: Harvard University Press.

Medin, D. & A. Ortony 1989. Psychological essentialism. In *Similarity and analogical reasoning* (eds) S. Vosniadou & A. Ortony, 179-195. New York: Cambridge University Press.

——— E. Lynch, J. Coley & S. Atran 1997. Categorization and reasoning among tree experts: do all roads lead to Rome? *Cognitive Psychology* **32**, 49-96.

——— N. Ross, S. Atran, R. Burnett & S. Blok 2002. Categorization and reasoning in relation to culture and expertise. In *Psychology of learning and motivation*, vol. 41 (ed.) B. Ross, 1-41. New York: Academic Press.

Morris, B. 1996. *Forest traders*. London: Athlone Press.

Nabhan, G.P. & S. St Antoine 1993. The loss of floral and faunal story. In *The Biophilia hypothesis* (eds) S.R. Kellert & E.O. Wilson, 229-50. Washington: Island Press.

Nigh, R. 2002. Maya medicine in the biological gaze. *Current Anthropology* **43**, 451-77.

Osherson, D., E. Smith, O. Wilkie, A. López & E. Shafir 1990. Category-based induction. *Psychological Review* **97**, 85-200.

Pinker, S. 1997. *How the mind works*. New York: Norton.

Posey, D. 1981. Wasps, warriors and fearless men: ethnoentomology of the Kayapó Indians of Central Brazil. *Journal of Ethnobiology* **1**, 165-74.

——— 1983. Indigenous ecological knowledge and development of the Amazon. In *The dilemma of Amazonian development* (ed.) E. Moran. Boulder, Colo.: Westview Press.

Proffitt, J., J. Coley & D. Medin 2000. Expertise and category-based induction. *Journal of Experimental Psychology: Human Perception and Performance* **26**, 811-28.

Raven, P., B. Berlin & D. Breedlove 1971. Origins of taxonomy. *Science* **174**, 1210-13.

Romney, A.K., S. Weller & W. Batchelder 1986. Culture as consensus: a theory of culture and informant accuracy. *American Anthropologist* **88**, 313-38.

Rosch, E. & C. Mervis 1975. Family resemblances: studies in the internal structure of categories. *Cognitive Psychology* **7**, 535-605.

———, ———, W. Grey, D. Johnson & P. Boyes-Braem 1976. Basic objects in natural categories. *Cognitive Psychology* **8**, 382-439.
Ross, N. 2002 Cognitive aspects of intergenerational change: Mental models, cultural change, and environmental behavior among the Lacandon Maya. *Human Organization* **61**, 125-38.
——— D. Medin, J. Coley & S. Atran 2003. Cultural and experiential differences in the development of folkbiological induction. *Cognitive Development* **18**, 35-47.
Smith, E. & D. Medin 1981. *Categories and concepts.* Cambridge, Mass.: Harvard University Press.
Sousa, P., S. Atran & D. Medin 2002. Essentialism in folkbiology. *Journal of Cognition and Culture* **2**, 195-203.
Sperber, D., D. Premack & A. Premack 1995. *Causal cognition*. Oxford: Clarendon Press.
Stierle, A., G. Strobel & D. Stierle 1993. Taxol and taxane production by *Taxomyces andreanae*, an endophytic fungus of Pacific Yew. *Science* **260**, 214-16.
Stross, B. 1973. Acquisition of botanical terminology by Tzeltal children. In *Meaning in Mayan languages* (ed.) M. Edmonson, 107-41. The Hague: Mouton Press.
Tanaka, J. & M. Taylor 1991. Object categories and expertise. *Cognitive Psychology* **23**, 457-82.
Tournefort, J. 1694. *Elémens de botanique*. Paris: Imprimerie Royale.
Trager, G. (1939) 'Cottonwood' = 'tree': a southwestern linguistic trait. *International Journal of American Linguistics* **9**, 117-18.
Wallace, A. 1889. *Darwinism*. New York: Macmillan.
Wolff, P., D. Medin & C. Pankratz 1999. Evolution and devolution of folkbiological knowledge. *Cognition* **73**, 177-204.

Progression et régression des connaissances : y aurait-il deux biologies ?

Résumé

L'enquête anthropologique suggère que toutes les sociétés classifient de la même manière les animaux et les végétaux. Paradoxalement, c'est dans les cultures qui ont connu les plus grandes avancées de la biologie que la connaissance pratique de la nature a le plus spectaculairement régressé. Les auteurs décrivent ici des recherches historiques, interculturelles et développementales consacrées à la manière dont on conceptualise habituellement la nature organique (biologie populaire), en se concentrant sur ses conséquences cognitives en ce qui concerne la régression des connaissances. Ils montrent que les résultats des études psychologiques de catégorisation et de raisonnement menées sur des « populations standard » ne peuvent être étendus à l'ensemble de l'humanité. En effet, les populations les plus fréquemment mises à contribution par les psychologues pour ces études (les lycéens et étudiants euro-américains) ont une expérience appauvrie de la nature, de sorte que les résultats peuvent induire en erreur s'il s'agit d'étudier l'acquisition des connaissances et le lien ontogénique entre biologie populaire et psychologie populaire. On sait également que les groupes vivant dans un même habitat peuvent avoir des comportements, des cognitions et des relations sociales extrêmement différents vis-à-vis de celui-ci. Il en découle de nouvelles implications pour les décisions affectant l'environnement et sa gestion, et notamment les problèmes liés aux ressources communautaires.

Scott Atran, CNRS – Institut Jean Nicod, 1 bis Avenue Lowendal, 75007 Paris, France; ISR-University of Michigan, Ann Arbor, MI 48106-1248, USA. satran@umich.edu

Douglas Medin, Department of Psychology, Northwestern University, Evanston, IL 60208, USA. medin@northwestern.edu

Norbert Ross, Department of Anthropology, Vanderbilt University, Nashville, TN 37235-7703, USA. norbert.o.ross@vanderbilt.edu