The Native Mind:
Biological Categorization, Reasoning, and Decision Making in Development and Across Cultures

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Abstract. This paper describes a cross-cultural and developmental research project on naïve or folk biology – that is, the study of how people conceptualize nature. Our methods and results integrate three distinct perspectives into a complex and coherent account of biological cognition. From the standpoint of mainstream cognitive psychology, we find that results gathered from "standard populations" in industrialized societies often fail to generalize to humanity at large. For example, similarity-driven typicality and diversity effects and basic level phenomena either are not found or pattern differently when we move beyond undergraduate participants. A second perspective involves the notion that domain-specific modules facilitate and structure cognition. Here again, standard populations may yield misleading results because such populations represent examples of especially impoverished experience with respect to nature. Conceptions of humans as biological kinds vary with cultural milieu and input conditions. We also show certain phenomena that are robust across populations, consistent with notions of domain-specificity. Third, we argue that cultural transmission and formation does not consist primarily in shared rules or norms, but in complex distributions of causally-connected representations across minds. This has novel implications for environmental decision making and management, including dealings with commons problems. Our framework addresses a series of methodological issues, such as the fallacy of conceiving culture to be a bounded entity, well-defined system, or independent variable, and the tendency to "essentialize" culture and treat it as an explanation rather than phenomena to be explained.

I. Introduction.

To get along in the world, people need to be able to understand and predict the general properties and behaviors of physical objects and substances (physics), the more specific properties of plants and animals (biology), and the particular properties of their fellow human beings (psychology). This paper describes an ongoing program of research in the domain of naïve or folk biology, including aspects of its interfacing with the other two domains. The topics range from simple categorization to complex environmental decision making. The contexts vary from the lowland rainforest of Guatemala to the most technologically-developed urban settings. The study populations extend from the standard undergraduate research pool to Itza' Maya elders in Guatemala who have no formal education, on the one hand, and to botany PhD's on the other; they also range from middle class children living near major USA universities to Yukatek Maya children of Mexico. There is no single logical thread that unites all facets of this research program. Rather, there are several interwoven threads that can be integrated into a fabric that provides a new perspective on a range of fundamental issues in cognition. This includes: 1. a need to revise current models of categorization, reasoning, and decision making, which have been developed on a narrow empirical base, culturally speaking, 2. an analysis of the relative contributions of universal versus culturally-specific processes to people's conceptions of biological kinds, and 3. tools for analyzing within- and between-group variation associated with the study of culture and development that allow for a distinctive approach to the conceptualization and study of culture.

This paper can be read from at least three perspectives. From the point of view of mainstream cognitive psychology, we find that results gathered from "standard populations" more often than not fail to generalize to humanity at large. In the area of categorization, similarity-driven typicality effects and basic level phenomena either are not found or play out differently when we move beyond undergraduate participants. In research on category-based reasoning, we find again that undergraduates are the "odd group out," which has corresponding implications for models of induction. In decision making, our observations reveal that abstract game-theoretic analyses of resource dilemmas miss content-based "mental models" of the environment that may play a crucial role in guiding people's decisions about cooperative versus selfish use of common-pool resources.

A second perspective on our studies is provided by the notion that domain-specific cognitive modules facilitate and structure cognition. We argue that this framework is useful but that, in the case of naïve biology, using standard populations may produce misleading results because such populations represent examples of especially impoverished experience with respect to nature. In the development of biological categorization and reasoning, we show that folkbiology does not derive from folkpsychology and that conceptions of humans as biological kinds vary extensively as a function of cultural milieu and input conditions.

Third, our research constitutes a distinctive point of view with respect to the recent upsurge of interest in cultural psychology (for a review and critique, see Oyserman, Coon and Kemmelmeier, 2002 and associated commentaries). That body of research has produced a variety of intriguing findings and has done psychology a service by calling attention to cultural variation. In our view, however, it risks being inherently self-limiting. First, some work in this tradition has tended to equate cultures with nations and even continents; yet, at the same time, it also describes and analyzes culture as if it were a personal psychological attribute or set of attributes (e.g., European individualism vs. Asian collectivism). Second, when a hypothesized cultural difference is reported, it is not clear how explanation can be extended beyond simple description; that is, a statement of the basis for a cultural difference may be confused with and block the search for a genuine causal analysis.

Our approach also differs from competing evolutionary accounts of culture in focusing on mental structures (cf. Dawkins, 1976; Lumsden & Wilson, 1981; Cavalli-Sforza & Feldman, 1981; Boyd & Richerson, 1985; Durham, 1991; Dennett, 1995; Sober & Wilson, 1998, Blackmore, 1999). From our perspective, cultural transmission depends not so much on imitation or other forms of relatively high-fidelity communication of shared rules and norms as upon cognitive inference and reconstruction from often fragmentary and noisy stimuli (Atran, 2001a). We argue that cultural transmission and formation does not consist primarily in shared rules or norms, but in complex distributions of causally-connected representations across minds.

From our perspective it is less useful to try to estimate population parameters for such norms and associated behaviors (especially when cultural studies consist of cross-national samples of college students) than it is to establish the pathways that determine how (in our case, biological) ideas affect (in our case, environmental) behaviors. We describe emergent cultural patterns that are derived statistically from measurements of inter-informant agreement. This "cultural –epidemiological" framework (Sperber, 1985) addresses a series of methodological issues such as 1.the fallacy of conceiving culture to be a bounded entity, well-defined system, or independent variable, 2.the tendency to "essentialize" culture and treat it as an explanation rather than as something to be explained, 3. the appropriateness of random sampling for understanding cultural phenomena, and 4. the limits of attempting to decompose culture into a factorial design.

The rest of this paper is organized as follows. First, we provide a framework where folkbiology is conceived to be the converging product of 1. an evolved, domain-specific cognitive module, 2. the structure of local biodiversity, and 3. cultural canalization. Next, we outline a distributional view of culture and methodological tools tailored to that view. Then we briefly describe the settings and populations for our research studies. With this as background, we go on to review our research findings on folkbiological development, categorization, induction, and mental models of the environment. In each of these sections, we point out the implications of these findings for theories of cognition. Finally, we show how these findings weave together the strands of folkbiology. Although the focus is on folkbiology, our studies and claims may be pertinent to other object categories and the default strategies that apply to them.

II. Evolutionary and cultural paths.

Cultural belief and practice 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 does have an evolutionary history**.** In every human society, people tend to think about plants and animals in the same special ways. These special ways of thinking, which can be described as "folkbiology," are basically different from the ways humans ordinarily think about other things in the world, such as stones, tools or even people:

> From the most remote period in the history of the world organic beings have been found to resemble each other in descending degrees, so that they can be classed into groups under groups. This classification is not arbitrary like the grouping of stars in constellations. (Darwin, 1859:431).

The structure of these hierarchically-organized groups, such as white oak/oak/tree or mountain robin/robin/bird, is referred to as "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).[1]

The human taxonomic system for organizing species appears to be found in all cultures (Berlin, Breedlove, and Raven, 1973., 1974; Atran, 1990). It entails the conceptual realization that, say, apple trees and robins belong to the same fundamental level of (folk)biological reality, and that this level of reality differs from the subordinate level that includes winesap apple trees and mountain robin as well as from the super-ordinate level that includes trees and birds. This taxonomic framework also supports indefinitely many systematic and graded inferences with respect to the distribution of known or unknown properties among species (Atran, 1998). Biological ranks are second-order classes of groups (e.g., species, family, kingdom) whose elements are first-order groups (e.g., lion, feline, animal). Folkbiological ranks vary little across cultures as a function of theories or belief systems (Malt, 1995). Ranks are intended to represent fundamentally different levels of reality, not convenience (Berlin, 1992).

There is growing cross-cultural evidence of a commonsense assumption that each species has an underlying causal nature, or essence, which is uniquely responsible for the typical appearance, behavior and ecological preferences of the kind (Atran, Estin, Coley & Medin, 1997; Atran, 1998; Atran, et al, 2001; Sousa, Atran & Medin, in press; cf. Gelman and Wellman, 1991). We speculate that this notion of biological essence may be universal. People in diverse cultures consider this essence responsible for the organism's identity as a complex entity governed by dynamic internal processes that are lawful even when hidden. This 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 conceptualized as the same animal although they look and behave very differently, and live in different places. Western philosophers, such as Aristotle and Locke, attempted to translate this commonsense notion of essence into some sort of metaphysical reality, but evolutionary biologists reject the notion of essence as such (e.g. Mayr, 1982). Nevertheless, biologists have traditionally interpreted this conservation of identity under change as due to the fact that organisms have genotypes separate from phenotypes.

Although science does not abide metaphysical essentialism, there is a wide variety of evidence supporting the notion of psychological essentialism (Ahn, et al, 2001); that is, even when people do not have specific ideas about essences they may nonetheless have a commitment to the idea that there is an underlying nature (i.e., they may have an "essence placeholder;" Medin and Ortony, 1989). This hidden, causal essence is presumably responsible for the manifest properties of the kind.[2] The fact that biological science can overturn psychological essentialism in theory construction in no way implies that psychological essentialism can be dismissed 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 (Atran, 1987).

For the moment we will defer addressing the question of whether a hierarchical taxonomy and the presumption of essence are domain-specific (see Hirschfeld, 1995, and Atran, 1995 for one round of arguments). It is clear that different kinds of categories may conform more or less well to a hierarchy (many social categories do not) and people may, at least in a weak sense, essentialize all categories (see Rips, 1995). But a system of rank is not simply a hierarchy, as some suggest (Rosch 1975, Carey 1995) and it is less clear that there is anything corresponding to a cross-culturally stable sense of rank for nonbiological kinds (for an attempt to do so for artifacts, see Brown, Kolar, Torrey, Troung-Quang & Volkman, 1976). None of our central claims hinge on whether or not patterns of categorization and reasoning are confined solely to naïve biology.

Summary. We believe that there are strong constraints on how people organize their local knowledge of biological kinds. These evolutionary constraints form a "learning landscape" that shapes the way inferences are generalized from particular instances or experiences. It produces consensus even though specific inputs vary widely in richness and content. Thus, many different people, observing many different exemplars of dog under varying conditions of exposure to those exemplars, may nonetheless generate more or less the same concept of dog.

To say an evolved biological structure is "innate" 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).

A culturally-specific learning landscape further constrains the canalization process, much as an artificially-built dam further channels the flow and shapes the path of water in a natural river basin. Cultural landscapes include ecological contours, so that the cultural paths chosen in life suggest an analogy to physical paths (Sperber, 1996; Atran, in press).

The existence of a physical path depends upon the:

(i) nature of the path's ecological setting, which constrains where it can be made to go;

(ii) behavioral itineraries that groove the path and determine where in fact the path leads; and

(iii) cognitive models that give purpose and direction to the path.

Likewise, the existence of any systematic distribution of ideas and behaviors, or cultural "path," results from an integration of distinct cognitive, behavioral, and ecological constraints that neither reside wholly within minds nor is recognizable in a world without minds. Cultural paths do not exist apart from the individual minds that constitute them and the environments that constrain them, any more than a physical path exists apart from the organisms that tread it and the surrounding ecology that restricts its location and course. As Hatano and Inagaki (in press) suggest, it is the confluence of these various sources of constraints that makes the cross-cultural comparisons possible.

Our burden of proof is to show that the above analogy forms a meaningful pattern rather than a mish-mash of vague ideas and speculations. As a guideline and overview, we provide a summary of our central theoretical and empirical claims, along with our assessment of the corresponding state of evidence, in Table 1. We will return to this table in the General Discussion.

Insert Table 1 about here

Our claims concerning folkbiology rely heavily on comparative research, typically within- and across-cultures. One cannot begin to conduct this type of research without making a series of methodological and conceptual commitments that constitute a view or theory of culture (and cultural comparisons). Before presenting our research program in folkbiology, we first outline the view of culture that has organized much of our research. As will be evident, methodological and conceptual approaches to cultural psychology are closely entertwined. The power and benefit of this conception of culture will be how it (a) changes the way that we think about cultural similarities and differences, and (b) leads to clear predictions about such similarities and differences.

III The Distribution View of Culture

The view of cultural paths in the previous section leads naturally to a distributional view of culture. *We believe that cultures should be studied as causally distributed patterns of mental representations, their public expressions, and the resultant behaviors in given ecological contexts*. Representations that are stable over time within a culture, like those that recur across cultures, are readily produced, remembered and communicated. The most memorable and transmissible ideas are those most congenial to people's evolved, modular habits of mind. Once emitted in a cultural environment, such core-compatible ideas will spread "contagiously" through a population of minds (Sperber, 1985). They are learned without formal or informal teaching and, once learned, cannot be easily or wholly unlearned (Atran and Sperber, 1991). One significant departure from a shared norms and rules perspective is that the distributions of ideas are themselves objects of study and disagreement across observers is treated as signal, not noise.

Before describing the distributional view in detail, we provide a backdrop by considering some of the conceptual and methodological hazards associated with cultural comparisons. One reason that comparative research has not been popular is that it is not always clear how to do it successfully. When one compares two groups and finds clear differences interpretative problems quickly emerge. Which of the many ways in which the two groups differ are crucial? For example, López, Atran, Coley, Medin, and Smith, (1997) found that US undergraduates and Itza' Maya of Guatemala showed different patterns of responding on a category-based inductive reasoning task involving mammals. Although this undermines the universality of the particular reasoning phenomenon, the two groups differ in myriad ways (e.g. age, education, literacy, livelihood, language, cosmology and so on). Which of these differences matters? Practically speaking, it may be impossible to disentangle these various factors. Without a clear theory to guide interpretation, one may be confronted by the dilemma of findings that consist of either weakly informative similarities or uninterpretable differences. Even when interesting cultural differences are uncovered, culture, at best, represents a promissory note for an explanatory debt (cf. Cohen, 2001; Nisbett, Peng, Choi, and Norenzayan, 2001).

A second and related problem is more conceptual in nature. Suppose we could control for age, education, literacy and the like in comparing Itza' Maya and undergraduates. How do we decide which variables represent "culture" and, therefore should not be controlled, and which variables do not and should be controlled. The Itza' Maya practice agro-forestry and also hunt and collect plants in the forest. Should these factors be controlled or are they part of Maya culture?

Now suppose that we control for every variable we can think of and still find differences. In this case, it seems that one is more or less forced to reify or essentialize culture. That is, the only explanation of the cultural difference involves appealing to some abstract notion of "culture." In short, it seems we may be caught between two equally undesirable possibilities: One is to end up with a notion of culture that solely has recourse to circular explanations of differences ("the Itza' are different because they are Itza'"). The other is to conclude that cultural comparisons just represent confounded experiments and that the notion of culture is not needed once proper experimental control is achieved.

The third problem associated with comparative research is the issue of sampling. If we want to know how the Itza' categorize and reason, it seems that we had better take a random sample of Itza', else our results may not generalize to the Itza' population as a whole. But the sample used by López, et al, 1997, was anything but random---it consisted of Itza' Maya elders who speak Itza' Maya. That fact alone makes the sample unusual and unrepresentative because Itza' Maya is a dying language; the "typical" Itza' speaks mainly Spanish. How can one justify nonrandom sampling?

Each of the above three problems stems from two related biases associated with culture comparisons. One bias, already mentioned, is to essentialize culture; the other is to treat culture as if it were an independent variable. We believe that if progress is to be made in cultural comparisons, both biases must be explicitly addressed and overcome. In the next section, we describe the strategy for cultural comparisons.

<u>An approach to comparative research</u>. There is no theoretically-neutral way to define culture. We have just suggested that the idea that culture is whatever is left when all potentially confounding variables are controlled is self-defeating. Granted, it is useful to control for variables that are clearly irrelevant to culture. But one must bear in mind that decisions about what is irrelevant are necessarily theory-based and commit one to a particular notion of culture.

Let's start with the view that cultures are best described in terms of a more or less widespread distribution of ideas (broadly construed) and behaviors in a group. Cultural differences in these distributions are what one seeks to understand. Note that we are characterizing, not defining culture. In this sense we are relying on folk conceptions of culture and seeking to understand them much as biology has relied on folk notions of species as a steppingstone to a deeper analysis (e.g. Atran, 1990). We know from social psychology that people tend to exaggerate between group differences and minimize within group differences, and that some groups may self-consciously make decisions with the goal of preserving and introducing group differences as a means of promoting cultural identity. Our approach is distinct in that it studies the distribution of ideas rather than simply assuming that cultures are homogeneous. Note also that for this approach to be meaningful, it has to make some theoretical commitments as to which ideas should be studied and which differences are candidates for closer scrutiny. The distribution view rejects essentialism and the associated idea that culture is a form of explanation of differences. It treats cultural differences as phenomena to be explained, as beginning points, not an endpoints.

The distribution view and comparative research methods. Treating cultural differences as a beginning point serves to clarify three other issues associated with comparative research: First, it avoids the (often ethnocentric) straightjacket of considering "culture" a well-bounded system or cluster of practices and beliefs (see Bruman, 1999, for examples) in favor of using a set of techniques for assessing group-wide patterns that statistically demonstrate, rather than assume, cultural consensus. In our work we have relied extensively on the cultural consensus model (CCM) of Romney, et al (1986), an important tool for analyzing commonalties and differences within and across cultural groups.

The Cultural Consensus Model. Before describing the cultural consensus model in detail some general notes of caution are in order. The CCM does not prescribe which ideas should be studied any more than analysis of variance dictates which variables should be measured. It is not a theory of culture or a theory of the cultural transmission of information. Rather it is a tool that can be used to evaluate such theories.

The cultural consensus model assumes that widely-shared information is reflected by a high concordance among individuals. When there is a single cultural 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). This model is successful to the extent that the data overall conform to a single factor solution (the first latent root is large in relation to all other latent roots) and individual scores on the first factor are strongly positive. Of course, general agreement may be coupled with systematic disagreement. The CCM is an effective tool for uncovering both shared and unshared knowledge. Another desirable characteristic of the CCM is that degree of agreement can be used to determine the minimum sample size needed to estimate the cultural consensus within some range of tolerance. In some of our studies as few as ten informants are needed to establish a consensus.

After the consensus parameters are estimated for each individual, the expected agreement between each pair of subjects is generated (as the product of their respective consensus parameters). Next, the standardized expected agreement matrix is subtracted from the standardized raw agreement matrix to yield a matrix of deviations from expected agreement (cf. Hubert & Golledge 1981). If raw and residual agreement are significantly associated, then a significant portion of residual agreement consists of deviations from the consensus. One can then explore other factors (e.g. cultural subgroups, social network distance), which might predict or explain the residual agreement. For example, Boster (1986) found that among the Aguaruna Jívaro people there was a shared cultural model for the identification of various varieties of manioc and that deviations from this shared model were related to membership in kin and residential groups (that is, agreement within these groups is higher than what one would predict on the basis of the overall cultural model).

The CCM not only justifies the aggregation of individual responses into a "cultural model," but also allows the possibility of combining the consensual cultural models of different populations into a "meta-cultural" model. This promotes exploration of possible pathways of learning and information exchange between cultural groups. This, in turn, can illuminate more general processes of cultural formation, transformation and evolution. With the CCM in hand as a methodological tool, we are ready to return to the distribution view of culture.

A second property of the distribution view of culture is that it leads one to employ sampling techniques most likely to reveal cultural differences rather than focusing on estimating population parameters. Consider again the López, et al studies with the Itza' Maya. Younger Itza' might have notions of biology that differ from those of Itza' elders, differences that reflect an assimilation to "Western culture." Thus a random sample may tend to hide rather than reveal cultural differences. Instead of randomly sampling farmers, López et al restricted their sample to Itza'-speaking Maya as the best representatives of Itza' culture. It's not that there was some pure Itza' culture in the past that nowadays is being degraded---cultural change is a constant. Itza' cultural life is a rich blend of ideas and habits stemming from different inputs, including a great deal of Spanish influence. Cultures are not static but relentlessly develop, dissolve, merge and mutate. Nonetheless, it seems sensible to look for sharp contrasts by means of selecting subpopulations that have retained more traditional knowledge. A random sample is only appropriate when one wants to make claims about population parameters, something that we believe is rarely relevant in cultural comparisons.

A third aspect of the distribution view is that once cultural differences are found it is natural to ask a series of more analytic questions about things like: 1. When and how do these differences emerge in development? 2. Are these ideas spread by means of abstract models and inference strategies or is the information conveyed in quite literal, concrete form? 3. Do factors like income or occupation or density of social networks or a variety of other input conditions moderate cultural differences (either within or between groups)? Note that one may look for variations that would be welcome by the "control for everything but culture" advocates, but within the present framework the goal in studying variation is quite distinct-- to have a theory about the distribution of ideas and flow of information, not to isolate some (magical, reified) entity, "culture."

IV. Study Populations and Related Methodology.

If it should turn out that different knowledge systems, goals and activities differentially affect people's ways of conceptualizing the natural world, then lopsided attention to a select participant pool (e.g. undergraduates at major research universities) risks overgeneralization and biases in interpretation. In the worst case, undergraduate performance becomes something of a standard, and when comparisons are made with different populations, any differences may be wrongly interpreted as 'failing' a given experimental task or being under the influence of 'extraneous' factors when performing it.

In the next several paragraphs we will describe the main study populations in our research. This will lay the groundwork for a discussion of a methodological strategy associated with cross-group comparisons. The reader less interested in the specific characteristics of the populations may wish to skip ahead to that section.

Mesoamerican populations. A good deal of our work concerns three cultural groups in the same municipality in Guatemala's Department of El Petén: native Itza' Maya, Spanish-speaking immigrant Ladinos and immigrant Q'eqchi' Maya. In all groups, men are primarily occupied with practicing 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 semitropical, with quasi-rainforest predominating (tropical dry forest or hot subtropical humid forest). Topographic and microclimatic variation allow for a dramatic range of vegetation types over relatively small areas, and sustaining both this diversity and people's livelihood over the last two millennia has required correspondingly flexible agro-forestry regimes (Sabloff & Henderson, 1993; Atran, 1993).

Native Itza' Maya. The Itza', who ruled the last independent Maya polity, were reduced to corvée labor after their conquest in 1697. San José was founded as one of a handful of "reductions" for concentrating remnants of the native Itza' population (and fragments of related groups). In 1960, the military government opened the Petén (which includes 35,000 km2, about 1/3 of Guatemala's territory) to immigration and colonization. In the following years, about half the forest cover of Petén was cleared. In a project engineered by the Agency for International Development (USAID) and supported by a debt for nature swap, Guatemala's government set aside remaining forests north of $17^{0}10'$ latitude as a Maya Biosphere Reserve, a designation recognized by UNESCO in 1990. The San José municipality now lies within the Reserve's official "buffer zone" between that latitude and Lake Petén Itza to the south. Today San José has some 1800 habitants, about half of whom identify themselves as Itza', although only older adults speak the native tongue (a Lowland Mayan language related to Yukatek, Mopan and Lakantun).

Immigrant Ladinos**.** The neighboring settlement of La Nueva San José was established in 1978 under jurisdiction of the Municipality of San José. The vast majority of the 85 immigrant households (about 600 people) are Ladinos (native Spanish-speakers, mainly of mixed European and Amerindian descent) most of whom were born outside of Petén. The majority migrated to the area in the 1970s as nuclear families stemming from various towns of southern Guatemala.

Q'eqchi' Maya .The hamlet of Corozal, also under jurisdiction of the Municipality, was settled at the same time by Q'eqchi' speakers, a Highland Maya group from the Department of Alta Verapaz just south of Petén. Q'eqchi' filtered in as nuclear families, migrating in two waves that transplanted partial Highland communities to Corozal: a) directly from towns in the vicinity of Cobán (capital of Alta Verapaz), b) indirectly from Alta Verapaz via the southern Petén town of San Luis (home to a mixed community of Q'eqchi' and Mopan Maya). Q'eqchi' immigration into Petén began as early as the 18th century, though massive population displacement into Petén is recent. The Q'eqchi' now constitute the largest identifiable ethnic group in Petén while maintaining the smallest number of dialects and largest percentage of monolinguals (Wilson 1995:38; cf. Stewart 1980). This reflects the suddenness, magnitude, and relative isolation of the Q'eqchi' migration. Although many of the nearly 400 Q'eqchi' of Corozal understand Spanish, few choose to willingly converse in it. Q'eqchi' is not mutually intelligible with Itza'. To understand some of our results with Lowland Q'eqchi' immigrants, we have also studied a native Highland Q'eqchi' community.

Yukatek Maya. We have also worked with children and adults from Yukatek-speaking rural villages in southcentral Quintana Roo, Mexico. Yukatek Maya were chosen because of their close linguistic and cultural connection with our well-studied Itza' population, and because there are thousands of Yukatek-speaking children but no more children who speak Itza' as their first language.

North American Populations. It has also been helpful to collect data from a number of USA populations. When we began to study folkbiology with the standard undergraduate populations it soon became clear that the typical college student knows very little about plants and animals. Consequently we sought out a variety of other US populations. For analogous reasons (compare Stross, 1973 with Dougherty, 1978) our developmental studies involved several different groups.

Undergraduates. This group hardly needs description. They consist of students taking introduction to psychology at major research universities in the Midwest.

Biology "Experts." This category includes diverse groups with distinct kinds of expertise: Bird watchers, parks maintenance workers, landscape architects, and professional taxonomists. They typically had at least 20 years experience in their occupation or avocation.

Menominee. Adults. The Menominee ("Wild Rice People") are the oldest continuous residents of Wisconsin. Historically, their lands covered much of Wisconsin but were reduced, treaty by treaty, until the present 95,000 hectares was reached in 1854. There are 4-5000 Menominee living on tribal lands in and around three small communities. Over 60% of Menominee adults have at least a high school education and 15% have had some college. The present site was forested then and now - there are currently about 88,000 hectares of forest. Many of the vast Great Lakes forests did not survive the post civil war flurry of logging. In contrast, Menominee have practiced logging on a sustainable basis for the last 150 years. The Menominee reservation is managed by a tribal legislature. Sustainable coexistence with nature is a strong value (Hall & Pecore, 1995). Hunting and fishing are important activities for most adult males and for many females.

Children. The Menominee children attended an elementary school on the Menominee reservation. Although they tend to know some Menominee words, especially those for clan animals, they are basically monolingual English speakers.

Rural Majority Culture. Adults. Adjacent to the Menominee reservation is Shawano County, which consists of farmland, small forests, and numerous lakes and rivers. Hunting, fishing, water recreation in the summer, and snow-mobiling in the winter are popular activities. Our adult participants came from in and around the community of Shawano.

Children. The majority culture children attended an elementary school in Shawano. About 20% of the children live on farms. As in the case of the Menominee children, it is not uncommon for preschool children to be introduced to fishing.

Urban children. The urban children attended an elementary school in Boston, Massachusetts. The school is located in East Boston and serves a middle class community.

Summary. Although the set of populations described above seems extremely heterogenous, our population contrasts were aimed at providing more leverage than would be possible with a single cross-group comparison. We have often relied on what we refer to as a "triangulation" strategy.

Triangulation as a research strategy. Because (cultural) groups cannot be found that represent orthogonal combinations of variables, it may be in principle impossible to disentangle the various sources of variation among groups. The general idea of triangulation is to use observations from a third group to get at least modest leverage for understanding initial group differences. The third group should resemble one group in some potentially important ways and the second group in other ways. If the third group performs like one of the groups and different from the other group, then the variables shared by the third group and the group it mimics become candidates for critical variables.

To illustrate this strategy, consider López et al, 1997. In that study, we compared Itza' Maya elders and University of Michigan undergraduates on categorization and reasoning involving local mammals (local to Petén, Guatemala and Michigan, USA, respectively.) In this task, people were told that one or more mammals could get some novel disease and then asked about what other mammals also might get the disease. For example, when people are told that coyotes get some new disease they may be more sure that wolves also get this disease than that cows get this disease. In this case, participants may be reasoning in terms of (taxonomic) similarity because coyotes are more like wolves than they are like cows. Both Itza' and USA undergraduates show reliable similarity effects.

Other arguments involved two premises. Suppose you are told that there is one new disease that we know affects coyotes and wolves, and another new disease that affects coyotes and cows. Now we ask which disease is more likely to affect all mammals. University of Michigan undergraduates overwhelmingly say the disease that coyotes and cows get is more likely to affect all mammals. They justify their answers by appealing to the dissimilarity of the two premises, or diversity. That is, they say that if some disease affects such different mammals as coyotes and cows, it is likely to affect all mammals. This reasoning strategy seems straightforward and the Osherson, Smith, Lopez, Wilkie, and Shafir, 1990, model for category-based reasoning predicts that people will prefer more diverse premises in drawing inductions to a category. What is surprising is that the Itza' Maya do not show a diversity effect. In some cases they are reliably below chance in picking the more diverse premises on these kinds of tests.

Why don't the Itza' use a diversity-based reasoning strategy? Obviously, there are any number of hypotheses one could conjure up. Perhaps the question wasn't asked quite the same way in Itza' Maya (back translation is no guarantee of equivalence), or perhaps formal education is a pre-requisite for this form of abstract thought, or perhaps the Itza' have a very different conceptualization of disease. It just isn't clear.

Here is where our triangulation strategy proved to be effective. In this case the third group was USA tree experts who were asked to reason about novel tree diseases. USA tree experts resemble Michigan undergraduates in many respects (language, formal education, etc.) and resemble Itza' with respect to having considerable domain knowledge. A typical diversity probe might be as follows: "White pine and weeping willows get one new disease and river birch and paper birch get another. Which is more likely to affect all trees?" Using these kinds of probes Proffitt, Medin, and Coley (2000) found that parks workers, like the Itza', showed reliably below chance diversity responding. Later on, we will describe what strategies Itza' and parks workers share. For now, we simply note that the triangulation strategy pinpoints domain knowledge as a key variable in diversity responding (though as we'll see, it is not the whole story).

At first glance, it might appear that the triangulation strategy is just a 2 X 2 design with one cell missing. But a 2 X 2 design presumes what the triangulation strategy is intended to discover, namely, which factors are crucial to group differences. The logic of triangulation implies compression of any number of possible 2 X 2 designs that together entail a host of possible explanations for group differences. Instead of 2^N controlled designs, each of which allows inference to a single factor, a carefully chosen third group deliberately confounds a number of variables. By carefully choosing a third group, C, that resembles the first group, A, in a number of ways and the second group, B, in a number of other ways one can assess the relative importance of the set of culturally-confounded variables by which C differs from A versus those by which C differs from B.

A 2 X 2 design also implies more precise matching and control of variables than is realistic in cross-cultural comparisons. To gain further leverage the triangulation strategy can be applied iteratively at different levels of resolution. For example, suppose we were to find that US experts resembled Itza' experts in some ways but differed from them in other ways. Rather than attributing any differences to culture, one might well attempt to develop another triangular comparison involving Itza' experts, US experts with goals and activities resembling those of the Itza', and US experts with goals and activities distinct from the Itza'. Again, it would be unlikely that one could obtain a precise match on goals and activities; however, one might well be able to produce greater cross-cultural than within-culture similarity in goals and activities.

A Final Methodological Point. The streets of unfortunate cross-cultural comparisons are strewn with studies that began with methodologies developed in the USA and then rigidly applied to other populations of interest. It is very important to be sensitive to the potential for cultural misunderstandings arising from task instructions and interpretation. This threat can be substantially reduced through careful pretesting informed by ethnographic, ethnohistorical, ethnobotanical and ethnolinguistic preparation.

For example, broad cross-cultural agreement in biological categorization should not conceal the fact that different elicitation procedures may yield different patterns of taxonomic or ecological sorting. Thus, in pretests with Itza', we asked them to sort things most "similar" (b'ay) or "alike" (je-b'ix) to replicate as closely as possible instructions given to American subjects (e.g., Boster & Johnson, 1989). Initial results were discouraging: consensus across participants was low, and informants seemed to justify sorts by often idiosyncratic and conflicting notions of use (e.g., horses and cows are more similar to one another than to tapirs because tapirs don't carry loads; tapirs and cows are more similar to one another than to horses because horses are not eaten at festivals). But ethnohistory indicates that the expression of a deeper taxonomic reasoning endures over time (Trager, 1939; Bartlett, 1940). Thus, 16th century Itza' taxonomically assimilated the horse (a perissodactyl) 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, et al, 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."

Similar sorts of analyses and pretesting accompanied preparation of all of our instructions. One advantage of tailoring instructions to a variety of nonstandard populations is that they can be further applied to other populations with greater ease and confidence than if they had been simply translated from instructions given to undergraduates or other groups affiliated with large research universities and urban environments in the USA. Moreover, we have found that the instructions so pre-tested usually can be successfully reapplied to standard populations.

Summary. We have spent considerable time in describing our framework for comparative research in folkbiology, in part because of its contrast with previous approaches to culture and comparison. The stage is now set to begin a systematic review of empirical results in relation to theories. In each study set, our findings contrast sharply with previous generalizations.

V. Relation of Folkbiology to Folk Psychology

One influential model of conceptual development in folkbiology is Carey's (1985, 1995) notion that young children's understanding of living things is embedded in a folkpsychological, rather than folkbiological, explanatory framework, and that until age 10, it is based on their understanding of humans. One particularly strong form of evidence comes from an inductive inference task where children are told that some novel property is true of one biological kind (e.g. "Humans have a little green thing inside them called an omentum.") and then are asked whether that property is true of other biological kinds (e.g. "Do you think that dogs also have an omentum?"). Carey reports three major findings to bolster the claim that children's conceptions of the biological world are anthropocentric. First, children more readily project properties from humans to other living kinds than they project properties from other living kinds to one another or to humans. The other two findings are consequences of this difference in induction potential. The second result is that there are asymmetries in projection: inferences from human to mammals are stronger than from mammals to humans. Third, 4-year old children violate projections according to similarity: inferences from humans to bugs are stronger than from bee to bugs. Together, these findings suggest that humans are the preferred base for children's inferences about the biological world.

Carey's claims have not gone unchallenged. Some developmental researchers have argued that young children do have distinct biological theories (e.g. Coley, 1995; Gelman and Wellman, 1991; Gelman and Hirschfeld, 1999; Hatano and Inagaki, 1995, 1999; Hickling and Gelman, 1995; Keil, 1995; Springer, 1992, 1996 but see also Solomon, Johnson, Zatchik, and Carey, 1996) and there is other work which suggests that the relative prominence of psychological versus biological construals of biological kinds is sensitive to contextual factors (Guntheil, Vera and Keil, 1998). So far, however, these challenges have focused on methodological issues. Our work suggests that there is an important cultural and experiential dimension that merits attention.

This research on children's biology has been conducted almost exclusively with individuals from North American, urban, technologically-advanced populations. In the few studies that go beyond this sample (e.g. studies by Inagaki and Hatano in Japan), the focus is still on urban, majority-culture children from technologically-advanced societies. Thus, it is not clear which aspects of children's naïve biology are likely to be universal and which depend critically on cultural conceptions and conditions of learning. Human-centered reasoning patterns might reflect lack of knowledge about nonhuman living things rather than a radically different construal of the biological world.

To evaluate the role of cultural milieu and conditions of learning in children's inductive reasoning we have studied four populations: urban Boston children, rural Wisconsin majority culture children, Menominee children, and Yukatek Maya children of varying ages (4 to 11) and adults (Ross, et al, 2002), Atran, et al, 2001). All testing in the USA was in English; Yukatek Maya was used for the Maya children and adults.

Detailed color drawings of objects were used to represent base and target categories. Four bases were used in Mexico: Human, Dog, Peccary and Bee. Targets were divided into two sets. Each set included a representative of the categories Human (man, woman), Mammal (coatimundi, deer), Bird (eagle, chachalaca), Reptile (boa, turtle), Invertebrate (worm, fly), tree (Kanan, Gumbo Limbo), Stuff (stone, mud), Artifact (bicycle, pencil) and Sun (included in both sets). The USA populations were given Human, Wolf, Bee, Goldenrod, and Water as bases and a corresponding set of mammals, birds, reptiles, invertebrates, plants, stuff and artifacts as targets.

As in Carey's studies, children were shown a picture of one of the bases and taught a new property about it. For example, the experimenter might show the dog picture, and say, "Now, there's this stuff called andro. Andro is found inside some things. One thing that has andro inside is dogs. Now, I'm going to show you some pictures of other things, and I want you to tell me if you think they have andro inside like dogs do." Participants were then shown each of the targets and asked: "Does it have andro inside it, like the [base]?" Properties were unfamiliarly internal substances of the form "has X inside." A different property was used for each base.

Results. The pattern of responding varied substantially across groups. The young urban USA children (5-6-year-olds) generalized in a broad, undifferentiated manner and the only clear trend was greater generalization from a human base to a human target than to other targets. Older urban children (9-10-year-olds) generalized in terms of biological affinity but showed a strong asymmetry in reasoning between humans and other animals. Overall, data from urban children provide a rough replication of Carey's original results.

The young, rural majority culture children revealed a different pattern; they showed the mature pattern of generalizing in terms of biological affinity. Interestingly, both they and older rural children showed asymmetries in reasoning between humans and animals and often justified a failure to extend a property from an animal to humans on the grounds that "people are not animals." This observation implies that the asymmetry does not derive from humans being conceptualized as the "prototypic" animal. Instead, seeing humans as animals may be something of a developmental achievement, as suggested by Johnson, Mervis, and Boster (1992). Finally, the older rural children gave some evidence of reasoning in terms of ecological relations, as when they justified generalizing from bees to bears on grounds that a bee might sting a bear or a bear might acquire the property by eating the bee's honey.

The Menominee children demonstrated yet a third pattern. First of all, even the youngest Menoninee children often reasoned in terms of ecological relations. In addition, children of all ages generalized in terms of taxonomic relatedness and showed no reliable human-animal asymmetries. The Menominee origin myth has people coming from the bear, and even the youngest children are familiar with the animal-based clan system. In short, there is some cultural support for a symmetrical relation between humans and other animals.

Findings from studies of inductive projection among Yukatek Maya also do not replicate Carey's results with urban American children (compare Figures 1 and 2) and are not consistent with the claim that folkbiology is anthropocentric until late childhood. Here we present data from younger children (4-5 year-olds). First, for Yukatek Maya children, like the Menominee children: 1. Projections from humans are no stronger than projections from other living kinds. 2. There is no overall human-animal asymmetry. 3. Young children do not violate their own perceptions of similarity out of preference for humans as an inductive base.

Insert Figures 1 and 2 about here

There are, however, some asymmetry effects for the youngest Yukatek girls with respect to a wild versus domestic animal base (Human -> mammal > Peccary -> human) and for the youngest children overall with respect to inferences involving invertebrates. The fact that such asymmetries are not generalized across the youngest age group suggests that they are the result of familiarity rather anthropocentric bias as such. Younger girls are less familiar with wild animals than younger boys, and younger children on the whole are less familiar with invertebrates than they are with humans or mammals. Less familiarity with wild animals and invertebrates may favor them less as sources of induction. The fact that dogs are a better base for induction than are peccaries is consistent with this observation. Apparently, the more properties a child knows about some kinds, the more likely they are to generalize some new property to other living kinds.

In important respects the data imply that humans are not a good inductive base for children. First, the fact that young children (especially the girls) generalize in a fairly undifferentiated way from humans suggests that they may not have a clear grasp of how humans fit into the tree of life. (The young girls show the same pattern with the peccary, an animal with which they are unfamiliar.) Second, older children and adults generalize more from nonhuman mammals to other mammals than they do from humans to mammals. This indicates that humans are, in some respects, special. This is consistent with the observation of Johnson et al. (1992) that many children do not think of humans as animals.

On the whole, Yukatek Maya children look much like Menominee children but with some intriguing gender differentiation. These gender differences may reflect the strong sexual division of activity that is institutionalized early in the first year of life. In the <u>jeetz~meek'</u> ceremony, Maya girls are introduced by the women to household utensils, whereas Maya boys are introduced by the men to agricultural and hunting tools. Later in life, Maya women will spend their time almost wholly in the vicinity of the house and house garden, in close interaction with domestic animals. By contrast, Maya men spend days, weeks and even months in the forest away from home. For Maya females, dogs are household animals, whereas men value dogs as hunting animals. Maya boys also venture out into the forest with their fathers at an early age, and so become familiar with wild animals, such as the peccary, before girls do. These findings suggest that induction patterns may be influenced by relative familiarity with animals and by the culturally-specific character of the functional and ecological relationships between humans and other natural categories of elements.

Overall, these results indicate that folkpsychology is not a necessary or universal source for folkbiology. Instead, it appears that lack of intimate contact with plants and animals is responsible for the anthropocentric bias observed with urban American children. Consistent with this view, Inagaki (1990) presents evidence that experience influences children's biological reasoning. She found that kindergarteners actively involved in raising goldfish were more likely than their counterparts who did not raise goldfish to reason about a novel aquatic animal (a frog) by analogy to goldfish rather than by analogy to humans.

Childhood Conceptions of Species Essences. Given the framework outlined at the beginning of this paper we would expect that essentialism would be among the most robust features in children’s (and adult’s) reasoning. Young of a species have the potential to develop certain adult characteristics before those characteristics appear. The origins of these characteristics can be explained in two broadly different ways: nature and nurture. Some characteristics seem likely to develop from birth because they are essential to the species to which the individual belongs, such as a squirrel’s ability to jump from tree to tree and hide acorns. Other characteristics are determined by the environment in which the individual is reared, such as a squirrel’s fear or lack of fear of human beings.

Gelman and Wellman (1991) argue that young children predict category-typical characteristics of individual animals based on the innate potential of the animal (i.e. the species of its birth parent) rather than the environment in which it was raised (i.e. the species of its adoptive parent). Using an adoption study, they showed that four-year-old children judge that a baby cow raised by pigs will have the category-typical characteristics of cows (*moos, straight tail*) rather than pigs (*oinks, curly tail*). They interpret the results as showing that preschoolers believe that the innate potential or essence of species determines how an individual will develop, even in contrary environments.[3]

This study has been criticized as inconclusive with regard to children’s assumptions about innate potential for two reasons. First, before the children in the study predicted the adult properties of the adopted baby, they were shown a drawing of the baby animal and told its species identity. Because the experimenters told the child that the baby and mother were of the same species, the study does not address the question of how the children identify to which species the baby belongs in the first place (Johnson & Solomon, 1997). To demonstrate that the children attribute property origins to inheritance from the birth species requires that the children make the same inferences in the absence of any explicit prior identification of the baby’s birth species (see Solomon et al., 1996). Given this explicit verbal identification, one cannot rule out that the children’s performance owes to an essentialist bias that is a general property of language. Because the animal was labeled as being a member of a particular species, children might expect that this identity is maintained over time, and that the animal would continue to have the properties of the labeled species, even in the absence of reasoning about the mechanism involved (Gelman & Hirschfeld, 1999). [In another study, however, Gelman and Wellman (1991) asked children to reason about plants without identifying the species membership. For example, they described a seed that came from an apple and was planted in a field a corn, without identifying the seed as “an apple seed.” The results were largely the same as with the animals (cf. Hickling & Gelman, 1995).]

Second, the study explored only known facts about species and their associated properties. It did not examine whether or not children use the concept of species essence or biological parentage as an inferential framework for interpreting and explaining hitherto unknown facts. It may be that a child has learned from experience, and as a matter of fact, that a calf is a cow because it was born to a cow. Still, the child may not know that having certain kinds of parents causes a cow to be a cow (Carey, 1995).

We have been studying several culturally-distinct populations to test the extent to which children’s assumptions about innate species potential govern projection of both known and unknown properties. In one study (for details see Atran et al, 2001), Yukatek Maya children and adults were presented with a forced-choice task involving an adoption scenario. They were asked whether an adult animal adopted at birth would resemble its adoptive parent (e.g., cow) or birth parent (e.g., pig) on four different individual traits: known behaviors (e.g. *moo* / *oink*), known physical features (e.g. *straight* / *curly tail*), unknown behaviors (e.g. *looks for chachalacas* / *looks for pigeons*), and unknown physical features (e.g. *heart gets flatter* / *rounder when it is sleeping*). Known traits were context-free, category-typical features that the children readily associate with species, whereas unknown traits were chosen to minimize any possibility of factual or pre-learned associations of traits with categories. Each unknown trait within a set was attributed to the birth parent for half the participants and to the adoptive parent for the other half. This assured that projection patterns of the unknown traits were not based on prior associations.

The stories were accompanied by sketches of each parent. Sketches were designed to unambiguously represent a particular species of animal with minimum detail. In addition, sketches of known physical features (e.g. a sketch of a curly or straight tail), unknown physical features (e.g. flat vs. round heart) and relevant aspects of unknown behavioral contexts (e.g., closed vs. open eyes when afraid, stops in front of mahogany vs. cedar trees) were shown to participants. These sketches in no way indicated the species to which the traits belonged.

The story was followed by two comprehension questions: 1.“Who gave birth to the baby? and 2.“Who did the baby grow up with?”. Children then were presented with the experimental probes. For example they might be told: “The cow mooed and the pig oinked. When the baby is all grown up will it moo like a cow or oink like a pig?” The probes were followed by a bias control in which the participant was asked: “When the baby was growing up did it eat with animals that looked like X or animals that looked like Y?” (Notice that this last probe involves an inference and is not simply a memory check).

Overall, the results showed a systematic and robust preference for attributions from the birth parent (see Table 2). This preference was observed for all Yukatek age groups and for known and unknown behavior and physical properties. The trend was somewhat stronger in older children and adults and slightly stronger for known than unknown properties. The low mean on the bias control probe for all groups indicates that the method of the current experiment did not bias participant responses toward the birth parent.

Insert Table 2 about here

Our findings are consistent with the idea that Yukatek Maya children and adults assume that members of a species share an innate causal potential that largely determines category-typical behavioral and physical properties even in conflicting environments. Projection of properties to the birth parent in the face of uncertainty and novelty implies that even the youngest Maya children tested (4-5 yrs.) use the notion of innate species potential, or underlying essence, as an inferential framework for understanding the nature of biological species. In work with USA urban and rural majority culture children, with Menominee children, and with three groups of urban children in Brasilia (Brazil), we also find that young children show a strong pattern of inferencing in terms of birth parents (e.g. Sousa, et al, in press) . The developmental trajectory of this pattern varies across populations, sometimes weakening in older children and other times strengthening. This is consistent with a universal initial assumption of an underlying essence for biological kinds that may be somewhat modified by the cultural landscape.[4] These findings, together with Gelman and Wellman's (1991) earlier results, suggest that such an essentialist bias in children may be universal.

There are two types of objections to our claims that we will briefly consider. One is simply an empirical issue: is this pattern of results truly universal? Bloch, Solomon and Carey (2001) report that 7-10 year-old Zafimaniry children from a remote village in Madagascar reasoning about an adoption scenario show a bias toward adoptive parents, an apparent counter-example to our claims. We have two reservations about this study. One is that the Zafimaniry conception of adoption is different in that it usually involves relatives and is not permanent. Hence, one would have more confidence in a study involving animals other than humans. Second, the features attributed to adoptive and birth parents were not counter-balanced and tended to be much more negative for the adoptive parent. This may also have affected the results. The ideal test case for our hypothesis is a culture where the adults are not essentialists about ethnicity (see Astuti, 1995, but also Gil-White, 2001 for cautions concerning claims about adult conceptions). Here we would still expect that young children would be essentialists (certainly for animals and perhaps for humans as well) even if adults were not (though adults may be essentialists about animals other than humans).

The second objection to our data is that we may be guilty of over-interpreting the results in the sense that projection on the basis of species membership should not be equated with projection on the basis of some essence (see Rips, 2001 for an amplification of this criticism). An alternative view is that children are employing ideas about causal relations but that they may have no notion of "essence" whatsoever (Strevens, 2000). Although this distinction may be subtle, we have discussed it at length elsewhere (see the Ahn, et al, 2001, commentary) and will confine ourselves to a few remarks in the context of summarizing this section.

Summary. Another response to the preceding section is to concede that the empirical observations are accurate but to deny that they meet the criterion for an autonomous folkbiology. One of the more difficult issues in theoretical disputes is separating conflicts over matters of fact from conflicts over meaning. For Carey, demarcation between folkbiology and folkpsychology involves the notion of intuitive framework theory. The attribution of an intuitive framework theory to young child "requires establishing that the child distinguishes entities in the domain of the theory from those not in its domain, and appeals to theory-specific causal mechanisms to explain the interactions among the entities in the domain" (Carey, 1995). On this view, attributing a folkbiology to young children entails attributing a biological causal mechanism that delimits an ontological domain (see also Au and Romo, 1999).

So far, we agree. But Carey's account also implicitly involves two a priori claims with which we do not agree: namely, that (1) causal understanding does not exist in the absence of any detailed knowledge of specific causal laws or mechanisms (see Keil, 1992, 1995), and (2) essentialism is too causally-vague and domain-general to distinguish biology from other domains. Concerning the first claim, the minimum conditions that Carey sets for a properly biological notion of causality tend to overplay the causal mechanisms that adults use to understand biological phenomena: "pre-school children have learned that 'germs' are a cause of disease, but we do not know whether this knowledge goes beyond naming 'germs' as the cause of disease….Such knowledge may simply be a learned input-output relation, such as that eating good foods keeps you healthy and makes you grow, and may not constitute knowledge of any mechanism" (Carey, 1995:284; cf. Kalish, 1993). Thus, 'germ' cannot count as part of a causal mechanism because there is no understanding of the specific processes involved. Ordinary adults, however, may have a barely more elaborate causal understanding of germs or genetics.[5] The problem here is not simply that of overestimating adult knowledge, but rather of implicitly subordinating the notion of causal mechanism to a preconceived standard of explicit detail.

Concerning the second claim, Carey holds that essentialism is not a serious candidate for causally organizing the biological domain because it is simply a general property of language: "Essentialism, like taxonomic structure, derives from the logical work done by nouns. The child has a default assumption that… every count noun carries with it the idea that the identity of the entity picked out by the noun is unchanged in the face of surface changes" (Carey, 1995:277) Nevertheless, this is a different sense of essentialism than the concept of innate causal and inductive potential than we (and others) intend.

On her definition of essentialism, all that is required is some sort of maintenance of identity over time. This notion of essentialism does not distinguish between presumptively complex causal concepts, such as "oak" or "robin", and presumptively simple causal concepts, such as "seat" or "hill" that depend only on surface features that are practically identical with underlying "essence": a seat is a seat because it can be sat upon, no matter whoever or whatever made it, and no matter whatever it is made of; a hill is a hill because it is higher than the surrounding landscape but lower than a mountain, whatever different and independent causes might be responsible for such a state of affairs.[6] Because this relatively unconstrained and a priori definition of essentialism extends to nonbiological concepts, it follows that this notion of essentialism cannot be the demarcating criterion for folkbiology.

Our claim is that from a quite early age children have intuitions that the mechanisms underlying essential causes are biological. The essential causal relations are those involving, for example, birth, biological relatedness and internal structure. It is unlikely that young children have a worked out a specific theory or detailed model that integrates inheritance, growth, physiological functioning, disease, death and so forth; however, it may be plausible to credit them with a generally biological framework.

In summary, the combination of developmental and cross-cultural studies confirms universal aspects of children's folkbiological cognition and suggests that biology is a conceptual domain that is distinct from psychology. These same sorts of comparative studies reveal components of biological cognition that varies systematically as a function of cultural milieu and input conditions (intimacy of contact with nature). Finally, we note that attributions of essences to species-like groupings has implications for the organization and structure of taxonomies and the basic level.

VI. The Essence of the Basic Level.

Ever since the pioneering work of Berlin and his colleagues, ethnobiological evidence has been accumulating that human societies everywhere have similar folkbiological structures (Berlin, Breedlove & Raven, 1974, Hunn, 1977, Hays 1983, Brown, 1984, Atran, 1990, Berlin, 1992). Striking cross-cultural similarities suggest a small number of organizing principles that universally define systems of folkbiological classification. Most folkbiological systems have between three and six ranks. Taxa of the same rank are mutually exclusive and tend to display similar linguistic, biological and psychological characteristics.

The most general rank is the folk kingdom. Examples are PLANT and ANIMAL. Such taxa are not always explicitly named, and represent the most fundamental divisions of the biological world. These divisions correspond to the notion of "ontological category" in philosophy (Donnellan, 1971) and psychology (Keil, 1979). From an early age, it appears, humans cannot help but conceive of any object they see in the world as either being or not being an animal (Inagaki & Hatano, 1993) and there is evidence for an early distinction between plants and nonliving things (Hatano & Inagaki, 1999). Conceiving of an object as a plant or animal seems to carry with it certain presumptions that are not applied to objects thought of as belonging to other ontological categories, like the category of substance or the category of artifact (Keil, 1989).

The next rank down is that of life form. Most life-form taxa are named by lexically unanalyzable names (primary lexemes), and have further named subdivisions. Examples are TREE and BIRD. Biologically, members of a single life form are diverse. Psychologically, members of a life form share a small number of perceptual diagnostics, such as stem habit, skin covering and so forth (Brown, 1984). Life-form taxa may represent general adaptations to broad sets of ecological conditions, such as the competition of single-stem plants for sunlight giving rise to trees (Hunn, 1982, Atran, 1985). Classification according to life form may occur relatively early in childhood. For example, familiar kinds of quadruped (e.g., dog and horse) are classed apart from sea versus air animals (Mandler, Bauer & McDonough, 1991).

The core of any folk taxonomy is the generic-species level (also called folk generic, Berlin,1992; see Atran, 1990 for a discussion of the historical development of biological categories). Like life-form taxa, generic-species taxa are usually named by primary lexemes. Examples are OAK and ROBIN. Sometimes generic species are labeled as binomial compounds, such as HUMMINGBIRD. On other occasions, they may be optionally labeled as binomial composites, such as OAK TREE. In both cases the binomial makes the hierarchical relation apparent between the generic species and the life form.

Generic species comprise the overwhelming majority of taxa in any folkbiological system. They often correspond to scientific genera or species, at least for the most phenomenally salient organisms, such as larger vertebrates and flowering plants (Atran, 1987, Berlin, 1992). Generic species are also most often the categories most easily recognized, most commonly named and perhaps the most easily learned by children (Stross, 1973). Ethnobiologists who otherwise differ in their views of folktaxonomy tend to agree that one level best captures discontinuities in nature and provides the fundamental constituents in all systems of folkbiological categorization, reasoning and use (Bulmer, 1974, Hunn, 1982, Ellen, 1993). In short, cultures across the world organize readily perceptible organisms into a system of hierarchical levels that are designed to represent the embedded structure of life around us, with generic-species level being the most informative and relevant.

Given these observations, results of psychological studies of privilege or basicness are striking and puzzling. In a justly celebrated set of experiments, Rosch and her colleagues set out to test the validity of the notion of a psychologically privileged taxonomic level (Rosch et al., 1976). Using a broad array of converging measures they found support for the view that there is a "basic level" in category hierarchies of "naturally occurring objects," such as "taxonomies" of artifacts as well as living kinds (cf. Brown, et al., 1976). For artifact and living kind hierarchies, the basic level is the most abstract level where: (1) many common features are listed for categories, (2) consistent motor programs are employed for the interaction with or manipulation of category exemplars, and (3) category members have similar enough shapes so that it is possible to recognize an average shape for objects of the category. The basic level is also preferred in adult naming, first learned by children and the level at which entities can be categorized most rapidly.

Thus, work by Berlin and by Rosch both indicate a privileged level in category hierarchies. Moreover, both claim that this privileged take on naturally occurring objects is directly tied to objective discontinuities in the real world. These objective discontinuities provide the information-rich bundles of perceptual attributes that presumably allow a domain-general perceptual processing mechanism to carve up nature at its fundamental joints.

But here's the puzzle: The basic level that Rosch et al., (1976) had hypothesized for living kinds, which Rosch initially presumed would accord with Berlin's folkgeneric rank, did not prove to be privileged. For example, instead of MAPLE and TROUT, Rosch et al. found that TREE and FISH operated as basic-level categories for American college students. Thus, Rosch's basic level for living kinds generally corresponds to Berlin's life-form level, which is super-ordinate to the generic-species level.

How can we reconcile the discrepancy between Berlin's observations and Rosch's data concerning privileged levels? In one attempt to do so, Dougherty (1978) argued that the basic level is a variable phenomenon that shifts as a function of general cultural significance and individual familiarity and expertise (cf. Tanaka & Taylor, 1991; Johnson and Mervis, 1997). Thus, most folk in industrial societies often have little distinctive familiarity with, knowledge of, and use for various species of trees, fish, birds and so forth. As familiarity with the biological world decreases, there is a gradual attrition of folkbiological knowledge up the hierarchy, with the basic level devolving from the generic-species to the life-form levels.

A related (but alternative) view of the Berlin/Rosch discrepancy is that it is sensitive to how privilege is measured. Specifically, some measures of privilege may be driven more by experience than others (see also Barsalou, 1991). In our studies, we have focused on inductive inference. Inductive inference allows people to extend knowledge beyond their immediate experience and beyond the information they are given, and is a crucial part of category formation and use (Rips, 1975, Smith & Medin, 1981). Our use of inductive inference as a tool is also motivated by the experiments in the last section suggesting that generic species are characterized by a presumption of essence that directs the search for underlying causal principles and theories (cf. Medin, 1989). Inductive inference must be a mainstay of any such search for underlying causal principles.

Although neither Berlin nor Rosch explicitly deal with inductive inference, such inferences are central to understanding the psychological privilege of certain categories. What is truly privileged about CAT relative to MAMMAL is that the amount of information that can be inferred about the category is substantially higher at the level of CAT. For example, knowing that a tabby eats fish, it may be prima facie reasonable to infer that all cats may eat fish, but unreasonable to infer from this that all mammals do. If a privileged level is the most abstract one that carries a large amount of information about the world, then categories at that level should strongly support a wide range of inferences about what is common among members. Specifically, the prediction is that inferences to a privileged category (e.g., WHITE OAK to OAK, TABBY to CAT) should be much stronger than inferences to a superordinate category (e.g. OAK to TREE, CAT to MAMMAL). Moreover, inferences to a subordinate category (e.g., SPOTTED WHITE OAK to WHITE OAK, SHORT-HAIRED TABBY to TABBY) should not be much stronger or different than inferences to a privileged category.

While all ranks may not be relevant to all cultures - or not relevant in the same ways - some categorization processes may be relatively immune to cultural differences. Thus, people from traditional versus high technology cultures may differ in terms of the level at which names readily come to mind, or the level at which taxa are most easily imaged, or the level at which their biological knowledge is most complete. Nevertheless, they may presume that the same rank is privileged for biological reasoning, namely, the rank of generic species.

In tests of ideas about rank and inference, Coley, Medin & Atran (1997) and Atran, et al, (1997) provided evidence that the generic-species level is privileged for induction for both American college students and Itza' Maya adults. Based on extensive fieldwork, we chose a set of Itza' folkbiological categories of the kingdom (K), life-form (L), generic-species (G), folk-specific (S), and folk-varietal (V) ranks. We selected three plant life forms (che' = tree, ak' = vine, pok~che' = herb/bush) and three animal life forms (b'a'al~che' kuxi'mal = "walking animal," i.e., mammal, ch'iich' = birds including bats, käy = fish). Three generic-species taxa were chosen from each life form; each generic species had a subordinate folkspecific, and each folkspecific had a salient varietal.

The properties chosen for animals were diseases related to the "heart" (pusik'al), "blood" (k'ik'el), and "liver" (tamen). For plants, diseases related to the "roots" (motz), "sap" (itz) and "leaf" (le'). Properties were chosen according to Itza' beliefs about the essential, underlying aspects of life's functioning. Properties used for inferences had the form, "is susceptible to a disease of the <root> called <X>." For each question, "X" was replaced with a phonologically appropriate nonsense name (e.g. "eta") to minimize the task's repetitiveness.

All participants responded to a list of questions in which they were told that all members of a category had a property (the premise) and were asked whether "all," "few," or "no" members of a higher-level category (the conclusion category) also possessed that property. The premise category was at one of four levels, either life-form (e.g. bird), generic-species (e.g. vulture), folk-specific (e.g. black vulture), or varietal (e.g. red-headed black vulture). The conclusion category was drawn from a higher-level category, either kingdom (K), life-form (L), generic-species (G), or folk-specific (S). For example, a folk-specific-to-life form question might be, "If all black vultures are susceptible to the blood disease called eta, are all other birds susceptible?" If a participant answered "no," the follow-up question would be "Are some or a few other birds susceptible to disease eta, or no other birds at all?"

The corresponding life forms for the Americans were: mammal, bird, fish, tree, bush and flower (on flower as an American life form see Dougherty, 1979). The properties used in questions for the student participants were "have protein X," "have enzyme Y," and "are susceptible to disease Z." These were chosen to be internal, biologically based properties intrinsic to the kind in question, but abstract enough so that rather than answering what amounted to factual questions participants would be likely to make inductive inferences based on taxonomic category membership

Figure 3 summarizes the results from all Itza' informants for all life forms and diseases, and shows the proportion of "all" responses (black), "few" responses (checkered), and "none" responses (white). For example, given a premise of folk-specific (red squirrel) and a conclusion category of generic-species rank (e.g., squirrel), 49% of responses indicated that "all" squirrels, and not just "some" or "none," would possess a property that red squirrels have. Figure 4 summarizes results of student response scores for all life forms and biological properties. Following the main diagonals of Figures 3 and 4 refers to changing the levels of both the premise and conclusion categories while keeping their relative level the same (with the conclusion one level higher than the premise). Induction patterns along the main diagonal indicate a single inductively preferred level. Examining inferences from a given rank to the adjacent higher-order rank, we find a sharp decline in strength of inferences to taxa ranked higher than generic species, whereas V->S and S->G inferences are nearly equal and similarly strong. Notice that for "all" responses, the overall Itza' and student patterns are nearly identical.

Insert Figures 3 and 4 about here

Moving horizontally within each graph corresponds to holding the premise category constant and varying the level of the conclusion. On this analysis, both Americans and Itza' show a large initial break between inferences to generic species versus life forms. However, in the combined response scores ("all" + "few") there is evidence of increased inductive strength for higher-order taxa among Americans versus Itza'. Only American subjects also show a consistent pattern of rating inferences to life-form taxa higher than to taxa at the level of folk kingdom.

Finally, moving both horizontally and along the diagonal, regression analysis reveals a small but significant difference between Itza' inductions using conclusions at the generic-species versus folk-specific levels: V->G and S->G are modestly weaker than V->S. In fact, most of the difference between V->G and V->S inductions results from inference patterns for the Itza' tree life form. There is evidence that Itza' confer preferential status upon trees at the folkspecific level (e.g. savanna nance tree).

These results indicate that both the inexperienced Americans and the Itza' elders prefer taxa of the generic-species rank in making biological inferences. In related work with USA botanical experts Schwartz and Medin,(2000) also found clear evidence of privilege at the generic-species level. If inferential potential were a simple function of perceptual similarity, then Americans should prefer life forms for induction (in line with Rosch et al., 1976). The findings suggest that root categorization and reasoning processes in folkbiology owe to conceptual assumptions (about the causal locus of biologically essential attributes at the generic-species level) and not exclusively to general, similarity-based (e.g., perceptual) heuristics. To be sure, language may signal expectation that little or poorly known generic species are more biologically informative than better known life forms for Americans (e.g., via common use of binomials, such as <u>oak</u> / <u>red oak</u>). Our experiments, however, still show reliable results in the absence of clear linguistic cues (e.g., <u>oak</u> / <u>white oak</u> / <u>swamp white oak</u> vs. <u>dog</u> / <u>poodle</u> / <u>toy poodle</u>).

The lack of close contact with biological kinds on the part of undergraduates may be precisely what allows us to tease apart the contributions of perceptual processes and abstract expectations to the privileged level in induction. There is now considerable evidence for perceptual learning (e.g. for recent work see Goldstone, 1994, Schyns, Goldstone, and Thibaut,

1998) in general as well as evidence that the basic level on perceptual tasks becomes more specific with expertise (e.g. Tanaka and Taylor, 1991, Johnson and Mervis, 1997). Expertise is almost always a relative term and one equally could cast these results into a different frame: so-called "expert' performance on perceptual tests could be the default stage of normal development and undergraduate performance on perceptual tests (favoring the more abstract life-form level) could be the result of a failure to undergo "normal" perceptual development with respect to biological kinds. If this were true, then we would expect Itza' to perform like experts on perceptual tests and only for cases of impoverished input would we expect a discrepancy between abstract expectations and perceptual processes. Arguably, there is an evolutionary design to a cognitive division of labor between domain-general perceptual heuristics and (domain-specific) learning and inference mechanisms, the one enabling flexible adaptation to variable conditions of experience, and the other invariably steering us to those enduring aspects of biological reality that are both causally-recurrent and relevant to the emergence of human life and cognition.

In the data presented above, we consistently found a decisive break in inductive strength just above the rank of generic species. Nevertheless, we also found secondary evidence that supports the downgrading of American folkbiological knowledge versus the upgrading of Maya knowledge, relative to the generic-species level. Specifically, we find Americans have more faith in inductions to superordinate life-form taxa than the Itza', and Itza' differentiate among subordinate taxa more than students. This observation, coupled with some suggestive data on the decreasing salience of biological kinds in western societies, raises further issues concerning the relativity of expertise.

Devolution and expertise. So far we have found it natural to treat undergraduates as the reference population and to categorize groups that know more than they do as "experts." Of course, by this standard, practically everyone with more contact with nature would be considered to be expert. An alternative perspective is suggested when one takes the knowledge of the typical member of a nonindustrialized society as the standard. With this reference point, undergraduate knowledge would be considered much below average or "devolved."

A recent survey we conducted at Northwestern University offers some index of what undergraduates know about one domain of biology, namely trees (Coley, et al, 1999). We provided students with the names of 80 trees and asked students to circle the trees they had ever heard of before, regardless of whether they knew anything about them. More than 90 percent said that they had heard of birch, cedar, hickory, maple, pine and spruce. But fewer than half indicated any familiarity with alder, buckeye, hackberry, hawthorn, honey locust, linden, sweetgum, and tulip tree, all of which are common to the campus area (and in the case of the buckeye, is accompanied by the fact that the Ohio State Buckeyes are a fellow Big Ten School!). Although it would take time travel to firmly establish that Northwestern students know less than their counterparts of the 19th century, there is indirect evidence that favors the devolution hypothesis.

Wolff, Medin, and Pankratz, (1999) examined a large sample of written material from the 16th through the 20th centuries contained in the online Oxford English Dictionary. Of interest was the relative frequency and specificity of the use of tree terms. We found a precipitous decline in the use of tree terms after, but not before the 19th century. The number of sources mentioning trees declined by 45% and the number of quotes fell 40%. Furthermore, the specificity of quotes declined between the 19th and 20th centuries. While the use of the life-form term, tree, only fell 26%, the use of generic-species terms (e.g. oak, maple, pine) fell by 50%. More detailed analyses showed that these declines were present regardless of whether the tree term was the topic of the sentence.

Finally, we found similar declines for other life-form terms, such as bird or grass, but only increases for non-biological super-ordinates, such as furniture and clothes.

The above evidence of diminished cultural support for biological kinds is consistent with our suggestion that undergraduates and urban, middle-class children are anything but a "standard" population when it comes to the domain of biology. In the previous section, we found that the standard population's (in this case children) patterns of inductive projection across life forms, kingdoms and ontological domains (humans, animals, plants, artifacts) depends upon familiarity with the categories in question and perhaps cultural construals of the role of humans in nature, and do not readily generalize to other populations and cultural settings. In this section, we found that inductive projections within the domains of animal and plants do show evidence of universal patterns of reasoning that were not previously apparent in standard populations (in this case, college students), and which appear to be relatively independent from cultural familiarity. In the next two sections, we will see further evidence that undergraduates are nonstandard with respect to folkbiological thought. We first examine typicality effects and then turn to the use of categories in reasoning.

VII. Typicality.

Next to the notion of a basic level, perhaps the most important notion in the psychology of categorization is that of typicality effects. The idea is that some instances of a category may be better examples of a category than others. For example, a common intuition is that robins are better examples of bird than are chickens. Furthermore, the consensus has been that the basis of typicality effects is similarity relationships---robins are better birds because they are more similar to other birds than are chickens (see Smith, Shoben and Rips, 1974; Rosch and Mervis, 1975 for empirical and theoretical treatments of typicality). Once again, however, these observations rest on a narrow empirical base with respect to study populations.

Work on typicality judgments among Itza' shows that inductively useful notions of typicality may be driven more by notions of idealness than central tendency (Atran, 1999). 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 three most highly rated mammals are the jaguar (also called 'The Lord of the Forest'), the mountain lion (the jaguar's principal rival) and the tapir (also called 'The Beast of All Seven Edible Kinds of Flesh'). The three most highly related snakes are the large and deadly fer-de-lance (Bothrops asper, also called 'The True Snake') and its companions, the large and venomous tropical rattlesnake (Crotalus durissus) and the smaller but deadly coral (Micrurus sp.). The three most representative birds are all large, morphologically striking and highly edible Galliformes (wild fowl): ocellated turkey, crested guan, and great curassow.

One might wonder if somehow the instructions were different or whether typicality has a different meaning in the Itza' language. Further observations undermine this possibility. Lynch, Coley and Medin (2000) found that USA tree experts based their typicality judgments on ideals (e.g. height, absence of undesirable characteristics) and that central tendency was uncorrelated with judgments. Lynch et al. used instructions that followed verbatim those by Rosch and Mervis (1975) in their original studies showing central-tendency based typicality effects.[7] The best predictor of undergraduate typicality ratings was word frequency. In other studies with bird watchers and fishing experts (majority culture and Menominee fishermen in Wisconsin) we also find that typicality is organized in terms of ideals and that central tendency is uncorrelated with judgments (Bailenson, et al, in press; Medin, et al, Reference Note 3). The exact ideas vary somewhat with cultural group. For example, Menominee fishermen rate the culturally-important sturgeon as a better example of fish than do majority culture fishermen. Some Menominee think of the sturgeon as sacred and the tribe continues to have a sturgeon ceremony each spring. In earlier centuries the sturgeon was one of the first species to migrate upriver to spawn in the spring and was a major source of food.

No doubt similarity structures and similarity-based typicality are important determinants in natural categorization. Our findings suggest that for American undergraduates these may be dominant factors. But for our relative experts (US experts and Itza'), who have substantial knowledge, goals and activities about the items they classify and reason with, information other than that derived from perceptual clustering and similarity judgment is relevant to understanding natural biodiversity. Behavior and ecology, for example, appear to be crucial to the deeper and broader understanding of nature that scientists and birdwatchers seek.

For Itza', the dimensions of perceptual, ecological and cultural salience all appear necessary to a determination of typicality, but none alone appears to be sufficient. For example, jaguars are beautiful and big (but cows are bigger), their predatory home range (about 50 km2) determines the extent of a forest section (but why just this animal's home range?), and they are "lords" of the forest (to which even the spirits pay heed). In other words, typicality for the Itza' appears to be an integral part of the human (culturally-relevant) ecology. Thus, the Itza' say that wherever the sound of the jaguar is not heard, there is no longer any "true" forest, nor any "true" Maya. Nothing of this sort appears to be the case with American undergraduate judgments of biological typicality.[8]

In summary, we consistently find that among people knowledgeable about a domain, typicality judgments are based on ideals. Only undergraduates appear to rely on central tendency or word frequency. Of course, one might play down the significance of these findings by suggesting that they only hold for direct judgments of typicality. As we shall see in the next section, however, these effects also extend to how categories are used in reasoning.

VIII. The Use of Categories in Reasoning.

Categorization tasks are of independent theoretical interest and self-contained, but they are also designed to provide the inferential framework for category-based reasoning. In this section we focus on models for the use of categories in inductive reasoning in general, and biological inference in particular. The empirical phenomena of interest are typicality and diversity effects in reasoning. We briefly mentioned diversity effects in illustrating our triangulation strategy and now we will reurn to them. To set the stage for our discussion, we briefly review one of the most influential models of induction, the similarity-coverage model (SCM) of Osherson, et al, 1990.

An important function of taxonomic classification is enabling generalizations between categories. Osherson et al. (1990) identified a set of phenomena that characterize category-based inferences in undergraduates, and formalized a model that predicts the strength of those inferences. Sloman (1993) has presented an alternative model, but for our purposes it makes the same predictions. Both models rely on the notion of similarity and similarity relations as a guide to induction. Rather than talk about inductive "inferences," Osherson et al. discuss inductive "arguments," in which facts used to generate the inference play the role of premises, and the inference itself plays the role of conclusion. Thus, inferring that all birds have ulnar arteries from the fact that Jays and Flamingos do, amounts to the argument: Jays have ulnar arteries, and Flamingos have ulnar arteries, therefore all birds have ulnar arteries. This argument is strong to the extent that belief in the premises leads to belief in the conclusion.

For all SCM phenomena, the properties (e.g., have ulnar arteries) are said to be "blank." They are designed such that they do not favor one category over another at the same rank or level. For example, "has ulnar arteries" should be a priori equally likely to be true of Jays and Flamingos. We have come to believe that it is nearly impossible to create truly blank properties (see Heit and Rubinstein,1994). In fact, later on we will show that even the "blankest" of blank properties (e.g. "has property x") are not independent of the categories to which they are attached. First things first though.

The SCM predicts that the strength of an argument from a premise to a conclusion will vary with the similarity of the premise category to the conclusion category. For example, an inference from cows to horses should be stronger than an inference from squirrels to horses because cows are more similar to horses than squirrels are. The SCM also predicts that typical members of a category will have greater inductive strength than atypical examples for the conclusions about the entire category. For example, an inference going from bears to all mammals should be stronger than an inference going from mice to all mammals because bears are more representative of the category than are mice. In the terms of the SCM, bear provides better "coverage" of the category than does mice because bears has greater average similarity to other category members than does mice.

Diversity also relies on the notion of coverage. Consider the following argument: "Cows and Horses get one disease, Cows and Squirrels get another disease, which disease is more likely to affect all mammals? López et al found that, for arguments like these, undergraduates strongly preferred the argument having the more diverse premises (in this case, Cows and Squirrels, rather than Cows and Horses). From the perspective of the SCM the argument with the more diverse premises is stronger because it provides better coverage. Cows and Horses each likely have greater average similarity to members of the mammal category but this coverage is redundant--- the mammals to which cows are highly similar are the same ones to which horses are very similar. On the other hand, the mammals to which squirrels are similar are different from the ones to which cows are similar. The SCM relies on a measure of maximal average similarity and thus is sensitive to the presence of redundancy. Hence, the SCM predicts that diverse arguments will have greater inductive strength.

In order to develop predictions associated with the SCM, López et al, employed a sorting task where participants were asked to sort local mammals into to groups, to "put the animals that go together by nature into as many groups as you want. Subsequent sorting into sub- and super-ordinate categories created a hierarchical taxonomy for each participant, which were then combined to create a group taxonomic hierarchy. The rationale for eliciting such taxonomic hierarchies was to be able to indirectly, but "automatically," compute measures of similarity, typicality and category coverage from a single cognitive structure, without having to directly elicit separate measures (e.g., through independent ratings).

To justify combining individual sorts into an aggregate cultural taxonomy, López et al, first applied the cultural consensus model to the informant by informant agreement matrix for both the Itza' and undergraduate sample. Both groups showed a strong consensus. With these results in hand, distance in the consensual group taxonomy provides a key measure of similarity that was then used to study category-based inferencing.

Similarity predicts that the stronger inference should be the one where the premise is closest to the conclusion, with "closeness" measured as the number of nodes in the taxonomic tree (produced by cluster analyses) that one has to go through to reach the conclusion category from the premise category. Like Similarity, the metric for Typicality is also given by the taxonomy itself, as the lowest average tree distance. Thus, the typicality of a taxonomic item (e.g., a generic species) is the average taxonomic distance of that item to all other items in the inclusive category (e.g., life form). Finally, diversity is based on the average lowest tree distance between either of the premise categories and the members of the conclusion category.

López, et al. (1997) used the similarity-coverage model to investigate inductive reasoning about mammals among U.S. college students and Itza' Maya speakers. Although we found reliable similarity and typicality effects in both groups, [9] the groups differed markedly in the extent of their use of diversity. As we noted earlier, U.S. undergraduates demonstrated powerful diversity effects whereas the Itza' were reliably below chance in the selection of arguments with more diverse premises both for mammals and palm.

Although the source of this striking finding was not obvious (see Atran 1998, Coley et al., 1999 for more discussion of possible explanations), two candidates are cultural influence and relative expertise. Perhaps diversity is a novice strategy used in situations where more specific knowledge is not available. Alternatively, perhaps it is a result of the emphasis on taxonomic classification in modern Western society. Our work among U.S. tree experts suggests that neither answer alone will explain the finding. Proffitt et al, 2000 found that groups of U.S. tree experts differ in their use of diversity-based reasoning: taxonomists and landscapers show reliable diversity-based reasoning (albeit nowhere as high as López et al.'s undergraduates), whereas maintenance workers show below chance diversity responding much like the Itza'. This suggests that neither relative expertise nor cultural influence alone determines whether diversity is seen as a viable inductive heuristic

Why do many experts and Itza' not show diversity? Consider, first, the Itza'. Itza' justifications revealed that diseases did not function as blank predicates for the Diversity items but instead serve as triggers for ecologically-based inductions. In many cases, ecological considerations led participants to conclude that the argument with more diverse premises was actually the weaker. For example, one Itza' favored the argument RAT, POCKET MOUSE / MAMMAL over TAPIR, SQUIRREL / MAMMAL. She argued that tapirs and squirrels are less likely to pass on the disease because they probably required an ecological agent (a bat biting them) to get the disease in the first place, whereas rats and pocket mice are close enough "companions" that they do not need an ecological agent (a bat biting them) to get the disease. Ecological considerations also led to diversity-based inductions in a few cases. For example, another Itza' reasoned, to the contrary, that rats and pocket mice live only where there is corn, sleep above ground, and do not travel in parts of the forest where other animals may catch their disease.

USA tree experts also frequently used content-based reasoning involving disease mechanisms and ecological diversity, which often led them to choose the less diverse premises (Proffitt, et al, 2000). Interestingly, the tree experts did not show typicality effects. Their justifications for typicality probes often appealed to "family size," where family refers not to scientific families but to generic species. This echoes our findings of privilege at the generic-species level noted earlier. To further test the generality of these findings on typicality and diversity, we tested Itza' on yet other kinds and properties (e.g. "has little things inside"), and we also tested other USA expert groups. Let's look at one of these lines of research in detail.

Triangulating with birds.

Bailenson, et al, (in press) studied three populations categorizing and reasoning about birds. The populations were 1. Itza' Maya of Guatemala, 2. USA bird experts (bird watchers), and 3. USA novices recruited through ads placed on campus. The stimulus materials were pictures of Chicago-area USA birds as well as pictures of birds of lowland Guatemala. The idea was to see if the experts responded differently to local versus exotic species. Itza' can be thought of as novices with respect to USA birds but they have extensive experience with birds that they may bring to bear with novel bird species. Each set consisted of full-color illustrations of 104 bird species laminated onto index cards.

The structure of the scientific taxonomy representing the US bird set was designed to correspond maximally with that representing the Tikal bird set. One notable difference was in the number of passerines (songbirds) in the two sets. Although passerines are the numerically dominant group both in Chicagoland and Mayaland, they are somewhat more prevalent in Chicagoland.

The first study used a sorting procedure to assess folk taxonomies and then use them to set up typicality and diversity reasoning probes. The study also compared within and across group patterns of sorting. In that regard there are two important questions: 1. Do people within a group agree sufficiently in their sorting that it is sensible to claim that there is a consensual cultural or group model? 2. Are the patterns of sorting reliably different across groups? To address these questions, we again used the cultural consensus model (CCM), allowing us to compare one cultural taxonomy to the other ones. To do this, we looked at patterns of residual agreement. If the groups differ, then individuals within a group should agree with each other to a greater extent than is predicted by the overall consensus analysis. Based on general ideas about the universality of folk taxonomies and the work of Boster (1986), we might expect that novice, expert, and Itza' sorts would correlate highly with scientific taxonomy.

All participants were told that we were interested in how they organized their knowledge about birds. First, we showed them all 104 bird cards one at a time and asked them to name them "as specifically as possible." Next, all 104 cards were placed in front of the participant, who was asked to "put together the birds that go together by nature into as many different groups as you'd like." The experimenters asked the informant to explain their basis for each category. We then followed the same procedure used by López et al to create higher and lower level partitionings. The result was a hierarchical taxonomy of birds for each participant.

Naming Accuracy. The naming data are useful in providing an independent index of expertise and relative familiarity with the two picture sets. We scored each naming response on a three-point scale, with a 3 representing an exact species match, a 2 representing a correct genus match, and a 1 representing a match at order or higher (i.e., a 'bird' response was scored a 1). For the Itza' this measure is somewhat conservative in that, unlike novices, they rarely said "bird" and instead often used intermediate categories such as "flesh-eating bird." The three groups named all the birds from both stimulus sets except the Itza', who only named birds from the Tikal set. Experts were more accurate at naming US birds (M = 2.55) than Tikal birds (M = 1.66), but novices showed little difference (M = 1.25 for US birds versus 1.14 for Tikal birds). These results establish that the US experts were more familiar with the US birds than the Tikal birds and that their naming skills were superior to those of novices for both sets of birds. The Itza' averaged 1.92 for Tikal birds and were less accurate at naming passerines (M = 1.39) than other birds (M = 2.11). Notably, USA experts were equally good on passerines and non-passerines.

Sorting. Each informant's taxonomy was obtained by translating into a taxonomic tree those groupings made during the free pile sorts (initial groupings), successive pile sorts (subsequent groupings of groupings) and successive sub-pile sorts (restoring initial groupings and then subdividing into further sub-groupings), exactly as in López, et al, 1997).. From each taxonomy, we derived a pair-wise bird-by-bird distance matrix by calculating the distance between all possible pairs of birds in the taxonomy. The lowest level at which two given birds go together in a folk taxonomy represents the distance between them. In each condition, the bird distance matrices produced by each informant were correlated with each other, yielding a single pair-wise subject-by-subject correlation matrix representing the degree to which each subject's taxonomy agreed with each other subject's taxonomy.

Combined Consensus. We first applied the CCM to the full set of data to see if there was an overall consensus. There was: the ratio of the first factor to other factors was high and accounted for a large proportion of the variance. Although we observed robust overall agreement, this was coupled with reliable group differences. For the US birds all three groups showed significant residual agreement. That is, in sorting US birds, each group's sorts reflected internal consistency beyond that captured by the consensus across groups. For Tikal birds, there was significant residual agreement for novices and Itza' experts. Apparently, the first factor accounted for almost all the consensus for experts. These results point to differences in the taxonomies produced by each group, which we will take up shortly.

Correspondence to Scientific Taxonomy. In order to compare performance from each group to science, we used the scientific taxonomy to derive a pair-wise bird-by-bird folktaxonomic distance matrix by calculating the distance between all possible pairs of birds in the taxonomy. We used classical evolutionary taxonomy because it represents a reasonable compromise between similarity-based "phenetic," or numerical, taxonomy and theory-based cladistic, or phylogenetic, taxonomy (see López et al, 1997, for further discussion). We then compared the average matrix from each group to the science matrix. The mean correlations for each of the groups on the US birds were .38, .60, and .45 for novices, USA experts, and Itza' experts, respectively. Note that Itza' sorts agreed more with science than did novice sorts. The mean correlations for each of the groups on the Guatemalan birds were .34, .70, and .61 for novices, USA experts, and Itza', respectively. Again, Itza' sorts corresponded more closely with science than did novice sorts.

The novice correlations with science are reliable but quite low, in no case accounting for more than 16% of the variance. We take this as evidence that the structure of nature is not nearly so transparent as previous researchers have suggested (e.g., Boster, Berlin & O'Neill, 1986), or perhaps that the structure of nature is not transparent in pictures of birds. It may be that our novices have had so little by way of meaningful interactions with birds that they have failed to learn which aspects, features, or dimensions are most relevant to organizing and classifying birds (see our earlier comments on perceptual learning).

There is some evidence that provides clear support for this interpretation. Johnson and Mervis (1997) tested bird experts, fish experts and novices on a triads task where participants were asked to pick out the two animals that were "most like the same kinds of thing." Some triads pitted overall morphological similarity against taxonomic membership. Not only were birds experts more likely to make the taxonomic choice for birds, and fish experts to make the taxonomic choice for fish; these two types of expert were also substantially more likely than novices to pick the taxonomic choice for the domain where they lacked expertise. Johnson and Mervis suggested that experts had learned to weight modified parts as much as features more related to overall similarity. This contrasts with novices who apparently gave the latter type of feature more weight. In short, the Johnson and Mervis findings support the idea that some combination of perceptual learning and what they referred to as "intuitive theories" (e.g. understandings of the functional significance for the animal of different features) leads experts to organize biological kinds in a manner closer to scientific taxonomy.

Our results are consistent with this general interpretation in that the bird watchers and Itza' were clearly using information not reflected in the novice sorts. In short, expertise appears to involve more than a passive reception of real world structure - it includes learning to attend to the features and relationships that are most informative, which does not necessary correspond with overall similarity (see also Boster and D'Andrade, 1989).

Category-based induction. We used the data from the sorting study to develop typicality and diversity probes to see how participants use bird categories and salient examples of birds in reasoning, focusing on two typicality and diversity. Given the results from López et al, 1997, and Proffitt et al, 2000, we expected that US novices might exhibit more diversity responses than either of the other two groups. It would not be surprising if the US bird experts showed diversity responses given that they are quite familiar with the scientific taxonomy. Overall, however, our hypothesis is that domain knowledge makes it less likely that a person will employ abstract reasoning strategies. Instead we expect to observe more concrete justifications such as the causal-ecological reasoning patterns we had seen before.

Properties for induction. Based on previous work we decided against using identical properties for the Itza' and US induction probes. Half of the probes involved disease and this was constant across groups. For the other half we used "enzyme" for North American subjects and "little things inside" for Mesoamerican subjects. We piloted both terms with both groups. We found in pilot work that North American adult participants are confused by "little things inside" but not "enzyme," "protein" or "disease X", whereas Maya subjects were confused by "enzyme" and "protein" but not by "little things inside" or "disease X." As in the sorting study we used probes involving both USA birds and birds of Tikal.

For both kinds of probes we presented two pairs of birds and then asked about the property in question (disease, enzyme, or little things inside). For example, for the typicality trials, we displayed both birds in each pair and said:

> "Let's assume that we discovered two new diseases. All we know about these diseases is that Disease A is found in these types of birds and Disease B is found in these. Which disease do you think is more likely to be found in all birds? "

For the diversity trials, we placed one pair of birds on the left-hand side and one pair of birds on the right hand side, and asked the same question.

Typicality Results. There were no differences as a function of property so we collapsed across this variable. Only the undergraduates (novices) showed any indication of a typicality effect. A look at the justifications for choices confirms this pattern. The most striking difference is that novices use typicality as a reason for the choice more than half of the time, while experts and Itza' <u>never</u> mention typicality. Both Itza' and US experts tended to use range or ecological factors as justifications.

The passerine effect. We also analyzed the responses to the probes not simply in terms of typicality but also in terms of whether one of the birds in a pair was or was not a passerine. The US experts and novices chose the passerine over the nonpasserine (66% and 86%, respectively) more than the Itza' (40%). In short, the Itza' experts tended to avoid passerines in their choices while the USA participants tended to choose them. As we will see, this difference probably derives from the salient role of non-passerines in Itza' Maya folkbiology.

Diversity. Again there were no differences as a function of property so we collapsed across this variable. Across conditions, US experts chose the more diverse pair on 58% of the trials, the novices also 58%, and the Itza' 45%. None of these percentages differed reliably from each other or from chance (50%). The diversity pattern for the experts was largely driven by two experts. The justifications are once again informative. The novices tended to use either typicality or diversity as a justification and, at least initially, found typicality to be more compelling. Interestingly, they appeared to show something of a "learning effect" in that diversity justifications increased from 17% to 43% from the first to the second half of probes. It was as if once they hit upon this strategy, they thought it was a good one and tended to continue using it. Two experts gave almost exclusively diversity justifications; however, the other USA experts and Itza' predominantly responded in terms of ecological/causal relations. (Experts and Itza' showed no changes in patterns of justifications between the first and second half of probes).

The passerine effect again. The US populations tended to choose probe pairs involving passerines, whereas Itza' tended to avoid them. This passerine effect suggests that the idealness of the birds may be driving our results more than coverage. As we noted earlier for the Itza', passerines are not considered "true birds" to the same extent as other birds in the environment. Even though "passerine" was rarely cited as a justification, American subjects tended to pick small songbirds as generalizing to the population of all birds while the Itza' preferred larger, more perceptually striking birds. Note, however, that for the Itza' and the experts the basis for responding is not idealness per se and their justifications did not directly appeal to either idealness or typicality. Given the prominent role of the larger game birds in the behavioral ecology of Mayaland, and the more interactive goals of Itza' in monitoring their ecology, the information provided by non-passerines would be more relevant to environmental understanding and management than information provided by songbirds. Itza' preferentially monitor those species in their ecosystem (e.g., game birds as opposed to passerines) that provide the most relevant information about the interaction of human needs with the needs of the forest. Similarly, the most common justification by the USA experts on diversity probes was geographical range. Only the novice appealed to typicality per se on diversity probes. For the novices, whose interest in and interaction with the behavioral ecology is of a much reduced and altogether different order, correlated perceptual information may be more relevant by default.

Summary of Bird Studies. Our triangulation strategy once again proved to be quite useful. For a number of important phenomena US experts and Itza' clustered together and contrasted with US novices. The expert groups sorted in closer correspondence with scientific taxonomy than did novices. This difference is particularly striking for Itza' on US birds because they were unfamiliar with Western science, scientific taxonomy, and the birds employed. US novices had prior exposure to the birds and to Western science but their sorts corresponded less well with scientific taxonomy than those of the Itza'. The data suggest that expertise confers benefits in abstracting important relationships in nature and, as a consequence, may lead to greater correspondence with scientific taxonomy. In that regard our results are well-anticipated by the findings mentioned earlier by Johnson and Mervis (1997) who showed that bird and fish experts were better able than novices to apprehend relational features tied to function and ecology.

The category-based induction findings also reinforce the view that the novices are the "odd group out." Novices relied very heavily on familiarity or typicality as the basis of their choices on both the typicality and diversity trials. Neither the Itza' nor the US experts ever gave typicality as a justification for either type of probe. Instead, they used knowledge about birds that the novices did not possess. For example, both the Itza' and US experts frequently mentioned the geographical range of birds, an explanation that the novices rarely produced. This is a truly striking qualitative difference.

We found patterns of expertise in natural categorization and reasoning that selectively transcend cultural boundaries: Itza' speakers and USA experts employ causal and ecological reasoning more than do USA novices, and the Maya and USA experts are better at discriminating one another's natural environment than the novices are at discriminating their own. One implication is that rich interaction with the environment and relative expertise is the evolutionarily-determined default condition for the operation of folkbiology. Trying to understand the structure of folkbiology by focusing exclusively on relatively unknowledgeable college students may be akin to an attempt to understand the structure of language by concentrating on feral children. This has serious implications given the fact that US undergraduates comprise the one subject-pool in the literature that is consistently and overwhelmingly relied on for making psychological generalizations - not only with respect to folkbiology but also virtually every aspect of human cognition. To be sure, the goal of the SCM and related model of induction was not to understand folkbiology but rather to develop models for how people reason with categories under certain default conditions. Apparently, these default conditions include little domain knowledge and shortly we'll see that even undergraduates violates similarity-based models when their (limited) domain knowledge is activated.

In further followup work with Menominee and majority culture fishing experts in rural Wisconsin, we find that ecological/causal reasoning dominates and that neither typicality nor diversity effects are observed in either group. Interestingly, the Menominee fishermen are much more likely to sort ecologically than are majority culture fish experts. This difference holds across a broad range of expertise and parallels our developmental findings on the use of ecological reasoning (Medin et al, in press).

One outstanding issue concerns the more general role that "standard" or "default" patterns of reasoning play in human cognition and everyday life. What knowledge conditions are required to enable someone to "override" reliance on similarity-based typicality and diversity? Would experts "fall back" on central tendency and coverage if denied access to a rich knowledge base (e.g., in a completely novel domain)? The answer to these and other related questions await further studies.

Implications for Theory: A Relevance Account.

The lack of generality of typicality and diversity effects represents a serious limitation of current models of induction, which seem to predict that these phenomena will be universal. Of course, one might suggest that these models are only meant to apply for truly blank properties and that people with some domain knowledge interpret these properties in such a way that, functionally, they are not blank. There are two problems with this counter-argument. One is that this move restricts the applicability of such models to the point of irrelevance. The second is that it not the case that experts and Itza' never show diversity justifications; rather, it is simply one strategy among many (and more often than not, not the most compelling one).

We think that our full pattern of results can best be understood with a theory that has not been applied previously to problems of category-based induction. One of our test sessions with a tree expert provided the impetus for this shift of view. The expert was being given typicality probes such as the following: "Suppose we know that river birch get Disease X and that white Oaks get Disease Y, which disease do you think is more likely to affect all trees?" In this case, the expert said Disease X, noting that river birches are very susceptible to disease; so, "if one gets it they all get it." The very next probe involved the gingko tree and the expert choose the disease associated with it as more likely to affect all trees on the grounds that "Gingkos are so resistant to disease that if they get it, it must be a very powerful disease." He then said that he felt as if he had just contradicted himself, but that nonetheless these seemed like the right answers.

Normatively, this expert's answers do not represent a contradiction (One can reason in terms of both susceptibility of trees to disease and strength of diseases). Instead, this expert was using the information that was most salient and readily available to him to guide his reasoning (birches are notoriously susceptible to, and gingkos notoriously resistant to, diseases). Simply put, the expert was using the knowledge that he considered most relevant.

We believe that Sperber and Wilson's (1996) relevance theory provides a good framework for understanding the patterns of responding in all our populations. Furthermore, it leads to a number of novel predictions that contrast with those of other models of induction. In relevance theory, relevance is seen as a property of inputs to cognitive processes:

> An input is relevant to an individual as a certain time if processing this input yield cognitive effects. Examples of cognitive effects are the revision of previous beliefs, or the derivation of contextual conclusions, that is, conclusions that follow from the input taken together with previously available information. Such revisions or conclusions are particularly relevant when they answer questions that the individual had in mind (or in an experimental situation, was presented with). Sperber, Van der Herst and Politzer (in press)

In our experimental setting, background knowledge about properties of trees and diseases fosters just the sorts of contextual conclusions we see. Sperber, et al, (in press) further elaborate:

> Everything else being equal, the greater the cognitive effects achieved by processing an input, the greater its relevance. On the other hand, the greater the effort involved in processing an input, the lower the relevance. One implication of the definition of relevance in terms of effect and effort is that salient information, everything else being equal, has greater relevance, given that accessing it requires less effort.

Consider again the Itza' pattern of sorting and reasoning about birds. Recall that their daily life circumstances lead them to attend to the larger, more ecologically important forest birds. These are ecologically important both to perceivable effects on the forest and to Itza' needs. For example, raptors compete with the Itza' for large game birds (e.g. the wild turkey) and so Itza' hunters clearly must pay attention to both groups of birds. Consequently, their choices of non-passerines on reasoning probes are driven by these omnipresent background concerns. Specifically, their extensive knowledge of large game birds and raptors has consequences for both effect and effort. All else equal, it is easier for them to retrieve knowledge about non-passerines and, when they do so, this retrieved knowledge has greater consequences.

Undergraduates, in contrast, have little background knowledge to bring to bear on the sorts of reasoning tasks we have used. Consequently, it is not surprising that they rely heavily on more abstract reasoning strategies. In ongoing research we have evidence that their responses are sensitive to both effect and effort. This line of work was motivated by a followup study involving reasoning about mammals. Here we tested undergraduates individually and asked them to justify their responses. The one-on-one context implicitly asks for more effort, which should lead to more effect. Under these circumstances diversity effects were much reduced and we started to see justifications in terms of the range and population size of different mammals.

The above pilot study has led us to examine relevance effects in undergraduate populations more systematically (Medin, Coley, Storms, and Hayes, Reference Note 4). The probes rely on identifying accessible background knowledge to bring out the effect side of relevance and manipulating the premise and conclusion categories to show consequences on the effort side. As an example of the former, we find that the argument that Bananas have Enzyme X, therefore Monkeys have Enzyme X is rated to be stronger than the argument that Mice have Enzyme X, therefore Monkeys have Enzyme X. In this case, relevant background knowledge that monkeys like bananas leads to a violation of similarity.

As an example of varying effort, undergraduates rate the inductive strength of the argument that Grass has Enzyme Y, therefore Humans have Enzyme Y to be less strong than the argument that Grass has Enzyme Y, therefore Cows and Humans have Enzyme Y. (The arguments are not juxtaposed but rather are used in a between-subjects design). In this case, we have what one could call a "conclusion conjunction fallacy" since, normatively, the former argument's conclusion cannot be less likely than the conclusion of the latter argument. From our perspective, we have made it easier for the participants to access a sensible causal pathway between grass and humans by providing the concept, cow. We probably could have produced the same results by simply asking or not asking participants to recall the last time they had seen a cow before giving the grass to humans argument. Using other probes aimed at producing differences in effect and effort, Medin et al showed that below chance diversity responding could readily be produced in undergraduates.

Summary. In some respects we have come full circle with respect to both theory and data on the use of categories in reasoning. We started by describing studies that reveal the standard undergraduate population as the odd group out, examined the basis for responding in "nonstandard" populations, but then were able to use relevance theory to produce comparable phenomena with undergraduates. Note, however, that in coming full circle we end up with a very different theory, one that holds promise for understanding inductive inferences in all of our populations. Equally important, it was the very use of nonstandard populations that allowed us to identify reasoning strategies that are salient among experts and Itza' but require careful attention to bring out in students. Had we restricted our focus to students, we might never have hit upon the relevance of relevance theory to induction.

Relevance theory can certainly be criticized. It is a considerably more abstract than the similarity-coverage model and it appears to be so general that it's hard to imagine it being falsified. It is much more a framework theory than a computational model. We believe that the best test of a framework theory is whether it is useful, independent of whether it is readily falsifiable. We have seen that relevance theory leads to some novel predictions, predictions that are outside the scope of other models of induction. Our next aim will be to combine this domain-general relevance framework with domain-specific evidence on the organization of biological thought in order to develop more specific predictions concerning folkbiological induction.

IX. Folkecology and the Spirit of the Commons.

The salience of ecological reasoning among the Itza', coupled with their record of sustainable agro-forestry, suggested to us that there may be a connection between the two. Furthermore, the fact that the Ladino and Q'eqchi' populations practice agro-forestry in a much less sustainable manner, raised the possibility that understandings of the forest may affect action on it. These conjectures led us to a series of systematic cultural comparisons that are pertinent to a variety of conceptual issues in cognition, decision making, and culture theory (Atran et al.,1999, in press; Medin et al., in press).

A critical case for the importance of cultural selection versus environmental determination comes from a variation on the "garden experiment" in biology. When members of a species have different phenotypes in different environments, samples are take from both environments and replanted in a common one. If the differences still exist, they are probably genetic (two genotypes); if not, then they are probably environmental (one genotype producing two phenotypes). Here we use a variation on this experimental approach. Our aim in this case is to isolate the influence of certain socio-cultural factors (social networks, cognitive models) from economic (sources and level of income), demographic (family and population size), and ecological factors (habitat and species) in environmental management and maintenance. Evidence for the importance of culturally transmitted factors on behavior would be indications that groups of people who have different cultural histories and cultural ideas behave differently in the same physical environment.

We used a threefold approach to understanding causal relations between individual cognitions, human behaviors that directly affect the environment, and cultural patterns that emerge from population-wide distributions of cognitions:

1. Folkecology. This involved a cross-cultural methodology for modeling people's cognitions of the ecological relationships between plants, animals and humans.
2. Cultural Epidemiology. This involved ways of mapping individual variation and inter-informant agreement in the flow of ecologically-relevant information within and

between societies, using social network analysis to trace potential transmission pathways in transfer of knowledge.

3. The Spirit of the Commons. This involved operationalizing the role of "non-economic" entities and values, such as supernatural beings, in environmental cognition and behavior.

The Lowland Maya region faces environmental disaster, owing in part to a host of non-native actors having access to the forest resources (Schwartz, 1995). A central problem concerns differential use of common-pool resources, such as forest plants, by different cultural groups exploiting the same habitat. Research on "the tragedy of the commons" indicates that individual calculations of rational self-interest collectively lead to a breakdown of a society's common resource base unless institutional mechanisms restrict access to co-operators (Hardin, 1968, Berkes et al., 1989). The reason is clear: in the absence of monitoring and punishment, exploiters gain the same benefits as co-operators but at reduced cost. Co-operators are driven to extinction, and exploiters flourish until the commons is destroyed. Still, exclusive concern with economic rationality and institutional constraints on action may not sufficiently account for differences in environmental behaviors (Ostrom, 1998). To make better sense of these differences, we examined links between environmental cognitions and behaviors.

Folkecology

Although folktaxonomies, which are ranked around generic species, are structured similarly across diverse cultures, we have found that this leaves aside important insights into how people actually parse the content of local biodiversity and reason about it. More generally, it ignores how people cognitively model the environment in ways relevant to behavior. There are precedents for our attempt to fill this void (e.g., Posey, 1983); however, to our knowledge, what follows is one of the first attempts to show the role of cognitive and cultural orientation in deforestation and land use in ways meaningful to natural science.

The Common Setting. As noted earlier, the forests of Petén are one common pool resource that is rapidly being depleted. The rate of deforestation, which averaged 287 km^2 yearly between 1962 and 1987, nearly doubled to 540 km^2 in 1988-1992, as population rose from 21,000 to over 300,000. Population estimates for 1999-2000 range from 500,000-700,000. A new European-financed paved road now links Guatemala City to Flores (the former Itza' capital of Petén). Projections based on remote sensing and ground measurements indicate a 14.5% increase in the rate of deforestation during 1999-2000. The major cause of deforestation remains population pressure from the overcrowded and tired lands of southern Guatemala.

For all of our three groups, people pay rent to the municipality for a farm plot. Each household (about 5 persons) has usufruct rights on 30 manzanas (21.4 ha) of ejido land (municipal commons). Farmers pay yearly rent of less than a dollar for each manzana cleared for swidden plots, known as milpa, whose primary crop is maize. All groups practice agriculture and horticulture, hunt game, fish, and extract timber and non-timber forest products for sale. Yearly crop patterns can vary widely, owing in part to microclimate and rainfall fluctuation. People can hold plots in scattered areas and can change plots. Plots from all groups may abut. Hunting is tolerated on neighbors' plots, but not access to another's crops or trees. Itza' and Ladinos interact often, as their villages are 1 km apart. Q'eqchi live 18 km from both groups; however, daily buses connect the Q'eqchi' to the other two groups (who also farm regularly around Corozal).

Multiple converging measures of soils, biodiversity, and canopy cover indicate that Itza' promote forest replenishment, Q'eqchi' foster rapid forest depletion, and Ladinos fall somewhere in between (Atran, et al. 1999). For example, for every informant in each population we sampled one hectare plots from their agricultural land (milpa), fallow land (guamil) and forest reserve. For each plot we measured: plot size, species diversity, tree count, coverage (m^2 foliage for each tree crown), and soil composition. Measurements of behavior patterns and their consequences for soils corroborate patterns from reported behavior, suggesting that Itza' agroforestry practice encourages a potentially sustainable balance between human productivity and forest maintenance, Q'eqchi' practices are destructive in the short term, and Ladino practices are intermediate. Given the results from our sample plots, Q'eqchi' forest-clearance rates (i.e., amount of land cleared divided by number of years that land is cultivated) are more than five times greater than those for Itza' (Atran, et al., in press). Ladino rates are twice that of Itza'. Remote sensing confirms the pattern of deforestation along Q'eqchi" migration routes for Petén (Sader, 1999). In this context, Itza' appear to behave "irrationally" insofar as their restraint subsidizes another group's profligacy: the more cooperators produce for free-riders, the more the free-riding population is able to expand and lay waste (Axelrod & Hamilton, 1981).

Mental Models of Folkecology. To determine if group differences in behavior are reflected in distinct cognitive patterns we elicited folkecological models. In preliminary studies, we asked informants "which kinds of plants and animals are most necessary for the forest to live?" From these lists we compiled a set of 28 plants and 29 animals most frequently cited across informants (plant kinds were all generic species, except for two life forms, GRASS and BUSH). The 28 plant kinds in the study include 20 kinds of trees and 1 ligneous vine counted among the species in the preceding study (starred in Table 2). Although these 21 species represent only 17% of the total number of species enumerated, they account for 44% of all trees in Itza' parcels, 50% in Ladino parcels, 54% in Q'eqchi' parcels. This confirms the salience of the species selected for the folkecology study.

How Plants Affect Animals. The plant and animal kinds are organized into categories used later in the analysis (Table 3). Instructions and responses were given in Itza', Spanish or Q'eqchi'. Equal numbers of informants were asked to explain how each plant helped or hurt each animal, and how each animal helped or hurt each plant.

The procedure had two parts. We asked participants how each plant affected each animal. The task consisted of 28 probes, one for each plant. On each trial, all animal picture cards were laid out and the informant was asked if any of the animals "search for," "go with" or "are companions of" the target plant, and whether the plant helped or hurt the animal. Questions were pretested for simplicity and easy applicability across cultures. Unaffiliated animals were set aside. For each animal, informants were asked to explain how the plant helped or hurt the animal. Next, they were asked how each animal helped or hurt each plant. To explore interactions among people and plants, we asked each informant to explain whether people in their community actually help or hurt each item on the plant list, and vice versa.

For each task, we used the CCM to determine if a single underlying model of ecological relations held for all informants in a population. To establish consensus, all tasks involved a minimum of 12 participants from each group, with equal numbers of males and females. Finding consensus justifies further study of group-wide patterns. Analyses of residual agreement were used to reveal differences among groups.

Each of the three groups produced a distinct model on the forest ecology task. Figure 5 shows the pattern of responding on plants helping animals. Two results are apparent: (1) Itza' and Ladinos show a highly similar pattern of relations, and (2) Q'eqchi' perceive many fewer relations, and those tend to be a subset of those seen for the other two groups. The overwhelming majority of interactions within each group involved plants helping animals by providing them food. Plants providing shelter to animals was also a common response. Using agreement adjusted for guessing as the dependent variable, a large cross-group consensus emerged. Often all Q'eqchi' reported no effect, making the modal answer, "no effect." Thus, Q'eqchi' responses drive the overall consensus. Given this situation, residual analyses are more effective than simple measures of inter-informant agreement in revealing cultural models.

Insert Figure 5 about here

Itza' and Q'eqchi' have greater within- than between-group residual agreement. Ladinos show higher within- than between-group residual agreement vis-a-vis Q'eqchi', but do not share more residual agreement with one another than with Itza'. This is consistent with the idea that the Ladino model is a version of the Itza' model. One distinction between Itza' and Ladinos was the latter's tendency to generalize the beneficial effect on animals of economically and culturally important plants, such as mahogany (the prime wood export) and ceiba (Guatemala's national tree) without apparent justification. Relations noted by Q'eqchi' were basically subsets of those reported by other groups. Overall, Ladino and Itza' models converge on how plants help animals. The Q'eqchi' model is a severely limited subset.

Animals Affecting Plants. Reports of how animals affect plants yielded larger differences (see Figure 6). Q'eqchi' signal too few interactions (only 10 out of 812 possible relations) for consensus analysis. Itza' and Ladinos show strong cross-group consensus, but also greater residual agreement within than between groups. Negative reports of animals hurting plants occur with equal frequency (8.0% of cases by Itza', 8.2% by Ladinos). Ladinos report very few relations of animals helping plants. For example, Itza' are 4 times more likely to report positive interactions and 3.4 times more likely to report reciprocal relations (a plant and animal helping each other).

Insert Figure 6 about here

These findings suggest a complex Itza' folkecological model of the forest, wherein different animals affect different plants, and relations among plants and animals are reciprocal. As Bartlett (1936) and Lundell (1937) noted when carrying out the first systematic ecological surveys of Petén, native Maya (Itza') awareness of local ecological associations served as remarkably detailed and accurate guides to subsequent scientific identification and analysis. On a qualitative level, the Ladinos appear to be operating under a different cultural model. In a preliminary interview where we asked Ladinos how animals help plants the typical response was. "Animals don't help plants; plants help animals." Ladinos also possess a relatively elaborate model, but relations are more unidirectional and less specific. Q'eqchi' acknowledge a much reduced role of plants, and almost no role of animals in the folkecology of the forest.

Human Impact. For each species we asked what its value was for people, and what people's effect was on the species. The species' value for people was coded for "use" or "cash" and human impact on species was assessed on a scale from negative (-1) through neutral (0) to positive (+1). Each population had sufficient statistical consensus among informants to warrant aggregating individual responses of the population into a cultural model. Itza' reported that classes of animals differentially affected classes of plants, whereas Ladinos reported more universal affects.

Ground-truthing. Itza' folkecological models also relate directly to observed behavior. Regression analysis revealed that for Itza', ratings of human impact (the extent to which people report their actions as helping or hurting particular species) and weed status (factoring out plants considered to be weeds) predicted frequencies of trees counted in informant parcels ($r^2 = .46$, with both predictors reliable). No comparable relation emerged for Ladinos or Q'eqchi'. Regressions also revealed different predictors of human impact on plants for each group. For Itza', ecological centrality (number of associations in a group's consensual ecological model for a given plant) and combined utility (value of a plant for wood, shelter and cash combined) predicted reported human impact ($r^2 = .44$, with both predictors reliable). In short, ecological importance and combined utility predicted which plants the Itza' seek to protect.

For Ladinos, cash value was the only reliable predictor of impact, indicating that Ladinos protect plants having cash value. For Q'eqchi', none of these variables predicted impact signature and the (non-significant) correlations were consistently negative, indicating the Q'eqchi' tend to destroy valuable plants. In sum, the three groups have very different mental models of the forest, and correspondingly distinct patterns of use. Only Itza' seem to have a positive vision of the role of plants, animals and humans in helping the forest to survive that is based on species reciprocity. For neither of the other two groups is there a reliable association between mental models of the forest and patterns of use.

Cultural Epidemiology.

Social network analysis bears out the close relationship in mental models and forest behaviors between Itza' and Ladinos. For each community we began with 6 men and 6 women not immediately related by kinship or marriage.[10] Each informant was asked to name, in order of priority, the 7 people outside of the household "most important for your life." Informants were asked in what ways the people named in this social network were important for their lives. Some days later each informant was also asked to name, in order of priority, the 7 people "to whom would you turn if there were something that you do not understand and want to find out about the forest/fishing/hunting." Informants were asked about the kind of information they would seek in these expert networks. After performing these tasks with our initial group of informants, we used a "snowball method" to extend these ego-centered networks to the wider context of patterned social communication in which they operate. Social interaction and expert networks were elicited from the first and last persons named in the social network.

Insert Figure 7 about here

The three populations markedly differ in their social and expert network structures, with different consequences for the flow of information about the forest.[11] Figure 7 provides visual representations of the social network analyses. For each group, there are two alternative representations: a circle graph and a multidimensional scaling. Representations of the Q'eqchi' show a dense, highly interconnected network, with no dominant individual or subgroup. This redundant social structure favors communal and ceremonial institutions that organize accountability, and which are manifestly richer among Q'eqchi' than among Itza' or Ladinos. Only Q'eqchi' practice agro-forestry in corporate groups: neighbors and kin clear and burn each household's plot, kin groups seed together, and the community sanctions unwarranted access to family stands of copal trees (Protium copal) whose resin is ritually burned to ensure the harvest. This implies that institutional monitoring of access to resources, cooperating kin, commensal obligations, an indigenous language, and knowledge of the land (including recognition of important species) may not suffice to avoid ruin of common-pool resources. For the Q'eqchi' of Corozal, continued corporate and ceremonial ties to the sacred mountain valleys of the Q'eqchi' Highlands do not carry corresponding respect for Lowland ecology. A relatively closed corporate structure that channels information focused on internal needs and distant places may function to impede access to ecological information relevant to commons survival.

The Q'eqchi' networks suggest that information pertinent to long-term survival of the forest comes from outside organizations with little long-term experience in Petén. What outside information there is seems unlikely to penetrate deeply into the Q'eqchi' community, because it is not conveyed by socially-relevant actors. For Itza', expert information about the forest appears integrally bound to intimate patterns of social life as well as to an experiential history traceable over many generations, if not millennia. For Ladinos, expert information is also likely to be assimilated into the community. Because Ladino experts (i.e., Ladinos most cited as experts by other Ladinos) are socially well-connected, information that may come through Itza' experts (i.e., those Itza' most cited as experts by other Itza' as well as by Ladino experts) has access to multiple interaction pathways.

The representations of the Itza' network indicate that node Y is the best socially-connected individual. This person is also cited as the top Itza' forest expert. This expertise has been independently confirmed. For example, in the Bailenson et al. study of tropical bird classification among American birdwatchers and Itza', Y scored highest among Itza' on measures of correspondence with scientific (classical evolutionary) taxonomy. The MDS scaling suggests that the Itza' community is currently divided into two social factions: one dominated by Y, and the other by V and W. Person W is V's father, and he is also cited as one of the top 3 Itza' forest experts. Y and V-W head two families that have continuous genealogical links to preconquest Itza' clans of the same name.

One possibility consistent with this structure is that ecological knowledge is directly transmitted from socially well-connected forest experts, such as Y to other Itza'. To evaluate the latter possibility, we analyzed patterns of residual agreement in relation to social and expert network structure. We wanted to see how other individuals and subgroups compared to our most cited expert Itza' informant, Y. We focused exclusively on the nonempty cells because knowledge transmission should primarily take the form of noting an existing relation, not the absence of relations. Analyses within the Itza' sample revealed little residual agreement and this agreement was inconsistent across different tasks. In no case could we discern relationships between residual agreement and social or expert network proximity. In other words, Itza' social structure does not show evidence of specific pathways for learning about the forest, at least among our sample.

There is an alternative scenario to learning about the forest that is more consistent with independent discovery than direct social transmission of ecological knowledge. When asked how they learn about the forest, Itza' mostly claim to acquire knowledge elicited in our tasks by "walking alone" in the forest they call "the Maya House." For Itza', diffusely interconnected social and expert networks suggest multiple social pathways for individuals to gain, and for the community to assimilate and store, information about the forest. Cultural stories, values and the like bias the interpretation of experience in different ways: for example, a bird or monkey eating fruit may be inferred to be transparently harmful by Q'eqchi' and Ladinos, but inferred by Itza' to be helpful. Although culturally channeled in this way, Itza' knowledge of specific plant-animal interactions appears to be acquired through individual experience and exploration.

Our analysis of cultural models and social transmission is frankly speculative but it does have some testable consequences. The general idea is that a person's cultural upbringing primes that person to pay attention to certain observable relationships at a given level of complexity. In addition, each person may be culturally-attuned to the relevant discoveries of other individuals whose knowledge forms part of the emergent cultural consensus. Such emergent belief structures resemble framework theories in their ability to integrate various background assumptions, and to take particular experiences and events and give them general relevance in terms of a much larger ensemble of complexly-related cases (Wisniewski and Medin 1994). Unlike framework theories, however, they need not be represented in any single mind; neither must they be inferentially consistent (Atran, 2001b).

Ladinos also have a distributive network of folkecological beliefs that is statistically reliable, but this network appears to be parasitic on the Itza' network. We believe that whereas Itza' observe the forest for what is important, Ladinos observe not only the forest but also the Itza' for what is important. The circle graph of the Ladino network shows a clear gender division of the community: persons C1-R are women; persons A-Q are men. At the center of the graph is person D1. This is the same person as V in the Itza' network. Both the circle graph and the MDS point to person I as the best socially connected individual. He is also cited most as the top Ladino forest expert.

More generally, the highest competence scores among the Ladinos in the combined Itza'-Ladino model of plant-animal relations belong to those Ladinos who most cite Itza' as their experts. Furthermore, these Ladino experts are also the most socially well-connected members of the Ladino community, and the persons most cited as experts by the rest of the Ladino community. Putting these findings together not only suggests that Ladinos are learning from Itza', but also that the social and expert network structure strongly facilitates this learning between the Ladino and Itza' communities as well as within the Ladino community.

Over time, socially well-connected expert Ladinos converge towards the consensus of Itza' experts, at least with respect to plants helping animals. For example, we found that judgments of plant-animal associations for the mostly highly rated Ladino expert actually comprised a *proper subset* of the judgements made by the most highly rated Itza' expert. It is highly improbable that Ladinos who approximate Itza' response patterns for hundreds of species relations actually observe and copy what Itza' say and think about each of the species pairs in question. How, then, are Ladino experts learning specific contents?

The Learning Landscape. In line with evolutionary models of social learning, one may assume that people, when in doubt or ignorance about a certain domain of activity vital to everyday life, will look to those with knowledge in order to emulate them (Boyd & Richerson, 1985, Henrich & Boyd, 1998). Observers do not have direct access to the deep knowledge they wish to emulate, but only to surface "signs" or "markers" of that knowledge. One promising strategy would be to first look for knowledge from those to whom deference (respect) is shown by others (Henrich & Gil-White, 2001). At least in many small-scale societies, knowledge-bearers tend to be elders, political leaders, economically well-off, and so on. In the Itza' case, forest experts are experts in a variety of relevant domains (e.g., soils, trees, hunting, collecting plants), elder males, and former political town leaders.

Ladinos today continue to express doubt about their forest knowledge and also express a desire to acquire knowledge from the Itza'. Apparently, the most respected and socially well-connected Ladinos attend to those Itza' to whom other Itza' defer; and these Ladinos, in turn, become subjects of emulation and sources of knowledge for other Ladinos. But how do Ladinos go about obtaining the relevant knowledge without initially knowing how it is relevant?

Nearly all evolutionary models of social learning assume that the most important and effective information to be learned is information about norms, that is, shared rules or principles of knowledge, judgement or behavior (Sober & Wilson, 1998; Laland & Olding-Smee, 2001; Henrich & Gil-White, 2001; Boyd & Richerson, 2001). Our evidence indicates that neither Ladino experts nor the wider Itza' or Ladino populations are learning pre-formulated norms or social rules about the forest from the Itza' experts or from imitating one another. Instead, Ladinos may be acquiring knowledge in part through different isolated examples that trigger inferential structures to support generalizations, and in part through stories and other evocative conduits. This is not do deny that people never transmit norms or rules (whether explicitly or implicitly). It is only to deny that social norms or rules are always the primary (or even a necessary) means of forging cultural consensus.

Our data suggest that two distinct forms of inference may affect mental models of the forest: 1. inferences from general knowledge of ecological relationships, such as whether relations are positive or negative and where in the forest they are likely to occur, and 2. category-based induction over ecological and taxonomic groups. Concerning the first form of inference, for example, a Ladino may observe or hear about a particular exemplar of ecological knowledge from a respected Itza' (perhaps embedded in a story), such as observing that Itza' elders look for fallen ramon fruits after spider monkeys have passed through the trees. Itza' do this because they know that spider monkeys like to play with and chew on ramon fruits, and then throw them onto the forest floor. Itza' pick up the fruits that are not chewed through and leave the rest, knowing also that the half-chewed fruits are even more likely than unchewed fruits to generate new ramon stands. From such Itza' behavior, a Ladino observer may deduce that: (a) ramon is desired and useful for people, and (b) spider monkeys can affect ramon seeds. But Ladinos do not generally learn that: (c) spider monkeys positively affect ramon seeds and so help both the forest and the people in it.

We also have tentative evidence that some Ladinos are making plausible but unwarranted inferences that Itza' do not. For example, in the absence of direct observation of furtive, nocturnal felines, it is plausible to believe that they would hide out under the protective cover of leafy fruit trees to prey upon other animals that feed on the fruit. Female Ladinos who seldom venture into the forest overwhelmingly (75%) infer that felines seek out fruit trees. Male Ladinos (17%) and Itza' (16%) know better because they go into the forest. Because Itza' hunt at night, they are generally aware (63%) that felines stalk their prey in areas of grassland and underbrush, rather than deep forest, whereas few Ladinos (12%) show such awareness. Along the same lines we find that both Ladinos and Itza' women are more likely than men to infer that animals hurt plants (though Itza' women are also more likely than Ladino men to infer that animals help plants). Itza' and Ladino men's judgements of negative relationships are significantly correlated ($R_{xy} = +.50$, $p < .01$) and that Itza' and Ladino women's judgments are also correlated ($R_{xy} = +.53$, $p < .01$) but that cross-gender judgements are not reliably correlated. Since the women spend much less time in the forest than the men, it seems plausible that their judgments are truly inferences.

Now consider the second form of inference. Although Ladino observers seem to lack the Itza' cultural bias of conceiving species relationships reciprocally, they are nevertheless able to spontaneously induce much more from a single instance of experience than simply (a) and (b). For example, we should expect Ladinos to generalize their observations along much the same lines as Itza' do when Itza' and Ladino taxonomies coincide. In the above scenario, Ladinos should "automatically" infer that howler monkeys and kinkajous similarly affect ramon because Ladinos, like Itza', recognize both generic species as belonging to the same intermediate folktaxon as the spider monkey (see López, et al, 1997). Further correspondences are predictable from the similarity between the two groups' appreciations of ecological associations. For both groups, the ramon tree and the chicle tree have very similar ecological profiles. Accordingly, both groups should readily generalize relations from, say, spider monkeys and ramon trees to kinkajous and chicle trees. An analysis of response patterns indicates that this is consistently the case.

One key constraint on inductive inference is the interpretation of the base event itself. In the above scenario, if the Ladino observer lacks a cultural propensity for conceiving of species relationships reciprocally, then he will neither learn that spider monkeys help ramon trees nor infer that kinkajous help chicle trees. In one line of followup work we have been examining ecological models among younger, Spanish-speaking Itza'. Relative to older Itza' speakers, we find considerable overlap but also what appear to be systematic under- and over- generalizations. Unlike the Ladinos, the younger Itza' generalize along lines of reciprocal relations. In fact, overall, they report as many positive animal-plant relationships as the older Itza'. This suggests that the younger Itza' retain the cultural bias for construing generic-species relationships reciprocally. In some cases their over-generalizations (relative to the older Itza') may reflect construing an asymmetrical relationship reciprocally, just as the Ladinos apparent construe reciprocal relationships asymmetrically. In short, individual Ladinos and younger Itza' seem to project fragmentary observations of older Itza' behavior to a richly textured cognitive model of folkecology by inference rather than imitation or invocation of norms (even the notion of "reciprocity" that we invoke to interpret Itza' responses is only a gloss for a distributed network of ideas).

We believe that social learning involves inferential processes that are mobilized according to several factors: (1) domain-specific cognitive devices (e.g., taxonomy for biological kinds), (2) prior cultural sensitivity to certain kinds of knowledge (e.g., species reciprocity in ecological relationships), (3) awareness of lack of knowledge and the motivation to acquire it (doubt), (4) selective attention (e.g., Itza' deference and attention to forest itself while Ladinos also focus on the behavior of Itza' elders), and (5) pre-existing values (weighted preferences) with respect to a given cognitive domain (e.g., overvaluing economic utility relative to other determiners of interest, such as sacredness or role in the economy of nature, see below).[12]

Overall, then, Ladino knowledge is a subclass of Itza' knowledge that under-represents the ecological complexity and spiritual integrity of Itza' knowledge. To be sure, the Ladinos use their own taxonomic and ecological knowledge of the forest to generalize their inferences from Itza' behavior. From studies of other Ladino communities in Petén, it seems that some "Peténero" Ladino communities have learned to think and act much as Itza' do after three or four generations of the kind of contact described between our Itza' and Ladino samples (Schwartz, 1990). This may well involve assimilating "spiritual values" of an Itza' kind, to which we now turn.

Spiritual Games.

Anthropologists and sociologists target norms as functional building blocks of cultures and societies. Economists and political scientists see norms as institutional means to solving public goods problems, like "The Tragedy of the Commons" (Hardin, 1968; Ostrom, 1990; Fukuyama, 1995). The general idea is that to solve problems of rational choice inherent in balancing individual with collective needs, individuals must be made to forsake a measure of self-interest, and to sacrifice resources in accordance with institutional norms that function to maintain the public good(s).

Yet, evidence from our "garden experiment" neither indicates the primacy of norms in explaining cultural differences in regard to The Tragedy of the Commons, nor does it indicate that institutional mechanisms are exclusive or primary means for preserving common resources. Immigrant 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 culturally hermetic).[13] The Itza' community is the most socially-atomized and the least institutionalized (at least in terms of coordinated agricultural schedules), but its individuals most clearly act to maintain the common environment. If neither institutionalized learning nor institutional control mechanisms are responsible for commons maintenance among Itza', what is?

Values. More generally, the puzzle for decision theory is: How do people manage limited resources in a sustainable manner without apparent institutional or other obvious normative constraints to encourage and monitor cooperation? Our tentative line of reasoning is that Itza', and perhaps other native peoples with a long history of ecological maintenance, might not treat resources as traditional decision and game theory suggests, that is, as objects of a payoff matrix (extensional items substitutable along some metric, such as one that assigns monetary value to every object). Instead, some people may treat resources, such as species, as intentional, relational entities, like friends or enemies.[14]

We asked people from each of the three Petén groups to rank order or each of 21 plant species in terms of their importance according to: (1) members of their own community, (2) & (3) members of each of the other two communities, (4) God, and (5) the forest spirits. Only Itza' see the forest spirits as actively protecting the forest: Itza' rankings from the point of view of the forest spirits are significantly related to Itza' models of human impact as well as ecological centrality. For example, multiple regressions show that male Itza' consensus on spirits together with the overall Itza' consensus on combined use (wood + shelter + cash) account for most of the variance in human impact, with spirits and use equally weighted predictors. The most reliable combination of predictors for what (male Itza' believe) the spirits think is ecological centrality and God. Ladinos and Q'eqchi' state belief in forest spirits, and Ladinos even provide normative and narrative accounts of spirit life similar to those of Itza'. Yet, in these two groups belief in spirits is not reliably linked to forestry practice.[15] Itza' rankings of God's preferences are related to the measure of combined use but ecological centrality is not.[16]

To date, rational-decision and game-theoretic accounts involving human use of non-human resources have not considered the possibility of resources (e.g., species) and humans both as "players" in the same game. Prima facie, such consideration is not plausible, because species are assumed not to have motives, desires, beliefs, or strategies for cooperation or deception that would be sensitive, and systematically responsive, to corresponding aspects of human intention. Nevertheless, both in increasingly globally-oriented ecological movements in the industrial world and in religious practices of small-scale societies there are public pronouncements of respect for species. Indeed, one claim for "animistic" and "anthropomorphic" interpretations of species in many small-scale societies is that the "intention gap" between humans and species is thus bridged (at least to human satisfaction) with outcomes mutually beneficial to the survival of species and of the human groups that live off of those species (cf. Bird-David, 1999).

Itza' men and women express the belief that they will be punished if they violate spirit preferences, although women are less clear about what such preferences are likely to be. Especially for men, the spirits are intermediaries or "spokesmen" for the forest species. This has intriguing implications for ecological decision and game theory in that individual Itza' may be basing cognitive and behavioral strategies for sustaining the forest more by playing a game with spirits than by playing a game with other people (on the wider role of spirits in Itza' life and religion, see Atran, 2001). Note that evolution itself provides mechanisms for interactive "games" that commensurate the incommensurable (e.g. "strategies" of bacteria and their hosts), and so may human minds (semantically rather than biologically) in ways consistent with maintaining absolute or asymptotic respect for sacred or "taboo" values basic to long-term survival and quality of life (Fiske & Tetlock, 1997, Medin, Schwartz, Blok, and Birnbaum, 1999).

Theories of rational action predict that increases in the number of non-cooperative players in the environment and their apparent disregard for the future should lead even native cooperators to abandon long-term interest for short-term gain, unless institutional restraints can compel individual action towards the common good. Yet, Native Itza' Maya, who have few cooperative institutions, show awareness of ecological complexity and reciprocity between animals, plants and people; whereas immigrant Q'eqchi' Maya, who have highly cooperative institutions, acknowledge few ecological dependencies. No doubt economic rationality and institutional constraints are important factors in determining and describing actions upon common-pool resources, but they may not suffice. There also appears to be an important cognitive dimension to behavioral research on how people learn to manage environmental resources. Valuation studies suggest that cognition of supernatural agents may serve not only to guarantee trust and foster cooperation between non-kin, as standard commitment theories assume (Frank, 1988, Irons, 1996), but also foster human interaction with nonhuman resources in relations of "indirect reciprocity" (Alexander, 1987).

Summary. It's no surprise that native Maya with centuries-old dependence on a particular habitat better resist actions that lead to its degradation than immigrants. What is surprising is that Ladino immigrants who share no evident tradition with native Maya come to measurably resemble them in thought and action, and much more than immigrant Maya do native Maya. Network analyses reveal reliable but non-institutionalized linkages that allow socially well-connected Ladinos access to Itza' forest expertise. The highest overlap, or "fidelity," among individual patterns may stem from inference based on individual exposure to role models, not instruction or imitation. No identifiable "rules, "norms" or other discrete bits of cultural information or behavior function as plausible candidates in our studies for cultural transmission and selection.

Further observations in Mesoamerica and North America.

We have used the same techniques to monitor ecological cognition and social networks for Yukatek Maya (Xk'opchen) and Ladinos (Xkomha) in Quintana Roo (Mexico), among Lacandon Maya (Metzäb'äk) and Tzeltal and Tzotzil immigrants in the Sierra Lacandon (Chiapas, Mexico), and among Native American Menominee and majority-culture rural groups along the Wolf River in Wisconsin (Medin et al., 2001). Preliminary studies in the Lacandon (interrupted by civil strife) suggest that the patterns of knowledge and behavior among Lacandon (Lakantun) Maya vs. Tzeltal and Tzoltil Maya born to families that immigrated into Sierra Lacandon from the Chiapas Highlands resembles that of Itza' to Q'eqchi' immigrants (Ross, in press). The fact that these descendants of immigrants have lived all their lives in the Sierra Lacandon suggests that mere personal exposure to the local ecology is not a deciding factor.

The Wisconsin studies concern fishing and hunting rather than agro-forestry but the theoretical question is the same: Are there distinct conceptualizations of nature that underlie the Menominee tradition of sustainable forestry (e.g. Hall and Pecore, 1995), healthy rivers and lakes and abundant fish and game? Our results to-date are most extensive for fish and fishing, but preliminary observations strongly suggest that we will find the same patterns for hunting. We have already mentioned that Menominee fishermen are more likely to sort ecologically than majority culture fishermen, and now we turn to more direct probes of folkecological models.

In the first probe, we explored the perception of species interactions. On many grounds one would not expect to observe group differences in perceived fish-fish interactions. First of all, informants from the two groups engage in essentially the same activities in terms of when and how they fish. Secondly, activities associated with fishing are intimately intertwined with fish-fish interactions. To be successful in fishing, one needs to know where fish are found and what they are eating. Food chains are an important component of fish-fish interactions. Third, our informants were experts who had been fishing on average for several decades and one might expect a convergence of knowledge, especially when that knowledge is relevant to certain activities.

Twenty-one familiar species were selected and represented on name cards. The experimenter randomly picked one fish as a base-card and compared it with every other species (presented in random order). For each informant, this procedure yielded 420 potential fish-fish relationships. For each fish-fish pair, the informant was asked if the base species affects the target species and vice versa (e.g., "Does the northern affect the river shiner?" and "Does the river shiner affect the northern?"). Informants were then asked whether the species affect each other in other ways. Responses were coded into 19 categories such as A eats B, A eats the spawn of B, A helps clean the bottom that helps B when it spawns, and so forth. Food-chain relations (A eats B) comprised the most frequent response.

Results. The CCM was used to probe for a single, general cross-group model for fish-fish interactions, as well as for each group's particular cultural model. Agreement was assessed on four levels: (1) both informants reported some kind of relation (no matter what the specific relation was), (2) both agreed on either a positive or a negative relation (no matter what the specific relation was), (3) both agreed on a food-chain relation and (4) both agreed on a reciprocal relation (no matter what the specific relations were).

CCM's were performed both on raw agreement as well as on the agreement adjusted for guessing. For both raw and adjusted agreement we found consensus for the combined meta-cultural model as well as for separate cultural models on three levels: (1) existence of a relation, (2) helping /hurting relations, and (3) food chain relations. We found consensus for reported reciprocal relations only with respect to raw observed agreement. Menominee show above chance agreement for the adjusted reciprocal relations: 69% of the agreement pairs are positive (by chance, half should be positive). Cross-group agreement is very close to chance (48% of agreements). Overall, the data indicate high agreement within and across groups for the different levels of encoding the data.

For all relations cited by at least 70% of the members of one group, we further find that: (1) 85 % are reported by both groups; (2) 14% (45 relations) are reported by Menominee but not majority culture; and (3) 1% (4 relations) are reported by majority-culture but not Menominee experts. Overall, Menominee report reliably-more relations than their majority-culture counterparts (62% vs. 46% of the possible relations). In short, the majority-culture ecological model appears to be subset of the Menominee model, a finding that parallels our results from the sorting task and the Itza'-Ladino comparison on the forest ecology task. On a more specific level, Menominee experts report significantly more positive relations (one species helping another) than their majority culture counterparts do while members of both groups mention about the same number of negative relations.

The groups also differ substantially with respect to reciprocal relations. On average, Menominee informants mention 59.5 reciprocal relations compared to 34.6 for majority-culture fish experts. Majority culture experts differ from their Menominee counterparts in that they are likely to report the prototypical adult-species relation. For example, majority culture experts are likely to report that northerns eat walleyes and not mention that a large walleye may eat a small northern.

Summary. The two cultural groups share a substantial amount of knowledge of species interaction. This should come as no surprise. Much of expert knowledge stems from actual observation while looking for fish, fishing, and even from cleaning the catch (e.g. stomach contents usually tell what the fish had been eating recently). However, the task also reveals clear cultural differences in the models of the individuals. These differences may be caused by the fact that the responses of majority culture informants concerning ecological relations seemed to be filtered through a goal-related framework. Goals may influence reports of ecological relations in at least two ways. One is to focus on ecological relations that apply to adult fish rather than those associated with the entire life cycle. Indeed, many of the relations reported by Menominee experts but not majority culture experts involve spawn, fry, or immature fish. The second difference is that relations present in pursuing goals may be "over-generalized" in the sense that they may be reported where they do not apply. Majority culture experts tend to report baitfish being affected by predator fish, even when the particular baitfish and predator tend not to be found in the same waters. Other than these few over-generalizations, the nominated relations appear to be accurate.

These observations suggest that some of the differences are more the effect of "habits of the mind," such as the higher saliency or accessibility of some knowledge over other knowledge. If this is correct, we might expect that the cultural differences in ecological knowledge would disappear if we used an unspeeded task directly probing for ecological information. In an additional experiment, we asked the experts to sort local fish species according to where they are found and indeed the cultural differences were absent. Both groups share essentially the same model and knowledge base. This finding is important on two accounts. First, it provides converging evidence that our informants do not differ in expertise per se. Second, the data support the idea that the cultural differences may lie in accessibility of knowledge or "habits of mind" rather than knowledge per se.

We have also begun to examine folkbiological models in less expert Menominee and majority culture populations. The results from our initial sorting task reveal an interesting picture with respect to explanations given for sorting. Like Menominee experts, Menominee non-experts tended to give relatively more ecological justifications (40%), and fewer goal-related (29%) and taxonomic-morphological (31%) justifications. The majority-culture non-experts, by contrast, gave fewer ecological justifications (16%) and more goal-related (43%) and taxonomic-morphological (41%) justifications. Whereas the pattern of justifications given by Menominee informants is robust across the two levels of expertise, the pattern given by majority-culture informants changes, such that, with expertise, majority-culture informants come to give more taxonomic-morphological and fewer ecological and goal-related justifications. Some majority culture experts explicitly mentioned how their orientation towards fishing had changed over the years, moving away from the stereotypic sportsman's model that targets fishing contests or going for the "trophy-fish."

Cluster analysis of sorts supports the sorting justifications. It also reveals substantial differences between cultural groups as well as strong similarities within groups across levels of expertise. For the majority culture, both experts and non-experts appear to sort according to goals, with some influence of morphological and taxonomic strategies such as size and folk-generic linguistic markings. By contrast, Menominee informants, across levels of expertise, appear to rely primarily on ecological closeness such as shared habitat.

Our data show that expertise cannot be separated from cultural milieu, even when people engage in more or less the same activities. In that respect, cultural paths (in the sense of reliable distributions of conceptual representations in a population of minds) appear to provide something of a framework theory for organizing experience. This is seen, for example, in the Itza' Maya tendency to see reciprocal relations (animals helping plants as well as being helped by them) and in Menominee fishermen's ecological orientation. The parallels between the Itza' and Menominee are striking, especially when one notes that both groups also have sustainable forestry practices. We have also been collecting data on Menominee and majority culture fishermen's goals, values, and attitudes toward fishing practices and we continue to observe cultural differences. For example, many Menominee fishermen believe that if a person treats nature in a greedy or wasteful manner then spirits will punish them. Menominee may also offer tobacco as a prayer of thanks (as do Itza' Maya).

<u>Summary and Implications</u>.

We have just reviewed a decade long project on mental models of nature that has naturally branched in several directions. Despite this complexity, the project nicely illustrates the framework that we described at the beginning of this paper. First of all, the view of culture as a patterned distribution of cognitions and behaviors set the stage for addressing issues of learning, inference, and transmission of information, within and between cultural groups. Second, our previous work on category-based induction enabled us to identify inferential patterns in knowledge acquisition and transfer. We saw that these patterns reflect both universal constraints on biological inductions and culturally-specific biases in construal and organization of information.

Equally significant, this body of work casts a different light on the tragedy of the commons and associated game-theoretic analyses. First, individual cognitions or mental models of resources are not irrelevant to environmental decision making as assumed by content-free framing in terms of utilities.[17] Second, differing conceptions of a common resource may require different abstract analyses, as we saw in the case of the Itza' belief in the forest spirits as guardians of the forest. In short, biological cognition can inform-- and indeed transform—models of decision making.

X. General Discussion, Implications, and Conclusions.

As in any woven fabric, the individual lines or threads become subsidiary to emergent properties. And the finished product can be examined from distinct points of view, such as its texture, its patterning, its utility, or even its symbolic significance. Except for the fact that our research program is still a work in progress, much the same can be said about it. Because it is incomplete, details may change and there may be important regularities still missing, either because more work is needed or because we haven't always looked at things from the right perspective. But we think we have found unmistakable patterns in cultural variations on biological cognition. In this final section we will review our project from the vantage of cognitive theories, domain specificity, and methodology for conceptualizing culture.

We are ready to return to Table 1, summarizing our claims, and the status of evidence bearing on them. As in the introduction, this summary can be seen from three distinct perspectives: theories of cognition, domain specificity, and methodologies for studying cultural variables.

Implications for Theories of Categorization, Reasoning, and Decision Making.

Categorization. Two of the most robust and significant findings in the psychology of concepts are basic level phenomena and typicality effects. Our work suggests important modifications in each of these.

Basic level and essentialism. A serious conceptual problem is that both ethnobiology and cognitive psychology have argued for one, especially salient level of categorization but have disagreed about which specific level is privileged in biological taxonomies. The studies of Rosch et al, (1976), using measures of knowledge, naming preferences and perceptual tests found converging evidence for the life-form level as the most relevant. Ethnobiology favors the generic-species rank as privileged.

Our studies provide a way of reconciling this divergence. We think that biological essentialism may be universal and that it is linked to an evolutionarily-adaptive appreciation of generic species. For contemporary peoples in small-scale societies who continue to live intimately with nature, the level of generic species is the most relevant, as it likely was also for our hominid ancestors. When we used an induction task where performance can be based on either or both knowledge and expectation, we found convergence across cultures and expertise on the generic-species level as privileged for biological inference. The fact that biological experts also privilege the generic-species level on perceptual tests suggests that the divergence in question has little to do with how psychologists versus ethnobiologists measure the basic level. Rather, the apparent salience of the life-form level for undergraduates on feature listing and perceptual tests appears to be a peculiarity of the devolved state of undergraduate biological knowledge in particular, and that of industrialized populations in general (for a German example, see Zubin and Köpcke, 1986).

Why should the generic-species level be privileged for biological inference in the face of uncertainty? Because that is where the action was and, often still is, in human dealings with biological kinds. It would also be sensible for the perceptual system to be tuned to this same level of biological reality, and we suspect that this is the default condition for human beings who depend directly on nature for survival (i.e., without the intermediary of supermarkets and shops). Some perceptual learning may be necessary to achieve this consonance (e.g. Goldstone, 1998; Schyns and Rodet, 1997), experience that undergraduates may lack. More generally, people may have a perceptual-familiarity heuristic that allows them to rapidly and economically navigate their everyday world. This heuristic may be importantly influenced by cultural support (Wolff, et al, 1999) and parental input. There is increasing evidence from studies with infants that words act as invitations to form basic level concepts (Waxman and Markow, 1995, Waxman, 1999), which in our society tend to focus on the life-form level (except for familiar pets and domestic animals; hence, bird, fish and *dog* are basic).

Typicality. The standard assumption has been that goodness of example, or typicality, is driven by similarity relations. A good example of a category is one that looks like its fellow category members and unlike members of contrasting categories (e.g. Rosch and Mervis, 1975; Smith, et al, 1974; Smith and Medin, 1981). As we noted, the SCM assumes that goodness of example effects extend to category-based induction.

Once again, however, results based on the standard undergraduate population proved to be atypical in the case of biological kinds. First, when the stimuli being judged are names of trees, undergraduates even fail to show similarity-based typicality. Instead, word frequency or familiarity is the best predictor (Lynch, et al, 2000). Apparently, undergraduates know too little about trees to even have a basis for computing similarities. More to the point, populations with domain familiarity, whether professional taxonomists or Itza' farmers, consistently organize categories in terms of ideals, such as the taxonomist's American elm or the Maya's wild turkey.

We believe that people who have serious commerce in a domain rarely approach it in a content-neutral manner, passively recording the regularities associated with the category. We saw that the Itza', for example, bias their observations of biological kinds toward those that are most perceptually- and ecologically-salient (e.g. large game birds, predators, and poisonous snakes). Parks workers worry about susceptibility to disease and other maintenance problems with local trees, and their typicality ratings reflect this concern. Majority culture fishermen attend to game fish and Menominee fishermen expand that focus to include sacred, culturally-important fish. In brief, the ways people deal with the world profoundly affect the ways they cognize it.

Much the same story can be told for typicality effects in reasoning, where responses to probes may be better predicted from knowledge of ideals than from computed central tendency. It is important to emphasize that the use of ideals in reasoning is indirect, rather than direct. That is, idealness per se plays no role in the rationale for responses. Instead, it is the implicit organization of knowledge organized around goals that both creates category ideals and drives category-based inference. For example, the Itza' Maya find passerines less relevant than gamebirds and raptors for understanding the forest (the forest being the primary focus of their understanding of the biological world). Consequently, they have much more knowledge about the large birds, knowledge that is recruited on reasoning tasks.

<u>Category-based Inference and Diversity</u>. Although previous induction models have implicitly assumed that diversity-based responding is universal, it clearly is not. When we probed Itza', bird watchers, tree experts and fishermen in areas where they had knowledge we hardly ever observed diversity responses (and sometimes found below chance diversity).

Obviously, observations such as these require a reformulation of inference theories. We described a new approach based on relevance theory, a natural marriage between the content biases we find in folkbiological cognition and the search for maximal relevance. This search "involves selecting the best possible context in which to process an assumption: that is, the context enabling the best possible balance of effort against effect to be achieved. (Sperber and Wilson, 1996,p.144)." Content bias is a fundamental component of background knowledge and the information-processing context. With this framework in hand, we were able to manipulate effort and effect with undergraduates and produce violations of diversity (and even similarity).

Itza' noncompliance with diversity-based reasoning apparently results neither from a failure to understand the principle of diversity nor from any problems of "computational load." As with the most evident divergences between American and Itza' performance on similarity and typicality tasks, divergence from diversity apparently results from real-world concerns. In the absence of a theory - or at least the presumption of a theory - of causal unity underlying disparate species, there is no compelling reason to consider a property discovered in two distant species as biologically-intrinsic or essential to both. This does not mean that Itza' do not understand a diversity principle. In fact, in a series of tasks designed to assess risk-diversification strategies (e.g., sampling productivity from one forest plot or several) Itza' consistently showed an appreciation of the diversity principle in these other settings (López, et al., 1997). This suggests that although diversity may be a universal reasoning heuristic, it is not a universally-relevant aspect of folkbiological taxonomy, as we also found in US populations having more direct interest in the natural world.

Mental models, protected values, and environmental decision making. In the area of decision making and the commons, the prevailing view has been that human behavior in society is driven by self-interest, mitigated by institutional constraints. Like models of induction that rely on universal similarity, abstract decision models employ a homogeneous notion of utility, where content biases and protected values simply are annoying. For example, protected values are annoying because their "utility" may be hard to measure (Baron and Spranca, 1997; Ritov and Kahneman, 1997), and content biases only serve to distort rational calculations of utility.

Thus, analyses of the 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. To be sure, there is a good body of social science research that identifies certain conditions for cooperation in artificial experimental situations (e.g. Messick and Brewer, 1986, Ostrom, 1998) but it is hard to see how to transfer these findings to complex, real world situations such as we find in Petén and Wisconsin. Furthermore, this body of research provides no role for content or values other than in terms of fungible (transparently interchangeable) gains and losses. There is no place for absolute or sacred human values (Rappaport, 1979), distinct kinds of concerns (see Tenbrunsel and Messick, 2001, for a nice counterexample), or for calculating the "interests" of nature (Wilson, 1992).

We find that content-structuring mental models are pertinent to environmental decision making. They not only predict behavioral tendencies and stated values, but also correlate reliably with the measurable consequences of those behaviors and values – even down to the level of soil composition and the number and variety of trees found on people's land. Perhaps most striking, Itza' construal of the value of a forest species as relational and subjectively-defined seems to recognize nature as a player with a stake in its own future. This is a different way people have of going about their business, and their environments may be the better for it. We think that this sort of analysis opens the possibility for making models of decision processes more insightful with respect to understanding human-environment interactions.

Domain Specificity, Modularity, and Cultural Variation.

We have provided evidence for structural and functional autonomy of folkbiology in human cognition. First, our cross-cultural experiments on children's inductions from human to animals and vice versa indicated that humans are not the prototype that organizes the domain of animals. Second, young children from diverse cultures, who were tested on inheritance and adoption tasks, showed evidence for understanding the concept of underlying biological essence as determining the innate potential of species. Together with previous research by other investigators, the data suggest that folkbiology does not come from folk psychology. Third, our inductions experiments with regard to the basic level indicated that folkbiological taxonomies are universally anchored upon the generic-species level, where inductive potential is greatest.

Fourth, our category-based induction experiments showed that people from diverse societies build topologically-similar biological taxonomies that guide inferences about the distribution of biological and ecological properties. Just how the taxonomies are used may vary across groups. For undergraduates, the taxonomy is a stand-in for ideas about the likely distribution of biologically-related properties (e.g. diseases). For the Itza' (and other knowledgeable groups) the taxonomy constrains the likely operational range of ecological agents and causes. Fifth, we also saw that these taxonomies constrain what we called the learning landscape and help determine the transmission of information both within and across cultural groups.

These universal tendencies are most salient outside the center of industrialized societies but nonetheless discernable everywhere. Our observations provide a cautionary tale: at least in the case of folkbiology, standard populations may be nonstandard and vice versa. For example, it was only when we confronted the custom of taking undergraduates as the base or standard that we began to see their reasoning strategies as a response to a lack of relevant domain knowledge.

Biology as a module of mind. Different cognitive scientists have offered alternative and sometimes conflicting notions of modules so we will take a few paragraphs to say what we mean by modules. We consider that there are roughly two classes of evolved cognitive modules: perceptual modules and conceptual modules. A perceptual module has automatic and exclusive access to a specific range of sensory inputs, its own proprietary database, and may not draw on information produced by other conceptual modules or processes. A perceptual module is usually associated with a constrained neural architecture, and fast processing that is not accessible to conscious awareness. Examples may be modules for facial recognition, color perception, identification of object boundaries, and morpho-syntax (Fodor, 1983).

A conceptual module works on a privileged, rather than strictly proprietary, database that is provided by other parts of the nervous system (e.g., sensory receptors or other modules), and which pertains to some specific cognitive domain (Atran, 1990:285). Examples include folkmechanics, folkbiology and folkpsychology.[18] The argument for conceptual modules involves converging evidence from a number of venues: Functional design (analogy), ethology (homology), universality, precocity of acquisition, independence from perceptual experience (poverty of stimulus), resistance to inhibition (hyperactivity), and cultural transmission. None of these criteria may be necessary, but the presence of all or some is compelling, if not conclusive. Here, we will only consider the latter two principles because they are rarely a part of discussions of modules (for a full discussion of principles, see Atran, 2001c).[19]

Resistance to Inhibition and Hyperactivity**.** One characteristic of an evolved cognitive disposition is evident difficulty in inhibiting its operation (Hauser, 2000). Consider beliefs in essences. Such beliefs greatly help people explore the world by prodding them to look for regularities and to seek explanations of variation in terms of underlying patterns. This strategy may help bring order to ordinary circumstances, including those relevant to human survival. But in other circumstances, such as wanting to know what is correct or true for the cosmos at large, such intuitively ingrained concepts and beliefs may hinder more than help

Because intuitive notions come to us so naturally they may be difficult to unlearn and transcend. Even students and philosophers of biology often find it difficult to abandon commonsense notions of species as classes, essences or natural kinds in favor of the concept of species as a logical individual – a genealogical branch whose endpoints are somewhat arbitrarily defined in the phyletic tree and whose status does not differ in principle from that of other smaller (variety) and larger (genus) branches. Similarly, racism - the projection of essences onto social groups – seems to be a cognitively facile and culturally-universal tendency (Hirschfeld, 1996). Although science teaches that race is biologically incoherent, racial or ethnic essentialism is as notoriously difficult to suppress as it is easy to incite (Gil-White, 2001).

Cultural Transmission: Human cultures favor a rapid selection and stable distribution of those ideas that: a) readily help to solve relevant and recurrent environmental problems, b) are easily memorized and processed by the human brain, and c) facilitate the retention and understanding of ideas that are more variable (e.g., religion) or difficult to learn (e.g., science) but contingently useful or important. Folkbiological taxonomy aids humans in orienting themselves and surviving in the natural world. Its content tends to be fairly stable within cultures (high inter-informant agreement, substantial historical continuity) and structurally comparable across cultures (Berlin, et al., 1973). Over time and different cultural settings, taxonomic structure and content may become deeper (as with Itza' awareness of trees) or shallower (as with many industrialized populations). Nevertheless, its organizational principles remain robust. Folkbiological taxonomy also continues to serve as a principled basis for transmission and acquisition of more variable and extended forms of cultural knowledge, such as certain forms of religious and scientific belief (Atran, 1990, 1998, in press).

In summary, the sort of cultural information that is most susceptible to modular processing is the sort of information most readily acquired by children, most easily transmitted from individual to individual, most apt to survive within a culture over time (provided adequate input and cultural support), most likely to recur independently in different cultures and at different times. Critically, it is also the most disposed to cultural variation and elaboration. It makes cultural variation comprehensible. This evolutionarily-constrained learning landscape can be viewed from two complementary perspectives. One the one hand, it is forgiving enough to allow strikingly different folkecological cognitions and behaviors among distinct cultural groups living in the same habitat. On the other hand, it also provides sufficient structure to allow us to understand these selfsame contrasts as variations on a panhuman theme of interactions between people and generic species.

Methodologies for Conceptualizing Culture.

We have presented a view of cultures as comprised of causally-distributed networks of mental representations, their public expressions (e.g., artifacts, languages, dances, etc.) and resultant behaviors in given ecological contexts. Ideas and behaviors become "cultural" to the extent that they endure among a given population. This view is in contrast with standard social and cognitive science notions of culture. Just as it was (and still is) difficult for biology to discard the essentialized notion of species in favor of species as a historical, logical individual (Ghiselin, 1981), it is difficult to abandon the commonsense notion of culture as an essentialized body (of rules, norms, and practices). In biology, it makes no sense to talk about species as anything other than more of less regular patterns of individual variation. Neither can one delimit species independently of other species. So, too, it makes little sense to study cultures apart from patterns of variation.

The distributive view of culture implies a methodology that departs in distinct ways from traditional anthropology, where the intrepid explorer becomes immersed in culture X and returns to report how Xers think and behave: "we are not interested in what A or B may feel *qua* individuals... we are interested only in what they feel and think *qua* members of a given community [where] their mental states receive a certain stamp, become stereotyped by the institutions in which they live" (Malinowski, 1961/1922). Rarely in ethnography does the explorer ever specify precisely which Xers think and behave this way (nor do they hint that all Xers might not think and behave this way). Social and political scientists treat culture as normative sets of rules and practices—an "inherited moral code" (Fukuyama, 1995). Cognitive psychologists who study culture explicitly acknowledge within-group differences, but seem content with showing statistically reliable differences.

Like modern biology, the distributive view of cultural phenomena does not take individual variation as deviation but as a core object of study. From this perspective, issues of cultural acquisition, cultural transmission, cultural formation and cultural transformation are intricately interwoven and, together, constitute the object of study. We have also seen how the cultural consensus model (Romney et al, 1986) can be a useful tool for analyzing patterns of relative agreement and disagreement within and across populations. In addition, social network analysis provided the means to examine likely pathways for learning and communicating information. Together, consensus modelling and network analysis enabled us to systematically explore the aforementioned issues in an integrated fashion.

For purposes of illustration, consider again our Itza' and Ladino study populations. First of all, somewhat to our surprise, we could not reject the possibility that the consensual ecological model of the Itza'-speaking elders was based a series of independent discoveries. We found no reliable residual agreement that could be traced either social or expert networks. We know that this finding does not owe to the insensitivity of our measures because these same networks revealed evidence that Ladinos were learning from Itza'. Our analyses suggest that the relevant conceptual biases for acquiring reciprocal understanding of species relationships are diffused throughout Itza' networks (extending, as we also saw, to younger Itza'). In this sense, "reciprocity" pervades Itza' "culture."

The Ladino settlement of La Nueva did not begin as a "culture" in any sense: it was founded by nuclear families stemming from scattered towns and villages with no apparent historical connections among them. Today, at least with respect to models of nature, Ladinos are forming patterns of cultural consensus, by assimilating ecologically-relevant information over expert and social networks, over- and under-generalizing that information in conformity with their taxonomies, and interpreting information in accordance with their own conceptual biases (e.g., non-reciprocity). And so the Ladinos form their unique cultural understanding, transforming (with varying fidelity) Itza' cultural models into their own.

XI. Conclusion.

In this paper, we have outlined a framework where cultural and ecological inputs combine with innate propensities to determine biological cognition. Although we have not specified the mechanisms underlying this innate potential and their development with experience, we have provided a functional analysis and a set of candidate universal principles. Against the backdrop of such principles, we see patterned variation as a function of ecological and social contexts. We have argued that the study of culture is the study of that variation within and across populations.

We are all born with native minds, though some develop in a manner better attuned to their natural surroundings than others. The full expression of the folkbiology module requires environmental triggering conditions and cultural support that may be lacking for certain groups in industrialized societies, including the usual subjects in most cognitive and developmental psychology experiments. From a theoretical perspective, the chief interest in studying these groups may not be to establish a baseline for generalizations about folkbiological knowledge, but to explore the cognitive consequences of limited input. From a more applied and practical standpoint, one may wonder how devolutionary processes in such groups affect environmental values, decision making and human survival.

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Table 1 Empirical and theoretical claims and the status of evidence bearing on them.

Claim:	**Status of evidence:**
Young children's biology is distinct from naïve or folk psychology.	Supported in Maya, Menominee and rural majority-culture populations.
Essentialism is a universal bias.	Inductive generalization over several populations but needs further case studies.
Essence and inductively privileged species (e.g. robin) not lifeform (e.g. bird)	Appears to hold across a variety of level corresponds to generic populations but needs further case studies.
Basis for typicality ratings and typicality effects in reasoning knowledge-dependent and undergraduates are often the "odd-group out"	Itza' Maya, bird experts, fish experts and tree experts differ from undergraduates.
Relevance theory provides a unifying framework for understanding category-based reasoning in all groups.	Speculative but consistent with the data; leads to some novel predictions.
Mental models of resources (e.g. forest)determine environmental decision making and transform the conceptualization of the commons dilemma.	Data are only correlational; teasing apart correlated factors remains a challenge; more cases needed.
Inferences associated with learning ecological models constrained by taxonomic/ecological groupings and cultural models.	Speculative but consistent with current data; more cases needed.
Folkbiology represents an innate module, with coherent variation as a function of culture and expertise.	Framework useful; results only partially predicted in advance.
Standard populations (e.g.undergraduates) may use impoverished default categorization and reasoning strategies (e.g. abstract similarity judgments) relative to those used by most of humanity (e.g. content-rich strategies)	Substantial within the domain of folkbiology. An open issue for other domains.

Table 2. Percent birth parent choice for each probe type for each group

(all results reliably different than chance)

	Known			***Unknown***			
GROUP	***behavior***	***phys feat***	***mean***	***behavior***	***phys feat***	***mean***	***Bias Control (Food)***
4-5 year olds	0.74	0.68	0.71	0.69	0.68	0.69	0.06
6-7 year olds	0.96	0.97	0.97	0.82	0.83	0.83	0.01
adults	1.0	0.96	0.98	0.90	0.93	0.92	0

Table 3. Summary of reliable main effects found for typicality and diversity trial justifications in bird study. Subject groups are represented by US nonexperts (N), US experts (E) and Itza' (I). Subject type effects are listed in the first subcolumn. Stimulus set effects are listed in the second subcolumn, and indicate a difference between justifications based on whether the American (US) or Itza' (TIK) stimulus set was used.

Justification Category	Typicality Trials		Diversity Trials	
	Subject Type	Stimulus Set	Subject Type	Stimulus Set
Typicality	N > E, I	US > TIK	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.

Table 4. Peten plants and animals

Ref.	Plant name	Scientific name	Ref.	Animal name	Scientific name
	FRUIT TREES			**ARBOREAL ANIMALS**	
P1 *	ramon	*Brosimum alicastrum*	A1	bat	Chiroptera
P2 *	chicozapote	*Manilkara achras*	A2	spider monkey	*Ateles geoffroyi*
P3 *	ciricote	*Cordia dodecandra*	A3	howler monkey	*Allouatta pigra*
P4 *	allspice	*Pimenta diocia*			*A. palliata*
P5 *	strangler fig	*Ficus obtusifolia*	A4	kinkajou	*Potus flavus*
		F. aurea	A5	coatimundi	*Nasua narica*
	PALMS		A6	squirrel	*Sciurius deppei*
P6 *	guano	*Sabal mauritiiformis*			*S. aureogaster*
P7 *	broom palm	*Crysophilia staurocata*			
P8 *	corozo	*Orbignya cohune*		**BIRDS**	
		Scheelea lundelli	A7	crested guan	*Penelope purpurascens*
P9	xate	*Chamaedorea elegans*	A8	great curassow	*Crax rubra*
		C. erumpens	A9	ocellated turkey	*Meleagris ocellata*
		C. oblongata	A10	tinamou	*Tinamou major*
P10	pacaya	*Chamaedorea tepejilote*			*Crypturellus* spp.
P11	chapay	*Astrocaryum mexicanum*	A11	toucan	*Ramphastos sulfuratus*
			A12	parrot	Psittacidae in part
	GRASSES / HERBS		A13	scarlet macaw	*Ara macao*
P12	herb/underbrush	(various families)	A14	chachalaca	*Ortalis vetula*
P13	grasses	Cyperaceae/Poaceae	A15	pigeon/dove	Columbidae
	OTHER PLANTS			**RUMMAGERS**	
P14 *	mahogany	*Swietania macrophylla*	A16	collared peccary	*Tayassu tacaju*
P15 *	cedar	*Cedrela mexicana*	A17	white-lipped pecc.	*Tayassu pecari*
P16 *	ceiba	*Ceiba pentandra*	A18	paca	*Cuniculus paca*
P17 *	madrial	*Gliricidia sepium*	A19	agouti	*Dasyprocta punctata*
P18 *	chaltekok	*Caesalpinia velutina*	A20	red-brocket deer	*Mazama americana*
P19 *	manchich	*Lonchocarpus castilloi*	A21	white-tailed deer	*Odocoileus virginianus*
P20 *	jabin	*Piscidia piscipula*	A22	tapir	*Tapirus bairdii*
P21 *	santamaria	*Calophyllum brasilense*	A23	armadillo	*Dasypus novemcintus*
P22 *	amapola	*Pseudobombax ellipticum*			
		Bernoullia flammea		**PREDATORS**	
P23 *	yaxnik	*Vitex gaumeri*	A24	jaguar	*Felis onca*
P24 *	kanlol	*Senna racemosa*	A25	margay	*Felis wiedii*
P25 *	pukte	*Bucida buceras*	A26	mountain lion	*Felis concolor*
P26 *	water vine	*Vitis tiliifolia*	A27	boa	*Boa constrictor*
P27	cordage vine	*Cnestidium rufescens*	A28	fer-de-lance	*Bothrops asper*
P28	killer vines	(various epiphytes)	A29	laughing falcon	*Herpetotheres cachinnans*

* Species counted in study of tree frequencies (= 44%, 50% & 54% of trees in Itza', Ladino & Q'eqchi' parcels, respectively)

Figure 1
Yukatek Maya Projections from Human

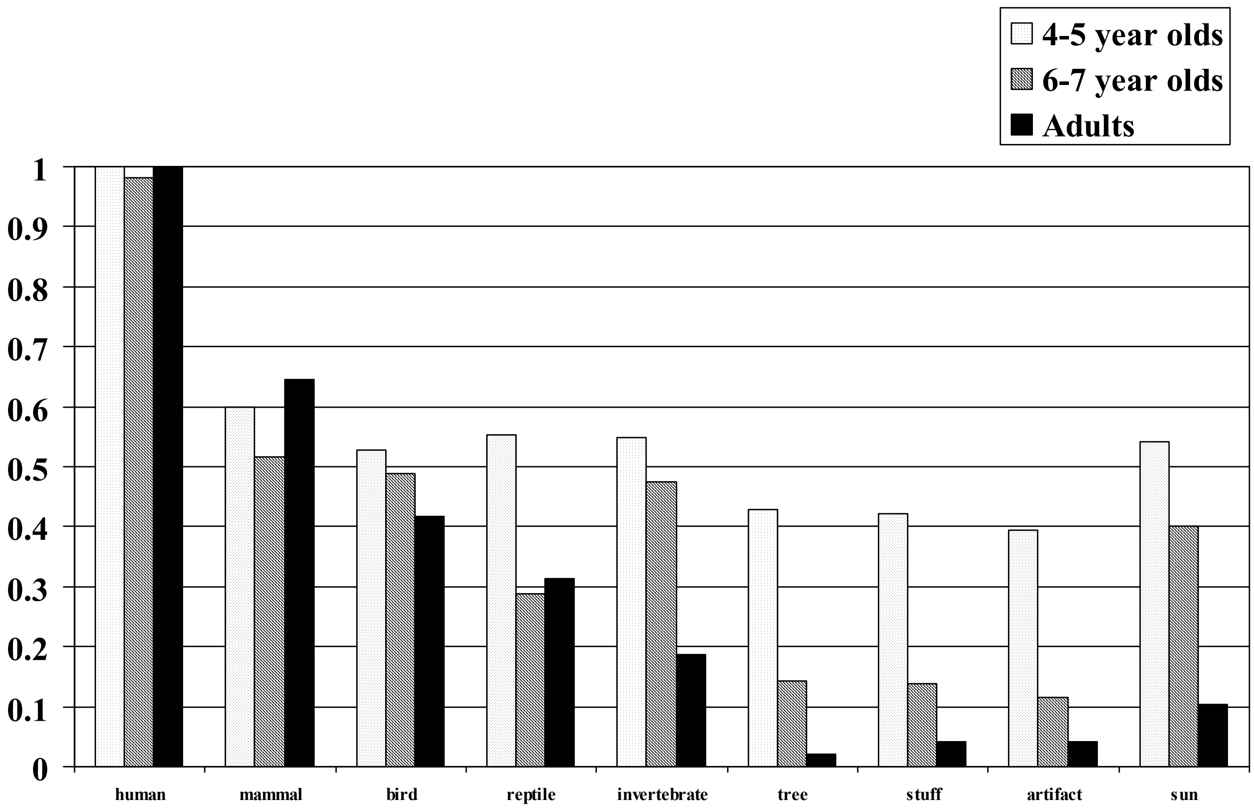

Figure 2
Yukatek Maya Projections from Dog

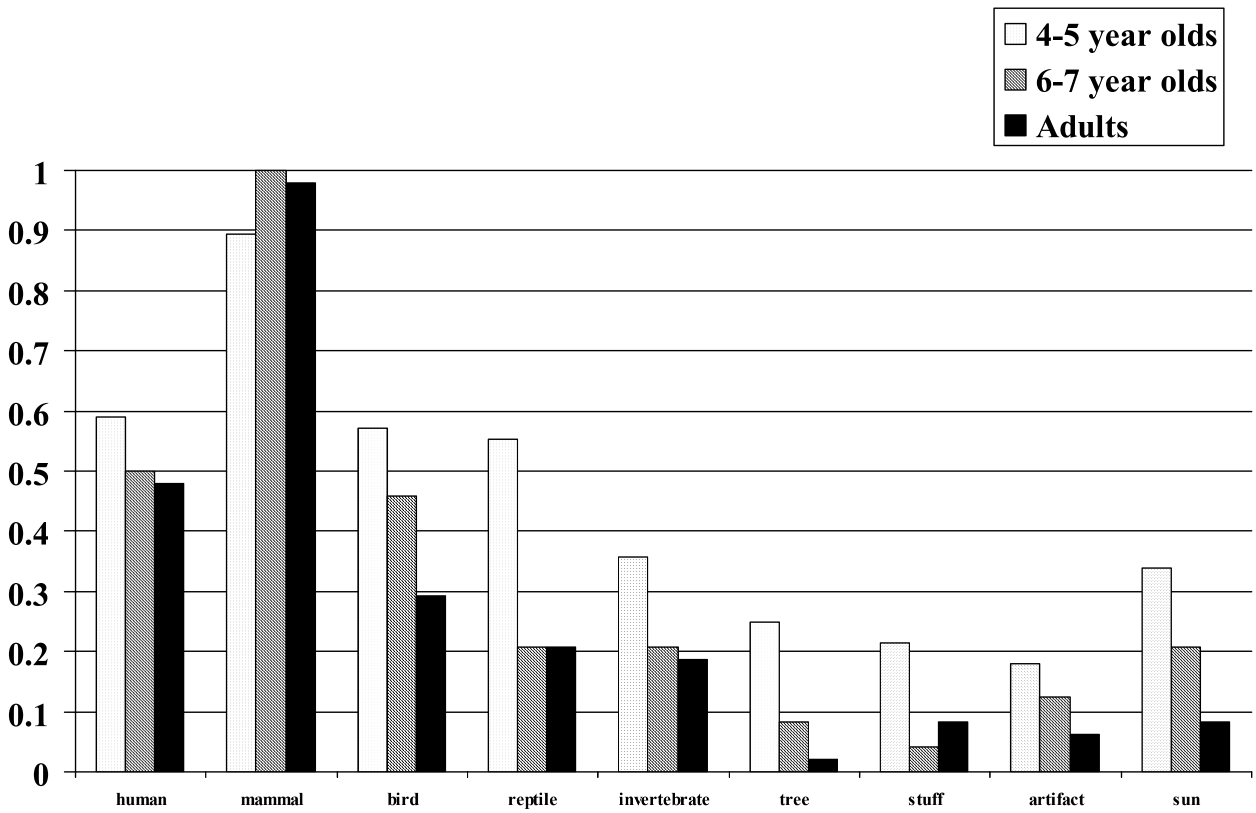

Figure 3
Combined Itza' results for all six life forms

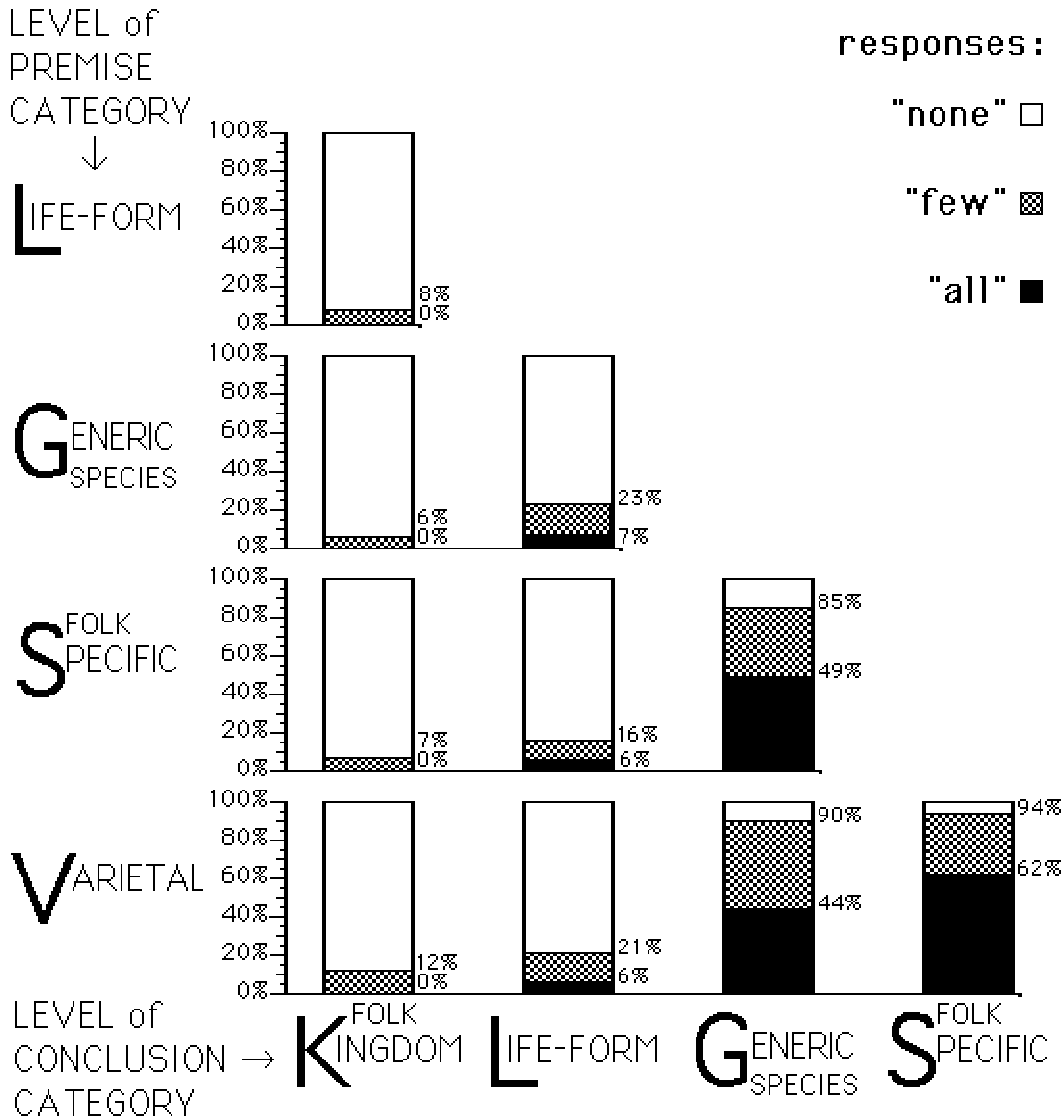

Figure 4
Combined Michigan results for all six life forms

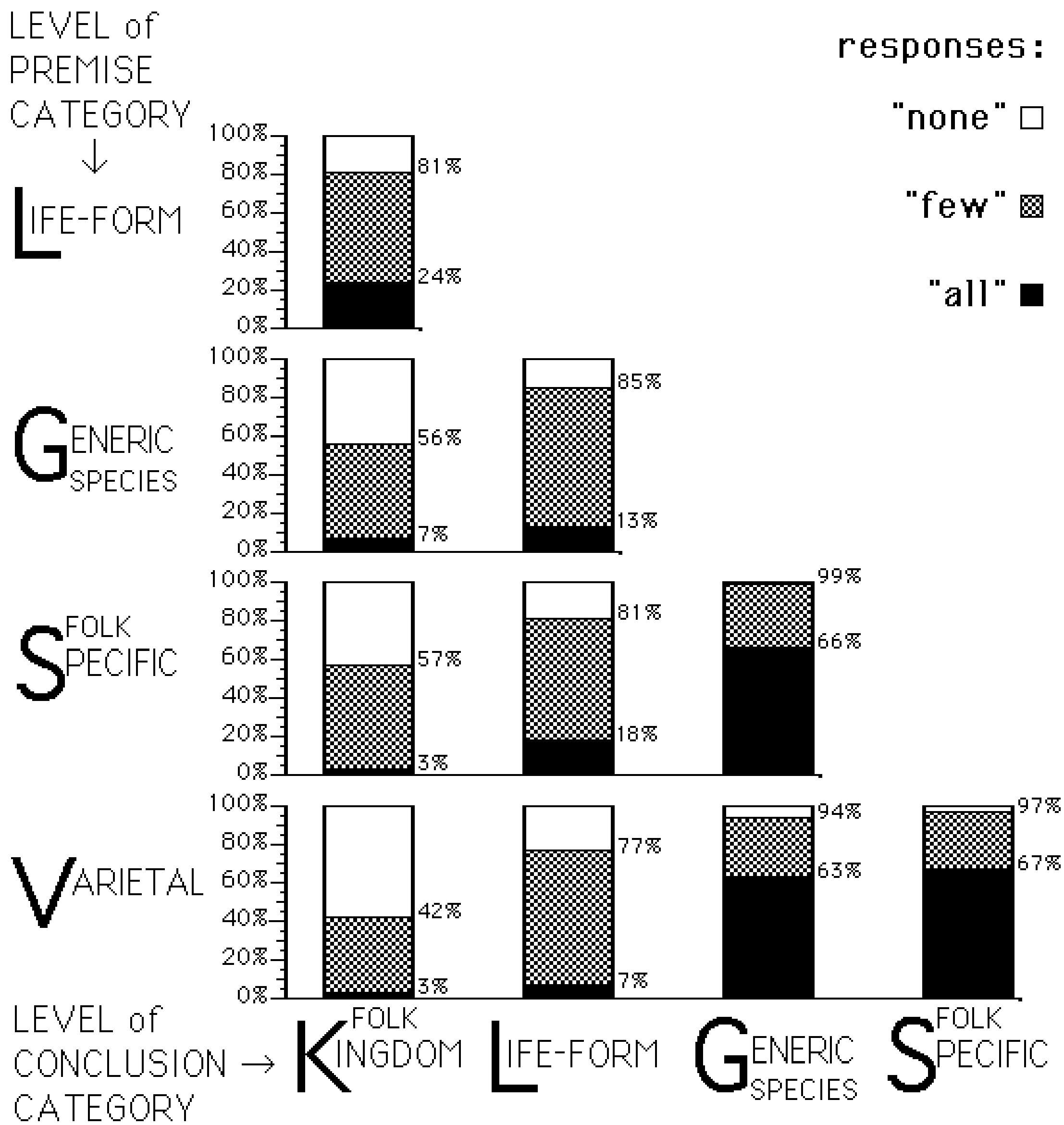

FIG. 5. *Frequency of reports of plants on animals for Itza', Ladinos, and Q'eqchi'. Plant and animal numbers refer to the ordering of species in table 3. The height of each point reflects the proportion of informants reporting such interaction.*

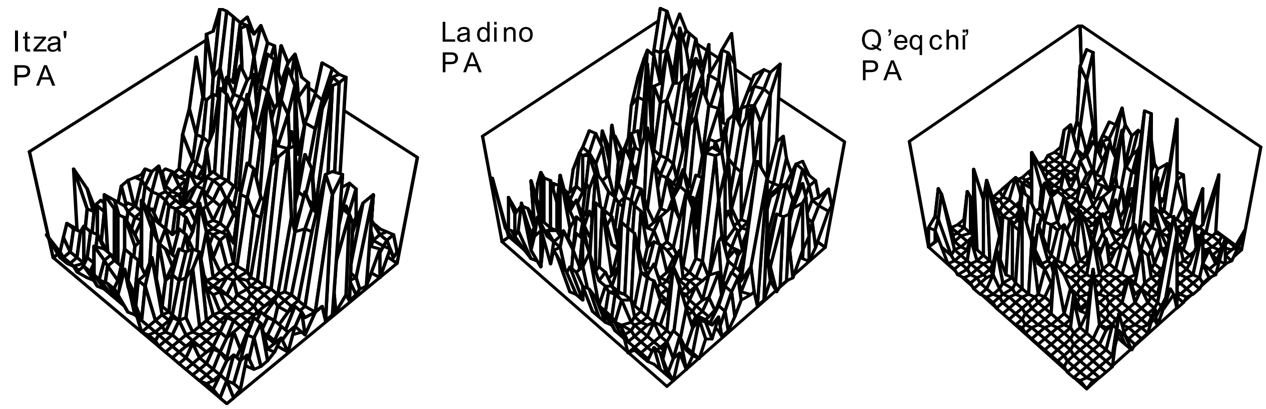

FIG. 6. *Frequency of reports of animals on plants for Itza' and Ladinos. Animal and plant numbers refer to the ordering of species listed in table 3. The height of each point reflects the proportion of informants reporting each interaction.*

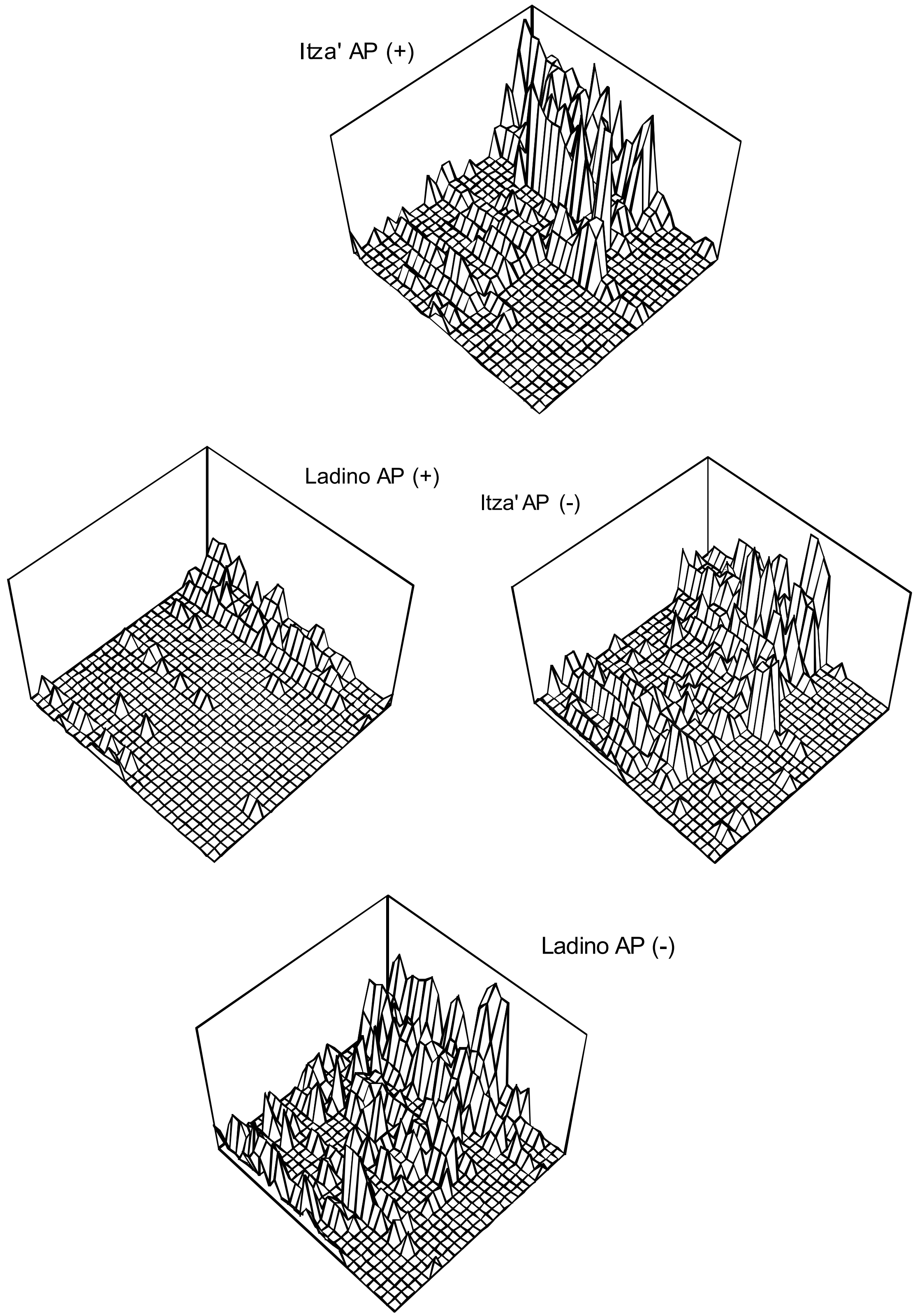
Itza' AP (+)
Ladino AP (+)
Itza' AP (-)
Ladino AP (-)

FIG. 7. *Social networks for Itza', Ladinos, and immigrant Q'eqchi'. Circle graphs* (top) *and multidimensional scaling* (bottom) *are alternative representations of the same data sets.*

[1] Phylogenetic comparisons of humans with other primates show some evidence for rudimentary forms biological conceptualization of species differences. For example, vervet monkeys have distinct alarm calls for different predator species or groups of species: snake, leopard and cheetah, hawk, eagle, and so forth (Hauser, 2000). Chimpanzees may even have rudimentary hierarchical groupings of biological groups within groups (Brown & Boysen, 2000). Only humans, however, appear to have a concept of (folk) species as such, as well as taxonomic rankings of relations between species.

[2] Despite the initial independence of work in domain-specificity and evolutionary psychology, there is now increasing convergence in the ways cognitive anthropologists and psychologists, and evolutionary biologists and psychologists, think about related issues. The general consensus is that domain-specific mechanisms likely evolved over millions of years of biological and cognitive evolution to deal with specific sorts of relevant and recurrent problems in ancestral environments ("task demands"), such as recognizing inert objects (e.g., rocks), reducing biodiversity to causally manageable proportions (e.g., species), or anticipating agents (e.g., the intentions of potential predators or prey).

Briefly, there is a folkbiological system (FBS) of the human mind. It discriminates and categorizes parts of the flux of human experience as "biological," and develops complex abilities to infer and interpret this highly structured domain. In a general sense, there is nothing intrinsically different about FBS – in terms of innateness, evolution or universality – than the visual system (VS) or any other evolved cognitive system. FBS is no more (or less) "autonomous" from the surrounding social environment, or from other mental systems, than VS is detachable from surrounding light and object patterning or from other physical systems (including linguistic and other cognitive systems of meaning, Marr, 1982). FBS and VS do not exist, and cannot develop, in isolation, but only as subsystems of even more intricate structures. Thus, claims about the biological "autonomy" or "modularity" of FBS or VS refer only to a specifiable level of systemic functioning within a system hierarchy. A difficult empirical issue concerns the extent to which other cognitive "performance" systems are themselves specifically adapted for folkbiology. The interface between folkbiological, folkmechanical and folkpsychological systems is more obscure (Au and Romo, 1999).

[3] Still other characteristics may be explained in terms of individual, random variation; however, our use of paired category-typical characteristics minimize this eventuality.

[4] For example, in Brazil, several of the 6-7 year-old children based their responding on an explicit analogy with the Disney movie, *Tarzan*, which was widely shown at the time of the study. They evinced a significant but weaker birth bias than 4-5 year-olds, consistent with Tarzan's mixed human/ape behavioral characteristics.

[5] This example illustrates another problem with Carey's idea of an implicit theory or explanatory framework. The claim that the knowledge that germs cause diseases is only a knowledge of input-output relations blurs the distinction between theory and tabulation of observable regularities that is fundamental to Carey's approach. Germs are not observable entities in this context and ought to be classified as theoretical entities. Granted there is no clear or neat distinction between observable entities and non-observable entities, or between empirical laws and theories. But without this distinction in principle, the notion of intuitive theory becomes incoherent.

[6] Carey's linguistic essentialism conforms to certain aspects of Streven's (2000) account of "minimalist" essentialism. Psychological essentialism and minimalist essentialism both allow that children may have little, if any, idea of specific causal mechanisms. According to Strevens (2000:163): "This is not to say that children think that there are no essences; rather, they have no opinion about what it is that makes the causal laws true." This suggestion resembles Medin and Ortony's (1989) idea of an "essence placeholder"; however, there is a difference. On Strevens' minimalist account, no concept of "common-cause" is needed to explain children's performance. Strevens' essentialism is even more liberal than Carey's in that mass terms, such as "mud" and "red things," may be just as good candidates for essentialism as count terms. Thus, red things share the disjunctive "essence" of whatever causes them to be red: red stars are red because of the way light filters through the earth's atmosphere to our retinas; British telephone booths are red because they are painted red, and so on. All that is needed is the presumption that something causes surface features. That something may have divided reference: one thing can cause a lion to roar and another thing, unrelated to the first, can cause a lion to have a mane. Finally, some causes might be deep and others superficial, such as believing a male lion's mane is genetically caused versus believing that it produced by fright, grooming by female lions or other external agents. Neither Carey nor Strevens provide clear descriptions of what they mean by an essence, except to allow essences to comprehend concepts that do not depend upon deep or common-

cause (Ahn et al., 2001; Atran et al., 2001).

[7] Barsalou (1985) argued that idealness rather than central tendency predicts typicality in goal-derived categories (e.g., foods not to eat on a diet, things to take from one's home during a fire, camping equipment), although central tendency still supposedly predicts typicality in "taxonomic" categories (furniture, vehicles), including folkbiological categories (birds).

[8] At the time this study was conducted we thought that we were observing central-tendency based typicality effects but we realized later that typicality in this sense was confounded with typicality based on ideals. Later studies (to be described shortly) suggest that idealness is the key factor.

[10] To ensure maximum social coverage from our sample, initial informants could not be immediate blood relatives (children, grandchildren, parents, grandparents, siblings, first cousins, nieces, nephews, uncles, aunts), affines (spouse, in-law) or godparents (compadres).

[11] The greatest overlap in the two networks occurs among Itza' and the least among Q'eqchi'. For Itza', 14 of the most cited social partners are among the 22 most cited forest experts. Although the Itza' social network is not highly centralized, the most cited social partner is also the second most cited forest expert, whereas the top forest expert is also the third most cited social partner. For Ladinos, 11 of the most cited social partners are among the 25 most cited forest experts. Of these 11, all are Ladino men. Ladino women tend to mention Ladino men as experts; however, the top Ladino experts most cite the same Itza' experts as the Itza' themselves do, suggesting diffusion of information from Itza' experts to a select group of socially well-connected Ladino men. For Q'eqchi', who have by far the most densely connected and centralized social networks, only 6 of the most cited social partners are among the 18 most cited forest experts (these are cited much less often as experts than outside institutions).

[12] Other learning factors may be involved in transmitting knowledge, including normative prototypes and narratives, but not in exclusive or straightforward ways. Thus, Ladino protoypes and stories of Itza' experts as forest wizards may share little actual content with the normative pronouncements and narratives of the Itza' themselves. Moreover, Itza' disavow teaching the Ladinos anything about the forest. How, then, might Ladinos eventually attain Itza'-like "spiritual" awareness? The line of reasoning that follows is frankly speculative and anecdotal, but one that should motivate further research.

Seeking to interview the two most cited Itza' experts, we found that both had gone on that particular day to the Ladino town of La Nueva. When they returned we asked them in separate interviews if they ever teach anything about the forest to the Ladinos; both denied doing so. Then, we asked why they had gone to La Nueva and what they did there. One said that he had gone because there were no lemons to be found in San José but he knew of some in La Nueva. He said that he had stayed so long in La Nueva after finding the lemons because he was trying to figure out with people there how it would be best to plant lemon trees. The other Itza' said that he had gone from our field station to visit his daughter, who is married to the son of the most cited Ladino expert. There he stayed telling stories of the barn owl (aj xooch' = Tyto alba) whose call augurs the death of strangers. People familiar with it cannot die from it. The Ladinos listened to every detail with obvious fascination.

A final anecdote concerns the sounds of the forest. This sensibility is not merely one of perception but of affective value. For example, Itza' give the short-billed pigeon (Columba nigrirostris) the onomatopoeic name ix-ku'uk~tz'u'uy-een. Itza' decompose this low, mournful sound into meaningful constituents, interpreted as follows: Pigeon was frightened of jaguar's coming. Squirrel saw this and told pigeon to leave her young with squirrel for protection. Pigeon came back to find that squirrel had eaten her young and that's why, as long as there is forest, one will hear pigeon lament that "squirrel (ku'uk) tricked (tz'u'uy = entangle) me (een)." But when we ask identifications from Ladinos, we are sometimes told that this bird's name, "Uaxactun-Uaxactun," signifies a lament for the ancient Maya spirits of Uaxactun and that's why "Itza" named it like that. Unlike Tikal, these Classical Maya ruins were given the name Uaxactun (waxak~tun = "eight stone") earlier this century by an American archaeologist, Sylvanus Morley. Thus, it is hardly likely that an Itza' elder would ever describe the pigeon's sound as these Ladinos think the Itza' do (although some non-Itza' speaking descendants of Itza' speakers describe it as do the Ladinos). Yet, this misinterpretation seems to reflect a sense of what a native Maya should attend to in the forest (see Atran, 2001b on the role of stories).

[13] The affective involvement of the Q'eqchi' with the landscape of their homeland may resemble Itza' involvement with Petén; but if so, little of it carries over from the Highlands to the Lowlands. As one NGO operative reported when he tried to encourage the Q'eqchi' to stress the same concern for protection of nature that he had witnessed around Cobán in order to better meet government criteria for gaining a concession in the Maya Biosphere: the Q'eqchi' responded that "in the mountains [of Cobán] we use the land with God's permission, but not in Petén," so that their only interest was in gaining a concession wholly given to agriculture (see Atran et al., in press, for details of Highland Q'eqchi' folkecology).

[14] There is nothing in principle to prevent rational-choice theory from assigning extensional values to relational entities (e.g., people may be willing to choose to save their pet over a favorite tree, their child over their pet, their nation over their children). Do sacred values form a special class of "protected values" that are internally negotiable but off-limits to more mundane, monetary exchanges? It is not clear how current approaches could model such choices, except as ad hoc "externalized contingencies" or as "pseudo-sacred" values infested with noise and confusion.

[15] We also asked 17 representatives of several nongovernmental organizations (NGOs) at a workshop on the Maya Biosphere Reserve (November-December, 1999) to rank the same trees as did Itza', Ladinos and Q'eqchi' (in terms of importance to forest life). For the NGOs, there was marginal consensus. The most valued species for NGO representatives are, 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 predict the consensus on preferences expressed by Ladinos and Itza'; however, the worst predictor of NGO rankings is Itza' male rankings of spirit preferences and Itza' ratings of ecological centrality.

[16] In one of the few studies to replicate findings on theories of mind in a small-scale society (cf. Wimmer and Perner, 1983), Knight, et al. (2001) showed monolingual Yukatek children a tortilla container and told them, "Usually tortillas are inside this box, but I ate them and put these shorts

inside." Then they asked each child in random order what a person, God, the sun (k'in), the principal forest spirits (yumil k'ax'ob, "Masters of the Forest"), and other minor spirits (chiichi') would think was in the box. Children over 5 attributed true beliefs according to a hierarchy with God at the top and people at the bottom. As do Itza', these Yukatek Maya consider the Masters of the Forest powerful and knowledgeable spirits that punish people who try to overexploit forest species. Yukatek children tend to believe that the forest spirits, like God and the sun, "live" (kukuxtal) but do not "die" (kukumil).

[17] A further observation is that the Itza' consider the ecologically-central ramon tree to be always worthy of protection and unlike the other two groups would never use ramon as firewood. Although research in the psychology of decision making sometimes views sacred or protected values as a hindrance to proper decision and a source of cognitive biases (e.g. Baron and Spranca, 1997), there is other evidence suggesting that protected values may be associated with the absence of framing effects and related biases (Fetherstonhaugh, Slovic, Johnson, and Friedrich, 1997; Friedrich, Barnes, Chapin, Dawson, Garst, and Kerr, 1999; Tanner and Medin, 2002).

[18] For Fodor (2000), the primary criterion for modularity is "encapsulation," that is, exclusive access to a proprietary input. Encapsulation is supposedly true only of perceptual modules, such as language or facial recognition. In ordinary circumstances, internal principles of grammar, phonetic rules and lexical structures provide a database for rapidly processing linguistic input with practically no regard for, or influence from, other cognitive systems. Similarly, folkbiological taxonomy arguably provides a privileged database for nearly "automatic" recognition of plant and animal exemplars in terms of the (folk)species to which they uniquely belong. Of course, almost by definition any conceptual system has some functional autonomy and is therefore "encapsulated." Virtually any game (e.g., chess) or routine activity (e.g., car driving) relies on a restricted database that gives it privileged access to a certain range of input. This would seem to trivialize the notion of modularity and rob it of any descriptive or explanatory force. Indeed, according to Fodor (2000:23), the best case that can be made for the computational theory of mind (i.e., the view that all conceptual processes are Turing-like computations over syntactic-like representational structures) is in terms of conceptual modularity; however, because conceptual modularity "is pretty clearly mistaken," then so very likely is the claim that the computational theory of mind has very much to tell us about how the mind configures the world. For Sperber (2001), Fodor's pessimism is unwarranted because it ignores the fact that privileged access to an input set depends on the competition for mental resources. Evolutionary task demands generally favor certain naturally-selected modular structures for processing certain types of naturally recurrent and statistically relevant input (all other things being equal). In principle, then, an explanatory account of modularity in terms of evolutionary task demands and related developmental considerations of modularity is preferable to a purely descriptive account in terms "encapsulation," "mandatoriness" and the like.

[19] Paul Griffiths (in press) argues that because the items on any such symptomatic list don't necessarily co-occur in any given case, and can't unequivocally demonstrate innateness, then notions of innateness are inherently confused and should be discarded. The same could be said against modularity. But the list represents only a family of evidential heuristics, and does not pretend to be a causal analysis of innateness or modularity.